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BOOK OF PROCEEDINGS

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[THE BOOK OF PROCEEDINGS]

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FOREWORD

It is with great pleasure that we present the papers compiled from the 2nd International Student Conference of Civil Engineering. This conference, organized jointly by the Faculty of Civil Engineering at the University of Prishtina "Hasan Prishtina" in Kosovo and the Faculty of Civil Engineering at the Polytechnic University of Tirana in Albania, stands as a testament to the collaborative spirit and scholarly endeavors of our institutions.

Our main aim in convening this conference has been to foster an environment where young minds in the field of civil engineering can come together, exchange ideas, and contribute to the advancement of knowledge in this vital domain. Over the course of three days, from 25 to 27 April 2024, we had the privilege of hosting a diverse array of participants, including esteemed keynote speakers from various corners of the globe.

We sincerely thank all the participants, speakers, organizers, and supporters who have contributed their time, expertise, and enthusiasm to make this conference a resounding success. We hope that these papers will serve as a source of inspiration and knowledge for current and future generations of civil engineers, driving progress and innovation in the field.

On behalf of the Faculty of Civil Engineering, I extend my heartfelt congratulations to all contributors and wish them continued success in their academic and professional pursuits.

Sincerely,

Prof. Ass. Dr. Florim GRAJÇEVCI

Dean of the Faculty of Civil Engineering, University of Prishtina "Hasan Prishtina".

Conference Chair

On behalf of the Organizing Committee.

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Keynote Papers

Flowing Towards Tomorrow: Unveiling the Water Wisdom of European Integration and a Sustainable Future

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In Southeast Europe, countries are at different stages of harmonizing, transposing, and implementing environmental legislation aligned with EU environmental legislation (acquis). So, Albania, Montenegro, Serbia, and the Republic of North Macedonia are official candidates, with accession negotiations and Chapters opened for these countries. Kosovo, Bosnia, and Herzegovina are potential candidate countries. The Republic of Moldova also has an EU Accession Agreement. Most EU candidate countries are under pressure to move forward faster with such alignment and require strengthened counties capacities, often requiring financial support. EU water policy is one of the cornerstones of environmental protection. The rules protect water resources and fresh and saltwater ecosystems and ensure clean drinking and bathing water. In this context, the Water Framework Directive provides the main framework and the objectives for European water policy. In the European Union's Water Framework Directive (WFD) context, "Good Status" refers to the ecological and chemical quality of water bodies such as rivers, lakes, coastal waters, and groundwater. The WFD aims to protect and improve the quality of water resources across EU member states. Water bodies must meet certain environmental objectives and standards the WFD sets to achieve Good Status. These objectives include criteria related to water bodies' biological, chemical, and physical characteristics. Achieving and maintaining Good Status requires comprehensive monitoring, assessment, and management of water resources. Member states must develop river basin management plans to outline measures for achieving Good Status and preventing further deterioration of water quality. Overall, Good Status represents a healthy and sustainable condition for water bodies, promoting biodiversity and ecosystem functioning and providing clean water for various uses such as drinking, recreation, and agriculture.

Keywords: *EU water acquis, Good Environmental Status, WFD Water Framework Directive, Sister Directives.*

1. INTRODUCTION

All four Western Balkan countries—Albania, Kosovo, Montenegro, and North Macedonia—are advancing their aspirations for EU integration and negotiations with EU member states. Among the 35 chapters, Chapter 27 focuses on Environment and Climate Change, shaping EU environmental policy. EU environmental policy aims to foster sustainable development and safeguard the environment for current and future generations. It emphasises preventive measures, the polluter pays principle, addressing environmental issues at their source, shared responsibility, and integrating environmental protection into other EU policies.

Under Chapter 27, the EU acquis comprises over 200 legal acts, categorised into 73 main directives and regulations. These encompass diverse areas, including horizontal legislation, water and air quality, waste management, nature protection, industrial pollution control and risk management, chemicals, noise, and climate change, divided into nine subchapters. One of these subchapters, "Water Quality," encompasses ten main directives. Consequently, in the four Western Balkan countries—Albania, Kosovo, Montenegro, and North Macedonia—Chapter 27 on the Water Subchapter, with numerous shared interventions aimed at fulfilment. Although

Kosovo and Albania took important steps towards the European Integration level to increase transposition and implementation of EUD (European Directives), significant challenges remain. EU integration, which considers the water quality subchapter of Kosovo and Albania, is part of this study. EU integration, particularly concerning the water quality subchapter, encompasses Kosovo and Albania as integral parts of this study.

The EU progress report for Kosovo [1] acknowledges the need to align water legislation with EU Directives. Urgent actions include establishing monitoring systems with publicly available data, enhancing water protection zones, and operationalising river basin district authorities. Adopting the White Drin basin management plan and expediting preparations for other river basin management plans is imperative. Compliance of small hydroelectric power plants with environmental legislation and appropriate assessments is crucial. Although progress has been made in preparing flood risk maps, untreated sewage remains a major source of water pollution, particularly in rivers. The development of wastewater treatment plants in larger cities should prioritise identifying agglomerations and sensitive areas following the Urban Wastewater Treatment Directive. Efforts to reduce water losses and improve wastewater collection need intensification.

The EU progress report for Albania [2] acknowledges the necessity of further aligning Albanian water legislation with EU Directives. Key recommendations include completing and adopting the River Basin Management Plans (RBMPs) for the Shkumbini and Vjosa. Albania is urged to strengthen transboundary basin management, particularly concerning the Drini-Buna and Vjosa river basins, in line with the Green Agenda for the Western Balkans. Collaboration with Greece in developing the Vjosa River Basin Management Plan is encouraged, given the river's ecological significance and national park status in Albania. Urgent action is needed to establish a national water monitoring program with adequate resources and ensure alignment with several EU water acquis. Albania should also enhance and expedite water reform measures, ensuring full alignment with the Urban Wastewater Treatment Directive. This entails extending sewerage networks, implementing appropriate tariffs for wastewater treatment plants, and constructing new facilities, especially in urban and coastal areas with significant tourism development.

2. METHODS

The methodology or approach employed in this research focuses on identifying challenges related to EU integration, with particular emphasis on the water quality subchapter for Kosovo and Albania. Both Countries are essential to this study, highlighting their significance in the EU integration process. The methodology for undertaking this research is relatively straightforward: data collection and analysis. Therefore, the main issues or problems that will be addressed in this paper are the following:

- Country's Context and Respective Water Potential,
- Country's Status of Chapter 27: "Environment and Climate Change" Sub-Chapter: "Water Quality",
- Country's WFD and its interaction with other EU legislation:
- How to Transform Challenges into Opportunities for water sustainability and integration.

2.1. Country Context, Water Potentials

The Kosovo hydrographic basin is 6.8% larger than its administrative-political surface, suggesting that most water originates within its boundaries. Kosovo’s water catchment area drains into the Black Sea (50.7%, represented by the Sitnica and Morava River Basins), the Adriatic Sea (43.5%, represented by the Drini i Bardhë River Basin), and the Aegean Sea (5.8%,

represented by the Lepenci River Basin). [4] It has been estimated that Kosovo has only 1,600 m^3 of water/year per inhabitant. [3]
The Albanian hydrographic basin is 50% larger than its administrative border, indicating that most water originates outside its boundaries. Albania's water catchment area flows into the Adriatic Sea (represented by the Drin-Buna, Mati, Ishmi, and Erzeni River Basins) and the Ionian Sea (represented by the Vjosa River Basin). Kosovo and Albania's joint water catchment area drains into the Adriatic Sea, encompassing the Drini i Bardhë River Basin and the Drin-Buna River Basins. [5] Rivers discharge about 1,300 m^3/water per second to the sea, making Albania the biggest water discharger in Europe per head of population. Albania has about 13,000 m^3/water available per inhabitant/year.
Albania also has three major natural lakes (Ohrid, Prespa and Skadar), 247 small natural lakes, and 650 artificial reservoirs. The country has access to the Adriatic and Ionian Seas with a coastline of 427 km, of which 273 km are on the Adriatic Sea and 154 km is on the Ionian Sea. The coast is also home to several major protected natural lagoons: Kune-Vain in the north, Karavasta and Narta, and Butrinti in the south.

2.2. Chapter 27: "Environment and Climate Change" Sub-Chapter: "Water Quality"

According to the new negotiation methodology, which the European Council approved in March 2020, the negotiations are carried out based on six groups of chapters (clusters), which consist of (1) The Basic Chapter Group, (2) The Internal Market Group; (3) Group Chapter on Competitiveness and Inclusive Growth; **(4) The Green Agenda and Sustainable Interconnection Group**; (5) Resources, Agriculture and Cohesion Group Chapter; (6) Group Chapter of Foreign Relations. Chapter 27 (group 4) comprises over 200 legal acts, out of which 79 main legal acts cover 9 subchapters such as horizontal legislation, **water quality** air quality, waste management, nature protection, industrial pollution control and risk management, chemicals, noise and forestry. Compliance with the EU environmental acquis requires significant investment. Environmental problems are mainly related to the impact of human activity on environmental resources.
These generally take the form of pollution, depletion or degradation of water, air and soil. Soil erosion, salinisation and water pollution, desertification, deforestation, and (for Albania) coast degradation are the biggest environmental damages and problems in places like Albania.
Water, waste and air management are among the most comprehensively regulated areas of EU environmental legislation. The sub-chapter of Water is composed of 10 pieces of legislation. The main Directive is Water Framework Directive 2000/60/EC (WFD), which is Europe's key tool for protecting the quality of its waters in response to the increasing threat of pollution and the increasing public demand for clean waters. [6] The key WFD objectives are expanding the scope of water protection to all waters (surface waters and groundwater), achieving "good status" for all waters by a set deadline, water management based on river basins, "combined approach" of emission limit values and quality standards; getting the prices right (including polluter pays principle); getting the citizen involved more closely and streamlining legislation. Based on the main requirements of the WFD, the following legal context's European Water Policy introduce targets and tools to be followed by Member States, such as the following session 2.3 and sub sessions from 2.3.1 up to 2.3.9.

2.3. WFD and its interaction with other EU legislation

The Water Framework Directive (2000/60/EC; WFD) is a comprehensive legislation that sets clear quality objectives for all European waters. One key purpose of the Directive is to prevent further deterioration and protect and enhance the status of aquatic ecosystems concerning their water needs, terrestrial ecosystems, and wetlands, which directly depend on the aquatic ecosystems. The WFD covers all waters, including inland waters (surface water and groundwater) and transitional and coastal waters up to one sea mile. For the implementation of the WFD, the totality of waters is attributed to geographical or administrative units, particularly river basins, river basin districts, and water bodies. [6] The WFD (2000/60/EC) reflects a new way of thinking and follows particularly key objectives expanding the scope of water protection to all waters: surface waters, including coastal waters, and groundwater, achieving "good status" for all waters by a certain deadline and preserving such states where it already exists, water management based on river basins, with a "combined approach" of emission limit values and quality standards, with appropriate coordination provisions for international river basins, where river basins are located in more than one Member State and/or also involve the territory of non-member States, setting prices for water use, taking into account the principle of cost recovery and following the polluter pays principle, getting citizens involved more closely.

Table 1. Status of the River Basin Management Plans, Kosovo – Albania

RBMPs	**Albania: Status of adoption**
Drin-Buna	Adopted Drin-Buna RBMP by the DCM Nr. 849, dated 4.11.2020 (Funded by WB and SIDA)
Mati	Prepared and consulted, approved by NWC Decision No. 3, dated 12.10.2012. Funded by EU and ADA through the EUSIWM Project. Adopted Mati RBMP NWC 2015 Adopted Mati RBMP by DCM No. 833, dated 28.12.2023. 2024–2029
Ishëm	Prepared and consulted, approved by NWC Decision No. 4, dated 31.05.2023. Funded by EU and ADA through the EUSIWM Project Adopted Ishem RBMP 2024–2029, by DCM No. 624, dated 8.11.2023.
Erzen	Prepared and consulted, approved by NWC Decision No. 5, dated 31.05.2023. Funded by EU and ADA through the EUSIWM Project Adopted Erzen RBMP 2024–2029, by DCM No. 623, dated 8.11.2023.
Shkumbin	Not adopted (IBECA project funded by EU)
Seman	Adopted by the DCM Nr. 453 of 10.6.2020 (funded by WB, SIDA)
Vjosa	Not adopted, AMBU/EUSIWM project prepared a diagnostic analysis
RBMPs	**Kosovo: Status of adoption**
Drini I Bardhë	RBMP is almost completed, and it has been under public discussion until the end of 2023. This plan was implemented through the SIDA funding
Ibër Lepencë Morava	Three RBMPs are almost completed (over 90%). The program of measures is in the process of drafting. These RBMPs have been implemented through the ARPL-MIRU/IWRMK

Source: The author compiled this table based on AMBU and ARPL 2023 data.

Status: WFD is partially transposed into Kosovo legislation. Albania has recently almost completed its transposition.

2.3.1 Directive 91/271/EEC Urban Wastewater Treatment (UWWTD)

Implementation Chapter 27 is considered one of the most expensive negotiations in EU chapters, primarily due to the water sector infrastructure (constitutes more than 60% of the public investment requirements for the whole Environmental Sector), particularly wastewater collection system and treatment, which requires significant environmental infrastructure development. The Directive establishes minimum requirements for the collection, treatment and discharge of urban wastewater and the treatment and discharge of wastewater from certain industrial sectors. Its objective is to protect the environment from the adverse effects of such wastewater discharges.

Important requirements are: Identify the relevant hydraulic catchment areas of the sensitive areas and ensure that all discharges from agglomerations with more than 10,000 p.e. located

within the catchment area of the sensitive areas shall have treatment more stringent than secondary treatment and establish a technical and financial programme for the implementation of the Directive for the construction of sewage collecting systems and wastewater treatment plants. Industrial effluents represent a priority issue, particularly in urban wastewater systems that receive mixed household and industrial wastewater, apart from rainfall water. In particular, the contribution from industry must be properly regulated to avoid operational problems at the Wastewater Treatment Plant (WWTP) and the transfer of pollutants in the effluent or sewage sludge. *[9]*. (UWWTD) Grand Total Capital Investment and Legal, Policy and Institutional Measures are estimated at 2,355 million euros.
Status: UWWTD is partially transposed into Albanian legislation. Albania [12] has delineated 165 agglomerations and 18 sensitive zones and has prepared the Developed Directive-Specific Implementation Plan, 2023-2050. The sludge production is projected to increase from 8 tonnes DS/year (t DS/y) to 40,000 t DS/y by 2050. A national plan to manage sewerage sludge for 2023-2050 has been prepared. [14] In Kosovo, the UWWTD has been fully transposed into national legislation through a bylaw known as the Administrative Instruction on the Discharge of Wastewater into Public Sewerage Systems and Water Bodies (2022). Kosovo is initiating the plan to ensure compliance with the measures required under this directive. Also, Kosovo has adopted Administrative Instruction no. 02/2022 for Conditions, Manners, Parameters, and Limit Values of Wastewater Discharge into Public Sewerage Networks and Water Bodies, similar to Albania.

2.3.2 Directive 98/83/EC Drinking Water (DWD)

Directive 98/83/EC on the "quality of water intended for human consumption: drinking water" is amended by Regulations (EC) 1882/2003, (EC) 596/2009 Commission Directive (EU) 2015/1787 and Commission Decision 95/337/EC concerning questionnaires relating to directives in the water sector. This Directive concerns the quality of water intended for human consumption. The main objective of this Directive is to protect human health from the adverse effects of water contamination intended for human consumption, guaranteeing its health and cleanliness.
Subject of this directive are all drinking water supply systems serving >50 people.
Status: In Albania [13], 1,185 (Water Supply Zones) WSZs were delineated (using approximately 1,600 wells), supplying 2,117 villages/cities (about 69 % of the total villages) were identified. About 92 % of Albania's population (2.83 million) live in these WSZs. The remaining 952 villages (31 % of total villages) in the country should be added to the list of WSZs. Of the two (2) WSZs in the category above 100,000 population are Tirana and Durres zones, 27 % of the total population is included. In contrast, in the class below 1,000 population, only 12 % of the people are included. (DWD) The capital investment and legal, policy and institutional measures are estimated at 1,380 million euros. Prioritisation of the capital investment measures 2023-2030 will include Rehabilitation of 175 springs and wells, including water resources fences (1st Level of Sanitary Protection Zone), Establishment of 2nd and 3rd Level of Sanitary Protection Zones in 334 WSZs, Construction of 243 new and rehabilitation of 5 existing chlorination units, Extension of 491 km of water supply network (including 5,309 m³ reservoir volume and 39,856 services connections, Rehabilitation/replacement of 1,007 km of the water supply network, including pumping stations, reservoirs and service connections, Establishment of 15 regional laboratories. In Kosovo, this directive has been fully transposed and implemented. The directive has been substantially transposed into the national systems of both Albania and Kosovo. However, the recast of the Drinking Water Directive (DWD) 2184/2020 has yet to be transposed into Albanian and Kosovo legislation. [8]

2.3.3 Directive 2006/7/EC Bathing Water (BWD)

Directive 2006/7/EC on "concerning the management of bathing water quality" is amended by Regulation (EC) 596/2009, and Directive 2013/64/EU ensures timely information to the public during the bathing season, with an obligation to disseminate actively and promptly information on bathing water quality. It applies to surface waters that can be used for bathing except for swimming pools and spa pools, confined waters subject to treatment or used for therapeutic purposes, and confined waters artificially separated from surface water and groundwater. Two main parameters for analysis are defined: intestinal enterococci and Escherichia coli. The waters are classified according to their level of quality: poor, sufficient, good or excellent, linked to clear numerical quality standards for bacteriological quality. Bathing is an extremely popular and important leisure activity in Albania. The Directive 2006/7/EC on Bathing Water is aligned with the Albanian legislation. The Green Coast beach in Palasa is now (2023) the first beach in Albania to receive the Blue Flag certification from the Foundation for Environmental Education. The iconic Blue Flag is one of the world's most recognised voluntary awards for sustainable tourism beaches, marinas, and boats. To qualify for this prestigious certification, stringent environmental, educational, safety, and accessibility criteria will be met and maintained.
Status: BWD has been fully transposed into both national legislations. In Kosovo, a bylaw exists - the Administrative Instruction on Criteria for Bathing Waters (2015). Both countries are committed to the following actions: Developing a monitoring calendar plan, Conducting proper bathing water monitoring, Assessing and classifying bathing water quality, Developing and maintaining bathing water profiles, Identifying pollution sources and conducting impact assessments to safeguard bather health, Implementing measures to prevent bathers from encountering pollution, Implementing measures to mitigate the risk of pollution, Providing public information on bathing water quality.

2.3.4 Directive 2006/118/EC Groundwater (GWD)

Directive 2006/118/EC "on the protection of groundwater against pollution and deterioration" establishes specific measures such as criteria for the assessment of good groundwater chemical status and criteria for the identification and reversal of significant and sustained upward trends and for the definition of starting points for trend reversals to prevent and control groundwater pollution. It also complements the provisions preventing or limiting inputs of pollutants into groundwater already contained in WFD and aims to prevent the deterioration of the status of all groundwater bodies. The remaining tasks for the implementation are to consolidate the Environmental GW Monitoring System in Albania, strengthen the capacities and research studies, improve and support the implementation of national water quality monitoring programs (in connection with RBMPs), establish an effective monitoring and enforcement system, including the accreditation schemes for laboratories on the groundwater status. 56 stations, number of designated groundwater water monitoring sites determining groundwater quality and 21 wells measure level water in all the aquifers of Albania with frequencies of 2-4 field visits per year (2022). Groundwater monitoring is conducted on the main aquifers for physicochemical parameters, NO3-, NO2-, NH4+, HCO3-, CO32-, Cl-, SO42 Na+, Ca2+, Mg2+, K+, Fe2+ temperature, dissolved oxygen, conductivity, pH, dry matter, total hardness, total mineralisation, and hazardous substances. The following metals are analysed once per year at a limited number of stations: Cd, Co, Cr, Mn, Ni, Pb, and Zn. Groundwater flow in Albania is 12.8 billion m3 /year. *[10]*
Status: GWD is in the advanced transposition stage into Albanian legislation through the Law on Integrated Water Resources Management (IWRM). Kosovo has been fully transposed into

legislation through bylaws such as the Administrative Instruction on the Classification of Groundwater Bodies (2017). [8]

2.3.5 Directive 2007/60/EC Floods (FRD)

Directive 2007/60/EC "on the assessment and management of flood risks" requires, if all water courses and coastlines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and take adequate and coordinated measures to reduce this flood risk. It also reinforces the rights of the public to access this information and to have a say in the planning process. This directive requests Preliminary Flood Risk Assessments describing the significant floods that have occurred in the past and similar events that could happen in future; Flood Hazard and Risk Maps, showing where a given flood could have adverse consequences; and Flood Risk Management Plans (FRMPs), defining measures to prevent, protect against and prepare for floods.
Status: The FRD has been fully transposed into Kosovo legislation through the Administrative Instruction on the Classification of Groundwater Bodies in 2017. Regarding implementation, Kosovo has identified 398 APSFRs (Areas with Potentially Significant Risk of Flooding), encompassing a surface area of 3,727 km² and serving 326,032 inhabitants or 56,846 households. Additionally, there are 24 cultural and historical sites and 39 protected sites and hotspots. In Albania, 46 APSFRs have been identified, with 23 having Flood Hazard Maps and 6 having Flood Risk Maps. Only one partial (transboundary) Flood Risk Management Plan has been prepared, covering the sub-Shkodra area of the Drin-Buna River Basin. [10]

2.3.6 Directive 91/676/EEC Nitrates

Directive 91/676/EEC on "concerning the protection of waters against pollution caused by nitrates from agricultural sources" aims to protect water quality across Europe by preventing nitrates from polluting ground and surface waters and promoting good farming practices. It forms an integral part of the WFD and is one of the key instruments in protecting waters against agricultural pressures. MS are obliged to monitor the nitrate concentrations in ground and surface waters, monitor eutrophication in surface waters, and review and, if necessary, revise or add to the designation of vulnerable zones. Important topics to be implemented: Designation of Nitrate Vulnerable Zones (NVZs) (Note: Albania can implement measures across the entire territory instead of designating NVZs), Implementation of Codes of Good Agricultural Practice for voluntary adoption by farmers, Implementation of mandatory action programs for farmers within NVZs, Identification of polluted water bodies or those at risk of pollution and Establishment of a National monitoring and reporting system. *[8] [10]*
Status: ND is in the early stage of transposition and Implementation for Albania and Kosovo.

2.3.7 Directive 2008/105/EC Environmental Quality Standards for Water (EQS)

Directive 2008/105/EC on "environmental quality standards/priority substances" lays down environmental quality standards (EQS) for priority substances and certain other pollutants to achieve good surface water chemical status and follow the provisions and objectives of WFD. MS should improve the knowledge and data available on sources of priority substances and how pollution occurs to identify targeted and effective control options.
Status: Directive 2008/105/EC Environmental Quality Standards for Water is substantially transposed into the Albanian and Kosovo legal framework. [8] [10]

2.3.8 Directive 2009/90/EC Quality Assurance Quality Control (QA/QC)

Directive 2009/90/EC on "technical specifications for chemical analysis and monitoring of water status" lays down technical specifications for chemical analysis and monitoring of water status by WFD. It establishes minimum performance criteria for analysis methods when monitoring water status, sediment, and biota and rules for demonstrating the quality of analytical results. It also requests that all analysis methods, including laboratory, field, and online methods used for chemical monitoring programmes carried out under WFD, be validated and documented following EN ISO/IEC-17025 standard or other equivalent standards accepted internationally. *Status: fully approximates [8] [10]*

2.3.9 Directive 2008/56/EC Marine Strategy (MSFD) including GES

Directive 2008/56/EC on the "establishment of a framework for community action in the field of marine environmental policy" (Marine Strategy Framework Directive) offers a framework for the sustainable use of marine waters and a comprehensive and integrated approach to coastal waters. The criteria and methodological standards for implementing the Marine Strategy on good environmental status and the specifications and standardised methods for monitoring and assessment were revised in 2017 through Directive 2017/845/EU.
Status: Albania has fully approximated this Directive with National Legislation on 7 February 2024. [10]

3. RESULTS AND DISCUSSION

The EU's acquis on the water is substantially transposed into Albanian and Kosovo legislation. To ensure long-term water sustainability and integration, the youth should adopt a holistic approach to water management, considering the interconnectedness of water bodies, ecosystems, and human activities. This involves comprehensive water management researches that balance competing demands while preserving environmental sustainability and enhancing water governance. Additionally, embracing innovative solutions like wastewater treatment and rainwater harvesting and leveraging emerging technologies like artificial intelligence and satellite imaging can improve water management efficiency. Addressing climate change impacts through resilient infrastructure, drought management, and flood risk reduction measures is crucial, as is promoting sustainable agriculture practices and empowering youth to adopt water-saving behaviours. It's essential to upgrade monitoring and evaluation mechanisms to track progress and adjust strategies.

4. CONCLUSION

In conclusion, adopting a holistic approach to water management is essential for ensuring long-term sustainability, particularly among youth. Comprehensive research is needed to develop effective plans that balance competing demands while preserving the environment and improving governance. Embracing innovative solutions like wastewater treatment and rainwater harvesting and utilising emerging technologies such as artificial intelligence and satellite imaging can enhance efficiency. Addressing climate change impacts and promoting sustainable agriculture practices are crucial, as is empowering youth to adopt water-saving behaviours. Upgrading monitoring and evaluation mechanisms is vital for tracking progress and adjusting strategies. Implementing these measures can transform water challenges into opportunities for long-term sustainability in Albania and Kosovo, securing a resilient water future for generations to come.

REFERENCES

[1] EU Progress Report, Kosovo 2023:

https://neighbourhood-enlargement.ec.europa.eu/document/download/760aacca-4e88-4667-8792-3ed08cdd65c3_en?filename=SWD_2023_692%20Kosovo%20report_0.pdf

Page 115.

[2] EU Progress Report, Albania 2023:

https://neighbourhood-enlargement.ec.europa.eu/document/download/ea0a4b05-683f-4b9c-b7ff-4615a5fffd0b_en?filename=SWD_2023_690%20Albania%20report.pdf. Page 120

[3] Strategjia Shtetërore e Ujërave në Kosovë 2017 – 2036, Page 39

[4] Programit Kombëtar Sektorial për manaxhimin e integruar të ujit, 2018-2030, Page 18

[5] Hans Mose Jensen & Periklis Panagiotidis (ICES) EEA project manager: Johnny Reker Delineation of the MSFD Article 4 marine regions and subregions Date: 14/07/2015, Page 14

[6] Handbook on the Implementation of EU Climate Change Legislation. Edited by Hulla & Co Human Dynamics 2015-2016

[7] Gjinali E, Shehu L, Miho O. "How many WWTPs does Albania need to treat urban polluted water according to EU criteria? "November 2022. Proceeding Book ISBN 978-9928-4429 2 5, ICCE International Conference of Civil Engineering on Application of Clean Technologies for a Sustainable Environment.

[8] Lorik Lajçi Transposition of the EU water law in Kosova, Progress and Challenges, Junior Professional Integrated Water Resource Management, November 2023

[9] Sewage Disposal in Kosovo Phase IV (Peja) Component B - Accompanying Measures, December 2019

[10] E. Gjinali, National Assessment and Action Plans on the Transposition, Implementation and Enforcement of the Water Quality Sub-Chapter, March 2024

[11] E. Gjinali, Presentation: Flood Risk Maps and Flood Hazard Maps for All River Basins in Kosovo, WB25-KOS-ENV-02 of the European Investment Bank as the Client and Ministry of Environment and Spatial Planning of Kosovo as the Beneficiary

[12] AKUK Directive-Specific Implementation Plan of the UWWTD, 2023-2050 (E. Gjinali co-author)

[13] AKUK Directive-Specific Implementation Plan of the DWD, 2023-2050 (E. Gjinali co-author)

[14] AKUK National Sludge Management Strategy, 2023-2050, March 2023. (E. Gjinali co-author)

Advanced numerical simulations of geotechnical challenges

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In numerical simulation of soil media, it is of great importance that the simulation should be as close as possible to the real phenomenon. In the field of geotechnical earthquake engineering multiphase modelling has great importance since the real behavior of the soil in loading and unloading is simulated. In defining the multiphase model, different approaches are available in the literature. Nevertheless, dynamic phenomena in porous media defining nonlinear material behavior including infinite soil media have not been considered. In this work, both the linear and nonlinear behavior of the soil medium and the simulations of boundary conditions in the soil medium are presented. The newly developed infinite elements in static, dynamic, and fully saturated conditions provide interesting and reliable results.

Keywords: *Numerical simulation, earthquake engineering, multiphase modelling.*

1. INTRODUCTION

Numerical simulation of heterogeneous materials has an important role in engineering applications. In geotechnical earthquake engineering, multiphase modeling has great importance since realistic predictions for the soil's behavior can be simulated both for displacement and pore pressure changes. In simulation of porous media such as soils, the behavior is governed largely by the interaction of the solid skeleton with water and/or air in the pores. Hence, coupled problems involving fluid flow and solid skeleton deformation need to be thoroughly examined.

In describing multi-phase media, various approaches are presented in literature. Firstly, the mixture theory at macroscopic level combined with the concept of volume fractions considers the individual constituents of the multiphase model enabling description of each phase in the multiphase model. This method has been mainly used by researchers such as Ehlers [1] Boer [2] etc. Secondly, the averaging theory applying the balance laws to the microstructure of the porous medium enables macroscopic definition of the constituent phases in multiphase media. Alternatively, the basic equations of multiphase media can be derived from extending the Biot's theory [3]. In this particular work, the development of multiphase model follows the model of Edip [4] and is based on the averaging theory.

2. DEVELOPMENT OF MULTIPHASE MODELLING

In defining porous media, one of the great difficulties is to mathematically represent the phases involved. In describing these porous soil media, factors like water saturation and pore pressure have a strong impact on the load distribution. In the description of the material, the macroscopic approach has been followed in which the soil behavior is homogenized over a representative volume element. The concept of volume fractions has been used to evaluate the participation of each constituent in formulation of the equilibrium equations for each phase and to take into consideration the interaction among the phases. Following the concept of volume fractions, the entire volume consists of solid fraction Vs and pore volume Vp. The pore volume fraction is composed of water phases Vw.

$$V = V_s + V_p = V_s + V_w \tag{1}$$

Upon loading, development of stress has been considered to take place in the solid skeleton of the multiphase medium and also in the water and air phases. The total stress has been obtained from the difference of the effective stress σ',which causes deformation of the solid skeleton.

$$\sigma = \sigma' - m^T \left(S_w p_w + S_g p_g \right) \tag{2}$$

In equation 2, m^T is the identity matrix to account for the pressure in the fluid phases. In order to consider the flow through the porous medium, the Darcy's law has been used. The validity of the Darcy's law for a single fluid flow has been extended to a second fluid by considering the relative permeability coefficients for water and air phases such that the equation for the whole system is presented as follows:

$$\begin{pmatrix} \mathbf{M} & \mathbf{0} \\ \mathbf{M}_f & \mathbf{0} \end{pmatrix} \begin{pmatrix} \ddot{\mathbf{u}} \\ \mathbf{0} \end{pmatrix} + \begin{pmatrix} \mathbf{C} & \mathbf{0} \\ \mathbf{C}_{sf}{}^{\mathbf{T}} & \mathbf{P}_{ff} \end{pmatrix} \begin{pmatrix} \dot{\mathbf{u}} \\ \dot{\bar{\mathbf{p}}}_f \end{pmatrix} + \begin{pmatrix} \mathbf{K} & -\mathbf{C}_{sf} \\ \mathbf{0} & \mathbf{H}_{ff} \end{pmatrix} \begin{pmatrix} \bar{\mathbf{u}} \\ \bar{\mathbf{p}}_f \end{pmatrix} = \begin{pmatrix} \mathbf{f}_{\mathbf{u}} \\ \mathbf{f}_f \end{pmatrix} \tag{3}$$

The nodal degrees of freedom for displacement and fluid pressure are taken into consideration as u and p_f. Their first and second time derivative of solid phase complete the system of equations. The different matrices of the system of equations describe different properties of the numerical model. The definition of saturation relationships enables usage of di fferent saturation models to perform analysis of partially saturated soil media.

The indices provide information about the nature and function of the matrix, which can be interpreted as follows. The coupling matrices C_{sf} describe the interaction of the solid phase with fluid phase. The compressibility of the various phases and their effects on the entire media is considered by compressibility matrix P_{ff}. The Permeability matrix H_{ff} on the other hand, concerns the flow behaviour. Detailed explanations for the matrices is given in Appendix 1.

3. SIMULATION OF BOUNDARY ELEMENTS

In numerical simulation of geotechnical problems it is common to take the soil medium as a wide region while the boundaries are far enough not to impact the results. In the case of static analysis Boussinesq's problem of a point load acting over the half space is considered. In order to numerically simulate the Boussinesq's problem the finite element region should be widened or the boundaries should be modelled accordignly. In dynamic analysis the situation is additionally complicated by the inertia terms such the radiation of the wave should be considered. Infinite elements gain in popularity as an efficient mean of extending the finite element method to cope with unbounded domains. The formulation of infinite elements is the same as for the finite elements in addition to the mapping of the domain. Infinite elements are first developed by Zienkiewicz et al. [5] .Since then have been developed in frequency and time domain. In the work of Edip [6] infinite elements with absorbing properties have been developed following the techniques considering the time domain in which the infinite element is obtained from a six nodded finite element as shown in Figure 1.

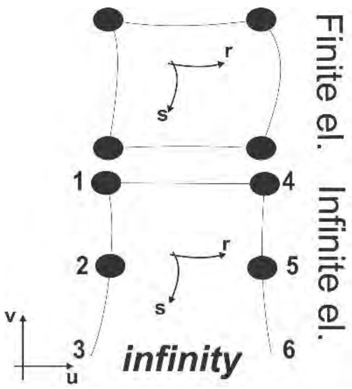


Figure 1. Model of soil layer with boundary conditions

The element displacement in u and v direction is interpolated with the usual shape functions N_1, N_2, N_4 and N_5

$$
\begin{aligned}
u &= [N_1 \quad N_2 \quad 0 \quad N_4 \quad N_5 \quad 0]\mathbf{u} \\
v &= [N_1 \quad N_2 \quad 0 \quad N_4 \quad N_5 \quad 0]\mathbf{v}
\end{aligned} \tag{4}
$$

In expression (4) **u** and **v** are vectors with nodal point displacements in global coordinates.

$$
\begin{aligned}
N_1 &= -(1-s)r(1-r)/4 \\
N_2 &= (1/2)(1-r^2)(1-s) \\
N_4 &= -(1+s)r(1-r)/4 \\
N_5 &= (1/2)(1-r^2)(1+s)
\end{aligned} \tag{5}
$$

For coordinate interpolation in r-s coordinate system a one-dimensional mapping is applied.

$$
\begin{aligned}
r &= [M_1 \quad M_2 \quad 0 \quad M_4 \quad M_5 \quad 0]\mathbf{r} \\
s &= [M_1 \quad M_2 \quad 0 \quad M_4 \quad M_5 \quad 0]\mathbf{s}
\end{aligned} \tag{6}
$$

3.1 Verification of infinite elements in static case

In the static analysis of geotechnical problems, one of the most challenging aspects is modeling the infinite region. Here, we present an analysis of an infinite plate with a circular hole of radius R=1.0 m subjected to a uniformly distributed pressure p=1 kPa. The domain is numerically simulated, comprising a plane strain 2D half-space, as illustrated in Figure 2.

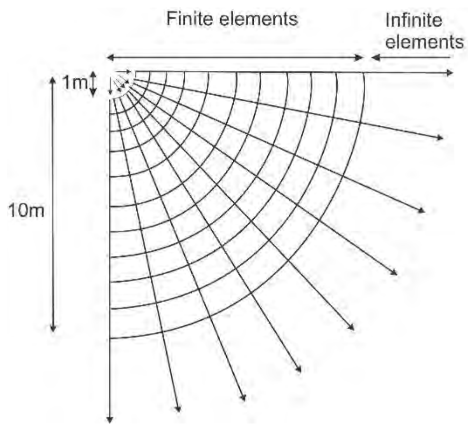


Figure 2. Mesh of finite and infinite elements

The material properties of the plate are : Young's modulus E=1kPa and Poisson's ratio n=0.25. The problem is numerically solved using 80 finite elements in total. The infinite region is simulated by using the 8 infinite elements. The results are compared with the solution done by T.T. Abdel-Fattah [7] in which the author uses decay type of infinite elements. The decay type used by T.T. Abdel-Fattah is of 1/r type and is considered to be stable in simulation of static problems.

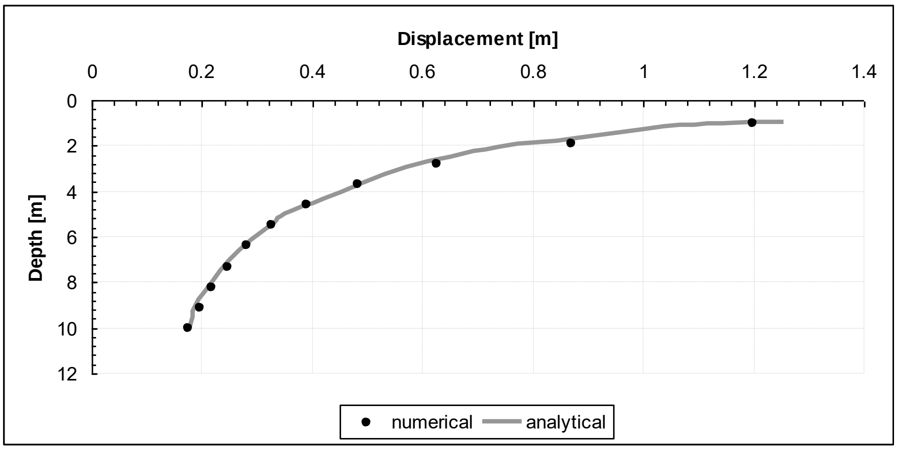


Figure 3. Radial displacement – analytical vs numerical

As can be seen from Figure 3, both analytical and numerical results for the radial displacement exhibit similarity, suggesting the precision of the coupled finite and infinite elements used in the analysis.

3.2 Verification of infinite elements in dynamic case

In dynamic case of implementation of infinite elements the absorbing properties are added to the infinite elements as given in the work of Sheshov et al. [8] The newly programmed infinite elements are used for simulation of two dimensional wave propagation. The soil medium is simulated in two alternative ways. First, only finite and infinite elements without absorbing boundaries and then the same infinite elements with absorbing properties are considered. Figure 2 shows the soil domain with a total width of 40m while the height is 20m.

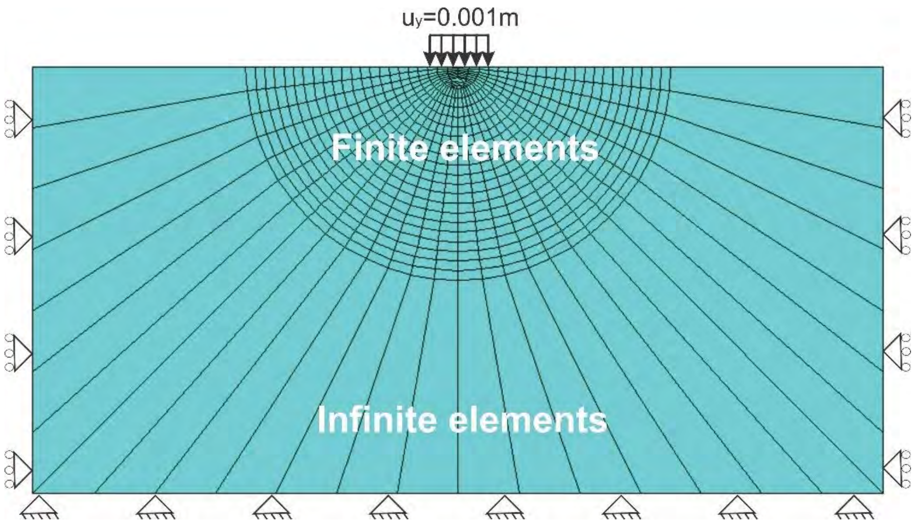


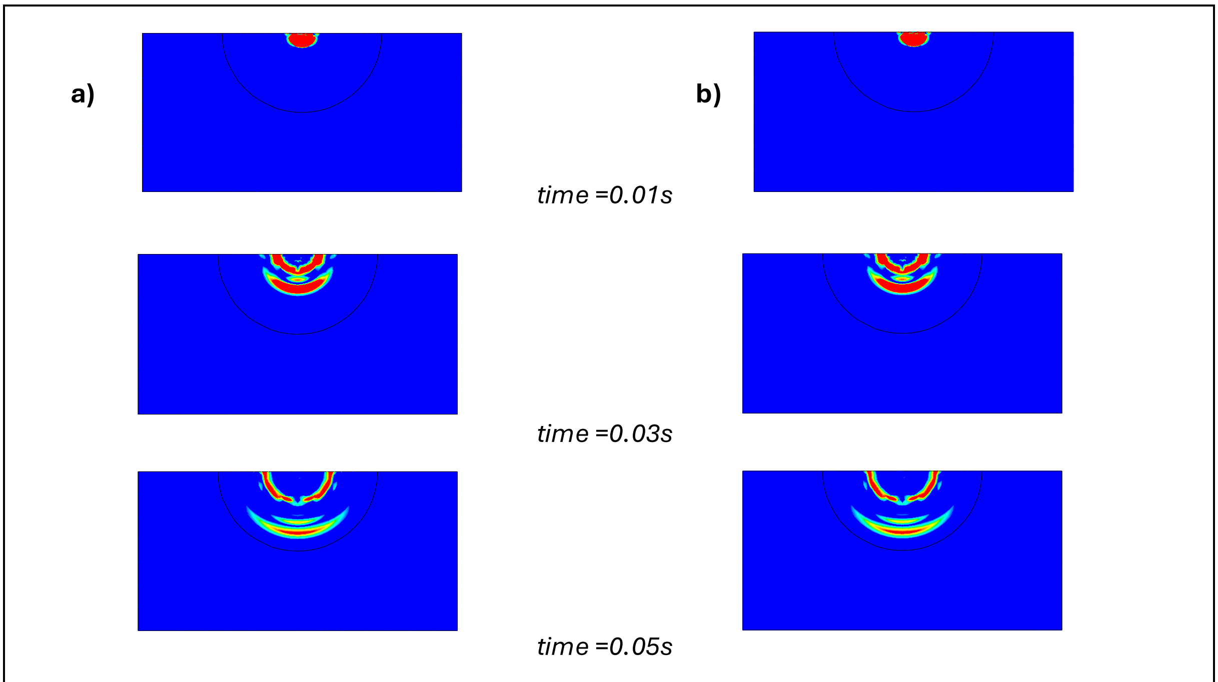
Figure 4. Soil domain of finite and infinite elements

The soil domain is discretized by finite and infinite elements. The soil properties are given in Table 1.

Table 1. Soil properties

Young's modulus	E	50000	kPa
Poisson's ratio	υ	0.35	-
Density	ρ	2.70	Ton/m^3

In this scenario, the applied displacement is treated as an impulse-type function. A nodal displacement of uy=0.001m is applied as an impulse function at the outset of the time period.



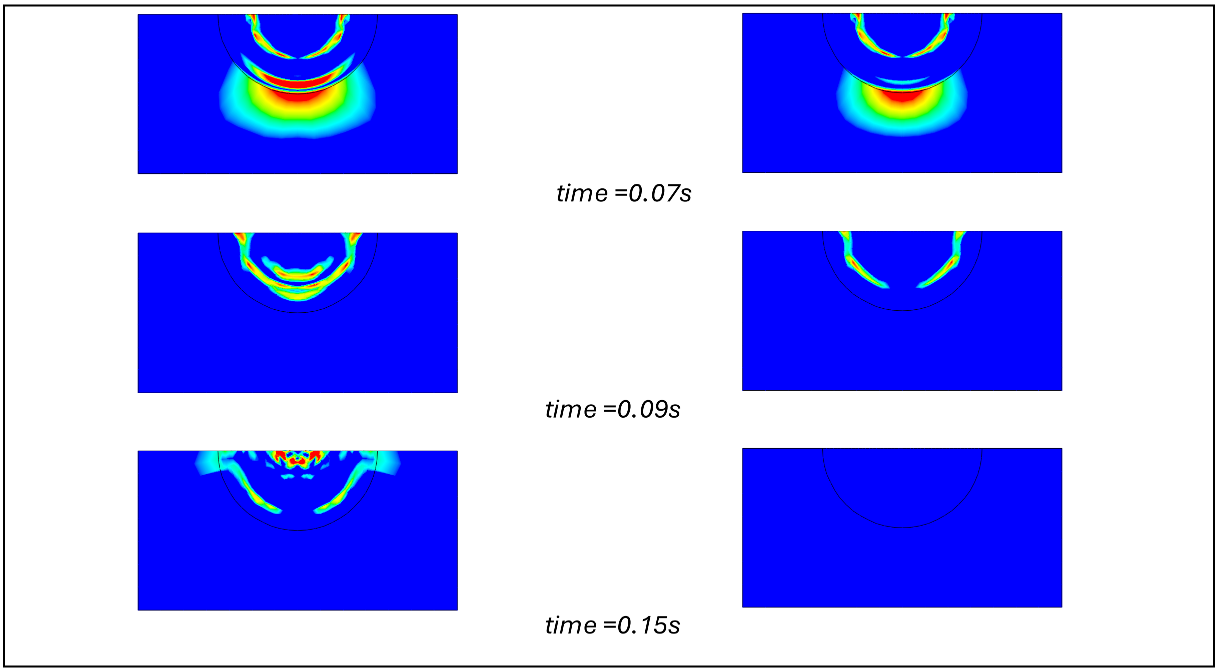


Figure 5. Wave propagation at different time spots using a) infinite elements and b) infinite elements with absorbing layer

As illustrated in Figure 5, two distinct waves propagate within the domain: the compression P wave and the shear S wave. The proposed infinite elements demonstrate the capability to absorb both types of waves, despite their differing propagation velocities. Notably, at time t=0.07 seconds, the P wave enters the infinite domain. With absorbing infinite elements, the wave is effectively absorbed, whereas in the absence of absorbing properties, the P wave reflects back into the finite element domain. By time t=0.09 seconds, within the domain surrounded by absorbing infinite elements, the propagation of the S-wave at the finite element boundaries becomes apparent. Conversely, in the domain lacking absorbing properties, the outward-propagating S-wave collides with the reflected P wave. At t=0.15 seconds, in the domain comprising infinite elements with absorbing boundaries, there is no reflected wave propagation, indicating successful absorption within the infinite element region.

3.3 Verification of infinite elements in multiphase simulation

In order to verify the infinite elements in saturated soil media a fully saturated soil domain is shown in Figure 6 below. The model considers the coupling of finite and infinite elements considering all degrees of freedom. The restraint conditions at the bottom are fixed boundaries as shown in the Figure 6.

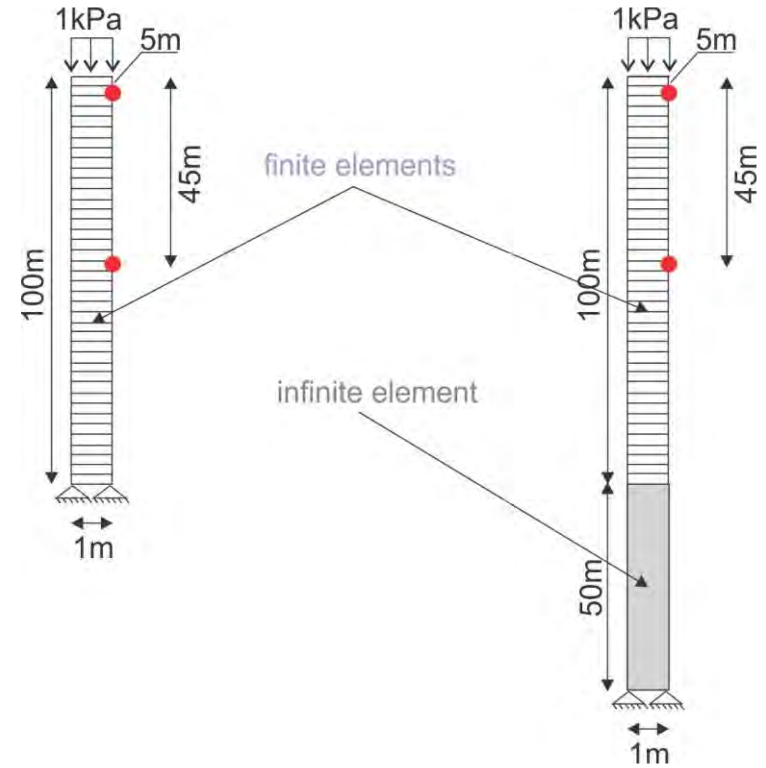


Figure 6. Fully saturated soil domain discretized by finite and infinite elements

As can be seen in Figure 6 the vertical soil column is modelled in two ways considering the discretization without and with infinite elements. The soil properties are given in the Table 2 below.

Table 2. Mechanical Properties of soil medium

Young's modulus of elasticity	E = 0.8333 kPa
Poisson's ratio	$\nu = 0.25$
Solid grain density	$\rho_s = 0.31$ kg/m³
Bulk modulus of solid grains	$K_s = \infty$
Bulk modulus of water	$K_f = 40$ kPa
Fluid density	$\rho_f = 0.2977$ kg/m³
Initial porosity	n = 0.33
Permeability	$k = 4.883 \times 10^{-3}$ m^2

In order to show the applicability of infinite elements in saturated soil model, the infinite elements have been placed at the bottom and two points of interest at depths of 5m and 50m have been selected to compare the of results. At the top of the soil layer, a fixed pressure of 1kPa is applied as a transient load.

In Fig. 7 and Fig.8 the time histories of displacements and water pressure at the depths of 5m and 45m for the transient wave propagation problem are presented. It can be observed that there is a good comparison between the analytical solution and the numerical one obtained by using coupled finite-infinite elements. However, when the fixed boundary is used at the bottom of the finite elements the accuracy of the numerical results become significantly worse because spurious reflections take place at the artificial boundary and the reflected waves propagate back to the near field system. The displacement is considerably underestimated in the case using the artificially fixed boundary. This fact indicates that, if the artificially fixed boundaries are used in the analysis, the near field of the system should be made large enough to avoid reflections on the artificially truncated boundary within the duration of the analysis. Otherwise, the numerical results will be affected by the reflected wave. Although a small numerical oscillation in the pore fluid pressure exists, in the case of using the absorbing boundaries it decreases quickly as time goes on. Thus, it is concluded that the use of the proposed absorbing boundary is an effective and efficient way of modelling the far field of the system for the transient wave problem. As can be seen from the figures, in the cases where the infinite elements are used the results show good correlation with the analytical results for both vertical displacement and water pressures. This verifies the correctness of the proposed infinite absorbing infinite elements.

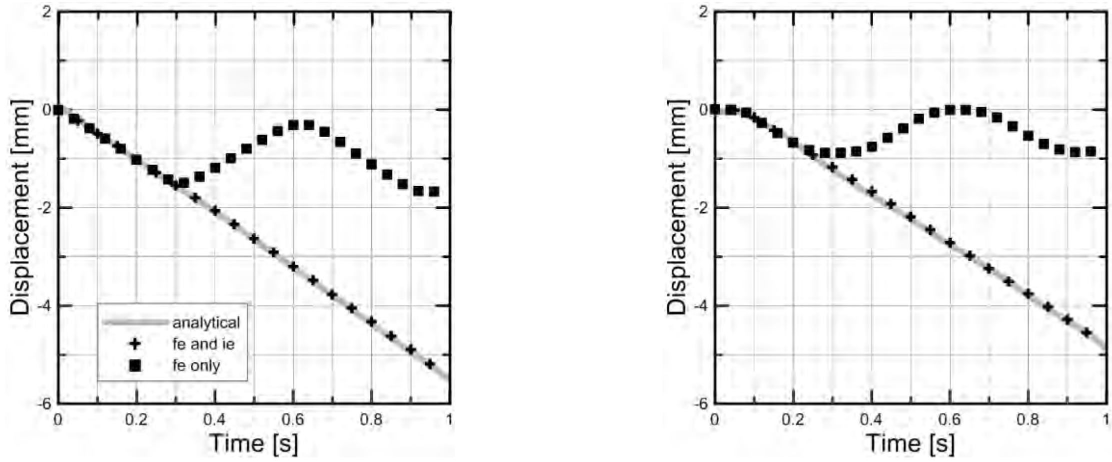


Figure 7. Time histories of displacement at 5m and 50m depth

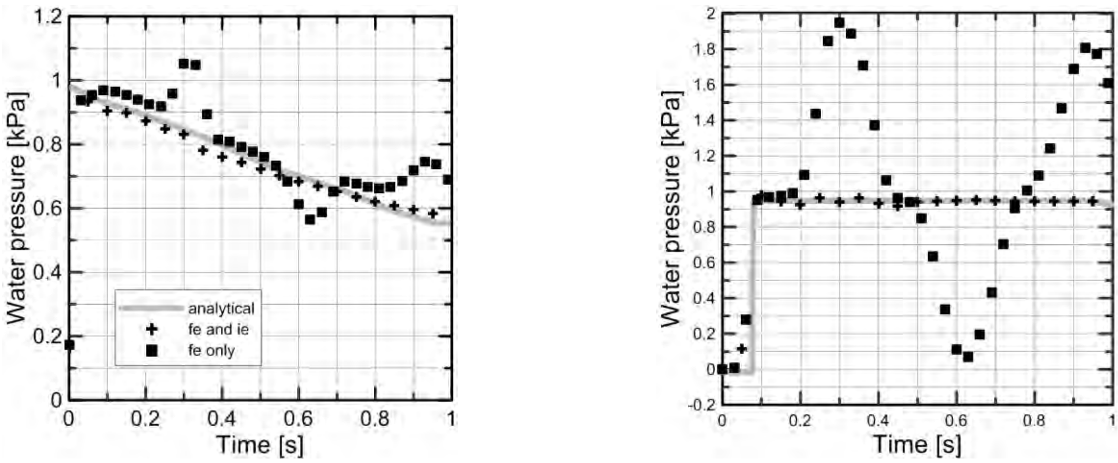


Figure 8. Time histories of pore water pressure at 5m and 50m depth

4. NUMERICAL SIMULATION OF AN EARTH DAM CONSIDERING INFINITE ELEMENT BOUNDARIES

The case study shown in Oettl [9] has been simulated in order to implement the proposed saturated infinite elements. In this study, water flow through an earth dam is simulated considering both dam body and the laying soil layers extending to infinity. The material parameters for the solid phase of the earth dam problem are given in Table 3.

Table 3. Material parameters for solid phase of the earth dam problem

Geometry		Dam	Dam	Soil layers	Infinite elements
Material parameters	Symbols	Hypoplastic	Linear	Linear	Linear
Density of solid phase	ρ_s (t/m^3)	2.7	2.7	2.7	2.7
Density of water phase	ρ_w (t/m^3)	1	1	1	1
Permeability	k (m^2)	10^{-7}	10^{-7}	10^{-7}	10^{-7}
Permeability of the drainage filter	k (m^2)	10^{-2}	10^{-2}		
Compression modulus of solid phase	K_s (kPa)	10^9	10^9	10^9	10^9
Compression modulus of water phase	K_w (kPa)	2 x 10^4	2 x 10^4	2 x 10^4	2 x 10^4
Dynamic viscosity of water	μ_w (kNs/m^2)	1.31 x 10^{-6}	1.31 x 10^{-6}	1.31 x 10^{-6}	1.31 x 10^{-6}
Elasticity modulus	E (kPa)		7000	9000	9000
Poisson's ratio	ν		0.3	0.3	0.3
Porosity	n	0.5	0.5	0.5	0.5
Critical friction angle	φ_c	35			
Granulate hardness	h_s (MPa)	1600			
Exponent	n	0.39			
Minimum void ratio	e_{d0}	0.62			
Critical void ratio	e_{c0}	0.94			
Maximum void ratio	e_{i0}	1.08			
Numerical parameter	α	0.2			
Numerical parameter	β	1			
Intergranular strain	R	0.0001			
Intergranular strain	m_r	2.5			
Intergranular strain	m_t	9.0			
Intergranular strain	β_r	0.25			
Intergranular strain	χ	9			

In this work, the same dam geometry as [9] is taken into consideration, whereas the material model for the body is taken as non-linear (hypoplastic) [10]. The analysis performed focuses on the dynamic analysis case with the inclusion of the surrounding field which is composed of infinite elements as shown in Fig. 6 and Fig.7.

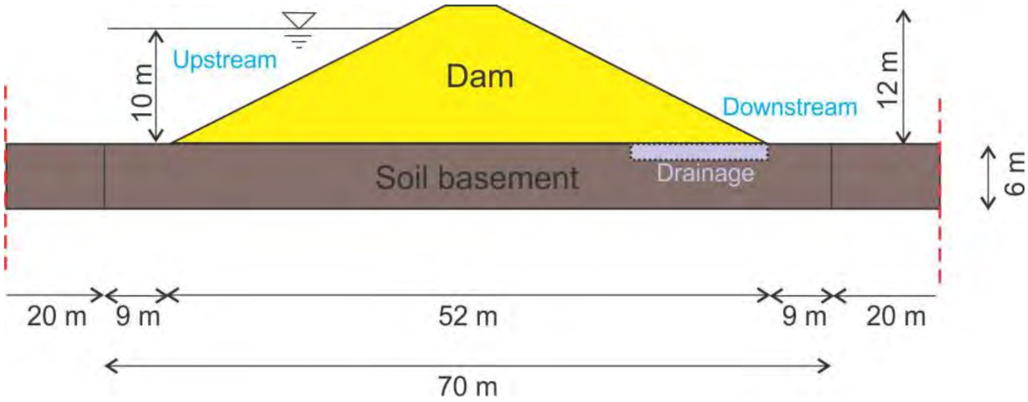


Figure 9. Coupled soil-dam system

The geometry of the dam is shown in Fig. 6 with the cross section width of 52 m at the base which is reduced to 4 m at the top. The height of dam is 12 m. In order to get a drainage of the leakage occurring through the dam and thus to prevent stability problems, a drainage with a length of 12 m is provided at the base of the downstream slope. The height of the water level at the upstream slope is 10 m. Furthermore, the soil used for the construction of the earth dam is considered to be homogeneous and isotropic with respect to the coefficient of water permeability. In the numerical simulation of the problem, both earth dam and base are taken into consideration. The domain is discretized by quadrilateral elements as given in Fig. 7.

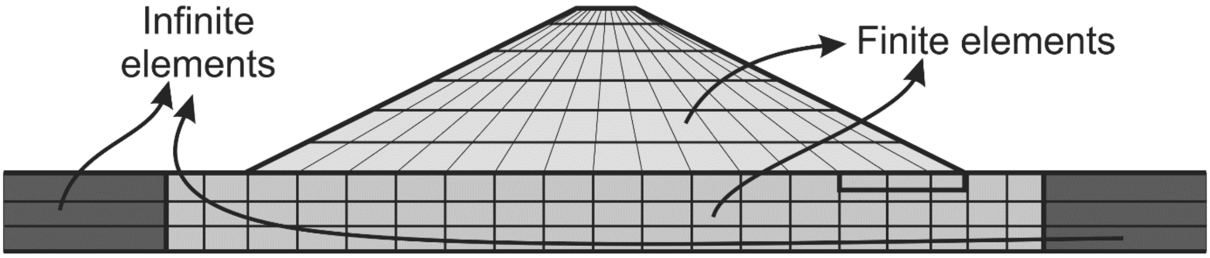


Figure 10. Element types in the simulation of dam problem

The air stress is taken to be atmospheric. The matric suction is equal to the negative value of the hydrostatic stress in the water phase which also governs the degree of saturation. This explains the reason behind defining saturation relations, namely, to facilitate the simulation of partially saturated soil media. It's worth noting that in classical seepage analysis, the soil skeleton is presumed to be rigid, and only the flow problem is examined. In this case, an earth dam of trapezoidal cross section built to retain reservoir water is considered numerically. The bottom boundary is modelled as a long layer of soil extending to infinite. At the drainage, in the bottom boundary of the dam, in the vicinity of the downstream slope, the initial water stress is set to zero. Therefore, a permeable boundary at the drainage is simulated. At the ends of the soil layer infinite elements are used to absorb the waves.

Similar boundary conditions with respect to the water phase are assumed for the dam at the top and at the upstream slope above the water level in the reservoir. The presence of infinite elements does not affect the fluid pressure distribution at the boundary with finite elements. The typical curve indicating the position of a zero hydrostatic water stress, i.e. the so called "phreatic surface", which stretches from the position of the water level to the upper end of the drainage region. In the region above this curve, the tensile water stress according to the initial conditions are accepted good. Due to the assumed atmospheric air stresses the development of the degree of water saturation is governed by the negative hydrostatic water stress. Starting from this steady state of saturation, the computation is carried out for a 10 seconds period of an earthquake input. The fully coupled analyses are performed using the acceleration time history of the El Centro earthquake [11] with a scaled peak ground acceleration of 0.25g and the results presented. Horizontal displacements and the pore pressure build up are shown in the Figures 11-12.

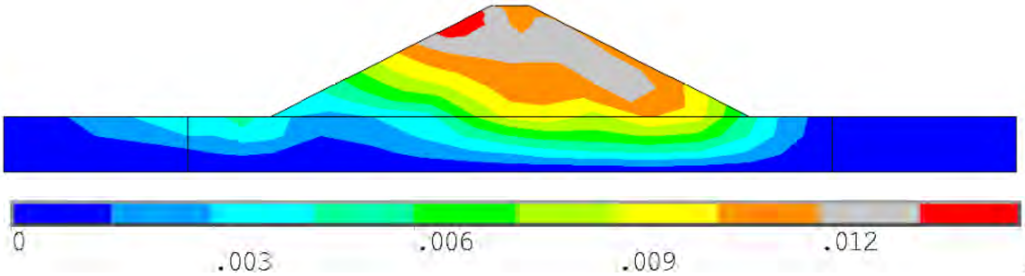


Figure 11. Horizontal displacement at the end of earthquake input

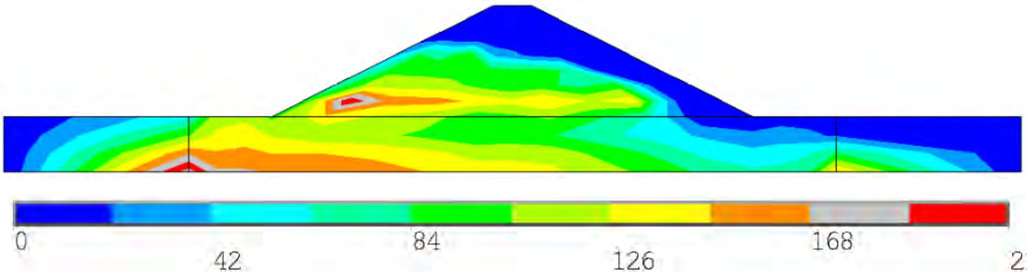


Figure 12. Pore pressure at the end of earthquake input

As can be seen from figures 11-12, the horizontal displacement distribution in the dam body at the end of earthquake input shows the deformation which is mainly due to the effect of the non-linear hypoplastic modelling of the solid phase of the soil medium. On the other hand, upon comparing the pore water pressure distributions, it is evident that there is an elevation in the pore water pressure at the upper section of the dam body due to the earthquake loading. In both cases the infinite elements have proven to be stable elements, facilitating the extension of the deformation and pore pressure spreading to infinity. Thus, it can be concluded that the infinite elements can be used as boundary conditions in saturated soil media in which the domain of interest lays within the region of the finite elements.

5. CONCLUSION

The proposed multiphase approach combined with boundary elements, is derived for simulation of unbounded saturated soil media. The usage of infinite elements as boundary conditions together with finite elements in numerical simulations gives good results. On the other hand, in case of numerical simulation of an earth dam, the pore pressure build-up and displacements have shown successful due to the non-linearity in the modelling of soil medium. The newly combined infinite elements have been considered as good replacement for far-field geometry in which the waves are absorbed successfully. The pore pressure build up and horizontal displacements for the earth dam presented, show the continuity between finite and infinite elements. Summarizing, the proposed multiphase simulation can be used for further more complex problems where experimental values are scarce. Thus, it can be concluded that the usage of the proposed numerical simulation is an efficient and inexpensive way of modelling the far field of the saturated soil domains.

6. APPENDIX

The mass matrices are given as follows:

$$\mathbf{M} = \int \mathbf{N_u}[\rho_s(1-n) + nS_w\rho_w]\,\mathbf{N_u}\,d\Omega$$

$$\mathbf{M}_f = \int \nabla\mathbf{N}_\mathbf{p}^\mathrm{T} \frac{\mathbf{k}k_{rf}}{\eta_f} \mathbf{N_u}\,d\Omega$$

The coupling matrix follows as:

$$\mathbf{C}_\mathrm{sf} = \int \mathbf{N}_p^T\,\alpha S_f m^T \mathbf{L}\mathbf{N_u}\,d\Omega$$

The compressibility matrix is given as:

$$\mathbf{P}_\mathrm{ff} = \int \mathbf{N}_p^T \left[\frac{S_f}{K_f} + (\alpha - n)\,\frac{S_f}{K_s}\left(S_f + p_c\frac{\partial S_f}{\partial p_c}\right) - n\frac{\partial S_f}{\partial p_c}\right]\mathbf{N_p}\,d\Omega$$

The permeability matrix can be written as:

$$\mathbf{H}_{ff} = \int \nabla\mathbf{N}_\mathbf{p}^\mathrm{T} \frac{\mathbf{k}k_{rf}}{\eta_f} \nabla\mathbf{N_p}\,d\Omega$$

The domain forces follow as:

$$f_u = \int \mathbf{N}_\mathrm{u}\,[\rho_s(1-n) + nS_f\rho_f]\mathbf{g}\mathbf{N_u}\,d\Omega$$

$$\boldsymbol{f}_f = \int \mathbf{N}_\mathbf{p}^\mathrm{T} \frac{\mathbf{k}k_{rf}}{\eta_f}\rho_f\mathbf{g}\,d\Omega$$

REFERENCES

[1] Ehlers, W. and P. Blome, *A triphasic model for unsaturated soil based on the theory of porous media.* Mathematical and Computer Modelling, 2003. **37**(5): p. 507-513.

[2] de Boer, R., *Theory of Porous Media*. 2000, Berlin: Springer-Verlag.

[3] Theodorakopoulos, D.D. and D.E. Beskos, *Application of Biot's poroelasticity to some soil dynamics problems in civil engineering.* Soil Dynamics and Earthquake Engineering, 2006. **26**(6–7): p. 666-679.

[4] Edip, K., et al., *Development of coupled numerical model for simulation of multiphase soil.* Computers and Geotechnics, 2018. **96**: p. 118-131.

[5] Zienkiewicz, O.C., C. Emson, and P. Bettess, *A novel boundary infinite element.* INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING, 1983. **19**(3): p. 393-404.

[6] Edip, K., *Development of three phase model with finite and infinite elements for dynamic analysis of soil media*. 2013, Ss. Cyril and Methodius: Institute of Earthquake Engineering and Engineering Seismology.

[7] Abdel-Fattah, T.T., H.A. Hodhod, and A.Y. Akl, *A novel formulation of infinite elements for static analysis.* Computers & Structures, 2000. **77**(4): p. 371-379.

[8] Sesov, V., et al., *Development of New Infinite Element for Numerical Simulation of Wave Propagation in Soil Media*, in *Experimental Research in Earthquake Engineering*. 2015, Springer. p. 423-436.

[9] Oettl, G., *A Three-Phase FE-Model for Dewatering of Soils by Means of Compressed Air*. 2003, Universitaet Innsbruck.

[10] Edip, K., et al. *Coupled Approach in Simulation of Earth Dam*. in *16th European Conference on Earthquake Engineering* 2018. Thessaloniki, Greece: The European Association for Earhtquake Engineering.

[11] Edip, K., et al., *Numerical modelling of saturated boundless media with infinite elements.* Acta Geotechnica, 2021. **16**(8): p. 2683-2692.

Applying concepts of Reliability, Risk, and Resilience in the Management of Civil Infrastructures

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This paper presents a comprehensive exploration of the interactions among reliability, robustness, risk, and resilience in the context of efficient and sustainable civil infrastructure management. For a thorough understanding of how these crucial concepts can be integrated to enhance the management of civil infrastructures, each concept is systematically explored. The discussion begins by defining reliability as the probability of a civil infrastructure achieving its intended function without failure during its service life, which is a crucial indicator for effective management. Risk is then characterized as the expected value of consequences arising from exposure to hazards, encompassing the modeling of exposure, infrastructure vulnerability, and the resultant consequences. The paper subsequently delves into the concept of robustness, highlighting its role in evaluating the potential for disproportionate collapse and its influence on reducing infrastructure vulnerability. In turn, resilience is explored as the capacity of infrastructure to withstand or rapidly recover from hazardous events, with a focus on criteria such as robustness, redundancy, resourcefulness, and rapid recovery. Quality control is positioned as a crucial component of infrastructure management, emphasizing the need for continuous monitoring and decision-making based on Key Performance Indicators (KPIs) like safety, availability, economy, and reliability. These KPIs are integral in developing a risk-informed approach, quantifiable in monetary terms, and pivotal in the decision-making process through Net Present Value (NPV) theory. The paper addresses advancements in management tools, focusing on the transition to risk- or resilience-based systems, the integration of robust predictive and decision-making tools, and the adoption of digital twin models. These developments signify a move towards more sustainable management practices. Finally, this paper outlines future research directions and potential contributions toward advancing the implementation of sustainable management of civil infrastructures.

Keywords: *Risk, Robustness, Resilience, Quality control, Sustainable Management, Infrastructure systems.*

1. INTRODUCTION

Civil infrastructures are crucial for maintaining and improving the quality of life and economic stability of societies. While a significant portion of the built infrastructure is reaching the end of its service life, the demands on these systems are intensifying, driven by factors like climate change effects, which manifest in increased frequency and severity of extreme weather events, such as hurricanes, heavy rainfall, floods, and wildfires [1], [2]. To address these challenges, infrastructure owners have developed methodologies to manage their assets efficiently, supported by quality control (QC) procedures [3]. When applied to civil infrastructures, QC specifies the procedures designed to guarantee that the service either meets or surpasses the expectations and requirements of users and the broader community [3].
Traditionally, asset management methodologies have focused on ensuring safety and serviceability while minimizing economic resources, emphasizing reliability and risk-based decision-making. Recently, the integration of resilience into these methodologies has gained increased attention, recognizing the benefits of infrastructure systems that can quickly recover and adapt after extreme events that disrupt the infrastructure operation [2]. Furthermore,

integrating sustainability considerations into infrastructure management is increasingly seen as a strategic imperative for the future of the built environment [4]. Recognizing this broadened and more holistic perspective, this paper aims to provide an overview of *i)* the central concepts to support the design and management of civil infrastructure: reliability, risk, robustness, resilience, and sustainability, *ii)* the characteristics of existing QC frameworks to ensure adequate infrastructure functionality throughout its service life, and *iii)* the emerging technologies that are envisaged to improve the efficiency in the life cycle management of critical infrastructures, such as Artificial Intelligence (AI), Structural Health Monitoring (SHM), Building Information Modeling (BIM), and Digital Twins (DT). As illustrated in Figure 1, the QC framework is identified as a pivotal point where the management concepts and technological innovations converge to optimize infrastructure management. Essentially, infrastructure systems face several threats that may cause their failure, such as aging, natural hazards, and climate change effects, and also influence their development, operation and even impose environmental emissions. To cope with these issues, the central concepts from Figure 1 have emerged to support the management of civil infrastructures, with escalating scope as represented by the increasing length of the arrows, i.e., from the specific scope of reliability to the broadest scope of resilience and sustainability. However, the review indicates a lack of a QC framework that incorporates all management concepts from a holistic perspective. Moreover, it evidences that the adoption of emerging technologies within quality control plans (QCPs) has been limited. Therefore, the paper suggests future research directions and potential contributions for the optimal integration of these elements to ensure efficient and sustainable decision-making throughout the infrastructure life cycle.
It is worth noting that many of the applications presented in this paper are focused on bridges. Nonetheless, the methodologies presented apply to other civil infrastructure.

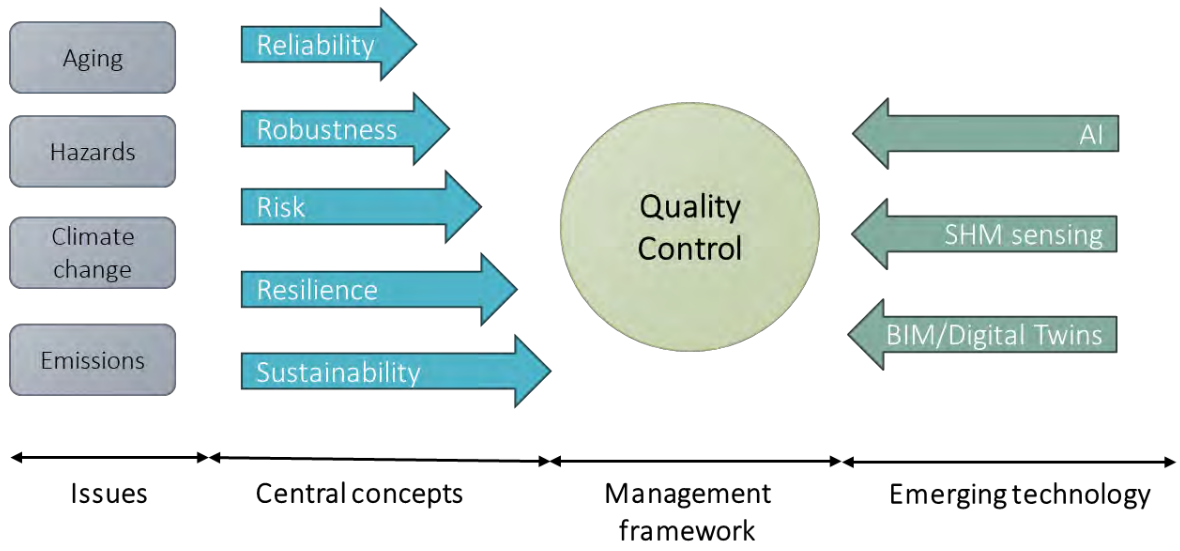

Figure 1. Integration of management concepts and emerging technologies in the development of QCPs for Civil Infrastructures

2. CENTRAL CONCEPTS FOR MANAGEMENT OF CIVIL INFRASTRUCTURES

2.1. Reliability

Modern codes establish safety and serviceability criteria based on reliability, defined as the probability that a component or system will remain functional throughout its service life. A standard reliability measure is the generalized reliability index, which is defined as [5]:

$$\beta = -\Phi^{-1}\left(P_f\right) \tag{1}$$

where P_f is the probability of failure and $\Phi^{-1}(\cdot)$ is the inverse Gaussian distribution. For a structural component with uncertain resistance represented by a random variable R, with probability density function $F_R(x)$, and subjected to an uncertain load represented by a random variable S, with probability density function $f_S(x)$, the probability of failure P_f can be calculated as [5]:

$$P_f = P(R - S \leq 0) = \int_{-\infty}^{\infty} F_R(x)\, f_S(x)\; dx \tag{2}$$

There is no general closed-form solution to the integral in Equation 2. Except for special cases, e.g., when the load and resistance are statistically independent and normally distributed variables, numerical approximate methods are necessary for most practical applications. For instance, conducting reliability analysis for a bridge involves the probabilistic characterization of materials, geometries, and model uncertainty for describing the resistance, and the characterization of permanent, variable and accidental loads, and load model uncertainty. Moreover, finite element models (FEM) are frequently necessary to conduct non-linear structural analysis and evaluate the maximum carrying capacity of the bridge structural system. Due to the computational intensity of employing FEM for probabilistic analysis, surrogate models have become widely adopted as they facilitate replacing a complex numerical model, such as FEM, with a less computationally demanding model capable of predicting the desired output with adequate accuracy for reliability analysis. Numerous techniques for surrogate modeling for reliability analysis are documented in the literature, including kriging, polynomial chaos expansion, neural networks, support vector machines, and response surface methodology (see [6] for a review). In this regard, Galvão et al. [7] employed kriging-based surrogate modeling in combination with non-linear FEM to estimate the probability of structural failure of a bridge, specifically focusing on the impact of construction error scenarios on structural safety. These types of analysis allow the comparison of the obtained reliability index with target reliability requirements recommended by codes. For instance, the Eurocode [8] specifies a target annual reliability index for safety at 4.7, which corresponds to an occurrence probability of 1.3×10^{-6}, while for serviceability, it is 2.9, corresponding to an occurrence probability of 1.9×10^{-3}. These values correspond to structures belonging to reliability class 2, which refers to structures with medium consequences of failure. Essentially, the selection of the target reliability level must consider the potential consequences of failure, including risk to life or injury, economic losses, and social impacts, as well as the costs and efforts necessary to mitigate the risk of failure [5].

2.2. Risk

Several methodologies for risk assessment have been formulated within different application domains. This variability often renders comparisons and integrations of risk assessments across various fields challenging. In the context of engineering decision-making, risk is typically defined as the expected consequences associated with a given event. Thus, the risk R_E associated with a specific event E is evaluated by multiplying the probability p_E of the event occurring (also known as probability of occurrence) with the associated consequences c_E of the event, expressed as [9]:

$$R_E = p_E \times c_E \tag{3}$$

Civil infrastructures are exposed to a variety of hazardous events (H_k). These events should be characterized probabilistically, represented as $p(H_k)$, where k ranges from 1 to n_H, where n_H indicates the total number of exposures (snow loads, earthquakes, floods, or combinations of these events). Moreover, civil infrastructures are commonly comprised of n_C individual components, each associated with a distinct set of damage states, symbolized as D_{ij}, where $i = 1,2,\dots,n_C$, and $j = 1,2,\dots,n_{Di}$, where n_{Di} is the number of damage states of component i. Thus, the risk due to direct consequences R_D can be evaluated through the expected value of the direct consequences, considering all n_H potential exposure events and all n_{CDS} damage states of all components as [9]:

$$R_D = \sum_{k=1}^{n_H} \sum_{l=1}^{n_{CDS}} p(D_l|H_k) \times C_D(D_l) \times p(H_k) \tag{4}$$

where $C_D(D_l)$ are the direct consequences associated with the l^{th} of n_{CDS} possible damage states of all components denoted as D_l, which are conditional on the exposure event as described by $p(D_l|H_k)$. In addition to direct consequences, indirect consequences may arise in civil infrastructures due to the process of internal redistribution after a hazard event or due to the loss of functionality, which depends on the state of its components. Thus, there are n_{SDS} possible different system states S_m associated with indirect consequences C_{ID}, conditional on the state of the components D_l, the direct consequences $C_D(D_l)$ and the exposure H_k. The risk due to indirect consequences is then assessed through the expected value of the indirect consequences regarding all possible exposures and component states, as [9]:

$$R_{ID} = \sum_{k=1}^{n_H} \sum_{l=1}^{n_{CDS}} \sum_{m=1}^{n_{SDS}} C_{ID}\big(S_m, C_D(D_l)\big) \times p(S_m|D_l, H_k) \times p(D_l|H_k) \times p(H_k) \tag{5}$$

Following risk assessments, the acceptability of associated risks becomes a crucial consideration. To this end, it is recommended to distinguish between tangible risks, i.e., quantifiable in monetary terms, and intangible risks, including loss of life, injuries, and environmental impacts [8], [9].

2.3. Robustness

In the domain of structural reliability and risk assessment, robustness is described as the ability of a structure to withstand a specified load condition or the consequences of human error without being damaged to an extent disproportionate to the original cause [8]. The Joint Committee on Structural Safety (JCSS) [9], a pre-normative body in civil engineering, describes the robustness of a system through a robustness index I_R defined as the ratio of direct risks to total risks within a given time period:

$$I_R = \frac{R_D}{R_D + R_{ID}} \tag{4}$$

This formulation of robustness characterizes the degree to which a system can contain or limit indirect consequences associated with a hazard event. In [10], another formulation of robustness was computed to assess the impact of design and construction errors on the structural safety of a prestressed reinforced concrete bridge. To this end, the performance of the structural system was measured through the reliability index, and a performance curve was computed over increasing error magnitudes. The robustness index was established based on the area under the normalized performance function curve over the range of damages. This method facilitates a comparative analysis of how various types and magnitudes of errors (or damages) affect the structural system's robustness. In principle, it is recommended to ensure that civil infrastructures are designed and managed with an appropriate degree of robustness.

2.4. Resilience

While the concept of resilience varies among disciplines, the definition of community seismic resilience from Bruneau et al. [11] has been widely adopted for civil infrastructures. In this context, resilience is described as the capacity of social entities, such as organizations and communities, to reduce hazard impacts, manage disaster consequences, and perform recovery efforts that lessen social disturbance and diminish the impacts of subsequent hazard events. Following this definition, resilience (R) has been mathematically described as [11]:

$$R = \int_{t_0}^{t_1} \left(100 - Q\,(t)\right)\, dt \tag{5}$$

where $Q\,(t)$ represents the quality of a community's infrastructure, which varies with time and takes a value of 100% if there is no degradation in service and 0% if no service is available. If an extreme event occurs at a time t_0, it may cause sufficient damage to the infrastructure, such that the quality will be reduced from 100% to 50%. Then, restoration activities are performed until a time t_1 when the infrastructure is completely repaired. In this manner, community resilience can be measured by the magnitude of the expected degradation in quality over time, i.e., the integral of the resilience curve. The shape of this curve is associated with four properties of resilience: *i)* Robustness, *ii)* Redundancy, *iii)* Resourcefulness, and *iv)* Rapidity [11]. Therefore, the concept of resilience for the management of civil infrastructures has broadened the plausible decision alternatives beyond strengthening infrastructures to decisions on improving preparedness and adaptive capacity. For instance, Arango et al. [12] introduced a resilience-based methodology to fire analysis using GIS (GIS-FA) to support the management of road transport networks under wildfire hazards. That methodology evaluates the infrastructure's preparedness level and provides guidance for proactive wildfire management strategies. It underscores the importance of both reactive actions, like emergency response, and proactive measures such as landscape management and infrastructure adaptation, as shown in [2]. These strategies are crucial in the face of climate-induced challenges and contribute to sustainability by reducing environmental, social and economic impacts [13].

2.5. Sustainability

In 1987, the report "Our Common Future" by Brundtland [14] placed the concept of sustainability at the forefront of the global political agenda. Following [14], the concept of sustainability can be defined as the "ability to conduct development in a manner that satisfies current needs without jeopardizing the ability of future generations to meet their own needs." As civil infrastructures play a critical role in the development of society, integrating sustainability principles into their planning, design, construction, and operation is compulsory. To this end, Life Cycle Assessment (LCA) and Social Life Cycle (S-LCA) have been prominent methodologies for evaluating the environmental and social impacts of infrastructure from the phase of design until the end-life, thus enabling decision-makers to identify and implement measures for reducing resource consumption, emissions, and overall environmental impact [4]. Moreover, the innovation in material sciences to incorporate sustainable and circular materials such as recycled composites and self-healing concrete, which reduce the carbon footprint of infrastructures, represents a step towards sustainable infrastructure development [15]. Further innovations such as modular construction techniques and prefabrication processes also contribute to minimizing resource and energy consumption, as well as implementing emerging technologies such as those depicted in Figure 1, which improve the efficiency in managing civil infrastructures.

3. QUALITY CONTROL FRAMEWORK FOR ASSET MANAGEMENT

The application of quality control plans to civil infrastructure refers to all activities and tools necessary to ensure quality in the service provided by the infrastructure during its service life. For the case of road infrastructure, the service quality is presumed to be met if performance goals are fulfilled from the road users' perspective. In this regard, a standardized approach for quality control of existing bridges was established within the COST Action TU1406 [16]. The suggested approach included defining performance indicators (PIs) for the assessment of roadway bridges, specifying performance goals (PGs), determining key performance indicators (KPIs), and establishing quality control plans (QCP). A PI refers to a measurable and quantifiable parameter related to bridge performance, which is collected through visual inspections, on-site tests, and structural health monitoring. KPIs are determined from several PIs to help assess the performance objectives for establishing QCPs. Within COST Action 1406, five KPIs were adopted for the QC framework [3]: Reliability, Availability, Safety, Economy and Environment. These KPIs were assessed qualitatively using an ordinal scale from one to five, with a score of one indicating optimal performance. In this way, the performance evaluation was visually represented through a "spider net" diagram, where the larger the area enclosed by the KPI values, the better the bridge performance [3]. This initial assessment comprised the static part of the QCP framework. A second dynamic assessment of the QCP consisted of forecasting the evolution of KPIs and evaluating different maintenance scenarios to identify the optimal one [3].
Baron et al. [17] demonstrated the application of the QCP to two existing reinforced concrete bridges, one in Portugal and another in North Macedonia. Four KPIs were evaluated, namely Reliability, Safety, Availability and Economy. The reliability was assessed through probabilistic analysis involving non-linear finite element analysis (FEM) models to compute the reliability index, considering the identified damages. Three maintenance scenarios were considered over a 100-year horizon: "Do nothing and rebuild," i.e., allowing deterioration to evolve and eventually rebuilding the structure; "Corrective," i.e., applying periodic corrective maintenance to improve the reliability; and "Preventative," i.e., performing preventative actions aimed at maintaining the reliability. To compare these scenarios, the KPIs should be normalized and discounted in the same manner as future expenditures are discounted to present, i.e., through Net Present Value (NPV) theory [3]. The net present KPIs assuming a discount rate of 2% were

represented in the "spider net" diagram, and the optimal scenario was deemed the one with the largest area enclosed by the normalized KPIs at a specified time period.
The QCP elaborated within the scope of the COST Action TU1406 aimed at supporting maintenance decisions based on the life cycle performance of bridges. However, the QC framework could be extended to incorporate new indicators related to the resilient and sustainable performance of road infrastructures. Such a holistic approach incorporating these indicators is lacking and is recommended as future research.

4. EMERGING TECHNOLOGIES IN ASSET MANAGEMENT

4.1. Artificial Intelligence (AI)

As highlighted in Section 2.1, Machine Learning (ML) techniques, including Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs), have been increasingly used for reliability analysis. SVMs have effectively addressed complex classification and regression problems for that purpose. A key feature of SVMs is their reliance on only a subset of data points for model construction (small experimental design), significantly enhancing computational efficiency [6]. Another application of ML techniques is presented in [18], where several models were implemented to predict the deterioration of transport infrastructures due to aging and environmental stressors. Among these, ML techniques, namely ANNs, offered a superior accuracy factor and achieved the lowest prediction errors. Therefore, it was proved that applying these techniques represents a convenient alternative to predict the performance of infrastructures over their life cycle and thereby optimize resource allocation of maintenance activities.
Furthermore, emerging research has increasingly incorporated ML algorithms in scour detection to enhance prediction accuracy. In a comprehensive review, [19] examined various ML algorithms, such as convolutional neural networks, support vector machines, and deep neural networks, and assessed their effectiveness compared to traditional empirical formulas used for scour prediction. This review highlights the promising capability of ML in not only improving prediction accuracy but also in efficiently managing complex data sets, including field and laboratory data on scour depth measurements taken with different technologies such as point laser sensors, vertical point gauges, and electronic total station devices. Therefore, integrating emerging phenonema, such as scour, detection technologies enhanced by utilizing ML algorithms represents a promising approach to enhance civil infrastructure monitoring and management. Also in the geotechnical field, important advances in incorporating ML algorithms are being made, markedly enhancing the safety of transportation infrastructure. [20] introduced an innovative classification system designed for rock and soil cuttings, alongside embankments. This system leverages the synergy of modern optimization techniques and soft computing algorithms, using visual characteristics as the basis for classification.

4.2. Structural Health Monitoring (SHM) Systems

Visual inspections are the most common and predominant condition assessment technique employed for managing civil infrastructures such as bridges [3]. However, due to the limitations of visual inspections, improved practices such as Structural Health Monitoring (SHM) have been encouraged to enhance the condition assessment of infrastructures and, thereby, predict their performance over their service life [18]. In this context, [21] introduced a method for SHM of a steel truss bridge by integrating vibration measurement tests with an Artificial Neural Network (ANN). In that study, a comprehensive approach that involves creating and updating a Finite Element Model (FEM) was used to assess the dynamic characteristic of the Chuong Duong Bridge. This updated FEM was then used to generate training data for the ANN, simulating various damage scenarios. The ANN's effectiveness in accurately identifying damage locations and levels was highlighted, showcasing its potential to enhance SHM practices. This innovative integration of vibration measurements with machine learning algorithms represents a significant advancement in ensuring the safety of critical infrastructure.

4.3. Digital Transformation: Building Information Modeling (BIM) and Digital Twins (DT)

Currently, many countries lack high-quality data for effective infrastructure management, partly due to inadequate information management systems [3]. To address this issue, the new generation of asset management systems is increasingly embracing digital transformation, incorporating Building Information Modeling (BIM) and Digital Twins (DT). An example of an advanced approach to bridge maintenance by employing the concept of a Digital Twin (DT) model was presented by [22]. This system integrates a detailed 3D information model with a digital inspection methodology, enhancing the efficiency and precision of bridge management processes. The DT model effectively captures the bridge's current state by harnessing advanced technologies such as UAV-based 3D scanning and image processing, facilitating accurate damage detection and assessment. The significance of this approach lies in the effective combination of a real-time 3D model with practical maintenance strategies, offering an innovative solution for supporting the long-term management of critical infrastructure. Another application of the concept of DT for effective infrastructure management was developed by [23]. In that work, the DT model incorporated fatigue assessment of railway steel bridges by employing an innovative integration of a Fatigue Analysis System (FAS) and Building Information Modeling (BIM). This integration enabled a dynamic, real-time simulation of various traffic and geometric conditions to predict fatigue damage effectively. The main advantage of the DT model was its ability to visualize fatigue progression in bridge components, enhancing predictive maintenance and decision-making processes. The DT model was validated through a case study of the Várzea Bridge in Portugal, demonstrating a high accuracy in forecasting fatigue states. Therefore, this integration of DT technology with traditional structural analysis methods represents a robust tool for infrastructure management.

5. CONCLUSIONS AND FUTURE WORK

This paper presents an overview of the crucial concepts for managing civil infrastructures, together with the exploration of emerging technologies to enhance infrastructure management, and their potential integration into future management systems through the development of quality control procedures. Firstly, this paper provides the definition of the concepts of reliability, risk, robustness, resilience, and sustainability within the scope of management of civil infrastructures. The relevance of considering each of these concepts for the design and management of infrastructures was highlighted, and decision strategies such as increasing preparedness for recovery through emergency response plans, adaptive capacity through landscape management, and sustainable construction practices and materials, are recommended over traditional solutions, such as strengthening infrastructures, which involve larger environmental footprints.

Furthermore, a quality control framework developed in the context of roadway bridges was presented, and its contribution to the achievement of management goals was highlighted. The framework provides a systematic methodology to link performance goals to performance indicators (PIs) and establish quality control plans (QCP). This framework can be adapted to develop QCP for other civil infrastructures. Nonetheless, the performance goals need to be specific to the service provided by the infrastructure, and PIs and key performance indicators (KPIs) should be defined accordingly. In addition, incorporating indicators to ensure a resilient

and sustainable performance of infrastructures is lacking and recommended as future research for the successful implementation of QCP.
Finally, this paper presents emerging technologies that support sustainable asset management through efficient decision-making that optimizes resource allocation and reduces environmental impact. This is achieved through Artificial Intelligence (AI) models that improve infrastructure performance predictions, computational efficiency to solve reliability problems, and the processing of complex data sets. Moreover, implementing technologies such as Structural Health Monitoring (SHM) contributes to a more accurate assessment of the infrastructure performance, facilitating improved and timely decisions regarding maintenance actions. Lastly, the digital transformation of asset management by incorporating Building Information Modeling (BIM) and Digital Twins (DT) is a prominent step forward to advance in the life cycle management of critical infrastructure. Future research should aim to incorporate each of these emerging technologies within QCP to ensure the achievement of the specified target performance.

REFERENCES

[1] I. Stipanović *et al.*, *WG2 Technical Report: Performance Goals for Roadway Bridges of COST ACTION TU 1406: Establishment of a Quality Control Plan*. Boutik, 2017.
[2] E. Arango, M. Nogal, H. S. Sousa, J. C. Matos, and M. G. Stewart, “Improving societal resilience through a GIS-based approach to manage road transport networks under wildfire hazards,” *Transp. Eng.*, vol. 15, p. 100219, 2024.
[3] R. Hajdin, M. Kušar, S. Mašović, P. Linneberg, J. L. Amado, and N. Tanasić, “Establishment of a Quality Control Plan-WG3,” *TU1406-Quality Specif. Roadw. Bridg. Stand. a Eur. Lev.*, 2018.
[4] O. J. U. Leal, A. Fekete, R. R. Eudave, J. C. Matos, H. Sousa, and E. R. Teixeira, “A Systematic Review of Integrated Frameworks for Resilience and Sustainability Assessments for Critical Infrastructures,” *Struct. Eng. Int.*, pp. 1–15, 2023.
[5] J. JCSS, “Probabilistic model code,” *Jt. Comm. Struct. Saf.*, 2001.
[6] R. Teixeira, M. Nogal, and A. O’Connor, “Adaptive approaches in metamodel-based reliability analysis: A review,” *Struct. Saf.*, vol. 89, p. 102019, 2021.
[7] N. Galvão, J. C. Matos, R. Hajdin, L. Ferreira, and M. G. Stewart, “Impact of construction errors on the structural safety of a post-tensioned reinforced concrete bridge,” *Eng. Struct.*, vol. 267, p. 114650, 2022.
[8] B. Standard and others, “Eurocode—Basis of structural design,” *Eurocode 0*, 2002.
[9] Joint Committee on Structural Safety (JCSS), “Risk assessment in engineering. Principles, system representation and risk criteria.” JCSS, 2008.
[10] N. Galvão, J. C. Matos, D. V Oliveira, and R. Hajdin, “Human error impact in structural safety of a reinforced concrete bridge,” *Struct. Infrastruct. Eng.*, vol. 18, no. 6, pp. 836–850, 2022.
[11] M. Bruneau *et al.*, “A framework to quantitatively assess and enhance the seismic resilience of communities,” *Earthq. spectra*, vol. 19, no. 4, pp. 733–752, 2003.
[12] E. Arango, M. Nogal, H. S. Sousa, J. C. Matos, and M. G. Stewart, “GIS-based methodology for prioritization of preparedness interventions on road transport under wildfire events,” *Int. J. Disaster Risk Reduct.*, vol. 99, p. 104126, 2023.
[13] P. Bocchini, D. M. Frangopol, T. Ummenhofer, and T. Zinke, “Resilience and sustainability of civil infrastructure: Toward a unified approach,” *J. Infrastruct. Syst.*, vol. 20, no. 2, 2014, doi: 10.1061/(ASCE)IS.1943-555X.0000177.
[14] G. Bruntland and others, “Our common future,” *World Comm. Environ. 1 Dev.*, pp. 45–65, 1987.

[15] E. R. Teixeira, R. Mateus, A. F. Camoes, L. Bragança, and F. G. Branco, "Comparative environmental life-cycle analysis of concretes using biomass and coal fly ashes as partial cement replacement material," *J. Clean. Prod.*, vol. 112, pp. 2221–2230, 2016.
[16] J. Matos, S. Fernandes, M. Q. Tran, Q. T. Nguyen, E. Baron, and S. N. Dang, "Developing a comprehensive quality control framework for roadway bridge management: a case study approach using key performance indicators," *Appl. Sci.*, vol. 13, no. 13, p. 7985, 2023.
[17] E. A. Baron, N. Galvão, M. Docevska, J. C. Matos, and G. Markovski, "Application of quality control plan to existing bridges," *Struct. Infrastruct. Eng.*, vol. 19, no. 7, pp. 990–1006, 2023.
[18] M. Santamaria Ariza, I. Zambon, H. S. Sousa, J. A. e Matos, and A. Strauss, "Comparison of forecasting models to predict concrete bridge decks performance," *Struct. Concr.*, 2020.
[19] S. Tola, J. Tinoco, J. C. Matos, and E. Obrien, "Scour detection with monitoring methods and machine learning algorithms—a critical review," *Appl. Sci.*, vol. 13, no. 3, p. 1661, 2023.
[20] J. Tinoco, A. Gomes Correia, P. Cortez, and D. Toll, "An evolutionary neural network approach for slopes stability assessment," *Appl. Sci.*, vol. 13, no. 14, p. 8084, 2023.
[21] M. Q. Tran *et al.*, "Structural assessment based on vibration measurement test combined with an artificial neural network for the steel truss bridge," *Appl. Sci.*, vol. 13, no. 13, p. 7484, 2023.
[22] S. L. Chang-Su Shim Ngoc-Son Dang and C.-H. Jeon, "Development of a bridge maintenance system for prestressed concrete bridges using 3D digital twin model," *Struct. Infrastruct. Eng.*, vol. 15, no. 10, pp. 1319–1332, 2019, doi: 10.1080/15732479.2019.1620789.
[23] I. A. Nhamage, N.-S. Dang, C. S. Horas, J. Poças Martins, J. A. Matos, and R. Calçada, "Performing Fatigue State Characterization in Railway Steel Bridges Using Digital Twin Models," *Appl. Sci.*, vol. 13, no. 11, p. 6741, 2023.

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Structural and Earthquake Engineering

The behavior of flat slabs reinforced concrete structures with different floors, in seismic areas.

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The design and construction of tall buildings in seismic-prone areas must adhere to technical standards and regulations. However, these standards are often challenged by the preferences of architects, designers, and investors. There is a common desire for quick and cost-effective completion of the design and construction process. Balancing these considerations is crucial to ensure the safety and integrity of tall buildings, especially in areas prone to seismic activity. Horizontal structural elements like flat slabs made of reinforced concrete are highly sought after for their applicability in various structural systems, providing versatility in building use. Constructors often request and emphasize the use of flat slabs to expedite construction, minimize physical effort, and simultaneously lower construction costs. Architects also frequently make these requests to enhance the flexibility of interior organization and reorganization in residential and functional spaces. For the effective utilization of flat slabs as a structural component, structural designers need to conduct thorough analyses to understand and mitigate various effects. This involves exploring the potential of different geometric shapes, establishing the minimum geometric conditions for use, assessing the material qualities of the elements, and considering the boundary conditions of supports. Careful analysis by structural designers is crucial to ensure the reliability and safety of structures employing flat slabs. Support spaces, dimensions of vertical elements like columns and walls, and the risk of punching shear from columns into the slab are critical variables directly influencing the size of flat reinforced concrete slabs. Challenges arise in dealing with deflection developments influenced by the rheology of materials. The potential for seismic actions further heightens the risk associated with using flat slabs in structures with expansive support spaces and substantial floor loads. Careful consideration and analysis of these variables are essential for ensuring the structural integrity and safety of buildings employing flat slab systems, particularly in seismic-prone areas.

Keywords: *Flat slab, strengthening, penetration, period of oscillation.*

1. INTRODUCTION

The main aim of the work is to study structures using flat plate structural systems (without beams), comparing them with cases of structural systems supported by beams in areas of moderate and high seismicity. Various simulations have been used to make a comparison between them.

- People protection
- Limiting deformation
- Ensuring important facilities remain functional [1]

The seismic behavior of a structure during an earthquake critically depends on parameters such as the structure's shape, size, earthquake intensity, structural system, and the type of slab[3]. Achieving structural performance is linked to the materials used, construction technology, accuracy of calculation methods, and, of course, the cost of implementation [5][6].

2. STANDARDS FOR STRUCTURES, DEMANDS

To be clasifying as regular in plan according to EN1998-1, 4.2.3.2, a building must satisfy all the following conditions.

- The area within the outlines does not exceed 5%

- The ratio of the longest dimension of the object to the shortest one should not be greater than 4 ($L_{min} < \cdot 4L_{max}$)
- In each analysis direction and at every level of the structure, structural eccentricity must satisfy the following condition $e_{ox} \leq 0.3r_x$; $e_{oy} \leq 0.3r_y$; $r_x \geq l_s$ [2][11]

Where: e_{ox}- length of mass and stifness center; r_x- torsion radius; l_s- inercial radius.

- Conditions for the base regulation as per EC1998-1, 4.2.3.

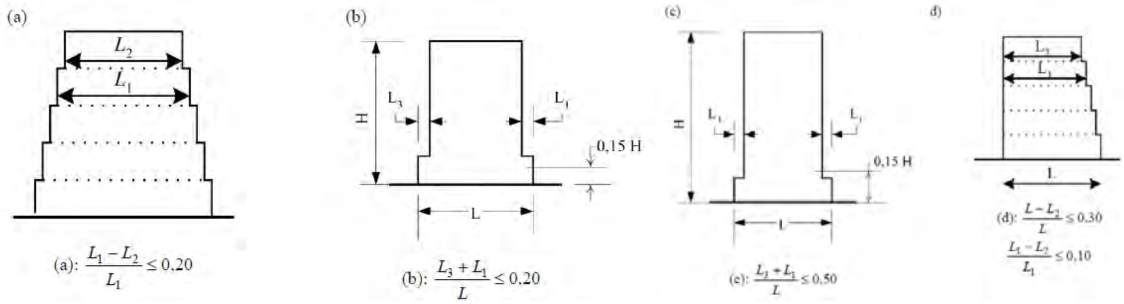


Figure 1. Regularity in verticality, according to European standards for the design and calculation of structures

Depending on the selection of structural elements in the design, we will have different structural systems such as:

Figure 2. Frame and dual frame structural shape.

3. IN BASE AND VERTICALITY NOT REGULAR STRUCTURE ANALYSIS OF BUILDING B+5

The reviewed building has a configuration of basement plus ground floor plus 5 upper floors. The positioning of the elements has been adjusted to accommodate architectural requirements.

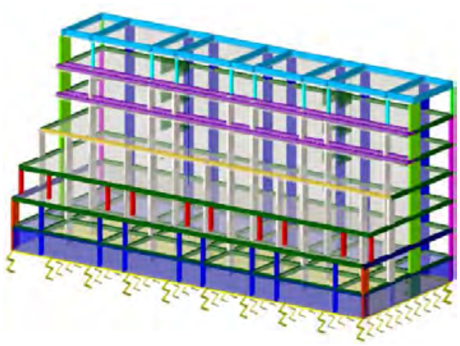


Figure 3. Computation modeling of the structure.

The structural system of the building is selected as a frame system with flat slabs, but there are also two cores made of reinforced concrete for the elevators.

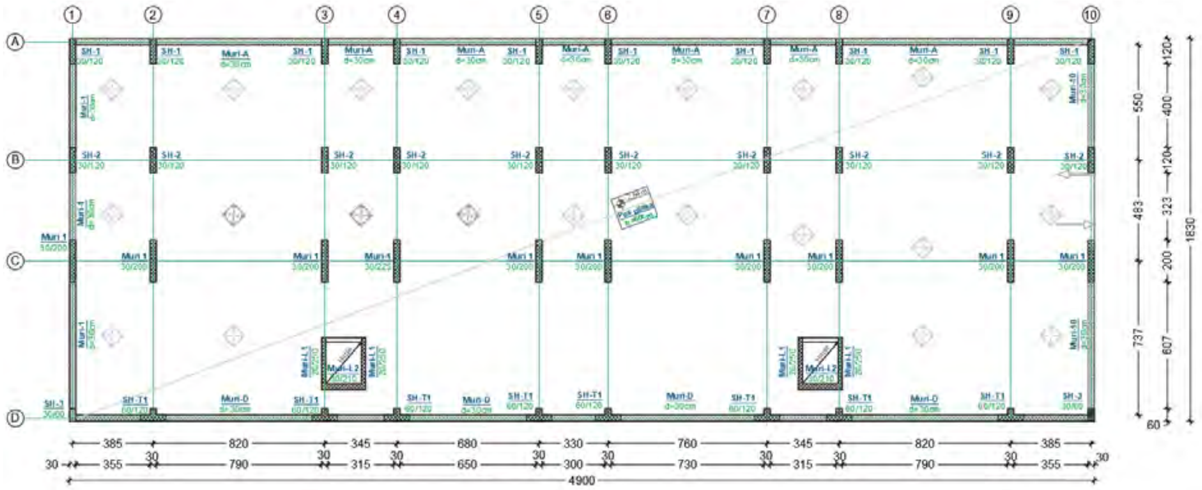


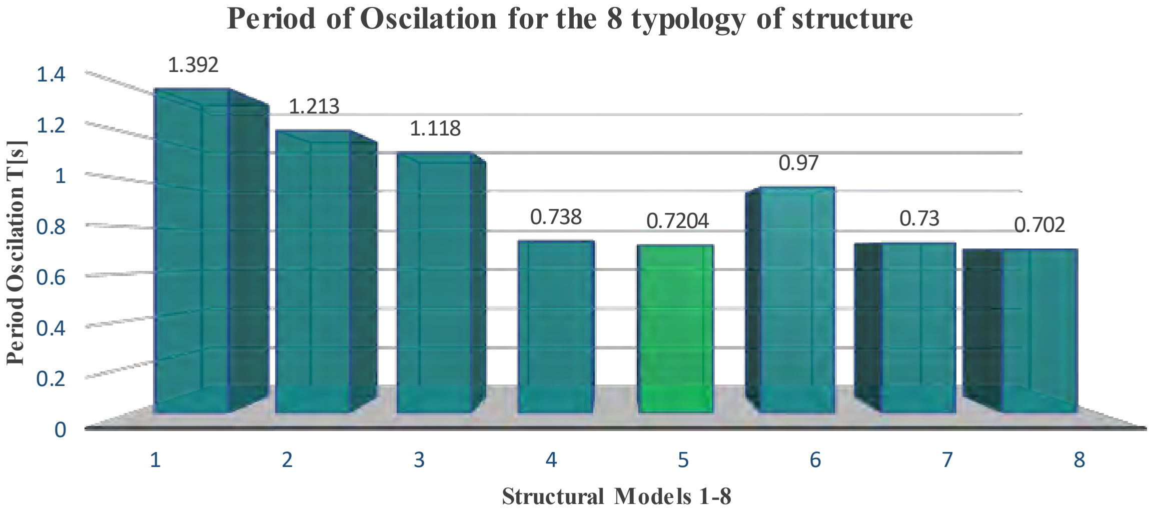
Figure 4. Building base planimetry, vertical structural arangment in base of building.

The obtained behaviour factor has $q=0.8\cdot q_o\cdot k_w=0.8\cdot 3.9\cdot 1.0=3.12$, shall be reduction of 20% because of not vertical regularity of building.

To analyze the optimal behavior of the structure, 8 different models with identical floor plans have been created, comparing the values of the periods.

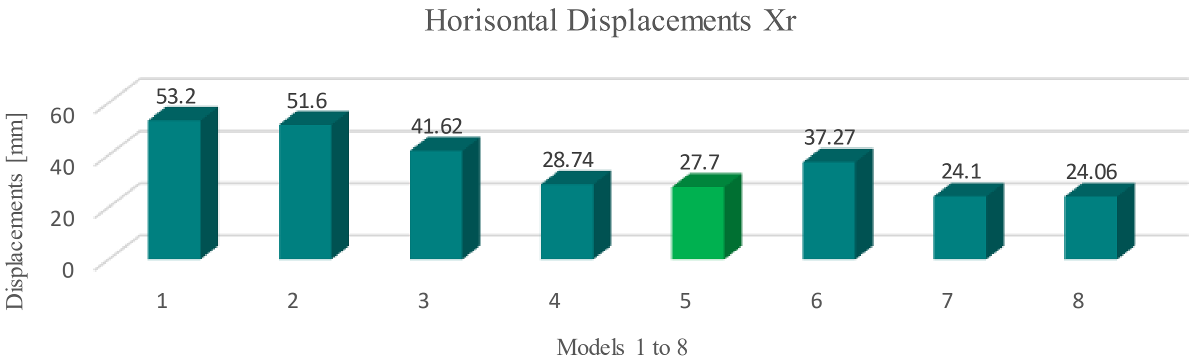
- Model 1, The concrete slab with a thickness of 20 cm (no beams at the perimeter) after the modal analysis of structure the obtained results shows the significantly large period value of oscilation T=1.392s. Therefore, the structure needs to be re-considered.
- Model 2, Same slab as previous from model 1, with the additional columns of cross sections T in axis D, becouse of the huge eccentricity. The vibration period of this system have bean reducted for 12.8% or T=1.213s however, the proposed system has not satifactory value of behaviour and produce a very flexibile structure.
- Model 3, Same model as previous models 1 and 2, containing the beams in perimeter of the slabs cross section of 30/50cm. For this model the oscilation period has bean reduced for the 7.8% compearing to the model 2 and has T=1,.118s.
- Model 4, same model as previous, additionaly are the two core of building contains with the seismic walls and the stairs. The oscilation period obtained has value of T=0.738s.
- Model 5, in this improved model the thickens of the slab has increase from 20cm to 25cm and the obtained oscilation period has T=0.7204s where 51.75% reduced from the model. All other members of structure as similar to model 4.
- Model 6, structure with fleat slabs thicknes of 30cm, without beams and the structural seismic core, the value of period of oscilation has T=0.970s.
- Model 7, The structure containig with the fleat slabs thicknes of 30cm, and columns section of T shape, without beams, without shear core walls the period of oscilation has T=0.730s and it can be easy to conclude that this model is aproache to the model 5.
- Model 8, Structure with the slab thickness of 30cm, beams on perimeter of slab, columns section T shape, seismic walls, ocur the lovest value of the period of oscilation of T=0.702s. This is consider the best solution of chosen structure and the consequence may be the higher price to construct them, due to this is chosen the model 5 for the detail analysis as a good model.

Table 1. Period of oscilation for the diferent typology of the structure



Also, it is made a comparison of the horizontal displacements among the 8 models, and we have obtained these results.

Table 2. Horizontal displacements for the diferent structural system analysed



As can be seen from the above diagram, it is observed that out of the 8 models, the one with flat slabs without drop panels and cores has the largest displacements, and the addition of these elements significantly reduces the displacement.[4]

After calculating the second-order effects for the main model (model number 5 - i.e., the system with 25cm slabs, perimeter beams, T columns, and cores made of reinforced concrete), this model satisfies the condition that Θ<0.1, as shown in the table below:

Table 3. Second order theory

$$\theta_x = {(P_{tot} \cdot d)}\Big/{(V_{tot}^{x-x} \cdot h)}$$

Floor	X_r (mm)	d_x (mm)	Y_r (mm)	d_y (mm)	P_{tot} (kN)	V_{tot}^{x-x} (mm)	V_{tot}^{y-y} (mm)	h (mm)	θ_x	θ_y	θ
Roof	27.7	3.4	22.19	3.44	5698.30	1088.8	415.68	3400.0	0.005233	0.0138	
5	24.3	4.69	18.75	3.86	12559.7	2253.8	843.56	3400.0	0.007687	0.0169	
4	19.61	5.37	14.89	4.22	19577.1	3203.8	1185.0	3400.0	0.009651	0.0205	
3	14.24	5.5	10.67	3.99	28240.0	4052.4	1477.1	3400.0	0.011273	0.0224	
2	8.74	5.09	6.68	3.44	39019.8	4702	1692.5	3400.0	0.012423	0.023	<0.1
1	3.65	3.43	3.24	2.39	50768.2	4990.9	1793.7	3400.0	0.010261	0.0199	

P	0.22	0.22	0.85	0.85	75008.3	5009.4	1833.1	3400.0	0.000968	0.0102	

4. STRUCTURAL ANALYSIS OF THE BUILDING B+5 WITH REGULAR VERTICALITY

The model of analysed building has dimensions of (40/19.40) meters. It will be utilized for commercial purposes on the ground floor and for residential purposes on the upper floors. The structural system of the building is selected as a frame system with flat slabs, but there are also cores made of reinforced concrete for the elevators. The building is regular in height, unlike the first object. The dimensions of the walls are: 30/160cm, 30/200cm, 30/300cm. There is an L-shaped wall with dimensions 120x30 + 30x120cm, and the core measures 400/20cm + 200/20cm. The slabs have a thickness of h=25cm and are directly supported on columns.
Initially, the shape of the columns were retangular adopted as 60/120cm, respecting the ductility condition of the column according to EN1998-1 5.4.3.2.1 (3), where v_d=N_{ED}/A_c·fcd<0.65. However, since the eccentricity was significant, the dimensions of the columns were changed.

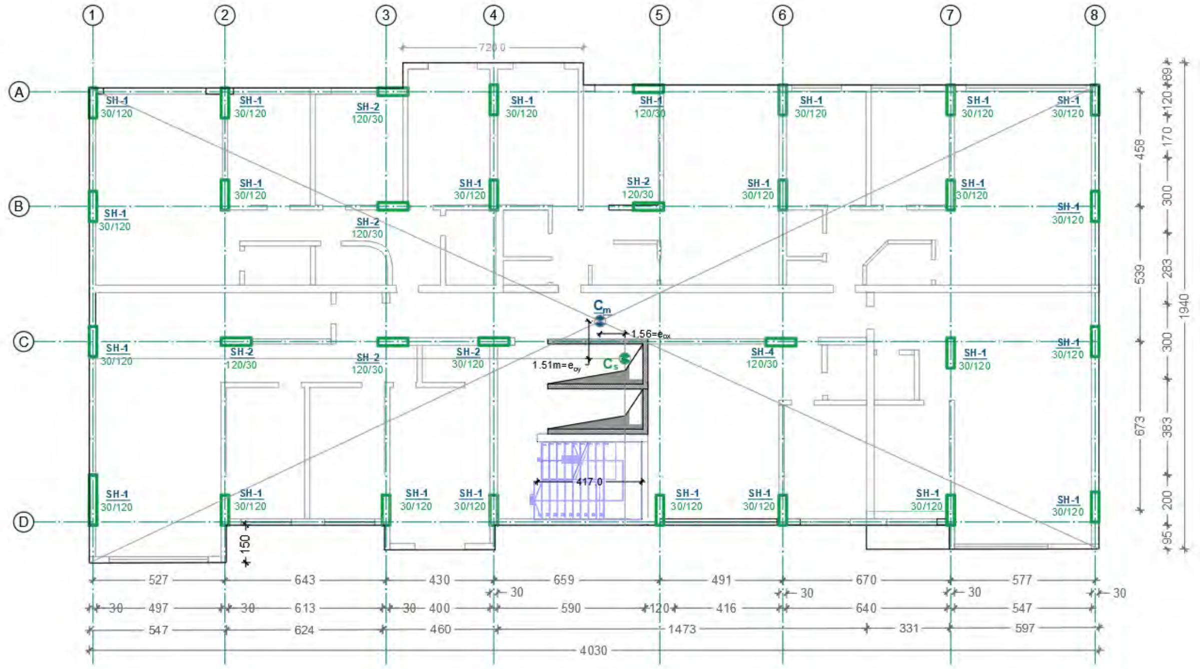


Figure 5. The position of the centre of the stifness and the mass for the model 1.

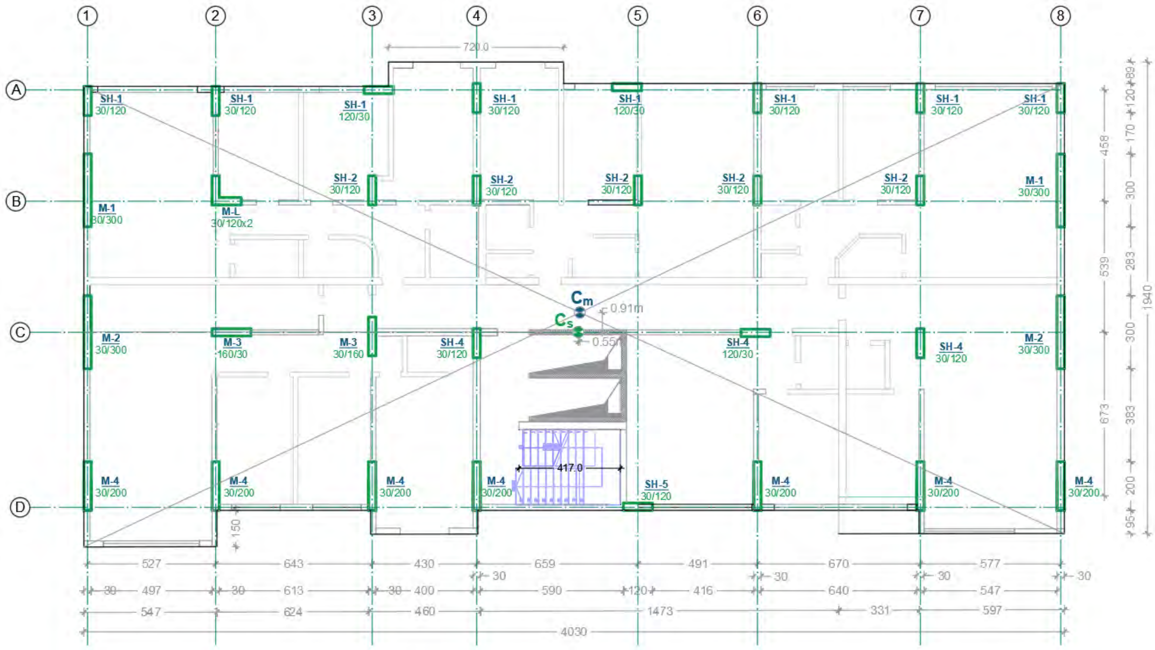


Figure 6. The position of the centre of the stifness and the mass for the main analysed model.

Unlike Figure 4, in this floor plan, we have columns and walls organized in two orthogonal directions depending on the necessity for the center of stiffness to be as close as possible to the center of mass. The walls on Axes 1 and 8 are placed with these dimensions, as in figure 5. After modal analysis, we observed that the first mode shape turned out to be torsional, and with this new positioning as in figure 6, the first two modes were found to be translational, with a value of T1=0.629s.

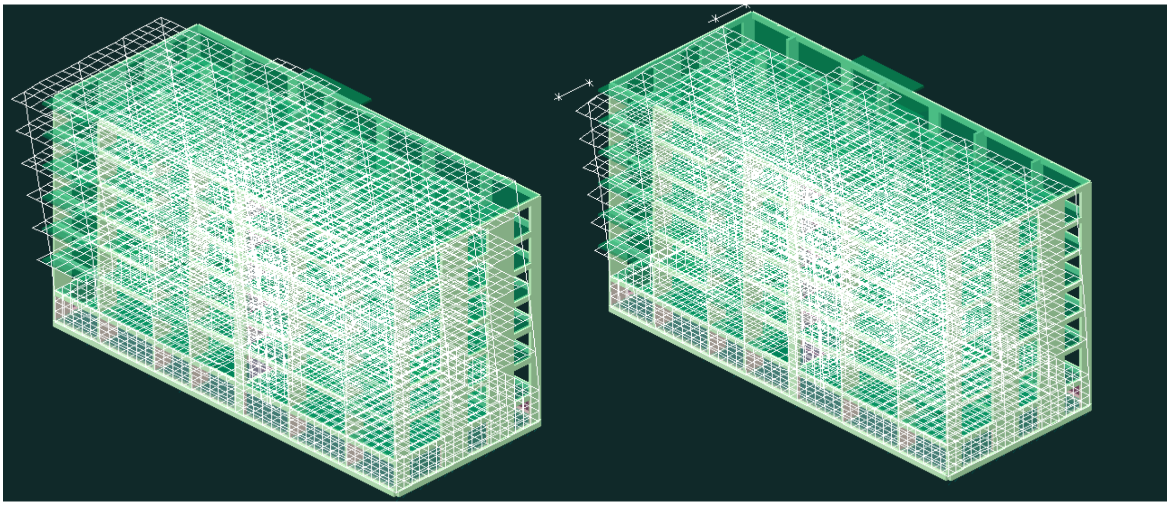


Figure 7. The first of two oscilation tone T_1=0.629s and T_2=0.5623s

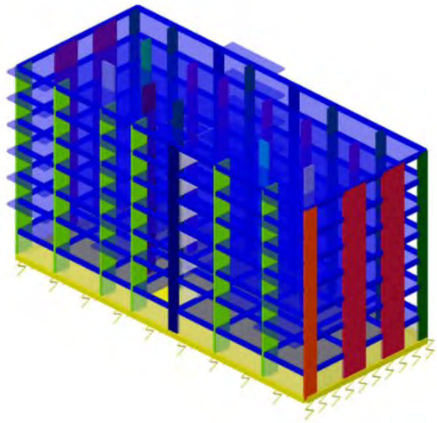


Figure 8. Structural computation model

The behavior factor for this model is $q=q_o \cdot k_w$=3.90, meaning there is no reduction in the behavior factor since we have regularity in the plan.
Furthermore, the second-order effects $\theta \leq 0.1$ are also accounted for by this structure.

Table 4. The second order effect P-Δ

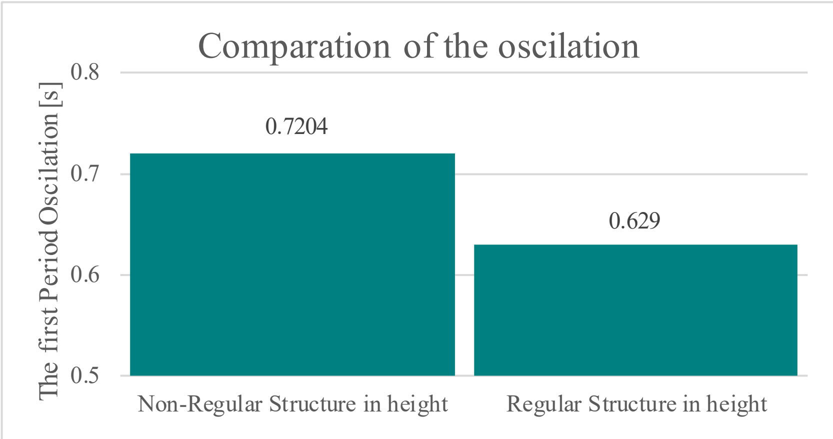
$$\theta_x = \left(P_{tot} \cdot d\right) / \left(V_{tot}^{x-x} \cdot h\right)$$

Floor	X_r (mm)	d_x (mm)	Y_r (mm)	d_y (mm)	P_{tot} (kN)	V_{tot}^{x-x} (mm)	V_{tot}^{y-y} (mm)	h (mm)	θ_x	θ_y	θ
Roof	18.92	2.79	21.37	3.5	8003.50	1667.9	226.66	3000.00	0.0044627	0.0412	<0.1
5	16.13	3.21	17.87	3.74	16655.30	3205.2	432.47	3000.00	0.0055601	0.04801	
4	12.92	3.41	14.13	3.84	25307.10	4436.6	596.08	3000.00	0.0064837	0.05434	
3	9.51	3.4	10.29	3.74	33958.90	5342.4	716.15	3000.00	0.0072041	0.05912	
2	6.11	3.14	6.55	3.35	42610.70	5922.5	793.92	3000.00	0.0075305	0.05993	
1	2.97	2.87	3.2	2.74	51417.20	6208.4	835.08	3000.00	0.007923	0.05624	
P	0.1	0.1	0.46	0.46	76165.30	6266.9	861.82	3500.00	0.0003472	0.01162	

5. THE COMPARATION OF OBTAINED RESULTS

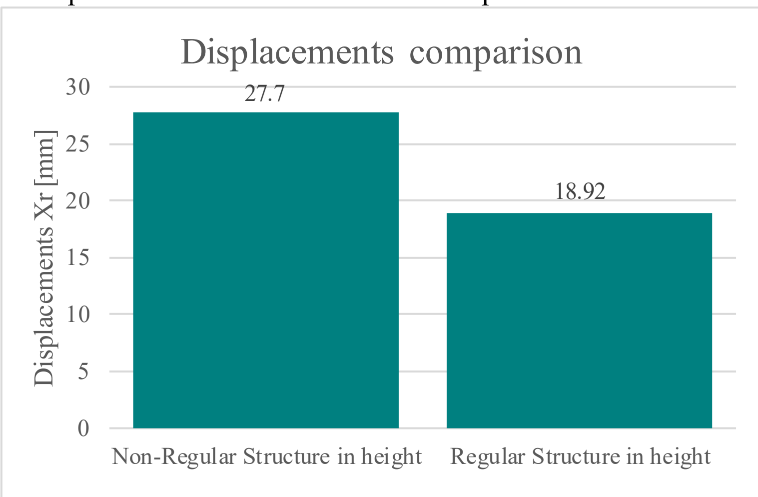
- The main difference between the first and second structures lies in the height irregularity, where the first structure is irregular in height. Therefore, the behavior factor "q" will be reduced by 20%. Consequently, to ensure the structure behaves adequately under all loads, a higher amount of reinforcement should be placed in the structure due to this reduction.
- The period of vibrations is 12.687% shorter in the structure with height irregularity compared to the one without irregularity.

Table 5. Period of oscillation comparation between the two structures



Furthermore, the displacements in the structure with height irregularity are 46.405% larger than those in the structure with regular height.

Table 6. Comparation vales of the horizontal displacements of two structures



6. CONCLUSIONS

Some of the main advantages of flat slabs are:

- Reduction in construction time, physical energy, and materials used in the finishing layers of structures, leading to a reduction in financial costs.
- Designers have greater flexibility in organizing and reorganizing the internal spaces of structures.
- Maximum utilization of floor space is achieved with this type of slab, as there is only one level of slab, i.e., flat slab.
- Since the required height is more easily achieved with these slabs, there can be a reduction in overall height.
- All mechanical and electrical installations can be directly installed in the underside of the slab instead of being recessed, allowing for more efficient use of space.

The main disadvantages of flat slabs are:

- Increased bending moments and acceptance of shear forces.
- They are not optimal for use over distances greater than 7 meters.
- Displacements may be more pronounced.

- In cases where the height of the ground floor is significant, there is an increased risk of the soft story mechanism.

Conclusions:

- Structures with flat slabs are more flexible than those with beams, experiencing larger horizontal and vertical displacements of slab elements and also larger relative floor drifts.
- In structures with irregularities in height, the value of the behavior factor "q" is reduced by 20%, which will result in the need for a larger amount of reinforcement in order to increase the structural capacity.
- Placing perimeter beams deeper than the slab increases the stiffness of the structure.
- The thickness of the slab has a positive impact on the stiffness of the structure; however, it should be adopted considering the cost, as increasing the slab thickness will increase the amount of concrete and thus the total cost.
- Proper positioning of reinforced concrete cores also has a positive impact on stiffness.

Recommendations:

- Importance should be given to organizing the vertical elements of the structure so that the distance between the center of mass and the center of stiffness is minimized and within close proximity to zero, as shown in figure 6. This phenomenon has been considered in the analysis of the two structures.
- Structural engineers should verify the stiffness against torsional flexibility in structures.
- Emphasis should be placed on the value of the period of vibrations, considering that the behavior of the structure under seismic actions is closely linked to it.
- In order to minimize the impacts on vertical elements, care should be taken regarding the modes of vibration of the structure induced by seismic action, where the first two modes of vibration should be translational rather than torsional.

REFERENCES

[1] Eurokodi 8. (a.d.). Eurokode, EN 1998, "Design of structures for earthquake Resistance", 2004.
[2] Florim Grajçevci. (a.d.). Projektimi i strukturave nga Betoni i Armuar.
[3] Veton Pira, V. (a.d.). Parimet e projektimit sizmik te konstruksioneve.
[4] Gokhan Tunc, Abdul Basir Azizi, Tuğrul Tanfener, "Effects of Slab Types on the Seismic Behavior and Construction Cost of RC Buildings "
[5] Altin Seranaj, "Reagimi i strukturave prej betoni të armuar pa trarë dhe strukturave me trarë me lartësi të vogël, në rajonet me sizmicitet të mesëm dhe të lartë"
[6] Rregullat per projektimin e ndertesave prej betoni bazuar ne eurokodin 8, material trajnues, Markel Baballĕku, Niko Pojani , E.Spance, Sh.Bogdani, N.Lako, A.Lako, H. Cullufi, N.Shkodrani.
[7] Eurocode: Seismic Design of Buildings Worked examples, Lisbon 2011 - B.Mosley, J. Bungey dhe R.Hulse,
[8] Projektimi i Strukturave prej Betoni të Armuar, Përkthyer nga POLIS,
[9] Geotechnische Nachweise und Bemessung nach EC7 und DIN 1054, Springer. - M.Setareh, R.Darvas,
[10] Seismic behavior of multi-story structure with different types of slabs, Mahesh Bakale
[11] M.Fardis, E.Carvalho, P.Fajfar and A.Pecker, Seismic Design of Concrete Buildings to Eurocode,
[12] Seismic Analysis of Flat Slab Structure, Sukanya Sawant, Prof K. R. Dabhekar

[13] Analysis of flat slab structure and conventional slab structure, Shital Borkar, Dr. Isha Khedikar, Dr. Kuldeep Dabhekar
[14] R. P. Apostolskaet. Al, "Seismic performance of flat-slab building structural systems."
[15] Gokhan Tunc, Abdul Basir Azizi, Tuğrul Tanfener, "Effects of Slab Types on the Seismic Behavior and Construction Cost of RC Buildings "

Designing cylindrical silos according to "Eurocode" European standards

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This work aims to instruct the design of silos according to European standards, considering these structures as special, sensitive, flexible, and with high load-bearing capacities. The geometry of the silo design is a potential issue considering their arched shapes, appropriate bottom shapes of the silo, and the flow of the deposited material during unloading. Geometric shapes with rotational symmetry around the circular silo create favorable effects and good structural performance even during loading and unloading processes. Geometric silo design aims to maximize the capacity of silos while minimizing construction costs. The development of silo design procedures takes into account the selection of the optimal hopper angle and minimum external dimensions of the silo. The ideal geometric shape of material discharge from the silo ensures smooth unloading. This refers to mass flow. The standards used for designing and calculating the effects and behavior of deposited materials in silos are crucial for their stability and functionality. Taking into account the developed design criteria for silos, the design component includes combinations of external actions, load patterns, primary and secondary effects on structural elements, and the relative flexibility of the elements. The buckling of cylindrical silo walls as a result of asymmetric filling is a significant consideration. If the point of drawdown at the bottom of the hopper is not at the vertical rotational axis of the silo and if the material flow channel interferes with the silo walls, non-uniform pressure develops, which manifests around the perimeter of the silo, causing horizontal and vertical buckling in the cylinder walls. This buckling presentation issue is crucial in the geometric selection of silos to avoid buckling. The theoretical part presents possible geometric shapes of silos, external actions from the most unfavorable cases of loading and unloading effects, the calculation of internal influences according to membrane theory, actions from wind and seismicity, and their combinations for various limit states. In the numerical part, an example is taken for the analysis and design of cylindrical silos based on the theoretical part. In the final section, the computer program Sofistik is utilized.

Keywords: *Silos, buckling, flexibility, granular materials.*

1. INTRODUCTION

The primary purpose of silos is to store and preserve various materials, typically agricultural grains, such as wheat, corn, or soybeans. However, silos can also be used to store other materials like cement, coal, wood chips, and more. The main objectives of silos include:

- Storage: Silos provide a controlled environment for storing bulk materials, protecting them from external elements such as moisture, pests, and contamination.
- Preservation: Silos help in preserving the quality of stored materials by minimizing exposure to air, moisture, and pests, which can lead to spoilage or degradation.
- Inventory management: Silos enable efficient inventory management by providing a centralized location for storing large quantities of materials. This facilitates inventory tracking and ensures adequate supply for various applications.
- Transportation: Silos can serve as intermediate storage facilities in supply chains, allowing for efficient transportation and distribution of materials from production sites to end-users.

- Processing: In some cases, silos are equipped with systems for material handling and processing, such as drying, blending, or conditioning, to enhance the quality or suitability of stored materials for specific purposes.

Overall, silos play a crucial role in various industries, including agriculture, manufacturing, construction, and logistics, by providing a means for safe, organized, and efficient storage of bulk materials (N. S. Fish.: The History of the Silos in Wisconsin, 1924-1925; John Scott.: Farm Buildings, 1914).

The loading and unloading of silos depend on their shape, and the choice of materials used for forming the structure is also very important. Depending on the function of the silo, they may have additional openings that serve for ventilation of spaces or even the installation of various machinery for loading and unloading.

Given the shape of the roof - the cover, as well as the base of the silo, more stable silo structures can be achieved. The shape of silos in plan view, ranging from polygonal sections, square, rectangular, pentagonal, and more sides up to circular, allow for greater overall stability. Silos can also be elevated from ground level to create higher pressures (such as in the case of water or liquid reservoirs) or supported on the ground forming structures with small bases and great heights. From these possibilities of formation in various bases and heights, silo structures of various types can be formed.

2. DESIGN BASED ON LIMIT STATE.

The limit state for structures implies the condition of the structure that should be stable, durable, and functional throughout its designed lifespan. The structural elements and the structure as a whole should be capable of accepting external forces so that the mechanical properties of the materials can withstand them without breaking, and deformations are within limits that ensure the uninterrupted function of the object and without significant residual deformations.

Designing and calculating silos according to the limit state implies maximizing the use of materials, limiting deformations, expansions, and vibrations while ensuring local and overall stability of the structure.

3. ACTIONS ON SILOS

The permanent actions G, g for silos include the weight of the supporting structure of the silo, cladding, hopper, roof, rings, and all other constructive and non-constructive materials built into the silo that are permanent.

Live loads in silos include wind, snow loads, as well as loading actions such as filling loads - deposits in silos, which can be liquid materials and solid materials in granular or powder forms. (EN 1990, 2001; EN 1991-1-4, 2005). Temporary actions are more complex in silos, for the sole reason that there may be different scenarios or situations of filling and unloading of loading deposits in silos. In Figure 2.1, cases of loads during symmetric and asymmetric filling are presented. Loads on the vertical walls of silos as a result of filling or partial unloading with small eccentricities are shown with symmetric loads as well as with asymmetric load situations. When the eccentricity is more pronounced, then the internal compression actions are symmetric, which occurs in asymmetric silos (EN 1991-4, 2006a; EN 1998-4, 2006b).

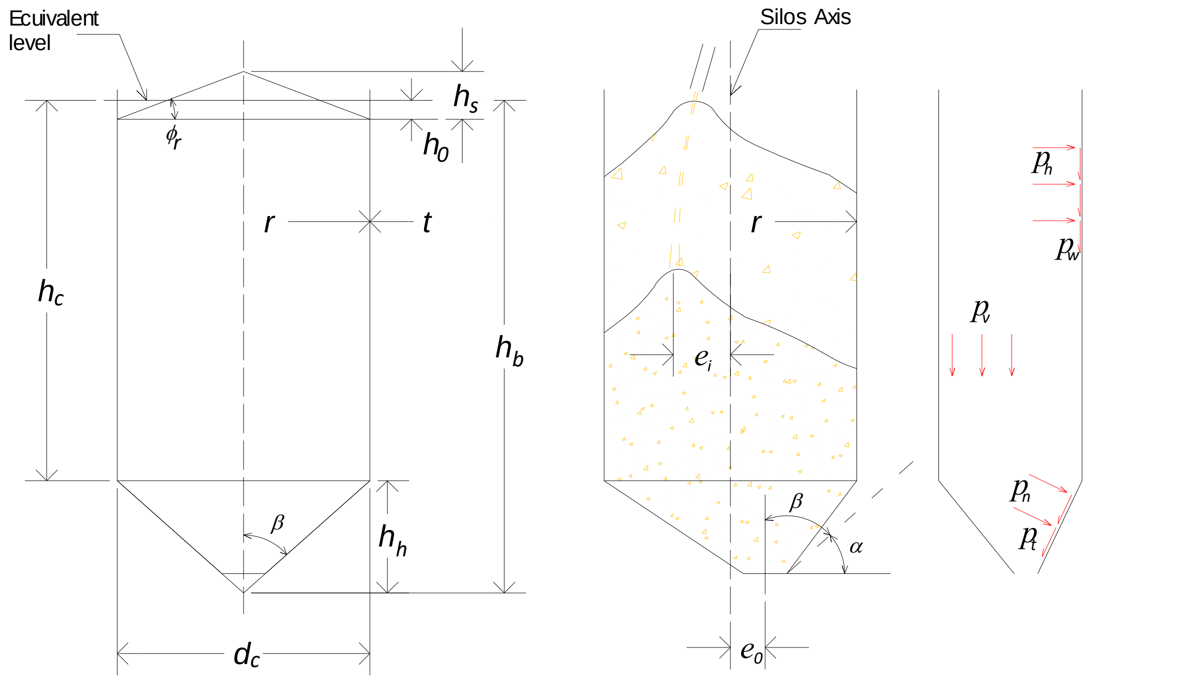


Figure 1. The simetrical load cases on silos

The silo with rotational symmetry axis has uniform pressure p_h acting on the inner walls of the cylinder, normal pressure p_n on the cylindrical hopper section, frictional load on the cylinder walls p, tangential friction on the hopper walls p_t, and pressure from the material volume p_v. The transition of pressure from the cylinder part to the hopper part is p_{vft}. Forces G_c and G_h are concentrated forces at the centers of gravity of the cylinder and hopper, respectively.

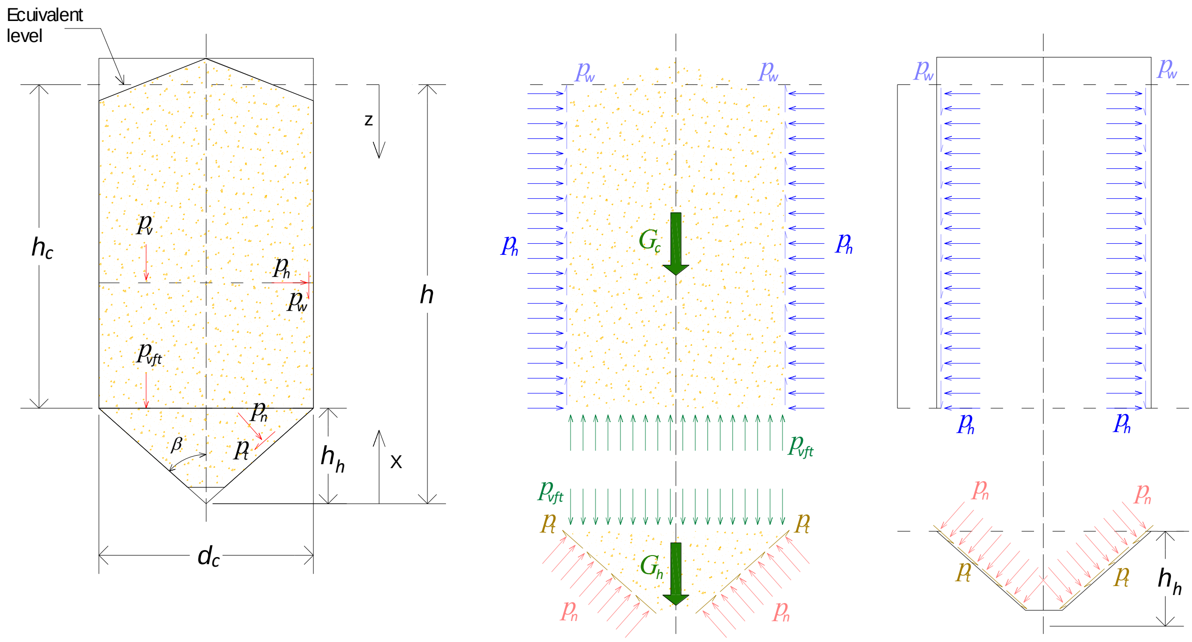


Figure 2. The silos indoor preasure in case of symetrical axis, preasure from the acumulated materials, resitance of the silos

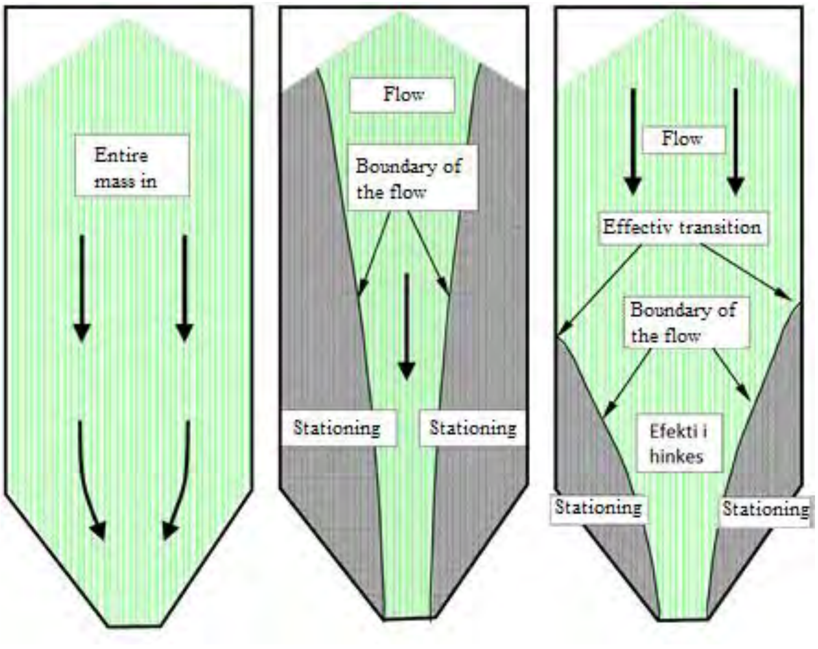
4. RELIABILITY DIFFERENTATION

During the design of silos, it is crucial to consider the varying levels of complexity inherent in the arrangement and construction of the silo structure, as well as the different failure modes that can occur. To meet the standards of one of the three reliability classes, design procedures should incorporate the specific requirements of these classes. These procedures aim to accurately assess the essential risk by factoring in costs and implementing necessary measures to mitigate the risk of structural failures.

Table 1. Consequence class depending on size and operation

Consequence class	**Design situation**
Consequence Class 3	Silos of capacities ower the 10,000 tons, for the appearing of the load situation: a) eccentric discharge of e_0/d_c>0,25, (figure 1.b) b) vertical silos with the top eccentricity e_t/d_c>0,25
Consequence Class 2	All silos covered by the standards of prEN1991-4 and are not part of other classes
Consequence Class 1	The silos with the capacyties les then 100 tons.

The loads from solid materials deposited in silos should be considered when the silo is at full capacity. Cases of loadings from depositions should be considered for both the filling and discharge conditions of the silos for the ultimate limit state and the serviceability limit state. Calculation for the special cases of filling and discharge should be addressed in the basic loading cases for different limit states of the structure.
For the calculation of each load case, it is essential to utilize the technical values of the deposited material, such as the coefficient of friction μ, the lateral pressure ratio K, the internal friction angle ∅i, which corresponds to the defined conditions of the loaded silo for each limit state.
Even in silos with axis symmetry, when loaded with full loads, different loading cases during their discharge must be constructed and accounted for in calculations. In figure 3.1, the cases of discharge formations are provided based on their trajectories, such as: mass flow, funnel flow, and combined flow.



a). Mass flow, *b). Flow in tube shape*

Figure 3.1 The base shape of the flow

When silos with significant heights, bending silos, are loaded asymmetrically or when the segregation effect of the deposited material occurs, the deposition in silos can result in asymmetric loading situations, causing non-symmetric pressures, as shown in figure 3.2.

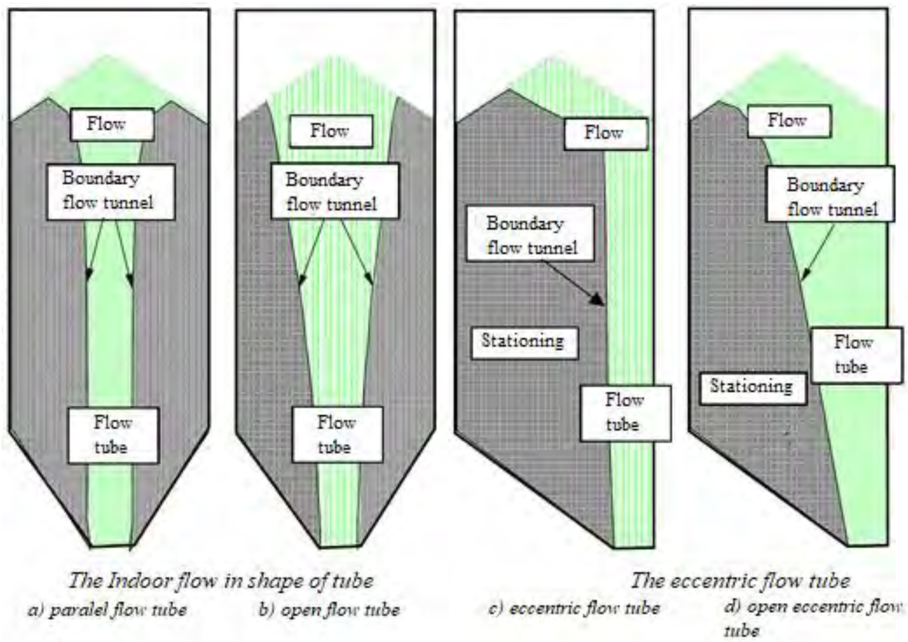


Figure 3.2. The flow shape off the materials in silos

1. LOADS ON VERTICAL WALLS OF SILOS

The various loads on silos can iclude:

- Dead Loads: These are the static loads exerted by the weight of the silo structure itself, including the weight of the silo walls, roof, and any equipment attached to it.
- Live Loads: These are dynamic loads resulting from the contents stored inside the silo, such as bulk materials, grain, or liquids. Live loads can vary depending on the material's density and distribution within the silo.
- Wind Loads: Wind forces exert pressure on the exterior surface of the silo, creating both lateral and uplift loads. The magnitude of wind loads depends on factors such as wind speed, exposure category, and the silo's height and shape.
- Seismic Loads: In seismic-prone regions, silos are subjected to earthquake-induced forces. These loads are influenced by factors such as soil conditions, seismicity of the region, and the structural characteristics of the silo.
- Temperature Loads: Temperature differentials between the interior and exterior of the silo can lead to thermal expansion and contraction, causing additional stresses on the structure.
- Environmental Loads: Other environmental factors, such as snow accumulation, ice formation, and corrosion, can also impose loads on silos, particularly in regions with harsh weather conditions.
- Operational Loads: These include loads resulting from operational activities such as filling, emptying, and handling of materials, as well as any dynamic forces induced by equipment like conveyor belts or agitators.
- Impact Loads: Sudden impacts from equipment or materials during loading or unloading processes can create localized stresses on the silo structure.

The various design situation refereing to the filling anddischarge activity it can ocure, as it is shown in figure 4.

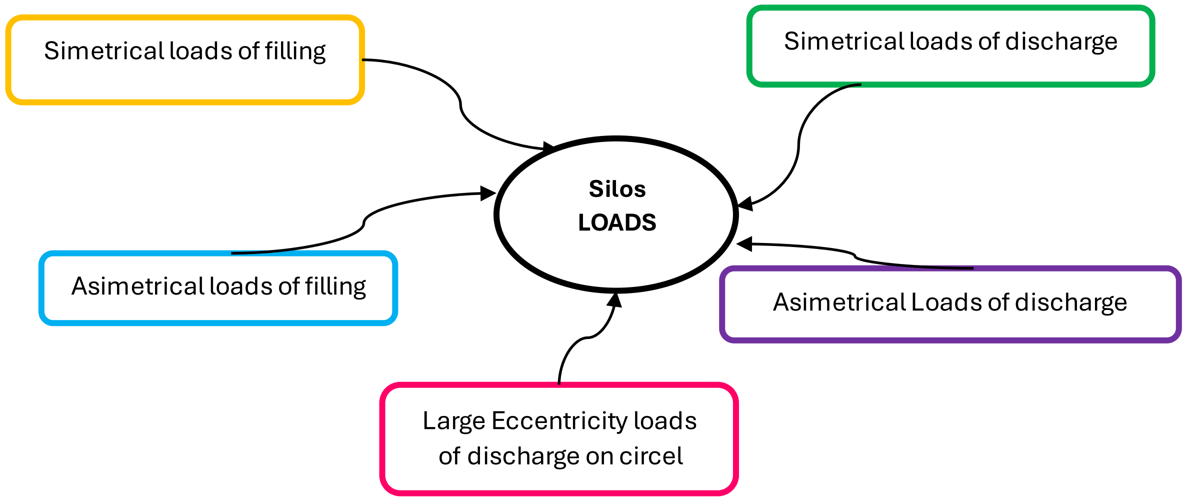


Figure 4 Loads path of silos in filling and discharge proces.

When categorising silos based on their length, we can consider the following types: Small-Scale silos; These are typically shorter in length and are often used for localized or on-farm storage of grains, seeds, or feed. They are commonly found in agricultural settings and may include bunker silos, bag silos, or small tower silos, Medium-Sized Silos; These silos are of intermediate length and are commonly used for commercial storage purposes. They may include tower silos, horizontal silos, or smaller concrete or steel silos. Medium-sized silos are suitable for storing moderate quantities of bulk materials, and Large-Scale Silos; These are longer and taller silos designed for high-capacity storage of bulk materials. Large-scale silos are commonly used in industrial settings such as grain elevators, food processing plants, or manufacturing facilities. They may include tall tower silos, extensive bunker silos, or large steel or concrete silos. Depending the type of the length of the silos, below are shown in scematic computation of the loads (Petrovi, S.: Steel silos for particulate solid material , Ljubljana, 2009).

Scheme 1. The loads on the bending silos and the medium size bending silos.

SIMETRICAL LOAD FILLING

Bending Silos	Medium bending silos

$$p_{hf}(z) = p_{ho} \cdot Y(z)$$

$$p_{wf}(z) = \mu \cdot p_{ho}(z)$$

$$z_0 = \frac{1}{K \cdot \mu} \cdot \frac{A}{U}, \quad p_{ho} = \gamma K \cdot z_0$$

Bending Silos:

$$Y(z) = 1 - e^{-z/z_o}$$

$$z_v(z) = z_o \cdot Y(z)$$

Medium bending silos:

$$n = -(1 + tan\phi_r) \cdot (1 - h_0/z_0)$$

$$Y(z) = 1 - \left(\frac{z - h_0}{z_0 - h_0} + 1\right)^n$$

$$z_v(z) = z_0 \left(\frac{h_0}{z_0} - \frac{1 - \frac{h_0}{z_0}}{n - 1}\left[1 - (1 - Y(z))^{\frac{n+1}{n}}\right]\right)$$

Scheme 1. Symetric discharge loads

SYMETRIC DISCHARGE LOAD

Discharge from the top

Bending silos or medium bending

$C_h = C_w = 1.0$

Discharge from botom

Medium bending silos

AAC 1

$C_s = h_c/d_c - 1.0$
$C_h = 1.15 + 1.5C_s$
$C_w = 1.0 + 0.1C_s$

AAC 2 and 3

$C_s = h_c/d_c - 1.0$
$C_h = 1.0 + 0.15C_s$
$C_w = 1.0 + 0.1C_s$

Bending Silos

AAC 1

$C_h = 1.15 + 1.5C_s$
$C_w = 1.4$

AAC 2 and 3

$C_h = 1.15$
$C_w = 1.10$

$p_{he} = C_h \cdot p_{hf}$
$p_{we} = C_w \cdot p_w$

Scheme 2 Load on bearing silos

Simetrical loads on fill and discharge of silos

Bearing silos

$z_0 = (1 + sin\phi_r) \cdot \boldsymbol{h_c}$

$p_{ho} = \boldsymbol{\gamma} \cdot \boldsymbol{K} \cdot \boldsymbol{z_0}$

$\gamma(z) = \frac{z}{z_0}$

$p_{hf}(z) = p_{ho} \cdot Y(z)$

Scheme 3 Non simetrical loads

Non simetrical on filling and discharge of loads in silos

Filling

$$C_{pf} = 0.21 \cdot C_{op} \cdot \left(1 - e^{-1.5(\frac{h_c}{d_c}-1)}\right) > 0$$

$$p_{hf,p} = p_{hf}(z_p/z_0)$$

$$p_{pf}(\phi) = C_{pf} \cdot p_{hf,p} \cdot cos\phi$$

Discharge

$h_c/d_c > 1.2$

$$C_{pe} = 0.42 \cdot C_{op} \cdot \left(1 - e^{-1.5(\frac{h_c}{d_c}-1)}\right) > 0$$

$h_c/d_c < 1.2$

$$C_{pe} = 0.27 \cdot C_{op} \cdot (h_c/d_c - 1) > 0$$

$$p_{he,p} = p_{he}(z_p/z_0)$$

$$p_{pe}(\phi) = C_{pe} \cdot p_{he,p} \cdot cos\phi$$

6. THE CALCULATION OF THE INTERNAL FORCES ON MEMBRANES

For the asimetrical loads, the membranes for geometrical cilinder shape, the equilibrum equations contains as below;

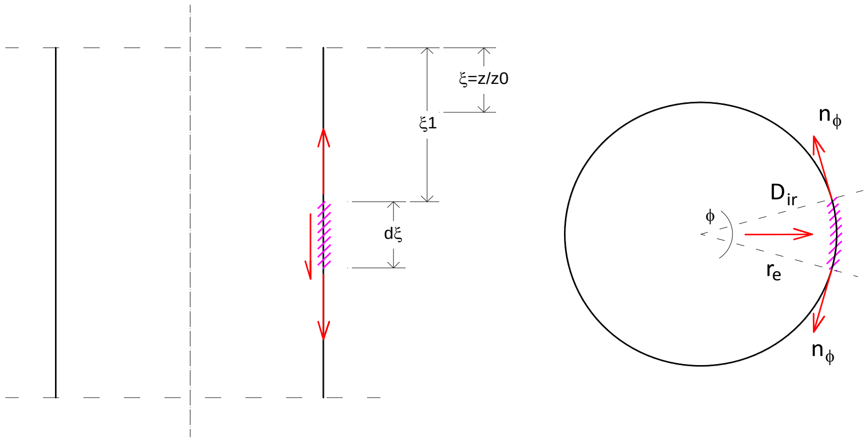


Figure 4. Pressure and the membranes force on the cross section of the wall of cilinder silos.

$$\Sigma_x = 0\,; \quad \frac{\partial N_\emptyset}{\partial_\emptyset} d_\emptyset d_y + \frac{\partial N_{y\emptyset}}{\partial_y} d_y\, r d_\emptyset + X r_o\, d_\emptyset d_y = 0 \tag{1}$$

$$\Rightarrow \quad \frac{1}{r_o} * \frac{\partial N_\emptyset}{\partial_\emptyset} + \frac{\partial N_{y\emptyset}}{\partial_y} + X = 0 \tag{2}$$

$$\Sigma_Y = 0\,; \quad \frac{\partial N_{\emptyset Y}}{\partial_\emptyset} d_\emptyset d_y + \frac{\partial N_y}{\partial_y} d_y\, r_o d_\emptyset + Yr\, d_\emptyset d_y = 0 \tag{3}$$

$$\Rightarrow \frac{1}{r_O} * \frac{\partial N_{\emptyset Y}}{\partial_\emptyset} + \frac{\partial N_y}{\partial_y} + Y = 0 \quad (4)$$

$$\sum_Z = 0 \; ; \quad \left(N_\emptyset d_y\right) d_\emptyset + Zr\, d_\emptyset d_y = 0 \quad (4.5)$$

The shear force depends from the quantity of the load componente for the hight of z:

$$N_\emptyset(z) = p_h(z)\, r \quad (6)$$

The force in the vertical section n_z in depth of $z = z_1$ it is obtained through the integration of the frictional influence p_w. During the filling proces of the silos and the discharge this force is negative.

$$N_\emptyset(z = z_1) = \int_0^{z_1} p_h\,(z)\, r \quad (7)$$

7. THE STUDY CASE – EXAMPLE OF CALCULATION OF SILOS

The type of bukle store in silis, sant.

The design values are taken from the anex C. Table E.1 of EN 1991-4, the category of wall has taken D2.

$\gamma = 14$	(kN/m^3)	$K_m = 0.45$	$(-)$
$\gamma_u = 16$	(kN/m^3)	$a_k = 1.11$	$(-)$
$\phi_r = 39$	$(°)$	$\mu = 0.48$	$(-)$
$\phi_{im} = 36$	$(°)$	$a_\mu = 1.10$	$(-)$
$a_\varphi = 1.09$	$(-)$	$C_{op} = 0.40$	$(-)$

7.1 The geomethry parameters of silos

Not independent free parameters

The height of silos - cilinder: $h_b = 15m$

The radius of cilinder: $r = 2m$

Simetrical half angel of hoppe: $\beta = 25°$

Thicnkess of the wall of silos: $t = 7mm$

Independent parameters

The height of the hoppe: $h_h = \frac{r}{tan\beta} = \frac{2}{tan25} = 4.289$

The heigh of the bukling up: $h_{tp} = r \cdot tan\phi_r = 2 \cdot tan39 = 1.619$

The depth were belong to the equivalent area: $h_o = \frac{r}{3} \cdot h_{tp} = \frac{2}{3} \cdot tan39 = 0.539$

Equivlent heght ofthe silos - cilinder: $h_{c=}h_h - h_{tp} + h_0 = 15 - 1.619 + 0.539 = 13.90m$

Equivalent hegh of the storage buckling: $h_{S=}h_h + h_C < 100 = 4.289 + 13.92 = 18.20m$

Diameter of the silos structure: $d_c = 2 \cdot r = 4m$

The additional limitation: $\frac{h_s}{d_c} < 10 = 4.55 < 10$

Perimeter of the cross section of silos: $U = \pi \cdot d_c = 3.141 \cdot 4 = 12.564m$

The cross section area of silos: $A = \pi \cdot \frac{{d_c}^2}{4} = \pi \cdot \frac{4^2}{4} = 12.564m$

The Volume of storage materials: $V_m = A \cdot \left(h_c - h_o + \frac{1}{3}\left(h_h + h_{tp}\right)\right)$

$= 12.564\left(13.90 - 0.539 + \frac{4.289+1.619}{3}\right)$

$= 192.86m^3$

Weight of the storage materials: $G_m = \gamma_u \cdot V_m = 16 \cdot 192.86 = 308.57kN$

Shell silos weight: $G_s = 2\pi t\left(r + \frac{t}{2}\right) \cdot \left(h_b + \frac{1}{3} \cdot h_h\right) \cdot \gamma$

Shell silos weight: $G_s = 2\pi t\left(r + \frac{t}{2}\right) \cdot \left(h_b + \frac{1}{3} \cdot h_h\right) \cdot \gamma =$

$= 2\mu \cdot 0.007 \cdot \left(2 + \frac{0.007}{2}\right) \cdot 15 + \frac{4.285}{3} \cdot 78.5$

$= 113.62kN$

Centre of gravity of the silos: $h_m = \frac{1+\frac{1}{18}\cdot\left(\frac{h_{tp}}{h_c}\right)^2 - \frac{1}{6}\cdot\left(\frac{h_h}{h_c}\right)^2}{1+\frac{1}{3}\frac{h_h}{h_c}} \cdot \frac{h_c}{2} =$

$\frac{1+\frac{1}{18}\cdot\left(\frac{1.619}{13.90}\right)^2 - \frac{1}{6}\cdot\left(\frac{4.289}{13.90}\right)^2}{1+\frac{1}{3}\cdot\frac{4.289}{13.90}} \cdot \frac{13.90}{2} =$

$= 6.124m$

Inertial moment of the cilinder of silos: $I = \frac{1}{8} \cdot \pi t \cdot (d_c + t) \cdot \left({d_c}^2 + 2d_c t + 2t^2\right)$

$= \frac{1}{8} \cdot \pi 0.007 \cdot (4 + 0.007) \cdot (4^2 + 2 \cdot 4 \cdot 0.007 +$

$2 \cdot t^2)$

$= 0.1768217m^4$

The depth and thickness of silos cilinder:

- The highest part of the wall of cilinder of silos $z = 5m$ and the thickness of the wall $t_1 = 5mm$
- The medium part of the wall of cilinder of silos $z = 5m$ up to $z = 7.7m$ the thickness of the wall of the cilinder $t_2 = 7.7mm$
- The last part of the wall of cilinder of silos $z = 7.7m$ up to $z = 13.90m$ the thickness of the wall of the clinder $t_3 = 10mm$

Depth and thickness of the wall of the hoppe:

- $x = 4.30m$ up to $x = 3.30m$ with thickness $t_4 = 6mm$
- $x = 3.30m$ up to $x = 0m$ with thickness $t_5 = 4mm$

The type of silos and hoppe determination:

The type of Silos: $\frac{h_c}{d_c} = \frac{13.90}{4} = 3.475 < 10 \rightarrow$ Bending silos

The type of the hoppe: $\mu_{min} = \frac{\mu}{a_\mu} = \frac{0.48}{1.10} = 0.4363 \rightarrow$ Climbe hoppe

$\tan 25° = 0.414$

7.2.The silos analysis and computation

Materials

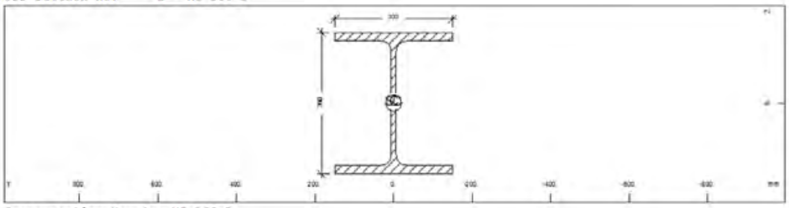
Mat	Classification	γ-M
1	S 355 (EN 1993)	1.00

Cross-sections static properties

SNo	Mat MRf	A[m2] It[m4]	Ay[m2] Az[m2] Ayz[m2]	Iy[m4] Iz[m4] Iyz[m4]	yc[mm] zc[mm]	ysc[mm] zsc[mm]	E[N/mm2] G[N/mm2]	g[kN/m]
1	1	1.8063E-02 2.981E-06	1.209E-02 4.395E-03	4.319E-04 1.014E-04	0.0 0.0	0.0 0.0	210000 80769	1.42 (BEAM)
	= HE 360 B							
2	1	7.2729E-03 3.709E-07	3.969E-03 2.821E-03	1.626E-04 1.044E-05	0.0 0.0	0.0 0.0	210000 80769	0.57 (BEAM)
	= IPE 360							

SNo	section number	ysc[mm],zsc[mm]	ordinate of shear centre
Mat	material number	E[N/mm2]	Young's modulus
A[m2]	sectional area	g[kN/m]	weight per length
Ay[m2],Az[m2],Ayz[m2]	transverse shear deformation area	MRf	reinforcement material number
Iy[m4],Iz[m4],Iyz[m4]	bending moment of inertia	It[m4]	torsional moment of inertia
yc[mm],zc[mm]	ordinate of elastic centroid	G[N/mm2]	Shear modulus

Cross section No. 1 - HE 360 B



Cross section No. 1 - HE 360 B

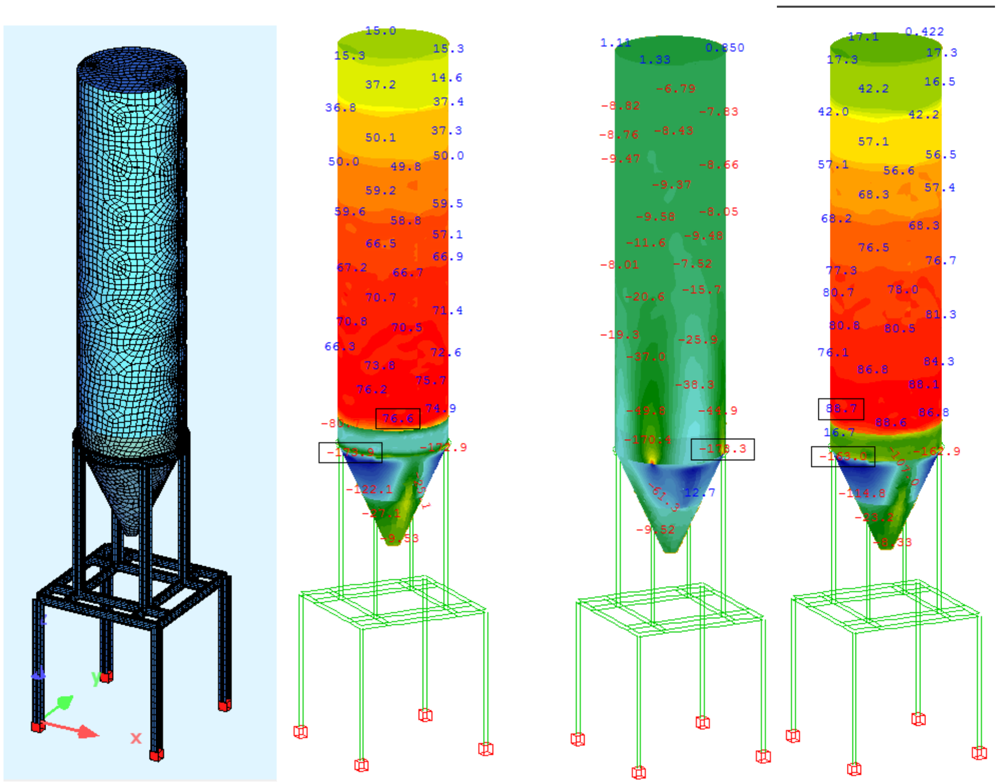


Figure 5. 3d model, Radial membrane force in direction x, from fill, direction y and direction x from discharge

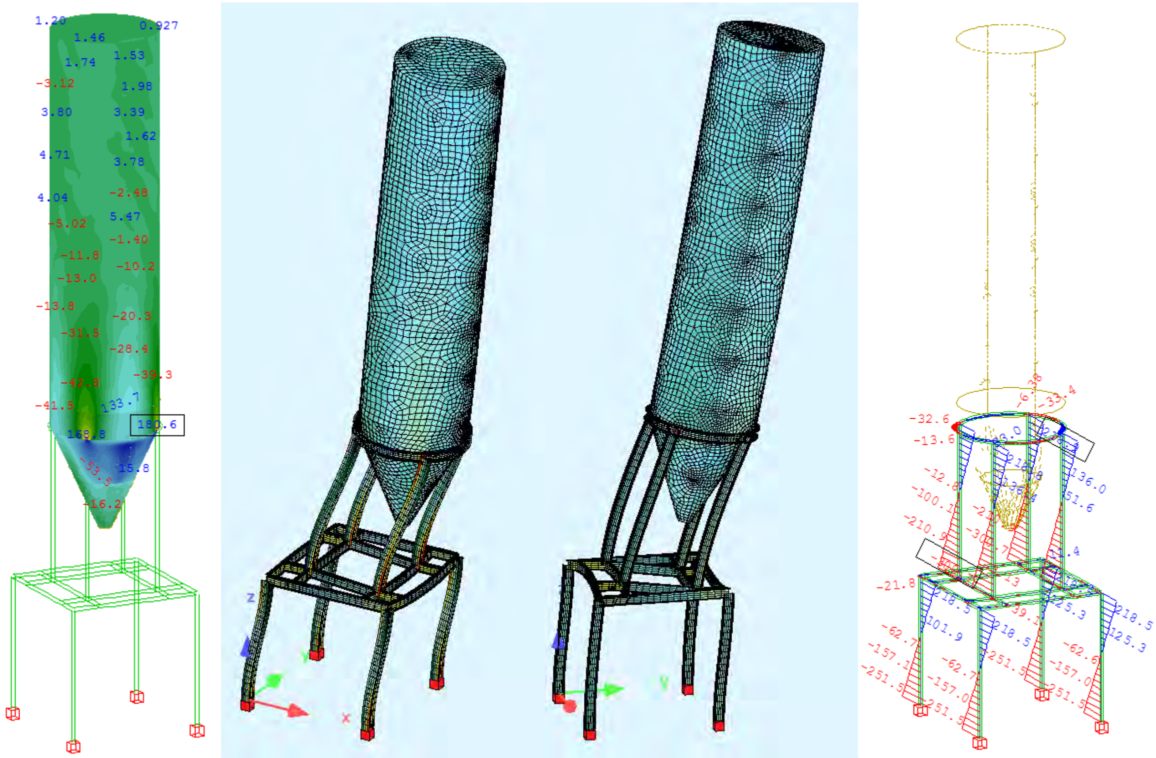


Figure 6. Membrane force direction y fro discharge, first mode shape f=1.46, T=0.68 s – direction x, second mode shape f=1.73, T=0.57 s – direction y, Bending moment Mz –seismic direction x.

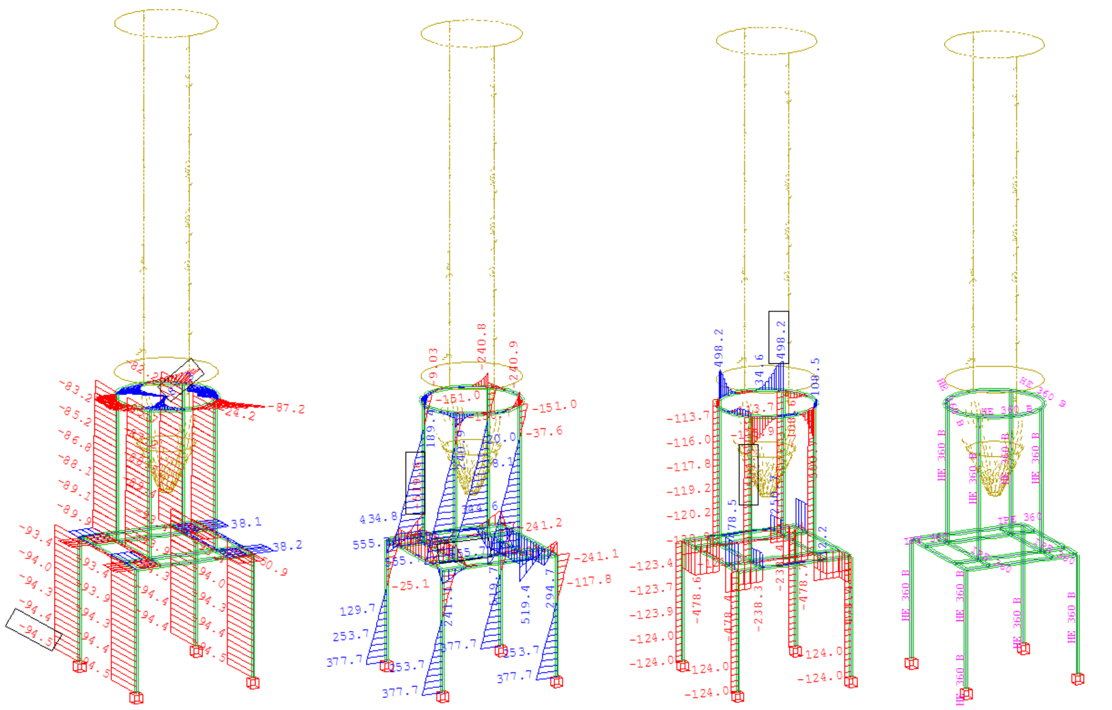


Figure 7. Shear force Vy – seismic – X, Bending Momements My –Seismic Y, shear force Vz – Seismic Y, Cross section calculated.

7.3.The results comparation from the numerical computation

Using linear analysis, the mass at the support of the structure has been neglected; therefore, the model only includes the supporting mass at the height hm from the transition between the cylinder silo and the hopper silo, resulting in only one possible oscillation in the horizontal direction. This means that this structural system has only one degree of freedom.

With nonlinear analysis using the finite element method, problem solving in structural mechanics is always carried out according to the step-by-step computational method. Therefore, this is of particular importance for the use of computer programs.

For nonlinear structural analysis, the first step involves dividing the structure into a number of small elements, with finite dimensions that may be uniform or non-uniform. The number and dimensions of the elements depend on the type of structure being analyzed, the type of acting load, and the accuracy required for solving the given problem.

Table 2. The Oscilations Periods

1.56	0.68	55.41
1.33	0.57	57.14

8. CONCLUSIONS

Lately, the use of silos in our country is not uncommon. In my research, I have found many such structures serving the construction industry, specifically in concrete factories where silos are used for cement storage, and in rarer cases, for water storage. Some of these factories plan to build smaller silos for the accumulation of concrete additives in powder form. In other cases where silos are found, they serve the food industry for wheat storage, silage, and in some cases, even in the chemical industry, for epoxy colors and other materials. These existing structures are made of steel and vary considerably in size from case to case.

To achieve smaller dimensions of silos, they are preferably constructed on strong foundations, such as rock ground. The geometric shapes of silos play a crucial role in determining their dimensions, and it is preferred for them to have a circular and symmetrical section. Other significant factors influencing the size of the silo include its height, material storage capacity, height of the silo support-construction, hopper shape, and hopper angle.

During the design of silos, special attention should be paid to the type of material being stored, its technical performance characteristics such as angle of repose, segregation tendencies, and the sticking of particles to prevent uneven and non-uniform discharges that can cause moments of bending in horizontal and vertical reference directions.

REFERENCES

[1] Master thesis “Projektimi i siloseve cilindrike sipas “Eurocode” standardeve evropiane”, MSc Altina Grajcevci, 2016.

[2] Eurokodi 0: Bazat e projektimit strukturor, EN 1990, 2001

[3] Eurokodi 1: Veprimet mbi struktura - Pjesa 1-4: Veprimet e përgjithëshme-Veprimi i erës, EN 1991-1-4, 2005.

[4] Eurokodi 1: Veprimet mbi struktura - Pjesa 4: Veprimet në sillose dhe rezervuare, EN 1991-4, 2006a.

[5] Eurokodi 8 : Projektimi i strukturave rezistente ndaj tërmetit - Pjesa 4: Sillose, Rezervuare dhe tubacione, EN 1998-4, 2006b.

[6] Pojani,N dhe Stavileci, M.:Metoda e elementeve të fundme, Prishtinë 2006.

[7] Pojani, N. dhe Lako, N: Dinamika e strukturave, Tiranë 2002.

[8] Jagxhiu, F.:Rezistenca e Materialeve-pjesa 1 dhe pjesa 2, Prishtinë 1995.

[9] N. S. Fish.: The History of the Silo in Wisconsin (Wisconsin Magazine Of History. Volume: 08 /Issue: 2 1924-1925), http://content.wisconsinhistory.org/u?/wmh,4312 (accessed January 27, 2010), 160. John Scott, Farm Buildings: A Practical Treatise (London: Crosby Lockwood and Son, 1914), 62.

[10] Petrovčič, S.: Steel silos for particulate solid materials – Part 1: Actions at filling and discharge, Ljubljana, 2009.

[11] Petrovčič, S.: Steel silos for particulate solid materials – Part 2: Membrane Forces at filling and discharge, Ljubljana, 2009.

[12] Skejiç, D: Bolanča, M.: Projektiranje silosa s aspekta načina protoka materijala pri pračnjenju, Zagreb, 2013.

[13] Tatomiroviç, M.: Opterećenja u celijama silosa od uskladištenih zranstih matrijala, Novi Sad, 2008.

[14] Deshmokh, S.: Comparison of design & seismic behavior of RCC silo, India, 2015.

[15] Pojani, N.:Inxhinieria sizmike, Tiranë 2003.

[16] Stavileci, M.: Teoria e sistemeve sipërfaqësore, Prishtinë, 1997

[17] Carson, J. W. and R. T. Jenkyn: Load Development and Structural Considerations in Silo Design

[18] Presented at Reliable Flow of Particulate Solids II, Oslo, Norway, August 1993. Used with the permission of the publisher.

[19] Briassoulis, D and D.A. Pecknold, M. ASCE, Anchorage requirements for Wind, loaded, empty silos, New York, 1986.

[20] Jenike, A.W.: Storage and Flow Solids, University of Utah Engineering Experiment Station, Bulletin No: 123, Nov. 1964

[21] Design Recommendation For Storage Tanks And Their Supports with Emphasis On Seismic Design, 2010 Edition, Architectural Institute of Japan

[22] J.W. Carrson Load Development and Structural Consideration in Silo Design

The Chronology and Post - Fire Effects on General Medicine Hospital Building, Tirana University Hospital Center

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This paper presents a case study of the fire's chronology and identification of it from a fire protection system. The way that other systems have reacted at the time of fire such as fire alarms, access controls, AHUs, pressurization systems, and elevators. This building has the implementation of BMS (Building Management System) and it is a new building finished just a year ago, so we present here the importance of monitoring the system at the time that a fire starts. And the benefits of integrating BMS with the fire identification system through smoke sensors. We also indicate that the REI compartment area, especially the application of REI walls and doors, had a high effectiveness in limiting the fire in the technical rooms on level 1 and ground floor. It indicates the effects and damage caused to the building, and what could have happened if the exposed to the fire had been longer. Here is highlighted also the general damage to the Hospital, including the departments that went out of service, which affects the hospital's functionality. After the fire, a site investigation was done to determine the post-fire damage assessment on the reinforcement structure, and the proposals for intervention and repairs of the structure.

Keywords: *Fire systems, BMS, structural damage, post-fire.*

1. INTRODUCTION

This paper is about the event of fire that happened on 11 February 2024 in General Medicine Hospital Center. The fire started on level -2, in the morning and lasted around 2.5 hours. The flames arrived till the ground floor, across the shaft of electrical cable. Ater the fire a site investigation has been done and here we are going to show some photo, and to explain reaction of other compartment and systems of the building at the moment of fire.
Considering the temperature of area and slab during the fire, measured by firefighter we will analyze changes of physical and mechanical characteristic of concrete and steel on the damage zones of structure. Also, we are going to explain here the damage done in the structure and an evaluation of bending moment before and after the fire of slab at level –2, taking into consideration construction project. Here are going to be mentioned even the collapse that was created on the service and functionality of some department of the hospital.
This Hospital is a new building finished just a year ago and it has the implementation of BMS system, so we are going to give some information about this too, and the way it works, emphases also the beneficial of monitoring and getting the information in real time

2. MATERIALS AND METHODS

2.1. Physical and chemical phenomena in concrete

In the event of a fire, a very sharp rise in temperature may trigger physical-chemical changes in the concrete, such as dehydration by drying of the concrete and decarbonization. These phenomena can cause shrinkage, losses of resistance and rigidity of the materials.
Dehydration and decarbonization are endothermic reactions: they absorb energy and therefore slow down heating. They therefore go hand in hand with absorption of heat which slows down

the heating of the material exposed to the fire. A dehydration and vaporisation front forms from the heated surface where the temperature barely exceeds 100 °C (see figure 1).
For concrete, the loss of resistance results mainly from the formation of internal cracks and the degradation/disintegration of the cement paste. As described above, several transformations resulting from the significant increase in temperature occur in the cement paste, causing a loss of cohesion. Generally speaking, the negative effects of heat mentioned above only act on an external layer 3 to 5 cm thick. It is worth remembering that, even damaged, concrete acts as an insulating layer, a thermal shield. It protects the load-bearing core from the full effect of the high temperatures.

Table 1. The concrete changes in an extremely complex manner during a fire

Temperature in the concrete (°C)	<100	>100	100 to 800	>300
Reaction Of Concrete	As a general rule this temperature is inoffensive to concrete. Simple expansive	The concrete loses its free water. The water which is not chemically bonded evaporates from the capillary pores	The concert loses its chemically bonded water from CHS	The paste in fact contracts while the granulates expand. Long – term heating at this temperature significantly reduces to traction. The concrete begins to disintegrate
Temperature in the concrete (°C)	400 to 600	+-575	>700	1150 to 2000
Reaction Of Concrete	Calcium hydroxide Ca (OH)2 is broken down into calcium oxide CaO and H2O.	Spontaneous transformation of quartz α into quartz β which goes hand in hand with an increase in the volume of concrete.	The transformation of limestone CaCO3 into Calcium oxide CaO and CO2 begins	The concrete begins to melt. First the cement paste, and then the aggregates.

2.2.The mechanical and thermal characteristics of concrete and steel.

The losses of strength in concrete and steel are shown below on the same graph. Re-rating factor ks(θ) for rezistenece and re-rating factor of stifness for concrete and steel.

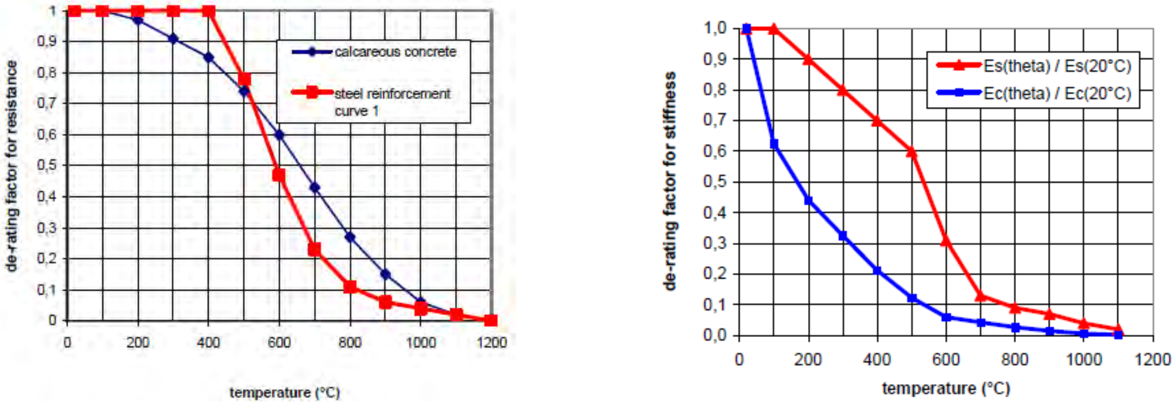


Figure 1. Comparison of the mechanical characteristics of steel and concrete due to temperature

The above graph is not common: it shows that the relative loss of rigidity is greater for concrete than for steel! This reflects the capability of concrete, as expressed above, to tolerate the restraint. This significant drop in the rigidity of concrete at high temperatures has relatively little influence on the rigidity of compressed elements in concrete as only the first few centimeters from the surface are affected. Conversely, the thermal diffusivity of steel, 25 times greater than that of concrete, combined with a low massivity of the pieces, has a serious influence on the buckling behavior of steel pieces.

2.3.Flexural of slab and Strengthening

Fibre reinforced polymers can easily be utilized to strengthen existing reinforced concrete slabs on grade to enhance flexural capacity, to avoid excessive slab deformations and to reduce stress concentrations around regions of cut-outs. The idea of bonding FRP sheets on the tension side of the slab is similar to the well-known method of flexural strengthening reinforced concrete beams in flexure by bonding FRP sheets.

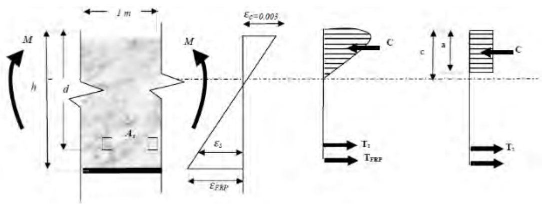


Figure 2. Cross section, stress and strain calculation for bending moment.

Capacity of tension bending moment of a reinforced slab, without the strengthen, as we know is:

$$M = A_s \times f_{yd} \times z \tag{1}$$

$$\text{where } f_{yd} = \gamma \times f_{yk} = 0.87 \times f_{yk} \text{ and } z = 0.9 \times d$$

$$M = 0.87 \times A_s \times f_{yd} \times 0.9 \times d = 0.783 A_s \times f_{yk} \tag{2}$$

Where, M is capacity of tension bending moment of a reinforced slab, A_s is reinforcement area, f_{yd} is designed resistance of steel and z is the distance.
The strain level in the FRP strengthening system is limited by the strain in the concrete or the ultimate strain in the FRP system and is given as:

$$\varepsilon_{fe} = \varepsilon_{cu}\frac{h-c}{c} - \varepsilon_{bi} \le K_m \varepsilon_{fu} \tag{3}$$

Where, ε_{fe} is the effective ultimate strain in the FRP at failure, ε_{cu} is the ultimate compressive strain in the concrete (0.003), c is the depth of the neutral axis, h is the depth of the section, and ε_{bi} is the existing tensile strain in the concrete substrate at the location of the FRP strengthening system when the FRP system is applied.

3. RESULTS AND DISCUSSION

3.1. Fire Event and damage

The fire started in the morning at level -2, according to information taken from fire identification system; smokes sensors were activated at 5:18. The flames arrived till the ground floor, across the shaft of electrical cable. The origin of the fire is not known for sure but there are indicators that show that flames have started from battery of UPS of Angiograph. This battery was under one of the main shafts of electrical cable that gives power to one quarter of the building and during the fire all the cables that passes throw this shaft were burnt till the ceiling of level 0. At level -1 the door of technical room was closed, which had delayed the smoke to spread at this level, but a different situation was on ground floor where the door was opened. Because of this, smoke was spread faster here, this can be noticed even from the amount of the activation sensor at ground floor. Even at level -2 two main doors were left open, as resalt the smoke at this area was with high intensity.

The flames inside the technical room at level -1, have lasted for more than an hour and only because it was used REI 120 walls and Door, the fire was not spread at the other area at this floor. The situation would have been worse if the technical room was not with REI material, or the door was left open. If the fire would have lasted longer and the temperature would been higher, there would have happened another big problem. The floor at level -1 has an Igloo, which means that between the slab of level -2 and the floor of level -1, there are installed Igloo with 70cm height, and then 20cm reinforced concrete. So, it would have been a big issue if the igloo was gone on fire, because would have been difficult to stop the spreading of fire under the floor and turn it off.

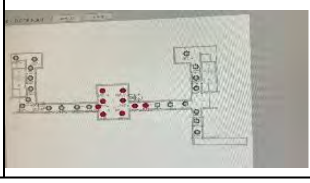
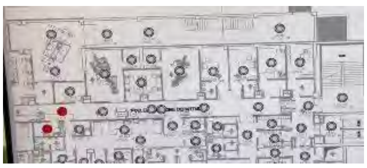
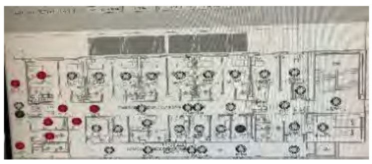
	Level -2	Level -1	Ground floor
Materials during and after the fire	 The area where the fire started	 Smoke at level -1. Coming from technical room	 Smoke at ground floor, coming from technical room
Sensors of smoke			

Figure 3. Smoke detector activation and photo

Beside the fire detection sensor, another system was affected by the fire and reacted at the same time with a smoke alarm. So, it was activated immediately the fire evacuation alarm, saying: “A fire has been detected at the building, please keep coming and go into nearest exited”. At the same time all AHUs were off and fire dampers were closed to stop the smoke spread throw the channel air.

3.2. BMS System, the way it works and the information getting from it.

As we mention above the building has implementation of BMS system. That is separated into mechanical and electrical BMS. Above we have attached some photos taken after the fire. To explain what information we can get from BMS we also have include some other photos taken during motoring process when everything was working properly.
The mechanical part of BMS is responsible for AHU, Chiller and Nuclear wastewater.
On the other hand, electrical BMS gives information in real time for Medium Voltage, Medical Gases, Pomp drainage, UPS and generator, Pressurized air, Septic water, Elevators etc. From the electrical BMS we can get in real time if there is any error or if an event is happening, for example in the photo below we can notice that the elevator nr .4 is out of service. Mechanical BMS is more interesting, because here we not only can take in real time parameters of mechanic equipment, but we also could change from here. For example, if we want to increase or decrease the temperature of the air ventilation coming into the building, we can do it from the computer without having the need to go fiscally where the equipment is installed.

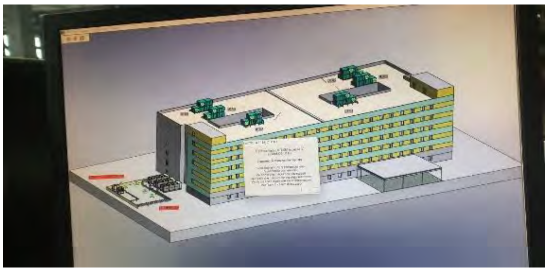
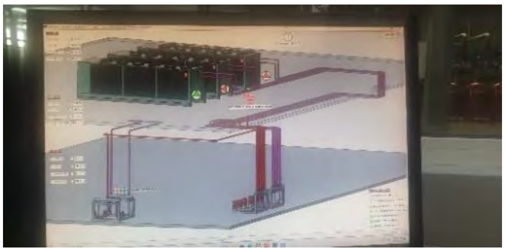
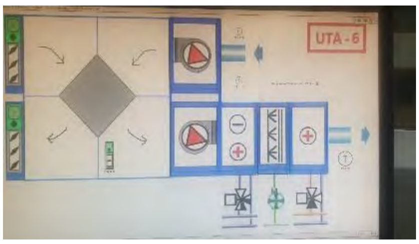
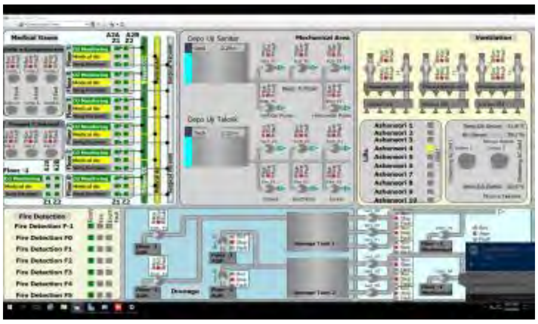
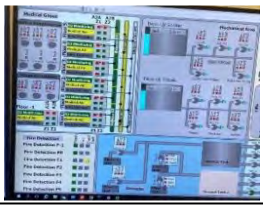
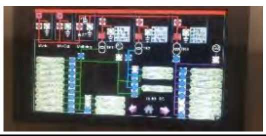
<table>
<tr><th></th><th>Mechanical BMS</th><th>Electrical BMS</th></tr>
<tr><td>Photo done after the event of fire</td><td>
Information for AHU it is not possible to take, because there is no power supply for AHU</td><td>
Here are still registered the fire alarms (Different sensor of smoke had different time of activation)</td></tr>
<tr><td>Photo done during the time that system was working properly, times before event</td><td>
</td><td>
</td></tr>
</table>

Figure 4. Electrical and mechanical BMS

3.3 Structural damage and suggestions for strengthening

After the fire was done an investigation on the site, to evaluate the situation on the building, considering structural and functionality damage of the hospital. Because of the fire a quarter of each floor of the object was without electricity, and out of service. At ground floor department of hemodynamic was not in function because, there was no power supply in three Angiographs equipment's, and was impossible to treat patient with cardiac sufficient. Most of the patients have cardiac issues that's why even the emergency was almost out of service. Besides this all AHU-s were off, as resalt there was no aspiration of air at all the building.

3.3.1 Site evaluation of structural damage

As we mentioned before, the fire started at level-2, the structured damaged here is done on slab and perimetral wall. It is around 2 m^2 slab damaged and 1.5 m^2 reinforced concrete wall. As shown above from the photos some parts of concrete are removed, which is protective layer (from 3 to 5cm). Fire compartment and REI materials that were used at the building had a high effective role especially at technical room at level-1. The door and the gypsum walls of this room were REI 120. Because of that the fire was locked only in that room for about 1.5 hours and did not spread around at floor -1. According to the firefight, at level -2 and in technical room at level -1, the temperature arrived 500 degrees Celsius. Below there are some photos taken at level -2 and -1 after the fire.

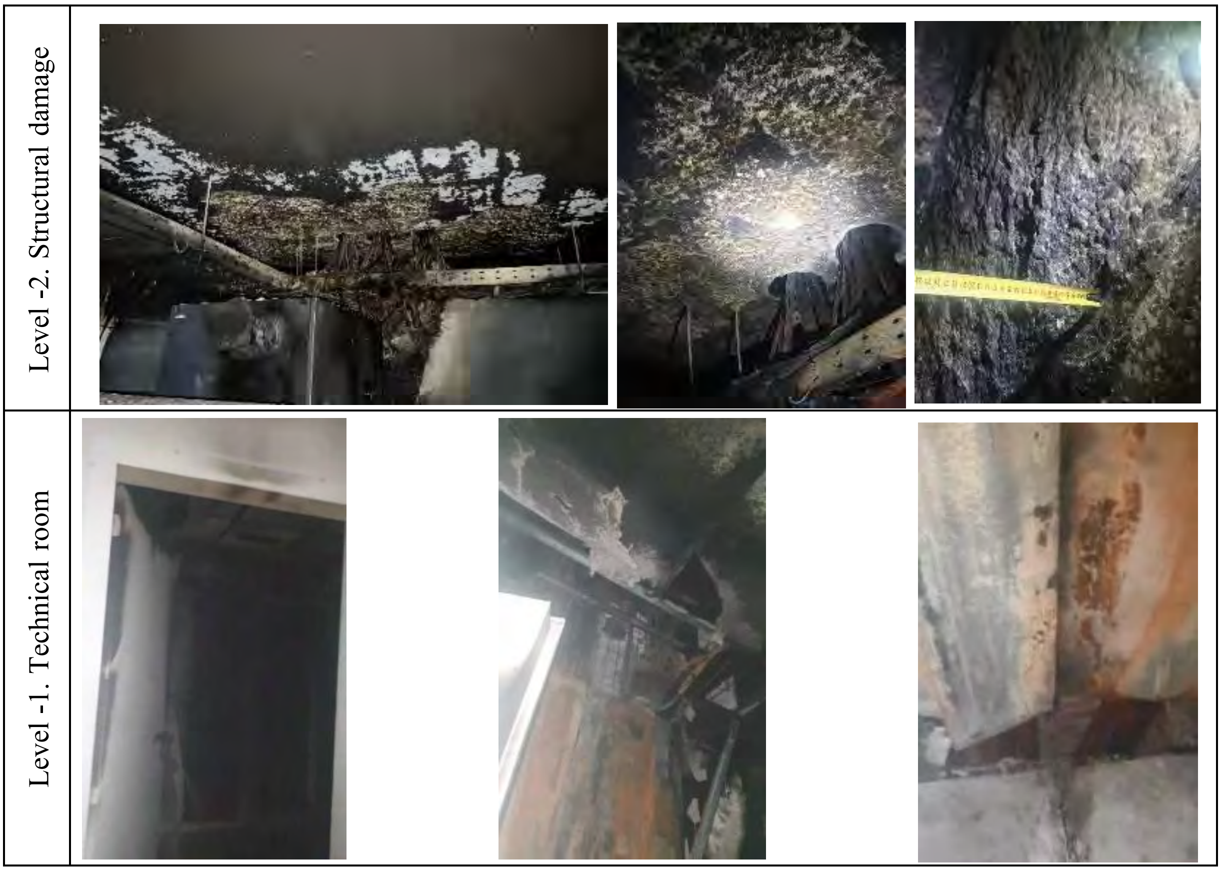


Figure 5. Structural damage of fire

3.3.2. Calculation of capacity of bending moment of slab before and after the fire and suggestions for strengthening

To calculate capacity of the slab we are going to take in consideration structural project of the building and the temperature registered from the firefighters,
From the temperature we have found the de-rating factor of resistance of steel.
According to the design reinforcement of the slab is Φ14/15cm with steel S500. For 1ml section of the slab we have:

$$A_s=100/15*3.14*D^2/4=100/15*3.14*0.14^2/4=10.26cm2$$

$$h=50cm \quad d=h-5=45cm \quad f_{yk}=5000daN/cm \quad f_{yd}=\gamma*f_{yk}=0.87*f_{yk}$$

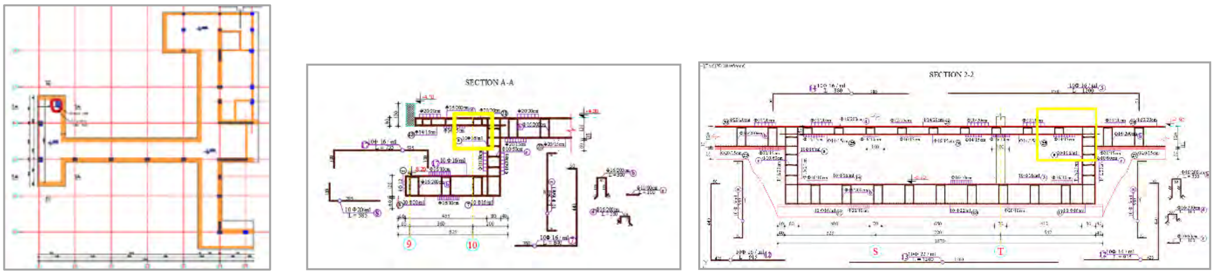


Figure 6. Reinforcement Concrete from structural project.

Capacity of the slab before the fire is:

$$M=A_s*f_{yd}*z=0.87*A_s*f_{yd}*0.9*d=0.87*10.26cm^2*5000daN/cm^2*0.9*45cm=18075.5daN*m$$

$$M_{before\,fire}=180.75KN*m \tag{4}$$

According to firefighters the temperature at level -2 have been around 500 degrees Celsius. This means that according to the diagram of fig. 1

$$f_{yd}'=0.77*f_{yd}=0.77*\gamma*f_{yk}=0.77*0.87*f_{yk}=0.67*f_{yk} \tag{5}$$

$$M=A_s*f_{yd}'*z=0.67*A_s*f_{yd}*0.9*d=0.67*10.26*5000*0.9*45=13920.5\ daN*m \tag{6}$$

$$M_{after\,fire}=139.21KN*m$$

3.3.3. Suggestion and techniques for strengthening with composites.

There are mainly three types of fibers that are used for strengthening civil engineering structures, namely glass, aramid and carbon fibers. It should be recognized that the physical and mechanical properties can vary greatly for a given type of fiber as well of course the different fiber types.
Advanced composites as strengthening materials consist of a large number of small, continuous, directional zed, non-metallic fibers with advanced characteristics, bundled in a resin or inorganic matrix. Depending on the type of fiber they are referred to as CFRP (carbon fiber based), GFRP (glass fiber based) or AFRP (aramid fiber based); when different types of fibers are used, the material is called “hybrid”.
Typical commercial products where composite materials of the fiber-reinforced polymer type (FRP) in the form of prefabricated strips have the properties given in Table 2

Table 2. Properties of typical commercial products of composite materials

Material	Elastic modulus	Tensile strength F_f (MPa)	Ultimate tensile Strain ε_{fu} (%)
Prefabricated strips			
Low modulus CFRP strips	170	2800	1.6
High modulus CFRP strips	300	1300	0.5

There are two main technics for strengthening, used in civil engineering: basic technique and special techniques. The basic composite material strengthening technique, which is most widely applied, involves the manual application of either wet lay-up (so-called hand lay-up) or prefabricated systems by means of cold cured adhesive bonding. This is the so-called classical FRP strengthening technique. Common in this technique is that the external reinforcement is bonded onto the concrete surface with the fibres as parallel as practically possible to the direction of principal tensile stresses. Besides the basic technique, several special techniques have been developed, such as automated wrapping, prestressed FRP, Fusion-bonded pin-loaded straps, prefabricated shapes, near-surface mounted reinforcement, application of textile-reinforced mortar (TRM) jacketing, mechanically fastened FRP etc.

4. CONCLUSION

Hight temperature on the damage zones of structure had changed physical and mechanical characteristic of the concrete and steel. Re-rating factor for resistance of steel is $k_s(\theta=500\,℃)=0.77$ and for concert is $k_c(\theta=500\,℃)=0.75$. It is important to measure that $k_c(\theta)=0.75$ coefficient is only for the protective layer of concert because even damaged concrete acts as a thermal shield that protects the load-bearing core from the full effect of the high temperatures. The significant drop in the rigidity of concrete at high temperatures has relatively little influence on the rigidity of compressed elements in concrete as only the first few centimeters from the surface are affected. So as conclusion the structural damage of fire in our case effect only the resistance of steel

During investigation on the site, we have emphasized the fact that structural damage of the building is at level -2. As conclusion to make the reinforcement we should at least to consider the bending moment from external force to be equal to the capacity of bending moment before the fire. For this reason we must consider $M_{ed}=M_{before,fire}=180.75KN*m$, in addition to this we must taking in consideration that the actual design strength of tension for steel is $f_{yd'}=0.67f_{yk}$

Fire compartment and REI material which have been used at the building had a high effective role especially at technical room at level -1, which had stopped the fire from spreading to other area at this floor.

For strengthening of the structure we could use CFRP, given in the table above (tab.2), by taking in consideration their type and characteristic of material and the technology of application.

Because of the fire, a quarter of the hospital was without electricity, the department of hemodynamic and main urgency was almost out of service, and the air ventilation of wall the building was without power supply.

If the fire had lasted longer the situation would have been more tragical, because of the layer of Igloo under the floor of level -1, that risked going on fire.

REFERENCES

[1] Fire Safety and Concrete Structures. *Materials* pg:43–50.

[2] FRP strengthened RC structural pg. 160

[3] Concrete Construction Engineering, Handbook. *Design of FRP Reinforced and Strengthened Concrete*. pg. 1062

[4] Project of the building. As Build

[5] Servers of control room at the building.

Different additional effects appearing from the structural construction stage.

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The Safety impact of structural construction can have safety effects on the stability, reliability, and functionality of the building. However, during the construction, these effects impact may also be on workers, residents, and visitors, including risks of accidents, injuries, and property damage if proper safety measures are not implemented. During the execution process of structures, especially in the case of reinforced concrete structures, avoiding the possibility of deviations both in geometric aspects and in materials is challenging. As a result of this issue, this paper addresses the topic of geometric deviations and material resistance during execution. Approaching the theoretical analysis of some of the defects that appeared in structures during construction and the wide range of additional effects that arise, as well as the preparatory steps for covering defects such as partial safety coefficients and the treatment of accidental eccentricity which are assumed at a percentage scale in the design phases, and the direct relationship of these factors will be shown to demonstrate how these defects affect the structure's response. The calculation of reinforced concrete structures based on structural standards allows for a limited percentage of deviations due to construction, which should not exceed these limits so that the structure's reactions to horizontal actions such as earthquakes, dead loads, and live loads do not exceed the values anticipated in the design stage. These effects are analyzed in the paper. Additionally, the effects of bending of structural elements influenced by axial compression forces are part of the treatment for the additional effects. The results of internal forces and bending moments from the designed plans are compared with the actual calculated values of forces and bending moments of the structure or their elements to assess geometric deviations and deviations in the concrete strength of structural elements, as well as the risks posed by these elements.

Key words: *Geometrical deviation, Material quality, partial safety coefficient, additional inner forces.*

1. INTRODUCTION

Recently, considering the continuous increase in population density, there has been a significant increase in the need for designing and constructing taller structures. Given the considerable heights and current construction techniques, it has been observed that during the realization of reinforced concrete structures, we may encounter local and global deviations in the structures. As a result of these deviations, efforts have been made to also consider additional influences resulting from these possible deviations. These additional influences have been termed second-order effects.

Second-order effects involve analysing a structure based on its deformed geometry. This type of analysis recognizes the deformation in a structure due to an externally applied load and determines its effect on the internal forces created by it. For smaller structures and buildings of lower importance, second-order effects may not be considered. However, for taller structures, this effect can reduce the load-bearing capacity of each element, particularly their bending moments, leading to continuous deformation in elements or even structural collapse in local or global parts. For taller buildings, considering these effects can play a crucial role in structural design and particular attention should be given to execution to ensure that these deviations do not exceed the projected values.

Second-order effects are a problem that is receiving significant attention in civil engineering, where not all structural design codes address this issue in the same way. Assumptions, simplifications, and approaches vary, as each country has its own unique way of addressing engineering problems.

Given that during design we use different codes depending on the country where the structure will be executed, and we use different assumptions for deviations depending on the code, it was deemed necessary to analyse a reinforced concrete structure calculated or designed and compare it with the real state as executed, and evaluate whether the deviations and material resistances assumed during design will be similar to those of the executed state. The structure is designed based on European standards and is implemented by engineers, following and respecting the design to the fullest extent. However, after measurements of several elements (columns) in the building floors by geodesists, some vertical deviations are evident, and we also address them to achieve the concrete casing.

For the actual calculation of the load-bearing capacity of structural elements such as the column in this case, the real measured strength of the concrete casted in these elements is used (cubic samples taken during the concrete pouring of the elements, tests using the Schmidt hammer, and core samples) to observe the behaviour and the actual current capacity of the elements.

The objective of this work is to analyze the existing structure and compare it with the values obtained from their design. Taking into account the real strength of the concrete and the actual measurements of the geodetic data, especially the theory of second-order effects in real time, the aim is to assess the actual situation of the structure and analyse the potential resistance or risk of the structure.

2. THEORETICAL ASPECTS OF ANALYSIS

When the structural member is load to axial forces and bending moments, it deforms or deflects. So, when the element deviates or creates an eccentricity from the designed axis, additional bending moments occur in certain elements of the structure due to the interaction of axial force and eccentricity gained. Depending on the dimensions of the element, these influences can play a significant role in structural design. These additional effects are called second-order effects.

In general, structural design codes assume that second-order effects may be neglected if they represent less than 10% of the first-order moment. However, this rule is not practical for the structural designer, as it requires calculating additional influences to determine if they are negligible. For this reason, regulations have developed simplified methods to verify if these effects are indeed a problem that needs to be considered.

In case second-order effects cannot be neglected, then a nonlinear analysis needs to be performed. This type of analysis should take into account the geometric and physical nonlinearities of the structural elements.

It is important to emphasize that there are two distinguishable types of second-order effects:

- Global effects (or P-Δ effects) affect the entire structure and occur in structures that exhibit significant horizontal displacements when subjected to vertical and horizontal loads. These types of structures are called flexible structures.
- Local effects (or P-δ effects) affect individual elements that undergo significant displacements when subjected to axial loads, regardless of what happens to the structure as a whole. Here, the moment-curvature diagram follows a nonlinear behavior, unlike what happens with the first-order moment.

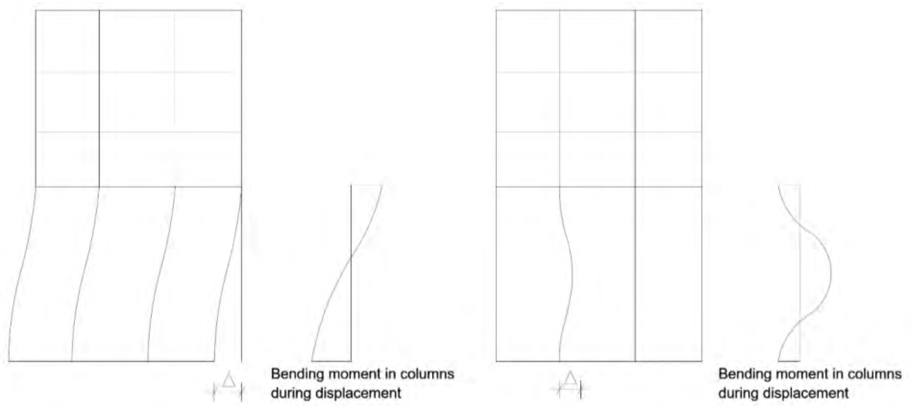


Figure 1. The way of columns deviation: (a) Effect P-Δ (entire structure); (b) Effect P-δ (Single Column) (Narayanan and Beeby, 2005).

The P-Delta method is an iterative approach that allows the calculation of global second-order effects by introducing fictitious horizontal (binary) forces that induce an equivalent effect to second-order moments. Here, the nonlinear analysis is replaced by as many linear analyses as needed for convergence, considering a predefined tolerance.

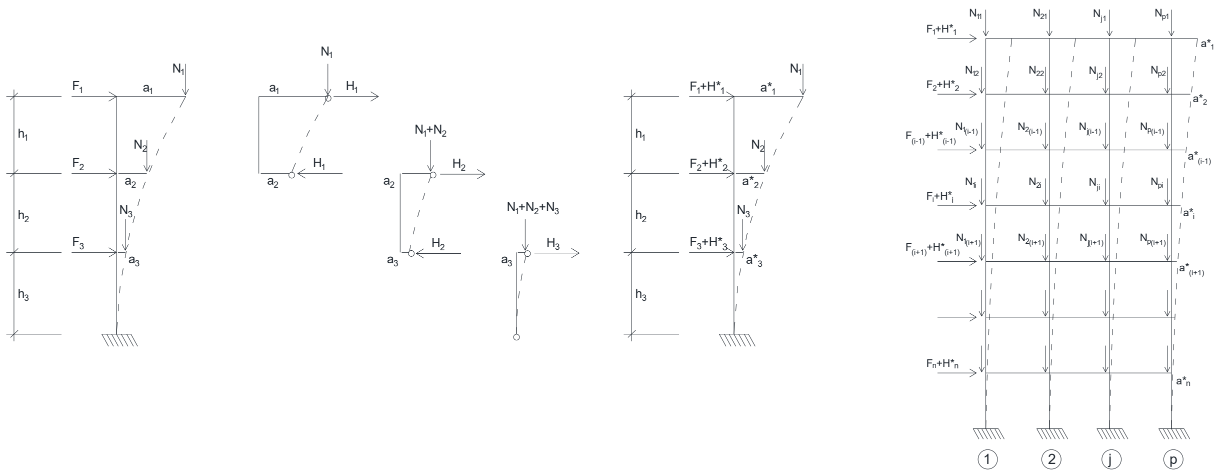


Figure 2. Method P-Delta: a) for the single column and b) for Frame structure (Longo, 2017)

For the Single Column

For the theoretical analysing of the single columns, it has to approve the several verification steppes:

- The displacements taken for the every floor, a_i from the linear analysis of structure,
- The computation of the relative displacements in evry floor, $\Delta a_i = a_i - a_{i+1}$,
- The computation of the horisontal – shear force, $H_i = N_i \frac{\Delta a_i}{h_i}$,
- For the cross section, the fictive shear force are, $H_i^* = H_i - H_{i-1}$, those shear force are added to the main shear force of Fi, where are $F^* = F_i - H_i^*$,
- To the next step it has to be computed the horisontal displacement iniciated from the additional shear force. This computation method has to converge.

For the entire structure

For the frame structure, the computation method is more or less same and the shear force are:

$$H_i = \sum N_{j,i} \frac{\Delta a_i}{h_i} \rightarrow H_i^* = H_i - H_{i-1} = \sum N_{j,i} \frac{\Delta a_i}{h_i} - \sum N_{j,i} - 1 \frac{\Delta a_{i-1}}{h_{i-1}} \tag{1}$$

Where: $\Sigma N_{j,i}$ is summary of the vertical load in floor i and above.

3. IMPERFECTIONS IN STRUCTURES

The different imperfections must take in consideration for the structural analysis as are:
- Geometrical imperfections,
- Material imperfections, and
- Structural imperfections.

3.1.The geometrical imperfections

Geometrical structural imperfection refers to deviations or irregularities from the intended geometric shape or alignment in structural elements. These imperfections can arise from various factors such as fabrication tolerances, construction errors, or deformations under load. They may include deviations in dimensions, curvature, alignment, or orientation of structural members relative to their intended positions or shapes. These imperfections can affect the behavior and performance of the structure, especially under load, and are important considerations in structural analysis and design.

3.2.The material imperefection

Material structural imperfection refers to irregularities or flaws inherent in the material itself that may affect its mechanical properties or structural behavior. These imperfections can occur during the manufacturing process, such as inclusions, voids, cracks, or variations in material composition. Additionally, material imperfections can result from environmental factors, such as corrosion or degradation over time.

In structural engineering, understanding and accounting for material imperfections are crucial for ensuring the safety and reliability of structures. Various testing and inspection methods are employed to detect and assess material imperfections, allowing engineers to make informed decisions during the design, construction, and maintenance phases of a structure.

3.3. The structural imperfections

In structural engineering, imperfections can manifest in different forms, including geometric irregularities (such as variations in dimensions, out-of-plumbness, or out-of-straightness), material inhomogeneities (such as voids, cracks, or material property variations), or boundary conditions (such as support settlements or restraints).

EN 1992-1-1 has a series of provisions regarding this, which affect the design of the structure as a whole, certain slender elements, and elements that transfer forces to the supporting members.

For design according to ULS (Ultimate Limit State), these imperfections must be taken into account, as they will lead to additional effects affecting the forces on the elements. The methods for calculating these actions vary from code to code.

The geometrical imperfection it may consider as a global - entire structure and the local – simple members of structure. The imperfection may represent from the initial angle off deformation,

$$\theta_i = \theta_0 \cdot \theta_h \cdot \theta_m \tag{2}$$

Where:

θ_i – initial base value
α_h – reduction factor for the length or hight

$$\alpha_h = 2/\sqrt{l};\ \ 2/3 \le \alpha_h \le 1 \tag{3}$$

α_m – reduction factor for the number of members

$$\alpha_m = \sqrt{0.5(1 + 1/m)} \tag{4}$$

l – length or light [m],
m – number of vertical members effects on the total imperfection.

Notice: The value of θ_0 is taken from the national annexes, however the recommendation values are $l/200$.

In the expression above the values for the l and m depends from three different cases shown in Figure 3.

- The isolated element, effects; l= real length of the member, m=1.
- Bearing member, effects; l=Hight of building, m= number of the vertical members contributing on the shear force of bearing system.
- Shear wall, effects; l=Hight of the floor, m=number of the member on the floor contributing on the shear base force.

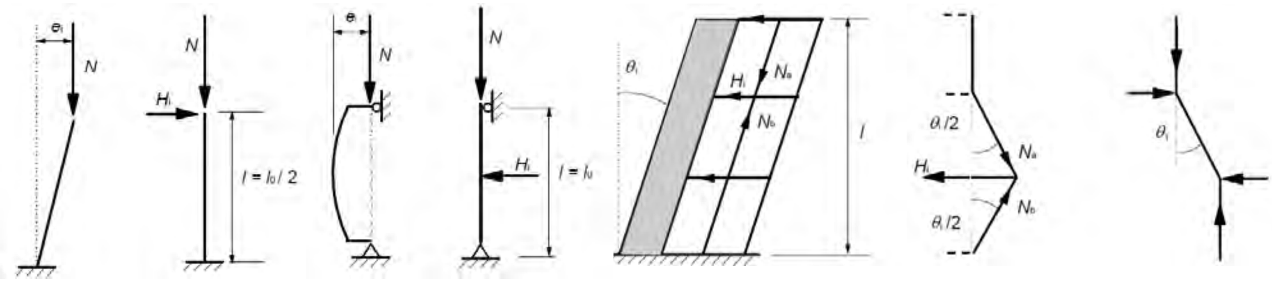


Figure 3. The types of the geometrical imperfections (EC 1992-1-1:2004 (E)).

For the single members, the effects of the imperfection may take in consideration in the two-alternative solution:

a. As eccentricity of e_i given in EC 1992-1-1:2004

$$e_i = \theta_i \cdot l_0/2 \tag{5}$$

Where: l_0 is the effective length of the column.

For the shear wall and the single columns, the $e_i = l_0/400$ value may use as simplify, corresponding with $\alpha_h = 1$.

b. As shear force, H_i in position of producing the maximum bending moment:

For the fixed members; Figure, a1 $H_i = \theta_i N$

For the fixed members; Figure, a2 $H_i = 2\theta_i N$

Where the N is axial load.

Notice: The eccentricity is suitable for statically determinate elements, while the lateral load can be used for both statically determinate and indeterminate elements. The force H_i can be replaced by some other equivalent lateral action. For structures, the effect of skewness θ_i can be represented by transverse forces, to be included in the analysis along with other actions.

The effect on the bearing system, Figure b.

$$H_i = \theta_i \cdot (N_b - N_a)$$

The effect of the shear wall, Figure 3c1.

$H_i = \theta_i \cdot (N_b + N_a)/2$

The effect on the roof shear wall, Figure 3c2

$H_i = \theta_i \cdot N_a$

Where, N_a and N_b are incline force contributing in the H_i.

As a simplified alternative for walls and single columns in structural systems, an eccentricity e_i = l_0/400 can be used to account for imperfections related to normal execution deviations.

4. THE ANALYSED STRUCTURE, STUDY CASE

The existing structure under analysis is a dual frame system with vertical elements such as columns and seismic walls with these floor levels: 4UG+B+23. The structure was constructed in September 2022. During construction, the materials used in this structure (concrete strength and reinforcement) were monitored and analysed through various types of tests (cubic samples directly from concrete casting on-site, Schmidt hammer tests, and samples taken from elements - cores). The data extracted from these samples assist in analysing material imperfections. For proper analysis of the structure's quality, especially regarding the verticality of columns and walls, data were obtained from inclinometers, which aid in analysing the geometric imperfections of the columns.

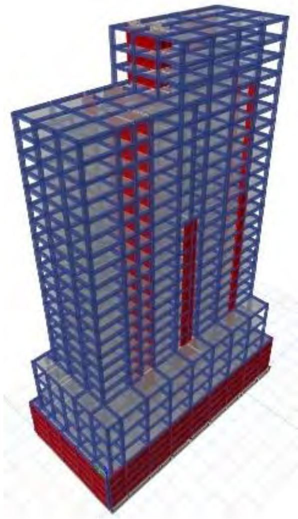


Figure 4. The Analysed Structure, 3D

4.1. A short description of the constructed structure.

All construction floors - slabs are made of reinforced concrete with a constant thickness of 20cm supported in both directions by beams. The beams have different cross-section depending on their position (60/60 and 60/45). The columns have different cross-section, and their shapes are rectangular. The design of the structure ensures that all columns meet the ductility class requirement – medium. The shear walls are placed at the base of the building in such a way that the centre of mass and stiffness are equal (to prevent torsion of the building). Additionally, the shear walls are designed with various dimensions to meet the requirements regarding the medium ductility class achievement. The foundation of the building is reinforced concrete slab type with varying depths (180cm and 300cm). The structural design is based on Eurocode standards for structures, especially for reinforced concrete structures in seismic zones.

4.2. The analyzed representative structural members chosen.

The entire structure consists of linear and surface members. The linear members include columns, beams, while the surface elements consist of slabs (concrete slabs) and vertical walls (seismic walls). For this work, linear structural elements such as columns have been analysed. The characteristic floors contain 28 main columns, and the entire structure has 686 columns interconnected with other structural elements. The selected representative element for analysis is based on the maximum vertical deviation (geometric imperfection), where this column element had achieved a smaller compressive strength than the designed one (material imperfection), taking into account the level and position of the element as well. The selection of columns is based on their significant impact on both geometric and material imperfections, reducing internal forces and increasing bending moment. All analyses are performed based on Eurocodes for constructions, specifically all standards related to reinforced concrete construction, particularly for the type of dual vertical system structures (Columns and Walls).

4.3.Real measurements taken

All geometric measurements taken in the field represent data on the assessment of the verticality and horizontality of structural components (Columns, walls, and slabs), as well as data on the compressive strength measurements of the concrete in these structural elements.

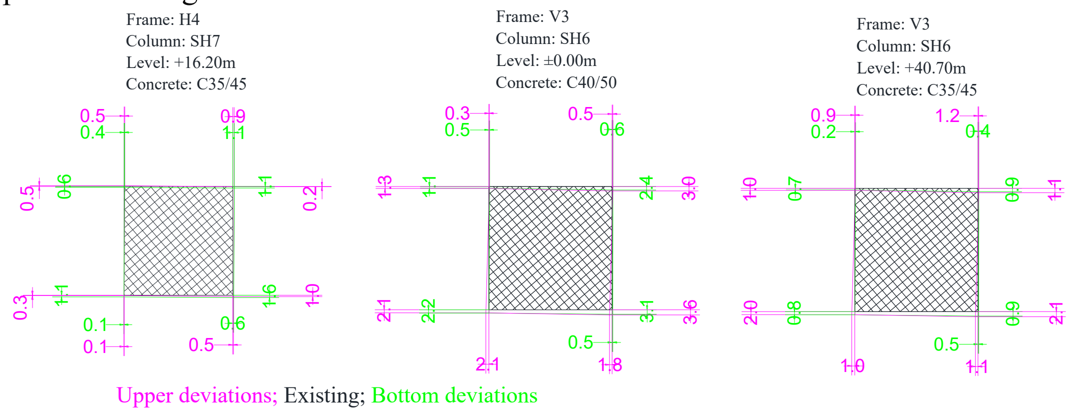


Figure 5. Columns geometrical deviations during their construction

Table 1. Comparation of the results from the design values taken and the constructed

Compared results from the design computation and the construted								
Description			Column 6 (POS SH_6) Level ±0.00m		Column 7 (POS SH_7) Level +16.20m		Column 6 (POS SH_6) Level +40.70m	
			DESIGN	CONSTRUTED	DESIGN	CONSTRUTED	DESIGN	CONSTRUTED
Statical values	M (bending moment)	kN·m	2551,8	3022,5	1449,13	1875,3	613,66	1392,5
	T (shear)	kN	168,19	168,19	224,5	224,5	359,23	359,23
	N (axial)	kN	7706,07	7706,07	7432,21	7432,21	3239,03	3239,03
Strength of materials	Concrete grade	Mpa	C40/50	C30/37	C35/45	C30/37	C35/45	C25/30
	reinforcement grade	Mpa	B500B	B500B	B500B	B500B	B500B	B500B
Slendernes of the structural members	Real length (l)	m	6	6	3,575	3,575	3,50	3,5
	Slenderness lentgth (lo)	m	21,78	21,18	15,94	15,73	20,7	19,77
	Ratio of thickness (λ)	-	88,76	86,31	73,81	72,82	95,6	91,55
	limited thickness (λlim)	-	25,23	21	28,13	33,22	53,63	57,55
	Local geometrical imperfection (ei)	m	0,025	0,036	0,019	0,016	0,025	0,021
	Second order eccentricity (e2)	m	0,26	0,31	0,125	0,186	0,29	0,31
	Supposed local geometrical imperfection (eo)	m	0,0283	0,0283	0,025	0,025	0,025	0,025
	Aproved reinforcement area (Asl,prov)	mm²	9812,5	9812,5	8705,65	8705,65	7598,8	7598,8
	Requaried reinforced area (Asl,req)	mm²	5202	12727,5	5325,5	11826	3937,5	5748,75

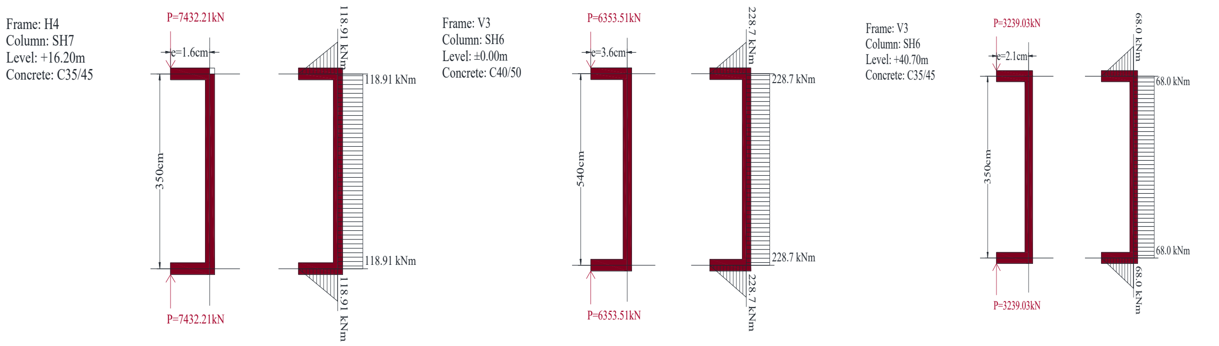
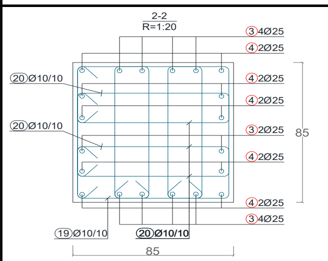
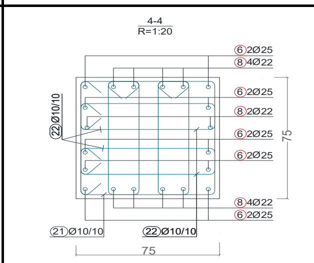
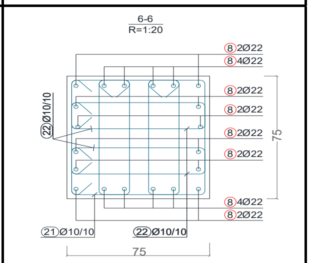


Figure 6. the additional values of the bending moments.

Table 2. Results comparation of the real insitu capacity with the designed for the representative columns chosen.

Theoretical obtined results from the real structure compeared with the values from the design of the resistance.								
Pos, members analysed			COLUMN 6 (POS SH_6) Level ±0.00m		COLUMN 7 (POS SH_7) Level +16.20m		COLUMN 6 (POS SH_6) Level +40.70m	
Grade of materials	Concrete grade	Mpa	C30/37		C30/37		C25/30	
	Reinforcement used grade	Mpa	B500B		B500B		B500B	
Description								
			Real Bending Moment from computation	Resistant Bending Moment	Real Bending Moment from computation	Resistant Bending Moment	Real Bending Moment from computation	Resistant Bending Moment
			Msds	MRd	Msds	MRd	Msds	MRd
Static values	M (momenti)	kN·m	3022,5	2949,36	1875,3	2334,4	1392,5	1712,52
Ratio of the Bending Momoent Values			MRd/Msds > 1.0; **2949.36/3022.5=0.976**		MRd/Msds > 1.0; 2334.40/1875.30=1.245		MRd/Msds > 1.0; 1712.52/1392.50=1.230	

4.4.Recommendations

Based on the above analyses of the constructed structural members with defects during their construction and comparing the results with the design - calculated model of the construction, particularly the columns, also taking into account the quality of the cast-in-place concrete, which has lower values than the designed one, it is noted that some of the columns in the building do not meet the required capacity. In the entire structure, 11 columns have been reinforced.

5. CONCLUSION

The advice for engineers is that during the construction phase of reinforced concrete structures, special attention should be paid to the verticality of columns and walls and the concrete grade of structural elements. Overcoming opposing moments occurs due to the increase in the values of bending moments and internal forces, while at the same time reducing the load-bearing capacity of the element's bending. When the quality of the concrete fails from the designed one and is combined with eccentricity as a result of improper construction, then the value of the load-bearing capacity of the structural elements falls below the required values.

REFERENCES

[1] Seismic Design of Concrete Buildings to Eurocode 8 (Fardis, Eduardo C. Carvalho, Peter Fajfar, and Alain Pecker)
[2] Worked examples for the design of concrete structures to EUROCODE 2; (Author: Tony Threlfall)
[3] The EC2 worked example: Description, actions, durability, materials (Authors: Francesco Biasioli; Giuseppe Mancini)
[4] Seismic strengthening of RC buildings (Authors: Georgios Tsionis, Roberta Apostolska, Fabio Taucer)
[5] Seismic Design of Concrete Buildings to Eurocode 8 (Authors: Michael N. Fardis, Eduardo C. Carvalho, Peter Fajfar, and Alain Pecker)
[6] Reinforced concrete design to eurocodes; design theory and examples (Authors: Prab Bhatt, Thomas J. MacGinley, Ban Seng Choo)
[7] Reinforced concrete design to Eurocode 2 (Authors: W.H Mosley; R. Hulse;J.H Bungey)
[8] Strength of Materials (Authors: Andrew Pytel and Ferdinand L. Singer)
[9] Mikrozonimi sizmik i Gjilanit
[10] Manual for the design of concrete building structures to Eurocode 2 (Authors: Dr D Pike; Prof A W Beeby;Dr P Chana; C Goodchild; J C Mason; K R Wilson)
[11] How to Design Concrete Structures using Eurocode 2 (Authors: A J Bond; O Brooker; A J Harris; T Harrison; R M Moss; R S Narayanan; R Webster)
[12] Geotechnische Nachweise und Bemessung nach EC 7 und DIN 1054 (Author: Conrad Boley (Hrsg.))
[13] Eurocode 2: Design of concrete structures EN1992-1-1 (Author: J.C. Walraven)
[14] Connections (Author: Anil K. Chopra)
[15] Designers guide to EN1992-1-1 and EN1992-1-2; Eurocode 2: Design of concrete structures Authors: R.S Narayanan, A. Beeby)
[16] Concrete Structures (Authors: Mehdi Setareh · Robert Darvas)

Assessing the Seismic Performance of a Communist-Era Albanian Residential Building Using Nonlinear Static and Dynamic Analyses

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In this study it is presented the seismic performance assessment of a 5-story premodern reinforced concrete building using static and dynamic nonlinear analyses procedures. The building was designed as a template model during the communism period in Albania to save architectural fees and build throughout the country. The current condition of these buildings is at a critical level due to many deficiencies. The investigations after the November 26, 2019 earthquake in Albania has shown that the aging of concrete, poor workmanship, corrosion of longitudinal bars, insufficient confinement reinforcement were among the main reason of the severely damages observed from this typology. In this study the mathematical model it is prepared in the Zeus-NL package, a powerful software capable of running enormous number of analyses almost effortlessly. The capacity curve of the building is assessed using static nonlinear analysis (Pushover) following Uniform, Inverted Triangular and Modal shape pattern in both orthogonal directions. Additionally, the demand calculations are performed using a group of 10 ground motion records for the utilization of the time history analyses. The limit states are defined as immediate occupancy (IO), life safety (LS) and collapse prevention (CP) following modern guidelines. The evaluation of the structural performance is achieved by monitoring the base shear ratio and the global drift ratio. Furthermore, the comparison of the lateral loading patterns for the pushover analysis effects on the capacity curve is derived in the end of the study.

Keywords: *Pushover Analysis; Time History Analysis; 5-story RC Building Typology; Seismic Performance Assessment;*

1. INTRODUCTION

Earthquakes are natural disaster that often are accompanied with loss of life and destruction of infrastructure. For the past 3 years several significant earthquakes have stuck different regions over the world, having a great impact impacting not only the country where the epicenter is located but also causing widespread destruction in surrounding areas. During the period November 2019 and February 2023, several significant earthquakes occurred with devastating consequences. Indonesia unfortunately is a meeting point of several tectonic plates, leading to several earthquakes structing the country several within short periods of time. The most recent one took place on 21 November 2022 with a magnitude of 5.6 Richter, resulting in more than 335 confirmed deaths caused by collapsed buildings [1].

In February 2023, one of the most powerful recent earthquakes in Europe occurred in Turkey and Syria. Their territorial border was struck by a sequence of earthquakes, including magnitudes of 7.8 and 7.5, respectively. The earthquake doublet and their aftershocks had led to confirmed deaths of more than 50 000 in Turkey and 7 200 in Syria [2].

Figure 1: Consequences from devastating earthquakes in Indonesia (a), in Albania (b) and Turkey (c)

Albania as well experienced a devastating earthquake on 26th of November 2019 causing at least 21 deaths and 600 injuries, with significant damage along the Adriatic coastline and in Tirana [3]. The devastating phenomena of these earthquakes are illustrated in figure 1 as shown.

2. 1982's TEMPLATE BUILDING

2.1. Description of the building

The building selected for this study was designed using premodern code as a residential building in Albania. The plan details are ensured from the technical archive of Tirana, Albania. The building is a 5-story, symmetrical, reinforcement concrete designed without shear walls in any of its directions.

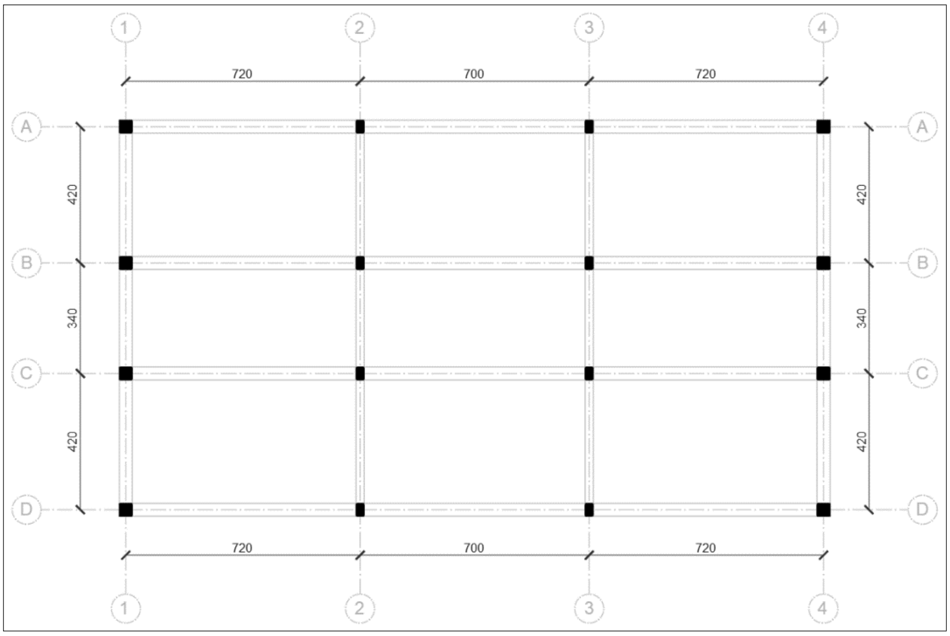

Figure 2: Plan layout of the template building

The story height is 2.8 m resulting in an overall building height of 14 m. In its longitudinal direction it is composed of three bays and in the transverse one by four columns as shown in figure 2. The overall plan area reaches about 252 m^2.

2.2.Materials and Section properties

The material and section properties for the template building selected in this study are determined based on the blueprint data. The concrete class specified in the plan details is given as M-200 known as “Marka 200” from the Albanian terminology. This is recognized as Concrete class C16/20 [4]. The reinforcement is used from the steel type Ç3 which corresponds to tensile strength of f_{ck}=250 MPa and elastic modulus E=210 GPa [4].

The template building is prepared as a moment resisting frame composed of no shear walls in any of its directions. The typical beam and columns cross-sections are provided in figure 3.

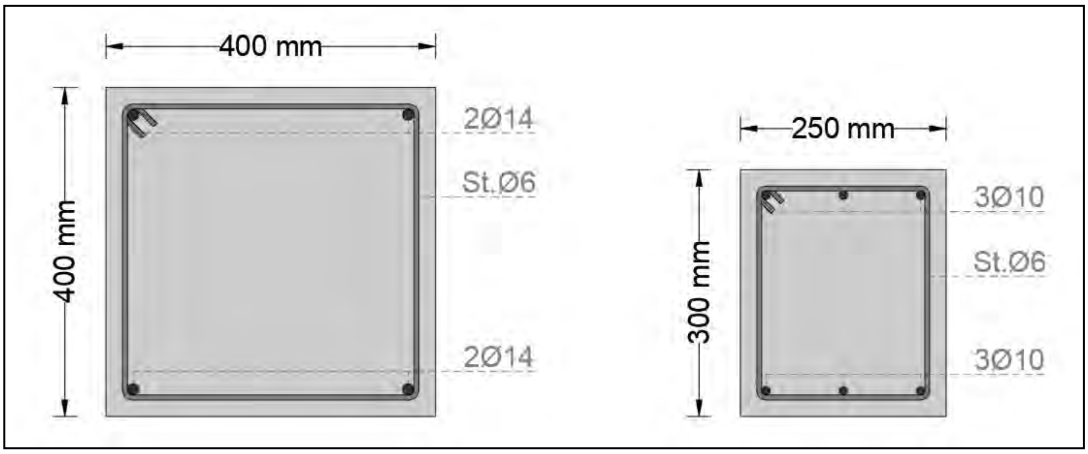

Figure 3: Typical column (left) and beam (right) cross-sections used in the 1982’s Template Building

3. MODELLING STAGE

The seismic global performance of the selected building in this study is evaluated using nonlinear analyses procedures performed by Zeus-NL platform [4]. Zeus-NL is a finite element software developed with a strong background especially for earthquake engineering applications [4, 5]. The template building is modelled by representative frames in x- and y-direction as shown in figure 4. The structural elements are modelled using a cubic elasto-plastic type 3D element to model beams and columns.

The bilinear elasto-plastic material model with kinematic strain hardening (stl_1) was used for the steel reinforcement, while the uniaxial constant confinement concrete material model ($conc_2$) was used for the concrete material which are integrated in the software library [6]. Once the analytical model is ready, the analyses can be performed under various static and dynamic loading applications.

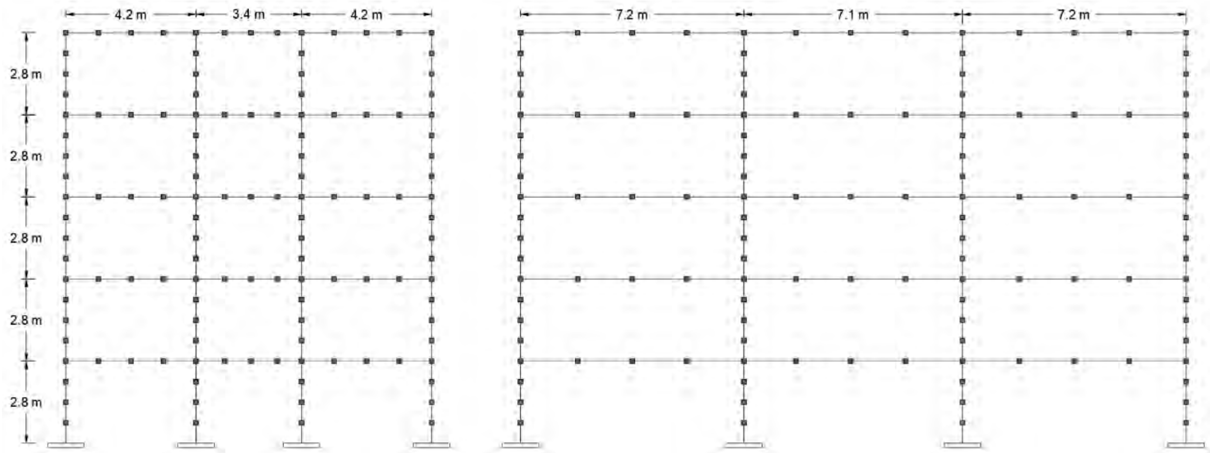

Figure 4: Representative frames used for the mathematical model, x-direction right and y direction left

4. STATIC AND DYNAMIC NONLINEAR ANALYSES

4.1. Modal analysis

After the preparation of the mathematical model in ZeusNL software, the modal analysis can be performed under the effect of the lumped masses assigned based on the dead load and live load calculations. Zeus-NL platform uses Lanczos algorithm [6] for the evaluation of the structural natural frequencies and mode shapes.

4.2. Static Pushover Analysis (SPO)

The capacity of the building is estimated using the nonlinear static analysis, also known as static pushover (SPO).

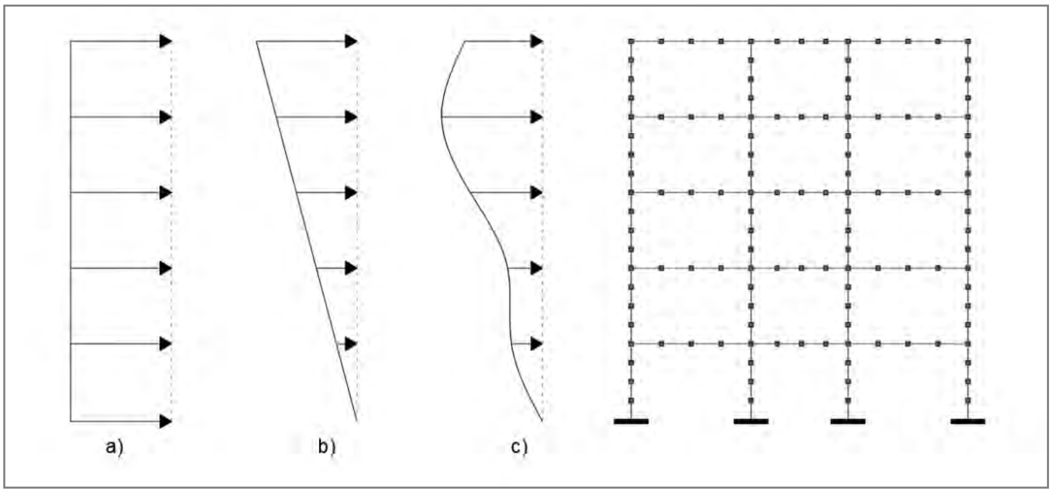

Figure 5: a) Uniform, b) Triangular and c) Modal lateral load patterns

The application of the SPO in Zeus-NL is done using both orthogonal directions. The final results gathered from the analyses are plotted in graph as the base shear ratio in y- and global drift ratio in drift in x- direction respectively. Furthermore, in this study there are used three different lateral loading patterns while performing the pushover analyses. This is done to depict the differences in the capacity of the building under uniform, inverted triangular and mode loading pattern as shown in figure 5.

4.3. Time History Analysis (TH)

The non-linear dynamic time history analyses were performed using a set of ten real ground motion records. The records were selected from different peak ground acceleration values as shown in the Table 1. Ground motion records were taken from the Pacific Earthquake Engineering Research Center (PEER) [7] and from the U.S Geological Survey (USGS) [8]. The accelerograms are presented in Appendix A. Each frame is subjected to ten dynamic time history analyses. The obtained results are selected as maximum base shear and maximum global drift.

Table 2. Ten ground motion records used for this study

No	Event	Year	Station	Ø°	Soil	M	R (km)	PGA (g)
1	Northridge	1994	LA, Baldwin Hills	90	B	6.7	31.3	0.239
2	San Fernando	1971	LA, Hollywood Stor. Lot	90	C,D	6.6	21.2	0.210
3	Tabas	1978	Iran, Dayhook	280	B	7.4	20.6	3.500
4	Loma Prieta	1989	WAHO	0	D	6.9	16.9	0.370
5	Loma Prieta	1989	WAHO	90	D	6.9	16.9	0.638
6	Imperial Valley	1979	Chihuahua	282	C,D	6.5	28.7	0.254
7	Corinth	1981	Greece, Corinth	0	C	6.6	19.9	0.264
8	Loma Prieta	1989	Coyote Lake Dam Downstream	285	B,D	6.9	22.3	0.179
9	Friuli	1976	Italy, Tolmezo	270	B	6.5	20.2	0.345
10	Loma Prieta	1989	Hollister South & Pine	0	D	6.9	28.8	0.371

Ø° Component, **Soil** USGS Geomatrix soil class, **M** moment magnitude, **R** closest distance to fault rupture

5. RESULTS

The modal analysis applied in the environment of Zeus-NL software of the template building provides the deformed shape for each of the modes. Consequently, figure 6 shows the period of the structure and the dominated shapes in x- and y- frames of the building.

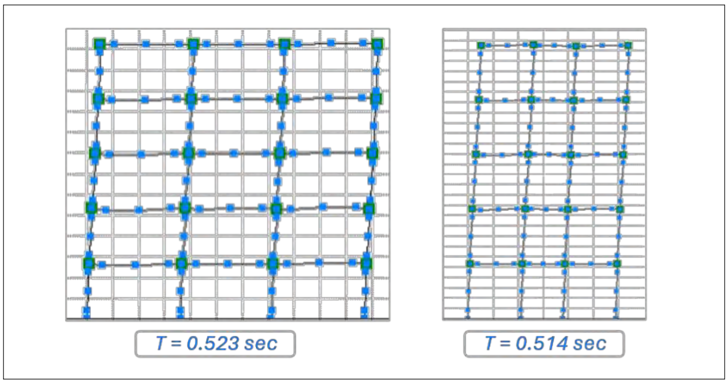

Figure 6. Deformed shape of the x (left) and y (right) frames from the modal analysis

Despite the strong background in running advanced analyses almost effortlessly, Zeus-NL lacks its user interface. For instance, the user must define the loading patters in the pushover analysis manually for each of the story nodes. Hence, the modal loading pattern is extracted from the deformed shape of the first mode in both orthogonal frames and applied as a loading shape laterally in the software. Simultaneously, the uniform and inverted triangular patterns are utilized.

Once the analyses are performed, the capacity of the building is estimated by the help of pushover results which are represented in x-axis by the global drift ratio and in y-axis with base shear ratio. The SPO curves for both directions of the building are shown in figure 7 and 8.

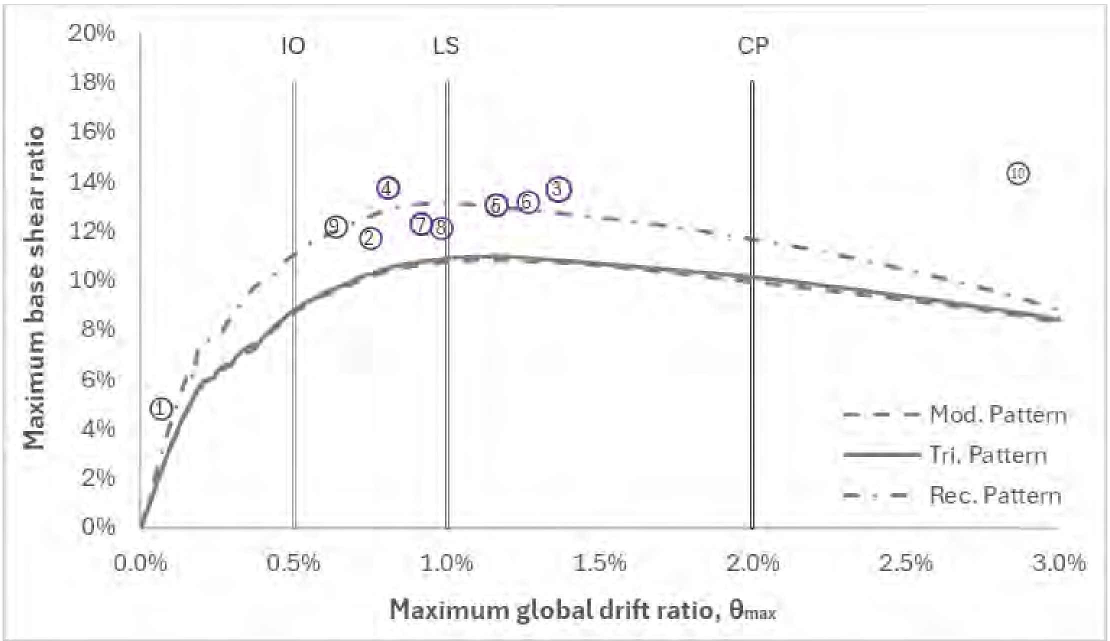

Figure 7. Capacity vs Demand with limit states in X-direction

As shown from the figures, the pushover curves with modal and triangular lateral loading pattern show very good correlation of the building capacity results. Nevertheless, the curve plotted from the uniform loading pattern indicates discrepancies from the other two curves thus overestimating the structural load bearing capacity. Similar results have been mentioned before by several researchers [9].

Additionally, the demand calculation of the building is done by the help of non-linear dynamic time-history analysis (TH). The time history data gathered from the software output, are adopted in the same graph with pushover curve to compare both results as shown in figures 7 and 8. Each of the time history results represents one earthquake circled and labeled in numbers which corresponds to the index provided in table 1.

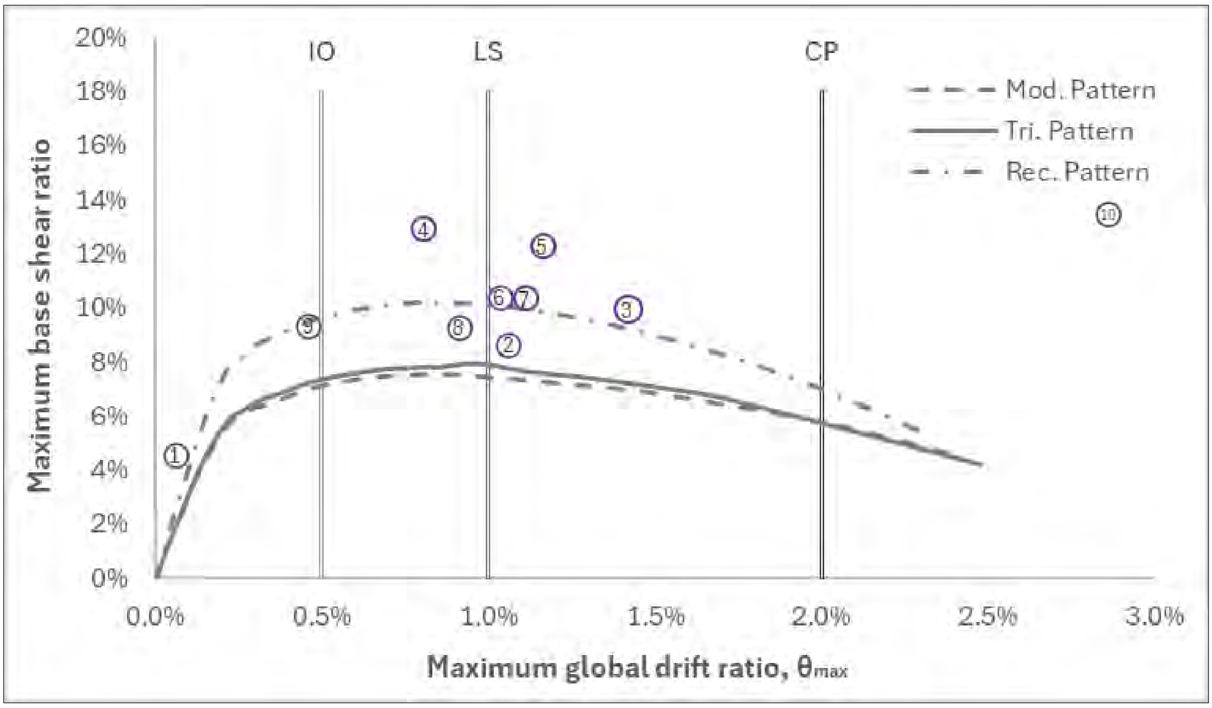

Figure 8: Capacity vs Demand with limit states in Y-direction

As demonstrated by the graph, the majority of the earthquakes exceed the base shear capacity of the selected building especially when considering the triangular or modal SPO curves. On the other hand, the uniform pattern, underestimates the demand of a few earthquakes.

FEMA 356 offers guidelines for assessing structural performance, particularly regarding drift values [9]. For properly designed structures under seismic loads, such as special moment frames (SMF), recommended drift values are 1% for immediate occupancy (IO), 2% for life safety (LS), and 4% for collapse prevention (CP) levels. It has been proposed that for intermediate moment frames, drift limits should be reduced to 0.5% for the IO performance level, 1% for LS, and 2% for CP performance levels [10, 11].

Further to the limit states, the building shows poor seismic performance. As illustrated by the boundaries of IO, LS and CP, most the of earthquakes violate these performance points showing higher global drift values. On the other hand, earthquake number 10 (*"Loma Prieta, 1989, Hollister South & Pine"*) surpasses the majority of the drift demands from other earthquakes. This may happen due to the inherent characteristics of the accelerogram [9].

6. CONCLUSIONS

In this study there are applied three analyses to get sufficient data for the global seismic performance evaluation of a premodern reinforced concrete template building designed with no modern seismic code provisions.

The uniform load pattern while applying the pushover curve overestimates the lateral load bearing capacity of the building while the triangular one shows good correlation with modal pattern. Therefore, when compared with uniform pattern, the inverted triangular load shape shows more realistic results associated with the modal type. The demand calculations is performed by means of Time History analyses using a set of ten earthquake records. The global drift values monitored in the roof of the building model are plotted in the same graph with pushover curves for structural performance evaluation. Furthermore, the immediate occupancy IO, life safety LS and collapse prevention CP limit states are defined based on FEMA guidelines and additional studies.

The template building designed with premodern codes in Albania, shows very poor seismic performance. Almost all earthquakes violate the IO and LS performance points.

REFERENCES

[1] S. P. e. al., A conjugate fault revealed by the destructive Mw 5.6 (November 21, 2022) Cianjur earthquake, West Java, Indonesia, DirectScience, https://doi.org/10.1016/j.jseaes.2023.105830, 2023.

[2] Zhe Qu, Feijian Wang, Xiangzhao Chen, Xiaoting Wang, Zhiguang Zhou, Rapid report of seismic damage to hospitals in the 2023 Turkey earthquake sequences, ScienceDirect, https://doi.org/10.1016/j.eqrea.2023.100234, 2023.

[3] T. Guardian, "The Guardian," 2020. [Online]. Available: https://www.theguardian.com/world/2019/nov/26/albania-earthquake-rescuers-search-rubble-after-most-powerful-tremor-in-decades. [Accessed 2024].

[4] Marsed Leti, Huseyin Bilgin, "Investigation of seismic performance of a premodern RC building typology after November 26, 2019 earthquake," Structural Engineering and Mechanics, vol. 89, no. 5, pp. 491-505, 2024.

[5] A. Elnashai, Zeus NL - A system for Inelastic Analysis of Structures, Urbana–Champaign: Creating a Multi-hazard Approach to Engineering, 2002.

[6] Dimitros Vamvatiskos, Cornell C.A, Incremental dynamic analysis. Earthquake Engineering,» doi:10.1002/eqe.141, pp. 491-514, 2002.

[7] A.S Elnashai, V. Papanikolaou, D.H Lee, ZEUS-NL User Manual, Mid-Amerika Earthquake Center, University of Illinois at Urbana-Champaign, 2002.

[8] PEER, Pacific Earthquake Engineering Research Center, University of California, 12 December 2020. Available: http://peer.berkeley.edu/, 2020.

[9] USGS, Geological Survey, U.S. Department of the Interior,» 12 December 2020. Available: https://www.usgs.gov, 2020.

[10] Leti, M., Bilgin, H., "Estimation of the seismic demand and capacity of RC buildings using nonlinear analysis procedures", 2017 ICCE, International Conference of Civil Engineering. Tirana, Albania," 2017.

[11] FEMA-356, Prestandard and commentary for the seismic rehabilitation of buildings', Washington: federal emergency management agency, 2000.

[12] Ramamoorthy S., Gardoni P., Bravcci J., Probabilistic demand models and fragility curves for reinforce concrete frame, Journal of Structural Engineering, 1563-1572, 2006.

A Practical Guide to Incremental Dynamic Analysis for a Premodern Reinforced Concrete Building Template in Albania

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The current study presents a methodology on the implementation of the Incremental Dynamic Analysis (IDA) on a premodern 5-stories reinforced concrete residential building. The building selected was designed and build during the communism period of Albania following no seismic guidelines. The mathematical model is prepared in the environments of Zeus-NL software, specifically designed for applications in earthquake engineering. For the utilization of the IDA, it is used a suite of 20 ground motion records showing no marks of directivity. The results of each analysis gathered from the software are further processed using the stepping algorithm to plot the IDA curve. For the intensity measure (IM) the 5% damped first mode spectral acceleration, $Sa(T_1,5\%)$ is selected, while the damage measure (DM) is represented in the plots by the maximum global drift ratio, Θ_{max}. The limit states are defined based on modern guidelines and former studies. On each of the IDA curves, the immediate occupancy (IO), collapse prevention (CP) and global instability (GI) performance points are presented. Beyond the interpretation of the structural performance based on the limit states, the generation of fractiles shows potential information at about any IM or DM step. Hence, the IDA fractiles are prepared into 16%, 50% (IDA median) and 84% as suggested in literature. Finally, the global seismic performance of the considered building will be interpreted based on the hundreds of nonlinear dynamic analyses under the IDA procedure.

Keywords: *Incremental Dynamic Analysis; Zeus-NL; Premodern RC Building Typology; Seismic Performance Assessment.*

1. INTRODUCTION

This paper undertakes a focused examination aimed at evaluating the seismic performance of a 5-story reinforced concrete building, typical of the design template commonly constructed in Albania during the 1980's. The seismic vulnerability of buildings utilized during that era presents a significant concern, arising from a combination of factors including outdated building codes and a lack of strict seismic regulations. Albania, like many regions with a history of seismic activity, has a significant portion of its population residing in structures erected between 1970 and 1990 [1]. Consequently, these buildings are particularly exposed to the devastating impacts of earthquakes, posing significant risks to the safety and well-being of inhabitants.

Ensuring the longevity and structural integrity of these aging constructions necessitates a thorough assessment of their seismic parameters. However, the evaluation of structural performance has always been a challenging task. Traditional nonlinear analysis methodologies, while useful, may lack the precision required to accurately assess the seismic fragility of these structures. In response to this challenge, our study introduces a modern analysis methodology known as Incremental Dynamic Analysis (IDA) [2]. IDA is expected to offer enhanced accuracy in seismic fragility assessment compared to traditional nonlinear approaches. The methodology employed in this paper involves the step-by-step definition of limit states using the state-of-the-art IDA approach, covering a diverse range of ground motion records. From capturing elastic behaviour to exploring potential structural instability or collapse, the analyses progress methodically to offer a comprehensive understanding of the seismic fragility of the chosen structure.

2. BUILDING MODEL AND GROUND MOTION SELECTION

In this study we have selected the "Banesa tip per qytetin" template as a representative of the aging reinforced concrete building from Albania's communist era. Designed in 1980's, this residential building template remains in active use to this day. In architectural terms, the building has a symmetrical layout, spanning 21.40 meters in length and 11.8 meters in width, divided into three bays and four frames. Standing at a total height of 14 meters, the five-story building features standard floor heights of 2.8 meters each, as shown in figure 1. Its structural framework consists of reinforced concrete moment frames without any shear walls in either direction.

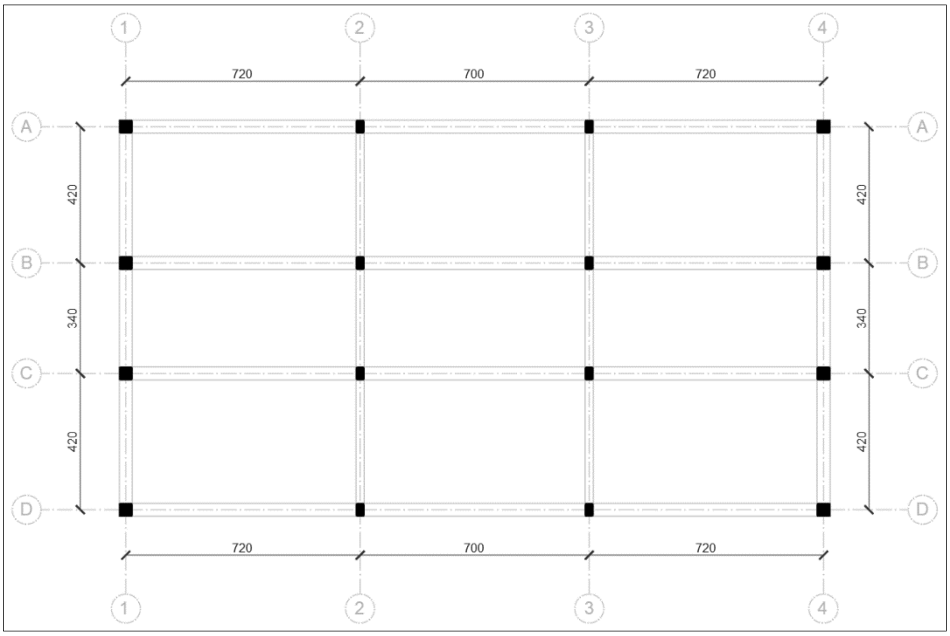

Figure 9. Plan layout of the template building

To conduct the mathematical modeling of the selected building, we employed Zeus-NL software, using cubic elasto-plastic 3D elements to represent beams and columns [3]. The steel reinforcement was characterized by a bilinear elasto-plastic model with kinematic strain hardening (stl1), while the concrete was represented using the uniaxial constant confinement concrete material model (conc2). The building is modelled by the representative middle frames in x- and y- direction. The concrete strength specified in the blueprint corresponds to a class of C16/20.

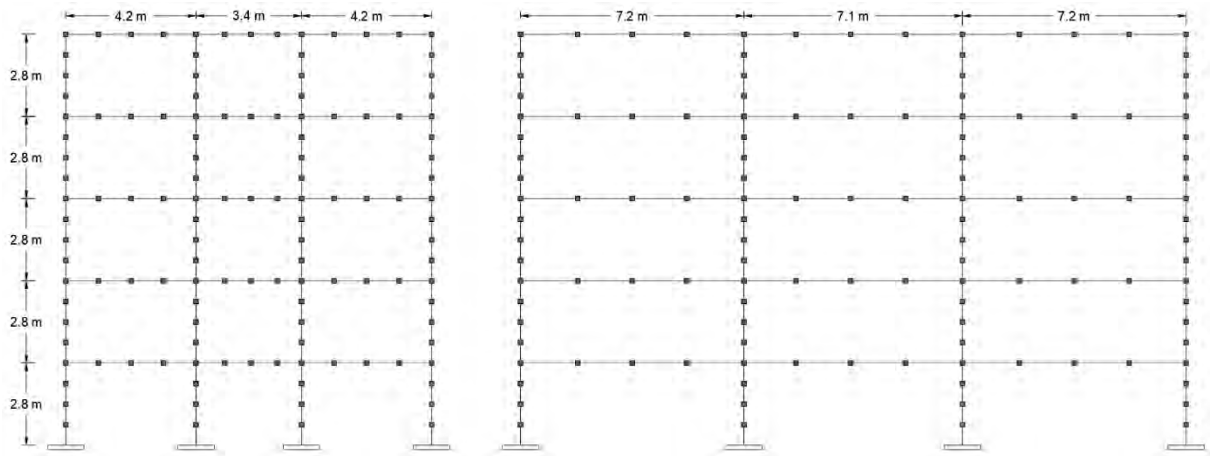

Figure 10. Representative frames used for the mathematical model, x-direction right and y direction left

Overall, this paper involves the analysis of two models employing one of the most advanced and contemporary methodologies available, Incremental Dynamic Analysis [2, 4]. To perform the analysis, in this study it is used a list of twenty ground motion records showing no marks of directivity. Existing literature recommends employing ten to twenty earthquake records to ensure adequate results while focusing on estimating seismic demand [5].

Table 3. Twenty ground motion records used for this study

No	Event	Year	Station	Ø°	Soil	M	R (km)	PGA (g)
1	Corinth	1981	Greece, Corinth	0	C	6.6	19.9	0.264
2	Kocaeli	1999	Turkey, Duzce	180	C	7.1	1.6	0.427
3	Erzincan	1992	Turkey, Erzincan	90	C	6.7	8.9	0.488
4	Friuli	1976	Italy, Tolmezo	270	B	6.5	20.2	0.345
5	Imperial Valley	1979	Chihuahua	282	C,D	6.5	28.7	0.254
6	Imperial Valley	1979	Plaster City	45	C,D	6.5	31.7	0.042
7	Imperial Valley	1979	Westmoreland Fire Station	90	C,D	6.5	15.1	0.074
8	Loma Prieta	1989	Agnews State Hospital	90	C,D	6.9	28.2	0.159
9	Loma Prieta	1989	Coyote Lake Dam Downstr.	285	B,D	6.9	22.3	0.179
10	Loma Prieta	1989	Hollister South & Pine	0	D	6.9	28.8	0.371
11	Loma Prieta	1989	Sunnyvale Colton Ave	270	C,D	6.9	28.8	0.207
12	Loma Prieta	1989	WAHO	0	D	6.9	16.9	0.370
13	Loma Prieta	1989	WAHO	90	D	6.9	16.9	0.638
14	Northridge	1994	LA, Hollywood Storage FF	360	C,D	6.7	25.5	0.358
15	San Fernando	1971	LA, Hollywood Stor. Lot	90	C,D	6.6	21.2	0.210
16	San Fernando	1971	LA, Hollywood Stor. Lot	180	C,D	6.6	21.2	0.174
17	Spitak	1988	Armenia, Gukasian	90	C	6.8	36.1	0.207
18	Superst. Hill	1987	Wildlife Liq. Array	360	C,D	6.7	24.4	0.200
19	Tabas	1978	Iran, Dayhook	280	B	7.4	20.6	3.500
20	Northridge	1994	LA, Baldwin Hills	90	B	6.7	31.3	0.239

These records were carefully selected to represent real earthquake scenarios [3]. The ground motion data are sourced from reputable institutions such as the Pacific Earthquake Engineering Research Centre (PEER) [4] and the U.S Geological Survey (USGS) [5].

3. METHODOLOGY FOR SEISMIC VULNERABILITY ASSESSMENT

3.1. Performing Incremental Dynamic Analysis

Once the template building is modelled in Zeus-NL software and seismic ground motion records are identified, the next step involves conducting nonlinear dynamic analysis. Incremental Dynamic Analysis (IDA) [2], also referred to as Dynamic Pushover Analysis (DPO) [6], traces its origins back to 1977 with its proposal by Bertero and its subsequent adoption by the Federal Emergency Management Agency [7]. This method, further advanced by Vamvatsikos and Cornell, utilizes earthquake records to perform time history analysis by incrementally increasing the intensity measure [8]. The goal is to transition the structure from its elastic range through yielding to total collapse by scaling each record accordingly. In this paper, we have used the stepping method employed in ZeusNL software for its straightforward implementation. This entails specifying the initial intensity measure, the maximum number of dynamic analyses, and the preferred intensity measure step [2]. Calculation parameters include the scale factor, earthquake intensity measure (5% damped spectral acceleration), and the structural response's damage measure (maximum global drift ratio). Despite its time-intensive nature, Zeus-NL software streamlines the process by automating record scaling, gathering response parameters, and plotting dynamic pushover points. This systematic scaling process facilitates the exploration of the system's response across a spectrum of seismic intensities. At each scaling factor, crucial response parameters such as base shear – global drift are charted on a 2-dimensional plot, mirroring the format of static pushover curves. Users can choose monitoring parameters such as base shear (v) and drift (d), with horizontal forces (v_i) from support nodes plotted against displacement or rotation differences to generate the curve [9].

3.2. Generating an IDA Curve

To generate an IDA curve using the analysis results, users must carefully select suitable Intensity Measure (IM) and Damage Measure (DM) parameters. Previous research suggests employing the 5% damped first mode spectral acceleration, $Sa_{(T1,5\%)}$, as the IM, coupled with the maximum global drift, Θ_{max}, for the DM when plotting IDA curves [8]. Following the gathering of IM and DM values from the analysis, the interpolation of the results is required. Interpolation is performed using a super spline function in Excel Spreadsheet. Figure 3 illustrates the resulting IDA curve generated through interpolation. Each dot represents a scale factor from the incremented dynamic analysis plotted in terms of the selected IM and DM parameters, while the line represents the interpolation from the collected data. As it can be seen, the curve progresses to a "flatline" after an intensity measure of 0.45g, indicating global instability where the structure responds with "infinite" Θ_{max}.

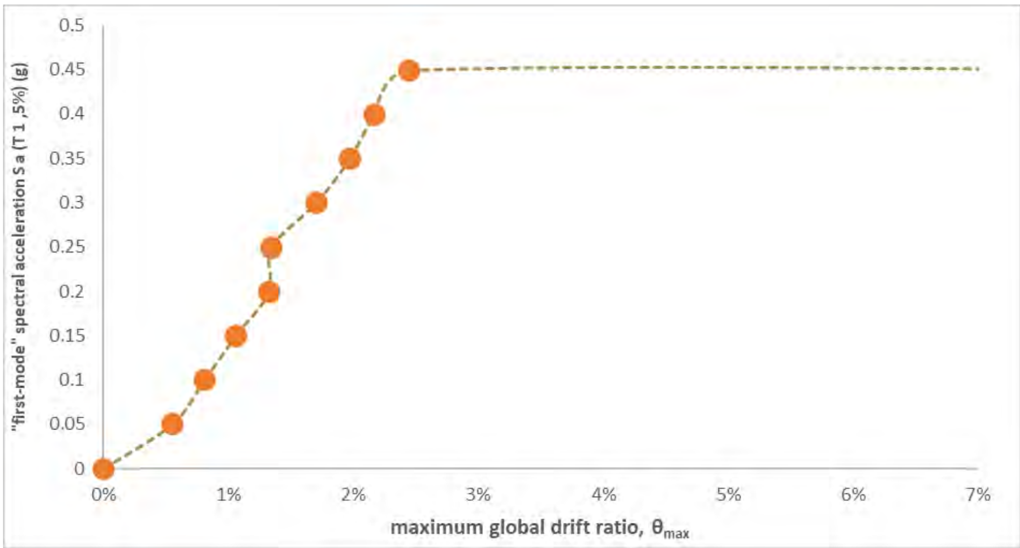

Figure 11. The interpolation of dynamic analyses points

3.3. Determination of limit states and fractiles

In Performance-Based Earthquake Engineering (PBEE), engineers use IDA curves to evaluate how buildings respond to seismic events, crucial for determining the structures' earthquake resilience levels [10]. Determining these levels isn't straightforward. There are three limit states considered in this study: Immediate Occupancy (IO) and Collapse Prevention (CP), as defined in FEMA guidelines [11] , along with Global Instability (GI), as suggested in prior research [12]. Different authors suggest Immediate Occupancy (IO) be set to 1% of Damage Measure (DM) for modern buildings, but reduced to 0.5% for premodern ones, as in this paper [13].

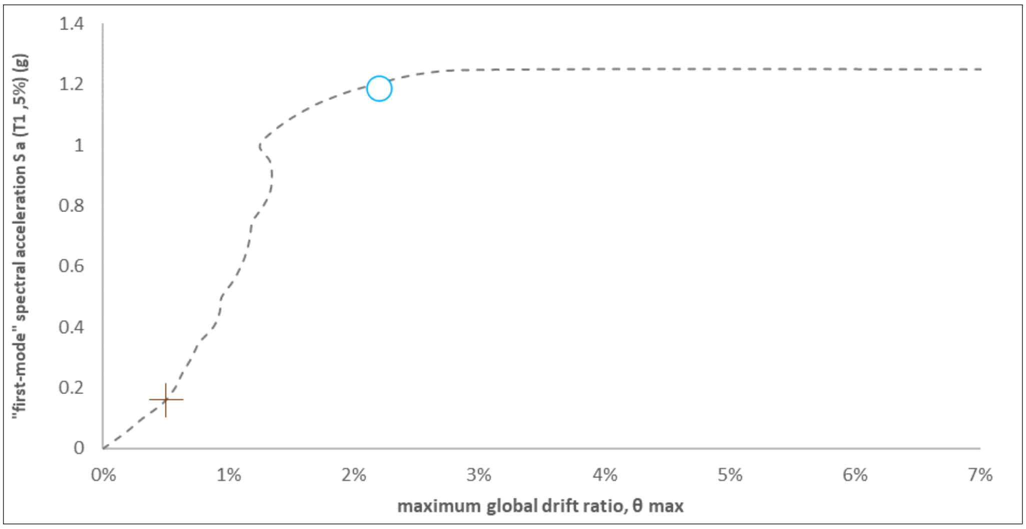

Figure 12. Defining IO and CP limit states in IDA curve

Collapse Prevention (CP) is set at the 20% tangent of the elastic slope, ranging from IO to θ_{max} = 10%. In cases where multiple points satisfy this rule; we consider the last point with the 20% slope [12]. If multiple flatlines appear, the first one is accepted and the rest ignored as they do not represent reliable results. Global Instability (GI) occurs when the IDA curve softens and reaches the flatline.

Following established methodologies [14], we chose to compute the 16%, 50%, and 84% percentile values. Using interpolation techniques, fractile values of Intensity Measures (IM) and Damage Measures (DM) are combined to construct the IDA fractile curves from 20 earthquake records given in this paper. Interpreting these fractiles simplifies the process of extracting essential information from demand calculations. In the same context, while each individual curve represents a deterministic outcome based on the structural model and ground motion record, incorporating probabilistic characterization becomes crucial in addressing the randomness associated with potential ground motion scenarios.

4. RESULTS

Over a hundreds of dynamic analyses which were conducted for the structural model under study, considering the frames in both directions. Each earthquake record contributed to the generation of 20 IDA curves for each frame. The graphs clearly illustrate the progression of the IDA curves, illustrating both softening and hardening until reaching the point of global instability (GI), indicated by flatlines on each curve, signifying the total collapse of the building.

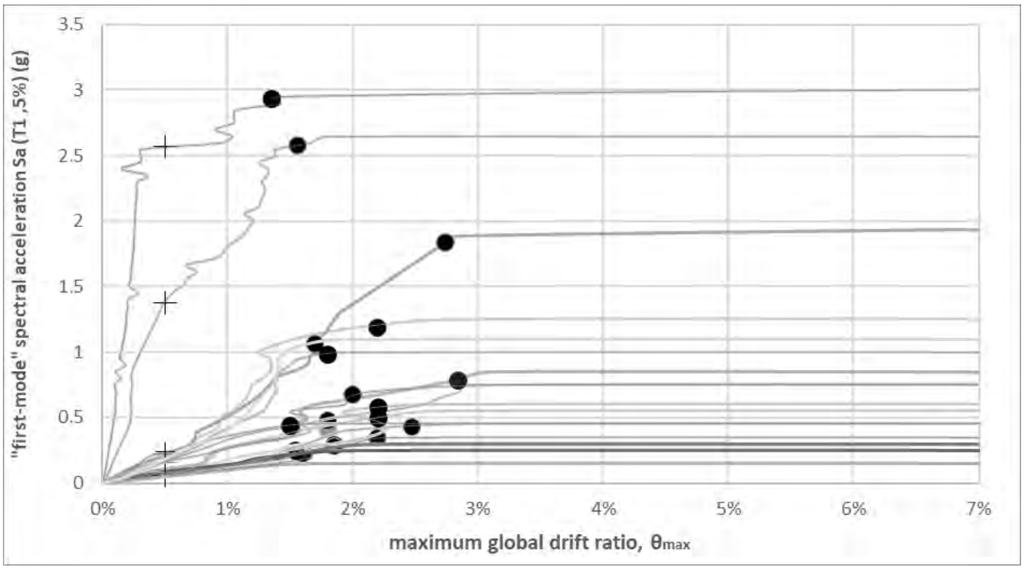

Figure 13: IDA Curves and Limit States for x-direction

Alongside the IDA curves, limit states are plotted as Immediate Occupancy, denoted by a "+" sign corresponding to 0.5% of the damage measure, and Collapse Prevention, calculated considering either 20% of the elastic slope or 10% of the damage measure, represented by dots on the graphs. Once the IDA curves and limit states are prepared, it becomes more practical to assess the impact of each earthquake record on our building. From the graphs, it is evident that the x-direction model will fail within a range of approximately 0.15g to 1.3g for most earthquakes. However, earthquakes such as Friuli (PGA = 0.345), Loma Prieta WAHO 000 (PGA = 0.370), and Loma Prieta WAHO 090 (PGA = 0.638) will lead to structural failure at later stages, corresponding to higher intensity measures. This observation is notable in both directions of the model.

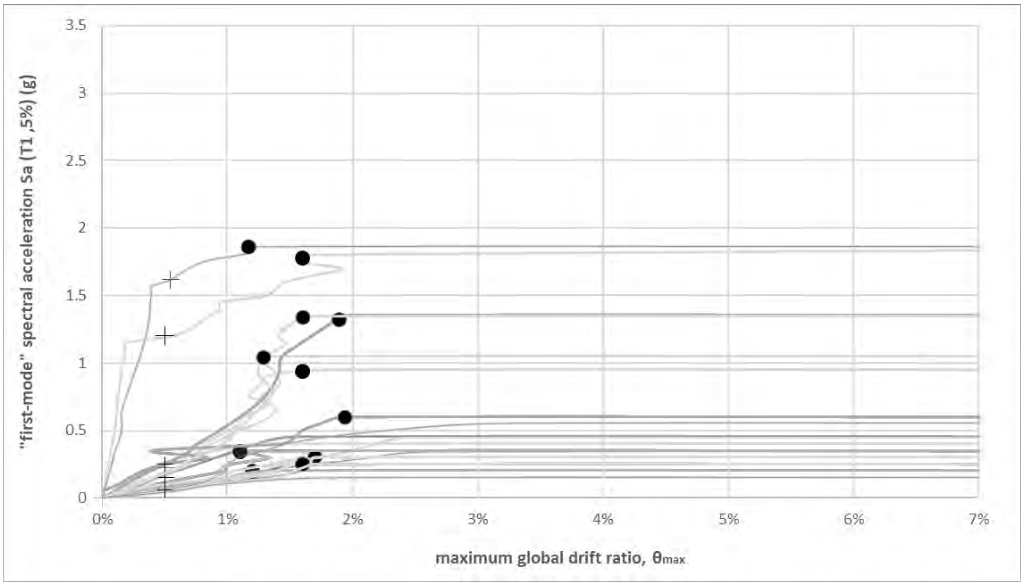

Figure 14. IDA Curves and Limit States for y-direction

The insights gained from summarizing the IDA curves into 16%, 50%, and 84% fractiles are important for seismic performance assessment.

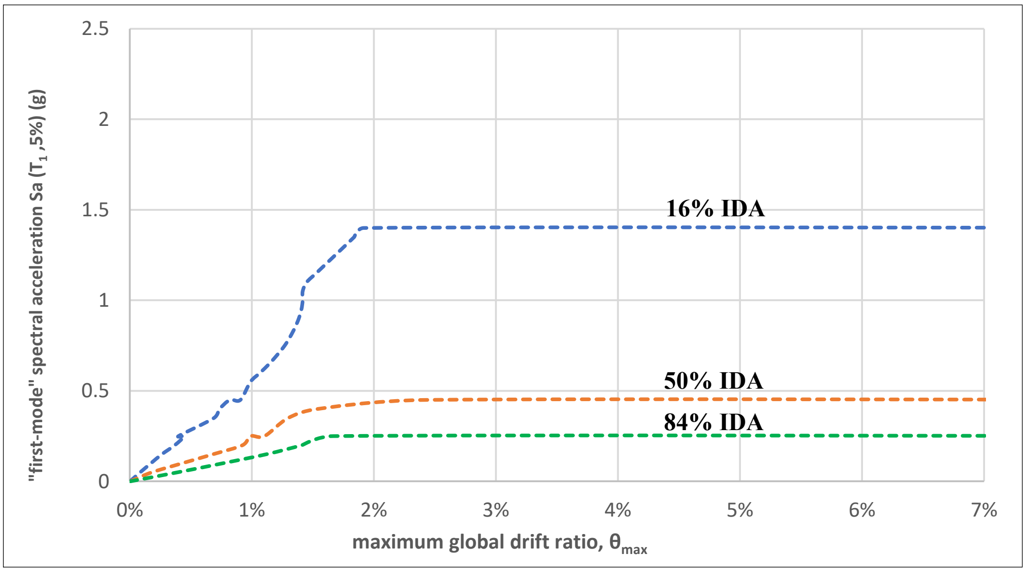

Figure 15. *IDA Fractiles developed for x-direction*

This summarization allows for observing the structure's response at each increment of intensity measure, from its initial state until the complete collapse of the building. For example, as shown in figure 7, at an intensity measure of 0.3g, it's observed that for the model in the x-direction, 16% of the records yield $\theta_{max} \leq 0.75\%$, 50% produce $\theta_{max} \leq 1.15\%$, and 84% result in $\theta_{max} \leq 2.15\%$. Similarly, fractiles assist in gathering information on intensity measures for a target displacement. Thus, in the y-direction of the model, $\theta_{max} = 1.0\%$ is reached when 16% of the records are scaled to 0.55g, 50% at $Sa_{(T1,5\%)} = 0.25g$, and 84% at $Sa_{(T1,5\%)} = 0.15g$.

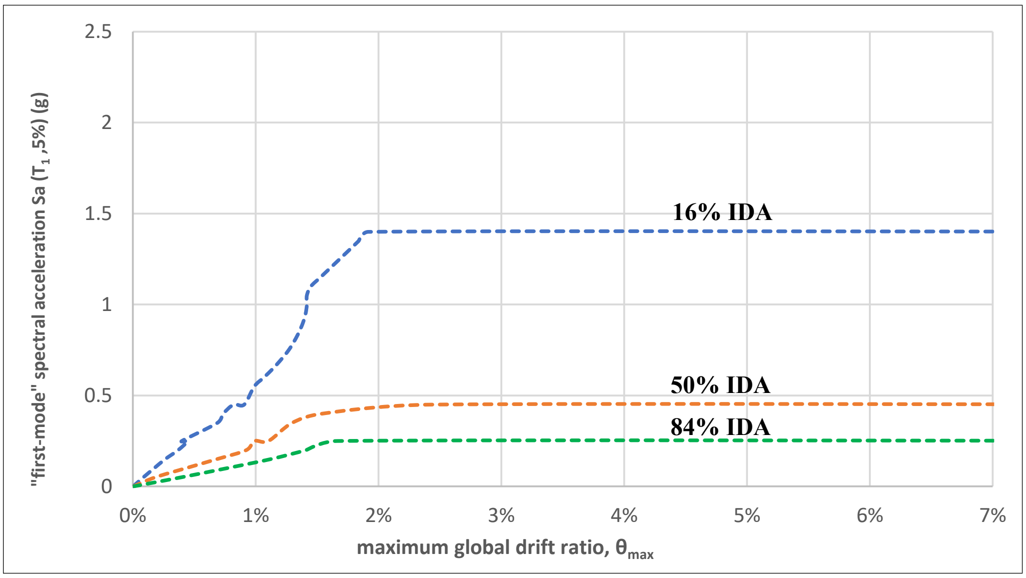

Figure 16. *IDA Fractiles developed for y-direction*

5. CONCLUSIONS

This paper has undertaken a comprehensive investigation into the seismic performance of a five-story pre-modern building situated in Albania, originally designed in 1982. This moment resisting frame template residential building does not have any shear walls and lacks proper design, reinforcement as well as concrete strength. The structural analysis is conducted within the ZeusNL software environment, employing a fiber approach modeling technique for nonlinear analysis. Taking advantage from the methodology of Incremental Dynamic Analysis (IDA), a number of analyses have been carefully conducted involving the careful selection of appropriate intensity measures (IM-5% damped first mode spectral acceleration) and damage measures (DM-maximum global drift ratio). For this purpose, a suite of 20 ground motion records is employed. The results are examined and processed to estimate the building's response under seismic loading conditions.
Limit states are constructed on each curve, including Immediate Occupancy (IO), Collapse Prevention (CP), and Global Instability (GI), based on guidelines from FEMA 356. Furthermore, the IDA curves are summarized into 16%, 50%, and 84% fractiles. This approach allows for a deeper understanding of the building's behaviour in terms of probabilistic considerations.

REFERENCES

[1] S. Aliaj, S. Kociu and B. Muco, Seismicity, seismotectonics and seismic hazard assessment in Albania, The Academy of Sciences of Albania, 2010.

[2] D. Vamvatsikos and C. A. Cornell, "Incremental dynamic analysis," Earthquake Engineering & Structural Dynamics, no. 491-514. doi:10.1002/eqe.141, 2002.

[3] A. S. Elnashai, V. Papanikolaou and D. Lee, ZEUS-NL User Manual, University of Illinois at Urbana-Champaign: Mid-Amerika Earthquake Center, 2002.

[4] D. Vamvatsikos and C. A. Cornell, "The Incremental Dynamic Analysis And Its Application To Performance-Based Earthquake Engineering," in European Conference on Earthquake Engineering, London: Elsevier Science Ltd, 2002.

[5] N. Shome and C. Cornell, "Probabilistic Seismic Demand Analysis of Nonlinear Structures," Stanford University, 2002.

[6] PEER, "Pacific Earthquake Engineering Research Center," University of California, 12 December 2020.

[7] U. U., "Geological Survey," U.S. Department of the Interior,, 12 December 2020.

[8] M. A.M and E. A.S, " Static pushover versus dynamic collapse analysis of RC buildings," Eng. Struct, vol. 23, p. pp. 407424, 2001.

[9] (. F., Recommended seismic design criteria for new steel moment-frame buildings, Washington, DC: Federal Emergency Management Agency, 2000.

[10] C. C. Vamvatsikos D., "Applied Incremental Dynamic Analysis," Earthquake Spectra, no. 523-553, 2003.

[11] H. Bilgin and I. Frangu, "Predicting the seismic performance of typical R/C healthcare facilities: emphasis on hospitals," International Journal of Advanced Structural Engineering, Vols. cilt 9, no. 3, pp. 277-292, 2017.

[12] F. 356, Prestandard and commentary for the seismic rehabilitation of buildings, Washington DC: Federal Emergency Management Agency, 2000.

[13] M. Leti and H. Bilgin, "Application of Incremental Dynamic Analysis to a Moment-Frame Reinforced Concrete building in Albania designed in 1982.," in PACE 2021- International Congress on the Phenomenal Aspects of Civil Engineering, 2021.

[14] K. Soni Priya, T. Durgabhavani and K. Mounika, "Non-Linear Pushover Analysis of Flatslab Building by Using SAP2000," in International Journal of Recent Technology and Engineering (IJRTE), 2012.

[15] J. Moehle and G. G. Deierlein, "A FRAMEWORK METHODOLOGY FOR PERFORMANCE-BASED EARTHQUAKE ENGINEERING," in 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, 2004.

[16] T. D. K. M. M. P. K. Soni Priya, "Non-Linear Pushover Analysis of Flatslab," International Journal of Recent Technology and Engineering (IJRTE), Vols. 2277-3878, Volume-1, 2012.

[17] A. Ghobarah, "Performance-based design in earthquake engineering: state of development," Engineering Structures, ELSEVIER, no. DOI: 10.1016/S0141-0296(01)00036-0, 2001.

[18] FEMA-350, Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings, Federal Emergency Management Agency, 2000.

[19] G. Chan, "NONLINEAR ANALYSIS OF MULTISTORY STRUCTURES USING NONLIN," Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 2005.

[20] ASCE., "Seismic rehabilitation of existing buildings," Reston, VA: American Society, 2007.

[21] N. Luco and A. Cornell, " Structure-specific scalar intensity measures for near-source and ordinary earthquake ground motions," USGS, no. cilt 23, no. 2, pp. 357-392, 2007.

Experimental and Theoretical Investigation of the Behavior of a Concrete Beam Reinforced with Conventional Steel Bars

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This research study conducts a comprehensive examination of the structural behavior of reinforced concrete beams that utilize conventional steel reinforcement bars, framed within the context of European norms and standards (Eurocodes). Through an experimental approach, the study investigates these beams under static loading conditions, gathering experimental data on maximal force, displacement trajectories, crack initiation and development, and ultimate failure modes. Simultaneously, robust theoretical analysis is carried out using analytical methods and advanced finite element modeling (FEM) to simulate and assess the experimental findings, ensuring alignment with Eurocode principles and calculations for direct comparison between empirical and theoretical results. The primary objective is to critically evaluate the correlation between the predictions based on Eurocodes and the actual structural performance, with a focus on the effectiveness of conventional reinforcement practices in enhancing structural integrity and load-bearing capacity. The insights gained from this study are crucial for refining design strategies and advancing engineering practices, leveraging the latest advancements in experimental equipment utilized in academic and research settings. This research not only validates the reliability of theoretical models based on Eurocodes but also identifies potential areas for further improvement in the design and analysis of reinforced concrete structures within the European context.

Keywords: *Reinforced Concrete Beams, Experiment, Displacement, Cracks, Failure.*

1. INTRODUCTION

Reinforced concrete beams are very important elements in structures, they enable the stability and durability of buildings, bridges and other engineering structures. The beams are usually made of reinforced concrete, therefore, they combine the property of concrete, which is resistance to compression stress, with the property of reinforcement, which is resistance to tensile stress. The importance of reinforced concrete beams lies in their ability to accept large loads and to resist various influences such as shear forces and bending moments, engineers and researchers have worked on various theories [1-2] to forecast the behaviour of RC beams under different load conditions. These abilities make them indispensable elements in the construction of engineering works, even where large spaces and high holding capacities are required. Reinforced concrete beams offer many advantages over other materials. They are cost-effective and can be molded into different shapes to meet project requirements [3]. Also, reinforced concrete buildings offer long-lasting durability with minimal maintenance costs. With proper maintenance and continuous inspection, these buildings can serve for decades. While such beams are used everywhere in buildings, there remains a good opportunity to understand their performance under different loading conditions. The research aims to address this gap by conducting experimental and theoretical investigations on the behaviour of these beams. In particular, the study seeks to analyse the load-bearing capacity, stresses and cracks in an experimental form and compare them with the analytical results and simulations using the FEM method [4]. The research aims to provide valuable knowledge for the improvement of design and construction practices in civil engineering.

2. EXPERIMENTAL PROGRAM

2.1.General Description

The experimental test program consists of two RC beams that were tested under four-point bending test, they were designed and tested to understand their structural characteristics under various loading conditions. The beams had dimensions of 150mm x 350mm x 3000mm. The reinforcement is from class B500C, whereas, the concrete used in the beams was subjected to compressive strength testing, with cubes cured for 28 days showing an average compressive strength of 42.8 MPa. The longitudinal-steel reinforcement included two layers of reinforcement: 3 bars with a diameter of 12mm were used in the tensile zone, and 2 bars with a diameter of 10mm were used in the compressive zone. The transverse-steel reinforcement consisted of 17 stirrups with a diameter of 8mm which were placed as shown in Figure 1.

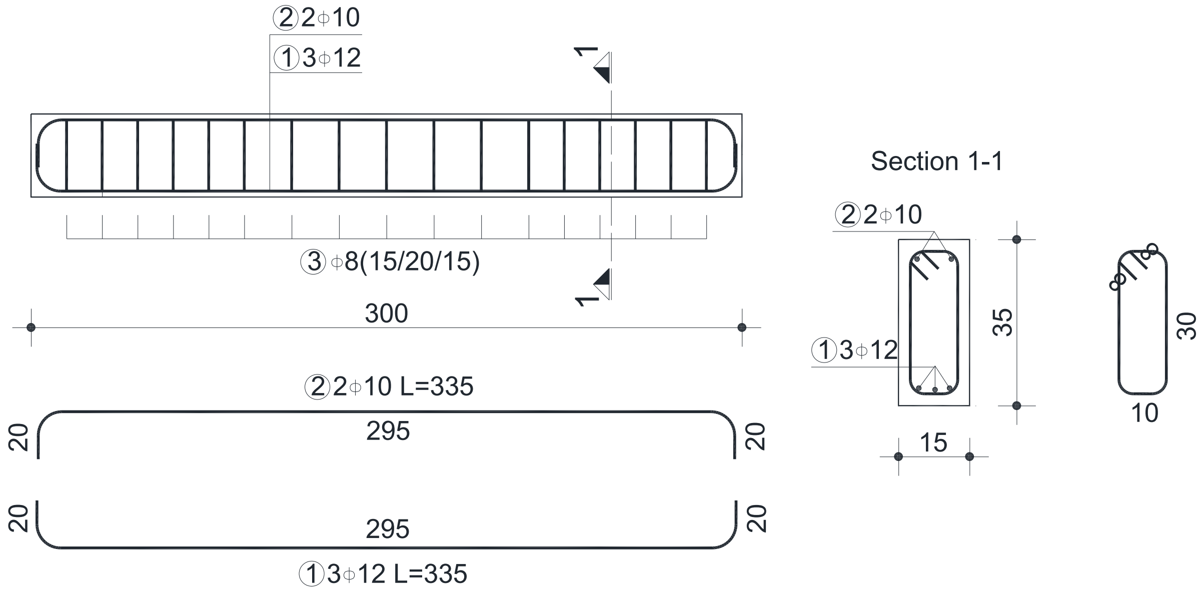

Figure 17. Details of test specimens (unit: cm)

Table 4. Geometric Characteristics of Beam Samples

Beam	L [cm]	b [cm]	h [cm]	$C_{,nom}$ [cm]	As_1 [cm^2]	As_2 [cm^2]
	300	15	35	2.5	3.39	1.57

In addressing the theoretical aspect of our investigation, Figure 2 presents a block diagram that describes the procedural steps followed in the analysis, whereas for addressing the Finite Element Method, Diana FEA [5] was used to create the model.

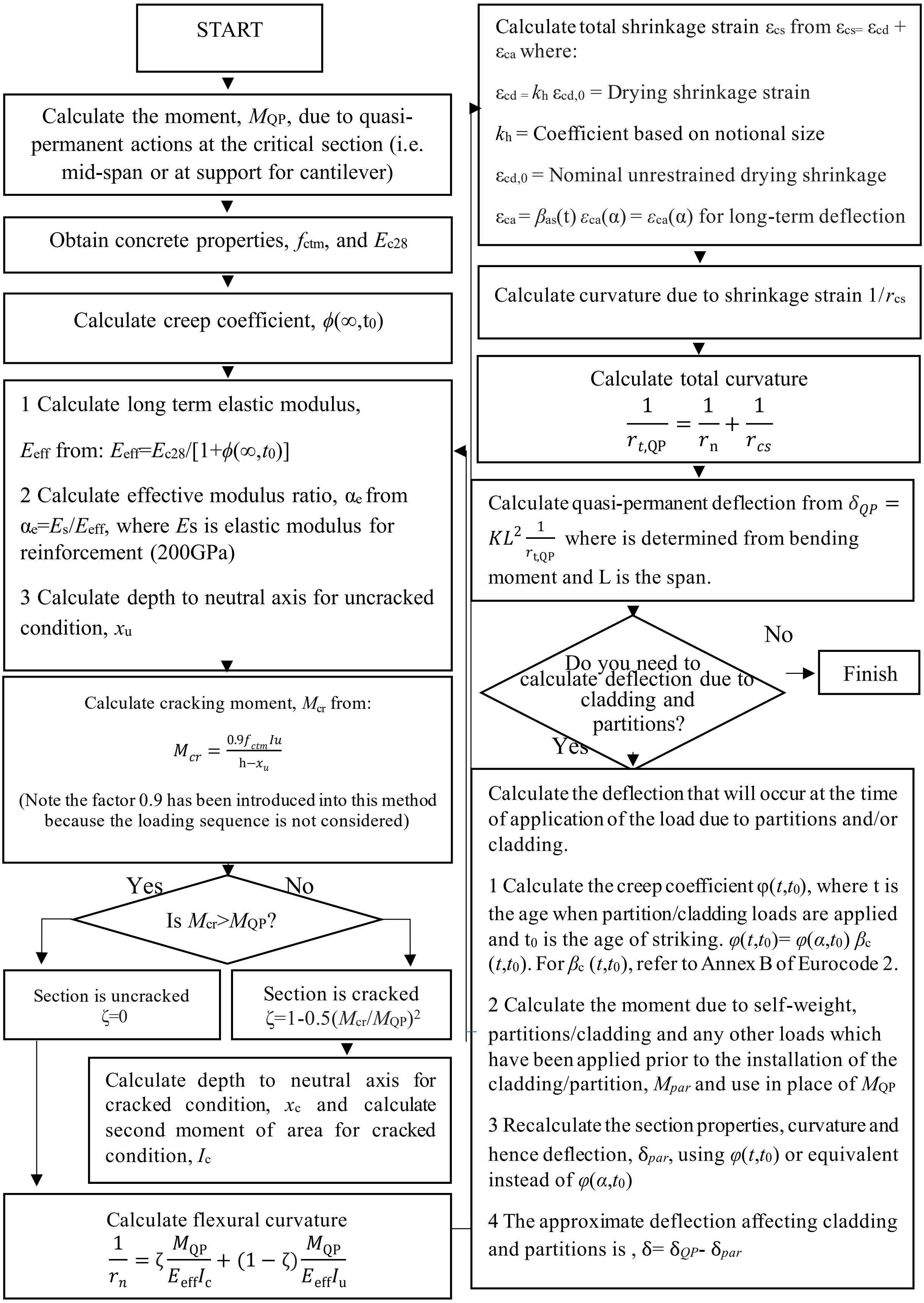

Figure 2. Block Diagram for calculating deflection [2]

2.2.Materials and preparation of beams

Before the beams were constructed, reinforcement bars were tested in the laboratory for tensile strength according to EN ISO 15630-1:2019 [6]. Results can be seen in Table 2. The steps taken to create experimental beams encompass several key activities: mixing and preparing concrete from the given mix-design (refer to Table 3), constructing the reinforcement framework (including both longitudinal bars and stirrups), setting up and stabilizing the molds, and finally, casting the concrete (refer to Figure 3).

Figure 3. Sequence during the construction of beams

Table 2. Mechanical properties of the reinforcement

Sample No.	Diameter (mm)	Length (mm)	Area (mm^2)	Mass (kg)	Tensile Strength (R_m) (MPa)	Yield Strength (ReH) (MPa)	Ductility $(k=f_t/f_y)_k$	Elasticity Modulus E (MPa)
M-1	7.90	431	48.99	0.17	718.2	648.2	1.110	216000
M-2	9.90	430	76.94	0.27	692.3	553.8	1.250	213000
M-3	11.70	434	107.5	0.37	716.7	613.1	1.170	196000

Table 3. Mix-Design for Designed Concrete: C30/37;XC1;Cl 0.20;Dmax 32;S4

Compressive strength class	CEM II/A-LL 42.5 R (kg/m^3)	Total water content (kg/m^3)	w_{eff}/c ratio	Hiperplast 235 LT (%)	Limestone Crushed Aggregate, (kg/m^3)			
					0/4	4/8	8/16	16/31.5
C30/37	360	192	0.5	0.7	915	180	420	310

To determine the compressive strength of concrete, a series of laboratory examinations were conducted on a total of 12 concrete samples in accordance with EN 12390-2 [7]. These samples were tested at predetermined intervals following their preparation, after 24 hours, 48 hours, 7 days, 14 days, and finally, 28 days in compliance with EN 12390-3 [8]. The results of these tests are presented in Figure 4, and they are presented as mean values. Because the experiment was conducted after approximately 100 days, the compressive strength of concrete increased by approximately 10%, based on Section 3 of EN 1992-1-1 [1].

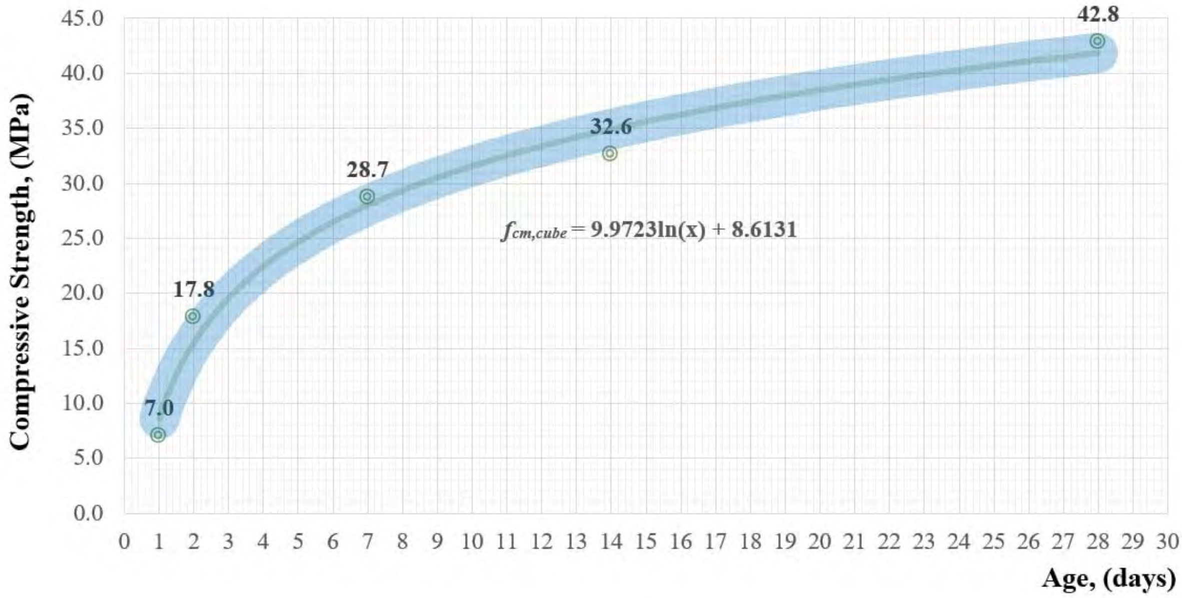

Figure 4. Relationship of compressive strength with age of concrete

The compressive strength of concrete at an age (t) depends on the type of cement, temperature and curing conditions. For a mean temperature of 20°C and curing in accordance with EN 12390-2 the compressive strength of concrete at various ages $f_{cm}(t)$ may be estimated from Expressions (1) and (2) [1,7].

$$f_{cm}(t) = \beta_{cc}(t) \cdot f_{cm} \tag{1}$$

where f_{cm} (t) is the mean compressive strength at an age of t days

$$\beta_{cc}(t) = \exp\left\{ s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\} \tag{2}$$

The coefficient s depends on type of cement: s = 0.20 for rapid hardening cement (Class R), according to EN 197-1 [9]. From equation (2), $\beta_{cc}(100)$ was calculated with value of $\beta_{cc}(100) \approx 1.1$, according to equation (1) the actual resistance in compressive strength after t = 100 days when evaluated with above equations, reaches value of f_{cm}=47.10 MPa.

2.3.Test setup and execution

The experimental setup for the four-point bending test of the reinforced concrete beams was designed to capture data on deflection and strain under loading using DAQ system from HBM Quantum X. The test configuration included two LVDTs positioned at mid-span to measure the vertical deflection of the beams, additionally, four strain gauges were installed along the length of the beams: two gauges were placed on the tensile zone to monitor the elongation under load, and two on the compression zone to measure the compression of the concrete (see Figure 5 to Figure 7). For precise and reliable examination, results were requested from the laboratory of “ProIng”, Pristina, in order to calibrate the exanimating machine–piston. The calibration of the hydraulic piston has been made via the equipment of "HBM Quantum X" and the validated force of pressure was within an accuracy of +/-0.50 kN [10].

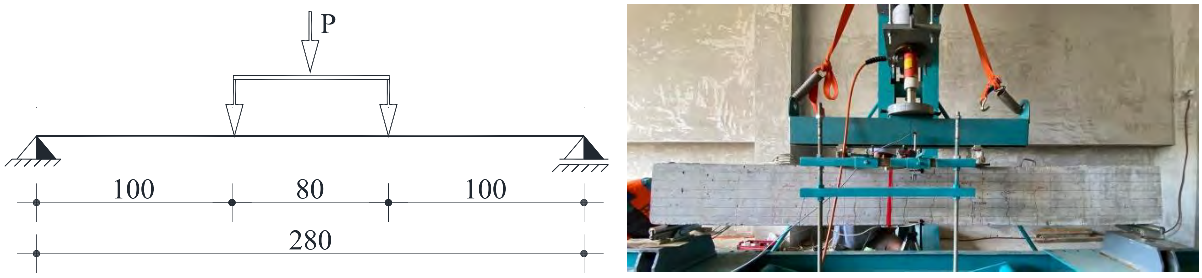

Figure 5. View of the RC beam four-point bending test layout (Static Scheme)

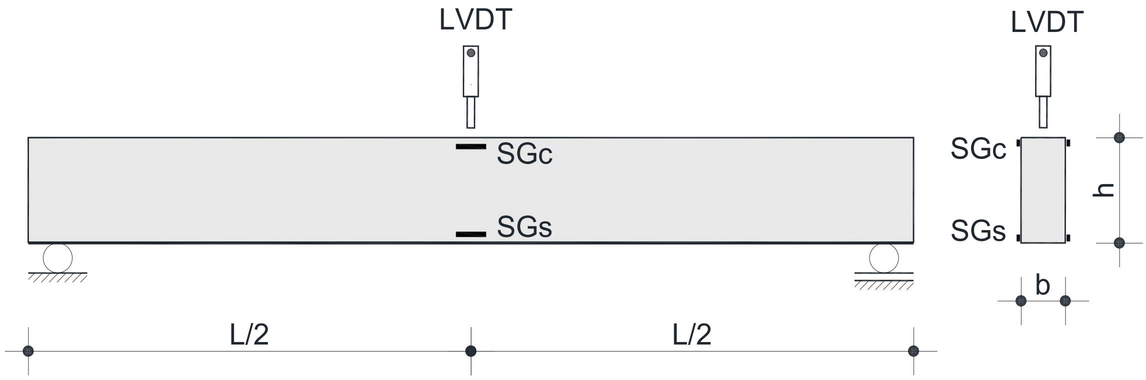

Figure 6. Measuring sensors used in the experimental study

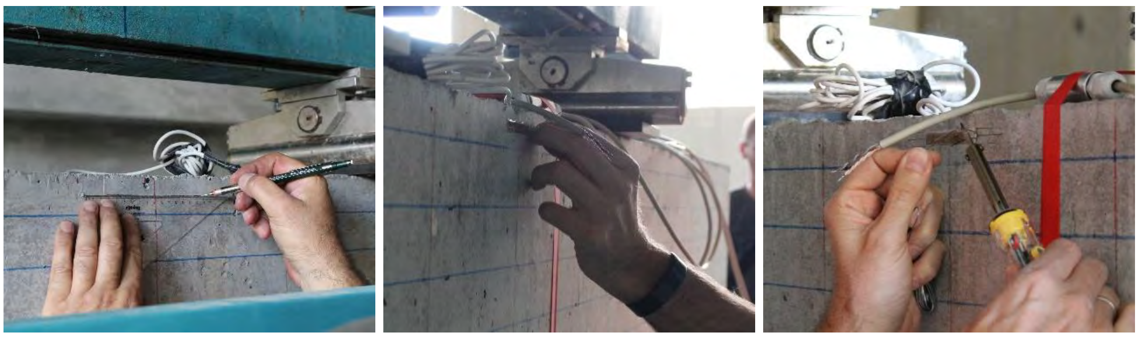

Figure 7. Positioning and attachment of Strain Gauges

3. RESULTS AND DISCUSSION

Discussion of results is done by interpreting the data obtained from 3 sources, experiment, theoretical calculations and Diana FEA presented in tables and visualized in a graphical presentation by OriginPro [11]. From Figure 8. it can be seen that the experimental data shows a consistent non-linear increase in the force-deflection curve. The Diana FEA closely mirrors this trend at higher forces, though it significantly underestimates deflection at lower forces. The theoretical line overpredicts deflection up to 45 kN and then aligns with the experimental curve. Data from Figure 9. captures the stress in the compressive zone, where both the Diana FEA and theoretical predictions have an upward trend at a consistently higher rate than the experimental data. Stress in the tensile zone (addressed in Figure 10) shows the theoretical model overestimates the stress at all force levels, while the Diana FEA predictions, though closer to the experimental data, underestimate these values. Figure 11. illustrates the various phases of loading and the corresponding development of cracks under different load conditions, with an increment of 15kN. The crack development is also presented and drafted by CAD [12], and the crack development is compared with the model in Diana FEA which shows a match between them, but it should be noted that the crack widths and crack spacings were not subjected to analysis in our study.

Force (kN)	Midspan deflection (mm)		
	Experimental	Theoritical	Diana FEA
15	1.36	1.40	0.28
30	2.80	3.70	2.51
45	4.65	5.60	4.05
60	6.80	6.80	6.70
75	9.00	9.50	9.08
90	11.92	11.30	11.18

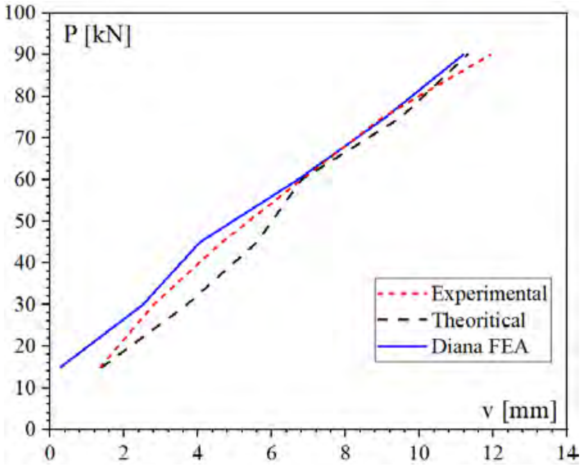

Figure 8. Graphical and tabular data presentation of the diagram force-deflection in midspan

Force (kN)	Stress in compressive zone (N/mm²)		
	Experimental	Theoritical	Diana FEA
15	1.40	5.27	2.11
30	6.30	9.75	9.84
45	12.76	14.24	14.15
60	17.47	18.73	19.63
75	22.36	23.22	24.81
90	30.97	27.71	29.15

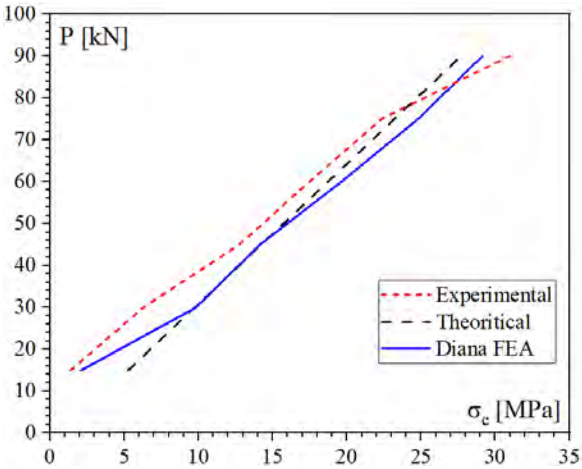

Figure 9. Graphical and tabular data presentation of the diagram force-stress in compressive zone

Force (kN)	Stress in tensile zone (N/mm²)		
	Experimental	Theoritical	Diana FEA
15	10.08	91.46	10.70
30	102.90	169.40	149.78
45	238.56	247.35	215.62
60	308.98	325.30	289.71
75	367.18	403.24	359.22
90	450.16	481.20	429.98

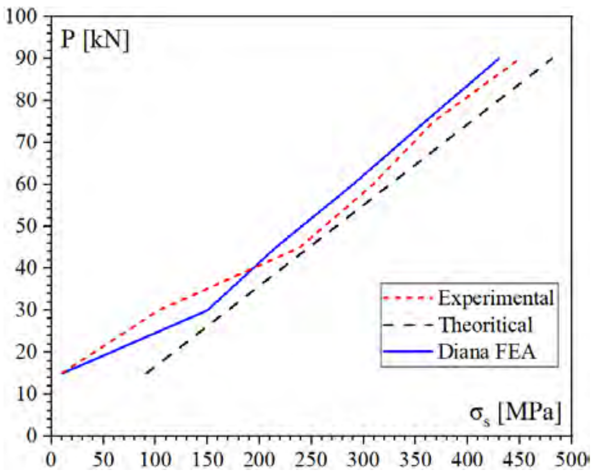

Figure 10. Graphical and tabular data presentation of the diagram force-stress in tensile zone

** Results shown (experimental) in the above figures are mean values!*

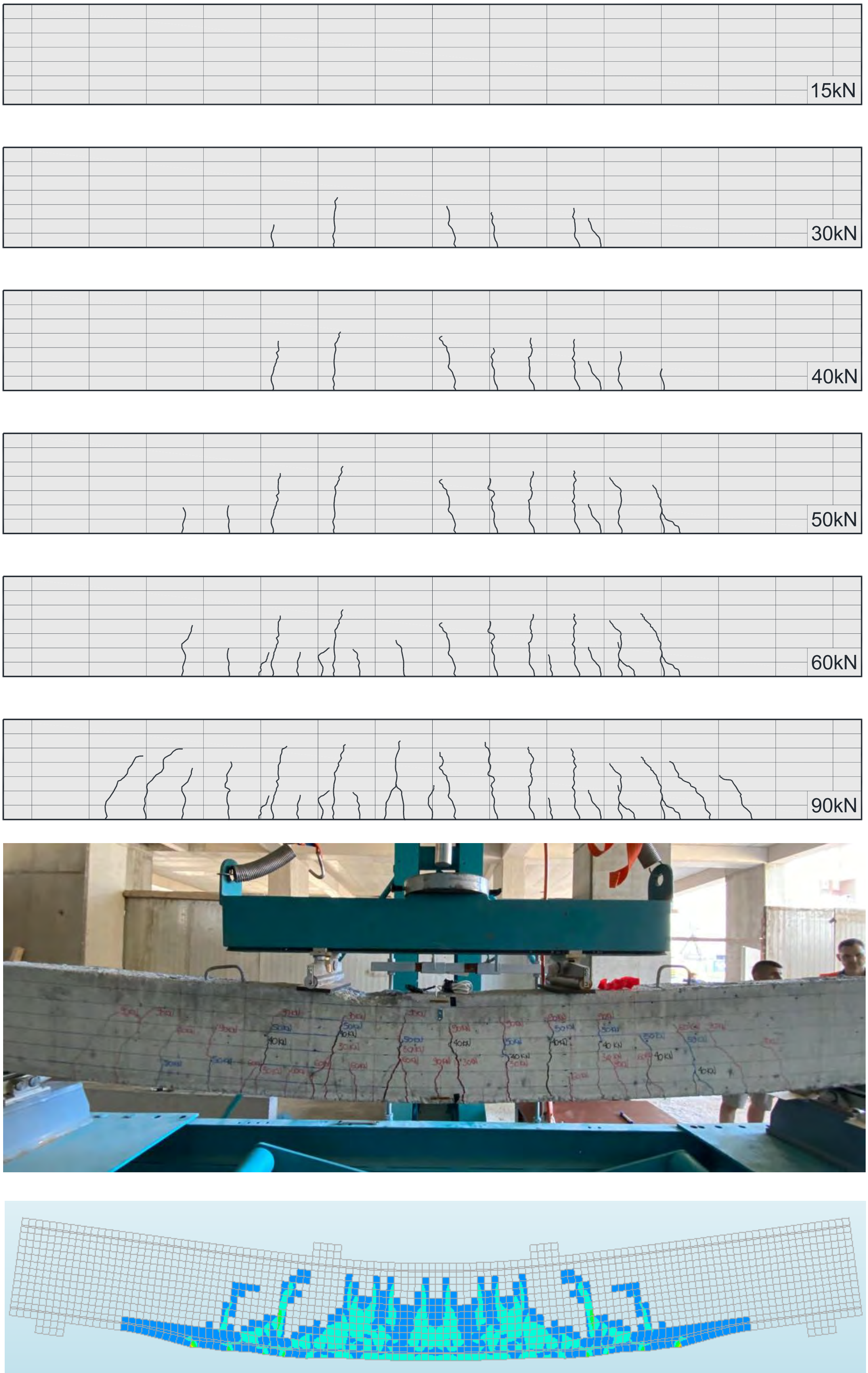

Figure 11. Development of crack patterns in experiment and numerical model in Diana FEA [5,12]

4. CONCLUSIONS

In conclusion, the comparative analysis of the beam's response under applied forces through experimental, theoretical, and Diana FEA methodologies has provided valuable insights into the structural behaviour of the beams. For midspan deflection the theoretical calculations show about 8% higher values in comparison with experimental data, while Diana FEA underestimates the deflections by about 7%. In terms of stress in the compressive zone, the theoretical calculations overestimate the values, but now for about 9% in difference with Diana FEA which overestimates the values for 12%. For stress in the tensile zone, theoretical calculations have about 12% higher values than experimental data, unlike Diana FEA which underestimates the values by about 10%. These findings illustrate a trend where theoretical calculations tend to overpredict both deflection and stress values, while Diana FEA is generally closer to the experimental model, it still has room for improvement, especially at lower force values.

REFERENCES

[1] EN 1992-1-1: Eurocode 2: Design of concrete structures-Part 1-1: General rules and rules for buildings, December 2004.

[2] A.J. Bond et. al.''How to Design Concrete Structures using Eurocode 2''.CCIP–006 Published December 2006 ISBN 1-904818-4-1.

[3] W. Kan, Z. Yang, and W. Yin, "Simulation of Four-Point Bending Fracture Test of Steel-Fiber-Reinforced Concrete," Materials, vol. 15, no. 20, p. 7146, Oct. 2022, doi: 10.3390/ma15207146.

[4] P. van der Aa and J. Manie, "Simple to Advanced Finite Element Shape Modelling with DIANA," High Tech Concrete: Where Technology and Engineering Meet, pp. 1183–1190, Aug. 2017, doi: 10.1007/978-3-319-59471-2_137.

[5] DIANA FEA BV. (2020). Diana - Finite Element Analysis, Delft, The Netherlands. Available online:

[6] EN ISO 15630-1:2019 Steel for the reinforcement and prestressing of concrete - Test methods - Part 1: Reinforcing bars, rods and wire (ISO 15630-1:2019)

[7] BS EN 12390-2:2019, Testing hardened concrete — Part 2: Making and curing specimens for strength tests, Brussels, Belgium, 2019.

[8] BS EN 12390-3;2019, Testing hardened concrete — Part 3: Compressive strength of test specimens, Brussels, Belgium, 2019.

[9] Cement - Part 1: Composition, specifications and conformity criteria for common cements, November, 2011.

[10] F. Grajçevci, A. Mujaj, D. Kryeziu, and E. Shehu, "Experimental and Numerical Analysis of Concrete Columns under Axial Load Based on European Design Norms" Civil Engineering Journal, vol. 10, no. 2, pp. 419–430, Feb. 2024, doi: 10.28991/cej-2024-010-02-05

[11] OriginLab Corporation. (2024). OriginPro. Northampton, United States. Available online: https://www.originlab.com/ (accessed on January 2024).

[12] O'Brien, M. (2018). Product News: AutoCAD 2019 Including Specialized Toolsets Now Available. AutoCAD 2019, Autodesk, San Francisco, United States.

Reliability analysis of factor of safety in retaining walls reinforced with geogrids or geotextiles.

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Allowable stress design (ASD) and semi-probabilistic design (SPD) are two traditional design techniques for geosynthetic reinforced soil walls (RSW) that are used to calculate the factors of safety against failure mechanisms. These techniques are unable to account for every uncertainty. The implementation of probabilistic techniques in geotechnical engineering has grown dramatically in the last several years. Because there is a shortage of experience and literature, we have discovered that many engineers are worried about the implications of these advancements and how they may be confidently implemented. Our main objective is to describe probabilistic approaches that emphasize the basis of the methodologies as well as their real-world relevance to the geotechnical and geological engineering profession. The geotechnical world is different in many ways from the structural and mechanical world, and a study dealing with reliability methods from a geotechnical point of view is needed. Geotechnical engineers and geologists work with materials whose characteristics and distribution are frequently uncertain, tackling challenges where loads and resistances interact closely. Traditionally, the geotechnical field has addressed uncertainties in significant projects through an 'observational' approach, which is quite compatible with reliability-centered techniques. The research delves into constructing a framework aimed at ensuring the reliability design of (RSW) by specifically addressing uncertainties in the design process and considering the actual safety and reliability levels. It will explain the fundamentals of probabilistic analysis and design concerning both the internal and external stability limit states of RSW. The analytical model for the five failure mechanisms of internal and external stability are defined, and are used to calculate margins of safety in terms of probability of failure through probabilistic methods, where parameters can be set as either deterministic (with no associated variability) or probabilistic (with associated variability). The outcomes aim to offer a valuable decision-making tool for the preliminary design of RSW based on specified reliability targets. An example is provided to illustrate the significance of the proposed framework. Factors of safety and reliability work in tandem, each possessing its own strengths and weaknesses. Understanding both the factor of safety and the probability of failure values is more beneficial than solely knowing one of them.

Keywords: *Reliability analysis, Analytical model, Probability of failure (Pf), Reliability index (β), Coefficients of variation (COV), Probabilistic methods.*

1. INTRODUCTION

During the design of engineering works, many approximations are made which can be grouped into two large groups; in approximations for the structure, in approximations for the soils. These approximations are dictated by real problems and their approach to known theories. The approximations define the differences between the procedures for performing practical reliability analyses. Most practical methods of reliability analysis rely on approximations, even if some steps are correct. In order to have as many results as possible and the possibility of comparison, it is important to anticipate that different methods can give different results. One of the assumptions we make when calculating the probability of failure from the reliability index is that the margin or safety factor follows a normal distribution, which is not always correct. Therefore, it is advisable to compare results from multiple approaches to better understand possible errors in computational methods.

The design and calculation of Walls of all types, including Reinforced walls, is necessarily based on the geotechnical properties of the soil. Depending on the size and importance of the project, the geology of the area, the geotechnical study may vary in methodology and the number of in-situ and laboratory tests to determine, with a certain degree of confidence, the properties of the soil.

Geosynthetics are man-made products with a very high degree of confidence, since all properties are determined as minimum average values in traction etc, or 95% lower confidence limit values, due to industrial production which allows many tests to be carried out. under the same product under the same conditions.

The purpose of this paper is to demonstrate that high confidence in the design of an RSW can be achieved even with high variability of soil parameters, as a result of the wide range of geotechnical parameter values.

In this paper, the effects of uncertainties associated with geotechnical parameters are evaluated using advanced reliability methods for estimating failure probabilities for the respective failure modes. Reliability is calculated based on the stochastic nature of geotechnical parameters.

This reliability technique offers helpful information on the degree of design performance under uncertainties and takes into account the stochastic nature of geotechnical and geosynthetics factors. A case study is provided to illustrate the efficacy of the suggested structure, the study is based on the high way desing of The Corridor VIII which is one of the Pan-European corridors . Based on the target reliability standards, reliability index *(β)*, the suggested reliability method gives the engineer a helpful tool to help them make a more accurately design choice.

2. VARIABILITY OF PARAMETERS OF SOILS AND GEOSYNTHETICS

It is recognized that each geotechnical engineer evaluating a geotechnical study will determine different design values based on his knowledge of the test method, location, geology, and operators [1].

According to EN 1990 (2002), the engineer must ascertain the characteristic value (Xc) of all materials, including soil. Xc should be defined as the 95% breakable value when a high value of the material or product property is unfavourable, and as the 5% breakable value when a low value is unfavourable. This definition is useful for artificial materials like concrete or geosynthetics, but it might not be applicable to soil because some characteristics can vary by up to 60% [5].

Therefore, the definition of characteristic value is modified to "a careful estimate of the value that affects the occurrence of the limit state" in Eurocode 7 (EN 1997-2, 2007), leaving the designer's decision-making to depend on the structure's category.

In order to improve the definition of characteristic values, the designer must have repeated correlated values. As an illustration, gathering more than five samples of the soil's cohesiveness, density, and friction angle for which the variance is known would be necessary to obtain the quantity of data needed for a slope stability analysis that only takes into account uniform and homogenous soil, which is already a simplification. The quantity of data can only occasionally, in certain circumstances (such as in the case of power plants, airports, and industrial zones), enable the designer to achieve a good estimate of the characteristic values with a very small coefficient of variation (CoV) after conducting a thorough geotechnical investigation.

2.1.Probabilistic model of geosynthetic reinforced soil walls

For deterministic RSW analysis, there are primarily three forms of stability: global, internal, and external stability. The overall stability of the reinforced earth wall is influenced by external stability, so it is important to make sure that all potential failure modes—such as sliding, overturning, and bearing capacity failures—are considered.
Only the internal and external stability boundary conditions are taken into account in this study.

The equations that give the difference between the resisting and active forces or moments for each of the modes of failure that are taken into consideration, M(x) = (R – Q), represent the limit state functions M(x) that can be derived to evaluate the performance of the RSW against each failure mode for external and internal stability. R stands for resisting forces or moments, and Q for active forces or moments.

In this study, these boundary functions are established for the design of RSW in uniform granular soils with zero effective cohesion, but they can be easily extended to the case of cohesive soils.

The following list of preconditions, which are based on the active and resistant forces or moments for each failure mode, lists the necessary steps to determine the limit state functions M(x). Figure 1 illustrate the schematics for each failure mode, with the assumption that all protection layers have a constant vertical spacing S.

The same principles apply to any geosynthetic reinforcement, however in this framework we will just discuss geogrid as the reinforcing material.

2.2. Sliding Failure

For RSW, critical slide usually occurs along the geosynthetic reinforcement at the base, when the friction between the fill and the geosynthetic is insufficient to compensate for the external load, which causes the retaining wall to slide. The limit state function for sliding failure is:

$$\mathbf{M_{ds} = L \cdot f_{ds} \cdot \tan\varphi_f \cdot \gamma_R \cdot H + q - (0{,}5 \cdot \gamma_s \cdot H2 + q \cdot H) \cdot \tan2(45 - \varphi_s/2)} \quad (1)$$

where:

φ_f, φ_s - friction angle of foundation soil and back soil, respectively (deg)
γ_R, γ_s - unit weight of reinforced soil and back soil, respectively (kN/m3)
f_{ds} - direct shear factor (-)
H - height of wall (m)
L - length of reinforcement (m)
q - uniformly distributed surcharge (kPa).

2.3. Overturning Failure

Overturning occurs when soil behind the RSW body is large enough to offset the retaining wall by rotating around the lowest left key point of the wall. The limit state function for overturning is given by the difference of the resisting and active overturning moments about that point:

$$\mathbf{M_{ot} = 0{,}5 \cdot L \cdot \gamma_R \cdot L \cdot H + q \cdot L - (1/6\, \gamma_s \cdot H^3 + 0{,}5 \cdot q \cdot H^2) \cdot \tan2(45 - \varphi_s/2)} \quad (2)$$

Here all the uncertainty in the true magnitude of the load and resistance terms for the limit states shown above is only due to the estimation of the friction angle (φ) and unit weight (γ) of the soils, and the tensile strength of designed TD geogrids; however, all parameters in the limit state functions defined above can be considered as stochastic variables.

The probability distribution of all parameters is assumed to be the normal distribution.

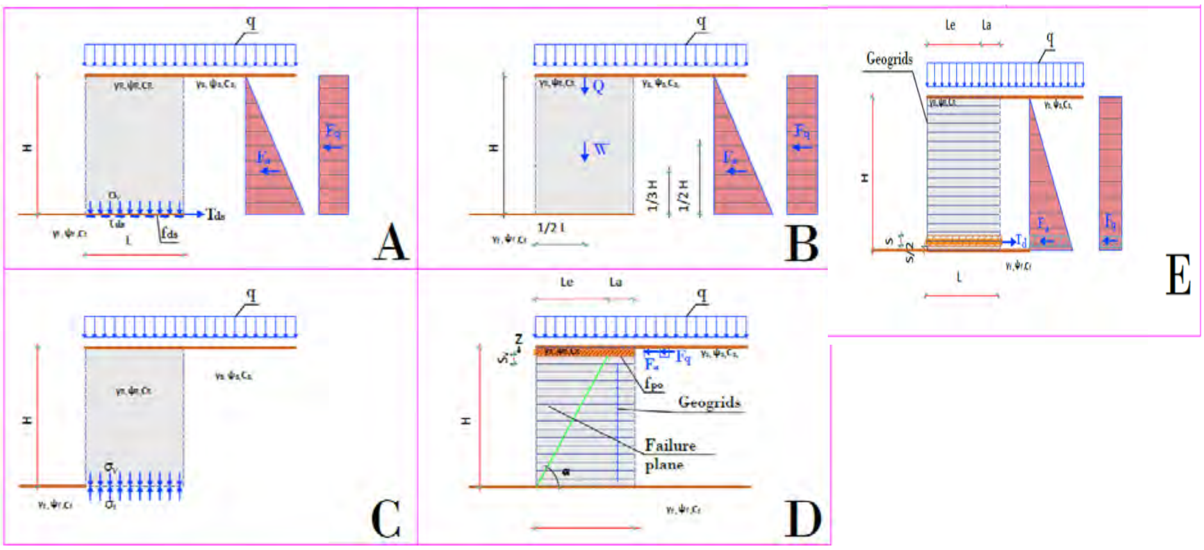


Figure 1. Schemes of the limit states for internal and external stability of RSW: **a.** sliding; **b.** overturning; **c.** bearing capacity; **d.** pullout; **e.** tensile failure

2.4. Brief description of the project

2.4.1. Geographical position of the road segment

The road segment under study has a length of 40 km and stretches along the Shkumbin River valley, from the roundabout of Rrogozhina to Bradashesh, at the entrance to the city of Elbasan. This project is part of Corridor VIII in the Western Balkans connecting with Albania.
From a geomorphological point of view, the road passes almost entirely on the first terrace of the Shkumbin River and partly on its current dam. The relief is relatively flat with small gradients and a small slope.

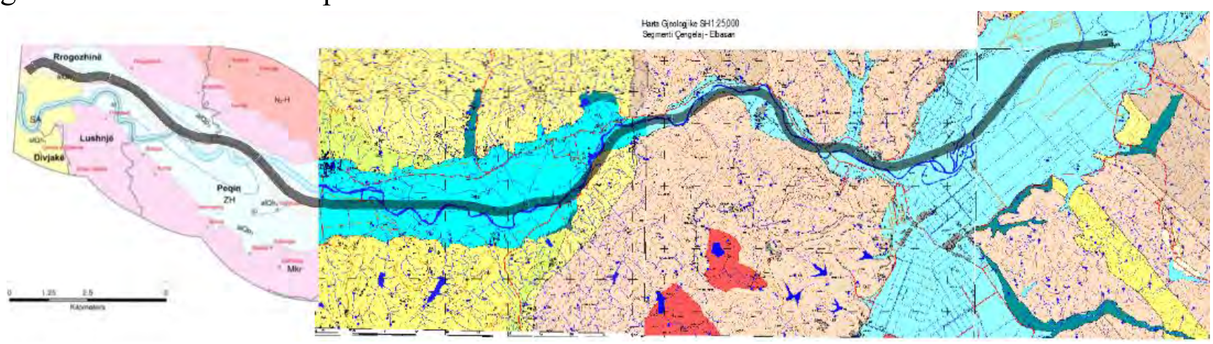


Figure 2. Plan & geomorphological view of road segment

2.4.2. Physical - mechanical properties of soil (geotechnical)

The geotechnical data were extracted from the literature of geological-engineering studies carried out in the territory of Elbasan district, as well as cases where there were no such data were taken from the literature. As it was said in the chapter on geological framing of lithological formations.

In the territory of Elbasan Municipality, the following different lithological types are found:

- Strong rocks
- Medium rocks
- Soil without cohesion
- Cohesive soil

From the evaluations of various tests, we have reached the variable values of the specific weight γ(24-29) kN/m3 and the angle of internal friction φ(18-28)°

Figure 3. General RSW design and section view

3. EXAMPLE OF RELIABILITY ANALYSIS OF GRSW

We will deal with the reliability of soil parameters.
The methods we will use are the *Exact Method,* the *First Order Second Moment* (FOSM) Method, and the *Point Estimation Method*.
The safety factor for control in sliding and overturning is given by:

$$F = \frac{R}{Q}$$

We will use the margin of safety M=R-Q assuming a normal distribution
For simple calculations, we will use wall with vertical face and distributed load in the upper part.

$R_{ds} = L \cdot f_{ds} \cdot \tan\varphi_f \cdot \gamma_R \cdot H + q$

$R_{ot} = 0{,}5 \cdot L \cdot \gamma R \cdot L \cdot H + q \cdot L$

$Q_{ds} = -(0{,}5 \cdot \gamma_s \cdot H2 + q \cdot H) \cdot \tan2(45 - \varphi_s/2)$

$Q_{ot} = -(1/6\, \gamma s \cdot H3 + 0{,}5 \cdot q \cdot H\,2) \cdot \tan2(45 - \varphi s/2)$

The calculations of the margin of safety are carried out in tables, where for simplicity the coefficients A,B,C,D are used for constant values, and the coefficients X,Y for the variables of the natural soil.
Below we give the table, where the values of the coefficients are as follows:

$A = L^2 \cdot F_{ds} \cdot tg(\varphi_F) \cdot (\gamma_R \cdot H + q)$	$X = \gamma_s$
$B = -1/2 \cdot H^2$	$Y = tg^2(45 - \varphi_s/2)$
$C = -q \cdot H$	

$M_{ds} = A + B \cdot X \cdot Y + C \cdot Y$ (for sliding)

$A = 1/2 \cdot L^2 \cdot \gamma_R \cdot H$	$X = \gamma_s$
$B = 1/2 \cdot L \cdot q \cdot D$	$Y = tg^2(45 - \varphi_s/2)$
$C = -1/6 \cdot H^3$	
$D = -1/2 \cdot q \cdot H^2$	

$M_p = A + B + C \cdot X \cdot Y + D \cdot Y$ (for overturning)

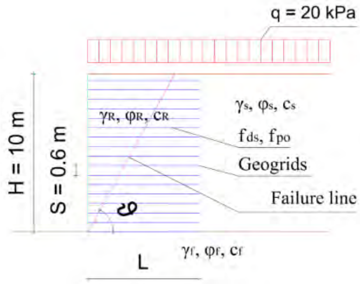


Figure 4. Geometry of the RSW for the example calculation

Wall geometry	**Symbol**	**Value**	**Unit**	**COV (%)**
Height	**H**	m	10	0.00
Length of geogrids	**L**	m	5.6	0.00
Vertical space between geogrids	**Simboli**	m	0.6	0.00
Number of geodrids	**N gj**	cope	17	0.00
Uniform sucharge	**q**	Kpa	20	0.00
Parametrat e tokes	**Symbol**	**Value**	**Unit**	**COV (%)**
Saturated unit weight of the reinforced soil	**γR**	KN/m3	23	5.00
Friction angle of the reinforced soil	**ϕR**	deg	33	5.00
Cohesion of the reinforced soil	**C'R**	Kpa	0	20.00
Saturated unit weight of the backfill soil	**γS**	KN/m3	18	20.00
Friction angle of the backfill soil	**ϕS**	deg	30	20.00
Cohesion of the backfill soil	**C'S**	Kpa	0	20.00
Saturated unit weight of foundation soil	**γf**	KN/m3	18	20.00
Friction angle of the of foundation soil	**ϕf**	deg	28	20.00
Cohesion of the of foundation soil	**C'f**	Kpa	0	20.00
INTERFACE PARAMETERS	**Symbol**	**Value**	**Unit**	**COV (%)**
Direct shear factor	f_{ds}	m	0.95	0
Pullout factor	f_{po}	m	0.95	0
GEOSUNTHETIC REINFORCMENT	**Symbol**	**Value**	**Unit**	**COV (%)**
T ult I gjeogridit	**Tult**	kN/m3	70.00	1
Reduction Factor for creep	**RFcr**	-	1.39	1
Reduction Factor for instalation damage	**Rfid**	-	1.10	1
Reduction Factor for chemical damage	**RFch**	-	1.20	1
Reduction Factor for biological damage	**RFb**	-	1.00	0

Figure 5. Input data for the example calculation.

$M_p = A + B + C \cdot X \cdot Y + D \cdot Y$ (analytical equation for overturning)

	Y	ϕS	tg(45-ϕS/2))^2					
	X		Y	A	B	C	D	M
	24.1	19	0.5088	2822.4000	313.6000	-166.6667	-1000.0000	583.5852
	25.74	20.08	0.4888	2822.4000	313.6000	-166.6667	-1000.0000	550.0609
	26.81	21.56	0.4625	2822.4000	313.6000	-166.6667	-1000.0000	606.6267
	28.62	27.46	0.3688	2822.4000	313.6000	-166.6667	-1000.0000	1007.9992
Shuma	105.27		1.8290					2748.2720
E(x)	26.3175	E(y)	0.457244				E(M)	687.0680
	2.69872		0.0028761					3131.8303
	Varianca X		Varianca Y					Varianca M
	1.64278		0.0536293					55.9628
	dev_sta Y=		dev_sta tan fi=					dev_sta I M=

Figure 6. Exact method **(m1)**

	M	p	p*M	p*M^2
	583.5852131	0.25	145.8963033	85142.92524
	550.0608872	0.25	137.5152218	75641.74491
	606.6267465	0.25	151.6566866	91999.0024
	1007.999192	0.25	251.999798	254015.5928
Shuma	2748.272039		687.0680097	506799.2654
Mesatarja	687.0680		171.7670	126699.8163
		V M=p*M^2- (p*M)^2=	97195.9132	
		devijimi standart I M=	311.7626	
		B=	**2.203817999**	
		Pf=	1.3769%	

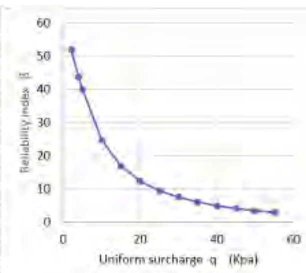
Figure 7. Point Estimation Method(M3)

E M	687.068010	
V M=	86717.45332	
dev_sta l M=	294.4782731	
B=	**2.333170466**	
Pf=	0.981960%	

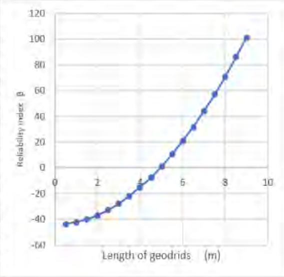
Figure 8. First order second moment (FOSM) method (m2)

For the example taken into consideration, we have calculated the reliability index for the margin of safety for overturning with: H-Variable, L-Variable, q-Variable:

q	β
2	51.95107
4	43.93482
5	39.84386
10	24.78937
15	16.87302
20	12.35153
25	9.485922
30	7.52238
35	6.097846
40	5.019115
45	4.174773
50	3.496341
55	2.93952



L	β
0.5	-43.5754
1	-42.2271
1.5	-39.98
2	-36.834
2.5	-32.7891
3	-27.8454
3.5	-22.0028
4	-15.2614
4.5	-7.62109
5	0.918058
5.5	10.35607
6	20.69293
6.5	31.92866
7	44.06324
7.5	57.09668
8	71.02898
8.5	85.86014
9	101.5902



H	β
1	349.4203
2	315.1042
4	141.4692
6	71.94027
8	35.79863
10	12.35153
12	-4.91478
14	-18.6213
16	-30.0146
18	-39.7637
20	0.115881

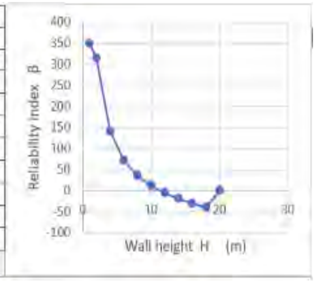


Figure 9. Reliability index for H-Variable, L-Variable and q-Varible.

Below is given the behavior of the probability of failure (Pf) for different variables of H-Variable, L-Variable, q-Variable (Note that while calculating the probability of failure for variable values of H,L,q the other data to be considered same as input data Figure 5.

Mds=A + B ·X·Y + C·Y(analytical equation for sliding)

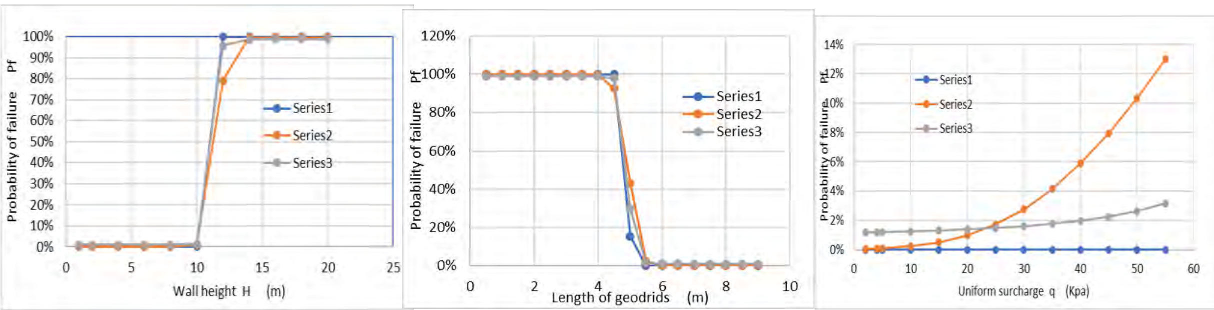


Figure 10. Series 1-Exact Method (M1), Series 2-First Order Second Moment (FOSM) Method (M2), Series 3-PointEstimation Method (M3)

It is possible to determine that sliding controls the external stability requirements whereas rupture controls the internal stability needs by comparing the failure probability for various data sets. For all failure modes except rupture, the shorter wall height and longer reinforcement length often suggest more safety and less failure probability. A more informed design option can be made by taking into account the ultimate reliability requirements for both the factor of safety and the reliability factors for sliding and overturning, based on the findings from this example.

	Y	ϕS	tg(45-ϕS/2))^2					
	X		Y	tan ϕf	A	B	C	M
	24.1	19	0.5088	0.5317	707.1735	-50.0000	-200.0000	-7.6722
	25.74	22.4	0.4482	0.5317	707.1735	-50.0000	-200.0000	40.7713
	26.81	21.56	0.4625	0.5317	707.1735	-50.0000	-200.0000	-5.3835
	28.62	27.46	0.3688	0.5317	707.1735	-50.0000	-200.0000	105.6537
∑	105.27		1.7883					133.3694
E(x)	26.3175	E(y)	0.447073				E(M)	33.3423
	2.69872		0.0025438					5872.1227
	Varianca X		Varianca Y					Varianca M
	1.64278		0.0504363					76.6298
	dev_sta Y=		dev_sta tan fi=					dev_sta I M=
B=	0.43510946							
Pf=	33.17%							

Figure 9. Exact Method (M1)

M	p	p*M	p*M^2
-7.672191888	0.25	-1.918047972	14.71563209
40.77133454	0.25	10.19283364	415.5754301
-5.38351111	0.25	-1.345877777	7.245547967
105.6537317	0.25	26.41343292	2790.677754
133.3693632		33.3423408	3228.214364
33.3423		8.3356	807.0536
	V M=p*M^2- (p*M)^2=	737.5716	208.4459
	devijimi standart I M=	27.1583	14.4377
	B=	1.227704903	2.309401077
	Pf=	10.98%	1.05%

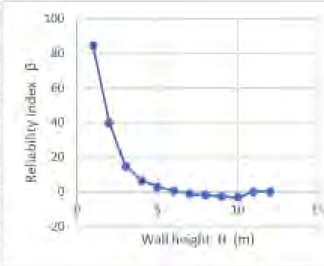
Figure 10. Point Estimation Method(M3)

E M	33.342341	
V M=	1633.883199	
dev_sta I M=	40.42132109	
B=	**0.82487014**	
Pf=	20.47%	

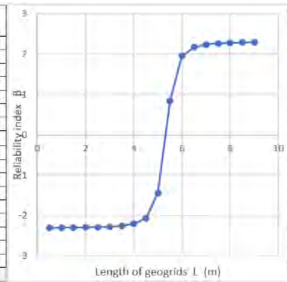
Figure 11. First Order Second Moment (Fosm) Method (M2)

The calculations of reliability index for the margin of safety for sliding are calculated with H-Variable, L-Variable, q-Variable:

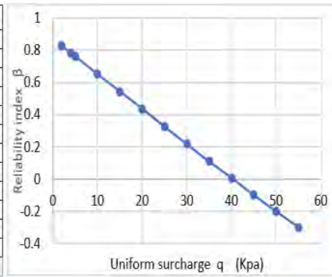
1	84.61476
2	39.87463
4	14.64442
6	6.530001
8	2.668249
10	0.435109
12	-1.01372
14	-2.0275
16	-2.77572
18	-3.35024
20	0.115881
H	β



0.5	-2.30071
1	-2.29861
1.5	-2.29564
2	-2.29126
2.5	-2.28441
3	-2.27284
3.5	-2.25107
4	-2.20278
4.5	-2.06293
5	-1.44118
5.5	0.838985
6	1.950873
6.5	2.171923
7	2.238965
7.5	2.266966
8	2.281137
8.5	2.289257
9	2.294329
L	β



2	0.827949
4	0.784513
5	0.762753
10	0.653653
15	0.544318
20	0.435109
25	0.326382
30	0.218474
35	0.111708
40	0.006382
45	-0.09723
50	-0.19889
55	-0.29837
q	β



Below is given the behavior of the probability of failure (Pf) for different variables of H-Variable, L-Variable, q-Variable (Note that while calculating the probability of failure for variable values of H, L, q the other data to be considered same as input data Figure 5):

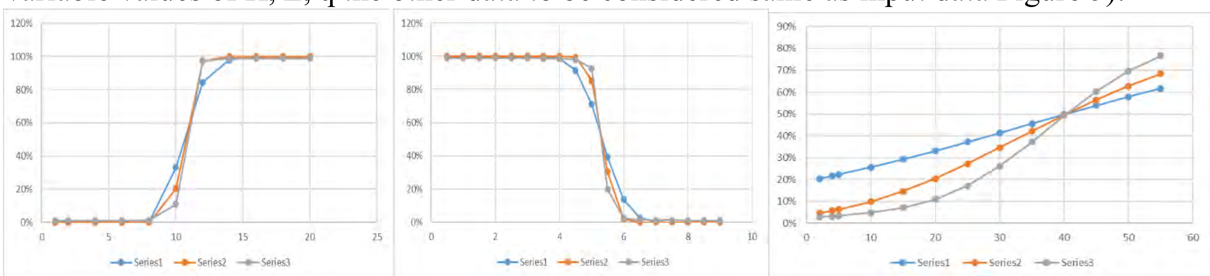


Figure 12. Series 1-Exact Method (M1), Series 2-First Order Second Moment (FOSM) Method (M2), Series 3-PointEstimation Method (M3).

4. CONCLUSIONS

Geogrid-reinforced retaining walls play a vital role in stabilizing earthworks and are commonly used in geotechnical engineering. However, the variability in soil properties due to geological deposition, post-deposition processes, and limited site investigation data requires a stochastic analysis with random fields.

The uncertainties surrounding geotechnical and loading parameters greatly influence the design of geosynthetic-reinforced soil walls.
This study examines the reliability of a geosynthetic reinforced soil wall based on three methods Exact Method, (FOSM) Method and the Point Estimation Method while taking different design uncertainties into account. To illustrate the efficacy and efficiency of the suggested reliability method taking into account external failure data, an example application for a geosynthetic reinforced soil wall with granular fill with limited data from field tests is taken out.
The outcomes from the three approaches align closely for the FOSM and Point Estimation methods. However, the Exact method yields slightly higher results, indicating a greater reliability of the safety factor, particularly concerning overturning failure. On the other hand, the reliability of the safety factor concerning sliding failure is lower with the Exact method but higher with the FOSM and Point Estimation methods.
It is possible to determine that sliding controls the external stability requirements whereas rupture controls the internal stability needs by comparing the failure probability for various data sets.The use of more values is needed to achieve a more accurate result.
The findings indicate that, in most rupture scenarios, the probability of failure reduces with decreasing wall heights and increasing reinforcement lengths. This is because less load is placed on the reinforced backfill and more stability is created throughout the structure with longer reinforcement.
Based on the target reliability standards, the study's results can assist engineers make better design decisions.

REFERENCES

[1] Baecher and Christian 2003-Reliability-and-statistics-in-geotechnical-engineering
[2] Soil Strength and Slope Stability-2014 (J. Michael Duncan,Stephen G.Wright,Thomas L. Brandon)
[3] J. Geotech Geoenviron. Eng., 2004, 130 (10): 985-1003 John T.Christian, Hon.M.ASCE[2] Geotechnical Engineering Reliability: How well do we know what we are doing?
[4] ISO TR 20432 (2007): Guidelines for the determination of the long-term strength of geosynthetics for soil reinforcement Linear Composited Ltd (2015)
[5] Taylor and Francis Phoon, K.K. Kulhawy, F.H. (1999) – Evaluation of geotechnical property variability, Canadianian Geotechnical Journal36(4), pp. 625-639
[6] Goh, A. T. C., and Kulhawy, F. H. (2005). “Reliability assessment of serviceability performance of braced retaining walls using a neural network approach.” International Journal for Numerical and Analytical Methods in Geomechanics, 29(6), 627-642.
[7] EN 13251 (2002) – Geotextile and Geotextile-related products – Required characteristic for use in earthworks, foundations and retaining structures

Computational Methods in Civil Engineering

Analysis of Cold-Formed Sections Elements under compression loads: Conventional methods vs Finite Element Approach

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This research endeavours to comprehensively examine the analysis of steel cold-formed section elements under compression loads employing Abaqus finite element software. The study is motivated by the imperative to rigorously evaluate the efficacy and computational performance of Abaqus relative to traditional analytical methodologies in the context of cold-formed steel structures. Employing a rigorous analytical framework, incorporating numerical simulations and empirical validation, we aim to elucidate the comparative merits and limitations of Abaqus in modelling the complex mechanical behaviour of steel cold-formed sections under compressive loading regimes. Through a series of meticulously designed experiments, we scrutinize various aspects of the structural response of steel cold-formed sections, including buckling modes, stress distributions, and load-carrying capacities. We focus particularly on the comparison of buckling load distributions obtained from Abaqus simulations and those derived from conventional analytical methods. By meticulously examining the discrepancies between the two approaches, we seek to shed light on the accuracy and reliability of Abaqus in predicting critical buckling phenomena inherent in steel cold-formed sections.

Keywords: *Cold-formed sections, axial loads, finite element analysis, deformations, local buckling.*

1. INTRODUCTION

In the realm of structural engineering, the design and analysis of cold-formed steel sections under various loading conditions represent a critical area of research and application [1]. These sections are highly regarded for their advantageous strength-to-weight ratio and versatility in construction projects [2] Among the various cold-formed profiles, the C-shaped sections have garnered significant attention due to their efficient performance in bearing axial loads, which are common in building frameworks, purlins, and studs.

The process of designing such elements, particularly when utilizing high-grade S355 steel known for its superior mechanical properties, demands a meticulous approach that integrates theoretical computations with practical simulations. This comprehensive procedure ensures both efficiency and reliability in structural performance.

This paper focuses on the comprehensive procedure of designing a C-shaped cold-formed section made from class S355 steel, subjected to an axial load. The approach encapsulates a dual-phase analysis: initially leveraging the power of numerical equations formulated within an Excel environment for preliminary assessments, followed by detailed simulations using the ABAQUS Finite Element Method (FEM) software for an in-depth structural behavior analysis.

The integration of findings from both Excel-based numerical equations and ABAQUS FEM designs aims to validate the design of the C-shaped cold-formed section, ensuring it meets the requisite performance standards while optimizing material usage. This comprehensive methodology not only underscores the importance of a synergistic approach to structural design but also paves the way for future advancements in the design and analysis of cold-formed steel sections.

2. MATERIALS AND METHODS

Cold-formed steel, often abbreviated as CFS, is a type of steel that is shaped and formed at room temperature using a series of rolling or pressing processes. These processes typically involve bending, folding, or stamping the steel into the desired shape without the need for heating, in contrast to hot-rolled steel which is shaped while at high temperatures. Cold-formed steel can be fabricated from a variety of steel grades, each with its own set of mechanical properties. Common grades used include EN – 1993-1-1, ASTM A1008/A1008M (commercial grade), ASTM A653/A653M (structural grade), and ASTM A500 (high-strength low-alloy grade). The choice of grade depends on factors such as required strength, ductility, and corrosion resistance. The analysis of cold-formed steel (CFS) sections under compression loads is critical in the design and assessment of lightweight steel structures. These elements are widely used in construction due to their high strength-to-weight ratio, versatility, and efficiency in material use. However, their stability behavior under compression, characterized by phenomena such as local buckling, distortional buckling, and global buckling, requires sophisticated analytical approaches. This discussion compares conventional methods and the Finite Element Analysis (FEA) approach in analyzing cold-formed sections under compression loads.

2.1.Cold form steel design based on SK-EN 1993-1-3.

According to Eurocode the structure should satisfy several criteria and considerations to ensure its safety, stability, and performance.

2.1.1. Ultimate Limit State

For a member in axial tension, the following expression shall be satisfied.

$$N_{t,Rd} = \frac{f_{ya} A_g}{\gamma_{mo}} \text{ but } N_{t,Rd} \leq F_{n,Rd} \tag{1}$$

where:
A_g is the gross area of the cross-section,
$F_{n,Rd}$ is the net-sectiom resistance for the appropriate type of mechanical fastener.

For a member in axial compression, the following expression shall be satisfied.

$$N_{c,Rd} = \frac{f_{yb} A_{eff}}{\gamma_{mo}} \text{ - for when the effective area } A_{eff} \text{ is less than the gross area } A_g \tag{2}$$

$$N_{c,Rd} = \frac{A_g \left(f_{yb} + \left(f_{ya} - f_{yb} \right) 4 \left(1 - \frac{\bar{\lambda}_e}{\bar{\lambda}_{e0}} \right) \right)}{\gamma_{mo}} \leq \frac{f_{ya} A_g}{\gamma_{mo}}$$

For a member in compression perpendicular to the grain, the following expression shall be satisfied.

$$\sigma_{c,90,d} \leq k_{c,90} \cdot f_{c,90,d} \tag{3}$$

where:

A_{eff} is the effective area of the cross-section by assuming a uniform compressive stress equal to f_{yb},

f_{ya} is the average yield strength.

f_{yb} is the basic yield strength.

For a member in bending, the following expression shall be satisfied.

$M_{c,RD} = \frac{W_{eff} f_{yb}}{\lambda_{Mo}}$ - if the effective section modulus W_{eff} is less than the gross elastic section modulus

$$M_{c,RD} = \frac{f_{yb}\left(W_{el} + \left(W_{pl} - W_{el}\right)4\left(1 - \frac{\bar{\lambda}_{e\max}}{\bar{\lambda}_{eo}}\right)\right)}{\gamma_{Mo}} \quad (5)$$

(6)

where:

$\bar{\lambda}_{e\max}$ is the slenderness of the element which correspond to the largest value of $\frac{\bar{\lambda}_e}{\bar{\lambda}_{eo}}$

2.1.2. SLS

The Serviceability Limit State (SLS) is a crucial concept in structural engineering, particularly within the framework of design codes such as the Eurocodes. It pertains to the conditions under which a structure must remain functional and comfortable for its intended use, without causing undue distress or discomfort to its occupants. Unlike the Ultimate Limit State (ULS), which focuses on the maximum strength of a structure and its components to avoid collapse, the SLS concerns itself with aspects that ensure the structure is fit for use and durable over its intended life span.

Key considerations under the SLS include:

Deflections: The deflections may be calculated assuming elastic behaviour.

The influence of slip in the connections (for example in the case of continuous beam systems with sleeves and overlaps should be considered in the calculation of deflections, forces and moment

Plastic deformation: The influence of slip in the connections (for example in the case of continuous beam systems with sleeves and overlaps) should be considered in the calculation of deflections, forces and moments.

Design based on Abaqus.

The same structure that was calculated with numerical equations, was also analysed using FINITE ELEMENT METHOD using Abaqus finite element software. Abaqus finite element software is commonly used in the analysis and design of cold-formed steel structures due to its robust capabilities in simulating complex behaviors under various loading conditions. Abaqus allows engineers to accurately model the geometry and material properties of cold-formed steel sections. This includes defining the cross-sectional profiles, thicknesses, and material properties such as yield strength, modulus of elasticity, and strain-hardening behavior.

The following algorithm outlines the typical steps used when employing Abaqus for designing structures with cold-formed steel.

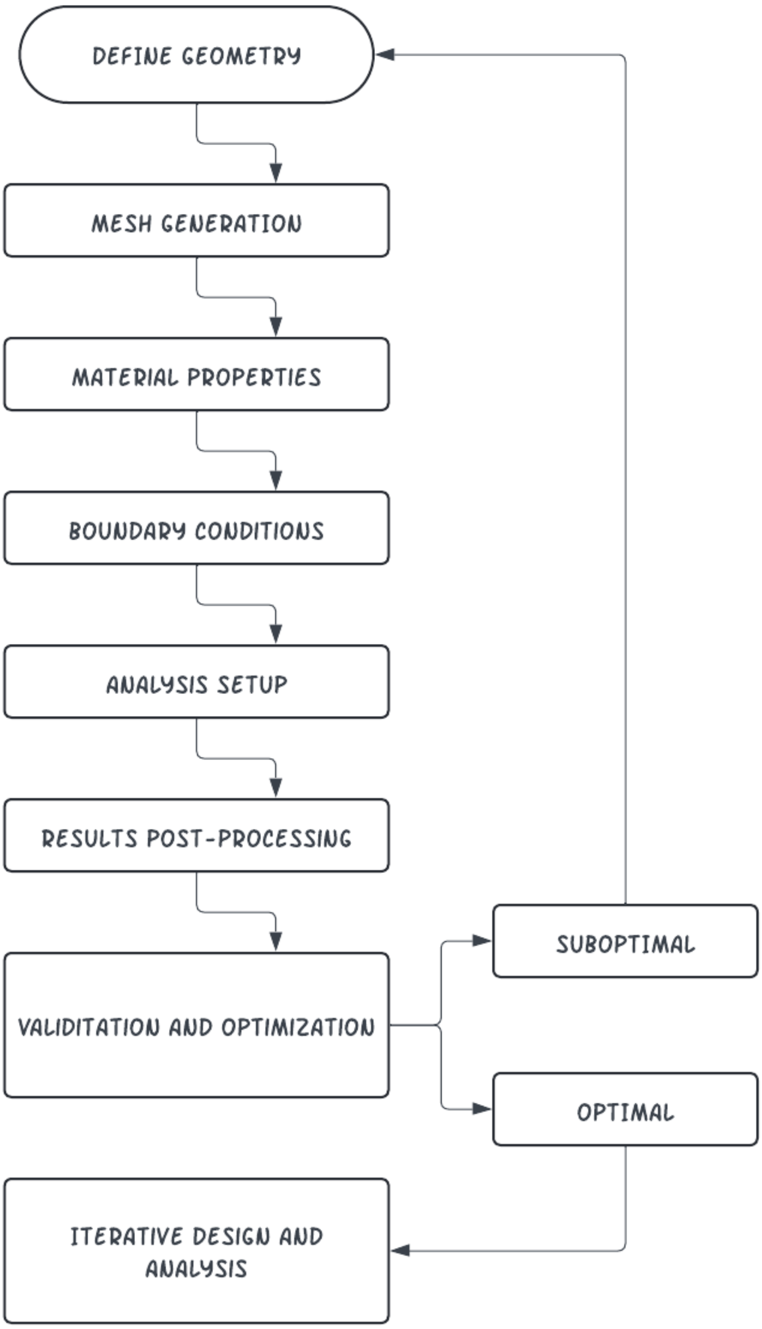

Figure 18. Algorithm for designing structures with cold-formed steel

3. RESULTS AND DISCUSSION

In this section, we present the results of our analysis, comparing the performance of the cold-formed steel column obtained from Abaqus finite element simulations with those calculated using the equations outlined in the Eurocode EC-1991-1-3. The comparison aims to validate the accuracy and reliability of both numerical and analytical methods in predicting the structural behavior of cold-formed steel members under axial loading. The table below provides a comprehensive comparison of key parameters, including load capacity, deflection, and buckling load, obtained from both methods. This comparison serves to assess the agreement between the numerical simulations and analytical calculations, shedding light on the efficacy of the design approach employed for cold-formed steel structures.

Table 5. Load Differences FEM vs Numerical.

	Abaqus Results (kN)	EC-1991-1-3 Results (kN)
Load Capacity (L=3m and buckling length about both axis Lx=Ly=3m)	29.02	27.87
Load Capacity (L=3m and buckling length about both axis Lx=Ly=1m)	72.48	67.70

The comparison between conventional methods and the Finite Element Analysis (FEA) approach for analyzing cold-formed sections under compression loads reveals distinct advantages and limitations inherent to each method. These differences can significantly impact the choice of method for specific project needs, design objectives, and constraints.

Table 6. Advantages and Limitations FEM vs Numerical

Aspect	Conventional Methods	Finite Element Analysis (FEA)
Advantages		
Simplicity	Simplified models for quick analysis	Detailed models accounting for complex interactions
Speed	Faster preliminary design and assessment	-
Code Compliance	Directly tied to design codes	-
Accessibility	Easily applied with basic training	Can handle almost any geometry and material behavior
		Allows for detailed analysis including nonlinear effects
		Optimization capabilities for material use and design
Limitations		
Conservatism	May result in over-conservative designs	Requires specialized software and significant computational resources
Scope	Limited in predicting behaviors for unconventional geometries	Demands a high level of expertise for accurate modeling
Approximations	Relies on empirical data and simplifications	Time-consuming process from modeling to analysis

4. CONCLUSION

In synthesizing the insights gained from the comparison of traditional methods and Finite Element Analysis (FEA) for cold-formed steel (CFS) sections under compressive loads, several key conclusions emerge that highlight the path forward and the evolving landscape of structural design:

Integrated Design Process: The future of CFS design lies in an integrated design process that leverages the rapid, code-based calculations of traditional methods for initial sizing and the detailed, nuanced analysis capabilities of FEA for optimization and exploration of innovative solutions.

Optimization of Resources: Both methods contribute significantly to the optimization of material usage and environmental sustainability. By employing traditional methods for preliminary design and FEA for fine-tuning, designers can achieve structures that are not only safe and compliant but also material-efficient and less impactful on the environment.
Enhanced Understanding of Structural Behavior: FEA offers unparalleled insights into the complex behavior of CFS under compressive loads, including local buckling, distortional effects, and global stability. This deepened understanding informs better, more resilient designs and bridges gaps in knowledge that traditional methods alone might not address.
Safety and Reliability: The dual approach of employing both methods enhances the safety and reliability of CFS structures. Traditional methods ensure adherence to established safety margins and design codes, while FEA allows for the exploration of boundary conditions and loading scenarios beyond those codes, contributing to a more robust understanding of structural performance under varied conditions.
Education and Skill Development: There is a clear indication that continuous education and skill development in both traditional analytical techniques and advanced FEA are essential for the next generation of structural engineers. Staying current with software advancements, understanding the limitations of each method, and applying them judiciously will be key to advancing the field.
Adaptation of Codes and Standards: As our collective understanding of CFS behavior under compressive loads deepens, largely through FEA, there will be a necessary evolution of design codes and standards to incorporate these insights. This adaptation will likely result in more nuanced and sophisticated design requirements, pushing the industry towards safer, more efficient practices.
Collaboration Across Disciplines: The challenges and opportunities presented by CFS design under compression loads highlight the importance of interdisciplinary collaboration. Insights from materials science, computational mechanics, and practical construction experience are all critical in pushing the envelope of what's possible in CFS design.
Global Perspective on Design Practices: The comparison underscores the value of a global perspective on design practices, where diverse approaches and solutions can inform and inspire more universally applicable design strategies for CFS. The exchange of ideas and best practices across borders can accelerate innovation and efficiency in structural design worldwide.

In conclusion, the complementary use of traditional methods and FEA in analyzing CFS sections under compression not only highlights the strengths and limitations of each approach but also charts a course for the future of structural design—a future that embraces complexity, prioritizes sustainability, and fosters innovation through integrated analytical strategies.

REFERENCES

[1] Jones, 2018; Wang et al., 2020

[2] Li & Chen, 2019; Zhang & Wang, 2021

[3] Hancock, G.J., Baker, A.C., Yu, W.W. (2010). "Buckling of Cold-Formed Steel Compression Members". John Wiley & Sons.

[4] Schafer, B.W., Peköz, T. (2002). "Direct Strength Method for Cold-Formed Steel Members and Connections". American Iron and Steel Institute (AISI), Washington, DC.Design of Modern Timber Structures by Hans Joachim Blaß and John W. van de Kuilen

[5] Eurocode 3: Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting. (2006). European Committee for Standardization (CEN), Brussels.

[6] Hancock, G.J., Young, B. (2008). "Stability of Cold-Formed Steel Beams under Non-Uniform Bending". Journal of Structural Engineering.

[7] CEN (1990). EN 10045-1:1990 – Metallic materials – Charpy impact test. Part 1: Test method, European Committee for Standardization, Brussels

[8] CEN (1993). EN 10034:1993 – Structural steel I and H sections –Tolerances on shape and dimensions, European Committee for Standardization, Brussels

[9] CEN (2000). EN 10020: 2000 – Definition and classification of grades of steel, European Committee for Standardization, Brussels.

[10] CEN (2001). EN 10002-1:2001 – Tensile testing. Part 1: Method of test at ambient temperature, European Committee for Standardization, Brussels.

[11] CEN (2002a). EN 1990:2002 – Eurocode, Basis of Structural Design, European Committee for Standardization, Brussels.

[12] CEN (2002b). EN-1991-1-1:2002 – Eurocode 1: Actions on Structures– Part 1-1: General Actions – Densities, self-weight, imposed loads for buildings, European Committee for Standardization, Brussels.

[13] Fiorino L, Iuorio O, Landolfo R (2011). Seismic Analysis of Sheathing-Braced Cold-Formed Steel Structures, Engineering Structures, Vol. 34, 538–547.

[14] Fischer M, Zhu J (1996). The method of effective width and for bars with thin-walled cross-sections-remarks of insufficiencies and improvements, Coupled Instabilities in Metal Structures-CISM'96, Imperial College Press, London, 141-148.

[15] Fenster SMC, Girardier EV, Owens GW (1992). Economic Design and the Importance of Standardised Connections, In Constructional Steel Design: World Developments (Dowling PJ et al, Eds.). Elsevier Applied Science, Barking, Essex, UK, 541-550.

[16] Fülöp L, Dubina D (2003). Experimental program to evaluate the shear capacity two new types of screws. Research report (in Romanian), PU Timisoara. Beneficiary LINDAB Romania Ltd.

[17] Fülöp L, Dubina D (2004). Performance of wall-stud cold-formed shear panels under monotonic and cyclic loading. Part I: Experimental research, Thin-Walled Structures, Vol. 42(2), 321–338.

[18] Fülöp L, Dubina D (2004). Performance of wall-stud cold-formed shear panels under monotonic and cyclic loading. Part II: Numerical modelling and performance analysis, Thin-Walled Structures, Vol. 42(2)

[19] Fülöp L, Dubina D (2006). Design criteria for seam and sheeting-toframing connections of cold-formed steel shear panels, Journal of Structural Engineering, American Society of Civil Engineers - ASCE, Vol. 132(4),

[20] Galambos TV (1998). Guide to Stability Design Criteria for Metal Structures, 5th Edition, John Wiley and Sons.

[21] Gardner L, Nethercot DA (2001). Behaviour of cold-formed stainless steel cross-sections, Proceedings of 9th Nordic Steel Construction Conference – NSCC2001, Helsinki, Finland, 18-20 June, 781-789.

Assessing the Load-Bearing Capacity of Frame Systems and increasing it through the application of FRP Techniques

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This paper presents a reliability study on reinforced concrete (RC) frame system retrofitted by Fibre Reinforced Polymers (FRP) confinement using the Join Method applications.The analyse concrete frame system with columns dimensions , 30/80 cm and beams 30/60 cm, design with details , respectively oriented in class of concrete C 30/37. The testing of the concrete in frame including the columns and bems result with low concrete class C 20/25 compared with design class. In Process of evaluations the structural assessment, this study rigorously examines the geometric implications and their influence on load distribution within the ram system. Through rigorous analytical computations, the effects of bending moments (M), shear forces (V), and axial loads (N) are meticulously evaluated to discern their impact on the structural stability and performance of the ram system. Moreover, the research extends its focus towards evaluating the efficacy of FRP application methods in Improving the load-bearing capacity of the frame system. In scope of the analyses nowedays used the different softwares , but in this case is applied the HORSE software, the study conducts simulations and analyses to gauge the feasibility and effectiveness of FRP reinforcement techniques. This paper reviews and identifies gaps in knowledge of use the FRP materials in confinement and retrofiting the frame system , focueed in joints and applications in new or existing constructions in achieve the targeting values of load bearing capacity.

Keywords: *Load-bearing capacity, Frame system, FRP application, Structural integrity, Bending moments, HORSE Software.*

1. INTRODUCTION

Properly structural design request the, ensuring that columns match the design specifications is crucial for safety and stability. However, there are occasions when columns fail to meet the designated characteristics of the concrete outlined in the project plans. This discrepancy can arise due to various factors, including errors in material composition, improper mixing, or inadequate curing processes during construction. For instance, if the concrete used in a column has lower compressive strength than specified, it may be prone to cracking or deformation under load, jeopardizing the safety of the entire structure (Fig. 1).

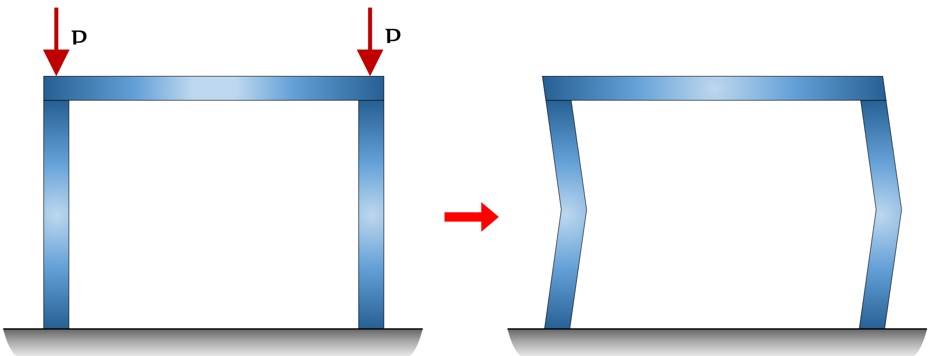


Figure 1. Columns deformation under loads.

To address this issue and rectify the discrepancies in the column's concrete characteristics, we may employ various remedial measures. One effective solution increasingly adopted in the construction industry involves the use of Fiber Reinforced Polymers (FRP) for reinforcement. By applying FRP wraps or sheets to the column surface, we can enhance its load-bearing capacity, restore structural integrity, and mitigate the risks associated with substandard concrete characteristics.

2. METHODOLOGY, APLICATIONS-CASE STUDY

The research process in this case consisted of collected paper on experimental study cases and the application of FRPs in full-scale or alreaday existing structures.
For applying the methodology in this case study we used the already out put results for Class of concrete, design for C30/37 and result with class C16/20.
In this case of frame with a height of 4m and a width of 5m, poor concrete quality can result in a lack of strength and stability in the column. This would increase the risk of changes in the shape and compression of the column, making it more prone to cracking or deformation under heavy loads.
The cross-sectional dimensions for both the beam and the column are equivalent, each measuring 0.5 meters in width and 0.5 meters in height. And they are reinforced with different quantities of reinforcement bars, column with 452 mm^2 and beam with 549 mm^2 (Fig. 2).

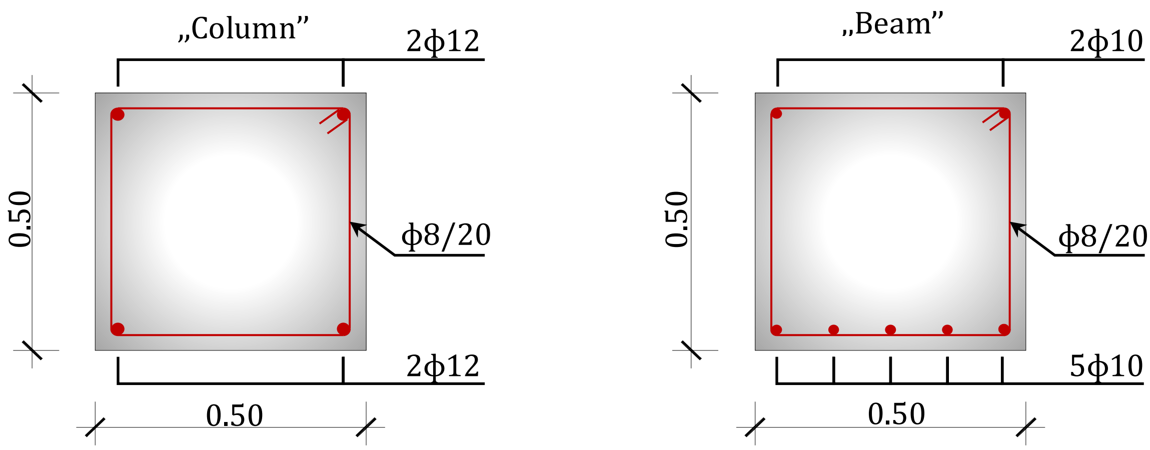


Figure 2. The cross-sectional of column and beam.

The frame is loaded with axial forces at its end, with a value of 3200 kN each (Fig. 3).

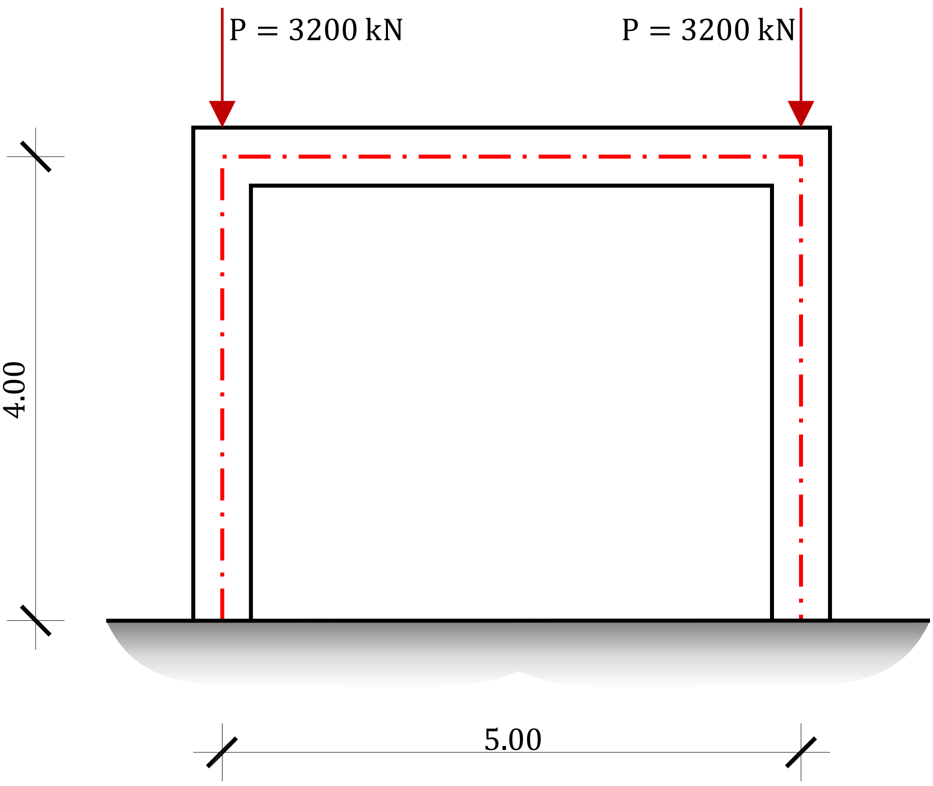


Figure 3. The height and width of the frame.

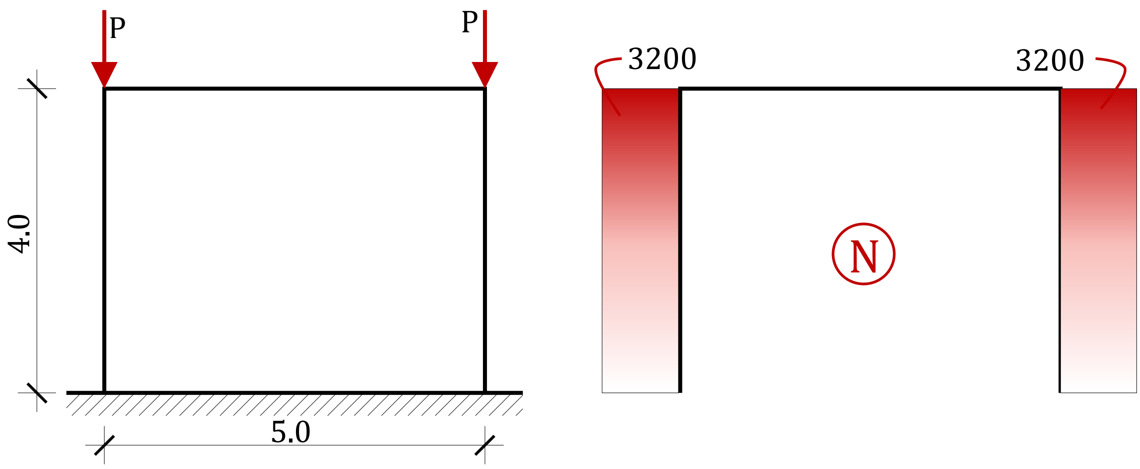


Figure 4. The influences from axial force.

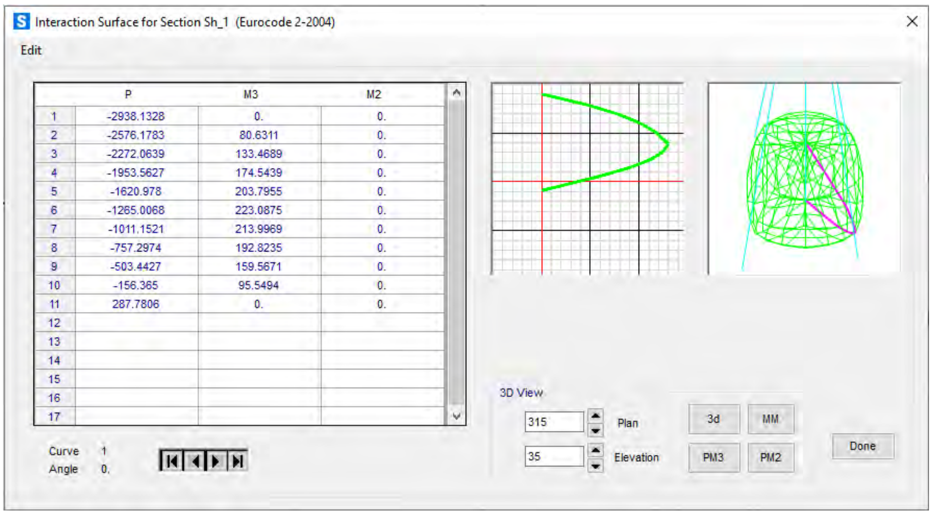
To assess the load-bearing capacity of columns, we need the axial force diagram from external influences and compare it with the column's bearing capacity to determine the necessity of FRP reinforcement.

3. THE LOAD-BEARING CAPACITY OF A COLUMN

The load-bearing capacity of a column refers to the maximum amount of load or weight that a column can support before it fails or experiences excessive deformation (Fig.5). This capacity is influenced by various factors including the material properties of the column (such as its strength and stiffness), its dimensions (such as cross-sectional area and length), the type of loading (such as compression, bending, or a combination of both), and the support conditions. The load-bearing capacity of a column is usually determined through structural analysis and calculations based on engineering principles and codes. Various analytical methods, such as Euler's buckling formula, axial compression formulas, and finite element analysis (FEA), may be employed to evaluate the behavior of columns under different loading conditions.

Figure 5. Typical cases of column collapse.

However, in our example, we have calculated the load-bearing capacity of the column using the SAP2000 software program, and the result is as follows (Fig. 6):



	P	M3	M2
1	-2938.1328	0.	0.
2	-2576.1783	80.6311	0.
3	-2272.0639	133.4689	0.
4	-1953.5627	174.5439	0.
5	-1620.978	203.7955	0.
6	-1265.0068	223.0875	0.
7	-1011.1521	213.9969	0.
8	-757.2974	192.8235	0.
9	-503.4427	159.5671	0.
10	-156.365	95.5494	0.
11	287.7806	0.	0.
12			
13			
14			
15			
16			
17			

Figure 6. Interaction surface for column.

The results for load-bearing capacity of the column is 2938.13 kN, while the applied load 3200 kN exceeds this capacity. Therefore, the column is unable to withstand the external forces. The column may bend or buckle sideways, causing it to lose its ability to support the load vertically. This buckling behavior arises due to the interaction between the compressive load and the column's stiffness. When the load is high enough, it causes the column to deflect sideways rather than continuing to compress linearly. This lateral deflection can lead to instability and ultimately structural failure if not addressed.

As we can see in the table below from the report specified and extracted from the SAP2000 software program.

Table 1. Column Summary Data – Eurocode 2-2004 (SAP2000)

Concrete Details 1 - Column Summary Data - Eurocode 2-2004				
Design Opt	**Status**	**PMMRatio**	**ErrMsg**	**WarnMsg**
Text	Text	Unitless	Text	Text
Check	See WarnMsg	0.0325	No Messages	Reinforcing provided minimum requir
Check	See WarnMsg	0.0201	No Messages	Reinforcing provided minimum requir
Check	See WarnMsg	0.1251	No Messages	Reinforcing provided minimum requir
Check	Overstressed and See WarnMsg	1.8302	No Messages	Reinforcing provided minimum requir
Check	See ErrMsg and WarnMsg		Column factored axial load is too high. Kr becomes negative (EC2 5.8.8.3(3) Eq. 5.36);	Reinforcing provided minimum requir
Check	Overstressed and See WarnMsg	1.8175	No Messages	Reinforcing provided minimum requir

After concluding that the axial force exceeds the load-bearing capacity of the column, we have decided to reinforce the column with FRP (Fiber-Reinforced Polymer). We used the HORSE software for the detailed calculations of reinforcement with FRP.

4. CALCULATIONS OF CFRP STRENGTHENED COLUMN

4.1. Design Criteria

ACI 318M-14 Building Code Requirements for Structural Concrete

ACI-440-2R-17 Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures

Table 2. Design Requriement and Basc Information

Design Requriement and Basic Information	
Information of existing membet	
Height [mm]	500
Width [mm]	500
Radius of edges of a prismatic cross section confined with CFRP [mm]	25
Area of the steel reinforcement [mm2]	113.1
Concrete compressive strength [Mpa]	20
Yield strength of tensile reinforcement [Mpa]	319
Elastic modulus of tensile reinforcement [Mpa]	200000
Required axial load [kNm]	3500

Table 3. Strengthening system

Strengthening system	
Material	HM-60-II
Ultimate tensile strength of the FRP material as reported by the manufacturer [MPa]	3491
Ultimate rupture strain of FRP reinforcement	0.0144
Elastic modulus of CFRP [MPa]	243103
Environmental reduction factor	0.85
Design ultimate tensile strength of FRP [MPa]	2967.35
Design rupture strain of FRP reinforcement	0.0122
Number of layers	6

Table 4. The holding capacity of the column before and after CRFP

The holding capacity of column	
Original capacity	$\phi P_{n,existing}$=3200 kN
Required capacity	$P_{u,req}$ =3500kN
Capacity after strengthening	$\phi P_{n,existing}$=3700.09 kN
Strengthening system	Material：CFRP HM-60-II
	Number of layers：6
Conclusion	OK

In Figure 7, the method of preparing the surface of the element before the FRP installation is shown, while in Figure 8, the method of FRP installation is presented.

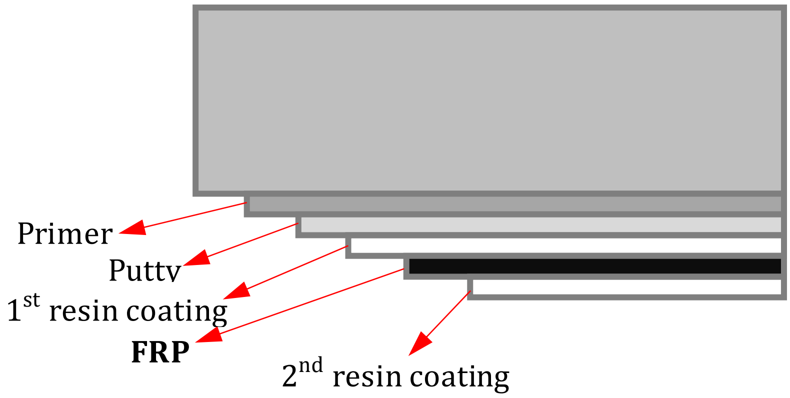


Figure 7. Preparation of element before the FRP installation.

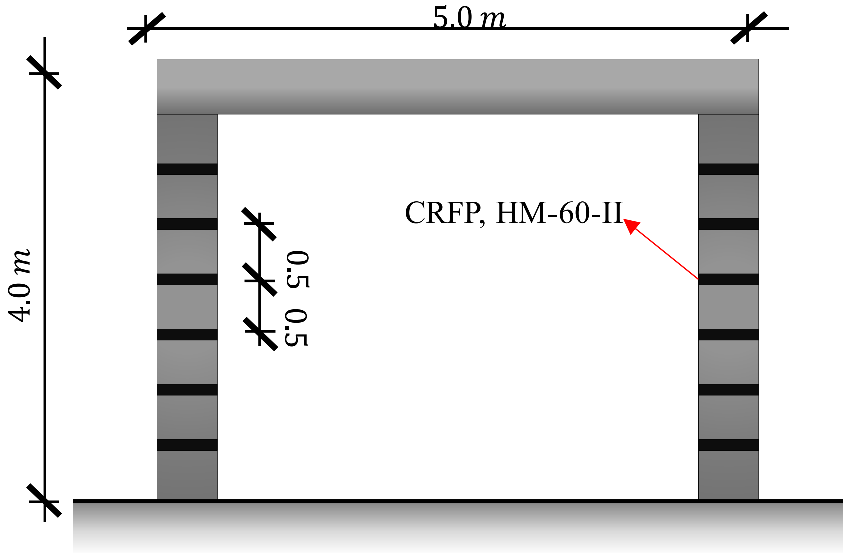


Figure 8. Method of installation of CRFP in columns.

Figure 9. HM-60-II 6×100mm

5. CONLUSIONS

Utilizing Finite Element Analysis (FEA) software like SAP has proven effective in assessing the load-bearing capacity of frame systems. Through simulation, we can gain insights into structural behavior and identify potential weaknesses, allowing for targeted reinforcement strategies.
The occurrence of column collapse underscores the importance of thorough structural evaluation and strengthening measures. By implementing FRP techniques, such as carbon fiber reinforcement, we can significantly enhance the load-carrying capacity of structural members, mitigating the risk of failure.
Integrating advanced computational tools like SAP and HOURS program enables engineers to make informed decisions regarding the selection and application of CFRP materials. This comprehensive approach ensures that structural enhancements are tailored to specific needs, optimizing performance and durability.

Notes：

The HORSE software application and the results derived from its utilization are intended only for use by professional users with expert knowledge in the area of the intended application. Users must independently verify the results before any use and take into account the site and application conditions, product data sheet and product literature, technical state of the art as well as local applicable standards and regulations.

REFERENCES

[1] American Concrete Institute (ACI). (2008). "Guide for the design and construction of externally bonded FRP systems for strengthening concrete structures", *ACI 440 2R, ACI Committee 440*, Farmington Hills, Mich.
[2] Akguzel, U., and Pampanin, S. (2010). "Effects of variation of axial load and bidirectional loading on seismic performance of GFRP retrofitted reinforced concrete exterior beam-column joints", *Journal of Composites for Construction,* 14(1), 94–104.
[3] Al-Salloum, Y. A., Almusallam, T. H., Alsayed, S. H., and Siddiqui, N. A. (2011). "Seismic behavior of AS-built, ACI-complying, and CFRP repaired exterior RC beam-column joints*", Journal of Composites for Construction,* 15(4), 522–534.
[4] Antonopoulos, C. P., and Triantafillou, T. C. (2002). "Analysis of FRP-Strengthened RC beam-column joints", *Journal of Composites for Construction,* 6(1), 41–51.
[5] Antonopoulos, C. P., and Triantafillou, T. C. (2003). "Experimental investigation of FRP-strengthened RC beamcolumn joints", *Journal of Composites for Construction,* 7(1), 39–49.
[6] European Standard. (EN 1998-1:2004). "Design of structures for earthquake resistance, Part 1: General rules, seismic actions and rules for buildings". Eurocode 8, Dec. 2004, Brussels.
[7] Garcia, R., Hajirasouliha, I., Pilakoutas, K. (2010) Seismic behaviour of deficient RC frames strengthened with CFRP composites, Engineering Structures, 32 (10), 3075-3085.
[8] Ilki, A., Bedirhanoglu, I., and Kumbasar, N. (2011). "Behavior of FRP-retrofitted joints built with plain bars and low-strength concrete". *Journal of Composites for Construction,* 15(3), 312–326.
[9] Karayannis, C. G. and Sirkelis, G. M. (2008). "Strengthening and rehabilitation of RC beam–column joints using carbon-FRP jacketing and epoxy resin injection", *Earthquake Eng. Struct. Dyn.*, 37(5), 769– 790.

[10] Parvin, A., Altay, S., Yalcin, C., and Kaya, O. (2010). "CFRP rehabilitation of concrete frame joints with inadequate shear and anchorage details", *Journal of Composites for Construction,* 14(1), 72–82.

[11] Shrestha, R. Smith S. T. and Samali B. (2009). "Strengthening RC beam–column connections with FRP strips", *Proceedings of the Institution of Civil Engineers Structures and Buildings,* 162(SB5), 323–334.

[12] Tsonos, A.G., Stylianidis, K.A., (1999). "Pre-seismic and post-seismic strengthening of reinforced concrete structural subassemblages using composite materials (FRP)", *Proc., 13th Hellenic Concrete Conf.*, Rethymno, Greece, 1, pp. 455-466.

[13] Tsonos, A. G. (2008). "Effectiveness of CFRP-jackets and RC-jackets in post-earthquake and pre-earthquake retrofitting of beam–column subassemblages", *Eng. Struct.*, 30(3), 777–793.

[14] Uzumeri, S. M. (1977). "Strength and ductility of cast-in-place beam column joints", *Reinforced Concrete Structures in Seismic Zones, American Concrete Institute,* Detroit, Michigan, 293-350.

[15] Vollum, R.L. and Newman J.B. (1999). "Strut and tie models for the analysis/design of external beam-column joints", *Magazine of Concrete Research*, 51(6), 415-425.

Comparative Analysis of Displacement in Dual Systems with Shear Walls: Utilizing Finite Element Method, Software, and Approximate Expression

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Structural analysis for buildings in seismic zones involves the consideration of numerous parameters that significantly influence the final values of structural dimensions. Structural analysis has progressed to various professional software platforms, where engineers often may not be aware of the input values and calculated results because of the speed up of the demands. Comparing the calculated values obtained from different software and the finite element analysis with the approximate calculations would be a possibility for assessing the performance of the structure. This paper endeavors to tackle a fundamental challenge in the realm of reinforced concrete structure design: the accurate assessment of displacements within a towering structure standing at a height of 26.6 meters. With a targeted focus on a six-story building (ground plus six levels), this investigation is dedicated to guaranteeing structural robustness and safety amidst a spectrum of dead loads, temporary and seismic loads. To evaluate the structural performance values in this study, the lateral displacement values at the top of the structure obtained from software, finite element analysis, and approximate calculation methods will be compared. For the structure, the design parameters have been incorporated: soil acceleration of 0.25, concrete class C35/45, and reinforcement type B500C. Considering that the most common type of structural system used in seismic zones, especially for taller buildings, is the frame dual system, this is the rationale behind conducting the analysis in this study. The structural analysis of frame system with dual vertical members is focused on the seismic wall contribution to horizontal displacement. This entails using Finite Element Method (FEM) analyses, advanced software simulations, and precise approximate expressions to evaluate the structural performance and identify potential variations across different approaches. This study aims to enhance our understanding of how structures perform by using advanced numerical methods and approximations.

***Keywords**: Comparative Analysis, Displacement, Dual Systems, Shear Walls, Finite Element Method, Structural Optimization.*

1. INTRODUCTION

In structural engineering, managing displacement and ensuring stability against lateral forces like wind and seismic activity are critical concerns. Walls that primarily resist lateral loads due to wind or earthquakes acting on the building are called shear walls or structural walls. These walls provide lateral bracing for the rest of the structure [1]. In the context of high-rise structures, the integration of shear walls with other structural systems, such as frames, commonly known as dual systems with shear walls, has led to superior displacement control.

Through this comparative study, we aim to assess the effectiveness and precision of various analytical methods in predicting displacement patterns within dual systems featuring shear walls. By using advanced computational tools alongside simplified analytical approaches, our objective is to provide detailed understandings into the intricate relationships among structural components and their impact on overall displacement dynamics.

The findings of this research hold significant implications for structural engineers and designers, offering valuable guidance in the optimization of dual system with shear walls configurations to achieve desired performance objectives while meeting stringent safety standards. Moreover, this study contributes to the ongoing discourse surrounding the utilization of computational methods and analytical approximations in structural engineering practice, advancing our understanding of displacement behavior in complex building systems. By exploring into various approaches for displacement analysis, this research equips engineers with the tools to effectively manage displacements right from the preliminary dimensioning of structural elements using approximate expressions, thereby ensuring controlled displacement within the structure.

2. DISPLACEMENT CALCULATIONS USING FINITE ELEMENT METHOD, SOFTWARES AND APPROXIMATE EXPRESSIONS

2.1 Calculating displacements with Finite element method.

The finite element method is a numerical method for solving problems of engineering and mathematical physics. The finite element formulation of the problem results in a system of simultaneous algebraic equations for solution, rather than requiring the solution of differential equations. These numerical methods yield approximate values of the unknowns at discrete numbers of points in the continuum. Hence, this process of modeling a body by dividing it into an equivalent system of smaller bodies of units (finite elements) interconnected at points common to two or more elements (nodal points or nodes) and/or boundary lines and/or surfaces is called discretization. [2] For the simplicity of the calculation, so that when using the finite element method we don't end up with high-order matrices, structures whose mass is concentrated on the floor, for analytical purposes we use an idealized structural system where rotational degrees of freedom are neglected, focusing only on translational degrees of freedom called Shear Buildings.

In a shear building: mass is concentrated at the level of the floors (Lumped Mass), beams have high stiffness ($EI = \infty$), the rotations of the joints are taken to be zero and the axial deformations of the elements are neglected. [3]

Below is presented the model of a Shear Building that contains:

1. Stiffness on each floor presented by: k_1, k_2, k_3
2. Forces acting on each floor horizontally: P_1, P_2, P_3
3. Masses concentrated on the floor: m_1, m_2, m_3
4. Principle of obtaining the stiffness matrix

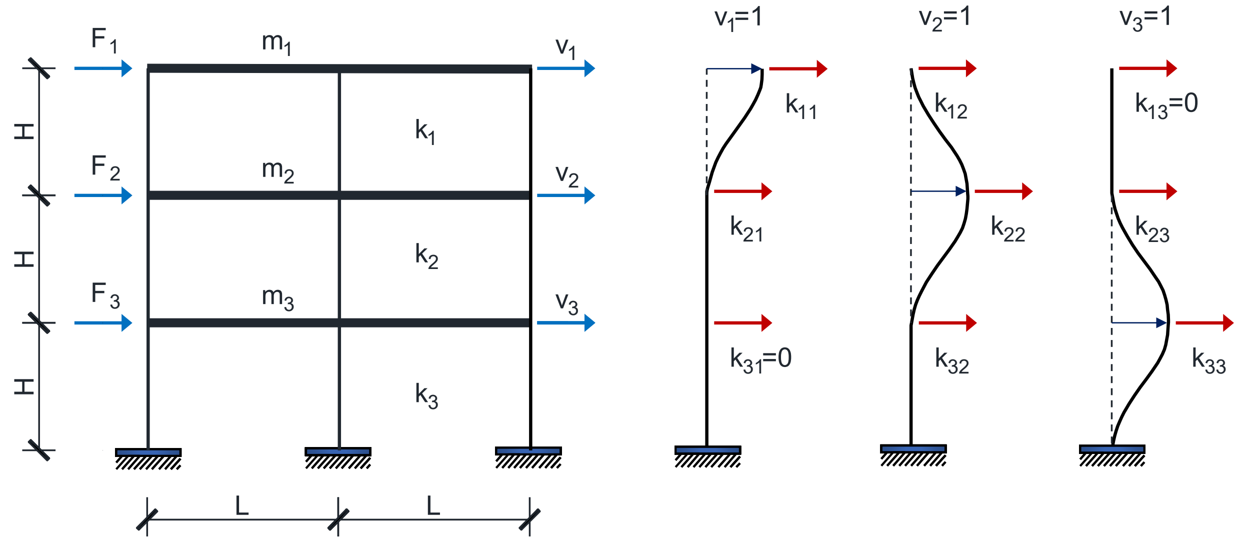


Figure 1. Shear Building Model

Stiffness matrix is a key component in the finite element method (FEM) used to model the behavior of structures subjected to loads. It represents the relationship between applied forces and resulting displacements within an element or a structural system. You will learn that the global nodal forces {F} and the global nodal displacements {v} are related through use of the global stiffness matrix [K] by:

$$\{F\} = [K] \cdot \{v\} \tag{1}$$

Equation (1) is called the global stiffness equation and represents a set of simultaneous equations. It is the basic equation formulated in the stiffness or displacement method of analysis. To obtain a clearer understanding of elements K, P and v, we write out the expanded form of Eq. (1) as:

$$\begin{Bmatrix} F_1 \\ F_2 \\ F_3 \end{Bmatrix} = \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{31} & k_{33} \end{bmatrix} \begin{Bmatrix} v_1 \\ v_2 \\ v_3 \end{Bmatrix} \tag{2}$$

where, in structural theory, the elements kij and Kij are often referred to as stiffness influence coefficients. [2]

$$k_{11} = k_1;\ \ k_{22} = k_1 + k_2;\ k_{33} = k_2 + k_3;\ k_{12} = k_{21} = -k_1;$$

$$k_{13} = k_{31} = 0;\ k_{23} = k_{32} = -k_2 \tag{3}$$

2.2 Calculating displacements with Software

With the creation and development of computers, computer simulation has become the third means of scientific research after theory and experiment. [4] In modern engineering, calculating displacement using software involves advanced numerical techniques such as the Finite Element Method (FEM) or Finite Element Analysis (FEA). These software packages allow engineers to simulate and analyze the behavior of structures under various conditions, enhancing in design and optimization.

FEA works by dividing complex structures into smaller elements, each represented by mathematical equations. These equations consider factors such as material properties, applied loads, and boundary conditions to predict displacement and deformation.

In engineering software, linear analysis, non-linear analysis, linear dynamic analysis, and dynamic non-linear analysis are indispensable tools for understanding structural behavior under different conditions.

2.3 Calculating displacements with approximate expressions

In engineering, calculating displacement with approximate expressions involves utilizing simplified mathematical models and formulas to estimate the behavior of structures under various conditions.

These approximate methods are often used when analytical solutions are not feasible or when quick estimates are needed. These methods are typically employed in linear static analysis, where the behavior of structures is assumed to be linear and the loads are constant. They offer advantages such as simplicity, computational efficiency, and ease of implementation. Additionally, they can provide valuable insights into the behavior of structures without the need for complex numerical simulations.

However, it's important to note that approximate methods may introduce some level of error compared to more rigorous numerical techniques like finite element analysis. They are best suited for preliminary design evaluations, sensitivity analyses, and quick estimations of structural response.

3. EXAMPLE OF A STRUCTURE STANDING AT A HEIGHT OF 26.6 METERS

In the example that has been reviewed, a six-story building (ground plus six levels), reinforced concrete structure whose layout is shown in Figure 2 was analyzed. In this structure, the height of each story was 3.80 m, the design parameters have been incorporated: soil acceleration of 0.25, concrete class C35/45, and reinforcement type B500C.

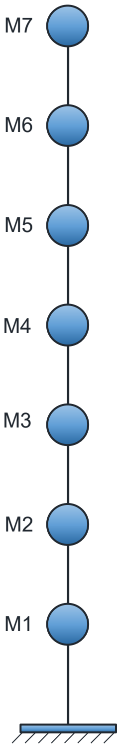
Based on the requirements required by [SK EN-1998-1-1], from the condition for local ductility of the elements preliminary dimensions have been determined.

In the example weight of the building was calculated considering all the elements of the structure as well as the load of the floor layers and live load, and for calculation purposes it is concentrated on the floors in accordance with [SK EN 1998-1-1], as shown in Figure 3.

By the criteria for regularity of the structure in the plan and elevation this structure is categorized into regular structure, therefore the lateral force method was used to determine displacements.

The stiffness for columns and shear walls is expressed through the following expressions by taking in account the decrease the modulus of elasticity by 50% since an accurate analysis of the cracked elements is not performed [5]:

$$k_c = \frac{12E_{0.5}I}{H_1^3} \qquad k_{sh,w} = \frac{1}{\frac{H_1^3}{12E_{0.5}I} + \frac{1.2H_1}{GA_w}} \tag{4}$$



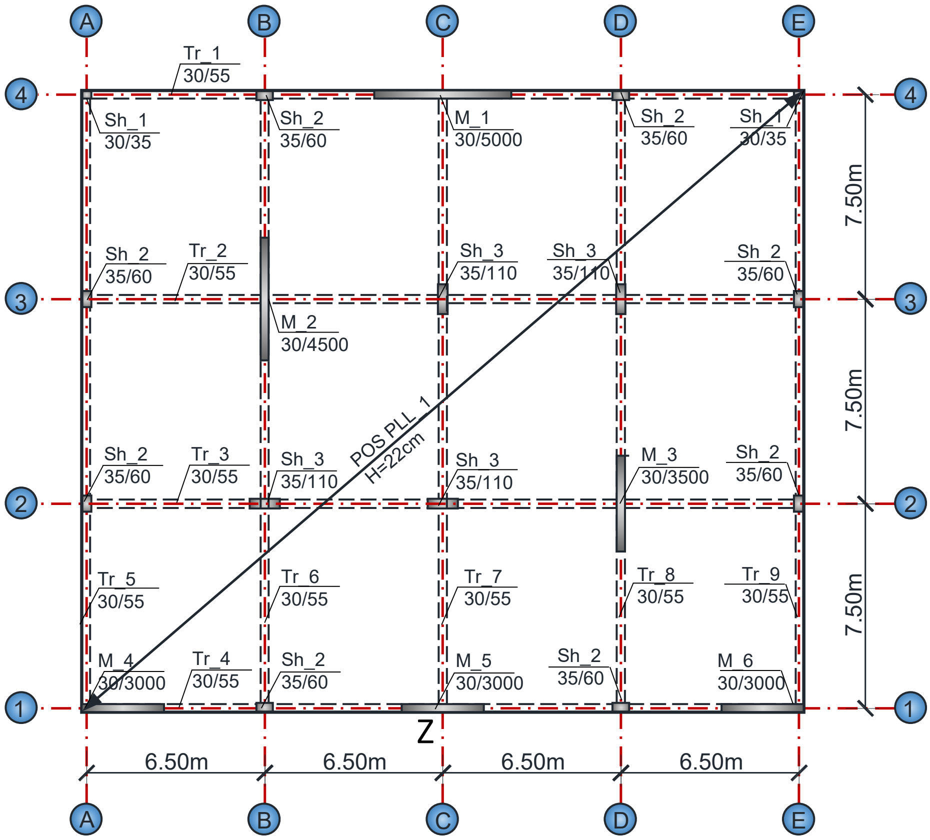


Figure 2. Dynamic Model MDOF

Figure 3. Layout of the analyzed building

In this equation $E_{0.5}$ - represents modulus of elasticity of concrete reduced by 50%, I – represents moment of inertia of vertical elements, G – represents the shear modulus and H_1 – represents the height of the storey.

Based on [SK EN 1998-1-1; 4.3.3.2.2] the basic expression for calculating the seismic force acting on a structure's base is:

$$F_b = S_d(T_1) \cdot m \cdot \lambda \tag{5}$$

In this equation $S_d(T_1)$ - is the ordinate of the design spectrum at period T_1, m - is the total mass of the building, above the foundation or above the top of a rigid basement and λ - is the correction factor [see 4.3.3.2.2 of SK EN 1998-1-1].

Based on [SK EN 1998-1; 4.3.3.2.3] the expression for the distribution of the seismic force across the floors of the structure is presented as follows:

$$F_i = F_b \cdot \frac{z_i \cdot m_i}{\sum z_j \cdot m_j} \tag{6}$$

In this equation F_i - is the horizontal force acting on storey i, F_b - is the seismic base shear in accordance with expression (5), z_i,z_j - are the heights of the masses mi mj above the level of application of the seismic action (foundation or top of a rigid basement) and m_i,m_j - are the storey masses.

From the calculation of the stiffness matrix from Eq. (3 and 4), the force vector that is obtained by first calculating the force at the base from Eq. (5), then its distribution through the floor through Eq. (6) we arrive at the completion of Eq. (1) from which the displacements are then determined.

$$\{v\} = [K]^{-1}\{P\} \tag{7}$$

The building shown in Figure 2 is modeled using SAP2000 software. In order to facilitate a more accurate comparison of the results between FEM and SAP2000 after modeling, slabs were assumed to be infinitely rigid and at each storey rigid diaphragms were assigned, so that only translational degrees of freedom were considered, excluding rotational degrees of freedom. Meanwhile, seismic load data were automatically inputted into the software, including parameters such as soil acceleration, spectrum type, soil category, correction factor, and behavior factor.

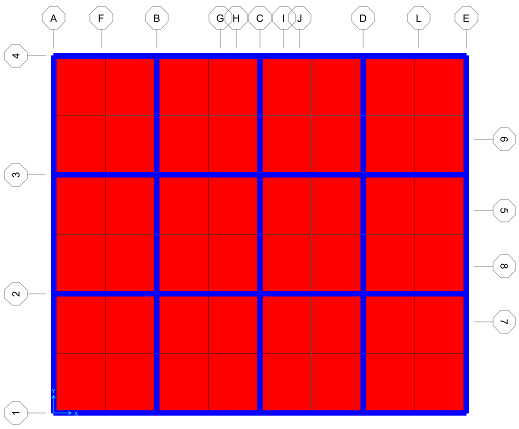


Figure 4. Layout of the analyzed Structure

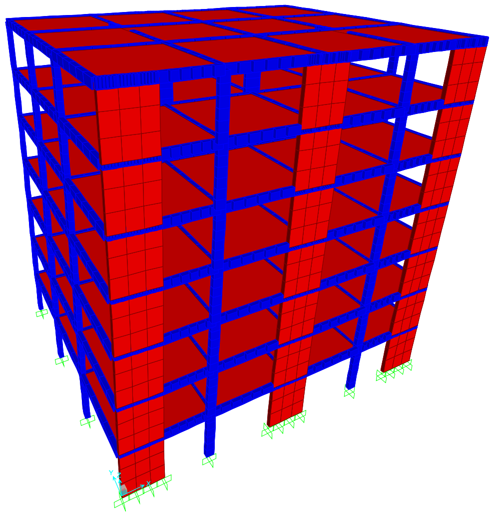


Figure 5. The 3D Structural Model – SAP2000

To calculate displacements using approximate methods, equivalent moment of inertia method, treating structure as a cantilever for this research has been used.

Considering structure as cantilever, lateral loads calculated in floors from seismic force in base will be transitioned to a uniformly distributed load through the following expression:

$$M_0^i = \sum F_i \cdot h_i \tag{8}$$

F_i – forces acting on the floors in the i storey

h_i – height from the base to the acting load

Moment of the cantilever will be equal:

$$M_0^i = \frac{q_{Ek} \cdot H^2}{2} \tag{9}$$

M_0^i – moment in the base of the structure from the loads acting in floors in the i direction

q_{Ek} – uniformly distributed load

H – total height of the structure

Horizontal displacement of the structure from uniformly distributed load is calculated with the expression below:

$$v_i = q_{Ek} \cdot \frac{H^4}{8 \cdot E_{0.5} \cdot I_j^{Ek}} \cdot \left[6 \cdot \left(\frac{z}{H}\right)^2 - 4 \cdot \left(\frac{z}{H}\right)^3 + \left(\frac{z}{H}\right)^4\right] \tag{10}$$

v_i - horizontal displacement in the i direction

I_j^{Ek} - equivalent moment of inertia in j direction

z - the height to the floor where the displacement is calculated

From the application of the methods and expressions presented above, the structure displacements are presented in tabular and graphic form below.

Table 2. Comparison of lateral storey displacements under different methods in X direction

Lateral Displacements in the x axis (mm)			
Number of Storey	**Finite Element Method**	**Software (SAP2000)**	**Equivalent Moment of Inertia Method**
Ground Floor	1.49	1.05	0.09
1.	2.94	2.47	0.35
2.	4.28	3.97	0.71
3.	5.46	5.35	1.15
4.	6.43	6.62	1.62
5.	7.14	7.62	2.12
6.	7.53	8.37	2.61

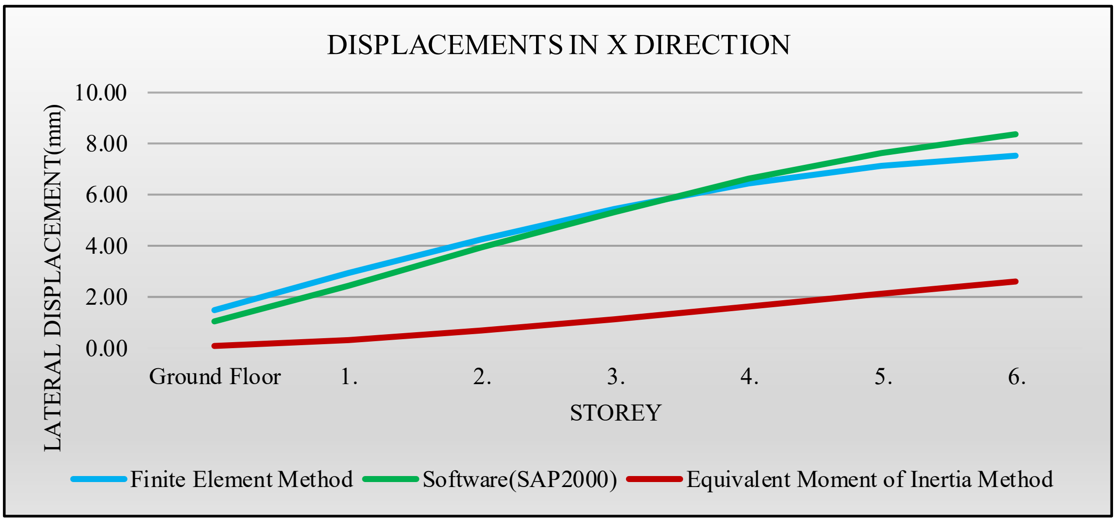


Figure 2. Graphical comparison of lateral storey displacements under different methods in X direction

Table 3. Comparison of lateral storey displacements under different methods in Y direction

Lateral Displacements in the y axis (mm)			
Number of Storey	**Finite Element Method**	**Software (SAP2000)**	**Equivalent Moment of Inertia Method**
Ground Floor	2.26	1.60	0.07
1.	4.45	4.10	0.27
2.	6.48	6.40	0.55
3.	8.27	8.60	0.89
4.	9.74	10.50	1.26
5.	10.80	12.00	1.65
6.	11.39	13.00	2.04

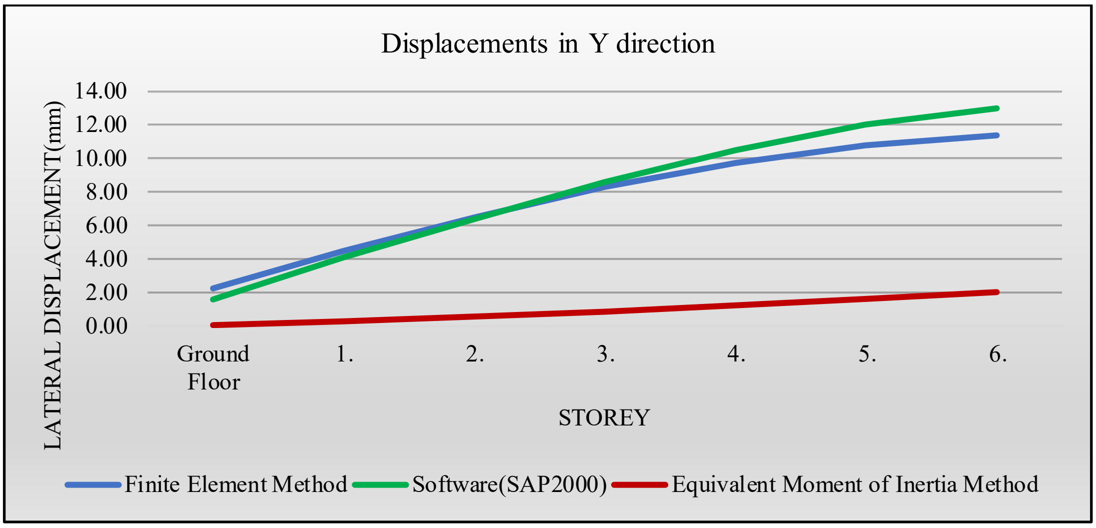


Figure 3. Graphical comparison of lateral storey displacements under different methods in Y direction

The approximation made for the calculation of displacements in SAP2000 where slabs were assumed to be infinitely rigid and at each storey rigid diaphragms were assigned for this structure has a considerable impact, therefore the comparison of the displacements in SAP2000 when the stiffness of slabs is real and infinitely rigid is presented below:

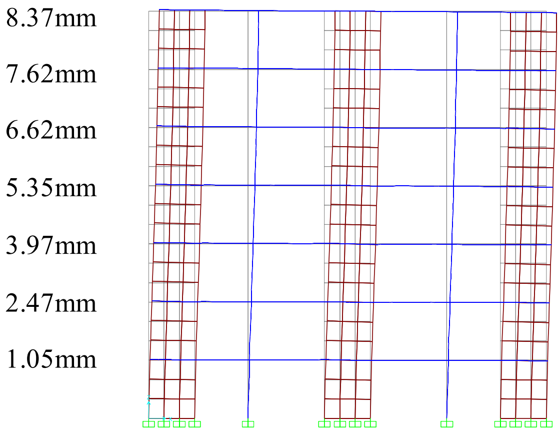


Figure 8. Structure with infinite stiffness of slabs

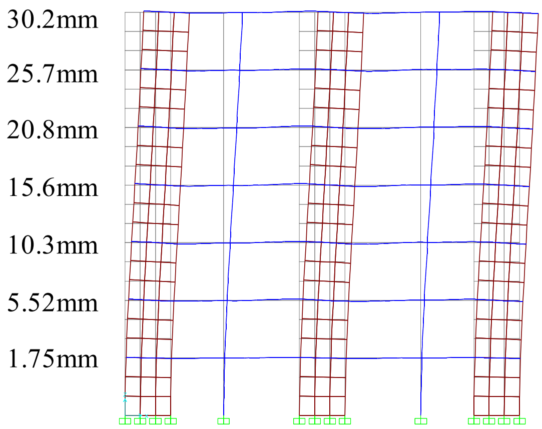


Figure 9. Structure with real stiffness of slabs

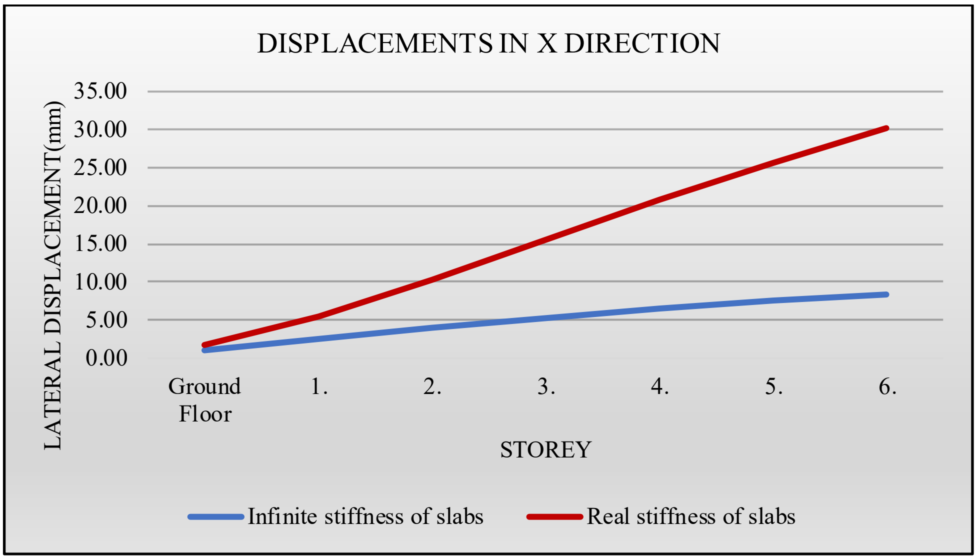


Figure 4. Graphical comparison of lateral storey displacements by real stiffness slabs and infinite stiffness slabs

4. CONCLUSIONS

For the dual frame structural systems with columns and shear walls, it's crucial to consider the actual stiffness of the slabs and the contribution of the beams. This consideration significantly impacts the magnitude of displacements, which directly influences internal forces. These internal forces, in turn, determine the dimensions of structural elements.

Through the comparative analysis, it is notifying that FEM results closely align with those obtained from software simulations. This alignment can be attributed to the fact that both methods fundamentally rely on similar principles and computational techniques. However, software's results exhibit higher accuracy due to its ability to finely divide the structure into smaller elements, enabling a more precise representation of the system's behavior.

Despite their limitations of approximate expressions methods in accuracy and reliability, these methods offer valuable insights, particularly during the preliminary stages of structural design. While they may not provide precise results, they can still serve as useful tools for initial dimensioning and decision-making processes

Engineers must strike a balance between computational efficiency and result reliability based on project requirements and available resources. This optimization ensures efficient design iterations while maintaining acceptable levels of accuracy.

REFERENCES

[1] N. Lamprini, "Reinforced Concrete Shear Walls A general view of their design using strut and ties," Athens, 2020

[2] D. L. Logan, A FIRST COURSE IN THE FINITE ELEMENT METHOD, Mona Zeftel, Content Developer and Teresa Versaggi, 2017

[3] "Scribd," [Online]. Available: https://www.scribd.com/document/431351938/Simplified-Multi-Storey-Shear-Building-Model

[3] Z. Zhang, "Application of finite element analysis in structural analysis and computer simulation," Sciendo, Guangdong, 2023.

[4] P. W. Richards, Seismic Principles ASCE 7-10/2016 CBC, 2017

[5] Eurocode 8: Design of structures for earthquake resistance -BS EN 1998-1:2004

[6] Designers' Guide to EN 1992-1-1 and EN 1992-1-2, Eurocode 2

[7] Eurocode: Seismic Design of Buildings Worked examples, Lisbon 2011

[8] B.Mosley, J. Bungey dhe R.Hulse, Projektimi i Strukturave prej Betoni të Armuar. Përkthyer nga POLIS

[9] R.Chudley & R. Greeno, Building Construction Handbook, eighth edition, Elsevier.

[10] Anil K. Chopra, Connections, EERI.

[11] Conrad Boley Hrsg. Geotechnische Nachweise und Bemessung nach EC7 und DIN 1054, Springer.

[12] M.Setareh, R.Darvas, Concrete Structure, Second Edition, Springer

[13] A cement and concrete industry publication, How to Design Concrete Structures using Eurocode 2

[14] Manual for the design of the concrete building structures to Eurocode 2

[15] M.Fardis, E.Carvalho, P.Fajfar and A.Pecker, Seismic Design of Concrete Buildings to Eurocode

Advanced Modeling Techniques in Structural Analysis using Finite Element Method

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This study provides a comprehensive overview of Finite Element Method (FEM), covering fundamental aspects such as concepts, applications, types of elements, and degrees of freedom. The research explores how FEM plays a crucial role in predicting structural behavior, emphasizing its application for robust structural analysis. The study delves into practical examples, including structures featuring 2D and 3D truss elements, 2D and 3D frame elements, shell and plate elements. Additionally, it examines advanced concepts such as Semi Rigid Connections, End Length Offset, Beams and Shells on Elastic Foundation using the well-established Winkler model, and the analysis of Structures on Elastic Foundation with Rectangular Finite Elements using advanced concept of discretizing elastic half space into 2D Soil elements, employing SAP 2000 software. The study also includes a comparative analysis between SAP 2000 output results and solutions obtained through analytical methods. Through this in-depth exploration, the research aims to contribute valuable insights towards optimizing FEM for precise and efficient structural assessments.

Keywords: Finite Elements, Structural Analysis, Elastic Foundations, Semi Rigid Connections, End Length Offset,

1. INTRODUCTION

In the intricate world of structural analysis, where precision and innovation converge, the Finite Element Method (FEM) stands as a beacon of excellence. As structures become increasingly complex and demand higher performance standards, the need for advanced modeling techniques becomes paramount. In this introductory journey, we embark on a quest to unravel the intricacies of structural analysis using cutting-edge methodologies within the Finite Element Method.

The Finite Element Method, born out of mathematical ingenuity and engineering pragmatism, has revolutionized the field of structural analysis. Its ability to dissect complex structures into manageable elements, coupled with its robust numerical algorithms, empowers engineers to simulate real-world behaviors with unparalleled accuracy. However, to truly harness the full potential of FEM, one must delve beyond the basics and explore the realm of advanced modeling techniques.

This comprehensive guide serves as a gateway to mastering the intricacies of advanced modeling within structural analysis. From refining meshing strategies to incorporating nonlinear material properties, each chapter delves deeper into the sophisticated arsenal of tools available to modern structural engineers. Through a blend of theoretical principles, practical applications, and illustrative examples, readers will journey from foundational concepts to

cutting-edge methodologies, equipping themselves with the skills needed to tackle the most challenging structural problems.
Throughout this exploration, we will navigate through various advanced topics, including:
Advanced Meshing Strategies: Unraveling the intricacies of mesh refinement techniques to achieve optimal accuracy while minimizing computational overhead.
Nonlinear Material Modeling: Delving into the complexities of material behavior beyond linear elasticity, including plasticity, viscoelasticity, and hyperelasticity.
Contact and Friction Analysis: Exploring the nuanced interactions between structural components through contact and friction modeling, essential for simulating assemblies and joints.
Dynamic Analysis and Modal Analysis: Understanding the dynamic response of structures under varying loads and frequencies, unlocking insights into natural frequencies, modes shapes, and dynamic stability.
Advanced Boundary Conditions and Constraints: Harnessing the power of sophisticated boundary conditions and constraints to simulate real-world scenarios, including thermal effects, fluid-structure interactions, and seismic loading.

SAP2000 is a comprehensive structural analysis and design software developed by Computers and Structures, Inc. (CSI). It's widely used by structural engineers to analyze and design various types of structures, including buildings, bridges, towers, dams, and more. Here's an overview:
Structural Analysis Capabilities:
Linear and Nonlinear Analysis: SAP2000 performs both linear and nonlinear static and dynamic analysis, allowing engineers to simulate a wide range of structural behaviors accurately.
Element Types: It supports various types of finite elements, including frame elements, shell elements, and solid elements, enabling detailed modeling of structural components.
Loading Conditions: Engineers can apply a variety of loading conditions such as dead loads, live loads, wind loads, seismic loads, temperature effects, and more to simulate real-world scenarios.
Response Spectrum Analysis: SAP2000 facilitates response spectrum analysis, a crucial method for assessing the structural response to seismic events and other dynamic forces.
Time History Analysis: Engineers can perform time history analysis to evaluate the structural response under dynamic loads over time, essential for seismic and wind engineering.
Buckling Analysis: The software includes buckling analysis capabilities to assess the stability of structural members and identify critical load levels.

1.1. Introduction to End Length Offset in SAP2000:

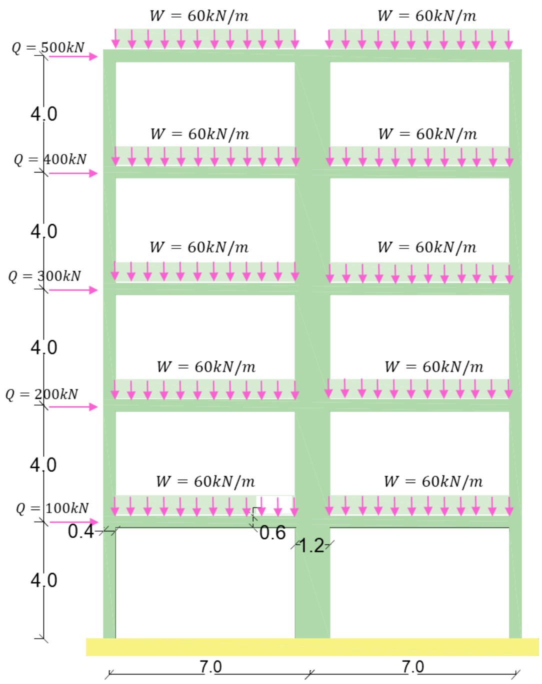
In structural analysis and design, precise modeling is paramount to accurately simulate real-world behavior. SAP2000, a leading software in structural engineering, offers a powerful tool known as End Length Offset. This feature allows engineers to refine the modeling of members by adjusting their effective lengths at connections, yielding more accurate results in analysis and design.
End Length Offset enables users to account for the influence of connections on the behavior of structural members. By specifying offsets at the ends of members, engineers can effectively model various connection conditions, such as pinned, fixed, or semi-rigid connections. This level of detail is crucial for capturing the true response of structures subjected to complex loading scenarios.
Moreover, End Length Offset facilitates the simulation of non-standard boundary conditions and structural configurations. Whether dealing with irregular geometries, architectural constraints, or specialized connection types, engineers can utilize this feature to tailor their models to specific project requirements with precision and confidence.

In essence, End Length Offset empowers engineers to refine their structural models, enhance analysis accuracy, and ultimately deliver safer and more efficient designs. Its intuitive interface and robust capabilities make it an indispensable tool in the arsenal of structural engineering professionals using SAP2000.

2. MATERIALS AND METHODS

The initial geometry of the analysed 2D reinforced concrete frame structure is as illustrated in the fig.1, the material used is C25/30 and and the frame is loaded with distributed forces of W=60kN/m and horizontal forces of Q=100, 200, 300, 400, 500kN.
The problem is first analysed with the columns fixed and beams and columns without and with End Length Offset.
Then the 2D frame is analysed with strip on Elastic Foundation of different spring stiffnes and the results are as illustrated below.

Figure 1. 2D RAM analysed



The problem is also analysed on Elastic Foundation (strip T shape) with Rectangular Finite Elements using advanced concept of discretizing elastic half space into 2D Soil elements.

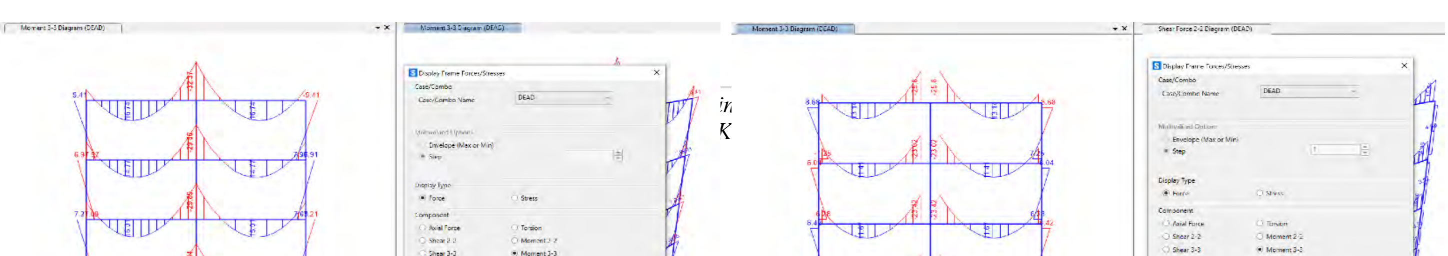


Figure 2. Diagram of moments without and with End Length Offset

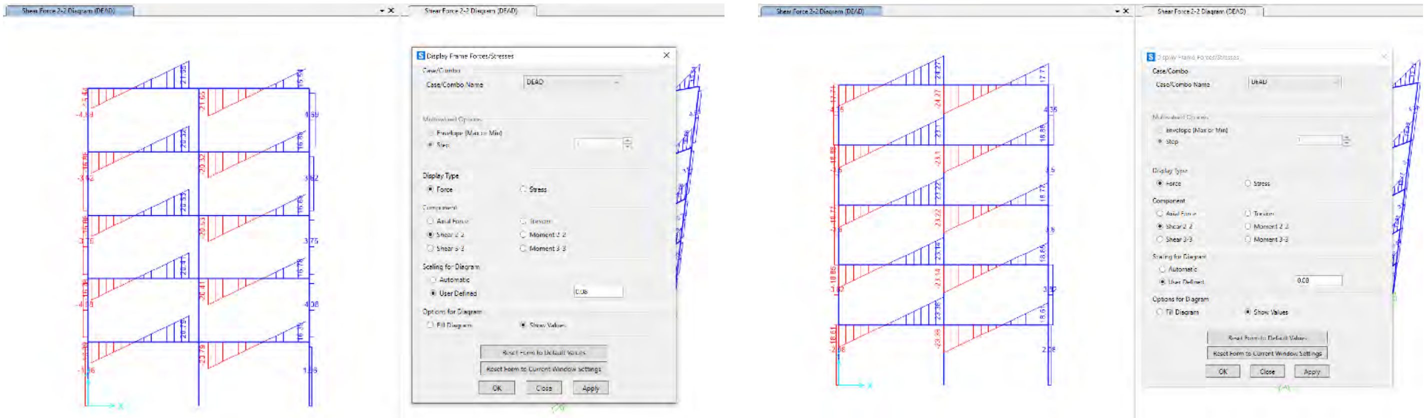


Figure 3. Diagram of shear force without and with End Length Offset

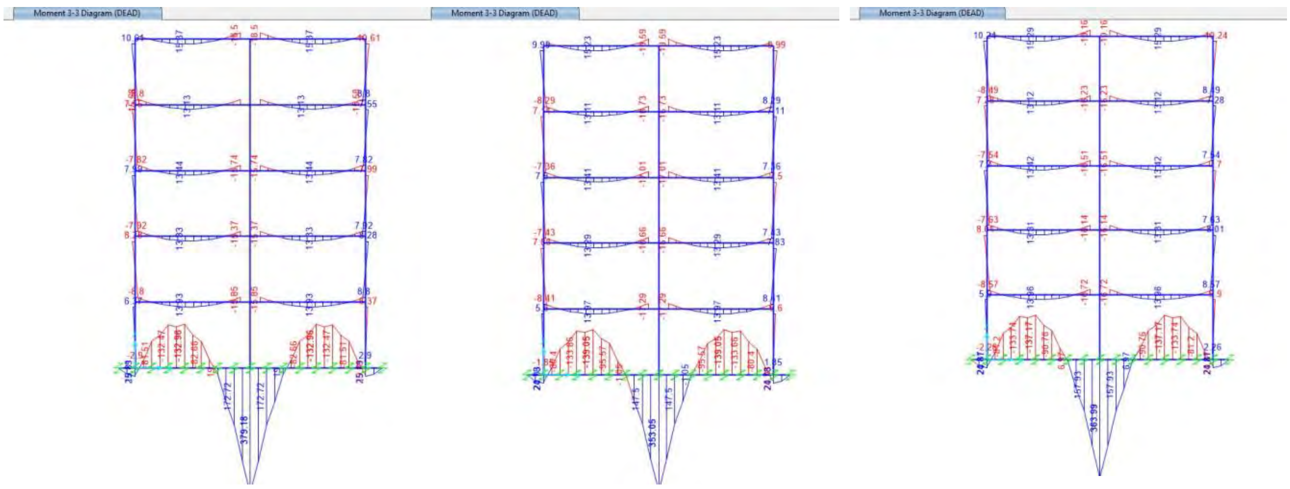


Figure 4. Diagram of moments for stiffnes Ks=10000,30000,50000 [kN/m^3]

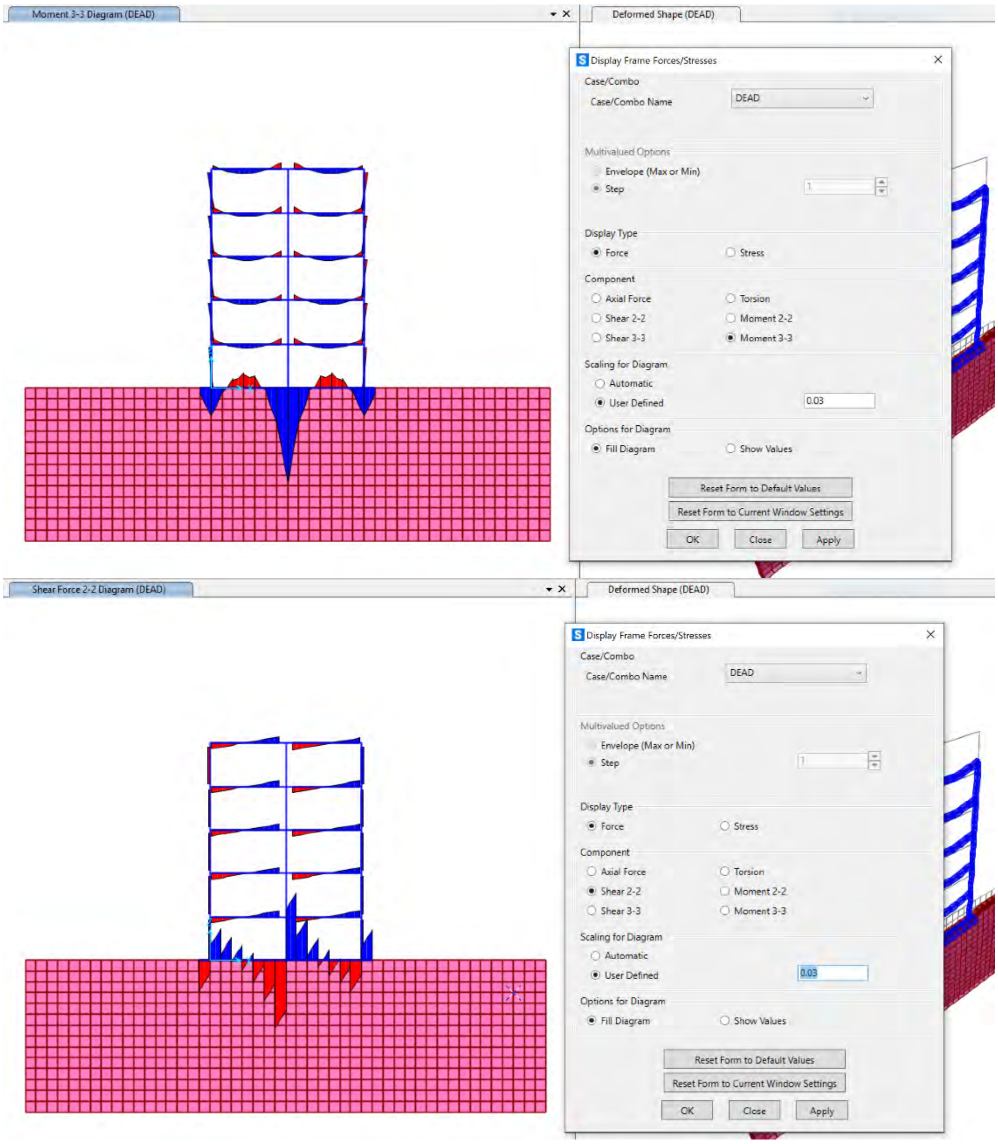
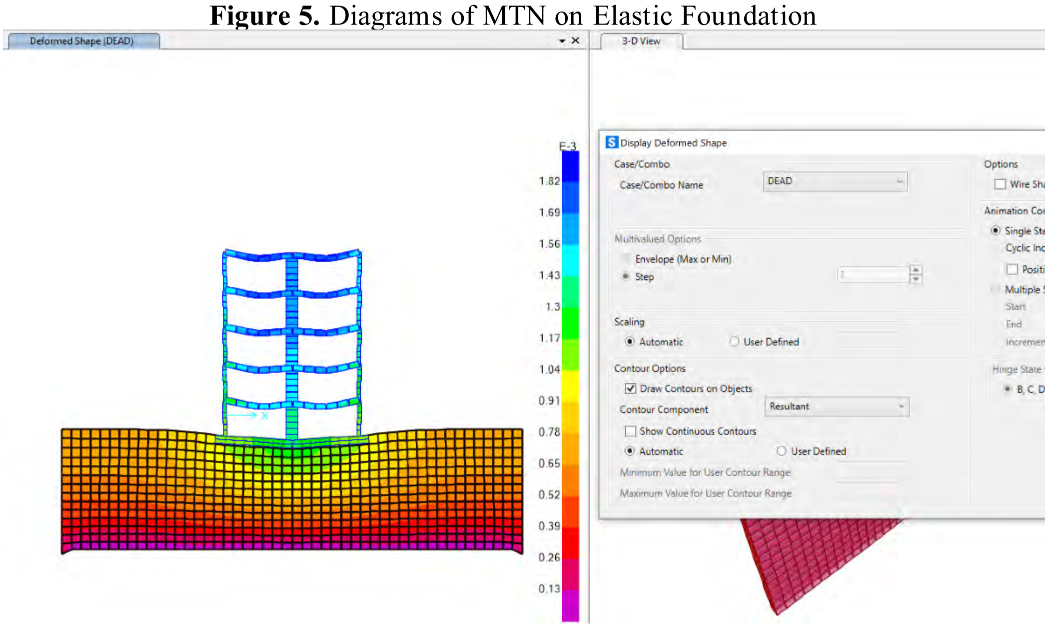


Figure 5. Diagrams of MTN on Elastic Foundation



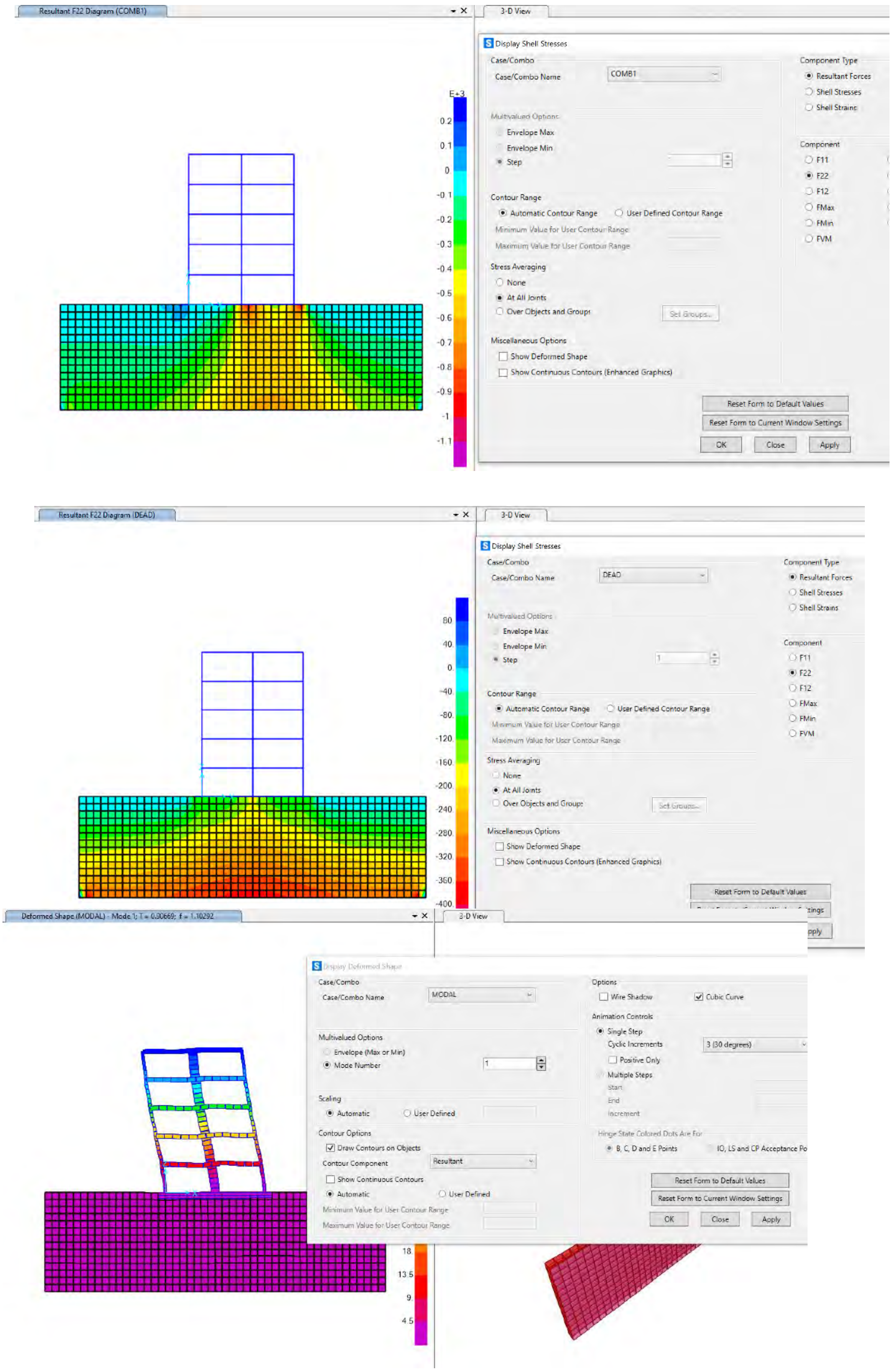
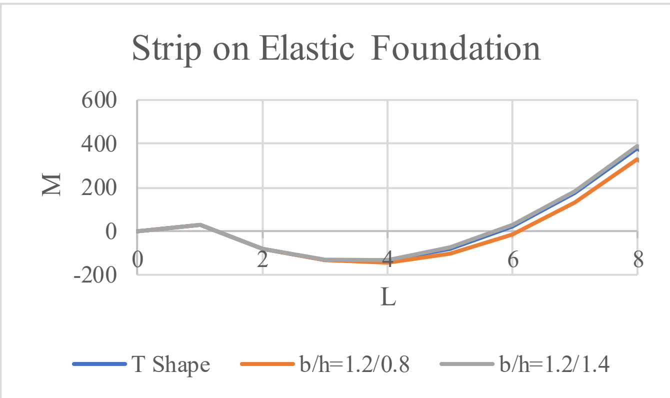


Figure 6. Results of Deformed Shape, Shell Stresses on elastic foundation and Modal Analysis

3. RESULTS AND DISCUSSION

T Shape		b/h=1.2/0.8			b/h=1.2/1.4
Ks=10000		Ks=10000			Ks=10000
Point	M	Point			M
0	0	0	0	0	0
1	25.19	1	25.65	1	24.97
2	-81.51	2	-78.2	2	-81.29
3	-132.47	3	-135.64	3	-130.64
4	-132.96	4	-144.32	4	-129.45
5	-82.66	5	-103.93	5	-77.41
6	19	6	-13.06	6	25.97
7	172.72	7	130.45	7	181.31
8	379.18	8	328.82	8	389.23



Ks=10000		Ks=30000		Ks=50000	
Point	M	Point	M	Point	M
0	0	0	0	0	0
1	25.19	1	24.6542	1	24.78
2	-81.51	2	-81.2	2	-80.4
3	-132.47	3	-133.74	3	-133.66
4	-132.96	4	-137.17	4	-139.05
5	-82.66	5	-90.76	5	-95.57
6	19	6	6.97	6	-1.05
7	172.72	7	157.93	7	147.5
8	379.18	8	363.99	8	353.05

REFERENCES

[1] The Finite Element Method: Its Basis and Fundamentals

[2] Computers and Structures, Inc. (2025). SAP2000 (Version 23) [Software]. Computers and Structures, Inc. https://www.csiamerica.com/products/sap2000

[3] Zienkiewiecz O.: The Finite Element Methods, McGraw-Hill, New York, 1987

[4] Cook, Robert Davisetal, Concepts and Applications of Finite Element Analysis, Wiley, John & Sons, 1999

Optimization of Dimensional Parameters for Structural Elements in Frame Systems

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Reinforced concrete structural systems represent a widely utilized and versatile approach in modern construction, offering a robust and durable framework for a variety of building types and applications. These systems typically consist of reinforced concrete elements such as columns, beams, slabs, and walls, integrated within a cohesive framework to support and distribute loads throughout a structure. The inherent strength and adaptability of reinforced concrete make it an ideal choice for withstanding various forces, including gravity loads, lateral loads (such as wind and seismic forces), and environmental factors. The integration of steel reinforcement within concrete elements enhances their tensile strength, allowing for efficient load transfer and structural stability. In the frame of a reinforced concrete structural system, the design and optimization of dimensional parameters play a critical role in ensuring structural integrity, performance, and efficiency. These parameters include the dimensions of individual structural elements (such as column cross-sections and beam depths), reinforcement detailing, spacing, and arrangement, as well as overall system configuration and layout. Through careful analysis, design, and optimization of dimensional parameters, engineers can achieve an optimal balance between structural strength, durability, and economy, tailored to the specific requirements and constraints of each project. This process involves considering factors such as loading conditions, material properties, construction techniques, and applicable design codes and standards. An essential consideration in determining these dimensions is the ductility class chosen for the structural design. Structures featuring larger cross-sectional dimensions, under similar soil conditions to those with smaller dimensions, have exhibited greater stiffness. Overall, reinforced concrete structural systems offer a reliable and versatile solution for constructing a wide range of buildings and infrastructure, with the optimization of dimensional parameters playing a crucial role in achieving safe, efficient, and cost-effective designs.

Keywords: *Structural frame system, optimization, seismic force, ductility.*

1. INTRODUCTION

Frame systems are fundamental to a building's integrity, offering essential support and resilience that underpin the performance and functionality of the entire structure. Their design can differ significantly, reflecting variations in the materials selected, the intricacy of construction, and the methods employed. These decisions are often influenced by factors such as the intended use of the building, prevailing architectural trends, local environmental conditions, and budgetary constraints. The geometric configurations of frame systems—including element sizes, shapes, and spatial organization—play a pivotal role in determining their structural efficacy.

Optimizing these parameters can lead to improved structural integrity, efficiency and cost-effectiveness. Structural optimization is often employed to improve the performance of load bearing systems subject to a given set of boundary conditions. This includes, for instance, maximization of material usage efficiency through minimization of the structure weight. Optimal structure layouts can be obtained through optimization of the structure geometry, the topology and the member cross section sizing. [1]

Furthermore, the implementation of structural optimization techniques serves to reduce engineering and construction expenses by streamlining the repetitive sizing tasks associated with structural members. This approach not only economizes on costs but also encourages the development of creative design solutions, uniquely suited to individual elements and materials within the structure.

This technical investigation focuses on the structural performance of a two-story frame system under variations in vertical column dimensions. The intent is to assess the implications of different column cross-sectional sizes on the overall behavior of the frame system.

Three distinct frame models will be studied, each featuring different column dimensions while maintaining uniform beam and slab sizes. This approach enables a controlled comparison of columnar effects on the structural system.

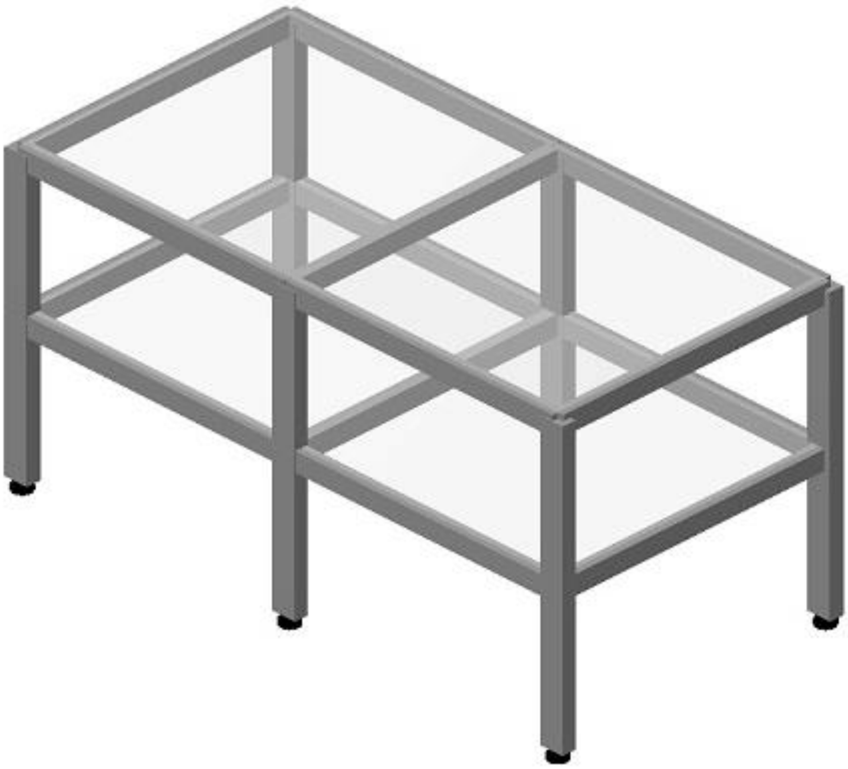


Figure 1. The structural model

The structural response of each model will be evaluated under a fixed gravity load $g = 4.0\ kN/m^2$ and imposed load $q = 5.0\ kN/m^2$. The primary objectives are:

- To determine the load-carrying capacity of columns with varying cross-sections.
- To calculate the periods of oscillation for three distinct frame models
- To identify necessary column reinforcement based on cross-sectional dimensions.

Numerical modelling will be utilized to simulate the mechanical behavior of the frame system under standard operational conditions and potential hazards. In our investigation, we aim to evaluate the impact of vertical column dimensions on the static and dynamic responses of a two-story frame system. The assessment will extend to determining the corresponding resisting moments, enhancing our understanding of the models' dynamic behavior and capacity to withstand various loading conditions.

Through comparative analysis, we anticipate recognizing the influence of vertical column dimensions on the frame system's structural response. The findings will offer critical insights into optimizing column design for similar structural systems.

In this revised structure, the aim is to clearly define the different sections of the investigation, set clear objectives, and outline the methodology and expected outcomes in a concise manner.

2. MATERIALS AND METHODS

In this study, to evaluate the structural response of differing column geometries in a frame system, three models with varying column dimensions will be analyzed using computational analysis through Tower Software that is an advanced software for structural analysis, utilizing finite element analysis, the structure is divided into smaller segment for precise load and moment calculations, considering material properties and load application. For oscillation periods, its dynamic analysis assesses structural response to dynamic loads such as wind or seismic forces through calculation of natural frequencies and dynamic responses, providing crucial data for ensuring stability under dynamic conditions.

The frame under consideration consists of two bays with spans measuring 6.0 meters each in the x-direction and a single bay with a span of 6.0 meters in the y-direction. The height of the floor in each bay is 3.0 meters.

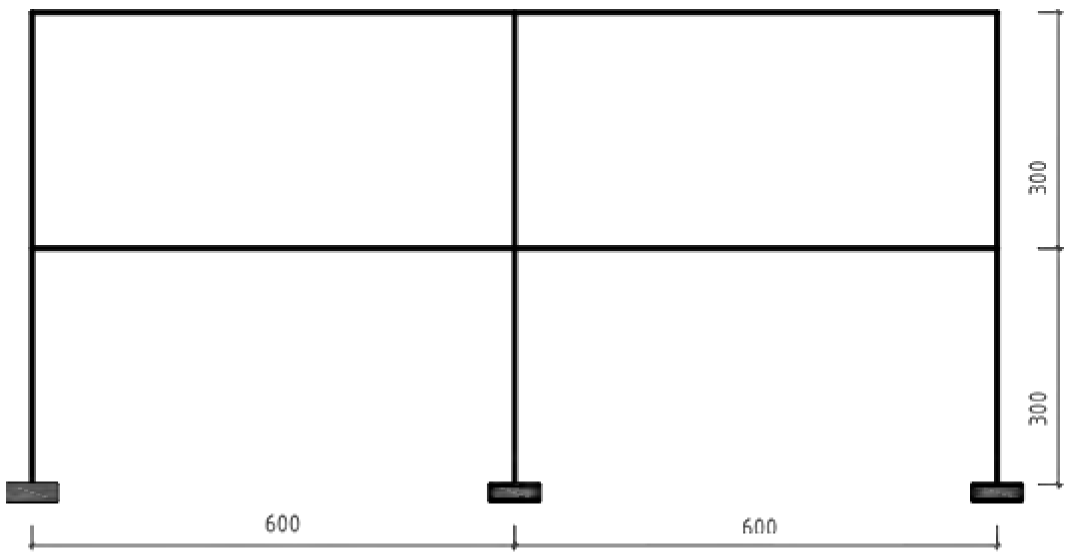


Figure 2. Reinforced concrete frame

The concrete to be utilized in construction shall conform to a strength class of $C30/37$, the reinforcement to be employed shall meet the requirements of class $B500\ C$, which specifies a characteristic yield strength of 500 MPa with ductile behavior suitable for seismic-resistant structures.
Tower Software will be employed to simulate the behavior of three frame system models with variable column dimensions: the first model will have columns with dimensions of $\mathrm{b}/h = 40/40\ cm$, the second model will have columns with dimensions of $b/h = 50/30\ cm$, and the third model will have columns with dimensions of $b/h = 25/60\ cm$. Beams in all models will be standardized at $b/h = 25/40\ cm$.

Quantitative evaluations will include static load effects and oscillatory characteristics for each configuration. The load combinations will be synthesized using partial safety factors in compliance with Serviceability Limit State and Ultimate Limit State guidelines to identify the most critical load scenarios:

Primary load combination: $E_d = \sum_{j\geq 1}^{n} \gamma_{g,i} \cdot G_{k,j} + \sum_{i\geq 1}^{n} \gamma_{q,i} \cdot Q_{k,i}$ (1)

Seismic load combination: $E_d = \sum_{j\geq 1}^{n} G_{k,j} + \xi \cdot A_{Ed} + \sum_{i\geq 1}^{n} \psi_{2,i} \cdot Q_{k,i}$ (2)

These analyses aim to discern the model that demonstrates the most efficient structural behavior regarding static effects and required reinforcement under different loading conditions.

To ascertain the resisting moment capacities of the vertical structural elements-columns, a detailed analysis will be facilitated by the use of CSiCol. Using CSiCol software, the moment capacity of columns is determined by evaluating column geometry, material properties, reinforcement details, and load application. The software accounts for concrete confinement, reinforcement detailing, and the impact of column slenderness to accurately assess the moment resistance. With its robust capabilities, CSiCol will provide precise assessments of the columns' structural performance under various loading conditions.

3. RESULTS

In this research, are analyses the theoretical optimization of column dimensions in a uniform two-story-two-bay frame subjected to load combinations involving dead, live, snow, and seismic loads with overall frame dimensions, we systematically vary the cross-sectional sizes of the columns across three distinct models to ascertain the optimal column dimensions. After thorough analysis of the three models discussed and in line with the stated objectives of this research, we applied the earlier presented methodology to derive the ensuing results.

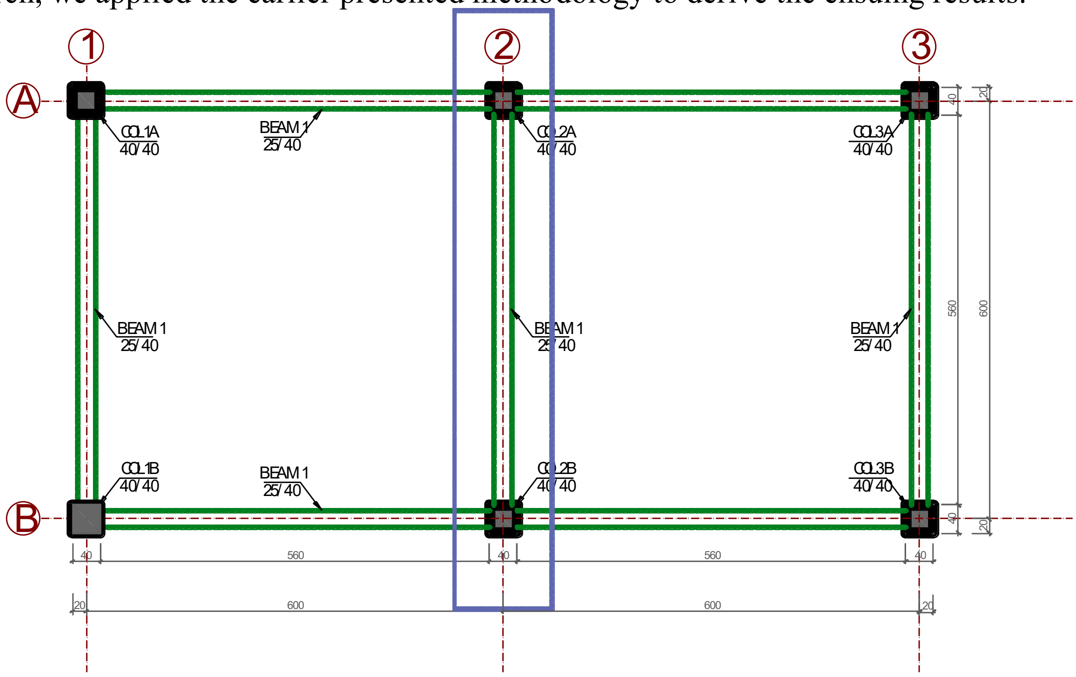


Figure 3. Layout of the Building. The Columns of cross sections 40/40 cm in model 1.

The Oscillation period of structure vale, reinforcement quantity and the Bending moment from action in structure and their capacity are shown below:

$T_1 = 0.3608\ sec$
$A^{req}_{sl,col2B} = 25.11 cm^2$
$A^{prov}_{sl,col2B} = 26.24 cm^2$
$M_{ED} = 121.82\ kNm$
$N_{ED} = 444.58\ kNm$
$M_{RD} = 273.9\ kNm$

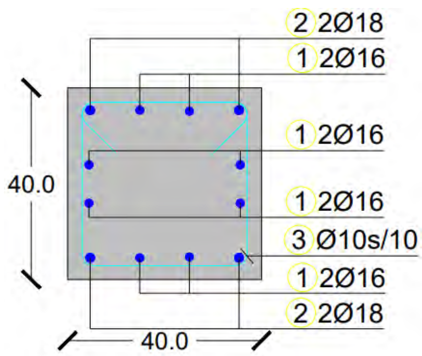


Figure 4. Cross-section of column 40/40 cm reinforced

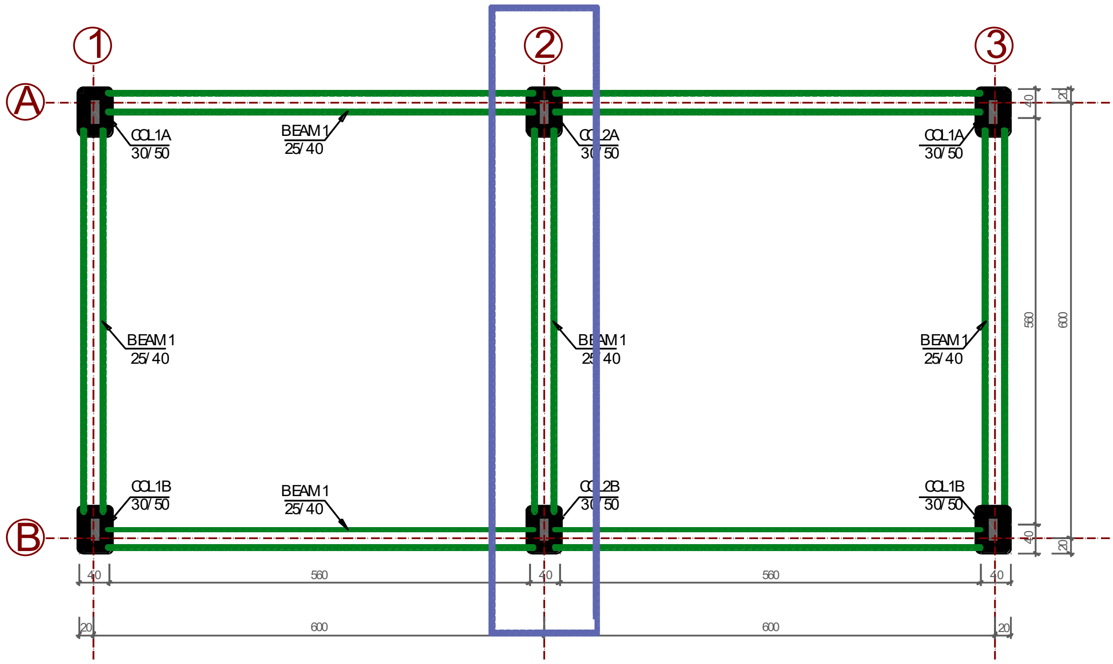


Figure 5. Layout of Building. The Columns of cross-sections 50/30 cm in model 2.

$T_1 = \ 0.4316\ sec$
$A^{req}_{sl,col2B} = 28.46\ cm^2$
$A^{prov}_{sl,col2B} = 30.48\ cm^2$
$M_{ED} = 129.82\ kNm$
$N_{ED} = 416.36\ kN$
$M_{RD} = 322.22\ kNm$

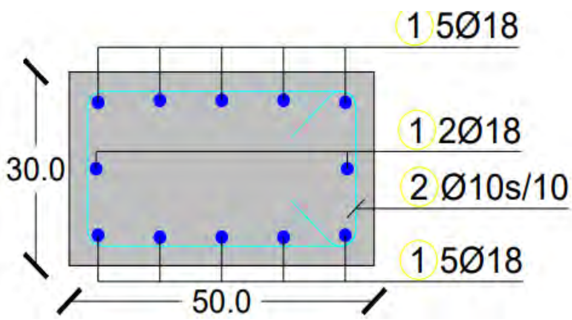
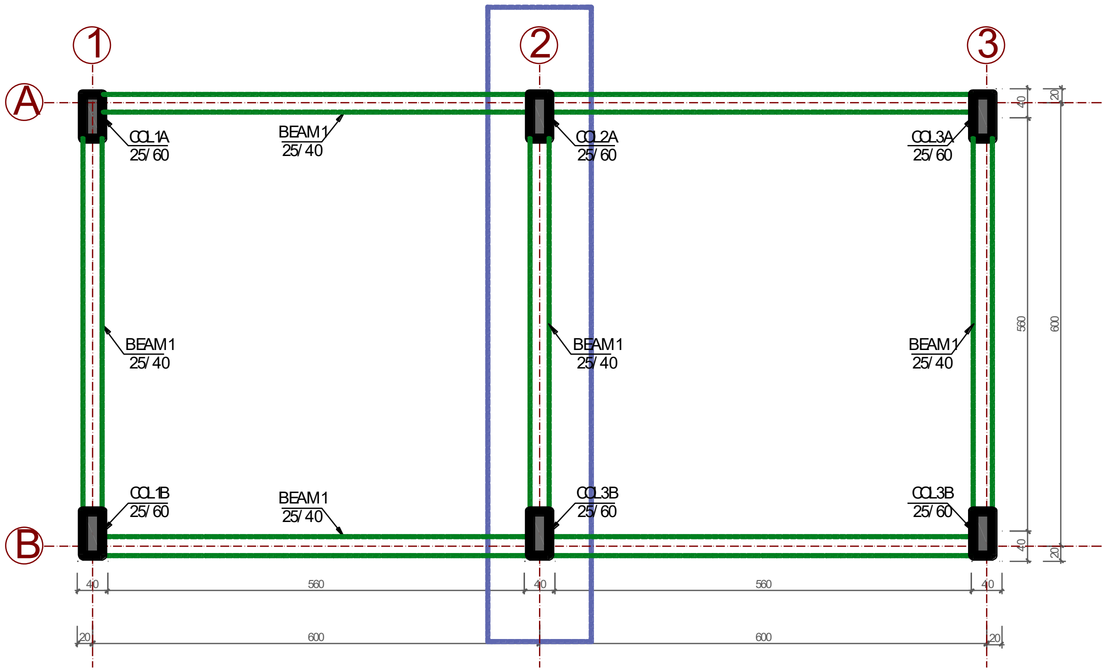


Figure 6. Cross-section of column 50/30 cm, reinforced.



$T_1 = \ 0.4852\ sec$
$A^{req}_{sl,col2B} = 30.22cm^2$
$A^{prov}_{sl,col2B} = 30.48\ cm^2$
$M_{ED} = 137.92\ kNm$
$N_{ED} = 433.16\ kN$
$M_{RD} = 393.22\ kNm$

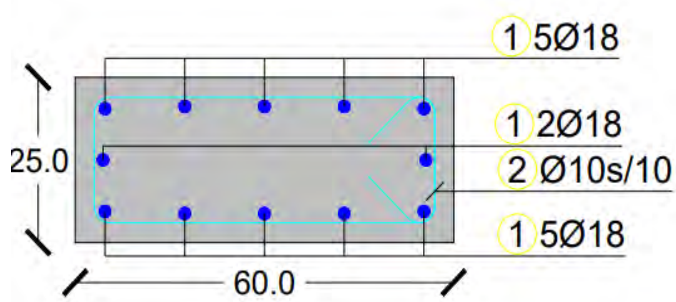


Figure 7. Model 3: The final model investigates columns with cross-sections of $b/h = 25/60\ cm$

4. CONCLUSION

The comparative assessment of these theoretical models shows that optimizing column dimensions is crucial for the structural efficiency and performance of frame systems. The optimization process highlights the interplay between cross-sectional size and the resulting mechanical behavior of the structural system under load. The findings provide valuable insights for engineers and designers, allowing for the informed selection of column dimensions that achieve desired performance metrics while also considering economic and material considerations.

Drawing conclusions from the data analyzed for each variant, it becomes apparent that the first variant emerges as the most favorable option. Its superiority is twofold: not only does it achieve the highest efficiency, with an impressive 44.47%, but it also requires the least amount of

reinforcement compared to the second and third variants, which demonstrate lower efficiencies of 40.28% and 35.07%, respectively.
Moreover, it is worth highlighting that the first variant exhibits uniform stiffness in both orthogonal directions, leading to a reduced period of oscillation. This is in stark contrast to the other two variants where the stiffness varies between orthogonal directions, resulting in comparatively longer oscillation periods. This uniformity in stiffness within the first variant translates into a more balanced and predictable structural performance, especially under dynamic conditions such as seismic events.

REFERENCES

[1] Brütting J., Senatore G., Schevenels M., Fivet C., Optimum Design of Frame Structures From a Stock of Reclaimed Elements

[2] EN 1990.2002 6.4.3.3 and 6.4.3.4

[3] Nigdeli S. M., Bekdaş G., Detailed optimum design of reinforced concrete frame structures

[4] Zhang C., Design optimization of irregularity RC structure based on ANN-PSO

[5] Abobakr A. A. Aga, Fathelrahman M. Adam, Design Optimization of Reinforced Concrete Frames

[6] Sococol I., Mihai P., Petrescu T. C., Nedeff F., Numerical study regarding the seismic response of a moment-resisting (MR) reinforced concrete (RC) frame structure with reduced cross-sections of the RC slabs

Implementation of Partial Fixities Using Existing Stiffness Equations in Finite Element Models

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Finite Element (FE) models are crucial tools used in solving various complex engineering problems, and their effectiveness often depends on the ability of the model to accommodate different types of end-connections such as releases and partial-fixities. Traditionally, incorporating these features into an FE model demands extra theoretical work during the element creation phase. This study demonstrates that the standard stiffness equations of any FE model, originally designed for rigid connections, can be adapted to include end-releases and partial-fixities without additional complex theoretical work on the element. In this study, a simple three-step matrix-equation modification technique to add and releases and partial-fixities to a finite element model is presented. These steps include isolation of the element from the rest of the system-mesh by introducing new degrees of freedoms (DOFs); introduction of elastic springs to link the isolated element with the rest of the system-mesh again and lastly, re-integration of the element into the system equation by removing the newly added DOFs from the resulting equations. Demonstrated through examples, the application of this method involves only simple matrix operations and is broadly applicable not only to 1D bar-type structures but also to a wider range of elements, including elasticity elements of 2D and 3D types.

Keywords: *Finite elements, Partial-fixities, End-releases, Practical approach, Matrix-equation modification.*

1. INTRODUCTION

The Finite Element Method (FEM) stands as a widely accepted and prevalent approach in solving a broad range of engineering challenges, serving as the de facto standard in the industry. FEM facilitates the creation of varied element models tailored to specific types of problems. Nevertheless, it encounters unique situations that demand specific conditions to be met within the problem's boundaries. For instance, conducting a realistic structural analysis using FEM without employing specific end connections, notably releases and/or partial fixities (R/PFs), is practically unfeasible [1]. Various applications such as bridges [2], buildings, precast structures [3], aircraft wings [4] utilize detailed analysis incorporating R/PFs, which significantly influences the overall structural behavior [5]. Consequently, R/PFs play a crucial role in numerous studies related to structural design and optimization, underscoring their importance in enhancing structural performance and efficacy [6].

The foundational theory and practical implementation of releases and/or partial fixities (R/PFs) in one-dimensional (1D) elements are well-established in the literature. [7] is among the pioneers to integrate R/PFs within the framework of the matrix stiffness method. Following this, [8] introduced the concept of employing connection elements specifically designed for R/PFs to simulate the effects of such connections. Studies [9] and [10] respectively utilized stiffness equations of elements and an energy-based approach to incorporate R/PFs into 1D elements, focusing solely on solutions applicable to rotational degrees of freedom (DOFs). In research [11], the application of R/PFs, particularly for rotational aspects, was extended to beam elements by adapting existing stiffness equations. [12 and 13] offered a concise formulation for 1D elements wherein all DOFs are connected to the system through springs, providing a broader perspective. Specialized software solutions for the implementation of releases and/or partial fixities (R/PFs) have been developed, as mentioned in [14, 15 and 16]. While many commercial software packages offer native support for R/PFs in one-dimensional elements, for those that do not, a workaround involves manually separating the nodes and inserting spring-like elements to simulate R/PFs. Although this approach may be more cumbersome, it is employed in this study for verification purposes.

The motivation behind revisiting this topic, despite its extensive exploration and historical context, stems from a perceived gap in the literature where R/PFs are predominantly discussed in relation to one-dimensional elements. This paper aims to shift the perspective towards a broader application of R/PFs in custom finite element (FE) models. By doing so, it elaborates on the method with a straightforward yet universally applicable formulation. Additionally, the paper demonstrates the method's applicability in elasticity elements through theoretical discussion and an illustrative example written in Python programming language.

2. MATERIALS AND METHODS

A FE equation of a typical linear element is given in its well-known compact form as in Eq. (1) , where $[K]$ being the stiffness matrix, $\mathbf{U}$ is the degree of freedom (DOF) vector, $\mathbf{B}$ and $\mathbf{Q}$ are the body and boundary force vectors respectively.

$$[K]\mathbf{U} = \mathbf{B} + \mathbf{Q} \tag{1}$$

The element is separated from the remainder of the system by defining its independent equation based on the element's own variables, $\hat{\mathbf{U}}$ and $\hat{\mathbf{Q}}$, as presented in the following Eq. (2)

$$[K]\hat{\mathbf{U}} = \mathbf{B} + \hat{\mathbf{Q}} \tag{2}$$

Figure 1 depicts such a separated node with a DOF $\hat{U}_i$ from the rest of the system, and is reconnected by an elastic spring with a spring coefficient k_{si}.

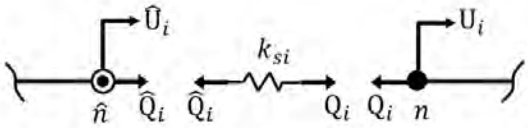

Figure 19. A disconnected node from the rest of the system, re-attached by a spring.

Considering the equilibrium equation of the individual spring as $Q_i = \hat{Q}_i = k_{si}(U_i - \hat{U}_i)$, one can expand this equation to all DOFs of the system and write the Eq. (2) in its new form, given in Eq. (3).

$$[K]\hat{\mathbf{U}} = \mathbf{B} + [k_s](\mathbf{U} - \hat{\mathbf{U}}) \tag{3}$$

where, $[k_s]$ is a diagonal matrix that constitutes the corresponding spring stiffnesses of each DOFs. In order to retain element equations in its original form, but with springs defined for each DOF, firstly $\hat{\mathbf{U}}$ is solved from Eq. (3) as

$$\hat{\mathbf{U}} = [K_s](\mathbf{B} + [k_s]\mathbf{U}),$$
$$[K_s] = ([K] + [k_s])^{-1} \tag{4}$$

Finally, considering the spring equilibrium equation, $\hat{\mathbf{Q}} = \mathbf{Q}$, and substituting Eq. (4) into Eq. (2), the new stiffness equation of the element attached with the springs is obtained as

$$[K][K_s][k_s]\mathbf{U} = [k_s][K_s]\mathbf{B} + \mathbf{Q} \tag{5}$$

It's important to highlight that through the application of Eq. (5), end springs can be seamlessly integrated into any FE model. The subsequent sections of the text delve into the practical aspects of utilizing this equation.

3. RESULTS AND DISCUSSION

In order to demonstrate that the proposed method, an example application will be given, the well-known plane stress element. The stiffness matrix and body force vector of the element is given as

$$[K] = \iint_A [B]^{\mathrm{T}}.[C].[B]\,h\,\mathrm{dA},$$
$$\mathbf{B} = \iint_A [\psi]^T.\mathbf{b}\,h\,\mathrm{dA} \tag{6}$$

where, $[B]$ is the strain-displacement matrix, $[C]$ is the material matrix, $[\psi]$ is the shape functions matrix, $\mathbf{b}$ is the body force vector and h is the thickness of the element. Figure 2 illustrates a typical 4-node plane-stress element and in Listing 1, the implementation of the element in a classical FE framework is given in Python programming language.

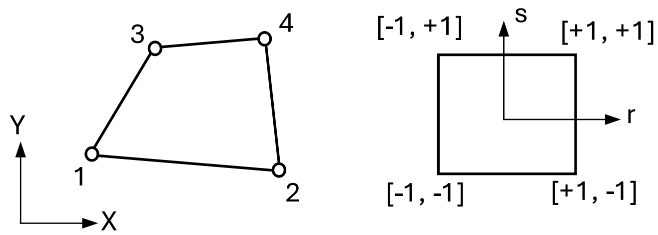

Figure 2. A 4-node plane element illustration of both its real and master space.

Listing 7. Implementation of the plane-stress element in Python.

```
import numpy as np
det = np.linalg.det      # determinant
inv = np.linalg.inv      # inverse

def assemble_element(Ke, Be, Ks, Bs, dof):
    for i in range(len(dof)):
        Bs[dof[i]] += Be[i]
        for j in range(len(dof)):
            Ks[dof[i], dof[j]] += Ke[i, j]
```

```
def integrate_gauss_N2(g):
    return g(-1/3**0.5, -1/3**0.5) + g( 1/3**0.5, -1/3**0.5) + \
           g(-1/3**0.5,  1/3**0.5) + g( 1/3**0.5,  1/3**0.5)

# shape functions vector
def f(r, s): return 0.25 * np.asarray([(1-r)*(1-s), (1+r)*(1-s), (1-r)*(1+s), (1+r)*(1+s)])

# derivatives of shape functions w.r.t master coordinates
def df_dr(r, s): return 0.25*np.asarray([[-(1-s), -(1-r)],[(1-s), -(1+r)],[-(1+s), (1-r)],[(1+s), (1+r)]])

# jacobian matrix
def J(r, s, X): return X @ df_dr(r, s)

# derivatives of shape functions w.r.t real coordinates
def df_dX(r, s, X): return df_dr(r, s) @ inv(J(r, s, X))

def K_stiffness_matrix(X, E, p, h):
    C = E/(1-p**2)*np.asarray([[1, p, 0],[p, 1, 0],[0, 0, 0.5*(1-p)]])
    def SDM(r, s): # strain-displacement matrix
        temp = np.zeros((3, 8))
        df = df_dX(r, s, X)
        temp[0, 0:4] = df[:, 0]
        temp[1, 4:8] = df[:, 1]
        temp[2, 0:4] = df[:, 1]
        temp[2, 4:8] = df[:, 0]
        return temp
    def dK(r, s): return SDM(r,s).T@C@SDM(r, s)*h*det(J(r, s, X))
    return integrate_gauss_N2(dK)

def B_body_force_vector(X, h, bx, by):
    def dB(r, s): # strain-displacement matrix
        SFV = f(r, s) # shape functions vector
        SF8 = np.concatenate((SFV, SFV))
        return h*det(J(r, s, X))*SF8*[bx, bx, bx, bx, by, by, by, by]
    return integrate_gauss_N2(dB)
```

The selected plane-stress problem is shown in Figure 3. An irregular mesh is used to include the effects of all possible variables in the problem. Body forces are also included as self-weight. The elastic spring connection is inserted only in the horizontal direction. Vertical connection between the parts is rigid. Spring coefficient, thickness, elasticity modulus, Poisson's ratio and unit weight are selected as; k=30000kN/m, h=0.01m, E=70GPa, v=0.3 and ρ_w=77kN/m^3.

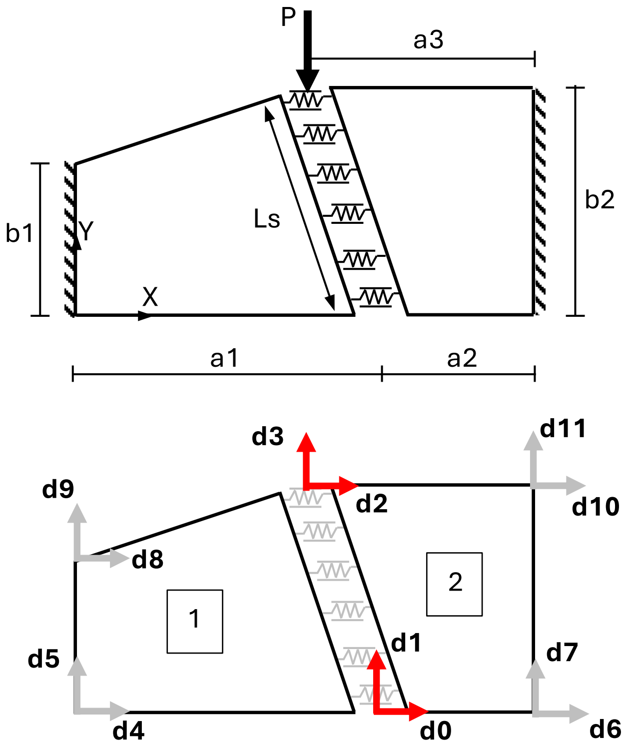

Figure 3. Two plane-stress elements connected to each other by horizontal elastic springs. Geometry and finite element mesh (P=1000kN).

The application of element springs and the Python implementation of the complete solution of the example structure is given in Listing 2.

Listing 2. Solution of the plane-stress elastic spring example in Python.

```
# Definitions of the elements and springs
a1, a2, a3, b1, b2 = 4, 2, 3, 2, 3     # Dimensions [m]
Ls = ((a3-a2)**2 + b2**2)**0.5   # Total length of the surface with springs.
E = 70_000_000   # Young's Modulus [kN/m^2]
p = 0.3              # Poisson's Ratio
h = 0.01             # thickness [m]
qw = 77              # unit weight [kN/m^3]
k = 30_000           # spring stiffness [kN/m^2]
X1 = np.asarray([[0, a1, 0, a1+a2-a3], [0, 0, b1, b2]])  # coordinate matrix of element 1
X2 = np.asarray([[a1, a1+a2, a1+a2-a3, a1+a2], [0, 0, b2, b2]]) # coordinate matrix of element2
inf = k*1e6   # a big number to define infinitely rigid springs
ks1 = np.diag([inf, k*Ls/2, inf, k*Ls/2, inf, inf, inf, inf])  # defines [ks] matrix of element 1




# Assemblage and solution of the system equations
K1 = K_stiffness_matrix(X1, E, p, h)        # get stiffness matrix of element 1
K1 = K1 @ inv(K1 + ks1) @ ks1               # convert K1 into new stiffness matrix (see Eq. (5))
K2 = K_stiffness_matrix(X2, E, p, h)        # get stiffness matrix of element 2

B1 = B_body_force_vector(X1, h, bx=0, by=-qw)  # get body force vector of element 1
```

```
B1 = ks1 @ inv(K1 + ks1) @ B1            # convert B1 into new body force vector (see Eq. (5))
B2 = B_body_force_vector(X2, h, bx=0, by=-qw)  # get body force vector of element 2

dof1 = [4, 0, 8, 2, 5, 1, 9, 3]      # DOF numbers of the first element
dof2 = [0, 6, 2, 10, 1, 7, 3, 11]   # DOF numbers of the second element

Ks = np.zeros((12, 12))   # initialize stiffness matrix of the system
Bs = np.zeros((12))       # initialize body force vector of the system
Ps = np.zeros((12))       # initialize concentrated force vector of the system
Us = np.zeros((12))       # initialize displacements of the system of the system

Ps[3] = -1000                                  # nodal force [kN]
assemble_element(K1, B1, Ks, Bs, dof1)   # assemble element 1 into system
assemble_element(K2, B2, Ks, Bs, dof2)   # assemble element 2 into system

Us[0:4] = inv(Ks[0:4, 0:4]) @ (Bs[0:4] + Ps[0:4])   # calculate nodal displacements
Ps[4:12] = Ks[4:12, 0:4] @ Us[0:4] - Bs[4:12]        # calculate support reactions
```

The analysis results of the example plane stress solution with the proposed method are given in Table 2. In order to verify the results in SAP2000 [17], one should turn-off the so called "incompatible modes" of the plane element, which is active by default in the software.

Table 8. Analysis results for the plane-stress problem. Displacements and support reactions.

Vert. Disp. [mm]	**Proposed Method**	**SAP2000 V18.2.0**
Node 2	-2.16**936**	-2.16**863**
Node 5	-3.122**96**	-3.122**36**
Support React. Vertical [kN]	Proposed Method	SAP2000 V18.2.0
Node 1	405,**194**	405,**169**
Node 3	294,9**33**	294,9**47**
Node 4	-8.2**93**	-8,2**72**
Node 6	320.8**71**	320,8**59**
Support React. Horizontal [kN]	Proposed Method	SAP2000 V18.2.0
Node 1	327,**535**	327,**481**
Node 3	-449,**304**	-449,**237**
Node 4	-289,0**92**	-289,0**40**
Node 6	410,**861**	410,**796**

4. CONCLUSION

This study introduced a pragmatic approach for enhancing current FE models with edge partial-fixities and releases, illustrated through an example that the method's application involves straightforward matrix manipulations. The findings revealed that the precision of the method can be adjusted using a singular magnification factor. Despite necessitating matrix inversion for deriving stiffness equations, even in scenarios involving a single spring, the method's adoption in commercial software might not be the most efficient in terms of speed. However, it remains a favorable choice due to its ease of applicability.

REFERENCES

[1] Amba-Rao C. L. (1996) Method of calculation of frequencies of partially fixed beams carrying masses. *Journal of the Acoustical Society of America*, 40(2): 367-371.

[2] Çavdar Ö., et al. (2009) Stochastic Finite Element Analysis of Structural Systems with Partially Restrained Connections subjected to Seismic Loads. *Steel and Composite Structures*, 9(6): 499-518.

[3] Shahab R., et al. (2019) Proposed Simplified Approach for the Seismic Analysis of Multi-Storey Moment Resisting Framed Buildings Incorporating Friction Sliders. *Buildings*, 9(5): 1-22.

[4] Lin H., Jhou J., Stearman R. (1989) Influence of Joint Fixity on the Structural Static and Dynamic Response of a Joined-Wing Aircraft: Part I: Static Response. *SAE Transactions*, 98(1): 221-234.

[5] Altunışık A. C., et al. (2010) Finite Element Model Updating of an Arch Type Steel Laboratory Bridge Model Using Semi-Rigid Connection. *Steel and Composite Structures*, 10(6): 543-563.

[6] Simões L. M. C. (1996) Optimization of frames with semi-rigid connections. *Computers & Structures*, 60(4): 531-539.

[7] Monforton G. R., Wu T. S. (1963) Matrix Analysis of Semi-Rigidly Connected Frames. *Journal of the Structural Division*, 89(6): 13-42.

[8] Li T. Q., Choo B. S., Nethercot D. A. (1995) Connection element method for the analysis of semi-rigid frames. *Journal of Constructional Steel Research*, 32(2): 143-171.

[9] McGuire W., Gallagher R. H., Ziemian R. D. (2000) Matrix Structural Analysis. 2nd ed, *John Wiley & Sons Inc*., USA.

[10] Aköz A. Y. (2005) Enerji Yöntemleri, *Birsen Yayınevi*, Turkey.

[11] Kassimali A. (2012) Matrix Analysis of Structures. 2nd ed. *Cengage Learning*, USA.

[12] Yılmaz M. (2022) Sonlu Elemanlar Analizi: Teori ve Python Uygulamaları. *Birsen Yayınevi*, Turkey.

[13] Yılmaz M. (2022) A Practical Approach to Implement Releases and Partial Fixities in Finite Elements Using Already Existing Stiffness Equations. *Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi*, 13(3): 571-578.

[14] Kartal M. E., et al. (2010) Effects of Semi-Rigid Connection on Structural Responses. *Electronic Journal of Structural Engineering*, 10: 22-35.

[15] Pinheiro L., Silveira R. A. (2005) Computational procedures for nonlinear analysis of frames with semi-rigid connections. *Latin American Journal of Solids and Structures*, 2(4): 339-367.

[16] Çetin S. Y., Görgün H., Kaya D. (2022) A computer program for linear analysis of two-dimensional semi-rigid frames. *Dicle University Journal of Engineering*, 13(2): 351-358.

[17] CSI, SAP2000 Integrated Software for Structural Analysis and Design, *Computers and Structures Inc*., Berkeley, California, USA.

Analysis of vertical structural elements for varying class of ductility in Dual Systems with Shear Walls: Utilizing seismic design standards, specifically Eurocode 8

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The importance of ductility class for seismic structural walls lies in its ability to withstand and absorb seismic forces while maintaining structural integrity and preventing catastrophic failure during earthquakes. Ductility refers to the capacity of a material or structure to deform plastically before failure, which allows it to dissipate energy and reduce seismic damage. The ductility class of a seismic structural wall determines its ability to undergo controlled deformation without collapse, thus enhancing the resilience of the overall structure against seismic events. Choosing an appropriate ductility class is crucial in seismic design to ensure the safety and stability of buildings and infrastructure in earthquake-prone regions. It influences the design parameters, reinforcement detailing, and overall performance of the structural system under seismic loading, as specified by seismic design codes and standards such as Eurocode 8. The paper presents a comprehensive analysis of vertical elements, centering on their response to seismic loading conditions across varying classes of ductility. Ductility serves as a cornerstone in enabling structures to effectively absorb energy during seismic events, thereby reducing the risk of damage and collapse. Also, the commences with an exploration of the significance of ductility in seismic design and its ramifications for the performance of columns and shear walls are explained in the paper. By referencing established seismic design standards such as Eurocode 8, the research outlines the categorization of ductility class and elucidates their importance in structural engineering. The paper conducts a seismic analysis of vertical elements in a tall structure standing 24 meters high (ground plus five levels), considering different class of ductility for specific material properties (Concrete grade of C40/50 and B500C reinforcement) under an assumed ground acceleration of 0.22g. The analysis of the structure was done with Tower software. The research analyzes the performance of columns and shear walls across multiple ductility class, with the goal of improving understanding and design practices for seismic-resistant structures.

Keywords: *Seismic action, ductility class, column, shear walls.*

1. INTRODUCTION

The behavior of high-rise structures under varying degrees of ductility is a critical aspect of structural engineering, influencing both safety and performance. In this analysis, we utilize Tower 8 software to investigate and compare the response of high-rise buildings in two distinct states of ductility: high ductility and medium ductility.

Focusing on the critical zone of vertical elements, specifically the first level, our analysis examines the behavior of key components such as columns and shear walls. We aim to understand how these elements perform under seismic forces in different ductility scenarios, with a particular emphasis on the effects of high and medium ductility on structural response.

It is important to note that this research paper excludes the treatment of joints between columns and beams, as well as connections between shear walls, beams, and slabs. Instead, our focus lies solely on the behavior of vertical elements within the specified critical zone.

Through comprehensive analysis and comparison, we seek to identify the implications of ductility on the design and dimensioning of vertical elements. Additionally, we investigate the effects of P-delta effects, recognizing their significance in high-rise structural behavior under lateral loads.

By elucidating the differences in structural response between high and medium ductility scenarios, this research contributes to the advancement of design practices and risk assessment strategies for high-rise buildings. Ultimately, our findings aim to inform more resilient and efficient structural designs, ensuring the safety and durability of tall buildings in seismic-prone regions.

2. METHODOLOGY, APLICATIONS-CASE STUDY

The research employs a comprehensive methodology to investigate the seismic behavior of an object.The stuctural analysis of object is conducted using software Tower 8, considering material properties, structural configurations, and seismic loading conditions. Both high and medium ductility cases are simulated to evaluate the structure's response. Seismic forces across stories, displacement patterns, and required reinforcement are compared between the two ductility scenarios.

The focal point of the case study is seismic analysis of vertical elements in a tall structure standing 24 meters high (ground plus five levels),the ground below object is type B with a ground acceleration of 0.22g, material properties (Concrete grade of C40/50 and B500C reinforcement) in general it represents a typical structure in seismic-prone areas. Utilizing Tower 8 software, the study provides insights into the structural behavior under seismic loading, facilitating comparisons between different ductility cases and assessing the effectiveness of confined concrete in enhancing ductility. This case study contributes valuable findings to seismic engineering practices, aiding in the optimization of structural design for improved seismic resilience.

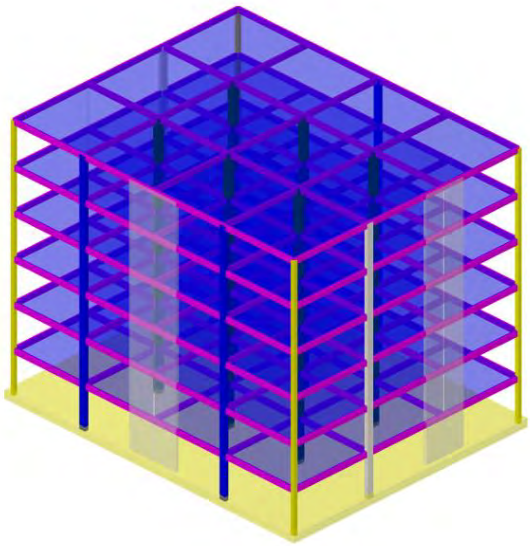

Figure 1. Structural model

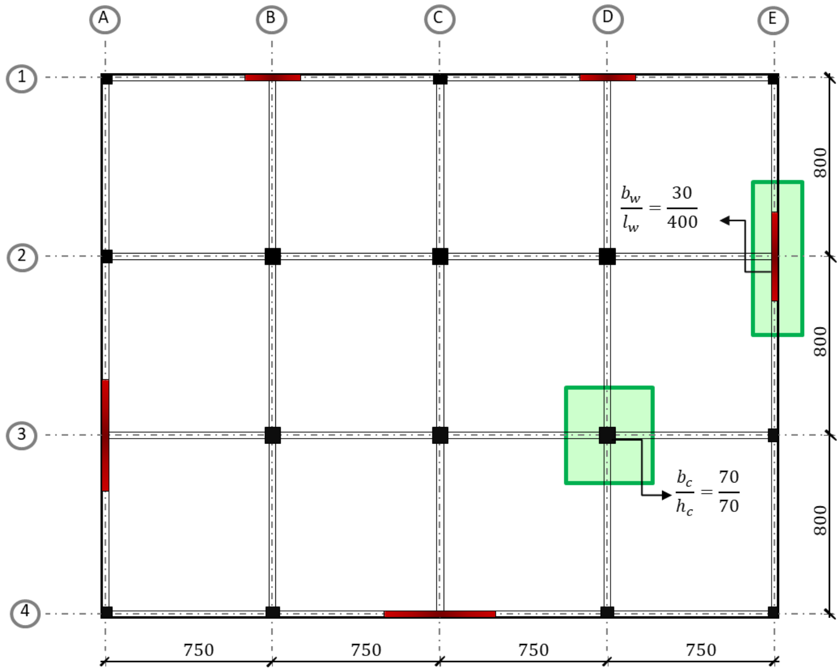

Figure 2. Layout of vertical elements in floor plan.

3. SEISMIC ANALYSIS OF STRUCTURE ACCORDING TO EUROCODE 8

In general, the seismic forces acting on a building depend on various factors including its location, soil conditions, building height, structural system, and local building codes. Engineers use seismic design codes and standards, such as those developed by the Eurocodes or similar standards in other countries, to determine the appropriate level of seismic design for a particular structure.

3.1. Seismic forces for DCH and DCM

The seismic forces experienced by a building are typically determined through seismic analysis, which involves evaluating the response of the structure to seismic loading. This analysis considers factors such as the building's mass, stiffness, and damping characteristics, as well as the characteristics of the ground motion expected at the building's location.

Seismic forces refer to the forces exerted on a structure during an earthquake. They are crucial to consider in the design and construction of buildings and other infrastructure to ensure their safety and stability during seismic events. DCH and DCM likely refer to different types of structures or construction methods, but without further context, it's hard to provide specific information.

Once the seismic forces are determined, engineers use this information to design the structural elements of the building to resist these forces and ensure the building's safety during an earthquake. This may involve designing elements such as beams, columns, walls, and foundations to be sufficiently strong and ductile to withstand the expected seismic loading without collapsing or suffering excessive damage.

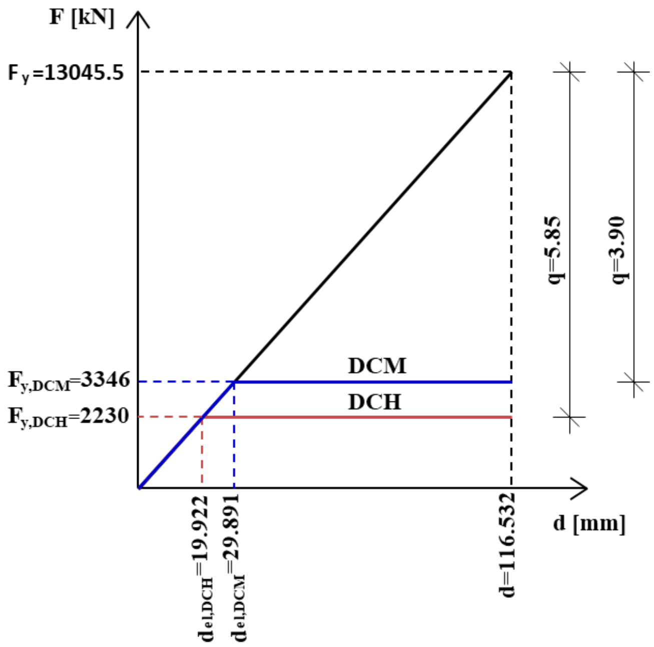

Figure 3. Ductility levels.

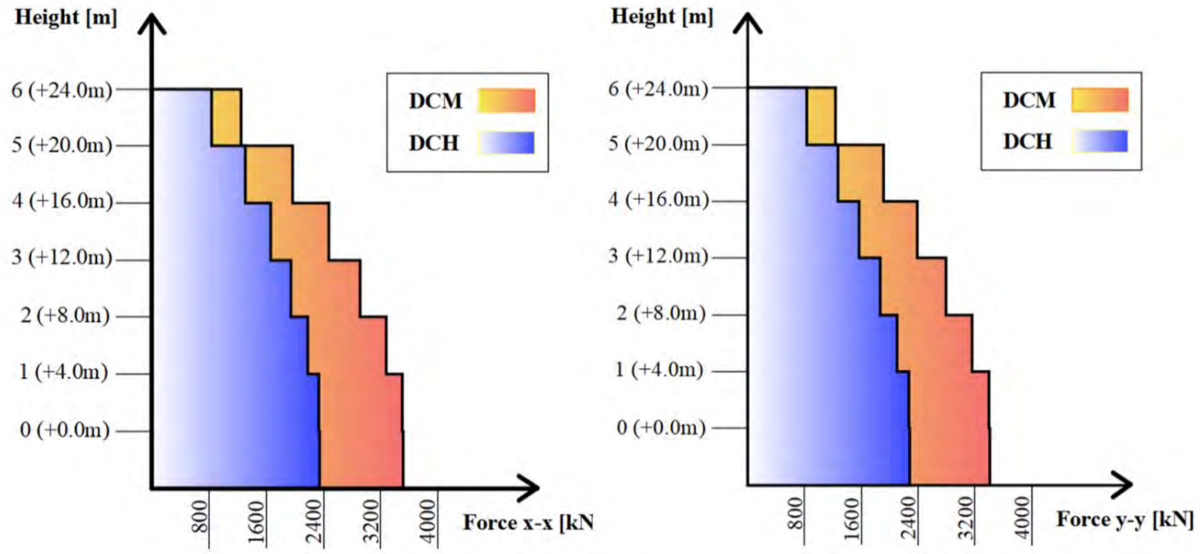

Figure 4. Shear forces through the floors.

3.2. Relative displacement between floors and P-Δ effect

The relative displacement between floors and the P-Δ effect are both important considerations in the analysis and design of buildings, particularly in the context of seismic engineering.

Relative displacement between floors, In a multi-story building subjected to seismic forces, each floor may experience different levels of displacement due to the building's response to ground motion. The relative displacement between floors refers to the difference in displacement experienced by adjacent floors of the building. This relative displacement can induce forces and stresses on the building's structural elements, such as columns, beams, and connections, which need to be accounted for in the design to ensure the building's integrity and safety.

The P-Δ effect is a phenomenon in structural engineering that arises due to the deformation of a structure under load, particularly in statically indeterminate structures. When a structure undergoes significant deformation, the distribution of internal forces changes, leading to additional bending moments and axial forces in the structure. The P-Δ effect is especially relevant in tall buildings and structures subjected to lateral loads, such as wind or seismic forces. During seismic events, the lateral displacement of a building induces additional forces on the structure, which can exacerbate the P-Δ effect.

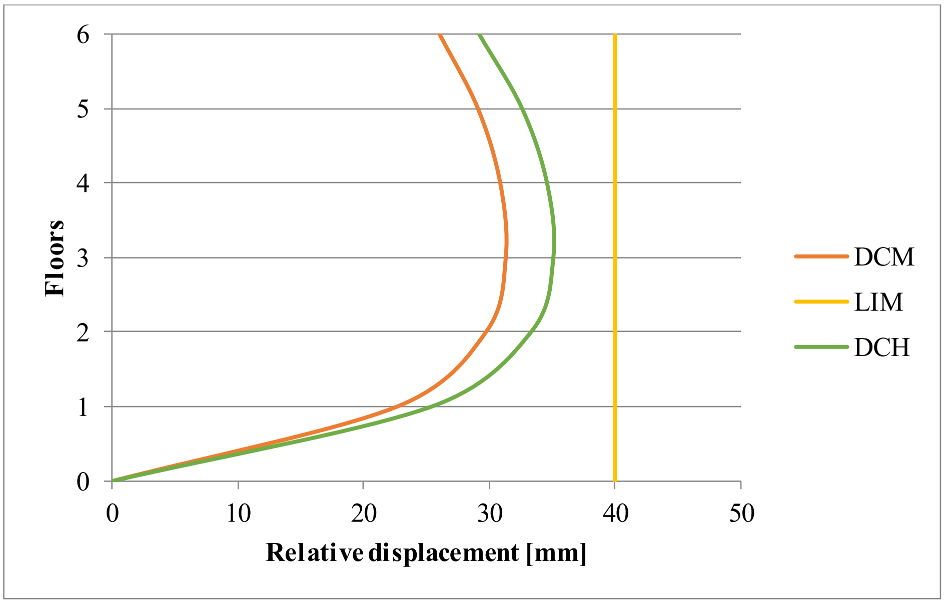

Figure 5. Relative displacement between floors - "Drifts".

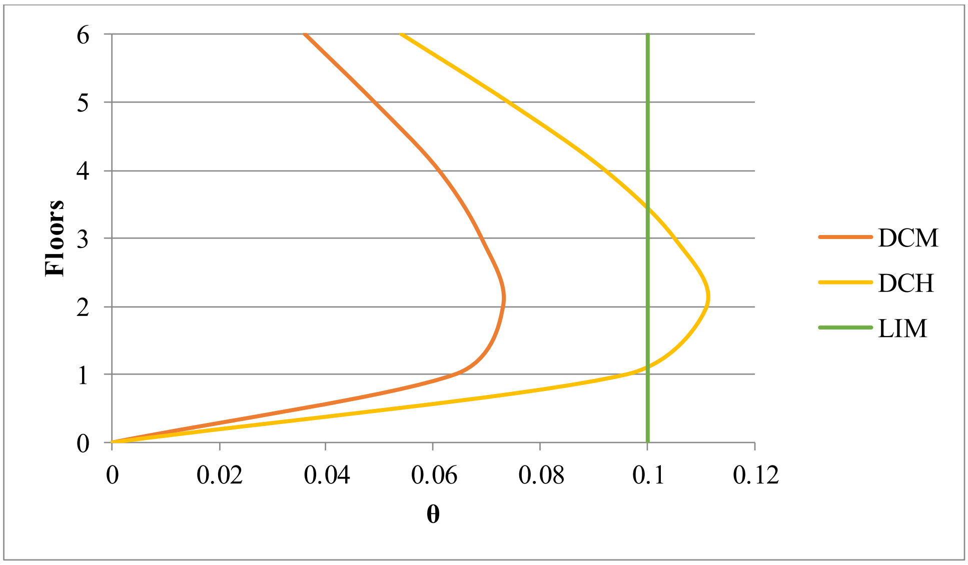

Figure 6. P-Δ effect.

4. DESIGN AND DETAILING OF VERTICAL ELEMENTS

The design and detailing of vertical elements in buildings, such as columns and walls, are crucial aspects of structural engineering, particularly in seismic regions where these elements must resist significant lateral forces. Here's an overview of the key considerations:

- Material selection, Vertical elements are typically constructed using reinforced concrete, steel, or sometimes composite materials. The choice of material depends on factors such as the structural requirements, architectural preferences, construction methods, and local building codes and regulations.

- Structural Analysis, Engineers perform structural analysis to determine the forces and moments acting on vertical elements, considering both gravity loads and lateral loads. Analytical methods range from simplified hand calculations to sophisticated computer simulations, depending on the complexity of the structure.
- Load Path and Contonuity, Vertical elements must provide a continuous load path from the superstructure to the foundation to ensure structural stability and integrity. Proper detailing of connections and continuity reinforcement is essential to achieve this. For example, column-to-beam connections should be designed to transfer vertical loads, as well as resist lateral forces and moments.
- Seismic design, In seismic regions, vertical elements must be designed to withstand the lateral forces generated by earthquakes. This involves detailing them to be ductile and capable of undergoing significant deformations without collapsing. Seismic design codes and standards provide guidelines for detailing requirements, such as minimum reinforcement ratios, detailing of confinement reinforcement, and special detailing considerations for regions of high seismicity.
- Reinforcement Detailing, The detailing of reinforcement in vertical elements is critical to ensure their structural performance. This includes specifying the size, spacing, and configuration of reinforcement bars, as well as detailing for development length, anchorage, lap splices, and detailing for seismic resistance.

4.1. Column for DCM and DCH

In seismic design, structures are often categorized based on their expected performance during earthquakes. The common classifications for the ductility of structures are Medium Ductility Class DCM, Lower Ductiliity Class DCL and High Ductility Class DCH. The ductility class of a structure influences the level of detailing and reinforcement required for its components, including columns.

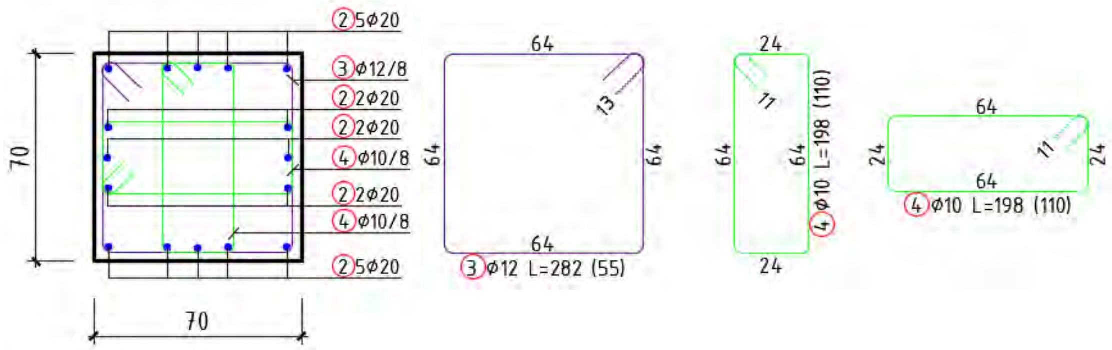

Figure 7. Column Reinforcement approval for DCM

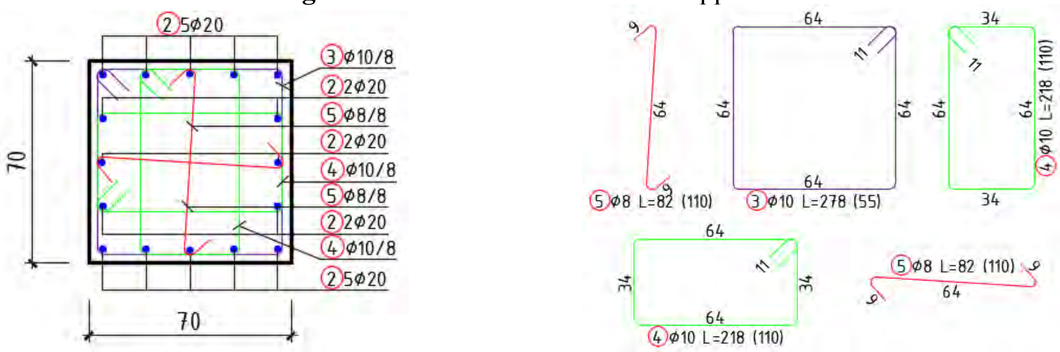

Figure 8. Column Reinforcement approval for DCH

4.2. Shear wall for DCM and DCH

Seismic walls, also known as shear walls, play a crucial role in providing lateral resistance to buildings during seismic events. Similar to columns, seismic walls are also categorized based on their expected performance during earthquakes. In the Figure below are shown the reinforceent way of creating the DCM shear wall and the DCH shear wall.

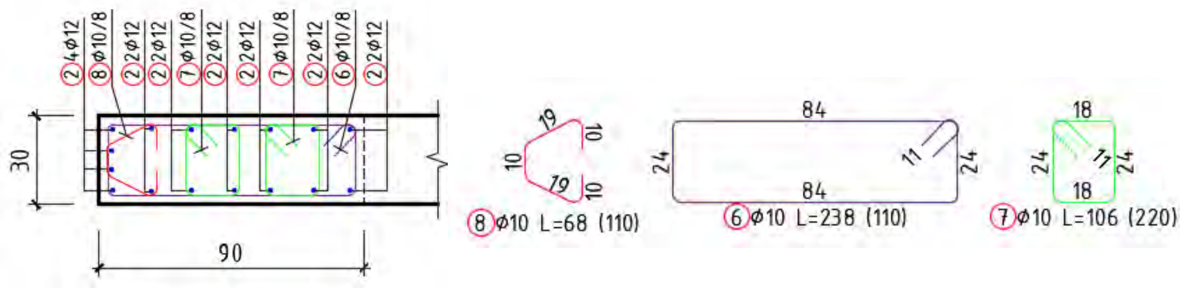

Figure 9. Boundary element reinforcement detail of wall for DCM.

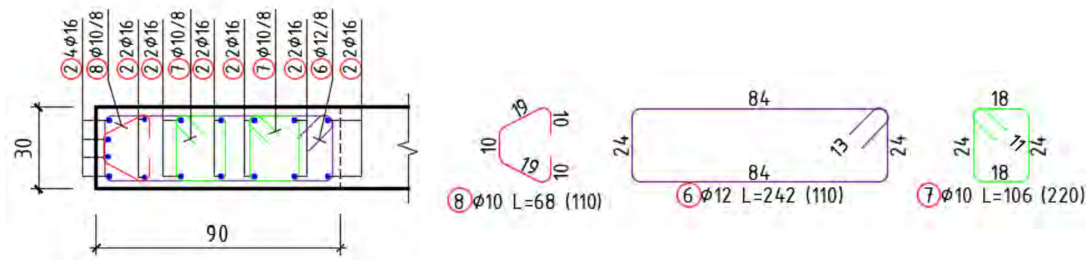

Figure 10. Boundary element reinforcement detail of wall for DCH.

The Figure 11 shows the Comparison of ductility classes in the quantity of reinforcement

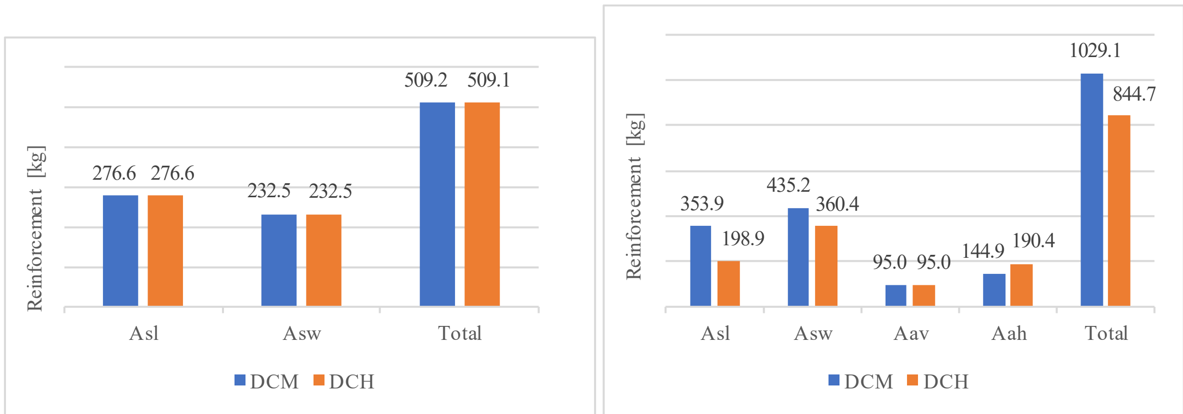

Figure 11. Comparison of ductility classes in the amount of reinforcement for column and wall.

5. CONCLUSION

The research analysis the seismic behavior of a tall structure standing 24 meters high, providing critical insights into its resilience and response to seismic forces. Through analysis utilizing Tower 8 software, are illuminated several key aspects:

Structural Resilience: Ductility scenarios emerge as pivotal factors influencing the behavior of the structure under seismic loading. the study underscores the importance of considering various ductility levels in the design and assessment of structures, as they significantly impact the structure's ability to withstand seismic forces and deformations.

Seismic Forces: Adhering to Eurocode 8 guidelines, are classified the structure based on its response to seismic forces. By scrutinizing the distribution of forces across stories, it is ensured the fidelity of our model and explored reinforcement strategies aimed at mitigating potential damage during seismic events, bolstering the structure's resilience.

Displacement Patterns: Analysis of displacement patterns across stories, particularly in high and medium ductility scenarios, has unveiled critical insights into structural response. By examining relative displacements between stories or "drifts" and accounting for the P-Δ effect, we have provided valuable considerations for the design of columns and shear walls, ensuring they can accommodate seismic-induced displacements effectively.

Reinforcement Requirements: The study adheres to Eurocode 8 standards to determine the longitudinal and transverse reinforcement requirements essential for structural integrity, especially in seismic-prone regions. Furthermore, also it is investigated the impact of confined concrete on ductility, revealing its potential to enhance structural resilience by improving confinement and reducing vulnerability to seismic loading.

REFERENCES

[1] Eurocode 2. Design of concrete structures- Part 1-1: General rules and rules for buildings.

[2] Eurocode 8. Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings.

[3] Fardis, M. N., Carvalho, E. C., Fajfar, P., & Pecker, A. (2015). Seismic design of concrete buildings to Eurocode 8.

[4] Fardis, M. N. (2009). Seismic design, assessment and retrofitting of concrete buildings: Based on EN-Eurocode 8.

[5] Bisch, P., Carvalho, E., Degee, H., Fajfar, P., Fardis, M., Franchin, P., Kreslin, M., Pecker, A., Pinto, P., Plumier, A., Somja, H., & Tsionis, G. (2012). Eurocode 8: Seismic design of buildings worked examples.

[6] Toniolo, G., & Di Prisco, M. (2017). Reinforced concrete design to Eurocode 2.

[7] The Institution of Structural Engineers. (2010). Manual for the seismic design of steel and concrete buildings to Eurocode 8.

[8] The Institution of Structural Engineers. (2006). Standard method of detailing structural concrete: A manual for best practice.

[9] Garevski, M., & Ansal, A. (2010). Earthquake engineering in Europe.

[10] Elawady, M. H. S. (2017). Ductility considerations in seismic design of reinforced concrete buildings.

[11] Varsamis, C. (2017). Optimal design of ductile R/C walls based on Eurocode 8.

[12] Park, R. (1991). Ductility of structural concrete.

[13] Pojani, N. (2003). Inxhinieria sizmike.

[14] Baballëku, M., Pojani, N., Spacone, E., Bogdani, S., Lako, N., Lako, A., Cullufi, H., & Shkodrani, N. Rregulla për projektimin e ndërtesave prej betoni, Bazuar në Eurokodin 8.

The Debut of Base Isolators in Albania.

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Albania, situated in the Alpine-Mediterranean seismic belt, faces seismic challenges accentuated by its geological and tectonic structure. Despite implementing seismic provisions, historical earthquakes exposed vulnerabilities due to inadequate enforcement. The seismic hazard map aids earthquake-resistant design, illustrating Peak Ground Acceleration for a 475-year return period. The presentation introduces base isolators—a seismic protection method separating structures from foundations. Albania's inaugural use of this technology in Tirana exemplifies an irregular plan shape with a dual system reinforced concrete structure. Initially designed as a fixed base, it transitioned to isolation, marking a pioneering example in the country. Exploring two isolator types, elastomeric bearings and frictional pendulum bearings, reveals their unique mechanisms. Elastomeric bearings use rubber-like materials for flexibility, while frictional pendulum bearings employ sliding surfaces and pendulum mechanisms for controlled rocking. The study case, Albania's first base-isolated building, falls within the category of residential and service-oriented civil constructions. The load-bearing structure comprises a dual-system reinforced concrete skeleton, featuring two basement levels for car parking, two above-ground floors for service spaces, and 6-7 subsequent residential floors. This application highlights seismic resilience and innovation in Albania's structural engineering, considering essential parameters in isolator selection. Load calculations adhere to European standards, considering dead loads, live loads, and seismic masses. The presentation concludes by showcasing tables and diagrams illustrating vibration modes, displacements, inertial forces, and moment distributions on fixed and isolated bases. These visuals highlight the practical benefits of base isolators, contributing to increased seismic resilience and safety in Albanian constructions.

Keywords: *Seismic Innovation, Base Isolation, Resilient Albania, Tirana Case Study, Structural Safety, Earthquake Protection.*

1. INTRODUCTION

Albania is part of the Alpine-Mediterranean seismic belt. The most vulnerable areas are primarily the Albanian coastline, and the second-risk zone is the Leskovik-Korçë-Pogradec area, while the third zone is considered to be Lushnje-Elbasan-Peshkopi. Such distribution seems to be related to the geological and tectonic structure of our territory. According to assessments, with a probability of 75%, Albania is affected by an earthquake every year with a magnitude not exceeding 4.7 on the Richter scale, once every 50 years by an earthquake with a magnitude no greater than 6.1, and once every 100 years by an earthquake with a magnitude not exceeding 6.4.

Since 1905, Albania has been struck by 7 destructive earthquakes, which caused more than 200 fatalities, and left nearly 10,000 people homeless. Although seismic provisions have been implemented in the country around the fifties, the poor enforcement of seismic regulations and inappropriate construction practices led to a large portion of the building stock vulnerable to earthquake shaking.

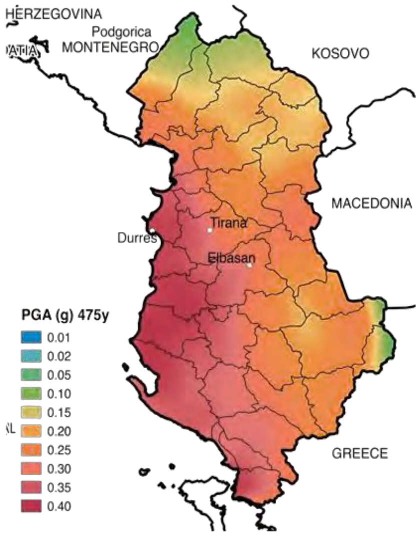

Figure 1. Seismic hazard map of Albania

Acceleration (PGA), reflecting variations in ground shaking intensity during earthquakes for a 475-year return period. This visual guide assists in identifying seismic hazards for effective, long-term earthquake-resistant design considerations.

2. BASE ISOLATORS EXPLANATION

2.1. The purpose of base isolators

A base isolation system is a method of seismic protection where the structure (superstructure) is separated from the base (foundation or substructure). By separating the structure from its base, the amount of energy that is transferred to the superstructure during an earthquake is reduced significantly.
These base isolation systems often tend to include one or more types of bearing to support the weight of the structure. Some examples of these components are elastomeric pads, sliding plates, or inverted pendulums. All of these components can provide some level of energy dissipation, but typically only in the form of hysteretic damping. Hysteretic damping has certain limitations in terms of energy absorption and can excite higher modes in some cases.

2.2. The working principle of base isolators

The base isolator works similarly to the car suspension, which allows a car to travel over rough ground without the one sitting in the car being thrown out. The Base Isolation system decouples the structure from the horizontal components of ground motion by interposing a low horizontal stiffness structural element between the structure and the foundation. Thus, by applying this isolation system the fundamental frequency of structure becomes much lower than the frequency of fixed base structure and predominant frequency of ground motion.

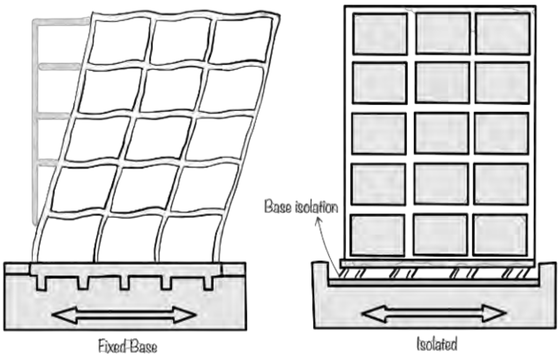

Figure 2. Fixed Base vs Isolated base

During an earthquake, a building can move a significant amount of mm, therefore there must be the way for movement during an earthquake. This base isolation technology makes a medium rise building or a reinforced concrete structure to withstand the earthquake and protecting the occupants and the structure. Isolator reduces the energy of the structure, and it is also used to decrease the earthquake energy (E) acting on the structure.

E=E (k)+ E (s)+ E(h)+ E(v), where E is energy induced by seismic shaking, E(k) is the kinematic energy, E(s) is the elastic strain, E(h) is the hysteric damping energy, E(v) is the viscous damping energy.

2.3. Types of base isolators

Seismic Base Isolators are categorized into two types: Elastomeric bearings and Frictional Pendulum bearings, also known as Sliding Isolator bearings. These types are further divided based on the materials used and the intricate design into elastomeric and frictional pendulum bearings.

2.3.1. Elastomeric bearings

Elastomeric bearings consist of steel plates that are bonded to the rubber through the vulcanization process and thus increase the resistance of the bearing to vertical load.

2.3.2 Frictional Pendulum

Friction pendulum bearings are made up of dense chrome over steel concave or flat surface in contact with an articulate friction slider which are free to slide during lateral displacement.

3. THE FIRST BUILDING WITH BASE ISOLATORS IN TIRANA

The structure falls within the category of residential and service-oriented civil constructions, assigned an importance coefficient of '1'. The load-bearing structure is composed of a dual-system reinforced concrete skeleton. The building, as depicted in the front view, showcases an irregular plan shape. It comprises two basement levels designated for car parking, two above-ground floors for service spaces, and 6-7 subsequent floors dedicated to residential purposes.

This visual representation provides a comprehensive overview of the building's design and functionality.

In the given scenario, the project was initially planned as a fixed-base structure. However, when the decision was made by the investors to proceed with an isolated structure, construction had already reached the "-2" level. As a result, the selection of the isolation system was constrained by these circumstances. The friction pendulum system was considered the most suitable option due to its minimal space requirements for installation, ease of maintenance, and cost-effectiveness. This would mark the first instance in Albania of a multi-story structure with isolation.

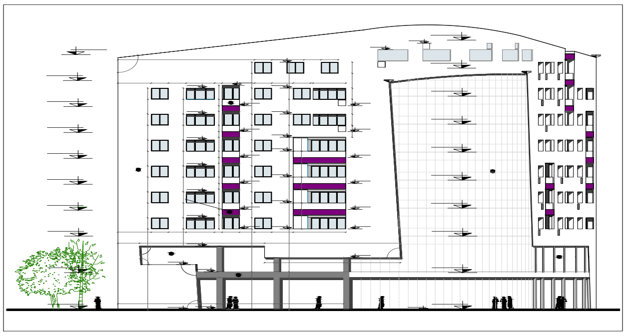

Figure 3. Front facade of the building

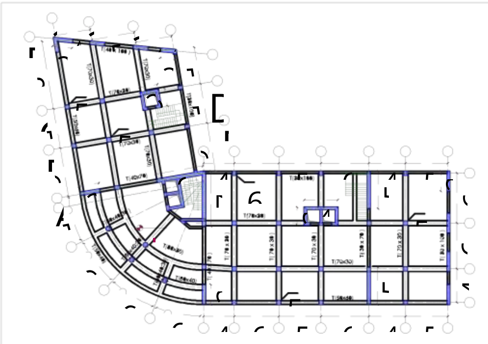

Figure 4. Building's Planimetry

3.1 Load Calculations

We determine loads based on European standards EC-2 (UNI ENV 19921-1) and EC-8 (UNI ENV 1998-1-1 - EN 1998-1:2004). Initial slab sizing involves monolithic plates, 15cm thick for residential floors and 20cm for service floors. Calculation programs generate loads on beams, columns, and walls from their dimensions. Initial dimensions are estimated roughly. We also specify the types of layers and masonry. Using this information, we calculate loads accordingly.

Dead loads
In residential floors:
- Slab: Surface load with a value of gslab=4 kN/m^2.
- Layers: Surface load with glayers=1.5 kN/m^2.
- Walls: Surface load with gw=2.5 kN/m^2.

In parking levels and shops:
- Slab: Surface load with gsl=5 kN/m^2.
- Layers: Surface load with gl=1.5 kN/m^2.

- Walls: Surface load with gw=3.5 kN/m^2.

In outdoor areas:

- Slab: Surface load with gsl=7.5 kN/m^2.
- Filling: Surface load with gl=12 kN/m^2.

Temporary loads:

- For apartments: Surface load with pa=2 kN/m^2.
- Shops: Surface load with gm=4 kN/m^2.

Outdoor space: Surface load with gm=10 kN/m^2.

The static loads in a base-isolated building are the same as those in a traditional building. The only differences lie in the surfaces of the isolation system. The floor slab of each story has a significant self-weight due to the required stiffness.
A quadratic linear plate element will be used for the foundation slab, which also accounts for deformations due to compressive forces along the plate's direction vector. This element consists of four nodes with six degrees of freedom each.
Beam-column elements will be modeled using linear elongated elements with two nodes, each with six degrees of freedom, to ensure compatibility between the adjacent elements.

Combination	Loads		Seismic	
	Dead	Live	X-axis	Y-axis
DCON1	1.35	(--)	(--)	(--)
DCON2	1.35	1.5	(--)	(--)
DCON3	1	0.45	1	0.3
DCON4	1	0.45	0.3	1
DCON5	1	(--)	1	0.3
DCON6	1	(--)	0.3	1

Table 1. Load Combinations

TONE	MODE-1	MODE-2	MODE-3	MODE-4	MODE-5	MODE-6
PERIODE (sec)	1.02	0.94	0.62	0.27	0.22	0.16
TYPE	Trans.	Trans.	Rot.	Trans.	Trans.	Rot.

Table 2. Modes of vibrations for a structure with a fixed base.

Quota	D_x	D_y	d_x	d_y
Floor 8	4.3	3.0	0.4	0.3
Floor 7	3.9	2.7	0.4	0.3
Floor 6	3.5	2.4	0.4	0.3
Floor 5	3.1	2.1	0.4	0.3
Floor 4	2.6	1.8	0.5	0.3
Floor 3	2.2	1.5	0.5	0.3
Floor 2	1.7	1.2	0.4	0.3
Floor 1	1.3	0.9	0.6	0.4
Floor 0	0.7	0.6	0.4	0.3
Floor(-1)	0.2	0.3	0.2	0.2
Floor (-2)	0.1	0.1	0.1	0.1

Table 3. The absolute and relative displacements in each DCON3 story for the fixed-base structure.

Quota	D_x	D_y	d_x	d_y
Floor 8	2.8	4.7	0.3	0.4
Floor 7	2.5	4.3	0.3	0.4
Floor 6	2.2	3.8	0.3	0.5
Floor 5	2.0	3.4	0.3	0.5
Floor 4	1.7	2.9	0.3	0.5
Floor 3	1.4	2.4	0.3	0.5
Floor 2	1.1	1.9	0.3	0.5
Floor 1	0.8	1.5	0.4	0.6
Floor 0	0.4	0.9	0.3	0.5
Floor-(1)	0.2	0.4	0.1	0.3
Floor-(2)	0.1	0.1	0.1	0.1

Table 4. The absolute and relative displacements in each DCON4 story for the fixed-base structure.

Floor	Section		N	V_x	V_y	T	M_x	M_y
8	9	Max	8156.31	1697.48	1136.56	21354.24	97574.15	6502.536
	8	Max	9131.41	1697.48	1136.56	21354.24	112824.3	7596.03
7	8	Max	20044.93	3641.41	2343.46	50643.07	259574.1	46342.52
	7	Max	21536.99	3641.41	2343.46	50643.07	286278.7	49855.9
6	7	Max	32525.5	5274.84	3282.1	75487.99	436272.9	90250.86
	6	Max	34113.37	5274.84	3282.1	75487.99	467614	87249.48
5	6	Max	44882.71	6564.83	3951.46	94419.24	614564.7	126303.1
	5	Max	46658.23	6564.83	3951.46	94419.24	651155	119889.8
4	5	Max	57208.39	7615.89	4451.65	109519.6	794429.9	158647.1
	4	Max	59232.19	7615.89	4451.65	109519.6	836692.9	148650.7
3	4	Max	69563.17	8527.41	4899.12	122780.9	975909.9	187842.9
	3	Max	71774.63	8527.41	4899.12	122780.9	1023039	174622.7
2	3	Max	81886.42	9357.52	5373.09	135084.3	1157981	214761.8
	2	Max	84321.91	9357.52	5373.09	135084.3	1210514	198061
1	2	Max	94943.65	10186.34	5935.77	147702.9	1350496	246086
	1	Max	98868.24	10186.34	5935.77	147702.9	1437045	224350.5
0	1	Max	109976	10751.73	6405.4	156525.3	1584130	274146.4
	0	Max	114062.1	10751.73	6405.4	156525.3	1678369	247380.3
-1	0	Max	136283	10941.81	6692.54	160788.6	2086745	442566.8
	-1	Max	142812.3	10941.81	6692.54	160788.6	2221689	448105.4
-2	-1	Max	163230.5	10995.39	6784.11	162082.2	2583546	619502.8
	-2	Max	168171.6	10995.39	6784.11	162082.2	2686214	623286.6

Table 5. Internal forces of DCON3

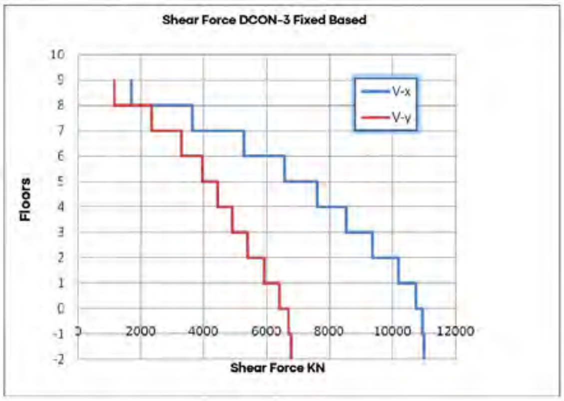

Figure 5. Shear Force DCON3-Fixed Based

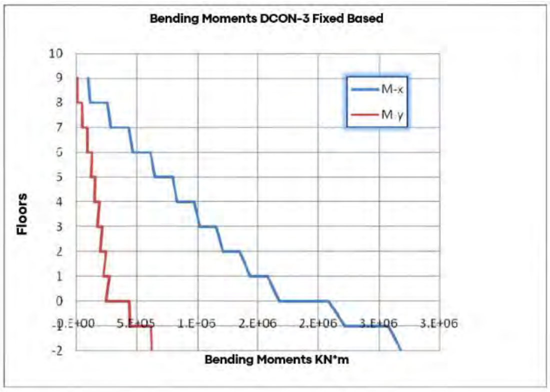

Figure 6. Bending Moment DCON3

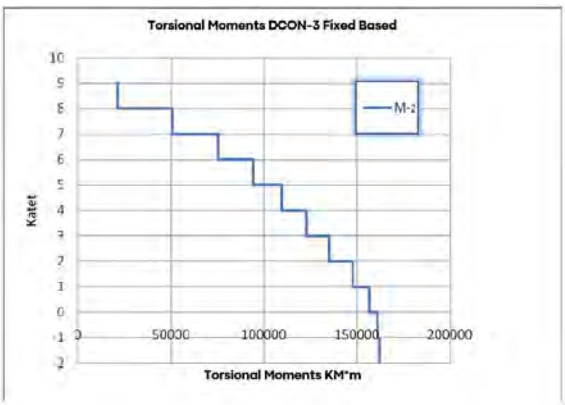

Figure 6. Torsional Moments DCON-3

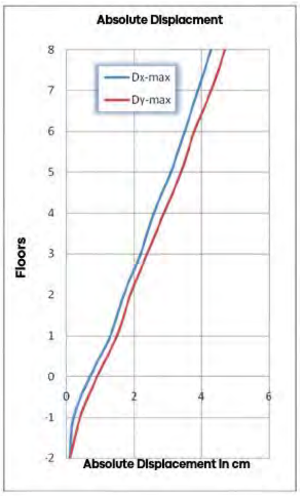

Figure 7. Absolute Displacement

3.3 Seismic response of the isolated system

Seismic response of the isolated system refers to how a structure equipped with seismic isolation systems reacts or responds to seismic forces during an earthquake. Seismic isolation systems are designed to mitigate the transmission of earthquake-induced forces from the ground to the structure, thereby reducing the structural damage and protecting occupants and contents.

QUOTA	D_x	D_y	d_x	d_y
FLOOR 8	18.0	5.8	0.3	0.1
FLOOR 7	17.7	5.6	0.3	0.1
FLOOR 6	17.4	5.5	0.3	0.1
FLOOR 5	17.1	5.4	0.3	0.1
FLOOR 4	16.8	5.2	0.3	0.1
FLOOR 3	16.5	5.1	0.3	0.1
FLOOR 2	16.1	5.0	0.4	0.1
FLOOR 1	15.8	4.8	0.5	0.2
FLOOR 0	15.3	4.7	0.4	0.6
ISOL.SIS	14.9	4.1	14.9	4.1
UNDERSTR	0	0	0	0

Table 6. Relative and absolute displacement for DCON-3

Floor	Section		N	V_x	V_y	M_x	M_y
8	9	Max	7637.69	819.85	251.25	91467.77	1783.119
	8	Max	8554.43	819.85	251.25	104392.4	4337.322
7	8	Max	19017.39	1929.66	586.95	243269.4	43181.35
	7	Max	20427.39	1929.66	586.95	265485.2	49571.37
6	7	Max	30965.64	3020.66	916.97	407034.5	90373.1
	6	Max	32460.44	3020.66	916.97	431976.5	91793.24
5	6	Max	42790.51	4040.88	1226.51	570614.5	131276.3
	5	Max	44461.98	4040.88	1226.51	599262	130369
4	5	Max	54583.86	4990.97	1516	734806.7	169138.6
	4	Max	56492.61	5010.36	1521.94	767963.3	165238.3
3	4	Max	66406.31	5908.81	1797.02	900249.7	203840.6
	3	Max	68491.72	5928.92	1803.2	937332.1	196915.5
2	3	Max	78257.04	6801.49	2071.33	1067075	236264.7
	2	Max	80555.48	6801.49	2071.33	1108609	225783.1
1	2	Max	90854.09	7787.32	2374.76	1245863	270745.6
	1	Max	94314.88	7787.32	2374.76	1309187	253562.5
0	1	Max	104963.6	8820.3	2692.45	1451632	299707.7
	0	Max	108580.5	8820.3	2692.45	1520479	276211.9

Table 7. Internal forces for DCON-3

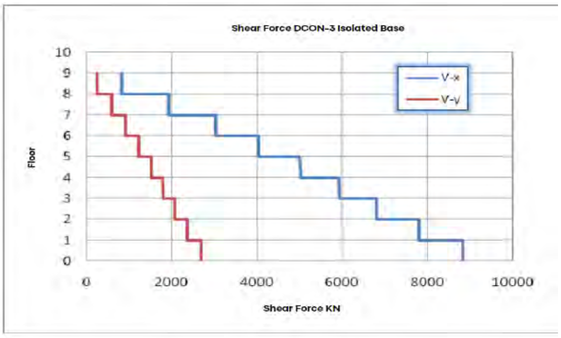

Figure 8. Shear Force DCON-3 Isolated Base

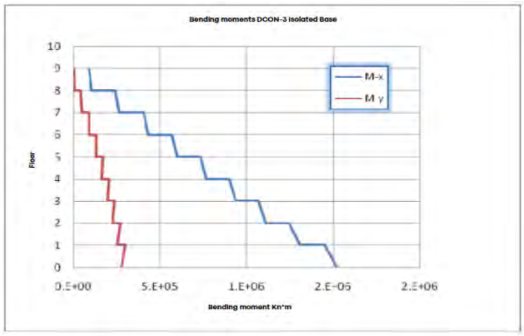

Figure 9. Bending moments DCON-3 Isolated Base

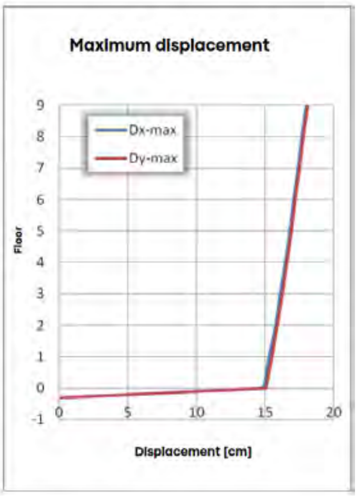

Figure 10. Maximum displacements

As the two shear force diagrams were presented side by side, a notable contrast emerged between the fixed base and isolated base configurations. Remarkably, the isolated base configuration revealed a reduction of approximately 18 percent in shear force compared to its fixed counterpart. This observation underscores the efficacy of base isolation techniques in diminishing seismic forces and fortifying structural resilience.

4. CONCLUSION

To address seismic challenges in building structures, we have two options: sticking with the traditional fixed-base method or opting for seismic isolation. For buildings of medium height, like multi-story structures, seismic isolation offers clear advantages. It's a smarter choice for several reasons:
- It reduces overall horizontal seismic forces, as demonstrated by our case study, which showed an 18% decrease.
- Isolated structures experience greater displacement compared to fixed-base ones, but this remains within acceptable limits during intense shaking.
- Deformations in isolated structures are lower than in fixed-base counterparts.
- Occupants feel safer and more comfortable during seismic events.
- It prevents damage to both structural and non-structural elements, leading to lower repair costs.
- Isolated structures are better at handling low-frequency earthquakes.

These benefits underscore the effectiveness of seismic isolation in bolstering structural resilience and seismic safety, making it a preferable option for earthquake-resistant building design.

REFERENCES

[1] Anand Paul. "Anand Paul". 2024. Civildigital.Com. https://civildigital.com/base-isolation-system-outline-on-principles-types-advantages-applications/.
[2] "Kur dhe pse bien tërmetet në Shqipëri, një histori e aktivitetit sizmik në vendin tonë". 2024. Dritare.Net. https://dritare.net/kur-dhe-pse-bien-termetet-ne-shqiperi-nje-histori-e-aktivitetit-sizmik-ne-vendin-tone.
[3] "Earthquakes in Albania". 2024. Www.Worlddata.Info. https://www.worlddata.info/europe/albania/earthquakes.php.
[4] "". 2024. Dspace.Mit.Edu. https://dspace.mit.edu/bitstream/handle/1721.1/82820/862818888-MIT.pdf.
[5] "Home". 2024. Theconstructor.Org. https://theconstructor.org/earthquake/what-base-isolation-system-building-construction/36142/.
[6] "". 2024. Www.Irjet.Net. https://www.irjet.net/archives/V8/i10/IRJET-V8I10285.pdf.
[7] "What is a Base Isolation System?". 2024. Www.Taylordevices.Com. https://www.taylordevices.com/base-isolation/.
[8] Murtaj, Luan- *Izolimi Antisizmik në Bazë i Strukturave Ndërtimore* ,Tiranë, Qershor 2016

Comparative Assessment of Glulam Design Methodologies: Finite Element Analysis, Software Tools, and Approximate Formulations

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This paper presents an extensive comparative analysis of design methodologies for glulam structures, encompassing Finite Element Analysis (FEA), specialized software applications, and simplified analytical formulations. Glued laminated timber (glulam) constructions have surged in popularity due to their sustainability and structural efficacy. The Finite Element Method (FEM) offers a detailed and versatile approach, allowing for intricate modeling of glulam structures and comprehensive analysis of their behavior under various loading conditions. However, its implementation requires substantial computational resources and specialized expertise. Conversely, specialized software tools provide a more user-friendly and streamlined approach to glulam design, offering pre-defined templates and automated processes for structural analysis and optimization. While these tools may sacrifice some level of flexibility and precision compared to FEM, they offer significant advantages in terms of efficiency and ease of use. Additionally, approximate analytical formulations offer a simplified yet expedient means of estimating key design parameters for glulam structures. These expressions, often derived from empirical relationships or design codes, provide quick estimations of structural capacities and member sizes, making them particularly useful for preliminary design stages or rapid assessments. Through a series of case studies and comparisons, this study aims to elucidate the strengths and weaknesses of each design methodology, providing engineers and designers with valuable insights to guide their decision-making process. By understanding the trade-offs inherent in each approach, practitioners can make informed choices to achieve optimal and efficient glulam structure designs.

***Keywords**: Glued laminated timber (glulam), Structural design, Comparative analysis, Finite Element Method (FEM).*

1. INTRODUCTION

A glulam structure represents a harmonious fusion of strength, efficiency, and versatility. At the heart of every glulam structure lies a careful balance between form and function. Glulam beams are engineered using advanced computational models and rigorous analysis techniques to ensure they meet stringent performance requirements while achieving the desired architectural aesthetic. The laminated layers of timber are carefully selected and bonded together with high-strength adhesives to create a composite material that is stronger and more dimensionally stable than solid wood.

The topic of this paper is to analyze the structure of a 18m span glulam arch structure, with a height of 5.5m. The main beams are located every 8m.

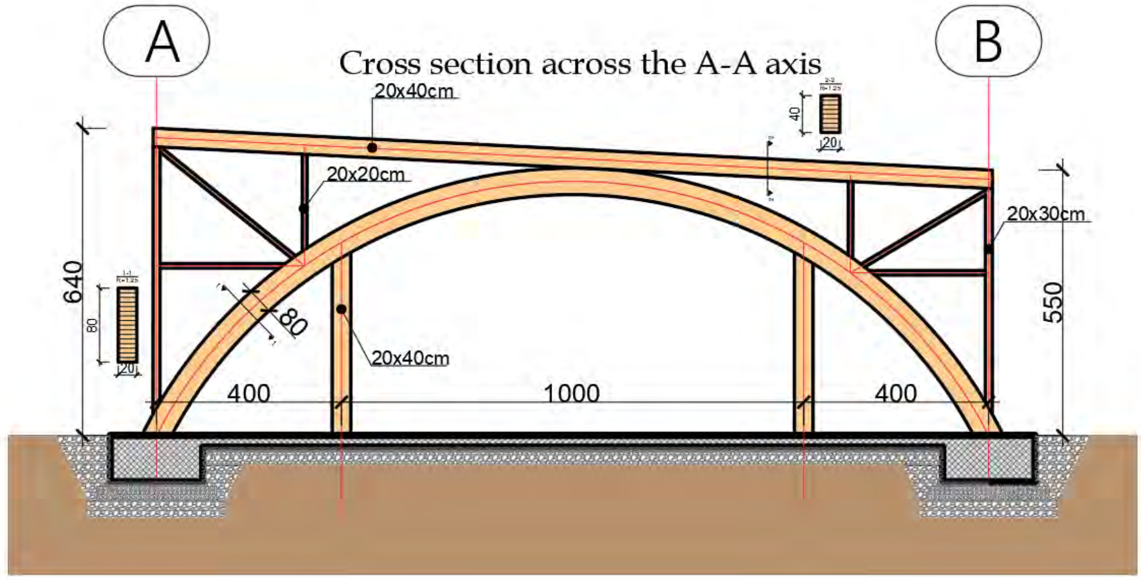

Figure 20. Cross section of the structure

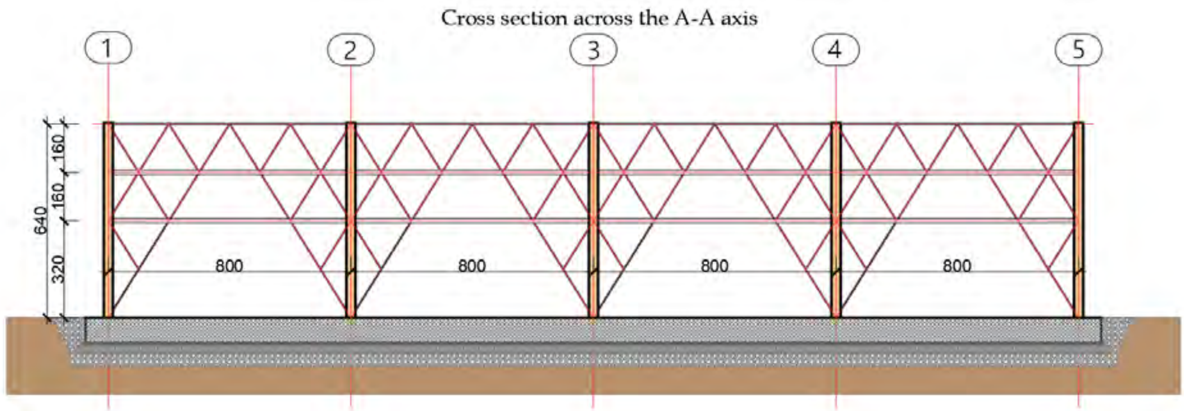

Figure 21. Front view of structure

The loads taken into consideration for this structure are Dead Load, Live Load (Category H) according to SK-EN-1991-1-1 $\left(q_k = 0.40\,kN/m^2\right)$, snow according to SK-EN-1991-1-4 $\left(s_k = 1.20\,kN/m^2\right)$ and wind loads according to SK-EN-1991-1-3. Load combinations are established in accordance with Eurocode 0.

2. MATERIALS AND METHODS

Glulam (also known as glued laminated timber, laminated wood, glulam beam, or classic glulam) is a composite material with more uniform distribution and higher values of mechanical characteristics than wood. Thin laminates are arranged so that the grain is generally parallel; they are glued together with structural adhesives that are rigid and durable, water resistant, and resistant to humidity, temperature, and biological factors. Laminated construction elements are industrial construction elements characterized by a high degree of prefabrication. Glulam is one of the lightest construction materials. Moreover, due to its outstanding elastic and mechanical characteristics it can be used for production of individual beams and columns as well as for large-span planar and spatial construction. For this structure it was used GL 32C based on SK-EN 1995-1-1.

1.1 Glued laminated structure design based on SK-EN 1995-1-1.

According to Eurocode the structure should satisfy the Ultimate Limit State and Serviceability Limit State criteria.

4.1.1. Ultimate Limit State

For a member in tension parallel to the grain, the following expression shall be satisfied.

$$\sigma_{t,0,d} \leq f_{t,0,d} \tag{1}$$

where:
$\sigma_{t,0,d}$ is the design tensile stress along the grain,
$f_{t,0,d}$ is the design tensile strength along the grain.

For a member in compression parallel to the grain, the following expression shall be satisfied.

$$\sigma_{c,0,d} \leq f_{c,0,d} \tag{2}$$

where:
$\sigma_{c,0,d}$ is the design compressive stress along the grain,
$f_{c,0,d}$ is the design compressive strength along the grain.

For a member in compression perpendicular to the grain, the following expression shall be satisfied.

$$\sigma_{c,90,d} \leq k_{c,90} \cdot f_{c,90,d} \tag{3}$$

where:
$\sigma_{c,90,d}$ is the design compressive stress in the effective contact area perpendicular to the grain,
$f_{c,90,d}$ is the design compressive load perpendicular to the grain,
$k_{c,90}$ is a factor taken into account the load configuration, the possibility of splitting and the degree of compressive deformation

For a member in bending, the following expression shall be satisfied.

$$\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \tag{5}$$

$$k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \tag{6}$$

where:
$\sigma_{m,y,d}$ and $\sigma_{m,z,d}$ are the design bending stresses about the principal axes.
$f_{m,y,d}$ and $f_{m,z,d}$ are the corresponding design bending strengths.

The value of the factor should be taken as follows: For solid timber, glued laminated timber and LVL: for rectangular sections $k_m = 0.7$ for other cross-sections: $k_m = 1.0$.

4.1.2. SLS

The Serviceability Limit State (SLS) is a crucial concept in structural engineering, particularly within the framework of design codes such as the Eurocodes. It pertains to the conditions under which a structure must remain functional and comfortable for its intended use, without causing undue distress or discomfort to its occupants. Unlike the Ultimate Limit State (ULS), which focuses on the maximum strength of a structure and its components to avoid collapse, the SLS concerns itself with aspects that ensure the structure is fit for use and durable over its intended life span.

Key considerations under the SLS include:

Deflections: Ensuring that deflections in structural members are within acceptable limits so as not to impair the structure's integrity or functionality. Excessive deflection can lead to damage in non-structural elements, such as partitions or finishes, and can also be visually disturbing and cause concern to occupants.

$$w_{net,fin} = w_{inst} + w_{creep} - w_c = w_{fin} - w_c \quad (5)$$

Vibrations: Structures must be designed to avoid uncomfortable or harmful vibrations, which can arise from human activities, machinery, or environmental forces like wind. Excessive vibrations can lead to a perception of instability and discomfort for occupants.

2.1.7. Design based on Robot Structural Software

The same structure that was calculated with numerical equations, was also analysed using FINITE ELEMENT METHOD using Robot Structural software. Robot Structural Analysis is a software package used for structural analysis and design in engineering. It works by utilizing finite element analysis (FEA) techniques to simulate the behavior of structures under various loads and conditions. Users input the geometric and material properties of the structure, along with the applied loads and boundary conditions. The software then discretizes the structure into finite elements, applies the appropriate mathematical equations to each element to calculate stresses, strains, and deformations, and finally combines these results to provide comprehensive insights into the structural performance. Additionally, Robot Structural Analysis includes features for code-based design, allowing users to verify designs against relevant building codes and standards.

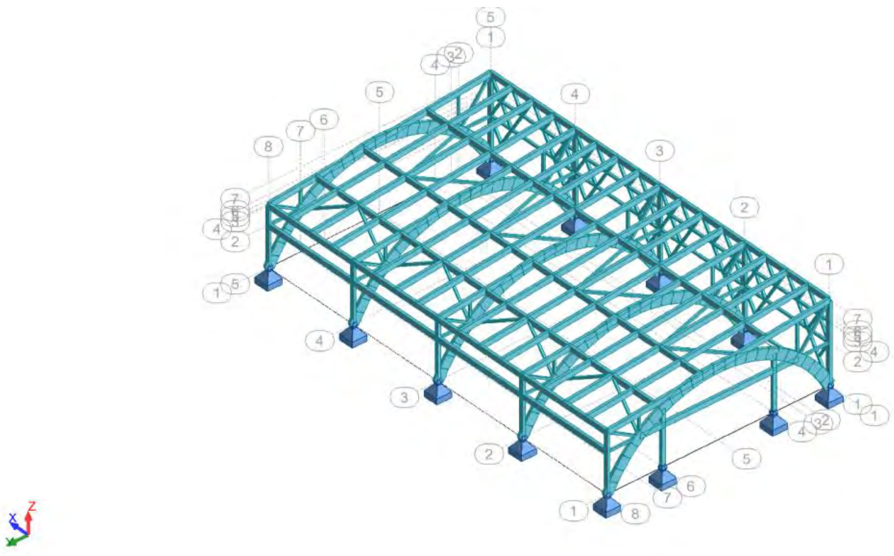

Figure 22. 3D Structure in Robot

3. RESULTS AND DISCUSSION

After analysing the structure using both ways we achieved the following results:

Both numerical methods and Finite Element Method (FEM) share commonalities in their fundamental approach to solving engineering problems, therefore we obtained similar results. Primary beam was loaded in bending with compressive force. Purlins were loaded in biaxial bending. Secondary beam was loaded from the purlins as a concentrated load even though we used same section for architectural purposes.

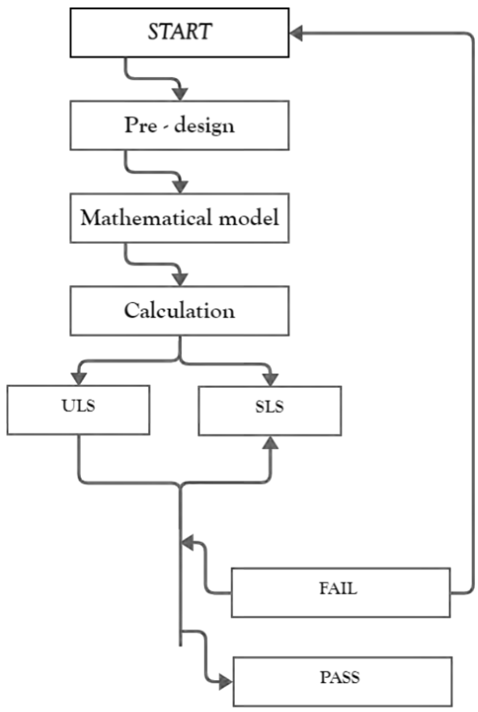

Figure 23. Algorithm of Design procedure

The dimensioning of the elements has been done in accordance with the expressions presented above, where the resulting outcomes have been very anticipated and closely aligned, both with the initial assumptions as well as with the two analyzed methods. The primary effect in the analysis was due to buckling and lateral deflection of the arch element.

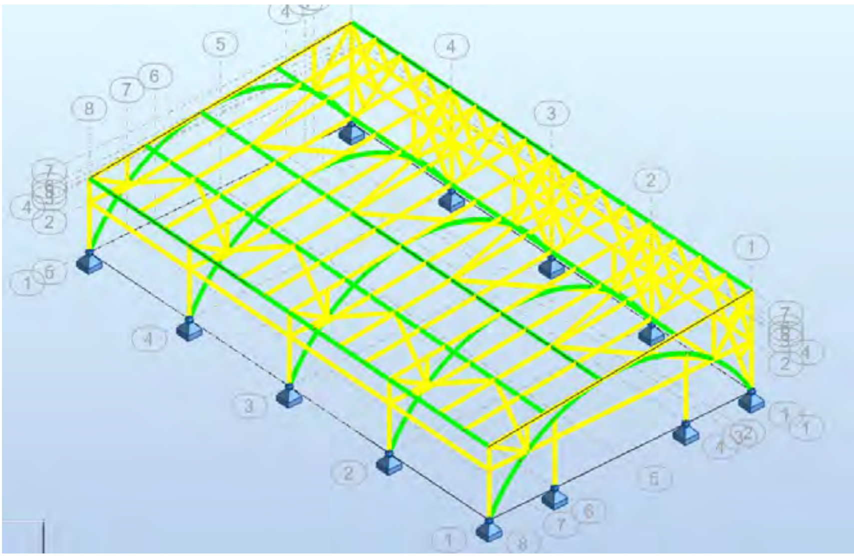

Figure 24. Usage ratio per elements

Table 9. Maximal usage ration per elements

	Purlins	Secondary beam	Primary beam (arch)	Bracings
Numerical	0.251	0,804	0.605	0.420
FEM	0,278	0,772	0.671	0.548

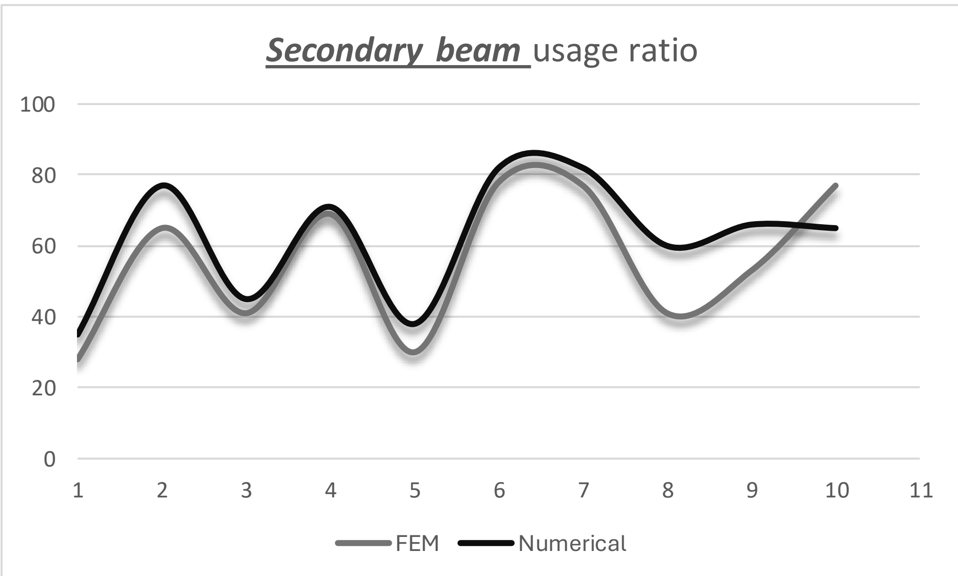

Figure 25. Secondary beam usage ratio

4. CONCLUSION

In conclusion, the comparative analysis between numerical methods and Finite Element Method (FEM) approaches in the design of glulam structures reveals a striking similarity in outcomes. Despite the intrinsic differences in their procedural frameworks and computation intricacies, both methodologies have demonstrated remarkable consistency in the results obtained for the structural design of glulam assemblies. This convergence underscores the reliability, robustness, and complementary nature of both strategies in navigating the complex engineering challenges posed by such constructions. The numerical method, with its direct and often simplified approach, offers an intuitive understanding of structural behavior, making it a valuable tool for preliminary assessments and educational purposes. On the other hand, the FEM provides a more detailed and nuanced insight into the structural responses under various loading conditions, thanks to its ability to model complex geometries and material heterogeneities with greater precision. The near-identical performance predictions by both methods not only validate their individual effectiveness but also highlight their potential for synergistic application in the engineering workflow. By leveraging the strengths of both numerical and FEM analyses, engineers can achieve a more comprehensive and reliable design process for glulam structures, ensuring structural efficiency, economy, and safety. This alignment of outcomes from both methodologies reinforces the confidence in modern engineering practices and paves the way for innovative architectural achievements with glulam technology.

REFERENCES

[1] Blass, H. J., & Fellmoser, P. (2004). Design of solid wood panels with cross layers. Journal of Structural Engineering, 130(8), 1165-1174.
[2] European Committee for Standardization. (2004). Eurocode 5: Design of timber structures - Part 1-1: General common rules and rules for buildings. Brussels: European Standard EN 1995-1-1.
[3] Fortino, S., Toratti, T., & Milani, T. (2009). Finite element analysis of glued-laminated timber beams. Engineering Structures, 31(3), 645-655.
[4] Fragiacomo, M., Menis, A., & Clemente, I. (2018). Advanced numerical modeling of glued-laminated timber structures. Journal of Structural Engineering, 144(3).
[5] Gere, J. M., & Timoshenko, S. P. (1997). Mechanics of materials (4th ed.). Boston, MA: PWS Publishing Company.
[6] Gustafsson, P. J., & Ormarsson, S. (2009). Numerical analysis of moisture-related distortions in timber structures. Journal of Wood Science, 55(5), 337-344.
[7] Kandler, G., Fink, G., & Kohler, J. (2016). Reliability of timber structures under natural and model uncertainties. Engineering Structures, 117, 263-271.
[8] Smith, I., Landis, E., & Gong, M. (2003). Fracture and fatigue in wood. John Wiley & Sons. Thelandersson, S., & Larsen, H. J. (Eds.). (2003). Timber engineering. John Wiley & Sons.
[9] Zhou, F. H., & Gong, M. (2005). Finite element simulation of glued-laminated timber beams. European Journal of Wood and Wood Products, 63(6), 409-415.
[10] Autodesk. (2019). Robot Structural Analysis Professional. [Software]. Available from https://www.autodesk.com/products/robot-structural-analysis/overview.
[11] Zink, A. G., & Davidson, R. W. (2011). Comparative analysis of elastic and mechanical properties in engineered wood beams with varying adhesives. Journal of Materials in Civil Engineering, 23(10), 1421-1428.

Membrane and Bending Behavior of Plates and Shells using FEM approach focusing on Form Finding Concept

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This research focuses on the membrane and bending behavior of plates and shells, employing a Finite Element Method (FEM) approach with a primary focus on the Form Finding concept. The study begins by presenting general information about shells, encompassing their fundamental characteristics, geometrical considerations, and the exploration of diverse shapes in shell structures, providing insights into their behavior. Another aspect of this study is the Concept of Form Finding, where the exploration of shapes and structural configurations takes center stage. The application of Form Finding in the context of FEM is explored, emphasizing its significance in optimizing the structural performance of shell structures. Furthermore, it discussed distribution of forces on shell structures, employing both analytical and numerical methods using SAP2000 software under various loading conditions. In essence, this research provides a holistic exploration of membrane and bending behavior in plates and shells, emphasizing the Form Finding concept. The integration of analytical and numerical methods, particularly with SAP2000, enhances the understanding of force distribution, contributing valuable insights to the optimization of shell structures in practical applications.

Keywords: *Finite Elements, Membrane Behavior, Bending Behavior, Form Finding, Shell Structures.*

1. INTRODUCTION

Plates and shells are initially flat and curved surface structures, respectively, whose thicknesses are slight compared to their other dimensions. Plates may be classified into three groups: thin plates with small deflections, thin plates with large deflections, and thick plates. According to the criterion often applied to define a thin plate (for purposes of technical calculations), the ratio of the thickness to the smaller span length should be less than 1/20. Ascertaining the distribution of stress and displacement for a plate subject to a given set of forces requires consideration of the basic principles, pertaining to certain physical laws, material properties, geometry, and surface forces. These conditions are used to solve the bending problems of plates in the paper to follow.

The fundamental assumptions of the classical or the Kirchoff theory for elastic, thin plates are based on the geometry of deformations. They may be stated as follows:

1. The deflection of the midsurface is small compared with the thickness of the plate. The slope of the deflected surface is therefore very small, and the square of the slope is a negligible quantity in comparison with unity.

2. The midplane remains unstrained subsequent to bending.

3. Plane sections (mn) initially normal to the midsurface remain plane and normal to that surface after the bending. This means that the vertical shear strains γxz and γyz are negligible. The deflection of the plate is thus associated principally with bending strains. It is deduced, therefore, that the normal stain σz. resulting from transverse loading may also be omitted.

4. The stress normal to the midplane, σz, is small compared with the other stress components and may be neglected. This supposition becomes unreliable in the vicinity of highly concentrated transverse loads.
Curved surface structures are termed thin shells, to describe the shape of a shell, we need only know the geometry of the midsurface and the thickness of the shell at each point. Shells of technical significance are often defined as thin when the ratio of thickness t to radius curvature r is equal to or less than 1/20. For thin shells of practical importance, this ratio may be 1/1000 or smaller.
The major thin-shell structures include concrete shell structures, often cast as a dome, bridge, or saddle roof; lattice shell structures, so-called gridshell structures, usually in the form of a dome or hyperboloid structure; membrane or fabric structures and other tensile structures, cable domes, and pneumatic structures. The thin-walled shell structures have more strength with respect to their self-weight and high stiffness, they are gaining in popularity in areas where there is risk of earthquake and hurricane. The analysis of shell-like structures often embraces two distinct, commonly applied theories. The first of these, the membrane theory, usually applies to a rather large part of the entire shell. A membrane, either flat or curved, is identified as a body of the same shape as a plate or shell but incapable of conveying moments or shear forces. In other words, a membrane is a 2D analog of a flexible string with the exception that it can resist compression. The second, the bending theory or general theory, includes the effects of bending. Thus, it permits the treatment of discontinuities in the stress distribution taking place in a limited region in the vicinity of a load or structural discontinuity. However, information relative to shell membrane stresses is usually of much greater practical significance than the knowledge of the bending stresses. The former are also far simpler to calculate.

2. CONCEPT OF FORM FINDING

2.1.Form finding models.

In the design of shell structure configurations, the external loads, internal forces and displacements of the structure must be considered simultaneously in three dimensions. The sustainable approach for the shaping of those continuous surface systems is by the application of form-finding techniques. For a long time, the form-finding was exclusively done through construction of the precise scale physical models. Those physical experiments remain important and useful medium of the design exploration in the early stage of the design process and education, facilitating architects to be directly included in the design process of surface structures. The application of physical models was suppressed by the development of the computational analyses, especially using finite element analysis (FEA). Computational form-finding tools usually simulate behavior of physical models, striving to overcome restrictions of manual experiments by the application of more efficient, reliable, and precise computational simulations.

Independently from the applied medium, the form-finding can be used for conceiving and testing of design solution, comprehension of load transfer, estimation of the stresses and deformations. The form-finding is an iterative process in which structurally rational forms are obtained through incremental adjustments of form, forces, supports, material, thickness, etc.

2.1.1. Inverted models

Form-finding processes are commonly based on: – principle of the inverted hanging model and – concept of stress control. Both principles could be realized by physical and computational

tools. The forms of the first thin shells built in the beginning of the XX century are realized mainly by the application of the simple geometric shapes (spheres, cylinders, parabolic shapes, hyperbolic paraboloids, rotational hyperboloids, etc.) and known relations between span and curvatures. Although development of lightweight structures in certain way stimulated engineers to investigate, the application of the simple forms was partly due to the fact that the calculations could be only conducted for the analytically defined geometries. However, those geometries cannot provide exclusively membrane state of stress, causing the need to introduce additional elements such as edge beams, diverse kind of stiffeners, prestressing, etc.
The hanging models are based on the specific behavior of catenary, which were applied for the design of the concrete shells from the middle of the XX century. They are used in the simulation of hanging structures, which shape emerges as a response to the magnitude and the position of the forces acting on them. Contrary to the common procedure in which a structure is determined for the previously defined shape the inverted hanging model procedure implies that: assigning several geometric parameters such as span, height, load and desirable stress and displacement constraints, initiates finding of the natural equilibrium shape. Shells achieve the stiffness only if their form provides membrane state of stress that is in an equilibrium with the external forces. For example, the chain hanged between two points loaded by the concentrated force in the middle position will take "V" shape, while under the equally distributed load it will take parabolic shape. While the hanged chain represents tensioned element, an arch obtained by the inversion represents a compression structure. Placing chains in two directions results in a cable net that approximates surface, and its inversion gives vaults and shells. In these systems the impact of the self-weight does not cause banding, influencing efficient use of the material and facilitating application of thin structural elements, frequently without the need for pre-stressing (Figure 1).

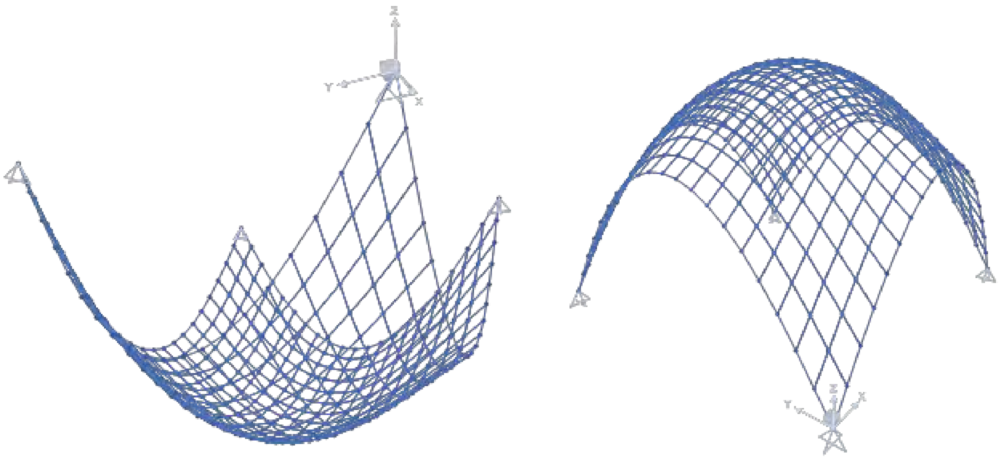


Figure 26. Illustration of the principle of the inverted hanging model

3. DISTRIBUTION OF FORCES

The first problem overviews the so-called *hoop* force Nθ and the *meridional* force Nφ which are distributed on the spherical shell and are analysed with the equations below. The initial geometry of the shell is a spherical shell with a radius of $10m$, thicknes $t=0.2m$ *C30/37* and loaded with the distributed force $q=10kN/m^2$.

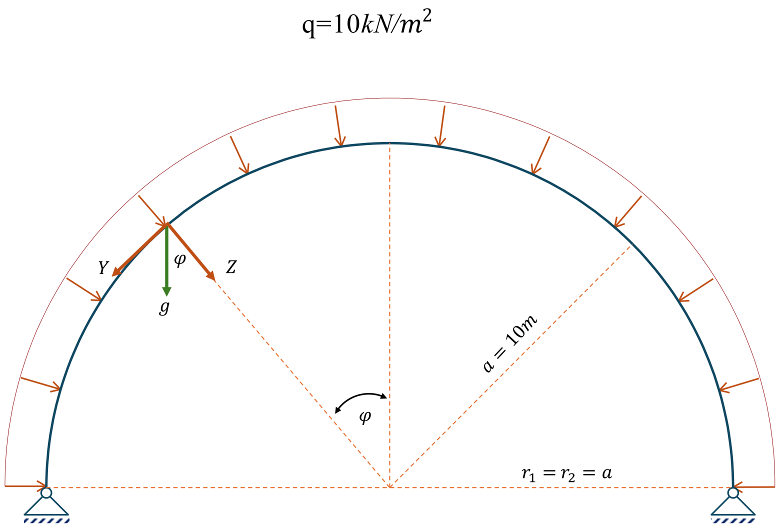


Figure 2. Spherical shell

$$N_{\varphi} = -\frac{1}{r_2 \sin^2 \varphi}\left[\int r_1 r_0 (Z\cos\varphi + Y\sin\varphi)\, d\varphi + C\right] \quad (1)$$

$$N_{\theta} = -N_{\varphi}\frac{r_2}{r_1} - Zr_2 \quad (2)$$

The same problem is analysed with the software SAP2000 modeled with finite elements, and the analytical results compared to those from the software are almost identical.

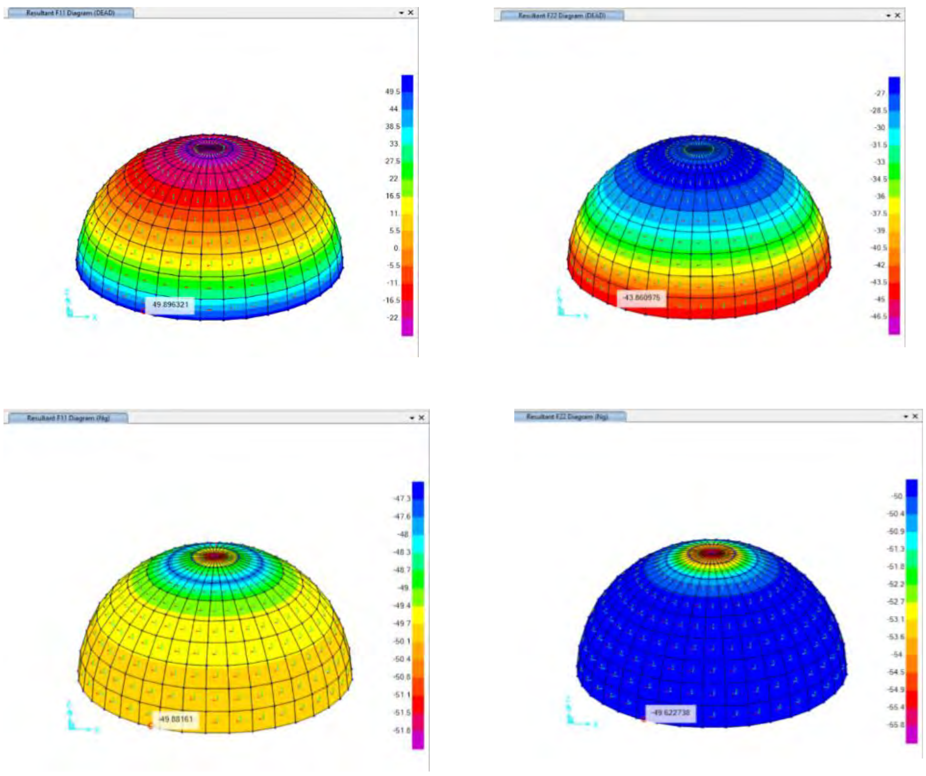
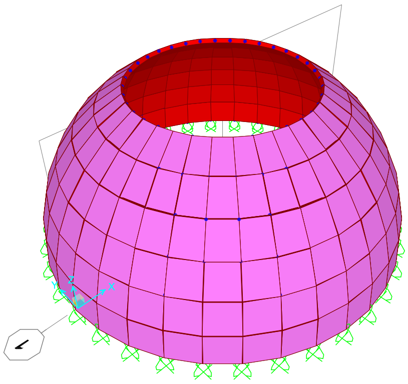
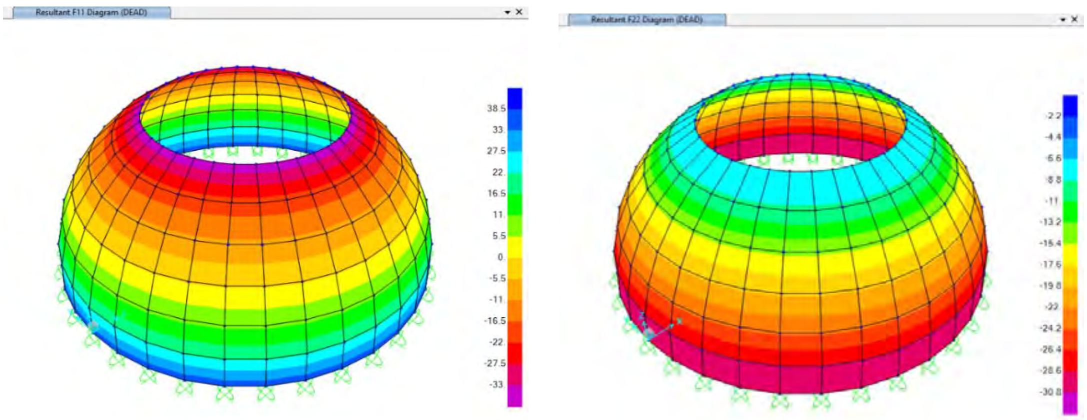


Figure 3. Spherical shell analysed with SAP2000

The other example is another spherical shell analysed with SAP2000 which has a radius of 8m and a thicknes of t=0.2 and material C30/37 and an opening in the top. The problem is analysed only frome the dead load of the sphere and the bending and membrane behavior are ilustrated below.





` **Figure 4.** Membrane behavior

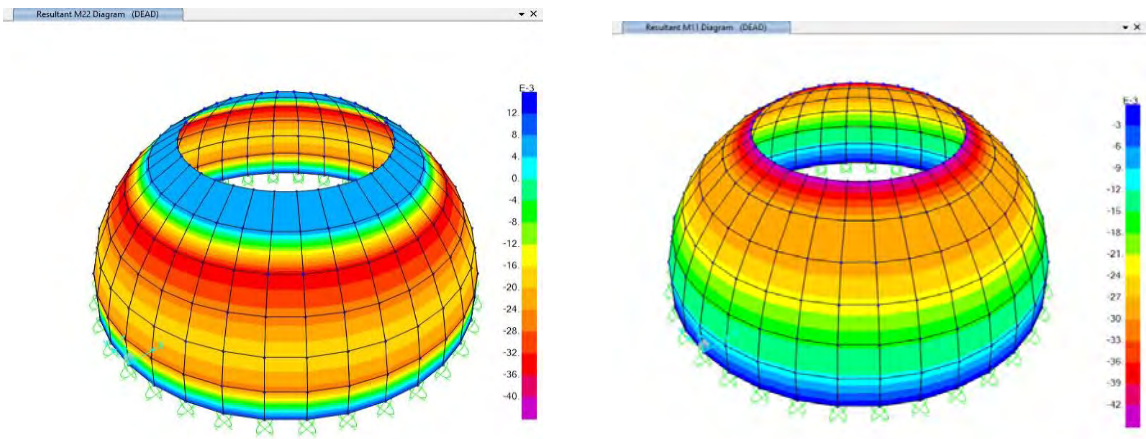


Figure 5. Bending behavior

The membrane theory cannot, in all instances, provide solutions compatible with the actual conditions of deformation. This theory also fails to predict the state of stress at the boundaries and in certain other areas of the shell. These shortcomings are avoided by application of bending theory, considering membrane forces, shear forces, and moments to act on the shell structure.

4. CONCEPT OF FORM FINDING ILUSTRATED WITH SAP2000

Based on information of the structural performances the objective of the form-finding process is to find the satisfactory shape through the process of the modification of the initial geometry. The initial geometry in this experiment is a 20m square flat plate. The thickness of the plate is 15 cm. The initial geometry is modeled using finite elements in both directions of the plate.

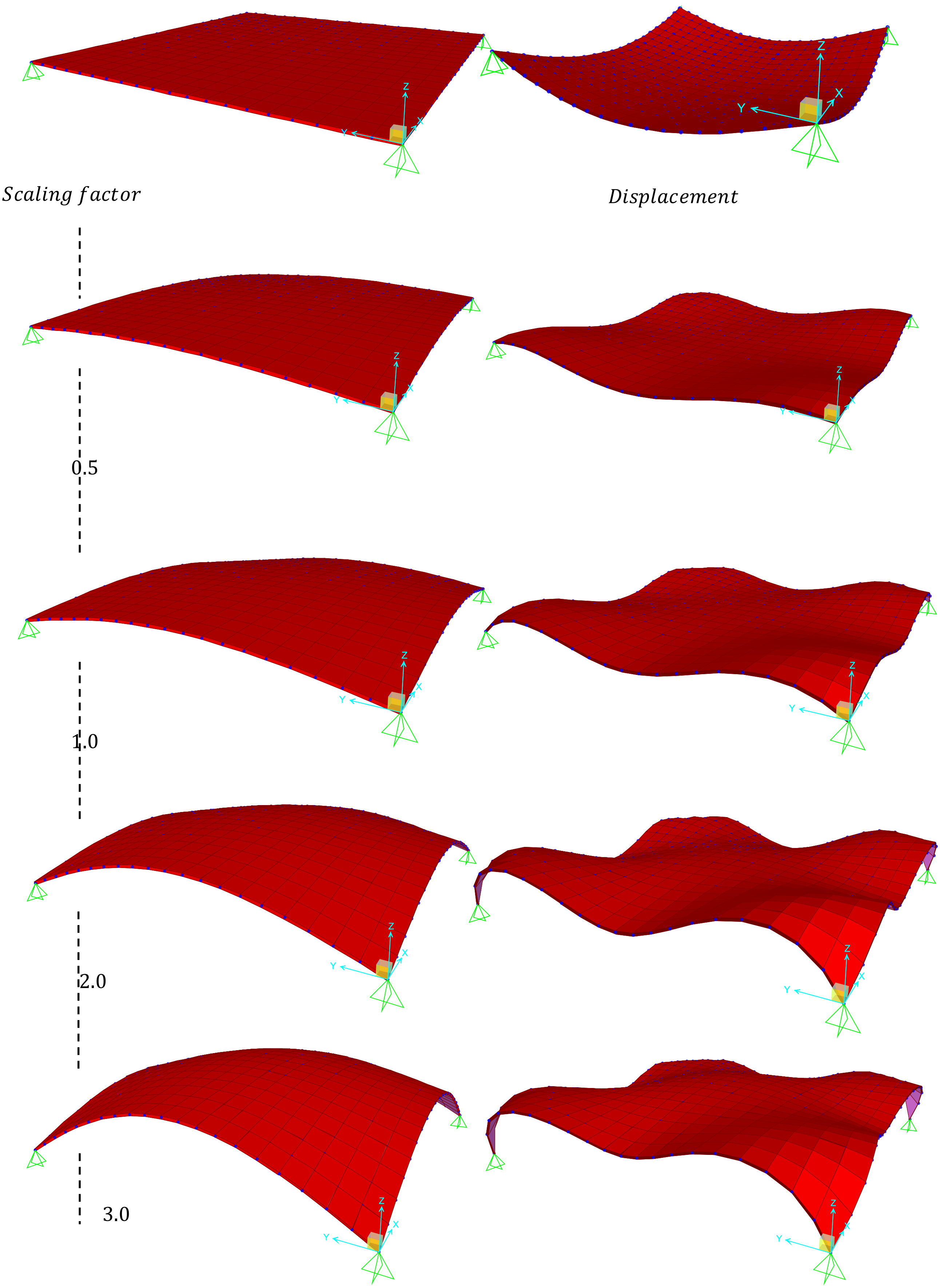


Figure 6. Variant forms obtained by application of the inverted displacement principle

5. CONCLUSION

In conclusion, the study of bending and membrane behavior in plates and shells is essential for understanding how these structures deform and respond to external forces. Bending behavior involves the flexure of a structure due to applied loads, while membrane behavior focuses on the distribution of stresses within the surface. Together, these phenomena play a critical role in the design and analysis of various engineering structures, from buildings to aerospace components, ensuring their safety, efficiency, and durability.
On the other hand, computational form-finding experiments represent a useful tool that supports designs in the conceptual phase and the medium of communication between architects and engineers in the collaborative process. By mimicking natural processes or employing computational algorithms, form finding enables the creation of elegant, structurally optimized shapes that minimize material usage and maximize performance.

REFERENCES

[1] Timoshenko S.: Theory of plates and Shells, New York,1965.

[2] Ansel C. Ugural: Plates and Shells, Theory and Analysis, fourth edition

[3] Zienkiewiecz O.: The Finite Element Methods, McGraw-Hill, New York, 1987.

[4] ARGYRIS, J., ANGELOPOULOS, T., AND BICHAT, B. A general method for the shape finding of lightweight tension structures. Computer Methods in Applied Mechanics and Engineering 3, 1 (1974)

[5] Adriaenssens, S., Block, P., Veenendaal, D., Williams, C.: Shell Structures for Architecture: Form Finding and Optimization, Routledge, 2014.

[6] Zalewski, W., Allen, E.: Shaping Structures, John Wiley & Sons, 1998

AutoCAD Scripting for Efficient Spatial Design and Drafting

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This research is about extension of an automated computational design process, by bridging the gap between initial spatial planning and detailed CAD drafting. Here we introduce an approach to transform Graphical User Interface (GUI) generated layouts into precise CAD drawings. The method is illustrated through proposing an algorithm which develops the executable code-lines for the implementation of AutoCAD scripting automation for architectural plan layouts. The implementation is done using environment of Python software in PyCharm editor. The automation is categorized into various drawing stages taking into account all possible drafting details. This is done to perform a professional output as close as possible to a manual drawn plan by a human. In the end of this study, it is presented the final output of the prepared algorithm. In addition, the accuracy of the final drawing and computational time are evaluated.

Keywords: *Architectural Design Optimization, AutoCAD Scripting, Spatial Layout, Generative Design, Python Programming Language*

1. INTRODUCTION

In contemporary architectural practice, the shift from conceptual drawings to detailed drafting represents a critical stage in the design process. Professional designers often face challenges during this transition, including the considerable time consumption and the potential for errors inherent in manual drafting methods. This phase requires attention as professional designers attempt to embody their visionary concepts within concrete, CAD-based blueprints pivotal for guiding construction.

Addressing the importance for efficiency and accuracy in architectural design workflows, recent studies have explored various approaches to automate the generation of architectural plans [1, 2, 3, 4, 5]. However, many of these efforts have focused primarily on generating automated plans from scratch, neglecting the potential for using existing graphical user interface (GUI) layouts. This oversight identifies a gap within current research, prompting an approach of translating GUI-generated layouts directly into CAD drawings.

This research study develops an AutoCAD script that provides a streamlined solution to the time-consuming task of drafting architectural plans. The scripting methodology proposed enhances the efficiency and accuracy in the design process, allowing architects to devote more time to creative exploration and problem-solving. Contrary to initiating designs from scratch, the proposed approach capitalizes on the preliminary spatial configurations conceived through GUI interactions, ensuring the preservation of the original conceptual essence whilst facilitating an automated transition to CAD drafts.

The essence of the study focusses on the use of AutoCAD scripting to facilitate the translation of GUI layouts into precise CAD drawings. AutoCAD scripting offers a flexible and efficient means of automating repetitive tasks within the AutoCAD environment [6]. To develop scripts in AutoCAD, a simple text editor like Notepad [7] or an advanced Auto LISP editor like Visual LISP can be used. Once the script is generated, it can be seamlessly integrated into the AutoCAD workflow, either through the "SCRIPT" command or by directly dragging and dropping the script file into the workspace.

2. MATERIALS AND METHODS

2.1.AutoCAD Scripting Definition

AutoCAD scripting represents a fundamental aspect of automating tasks within the AutoCAD environment, offering users the ability to streamline repetitive processes and enhance productivity. At its core, AutoCAD scripting involves the generation of custom scripts, which are essentially sequences of commands that instruct AutoCAD to perform specific actions. These scripts can range from simple tasks like drawing geometric shapes to more complex operations such as generating architectural plans or performing advanced analysis.

One of the main advantages of AutoCAD automation is its ability to reduce the manual effort required to execute repetitive tasks. By encapsulating sequences of commands into reusable scripts, users can eliminate the need to manually execute each step of a process, saving significant time and effort. This is particularly beneficial in architectural design, where tasks as drawing floor plans, elevations, and sections often involve repetitive actions that can be automated through scripting.

Moreover, AutoCAD scripting empowers users to customize their design workflows according to their specific needs and preferences. By making custom scripts tailored to their unique requirements, architects can optimize their design processes, improve efficiency, and maintain consistency across projects.

2.2.Basic Scripting Concepts

In AutoCAD scripting, commands serve as the primary mechanism for instructing the software to perform specific actions. A command in AutoCAD is essentially a predefined function that executes a particular operation, such as drawing a line, inserting a block, or setting a layer. Understanding how commands work is essential for generating effective scripts to automate tasks within AutoCAD.

When scripting with Notepad, the procedure consists of writing a sequence of commands in a plain text file and saved using “.scr” extension. Each command is written on a separate line and may be preceded by an optional comment that begins with a semicolon (;).

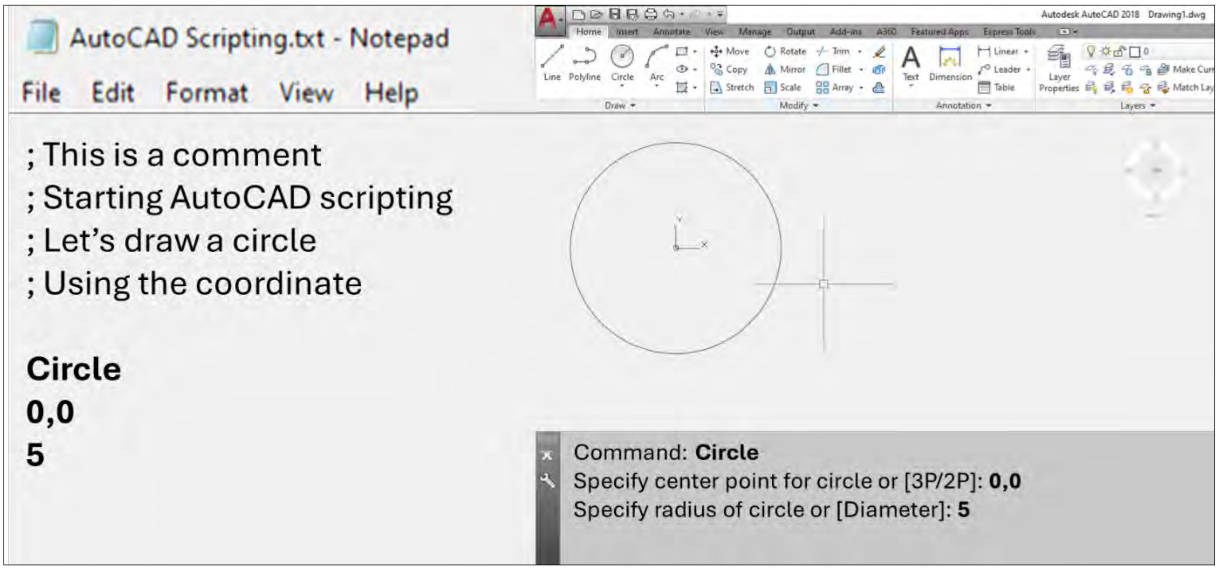

Figure 27: Script preparation in Notepad

As shown in figure 1, the script begins with a few comments followed by the “Circle” command, which activates the circle function in AutoCAD by specifying its center coordinate at point (0,0) and radius 5 units.

Commands in AutoCAD scripts can include parameters that specify additional information required for the command to execute correctly. For instance, the LINE command accepts two sets of coordinates to define the start and end points of the line. Parameters are typically separated by commas or spaces, depending on the command syntax.

By mastering the use of commands in AutoCAD scripts, users can generate powerful automation tools to streamline their design workflows. Whether it's generating complex geometries, modifying existing drawings, or performing batch operations, commands are the building blocks of efficient scripting in AutoCAD.

2.3.Preparing CAD Environment

Before scripting architectural plans in AutoCAD, it's crucial to ensure that the CAD environment is properly configured to facilitate smooth execution of scripts. Following this, all groups or layers are cleared to ensure that the script runs smoothly when updating the new drawing. The "purge" command is used to clean out any unnecessary elements from the drawing file. Once the workspace is emptied, it is ready to begin the new design in the AutoCAD software. This preparation of the work environment establishes a clean basis for the next design layout.

2.4.Recalling sets of drawings

One of the main challenges while automating the AutoCAD drawings is to understand the difference between scripting and manual tasks. The commands such as “Click”, “Select” are very crucial but yet difficult to be automated unless the right procedure has been utilized.

Therefore, the selection of multiple and separate drawings may be needed in specific cases. To achieve this task, the procedure of grouping is used in our methodology. Hence, each of the objects which is supposed to be recalled later is assigned to a group-name thus making possible the selection and any possible modification of that specific set of drawings.

2.5.Categorization of drawings into layers

The usage of multiple layers in AutoCAD generally is a well-known process to keep the drawings organized. Nevertheless, for the automation procedure, we will implement the utilization of layer categorization also to avoid possible errors. It has been observed that in some cases the script will fail to run successfully due to overloaded drawings in the working space [8]. To eliminate this issue, once a category of drawings is finalized, the script will automatically keep all layers turned off except the one which is under execution. This method is seen as a good solution approach to fix this problem.

2.6.Styling

For accomplishing a good yet professional architectural plan, it is needed to adopt the CAD automations as much as possible to match human drawings. The set of properties such as color, transparency, hatch, line weight, and line types are essential to make the difference. Accordingly, the script prepared for this task has specific code lines to handle with this process according to user preferences.

2.7.Implementation of Automation

Writing lines of codes for AutoCAD scripting means in simple words replicating various AutoCAD commands by following sets of rules and constraints. However, this would still be a very tedious and time-consuming procedure to be done manually. Therefore, the entire script steps are prepared in the environment of Python programming language [9] using the PyCharm editor [10].

3. ANALYSES AND TEST

The configuration of the entire procedure is divided by architectural plan categories presented as follows so the script can be tested and analyzed in various functions.

3.1. Outer and Inner Walls

As the coordinates and parameters and previously defined by another stage, it is important to adopt and convert these coordinates and parameters into real drawings inline with architectural code of aesthetic. As shown in figure 2, the outer and inner walls are drawn by considering multiple steps. For instance, the first step is to adopt the coordinates for the external line of the outer wall. Further, the internal line is implemented by utilizing the offset command in AutoCAD by the script. Later hatch is applied to the area between the lines which are selected by using the utilities of recalling using group name.

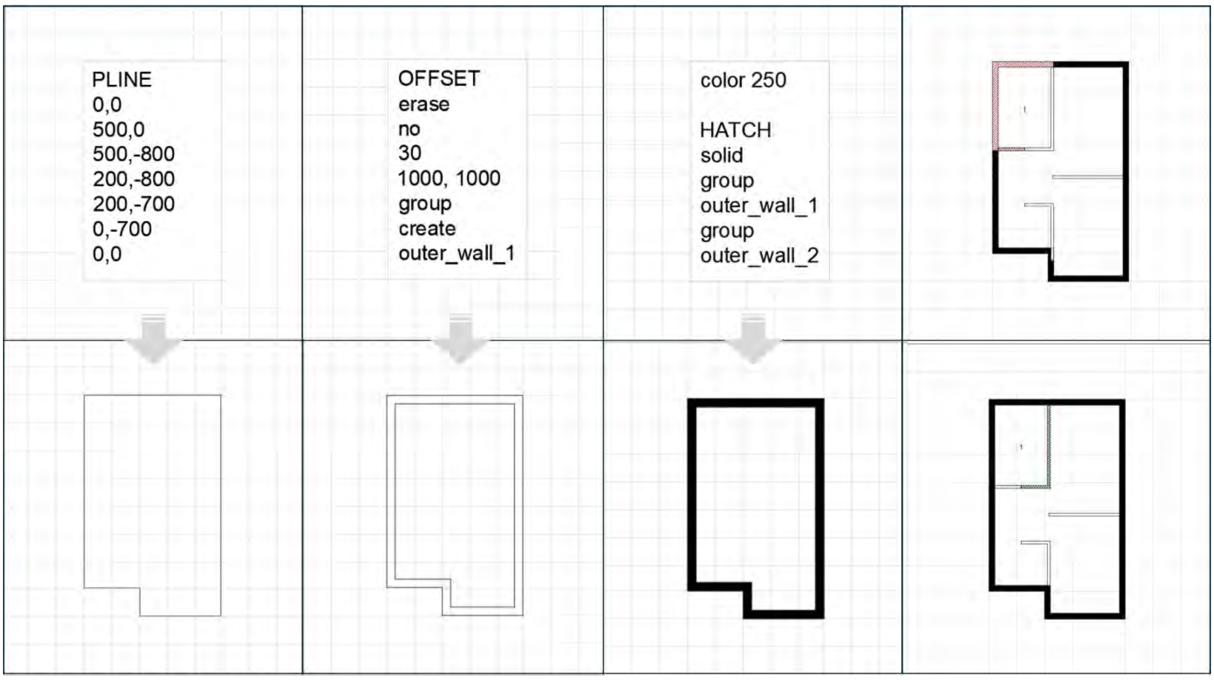

Figure 28: Sequential execution of commands to script the drawing stage of outer and inner walls

Simultaneously the code is modified and tested for the inner walls drawing as shown in the figure above.

3.2. Doors and Windows

The drawing of doors and windows takes into account more complex methods compared to outer and inner walls. We have configured our algorithm to consider various preferences from user/architect for the implementation of this stage. As the need to have different designs of these objects, script integration is utilized based on template drawings. For this task, the script gets sets of groups predesigned and allocates them into the corresponding location of coordinates. Figure 3 demonstrated the example of allocating windows into the plan.

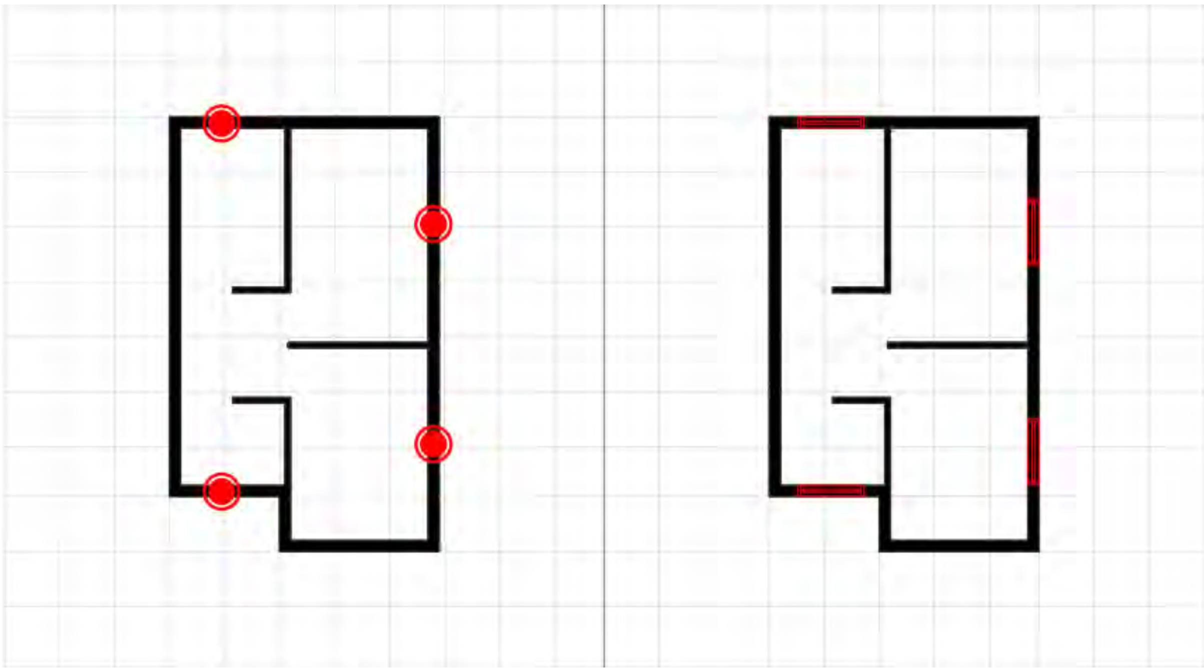

Figure 29: Representation of calculated coordinates for the arrangement of the window block

On the other hand, the doors need to be analysed in more details. The location and point of reference must be associated with correct orientation of each of the doors depending in the direction of the rooms. As shown in Figure 4, among eight ways of door orientation, only one would be acceptable. In this way, the algorithm decides automatically which must be used in any room orientation of the plan layout.

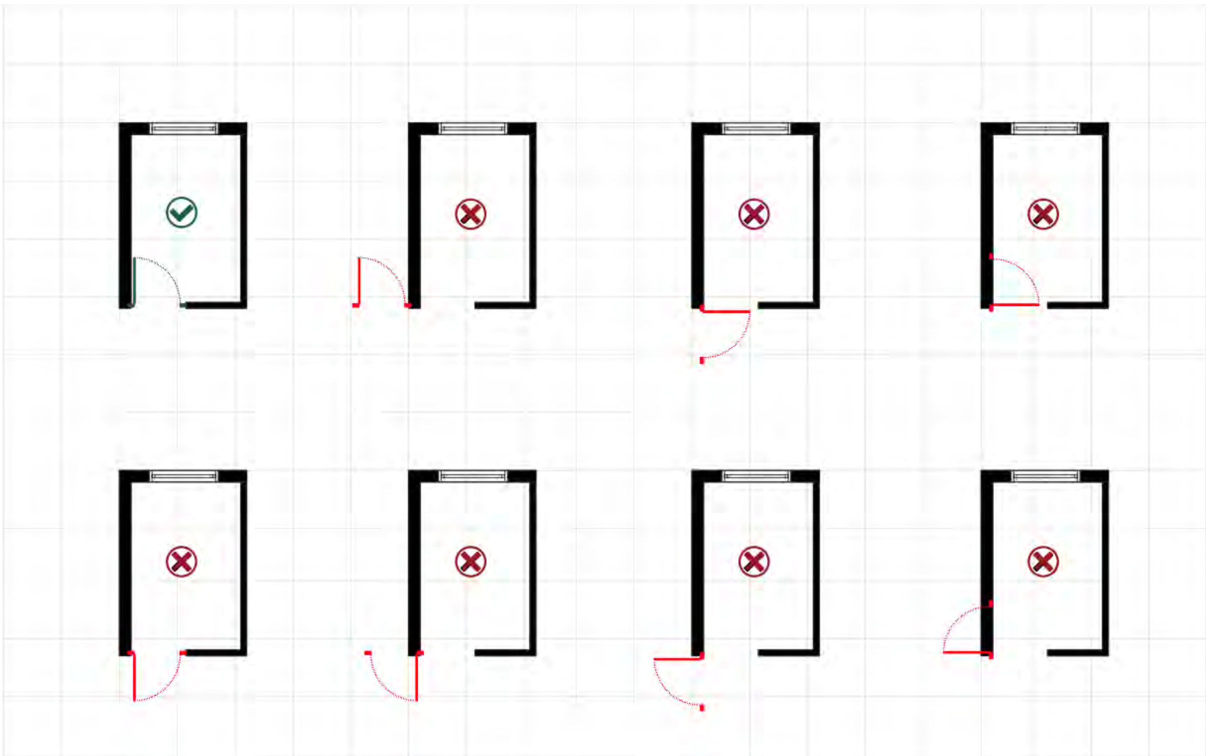

Figure 30: Possible orientations of the door for the first corner in one room

3.3. Furniture

Indeed, the most challenging stage of AutoCAD automation for the method we are proposing is the drawing phase of furniture and properly allocating them into each of the rooms of the plan. It is crucial to recognize that each room have a different set of furniture. Moreover, the allocation of the furniture must be set carefully in each side of the room. The mirroring is also an important step to be considered in the constrains of the algorithm, so the furniture doesn't face the wall but the room space. Additionally, the location of some furniture (for example garderobe or refrigerator) cannot be in the same side of room where the window is placed whereas some of them (for example sofa) can be flexible.

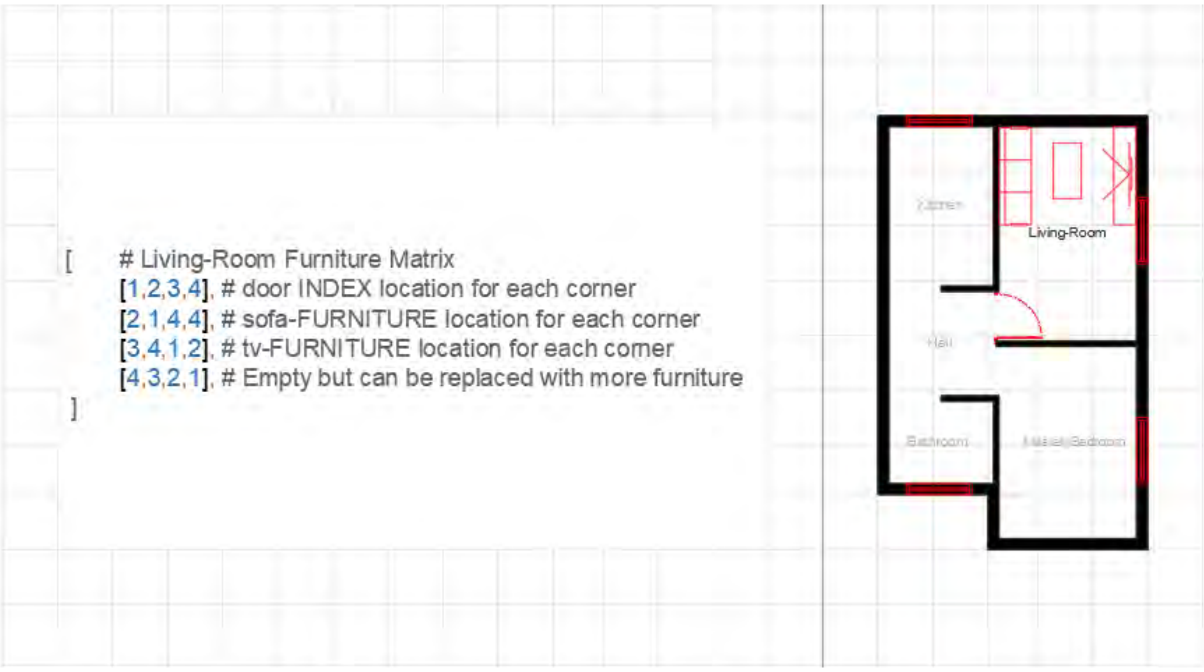

Figure 31: Sample of a part of the matrix used for the definition of rules and constraints for furniture and doors.

Therefore, we have configured the algorithm in a sophisticated way to accept each of the furniture based on a matric of constrains. The matric is one for the fundamental elements of the algorithm for a proper allocation of drawings. Simultaneously, the scaling must be set accordingly to match the variable width of the space/room. Figure 5 illustrates this step in more details.

3.4. Dimensions and Template

Generation of the dimensions is done based on various calculations. Each of the external wall coordinate is initially filtered and ordered. Additionally, the style of the dimensions is saved in the algorithm as default value which can be customized by the user/architect anytime. As shown in Figure 6 (left), the dimensions are demonstrated in the left side of the plan. Similarly, dimensions in the other side of the plan are generated by the script and assigned in dimension layer.

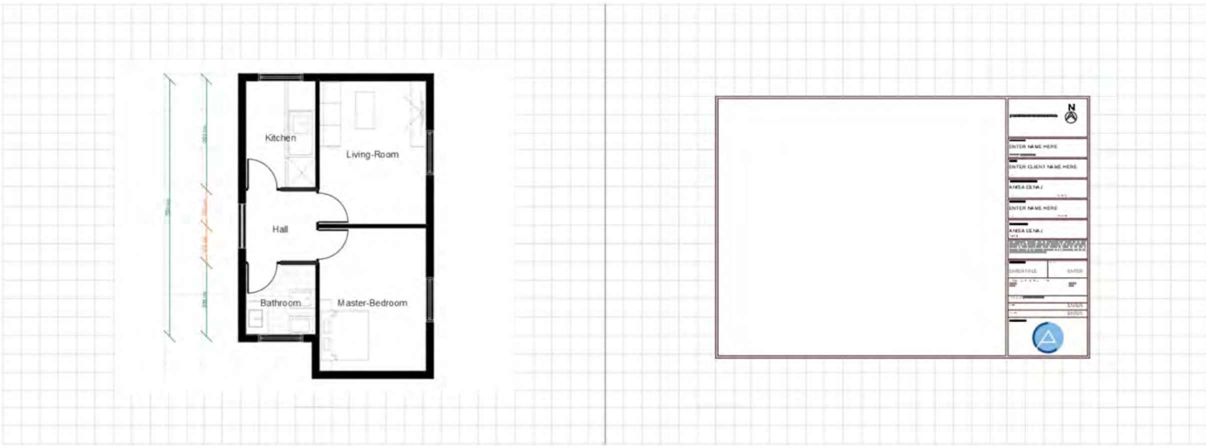

Figure 6: (In the left) illustration of the dimensions, (In the right) Demonstration of the arrangement of the template

The concluding part of the algorithm relies on the drawing of the plan template which must enclose the entire plan in addition to the margins as shown in figure 6, right.

4. RESULTS AND CONCLUSIONS

The script is finally saved as hundreds of code and command lines from our algorithm. Additionally, it can be imported from AutoCAD or simply access the drag and drop facility of the software. As shown in Figure 7, the final result is free of errors and mistakes. Every single category of drawing is allocated in its corresponding location. The doors and windows are oriented properly while each of the furniture is scaled and aligned based on the space dimensions.

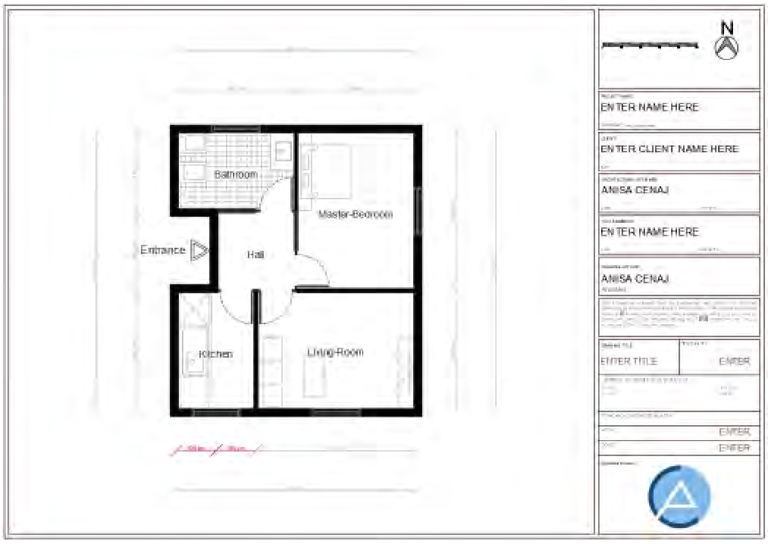

Figure 7: Finalized version of the AutoCAD drawing

In cases when multiple furniture is to be aligned next to each other, it is shown that there is no overlapping or gap in between them. This is another step to confirm the accuracy of the automated drawing when triggered properly.

The methodology on the algorithm presented in this study shows an excellent example of implementation for the AutoCAD drawing automations when thousands of plans are to be prepared in just a fraction of time. From the output of this study, the entire drawing is prepared in about 0.3 seconds. Such examples are proposed as a powerful tool for architects to facilitate the accuracy of drawings and acceleration of the drafting stage.

REFERENCES

[1] M. Hansmeyer, "Computatuonal Architecture," [Online]. Available: https://www.michael-hansmeyer.com/l-systems. [Accessed 2023].

[2] Katarzyna Grzesiak-Kopec, Barbara Strug, Grazyna Slusarczyk, "Evolutionary Methods in House Floor Plan Design," *MPDI,* no. 8229, p. 14, 2021.

[3] Maciej Nisztuk, Paweł B. Myszkowski, "Hybrid Evolutionary Algorithm applied to Automated Floor Plan Generation," *International Journal of Architectural Computing,* vol. 17, pp. 260-283, 2019.

[4] Nitant Upasani, Krishnendra Shekhawat, Garv Sachdeva, "Automated generation of dimensioned rectangular floorplans," *Automation in Construction,* vol. 113, p. 103149, 2020.

[5] Wamiq Para, Paul Guerrero, Tom Kelly, Leonidas Guibas, Peter Wonka, "Generative Layout Modeling using Constraint Graphs," in *IEEE Xplore*, 2020.

[6] Autodesk, "Autodesk," Autodesk Inc, 2020. [Online]. Available: https://www.autodesk.com/.

[7] Microsoft, "Notepad," Microsoft. [Online].

[8] Marsed Leti, Nertila Syri, Ilirjana Hajdarmataj, Antonela Ndoj, "An innovative and practical solution for the surface and volume computations in land surveying," in *4th International Balkans Conference on Challenges of Civil Engineering*, Tirana, 2020.

[9] P. S. Foundation, "Python," 2021. [Online]. Available: https://www.python.org/.

[10] JetBrains, "PyCharm," 2021. [Online]. Available: https://www.jetbrains.com/pycharm/.

Construction Technology and Management

The silent struggle of mental, physical, and emotional health in the construction industry

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The construction industry plays a crucial role in the development and functioning of societies. Based on this, it faces a variety of challenges, which can be attributed to a combination of internal and external factors. One of these factors, which often is not paid attention to, is related to health issues. While focusing on getting the work done, physical and mental wellness is left behind. As we all know, working in a dynamic environment such as construction, is physically demanding. Safety risks, long hours or weather conditions leave their mark on workers' well-being. In Albania, workers face a heightened risk of injuries daily, primarily attributed to inadequate safety management practices at their workplaces. Despite meticulous documentation of each accident, minimal actions with limited effectiveness are undertaken to enhance the safety of the workers. This paper aims to identify the risks faced, their consequences and strategies or recommendations to improve this situation. To achieve the objectives of this study, a survey was developed and distributed among workers and employees. The collected data was analysed, and the results were used to enhance health and safety of workers. Building itself is undoubtedly challenging, but do not health and happiness pose an even greater challenge? Setting the stigma aside, can we attribute these health issues to a lack of awareness or limited access to opportunities?

Keywords: *Health and safety, Workers, Statistics, Challenges, Construction Industry, Well-Being.*

1. INTRODUCTION

The construction industry plays a crucial role in the progressing and functioning of societies. In recent years, the country's economy has taken a development boost from the construction field, influencing directly or indirectly. According to INSTAT, the construction industry in the fourth quarter of 2023 contributed to the GDP growth by 1.28% compared to the same quarter of the previous year, with the construction industry itself experiencing a growth of 10.8% during this period.[1] Indirectly, the construction industry helps in evolving other economical key sectors, for example in 2023 alone, 59 building permits were issued for hotels and similar facilities, predicting an increase of up to 82,000 square meters of serviceable space by the tourism sector and beyond.[2]

Construction can indeed drive economic growth by creating jobs, stimulating demand for materials and services, and attracting investment. The population employed in this field is considerable, circa 8.1% of employed states' population (Table 1). The significance of employment is more noticeable in the male gender where more than 15% of men in Albania work in construction, whereas less than 1% of women are involved in this sector. [3]

Table 10. Employment structure by economic activity in % (INSTAT,2021)

Economic activity	**2020**	**2021**
Total (number)	1,243,343	1,248,749
Agriculture	36,1	33,8
Manufacturing	11,2	11,2

Construction	**7,0**	**8,1**
Mining and quarrying, Electricity, gas and water supply	2,3	2,6
Trade, transportation, Accommodation and food and business and administrative services, Public Administration, community	27,2	26,6
Social and other services and activities	16,2	17,7

The amount of money earned has made people selfish but not in a good way, the possession of wealth has had a detrimental effect on their behavior or attitudes. By prioritizing the economy, both employers and employees often overlook the most important thing: health. While focusing on getting the work done, physical and mental wellness is left behind.
In Albania, policies and measures to ensure health and safety in the construction sector are minimal and often only emerge after significant incidents. Compared to European countries, this approach is negligible and excludes a long-term perspective for addressing fundamental issues. In this study, we have chosen a personal approach by interviewing individuals involved in this industry through three surveys conducted last month.
Working in the construction industry is physically demanding, making this field one that requires individuals to be in good physical condition and capable of enduring long hours of labor in various weather conditions. When workers put their well-being in a secondary plan, it is easier for them to be harmed at work. Below, we will narrate a specific instance through the confession of a construction worker with 20 years of experience interviewed by us (we will not include the name for privacy reasons). ***X:*** *"While I was handling the concrete pump, as it is known, it gets a bit heavy especially at the 10th hour of work. I was attempting to navigate through the tied rebars and prepare to pour concrete into the 80 cm foundation slab for a seven-story building. In my rush, despite having done this many times before, my foot slipped, and I ended up caught between the bars, sustaining fractures and bruises. It seems fatigue takes its toll at this age; oh, if only I were 20 again..."*

2. MATERIALS AND METHODS

2.1.Economic statistics

For this paper, we used INSTAT (Institute of Statistics in Albana) to get information for economic situation related to construction industry.

2.2.Survey statistics.

We visited several construction sites and design offices after using Google Forms to create three different surveys to gather insights, respectively:
"KANTIER 1" (On Site 1), used for the construction workers. 50 workers were interviewed, mostly aged 40+ years old.
"KANTIER 2" (On Site 2), used for the on site engineers. 30 engineers were interviewed, mostly aged 21-29 years old.
"ZYRA 1" (Office 1), used for the office engineers. 30 engineers were interviewed, mostly aged 21-29 years old.

3. RESULTS AND DISCUSSION

In Albania, workers face a heightened risk of injuries on a daily basis, primarily attributed to inadequate safety management practices at their workplaces. The workers' thirds do not recognize the Health and Safety Engineer at the construction site where they work. (Table 2). Meanwhile, 36.6% of on-site engineers have not done more than 3 technical training sessions during their careers, where 30% have never done one. (Table 3) This result comes as a consequence of justifications such as: "*workers don't need such things because they have experience*", which is immediately contradicted by the result of "Office 1", which shows us that only 33.3% of office engineers are trained before entering the construction site (Table 4).

Table 2. Q: Do you know the HSE at the site where you work?

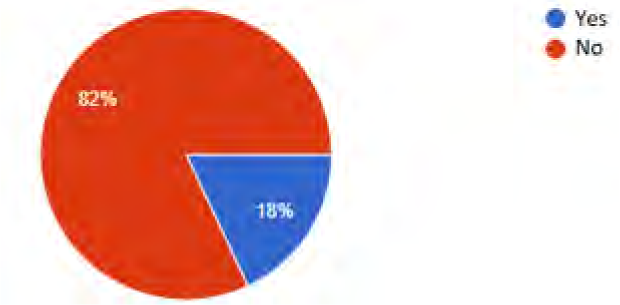


Table 3. Q: Have you ever done technical training for workers? If so, how often?

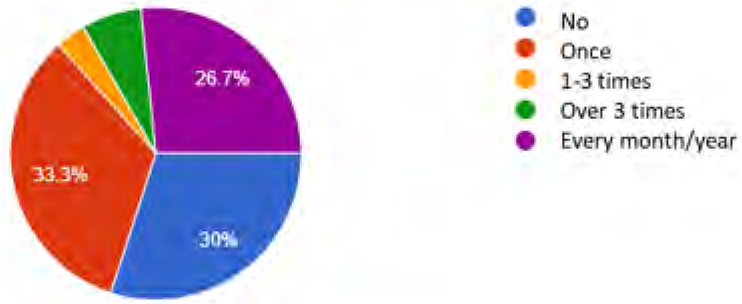
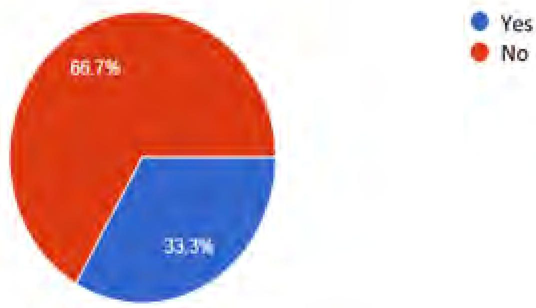
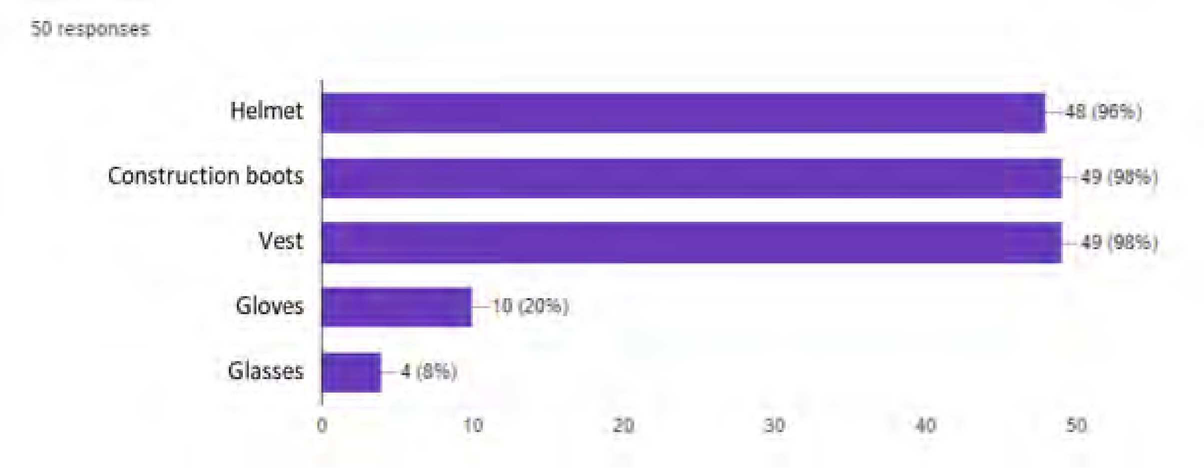


Table 4. Q: Have you participated in any technical training before entering a construction site?



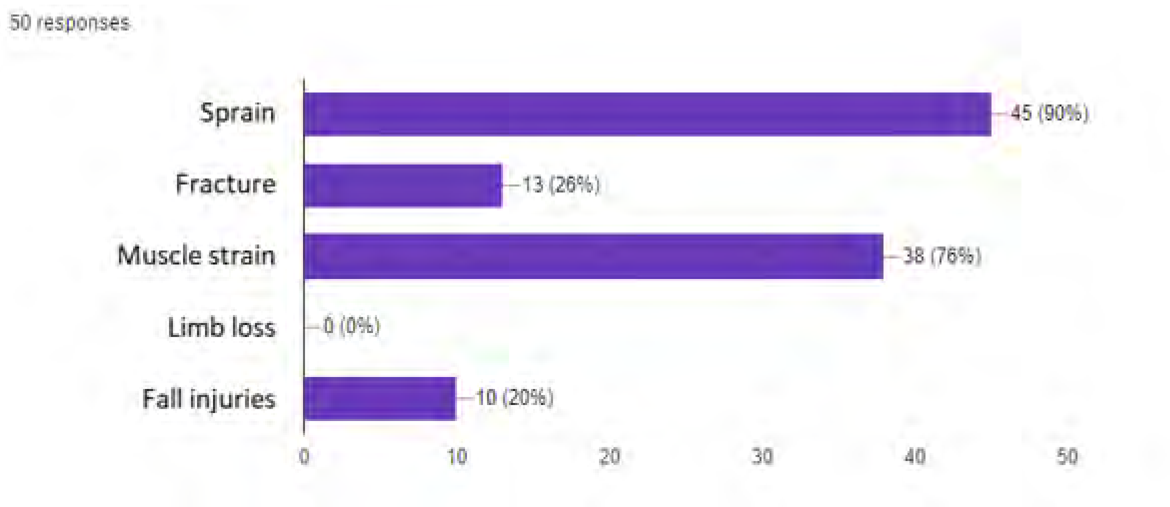
In reality, there is a paradoxical situation regarding the use of PPE. According to surveys, the main equipment such as helmets, construction boots, vests, and gloves are almost always present.

Table 5. Which of these PPE do you use?



However, it appears that the equipment does not directly contribute to reducing the injuries suffered at work, as even workers who use this PPE still experience injuries such as sprains, muscle strains, injuries from falls, and various fractures.

Table 6. What are the injuries that happened to you?



From all three surveys, it has been observed that both engineers and workers visit the doctor quite significantly in the Albanian reality. However, the stigma of neglecting self-care becomes apparent when it comes to visiting a psychologist. Combining the results of all three surveys, the outcome is alarming; only 1 out of 10 respondents have had a session with a psychologist. Only from the comments received regarding questions about how happy they feel at work:

"*Happy, sometimes disappointed*",

"*Routine with good moments and not so good ones*"

"*Sometimes I feel tired and unmotivated to work*", the need for counseling is clearly vital.

The lack of expressing problems to qualified individuals or even to acquaintances themselves leads to a passive approach towards them. By not voicing them out, people may think the problem will go away on its own. Often, they seek solace in temporary calming ways, but with problematic consequences for their future. In Albanian culture, tobacco is known as the best companion, unfortunately, our survey supports this wise saying. Increasing the dose of nicotine and caffeine when involved in the construction industry seems inevitable. Extended hours are a burden for achieving an objective and subjective balance between work, family, and society.

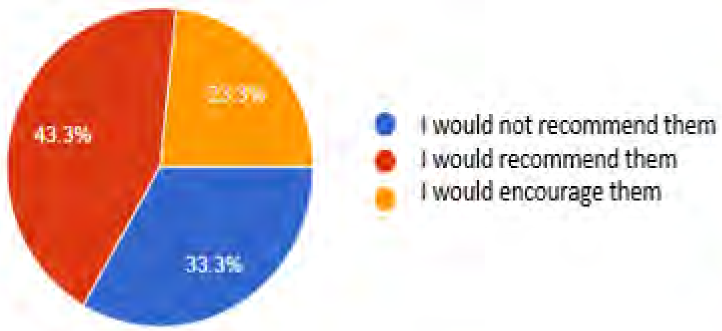
Neglecting social life outside the workplace affects emotional and psychological well-being. Very few construction workers have met new people outside the construction site in recent months, and the same goes for engineers, whose social circle narrows only to colleagues even though they are at a fairly young age. All these combined lead to maximum degradation where almost 100% of the surveyed participants suffer from stress and anxiety.

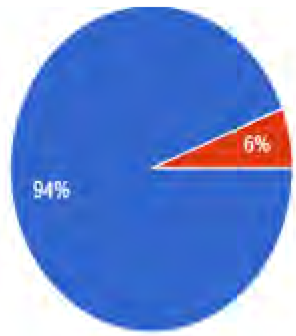
Studies conducted worldwide show a direct link between the desire to go to work and mental well-being [4]. In Albania, salary plays a crucial role in this aspect, where in the question "Are you satisfied with the job you do and the salary you receive for it?", a drastic percentage respond with "no". Also, in the question "Have you considered changing profession?", a high percentage answer "yes". The situation changes only for experienced engineers, who are more satisfied with their work and express that they would encourage their children to follow the same path as them. The difference stemming from the pay is clearly depicted through the comparison of the charts below.

Table 7a) b). How would you recommend your child the profession you practice?

a) Engineers

b) Construction workers





4. CONCLUSION

Construction is one of the most challenging fields where people can work, and changing employees' mindsets to ensure safety on the construction site is equally difficult. Through our survey, we found out that the use of hardware equipment alone is insufficient if there is not a conscious effort through frequent, serious, and honest instructions.

We conclude that emotional and mental problems stem more from a lack of awareness than from a lack of opportunities. Regardless of status or income, we see that the majority of respondents answer the question about their most recent family activity in the same way; rarely, indicating to us that this is a subconscious choice. To be concerned is facing the harsh reality that the majority of surveyed parents have no idea what their children's preferred food is…

To improve the situation, there is no need for complex strategies to be undertaken, but rather simple actions such as conducting similar surveys to ours or having honest conversations. Carefully implemented responses could completely change the situation. Based on the responses from our surveys:

"Implementing flexible working hours and reduced schedules",

"Ensuring payment is made on time and in line with the service provided",

"Respecting clear limitations on working hours specified in the contract would lead to improvement. This would enable a better balance between work and life".

Acknowledging mental health concerns within the construction sector is imperative. Companies must prioritize the well-being of their employees by establishing a nurturing work atmosphere, ensuring accessibility to mental health support services, and advocating for policies that encourage a harmonious balance between work and personal life. Through these endeavors, organizations can empower their workforce to effectively manage mental health challenges, leading to a more thriving and efficient work environment.

REFERENCES

[1] https://www.instat.gov.al/media/13140/pbb-tr4-2023.pdf

[2] https://www.instat.gov.al/al/temat/industria-tregtia-dhe-sh%C3%ABrbimet/nd%C3%ABrtimi/#tab2 Treguesit e lejeve të ndërtimit

[3] https://www.instat.gov.al/media/10066/tregu-i-punes-2021.pdf Tab.1.8 Page.34

[4] https://www.who.int/news-room/fact-sheets/detail/mental-health-at-work

From Drafting Tables to Digital Models: The Revolution of Civil Engineering in Albania

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This research paper presents a comprehensive comparative analysis of building projects pre and post the adoption of Building Information Modeling (BIM) in Albania. The study aims to shed light on the transformative impacts of BIM on architecture, engineering, and construction processes by examining a diverse range of buildings. Through rigorous evaluation of efficiency, accuracy, and overall effectiveness, this research compares BIM against traditional methods prevalent in design and construction phases. Moreover, a survey among 100 Albanian engineers is conducted to gauge their proficiency in various BIM software packages. The objectives of this study include identifying and analyzing differences in project outcomes, efficiency, and design quality between traditionally designed buildings and those leveraging BIM. Additionally, the research evaluates the advantages of BIM in project management, stakeholder collaboration, and sustainable design practices. Furthermore, potential disadvantages or challenges associated with BIM implementation are identified, including barriers to adoption and learning curves. This paper contributes to the growing body of knowledge on BIM's impact on the built environment and offers insights for practitioners, policymakers, and educators seeking to optimize building project workflows in Albania and beyond.

Keywords: *Building Information Modeling (BIM), Construction Efficiency, Design Accuracy, BIM Adoption Challenges, Sustainable Design Practices.*

1. INTRODUCTION

The evolution of civil engineering practices, particularly in Albania, has seen a significant shift from traditional drafting tables to digital models, primarily through the adoption of Building Information Modeling (BIM). This shift has not only revolutionized the way buildings are designed and constructed but has also brought about a need to assess the impacts of such technological advancements on the industry. This study focuses on comparing the traditional methods of civil engineering with the contemporary BIM approaches to understand the benefits and challenges associated with the transition.

2. MATERIALS AND METHODS

2.1 Building Information Modeling (BIM):

2.1.1 What is BIM?

Building Information Modeling (BIM) is a digital representation of the physical and functional characteristics of places. It's a process supported by various tools, technologies, and contracts involving the generation and management of digital representations of physical and functional characteristics of places. This process facilitates the exchange and compatibility of information in digital format. In civil engineering, BIM is particularly valuable as it allows for integrated planning, design, construction, and management of buildings and infrastructure projects.

2.1.2 How BIM was founded in Civil Engineering?

The roots of BIM in civil engineering and construction date back to the 1970s and 1980s with the development of computer-aided design (CAD) systems, but it significantly evolved in the late 1990s and early 2000s. The term "Building Information Model" was first used by Autodesk in the early 2000s, and it marked the beginning of a significant shift towards more integrated planning and project management approaches in the construction industry. Before this point, digital tools were primarily used for drafting and did not facilitate the integrated, collaborative approach that BIM embodies.
BIM's foundation in civil engineering is largely attributed to its ability to streamline the project lifecycle, reduce information loss, and facilitate collaboration among all project stakeholders. By using BIM, engineers, architects, contractors, and clients can all access the same information, ensuring that everyone is working from the most current design. This helps in identifying potential issues early in the design phase, which can reduce costly changes and delays during construction.
The adoption of BIM in civil engineering and construction has been driven by its potential to save time and costs, improve safety, and enhance the quality of the built environment. Governments around the world have recognized these benefits, with some mandating the use of BIM for publicly funded projects, further cementing its importance in the industry.
The foundational principles of BIM in civil engineering revolve around the creation and use of coordinated, consistent digital information models throughout the entire lifecycle of a project. This lifecycle management approach is what sets BIM apart from traditional CAD systems and has established it as a cornerstone of modern civil engineering and construction practices.

2.2 Civil engineering before and after BIM:

- Design Process:

Before BIM: Traditional design involved 2D drawings and manual calculations.
After BIM: Designers use 3D models for visualization, clash detection, and coordination.

- Collaboration:

Before BIM: Communication relied heavily on paper drawings and physical meetings.
After BIM: Collaboration is streamlined through centralized digital models accessible to all stakeholders, reducing errors and misunderstandings.

- Clash Detection:

Before BIM: Clash detection was manual and time-consuming, often leading to conflicts during construction.
After BIM: BIM software allows for automated clash detection, resolving conflicts virtually before construction begins.

- Quantity Takeoff and Cost Estimation:

Before BIM: Estimating quantities and costs involved manual measurement from drawings.
After BIM: BIM software provides accurate quantity takeoff and cost estimation directly from the model, saving time and reducing errors.

- Facility Management:

Before BIM: Facility management relied on paper-based documentation and manual updates.
After BIM: BIM models serve as a comprehensive database for facility management, providing real-time information on maintenance schedules, asset management, and space utilization.

- Communication with Clients:

Before BIM: Clients had limited understanding of design intent until construction was well underway.
After BIM: Clients can visualize projects in detail through 3D models, enhancing communication and understanding of design proposals.

- Risk Management:

Before BIM: Identifying and mitigating risks relied heavily on experience and intuition of the engineers.
After BIM: BIM facilitates risk management through virtual simulations, allowing engineers to identify and address potential issues before construction begins.

- Buildings in Tirana:

  Before BIM:
  After BIM:

2. RESULTS AND DISCUSSION

Building Information Modeling (BIM) has transformed the civil engineering industry, offering numerous advantages over traditional methods. This comparison outlines the key benefits before and after the adoption of BIM in civil engineering.



Before BIM:

- Engineers had more time to think and work for the design of the project. They weren't rushed to do it in a short period of time like today.
- Visualization was challenging, so engineeres developed strong spatial reasoning skills.
- Every part of the project were checked by engineers hand to hand, making them more prepared and more knowledgeable than engineers today.
- Before BIM, collaboration and coordination were more reliant on face-to-face communication, which may have fostered stronger personal connections among team members.

After BIM:

- BIM brings numerous benefits, including enhanced visualization, improved collaboration, and reduced errors.
- The ability to detect clashes early in the design phase saves time and money.
- BIM facilitates better communication with clients and stakeholders, leading to increased satisfaction and clearer project understanding.
- The integration of sustainability analysis within the design process promotes environmentally responsible construction.
- BIM provides realistic 3D models, enabling better visualization and understanding of the project for all involved parties.

3. CONCLUSION

Overall, while traditional methods had their strengths, the advantages brought by BIM in terms of efficiency, accuracy, and collaboration often make it the preferred choice for modern civil engineering projects. BIM's ability to streamline processes, minimize errors, and improve project outcomes suggests that, in many cases, the benefits of adopting BIM outweigh any advantages associated with traditional methods. But if we talk about engineers they were better before BIM, because they had to check every little detail of the building themselves, there were no softwares to check it for them. Their intuition and visualization were also stronger, because they had to visualize the building before it began without the help of today's BIM softwares where you can see inside the building at any moment and time at high precision.

REFERENCES

[1] Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. John Wiley & Sons.

[2] Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357-375.

[3] Autodesk. (n.d.). What is BIM? Retrieved from: https://www.autodesk.com/solutions/bim

[4] BuildingSMART International. (n.d.). What is BIM? Retrieved from: https://www.buildingsmart.org/what-is-bim/

Concrete Saving New Technology U-BOOT SLABS

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Buildings are composed of various structure elements such as footings, columns, beams, slabs, and walls. Each of these structural members play a certain role against loads in a structure. Slab is an important structural element and requires a large amount of concrete. For this reason, we want to reduce weight without affecting the slab function. The U-BOOT Technology is the ideal solution to create a large span slab and to accommodate heavy loads. This technology provides a reduced quantity of concrete and steel. U-BOOT is a recycled polypropylene formwork technology used for construction purposes, which means it is environmentally green and economic. In Albania, this technology was used for the first time in residential villas located in Mullet, Tirana. After this successful application, U-BOOT will be an important part of construction in Albania.

Keywords: *U-BOOT, Construction, Slab, Concrete, Load, Economic*.

1. INTRODUCTION

U-boot technology comes to 2001 when Robert-II Grande, an Italian engineer, developed and patented a new system of hollow former to reduce transport vehicles. This is a new technology that has been in operation since 2002.
It is a form of recycled polypropylene that can be used to to construct two-way slab, large span slab, and mushroom slab and raft foundation in RCC structure. U-boot concrete is an easy solution to many problems in laying slabs and laying foundations where the ground layer capacity is very low. It creates lighter economical design for structure.
It is suitable for high rise building, hospitals and parking management, residential, industrial buildings, and also residential villas which we are representing in this project.

2. MATERIALS AND METHODS

2.1. Production, Dimensions and Transportation/Installation.

This new technology is produced with recycled plastic material resulting from plastic scrap post-consumer and industrial waste. The use of recycle materials saves a lot of emissions, just think that for every kilogram of recycle plastic save 1.5 kg of CO_2.
Objects of various lengths can be loaded into sandwiches that lift two or more basic items. There are two different kinds of U-Boot:

1. A single boot is frequently used while laying reinforced slabs.
2. A double boot is used when constructing double-reinforced slabs.
   According to both kinds, the available sizes are:
   - Single:16,20,25,30 cm (height)
   - Double:32,36,40,41,45,46,50,55,60 cm (height)

The U-Boot formwork is 52cm x 52cm in size and is structured in the shape of a drunken pyramid.

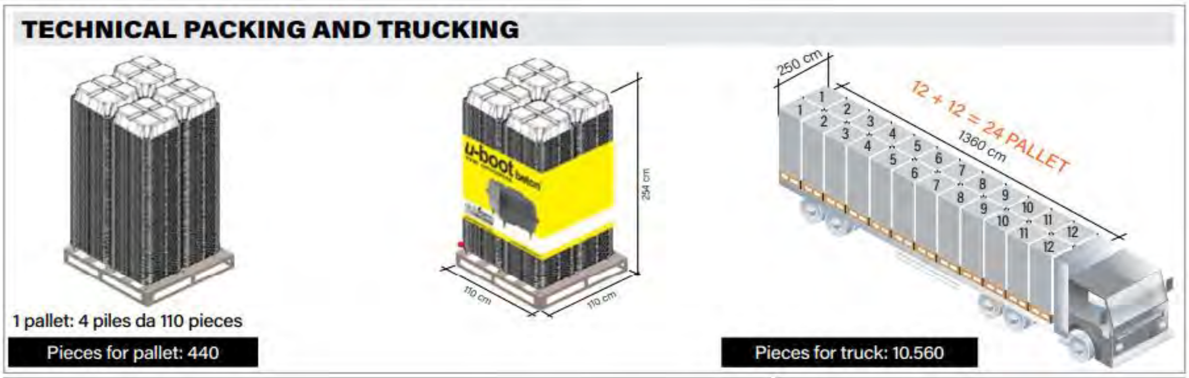


Figure 1. Transportation method for U-Boot.

The product "does not fear the weather" and can be stored outside. Take the utmost care to prevent the product from being deformed or overstressed during the unloading, storage and assembly. In case of disposal the product is totally recyclable.

The installation process:
The components of the U-Boot are the connecting bridge, spacer joint, and lock plate. The spacer joint is used to attach two or more U-buttons when adjusting to the shutter, so that the distance between the spaces of the U-boot concrete can be adjusted, to fix the position of U-Boot during construction to maintain the rigid interconnection that ensure perfect geometric compliance with design as well as bearing capacity of formwork.
The lock plate is used to close the U boot concrete box which can withstand the flow of concrete in the box. A connecting bridge is required to connect the two concrete pieces' length wherever necessary to increase the length of the concrete.
In our case, instead of using lock plates we tried to use black plastic wrapping, for the same purpose and for economic reasons. This operation resulted successful.

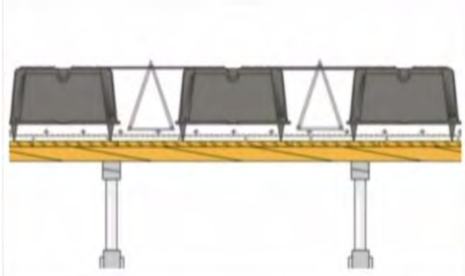
Construction process of U-Boot:

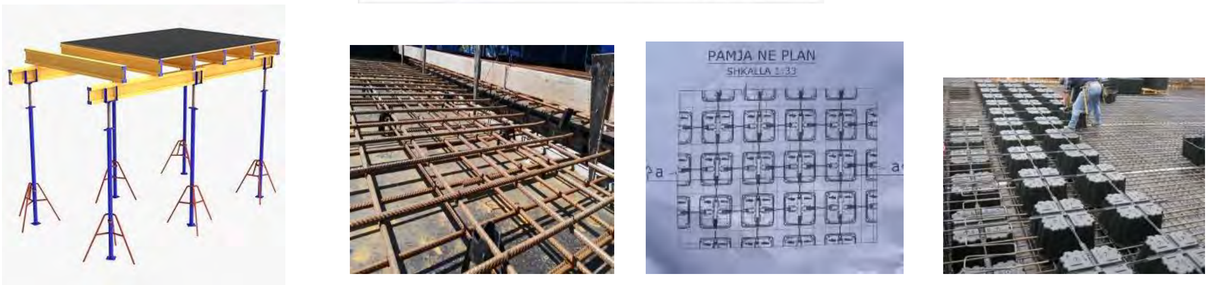
- Formwork (a)
- Placing of the lower layer of reinforcement (b)
- Placing of U-Boot shells (c)
- Placing of upper layer of reinforcement (d)
- Concreting (e)
- Curing (f)

- Normal formwork is laid to this type of U-boot technology,steel or wood formwork is used.
- After the formwork,we lay the lower layer of reinforcement bar.This reinforcement design is based on the two way slab.
- U-Boot is now placed above the first layer of reinforcement, joined with the help of spacer joint for proper bonding.If we use single U-Boot then closing plate is necessary,so the concrete may not get into U-boot.
  Thanks to the conic elevator foot, the U-Boot Beton formworks will be lifted from the surface, making it possible for the lower slab to be formed. If double or triple elements are used, these elements must first be assembled.

- Place the upper layer of reinforcement in two directions as per design and make sure the U-Boots are at the right position joined with help of spacer joint, as well as the reinforcement for shear and punching where necessary, according to the design.
- The concrete casting must be performed in two phases so that the U-Boot-s may not float:
  1. An initial layer will be cast to fill a thickness equal to the height of the elevator foot. Casting will continue for this first portion of the slab until the concrete starts to set and become semi fluid.
  2. Once suitably set, the casting can be restarted from the starting point, completely burying the U-Boot® Concrete.
- The casting is then levelled and smoothed in a traditional manner.
- In most of the cases,there is an extra step after placing the U-Boot-s: “Triangular reinforcement”.

The concrete mass between the U-Boot shells can work as a beam by this reinforcement.





(a) (b) (c)

(d) (e) (f)

Figure 2. Schematics of U-Boot.

2.2.Advantages and disadvantages

Advantages:

1. The weight of the concrete is reduced up to 40%, which reduces deformation, load on foundation as well as the section of the columns.
2. Absence of beam because of its flexibility span up to 20m, as well as reduces the number of columns.
3. It is anti-seismic as it reduces seismic mass.

4. It is economical due to the possibility of big spans without beam, it saves tremendous amount of concrete.
5. Increases number of floors.
6. Reduced slab thickness.
7. Reduced foundations- less deep foundation excavation.
8. Improved acoustic behavior.
9. Environmentally green and sustainable.
10. Due to the high durability of the U-boot material, the structure provides the same amount of volume.
11. Polypropylene material, because the melting point of polypropylene is 145 **°C** the structure is generally heat-resistant and fire-resistant. Can't catch the fireside so easily.

Disadvantages:

1. Since it is an emerging technology, there may be a labor problem.
2. It is not available in all countries; it is available only in some countries.
3. Though the intermediate beams are reduced, the construction cost rises because the cost of a u-boot is too high.

3. RESULTS AND DISCUSSION

3.1. U-Boot slab behavior

a) Bending – The bending strength of U-Boot slabs was investigated in laboratory tests using various slab depths and void former sizes. The bending behaviour has been proved to be comparable with the one of solid slabs.

b) Stiffness – The void formers in U-Boot slab reduce its stiffness compared with solid flat slabs.

c) Shear – According to current standards, calculation of the shear strength for traditional one – way spanning hollow core slabs is based on the smallest available web width of a hollow cross section. With such criteria used for two-way spanning voided slabs, the resulting shear strength for U-Boot flat slab would only be about 10 % of the shear strength of a solid flat slab with same thickness.

d) Punching – Due to shear force limitations areas with high shear force concentration such as around columns heads are to be executed without U-Boot cage modules. The critical perimeters that are relevant for the punching shear design are located within these solid areas. The punching shear considerations in these areas are therefore as for solid flat slabs. It is recommended to explicitly verify that the determining perimeter for punching is located inside the solid zone as shown on Figure 3. Should this not be the case, the solid zone has to be increased accordingly. The reduced dead weight of the U-Boot flat slab decreases the column reactions and allows optimizing the necessary amount of punching reinforcement.

Figure 3. U-Boot slab behavior.

4. CONCLUSION

- By using this technology, we can save more concrete and steel by that structure is more economical for us.
- Less use of iron in the slabs, pillars, and foundation up to a total of 15%.
- There are anti-seismic advantages connected to reduced building weight slimmer pillars and foundations, there is low chance of seismic effect on the buildings.

Because the structural behavior of this new kind of monolithic flat slab is the same as for solid slab, excluding slab-edge column connection, we surely can talk appropriateness of use and advantages of the new technology.
This technology is very prospective in modern construction and perhaps the future of civil engineering belongs to this new kind of hollow slab.

REFERENCES

[1] https://www.google.com/url?q=https://www.researchgate.net/publication/343493290_A_Review_Paper_on_U-Boot_Beton_The_Concrete_Saver&sa=U&ved=2ahUKEwiakPS1nYCFAxXTX_EDHdBFClEQFnoECBgQAQ&usg=AOvVaw2hRAiJ3dSflXAThjhUsWij

[2] https://www.google.com/url?q=https://www.irjmets.com/uploadedfiles/paper/issue_5_may_2022/21985/final/fin_irjmets1651657088.pdf&sa=U&ved=2ahUKEwjM1LT8nYCFAxUVRfEDHfeUA64QFnoECCIQBg&usg=AOvVaw36oabs3XiT6_K6CnG59mE6

[3] https://www.google.com/url?q=https://www.skyfilabs.com/project-ideas/application-of-u-boot-technology%23:~:text%3DThere%2520are%2520many%2520real%252Dtime,with%2520less%2520number%2520of%2520labors.%26text%3DIt%2520also%2520helps%2520to%2520reduce%2520the%2520slab%2520thickness.%26text%3DIt%2520helps%2520us%2520to%2520reduce,the%2520structure%2520on%2520the%2520foundation.&sa=U&sqi=2&ved=2ahUKEwjQ0PqynoCFAxV1RvEDHciRAn0QFnoECBQQBQ&usg=AOvVaw0KfF5GNPWcOdwptLpVg7mY

[4] https://www.google.com/url?q=https://kahedu.edu.in/benefits-of-u-boot-technology-in-the-construction-field/&sa=U&sqi=2&ved=2ahUKEwjQ0PqynoCFAxV1RvEDHciRAn0QFnoECCgQAQ&usg=AOvVaw2plnPVvQH9Y8CRKt_iRrxl

[5] https://www.google.com/url?q=https://www.daliform.com/en/disposable-formwork-for-two-way-lightened-voided-slabs/&sa=U&ved=2ahUKEwjn3pGHn4CFAxVQR_EDHUG8AzMQFnoECBoQAQ&usg=AOvVaw3lk8IRmRm-XaYe8r-lnHDw

[6] https://www.google.com/url?q=https://www.skyfilabs.com/project-ideas/application-of-u-boot-technology&sa=U&ved=2ahUKEwi4rKfnn4CFAxWrYPEDHZ4xC8k4ChAWegQICxAB&usg=AOvVaw2rGHXitowYAq0gsmH7Dmgn

[7] https://www.google.com/url?q=https://www.slideshare.net/akshayapriyadharshini/u-boot-technology-88486023&sa=U&sqi=2&ved=2ahUKEwiqkdaRoICFAxX4Q_EDHSvEBLwQFnoECBcQAQ&usg=AOvVaw30L3cADwRn-5Qb_ioYTi24hfg

[8] https://www.google.com/url?q=https://knowledgecenter.ubt-uni.net/cgi/viewcontent.cgi%3Farticle%3D1475%26context%3Dconference&sa=U&sqi=2&ved=2ahUKEwjEiK6sooCFAxUWcvEDHb30A-8QFnoECBUQAQ&usg=AOvVaw3-x7vStCIaECZRpyQORNyAfhcbv

Time Programming and Cost Control in Construction Projects

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In the dynamic field of construction project management, the interplay between time programming and cost control is of paramount importance. Time programming, a systematic approach to scheduling tasks and activities, often visualized through tools such as Gantt charts, serves as the backbone of project execution. It provides a clear roadmap for the project, facilitating efficient resource allocation and timely completion of tasks. On the other hand, cost control is a strategic process that involves monitoring, analyzing, and adjusting project costs to prevent budget overruns and ensure financial viability. The correlation between time and cost, often referred to as the time-cost trade-off, is a fundamental concept in project management. It suggests that any change in the project's timeline will have a direct impact on the project's cost and vice versa. This paper examines the intricate relationship between time programming and cost control in construction projects. It explores how effective time programming can aid in cost control by ensuring efficient resource utilization and preventing costly delays. Vice versa, also discusses how diligent cost control can inform time programming, leading to more accurate and realistic schedules. The paper draws on recent research and case studies to illustrate these concepts, providing valuable insights for construction project managers, stakeholders, and researchers.

Keywords: *Project Management, Timely Completion, Monitoring Cost, Resource Allocation, Realistic Schedules, Financial Viability.*

INTRODUCTION

Construction projects are undoubtedly some of the most complex projects, spread throughout a number of stakeholders and require meticulous coordination and planning to ensure successful completion. Duration, Cost and Quality are the essential triad upon which, it's ultimately decided on whether the project was successful or not. The importance of time and cost control in construction projects cannot be overstated.

Delays and budget overruns not only compromise the project at hand, but also incur financial and reputational damage for the stakeholders. Adequate planning and time programming along with correct resource allocation and proactive monitoring, ensures that such issues are mitigated throughout the project duration.

The purpose of this paper is to introduce and give deeper insight into the time and cost management, and the possibility of maneuvering with one or the other element to reach desired results in our construction projects.

1. PLANNING AND TIME PROGRAMMING

According to A Guide to the Project Management Body of Knowledge (PMBOK, 6th ed.), a project is a temporary endeavor undertaken to create a unique product, service, or result.

In the case of construction projects, it is the organized effort, taken to design and build entities that include but are not limited to residential buildings, highways, dams, railways, water treatment plants, etc. that serve the owner in a plethora of ways starting from the basic needs such as safe living, water supply, transportation, communication and so on.

What is planning?

Planning, according to psychology is the process of *mental time travel*, or more simply put, the ability to think further in time.

Planning is an essential part of any project; it enables project managers to turn an intangible idea into reality. Planning primarily deals with selecting the adequate method and procedures needed to achieve the objectives of a project.

It is a foundation for several related functions, such as cost estimating, scheduling, project control, quality control, safety management, etc.

Planning lays out the basics of a project, including scope definition, resource allocation, stakeholder involvement, and risk management.

The questions answered in the planning phase are: What needs to be accomplished? and, How will it be accomplished?

What is time programming?

Time programming or construction scheduling on the other hand takes what has already been laid out in the plan and puts it in a time perspective.

To do this, we must first break the project down into smaller, more manageable units of work, to each of which, we will assign necessary resources such as labor, materials, and equipment.

Through scheduling, we determine the time necessary to complete each unit of work and the sequence in which these work units will progress, for the project to be completed on time.

The questions answered in the scheduling phase are: When will each work unit be performed? and, In what sequence should each work unit be completed?

A time program will contain activity sequencing, resource allocation, duration estimation, baseline schedule, critical path analysis, and progress tracking.

Why do we schedule projects?

Project scheduling is of great interest to all parties involved, but most imperative to the executor of works - The Contractor, and the investor - The Owner.

For the Contractor, it highlights the necessity to:

- Establish the project completion date,
- Determine the start and end of every specific activity,
- Coordinate material procurements and subcontractors,
- Predict and calculate the cash flow,
- Serve as a monitoring tool,
- Evaluate the effect of Variation Orders,
- Keep track of delays, and offer proof for rightful compensation.

For the Owner, it highlights the necessity to:

- Establish the Owner's idea of the project's completion date,
- Ensure proper planning and keep track of the Contractor's planning,
- Calculate and predict cash flow,
- Have a progress monitoring tool,

- Evaluate the effect of Variation Orders
- Provide proof of delay events and their impact, for rightful compensation.

2. GANTT CHARTS

Gantt or bar charts are simple project scheduling charts developed in 1917 by mechanical engineer Henry Gantt. PMI (PMI, 2017) defines it as "a graphic display of schedule-related information. In the typical bar chart, schedule activities or work breakdown structure components are listed down the left side, dates are shown across the top, and activity durations are shown as date-placed horizontal bars."

As previously mentioned, before doing any scheduling, similarly, before creating a bar chart, we should break down the project into small work units which we will define as tasks or activities. There is no correct way of breaking down a project, every project is unique therefore every breakdown will be unique.

The preliminary breakdown can be as detailed as deemed necessary by the scheduler. The level of detail required in the schedule is predicated on the level of control needed to manage the project.

While each project manager may have their own special way of developing a task list, there are a few general considerations that may be helpful:

- Too much detail can be too complicated and intimidating to the participants, who will, in turn, ignore it altogether.
- With too little detail, tasks are omitted. Vague schedules cannot be used as a management tool.
- More detail is required at extremely critical stages or sequences.
- Tasks that lead to a milestone should be detailed so nothing is omitted that might prevent the milestone from occurring.
- Tasks that are performed by owners, inspectors, and design team members should also be listed.

3.1. Task Durations

Each bar in the chart will represent a task or activity that will take its place in a coordinate system where the Y axis represents time.

Duration is simply defined as the time necessary to complete a task. It's the difference between the start and end date, which as a standard practice, is measured in workdays.

Task duration can be calculated through the Labor-Hour Productivity method. This method is based on the amount of work, that, a hired team of workers can perform in a workday.

For example, if the task at hand is building a masonry wall of 6sqm, and the team of workers can perform 0.5sqm of wall in one hour *(this is determined through labor norms)*. The duration of the activity would be:

Total quantity of labor hours: TLH =(6sqm/0.5sqm)*1h =12h

Let's assume that daily labor hours are LH = 6h/day

Duration of activity: D =TLH/LH =12h/6h =2 days

This method of calculating allows flexibility in changing the duration of activities by concentrating more workforce.

3.2. Advantages and Disadvantages of Gantt charts

Advantages:

- Simplicity: The biggest advantage of Gantt charts is their simplicity. The clear visual representation they provide is easily read by any party at a glance.
- Progress tracking: Allowing stakeholders to identify potential problems and delays waiting to happen.
- Flexibility: They offer easy modification and updating to accommodate eventual changes in scope, timelines, resources, etc.

Disadvantages:

- Gantt charts' strong and weak point is simplicity. It is rarely used in large projects because it becomes too complex and difficult to follow.
- Dependencies: They oversimplify the dependencies between tasks, rendering an inadequate representation of interrelationships between tasks.
- Overemphasis on time: The primary focus of these charts is time, leaving little space in including resource constraints, quality, or budget considerations, for the accommodation of which, separate charts need to be created.

New technologies such as Primavera, or MS Project have minimized or even eliminated some of the disadvantages of bar charts by enabling the user to organize, filter, roll up, summarize, or do almost anything to dynamically customize bar charts.

3. RESOURCE ALLOCATION

In project management, the term resources is used to indicate three main categories: labor (human), equipment, and materials. Ultimately, everything is translated into a monetary quantity that is financial resources.

4.1.Labor

Labor can be classified into the following subcategories:

1. Salaried staff: Salaried staff such as project managers, superintendents, project engineers, and secretaries usually get paid an assigned salary for the duration of the project or their assignment. Their salaries usually count as part of the company's indirect expenses (overhead), not as labor.

2. Hourly workers: These workers are hired to perform a specific task or activity that contributes directly to the project and they are usually paid for actual hours worked.

Examples include carpenters, masons, plumbers, ironworkers, electricians, foremen, and so on.

From a cost estimating perspective, labor includes only the second category, while the first category employees are considered overhead (indirect expenses).

4.2.Equipment and Materials

Equipment and materials also can be further classified into two subcategories:

1. Construction materials and equipment: Although they are not permanently fixed in the project, these materials and equipment are utilized during the construction process. Cranes, bulldozers, scrapers, mechanical trowels, heaters, and other tools are examples of construction equipment.

Inexpensive personal tools are typically handled differently (either as the laborer's personal property or as a lump sum payment for all items). Scaffolding and formwork materials are two examples of construction materials.

2. Installed materials and equipment: After a project is finished, these materials and equipment remain there permanently. Heat pumps, emergency power generators (which are typically built in hospitals, industrial projects, and certain other projects), culinary equipment, and other specialized equipment in industrial projects are a few examples of installed equipment.

Concrete, rebar, brick, mortar, insulation, framing wood, paint, roof shingles, floor tile and carpet, bathroom accessories, plumbing pipes and fittings, and electrical wiring are a few examples of installed materials. While escalators and elevators might be categorized as installed materials or installed equipment, they are typically installed by the same vendor and are included as subcontractor costs in the estimate.

The equipment category primarily consists of construction equipment for estimators. Installed equipment falls in the materials category.

A term important in the resource aspect of managing is resource-leveling. Resource dispersion fluctuates greatly daily throughout the project. This fluctuation is impractical as it puts the Contractor in a position to either utilize the maximum number of resources each work day or constantly lay off and rehire workers.

To avoid this issue, managers group together activities that require the same or similar resources, thus limiting the expenses not only in labor but also in rent, fuel, maintenance of equipment, and so forth.

4. COST ESTIMATION AND CONTROL

There is a cost for every section of the Technical Specifications as well as every work item that makes them up. The Estimate Summary is the summary of these expenses. The Estimate Summary will serve as the starting point for cost control if the contractor wins the tender and is given the project. It is the task and corresponding cost for the task that will represent a line in the budget.

The process of analyzing, estimating, and forecasting project-related expenses is known as ***cost control***. Its objective is to reduce such expenses as well as any effects that variations might have on cost while the project is underway. Four fundamental components make up project cost control:

1. Establish a baseline as a cost performance metric.
2. Measure actual costs against the baseline.
3. Accurately predict variations from the baseline cost.
4. Take corrective action(s) to minimize or eliminate the deviations.

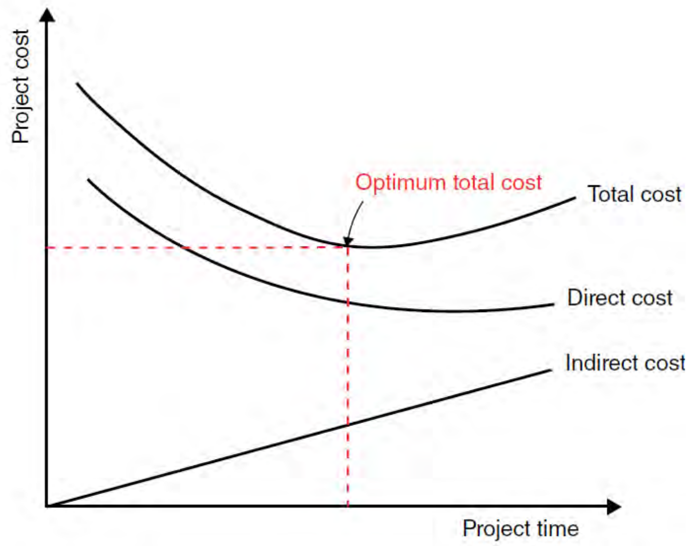

Figure 1. Optimum total project cost [1].

5.1.Direct and indirect costs

A contractor's main expenses can be broken down into two categories, direct and indirect costs.

Direct Costs:

- ***Labor***, specifically hourly workers, for whom a labor expense is directly linked to a particular work item,
- ***Materials***, such as concrete, rebar, bricks, lumber, pipes, granular filling material, drywall, carpet, structural steel, and installed equipment, such as elevators, air-conditioning units, and kitchen equipment,
- ***Equipment***, mainly construction equipment (bulldozers, excavators, cranes, concrete pumps, etc.)
- ***Subcontractors*** (even though subcontractors' charges comprise labor, materials, equipment, overhead, and possibly sub-subcontractors, the general contractor treats these charges as a direct cost)

Indirect Cost:

- ***Project overhead***, such as the following:
  Project staff, temporary structures, and temporary utilities such as office trailers, cars and trucks assigned to the project, office equipment, and so forth. These are only assigned to the project.
- ***General overhead,*** main office expenses (rent, maintenance), personnel, equipment and vehicles, and services such as lawyers and accountants.
- ***Profit,*** or defined as "return for taking risk", it's generally in the range of 5-10% of the project.
- ***Contingency fees*** are money allocated to cover unpredictable events.

5. TIME–COST TRADE-OFF

The main objective of any project manager is to complete the project in the shortest time possible, because essentially, the faster the project is finished, the faster the investment will be returned.

The project duration though, can only be shortened through an increase of resources, and vice versa, the decrease in cost of the project can be achieved through lengthening the project duration. This puts the project in a loop that is called the **Time-Cost trade-off**.

But why does the direct cost of an activity increase when we shorten its time for completion? The reason for this increase can be as simple as personnel working overtime or on the weekends, which has to be compensated at a higher rate than the regular working days, this in turn shortens the duration of the activity in days. Along the same lines, some ways in which the duration of activities can be shortened is:

- Applying multiple shifts work.
- Working extended hours (over time).
- Offering incentive payments to increase productivity.
- Working on weekends and holidays.
- Using additional resources.
- Using materials with faster installation methods.
- Using alternate construction methods or sequence

A simple representation of the Time-Cost trade-off can be seen in the graph below where the interrelationship between the direct cost of a single isolated activity and its duration is linear.

For a project manager, the two extremes of the time-cost trade-off are using minimal direct cost – *normal duration* and minimal possible duration – *crash duration*.

$$\text{Time-Cost Ratio} = (\text{Cost(C)} - \text{Cost(N)})/(\text{Duration(N)} - \text{Duration(C)})$$

Where:

Cost(C) = crash cost
Cost(N) = normal cost
Duration(N) = normal duration expressed in workdays
Duration(C) = crash duration expressed in workdays

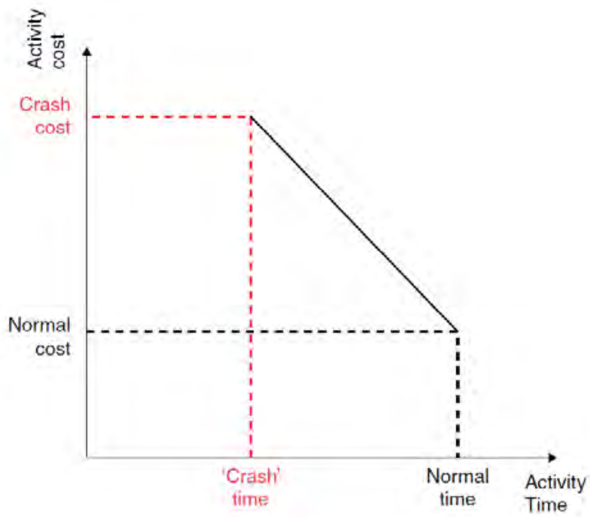

Figure 2. Duration and Direct Cost relationship [1].

The linear relationship shown in Figure 2 between these two points implies that any intermediate duration could also be chosen. It is possible that some intermediate point may represent the ideal or optimal trade-off between time and cost for an activity.

When ‘crashing’ activities, it is necessary to consider both direct costs and indirect costs. The total cost of an activity is the direct cost of an activity plus the indirect cost. Increasing the resources allocated for the activity reduces the duration of the activity, but a point is reached where the use of additional resources does not result in any overall savings on the project. This, the optimum total project cost, is shown in Figure 1 [1].

6. CONCLUSIONS

No two construction projects are the same, each one is unique and can never be recreated with the very same attributes. Planning is essential in turning our engineering ideas into reality, but scheduling is what determines the tangible, measurable way, of how the idea will come to life.

Time programming is an imperative tool for all stakeholders, to be able to establish completion dates, coordinate resources, monitor progress, and evaluate the effect of changes in the overall duration and cost of the project.

Gantt charts are a simple yet very functional tool for time programming, even though they have their limitations, they are still widely used because of their simplicity and easy-to-read nature.

The Time-Cost trade-off involves balancing project duration and resources to achieve the most efficient outcome, with the possibility of finding an optimal trade-off point between time and cost.

In conclusion, project managers aim to complete projects quickly to ensure a faster return on their investment, and utilizing the time-cost trade-off is just one of the many ways through which this goal can be achieved.

REFERENCES

[1] Baldwin, A., & Bordoli, D. (2014) A Handbook for Construction Planning and Scheduling. Wiley.
[2] Project Management Institute. (2008). A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Fourth Edition. PMI.
[3] Mubarak, S. (2019). Construction Project Scheduling and Control. Wiley
[4] Del Pico, W. J. (2013). Project Control: Integrating Cost and Schedule in Construction. John Wiley & Sons.
[5] Sears, S. K., Sears, G. A., & Clough, R. H. (2008). Construction Project Management: A Practical Guide to Field Construction Management. Wiley.
[6] Hendrickson, C., Au, T., & Koo, C. (1989). Project Management for Construction. Prentice Hall College Div.
[7] Twort, A. C., & Rees, G. (2004). Civil Engineering Project Management. CRC Press.
[8] Potts, K., & Ankrah, N. (2014). Construction Cost Management: Learning from Case Studies. Routledge.
[9] Fu, Fang & Zhang, Tao. (2016). A New Model for Solving Time-Cost-Quality Trade-Off Problems in Construction. PLOS ONE. 11. e0167142.10.1371/journal.pone.0167142.
[10] Hinze, J. W. (2011). Construction Planning and Scheduling. Pearson.
[11] Gould, F., & Joyce, N. (2008). Construction Project Management: Planning, Scheduling, and Controlling. Pearson.
[12] Newitt, J. S. (2011). Construction Scheduling: Principles and Practices. Pearson.
[13] Spreadsheet Aids for Financial Planning for Construction Projects.
[14] Smith, J. G. (2009). Construction Management: Subcontractor Scopes of Work. CRC Press.
[15] Peurifoy, R., Schexnayder, C., & Shapira, A. (2005). Construction Planning, Equipment, and Methods. McGraw-Hill Education.

Construction Materials

Experimental Analysis of the Structural and Environmental Dynamics of Partial Replacement of Cement with Glass Powder in Concrete

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This paper delves into the dynamic interplay between structural integrity and environmental sustainability by investigating the effects of partially replacing cement with recycled glass powder in concrete formulations. The study employs a comprehensive laboratory experimentation approach, systematically evaluating various mechanical, durability, and microstructural aspects of concrete mixtures incorporating different proportions of cement replaced by finely ground recycled glass powder. The laboratory experiment encompasses an array of tests, including but not limited to compressive strength and flexural strength, to discern the nuanced impact of recycled glass powder on the fundamental mechanical properties of concrete. Through meticulous analysis, the research aims to provide a deeper understanding of how these alternative mixtures perform under different loading conditions, shedding light on their structural viability in construction applications. Beyond structural considerations, this study delves into the environmental implications of incorporating recycled glass in concrete. A comprehensive lifecycle analysis is conducted to quantify the environmental benefits, including reduced carbon emissions and a diminished reliance on traditional cement production. By elucidating the environmental footprint associated with these mixtures, the research seeks to contribute to the broader discourse on sustainable construction practices. The findings from this study hold significant implications for the construction engineering community, offering a nuanced perspective on the potential of recycled glass powder as a sustainable alternative to traditional cement. With a focus on both structural performance and environmental impact, this research aims to empower decision-makers in the construction industry to make informed choices that align with the principles of circular economy and sustainable development.

Keywords: *Glass Powder, Concrete Mixtures, Laboratory Investigation, Structural Integrity, Eco-Concrete, Environmental Impact.*

1. INTRODUCTION

The imperative to address the environmental impact of the construction industry has prompted a scientific exploration into innovative materials and methodologies. This research investigates the partial replacement of cement with glass powder in concrete structures, presenting a nuanced approach to sustainable construction practices. The intrinsic ubiquity of glass waste and its potential as a substitute for cement in Kosovo underscore the regional relevance and environmental significance of this inquiry.

Cement, a cornerstone of traditional concrete formulations, contributes significantly to the carbon footprint of the construction industry [1]. As sustainability becomes an increasingly critical concern, this study focuses on the strategic replacement of cement with glass powder, aiming to unravel the ecological benefits and contribute to the evolving landscape of sustainable construction practices.

Glass, an abundant and versatile material, presents a complex opportunity for elevating the environmental performance of concrete structures [2]. The ample supply of glass waste, often relegated to landfills, necessitates a scientific exploration into its utilization as a partial replacement for cement. This research not only addresses waste management intricacies but also aligns with global endeavors to minimize the environmental footprint inherent in traditional concrete production processes.

In Kosovo, a region endowed with natural resources, the escalating carbon dioxide emissions from conventional construction practices pose a formidable challenge to environmental sustainability [3]. The imperative to investigate eco-friendly alternatives becomes paramount. This research endeavors to fill this scientific gap by rigorously examining the feasibility and performance implications of partially replacing cement with glass powder in concrete, presenting a cogent contribution to Kosovo's quest for a more sustainable construction industry.

The laboratory experiments conducted for this study entail a meticulous assessment of various material properties, including but not limited to compressive strength, durability, and environmental impact, ensuring a robust evaluation of the proposed glass powder substitution in concrete mixtures [4]. The integration of glass powder into concrete formulations represents not only a departure from traditional practices but also a potential enhancement of structural performance while concurrently addressing environmental concerns.

To anchor our research within the scientific discourse, we critically review the existing literature on the environmental impact of conventional building materials [5], the specific properties of glass as a cement substitute [6], and the nuanced characteristics of glass powder in concrete mixtures [7]. Throughout the introduction, references to authoritative sources are meticulously cited, establishing a comprehensive scientific foundation for our investigation and positioning it within the broader dialogue on sustainable construction materials.

2. MATERIALS AND METHODS

2.1.Materials

2.1.1. Portland Cement

Portland cement, the fundamental binder in traditional concrete formulations, is central to the construction industry due to its exceptional binding properties. However, the production of Portland cement is energy-intensive and contributes significantly to carbon dioxide emissions. The quest for sustainable construction practices has led to research focusing on alternative materials to partially replace Portland cement. Glass powder, derived from recycled glass, emerges as a promising candidate for cement replacement due to its pozzolanic properties and potential to enhance the environmental performance of concrete. Studies have indicated that incorporating glass powder as a partial replacement for Portland cement can lead to improved mechanical properties and reduced environmental impact. This research builds upon the premise of sustainability in concrete construction by investigating the feasibility and performance implications of partially replacing Portland cement with glass powder, aligning with the global effort to foster environmentally friendly construction materials [8]. The cement type used in this case is CEM I 42.5 N according to standard EN 197-1. Sample of cement and glass powder is brought to chemistry faculty laboratory where have been examined and results are presented in table below. (Table 1)

Table 1. The chemical composition of the pozzolanic cement and glass powder used in this study.

Chemical Composition	Cement (%)	Glass powder (%)
Al_2O_3	5.78	1.04
CaO	62.9	9.32
Fe_2O_3	3.66	0.07
K_2O	0.58	0.18
MgO	2.47	4.27
Na_2O	0.41	13.64
SiO_2	20.82	71.38
SO_3	2.49	0.22

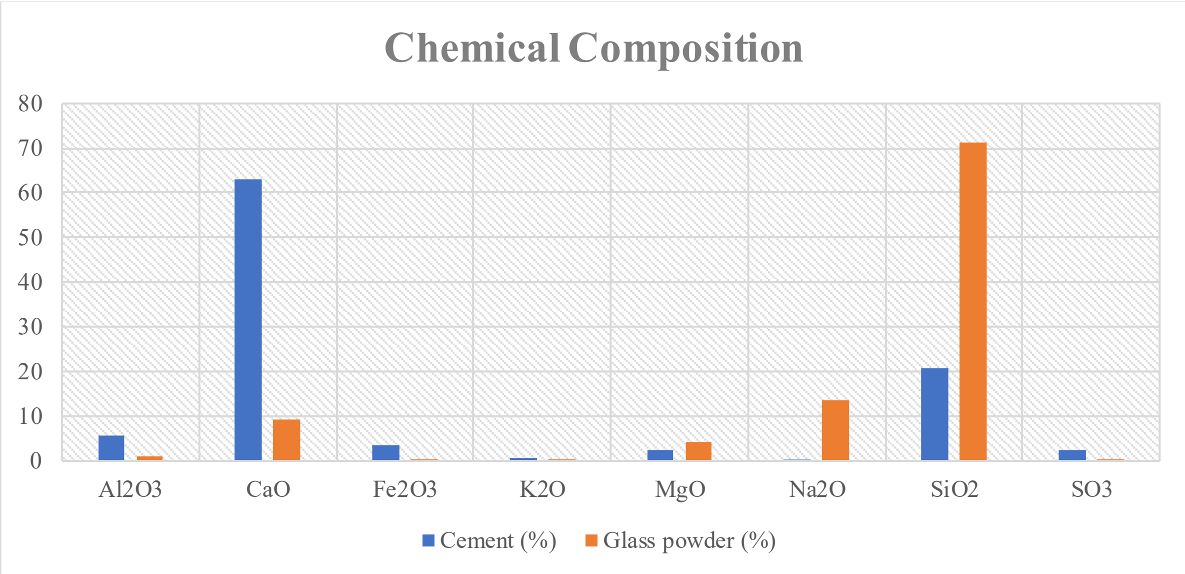
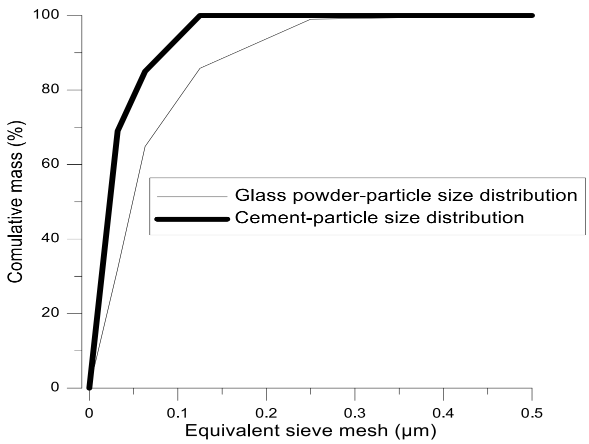


Figure 1. Graphical interpretation of chemical composition

2.1.2. Glass Powder

The typical industrial glass product used in this study is obtained from clear glass factories. Its chemical composition can be observed in (Table 1). The Glass Powder is obtained with a process of crushing and dry grinding, followed by a process where the particles are separated according to the size required (0.09mm), in this case glass is obtained from a recycling glass factory where the powder is sieved and resulted with a passing grading curve presented in Figure 2. To be mentioned is the fact of factories that grind glass into particles that are the same as cement, not only in the Kosovo industry but also in the Balkan industry. The chemical composition of GP determined from laboratory is compared with cement and according to European standards (EN 450-1), and ASTM C 618, $SiO_2 + Al_2O_3 + FeO_3$ minimum requirement for a standard pozzolana is 70% the results obtained from waste glass samples exceed this condition. Minor compounds such as BaO, TiO, MnO are also found in glass samples where the amount of individual component was not more than 0.3%.

a)



b)

Figure 2. a) Crushing Process,
Figure 2. b) Cement vs Glass Powder particle size distribution

c.1)

c.2)

c.3)

Figure 2. c.1, c.2, c.3) Preparatory phase of Cement and Glass Powder

2.2. Mix Proportion

2.2.1. Cement Mortar

Ordinary Portland Cement (CEM I 42.5 N) was replaced by different amounts of glass powder. The proportions of the mortar mixture for a set of standard samples are provided in (Table 2) according to EN 196-1. In order to analyze the influence of different dosages of glass powder, apart from normal samples, three other mortar mixtures were prepared with 10%, 20% and 30% GP as replacement of cement. They were prepared with a water to cement ratio of 0.5 and cement to sand ratio of 1:3.

Table 2. Mortar mixture proportions.

	Sand (g)	Cement (g)	Water (g)	GP (g)	Consistency (mm)
CM	1350	450	270	-	110
CM-GP1	1350	405	270	45	110
CM-GP2	1350	360	270	90	110
CM-GP3	1350	315	270	135	110

Regarding the curing of specimens, all of them were stored in a humidity chamber, where the temperature was maintained constant at 20°C and the relative humidity (RH) was 95%, during the first 24h after setting. Once that period finished, the specimens were de-moulded and kept immersed in water in optimum laboratory conditions (20°C and 100% RH), up to the corresponding testing age.

2.2.2. Concrete

A combined grading of four fractions with nominal size coarse aggregate gradings were used with the ratio of 52:16:14:18 percent respectively. Particle size distribution curve combined with coarse aggregate by the sieve analysis, result with permissible limits. Similar to cement mortar samples the design mix of concrete is conducted by including glass powder as cement replacement with ratios of 10%, 20% and 30%. The detailed mix design is provided in (Table 3).

Table 3. Mix proportion of concrete

	Coarse aggregate (kg)	Fine aggregate (kg)	Cement (kg)	GP (kg)	Water (kg)
CM	602.3	1280	350	-	157.5
CM-GP1	602.3	1280	315	35	157.5
CM-GP2	602.3	1280	280	70	157.5
CM-GP3	602.3	1280	245	105	157.5

2.3. Testing Methodology

2.3.1. Consistency of Cement Mortar and Concrete

The flow was measured according to EN 1015-3 with a mini slump cone typical for mortar examinations, whose internal diameter was 100 mm, on a 250 mm flow table disc. The procedure was as follows: the mould was first filled with fresh mortar, and then it was raised vertically to extend the mortar on the disc, shaking the flow table 10 times at a constant rate. Two perpendicular diameters of the mortar were then measured and recorded. Concrete slump test or slump cone test is used to determine the workability or consistency of concrete mix prepared at the laboratory during the progress. Concrete slump test is carried out from batch to batch to check the influence of glass powder in workability. The slump is carried out as per procedures mentioned in ASTM C143 and EN 12350-2.

2.3.2. Compressive and Flexural Strength

Complying with EN 196-1 standard [9], three different prism specimens measuring 4 cm × 4 cm × 16 cm were tested for each series at 7 and 28 curing days, from which the compressive and flexural strengths were obtained. In relation to cement specimens a set of three cubes and prisms in each case are tested for compressive and flexural strength in accordance with EN 206-1. In this research, cube concrete sample with the size of 150x150x150mm and prism samples were manufactured by using concrete mixer located at Structural Laboratory, Faculty of Civil Engineering. There were nine samples including the control sample were used. Each sample has been incorporated with different percentages of glass waste (10%, 20% and 30% of glass waste). During batching process, precaution was taken to ensure that the glass powders were blended well in the concrete mixer. The aggregate used in this experiment is the standard one which is separated from fraction 1 by sieving process, using the product that passes the 2mm sieve and sieved according to percentages through the set of sieves up to 0.08mm sieve.

Figure 3. Cement mortar preparation according to the standards

2.3.3. Environmental Consideration

Recent research has delved into the environmental implications of partially replacing cement with glass powder in concrete construction. Studies have indicated potential benefits, such as reduced carbon emissions and energy consumption compared to traditional cement production methods. The incorporation of glass powder, often derived from recycled glass, aligns with sustainable practices by addressing waste management concerns and contributing to a circular economy [10, 11]. While promising, the research emphasizes the need for a comprehensive life cycle analysis to assess overall environmental impact, considering factors like transportation emissions and the chemical composition of the glass powder. These findings contribute to the ongoing efforts in the construction industry to adopt more sustainable practices and materi als [12].

2.3.3.1. Greenhouse Gasses (GHG) Analysis

To analyze the CO_2 values referent models [13] are used to determine the glass particle size corresponding to the 25th, 50th, 75th and 90th percentiles of the particle size, respectively, depending on the grinding time. A relation is done between the productions of GP with determined fineness module of glass sample used in this research. Equation (1) (which presents R2 = 0.963) is used inversely to calculate the approximate grinding time taken to obtain particles of the size used in this study.

$$D90 = -360 \lg(\lg(t)) + 137.1 \qquad \ldots(1)$$

where D75 is the size (µm) of the opening of the sieve, through which 75% of the sample mass passes, and t is the grinding time in minutes. Inversion is proposed to obtain the ratio showed in Equation (2).

$$t = 10^{10^{D\frac{75-137.1}{-360}}} \qquad \ldots(2)$$

The electricity consumption in the process of grinding and segregating the glass is from 3 to 15 kWh per ton [14]. In order to determine the influence of CO_2 emissions on electricity production, a comparison was made between the amount of CO_2 per ton of GP depending on their emissions per kWh ($kgCO_2/kWh$) and cement where the CO_2 emission recorded in the ICE Database is considered [15]. For determined cement used in this research, it was considered a factor of 0.912 $kgCO_2/kg$ and an embodied energy of 4.6 MJ/kg (1277 kWh/ton) [16] in comparison to GP where an estimation was made of the energy consumption and the average CO_2 emissions provided by the OECD [14] per kWh associated with the generation of electricity (0.444 kg CO_2/KWh). In terms of the GHG and energy consumption, the contribution of GP is negligible compared to the cement.

2.3.4. Testing Machine

For compressive and flexural strength testing, a hydraulic press, designed to apply controlled loads until the concrete samples failed, was employed. This machine is crucial for assessing the maximum load the concrete can withstand before fracturing, providing a direct measure of its structural integrity under compression. For flexural strength assessments, a flexural testing machine was used. This apparatus tests the ability of the concrete to bear bending stresses by applying a load at a specific rate to the concrete beam until it bends and breaks. The flexural test is especially important for understanding how the concrete would perform in practical scenarios where bending stresses are common, such as in beams and slabs. These machines are integral to the experimental framework as they provide quantitative data that is essential for evaluating the suitability of glass powder as a replacement for cement in concrete. Their precise measurements help ensure that the findings are reliable and can be used to inform both the scientific community and construction industry practices effectively.

Figure 4. Testing machine and procedure

3. RESULTS AND DISCUSSION

3.1. Flow Test

Previous studies [17] indicated that workability is increased by addition of glass powder. The increase of mortar flow is related to the nature of glass and fineness module where cleaner and finer GP have shown effects on workability. GP utilized in this study had minor effect as there was minor difference between the flow results at different glass replacements levels with percent corresponding to 10, 20 and 30% GP respectively. Results show that the consistency is the same in all four etalons, but while working process when the product is placed in mold it was observed that the product of CM-GP3 is more workable than CM.

Table 4. Spread Results of Flow Test

Spread (mm)	
110	CM
110	CM-GP1
110	CM-GP2
110	CM-GP3

3.2. Setting time

Vicat apparatus is used to determine the initial and final setting time of cement paste. Complying with EN 196-3, the mould is placed in Vicat instrument where the distance from the edge of the needle and base plate is measured. Replacing cement with GP increases the setting time and duration of the setting. With regards to workability, GP serves as a retarder increasing the period of hardening process. This property is also related to pozzolanic effect of GP and the mechanical behaviour as yielding effect.

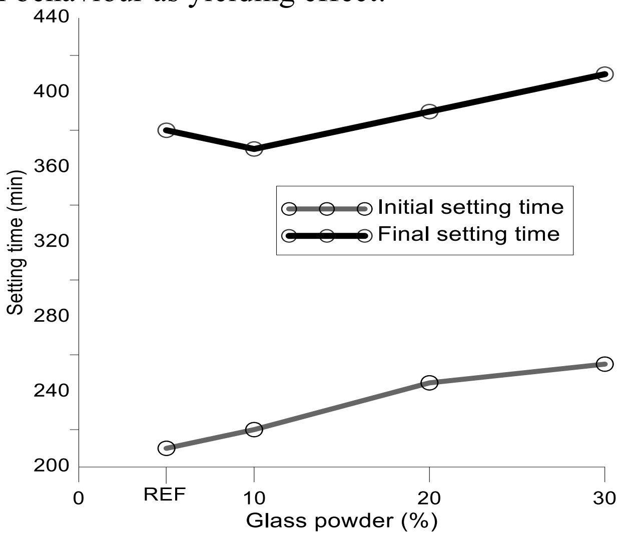


Figure 5. Initial and final setting time for different GP-cement replacements

3.3. Compressive and Flexural Strength of Cement Mortar

According EN 196-1, mortar specimens are used to evaluate the compressive strength performance of cement. The testing results consist of mortar compressive strength for individual samples, mean strength, and standard deviation. In Figure 5 are presented the test results of standard mortar modified with 0%, 10%, 20% and 30% GP cement replacement after 7 and 28 days of curing. 3 samples of each mixture were tested, which means that a total of 12 samples were tested for compressive strength while testing them in bending, the same were also examined to determine the compressive strength, a total of 24 samples, i.e. 6 samples for each mixture. According to the results obtained from 7 days, then none of the mixtures with different percentages of glass powder showed satisfactory results in terms of compression and bending resistance, in percentage we can provide that the compressive strength in day 7 decrease around 15% between each sample with 10, 20 and 30 % of Glass Powder but in the day 28 the decrease is around 13% in each mixture. The effect of using glass powder as cement replacement on prismic concrete compressive strength (fck) at 7 and 28 days is shown in Figure 7 where we can observe that the use 10% or greater GP as cement replacement indicate opposite effects in sense of mechanical properties but it is a good indicator that maybe after day 28 close results can be given between the mixtures, especially between the mixture with 10 percent GP and the one with pure cement. During the process of testing the samples according to the shape of the break, it is observed that the cutting of the samples was done in the X shape, that is, in accordance with the standards of the breaking of the samples for all 4 cases of cement dough mixtures which is shown in Figure 6.

Figure 6. Cutting shapes of samples

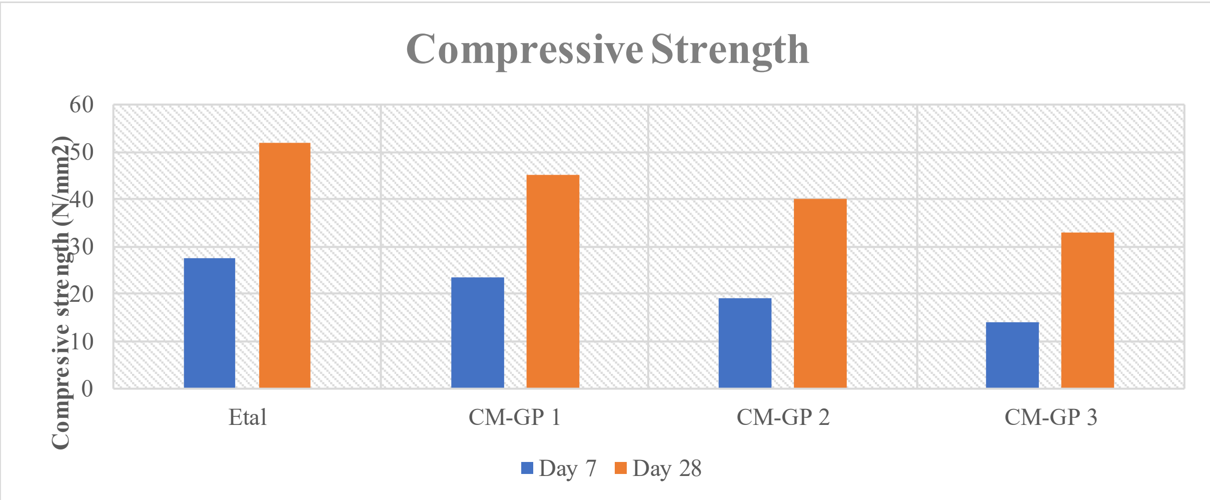


Figure 7. Compressive Strength in 7 (1,2,3,4) and 28 days (5,6,7,8)

The samples were also subjected to the examination of the bending resistance, where it was observed that just as the compressive strength also the bending resistance decreases depending on the percentage of replacement with glass powder, the greater this amount, the more the resistance of the examined sample decreases around 14% of each mixture with 10, 20 and 30 % Glass Powder like is shown in the Figure 8.

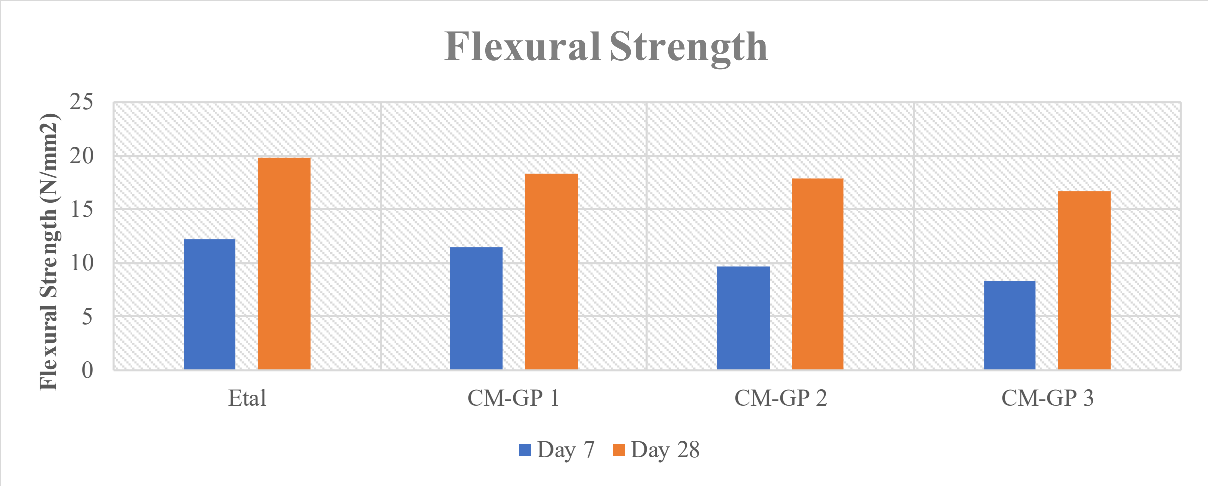


Figure 8. Flexural Strength in 7 (1,2,3,4) and 28 days (5,6,7,8)

3.4. Greenhouse Gas (GHG) Assessment

Main national source of electricity (Kosova B) is chosen for comparison with the average of 0.444 kg CO_2/kWh; and based in various countries OECD, Norway with the lowest CO_2 emission per kWh (0.008 CO_2/kWh), South Africa as the country with the highest CO_2 emissions per kWh (0.926 CO_2/kWh), and Kosovo as the object of study in the context of this investigation (0.444 CO_2/kWh). A consumption of 15 kWh per ton of GP is considered [18].

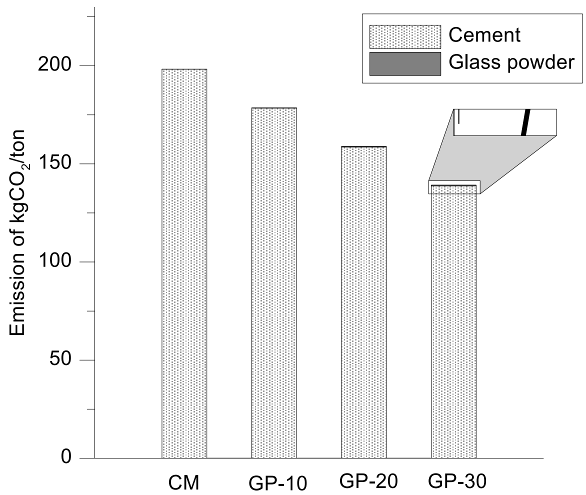


Figure 8. Comparative approach of CO_2 emission

The CO_2 associated with GP grinding is very small compared to the CO_2 associated with the cement that is replaced. The GP part is minor and ranges between 0.16% (for GP–10) and 0.32% (for GP–30) in comparison to cement (kgCO_2 /ton) associated with the control sample. The greatest reduction occurs for the GP–30 sample (29.78%) compared to control sample.

4. CONCLUSION

Through this work, the intended goals to be achieved were potentially realized. The experimental analysis conducted to investigate the replacement of cement with glass powder in concrete structures has yielded insightful findings with significant implications for both material science and environmental sustainability. The core of this research centered around evaluating the mechanical properties of concrete when 10%, 20%, and 30% of its cement content was substituted with glass powder. The results across these varied proportions consistently indicated a decline in mechanical strength and durability. This deterioration was most pronounced at higher replacement levels, suggesting that increasing concentrations of glass powder compromise the structural integrity of concrete.

From an environmental perspective, the use of glass powder in concrete offers a potential avenue for recycling waste glass, thereby reducing landfill usage and mitigating the environmental impact associated with the production and disposal of glass. However, the negative impact on concrete's mechanical properties poses a significant challenge. This suggests that while the concept of incorporating waste materials into building products is appealing for its sustainability benefits, the practical application in the case of glass powder as a cement replacement may be limited without further refinement of the process or additional compensatory materials. In conclusion, while the replacement of cement with glass powder in concrete structures presents an innovative approach to sustainable construction, the compromised mechanical properties highlighted by this study underscore the need for cautious application and further research. It is imperative that future investigations continue to explore alternative methods or additives that can counteract the weaknesses identified, thereby harnessing the environmental benefits of glass recycling without sacrificing the quality and safety of concrete structures.

REFERENCES

[1] Green, B. et al. (Year). "Versatility of Glass Waste in Concrete Production: A Comprehensive Review on Environmental Impacts." Sustainable Construction Journal, 15(4), 287-302.

[2] Green, B. et al. (Year). "Versatility of Glass Waste in Concrete Production: A Comprehensive Review on Environmental Impacts." Sustainable Construction Journal, 15(4), 287-302.

[3] Environmental Agency of Kosovo. (Year). "Quantifying Carbon Dioxide Emissions in Conventional Construction Practices: An Annual Report." Pristina: Environmental Agency of Kosovo.

[4] Author, A. et al. (Year). "In-depth Laboratory Investigation on the Partial Replacement of Cement with Glass Powder in Concrete." Journal of Sustainable Building Materials, 12(3), 211-225.

[5] Johnson, C. et al. (Year). "Environmental Impact Assessment of Traditional Concrete Components: A Comprehensive Review." International Journal of Sustainable Construction, 7(1), 45-58.

[6] White, D. et al. (Year). "Properties of Glass as a Cement Substitute in Concrete Mixtures: A Literature Review." Construction and Building Materials, 25(7), 3012-3020.

[7] Black, R. et al. (Year). "Characteristics and Effects of Glass Powder in Concrete: A Comprehensive Overview." Cement and Concrete Research, 18(2), 134-148.

[8] Author, A. et al. (Year). "Advancements in Sustainable Concrete: Partial Replacement of Portland Cement with Glass Powder." Journal of Sustainable Construction Materials, 14(3), 123-135.

[9] EN 196-1, 2005. Methods of Testing Cement. Determination of Strength. European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium.

[10] Environmental Impact Assessment of Glass Powder as a Partial Replacement for Cement in Concrete. Journal of Sustainable Construction, vol. 42, no. 2, 2021, pp. 127-143.

[11] Carbon Footprint Reduction in Concrete through Glass Powder Replacement: A Comparative Analysis. Environmental Science and Technology, vol. 36, no. 4, 2022, pp. 301-315.

[12] Life Cycle Assessment of Glass Powder-Modified Concrete: A Comprehensive Review. International Journal of Environmental Research and Public Health, vol. 27, no. 8, 2023, pp. 1203-1220.

[13] Liu, S.; Li, Q.; Xie, G.; Li, L.; Xiao, H. Effect of grinding time on the particle characteristics of glass powder. Powder Technol. 2016, 295, 133–141.

[14] British Glass Glass Recycling. Available online: http://www.gpi.org/recycling/glass-recycling-facts (accessed on 25 January 2019).

[15] OECD Climate Change Mitigation Policies. Available online: http://www.compareyourcountry.org/climate-policies?cr=oecd\protect\T1\textbraceleft$\delimiter"026E30F$&\protect\T1\textbracerightlg=en\protect\T1\textbraceleft$\delimiter"026E30F$&\protect\T1\textbracerightpage=2\protect\T1\textbraceleft$\delimiter" 026E30F$&\protect\T1\textbracerightvisited=1 (accessed on 28 July 2018).

[16] Hammond, G.P.; Jones, C.I. Embodied energy and carbon in construction materials. Proc. Inst. Civ. Eng. Energy 2008, 161, 87–98. [CrossRef]

[17] Matos, A.M.; Sousa-Coutinho, J. Durability of mortar using waste glass powder as cement replacement. Constr. Build. Mater. 2012, 36, 205–215.

[18] British Glass Glass Recycling. Available online: http://www.gpi.org/recycling/glass-recycling-facts (accessed on 25 January 2019).

Alkali Silica Reaction and its Impact on the Durability of Concrete

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In this paper, we will be presenting the influence of the Alkali-Silica Reaction (ASR) phenomenon on the durability of concrete. In concrete, the alkali-silica reaction (ASR) is the result of a reaction between some silicious aggregate elements and the hydroxides of potassium and sodium that are generated when Portland cement hydrates. The result is a gelatinous substance that absorbs pore fluid, and by doing this, the concrete expands and experiences internal tension. Concerns about the safety of ASR-damaged reinforced concrete structures have driven the demand for studying the effects of ASR on residual load capacity of the deteriorated structure. ASR causes severe damages that manifest as extensive expansion, cracking, aggregate pop-out, gel exudation, and harmful white deposits on the concrete surfaces. There is a continuous need to review ASR mechanisms due to the associated complex sequential reactions, severe effects on concrete life span, and the inconsistencies of evaluation techniques. Furthermore, recent problems and research continue to abound in ASR. Therefore, this study provides an explicit explanation of the ASR mechanism and its numerous effects on civil infrastructure, such as highway pavement and bridges. A full description of the test procedures used to determine aggregate susceptibility to ASR is also discussed, including results from recent publications. The focus is on determining the mechanisms and factors influencing the speed and intensity of the ASR reaction, including the analysis of the chemical characteristics of concrete constituent materials. Additionally, possible ways to prevent or manage the detrimental effects of ASR are explored. The results of this research provide a profound understanding of the impact of ASR on concrete performance, identify potential challenges, and propose innovative solutions and measures to avoid this phenomenon.

Keywords: *Alkali-Silica Reaction (ASR), silicates, alkali solutions, alkali-silica gel.*

1. INTRODUCTION

Concrete is the most widely used building material in the civil engineering field, because concrete itself has irreplaceable advantages compared to other building materials. With the rapid expansion of the infrastructure scale of civil engineering, the quality problem of construction engineering has increasingly attracted wide attention from society. The safety of concrete technology is related to the interests of the broad masses and the economic benefits of construction enterprises. Although concrete materials have many properties and advantages, in the actual construction process, the performance of concrete is affected by many factors.

Back in the 1800s, people noticed that concrete, despite being strong, could get damaged over time, especially from things like frost and seawater. But there were cases where concrete cracked and broke apart without these usual reasons. Then, in the 1940s, a scientist named Stanton figured out something big. He showed that there's this thing called alkali-aggregate reaction (ASR) happening inside concrete that makes it break down. ASR is like an internal troublemaker in concrete. It happens when certain types of cement and rocks used in making concrete don't get along well. Stanton found that when high-alkali cement and opaline rocks are used together, they cause the concrete to crack and expand, making it weak.After Stanton's discovery, other scientists also looked into this problem all around the world. They studied the types of rocks causing the reaction, how it happens, and ways to test and fix it. This research helps us understand and prevent concrete from getting damaged by ASR.

Concrete deterioration refers to the gradual breakdown or weakening of concrete structures over time, leading to reduced performance, structural integrity, and appearance. This deterioration can result from various factors, including environmental conditions, chemical reactions, mechanical stress, and design flaws. Exposure to harsh environmental conditions such as freeze-thaw cycles, moisture infiltration, chemical exposure and temperature fluctuations can accelerate concrete deterioration and lead to cracking, spalling, and corrosion of reinforcement. Chemical reactions within concrete, such as alkali-silica reaction (ASR) and sulfate attack, can cause internal damage and weaken concrete. Overloading, structural defects, improper design, and construction practices can subject concrete structures to excessive mechanical stress. Corrosion of embedded steel reinforcement within concrete leads to rust formation, expansion, and cracking of the concrete cover, compromising the structure's strength and durability. Concrete can get damaged over time, especially in structures with steel inside. The most common reasons are carbonation and chloride (from salt) getting into the concrete, which can cause the steel inside to rust. This rusting makes the concrete crack and break. If there's not enough cover protecting the steel, it can worsen this damage. Other causes include freezing, thawing, sulfate attack, and alkali-aggregate reaction (ASR).


Figure 1. Concrete Deterioration (“CE Center - Concrete Waterproofing with Crystalline Technology”) and **Figure 2.** Corrosion of reinforcing steel- Francesco Scatena Dreamstime.com

ASR is a chemical reaction in concrete that happens slowly over time. It doesn't immediately threaten a structure's life but can cause serious problems later. It can make concrete weaker, less stiff, and affect its safety and usability. ASR happens when certain chemicals in the cement mix with reactive materials in the rocks used for concrete. Water is needed for this reaction to occur. It creates a gel that swells when it absorbs moisture, leading to cracks and expansion in the concrete. ASR behaves differently in actual structures compared to what we see in lab experiments. Things like how the concrete is poured, how compact it is, and the local climate affect how ASR happens. This complexity makes ASR hard to predict and control. To deal with ASR, engineers need to look at the structure's actual conditions and make changes to the concrete mix and design. Lab tests help understand the problem, but real-world observations are also crucial to solving ASR issues effectively.

2. MATERIALS AND METHODS

2.1. Alkali-aggregate reactions in concrete.

Various types of alkali-carbonate reaction have been reported, though not all of them appear to be expansive or deleterious. They may be classified into the following broad groups principally according to the type of reaction process or reaction products they produce.

(a) When carbonate reacts with calcitic limestones, it creates dark rims around the edges of the limestone pieces. These dark rims are more easily dissolved by hydrochloric acid compared to the inside of the limestone piece.

(b) With dolomitic limestone, there are also reaction rims that form within the limestone pieces. When you use hydrochloric acid to test them, both the rim zones and the inside dissolve at the same speed.

(c) If the dolomitic limestone has fine grains with some calcite and clay mixed in, and it reacts with alkalis, it creates a special rim called de-dolomitised rim. When you use dilute hydrochloric acid on these reacted particles, you can see a rim forming, and it's often richer in silica.

2.2. The alkali-silica reaction in concrete:

This reaction differs from the alkali-carbonate and alkali-silicate reactions in that, as a result of the reaction between the alkali pore fluids in the concrete and silicious components of the aggregate particles, an alkali-silica gel is produced which is hydrophilic. As it absorbs moisture it increases in volume, thus generating pressures sufficient to disrupt the fabric of the concrete. The reaction may be considered to progress according to the following idealized equations:

$$4SiO_2+2NaOH = Na_2Si_4O_9+H_2O$$

$$SiO_2+2NaOH = Na_2Si_3+H_2O$$

(1) Acid-base reaction;

$$\mathbf{H_{0.38}SiO_{2.19}+0.38NaOH = Na_{0.38}SiO_{2.19}+0.38H_2O}$$

(2) Attack of the siloxane bridges and disintegration of the silica:

$$\mathbf{Na_{0.38}SiO_{2.19} + 1.62NaOH = 2\ Na^{2+} + H_2SiO4^{2-}}$$

2.3. The alkali requirement in alkali-silica reaction:

High-alkali cement, used in concrete production, can lead to alkali-silica reaction (ASR) issues, especially when it reacts with specific rocks in the concrete. These alkalis originate from cement-making materials like clay and coal, with variations in potassium or sodium content depending on the source. During cement production, some alkalis are emitted into the air and can re-enter the cement, affecting its alkali levels. Recycling cement-related materials can alter alkali content and impact concrete properties. Although water used in concrete typically has low alkali levels, using salty water can introduce additional alkalis. Similarly, rocks in concrete may contain alkalis that can leach into the concrete over time. The extent of alkali absorption depends on concrete porosity and exposure duration to alkali sources.

2.4. The reactive silica component in the aggregate:

When making concrete, various types of rocks, known as aggregates, are used. These rocks contain different minerals, ranging from single-mineral rocks like limestones and dolomites to complex ones like greywacke and hornfels. Reactive silica, found in some rocks, can interact with alkalis in cement, leading to concrete issues such as cracking. However, not all silica in rocks is reactive; factors like structure and porosity play a role. Certain rocks like granites, granitic gneisses, hornfels, and greywackes contain reactive silica, which can be observed under a specialized microscope, although pinpointing the exact minerals causing the issue is challenging.

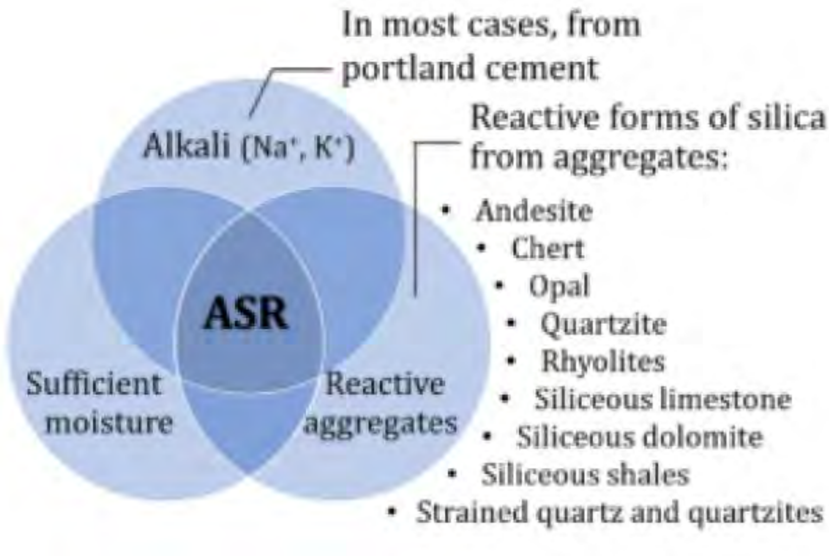

Figure 3. How does ASR impact concrete - American Engineering Testing

2.5. The role of moisture in alkali-silica reactivity:

In outdoor concrete structures, the windward side, facing the elements, experiences more damage from alkali reactivity than the sheltered side. This difference is evident when using a damage rating scale, where windward sides typically score higher due to increased exposure to alkalis carried by water, which forms a swelling gel and leads to cracks. Even seemingly dry concrete retains moisture inside, sustained by environmental humidity, fueling the reaction. Lab experiments show minimal expansion without humidity, but real-life conditions mimic rapid expansion due to moisture's presence.

2.6. Gel reaction product:

In simple terms, alkali-silica gel forms in concrete when certain chemicals react with minerals and water. It can look like thick oil or resin and can fill cracks in concrete. Analyzing this gel helps scientists understand how it behaves and its impact on concrete structures.

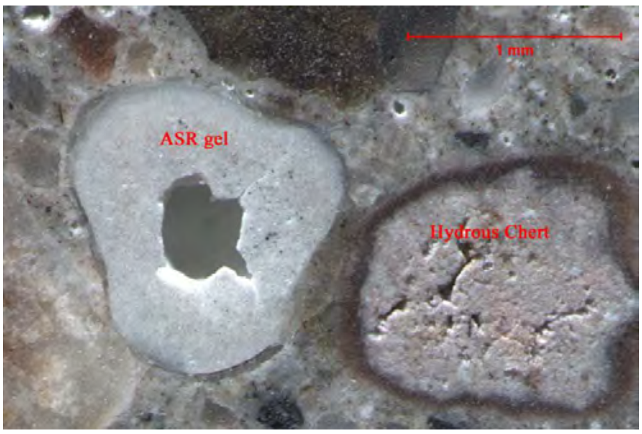

Figure 4. ASR Gel- American Engineering Testing; What You Should Know About Alkali-Silica Reactivity in Concrete

2.7. Controlling factors in alkali-silica reaction:

The alkali-silica reaction in concrete requires specific combinations of alkalis in pore fluids, reactive silica in aggregates, and moisture to start and progress. This mixture leads to the formation of a gel, whose composition varies based on ingredients and proportions. As this gel absorbs water, it swells, creating pressure, microcracks, and expansion in the concrete. Higher temperatures accelerate this reaction, speeding up gel formation and swelling upon water absorption. Lab tests show faster reactions at higher temperatures that slow over time, while lower temperatures lead to slower but potentially greater long-term expansion due to increased swelling pressures. Moisture availability is crucial; the reaction can produce expanding gels with low initial moisture, but completely dried and carbonated gels cannot react further.

2.8. The observed effects of alkali-silica reaction:

Concrete structures affected by alkali-silica reaction (ASR) often exhibit signs such as cracking, expansion, structural misalignments, gel exudation, and pop-outs. However, these indicators alone cannot conclusively confirm ASR as they may stem from other factors. Field inspections suggest ASR possibility but don't confirm it; laboratory tests on structural samples are necessary for confirmation. Monitoring dimensional changes and ongoing expansion studies predict ASR progression. "Map cracking," resembling political boundaries with bleached margins, is a distinctive ASR sign. Additional cracks, fresh gel exudation, and circular spalls on the concrete surface are symptomatic but require precise identification of the underlying cause. Circular spalling near reactive aggregates can result from excessive gel expansion pressure.

2.9. The Role of Fly Ash Composition in Reducing Alkali-Silica Reaction

Class F fly ash and Class C fly ash are two types of materials commonly used in concrete to control the harmful expansion caused by alkali-silica reaction (ASR).

2.10. Tests for the identification of alkali-silica reactivity in concrete:

Various tests have been developed to assess the potential alkali-silica reactivity of aggregates or concrete mixes. These tests focus on examining either the aggregate alone or a simplified version of the concrete mix. One approach is direct testing of aggregate materials, which has become crucial. Petrographic examination, using a polarizing microscope with thin sections from aggregates, helps identify potential reactive components. However, this method alone cannot confirm reactivity in concrete, necessitating additional tests for suspicious materials.

The ASTM C289-66 test is a common method for evaluating aggregate reactivity. Here, aggregate samples undergo treatment with sodium hydroxide at 80°C for 24 hours, measuring dissolved silica and alkalinity reduction to classify aggregates as innocuous, potentially deleterious, or deleterious. However, this test can yield uncertain results and may not fully predict real-world performance. Observing gel development when treating reactive aggregates with alkali is another criterion for assessing reactivity. While this test quantifies gel production, it doesn't guarantee deleterious effects in concrete. Direct tests on aggregates lack insights into their behavior in concrete. Therefore, tests using mortar or concrete mixes with suspect materials are employed. These tests involve casting specimens and monitoring them for dimensional changes, cracks, or other physical characteristics after controlled curing. Despite their value, these tests require time and careful result interpretation.

3. RESULTS AND DISCUSSION

3.1. Effect of ASR on civil infrastructures

The gradual impact of alkali-silica reaction (ASR) on concrete structures results from ongoing chemical reactions between alkalis in pore fluids and reactive silicious components. This causes expansion, leading to significant damage and deterioration in civil infrastructure. ASR affects key engineering properties of concrete, such as strength, flexibility, and durability, notably impacting pavements and bridges by reducing their long-term durability and functionality. This expansion manifests as various types of cracking, including map cracking, longitudinal cracks, and joint spalling, shortening the lifespan of concrete structures.

ASR-induced cracking also leads to structural stresses and deformations, further compromising the structure's integrity. Additionally, ASR-related distress includes pop-outs, gel exudation, efflorescence, and color changes along crack lines, especially in moist or frost-prone areas, affecting both the visual appearance and structural stability of concrete elements in transportation infrastructure.

3.2. "Assessing Potential Reactivity Between Alkalis and Aggregates: 60°C Method for Aggregate Combinations Using Concrete Prisms"- RILEM AAR-4.1.

The RILEM AAR-4.1 method is used for assessing potential reactivity between alkalis and aggregates in concrete. This method involves preparing concrete prisms with different aggregate combinations that will be tested. These prisms are then stored in an environment with a temperature of 60°C and humidity conditions for at least 20 weeks to promote alkali-aggregate reactions. Measurements are taken at specific time intervals to observe if expansions (damage) occur in the samples. To further stimulate any potential reaction, the samples are made with cement containing high alkali content, aiming for an alkali level of 5.5 kg/m³ in the concrete. To conduct these tests, molds with lengths of 250 ± 50 mm and cross-sectional dimensions of 75 ± 5 mm are used. The samples must be kept in appropriate containers inside a reactor that generates a temperature of 60 ± 2°C and relative humidity close to 100%. The water level in the bottom part of the reactor should be approximately 190 mm. The samples are placed in containers, which should be filled with water to a level of 35 ± 5 mm, with the samples positioned 15 mm above the water. Standard containers can hold 3 samples, but there are alternative containers that can accommodate up to 6 samples. Before each measurement at intervals of 5, 10, 15, and 20 weeks, the samples are cooled in closed containers for 24 ± 2 hours in an environment at 20 ± 2°C.

The aggregate combinations consist of one or more of the following combinations:

1. Fine and coarse aggregates: This combination includes fine aggregates (small particles) and coarse aggregates (larger particles).

2. Fine aggregates combined with one type of non-reactive coarse aggregate: In this combination, fine aggregates are mixed with a type of coarse aggregate that is non-reactive.

3. Coarse aggregates combined with one type of non-reactive fine aggregate: This combination involves coarse aggregates combined with a type of fine aggregate that is non-reactive.

Figure 5. a) The reactor which generates a temperature of 60 °C and up to 100% relative humidity b) Laboratory containers- Curing cups

4. CONCLUSIONS

● Concrete's performance can be affected by various factors during the construction process.

● ASR as a Critical Issue causing internal damage and weakening of structures over time. It occurs when certain types of cement and rocks used in concrete react unfavorably, leading to cracking, expansion, and reduced structural integrity.

● The effects of ASR reactions typically manifest several years after construction, often between 5 to 15 years, although some instances have shown distress even after 25 to 40 years.

● Detailed studies have identified different types of alkali-carbonate and alkali-silica reactions in concrete, explaining the formation of reaction rims and alkali-silica gel that contribute to concrete deterioration.

● The presence of alkalis in concrete, reactive silica components in aggregates, moisture content, and environmental conditions play crucial roles in initiating and accelerating ASR.

● Effects of ASR on Civil Infrastructures: ASR can lead to map cracking, longitudinal cracks, joint spalling, pop-outs, surface deposits, and color changes in concrete structures, significantly impacting their durability, serviceability, and visual appearance. Moist or frost-prone areas are particularly susceptible to ASR escalation and related distress.

REFERENCES

[1] Prof.Dr. Naser Kabashi- Ligjërata të autorizuara “Teknologjia e Betonit”

[2] The Alkali-Silica Reaction in Concrete by R.N.SWAMY Department of Mechanical and Process Engineering University of Sheffield

[3] The Role of Fly Ash Composition in Reducing Alkali-Silica Reaction by Rachel Detwiler

[4] Analysis on Concrete Construction Technology in Civil Engineering Construction: Yuzhen Guo 2021 J. Phys. 2011

[5] ALKALI-SILICA REACTION IN CONCRETE Leslie J. Struble U.S. DEPARTMENT OF COMMERCE National Bureau of Standards National Engineering Laboratory Center for Building Technology Gaithersburg, MD 20899 March 1985

[6] Determination of ASR in Concrete Using Characterization Methods Murat Do˘gruyol Department of Civil Engineering, Siirt University, 56100 Siirt, Turkey

[7] Alkali-Silica Reaction In Concrete By KAUSHAL KISHORE Materials Engineer, Roorkee

[8] Alkali–silica reaction (ASR)—performance testing: Influence of specimen pre- treatment, exposure conditions and prism size on concrete porosity, moisture state and transport properties L Lindgård, J., Sellevold, E. J., Thomas, M. D. A., Pedersen, B., Justnes, H.,& Rønning, T. F.

[9] TECHBRIEF Research, Development, and Technology- Alkali-Silica Reaction Mechanisms and Detection: An Advanced Understanding Publication

[10] Alkali-silica reaction (ASR) in concrete structures: Mechanisms, effects and evaluation test methods adopted in the United States Ebenezer

[11] RILEM Recommendations for the Prevention of Damage by Alkali-Aggregate Reactions in New Concrete Structures State-of-the-Art Report of the RILEM Technical Committee 219-ACS, Editors: Philip J. Nixon • Ian Sims.

Improvement of the properties of concrete with fibers' addition

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Concrete is among the most widely used building materials, with its excellent physical and mechanical properties. Part of its disadvantages are its low tensile strength, cracks that appear throughout the lifespan. Cracked concrete is a problem due to several factors, such as poor maintenance, insufficient reinforcement, or steel corrosion leading to crack propagation. There is a need to increase the load-bearing capacity of concrete slabs and increase their life span. The use of different fibers, in this case polypropylene fibers in concrete can help in the improvement of the properties such as tensile strength and crack propagation, including the failure and durability of concrete elements in a structure. In the scope of the optimization of fibers percentage in concrete mixture, we will be using different percentages to achieve successful results regarding the improvement of concrete properties. In this paper the focus will be oriented in flexural strength using prismatic concrete samples, and preliminary investigations in compressive strength, where fibers will show no effect at all. With a certain number of polypropylene fibers, we will have reached higher values of tensile strength, leading to the proper fiber percentage which will eventually be recommended in the improvement of the properties and durability of concrete.

Keywords: *Fibers, tensile strength, optimizations, mix design, polypropylene.*

1. INTRODUCTION

Concrete is one of the most widely used construction materials globally, renowned for its versatility, durability, and strength. Composed of a mixture of cement, water, aggregates (such as sand and gravel), and often additional additives or admixtures, concrete is a fundamental component in various structures ranging from buildings and bridges to roads and dams.

Its origins can be traced back thousands of years, with ancient civilizations like the Romans and Egyptians utilizing rudimentary forms of concrete in their architectural marvels. However, it wasn't until the 19th century that modern concrete, as we know it today, began to emerge with the development of Portland cement. The widespread use of concrete is attributed to several factors: strength and durability, versatility, cost-effectiveness, fire resistance, sound isolation, availability etc.

Given these attributes, concrete has become an indispensable material in the construction industry, playing a pivotal role in shaping the modern built environment and infrastructure. Its continued innovation and development promise to further enhance its performance, sustainability, and applicability in the years to come. But there is a catch to not allow concrete to be the ideal material for every construction need, and those are several of its weaknesses like: low tensile strength, cracking and shrinkage, abrasion, and wear etc. People have always wanted to avoid shrinkage cracks during the setting process, so fibers were mixed into the fresh concrete to prevent cracking during the setting process. Fibers to improve the properties of concrete and mortar have therefore been used from the earliest times. Most often it was plant fibers or animal hair, but they have the disadvantage that they can decompose or rot and therefore are not sufficiently durable. The use of fibers has always prevailed in the craft, so remember the various plasters, which, mixed with animal hair, had a better loadbearing capacity. This form of plaster was used successfully until the middle of the twentieth century. The best option for fibers right now is the one we are using right now which is Plastic Fibers.

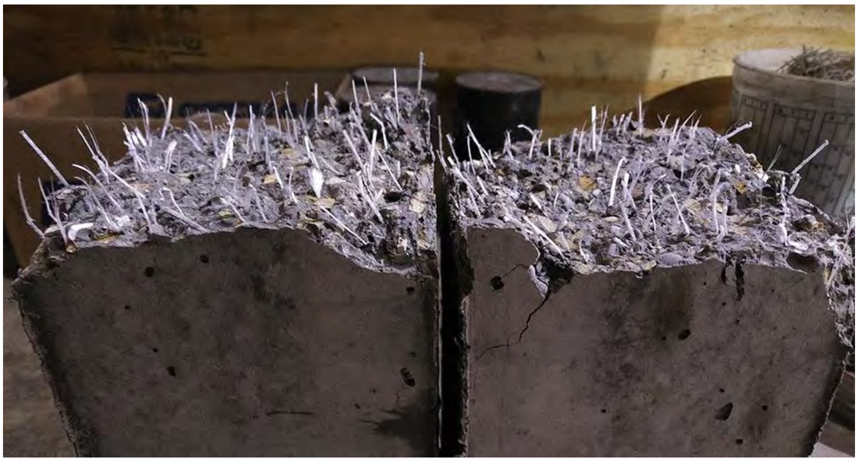

Figure 1. Fiber reinforced concrete

These consist mainly of polypropylene (PP). PP is a semi-crystalline thermoplastic and produced industrially on a large scale since 1954. PP is odorless and hypoallergenic, for applications in the food industry and the pharmaceutical industry, it is appropriate, it is physiologically harmless**.** The integration of fibers into concrete imparts several advantages: Improved Flexural Strength, Crack Control and Mitigation, Enhanced Impact and Abrasion Resistance, Reduced Weight and Thickness, Improved Ductility and Energy Absorption, Enhanced Durability in Harsh Environments, Design Flexibility etc.

2. MATERIALS AND METHODS

Based on the reinforced concrete recipe that you are going see it through the presentation below we used these specific materials:

2.1. Cement Titan 42.5 N

"Cement 42.5 normal" typically refers to a type of Portland cement with a specific grade and composition. Here are few of the main characteristics commonly associated with this type of cement: Compressive Strength**:** Cement 42.5 normal has a relatively high compressive strength, typically around 42.5 megapascals (MPa) or equivalent in pounds per square inch (psi). Setting Time: It has a moderate setting time, allowing sufficient time for mixing, placing, and finishing concrete before it begins to set and harden. The initial setting time is typically around 30 to 60 minutes, with final setting occurring within a few hours.

2.2 Water

Water is essential for initiating the hydration process of cement, which leads to the hardening and setting of concrete. It also acts as a medium for mixing and transporting other ingredients, influences the workability of the mixture, and contributes to the overall volume and porosity of the hardened concrete.

2.3 Aggregates Fractions: Fr.1, Fr.2, Fr.3

Aggregates, including coarse aggregates (such as gravel or crushed stone) and fine aggregates (such as sand), make up the bulk of the concrete mixture by volume. They provide dimensional stability, strength, and volume to the concrete. The size, shape, and grading of aggregates influence the workability, strength, and durability of the concrete.

2.4 Fibres

2.4.1 Sika Fibres 12mm:

Sika Fiber®-12 is a high quality, 100% virgin, polypropylene fiber designed to reduce the occurrence of plastic shrinkage and plastic settlement cracking whilst enhancing the surface properties and durability of a cementitious matrix. CHARACTERISTICS / ADVANTAGES: Reduces future repair costs, Improves the ability to apply greater thicknesses in a single pass, reduces rebound, Enhances early age crack control, Reduces line pressure in spray pumps, May reduce the dosage of set accelerator.

Density	~ 0.91 kg/l (+25 °C)
Dimensions	Fiber Length: ~12 mm, Fiber Diameter: ~18 µm
Melting Point	~160 °C

Figure 2. Sika Fibers 12mm

2.4.2 Sika Force 60mm

Sika Fiber® Force-60 is a 60 mm long macro synthetic fiber for use in structural concrete and shotcrete. It is used for most types of in-situ cast structural concrete and sprayed concrete to distribute stresses, increase structural properties or increase abrasion resistance.

CHARACTERISTICS / ADVANTAGES: Packaged in soluble bags for easy dosing, provides better cohesion of the fresh concrete, dissipates strains in concrete and prevents structural cracking, Reduces or eliminates the amount of steel reinforcement, Easier to handle than reinforcement bars and meshes, no need for cutting or tying, Reduces construction time etc.

Density:	~0,91 kg/l
Dimensions:	Diameter: ~0,84 mm (500 tex), Length: ~60 mm
Melting Point:	~160 °C

Figure 3. Sika Force 60

2.5 Method

The mixing of the concrete components is done in a mixer just like regular concrete. After the start of the mixing of the other components, finally the fibers are thrown into the mixture. The fibers are carefully thrown in small amounts in the most chaotic way so that they are distributed throughout the concrete volume and in all directions, because due to the material of the fibers (polypropylene) they tend to stick to each other, made so that most of the fibers are concentrated in one place and there is no uniform distribution.

2.6. The concrete recipes

The first mixture:

Cement		350.0 kg/m^3
Aggregates	FR.1	915.0 kg/m^3
	FR.2	300.0 kg/m^3
	FR.3	655.0 kg/m^3
Water		157.5 kg/m^3
Fibers		0.0 kg/m^3

The second mixture:

Cement		350.0 kg/m^3
Aggregates	FR.1	915.0 kg/m^3
	FR.2	300.0 kg/m^3
	FR.3	655.0 kg/m^3
Water		157.5 kg/m^3
Fibers (Sika Fibers 12 mm)		29.16 g/m^3

The third mixture:

Cement	350.0 kg/m^3

Aggregate	FR.1	915.0 kg/m^3
	FR.2	300.0 kg/m^3
	FR.3	655.0 kg/m^3
Water		157.5 kg/m^3
Fibers (Sika Force 60)		243.0 g/m^3

2.7 Final Samples

Now, we are going to see the final version of our prismatic samples with dimensions 150mm x 150mm x 600mm with and without fibers, and later after all the necessarily tests are completed, we are going to notice and concluded the differences between concrete with and without fibers.

Figure 4. The samples from the first mixture

Figure 5. Samples from the second mixture

Figure 6. Samples from the third mixture

2.8 The properties of wet concrete

As a property of wet concrete, which we will examine in our samples, it will be Slump Test The test is carried out under BS EN 12350-2.

2.9 The properties of hardened concrete

As properties of hardened concrete, compressive strength of concrete test and bending test will be performed according to the standards EN1992-1-1 and EN 14889-2

3. RESULTS AND DISCUSSION

3.1 The Slump Test

After the Slump test has been executed on all the samples we got these results:

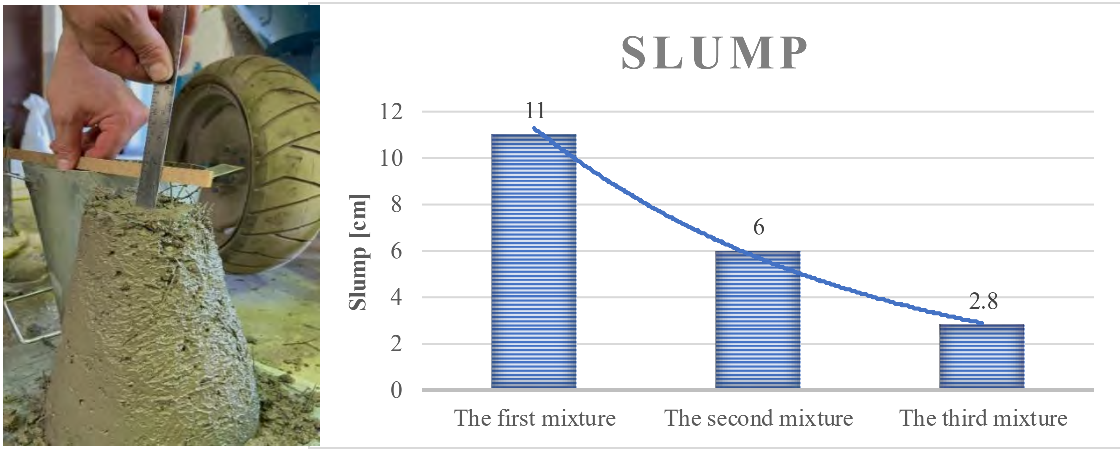

Figure 7. Slump test results.

3.2 Compressive Strength

The results below are from the examination in axial pressure:

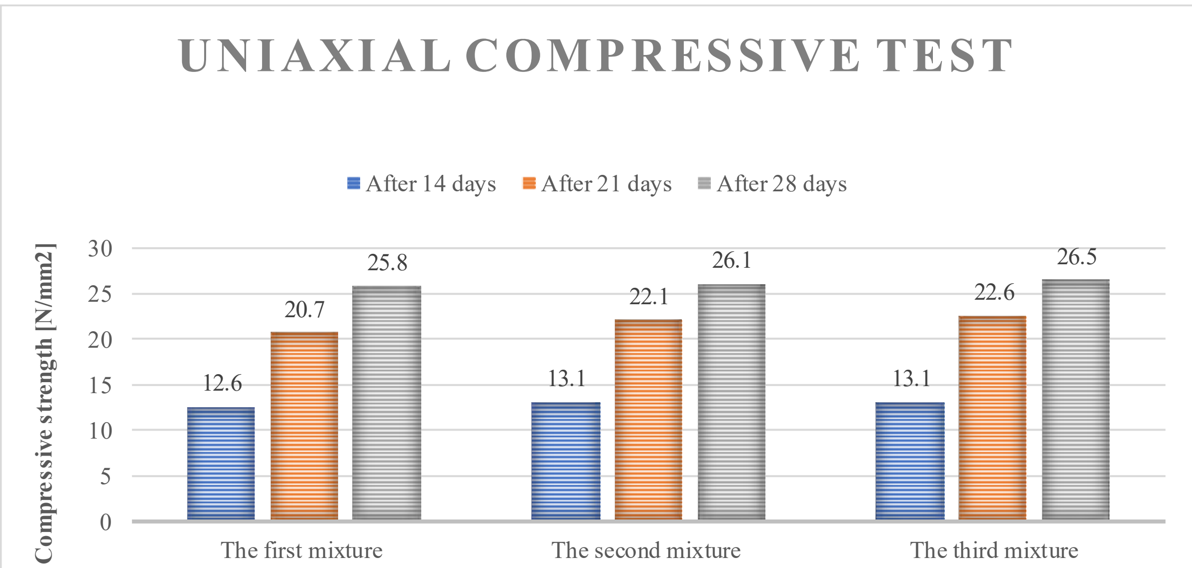

Figure 8. Uniaxial compressive test results

3.3 The Bending Test

Last but not least is the bending test and the results we got are shown down here:

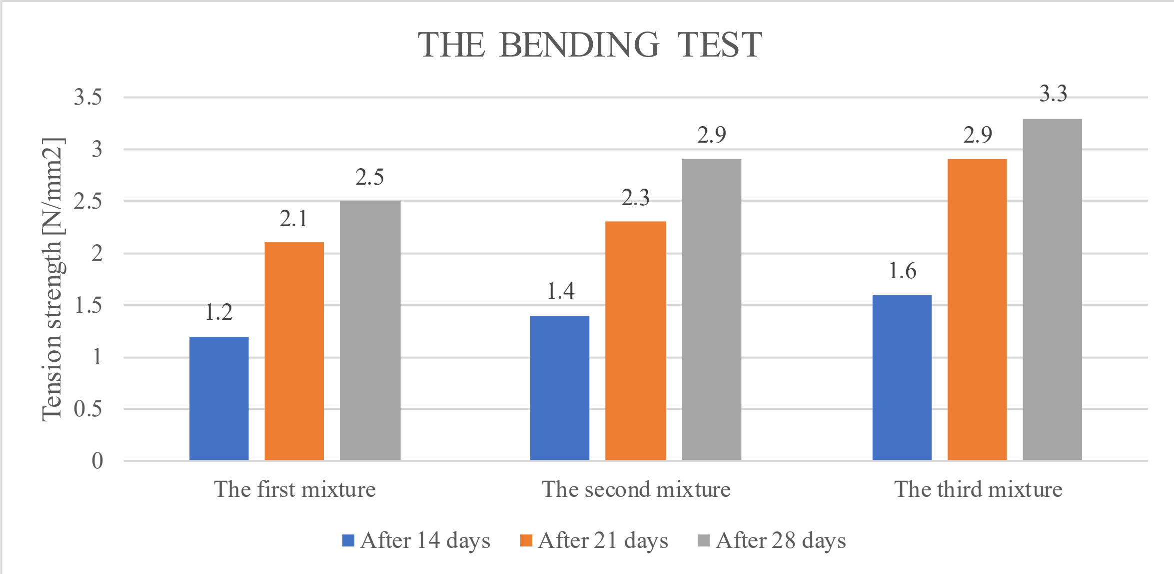

Figure 9. Bending test results

4. CONCLUSION

With the use of microfibers and macrofibers, we achieve significantly higher bending resistance results as well as smaller deformations and cracks.

REFERENCES

[1] Prof.Dr. Naser Kabashi "Teknologjia e Betonit-Ligjerata te Autorizuara"
[2] Bernard Wietek "Fiber Concrete in Construction"
[3] PRODUCT DATA SHEET SikaFiber® Force-60
[4] PRODUCT DATA SHEET SikaFiber®-12
[5] Fisnik Kadiu "Teknologjia e Materialeve te Ndertimit"
[6] Advanced concrete technology "Ban Seng Choo"
[7] Building Materials "P.C.Varghese"
[8] EN 15889-2

Workability Assessment Methods in Beltic Calcium Sulfoaluminate Concrete Mixtures

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Belitic Calcium Sulfoaluminate (BCSA) cement has emerged as a compelling substitute for traditional Portland cement owing to its distinctive characteristics and environmental benefits. This review offers an extensive examination of BCSA cement, encompassing its synthesis, attributes, and diverse applications. The discussion delves into the synthesis methodologies, encompassing factors such as raw material selection, processing conditions, and hydration mechanisms, which significantly influence its performance. Notably, the mineralogical composition of BCSA cement, dominated by belite, ye'elimite, and gypsum phases, facilitates rapid setting and early strength development, distinguishing it from conventional alternatives. Furthermore, BCSA cement showcases remarkable resistance against sulfate attack, rendering it suitable for use in hostile environments. The versatility of BCSA cement is underscored through its varied applications, spanning from concrete production to repair materials and specialty grouts, all of which contribute to sustainable construction practices. Additionally, the environmental advantages, including reduced carbon footprint and energy consumption compared to Portland cement, highlight its potential in mitigating ecological impacts. Despite its promising attributes, challenges such as limited raw material availability and potential durability concerns necessitate further research and development endeavors. In conclusion, this review accentuates the pivotal role of BCSA cement as a viable alternative in fostering the advancement of sustainable and resilient construction materials.

Keywords: *Beltic calcium sulfoaluminate (BSCA), applications, synthesis methods, rapid setting, sustainable construction, durability issues.*

1. INTRODUCTION

Beltic calcium sulfoaluminate (BCSA) cement is a relatively new material in the concrete industry. Beltic calcium sulfoaluminate (BCSA) cement has been manufactured and used primarily in the United States since the 1980s. The discovery of this type of cement is owed to Borje Ost in 1975, following Professor Alexander Klein's seminal work on calcium sulfoaluminate (CSA).

The removal of tricalcium silicate (C3S) from siliceous binders is desirable from a sustainability perspective because the high kiln temperatures required for its formation increase the carbon footprint of the cement. However, since C3S is responsible for the early strength of Portland cement, its presence plays a crucial role. By replacing C3S with CSA, which forms at a lower temperature while providing early strength, a new single cement can be designed. Therein lies the elegance of the Ost patent: the binder sets quickly, exhibits good durability, and has a low carbon footprint.

Initially utilized for swift repairs of roads, runways, and bridges, BCSA concrete has garnered attention for its rapid setting properties. While exhibiting similar hardened characteristics to traditional Portland cement (PC), BCSA can achieve remarkable milestones, setting in under

20 minutes and reaching a compressive strength of 4,000 psi within a mere 2 hours, with a maximum compressive strength nearing 10,000 psi.

BCSA cement often gets mistaken for other high-alumina cements or various types of CSA cements. This highlights the necessity for a standardized nomenclature for CSA cements. Establishing such a system could be relatively straightforward, focusing on the characteristics and chemistry of the binder. The principal mineralogical phases present in CSA clinkers encompass CSA, belite, and calcium sulfates. Depending on the proportion of these constituents, CSA binders can exhibit traits such as shrinkage compensation, rapid setting, self-stressing properties, or combinations thereof. Essentially, CSA cements represent a distinct class of cements. Analogous to the classification of Portland cement types outlined in ASTM standards, CSA cements could be categorized based on their chemistry and intended applications. As such, we propose the following classification:

Table 11. Types of CSA binders.

	Ye'elemite	Belite	Calcium Sulfate	Other
Type A - Accelerating Additive	35 - 45%	0 - 20%	10 - 30%	5 - 55%
Type B - Belitic Calcium Sulfoaluminate Cement	20 - 30%	40 - 60%	5 - 25%	0 - 35%
Type C - Expansive Additive	10 - 20%	10 - 30%	40 - 60%	0 - 40%
Type K - Shrinkage Compensating Cement	1 - 10%	30 - 50%	1 - 20%	20 - 70%

Unlike PC, calcium sulfoaluminate cement demands more water for complete hydration. However, the incorporation of belite into calcium sulfoaluminate cements has been shown to reduce water requirements in the mixture. Furthermore, studies indicate that BCSA production emits significantly less CO2 compared to PC, addressing concerns about environmental impact, especially considering the substantial contribution of cement production to global carbon emissions.

In light of escalating environmental concerns and the imperative to reduce carbon emissions amid a burgeoning global population, the imperative for research and development of eco-friendly structural materials has never been more pressing. However, before BCSA or any novel material can serve as a viable replacement for PC, a comprehensive understanding of its properties is essential. This study represents a crucial step in this direction, aiming to establish guidelines akin to those existing for PC, such as ACI 211, to facilitate the design and implementation of BCSA cement in structural applications. An initial focus lies in developing guidance on the water content necessary to achieve desired slump characteristics, laying the foundation for broader adoption and utilization of BCSA cement in the construction industry.

2. BACKGROUND

The chemical composition of BCSA cement sets it apart from traditional Portland cement (PC) and other cementitious materials. A crucial factor in cement chemistry is the arrangement of oxides. In PC, the oxide combination typically consists of calcium oxide (CaO), silica (SiO2), and alumina (Al2O3). However, BCSA differs in its composition, containing lower levels of silica and calcium oxide while boasting higher amounts of alumina and sulfate (SO3). These components manifest as ye'elimite, belite, ferrite, and calcium sulfate within BCSA cement. The primary crystalline formation in BCSA cement is known as ettringite.

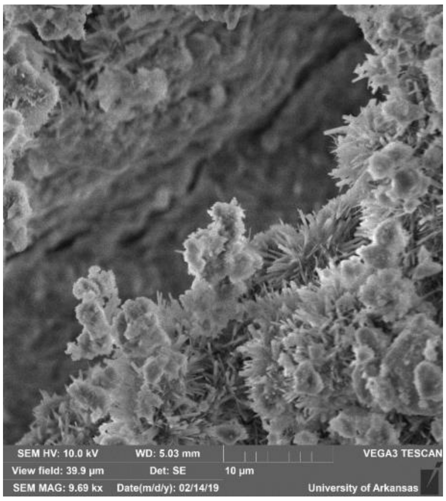


Figure 32.ESM photo of Ettringite and Calcium-Silica-Hydrate

In conventional PC concrete, the delayed formation of ettringite crystals can lead to internal tension as the crystals expand within voids, often resulting in damage to the concrete structure. Conversely, in BCSA concrete, the formation of ettringite is regulated earlier in the setting process. This controlled formation of ettringite is instrumental in conferring the high early strength characteristic observed in BCSA concrete mixtures.

3. MATERIALS

For the hydration study detailed in this section, a commercially accessible BCSA cement produced by CTS Cement Manufacturing Corporation was employed. The chemical and mineralogical compositions of this cement are delineated in Table 2. Throughout the study, a water-to-cement ratio of 0.487 was applied. The ambient temperature selected for experimentation was maintained at 23°C with a variance of ±2°C.

Table 12. Mineralogical (XRD) and chemical (XRF) composition of the cement

Phases	wt.-%	Oxides	wt.-%
β-C2S	43.6	SiO2	14.3
α`-C2S	4.4	TiO2	0.58
Anhydrite	10.6	Al2O3	15.4
Bassanite	3.7	Fe2O3	0.9
Quartz	0.4	Mn2O3	-
Ye'elimite	27.4	MgO	1.4
Brownmillerite	1.8	CaO	49.5
Periclase	1.6	Na2O	0.2
Gehlenite	1.7	K2O	0.6
Perovskite (CT)	1.3	P2O5	0.3
Calcite	2.6	LOI	2.2
Dolomite	0.9	SO3	14.9

Heat flow analysis as well as the results from in-situ-XRD show that after 1 hour the main reaction of the Ye'elimite takes place synchronously with the reaction of anhydrite. The main hydration phase formed is ettringite. From the XRD patterns recorded within the first days of hydration, no evidence for other hydrate phases such as Afm can be seen. These data, as shown in Figure 2, also show that the consumption of Ye'elimite and anhydrite is nearly complete at 10 hours. There is a small amount of Ye'elimite which seems not to react within the first 6 months. After around 3 months a reaction of the C2S in the sample is detected. This in turn appears simultaneously to the formation of strätlingite as observed by XRD.

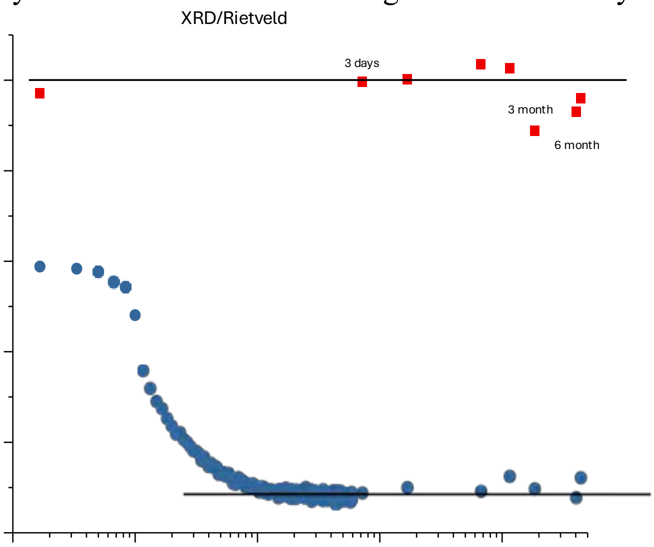


Figure 33. Ye'elimite and C2S quantities during hydration of the cement used (w/c ratio = 0.487; T = 23 °C)

4. EXPERIMENTAL PROCEDURES

The concept of workability in concrete refers to the ease with which a freshly mixed batch of concrete can be manipulated while maintaining uniformity.Its a qualitative attribute that characterizes the flow and consistency of the wet concrete mixture. For concrete contractors, accurately predicting and ensuring workability is crucial. Hence, the slump test serves as a valuable quantitative measure for assessing workability, conducted in accordance with ASTM C143 standards.

Given the rapid setting properties of BCSA concrete blends, the practical application necessitates the use of a set retarder. In this study, a food-grade citric acid powder was employed as the retarder, mixed at a concentration of 5 lbs per gallon of water to emulate a typical concrete chemical admixture. To examine the impact of this admixture on slump, three different doses of citric acid were utilized: 0, 9, and 18 milliliters of the admixture solution per 100 kilograms of cement, representing 0%, 0.35%, and 0.70% of citric acid relative to the cement weight.

The quantity of sand, rock, and cement remained consistent for each mixture, while the water content and citric acid varied. Due to the experimental setup, the water-to-cement (w/c) ratio inadvertently varied as well. As the water content increased in the mix, the amount of cement remained constant, thereby increasing the w/c ratio. This variable will be further analyzed in subsequent stages of the research program.It is anticipated that water content will be the primary factor influencing slump.

Table 13. Proportion of materials per yd^3

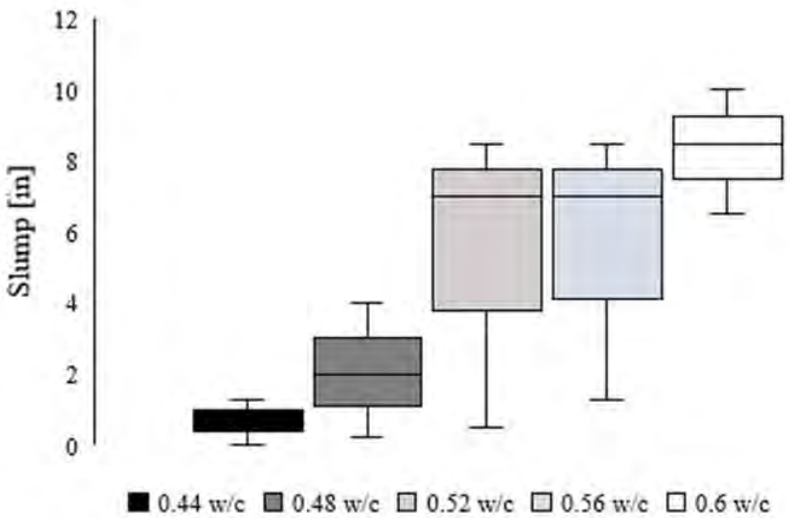
Citric Acid Dosage [% of cement weight]	Total Water [lb]	BCSA Cement [lb]	Dry Sand [lb]	Dry Rock [lb]	Sand Water [lb]	w/c
0	275	625	1200	1773	6.6	0.44
	300	625	1200	1773	6.6	0.48
	325	625	1200	1773	6.6	0.52
	350	625	1200	1773	6.6	0.56
	375	625	1200	1773	6.6	0.60
0.35	275	625	1200	1773	6.6	0.44
	300	625	1200	1773	6.6	0.48
	325	625	1200	1773	6.6	0.52
	350	625	1200	1773	6.6	0.56
	375	625	1200	1773	6.6	0.60
0.70	275	625	1200	1773	6.6	0.44
	300	625	1200	1773	6.6	0.48
	325	625	1200	1773	6.6	0.52
	350	625	1200	1773	6.6	0.56
	375	625	1200	1773	6.6	0.60

For each batch, a drum mixer was utilized, and a ventilation system was employed to minimize the presence of airborne cement particles. Before commencing mixing, the ambient room temperature and water temperature were recorded, and the prescribed dose of citric acid was added to the water. Through experimentation, it was determined that the optimal mixing sequence involved adding half of the coarse aggregate first, followed by the fine aggregate, BCSA cement, water, and concluding with the remaining half of the coarse aggregate. This method facilitated a more homogeneous mixture by breaking up any clumps of sand or cement that may have accumulated at the back of the mixer. All materials were added to the mixer swiftly, and mixing was allowed to continue for a duration of 3 minutes. Throughout this mixing phase, the slump cone, tray, and all utensils were moistened and prepared for testing. Upon completion of the 3-minute mixing cycle, the mixer was turned off, and the slump test was promptly initiated following ASTM C143 guidelines. After conducting the slump test, it was crucial to introduce water into the remaining concrete within the mixer and resume mixing. This additional water aided in breaking up the concrete, which was already beginning to set, and facilitated easier cleanup. Subsequently, the mixer and all utensils were thoroughly cleaned and readied for the next batch.

4.1. Result and analysis

A positive correlation was observed between water content and slump in BCSA concrete mixtures, as depicted in Figure 3. While each dosage of citric acid exhibited a rise in slump with increasing water content, the 0% and 0.35% dosages, relative to the weight of cement, demonstrated more consistent results across two trials when compared to the 0.70% dosage.

In Figure 4, analyzing slump variation within different water-to-cement (w/c) ratio groups, it was noted that extreme w/c ratios of 0.44 and 0.6 exhibited less variability in slump, with ranges of 1.88 inches and 2.75 inches, respectively. Conversely, intermediate w/c ratios displayed increased variability, contrary to initial expectations.



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12 **Figure 34.**Combined citric acid slump at varying water contents

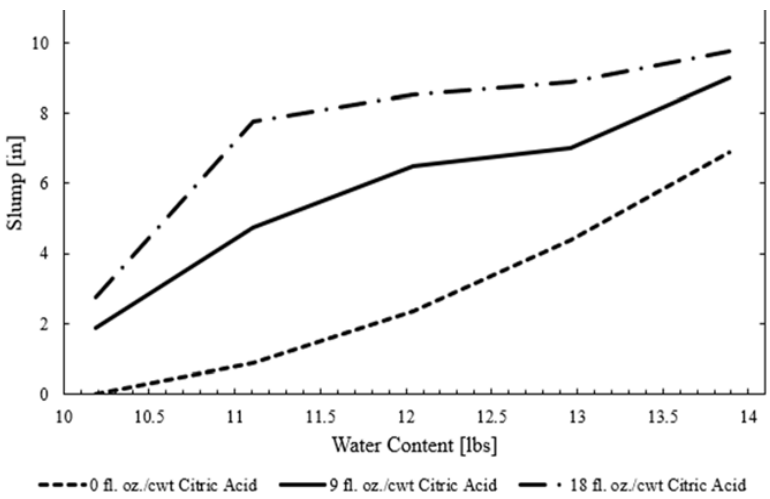

Figure 35. Slump variability between water-cement

5. CONCULSION AND RECOMMENDATION

Based on the findings of this study, the following conclusions can be drawn:

a. There exists a direct correlation between water content and slump in BCSA concrete mixtures.

b. The incorporation of citric acid into a mix enhances slump at various water contents, thereby improving the workability of the mixture.

c. To achieve a usable mix with adequate working time, it is advisable to include a citric acid dose of at least 0.35% of the cement weight, considering setting time and reduced workability.

d. A citric acid dose equivalent to 0.35% of the cement weight results in a more uniform mix with sufficient working time.

Further research is essential to validate the outcomes of this study. This paper elucidates fundamental relationships among citric acid dosage, water content, and slump in BCSA concrete mixtures, providing a foundation for future investigations. Subsequent research endeavors could enhance this study by:

a. Conducting additional trial batches to minimize errors, with a recommended minimum of 3 data points per sample.

b. Ensuring consistency in slump test execution by assigning a single individual to conduct the tests, thereby reducing variability.

c. Standardizing mix designs to maintain a constant water-cement ratio throughout the experiments.

REFERENCES

[1] L. E. Burris and K. E. Kurtis, "Influence of set retarding admixtures on calcium sulfoaluminate cement hydration and property development," *Cement and Concrete Research,* vol. 104, pp. 105-113, February 2018.

[2] R. Maddalena, J. J. Roberts and A. Hamilton, "Can Portland cement be replaced by low- carbon alternative materials?" *Journal of Cleaner Production,* vol. 186, pp. 933-942, 10 June 2018.

[3] American Concrete Institute, "Standard Practice for Selecting Proportions for Normal, Heavweight, and Mass Concrete," American Concrete Institute, 2009.

[4] Understanding Workability in Belitic Calcium Sulfoaluminate Concrete Mixtures by Caleb W. Chesnut

[5] Belitic calcium sulfoaluminate cement: Hydration chemistry, performance, and use in the United States by Eric Pascal

[6] ASTM, "ASTM C143 Standard Test Method for Slump of Hydraulic-Cement Concrete," ASTM International.

[7] E. O. Soriano S., "The Influence of Citric Acid on Setting Time and Temperature Behavior of Calcium Sulfoaluminate-Belite Cement," Fayetteville, 2019.

Geotechnical Engineering

Enhancing Dam Protection and Stability through Optimized Construction Material Selection in Geotechnical Context.

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The meticulous analysis and selection of construction materials play a pivotal role in safeguarding the longevity and safety of dams within geotechnical frameworks. This research delves into the geotechnical intricacies surrounding dam construction, aiming to recommend optimal materials that bolster both protection and stability.By conducting a thorough examination of site-specific conditions encompassing soil attributes, groundwater levels, and erosion potential, this study discerns the prerequisites for ensuring dam integrity. A range of construction materials, such as concrete, rockfill, geomembranes, and geotextiles, undergo scrutiny to ascertain their efficacy in combatting erosion, curbing seepage, and upholding structural robustness. The methodology entails a comparative evaluation of mechanical properties, durability, and environmental ramifications across different materials, considering factors like cost efficiency and sustainability. Furthermore, the study integrates risk assessment methodologies to pinpoint potential failure modes and optimize material selection for bolstered dam performance. These insights gleaned from the research shed light on tailoring construction material choices to the unique geotechnical demands of dam projects. By amalgamating engineering principles with environmental considerations, this study contributes to the development of resilient dam structures that adhere to safety standards while minimizing ecological footprints.

Keywords: *Dams, Geotechnical frameworks, Construction materials, Geotechnical demands, Environmental impact*.

1. INTRODUCTION

As is well known, the construction of dams dates back many centuries, and the main objective has been the storage of water and flood control. Due to many reasons, mainly social and environmental, the construction of new dams has led to the operation and conservation of existing structures. This fact has caused geotechnical engineering to be involved in dam safety management; therefore, it is essential to know the principles of analysis and design with which they were constructed [1].

In the geotechnical aspect, dams are significant structures that require thorough consideration of soil mechanics, geological conditions, and engineering principles to ensure their stability and performance.

The dams and supporting objects, together with the foundation on which they rest, must indisputably maintain stability for any condition and load case that occurs both during the period of construction and during use. Based on this fact, the shape and dimensions of the special constructive elements, as well as the object as a whole, depend closely on the possible load conditions [2].

However, ensuring the safety and stability of dams is paramount, considering the potential risks associated with their failure, including loss of life, property damage, and environmental devastation. By optimizing material selection, engineers can mitigate risks, improve resilience, and prolong the service life of dams, thereby safeguarding critical infrastructure and the surrounding environment. It outlines key considerations, challenges, and strategies associated with material selection, along with case studies and best practices from notable dam projects around the world. Through a comprehensive analysis, this paper aims to provide insights and recommendations for engineers, policymakers, and stakeholders involved in dam construction and management, ultimately contributing to the advancement of sustainable and resilient infrastructure development [3][4].

2. CLASSIFICATION OF TYPES OF DAMS

Dams are often thus classified in terms of the type of use intended for the dam, the type of materials used in constructing the dam or in terms of various Dam Safety regulations.

2.1.Dam type, determined by material used in construction.

Due to the advances in engineering and the understanding of how certain materials work together, has resulted in various dams being constructed based on material type. Earth and concrete form the backbone of most designs and have the following types of dams associated with each material [1]:

Earth as material:

Embankment Dams

Embankment dams are the most common type of dam in use today. Materials used for embankment dams include natural soil or rock, or waste materials obtained from mining or milling operations. An embankment dam is termed an "earthfill" or "rockfill" dam depending on whether it is comprised of compacted earth or mostly compacted or dumped rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass weight, type and strength of the materials from which the dam is made.
A cross-section (or slice) through an embankment dam shows that it is shaped like a bank, or hill. As a result, the name of this dam is derived from the shape.

Concrete as material:

Concrete dams may be categorized according to the designs used to resist the stress due to reservoir water pressure. Three common types of concrete dams are: **gravity, buttress** and **arch**.

Arch Dams

An arch dam is a concrete dam that is curved upstream in plan. The arch dam is designed so that the force of the water against it, known as hydrostatic pressure, presses against the arch, causing the arch to straighten slightly and strengthening the structure as it pushes into its foundation or abutments. An arch dam is most suitable for narrow canyons or gorges with steep walls of stable rock to support the structure and stresses. Since they are thinner than any other dam type, they require much less construction material, making them economical and practical in remote areas.

Classification
In general, arch dams are classified based on the ratio of the base thickness to the structural height (b/h) as:

- Thin, for b/h less than 0.2,
- Medium-thick, for b/h between 0.2 and 0.3, and
- Thick, for b/h ratio over 0.3.
- Arch dams classified with respect to their structural height are

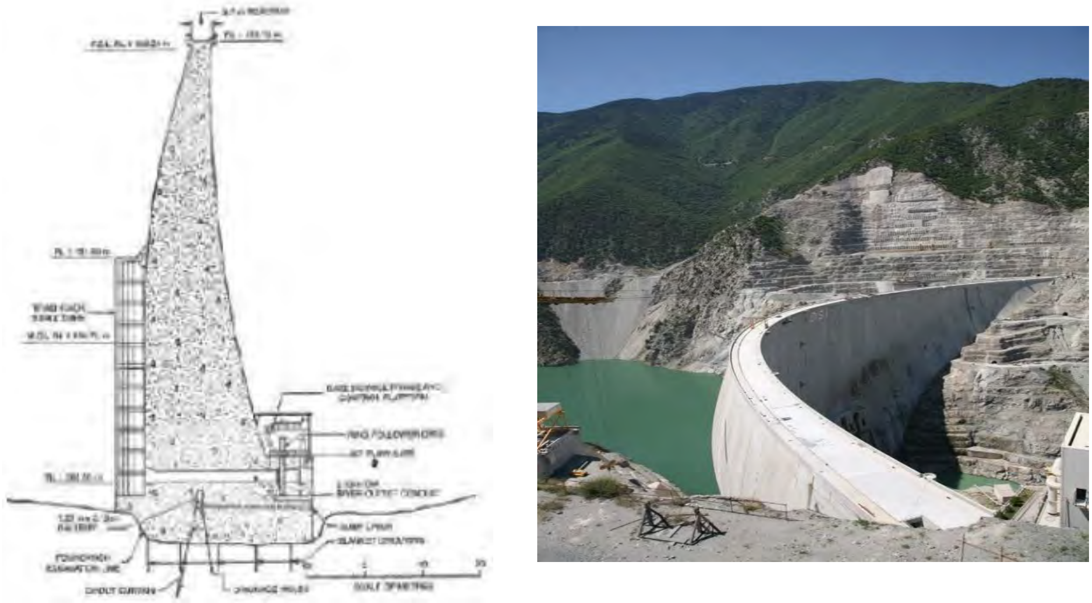

Figure 1. Diagram of typical arch dam [3]

Gravity Dams

A gravity dam is a dam constructed from concrete or stone masonry and designed to hold back water by using only the weight of the material and its resistance against the foundation. Gravity dams are designed so that each section of the dam is stable and independent of any other dam section. Gravity dams generally require stiff rock foundations of high bearing strength (slightly weathered to fresh), although in rare cases, they have been built on soil. The stability of the dam primarily arises from the range of normal force angles viably generated by the foundation. Also, the stiff nature of a gravity dam structure endures differential foundation settlement poorly, as it can crack the dam structure. The main advantage to gravity dams over embankments is the scour-resistance of concrete, which protects against damage from minor over-topping flows. A disadvantage of gravity dams is that their large concrete structures are susceptible to destabilizing uplift pressures relative to the surrounding soil.

Concrete dams include:

- mass concrete dams, made of:
- conventional concrete
- Roller-Compacted Concrete (RCC)
- masonry
- hollow gravity dams, made of reinforced concrete.
- Composite dams are a combination of concrete and embankment dams.

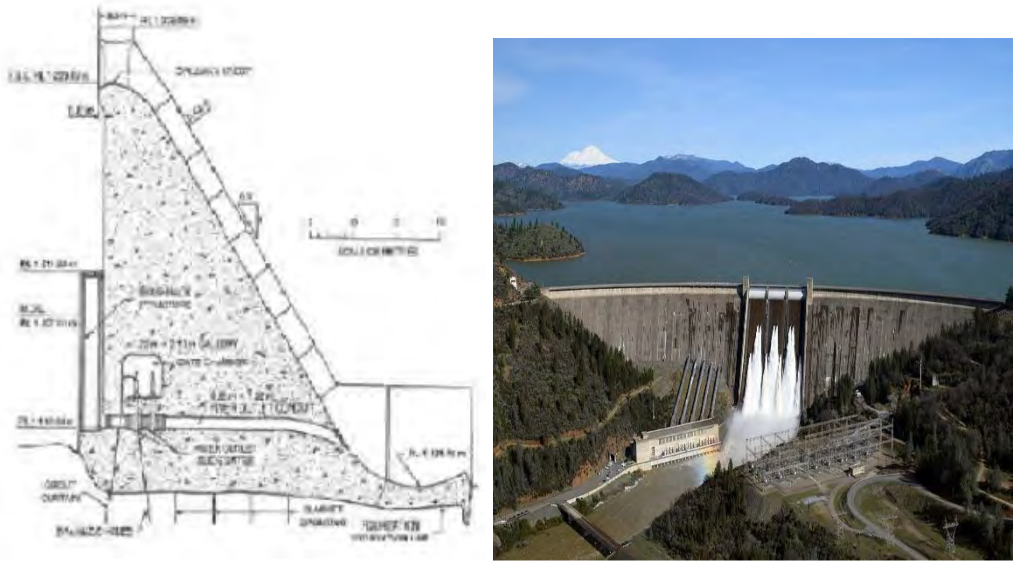

Figure 2. Diagram of typical gravity dam [3]

Buttress Dams

A buttress dam is a specific type of gravity dam in which the large mass of concrete is reduced, and the forces are diverted to the dam foundation through vertical or sloping buttresses.
The dam wall may be straight or curved. Most buttress dams are made of reinforced concrete and are heavy, pushing the dam into the ground. Water pushes against the dam, but the buttresses are inflexible and prevent the dam from falling over. A buttress dam is a good choice in wide valleys where solid rock is rare. The Romans were the first to use buttresses to increase the stability of a dam wall. Buttress dams of slab concrete construction became popular in the United States in the early 20th Century with the patented process of Norwegian-American civil engineer.

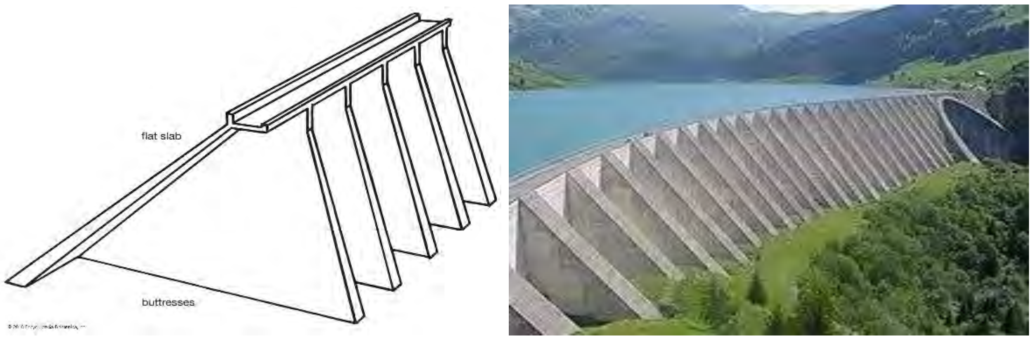

Figure 3. Diagram of typical Buttress dams [3]

2.2.Effect of Materials Quality on Stability of Embankment Dam

Embankment dams are constructed of all types of geologic materials, with the exception of organic soils and peats. Most embankments are designed to utilize the economically available on-site materials for the bulk of construction. Special zones such as filters, drains and riprap, may come from off-site sources. Soil materials used in embankment dams commonly are obtained by mass production from local borrow pits, and from required excavations where suitable. Rockfill dams are basically embankment dams [1][3].
High stability and perviousness are their special characteristics. The impervious element in a rockfill dam is provided either by an impervious membrane of manufactured materials or by an

earth core. Due to free drainability and high frictional strength, rockfill dams have a high inherent stability. The rockfill dams with earth cores using the principle of fill-material zoning are mostly economical because all types of locally available rock low-strength (3.5MPa to 17MPa), medium strength (17MPa to 70MPa) and high-strength rock (70MPa to 200MPa) can be used if the structure is properly zoned; the weaker rock is placed in less critical zones under less stress and hard rock is used where greater strength is required [4].

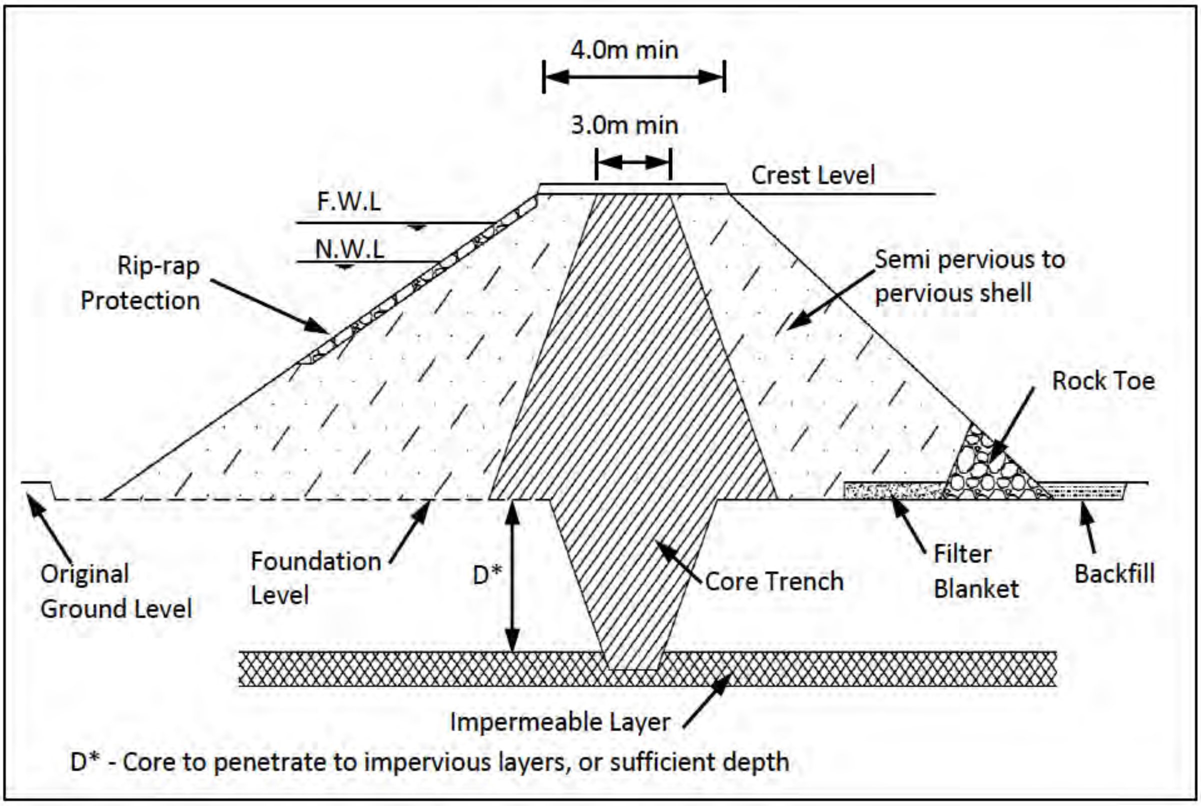

Figure 4. Diagram of typical embankment dams [3]

2.3.Concrete facing for rockfill dams.

Rockfill dams with upstream water barriers of wood have been used as early as 1850 by the gold miners in California. Later the wooden facing was replaced by concrete. Chatworth Park Dam in California constructed in 1895 was the first rockfill dam known to use concrete facing for the water barrier [1].

Types of Materials

The principal materials required for embankment dams with concrete facing as water barrier are **aggregates, cement and additives** for concrete; **earthfill** for upstream fill; **granular fill** for filters; **rockfill** or **gravel fill** for the main body of the embankment; **water stop** to seal the joints in the concrete slab; and **asphalt**, **shotcrete** or other materials for protection of the slope under the concrete face slab.

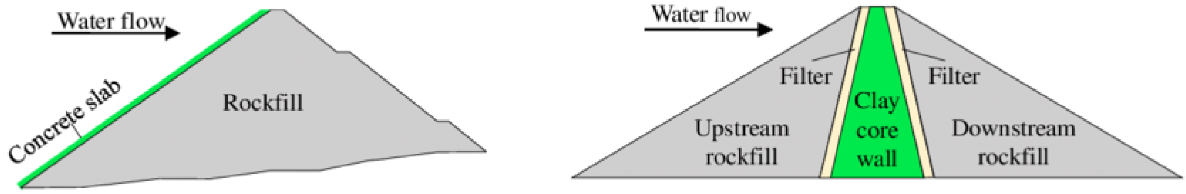

Figure 5. Typical Section of Rockfill Dam with Concrete Face [3][4]

2.4.Geosynthetic materials

The term geosynthetics includes both geotextiles and geomembranes. These two broad categories are differentiated by their permeability. Geotextiles are commonly considered to be permeable fabrics, while geomembranes are commonly defined as low-permeability waterbarriers. Geotextiles are designed to be placed beneath soil, rock, or other materials to provide support, stabilization, and separation. They can also be used to filter water and prevent erosion [1][4].

All though all termed in one bracket, geosynthetics come in many types. The various types are as follows:

Geotextiles: Geotextiles are porous fabrics made of a synthetic fiber. They are typically manufactured and delivered in rolls. Adjacent strips are commonly overlapped, though they are occasionally sewn together. Geotextiles are predominantly manufactured from polyester and polypropylene; other materials that are used include nylon, polyethylene, polyvinyl chloride and fiberglass.
Geomembranes: Geomembranes are low-permeability water barriers. They are commonly manufactured and delivered in rolls and seamed on site. Some geomembranes have been formed in large panels before installation and delivered to the site for installation. Geomembranes are manufactured from synthetic polymers and/or bituminous materials. The synthetic polymers can be categorized in two broad groups: thermoplastics and elastomers.

Properties of the materials resistance to mechanical stresses mobilized from applied loads or installation conditions.

Compressibility: The change in thickness of the fabric, due to varying normal pressures. The manufacturing way of producing the type of fabric/material, has an effect on amount the material can compress. Figure 2.6 shows the varying compressibility, regarding the different manufacturing styles.

Tensile Strength: One of the properties that constitutes the usage of a geotextile in design. The property, measures the amount of tensile stress (amount of force over a distance, measured in KN/m) a material can undergo. The Strain of the material, at the different tensile stresses, is also compared of the material.

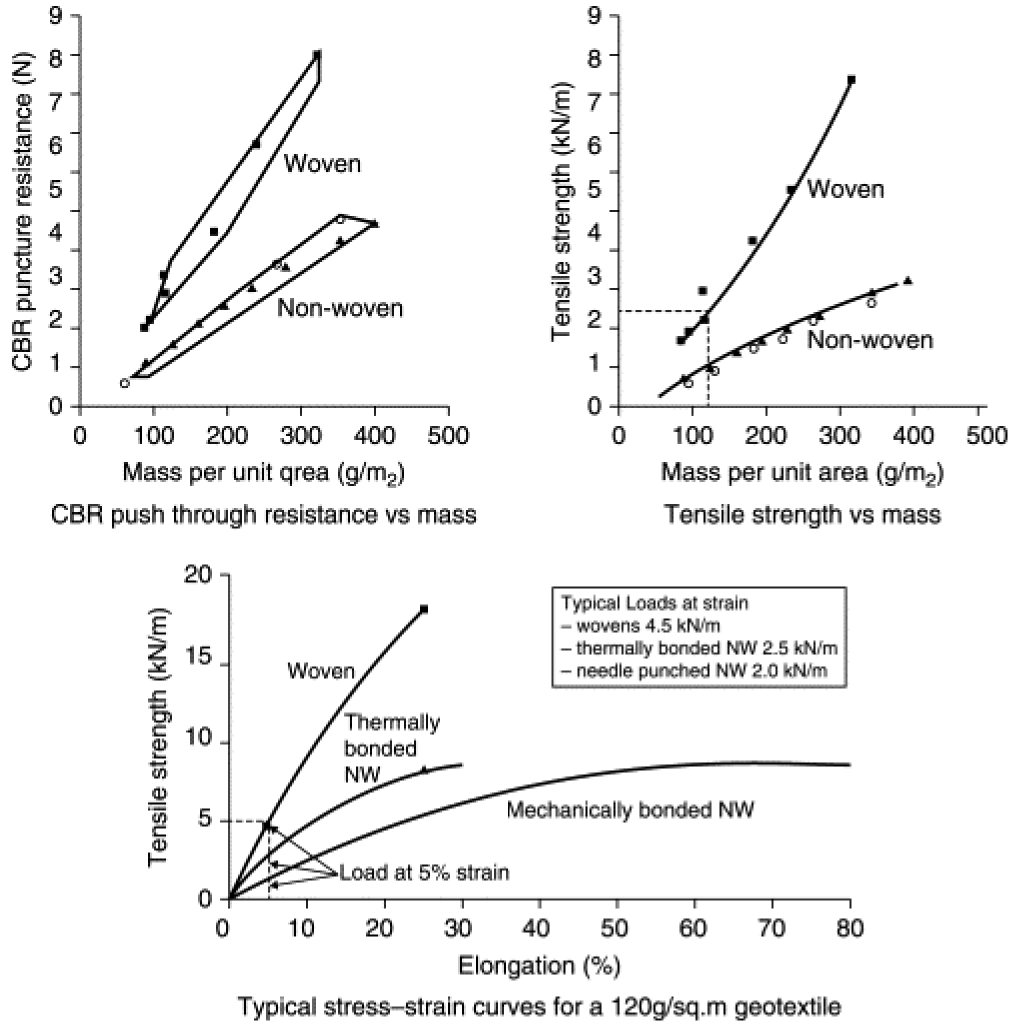

Figure 6. Tensile test response of various geotextiles

3. CONCLUSION

In conclusion, enhancing dam protection and stability through optimized construction material selection in a geotechnical context is essential for ensuring the resilience, safety, and longevity of dam infrastructure. Through this research, several key findings and conclusions emerge:

- Selecting the most appropriate construction materials, such as high-performance concrete, geosynthetics, rockfill, and steel reinforcement, plays a critical role in enhancing dam protection and stability. These materials offer superior strength, durability, and resistance to geotechnical hazards.
- the classification of types of dams serves as a valuable tool for engineers, planners, and policymakers in selecting and designing appropriate dam structures to meet specific project objectives while ensuring safety, sustainability, and environmental stewardship. By considering the diverse range of dam types and their respective characteristics, stakeholders can make informed decisions to achieve successful outcomes in dam development and management.

- geosynthetic materials represent valuable tools in the toolkit of modern engineering practices, offering versatile solutions for addressing geotechnical, environmental, and infrastructure challenges. By leveraging the unique properties and capabilities of geosynthetics, engineers and practitioners can achieve cost-effective, sustainable, and resilient solutions across a wide range of civil and geotechnical engineering projects.

- Geotechnics plays a fundamental role in the proper functioning of earth and rock-fill dams. For this reason, it is essential to perform geotechnical studies from the selection of the dam site and its intervention in the methodology of the design of the embankment and other elements that make up the dam and to monitor the behavior of the entire dam during its useful life.

REFERENCES

[1] Z.Idrizi (2016), Objektet Hidroteknike; Authorized Lectures; University of Prishtina, Kosovo.

[2] Cooke, J. Barry, James L. Sherard. "Concrete-face rockfill dam: II. Design." Journal of Geotechnical Engineering 113, no. 10 (1987): 1113-1132

[3] Geotechnical Engineering of Dams" by Robin Fell and Patrick MacGregor

[4] "Geotechnical Risk and Safety in Dam Design and Construction" by J. Michael Duncan, Joe K. Law, and Kenji Ishihara

A case study or probabilistic laboratory of soil liquefaction

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Soil liquefaction is a major problem for structures built onto sandy soils. The probability of liquefaction is evaluated in those cases when these types of soils lie below the level of underground water. In our country this phenomenon is mostly present in the western part of Albania, especially in the areas along the coastline of the Adriatic Sea, mainly composed of soils with low plasticity such as dust, sandy dust or sand. The purpose of this research is the probabilistic assessment of soil liquefaction in the coastal area of Akarnia, Vlora. Probabilistic and deterministic liquefaction assessment procedures were used to define whether this phenomenon occurs or not. The evaluation of the probability of liquefaction was carried out according to the method of JUANG et alii (2002). This method determines the evaluation probability as a function of the safety factor, which is defined as the ratio of the coefficient of cyclic resistance (CRR) at a given depth to the coefficient of cyclic stresses (CSR) induced by the earthquake at this depth for an earthquake case. The evaluation of the safety factor according to the method of NCEER (1998), is based on the data obtained from the CPTU test. The liquefaction potential evaluation combined according to the two methods that evaluates SF and PL gives us a much more accurate information for the evaluation of this phenomenon in our study area and shows that this phenomenon should obviously be taken into consideration for the design of different structures.

Keywords: *Soil liquefaction, safety factor, probabilistic liquefaction, cyclic stresses, cyclic resistance, CPT.*

1. INTRODUCTION

The area under study is located in the administrative unit of Novoselë in the district of Vlora, in the southwest of Albania. Based on the geographical position of the village of Akërni, which is located in the Pranadreatic Lowland captured by post-Pliocene pressure movements (PL zone) which includes the hilly and plain terrains of the Pranadreatic molasses basin. The Pranadreatic lowland stretches from Hani i Hotit in the north to Vlora in the south and is characterized by high seismic activity.

According to the seismic map of Albania, this area has experienced a maximum magnitude of 4.5~6.6. The highest magnitude recorded in this area is 6.6 (in the earthquake of October 12, 1851 with coordinates 40o.5 N, 19o.5 E) [1]

To carry out this research study, two security levels were taken into consideration as 10% in 10 years with a maximum acceleration a_g=0.145, 10% in 50 years with a maximum acceleration ag=0.303 with payback periods of 95 years and 475 years respectively and 4 CPTU tests were performed in different locations along the coastline (as shown in Figure 1). The tests in this area were carried out with chain machines (CPTs) equipped with a set of hydraulic rams type TG 63 – 150 RIG (CPT AL 001). The data used in the calculation in the CPT method are: the resistance at the top of the cone, the frictional resistance of the sides of the cone, other data obtained from the correlations of the initial measurement data in the field, the magnitude of the earthquake, the maximum acceleration on the surface of the soil, the depth of the underground water level from the surface of the soil, the volumetric weight of the soil layers.

2. LIQUEFACTION SUSCEPTIBILITY BASED ON *IN-SITU* METHODS

The liquefaction assessment is conducted using the Cone Penetration Test (CPTU) which is considered to be a reliable device for soil investigation by today's standards, providing important information on soil type and geotechnical parameters.

The employed evaluation methodology consists on the use of equations proposed by various authors [4-6]. The liquefaction probability calculations utilize safety factors, which are defined as the ratio of the Cyclic Resistance Ratio (CRR) to the Cyclic Stress Ratio (CSR). Robertson and Wride [4] suggested estimating the grain size characteristics using the soil behaviour chart by Robertson (1990) and the soil behaviour type index, Ic.as follows:

$$\mathrm{I_c} = [(3.47 - \log \mathrm{Q_{tn}})^2 + (1.22 + \log \mathrm{F_r})^2]^{0.5}$$

$$\mathrm{Q_{tn}} = \left[\frac{(\mathrm{q_t} - \sigma_{\mathrm{vo}})}{\mathrm{p_a}}\right]\left(\frac{p_a}{\sigma'_{vo}}\right)^n$$

Q_{tn} is the normalized CPT penetration resistance (dimensionless); n = stress exponent; F = fs/[(qc - σ_{vo})] x 100% is the normalized friction ratio (in percent); fs is the CPT sleeve friction stress; σ_{vo} and σ'_{vo} are the total effective overburden stresses respectively, Pa = is the atmospheric pressure and qc = is the measured tip resistance.
The stress exponent "n" varies according to the soil type. The typical value of "n" is 0.5 for clean sands and 1or clays. For silts and silty sand an intermediate value between 0.5 and 1 is appropriate.

2.1. Evaluation of Cyclic Stress Ratio (*CSR*)

Simplified method to estimate CSR was also developed by Seed and Idriss (1971) based on the peak ground surface acceleration (a_{max}) at the site. The simplified approach can be summarized as follows:

$$CSR = \frac{\tau_{av}}{\sigma_{vo}} = 0.65 \cdot \left(\frac{a_{\max}}{g}\right) \cdot \left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right) \cdot r_d$$

Figure 36. Geographic location of the study area.

Where τ_{av} is the average cyclic shear stress; a_{max} is the maximum horizontal acceleration at the ground surface; g is the acceleration due to gravity; σ_{vo} and σ'_{vo} are the total and effective vertical overburden stresses, respectively, and rd is a stress reduction factor which is dependent on depth. The factor rd can be estimating using the following tri-linear function, which provides a good fit to the average of the suggested range in rd originally proposed by [6]:

$$
\begin{gathered}
rd = 1.0 - 0.00765z \\
\text{if } z < 9.15 \text{ m} \\
= 1.174 - 0.0267z \\
\text{if } z = 9.15 \text{ to } 23 \text{ m} \\
= 0.744 - 0.008z \\
\text{if } z = 23 \text{ to } 30 \text{ m} = 0.5 \\
\text{if } z > 30 \text{ m}
\end{gathered}
$$

2.2. Cyclic Resistance Ratio, CRR7.5 Based on CPT Data

The CRR is evaluated by using the CPTU test, which is considered to be a reliable test for soil investigation by today's standards, providing important information on soil type and geotechnical parameters. For the cyclic resistance ratio of clean sands and a magnitude of 7.5 (CRR7.5), [4][6] have proposed the following equations:

$$\mathrm{CRR}_{7.5} = 0.833\left[\frac{(qc1N)cs}{1000}\right] + 0.05 \qquad \text{if } (q_{c1N})_{cs} < 50$$

$$\mathrm{CRR}_{7.5} = 93 \cdot \left[\frac{(qc1N)cs}{1000}\right]^3 + 0.08 \qquad \text{if } 50 \leq (q_{c1N})_{cs} \leq 160$$

where:

$(q_{c1N})_{cs}$is the normalized cone penetration resistance, corrected for the fine content influence

$$(q_{c1N})_{cs} = K_c\ (q_{c1N})_{cs}$$

"K_c" = is a correction factor that is a function of grain size characteristics (combined influence of fines con-tent and plasticity) of the soil.

$$Kc = 1.0 \qquad \text{if } Ic \leq 1.64$$

$$K_c = 5.58 \cdot I_c^3 - 0.403 \cdot I_c^4 - 21.63 \cdot I_c^2 + 33.75 \cdot I_c - 17.88 \quad \text{if } Ic > 1.64$$

and (q_{c1N}) is the normalized (stress-adjusted) cone pene-tration resistance defined as follow:

$$(q_{c1N})_{cs} = C_q * (q_c / P_a)$$

$C_q = (P_a / \sigma'_{vo})^n$ being the normalized tip resistance factor

2. 3. Evaluating Factor of Safety, FS

The factor of safety is defined as the available resistance of the soil to liquefaction (expressed in terms of the cyclic stresses required to cause liquefaction). When the coefficient of cyclic stresses and the coefficient of cyclic resistance are determined, then the value of the safety factor can be determined, based on which value it is determined whether liquefaction occurs or not. This factor, according to Lee et al., 2003, is given by the following formula:

$$\text{Factor of Safety, FS} = \left(\frac{\text{CRR7.5}}{\text{CSR}}\right) MSF$$

Where MSF is the magnitude scaling factor to convert CRR7.5 for M = 7.5 to the equivalent CRR for the design earthquake.

$$\text{MSF} = \left(\frac{174}{M^{2.56}}\right) MSF$$

*In this study it is considered that for the value of the safety factor FS ≤ 1, liquefaction does not occur and for the value of FS > 1 it occurs.

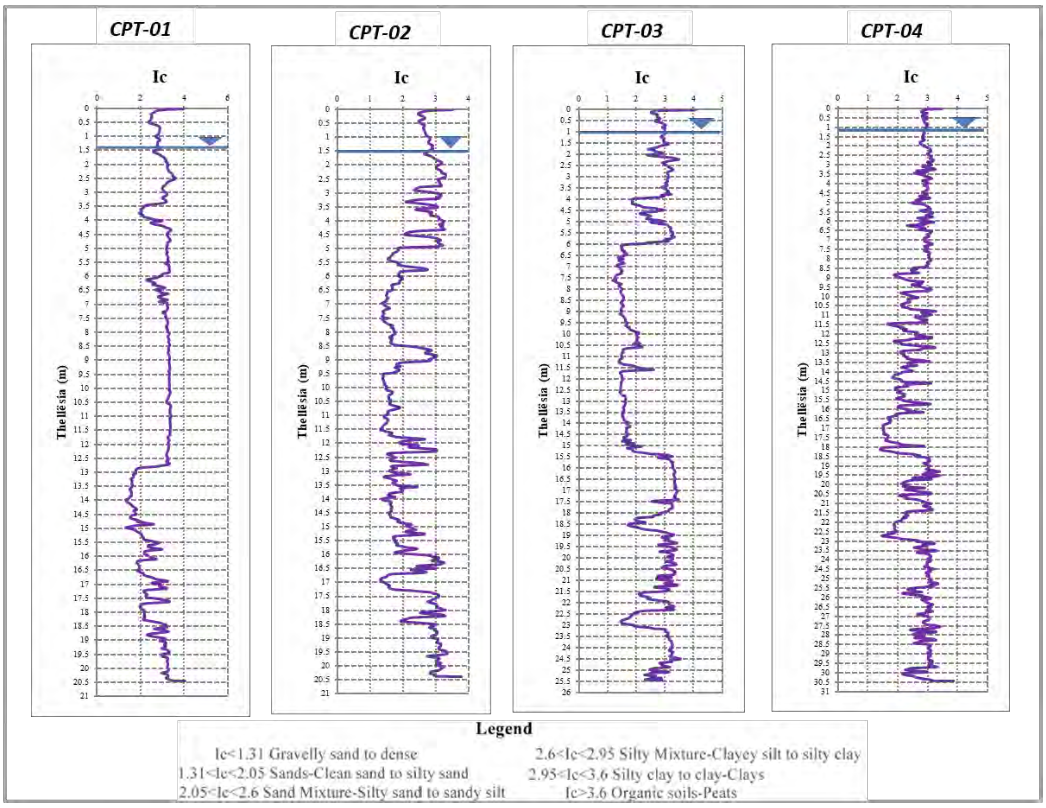

Figure 2. Detailed Ic profile for all CPTU test.

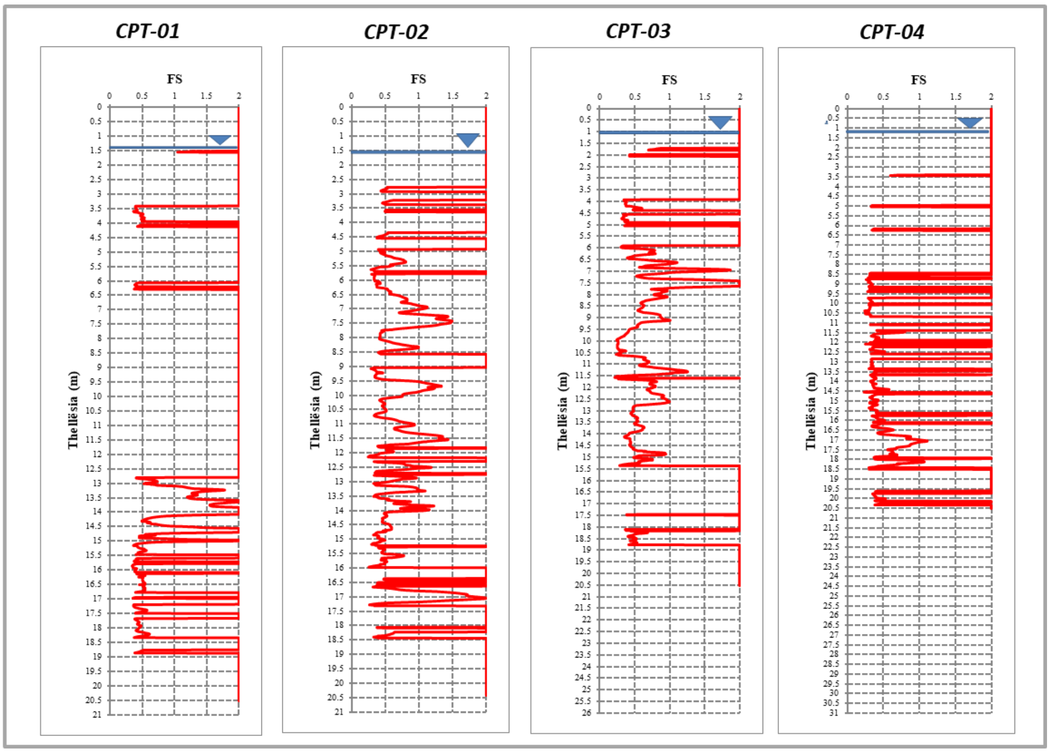

Figure 3. Evalution of Factor of Safety (FS) with the deterministic method ag = 0.30g

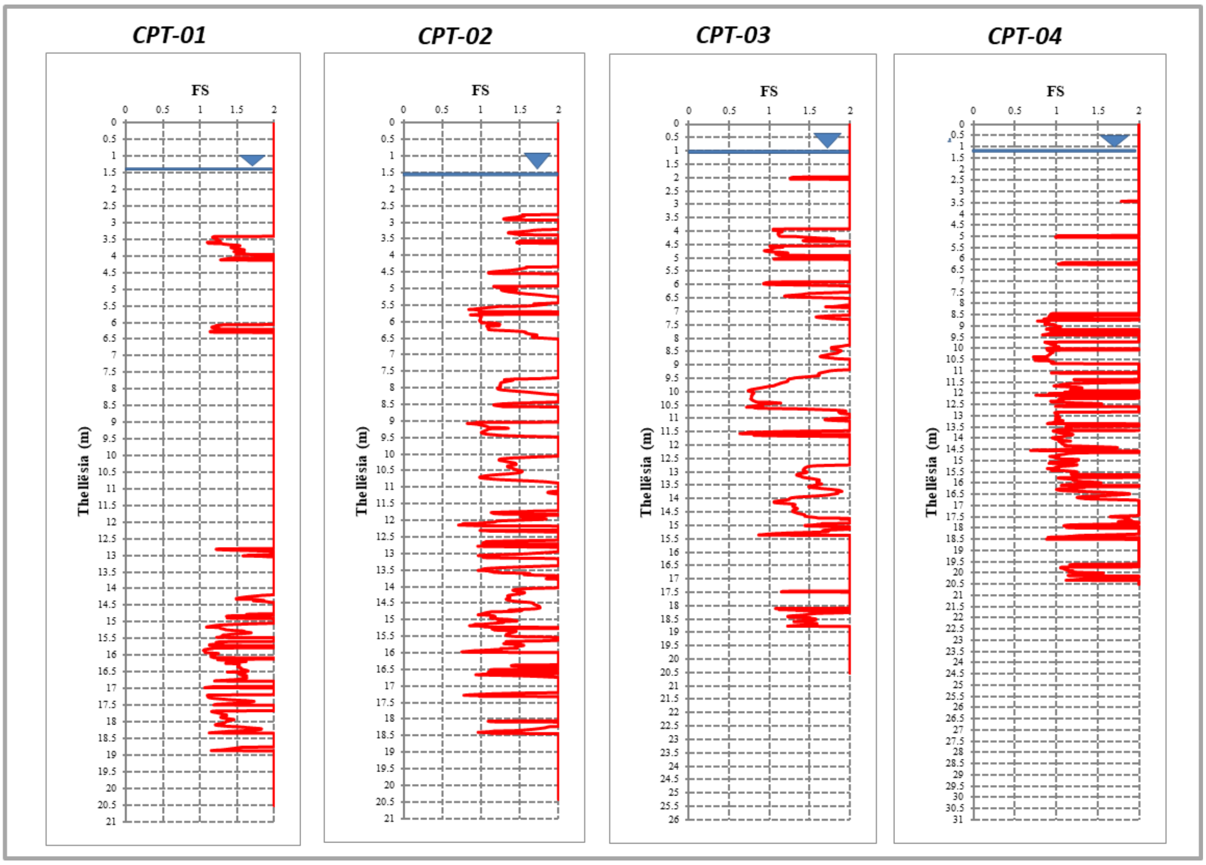

Figure 4. Evalution of Factor of Safety (FS) with the deterministic method ag = 0.15g

The real probability of liquefaction, P_R [L], is the probability of liquefaction during the lifespan of an engineering structure for different levels of safety, corresponding to different seismic hazard levels. For a given seismic hazard level, P_R [L], is calculated by combining the conditional probability of liquefaction for the corresponding acceleration, P [L|PGA = a], with the probability of occurrence of the scenario causing the exceedance of this acceleration

P [PGA >a].

$$P_R [L] = P [L|PGA = a]*P [PGA > a]$$

The conditional probability of liquefaction, P [L|PGA = a], is calculated using the correlation proposed by JUANG *et alii* (2002), which represents a direct correlation between the safety factor, FS_L, obtained in a deterministic way as proposed by Robertson and Wride, and the probability of liquefaction.

$$P [L|PGA = a] = \frac{1}{1+(FS_L/A)^B} \text{ with } A = 1.0 \text{ and } B = 3.3$$

The seismic hazard curve, is used to determine the probability of exceeding the acceleration

P [PGA > a] during the lifespan of the structure (50 years). The calculations are repeated for each hazard level described above.

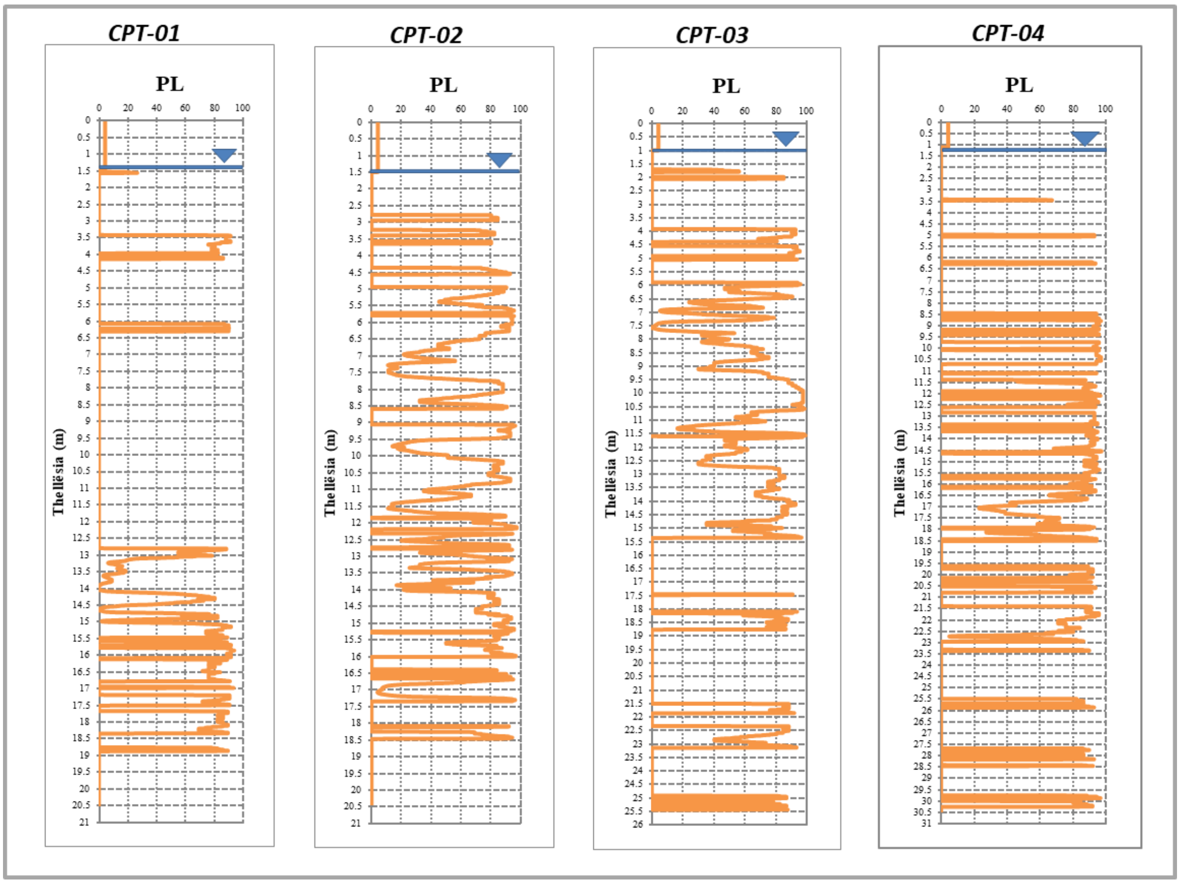

Figure 5. Conditional probability of liquefaction ag = 0.30g.

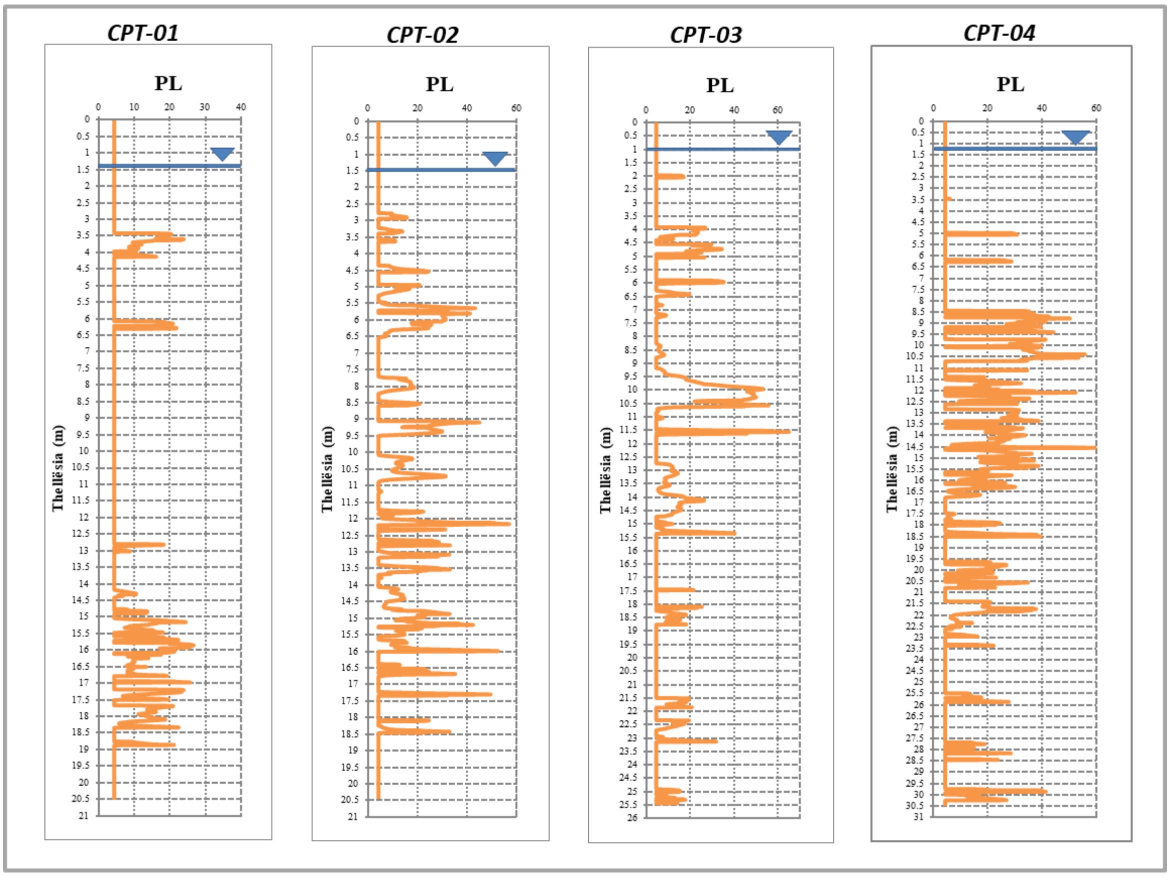

Figure 6. Conditional probability of liquefaction ag = 0.15g.

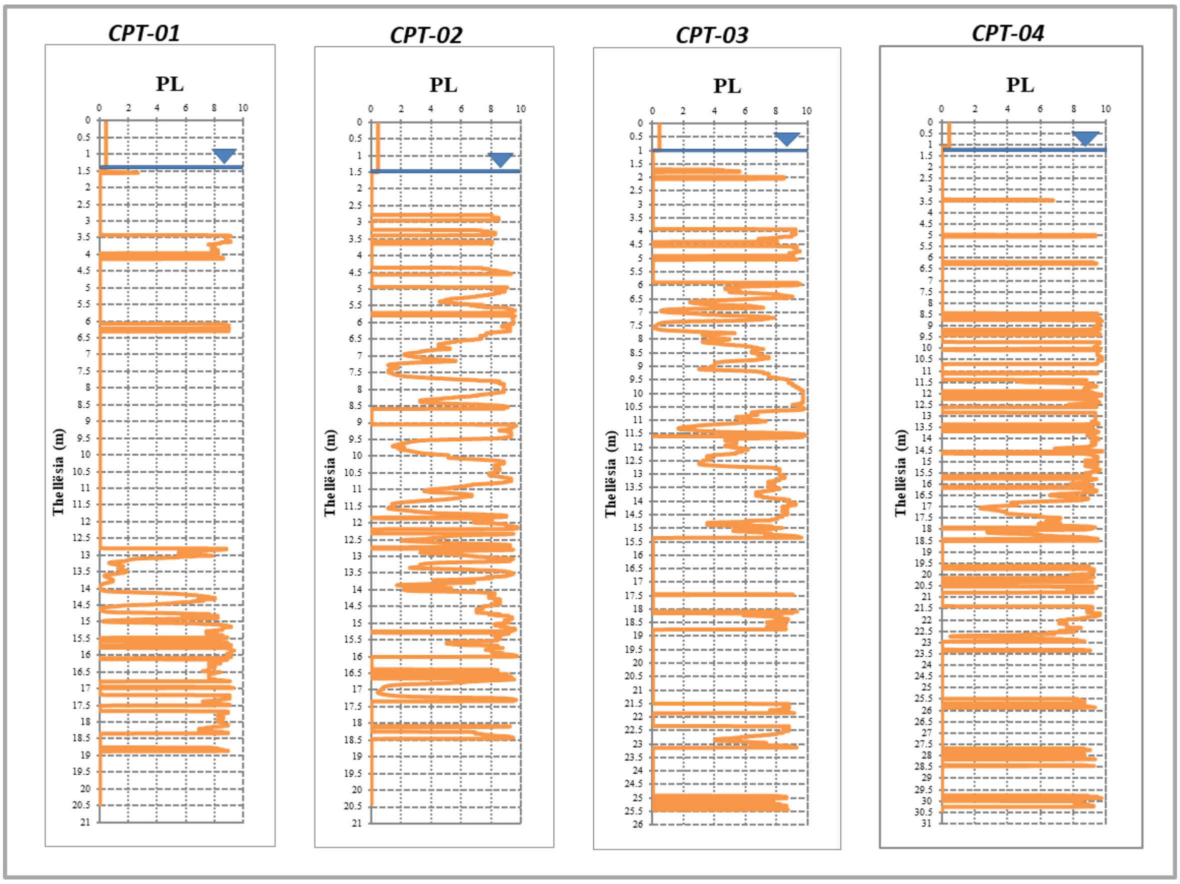

Figure 7. Real probabilities of liquefaction ag = 0.35g.

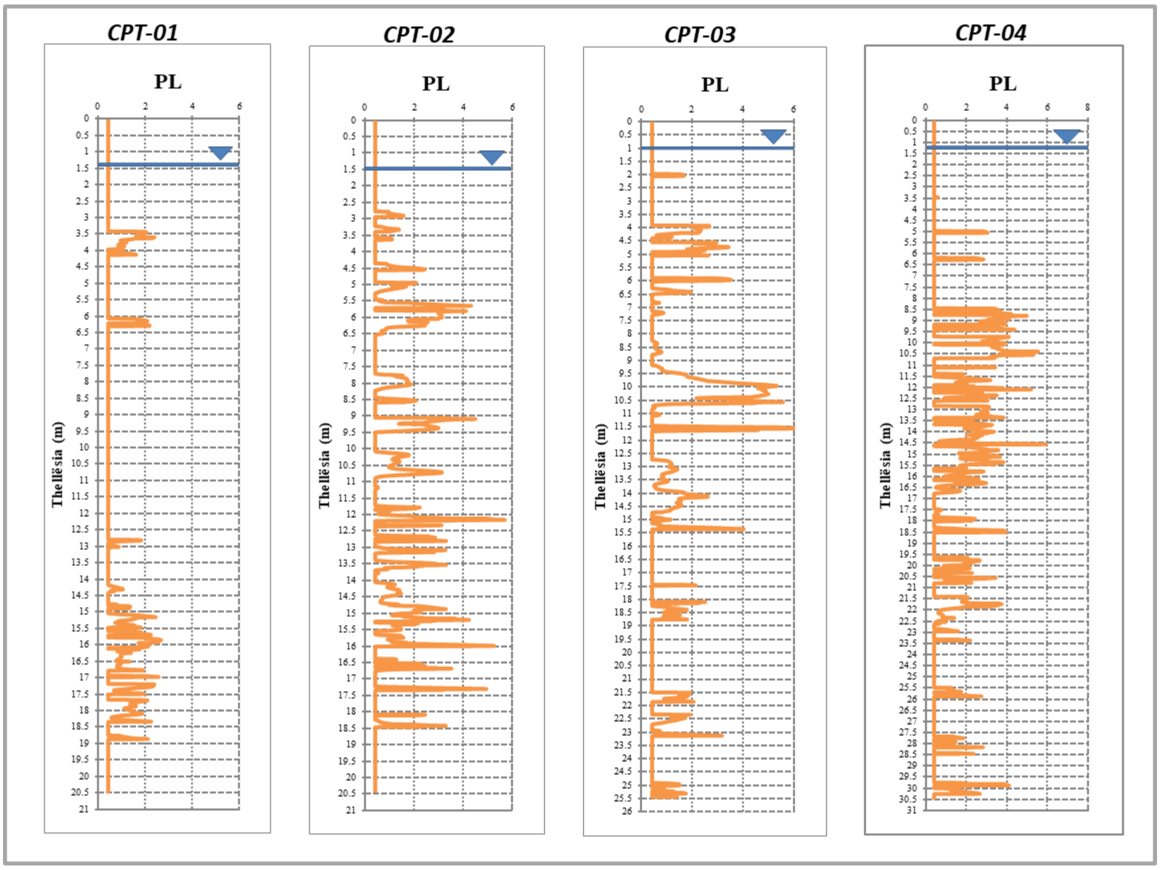

Figure 8. Real probabilities of liquefaction ag = 0.15g.

3. CONCLUSION

1. The CPT test is an ideal in-situ test to assess the liquefaction potential of soils due to its repeatability, reliability, continuous data and cost-effectiveness.
2. From the surface evidence the liquefaction fenomen it appears up to a depth of 20 m. Base of calculations performed in the study area, the depth where liquefaction occurs (FS<1) varies from the level of the underground water to a depth of 30 m. In this case this phenomenon does not appear near the earth's surface.
3. Calculations according to the probabilistic method show that in depths with the possibility of liquefaction, the liquefaction potential (PL) varies from 30% - 95% for the graund acceleration ag = 0.30g. calculations and from 30.0% - 44% for the graund acceleration ag = 0.15g.
4. It can be seen that as the fine fraction increases, the safety factor increases and the probability that liquefaction occurs decreases.
5. Low values of the safety factor are associated with high values of the probability.

REFERENCES

[1] Shyqyri Aliaj, Siasi Koçiu, Betim Muço, Eduard Sulstarova. Sizmiciteti, sizmotektonika dhe vlerësimi i rrezikut sizmik në Shqipëri. Akademia e Shkencave të Shqipërisë. Tiranë 2010.

[2] Shkëlqim Daja, Neritan Shkodrani, Arjan Lako & Besnik Ago - Real liquefaction probability of non-cohesive soils in Semani area, in Albania

[3] Shpresa Gashi, Neritan Shkodrani - Seismic Soil Liquefaction for Deterministic and Probabilistic Approach Based on in Situ Test (CPTU) Data

[4] Robertson P.K., Wride C.E. (1998), Evaluating cyclic liquefaction potential using cone penetration test, Canadian Geotechnical Journal, 35, 442-459.Barla M. (2011) Elementi di meccanica e ingegneria delle rocce, *Celid*, Italy.

[5] UANG C.H., JIANG T. & ANDRUS R.D. (2002) - Assessing probability – based methods for liquefaction evaluation. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 128 (7), 690-702.

[6] SEED H.B. & IDRISS I.M. (1971) - Simplified procedure for evaluating soil liquefaction potential, Journal of Geotechn. Engin. Division, ASCE, 97 (9), 1249-1273.

General limit equilibrium analysis in 2d and 3d of a large landslide in Italian Alps

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This scientific research describes the study of an extremely slow, active, continuous and submerged landslide in the Isarco Valley, Eastern Alps, Italy. The slide interacts with the viaducts on the E45 motorway. Due to the special importance of the highway, due to the fact that it connected two neighboring countries, Italy-Austria, partners in the economy and in many other fields, it turned out to be uneconomical to move the railway and the highway and this project was entrusted to the University of Trento, with the aim of studying and solving the problem of the landslide which damaged the piles of the bridges on this slope. Extensive multi method field investigation, surface and subsurface displacement monitoring and limit equilibrium analyses were adopted to fully characterize the slope dynamics. In order to overcome the limitations due to systematic errors affecting every single monitoring system and analysis method, a solution based on additional and coherent tests was presented to check the reliability of data and results. In this framework, the geological and geotechnical models on the investigated slopes were progressively refined. This allowed the evaluation of the type of interaction between the slope and the highway viaducts. In this scientific research, the laboratory data of drillings carried out in 2023 were compared with those carried out in 2010 to evaluate the shear resistance of the soil. Then, by means of inclinometric, stratigraphic, geomorphological and piezometric data, the pore water pressure was constructed and the sliding surface was hypothesized. In the following, slope stability calculations were performed to determine the factor of safety in the RocScience program, in two- and three-dimensional analyses.

Keywords: *viaducts, railway, highway, geological & geotechnical models, water pressure, two & three-dimensional analyses.*

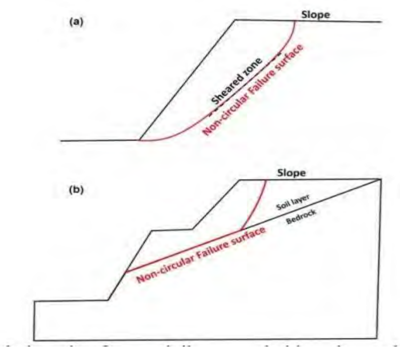
1. INTRODUCTION

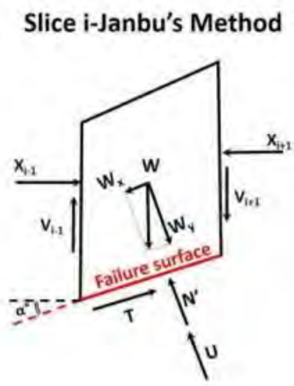
The project presents a recent study conducted in the Italian Alps on a massive landslide. This landslide has been monitored for a long time, over two decades and many studies and analyses have been conducted showing that the slope is moving at a very slow speed. Our study was recently conducted, using different analyses and methods without relying on those conducted in previous studies, yielding a new safety coefficient to compare these findings with those from 2006, 2009, 2012, 2018. We draw a conclusion and a possible solution based on the conclusions drawn from the analyses and methods.

2. METHODS

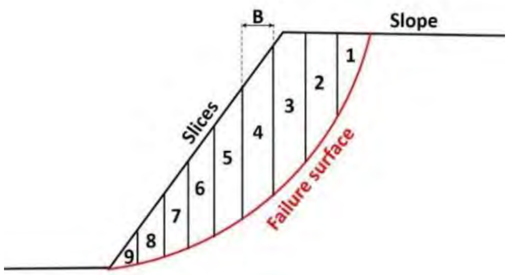
2.1. Approximate methods

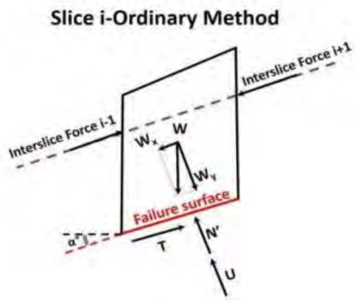
a) Janbu's Methods





b) Ordinary Methods



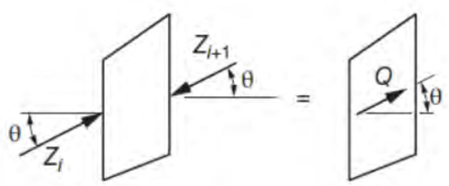


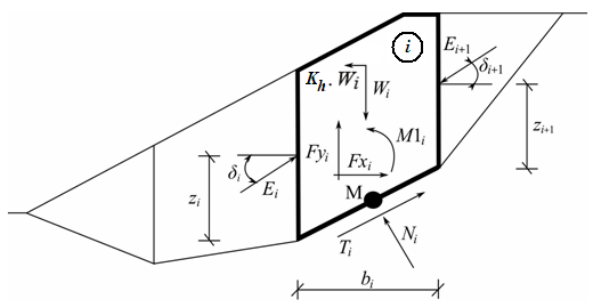
c) Lowe and Karafiath Methods
d) Modified Swedish Method

2.1.2. Accurate methods

a) Spencer Methods

b) Morgenstren & Price Methods





c) Sarma Methods

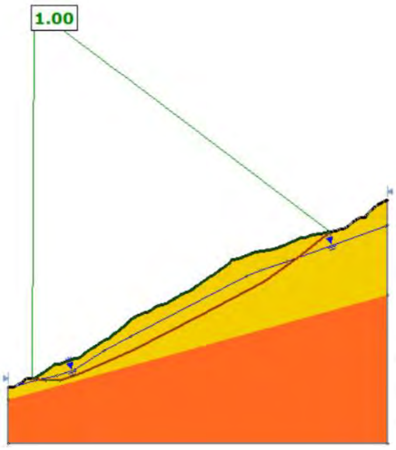
It should be emphasized that none of the procedures satisfy all equilibrium conditions. Additionally, all methods provide similar results in terms of safety factor values (Fredlund and Krahn, 1977; Duncan and Wright, 1980). Among the aforementioned procedures, the Spencer Method is considered the simplest in terms of satisfying equilibrium equations. Whereas the Sarma Method is valuable for calculating the seismic coefficient. The Morgenstern and Price Method is most useful when intermediate forces play a significant role in stability and is considered the most efficient among these methods.

- Calculations in 2D
- Calculations in 3D
- Back Analyses for sections

3. RESULTS AND DISCUSSION

Results of back Analyses in 2D

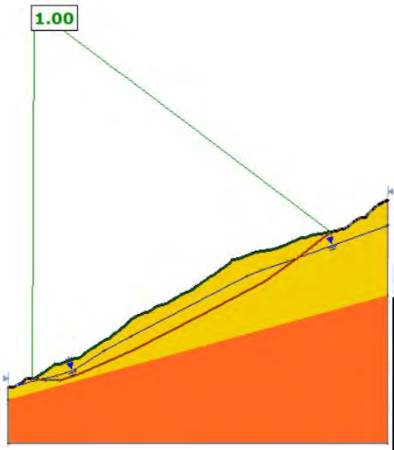
a) Results of Back Analyses for Section L5; Safety Factor for the calculated methods in Section L5.



L5	
γ [kN/m3]	φr' [°]
19.5	33.87
21.4	33.26
23.3	32.55

Method Name	Min FS
Ordinary / Fellenius	1.04
Bishop simplified	1.02
Janbu corrected	1.01
Spencer	1.01
GLE / Morgenstern-Price	1.00
Sarma	1.02

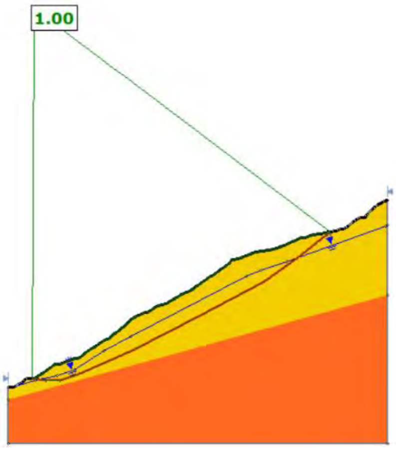
b) Results of Back Analyses for Section L7; Safety Factor for the calculated methods in Section L7.



L7	
γ [kN/m3]	φr' [°]
19.5	34.28
21.4	33.21
23.3	32.551

Method Name	Min FS
Ordinary / Fellenius	1.04
Bishop simplified	1.01
Janbu corrected	0.99
Spencer	1.00
GLE / Morgenstern-Price	1.00
Sarma	1.00

c) Results of Back Analyses for Section L9; Safety Factor for the calculated methods in Section L9.

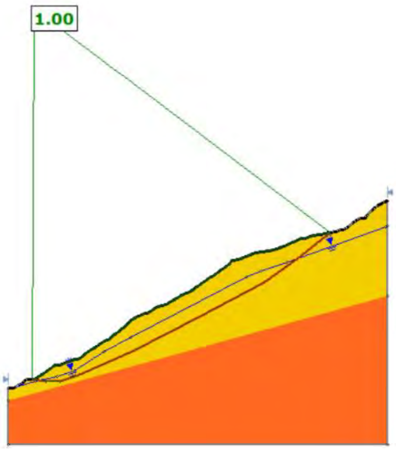


L9	
γ [kN/m3]	$\varphi r'$ [°]
19.5	34.796
21.4	33.89
23.3	33.06

Method Name	Min FS
Ordinary / Fellenius	1.03
Bishop simplified	1.01
Janbu corrected	0.99
Spencer	1.01
GLE / Morgenstern-Price	1.00
Sarma	1.01

d) Results of Back Analyses for Section L11;

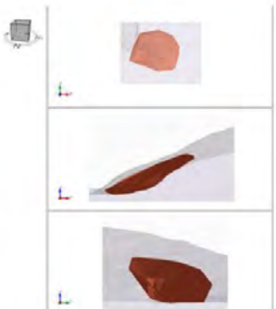
Safety Factor for the calculated methods in Section L11.



L11	
γ [kN/m3]	$\varphi r'$ [°]
19.5	28.77
21.4	28.56
23.3	28.26

Method Name	Min FS
Ordinary / Fellenius	0.967
Bishop simplified	0.990
Janbu corrected	0.971
Spencer	0.990
GLE / Morgenstern-Price	0.981
Sarma	0.987

❖ **Results of back Analyses in 3D**



γ [kN/m^3]	φ_r' [°]
19.5	28.46
21.4	28.08
23.3	27.75

Values of the safety factor as a function of the methods.

Metodo	Morgenstern & Price	Bishop semplificato	Janbu	Spencer
F_s	1.000	1.032	0.981	1.004

Based on geological and geomorphological analyses of the slope, in accordance with inclinometric and stratigraphic indications, the critical slip surface was identified. The mobilized angle of frictional resistance was calculated using Back Analysis. The results indicate that the two-dimensional analysis provides a lower safety coefficient compared to that of the three-dimensional analysis. This can be explained by referring to the literature to better understand the mechanism behind these results. Comparison of calculation methods showed a reliability of about 1%, making the chosen calculation method reliable. Findings also showed that the safety factor varies linearly with changes in the level of groundwater, indicating the possibility of increasing slope stability by reducing pore pressure through drainage interventions. These results are important for the prediction and design of drainage systems for slope stabilization.

The mobilized angle of frictional resistance for analyses in 2D and 3D.

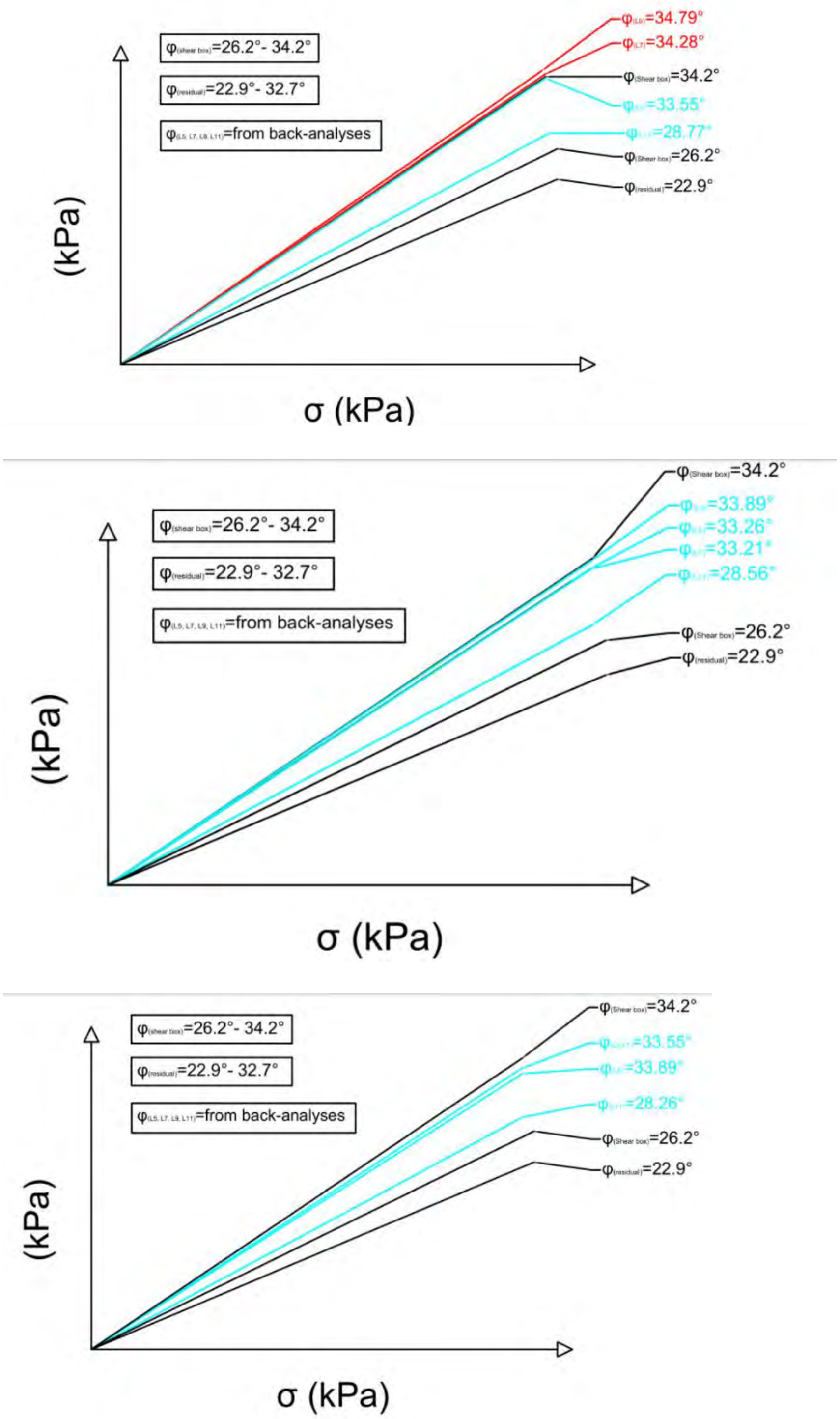
γ	2D BACK - ANALYSIS				3D BACK - ANALYSIS
	L5	L7	L9	L11	Model 3D
[kN/m3]	φ'_r [°]				
19.5	33.87	34.28	34.796	28.77	29.14
21.4	33.26	33.21	33.89	28.56	28.89
23.3	32.55	32.551	33.06	28.26	28.44

4. CONCLUSION

The grain size distributions of the landslide material are provided in Chapter 2. The data correspond to the natural material, and fine material was used to conduct tests in the shear box (Direct Shear Tests). The aggregates are well-graded, and generally, the grain size distribution of the aggregates collected on the sliding surface did not appear to be different from other aggregates, even though fine material was also included for the direct shear test.

The results obtained from the direct shear tests (performed for a maximum stress ranging from 300-600 kPa) are summarized in the following figures. The friction angle from the direct shear test varies from 25.2° - 34.4° for constant volume conditions and from 22.9° - 32.7° for residual resistance. Back analyses for the considered non-circular landslide, repeated several times, result in failure at γ = 19.5 kN/m3 for the L7 and L9 circular failure surfaces, as they exceed the friction angle from the direct shear test.

The mobilized resistance angle in shear coincides with the angles in residual resistance from laboratory tests for soil particles smaller than 2 mm, which is undesirable because the field soil is heterogeneous and well-graded. As a result, a mobilized resistance close to the maximum is expected. These results for the actual mobilized resistance angle in shear are provided in Figure, compared to those obtained from the direct shear test.



Evidence of soil liquefaction and impacts on infrastructure following the 2019 earthquake in Albania: A case study in Durres and Lalëzi bays.

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The 26 November 2019 earthquake of magnitude 6.3 with epicenter in Lalëzi Bay, Albania, caused significant structural damage in Durres, Vore, Thumane, Shijak and Tirana. A thorough investigation conducted from November 26 to December 5, 2019, covered Durres and Lalëzi Bays, covering an area of about 75 km². Field surveys focused on mapping liquefaction evidence to understand spatial distribution and collect data for further analysis, including geotechnical boreholes and Cone Penetration Testing (CPTU). Notable manifestations of liquefaction were observed in Juba, Rrushkulli, and Hamallaj areas, consisting in line-arranged sand boils, lateral spreading cracks, differentiated settlements, and road pavement deformations. Additionally, a continuous coring borehole, accompanied by Standard Penetration Tests (SPT), provided insights into soil profiles and liquefaction occurrences. Comparative analyses of grain size distributions and mineralogical compositions confirmed liquefaction occurrences within the studied soil column. This study offers valuable insights into the geological characteristics and stress history of liquefied soils, emphasizing the widespread implications of the seismic event on infrastructure and environmental stability.

Keywords: *Soil liquefaction, earthquake, infrastructure, Durres, Albania*

1. INTRODUCTION

The liquefaction is a well-known phenomenon in geotechnical engineering that occurs in water-saturated sandy deposits during a seismic motion. The Periadriatic lowland and especially the coastal areas are in large part composed by this kind of deposits. The phenomenon is not new in Albania. Sand volcanos are described, after the March 18, 1962 earthquake epicenter in the Fier area, with Magnitude 6.1 and during the April 15, 1979 earthquake with magnitude of 6.9 (Aliaj et al, 2010). Daja et al, 2013 [1] [2], calculated the probability of liquefaction, for three different hazard levels, in Semani area (Fier Albania) following the procedure proposed by Robertson & Wride 1998. CRR was estimated based on CPTU measurements. Based on the results of this study, a qualitative prediction of the areas likely to be affected by the phenomenon, for the same hazard level in the Albanian coastal areas was made by Daja et al, 2016. Since there are few studies in this field in Albania, the earthquake of November 26, has created the possibility to study the soil liquefaction. The purpose of this research is to identify all superficial evidences of the phenomenon aiming not only to understand its spatial distribution but to collect data for further analysis based on geotechnical measurements, such as geotechnical boreholes, CPTU measurements etc.

In the Bay of Lalëzi the phenomenon was best expressed in the area of Juba and Rrushkull in both sides and vicinity of the Erzeni River. Liquefaction phenomena were also observed in the area of Hamallaj near the coastline.

This work consists in mapping the liquefaction evidences, analyzing the liquefied soils by comparing the ejected sands with in-situ sands, calculation of minima PGA needed to trigger the liquefaction and some interpretations regarding the spatial distribution of the phenomenon.

2. METHODOLOGY

The study method used consists of field surveys in the areas with liquefaction evidences, site investigations and laboratory analysis. The CRR (Cyclic Resistance Ratio) is calculated based on SPT results. The minimum acceleration necessary to trigger the liquefaction was calculated using the principle of equilibrium using the F_{SL} (Safety factors) of 1 and 1.2.

3.1.Field surveys

Initially, field surveys were concentrated in residential areas where there were many damaged buildings. Once the areas were identified, detailed surveys took place. At each site, the geographic position, the main orientation of the sand volcanoes alignment, the size of the craters, the distance between them, and where possible, the volume of the ejected sand were estimated.

The superficial evidences of the liquefaction phenomenon was better expressed in the areas of Juba, Rrushkull and Hamallaj (**Figure 37**).

In this area, series of sand boils arranged along lines representing cracks of different lengths and directions, are observed. The maximum extension of these line-arranged sand volcanoes reaches 25 -30 m. In general along a soil crack there is a main crater of the sand volcanoes accompanied in both sides by smaller ones. The diameter of the “craters” varies from dozens of centimeters up to 1.0-1.2 m. In addition to sand volcanoes, damages have been observed in engineering facilities such as damage to the surrounding walls as well as to the sidewalks of the habitations, differential settlements, roadbed cracking accompanied by sand ejections etc. (**Figure 38**).

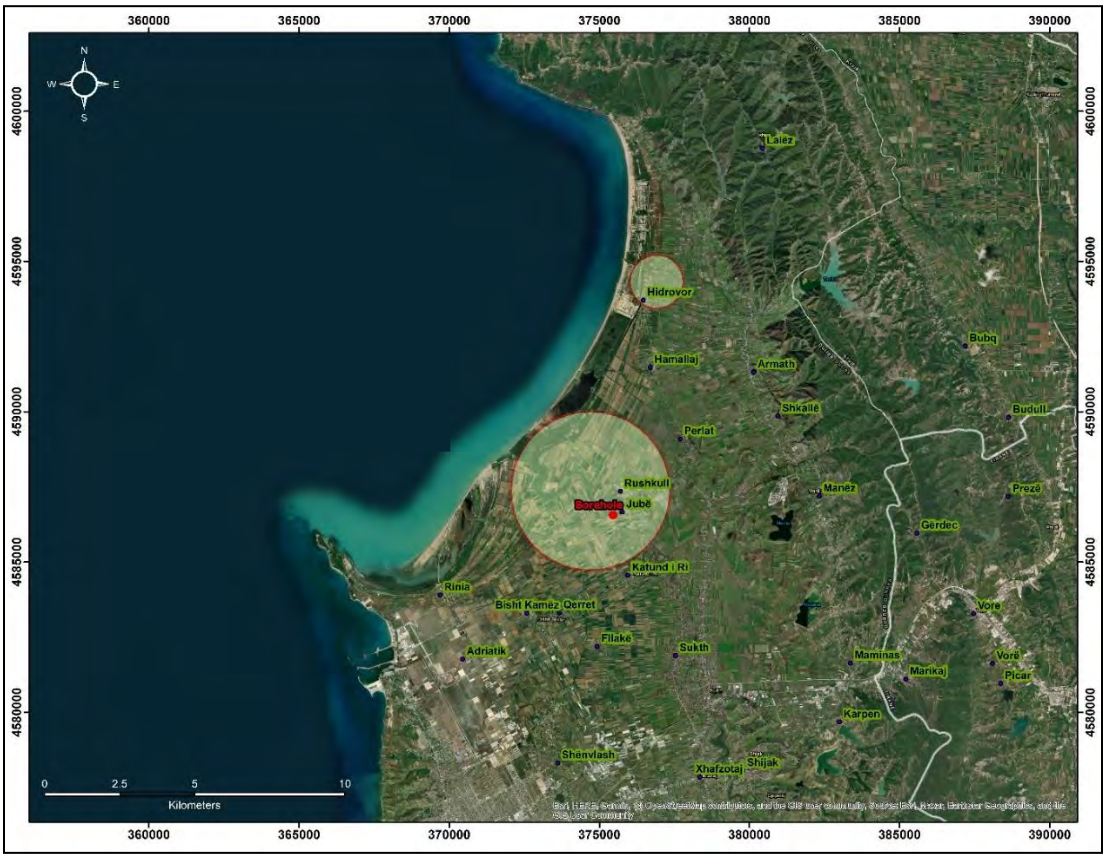

Figure 37. Geographic location of the study area

Figure 38. View of liquefaction evidences in the area

During this campaign, samples were taken for soil classification in order to compare with the results of the site investigation and laboratory results.

3.2.Site investigation and laboratory results

In order to define the stratigraphy and the structure of the soils, taking samples for laboratory analyses, carrying out SPT tests and to provide information regarding the hydrogeological conditions, a continuous coring borehole up to the depth of 15 m was made. It was placed in the Juba area where the superficial evidences of the liquefaction were best expressed.

3.3.N_{SPT} based Cyclic Resistance Ratio

The normalized Cyclic Resistance Ratio (CRR) for a magnitude of 7.5 is calculated based on the N_{SPT}-value according to the procedure proposed by Idriss & Boulanger (2004, 2008) as follows:

$$CRR_{M=7.5,\sigma_v^{'}=1atm} = \exp\left[\frac{(N_1)_{60cs}}{14.1} + \left(\frac{(N_1)_{60cs}}{126}\right)^2 - \left(\frac{(N_1)_{60cs}}{23.6}\right)^3 + \left(\frac{(N_1)_{60cs}}{25.4}\right)^4 - 2.8\right]$$

$(N_1)_{60cs}$ – representing the N_{SPT} corrected for the SPT equipment characteristics, borehole diameter, overburden effective stresses and soil fine content.

It is calculated as $(N_1)_{60cs} = (N_1)_{60} + \Delta(N_1)_{60}$

Where:

$$(N_1)_{60} = N_{SPT} \cdot C_E \cdot C_B \cdot C_R \cdot C_S \cdot C_N$$

N_{SPT} is N-value of SPT; C_E - hammer energy efficiency; C_B -borehole diameter correction; C_R - rod length correction; C_S = non-standardized sampler configuration correction and C_N is the effective overburden pressure correction.

The borehole correction factor C_B and the sampling method correction factor C_S are set equal to unity because the standard procedures were followed [3].
The energy ratio and the rod length factors used in the calculations are those recommended by Youd et al 2001 [4]. The Donut hammer type was used and the respective factor was set equal to 0.75. The road length factors are C_R=0.75 for rod length less than 3 m; C_R=0.80 for rod length between 3 m and 4 m; C_R=0.85 for rod length between 4 m and 6 m; C_R=0.95 for rod length between 6 m and 10 m and finally C_R=1.00 for rod length more than 10 m.
The overburden correction factor was calculated based on Idriss & Boulanger (2008) recommendations as follows:

$$C_N = \left(\frac{P_a}{\sigma_v^{'}}\right)^m \quad with \;\; m = 0.784 - 0.0768\sqrt{(N_1)_{60cs}}$$

Where "*m*" is the power factor expressing the dependence of the C_N from the N_{SPT} corrected for the SPT equipment characteristics, borehole diameter, overburden effective stresses and soil fine content. In order to avoid the vicious cycle a simple iteration procedure in an excel spreadsheet is used for the determination of the factor "*m*".
The relation developed by Idriss and Boulanger (2004-2008) is used for the calculation of the equivalent clean sand adjustment factor as follows:

$$\Delta(N_1)_{60} = \exp\left[1.63 + \frac{9.7}{FC + 0.01} - \left(\frac{15.7}{FC + 0.01}\right)^2\right]$$

The soils' CRR is also affected by the duration of the shaking (which is correlated to the earthquake scaling factor, MSF) and effective overburden stress (which is expressed through a Ks factor) [3].

$$CRR_{M,\sigma_v^{'}=1atm} = CRR_{M=7.5,\sigma_v^{'}=1atm} \times MSF \times K_\sigma \times K_\alpha$$

The Magnitude Scaling Factor is calculated using the formula proposed by Idriss (1999) [5]as follows:

$$MSF = 6.9\exp\left(\frac{-M}{4}\right) - 0.058 \le 1.8$$

The overburden stress correction factor was calculated as follows:

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma_v^{'}}{P_a}\right) \le 1.1 \quad with \;\; C_\sigma = \frac{1}{18.9 - 2.55\sqrt{(N_1)_{60cs}}} \le 0.3 \qquad K_\alpha = 1$$

3.4.Cyclic Stress Ratio CSR

The cyclic stress ratio, CSR, is given by Seed and Idriss 1971 [6]:

$$CSR = \frac{\tau_{av}}{\sigma_{vo}} = 0.65 \cdot \left(\frac{a_{max}}{g}\right) \cdot \left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right) \cdot r_d$$

where, CSR is the Cyclic shear Stress Ratio; σ_{vo} - total overburden pressure; σ'_{vo} - effective overburden pressure; a_{max} - maximum acceleration in units of g; g - gravity acceleration and r_d the factor that accounts for the flexibility of the soil column.
The total (σ_v) and effective (σ_v') vertical stresses are estimated from the geotechnical model of the study area.
The stress reduction factor, r_d, is calculated using the relation proposed by Idriss 1999 as follows:

$$r_d = \exp[\alpha(z) + \beta(z) \times M]$$

$$with \quad \alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right) \; and \; \beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$$

3.5.Peak ground acceleration calculation

Based on the equilibrium concept, the minimum accelerations sufficient to trigger the soil liquefaction have been calculated at the depth intervals where the SPT tests were performed.
Accelerations are calculated by considering the factor of safety against the liquefaction FSL=1.0 and FSL=1.2, as follows:

$$\frac{a_{max}}{g} = \frac{CRR_{M,\sigma'_v=1atm}}{0.65 \times r_d} \times \frac{\sigma'_{vo}}{\sigma_{vo}} \times \frac{1}{F_{SL}}$$

4. RESULTS

The soil profile is composed by beige silts and sandy-silty clays in the upper part followed by grey sands and silty sands. The SPT N values varies from 2 to 4 indicating very loose to loose non cohesive soils.
From the ground level to the depth of 3.3 m the soils are represented by silts (ML), followed by a layer of sandy-silty clays (CL-ML) up to the depth of 4.2 m. Well graded sand with silt (SW-SM) are encountered in the depth intervals from 4.2 m to 5.0 m while from 10.2 to 12.3 m below ground level Poorly graded sand with silt (SP-SM) are encountered. The rest of the soil columns (5.0 to 10.4 m and 12.3 to 15 m) is composed by grey silty sands (SM).
The Liquid Limit (LL) varies from 27.05 % to 37.43 % while the Plasticity Index varies from 5% to 12 %. The fine content (FC) varies from 5.26% to 14.05 % for the samples taken from the ejected sands, and from 7.6% to 24.77 % for the sandy samples taken during the boring. For the silts and sandy silty clays, the FC varies from 54.18 % to 93.6 %.
In the table below the minima PGA necessary to trigger the liquefaction for FSL=1 and FSL=1.2 **Table 14**.

Table 14. Values of minimum acceleration to trigger the liquefaction (FSL=1 and FSL=1.2))

nr	Depth (m)	N_{SPT}	$CRR_{7.5}$	$CRR_{6.3}$	PGAmax/g (FSL=1.0)	PGAmax/g (FSL=1.2)
1	4.7	2	0.07843	0.108621	0.170	0.141
2	6.2	3	0.089664	0.123003	0.175	0.146
3	9.0	4	0.096368	0.129922	0.172	0.143
4	10.5	5	0.083252	0.111577	0.146	0.122
5	12.0	4	0.106697	0.141328	0.185	0.154

6	14.0	4	0.103588	0.135998	0.181	0.151

Table 15. Summary of field investigations and laboratory tests

Depth (m)		Description	SPT results		Grain size distribution			Atterberg limits			USCS Classification
from	to		Depth (m)	N_{SPT}	% Gravel (>4.75 mm)	% Sand (0.075 – 4.75 mm)	% Fine content (<0.075 mm)	LL (%)	PL (%)	IP (%)	
0.0	2.7	Beige, moist, medium plastic silt **(ML)**, containing thin intercalations of grey silt.				6.4	93.6	37.43	25.08	12.35	ML
2.7	3.0	Gray, moist, low plastic, soft to firm sandy silt **(ML)**.				45.82	54.18	27.27	22.37	4.90	ML
3.0	3.3	Beige, moist, soft to firm silt **(ML)**.				6.4	93.6	37.43	25.08	12.35	ML
3.3	4.2	Gray**,** moist, low plastic soft to firm Sandy Silty Clay **(CL-ML)**.				31.06	68.94	27.05	22.37	6.12	CL_ML
4.2	4.9	Gray, loose, wet **Well graded sand with silt (SW-SM)**.	4.7	2		86.67	11.33				**SW-SM**
4.9	9.4	Gray, fine, loose, wet **Silty Sand (SM)** containing thin intercalations of beige fine sands.	6.2	3		84.58	15.42				**SM**
		Silty Sand (SM) as above	9.0	4		86.64	13.56				**SM**
		Silty Sand (SM) as above	10.5	5		76.89	23.11				**SM**
9.4	10.2	Gray, fine, loose, wet **Silty Sand (SM)** containing rests of shells				84.89	15.11				**SM**
10.2	12.3	Gray, fine, loose, wet **Poorly graded sand with silt (SP-SM)**	12	4		92.4	7.6				**SP- SM**
12.3	15	Gray, fine, loose, wet **Silty Sand (SM)** containing rests of shells	14	4		75.23	24.77				**SM**

5. CONCLUSION

The phenomenon is better expressed in those areas where the sandy deposits are covered by a superficial layer of cohesive soils (ML, CL-ML) leading to the creation of undrained conditions. Comparing the grain size distribution and mineralogical composition of the ejected sands with those obtained from the borehole as well as based on N_{SPT} values it can be concluded that the studied soil column (up to 15 m) has been subject to the phenomenon of liquefaction.
The necessary minima PGA to trigger the phenomenon varies between 0.146 g and 0.185 g, and between 0.122g and 0.154 g corresponding respectively to a safety factor (F_{SL}) of 1.0 and 1.2.
The spatial distribution of the phenomenon on both sides and in the vicinity of the Erzeni River shows that this phenomenon has affected the deposits related to the recent activity of the river as well as the beach deposits.

REFERENCES

[1] Daja S., Shkodrani N., Lako A., Ago B., "Real liquefaction probability of non-cohesive soils in Semani Area, in Albania," *Ital. J. Geosci.,* Vols. 132, No. 2, pp. 213-219, 2013.

[2] Daja S., Ago B., Muci R., "Liquefaction potential in the Adriatic coastal areas in Albania," *Bulletin of the Geological Society of Greece,* vol. L, pp. 2363-2371, 2016.

[3] Idriss, I. M.; Boulanger, R. W.;, "Soil liquefaction during earthquakes, Monograph MNO-012," Earthquake Engineering Research Institute, Oakland, CA, 2008.

[4] Youd T. L., Idriss I. M., "Liquefaction resistance of soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils," *Journal of Geotechnical and Geoenvironmental Engineering,* vol. Vol. 127, no. No. 4, pp. pp 297-313, 2001.

[5] I. M. Idriss, "An update to the Seed-Idriss simplified procedure for evaluating liquefaction potentional," TRB Workshop on New Approaches to Liquefaction, Publication No. FHWA-RD-99-1965, Federal Highway Administration, 1999.

[6] Seed, H. B.,& Idriss, I. M., "Simplified procedure for evaluating soil liquefaction potential," *Journal of Geothechnical engineering,* vol. 9, pp. 1249-1273, 1971.

Structural and earthquake engineering

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Structural and Earthquake Engineering focuses on the analysis, design, construction of structures resilient to earthquakes and safe constructions for human use in earthquake scenarios. Engineering methods include seismic analysis, modeling, and simulating the behavior of structures under earthquake actions. Sophisticated numerical and scientific techniques are used to understand how structures will be affected by earthquakes and to develop appropriate designs. Our research includes the development of resilient structures, minimization of damage in earthquakes, improvement of construction safety, laboratory, and field testing to verify the behavior of structures under earthquake stress. Structural Engineering and earthquakes are complex challenges that require deep scientific knowledge and advanced technology to ensure resilient and safe constructions for citizens and infrastructure. Conclusions from research in this field help to improve construction practices and prepare for future earthquakes.

Keywords: *Seismic, safety, resilient, improvement.*

1. INTRODUCTION

In this paper we will focus on the understanding, causes and risks of earthquakes focusing on earthquakes that had a big impact on society through years. More precisely we will focus on the last earthquakes in Turkey and Japan as a comparison, damages caused, the reasons of those damages and structuring of earthquake proof buildings.

2. STRUCTURES DURING EARTHQUAKES

2.1. What is an earthquake?

An earthquake is a natural event that occurs when there is a sudden release of energy in the Earth's crust, causing seismic waves. Earthquakes are typically caused by the movement of tectonic plates beneath the Earth's surface. When these plates collide, slide past each other, or move apart, stress builds up along their boundaries. When this stress exceeds the strength of the rocks, it is released in the form of an earthquake.

2.2. Why does a building collapse?

1. **Weak Foundations**: Inadequate or poorly constructed foundations can lead to building collapse. The solidity of the soil and the weight of the building are critical considerations. For instance, building on swampy ground without strong foundations can be risky[1].

2. **Substandard Materials**: The use of weak or counterfeit building materials is a significant issue. Sometimes, scrap metal is substituted for steel, compromising the structure's integrity. Contractors may also cut costs by using incorrect materials.

3. **Mistakes During Construction**: Even when the right materials are provided, unskilled workers might mix concrete incorrectly. This results in concrete that lacks the necessary strength to bear the load. Cutting costs by hiring cheaper, untrained labor can be detrimental[1].

4. **Overloading**: Buildings collapse when there is more weight on a portion than it is designed to support. Overloading can occur due to excessive loads, such as additional floors or heavy equipment[2].

5. **Material Deterioration**: Chemical changes over time weaken building materials. Rust, rot, and decay can compromise structural elements, making them susceptible to collapse[2].

6. **Design Flaws**: Poor architectural design, inadequate structural calculations, or flawed engineering can lead to building instability. Neglecting safety factors during design can have dire consequences

2.3. How are Buildings engineered to not collapse?

Our goal for this phase is to find all the loads that the building is going to experience and design. There are two types of loads that the building is going to experience. There's gravity and there's lateral loads. Gravity loads, as the name suggests, are all the loads that are pointing towards Earth. To put it simply, this is how much the building ways. This is the weight of the construction materials. This is the weight. Structural engineers work with architects to figure out what type of loading these spaces are going to experience. Every building, so residential loading, we need to design A skeleton that can take this look. For our case, this is going to be the floor system. We're going to be using a concrete floor slab system that's going to be reinforced with steel bars. And note that there's different types of systems out there. The concrete floor slab will take all the weight that the apartments are going to put on it, and it's going to transfer all of those loads into the columns. If the columns fail, the building is going to collapse and besides that they take all of the building loads and transfer them to the foundations. Once all the building loads go to the foundations, the foundations transfer the building loads to the soil by completing this load path. That's how we know that the building is going to be stable and stand up.

Think of this phase as designing the muscular system of the building that connects everything together.

You can think of our concrete core walls as a stack of Legos. When you push it down, for the most part it's not going to go anywhere, but it's super weak in tension, meaning that if you apply any lateral loads. Such as winds or earthquakes, the concrete is going to fail. But if we add reinforcing to it, let's say duct tape for our Lego example, then the concrete lapses. That's why we need to add steel bars to reinforce the concrete.

2.4. Earthquakes as a phenomenon

Tectonic Plate Movement: The Earth's crust is divided into several large and small tectonic plates that float on the semi-fluid asthenosphere beneath them. These plates are in constant motion, driven by the heat generated from the Earth's interior and gravitational forces. When these plates interact, they can collide, slide past each other, or move apart, leading to stress buildup along their boundaries.

Stress Accumulation: As tectonic plates move, they can create stress along fault lines, which are fractures in the Earth's crust. This stress can gradually accumulate over time, causing rocks on either side of the fault to deform and store elastic energy.

Energy Release: When the accumulated stress exceeds the strength of the rocks, it is suddenly released in the form of seismic waves. This release of energy is what causes an earthquake. The seismic waves radiate outward from the earthquake's epicenter, shaking the ground and causing the characteristic shaking that we feel during an earthquake.

Epicenter and Focus: The point on the Earth's surface directly above the origin of the earthquake is called the epicenter. The actual point within the Earth where the earthquake originates is known as the focus or hypocenter. The depth of the focus can vary, and it influences the intensity of shaking felt at the surface.

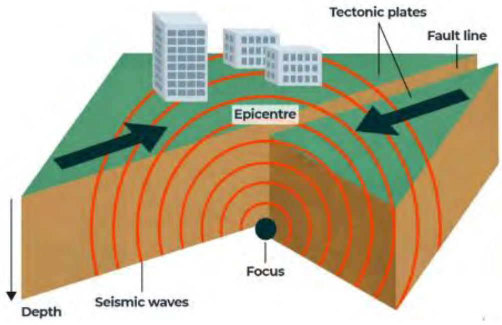

Figure 39. Earth's tectonic plates moving against each-other, along a fault line.

Types of Waves: Earthquakes generate several types of seismic waves:

Primary (P) Waves: These are compressional waves that travel through solid, liquid, and gas. They are the fastest seismic waves.

Secondary (S) Waves: These are shear waves that travel only through solids. They are slower than P-waves and cause shaking perpendicular to their direction of travel.

Surface Waves: These waves travel along the Earth's surface and are responsible for the most significant ground shaking and damage during an earthquake.

Magnitude and Intensity: Earthquakes are measured using scales such as the Richter scale or the moment magnitude scale (Mw). These scales quantify the energy released by an earthquake and its potential to cause damage. The intensity of an earthquake's effects can vary widely based on its magnitude, depth, distance from populated areas, and local geological conditions.

2.5. Risks of earthquakes

- Structural Damage
- Casualties and Injuries
- Displacement and Homelessness
- Landslides
- Tsunamis
- Infrastructure Disruption
- Economic Impact
- Psychological and Social Impacts

- Environmental Consequences
- Cascade Effects

2.6. 10 Largest earthquakes ever recorded.

1. Valdivia, Chile, 1960- The biggest earthquake ever recorded occurred in 1960 near the city of Valdivia, Chile. With a magnitude of 9.5 which lasted 10 minutes, it was one of the deadliest earthquakes in history, killing an estimated 5,700. Two days after the earthquake, the Cordón Caulle volcano erupted as a result of the seismic activity, ejecting ash and steam into the atmosphere.

2. Alaska, USA, 1964- Large areas of North America were affected when nearly 1,000km of fault along the Pacific-North American tectonic plates ruptured at once, causing an earthquake which shook for nearly 5 minutes with a magnitude of 9.2.

3. Sumatra, Indonesia, 2004- This huge 9.1 magnitude earthquake caused an uplift on the ocean floor of over 20m and created a devastating tsunami wave that reached over 30m high. This terrifying wave hit coastal areas in 14 countries, killing an estimated 228,000 people with Indonesia, Sri Lanka, India and Thailand.

4. Tohoku, Japan, 2011- The Tohoku earthquake and tsunami occurred on 11 March 2011 and is the biggest earthquake recorded in Japan with a magnitude of 9.1.

5. Severo-Kurilsk, Russia, 1952- Severo-Kurilsk is on the Kuril Islands, Russia, a small volcanic archipelago 1,300km northeast of Japan. In 1952 nearly half of the population of this small town was wiped out when a huge 18m wave caused by a 9.0 magnitude earthquake flattened the whole area.

6. Chile, 2010- An 8.8 magnitude earthquake rocked the coast of central Chile in the early hours of 27 February 2010, close to the coastal city of Concepcion. The intense shaking lasted around 3 minutes and was felt as far away as Sao Paulo, Brazil, 4,620km away.

7. Rat Island, USA, 1965- An 8.8 magnitude earthquake on Rat Island in 1965 caused a tsunami wave over 10m in height on Shemya Island 304km away.

8. Assam, India, 1950- The strongest earthquake ever recorded on land with a magnitude of 8.6 took place between Assam in India, and Tibet, with an epicentre located in the Mishmi Hills of northeastern India.

9. Aleutian Islands, USA, 1946- In April 1946, an 8.6 magnitude earthquake caused a widespread tsunami travelling at a reported 800km/h right across the Pacific Ocean, causing widespread devastation.

10. Indian Ocean, 2012- On 11 April 2012, a huge 8.6 magnitude earthquake 610km off the Banda Aceh coast was recorded, followed closely by another with a magnitude of 8.2.

2.7. Methods to structure earthquake proof buildings

One big misconception that we need to get out of the way first is that buildings will get damaged during big earthquakes. But structural engineers designed these buildings so they don't collapse so people can evacuate the building safely after noon. Can't we just build them like Legos and they'll stand up but during an earthquake or heavy winds they're most likely going to collapse which brings us to:

1. Using moment frames

Structural engineers sometimes use what they call moment frame connections to strengthen the joints. These are basically joints that are heavily welded or heavily bolted. During earthquakes building will stand, but it can wobble and deform quite a bit, and that's one of the cons of using a moment frame system along with it not being the most economical solution. But architects love them because you don't have any walls or braces in the way. You can open up the floor plan a lot more with these.

2. Bracing systems

These are the bread and butter for steel buildings. Braces are stiff, strong, and economical against resisting earthquakes, but they do get in the way of the architecture. Braces, as the name suggests, brace the building during earthquakes and they are effective. If we install braces on the molar model, you can see that during earthquakes they are stiffer and deformed less than the ones with the normal frames. Buildings can deform and get mangled but without tearing apart. The earthquake forces focus all of their energy on the weakest link, the brace. And that's good because they ignore the most important parts of the structure, which are the beams, floor systems and columns.

3. The shear wall systems

structural engineers call them shear walls, but they're basically walls that take the earthquake forces and they prevent the building from shearing off the foundation. When we install shear walls on the molar model, you can see that these are basically the strongest and the stiffest of structural systems, so it's pretty common to see them used in mid rises and high-rise projects. They're the most economical option to resist earthquake forces as well.

4. Dampers

Dampers reduce earthquake vibration on the building or structure. There are various damper systems such as liquid filled dampers, mass tuned dampers or viscous dampers. Let's focus on liquid filled dampers. On top of the building, the water sloshes around in the damper during an earthquake and this sloshing reduces the earthquake vibrations to the structure.

5. Seismic base isolation

This method involves putting roller skates under the building so it's kind of floating above the ground. You can't get hit by an earthquake if you're not touching the earth? This includes putting base isolators, which are usually in the form of ball bearings, rubber bearings, or friction bearings underneath the structure.

3. COMPARISON BETWEEN BUILDINGS WHICH DID AND DID NOT COLLAPSE

3.1 Why did buildings in Turkey collapse?

Across the border in Syria, buildings in these areas were already weakened by the prolonged civil war. But what really complicates this disaster is that Turkey was aware of the buildings that were the highest risk. They're called soft story structures. A soft story building is typically a large structure with multiple floors and an open plan on the bottom. That bottom floor can sometimes be a parking garage, space for small businesses or extra homes. But they historically do a poor job of withstanding medium to powerful earthquakes. Columns could be made of brittle concrete, and the stories on top might be made of stone and a stronger mix of concrete. Sometimes the bottom floor has fewer walls than the ones above with sides that may be left open or columns that aren't connected by walls. This means that a soft story is the weakest floor and cannot fully support the heavier ones above it. So, when an earthquake hits, the structure may shake until the bottom floor collapses. There is a way to keep soft story buildings intact in the event of an earthquake, retrofitting them with materials that can support the weight of the structure. Columns can be replaced or reinforced with steel frames, open walls can be reinforced too, and extra bolts and braces can be drilled into the foundation. So, if the structure shakes their support from that bottom floor. Around 6.7 million residential buildings in Turkey need retrofitting or reconstruction but until now only about 4% of those buildings were transformed.

Figure 40. Collapsed building, Turkey 2023

3.2. How is Japan earthquake-proof?

An object that cannot be moved cannot stay that high if the ground beneath it wants to shake it down to its core, in Japan these skyscrapers have to move. After 2011 earthquake in Japan all even smaller temporary structures have to be resilient against earthquakes across the country. There are two primary levels of resilience that these engineers work towards. First is to withstand more minor earthquakes like the one that Japan may see several times throughout its lifetime. For this magnitude, any damage is unacceptable as they want the building to be so well designed. That these earthquakes can pass, and the building is left unscathed. The second level of resilience is the ability to withstand extreme earthquakes. Preserving buildings, ideally, is no longer the goal. Instead, any damage that does not cause human casualty is acceptable, and the designs are meant to protect lives. That is actually the minimum requirement. To withstand these incredible forces, buildings have to be made to absorb as much of the seismic energy as possible so they will not collapse. Buildings or structures are set supports of shock absorption, which are sometimes as simple as blocks of rubber that are about 12 to 20 inches thick. This shock absorption works to resist the motions of the earthquake and take the pressure off of the buildings. They sit on rubber pads wherever they build columns, down to the foundation. Motion dampers throughout the height, however, can also improve resilience. If you put dampers throughout at certain levels, like every other floor, you can reduce the overall motion of the building during an earthquake to a much smaller amount and prevent widespread structural damage. They use rods of carbon fiber to help anchor it. They use the combined 1031 rods attached to the roof. This may be the first time that carbon fiber has been used in this way.

REFERENCES:

[1] https://youtu.be/141Zmuw9Xcg?si=83ZFdMt3zDUkCUVM
[2] https://youtu.be/TnlCRoBAcuw?si=WFwSnTokDQ1OMK3W
[3] https://youtu.be/ksyR3jWgFKc?si=6bkOERlnIZvZH4OC
[4] What Causes Earthquakes (youtube.com)
[5] 🔬 Science Max - EARTHQUAKES - Home Experiments 🌎 (youtube.com)

The importance of engineering measures for the prevention of landslides caused by human activity in the area of Cfaka, Gjirokaster

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The city of Gjirokastra lies on rugged terrain, thus giving the city a dynamic character. The diversity of the relief has caused, from the compositional point of view, the neighborhoods to stand as separate units and the problems with the stability of the slopes are very widespread. The causes related to slope failure can be natural or artificial, caused by human activity. During the 1990s and before, a negligence in the geological and geotechnical studies of construction sites for multi-story buildings was found. In many cases, people not being specialists, especially geotechnical, do not understand the strained condition of the ground. People with their activity provoke and activate slope failure. In both cases the damage can be irreparable and not infrequently catastrophic. On the eastern-northeastern slope of the Cfaka hill, phenomena of segmented landslides of the rock mass are found, at different times. In this area, the state of critical balance is predisposed to slip without warning, bringing about the destruction of buildings and endangering the lives of the residents who live there. Therefore, the purpose of this study is to present a solution to this problem with pile walls and stabilization of the slope with Geocell material.

Keywords: *Landslides, slope failure, pile wall, Geocell material, Cfaka.*

1. INTRODUCTION

Studies and evaluations of geological-engineering conditions in the "Punetori" Quarter, on the eastern slope-northeast of the Cfakes hill, they find phenomena of segmented landslides rocks, at different times. In this area, the threatening state of its sustainability is clearly evident, as a result of the presence of the base formations which are the lower Oligocene flysch with a 25-35° dip in the direction of decrease in relief. They are formations with weak to medium cementation and are unstable against the action of the waters.
From the frequent artificial interventions for constructions, the premises for discovery of layers, cracks which allow the infiltration of water in the rainy season inside the rock formations and their weathering. It is emphasized that this area is in condition of critical balance and prone to slip without warning.
The excavation carried out for the construction of the retaining wall behind the warehouse, the dumped soil, as well as the discharge of used household water, as well as the landslide of 2011, have complicated the geological-engineering environment of the territory, for the proper functioning of engineering facilities, especially housing.

According to findings obtained on the ground, in this area the ground has cracked in some parts. This has caused damage and cracks in the surrounding houses. On this slope with extension almost in the northwest-southeast direction and northeast-east decline, are ascertained and evaluated from a geological-engineering point of view, some landslide phenomena segmented, at different times.

In the slope in question, we have an almost perfect match of the elements of alignment and the decline of the slope with the elements of extension and decline of the sacrificial layers, which build this slope. The relief is quite wavy and fragmented due to erosion and its phenomena landslides that occurred in a segmented way at different times, as well as fillings with materials from the excavations during the opening of the foundations of the buildings built on this slope.

Figure 1 & 2 Photo of the damage caused by the slide.

2. EVALUATION OF THE PARAMETERS FOR GEOTECHNICAL AND STRUCTURAL CALCULATIONS

Based on geological survey, seismic survey, seismic evaluation of the area and using several from the newest methods in the field of geotechnical engineering in general and mechanics the rock in particular, the physical-mechanical parameters of the rock mass were evaluated. Soil parameters were obtained according to the report, based on the four boreholes.
A summary of the soil parameters is given in Table 1.

Table 1. Soil parameters

Borehole	**S2**	**S2**	**S5**	**S5**
Sample	S2-SC1	S2-SC2	S5-D1	S5-SC1
Depth (m)	4.20-4.60	13.20-13.50	1.50-2.50	3.20-3.50
W (%)	15.2	19.2	10.9	10.1
γ (kN/m^3)	19.6	20.6		
γ_o (kN/m^3)	26.5	26.7	26.9	26.7
e				
LL (%)	36.5	41.8	41.7	39.5
PL (%)	24	23.3	26.4	23.3
PI (%)	12.5	18.5	15.3	16.2
Gravel (%)	28	39.3	39.2	37.5
Sand (%)	17.6	21	23.3	20
Powder (%)	29	17.7	20.6	19.2
Clay (%)	25.4	22	16.9	23.3
USCS	CL	CL	ML	CL
UCS (kPa)	243			
ϕ (^{o})	29.6	29.5		
c (kPa)	45.4	31.6		

To determine the parameters of the rock, the results of the 4 Boreholes were used, and the parameters needed to calculate the stability of the slopes and the protective measures were evaluated. A summary of these parameters is given in Table 2.

Table 2. Rock parameters from laboratory tests

Borehole	P1-AMP	S1	S5
Sample	C1	C1	C2
Depth (m)	1.0-1.2	6.30-6.50	9.50-9.80
ϕ_peak (°)	45.47		
c_peak (kPa)	220		
ϕ_res (°)	32.43		
c_res (kPa)	90		
UCS (MPa)		10.78	17.43
Etan (GPa)		2.35	3.92
Esec (GPa)		2.64	3.82
Eave (GPa)		2.5	3.72
UCS		5.39	8.72

From the evaluation of the above parameters, the following data (Table 3) can be given for the different areas and layers, for the evaluation of the rock without cracks. The linearization of the Hoek–Brown Criterion was used to obtain the Mohr–Coulomb parameters of the mass rock, although the input data according to the Hoek–Brown criterion, which is a non-linear criterion, unlike Mohr–Coulomb, which is the linear criterion, was used in the calculation.
By applying the Generalized Hoek-Brown criterion, the parameters for the rock mass were calculated (for reference, since the calculation programs used include the generalized Hoek-Brown criterion as a resistance criterion for rocks.)

Table 3. Rock parameters for use in calculations

Borehole	P1-AMP	S1	S5
Sample	C1	C1	C2
Depth (m)	1.0-1.2	6.30-6.50	9.50-9.80
mi	10	15	15
D	0	0	0
GSImax		40	60
GSImin		30	50
mb(max)		1.7598	3.5948
mb(min)		1.2313	2.5152
a(max)		0.5114	0.5028
a(min)		0.5223	0.5057
s(max)		0.001273	0.011744
s(min)		0.000419	0.003866
ϕm_max (o)		**30.98**	**37**
ϕm_min (°)		27.94	34
cm_max (MPa)		0.5216	1.1388
cm_min (MPa)		0.4382	0.9813
Em_max (MPa)		421.48	1986.4
Em_min (MPa)		214.85	1173.45

Figure 3 shows the position of each layer in the GSI diagram, as well as the corresponding rating according to the GSI system.

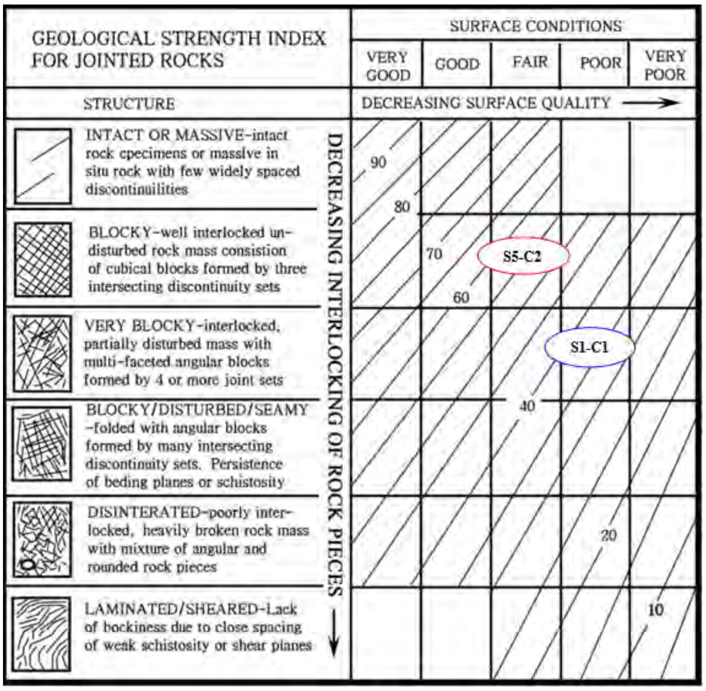

Figure 3. Classification of the rock massif according to the GSI system [1]

3. ENGINEERING MEASURES IN THE AREA

To stabilize the slide below the building no. 2 engineering measures have been taken:

1. Construction of the frame with piles (measure 2),
2. Construction of the wall piles (measure 4)
3. Systematization of the square and alleys with concrete
4. Systemization of surface water and used water,
5. Systemization of the area with slopes 5.5x2.5 m (α= 24°) with 2 m wide, reinforced banks with geocell NPA 356 x100 (cat. B).
6. Planting of the systemized area with acacia trees and construction of canals with multimat coating 100 at the end of each escarpment.

3.1. Measure no. 2 - Frame with two rows of piles, Ø 800, L=15 m. Reinforced concrete pile walls incastrated with reinforced concrete beams

Since the geological-engineering study highlighted the presence of a visible sliding plan, which endangers the objects that occur on the slope, an engineering measure was designed in the form of a frame, composed of two rows of piles with length L=15 m, one in the form of a wall with piles with diameter Ø800 placed every 1 m and connected with reinforced concrete beams at their heads and the other row with piles Ø800 every 3 m located at a distance of 4 m from the first row of piles. Both rows are connected to each other with reinforced concrete beams at the head of piles with dimensions 40 cm x 40 cm, in a part of them thus creating a frame with high gravity, which solves the risk problem of objects from the destruction, as a result of the landslide on the hill. The total length of the pile wall is L = 39.2 m, while the second row of piles is 16.2 m long. Such a solution it was given for the safety of the building from the works during the construction phase. In this way a minimum distance of 2 m from the edges of the building has been maintained.

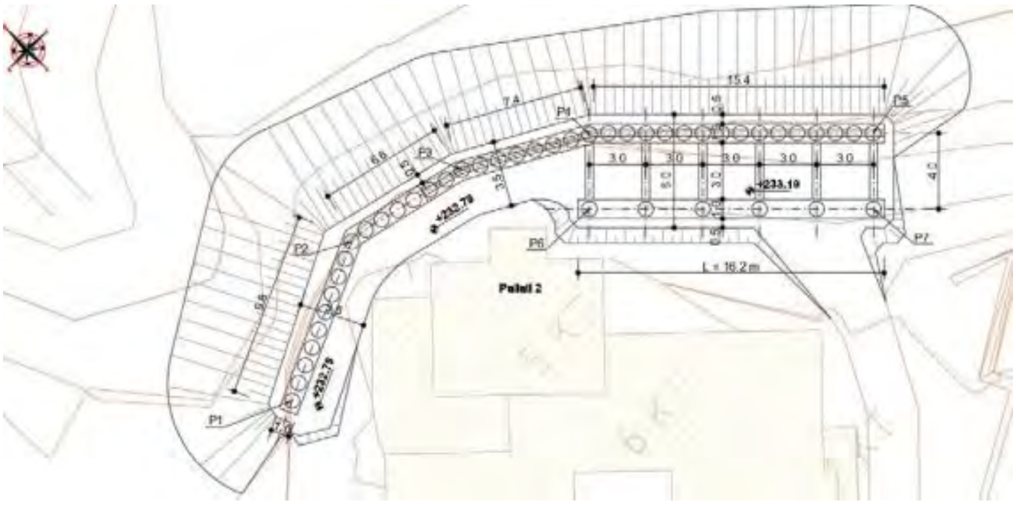

Figure 4. Measure no. 2

The design of the structure was done in such a way that the connecting beam of the structures does not have a large inclination, according to the instructions of the geotechnical engineer.
The reinforced concrete wall above the head of the piles was designed as a retaining wall for the road and the necessary fillings on the structure of the piles to reach the appropriate quotas, with a height of h=1.8 m. Also on the reinforced concrete wall, the placement of the handrail is foreseen, since the height of the wall with piles is significantly, to increase the safety of the residents of the area.

3.2. Measure no. 4 – Pile wall Ø 800, L=15 m. Reinforced concrete wall, incastrated in the reinforced concrete beam at the head of the piles

In the lower part of the slope, since the surface where the slide occurred is significantly, to prevent further sliding, which endangers the objects below it, designed a wall with piles, with the length of the piles L = 15 m, with a diameter of Ø800, placed every 1 m from one another. The piles will be embedded in the base rock formation to win full stability of the slope in the problem area. In the beam that connects the piles, a reinforced concrete wall is embedded with a height of 1.8 m which will serve as a retaining wall for the filling necessary for systematization of the escarpment. The overall length of the pile wall is L=51.2 m and it is designed as such to protect the entire area with problems. During the design, care was taken to maintain the distance from the objects in such a way as not to cause any possible damage during the works, also to create sufficient space for the realization of works during drilling and concreting of the piles.

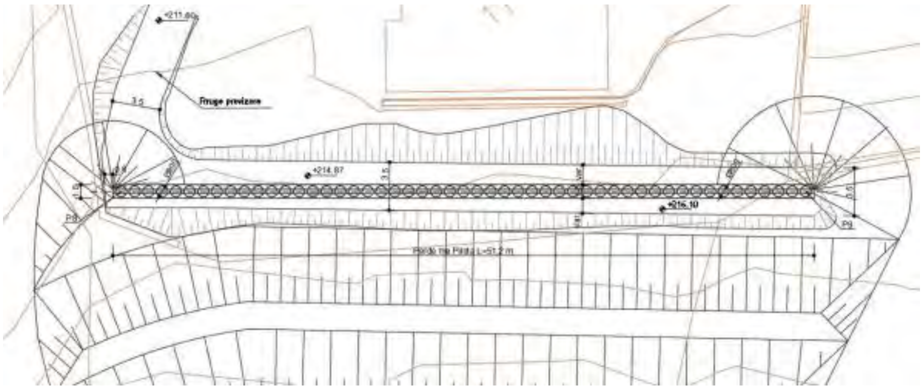

Figure 5. Measure no. 4

3.3 - Ground system with escarpments with Geocell, berm 2 m and planting with acacia every 4 m

To provide a permanent solution to the stabilization of the slope in its upper and lower part, to eliminate any possible surface slippage and to enable access and afforestation of the area, the systemization of the escarpment with a small inclination angle (α=24°) and with horizontal berms 2 m wide every 5.5 m.
These berms, in addition to their function to receive materials that may slide from the surface of the escarpments, will also serve as an access road for the maintenance of the escarpment and for planting trees.
The slopes will be reinforced with Geocell type 356x100, Category B, which are calculated for sliding and will ensure the stabilization of the slopes from any possible sliding or erosion problems. For the afforestation of the surface, the acacia tree was considered, since the acacia is known as a tree that has need for a significant amount of water. So, in addition to the consolidation of the terrain and the elimination of any possible erosion from the presence of trees, this will help the surface of the slope stay dry and free of surface and underground water. Acacias will be planted every 4 m.

[2]

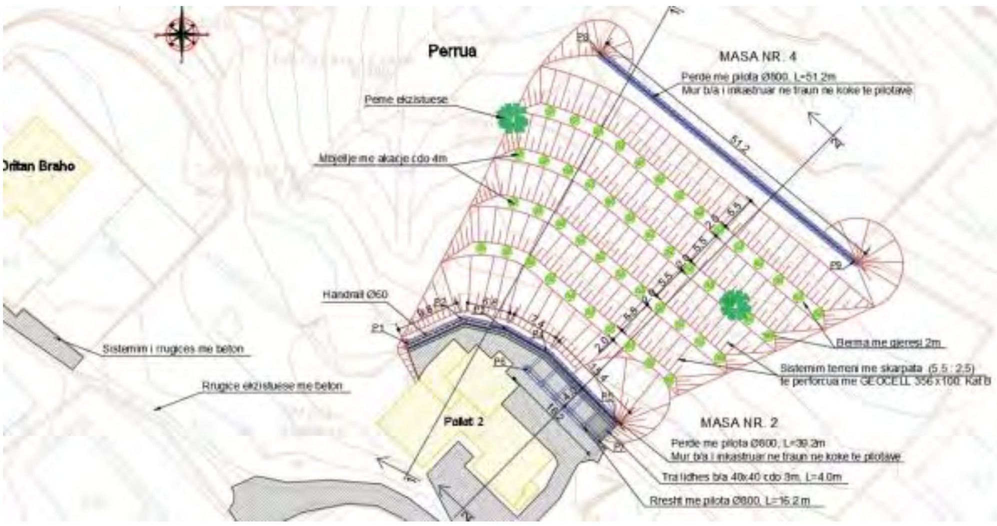

Figure 5. Stabilization of slopes with Geocell and berms and planting with acacia

3. CONCLUSIONS

Deforestation of the area and interventions in the lower base of the slope has brought about the destruction of the natural protective measure and the loss of stability of the slope.
Referring to the area and the location of the facilities in the area, the engineering measures are different, in accordance with the safety of the facilities, users and residents.
In the lower area of the sliding plane, in all cases, the construction of the piles is planned, which cross the sliding plane and ensure the stability of the slope.
It was considered necessary to use reinforced concrete elements in this area as materials with high bearing capacity.
To avoid slipping, the slope is arranged at a certain angle. In order to be friendly with the environment and to create a relaxing environment, artificial afforestation of the area is planned. Later, the continuation of afforestation as a natural process is foreseen. The growth of grass and shrubs will lead to a natural protection of the surface of the slope.

REFERENCES

[1] Laboratory test results by GEOTEST ltd and GeoENG ltd.

[2] PhD Eng. Erion Bukaci (2019) Geotechnical and structural design of supporting structures for the stabilization of the slide on the hill of Cfaka, near the national road Gjirokaster - Kakavia.

Hydraulic and Coastal Engineering

Proposing contemporary measures to prevent the phenomenon of erosion (Korthpula-Puke)

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Soil erosion represents one of the destructive phenomena of the earth's relief, both through surface and deep erosion. The visible activity of water erosion, typical for watersheds, observed in our country, is favored by many factors such as relief, geological composition, soil, climate, etc. Precisely the inhibition or prevention of this phenomenon, present in water catchment basins, especially in those with a substantial risk of erosion, brings to attention and instructs as necessary the performance of works of a biological, biotechnical, and engineering nature. In this binomial of bio-engineering works, the primary role, for the systematization of ponds and mountain streams, takes the vegetative cover, especially the forest cover, with the gradual installation of which its protective function also increases, but in parallel with the performance of such works, it is also recommended performing other works, of a biotechnical and engineering nature, with the function of holding solid materials, strengthening the bed and directing water flows. This project, which has as its theme the systematization of a forest area in the area of Korthpula in the Puka District is approaching this goal through biotechnical and engineering work. The practical realization of this project will have a positive effect on the protection of the soil from erosion and the prevention of sediments created by this phenomenon, which appears mainly during the period of the rains. Also, this project will lead us to the improvement and sustainable management of this ecosystem. In order for the effect of the measures to be as great as possible, it is proposed to do a combination of the biotechnical works with the engineering works provided for in the project, namely in the upper parts of the ravines, fences with single and double reinforcements will be built and in the lower parts of the ravines, ambushes with stone masonry will be built.

Key words: *Soil, erosion, watersheds, bioengineering, ravines.*

1. INTRODUCTION

Soil erosion represents one of the destructive phenomena of the earth's relief, both through surface and deep erosion. The visible activity of water erosion, typical for watersheds, observed in our country, is favored by many factors such as relief, geological composition, slope, vegetation cover, soil, climate, etc [1].

Precisely the inhibition or prevention of this phenomenon, present in water catchment basins, especially in those with a substantial risk of erosion, brings to attention and instructs as necessary the performance of works of a biological, biotechnical, and engineering nature [1].

In this binomial of bio-engineering works, the primary role, for the systematization of ponds and mountain streams, takes the vegetative cover, especially the forest cover, with the gradual installation of which its protective function also increases, but in parallel with the performance of such works, it is also recommended performing other works, of a biotechnical and engineering nature, with the function of holding solid materials, strengthening the bed and directing water flows[1].

This project, which has as its theme the systematization of a forest area in the area of Korthpula in the Puka District, is approaching this goal and such objectives, through the provision of two types of works (biotechnical and engineering) [3].

The practical realization of this project will have a positive effect on the protection of the soil from erosion and the prevention of sediments created by this phenomenon, which appears mainly during the period of the rains. Also, this project will lead us to the improvement and sustainable management of this ecosystem.

In order for the effect of the measures to be as great as possible, it is proposed to do a combination of the biotechnical works with the engineering works provided for in the project, namely:

- ✓ in the upper parts of the ravines, fences with single and double reinforcements will be built.
- ✓ in the lower parts of the ravines, ambushes with stone masonry will be built.

2. MATERIAL AND STUDY METHOD

2.1. Scope of the Study

Based on the evidence of the current situation of soil erosion in the Puka area, it was concluded that one of the most problematic areas in relation to this phenomenon was the Korthpula area.

For this reason, within this territory, an area was selected as a case study which is under private administration and is part of the Gomsiqë forest economy, which is located in the South West of the city of Puka, the village of Korthpule about 26 km away from it and is included in the geographical width north-east with coordinates 41°58'15.07"N - 19°48'8.02"E and 41°58'15.60"N - 19°48'4.25"E and south-west 41°58'9.10"N - 19° 48'8.19"E and 41°58'10.38"N - 19°48'3.32"E[2][3].

Figure 1. Orthophoto of the area

2.1.1. Geomorphological indicators of the study area

In the development of the phenomenon of erosion, a particularly key role is played by the different geomorphological indicators of the area, such as the average height, slope, density of the hydrographic network, etc. The identification of these elements for the study area was done by analyzing different materials and maps [2].

These data are reflected in the following table:

Table 1. Geomorphological indicators

Nr.	**Geomorphological indicators**		
	Average height (Hmes)	***Average Slope (i_{mes})***	***Density of the hydrographic network, (Drr)***
1.	568 m/sea level	33%	15 km/km^2

2.1.2. Pedology and geology of the study area

The object is located on the type of mountain brown soils (Albanian system) or on the **Calcaric Cambisols** type according to FAO. These lands lie in the area of the low mountains, at an altitude ranging from 600-1000 m above sea level. These soil types are distinguished by quite different profiles [4][5].

Regarding the geological formations, we can say that this area is part of the Neogene system, the Pliocene section and the rocks are sandy and friable conglomerates, which helps in the further development of the erosion phenomenon.

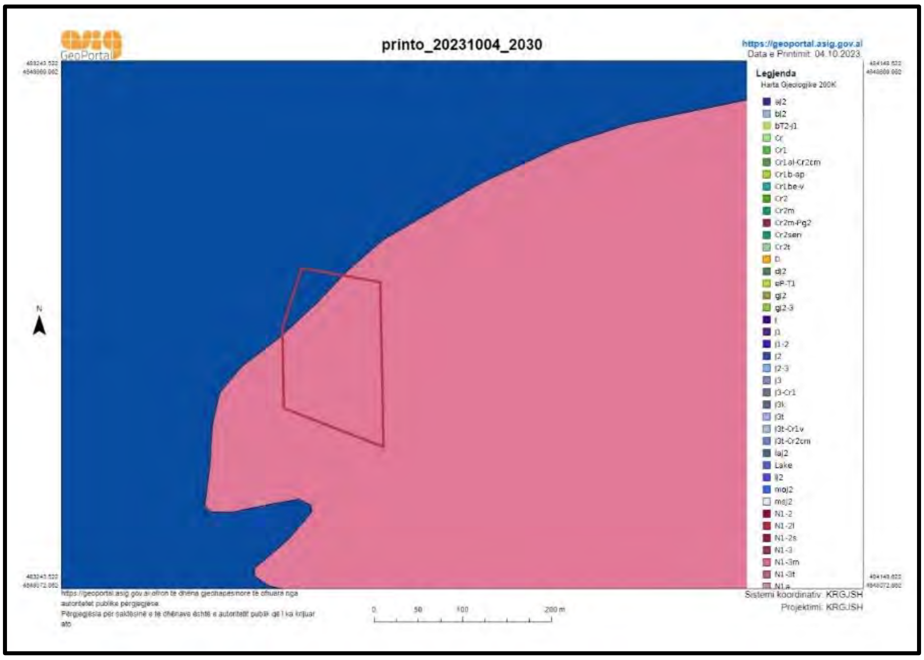

Figure 2. Geology of the study area

2.1.3. Vegetation

The area of the object where works will be intervened is 1.9 ha, which is mostly covered with vegetation. The largest part of the surface covered with vegetation is covered with the type of soft chestnut (Castanea sativa) which is spread uniformly over almost the entire surface. As far as shrubs are concerned, the most widespread are red juniper (Juniperus oxycedrus L.), Grathateli (Erica herbacea L.), Listera (Thymus longicaulis C. Presl.), red oregano (Origanum vulgare L.), etc. [4][7]

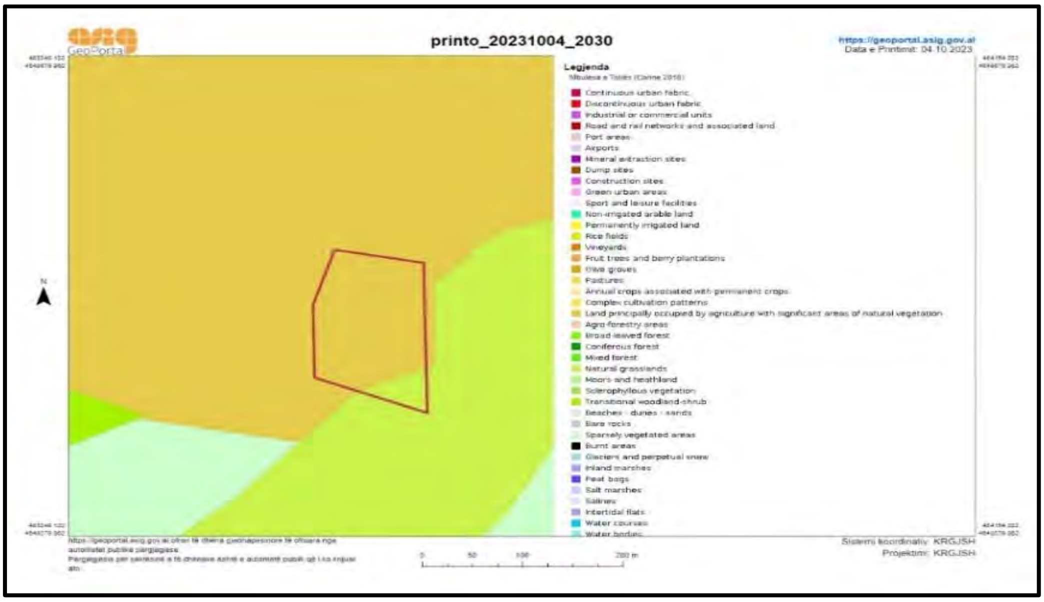

Figure 3. Use of the territory

2.1.4. Climatic conditions

All the main climatic elements, especially rainfall and temperatures, affect not only directly but also indirectly the birth and development of soil erosion, therefore their study is of particular importance for cases when we want to design measures for combating erosion as well as in the implementation of agro-silvotechnical works.

For the study of climatic elements, we have considered the long-term meteorological data from the Hydrometeorological Institute of Albania (IHMA), extracted, and processed from the 1951-1990 series for the Puke meteorological station [5].

The average annual temperature turns out to be 10°C, while the annual amount of precipitation turns out to be 2100 mm/year.

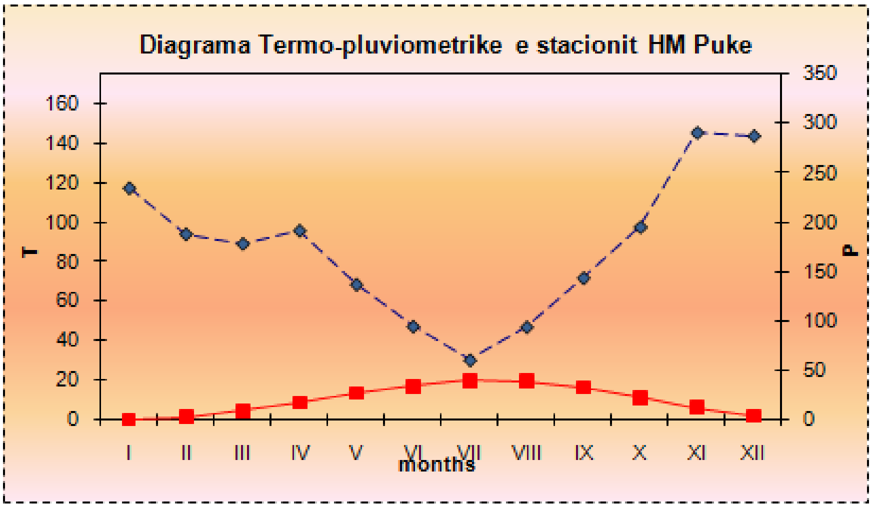

Figure 4. Thermo-pluviometric diagram of the Puka area

2.2. Study methodology.

The methodology used for the identification and design of contemporary measures for the prevention and minimization of the phenomenon of erosion in the study area has been concluded in the following steps.

- The first step: concluded in the identification of all water formations (rivers) where biotechnical and engineering works will be intervened. In order to make it possible to identify them as accurately as possible, we have used the autophotos of the area and various satellite images, as well as their identification and updating in the field.

- The second step: ascertains the construction of longitudinal and transverse profiles of these water formations, through their measurement on the spot by means of various modern geodetic devices. The construction of these profiles has helped us to determine the exact number and position of different works in the field.

- The third step: in order to determine the height of the work coverage, we calculated the compensation slope for each water formation (valley). The proposed measures will contribute to changing the longitudinal profile of the ravines by building a series of ambushes (pair fences and ambushes with stone walls and concrete belts). Based on the real situation and current conditions, we propose that the longitudinal profile after the construction of various works reaches a compensation slope of 3-5 degrees.

- The fourth step: after determining the height of the coverage of the works for each valley and to achieve the slope of the compensation, the positioning of each work to be built was done on the ground, thus compiling the map of the planned works for the study area.

- The fifth step: for each proposed work, their frontal, transverse, and top sections were drawn with real dimensions. The recording and sketching of the works with real dimensions served for the correct design of the volume and items of the works which are reflected in the relevant preventive measures. Based on the volume of work, the work schedule has also been drawn up, which defines the phases that must be followed by the project implementer.

3. RESULTS AND PROPOSED MEASURES

Considering the variety of landforms and current conditions, for the study area, the measures to combat erosion and retain solid materials in water formations should be as diverse and appropriate as possible to respond to each phase. of the development of the corrosion phenomenon and the damage is as small as possible.

In order for the effect of the measures to be as large as possible, a combination of the biotechnical works with the hydrotechnical ones foreseen in the project should be done, and specifically:

- ✓ in the upper and middle parts of the slopes, fences with single and double reinforcements should be built.
- ✓ in the lower part of the ravines where their depth and width are greater, ambushes will be built with dry stone walls and concrete belt.

From the assessments made, it results that to achieve a constant profile where the phenomenon of erosion and the transport of eroded materials is no longer conducted, for each brook it is necessary that the height of the covering with protective works is as follows [6][8]:

• for the ravine, no. RR1 about 1.5 m

• for the ravine, no. 1 about 1.5 m.

• for the ravine, no. 2 about 1.5 m.

• for the ravine, no. 3 about 1.5 m.

• for the ravine, no. 4 about 1.5 m.

• for the ravine, no. 5 about 2.25 m.

• for the ravine, no. 6 about 2.05 m.

• for the ravine, str. 7 about 12 m.

• for the ravine, no. 8 about 15.4 m.

• for ravine no. 9 about 11 m.

Based on the above as well as the evidence of the situation in the country, it is proposed to build in each ravine:

Table 2. The distribution of even fences and ambushes in each ravine

Nr.	Ravine Labeling	Double fences (number)	Barrier with dry wall and concrete layer
1.	Ravine Nr_RR1	**2**	**0**
2.	Ravine Nr_1	2	0
3.	Ravine Nr_2	2	0
4.	Ravine Nr_3	2	0
5.	Ravine Nr_4	2	0
6.	Ravine Nr_5	2	0
7.	Ravine Nr_6	1	1
8.	Ravine Nr_7	14	1
9.	Ravine Nr_8	14	3
10.	Ravine Nr_9	9	3

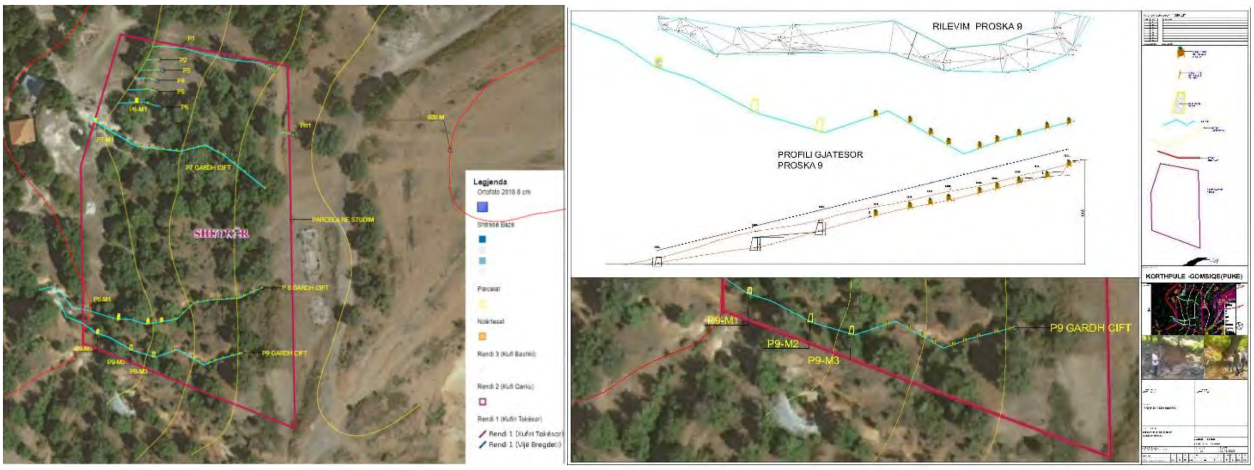

Figure 5. Distribution scheme of bioengineering and engineering works

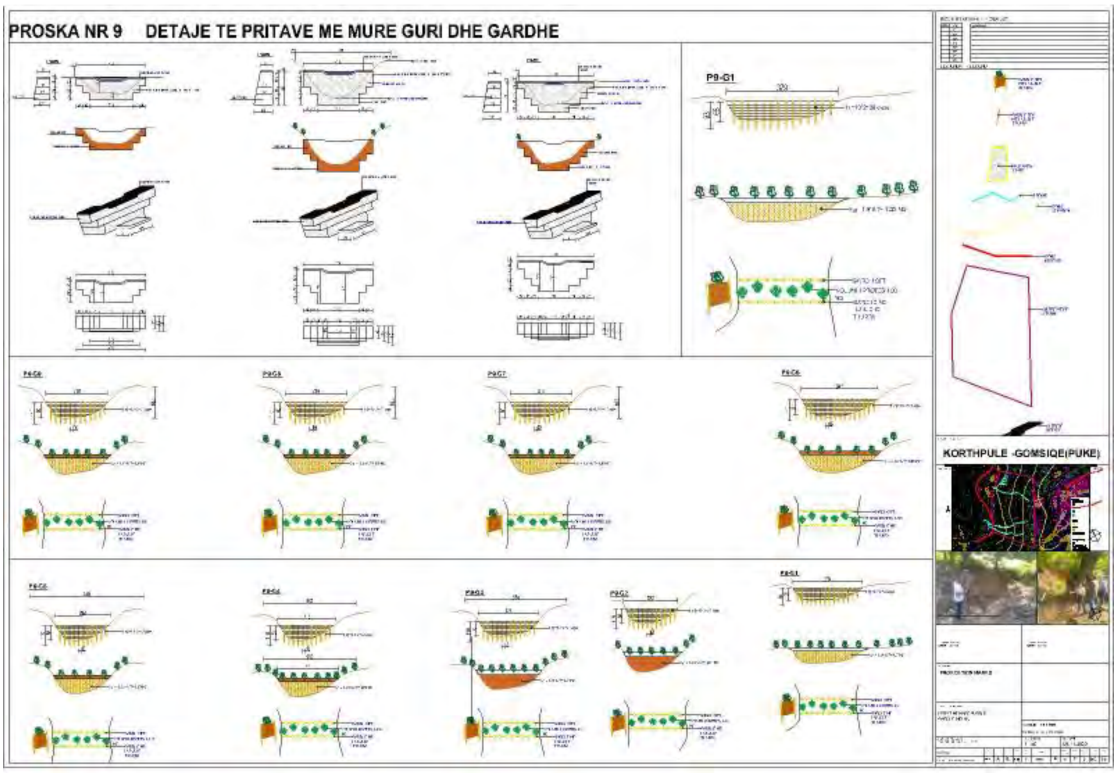

Figure 6. Illustrative photo of the construction of the profiles and details of the ambushes

In order to increase the sustainability of the project, the biggest risks that could lead to damage to the proposed works, biotechnical works (single and double fences) and engineering works (dry stone wall ambush and concrete strip) have been identified. Among the most likely risks are:

- Quality of works.
- Extreme weather conditions when water discharge is above project forecasts.
- Deliberate damage to works.
- Possible fires (intentionally/unintentionally), which can affect the damage of biotechnical works (single and double fences).

Based on the volume of the works as well as for their quality performance and within the technical conditions, it is proposed that their duration be extended to a period of 1 (one) year, starting at the beginning with the construction of double fences in the upper and middle parts of ravines and then with the continuation of the construction of the pits with dry rubble and concrete belt in their lower parts.

This division is made because the beginning of the works in the upper parts would make it possible to keep a significant amount of solid material corroded and deposited, leading in this way to increase the life and efficiency of the protective measures proposed in the following parts.

The drafting of preventive measures for performing the economic analysis of the project is based on two aspects, (1) the ecological conditions of the ecosystem, the volume of works, the technique of their execution and the technology used and (2) relying on the relevant manuals rates and financing opportunities.

We must underline that the mountain systems do not bring income directly, but they influence quite indirectly. These works have a tremendous impact on the protection of different environments and ecosystems from soil erosion, transportation and sedimentati on of eroded materials in the postme parts where they are deposited. Failure to carry out these works brings incalculable consequences, as has happened everywhere in our country, making it possible to fill agricultural lands with inert material, significantly reducing their productivity and in some cases putting them out of their productive function. Based on this context, the intervention with these works is also considered as the maximum effectiveness of the systems in the selected area [3][4].

4. CONCLUSIONS AND RECOMMENDATIONS

For the design of strategies and various application projects related to the sustainable management of water resources in a watershed, the trend of the phenomenon of erosion and sedimentation must be known.

- In order to make it possible to curb and minimize the amount of eroded and sedimented material not only in the watersheds of the Korthpula area in Pukë but also in other watersheds of the Drin River, it is necessary to intervene with various contemporary works and innovative as biological, biotechnical and engineering works.
- For the design of studies and application projects, modern methods and methodologies should be used, which should be based on green solutions and as naturalistic as possible.
- After the on-site completion of the works proposed for the following years by us and the relevant authorities, the process of monitoring the filling with solid materials in the works built along all the ravines of this area should be carried out.
- Estimating the amount of material eroded and deposited in these works would help us in providing an accurate overview of the amount of material eroded for the area taken in the study. These data will serve for the improvement and design of other feasible projects in the watersheds of this basin.

REFERENCES

[1] Alexander P. Austrian Forest service in torrent and avalanche control. 1994.

[2] ASIG, Various cartographic materials.

[3] Puke Municipality. Forest Economy management plan, Gomsiqë, Puka District.

[4] Bezzi, A. Pasture management. Technical assistance for the Forestry Project. FAO, Tirana 1999.

[5] Hydrometeorological Institute, Metrological Bulletin, Tirana, 1990.

[6] Construction Manual, VKM No. 629 dated 15.07.2015.

[7] Marco. O. Assessment of the risk of soil erosion in mountain watersheds "Scientific Monograph, Tirana -2010.

[8] Marco. O. Systemization of Watersheds, Cycle of lectures and practices, Faculty of Civil Engineering, 2023.

Application of the Erosion Potential Method in Lumbardhi i Deçanit Watershed

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Soil erosion is a gradual process that occurs when the impact of water or wind detaches and removes soil particles, leading to the deterioration of the soil. Understanding future conditions related to soil erosion is essential for sustainable management of water resources, especially watersheds in general. Calculating the amount of eroded and deposited soil in the watershed of the Lumbardhi i Deçanit using the Soil Erosion Potential Method (SEP) is considered cost-effective, as it allows us to establish direct connections between land use, current watershed management practices, and their impacts on water flows and soil erosion. The main objective of this study has been to assess the potential amount of eroded and deposited material in the watershed of Lumbardhi i Deçanit. About 53% of the watershed area is under erosion. The Lumbardhi i Deçanit watershed consists of 8 sub-watersheds. Using the Soil Erosion Potential Method (SEP), the calculation of the amount of eroded and deposited material has been carried out for these 8 sub-watersheds. The results of the calculations have determined the vegetation cover coefficient, soil resistance coefficient to erosion, and the type and degree of erosion in each sub-watershed. The point of this work is to draw conclusions about the necessary interventions with various biological and engineering works to enable the control and minimization of the amount of eroded and sedimented material in the sub-watersheds of the Lumbardhi i Deçanit Watershed.

Keywords: *Erosion potential method, Lumbardhi I Deçanit, watershed, soil erosion.*

1. INTRODUCTION

Knowing the amount of soil eroded and deposited in the Decan Lumbardh watershed, using modern methodologies, is considered cost-effective as it will allow us to establish direct links between land use, current watershed management practices and impacts in water runoff and soil erosion.
As the impact of the erosion of solid materials in a watershed is known, it is evident even in areas that are not directly exposed to erosion, but they suffer its consequences in the form of sediment deposition in water courses and reservoirs, resulting in in the reduction of water quality and the degree of loading of water flow with solid materials.
All these elements have a negative impact on the water regime. Moreover, the control of sedimentation in reservoirs requires a good knowledge of all possible significant sources of sediment production and their deposits. Recent studies show that deep soil erosion is often the main source of sedimentation.

2. MATERIALS AND METHODS

2.1. Scope of the study

Lumbardhi i Deçani flows in the western part of Kosovo, it is the right branch of Drin i Bardhë, with a length of about 53 km. It joins the Drini e Bardhë near the village of Kralan, Municipality of Gjakova.

Watershed of Lumbardhi i Deçanit has an area of about 268.3 km^2, it is located between the coordinates 42°39'34" and 42°30'50"N of the northern latitude and between the coordinates 20°4'21" and 20°32' 51"E of eastern longitude. It lies almost entirely in the administrative territory of the Municipality of Deçan, only in the lower part of its course it passes into the territory of the municipalities of Gjakova and Peja.

Watershed of Lumbardhi i Deçanit has a very high hypsometric dislevel of about 2180 m, most of the basin is a mountainous area, only during the middle course and the lower course in the eastern part it passes into the plain area, in which part the majority are elevated of settlements.

Table 1. Forms of land use in the watershed

From which:

Total surface		Forests		Green surfaces		Bare Lands		Built-up Areas		Water surfaces		Rocky area	
(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
26830	100	14260	53,2	3625	13,5	4373	16,3	1267	4,7	100	0,004	3320	12,4

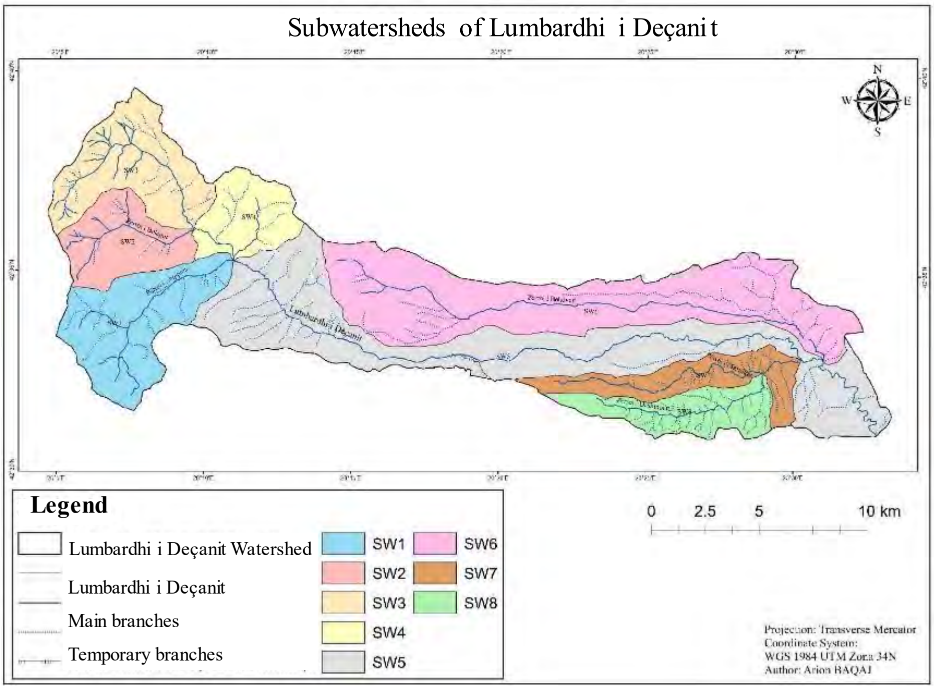


Figure 1. Subwatersheds of Lumbardhi i Deçanit

2.2.Study methodology.

Taking into account the climate-terrestrial, biological conditions and the parameters that characterize the watersheds of Lumbardh i Deçan, as well as referring to the contemporary literature, to estimate the amount of eroded material in these watersheds, we propose to use the Method of Erosion Potential (MEP). Since this methodology is complex and quite accurate in estimating the rate and intensity of solid material eroded and deposited in watersheds. In this method, we used topographic and hydrographic information to identify the areas that are most affected by erosion and to assess the risk of erosion in the areas around Lumbardhi. The use of this method (MEP) for stationary conditions, which represent the places in the Deçan area and its surroundings, creates the possibility of evaluating the side effects of soil erosion processes which can only be captured by leveling the watershed. In addition, the Potential Erosion Method (MEP) also recognizes the types of surface erosion on the slopes of watersheds, considering the fact that it uses parameters such as soil moisture, soil type, terrain changes, vegetation mix and agricultural practices. The annual erosion levels obtained by the MEP (Potential Erosion Method) are expressed in [m3/ha years], while the erosion levels obtained through other methodologies are expressed in [t/ha years], understanding that the data obtained from this method are much more accurate. This method analyzes and takes into account a number of elements that are related to each other through the following variables.

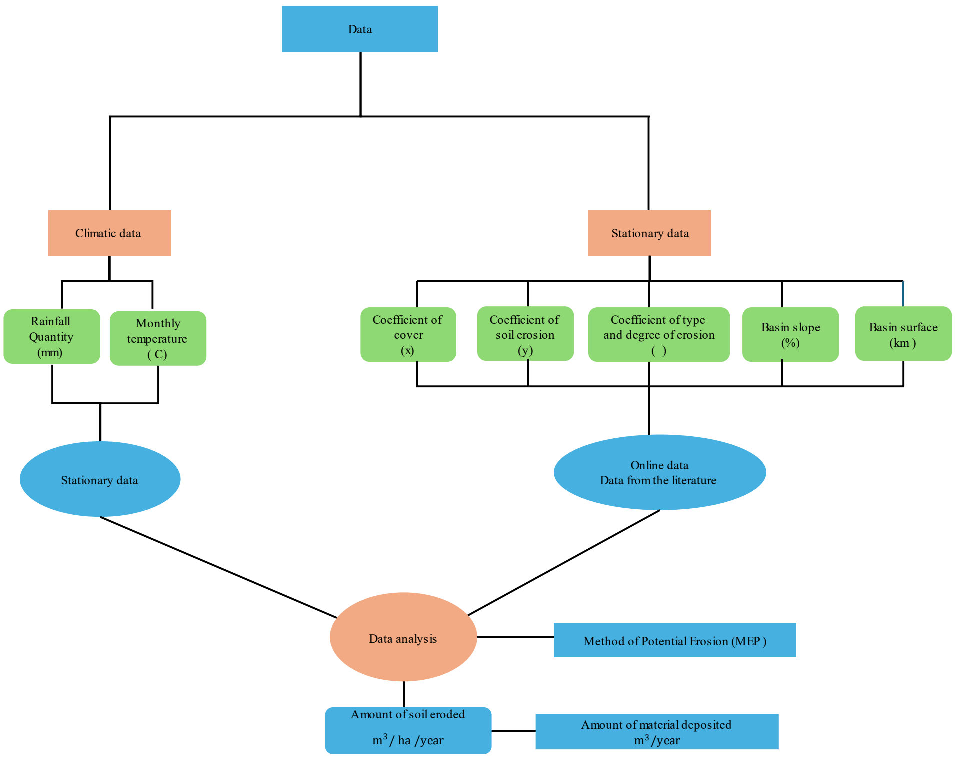


Figure 2. Diagram used to calculate eroded and deposited material.

The presented scheme describes the approach that will be used during the study. The main variables are:

– Climatic data that are described as primary data are collected and processed for the period of 2020, from the meteorological station of Pejë and Gjakovë as the nearest stations. The detailed data will be the average monthly precipitation (h) and the average monthly temperature (t) which will serve us to calculate the temperature coefficient (T).
– Terrestrial data, as secondary data, will be collected from relevant maps (GIS) as well as from field data, namely:
– To estimate the land cover coefficient (x).
– Soil erodibility coefficient (y).
– Coefficients of type and rate of erosion (φ) will be estimated from field observations and from digital topographic maps.

- The average slope of each sub-catchment (i_m) will be estimated by the Digital Assessment Model (DAM).
- The surface of the Lumbardh i Deçanit (Sp) catchment basin will be determined by Topographic Maps.

The data collected from the above sources will be analyzed through a software of built by us, according to the Potential Erosion Method (MEP). Data connection of above will be analyzed using the following equations:

$$W = \eta \cdot S \cdot T \cdot h \cdot \sqrt{Z^3}$$

Where: W – the amount of material eroded in the watershed/sub-basin (m^3/year);
S – the area of the watershed/sub-basin (km^2);
T – temperature coefficient;
h – the height of the average multi-year rainfall measured in the catchment basin (mm/year);
Z – the relative erosion coefficient calculated for the watershed.

The temperature coefficient T is calculated from the following equation:

$$T = \sqrt{t/_{10} + 0.1}$$

Where: t – Multiannual average temperature measured in the watershed (°C).

The relative erosion coefficient Z is found from the following equation:

$$Z = x \cdot y \cdot (\varphi + \sqrt{i_m})$$

Where: x – Coefficient which determines the protective nature of soil vegetation;
y - Coefficient which expresses the resistance of the soil type to the phenomenon of erosion;
φ – Coefficient which expresses the presence and rate of erosion in the watershed;

The values of the aforementioned coefficients (x, y and ϕ) are given in the table below.

Nr.	**Coefficient of land cover**	**x**
1	Mixed and dense forest	0.05 – 0.20
2	Thin forest with grove	0.05 – 0.20
3	Coniferous forest with little grove, scarce bushes, bushy prairie	0.20 – 0.40
4	Damaged forest and bushes, pasture	0.40 – 0.60
5	Damaged pasture and cultivated land	0.60 – 0.80
6	Areas without vegetal cover	0.80 – 1.00

Nr.	**Coefficient of soil erodibility**	**Y**
1	Hard rock, erosion resistan	0.2 – 0.6
2	Rock with moderate erosion resistance	0.6 – 1.0
3	Weak rock, schistose, stabilized	1.0 – 1.3
4	Sediments, moraines, clay and other rock with little resistance	1.3 – 1.8
5	Fine sediments and soils without erosion resistance	1.8 – 2.0

Nr.	**Coefficient of type and extent of erosion**	**Φ**
1	Pond without the presence of erosion, coated surface	0.1
2	Pond with few signs of erosion	0.2

3	20-50% of the watershed has signs of surface erosion	0.3 – 0.5
4	50% of the catchment area has deep erosion	0.6 – 0.7
5	80% of the surface of the watershed has deep erosion	0.8 – 0.9
6	The watershed has quite strong erosion	1.0

The total volume of sediment produced in the watershed does not fully reach downstream or in the parts where reservoirs or hydrotechnical works have been built placed transversely with the flow of water.
A good part of the sediments are deposited in the flow beds in different areas watershed, therefore, it is essential to calculate the real amount of sediment (G) in m^3/year. This is accomplished through the use of the following equation:

$$G=WxDr$$

Where: W - the amount of eroded material in the watershed (m^3/year)
Dr – Sediment distribution coefficient

The calculation of the sediment distribution coefficient Dr is done by means of the equation below:

$$Dr = \frac{\sqrt{HxP}}{0.25 \cdot (L+10)}$$

Where: H – Average height of the watershed (km);
P – Perimeter of the watershed (km);
L – Length of the watershed (km).

Based on contemporary literature and our experience, the potential risk classes of erosion, depending on the value of eroded material per hectare per year, will be divided as follows:

Nr.	*Loss of land (m^3/ha/month)*	*Risk of erosion*	*Categories of soil erosion*
1.	<2.45	Very low	I
2.	2.45 – 5.00	Low	II
3.	5.0 – 10.00	Mediun	III
4.	10.0 – 20.00	High	IV
5.	>20.00	Very high	V

3. RESULTS AND DISCUSSION

The amount of eroded and deposited material for the Lumbardhi Deçani watershed is based on the application of the Potential Erosion Method (MEP). The data obtained from the application of this method are given in the tables and graphs below.

Table 3. Collected data on the situation of sub-watersheds.

		SWB_1	**SWB_2**	**SWB_3**	**SWB_4**	**SWB_5**	**SWB_6**	**SWB_7**	**SWB_8**
The surface of the watershed (km^2)	S	29	18	27	15	77	68	17	16
Plant cover coefficient	x	0.4	0.3	0.5	0.2	0.7	0.6	0.9	0.7

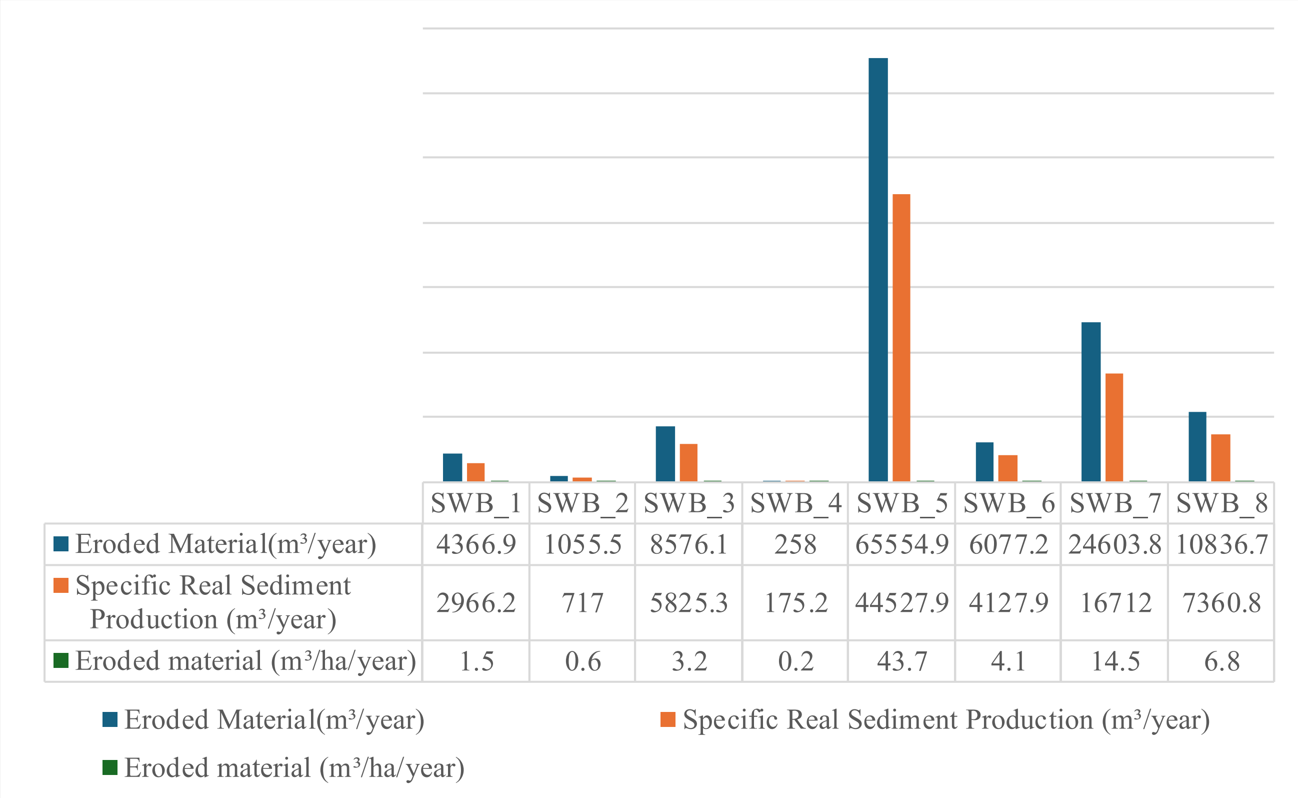
Coefficient of soil resistance to erosion	y	0.8	0.6	1.0	0.4	1.4	1.2	1.6	1.4
Type and rate of erosion in the sub-watershed		0.5	0.4	0.6	0.3	0.7	0.6	0.8	0.7
Average slope below the watershed	i	0.168	0.214	0.128	0.31	0.059	0.077	0.013	0.012
The average height of the bottom of the watershed (km)	H	1.783	1.883	1.86	1.70	1.38	1.40	0.513	0.51
The perimeter of the sub-watershed (km)	P	26.4	18.9	26.8	16.5	83.8	61.2	33.5	26
The length of the sub-watershed(km)	L	9	6.3	10.4	4.4	33.1	24.9	12.3	11

Table 4. Potential amount of material eroded and deposited in sub-watersheds

Months			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rain	(mm)	h	8.45	10	20.4	19.75	32.2	14.4	11.05	22.8	35.05	47.4	0.6	46.65
Temperature	(°C)	t	0.45	5.5	7.55	11.2	15.5	18.55	22.8	22.4	19.9	12.85	6.75	3.95
Temperature coefficient	(--)	T	0.38	0.81	0.92	1.10	1.29	1.40	1.54	1.53	1.45	1.18	0.88	0.70

Sub-watersheds	Relative erosion coefficient	Eroded material		Sedimentation distribution coefficient	Amount deposited
	(-)	(m^3/year)	(m^3/ha/year)	(-)	(m^3/ha * year)
	Z	W	E	Dr	G
SWB_1	0.29	4366.9	1.5	0.68	3.09
SWB_2	0.16	1055.5	0.6		
SWB_3	0.48	8576.1	3.2		
SWB_4	0.07	258.0	0.2		
SWB_5	0.92	65554.9	43.7		
SWB_6	0.21	6077.2	4.1		

SWB_7	1.32	24603.8	14.5		
SWB_8	0.79	10836.7	6.8		
Total		121329.1	4.52		



	SWB_1	SWB_2	SWB_3	SWB_4	SWB_5	SWB_6	SWB_7	SWB_8
Eroded Material(m^3/year)	4366.9	1055.5	8576.1	258	65554.9	6077.2	24603.8	10836.7
Specific Real Sediment Production (m^3/year)	2966.2	717	5825.3	175.2	44527.9	4127.9	16712	7360.8
Eroded material (m^3/ha/year)	1.5	0.6	3.2	0.2	43.7	4.1	14.5	6.8

Figure 3. Potential amount of eroded material

As can be seen from the data in the table and graph above, it turns out that the potential amount of eroded material for sub – watersheds is 121329.1(m^3/year) and the period where the phenomenon of erosion is greater is the autumn period, since the amount of rainfall is greater in these months.

Referring to the above data, it results that the potential amount of eroded material per unit of surface area (ha), for the water catchment basins of Lumbardhi i Deçanit, is 4.52 (m^3/ha/year). This value shows that the phenomenon of erosion in this basin is at low value.

Based on the calculations made, it results that the potential amount of material transported and deposited in the final part of the Lumbardhi i Deçanit catchment ponds is 3.09 (m^3/ha·year).

As it appears, the value of the potential amount of material transported and deposited in the bottom part of this watershed is less than the potential amount of eroded material, since a significant part of the eroded material is deposited along other water formations of which characterize the hydrographic network.

4. CONCLUSION

Through the application of the Potential Erosion Method (MEP), for the Watershed of Lumbardhi i Deçanit, it results that soil erosion in this watershed is high, corresponding to an average value of 4.52 m^3/ha/year.

For the design of strategies and various application projects related to the sustainable management of water resources in a watershed, the trend of the phenomenon of erosion and sedimentation must be recognized,
In order to make it possible to curb and minimize the amount of eroded and sedimented material in the Watershed of Lumbardhi i Deçanit, it is necessary to intervene with various biological and engineering works.

REFERENCES

[1] Arion Baqaj. (2020). Prioritizimi i pellgut lumor të Lumbardhit të Deçanit në bazë të veçorive hidromorfologjike

[2] Gavrilovic Z. The use of empirical method (erosion potential method) for calculating sediment production and transportation in unstudied or torrential streams (Editor White WW.R. In: International Conference on River Regime) John Wiley & Sons, (1988). 411–422 Chichester, UK.

[3] IHMK. (2020). VjetariHidrometeorologjik.https://ihmkrks.net/uplds/docs/Vjetari_final_2020-al.pdf

[4] Oltion Marko. (2022). Application of the Erosion Potential Method in Vithkuqi Watersheds (Southeastern Albania). Journal of Ecological Engineering. http://www.jeeng.net/pdf-146131-72852?filename=Application%20of%20the.pdf

[5] Oltion Marko. (2022). Vlerësimi i sasisë potenciale të materialit të gërryer dhe të depozituar në pellgun ujëmbledhës të rezervuarit të Gërdecit- Rrethi i Tiranës. ATPMQ. https://atpmq.fin.edu.al/wp-content/uploads/2022/12/Libri-i Punimeve_Konf_ATPMQ_Nentor-2022_ISBN.pdf

Exploring The Design and Effectiveness of Nature-Inspired Wave Breakers for Coastal Protection

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This paper delves into the innovative realm of nature-inspired wave breakers as a sustainable solution for coastal protection. Through a comprehensive literature review, we investigate the efficacy of traditional engineering solutions alongside the burgeoning field of nature-inspired design. Our exploration encompasses a multidisciplinary approach, scrutinizing hydrodynamic principles and engineering mimicry to understand the underlying mechanisms behind natural coastal features such as coral reefs and sand dunes. Utilizing hydrodynamic modeling, we evaluate the wave reduction capabilities and efficiency of engineered structures, while also conducting environmental impact assessments to gauge their ecological implications. Furthermore, our research integrates these nature-inspired wave breakers with traditional coastal engineering methods, assessing their compatibility and potential synergies. Through sustainability and resilience analyses, we investigate the long-term viability of these solutions amidst changing climatic conditions and sea level rise. Real-world case studies provide invaluable insights into successful implementations, highlighting adaptability and offering practical recommendations for future endeavors. Moreover, our study includes a comprehensive cost-benefit analysis, considering economic implications and environmental restoration benefits. Finally, we delve into the social aspects of community engagement, assessing perceptions, acceptance, and potential conflicts surrounding the implementation of nature-inspired solutions. Our findings affirm that nature-inspired wave breakers offer an effective and sustainable means of dissipating wave energy, complementing traditional methods while minimizing ecological impact. With positive community acceptance and a favorable cost-benefit ratio, these solutions present a promising avenue for coastal protection, underscored by real-world success stories and providing a blueprint for future research and implementation efforts.

Keywords: *Wave Breakers, Nature-Inspired Coastal Protection, Hydrodynamic Modelling, Integration Strategies, Community Acceptance, Cost-Benefit Analysis.*

1. INTRODUCTION

Coastal protection is of primary importance due to the increasing threats posed by climate change, rising sea levels, erosion and intensifying storms. To combat these challenges, traditional engineering solutions such as seawalls and wave breakers have been widely employed for coastal protection. While these structures provide immediate relief, they often come with significant drawbacks, including high construction and maintenance costs and disruption of natural ecosystems.
The study will be structured around several key points, each crucial for a comprehensive examination of nature-inspired coastal protection methods, but also innovative coastal protection methods. This project aims:

- Coastal Protection Methods
  Exploring existing research on coastal protection methods, examining their effectiveness, environmental impact, and innovation
- Understanding Nature's Defense: Exploring how natural coastal features like mangroves and coral reefs naturally protect coastlines from wave erosion.

- Engineering Mimicry: Investigating how engineering structures can replicate the protective qualities of natural coastal features to reduce wave energy.
- Considering Environmental Impact: Assess the environmental impact of these engineered wave breakers to ensure they don't harm coastal ecosystems.

By addressing these key points, this research aims to contribute to the development of innovative and sustainable approaches to coastal protection, ensuring the resilience of coastal communities in the face of climate change and environmental challenges.

2. NATURAL HABITATS FOR COASTAL DEFENCE

2.1. The role of Coastal Ecosystems in mitigating hazards

Half of the world's population lives within 60 km of the ocean, and three quarters of all large cities are coastal (UNEP, 2005). Coastal areas, face increasing hazards like erosion and flooding due to climate change, which brings higher sea levels and stronger storms. While we often use things like seawalls to protect these areas, they cost a lot to maintain. Natural things like reefs and dunes can also help protect coasts and have other benefits, but we're not using them as much because we're not sure how well they work compared to hard structures. This review looks at whether restoring or creating habitats along coasts can effectively protect them from these dangers. This is important for deciding how to manage coasts as climate change continues. These natural solutions have big potential but haven't gotten as much attention as their benefits for wildlife.

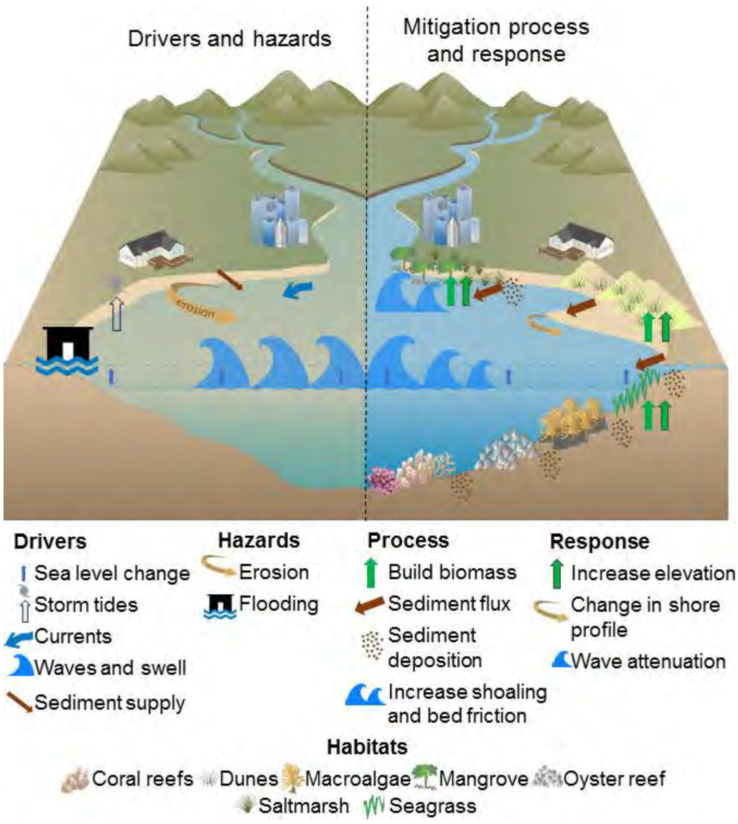


Figure 1. Coastal hazards and protection services provided by natural habitats.

2.2.Effectiveness and Challenges of Coastal Habitat Restoration

Coastal ecosystems, including sand dunes, beaches, salt marshes, seagrass and kelp beds, and coral and shellfish reefs, play a crucial role in mitigating coastal hazards (Fig.1). Research indicates that these natural habitats can provide effective alternatives to hard coastal defense structures, offering resilience and risk reduction against storms, hurricanes, tsunamis, and sea-level rise.

These habitats offer protection through various ecosystem processes, such as increased bed friction, sediment deposition, wave attenuation, and shoreline stabilization. For example, vegetated coastal habitats like seagrasses, saltmarshes, and mangroves can reduce water flow and wave height, while reef systems and subtidal habitats promote wave breaking and local water shallowing. Additionally, coastal vegetation and shellfish reefs help stabilize shorelines by promoting sediment deposition and reducing erosion.

Studies have shown significant wave height reductions ranging from 31% to 72% for different coastal habitats, comparable to low-crested detached breakwaters. Saltmarshes, in particular, have been found to positively affect shoreline stabilization, with the degree of attenuation depending on vegetation characteristics and environmental settings.

Sand dunes also provide protection against extreme events, although their effectiveness depends on their shape and height relative to storm surges or tsunamis. While there are few direct comparisons between dunes and hard structures, dunes have been shown to reduce wave strength and decrease structural damage during low-energy tsunamis.

However, the value of natural shellfish reefs for coastal defense remains underexplored due to widespread destruction. Recent simulations suggest increased wave energy due to historical oyster bed loss, highlighting the importance of preserving these habitats. Additionally, the percentage cover of ribbed mussels has been found to decrease saltmarsh shoreline erosion synergistically.

Despite their effectiveness, coastal habitats are dynamic ecosystems, introducing uncertainty in their long-term resilience. Seasonal variations in aboveground biomass and site-specific factors such as tidal inundation and foreshore width can impact their protective capacity. Furthermore, habitat destruction due to anthropogenic impacts, including contamination, resource extraction, and invasive species introduction, threatens their persistence.

Global losses of coastal habitats, such as oyster reefs, coral reefs, and wetlands, emphasize the need for habitat restoration and creation for coastal defense. Restoration efforts have gained traction, especially in densely populated areas where habitat destruction is most severe, coinciding with high human vulnerability to erosion and flooding.

In conclusion, natural coastal habitats offer significant potential for coastal defense, providing effective protection against hazards while offering ecological benefits. However, their dynamic nature and susceptibility to anthropogenic impacts highlight the importance of conservation and restoration efforts to ensure their long-term resilience and effectiveness in mitigating coastal risks.

3. ADVANCMENTS IN COASTAL ENGINEERING: INTEGRATING WAVE-ENERGY CONVERTERS WITH TRADITIONAL BREAKWATERS

3.1. Traditional Harbor Breakwater

Breakwaters have been around for thousands of years, with two main types: rubble mound and vertical. Ancient civilizations like the Egyptians and Romans started building them. Rubble mound breakwaters, like those used by the Greeks, break and reflect waves to protect harbors.
The function of a rubble mound breakwater, in the past and today, is mainly the energy dissipation of the incident waves by wave breaking, partly reflected back to the sea and partly transmitted into the harbor due to penetration and overtopping (Fig. 2). Various kinds of rubble mounts breakwaters are presented in Fig. 3.

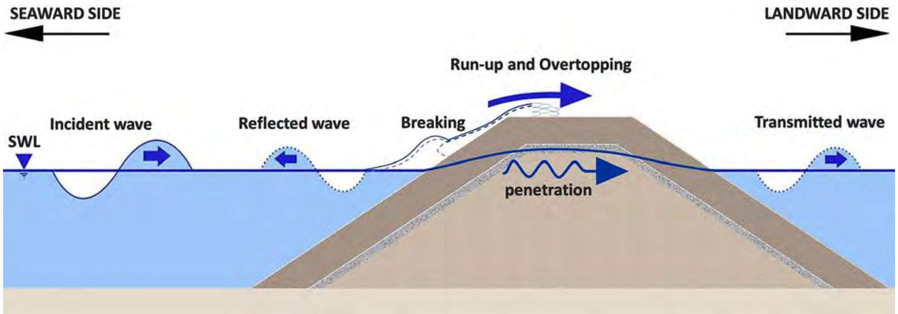


Figure 2. Hydraulic performance of rubble mound breakwaters

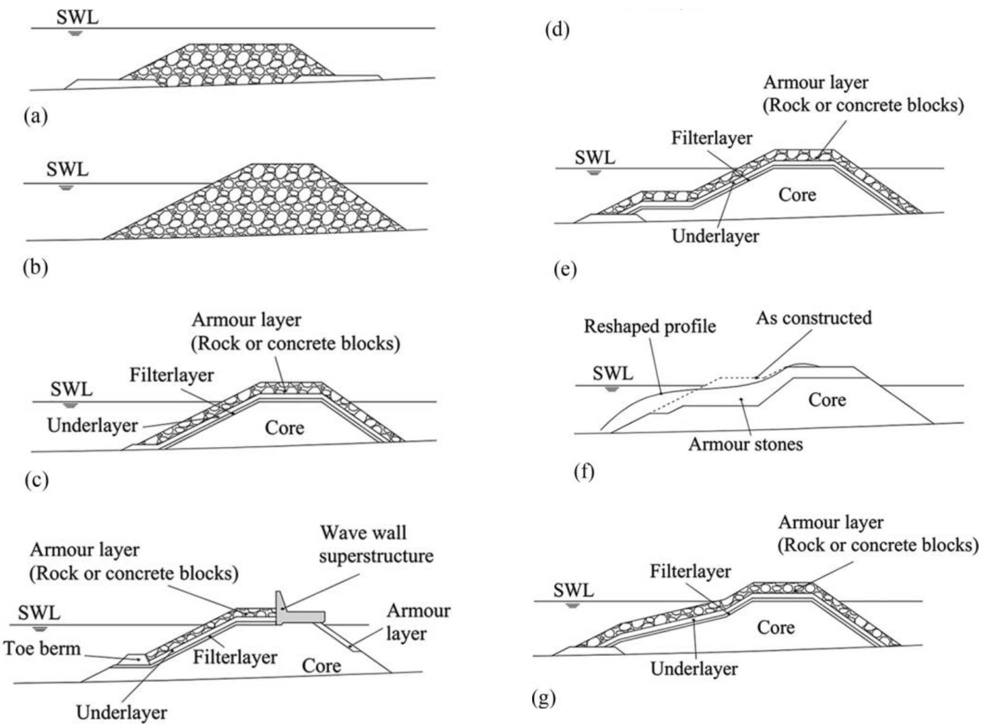


Figure 3. Types of rubble mound breakwaters: (a) reef breakwater; (b) rubble mound breakwater (RMB); (c) multilayer RMB; (d) multilayer RMB with superstructure; (e) multilayer RMB with bermed front (f) reshaping RMB (berm breakwater); and (g) multilayer RMB with S-shaped front.

The size of the rocks used affects their stability. The Romans invented vertical breakwaters, which are solid underwater walls made with special cement. The function of a vertical breakwater, in the past as today, is to reflect the energy of the incident waves back to the sea.

Wave energy is also dissipated due to wave breaking and transmitted into the harbor area due to overtopping (Fig. 4).

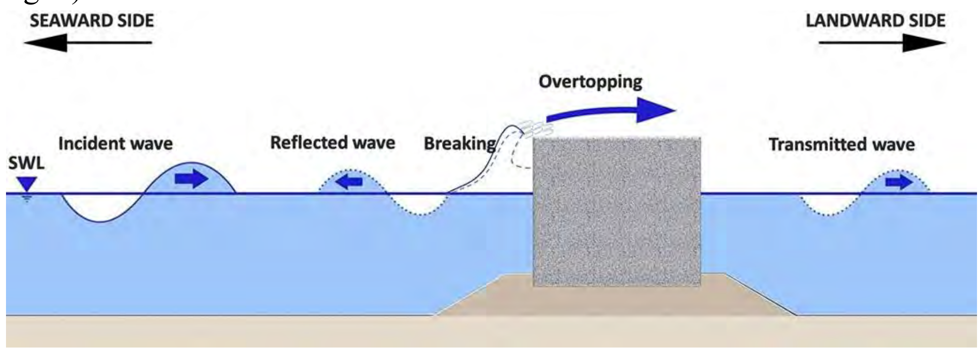
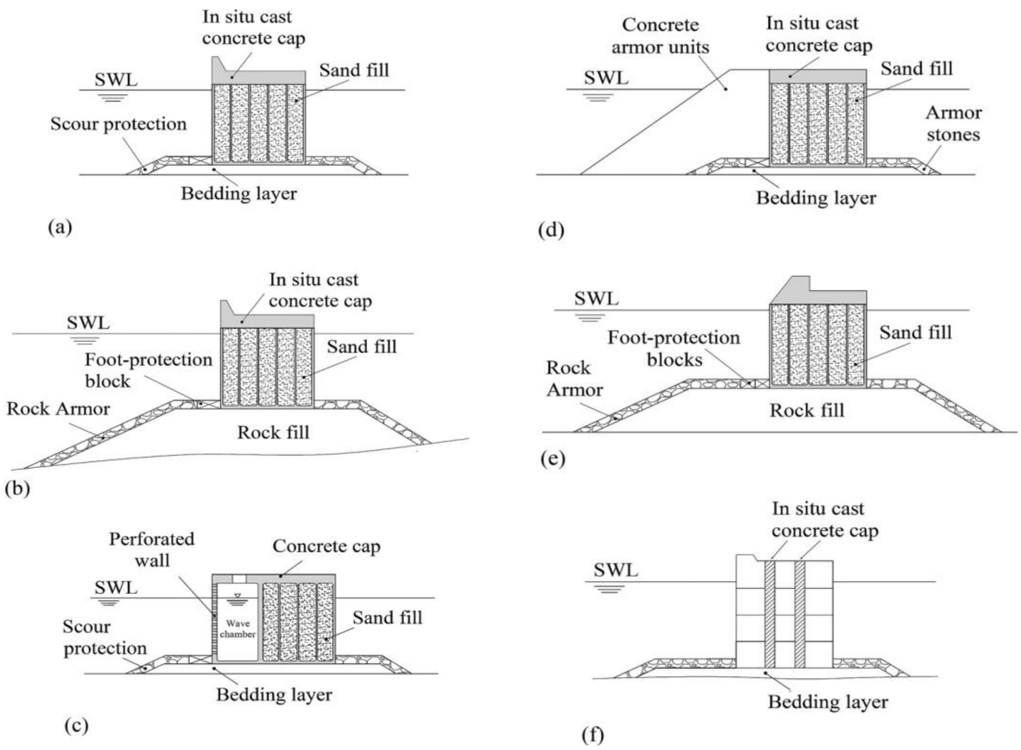


Figure 4. Hydraulic performance of vertical breakwaters

These lasted a really long time. Nowadays, we often use pre-made concrete blocks for vertical breakwaters, which are good at bouncing waves back. However, they can still get seriously damaged in big storms, costing a lot to fix. A study found that wave breaking is often the main reason for these damages, even in unexpected situations. So, while vertical breakwaters are useful, we need to be careful in how we design and maintain them to make sure they stay strong against nature's power. Various kinds of vertical breakwaters are presented in Fig. 5.

Figure 5. Types of vertical breakwaters: (a) vertical breakwater; (b) vertical composite breakwater; (c) perforated wall caisson breakwater; (d) horizontal composite breakwater; (e) sloping-top caisson breakwater; and (f) block work breakwater.



3.2. Innovative Breakwater-Integrated WECs (wave-energy converters)

After the oil crisis in 1973, the international community recognized the importance of investing in diverse, reliable, and affordable energy sources, which are alternative to the traditional ones, such as oil and gas. Among the renewable energy resources, the oceans represent a safe, inexhaustible, and largely untapped source that may significantly contribute to the electrical energy supply of vast regions with coasts facing the ocean. In the last decades, several engineers and researchers began massive research concerning wave-energy conversion systems.

Currently, more than 1,000 WECs have been designed and developed Worldwide. The idea to integrate WECs into traditional coastal structures is not recent, and lately, it is boosting innovation in the field, moving toward the highest level of research and development. The reasons lie in two main causes:

1. Many scientists involved in the renewable energy from the sea were and are coastal engineers. This inevitably led to bringing solutions and some creativity from the offshore WEC technologies to the maritime construction sector.

2. The main task and challenge for the scientific community operating in this sector are to reduce the construction, installation, and maintenance costs for these novel hybrid systems, ensuring high levels of operational efficiency, fatigue resistance, and structural integrity during both mild conditions and storm events.

Therefore, the concept of hybrid devices that can be integrated into existing or expanding coastal infrastructures was proposed to significantly decrease WEC costs. These innovative structures still have their principal function of sheltering a location from the action of waves (i.e., coastal and harbour protection) but with important benefits of the energy production due to the inclusion of the WEC. The integration of the WEC into a new breakwater has several advantages, such as low construction costs, considering that the breakwater would be built regardless of the inclusion of the WEC device (cost sharing). Furthermore, access for construction, installation, and maintenance is much easier compared to other stand-alone devices located offshore. In contrast, the energy extracted with these new technologies is minor compared to the devices located in the deep sea. Moreover, not all breakwaters are appropriate and feasible for integration, depending on their type, geographical location, and orientation with respect to the incident waves. The most relevant challenge for coastal engineers involved in this field is to design these nonconventional structures, ensuring hydraulic performances and stability similar to that provided by traditional breakwaters. The aim is to develop innovative structures, which are economically competitive, with the same or improved hydraulic performance and with the benefit of energy production.

It is worth noting that some wave activated body WECs (such as shaped floaters) mounted on existing breakwaters also exist. However, the breakwater serves as a support structure for the floating gate array, and no real WEC breakwater integration can be detected. In fact, during storm conditions, the floaters rise over the water level to protect the system from mechanical damage.

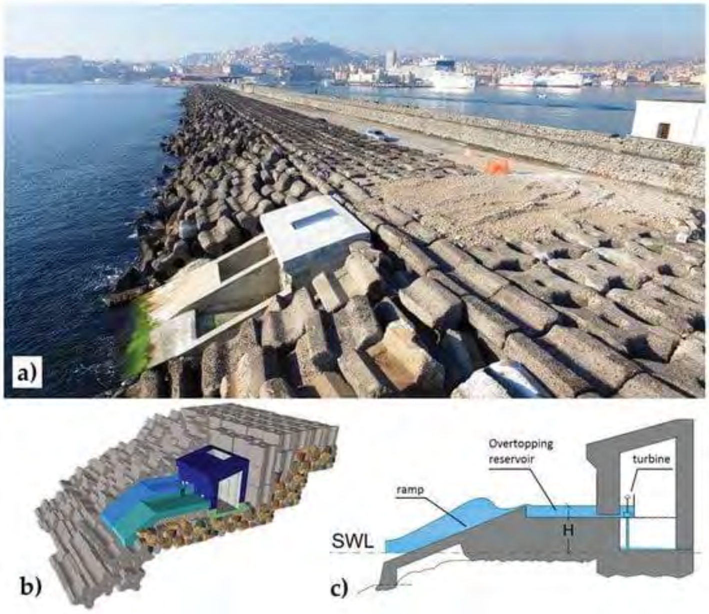
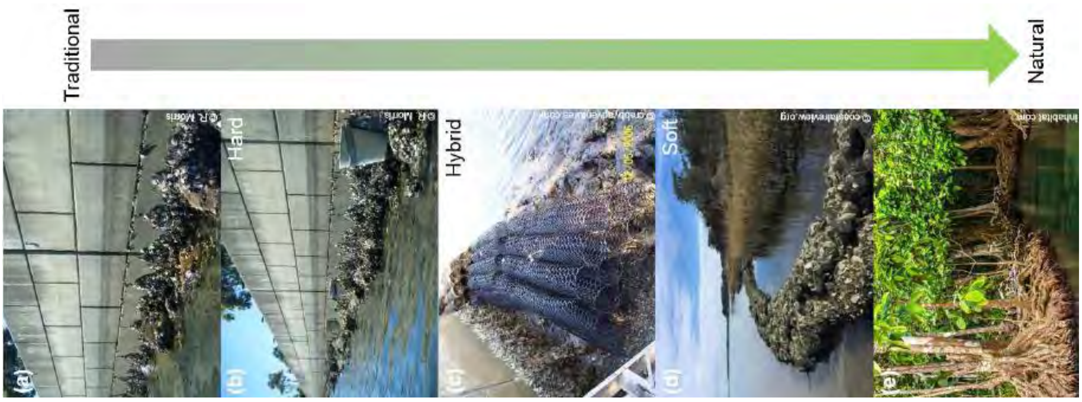


Figure 6. OBREC prototype at Naples Harbor: (a) prototype photo; (b) prototype structural components; (c) working principle (where SWL indicates the still water level).

3.3.Incorporating ecological engineering into coastal defence planning

Economic costs for coastal adaptation to climate change using hard infrastructure is substantial. Additional costs of US $ 4-11 billion per year are estimated for the coastal engineering protection measures required with projected climate change over the next 50 years. Equally, it has been well documented that building infrastructure in intertidal and subtidal systems have a number of negative ecological impacts. For example, artificial coastal defence structures often support less diverse communities than natural habitats, with greater numbers of non-native species. This change in assemblage composition is likely to affect ecosystem functioning in artificial systems, and consequently the services important to humans (e.g., food provision), although this remains an understudied topic. To mitigate impacts of built infrastructure in the environment, there is an increasing interest in ecological engineering, which is combining ecological processes with engineering principles to develop infrastructure that benefits both humans and nature. Coastal eco-engineering research to date has ranged from 'hard', to 'hybrid' to 'soft' solutions.

Figure 7. b) eco-engineered habitats can be retrofitted onto existing infrastructures. c) a shellfish



reef placed in front of a seawall. d) promotion of nature to enhance climate change mitigation and adaptation, explicitly as an alternative to (or to complement) built infrastructure

4. CONCLUSION

Natural Coastal Habitats for Defense: Coastal ecosystems such as sand dunes, saltmarshes, seagrass beds, and coral reefs offer significant potential for mitigating coastal hazards like erosion and flooding. They provide effective protection through processes such as wave attenuation, sediment deposition, and shoreline stabilization. Despite their effectiveness, challenges such as habitat destruction and dynamic nature necessitate conservation and restoration efforts to ensure long-term resilience.
Advancements in Coastal Engineering: Integrating wave-energy converters (WECs) with traditional breakwaters presents an innovative approach to coastal defense while harnessing renewable energy. This integration not only enhances energy production but also offers cost-sharing benefits with existing coastal infrastructure. Challenges include designing structures that maintain hydraulic performance and stability comparable to traditional breakwaters while incorporating WEC technology.
Incorporating Ecological Engineering: There is a growing recognition of the negative ecological impacts of traditional hard infrastructure in coastal defense. Ecological engineering, which combines ecological processes with engineering principles, offers a promising approach to develop infrastructure that benefits both humans and nature. From 'hard' to 'hybrid' to 'soft' solutions, there is a spectrum of approaches that can be explored to mitigate environmental impacts while enhancing coastal resilience.

In conclusion, a multi-faceted approach that integrates natural coastal habitats, innovative engineering solutions, and ecological principles is essential for effective and sustainable coastal defense strategies in the face of climate change and rising sea levels. This approach not only provides protection against coastal hazards but also promotes biodiversity conservation and renewable energy production, contributing to resilient coastal communities and ecosystems.

REFERENCES

[1] DR. REBECCA L MORRIS (2018) From Grey to Green: Efficacy of Eco-Engıneerıng Solutıons for Nature-Based Coastal Defence
[2] Diego Vicinanza. (2019) Review of Innovative Harbor Breakwaters for Wave-Energy Conversion *Article in Journal of Waterway, Port, Coastal and Ocean Engineering*
[3] S. J. Hawkins, A. L. Allcock (2019) Oceanography and Marine Biology.*An Annual Review*

Hydrology, Flooding and Resource Management

Sustainable Water Resource Management in Albania

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Water resources are considerable in Albania. Elements of natural water resources systems include the atmosphere, watersheds (drainage basins), stream channels, wetlands, floodplains, aquifers, lakes, estuaries, seas, and the ocean. Water resources management involves the monitoring and management of water quality as much as the monitoring and management of water quantity. The most fundamental human needs of water are for drinking, cooking and personal hygiene. In order to fulfill these needs, the quality of the water used should cause no risk to human health. The quality of the water in nature also affects the condition of ecosystems all living organisms depend on. Various models have been developed to assist in predicting the water quality impacts of alternative land and water management policies and practices. This research provides a pricing framework for decision-makers that will help in the development of strategies for water quality management. However, trading schemes can be complex to set up with factors such as the number of facilities involved in the scheme and the variety of the pollutants discharged influencing the complexity. Success depends upon achieving a balance between the environmental benefits of improving water quality and administration costs. In Europe the drive to improve water quality under the EU Water Framework Directive (WFD) encourages European citizens to get involved in improving water quality. Following recommendations from the IPCC3, the WFD aims to prevent and control emissions into water. Implementation of trading schemes could contribute to these goals.

Keywords: *Mathematical models, Tirana-Ishmi, basin, TDML, environmental protection, GIS.*

1. INTRODUCTION

Albania is a country whose surface water and ground water resources far exceed their usage. Most of economic activities relay on utilization of water resources, where over 90% of energy production comes from Hydropower Plants (HPPs), and agriculture fully depends on irrigation. Also, other sectors of economy like mining, industrial sector and tourism are also relied on clean and sufficient freshwater resources.

During the last decade, monitoring activities of water resources have been carried along the basin's catchment in the whole territory of the country: in Drini, Mati, Ishem-Erzen, Shkumbini, Seman, Vjosa River basins, and in the coastal Ionian area. Several monitoring stations are established along the coastline in main beaches area of the country, as Velipoja, Shengjini, Durrës, Kavajë, Vlora, Dhërmi, Himare, Borsh, and Saranda.

The country counts a number of 250 natural lakes of different types and categories, where techtonic ones are Lake of Shkodra, Ohrid, Prespa and Butrint etc, the karstic ones (around 82) are located at the Dumre area; and, glacial ones (around 56) are located in the Alps mountains, Lura lakes, and in the areas of Balgjaj, Martanesh, Shebenik, Valmar etc.

Almost 650 artificial reservoirs and lakes are spread inthe whole territory, where some of them were built for the construction of HPP (Fierze, Koman and Vau i Dejes lakes along the Drini cascade, and Ulza and Shkopet lakes along the Mati River). Space in the Adriatic and the Ionian coast has a total length of about 350 km and a coastline of 475 km. Along this space there are allocated main rivers delta estuaries (Drini, Mati, Ishêm, Shkumbini, Erzeni, Shkumbini, Seman, Vjosa rivers), lagoon system with a general surface of 1500km2 (Viluni, Patoku, Karavastase, Narta and Pashaliman lagoons), sandy and rocky beaches, wetlands, sandy dunes systems, forests etc.

2. THE CURRENT SITUATION OF ALBANIA'S WATER RESOURCES

Albania's water resources have been found to be abundant, in all regions of the country, with an uneven seasonal distribution: the available amount of surface water, and to a lesser extent also of underground water, decreases strongly during the summer months. This seasonal decrease varies with the importance of groundwater and with the existence of regulatory structures; so, the ponds of Shkumbini and Semani are particularly affected by the risks of water shortages during the hot and dry season. Data collection over the past six years has been insufficient, but water availability shows no trend of change.

The situation regarding water quality is not well known. Monitoring of quality parameters, both for surface and groundwater, has become much rarer and the effect of economic changes in recent years could not be assessed. However, it appears that poor quality may impose limitations on water use:

• from rivers such as Kiri (industrial waste), Mati (copper mine) (Fig.2), Gjanica (oil extraction) and Ishmi (industrial and domestic waste), the last two are the most serious cases.
• from underground waters near Lezha and Laçi (saline intrusion) and along Shkumbin and Gjanica.
• from Lake Ohrid near Pogradec (urban waste). (Fig.1)

Figure 41. River basin organisation

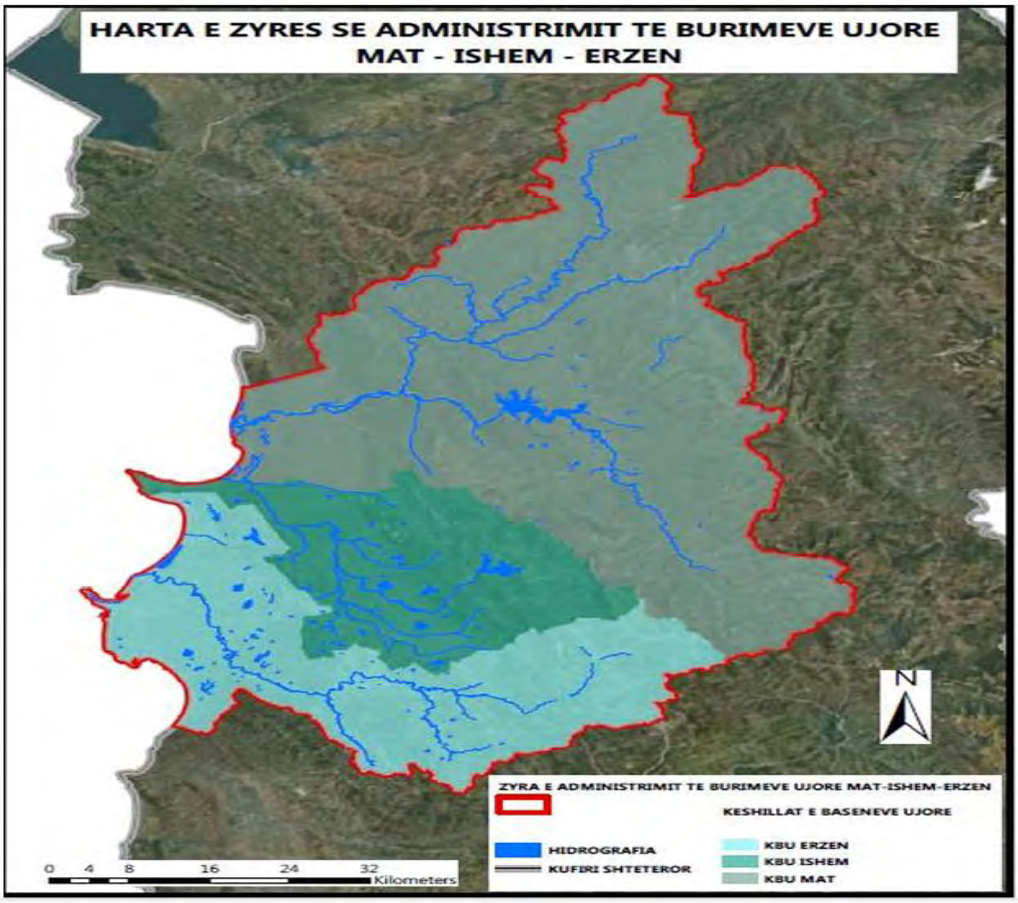

Figure 2. Administration map of the Mat-Ishem-Erzen water resources

2.1.Climate change risk on water resources in Albania

• Less water available on the source for water supply.

• Actually1 billion m3 of water is needed to irrigate the potentially irrigable area of 360,000 ha. The current water availability has been estimated to be between 0.6 and 0.7 billion m3. Due to the anticipated effects of climate change, there will be a need for 1.5 billion m3 of water storage per irrigation.

• Less electricity produced from Hydropower (actually 100 % of energy produced by hydropower);

• Flood risk increase on river deltas especially on Buna and Vjosa rivers.

• Droughts will last longer on low part and southeastern part of the country.

• Coastal erosion and coastal land lose risk will be higher.

2.2.Implementation of international agreements

The Government of Albania has concluded agreements with neighbouring countries, with the aim of solving water management issues, as well as promoting cooperation between these countries for the protection of transboundary waters, for the need to strengthen national and bilateral action, as well as for the prevention of pollution water resources. We point out:

• Ratification of the agreement with the state of Greece in 2003, where only one meeting was held in 2008, however, the parties are in constant contact. Despite the expectations from the agreement, the results were far from the expectations.

• The agreement between Albania and North Macedonia was signed for Lake Ohrid "For the protection and sustainable development of Lake Ohrid and its basin".

• In 2011, a Memorandum of Understanding was signed on the "Drin River: A shared strategic vision" between Albania, North Macedonia, Greece, Kosovo, and Montenegro.

2.3.Achievements of water quality in Western countries

Achieving water quality standard in the USA has been accomplished by making integral plans for protection of rivers and stream that have been developed for each impaired river or reach where water quality has been deteriorated. The plans obligatorily include developing TMDL.

The large number of data that are necessary to be collected for integral analyses, as well as difficulties that might arise during data processing, assume more frequent application of adequate water quality models. In the developed countries that managed to control water pollution, an important role has been posed to application of appropriate water quality models. It brings an insight into processes in watersheds, and also makes easier assessing of relative contribution of each polluter. Benefits of GIS technologies and models application may also be seen for improving trans-boundary communication and information exchange, e.g. within the Water Observation and Information System for Balkan Countries.

3. RESULTS AND DISCUSSION

Based on the OECD Framework for Water Management (OECD, 2015), in which section the main problems related to water management in Albania will be analyzed.

3.1 Institutional deficiencies

The OECD Principles for Water Management require the creation of a clear institutional framework, which well defines and divides responsibilities and roles for the design and implementation of water policies, operational and regulatory activities, while promoting coordination between responsible authorities.
From an institutional point of view, the management of water resources in Albania:

• is almost centralized.
• Frequent changes have led to the overlapping of responsibilities between institutions

In the MIBU Strategy it is mentioned that: "Management of water resources at an appropriate scale within the integrated management systems of the basin in order to reflect local conditions and coordination between different levels based on a good management of the hydrological cycle".

In this framework, the operation of the Water Basin Councils in Albania at the regional level should develop technical and administrative capacities.

3.2 Data and information deficiencies

For the design of policies related to the management of water resources, based also on the principles of the OECD, relevant data and information on water must be consistent, comparable and exchangeable.

This requires efficient cooperation for the exchange of information between water-related producers, data collectors and their users. The main shortcoming of information collection is the non-existence of methods for exchanging water data.

3.3 Financial deficiencies

Based on EU Principles for environmental policy, such as the "polluter pays" and "user pays" principles, as well as payment for environmental services. Payments for environmental services are also included in the regulations of institutions in Albania. Another problem is the analysis and evaluation of the costs for the implementation of the large investments of the EU Directives, which focus on the treatment of urban wastewater, the provision of drinking water and the management of flood risks. Establishing an effective and equitable administrative fee system will ensure that the funding gap is effectively reduced at the Water Basin level.

4. CONCLUSION

Based on the above analysis, we conclude that the institutional and legal framework of water resources management:
In Albania there is an institutional hierarchy, which makes decisions about protection, monitoring, evaluation and policies for water management. Water Legality is based on **Law No. 111/2012 "For Integrated Management of Water Resources"**.

From an institutional point of view - the management of water resources in Albania is almost centralized, frequent changes have led to the overlapping of responsibilities between central level institutes and the local one, which has resulted in a fragmented water sector, with inefficient activity and lack of transparency.

From a legal point of view - Law No. 111/2012 is an important basis for the management of water resources in Albania, however, the Albanian system lacks relevant secondary legislation, in terms of mechanisms that should be used in order to provide an effective and integrated water sector.

Data and information - There is a lack of consistent data for the design of policies related to the management of water resources.

Commitment with interest groups - regarding the design and implementation of policies related to water resources management is not continuous and representative of all interest groups.

The application of **GIS** and hydrological, hydraulic and water quality models, as well as other computer programs, in terms of the sustainable development of agriculture and water management in Albania, has obvious advantages.

Investment - The main sources of financing for water distribution companies have been the state budget and financing from foreign donors in the form of loans or grants in approximately equal ratios. These investments are mainly focused on the rehabilitation of water supply systems and analysis as well as the construction of wastewater treatment plants.

Analysis and evaluation of costs for the implementation of major investments of the **EU Directives**, with a focus on the treatment of urban wastewater, the provision of drinking water and the management of flood risks. Establishing an effective and equitable administrative fee system will ensure that the funding gap is effectively reduced at the watershed level.

REFERENCES

[1] Ligji Nr. 111/2012 “Për Menaxhimin e Integruar të Burimeve Ujore [link]

[2] https://www.oecd.org/cfe/regionaldevelopment/OECD-Principles-on-Water-Governance.pdf

[3] https://www.slideserve.com/rachelgarcia/integrated-water-resources-management-in-albania-and-climate-change-powerpoint-ppt-presentation

[4] https://kukesi.gov.al/wp-content/uploads/2021/04/Menaxhimi-i-burimeve-ujore-ne-Shqiperi_Kukes_ACER-2021.pdf

[5] https://ambu-gdi-online.hub.arcgis.com/

[6] https://euprojects.al/sq/euprojects/eu-support-to-integrated-water-management-eusiwm/

Transportation Engineering

Evolution of materials movement: A journey through construction transportation innovations

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The transportation of construction materials plays a significant role in the successful execution of infrastructure projects worldwide. This process has not always been easy, because throughout the years humanity has faced a lot of challenges and uncertainties. Therefore, they have come up with innovative solutions employed to enhance the efficiency and sustainability of transportation. It starts with ancient methods like manual labor and animal transport, highlighting their essential roles in early construction. The narrative then covers key milestones, from steam-powered locomotives to modern vehicles, revolutionizing efficiency for global construction. The diverse range of materials involved each require a unique transportation requirement and logistical thought. Also, a lot of factors need to be taken into consideration such as distance, mode of transport, environmental impacts, and financial possibilities. The development of technology of the moving process has made a colossal change on the duration of different constructions. By tracing materials movement from ancient times to today, this paper provides insights into the dynamic relationship between technology, sustainability, and efficiency in construction. It emphasizes the importance of ongoing innovation to meet the evolving demands of modern projects while promoting a more sustainable future.

Keywords: *Transportation, materials, technology, environmental.*

1. INTRODUCTION

Transportation of construction materials is a critical aspect of any building project, encompassing the movement of various materials from manufacturers or suppliers to the construction site. This process is fundamental to ensuring the timely and efficient progress of construction projects, as well as the overall success of the endeavour.
Effective transportation logistics play a pivotal role in optimizing resource utilization, minimizing costs, and reducing project delays. From coordinating delivery schedules to selecting appropriate modes of transportation, every aspect of construction material transportation requires meticulous planning and execution [1].

2. MATERIALS AND METHODS

2.1. Construction material transportation throughout time

Transportation of materials in the past varied greatly depending on the time period and geographical location. Early methods included human and animal labour, such as carrying goods on foot, using pack animals like horses or camels, and transporting materials via carts or boats. As societies advanced, technologies like the wheel, sledges, and eventually railways and steamships revolutionized transportation, enabling the movement of larger quantities of materials over longer distances [2].
In ancient times, horses were used to haul materials such as timber, stone, bricks, and other essentials for building. The process typically involved loading the materials onto carts or wagons

specially designed for transportation. These carts ranged from simple wooden structures to more sophisticated designs with wheels and axles, allowing for smoother movement over rough terrain. Horse transportation of building materials was fundamental in construction history, aiding in physical construction and societal growth by shaping cities, towns, and infrastructure globally.

The introduction of motorized vehicles revolutionized the transportation of building materials, marking a significant shift from reliance on animal power to mechanical propulsion. The transition, which began in the late 19th and early 20th centuries, brought about profound changes in the efficiency, speed, and scale of material transport, fundamentally reshaping construction practices and urban development.

One of the earliest motorized vehicles used for transporting building materials was the steam-powered traction engine. These heavy machines, equipped with large wheels and powered by steam engines, could haul substantial loads of materials over roads and rough terrain.

In the early 20th century, trucks and lorries powered by gasoline or diesel engines began to replace horse-drawn carts and wagons in urban areas and industrial centres. Flatbed trucks, dump trucks, and cement mixers became essential tools for moving materials such as steel beams, aggregates, concrete, and other construction supplies [3].

Transportation of building materials by motorized vehicles in the last 20 years has undergone significant changes driven by technological advancements, environmental concerns, and evolving construction practices.

Technological Advancements: The integration of advanced technologies such as GPS tracking has enhanced the efficiency and safety of material transportation. Fleet management systems allow companies to monitor vehicle performance, optimize routes, and reduce fuel consumption, leading to cost savings and improved logistics.

Emission Regulations: Many companies are investing in electric and hybrid trucks to reduce carbon emissions and minimize their environmental footprint. Additionally, alternative fuels such as biodiesel and natural gas are gaining traction as greener alternatives to traditional diesel.

Modular Construction: The rise of modular construction techniques, where building components are prefabricated off-site and assembled on-site, has impacted material transportation.

Safety and Compliance: With an increased focus on workplace safety and regulatory compliance, construction companies are investing in driver training programs, vehicle maintenance, and safety technology to mitigate the risk of accidents and injuries during material transportation.

By embracing innovation and sustainability, the construction industry continues to improve the efficiency, safety, and sustainability of material transportation, paving the way for a more resilient and sustainable built environment.

2.2. Transportation Methods

No matter how you ship, there are advantages and downsides to each method. The secret to finding the best transportation option for your business is understanding these differences.

2.2.1. Road Transportation

Road transportation has come a long way since the days of horse and wagon shipments. Truck transportation is ideal for industries that require quick, small shipments directly to a business, warehouse or consumer's door and is equipped to handle possible delays. The top benefits of truck freight include [4]:

Implements fewer restrictions: There are far fewer restrictions for truck freight, including heavy or hazardous materials. Trucks are also easier to track than other modes of transportation, so you always know exactly where your shipment is located.
Costs less than air and ship transportation: Truck freight is very economical compared to air and ship transportation because associated expenses, such as fuel and truck maintenance, are far less costly.
Allows for more accessibility: Road transportation is highly accessible. Most companies have easy access to a major highway system, while not every company has access to railroads, airports or ships for other forms of transportation.
Despite these numerous benefits, there are a few important factors to consider before selecting truck freight, such as:
Time: Truck freight can take longer and is more susceptible to shipment delays than other methods. Other factors, such as road closures, bad weather or heavy traffic, can also have unpredictable impacts on delivery times.
Control: Due to how truck freight works, you do not have as much control over how your products are handled. Road travel can be rough on some shipments, and some companies may mishandle your product.

2.2.2. Marine Transportation

Ships are capable of carrying immensely heavier loads for a fraction of the cost. It is the preferred transportation for large items shipped in bulk, such as metals, building supplies and others. The benefits of maritime transportation include [5]:
Accommodates more space and weight: Cargo ships range in length and can carry thousands of tons of weight. For this reason, ships are often the best option for oversized products or bulk quantities that must move at the same time.
Costs less than air transportation: Marine transportation is often a more economical choice than air transport due to the lower cost of fuel. Cargo ships operate on a set schedule, so there is also less opportunity for costly shipping delays.
Enhances the safety of the shipment: Because ships operate on a set route and planned schedule, your shipment will go through minimal handling. Most of the time, it will be securely stored in a slow-moving vessel, which is preferable for easily damaged goods.
Sea transportation may not always be the most economical or accessible choice, depending on the location of your warehouse.
Speed: Although ships are capable of carrying much bigger loads than other transportation methods, maritime shipping takes much longer.

2.2.3. Rail Transportation

Some benefits of trail transport are:
Offers more carrying capacity: Trains can transport heavy, bulk cargo over long distances. They can handle more weight than truck transportation.
Reduces the chances of delays: Trains operate on a fixed schedule, making them a predictable and reliable form of transportation. Because railroads operate independently, train shipments are often less prone to delays.
Minimizes its environmental impact: Trains tend to be less impactful than trucks, planes and ships because they require less fuel to operate.
The two main factors to consider with rail transport are:
Transit time: Rail transport is slower than truck and air freight, and they often require multiple transfers throughout the shipment process.

Accessibility: Not every area has access to railroad tracks, so rail transport almost always requires other forms of transportation to move products.

2.3. Types of construction materials which are transported.

Transporting and storing construction materials is a crucial aspect of construction management, as it affects the cost, quality, and safety of any project. However, different types of materials require different methods of handling and storage, depending on their characteristics, availability, and environmental conditions [1][6].

- *Bulk Materials:* Bulk materials are those that are loose, granular, or powdery, such as sand, gravel, cement, or asphalt. These materials are usually transported by trucks, trains, or barges, depending on the distance and volume involved. To store bulk materials, you need to consider the space, drainage, and protection required. Bins, silos, or stockpiles can be used for dry materials, and tanks or ponds for wet materials. Contamination, segregation, or moisture loss need to be prevented by covering, lining, or spraying the materials as needed.
- *Structural Materials*: Structural materials are those that are used to support or frame the building, such as steel, concrete, or wood. These materials are usually transported by trucks, cranes, or forklifts, depending on the size and weight involved. Racks, pallets, or platforms are used for horizontal materials, and stands, braces, or ties for vertical materials.
- *Finishing Materials*: Finishing materials are those that are used to enhance the appearance or performance of the building, such as tiles, paint, or insulation. These materials are usually transported by carts, dollies, or hand trucks, depending on the fragility and quantity involved. Shelves, cabinets, or boxes can be used for small materials, and rolls, bundles, or packages for large materials.
- *Special Materials*: Special materials are those that have specific properties or functions that require special handling or storage, such as hazardous, explosive, or perishable materials. These materials are usually transported by specialized vehicles, containers, or equipment, depending on the regulations and risks involved.

2.4. Shipping Construction and Building Materials: A Guide for a Smooth Journey

Planning and Coordination: The first step in shipping construction materials is careful planning and coordination. Builders and contractors work closely with suppliers to determine the quantity and type of materials needed for the project. They also consider the delivery timeline, ensuring the materials arrive just before construction begins. This planning phase is essential to avoid delays and keep the construction project on track [3-5].

Proper Packaging and Labelling: Before shipping, all construction materials must be properly packaged to protect them during transit. Fragile items, like glass or tiles, require extra care with secure packaging to prevent breakage. Additionally, all packages should be labelled clearly with information like the contents, handling instructions, and destination address. Proper packaging and labelling help ensure that the materials arrive in good condition and are easily identified upon arrival.

Choosing the Right Transportation Mode: Shipping construction materials often involves using different transportation modes. Trucks may be used for shorter distances, while cargo ships or trains might be more suitable for longer distances or international shipping. The transportation mode choice depends on factors like the quantity of materials, distance, and cost-effectiveness.

Loading and Securing the Materials: Once the materials are ready for shipping, they are loaded onto the chosen vehicles. This step requires careful planning to ensure that the materials fit securely and are evenly distributed to avoid any damage during transportation. Workers use equipment like forklifts or cranes to safely load heavy materials like steel beams or concrete blocks.

Freight Tracking: During shipping, keeping track of the package's journey is essential. Many transportation companies offer freight tracking services, providing a tracking number that allows builders and contractors to monitor the shipment's status in real-time. Freight tracking helps ensure the materials are on schedule and allows quick action in case of any unexpected delays.

Customs and Documentation (for International Shipping): Materials must go through customs clearance for international shipping. This involves providing the necessary documentation, such as invoices and permits, to comply with import and export regulations.

Unloading and Delivery: Upon arrival at the construction site, the materials are carefully unloaded from the vehicles. Workers use appropriate equipment and take safety precautions to handle the materials efficiently. Once unloaded, the materials are stored safely and organized, ready for use in the construction project.

2.5. Transportation of Concrete

Transportation of concrete is a way to move fresh concrete from where it is mixed to where it will likely be used in the structure. The method of moving concrete is decided ahead of time so that the right additives can be added to improve certain properties [2][4].

Methods for Transportation of Concrete:

Wheelbarrow: Concrete can be moved around on the ground with the help of a wheelbarrow. Pneumatic wheels can be installed on wheelbarrows to reduce the chance of concrete splitting during transport over long distances or on uneven ground.

Crane, Bucket, and Ropeway: When constructing skyscrapers, cranes come in quite handy. Cranes are quick and flexible, allowing the horizontal and vertical concrete transfer. Most concrete work, such as the building of dams and bridges, requires using a ropeway and buckets to move the heavy material from one place to another. Concrete is mixed on the bank and then transported in a bucket using a pulley or other mechanism to where it will be discharged.

Belt Conveyor: Modern belt conveyors can have a moving diverter, a reach that can be changed, and speeds that can be changed forward and backward. Conveyors can quickly move a lot of concrete where access is limited, and portable belt conveyors are used for short distances or lifts.

Truck Mixer and Dumper: Trucks, dumpers, and other open-body lorries can be used to move concrete quickly and cheaply for up to about 5 km. Most dumpers can hold 2-3 cubic meters, while a truck mixer can hold up to 4 cubic meters. During transport, wet concrete should be covered with tarps or other covers to keep it from drying out and getting stiff.

Chute: A chute can move concrete from the ground level to the lower level. It is used in places like trenches where there isn't enough room for workers to reach the concrete.

Transit Mixer: The transit mixer is one of the most popular tools for transporting concrete over long distances. Transit mixer is mounted on the truck and can hold between 4-7 cubic meters. With 2 to 6 turns per minute, the truck always moves the concrete around. A small pump is attached to the back of a truck mixer to let the concrete out. Concrete can be put into the mixer, either dry or wet. If the mix is wet, it must get to the site in one to one and a half hours.

Pumps and Pipelines: It's the most laborious method, but it's the only one that works well when space is at a premium or when a significant volume of concrete needs to be poured without using cold joints. Between 8 and 70 cubic meters per hour, concrete can be pumped [1][3].

2.6. Steel types and their transportation

Carbon Steel: Carbon steel is a widely used type of steel due to its strength and durability. Transporting carbon steel requires careful handling and appropriate equipment due to its weight and size. Carbon steel coils and sheets are commonly transported on flatbed trucks, and it is essential to secure them with chains and straps to prevent shifting during transportation.

Alloy Steel: Alloy steel is a type of steel that contains other elements, such as nickel, manganese, and chromium. Transporting alloy steel requires the use of specialized trucks with the necessary equipment to handle its weight and size. Alloy steel products, such as bars and plates, can be transported using flatbed trucks, while pipes and tubes require specialized transport equipment.

Stainless Steel: Stainless steel is a type of steel that is highly resistant to corrosion, heat, and chemical damage. Transporting stainless steel requires careful handling to prevent damage to the steel's surface. Stainless steel products, such as sheets and coils, can be transported using flatbed trucks, but it is crucial to protect them from moisture and other elements.

Tool Steel: Tool steel is a type of steel that is specifically designed for use in cutting, drilling, and shaping other materials. Tool steel products, such as dies and molds need to be secured with chains and straps to prevent shifting during transportation.

High-Speed Steel: High-speed steel is a type of tool steel that is designed to withstand high temperatures and friction. High-speed steel products, such as drill bits and saw blades, require careful handling and protection from moisture.

Electrical Steel: Electrical steel is a type of steel that is used in the production of electrical equipment, such as motors and transformers. Electrical steel products, such as laminated cores and transformers, require careful handling and protection from moisture and other elements during transportation.

2. CONCLUSION

The evolution of material transportation has already revolutionized the construction industry, enabled the creation of larger and more complex structures while fostering economic growth and global connectivity. Looking to the future, continued advancements in transportation technology promise to further enhance efficiency, reduce environmental impact, and unlock new possibilities in construction. This ongoing evolution will not only shape the built environment for future generations but also offer opportunities for innovation, sustainability, and economic development, ensuring a more interconnected and resilient world for generations to come.

REFERENCES

[1] Mantulenko, V.V., Domnina, S.V. (2022). Innovations in Construction and Transport. In: Ashmarina, S.I., Mantulenko, V.V. (eds) Proceedings of the International Conference Engineering Innovations and Sustainable Development. Lecture Notes in Civil Engineering, vol 210. Springer, Cham. https://doi.org/10.1007/978-3-030-90843-0_36.

[2] K. Kutzarova-Dimitrova, "Innovations in construction industry for transportation engineering," *Innovations*, vol. 8, no. 2, pp. 65–68, 2020, Accessed: Apr. 5, 2024. [Online]. Available: https://stumejournals.com/journals/innovations/2020/2/65

[3] R. Griffin and D. Bullock, "Emerging Technologies for Transportation Construction," 2000. Available: https://onlinepubs.trb.org/onlinepubs/millennium/00031.pdf

[4] S. Meeting and Washington (State). Department Of Highways, *Innovations in construction and maintenance of transportation facilities: proceedings of the sixth summer meeting of the Highway Research Board in cooperation with the Washington State Department of Highways, August 6-8, 1973, Olympia, Washington.* Washington, D.C.: Transportation Research Board, National Research Council, 1974.

[5] Scheinberg, Phyllis F. Surface Transportation: Prospects for Innovation Through Research, Intelligent Transportation Systems, State Infrastructure Banks, and Design-build Contracting: Statement of Phyllis F. Scheinberg, Associate Director, Transportation Issues, Resources, Community, and Economic Development Division, Before the Subcommittee on Transportation and Infrastructure, Committee on Environment and Public Works, U.S. Senate. United States, United States General Accounting Office, 1997.

[6] A. Chabot, P. Hornych, J. T. Harvey, and L. G. Loria-Salazar, *Accelerated pavement testing to transport infrastructure innovation*. Springer International Publishing, 2020.

Environmental Quality and Management

Education For Waste Management

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The issue of poor waste management is prevalent in many developing countries, primarily due to inadequate infrastructure, insufficient technical expertise, and a lack of environmental education and awareness. This paper proposes a multifaceted approach to improving waste management, by focusing on education and awareness-raising programs. Waste management and environmental education are essential components of sustainable development goals and including them in high school curricula can promote the knowledge and skills necessary for a sustainable future. Proper waste management practices can lead to economic benefits and reduce negative environmental impacts, while environmental education can foster critical thinking and problem-solving skills among students. Educators have a vital role in creating a positive educational environment that promotes waste management and environmental awareness to prepare students for a sustainable future. By developing environmentally conscious citizens who understand the importance of protecting the environment, we can achieve a more sustainable future while promoting critical thinking skills among students.

Keywords: *Environmental education, waste management, Albania, sustainable future, environmental awareness.*

1. INTRODUCTION

In developing countries like Albania, waste management is a major challenge due to a variety of factors. Besides the inadequate infrastructure, corruption [15][17][29][31], and lack of technical know-how, a common issue that hinders effective waste management there is also insufficient environmental education and awareness [2][4][7][12][18] [25-28]. As a result, many communities in these countries struggle with poor sanitation, public health risks, and environmental degradation [10][14]. Furthermore, the lack of monitoring mechanisms to track the amount and types of waste generated can make it difficult to plan and implement effective waste management strategies at the local, district, regional, and national levels [11][14]. Similar problems are evidenced in the case of Albania [16][24]. Municipal solid waste, which consists of everyday items such as paper, plastic, glass, and food waste, is typically collected and deposited into waste collection bins. Unfortunately, in many parts of our country, this waste is not separated by type, which makes it challenging to recycle or reuse [26]. Solid waste production in Albania varies by location, with urban areas generating roughly 370 kg per person [16], which has likely increased due to economic growth [21].

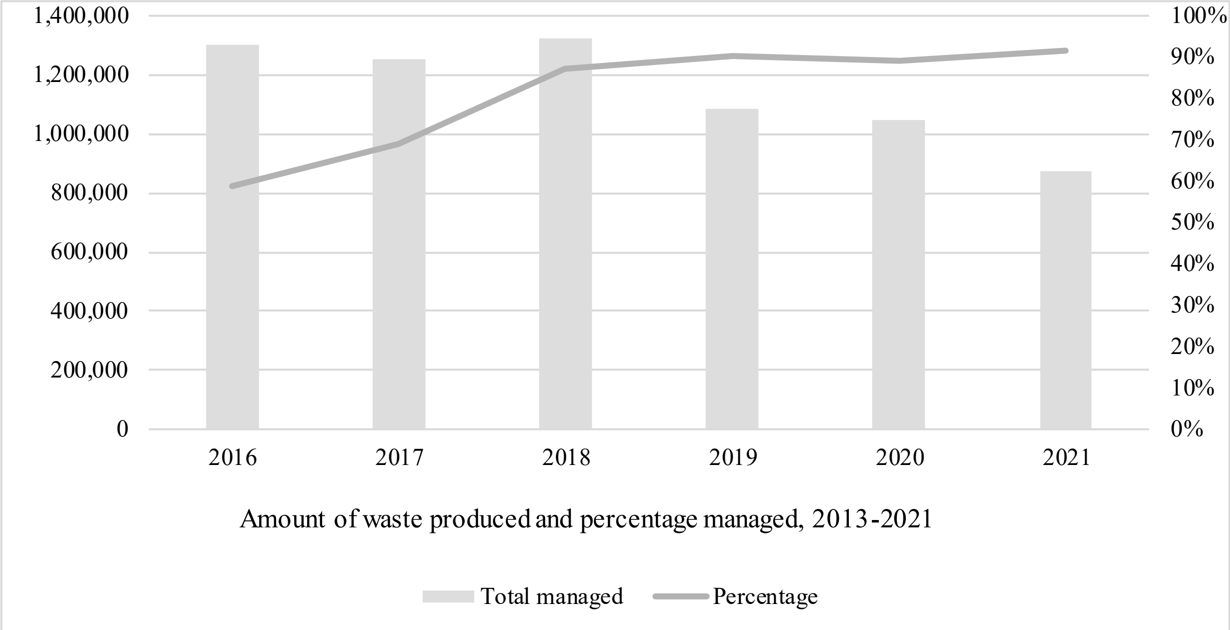

Figure 1. Waste management in Albania, 2020 [16]

Additionally, industrial waste resulting from products and services of small business entities in urban areas is often disposed of in the same waste sites as municipal waste, further contributing to the challenge of waste management [20]. This mixed waste disposal approach leads to increased waste volume, environmental pollution, and resource depletion [1][4][7][8][12][19-20]. It also limits the ability to recover valuable materials from the waste stream, which could otherwise be used in the creation of new products or for energy production. The consequences of poor waste management in developing countries can be severe. Improper disposal of waste can lead to air, water, and soil pollution, which can have negative effects on public health and the environment. Additionally, the economic costs of poor waste management can be significant, as communities may have to deal with increased healthcare costs and lost productivity due to illness caused by poor waste management practices. Effective waste management practices that prioritize waste segregation, recycling, and reuse are essential to reducing waste volume, mitigating environmental pollution, and minimizing the depletion of natural resources. Achieving these goals is critical to promoting a circular economy that supports sustainable development. However, environmental education must also play a crucial role in promoting the adoption of proper waste management practices. A recent survey conducted by the author in several major cities (18 municipalities) found that citizens often blame their own behavior for poor waste management at the district level (60 % of the respondents, n = 1.517, EcoDes Consultancy, 2022). While the majority expressed interest in sorting the recyclables (90 %). Therefore, raising awareness and educating citizens on the benefits of proper waste management practices is essential to promoting positive behavior change and reducing waste generation, ultimately leading to a more sustainable future. Addressing the issue of waste management in developing countries requires a multi-faceted approach. In addition to improving infrastructure and providing technical assistance, education, and awareness-raising programs are crucial for promoting sustainable waste management practices [7][10]. These programs can help to raise public awareness about the importance of proper waste management and provide communities with the knowledge and skills needed to implement effective waste management strategies. Additionally, monitoring mechanisms should be put in place to track the amount and types of waste generated, which can help to inform waste management planning and ensure that resources are allocated effectively. Several studies argue that any educational intervention should be integrated with the broader scope of formal education such as the education environment, education for sustainable development, and critical thinking [7][10]. However, while socially desirable, the National Curriculum Framework does not operationalize sufficiently this aspect of the education environment [23]. The issue is linked to civic education, education for sustainable development, environmental education, and critical thinking. These are some of the aspects covered in this paper.

2. CIVIC EDUCATION

As mentioned in the National Curriculum Framework (2017), the issue could be framed within the goals of civic education. Civic education focuses on developing the knowledge, skills, and values necessary for effective participation in society and the democratic process. While waste management and environmental education are essential components of civic education as they provide students with the knowledge and skills necessary to be responsible and engaged citizens in the context of environmental sustainability [30].

Civic education can promote waste reduction and sustainable waste management practices by encouraging students to become active participants in their communities. By fostering civic engagement and social responsibility, students can be empowered to take action on environmental issues such as waste management. This can include participating in local waste management initiatives, advocating for policies that promote sustainability, and engaging in community-based environmental projects.

Additionally, environmental education can help to promote civic education by encouraging students to engage with their communities and take an active role in creating positive environmental change. By promoting an understanding of the interconnections between social, economic, and environmental factors, environmental education can foster a sense of social responsibility and commitment to the common good. This can include promoting sustainable waste management practices, supporting local waste reduction initiatives, and advocating for policies that promote environmental sustainability.

Moreover, waste management and environmental education can help to promote civic education by fostering critical thinking and inquiry skills [3]. Encouraging students to analyze complex environmental issues, evaluate evidence, and make informed decisions, waste management, and environmental education can help to prepare students for active citizenship and effective participation in the democratic process [10].

As the global population continues to grow, so does the amount of waste generated. Proper waste management practices are crucial in ensuring a healthy environment and sustainable future. It is therefore imperative to include waste management and environmental awareness in the high school curriculum. This essay discusses the importance of including waste management and environmental awareness in the high school curriculum from an economic and pedagogical perspective, as well as some themes and goals, and how knowledge can be transmitted and transferred.

From an economic perspective, waste management and environmental awareness are crucial for sustainable development. Improper waste management practices result in environmental degradation and health hazards, which ultimately lead to economic losses. Environmental education and awareness can help students understand the consequences of poor waste management practices and how to reduce the negative impact on the environment. By incorporating these topics into the high school curriculum, students will be able to develop knowledge and skills that will contribute to a sustainable future. Additionally, proper waste management practices can lead to cost savings through the reuse and recycling of materials.

From a pedagogical perspective, including waste management and environmental awareness in the high school curriculum helps to develop critical thinking, problem-solving, and decision-making skills. Students will be exposed to complex environmental issues and learn how to analyze them, evaluate possible solutions, and make informed decisions. This will help them to become

responsible and active citizens who are capable of contributing to sustainable development. By learning about environmental issues, students will also develop a sense of environmental stewardship and personal responsibility for protecting the environment.
The themes and goals of waste management and environmental awareness in the high school curriculum include the development of knowledge, skills, and attitudes necessary for sustainable development. Students will learn about the principles of waste management, including the 3Rs (reduce, reuse, recycle) and proper waste disposal methods. They will also learn about the impact of waste on the environment, such as pollution, habitat destruction, and climate change. Additionally, students will learn about the importance of environmental conservation and sustainability and how individual actions can contribute to a healthier environment. The overall goal is to develop environmentally conscious citizens who understand the importance of protecting the environment and are equipped with the knowledge and skills to do so.
Knowledge can be transmitted and transferred through a variety of pedagogical approaches, including classroom lectures, discussions, case studies, and hands-on activities. Classroom lectures and discussions can be used to provide students with a theoretical understanding of waste management and environmental issues. Case studies can be used to analyze real-life environmental issues and evaluate possible solutions. Hands-on activities, such as recycling projects, can help students understand the practical applications of waste management and environmental awareness.

3. EDUCATIONAL FOR SUSTAINABLE DEVELOPMENT AND ENVIRONMENT

The importance of waste management and environmental awareness in the high school curriculum is reinforced by the need for formal environmental education and sustainable development at all school levels [7][30]. Such education should focus on the responsible management of chemicals and waste. They should also provide students with the knowledge and skills to understand the complexities of waste management.
In recent years, education for sustainable development (ESD) has emerged as a critical component of education. ESD seeks to develop the knowledge, skills, and values necessary to create a sustainable future [30]. Waste management and environmental awareness are crucial aspects of ESD, as they contribute to the development of a sustainable society. By including waste management and environmental awareness in the high school curriculum, educators can contribute to the implementation of ESD and the creation of a sustainable future.
One of the key principles of ESD is the integration of sustainability issues into all aspects of education. The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines ESD as "a vision of education that seeks to balance human and economic well-being with cultural traditions and respect for the earth's natural resources" [6][13]. Waste management and environmental awareness are crucial aspects of sustainability and should therefore be integrated into all aspects of education, including the high school curriculum.
Education and awareness-raising activities were essential for achieving sustainable waste management whereby teachers play an important role [22]. By educating students on proper waste management practices and the impact of waste on the environment, educators can contribute to the reduction of waste and the protection of the environment. Research has shown that including waste management and environmental awareness in the high school curriculum can have a positive impact on students' attitudes and behaviors, and students who participate in environmental education programs have a greater understanding of environmental issues and are more likely to engage in environmentally friendly behaviors [5].

Furthermore, the inclusion of waste management and environmental awareness in the high school curriculum can also contribute to the development of critical thinking and problem-solving skills, which are crucial for sustainable development [30]. By exposing students to complex environmental issues and providing them with the tools to analyze and solve them, educators can contribute to the development of responsible and active citizens [5][7][30].

The educational environment plays a crucial role in promoting waste management and environmental awareness. The educational environment includes the physical, social, and cultural context in which education takes place. By creating a positive educational environment that fosters sustainability, educators can further promote waste management and environmental awareness among students.

One way to create a positive educational environment is through the implementation of sustainable practices in schools. For example, schools can implement recycling programs, reduce energy consumption, and promote sustainable transportation options. These practices not only promote environmental sustainability but also provide opportunities for students to learn about waste management and environmental awareness in a practical context.

Additionally, creating a social and cultural context that values sustainability can promote waste management and environmental awareness among students. This can be achieved by promoting sustainability initiatives, creating opportunities for student involvement in sustainability projects, and providing a platform for student voices to be heard on sustainability issues.

Furthermore, the educational environment can also contribute to the development of critical thinking and problem-solving skills, which are crucial for sustainable development. By creating an environment that fosters creativity, innovation, and collaboration, educators can promote the development of these skills among students.

4. CRITICAL THINKING

The inclusion of waste management and environmental awareness in the high school curriculum aligns with the broader educational goals of promoting critical thinking skills. Critical thinking involves the ability to analyze, evaluate, and synthesize information in order to make informed decisions and is a key indicator of UNESCO's goals of education for sustainable development (EDS)[9][30].

The integration of environmental education into the high school curriculum is crucial in promoting critical thinking among students [3][10]. Educators can contribute to the development of critical thinking skills by encouraging students to think critically about environmental issues, exposing students to complex environmental issues, and providing them with the tools to analyze and solve them. Environmental education fosters the development of logical thinking, inquiry, and decision-making skills. Furthermore, environmental education helps students recognize the impact of the environment on their lives and the culture in which they live, which is essential for promoting sustainability.

This could be performed by stimulating and teaching scientific argumentation and providing students with the knowledge and skills necessary to address real-life environmental challenges. It helps students to understand the complexities of environmental issues and the interconnectedness of social, economic, and environmental factors. This understanding can empower students to act and make informed decisions about their own lives and the environment.

Research has shown that environmental education can have a positive impact on critical thinking skills as environmental education programs can improve students' critical thinking skills, including their ability to analyze, evaluate, and synthesize information [3][9]. Furthermore, environmental education can promote a sense of personal responsibility and a commitment to environmental sustainability.

Additionally, promoting waste management and environmental awareness in the high school curriculum can provide opportunities for students to develop critical thinking skills in a real-world context. For example, students can be encouraged to analyze the environmental impact of their own behavior and develop strategies to reduce waste and promote sustainability. Through these activities, students can develop critical thinking skills that are applicable to a range of real-world problems.

5. CONCLUSION

Poor waste management is a significant challenge in many developing countries. Inadequate infrastructure, lack of technical know-how, and insufficient environmental education and awareness are among the factors that contribute to this problem. Improving waste management in these countries requires a multi-faceted approach that includes education and awareness-raising programs, technical assistance, and monitoring mechanisms to track waste generation. By addressing these issues, developing countries can promote sustainable waste management practices and protect public health and the environment.

Civic education, waste management, and environmental education are interconnected in promoting active and responsible citizenship that leads to waste reduction, sustainable waste management practices, environmental sustainability, and engaged and active citizenship. Additionally, waste management and environmental education can help to foster critical thinking skills and social responsibility, which are essential components of civic education.

Waste management and environmental awareness are essential components of UNESCO’s sustainable development goals. By including these topics in the high school curriculum, students will develop knowledge and skills that are crucial for a sustainable future. From an economic perspective, proper waste management practices can lead to cost savings and reduce the negative impact on the environment. From a pedagogical perspective, these topics help to develop critical thinking, problem-solving, and decision-making skills. The themes and goals of waste management and environmental awareness include developing environmentally conscious citizens who understand the importance of protecting the environment. Knowledge can be transmitted and transferred through a variety of pedagogical approaches, including classroom lectures, discussions, case studies, and hands-on activities.

Environmental education plays a crucial role in promoting waste management and environmental awareness. By implementing sustainable practices in schools, creating a social and cultural context that values sustainability, and fostering critical thinking and problem-solving skills, educators can contribute to the development of environmentally conscious citizens. As educators, it is our responsibility to create a positive educational environment that promotes waste management and environmental awareness and prepares our students for a sustainable future.

In conclusion, promoting waste management and environmental awareness in the high school curriculum aligns with the broader educational goals of promoting critical thinking skills. Environmental education has been shown to improve critical thinking skills among students and promoting waste management and environmental awareness can provide opportunities for students to develop these skills in a real-world context. Additionally, the development of critical thinking skills is a key component of education for sustainable development and is crucial for creating a sustainable future.

REFERENCES

[1]Alcani, M., & Dorri, A. (2013). *Problems related to current situation of solid waste management in Albania*: researchgate.net.
[2]Alcani, M., Dorri, A., & Hoxha, A. (2015). *Some issues of municipal solid waste management in Albania and especially Tirana City*: researchgate.net.
[3]Arslan, S. (2012). The influence of environment education on critical thinking and environmental attitude. *Procedia-Social and Behavioral Sciences, 55*, 902-909.

[4]Bineri, O., Huqi, B., & Sallaku, F. (2012). *Strategies and technologies for sustainable urban waste management in Albania*: balwois.com.
[5]Carleton-Hug, A., & Hug, J. W. (2010). Challenges and opportunities for evaluating environmental education programs. *Evaluation and Program Planning, 33*(2), 159-164. doi:https://doi.org/10.1016/j.evalprogplan.2009.07.005 °https://www.sciencedirect.com/science/article/pii/S0149718909000706
[6]Combes, B. P. (2005). The United Nations decade of education for sustainable development (2005–2014): Learning to live together sustainably. *Applied Environmental Education and Communication, 4*(3), 215-219.
[7]Debrah, J. K., Vidal, D. G., & Dinis, M. A. P. (2021). Raising awareness on solid waste management through formal education for sustainability: A developing countries evidence review. *Recycling, 6*(1), 6.
[8]Engström, C. C., & Kässel, E. (2008). *Make love not waste: A study of a waste management project and its public awareness components in the Korca region, Albania*: diva-portal.org.
[9]Ernst, J., & Monroe, M. (2004). The effects of environment-based education on students' critical thinking skills and disposition toward critical thinking. *Environmental Education Research, 10*(4), 507-522.
[10] Faize, F. A., & Akhtar, M. (2020). Addressing environmental knowledge and environmental attitude in undergraduate students through scientific argumentation. *Journal of Cleaner Production, 252*, 119928.
[11] Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International journal of environmental research and public health, 16*(6), 1060.
[12] Gjoka, K. (2005). *Municipal solid waste management system in Tirana, Albania: potential for waste separation at source*: narcis.nl.
[13] Glavič, P. (2020). Identifying key issues of education for sustainable development. *Sustainability, 12*(16), 6500.
[14] Hoornweg, D., & Bhada-Tata, P. (2012). What a waste: a global review of solid waste management.
[15] Imami, D., Lami, E., & Uberti, L. J. (2017). Election cycles in mining licensing: theory and evidence from Albania. *Post-Communist Economies, 30*(1), 99-116. doi:10.1080/14631377.2017.1361692 °https://www.tandfonline.com/doi/full/10.1080/14631377.2017.1361692
[16] INSTAT. (2020). *Mbetjet e Ngurta Urbane [Urban solid waste]*. Tirana: Instituti i Statistikes Retrieved from https://www.instat.gov.al/media/9134/mbetjet-e-ngurta-urbane-2020__.pdf
[17] Kambellari, E. (2013). Corporate Crime in Albania: Building the Path to Face a New Form of Criminality. *European Journal on Criminal Policy and Research, 20*(2), 191-204. doi:10.1007/s10610-013-9223-5 °https://link.springer.com/article/10.1007%2Fs10610-013-9223-5
[18] Keçi, E. (2017). Ship-Generated Waste and Cargo Residues Institutional Framework and Management in Albania. *Academic Journal of Interdisciplinary Studies*. °https://www.mcser.org/journal/index.php/ajis/article/view/9808
[19] Kodra, A., & Milios, L. (2013). *Municipal waste management in Albania*.
[20] Kripa, D., & Nano, X. (2022, 17-18 November). *Theoretical Approach on Circular Economy in Built Environment, Case of Albania.* Paper presented at the CIRCULAR ECONOMY: Opportunities and Challenges, Skopje.
[21] Liço, E., Vito, S., Boci, I., & Marku, J. (2015). Situation of Plastic Waste Management In Albania Problems And Solutions According to European Directive. https://www.researchgate.net/profile/ilirjana-

boci/publication/274024269_situation_of_plastic_waste_management_in_albania_problems_and_solutions_according_to_european_directive/links/5512adca0cf20bfdad51bc0e/situation-of-plastic-waste-management-in-albania-problems-and-solutions-according-to-european-directive.pdf

[22] Liu, S.-Y., Yeh, S.-C., Liang, S.-W., Fang, W.-T., & Tsai, H.-M. (2015). A national investigation of teachers' environmental literacy as a reference for promoting environmental education in Taiwan. *The Journal of Environmental Education, 46*(2), 114-132.

[23] Ministry of Education Youth and Sports. (2017). *KORNIZA KURRIKULARE E ARSIMIT PARAUNIVERSITAR TË REPUBLIKËS SË SHQIPËRISË [Curricular framework of pre-university education]*. Tirana Retrieved from https://ascap.edu.al/wp-content/uploads/2017/03/Korniza-Kurrikulare.pdf

[24] Ministry of Tourism and Environment. (2020). *Dokumenti i Politikave Strategjike të Menaxhimit të Mbetjeve [Document of Strategic Policies for Waste Management]*. Tirana Retrieved from https://turizmi.gov.al/wp-content/uploads/2020/07/Dokumenti i Politikave Strategjike_AL.pdf

[25] Qafmolla, L., & Dollani, K. (2010). *National Policy for Safety Spent Sealed Sources, Radioactive Waste Management and their Decommissioning in Albania*: www-pub.iaea.org.

[26] Spahiu, E. (2022, 17-18 November). *Urban waste management in Albania and public investment funds allocated in the past years.* Paper presented at the CIRCULAR ECONOMY: Opportunities and Challenges, Skopje.

[27] Stela, M. (2015). *Urban waste management in Albania*: cyberleninka.ru.

[28] Stela, M., & Arjana, L. (2019). The importance of the management of plastic waste in Albania. *Perspectives of science and education*. °https://elibrary.ru/item.asp?id=39321652

[29] Turkeshi, E. (2014). Criminalizing waste management activities in Albania in the light of the European Union legislation. *European Journal of Crime, Criminal Law and Criminal ...*. °https://brill.com/view/journals/eccl/22/1/article-p79_5.xml

[30] United Nations Educational, S., & Organization, C. (2014). UNESCO roadmap for implementing the global action programme on education for sustainable development. In: UNESCO Paris.

[31] Zhilla, F. (2011). Organised crime and judicial corruption in the Western Balkans. *Journal of Financial Crime, 18*(4), 387-404. doi:10.1108/13590791111173713

Optimizing existing municipal waste management systems: a case study of Deçan

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Waste management is one of the main challenges facing communities today. In a context where environmental concerns and the need for a sustainable approach are becoming more and more important, Deçani is facing a big challenge to improve and adapt its waste management system. This study aims to address and offer concrete solutions for the improvement of the current waste management system in the municipality of Deçan. Through a deep analysis of the situation, we have now managed to identify the main challenges, as well as compile recommendations and sustainable strategies to address the needs and increase the overall efficiency of waste management. Thus, the efficient solution includes: a combined system on waste management in the Municipality of Deçan, divided into rural and urban systems. The solution in the rural area is a combined system of door-to-door collection and composting where each village will have a common composting machine, while the solution in the urban area is an underground management system based on a system with collection points and separation with recycling in frequented areas of the city. The collection in the rural part will be done once a week on a specific day for each village, while in the city the waste will be collected daily. Their transportation will be done with a special truck for each type of management system. This phase of defining the waste management system is a critical step towards creating an appropriate and functional model that will contribute to a cleaner environment and a community more aware of the impact of their actions on the local environment and global environment.

Keywords: *Solid Waste Management System, Municipal Waste, Waste Collection, System Design.*

1. INTRODUCTION

Deçan and its surrounding areas are experiencing a continuous increase in waste production, posing a significant challenge to the environment and the community's sustainability. With a substantial production of various types of waste, including plastic, paper, metals, biodegradable waste, and others, it is imperative to develop a structured plan for their management. A detailed assessment of the current waste situation reveals not only an increase in quantity but also the necessity for a more efficient approach to treatment and reuse. An in-depth analysis of waste types and their environmental impact is a crucial step in determining the main objectives of the waste management system. Moreover, community awareness plays a critical role at this stage. By fostering cooperation and educating residents about the importance of waste reduction and regular utilization of recycling services, we can create an environment where every individual contributes to waste management solutions. This situation presents an opportunity to formulate a sustainable and appropriate waste management plan for our city. Establishing a system that integrates community needs, environmental concerns, and technological innovation can significantly contribute to a cleaner environment and a more sustainable city in the future.

2. MATERIALS AND METHODS

The study was conducted through a comprehensive approach involving several key methodologies. Firstly, a thorough literature review was conducted to gather insights into current waste management practices, sustainable strategies, and technological advancements relevant to the context of Deçan. Data collection involved both primary and secondary sources, including interviews with local stakeholders such as municipal authorities, waste management personnel, and community members. Quantitative data regarding waste generation rates, composition analysis, and current waste management infrastructure were collected through field surveys and official reports from the Municipality of Deçan. Geographic Information System (GIS) mapping was utilized to visualize the distribution of waste collection points, landfill sites, and potential areas for infrastructure improvement.

The data collected were then analyzed using statistical tools, thematic analysis, and content analysis techniques to identify patterns, trends, and key insights. Based on the analysis results, a conceptual framework for optimizing the waste management system in Deçan was developed, incorporating recommendations for infrastructure upgrades, operational improvements, community engagement strategies, and sustainable practices. Cost-benefit analysis and environmental impact assessments were also conducted to evaluate the feasibility and effectiveness of proposed solutions. The proposed solutions include a combined system of door-to-door collection and composting in rural areas, along with an underground management system with collection points and recycling in urban areas. The implementation plan, timeline, and resource allocation for these solutions were also detailed in the study to facilitate practical implementation and monitoring of progress.

3. RESULTS

3.1. Baseline study

The municipality of Deçan is situated in the northwestern part of the Republic of Kosovo, covering an area of 293.940 km^2. It comprises an administrative center and 38 villages, with a total population of 40,019 inhabitants. Of these, 3,834 reside in urban areas, while 36,185 live in rural areas.

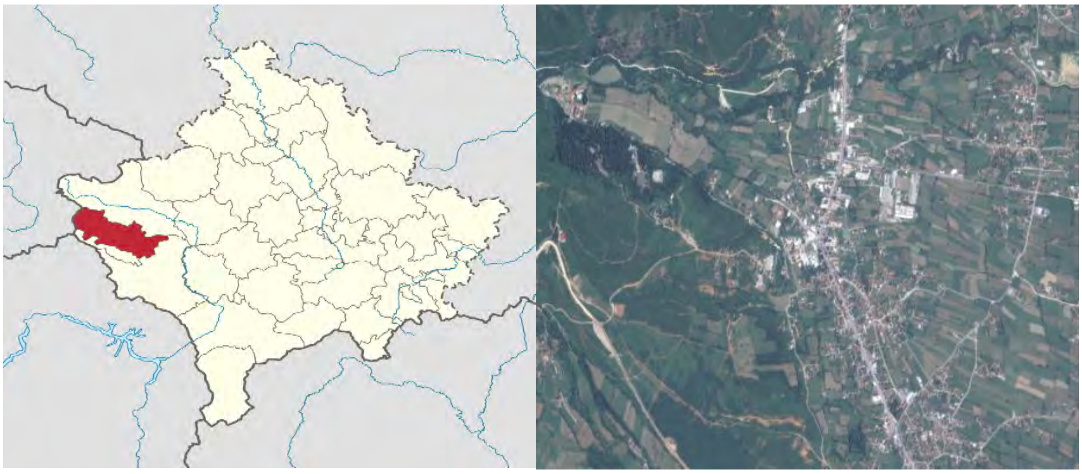

Figure 1. Geographical position of Deçan

According to the available data, the waste generation in both the city and surrounding villages is outlined in the table. It should be noted that the number of residents served has increased since 2019, and currently, the coverage extends to 100% of the territory.

Table 1. Waste generation (2019)

	General and service data	**Amount of waste collected (2019)**	**Waste Generation (2019)**

Municipality	Number of residents according to ASK - 2011	The number of residents served	Number of households according to ASK - 2011	Number of households served (12/2019)	Mixed waste collected (tons/year)	Mixed municipal waste collected (kg/year)	Waste generation per capita (kg/year)	Waste generation per capita (kg/day)
Deçan	40,019	24,731	5,887	3,628	5,743	538,000.00	80.23	0.22

Waste generation per capita is 80.23 kg/year. To calculate the daily generation, we divide the annual generation by 365 days:

$$Daily\ generation\ = \frac{80.23\ kg}{365\ days} \approx\ 0.22 \frac{kg}{day}$$

Knowing the daily waste generation, we find the weekly generation:

$$0.22 \frac{kg}{day} \times\ 7\ days\ =\ 1.54 \frac{kg}{week}$$

3.2. Proposed waste management system

The ongoing report on waste management in our city and surrounding villages has revealed that a combined system is the most favorable and efficient option for waste management in these diverse environments. In the city, the use of collection points emerges as the most convenient solution. This management structure provides organization and convenience for residents to dispose of their waste at dedicated points. Utilizing separate containers for different types of waste encourages their separation at the source, facilitating transportation and handling. The proposed system involves underground containers placed at various points across the city, the specifics of which will be discussed in the section on container dimensions and placement.

This management system will not only offer citizens accessible spaces and a cleaner environment (including the areas around the containers) but will also be visually appealing. The functioning of this system is illustrated below through photographic summaries depicting the process from container installation to restoration of the previous state (see Figure 2). Additionally, this system allows for recycling, with adhesive strips indicating separate containers for paper, plastic, metal, and organic waste. However, these containers will only be placed in areas frequented by the public, as consumers using them for household waste may be reluctant to cooperate with sorting.

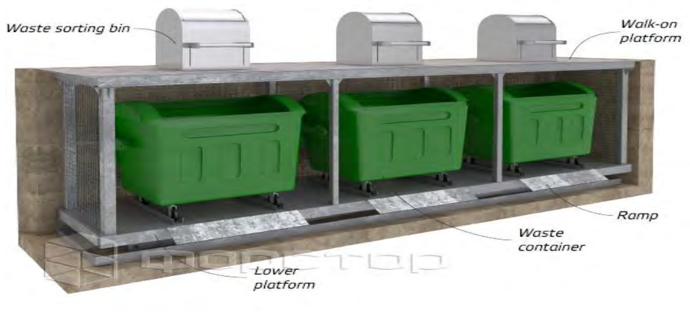

Figure 2. Interior view of an underground container

Meanwhile, in villages, a "door-to-door" garbage collection system is deemed most suitable. This model involves the regular collection of waste from individual homes, providing a personalized and localized approach to disposal. In addition, the practice of composting is an important method in villages, turning biological waste into useful resources for the soil and vegetation, and considering the fact that the city of Deçan has a large area of agricultural land with an area of 5504.53 ha. as well as other lands with a similar character:

- Arable land /are 4302.07 ha
- Meadows and pastures 198.6
- Unused agricultural land 150.4 ha
- Similar species

Moreover, composting is a significant practice in villages, transforming organic waste into valuable resources for soil and vegetation. Considering that Deçan has a considerable area of agricultural land, totaling 5504.53 hectares, including arable land, meadows, pastures, and unused agricultural land, composting is particularly beneficial in rural areas.

Composting is a natural process whereby organic matter is converted into humus-rich compost through the decomposition facilitated by bacteria, fungi, and other microscopic organisms in an environment with adequate air and water. Organic materials such as dead trees, grass, food waste, and other plant matter are placed in a designated area and allowed to decompose. Maintaining a proper balance of organic matter, air, water, and ambient temperature is crucial for successful composting.

The implementation of this integrated urban and rural waste management plan represents a significant stride towards offering efficient and sustainable solutions to tackle the challenges of waste generation and treatment in our diverse environment. Our ultimate aim is to foster a cleaner and more sustainable environment for all residents. A key determinant of satisfaction with the waste management system in a city is the extent of its coverage. Therefore, ensuring comprehensive coverage is a top priority in our system.

Table 2 presents data sourced from official publications of the Association of Municipalities and Communes of Kosovo (AMMK) and the Municipality of Deçan. Despite notable increases in recent years, the coverage rate for 2018/2019 remains unsatisfactory. As such, the primary goal of our project is to achieve 100% coverage at the city level, encompassing both urban and rural areas.

Table 2. Coverage rate wit waste collection service

Level of coverage with waste collection service					
Municipality	Service coverage rate for households (2018)	Service coverage rate for households (2019)	Increase or decrease in the coverage rate for households 2018-2019 (point %)	Business service coverage rate - 2019	Coverage rate with service for institutions (2019)
Deçan	30.80%	61.80%	31%	26.10%	93.90%

For the construction of the aforementioned system, careful consideration was given to the types of waste present. Following an analysis of the waste types in the municipality of Deçan, as presented in Table 3, efforts were made to comprehend and document the specific weight of each waste type, along with their respective percentages in the total waste collected for the study.

This analysis meticulously details and categorizes the various types of waste in a structured format, offering a clear overview of their weight distribution in a multidimensional context. The classification encompasses 2,273.70 kg (about 5012.64 lb) of paper and cardboard, glass, biodegradable waste, and other types, presented in both kilograms and percentages within the table.

Through this analysis, we have documented the varied weights of waste, highlighting the significance and impact of each type on the total waste studied in the municipality of Deçan. This information serves as the foundation for developing waste management strategies and enhancing the efficiency of the treatment process, with a focus on environmental sustainability and social responsibility.

Table 3. Type and content of waste.

Type of waste	**First analysis 2021**	
	Kilogram	Composition in %
Total municipal waste	2,273.70	
Paper and cardboard	484.48	21.30
Glass	131.87	5.80
Biodegradable waste	698	30.70
Textile	145.51	6.40
Plastic	432	19.00
Metal	25	1.10
Other municipal waste	356.97	15,7
Total in kg and in %	2,273.70	100.00

In analyzing the waste collection system in the municipality of Deçan, a need for organization and improvement of the container structure has been identified to align with the volume of waste generation and the characteristics of the population. To address this, we begin by calculating the density of waste. The annual waste generation is 80.23 kg per person per year for the residents of the 38 villages. Density is calculated by dividing the mass of annual waste by the volume it occupies in that time period. Considering that the annual waste generation per person is 80.23 kg, we need to determine the volume this waste occupies. If waste is collected once a week, and there are on average 6 members per household, we can calculate the weekly volume of garbage collected using the formula (applicable to the rural area):

- $Weekly\ Volume\ = Weekly\ Generation\ \times Number\ of\ Residents$
- $Weekly\ Volume\ = 1.54 \frac{kg}{week} \times 36{,}185\ inhabitants\ = 55{,}733.9 \frac{kg}{week}$

To find the density of waste, we need information on the effective volume of waste over the course of a year. The calculation for density will be:

- $Density\ = \frac{Mass\ of\ waste\ weekly}{365\ days}$
- $Density\ = \frac{55{,}733.9\ kg/week}{365\ days}\ = 152.69 \sim 153\ kg/m^3\ year$

Thus, the density of waste in the municipality of Deçan, based on their annual generation, is approximately **153 kg/m³ per year**.

Once we have the overall density, we can also determine the number of containers. According to information from the field, 120-liter containers are currently placed in the villages, but citizens report these as insufficient. Therefore, we assume that the containers have a volume of **240 liters**.

- Number of inhabitants: 36,185 inhabitants
- Average number of residents per household: 6 residents
- General density: 153 kg/m³
- Volume of a container: 240 liters

Firstly, we calculate the number of households using the ratio between the number of inhabitants and the average number of inhabitants per household:

$$Number\ of\ households\ = \frac{Number\ of\ inhabitants}{Average\ number\ of\ inhabitants\ per\ household}$$

$$Number\ of\ households\ = \frac{36{,}185}{6\ inhabitants}\ =\ 6{,}030.833 \sim 6{,}031\ households$$

Total volume of waste in a year: The annual waste generation per person is 80.23 kg. - The total density of waste is 153 kg/m³.

- The number of inhabitants is 36,185.

Calculation of the total volume of waste in a year:

- $Total\ volume\ of\ waste\ =\ Annual\ generation\ of\ waste\ per\ person\ \times\ Number\ of\ inhabitants$
- $Total\ waste\ volume\ =\ 80.23\ kg/year\ \times\ 36{,}185\ inhabitants\ =\ 2{,}903{,}715.55\ kg/year$

Calculation of the number of containers:

$$Number\ of\ containers\ = \frac{Total\ volume\ of\ waste}{Volume\ of\ one\ container}$$

$$Number\ of\ containers\ = \frac{2{,}903{,}715.55\ \frac{kg}{year}}{0.24\ m^3}\ =\ 12{,}098{,}814.79\ containers$$

Calculation of the number of containers based on the number of houses:

- The number of houses is 6,031.

$$Number\ of\ containers\ per\ house\ = \frac{Number\ of\ containers}{Number\ of\ houses}$$

$$Number\ of\ containers\ per\ house\ = \frac{12{,}098{,}814.79\ containers}{6{,}031\ houses}\ \approx\ 2{,}004.51$$

So, to cover the need for waste collection in a year, it will take about 2,005 containers per house based on the annual waste generation, density, and number of houses in the defined community.

This was about the rural area of the city; now we count the urban area. As was shown earlier, in the urban area, the collection system will be implemented at certain points where each neighborhood will have three containers with a volume of 1100 liters. The city of Deçan has an area of approximately 1 square kilometer (99.89 hectares), divided into four main units.

Therefore, we calculate the number of containers we need:

- $Number\ of\ containers\ =\ Number\ of\ neighborhoods\ (units)\ \times\ Estimated\ number\ of\ containers\ per\ neighborhood$

- $Number\ of\ containers\ =\ 4\ \times\ 3\ =\ 12\ containers$

For each neighborhood, we need a total of 12 containers with a volume of 1100 liters. Now, in the center of Deçan, in the two squares "Luan Haradinaj" and "Mentor Tolaj," as well as on the way to Deçan Canyon and Mineral Water, designated tourist areas, four containers with compartments for recycling will be placed: plastic, paper and cardboard, metals, and biodegradable waste.

In these four areas, 16 containers will be placed, which, together with the neighborhood containers, makes a total of:

- $Total\ number\ of\ containers\ in\ the\ urban\ area\ =$ $Containers\ in\ the\ neighborhood\ +\ Containers\ in\ squares\ and\ tourist\ areas$

- $Total\ number\ of\ containers\ =\ 12\ +\ 16\ =\ 28\ containers$

So, in the urban area, 28 containers with a volume of 1100 liters will be used.

Regarding the collection of containers in the door-to-door system, the collection will be done once a week in the morning, from 7:00 a.m. to 11:00 a.m., where citizens are obliged to place all waste in containers on their designated day and to position the containers at their doors, ensuring workers' access even if citizens are not at home.

In the city, the collection will occur every day, once a day, from 10:00 p.m. to 12:00 a.m.

Among other requirements, citizens are expected to separate and dispose of recyclable materials in the designated recycling containers, as this is crucial and helpful during the recycling process.

To calculate the number of trucks, we use the formula:

$$\boldsymbol{N = \frac{SF}{XW}}$$

Where:

- N represents the required number of trucks

- S stands for the number of houses

- F represents the number of collections per week

- X is the number of houses serviced by one truck per day

- W denotes the number of working days per week

Using these values, we can determine the number of trucks needed for the system to operate effectively.

$$N\ = \frac{(40{,}019\ \times\ 4)}{(240\ \times\ 5)} =\ 22.23 \sim 22\ trucks$$

4. CONCLUSION

The waste management solution in our city has been adapted and personalized to the needs and characteristics of each area. In the urban area, we have created and implemented an advanced underground collection system and a structured waste recycling program. This underground collection system is designed to ensure regular and efficient collection of various wastes, including innovative modalities aimed at reducing their impact on the environment.

On the other hand, in rural areas, we have implemented a specialized waste management system, including a door-to-door approach and a meticulous composting process to efficiently utilize organic waste. This door-to-door system ensures individual treatment of waste, including its processing at the local level, to utilize resources in a sustainable and appropriate manner for the rural environment.

The differentiation of these two systems was made to specifically adapt them to the needs and characteristics of each area of our city. This adaptation of the systems has been carried out in accordance with good standards of waste management practices and aims to ensure responsible and efficient treatment of waste, contributing to our goals to preserve and protect our shared environment.

REFERENCES

[1] "Local plan for environmental protection Deçan 2020-2023," Municipality of Deçan, [Online]. Available: https://kk.rks-gov.net/decan/wp-content/uploads/sites/9/2021/05/Plani-Lokal-Per-Mbrojtjen-e-Mjedisit-2020-2023.pdf.

[2] [Online]. Available: https://ammk-rks.net/assets/cms/uploads/files/Publikime-raporte//Raporti_mbeturinave_komunale_2019__ALB_version.pdf.

[3] [Online]. Available: https://kk.rks-gov.net/decan/qyteti/harta-e-qytetit/.

[4] [Online]. Available: https://kk.rks-gov.net/decan/wp-content/uploads/sites/9/2021/05/Plani-Lokal-Per-Mbrojtjen-e-Mjedisit-2020-2023.pdf .

[5] [Online]. Available: https://kk.rks-gov.net/decan/wp-content/uploads/sites/9/2021/05/Plani-Lokal-Per-Mbrojtjen-e-Mjedisit-2020-2023.pdf .

[6] [Online]. Available: https://kk.rks-gov.net/decan/wp-content/uploads/sites/9/2018/07/Riorganizimi-dhe-Plotesimi-i-Sherbimit-te-Mbledhjes-se-Mbeturinave.pdf.

[7] [Online]. Available: https://kk.rks-gov.net/decan/wp-content/uploads/sites/9/2023/02/Draft-Plani-Menaxhimi-i-Mbeturinave-2023-2027.pdf.

[8] [Online]. Available: https://forstor.ua/en/c-podzemnie-musornie-kontejnery-s-podyomnikom-46/.

Navigating Environmental Legislation: A Comparative Analysis of Kosovo and Turkey

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This study thoroughly examines environmental protection legislation in Kosovo and Turkey, tracing its historical evolution and dissecting legislative areas such as air quality, water resources, biodiversity preservation, and waste management. It provides detailed insights into current regulations and legal frameworks governing environmental policies in both nations. Emphasizing shared objectives of environmental protection and sustainable development, the study analyses the purpose and key definitions within the legislation of Kosovo and Turkey, highlighting punitive measures for environmental offenders. Furthermore, it scrutinizes renewable energy projects, including wind, hydro, and geothermal energy, to assess efforts towards sustainable energy practices. Additionally, the study evaluates Kosovo and Turkey's commitment to the United Nations Framework Convention on Climate Change, alongside their financial expenditures on environmental conservation. Overall, this comprehensive exploration aims to enhance understanding of legal frameworks, initiatives, and challenges in environmental protection in Kosovo and Turkey.

Keywords: *Environmental legislation, Kosovo, Turkey, Comparative analysis, Sustainable development, Renewable energy.*

1. INTRODUCTION

When we look at the historical development of environmental control for "Environmental Protection," we see that the earliest regulations on this topic began with industrial accidents in the late 1970s. In the early 1980s, new approaches to the concept of "environmental management" began to develop in connection with environmental protection and industrial activities within these frameworks; revised to improve their energy and environmental performance. By the mid-1980s, the environmental effects of raw materials and energy flows in industrial production systems were redesigned. This approach includes elements of environmental protection such as ensuring waste and by-products as inputs for reproduction, assessing the environmental impact of products, and analyzing the entire process flow for cleaner production [1-3]. By the 1990s, there was a need for a more comprehensive approach to the growing industry and service sectors, environmental education, measurement and monitoring of environmental values, waste reduction, and the determination of environmental management strategies, and as a result, the concept of "total quality," which is extremely important in terms of environmental protection. Today, along with environmental pollution, the gradual decline of resources we use in many areas, especially in energy, has taken alarming proportions for humanity. Humanity, which pollutes the environment rapidly and consumes resources in nature, actually makes the world where it lives from being a livable planet for all living beings [4-5]. This situation is not sustainable and is at a level that requires immediate action. The concept of environmental protection has evolved for all forms of life and habitats on Earth. Global warming and climate change are the priority topics on the agenda being discussed and sought solutions for worldwide today. At this point, environmental discussions and practices have become of undeniable importance. In this regard, Kosovo and Turkey are no exception, having built a good legal infrastructure on the environment [6-7].

2. METHODOLOGY

This comparative study delves into the environmental protection legislation of Kosovo and Turkey, providing an in-depth analysis of their historical evolution, legislative frameworks, regulatory measures, and punitive provisions for environmental offenders.

3. RESULTS AND DISCUSSION

Here, we summarize the findings and discuss key points of comparison between the two nations.

3.1. Legislative Development and Framework:

Turkey's environmental legislation dates back to the early 1980s, with the introduction of the Environmental Law in 1983. Over time, Turkey has demonstrated commitment to updating and modernizing its environmental legislation, particularly in alignment with EU standards. Kosovo, on the other hand, began regulating environmental issues post-independence in 2008. Its legislation is relatively newer and has been shaped with assistance from international experts, reflecting a commitment to align with EU standards. Both nations exhibit a clear intention to address environmental concerns through legal frameworks [8-10].

3.2. Coverage of Environmental Legislation:

Both Turkey and Kosovo have comprehensive environmental legislation covering various aspects such as waste management, water and air quality, biodiversity preservation, and pollution control. While Turkey's legislation primarily consists of laws, regulations, statutes, and national decisions, Kosovo's legal framework is ambitious and encompasses a wide array of environmental issues, reflecting its commitment to sustainable development [11-12].

3.3. Specific Regulations and Authorities:

Turkey and Kosovo have enacted specific regulations to address environmental concerns such as air quality control, environmental impact assessment, waste management, and hazardous waste control. Additionally, both nations have designated authorities responsible for enforcing environmental regulations and overseeing environmental protection efforts.

3.4. Comparative Analysis of Environmental Laws:

Turkey's Environmental Law is embedded within the broader framework of the Ministry of Environment and Urbanization, whereas Kosovo's Law on Environmental Protection falls under the Ministry of Environment and Spatial Planning. Kosovo's legislation is more detailed, comprising 101 articles, while Turkey's Environmental Law has 34 fundamental articles supplemented by additional provisions. Kosovo's law explicitly aims to align with EU environmental standards, while Turkey's law focuses on sustainable development principles [13-14].

3.5. Principles and Definitions:

Both nations share similar principles such as sustainable development, integration of environmental protection, and the "polluter pays" principle. However, Kosovo's legislation includes a broader range of definitions and principles, reflecting a more detailed approach to environmental governance.

3.6. Punitive Provisions:

Kosovo and Turkey have established punitive measures for environmental offenders. While Kosovo imposes fines ranging from 1,000 to 50,000 Euros for various violations, Turkey enforces fines for specific offenses, such as emissions standards violations and unauthorized facility operations.

Turkey's punitive provisions appear to be more extensive and cover a wider range of environmental violations compared to Kosovo [10][15-16].

3.7. Renewable Energy in Turkey:

Legislative Framework: Turkey has implemented the Law on the Use of Renewable Energy Resources for Electricity Generation since 2005, providing incentives for renewable energy projects such as wind, solar, geothermal, and biomass. Operators must obtain Renewable Energy Resource Certificates to access these incentives.

Current Status: As of 2022, renewable resources contribute a significant portion, approximately a quarter, to Turkey's energy consumption, encompassing both heating and electricity generation. This includes initiatives like rooftop solar water heating, utilization of underground hot water for baths and greenhouses, and wind power, which accounts for about a tenth of the country's electricity.

Wind Energy: Wind energy is a growing sector in Turkey, with about 10% of electricity generated from wind turbines, primarily located in the Aegean and Marmara regions. The country aims to expand wind energy capacity to nearly 30 GW by 2035, with 11 GW already installed since 2023.

Hydropower: Turkey's mountainous terrain and numerous rivers make hydropower a significant contributor, constituting about 30% of the country's electricity generation capacity. However, its output is variable, heavily dependent on rainfall, and can fluctuate significantly between wet and dry years.

Geothermal Energy: Geothermal energy plays a crucial role in Turkey, contributing 3% to electricity generation and making it the second-largest user of geothermal heating globally. Many buildings, including greenhouses and homes, utilize underground water for heating [17-20].

3.8. Renewable Energy in Kosovo:

Legislative Efforts: Kosovo has passed laws promoting the use of renewable energy sources to meet energy needs, enhance supply security, and improve environmental protection, health, and social benefits. These efforts aim to promote equal employment opportunities in the energy sector.

Current Challenges and Developments: Historically reliant on thermal power plants and energy imports, Kosovo is shifting towards renewable energy sources. However, challenges persist, particularly regarding investments in coal projects, which pose risks due to environmental and social concerns. Despite this, there is growing interest and investment in water and wind energy projects [13-15].

Wind Energy Projects: Kosovo has initiated several wind energy projects, including the Golesh Project, which faced operational issues due to aging turbines. Additionally, projects like Kika and Bajgorë aim to expand wind energy capacity, with support from international organizations such as the World Bank.

Energy Efficiency Initiatives: Efforts to improve energy efficiency, particularly in the construction sector, are underway in Kosovo, supported by projects like the Energy Efficiency and Renewable Energy Project funded by the World Bank. These initiatives aim to reduce energy consumption, decrease reliance on fossil fuels, and advance environmental policies and regulations [18-20].

3.9. Comparison and Implications:

Legislative Support: Both Turkey and Kosovo have enacted laws to promote renewable energy adoption, reflecting a global trend towards sustainability and environmental protection.

Resource Utilization: While Turkey has made significant strides in harnessing wind, solar, and geothermal resources, Kosovo is in the early stages of transitioning from traditional energy sources to renewables.

International Support: Both countries receive support from international organizations like the World Bank to advance renewable energy projects and improve energy efficiency, indicating global recognition of the importance of sustainable energy development.

Challenges: Both countries face challenges in transitioning to renewable energy, including operational issues, policy implementation, and financial constraints. Addressing these challenges requires collaboration between governments, private sector entities, and international partners [13-15].

4. CONCLUSION

This comparative analysis highlights similarities and differences in the environmental legislation of Kosovo and Turkey. Both nations have made significant strides in developing legal frameworks to address environmental challenges and promote sustainable development. While Turkey's legislation is more established, Kosovo's newer laws demonstrate a commitment to aligning with international standards. The punitive measures in both countries aim to deter environmental violations, with Turkey adopting a more extensive approach in terms of enforcement. Overall, this study provides valuable insights into the legal mechanisms for environmental protection in Kosovo and Turkey, contributing to a deeper understanding of environmental governance in these nations. While Turkey has made considerable progress in renewable energy adoption, Kosovo is at the nascent stage of its transition. However, with legislative support, international assistance, and ongoing initiatives, both countries have the potential to significantly increase their renewable energy capacity, contributing to energy security, environmental sustainability, and economic development.

REFERENCES

[1] Agjensia e Statistikave të Kosovës
[2] Albinot M. (2015) Legjislacioni i Republikës së Kosovës në fushën e mjedisit, Global Challenge, Vol. IV, No.3, 98-107.
[3] Çevre Kanunu (1983), Vol.22, No.18132
[4] Gazeta Zyrtare e Republikës së Kosovës
[5] Ligji per Mbrotjen e Mjedisit (2009), Ligji Nr.03/L-025 Prishtinë.
[6] Şükrü Ş. (2006) disscusion and evalution of mining and Environmental Laws of Turkey with Regard TO EU Legislation, Middle East Technical University, Master Thesis.
Links
[7] https://www.umad.de/infos/cleanair13/pdf/full_151.pdf
[8] https://en.wikipedia.org/wiki/Renewable_energy_in_Turkey
[9] https://uk.practicallaw.thomsonreuters.com/7-522 2040?transitionType=Default&contextData=(sc.Default)&firstPage=true#co_anchor_a248064
[10] https://konsultimet.rks-gov.net/viewConsult.php?ConsultationID=41676
[11] https://docplayer.net/52250083-Energjia-e-riperteritshme-si-shans-i-zhvillimit-ekonomik-ne-kosove.html
[12] https://kosovo.energy/opeds/sfidat-dhe-mundesite-e-energjise-se-riperteritshme-ne-kosove/
[13] https://kosovo.energy/opeds/energjia-e-ripertritshme-tregimi-qe-bashkon-ne-kosove-investitore-dhe-ndermarres-nga-e-gjithe-bota/
[14] https://www.worldbank.org/en/country/kosovo/brief/al-energy-efficiency-kosovo

[15] https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=2631
[16] https://www.academia.edu/20046363/Legjislacioni_i_Republik%C3%ABs_s%C3%AB_Kosov%C3%ABs_n%C3%AB_fush%C3%ABn_e_mjedisit
[17] https://www.google.com/search?q=T%C3%BCrkiye
[18] www.aa.com.tr/tr/gundem/cevreyi-kirletenlere-2023
[19] https://kallxo.com/gjate/ministria-e-mjedisit-me-2021-en-shqiptoi-vetem-19-gjoba-
[20] http://energjia.al/2020/03/12/kosove-142-gjoba-ne-4-muaj-per-ndotesit-e-mjedisit

Rehabilitation and Revitalization of Surface Mining Areas through the Integrated Waste Management System for Spoils and Constructions

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The territory of the Republic of Albania, as a consequence of demographic movements, welfare demands, market economy, urban development of the territory, and industrial development, has undergone significant changes, with particular importance placed on the construction sector. The utilization of natural resources in a manner that meets current needs while preserving the environment without compromising the ability of future generations to meet their own needs remains among the key challenges in environmental protection policies. Data obtained from environmental permits issued by the National Environmental Agency for the period 2014-2020 indicate that the mining sector has experienced an increase in economic operators, mainly in the field of mineral extraction (surface mining, etc.). As a result of territorial planning, there is an increase in the number of constructions permits and areas made available for residential and non-residential sectors. The development of the construction sector has been accompanied by an increase in the quantity of waste generated from demolitions and construction activities. The data published in the Environmental State Report for the year 2022 ranks this sector as the second major contributor to the amount of solid waste generated. This sector is one of the main contributors to the exploitation of natural resources, primarily in the supply of raw materials (construction minerals). If not managed according to environmental principles, the natural resources used for the extraction of construction minerals can threaten the balance and values of the natural landscape. Public authorities at central and local levels, together with economic operators in the construction field, are responsible for implementing the integrated waste management system generated from demolitions/construction efficiently. Proper management of these waste materials best satisfies the requirements for the rehabilitation and revitalization of surface mining areas, restoring their territory to a satisfactory condition.

Keywords: *Quarry, Natural Resources, Construction Sector, Waste, Rehabilitation, Revitalization.*

1. INTRODUCTION

The construction sector for the years 2019-2021, according to the monthly statistical report[i] of the Bank of Albania, ranks among the top 3 (three) key sectors of gross domestic product production according to the classification of economic activity. The development of the construction sector has been accompanied by the development of other economic sectors of the country. Both the construction sector and the manufacturing industry sector, after completing their activities, according to the current legislation for environmental protection[ii], environmental impact assessment[iii], and environmental permits[iv], have the legal obligation to preserve and rehabilitate the cultural and aesthetic values of the natural landscape to restore the activity area to a satisfactory condition, taking into account the state of the environment before the activity commenced. Environmental protection in its entirety envisages the use of natural resources in a manner that meets current needs while preserving the environment, without compromising the ability of future generations to meet their own needs.Based on the current legislation governing the mining sector [v] in the Republic of Albania and integrated waste management [vi], clear requirements are established for the rehabilitation of mining facilities and the integrated management of waste from construction and demolition.It results that from 2014 to 2020 [vii], a

total of 75 Type A environmental permits (III.1.C) and 1437 Type B environmental permits (III.1.B) have been issued, indicating that there are 318 licensed economic operators with Type B environmental permits (III.1.B) for the activity of mineral extraction (surface quarries), primarily used for the extraction of construction minerals.From the data published in the Environmental State Reports[viii] for the years 2021-2022[ix], it emerges that the construction sector ranks second as the major contributor to waste generation, mainly as a result of generating solid waste from construction and demolitions. Waste classification is carried out based on the Albanian Waste Catalog[x], which enables the categorization of waste types identified by a six-digit code, while the economic sectors and respective sub-sectors that generate these wastes are provided with two-digit and four-digit codes respectively. Waste from construction and demolition activities generated by the construction sector falls under code 17, which is further subdivided to identify the exact type of waste. The national strategy[xi] and plan[xii] for integrated management of solid waste assess that solid waste generated from construction and demolitions potentially meet the requirements, conditions, and technical standards for their reuse as material, product, or by-product for the rehabilitation of mining facilities. Optimization of all activities for the integrated management of waste from construction and demolitions for reuse in the rehabilitation and restoration of surface quarry territories, taking into account stakeholder groups, aspects of sustainable management, and the best available techniques, is carried out according to the integrated waste management system. The aim of this study is to rehabilitate and restore the territory of surface quarries used for the extraction of construction minerals through the implementation of an integrated waste management system for construction and demolition waste. This is to ensure environmental protection, balance, and the natural landscape values, as well as to return the territory to a satisfactory condition. This study provides a contribution to the development of national and local strategies and plans for waste management, which will be approved, reviewed, or modified in the future in the Republic of Albania. It sets clear objectives for the integrated management of construction and demolition waste, aiming to establish comprehensive approaches for their management.
The objectives of this study are as follows:

- To analyze the licensing process in the mineral extraction sector and the construction sector at the territorial level;
- To analyze the trend of waste generation from construction and demolition activities;
- To identify construction and demolition waste with potential for reuse in the rehabilitation and restoration of surface quarries;
- To analyze and identify techniques, requirements, and standards for the integrated management of construction and demolition waste;
- To implement an integrated waste management system for construction and demolition waste for the rehabilitation and restoration of surface quarry territories;

2. MATERIALS AND METHODS

The methodology used for the preparation of this study and the achieved results are based on contemporary methods, including qualitative and quantitative analysis.
The qualitative method used provides the opportunity for the collected and processed information to be reflected in the material in a systematic manner and to be ranked according to the importance of application, enabling readers to access accurate, comprehensive, accessible, and easily understandable information, with well-defined references.While the quantitative method used creates the possibility for the collected and processed information to be presented in the material in the form of statistics.

2.1.Collection of Information

For the information gathering process, initially, the identification of Type A and Type B licensed economic operators was conducted through the National Business Center [xiii] for the period 2014-2020. From there, the mining industry activities were identified for the extraction of minerals, sand, and clay from open-pit mines and quarries [xiv]. Meanwhile, data on the quantity of waste generated from construction and demolition for the years 2021-2022 were collected from environmental status reports [xv] published by the National Environmental Agency. All gathered information has been compiled and processed in an Excel program.

3. RESULTS AND DISCUSSION

3.1. Producing pollutive activities of Type A and B permitted through NLC for the period 2014-2020

In the following graph (Fig.1), the number of Type A and Type B licensed economic operators issued with environmental permits is presented for the period 2014 - 2020 at the national level. The highest number is for Type B economic operators with 1437 permits, while the number of Type A economic operators with permits is 75. From the data, it is evident that the highest number of Type A and Type B permits issued through the National Business Center (NBC) for the period under study is in the year 2016, with 404 Type B permits and 23 Type A permits.

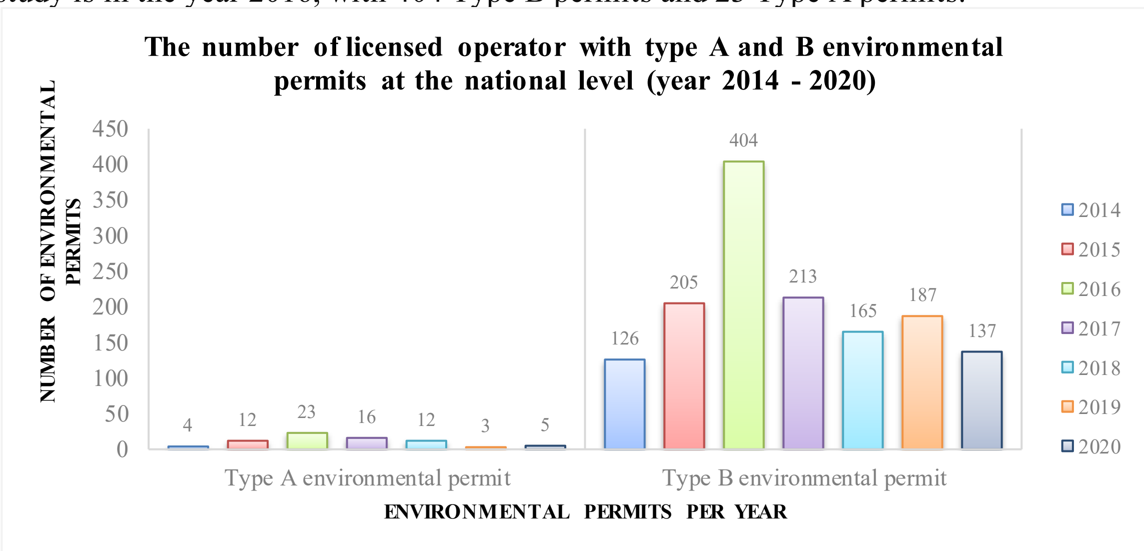

Figure 1. The number of licensed operator with type A and B environmental permits at the national level (year 2014 – 2020)

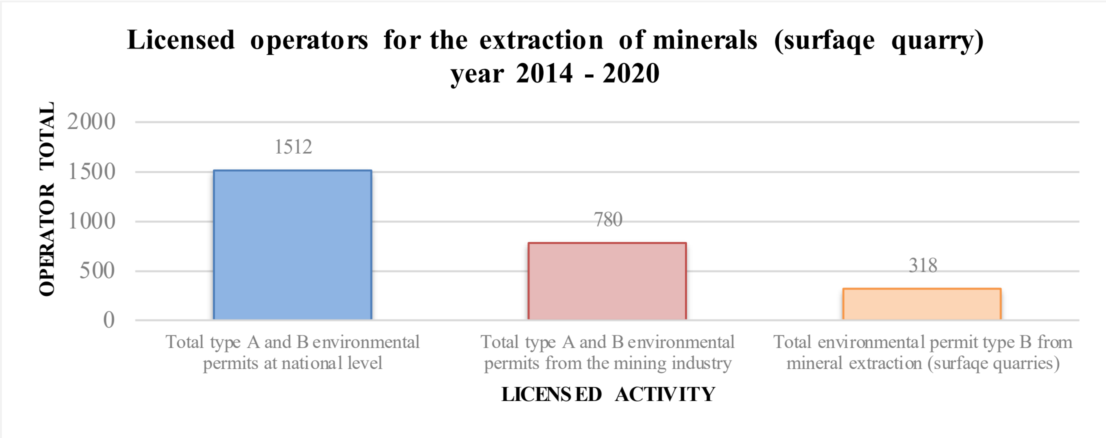

Figure 2. Licensed operator for the extraction of minerals (surface quarry) year 2014 - 2020

In the above graph (Fig. 2) for the period 2014-2020, it appears that out of a total of 1512 environmental permits approved at the national level for all industries, 780 environmental permits of type A and B have been approved for the mining industry, out of which 318 environmental permits are of type B for the activity of extracting minerals, sand, and clay from mines with open-pit exploitation and quarries (surface quarries).

Waste generation trends from construction and demolition for the period 2021-2022

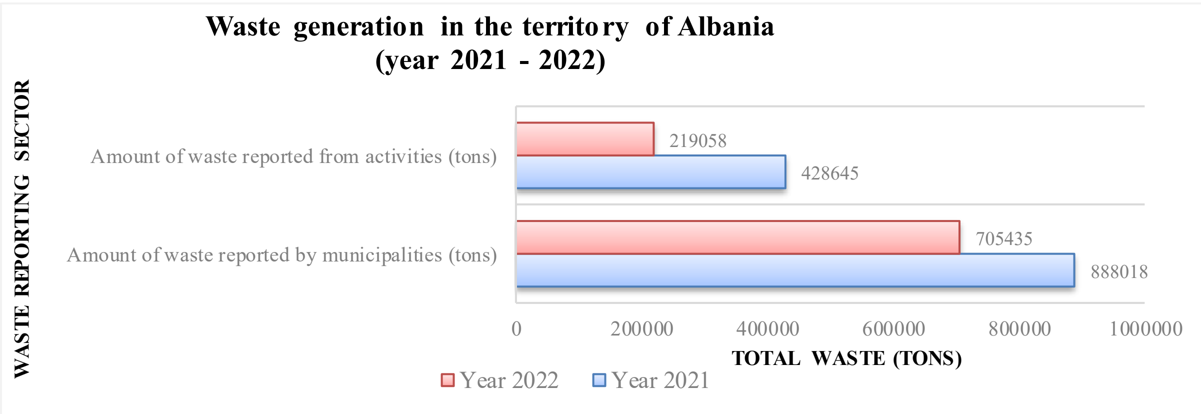

Figure 3. Waste generation in the territory of Albania (year 2021 – 2022)

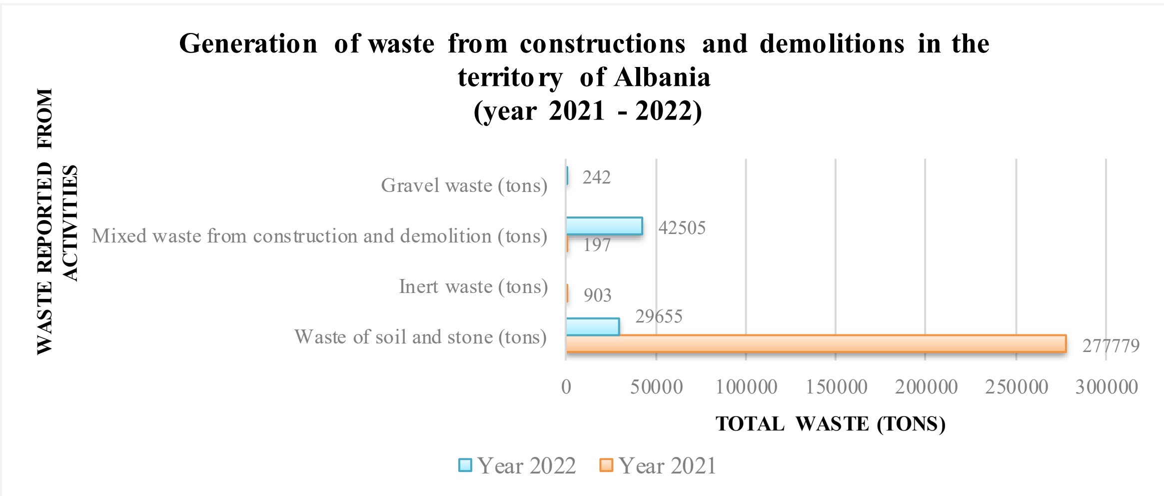

Figure 4. Generation of waste from constructions and demolitions in the territory of Albania (year 2021 – 2022)

In the above graph (Fig. 3), from the data analyzed at the national level from the reports of municipalities and activities on the total quantity of waste, it appears that from 2021 to 2022, there is a reduction in the quantity of waste. Similarly, regarding the waste generated from construction and demolition activities presented in the graph above (Fig. 4), it is evident that there is a reduction in the quantity of waste generated from 2021 to 2022. The data published on the quantity of waste generated from construction and demolition activities is linked to the trend of construction permits. Meanwhile, the reduction in the quantity of waste of rubble and stones is associated with opportunities for their reuse for filling purposes, systems, rehabilitation, etc.

The type of waste from construction and demolition that has the potential for reuse in the rehabilitation and restoration of surface quarry territory.

Based on the current legislation for integrated waste management, the main goal is:

a. Prevention and minimization of waste or reduction of negative impacts from the creation and integrated management of waste;
b. Improving the efficiency of their use;
c. Reducing overall negative impacts from resource use.

Waste generated from construction and demolition activities, according to data published by the National Environmental Agency in the Environmental Status Report for 2021 and 2022, ranks this sector as the second major contributor to the total amount of generated waste, after the urban sector. The current legislation for integrated waste management envisages several techniques and methods for prevention, reuse, recycling, recovery, and final treatment/disposal of waste generated from the construction sector. Referring to Decision no. 402, dated June 30, 2021, "Approval of the Waste Catalog," Annex 1, with code 17, we identify the economic sector of construction, thus the waste generated from construction and demolition activities, while with the six-digit code as a breakdown of code 17, we identify the specific type of waste from construction and demolition. From the waste codes of the construction sector, we identify waste with code 17 05 04 titled "Soil and stones." Waste with code 17 05 04 is generated from soil excavations as a result of construction. The techniques and methods for managing waste with code 17 05 04 - soil and stones include:

1- Using them for construction purposes in their natural state in the territory from which they were excavated;
2- By-product, when the primary purpose was not the production of waste with code 17 05 04, but it can be considered as not waste, but a by-product when it meets certain conditions;
3- As material when waste with code 17 05 04, after undergoing a recovery operation, including recycling, ceases to be waste if it meets certain conditions.

3.2. Techniques, requirements, conditions, and standards for integrated management of construction and demolition waste.

Integrated waste management is a complex activity that requires the implementation of processes or methods that do not endanger human health and do not harm the environment. Current legislation for integrated waste management envisages that waste is managed taking into account the waste hierarchy.

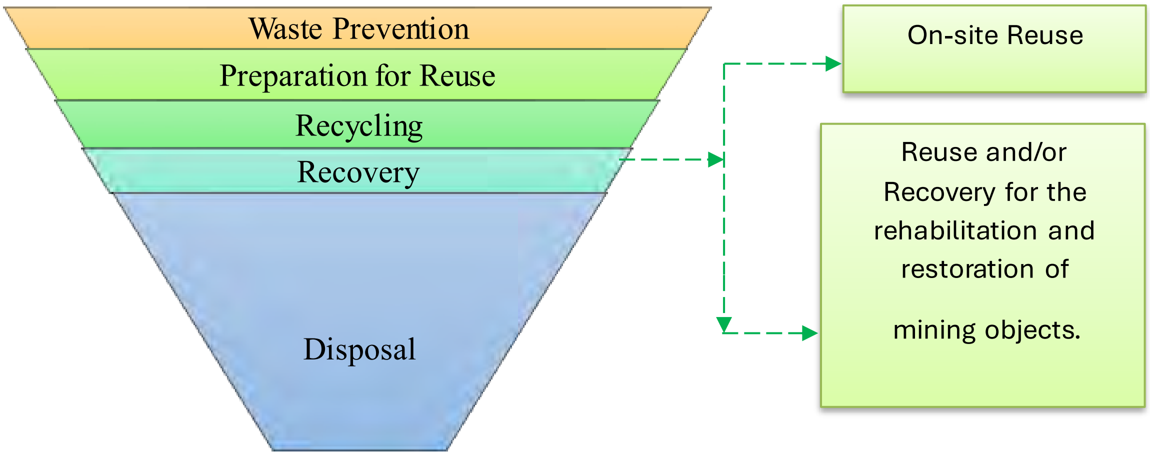

Figure 5. Waste management hierarchy and operations for reuse.

The aim of the integrated waste management system is to optimize all activities of integrated waste management, taking into consideration stakeholders, elements of integrated waste management, as well as aspects of sustainable management, to promote the best available techniques, economically feasible and socially acceptable, without degrading the environment. The system establishes means for promoting, reviewing, and setting environmental objectives and goals for the integrated management of construction and demolition waste generated as a result of excavation works during the implementation of projects for residential and non-residential urban building construction.

There are 2 (two) methods for using waste 17 05 04 - rubble and stones generated during excavation works:

First Method: The material generated as a result of excavation works during the implementation of residential and non-residential building construction projects is considered not to be waste but a by-product [xvi].

Economic operators generating waste from excavation processes (infrastructure productions) primarily aim not to generate waste from excavation processes, but to construct residential and non-residential buildings. For this reason, waste from excavation (such as debris and stones) may be considered a by-product only if they meet the conditions:

- Further use of this substance or object is ensured;
- The substance or object can be used directly without undergoing further processing beyond normal industrial practices;
- The substance or object is produced as an integral part of the production process;
- The further use of this substance or object meets the relevant technical standards for product protection and human health regarding that use and does not cause any adverse environmental or general health impacts.
- The further use of this substance or object is lawful.

The second method: The material generated as a result of excavation works during the implementation of projects for the construction of residential and non-residential urban buildings is classified as waste, but may cease to be waste when it undergoes a recovery operation, including recycling. Economic operators from construction processes (infrastructure productions) generate waste of rubble and stones, which due to technical capacities cannot undergo recovery operations. These operators must fulfill the conditions:

- The substance or object is widely used for specific purposes;
- There is a market or demand for such a substance or object;
- The substance or object meets the technical requirements for these specific purposes;

- The substance or object meets all relevant technical standards for products;
- The use of the substance or object meets all relevant requirements for environmental protection and health for that specific use and does not have negative impacts on the environment or health in general.

The restoration of mining activity territory to a satisfactory condition, taking into account the state of this territory before the activity began, is carried out by focusing on three main steps:

- Filling the quarry surface with material recovered from waste rock and gravel (17 05 04), generated from land excavation as a result of construction activities, mainly taking only the excavated part above the depth of 30-45 cm, which comes after the topsoil, with the aim of creating a stable layer;
- Filling the obtained surface with material classified as a by-product generated from land excavation as a result of construction activities, mainly taking only the upper part of the topsoil down to a depth of 30-45 cm, with the aim of creating conditions for agriculture and ecological improvement;
- Planting vegetation and trees to bind the soil structure of the quarry, creating conditions for cultivating agricultural products, and improving the ecological status of the area.

3.3. Implementation of the integrated waste management system for construction and demolition waste for the rehabilitation and restoration of surface quarry territory.

Implementation of the integrated waste management system for construction and demolition waste (rubble and stones) for the rehabilitation and restoration of surface quarry territory can be achieved through the following installations:

- Facilities for the production/fractionation of non-metallic minerals (construction minerals, rubble, and stones)
- Facilities for the recovery of non-hazardous waste (rubble and stones)

Supporting infrastructure (storage yards/facilities).

<u>The steps of the integrated waste management system are:</u>

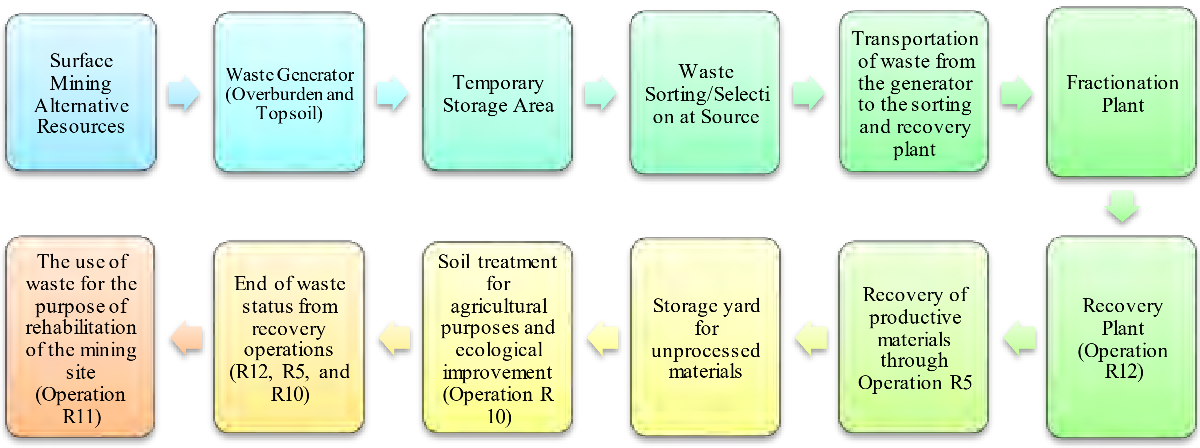

Figure 6. Steps of the integrated waste management system

<u>The phases upon which the integrated waste management system operates are:</u>

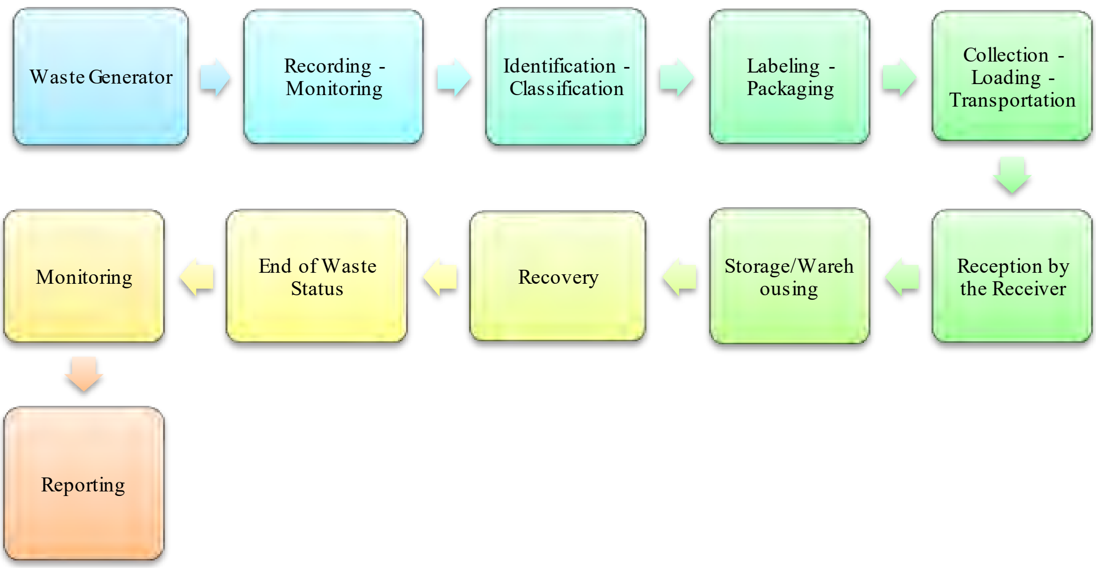

Figure 7. Stages of waste management

The Integrated Waste Management System for rubble and stone guarantees that:

- The entire management process is carried out safely
- It prevents and minimizes waste
- Enhances waste utilization efficiency
- Protects the environment and human health
- Recovers waste and prepares it for reuse and contributes positively to agriculture
- Improves the ecological landscape of the area

4. CONCLUSION

From this study, we conclude that:

- At the national level for the period 2014 - 2020, we observe a growing number of economic operators holding a Type B environmental permit for the activity of surface mineral extraction, primarily used for the extraction of minerals, sand, and clay from open-pit mines. This results in an increasing area in km2 utilized for mineral extraction
- The data reported by activities at the national level in the environmental state reports for the years 2021 and 2022 indicate large quantities of waste generated from construction and demolition activities, mainly consisting of rubble and stones, which have been collected, transported, and deposited in waste treatment areas.
- The lack of data and measurement of waste generation indicators from construction and demolition activities at the national and regional levels, according to waste treatment areas by the institution of the National Environmental Agency, makes it difficult to calculate the progress of waste generation from construction and demolition activities based on the number of approved construction permits at the national and regional levels.
- The current legislation for environmental protection and integrated waste management envisages that waste with code 17 05 04 - rubble and stones, if subjected to reuse and/or recovery operations, based on approved and proven techniques, requirements, conditions, and standards, yields very good results in meeting the requirements of the mining sector for the rehabilitation and restoration of exploited surface quarries.
- The integrated waste management system for construction and demolition waste (17 05 04 - rubble and stones) can be implemented by following simple steps through established

facilities using the best available techniques, as well as by passing through several phases of technically and legally applicable recovery operations.

- Optimizing all activities for the integrated management of construction and demolition waste (17 05 04) generated by the construction sector helps central and local authorities in drafting, approving, reviewing, or modifying national and local waste management strategies and plans. It enables the application of methods, techniques, requirements, and standards for their use in the rehabilitation and restoration of surface quarry territories.
- The implementation of an integrated waste management system for construction and demolition waste type 17 05 04 - rubble and stones ensures environmental protection as a whole, human health, the rehabilitation and restoration of the territory to a satisfactory condition, improvement of the landscape, and guarantees sustainable development of the country.

REFERENCES

[1] Monthly Statistical Report January 2024 of the Bank of Albania, real sector, chapter 4-1, NEA Rev.2 Code: A6_41-43 [Page 43]
[2] Law no. 10431, dated 9.6.2011 "On Environmental Protection", as amended, Article 3, letter "d", Article 18, and Article 50, points 1 and 4.
[3] Law no. 10440, dated 7.7.2011 "On Environmental Impact Assessment", as amended, Annexes I and II [Page 14-20].
[4] Law no. 10448, dated 14.7.2011 "On Environmental Permits", as amended
[5] Law no. 10304, dated 15.7.2010 "On the Mining Sector in the Republic of Albania", as amended
[6] Law no. 10463, dated 22.9.2011 "On Integrated Waste Management", as amended
[7] Semema K. Shkodrani N. (2022). The Impact Trends on the Environment by Industry and at the County Level for the Years 2014 – 2020. First National Scientific Conference "Application of Clean Technologies for a Sustainable Environment (ACTSE)", Albania, ISBN 978-9928-4735-2-3, pp. [153-163].
[8] Decision of the Council of Ministers no. 1189, dated 18.11.2009 "On the rules and procedures for drafting and implementing the national environmental monitoring program", Chapter IV, point 3 [Page 5]
[9] National Environmental Agency
[10] Decision of the Council of Ministers no. 402, dated 30.6.2021 "On the Approval of the Waste Catalog", Annex 1, point 3, code 17.
[11] Sectoral strategy of the national sectoral waste management plan, approved by the Decision of the National Territorial Council no. 1, dated 13.1.2020, point 8.10 Regulation of the national sectoral plan for the management of hazardous waste, approved by the Decision of the National Territorial Council no. 1, dated 13.1.2020, Article 21.
[12] qkb.gov.al/kerko/kerko-ne-regjistrin-kombetar-te-licencave-autorizimeve-dhe-lejeve/licensat-lejet-e-leshuara-nga-qkb/
[13] ID 3.7 according to Annex 1 of Law no. 52/2020 for some amendments to Law no. 10448, dated 14.7.2011 "On Environmental Permits", as amended [Page 9]
[14] akm.gov.al/raporte-dhe-publikime/
[15] Law no. 10463, dated 22.9.2011 "On Integrated Waste Management", as amended, Article 7
[16] Law no. 10463, dated 22.9.2011 "On Integrated Waste Management", as amended, Article 8.

Principles of Circular Economy as an instrument to increase the environmental responsibility of businesses.

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Climate disruptions nowadays have become a common thing, and the planet is becoming more aware of the fact that the continuous pumping of CO_2 into the atmosphere should decrease significantly to reach by 2050 the carbon neutrality target. We have extended the overuse of the planet's resources without giving proper thought to how our waste is being disposed of. At these circumstances, for the sake of people across the planet we must act now to protect and preserve our environment for this generation and be able to provide a safer and livable environment for the next ones. Environmental responsibility is our duty to protect and improve our environment. As a common understanding, being responsible toward the environment, for an individual, industry, community, or government, it means to assesses their environmental sustainability and apply this knowledge to their decision-making, through complying with the followings: i) Comply with environmental legislation; ii) Hazardous substances covered by environmental legislation; iii) Waste and recycling; iv) Conservation and biodiversity issues for businesses; v) Prevent and remedy pollution incidents. From this perspective being responsible for the environment is essential for businesses due to ethical benefits from planet protection and sustainable development, cost savings, brand reputation boosting, application innovation strategies and obtaining advantages over the competitive market. In this framework, the application of the principles of Circular Economy in a business, are becoming more and more as common understanding of being environmentally responsible. This study relates to the introduction of a practical methodology to identify and evaluate the level of recognition of businesses toward circular economy principles, how can they benefit from their application, how they can evaluate how circular and sustainable their daily activities are, and how potentially to increase their devotion toward embracing the principles.

Key words: *Circular economy principles, environmental responsibility, renewable energy sources, resources protection, water circularity, cost saving, circularity assessment.*

1. INTRODUCTION

According to the Albanian Statistics (INSTAT) [1], Albania managed about 1.1 M tons of municipal waste, of which paper and cardboard represent about 8% of total waste managed in Albania and plastic amount for about 9%. Currently, there are only seven small-scale plastic collection schemes at seven municipalities in the country, while the amount of dirty material collected by waste pickers is reported to be about 18%, mostly plastics.

There is a need for increased public awareness regarding the effects of poor waste management. Generally, there is a lack of understanding among the public about the damage causedby improper waste disposal. Rising awareness about these is crucial for garnering support and promoting positive changes in waste management practices.

Meanwhile, Albania submitted its first Nationally Determined Contribution (NDC) [2] in November 2015, with the commitment to reduce carbon dioxide (CO2) emissions compared to thebaseline scenario in 2016 and 2030 by 11.5%, or 708 kt CO_2 emission reduction in 2030. The revised NDC included data on the waste sector. The revised NDC reports that the emissions of thewaste sector amounted to 621 kt CO_2 equivalent (CO_2e) in 2009 and to 838 kt CO_2e in 2016 (+35.1%), showing little notable increase since 2009 and with a mitigation forecast until 2030 of only -1%. Albania's Fourth National Communication to UNFCCC [3] estimates that GHG emissions from the waste sector for the years 2009 to 2019 have increased by 42% from 620.90 ktCOe in 2009 to 881.56 kt CC e in 2019.

Based on Albania's National Greenhouse Gas Inventory Report [4] most of the GHG contribution from the waste sector comes from solid waste disposal of about 78% of CO_2e of the total emissions from the sector counting for 30.29 gigagrams (Gg), of methane (CH_4). Followed bythe Incineration and Open Burning of Waste of about 1.5% of CO_2e of the total emissions from thesector counting for 0.34 Gg of CH_4.

An important role is also the importance given to environmental responsibility by thebusinesses in the Republic of Albania, which executes 69.7% of total net sales in the economy whileenabling 69.9% of total investments according to the Institute of Statistics. This baseline study focuses on possibilities for implementing reuse business models in the circular economy of Albania.

2. MATERIALS AND METHODS

2.1. What is Circular Economy?

Kirchherr and Reike [5] define Circular Economy as an economic system in which various approaches are employed to reduce or overcome wastage of products, avoid product "end-of-life",close the material loops, and ensure that we will preserve the Earth's resources for future generations to come. The circular economy aims to preserve the value of products, materials, and resources for as long as possible by returning them to the product cycle at the end of their use whileminimizing the generation of waste.

2.2. What are the principles of Circular Economy?

The most widely used conceptualization of Circular Economy is likely the so-called "R" framework, of which the 3R and 6R frameworks are widely mentioned. In this research, we adopt the broader 6R framework.

Figure 1. Circular Economy Scheme

The 6-R Framework:

- Reduce
- Reuse
- Recycle
- Recover
- Redesign

- Remanufacture

2.3.What is the importance of Environmental Responsibility for Businesses?

Environmental responsibility is essential to businesses for several reasons, including ethical and practical benefits that can be divided into two categories Ethical and Practical Benefits. Overall, environmental responsibility is no longer just an ethical obligation, but a strategic business decision.By adopting sustainable practices, businesses can contribute to a healthier planet, gain competitiveadvantage, and ensure long-term success. Areas where Circular Economy Principles can be appliedin a business are:

- Use of resources
- Use of water
- Energy consumption and use of renewable resources
- The quality of the business product

2.4.The Benefits of Circular Economy Principles for business

The benefits of Environmental Responsibility for a business are divided into three main categories and not only; Reputation, Future of the Business and Environmental.

Reputation:

• Environmental responsibility goes beyond legal obligation, it is a moral and ethical obligation as well, and is rapidly spreading throughout the world.

• Businesses that produce environmentally friendly products enjoy a higher reputation amongconsumers and not only

• Businesses, which implement pro-environmental practices, will also create qualified staff,thanks to the capacities.

Future of a business:

The legislation will penalize businesses with low sensitivity and attention to the environment.The consumer will be oriented towards products/services that operate according to the rules of environmental sustainability.

• Environmentally friendly businesses will be the focus of collaborations with different donors

• Policy and financing: With an increasing number of regulations that stimulate circular EQpractices, businesses, aligning with government policies, can benefit from tax breaks, grants or subsidies. Aiming at the EU, Albania will equate its legislation with that of the EU, and environmental and pro-CE policies will be a condition for the activity, but there will also be subsidies from the relevant institutions, to support the industries to make this process easier.

• Scaled transition: By being involved as early as possible in EQ activities, the transition willbe easier and more scaled. The steps taken will be smaller, but more effective, since the benefits inCircularity will start sooner. CE pioneers will also be used as a reference for implementation in businesses that undertake these steps later, or as a consequence of legal obligations.

• Environmental protection and optimal use of natural resources: This economic model tendsto reduce impacts on natural systems and biodiversity (greenhouse gas emissions, pollution, waste) while promoting sustainable development and jobs. The population of the world is increasing, but the resources to continue life as we know it today are decreasing. According to

Global Footprint Network, 70% of the world's population lives in countries where resources are not sufficient to meettheir needs. One of the basic principles of the circular economy is the preservation and optimization of natural resources. Faced with increasing scarcity and competition for most resources, companiesthat have started applying Circular Economy will be able to take advantage of the situation.

Environment

• Reducing negative impacts to ensure a more acceptable environment for current and futuregenerations.
• Optimizing the use of resources reduces business costs, bringing concrete benefits
• Reduction of production costs: By adapting business technologies, applying EQ principles,production costs are reduced. Example; if we produce electricity with solar panels, we have clean energy production, although with an initial cost for implementation, with cost recovery in a low period and low maintenance costs, and with a high coefficient of material recycling after the life cycle.
• If materials are used as raw materials, which were generated as waste, from another industry,then its costs fall, reducing unit costs. We can also reuse the water generated by the industry, cleaning it, creating a closed cycle of water consumption.

Indicators that show how environmentally friendly a business is

• Resource productivity – how effective is the company to allocate the natural materialsextracted from the Planet
• Percentage of recyclable material used in packaging or production
• How recyclable is the manufactured product
• Percentage of recycled water used
• Percentage of recycled water discharge
• Percentage of consumption of renewable energies used
• Estimated environmental savings of rentals
• How repairable the product is
• Warranty period of their product
• Progress towards achieving objectives of the company.

2.5.Methodology

The following methodology was implemented in developing this baseline study.[6]

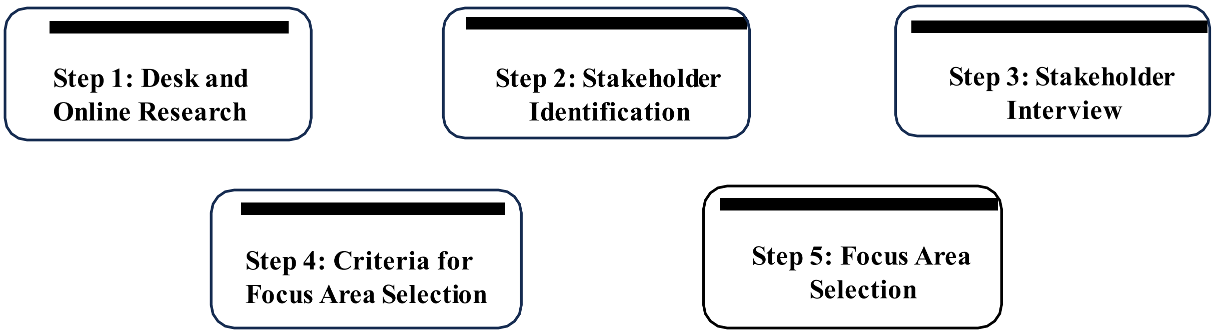

Figure 2. Methodology steps

2.5.1. Desk and Online Research

The first step in the methodology involved conducting desk and online re- search to analyze existing reuse systems and willingness in the context of Albania. This research included an examination of the current legislation and regulatory framework related to waste management andreuse. Additionally, potential businesses that have promoted their reuse systems through online channels were studied. The research was focused on sectors such as gastronomy, tourism, large- scale events or local beverage industry, retail and logistics. The potential reuse systems inagriculture sector were also considered and reviewed.

2.5.2. Stakeholder Identification and Preparation

To ensure a comprehensive analysis, a list of major cities, including Tirana, Durres, Lezha, andElbasan, was initially considered based on criteria such as population density, business activity, andpotential project impact. Subsequently, a list of major stakeholders was compiled, comprising mainnational and local government institutions, the business community, ongoing projects in the reuse sector, and relevant NGOs. The selection of stakeholders was carefully agreed upon to ensure diverse perspectives.

2.5.3. Stakeholder Interview

Interviews were conducted with the identified stakeholders and business operators to gain insights into their views, experiences, and contributions to the reuse systems in Albania. Key stakeholders included the Ministry of Tourism and Environment, Directorate for Circular Economy,Municipality of Tirana, and the General Directorate for Environmentand Sustainable Development.These interviews were crucial in understanding the existing waste prevention and reuse policy framework in the country and the commitment of authorities towards establishing a sustainable reuse framework.

The main questions (tailored based on the interview) were:

a) Are you aware of reuse concept in packaging?

b) Can you mention some products in which your business implementing this model or exist without you specifically using the model for that purpose?

c) What is the main reason you introduced the reuse models?

d) What are the key challenges you encounter in this specific business model?

e) How is the overall consumer behavior?
f) How do you find the role of the Municipality in supporting you in this respect?
g) How do you find the role of CCL in supporting you?
h) Do you implement gender policies in your business?
i) Do you face gender related barriers in running your business?

2.5.4. Criteria for Focus Area Selection

The methodology employed several criteria to determine the focus area for in-depth analysis.Factors considered included the presence of an established policy framework, the existence of innovation hubs, the level of business activity, the readiness of relevant institutions, and the consultant's expertise in the sector. Additionally, the potential for creating a sustainable impact wasalso taken into account.

2.5.5. Focus Area Selection

Based on the evaluation of the aforementioned factors, the baseline for the analysis was set to focus on the Municipality of Tirana. The decision to concentrate on this area was made due to its suitability for establishing a sustainable reuse system, supported by an already established policy framework, the presence of innovation hubs, and the municipality's commitment to a transformative waste management system.

3. RESULTS AND DISCUSSION

Inventory of existing, proven and/or functioning reuse solutions. Models of functional reuse were identified in all four dimensions of reuse models presented by the Ellen MacArthur Foundation [7].

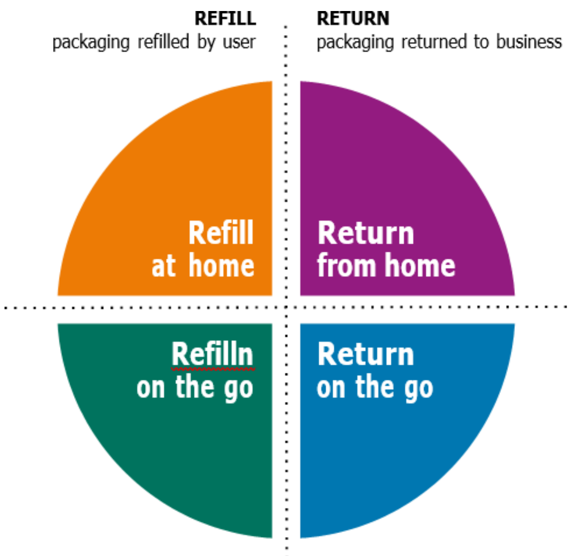

Figure 3. Models of Reuse by Ellen MacArthur Foundation

Refill at home: Refill at home is the most found model in Albania when it comes to customer level. The most common model is refill packaging in beauty, perfumes and hygiene. In this modelcustomers are provided with a shop refillable container, often in glass but also in plastic. Customerscan buy refill products which come in light packaging and in some cases with biodegradable packaging. The tendency is emerging, and more and more markets and shops provide these opportunities for their customers. It is very common in large retail supermarkets and smallneighborhood markets to find these products.

Refill on the go: Refill on the go for customers is also present in Tirana and other cities in Albania. Taking coffee or other beverages with your own containers in cafés is provided in Tirana.Another model is used by a shop chain which sell in large refill containers detergents used at home.Customers go to the shops which are located in several locations in Tirana and fill their containers which they bring from home. Additionally, the City of Tirana has also installed public drinking water taps in public spaces, which are used by citizens and visitors in the city to refill their bottles on the go.

Return from home: This model is less applicable at customer level but is more present at business level. The most common one is the water dispensers which are installed by water bottling companies at business premises based on an agreement on amount of order (quantities). Water dispensers use bigger plastic bottles up to 19L. These are replaced by the business at the office, later cleaned, sanitized, refilled, and reused for the same purpose. Return models by these companies are not widely known and less promoted for citizens. Businesses know more about it asthey are offered directly to use the service.

Return on the go: Return on the go at business level is present in small scale in Tirana although coffee on the go with your own container (refill) is very common. Some of the businessesmet during this baseline assessment operate on a small scale in services such as coffee and food service and dairy products. Under this model the customer buys the product such as yogurt in a returnable bottle, uses it at home and returns it at the market, where it is later collected by the supplier for later washing, sterilizing and refill.

4. RESULTS

At the end after this overview over the main principles of Circular Economy that might significantly affect and change the attitude of business to be more environmentally responsible within their premises and beyond are:

o*Enables the definition of a circular economy strategy* – the business understands where the weak points are in the management of resources and waste and embraces the principles of CircularEconomy to make the best allocation of resources, using innovation and technology.
o*Promotes proactive business practices* - about 67% of businesses in the world think that promoting the application of circular economy principles will attract more customers, investors andsuppliers.
o*It helps in obtaining international certifications that can also be done locally* - States quickly changed their legislation after the Paris Agreement in 2015 to penalize corporations with unsustainable business practices. Extended producer responsibility, or plastic taxes, and soon suchregulations will be widespread. Therefore, CE measurement will be a matter of legal compliance very soon.
o*Protecting the planet:* Businesses have a responsibility to minimize their negative impact on the environment, contributing to a healthier planet for future generations. This includes addressing issues such as climate change, pollution and resource depletion.
o*Sustainability:* By adopting sustainable practices, businesses contribute to the long-term sustainability of the planet and ensure that resources are available for future generations.
o*Cost savings:* Implementing environmentally friendly practices can lead to significant cost reductions. This can include reducing energy and water consumption, minimizing waste and usingsustainable materials, all leading to lower operational costs.

o*Increased brand reputation:* Consumers are increasingly aware of environmental issues and often favor businesses that demonstrate a commitment to sustainability. This can lead to improvedbrand image, customer loyalty and even attract new customers who appreciate

environmentally friendly practices.
o*Regulatory Compliance:* Businesses are subject to various environmental regulations and non-compliance can result in heavy fines and legal consequences. Taking proactive steps toward environmental responsibility ensures compliance with these regulations and avoids potential legal issues.

REFERENCES

[1] Institute of Statistics. (2021). Urban Solid Waste Reporthttps://www.instat.gov.al/media/10524/urban-solid-waste-2021_.pdf
[2] Albania Revised NDC. (2015). https://unfccc.int/sites/default/files/2022-08/Albania%20Revised%20NDC.pdf.
[3] The Fourth National Communication of Albania on Climate Change. (2022). https://unfccc.int/sites/default/files/resource/Fourth%20National%20Communication%20 of%20Albania%20to%20the%20UNFCCC_EN.pdf.
[4] Kamberi M., Islami B., Diku A., Profka D., Selfo Gj., Albania's National Greenhouse GasInventory Report. (2021). https://unfccc.int/sites/default/files/resource/National%20GHG%20Inventory%20Report% 20for%20 Albania.pdf.
[5] Engelenhoven T., Kassahun A., Tekinerdogan B., (2021) Article: Circular Business Processes in the State-of-the-Practice
[6] Cani E., (2023) Circular economy in Albania: Opportunities for reusable systems and women's participation
[7] Ellen MacArthur Foundation. (2019). Reuse – Rethinking Packaging.

Green Buildings

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In the context of our rapidly evolving world, the escalation of environmental pollution underscores the growing significance of green buildings. This study explores the multifaceted benefits of green buildings, encompassing economic advantages, sustainability, and ecosystem protection. Economically, green buildings are identified as favorable due to their efficient use of resources, cost-effectiveness, and sustainable construction materials. From a sustainability perspective, these structures emphasize optimal site planning and waste management, contributing to environmental conservation. Furthermore, green buildings play a crucial role in safeguarding the ecosystem by mitigating habitat destruction and supporting biodiversity, addressing the urgent need for environmental protection. Comprehensive research validates the pivotal role of green buildings in securing a sustainable future, predicting a surge in their integration within the construction industry. This necessitates the advancement of construction technologies and an acceleration of construction firms' efforts towards green building projects. Additionally, the paper highlights the importance of enhancing public awareness regarding sustainable practices. It advocates for a collaborative approach among engineers and architects to meticulously plan green projects, ensuring the maintenance of ecosystem balance. This study concludes that green buildings are essential for a sustainable future, recommending a concerted effort towards their development and widespread adoption.

Keywords: *Sustainability, Construction, Green, Ecosystem, Economic, Future.*

1. INTRODUCTION

Buildings have been one of the fastest growing industries for a long time, and these days, with the improvement of technology, more advanced buildings are being built, which consume a lot of energy, natural materials, and water and cause pollution. As a consequence, sustainable buildings should be normalized to provide comfort to nature and human beings. The concept of sustainable buildings started with the "back to nature" movement, which started in 1960 and has improved since 1970 to include office buildings that conserve energy. One of the most concerning aspects is economic development, as most, if not all, companies care most about the profit, as they choose the materials and plan the project according to the profit.
As a result, companies should follow the green economy criteria. In addition to using recyclable materials and efficiently planning the project, sustainably can decrease the cost of the project construction and help save the environment. Moving on to the construction process, which is the most important process, the company should be careful while deconstructing the old building to use the maximum possible amount of the old material and prepare the site wisely. Moreover, to highly consider waste management as waste causes pollution and consumes so much water. For example, with the high consumption of energy these days, buildings should be planned to save energy. One example would be to provide natural ventilation instead of air conditioners. Green buildings have a great role in protecting the ecosystem as they increase biodiversity, creating ecological and climate balance. It’s important to limit the natural harm that is caused by human activity. Therefore, people should be educated about the importance of the ecosystem and nature and how to sustainably deal

with it by recycling the material instead of dumping it. While shaping the future, sustainable buildings should be given more space in our lives due to their economic aspect, sustainability, and protection of the ecosystem.

2. EXISTING SITUATION OF MATERIALS, CONSTRUCTION AND DEVELOPMENT

2.1.Economic development and sustainability

Firstly, development is one of the most important priorities of all living things, so it is essential to improve in order to increase the comfort of life and to catch up with the rapidly developing age. The most logical way to catch up with the era in the 21st century is to cause the least environmental damage and to earn the most financial profit, and therefore, many sectors are trying to develop. At first glance, development and the economy seem to be very different things, but the impact of the economy on development is greater than expected. The construction industry has realized this importance by making sustainable buildings its primary goals. Regional economic development is one of the most important features targeted in the construction sector. Therefore, it is very important for the construction industry. For example, as Tıkansak (as cited in DergiPark) stated thanks to sustainable buildings in the construction sector, regional economic development occurs in many regions.
In terms of the use of construction materials, which are green industry products, in accordance with the green economy criteria, and the active use of the energy consumed in these buildings, the construction sector meets the sustainable economic growth criteria in this direction (2018, p.314). In this way, living things do not have to live with an obstacle. Sustainable buildings contribute to regional economic development and provide great convenience to the people who will live in the building. Thanks to sustainable buildings, regional economic development benefits many people and the environment. The development based on the increase in the profit rate of the construction company also causes an increase in the financial earnings of the construction sector.
Most companies are not very positive about doing the project unless they can increase the profit rate. Construction companies achieve the development based on the increase in the profit rate mostly by using sustainable buildings. For example, as Tıkansak (as cited in DergiPark) stated in particular, by determining the future of the construction sector, the main trends in the development based on the increase in the profit rate of the company in the sector, which are the main trends, were focused on the 5 construction of buildings with high energy efficiency (2018, p.325) In this direction, social and environmental responsibilities to business are loaded. For example, as Karademir (as cited in DergiPark) stated in the construction sector, as they cause high energy consumption in the World, companies are among the businesses that undertake these responsibilities (2021 p.64). In this direction, the world began to realize the harms of energy consumption to the economy, and it was obvious that some sectors should take responsibility, as a result, the construction sector started to build sustainable buildings.
As a result, the construction industry is increasing the importance it attaches to the construction of sustainable buildings, taking into account the contribution of regional economic development and increase in company rates to the economy. One of the extremely important issues is increasing sustainable buildings while shaping the future. First of all, these important effects of sustainable buildings show their visibility as causing the most economic development. One catastrophic event worth mentioning is the economic crisis in the construction industry, directly caused by rising construction costs. The construction of unsustainable buildings undeniably brings with it the economic crisis in the construction

industry. The more recyclable products are used in buildings, the more cost is reduced. In the end, the use of recyclable materials will result in less waste and then getting the job done at less cost. For example, as İpekçi (as cited in DergiPark) stated, these recycled building materials/components not only add ecological value to the building they are used in but also provide economic benefits and affect environmental and structural sustainability (2017, p.43). Based on this information and considering the directly proportional relationship between the use of recycled products in buildings, the reduction in environmental damage and economic profit, the increase in the number of sustainable buildings may eventually lead to an increase in the contribution rates to the environment and the economy. The increase in the use of these recyclable products will 6 have positive consequences for the natural environment and the economy in the construction sector. For example, as Karadayı (as cited in DergiPark) stated, considering that approximately 10% of the environmental impacts that occur during the life of a building are caused by the building materials used, the importance of building material selection comes to the fore (2017, p.44).

This dataset clearly demonstrates the positive results of using recyclable materials in these structures. In order to minimize the economic problems in the construction sector, it is necessary to take action and make conscious decisions. Another important factor worth mentioning in the economic contribution of sustainable buildings to the construction sector is the selection of settlements at a sustainable cost. Since the choice of settlement to be built in the construction sector leads to an increase in economic crises, the choice of settlement should be suitable for sustainability and therefore at a low cost due to this problem. In the end, the selection of sustainable settlements, which eliminates the economic distress, will result in comfort and efficiency for sustainable buildings.

For example, as Tosun (as cited in DergiPark) stated, sustainable urban planning, energy, environmental opportunities, transportation, etc. of the land. It aims at a mixed-use approach that aims to use it effectively in line with the (2013, p.32). From a more regional point of view, the importance of settlements suitable for sustainability was mentioned once again and what is the purpose of researching the targets in the direction of progress. turned out to be just as effective. One way to prevent many problems that will arise in this way is to find solutions for the selection of settlements in a sustainable economy. As a result, sustainable buildings should be given more place in our lives due to their economic aspect, sustainability, and protection of the ecosystem. Secondly, while supporting sustainability, the construction field has a major role that can be achieved by preparing the site properly and managing the materials wisely to construct with as minimal waste as possible. First, preparing the site is one of the most important stages 7 that needs to be done effectively, as this process also affects the future of buildings by preventing the excessive use of the environment.

To achieve sustainability during building, the Structure Approach should be followed, which consists of nine stages starting with Briefing. It is a critical stage in which stakeholders are guided about sustainability, which is presented explicitly. The briefing also highly affects the decisions that are taken in the following three stages: target settings, designing, and design development. Gibberd stated that during and after the process of design development, it's crucial to prepare and train a suitable team for the project, which will achieve sustainability with high-performance levels. At the end of the process, it is suggested by the structure approach that a user manual should be handed, so while deconstructing, the building is refurbished and reused, and if it is not possible, as much of the building as possible should be recycled or reused (2002). As with everything in the world, the foundation is the most important step because if it is built incorrectly, everything will fall later, which is why the construction process should be carefully planned. Second, materials should be chosen wisely to provide sustainability as well as comfort for the user, but more importantly, old ones should be reused to conserve natural resources, as they consume tons of sand and natural rocks globally.

2.2.Green materials, sustainable construction and waste management.

For instance, concrete is a material that is used in the majority, if not all, of construction sites. According to one study each year, approximately 11 billion tons of construction and demolition waste are recorded. However, the concrete recycling industry has emerged as a key strategy for meeting today's demands for sustainable development (Jin et al., 2015, pp. 894–895). In addition to glass, which is one of the most used materials not only in building structures but also in interior equipment such as light bulbs, crystals, and focal lenses. Spite the fact that glass can be recycled endlessly without losing its quality, some countries still have glass waste, like Nigeria. Moreover, glass waste can also be used in concrete aggregation and cement mixture (Ogundairo et al., 2019).

Nowadays, technology is improving every day, if not every minute, 8 and recycling should have priority over the development of new advanced materials. Finally, when it comes to sustainable building development, the construction process is regarded as the most important. It has a number of stages that must be precisely followed in order to achieve these developments with the least amount of waste produced. As well, recycling building materials has become one of the most important issues in modern times in order to preserve nature as much as possible. Moving on, sustainability greatly protects the environment in a variety of ways, including waste management and energy conservation.

Consider waste management, for example, as it greatly aids in the protection of the environment from climate change and pollution. Amaral stated that one of the most common mistakes that contribute to waste is a lack of design by architects. They should offer waste management solutions because poor decisions can result in a large amount of waste, and they should educate clients about the environmental benefits. Based on the United Nations Educational, Scientific, and Cultural Organization, 33 percent of the global population lacks a reliable source of drinking water, which is caused by excessive water pollution, as buildings withdraw approximately 12 percent of freshwater in the United States alone (2020). Given the current state of the world, waste management must be approached with caution, as it has a significant impact on both the environment and human beings.

Moving on to energy conservation, which helps to create a healthier environment by conserving natural resources and reducing pollution. Regarding the growth in the population, cities, and industries, and the desire for high standard of livings nowadays, a huge amount of energy is being consumed affecting climate change and increasing pollution. Litardo explained that buildings in European Union member countries consume 40% of total final energy and emit 36% of carbon. Furthermore, buildings consume 60% of the world's electricity, and this percentage has been increasing over time (2021). Artificial ventilation, for instance, which is used to provide indoor thermal comfort and 9 artificial lighting, consumes a significant amount of energy, particularly in the educational building sector, which can be solved by designing thermal isolation walls and providing better natural ventilation solutions.

Green roofed buildings are one of the best solutions for lowering indoor temperatures by half in the summer and isolating them from cool weather in the winter besides absorbing air dust and carbon and replacing it with oxygen. Another solution is to install electrical shades on the windows to block out summer sunlight while allowing in winter sunlight; this process reduces the use of air conditioning by 12 percent (Ma et al., 2021, pp. 807-808). There are numerous green ways to save energy, particularly electricity. Industries, as well as individuals, should participate in solving this issue. In conclusion, saving the environment has become one of the most critical issues discussed as the world improves on a daily basis, resulting in increased consumption of energy and natural resources. Some solutions have been provided, such as waste management through proper design, construction, and usage plans, as well as energy conservation through space design based on the surrounding conditions.

3. RESULTS AND DISCUSSION

Finally, an ecosystem is a continuous ecological system that consists of the interactions of living and non-living things in a certain section. One of the major responsibilities is protecting this ecological system, which includes humans as well. Every wrongdoing committed in place of safeguarding this ecosystem is a great wrong for humans as well as for other living organisms. These evils also include the structures that are built.

Sustainable building is one of the most crucial strategies to stop this method and safeguard the ecosystem. The protection and support of plants and biodiversity in our ecosystem's natural portion is one of the few mainly associated that sustainable buildings do for it. Numerous studies on special species have suggested that the increase in green areas substantially affects biodiversity. For instance, as Dr. Aronson (as cited in BBC News) stated, in comparison to undeveloped land, cities have only 8% of the bird species and 25% of the plant species (2014, 10 para.6). Based on this research, it is of great importance that the city settlements are smooth and the building structures are suitable for the environment. Green buildings are important in this urbanization because they offer advantages like water efficiency and energy savings. The building structure in settlements affects all other vital activities both naturally and humanly.

Factors affecting biodiversity, according to the World Conservation Union (as cited in Selim & Mutlu) include habitat loss and fragmentation, invasive foreign species, pollution, climate change, overuse, and rapid population growth (2013). The significance of sustainable buildings at this point emerges in terms of both supporting biodiversity and reducing ecological problems caused by climate change, which, as previously stated, is one of the factors affecting biodiversity. Cities and climate change have a symbiotic relationship. The reciprocal relationship prevents us from considering two phenomena separately. Therefore, climate change and biodiversity are considered as two intertwined phenomena. Climate change is one of the biggest problems of our developing world. A lot of research has been done on this subject and it has been proven that the effects of people's actions on climate change. For example, as United Nations Framework Convention on Climate Change (as cited in Özçuhadar) stated, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), the greenhouse gases that cause climate change, are thought to contribute 50%, 18%, and 6%, respectively, to the global warming effect brought on by human activity (2007, p.1).

According to this study, human-made structures like roads, bridges, and buildings play a significant influence in contributing to climate change. Green energy and sustainable construction should be favoured to stop this in order to lower gas emissions and create a more liveable planet. As a result, green buildings reduce vegetation, biodiversity, and the negative effects of climate change while also making the world more liveable.

There are human factors in addition to natural factors that affect ecosystem protection. These human elements also include the resources that people rapidly deplete. One 11 of the crucial issues we need to solve to protect the ecosystem is rapid resource consumption, which is particularly prevalent in the building sector. For the sake of future generations and resources that may become depleted, it is crucial to limit the harm that human activity causes to the environment and natural resources. As Tsoi et al. (as cited in Özçuhadar) stated, construction

and demolition wastes make up 48% of all solid wastes buried in the ground, according to a 2002 study on construction sector waste done in Hong Kong (2007, p. 5). Based on this study, it is seen that the fundamental changes to be made in the field of construction have great importance in resource consumption. At this point, green buildings, the new rising star of the construction industry, have an important mission. Because green buildings may effectively manage resources in this way by supplying the building's energy requirements from systemized facilities that utilize renewable natural resources. Resource management in green buildings minimizes consumption and is anticipated to be favored in new constructions because its goal is to provide the most benefit with the least resource consumption. As Mintlab stated, recycled materials make up 80% of concrete, brick, and insulating materials, 79 % of aluminum, 65 % of steel, and 21 % of glass. Buildings use renewable energy sources like the sun and wind to generate the energy they require (2021). Green buildings, as opposed to conventional ones, are extremely important for conserving our resources because they aim to maintain resource recycling at the highest level, provide safe and usable conditions, make waste usable, avoid environmental pollution by choosing renewable materials, and avoid risking consumable ones. On the other hand, one of the greatest harms that humans and the building industry do to the ecosystem, aside from depleting its resources, is the harm that they inflict on the environment and our energy sources. The features such as the materials used in the general buildings, the harmful gasses released after the energy, and the water consumption are the biggest proofs that the construction of traditional buildings should be reduced. According to USGBC (as quoted in 12 Ba Alawi) in comparison to other sectors, CO2 emissions from buildings will rise at a pace of 1.8 percent per year over the next 25 years (2021, p.7). In line with this estimation, it is possible to say that the importance and construction of green buildings will increase. As mentioned above, the construction industry and its activities cover a significant part of CO2 emissions and continue to increase this part. For instance, as Japan for Sustainability (as cited in Özçuhadar) noted, the building industry contributes 40% of Japan's 1.3 billion tons of annual CO2 emissions.
Transportation accounts for about 9 percent of total costs, followed by energy and ventilation (11.5 percent) and household operations (cooking, heating, etc.) at 13 percent. Buildings have the ability to cut CO2 emissions by up to 40%, according to studies (2007, p. 5). This circumstance has the potential to both expand the problem and evolve in a way that is solution-focused with the new structures to be added to the old building blocks. Given this situation, the keyword to reduce is now sustainable buildings. Green buildings stand out from typical structures in numerous studies and comparisons because they use less water, and energy, and cause less damage. For instance, Erten (cited in source Kılıç & Erikli) pointed out that research on green buildings is 33 - 39 % in CO2 emissions, 24 - 50 % in energy use, and 30 - 50 % in water consumption, compared to average structures created with standard methods. demonstrates that it may cut down on solid waste generation by 70% and maintenance expenditures by 13% (2021, p. 263). According to these findings and observations, increasing the development of green buildings should be the top priority in the near future. As a result, protecting the ecosystem in which we exist is a responsibility shared by all living things, especially because humans are the ones who cause the most damage. To exhaust the resources impacted by human causes and lessen environmental harm, action must be performed as soon as possible. All things considered, protecting the ecosystem in which we exist is a responsibility shared by all living things, especially because humans are the ones 13 who cause the most damage. To exhaust the resources impacted by human causes and lessen environmental harm, action must be performed as soon as possible.

4. CONCLUSION

As a result of these studies, in our ever-advancing and developing world, the environment is getting polluted and the importance of green buildings is increasing. Various positive aspects of green buildings are revealed when they are considered from different issues such as economics, sustainability and protection of the ecosystem. First of all, when the economy is considered, green buildings have proven to be economically preferable for different reasons such as development, cost and materials used in the construction of green buildings. On the other hand, when looking at sustainability, the preparation of the settlement is important in terms of construction and waste management is important in terms of the environment. These points are also taken into consideration in the construction of green buildings in the most proper way. Finally, since the importance of protecting the ecosystem is increasing day by day, we must protect our world in terms of natural and human aspects. Green buildings, which prevent ongoing destruction and rapid resource consumption, also contribute to biodiversity. Considering all these reasons, a lot of research supports that green buildings have an important role for our future. It is predicted that the construction of green buildings in the construction sector will increase rapidly. Therefore, the technologies to be used in the construction of these buildings should be developed and construction companies should accelerate their efforts in this direction. Another important topic is to raise awareness of people day by day. Incidentally, in order to maintain ecosystem balance in the future, it is recommended that both engineers and architects plan well for green projects.

REFERENCES

[1] Amaral, R. E., Brito, J., Buckman, M., Drake, E., Ilatova, E., Rice, P., ... & Abraham, Y. S.
[2] (2020). Waste management and operational energy for sustainable buildings: a review. Sustainability, 12(13), 5337. https://www.sciencedirect.com/science/article/pii/S1876610216302004
[3] Aronson, E. (2014). Kentlerdeki yeşil alanlar biyoçeşitliliği artıracak [Green spaces in cities will increase biodiversity]. https://www.bbc.com/turkce/haberler/2014/02/140212_kentlesme_biyocesitlilik.amp
[4] Baalawı, M.S.O. (2021). Yeşil binaların kriterleri ve değerlendirme sistemlerine genel bir bakış [An overview of the criteria and rating systems for green buildings]. https://openaccess.mef.edu.tr/bitstream/handle/20.500.11779/1691/FBE_%C4%B0%C5%9FaatProjeY%C3%B6netimi_MohammedSharifOmar.pdf?sequence=1&isAllowed=y
[5] Boyle, E. (2005). Proceedings of the institution of civil engineers engineering sustainability. https://www.icevirtuallibrary.com/doi/abs/10.1680/ensu.2005.158.1.41
[6] Gibberd, J. (2002, May). The sustainable building assessment tool assessing how buildings can support sustainability in developing countries. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.197.7550&rep=rep1&tye=pdf
[7] İpekçi, C., Tıkansak, K. & Coşkun, N. (2017) İnşaat sektöründe geri kazanılmış malzeme kullanımının sürdürülebilirlik açısından önemi [The importance of using recycled materials in the construction industry in terms of sustainability]. https://dergipark.org.tr/en/pub/tubav/issue/27937/31823715

[8] Jin, R., & Chen, Q. (2015). Investigation of concrete recycling in the US construction industry. Procedia Engineering, 118, 894-901. https://www.sciencedirect.com/science/article/pii/S1877705815021839
[9] Karademir, A. (2021). Sürdürülebilirlik uygulaması olarak yeşil bina ve LEED sertifikasyonu üzerine Türkiye'de inşaat sektöründe bir çalışma [A study in the construction industry in Turkey on green building and LEED certification as a sustainability practice]. https://dergipark.org.tr/tr/pub/adibd/issue/60270/948527
[10] Karakurt, E. (2021). Sürdürülebilir kentsel gelişim sürecinde kompakt kent modelinin analizi [The analysis of compact city model in the process of sustainable urban development]. https://dergipark.org.tr/tr/download/article-file/146112
[11] Kılıç, M. & Erikli, M. (2021). Yeşil bina kullanımının önemi ve Türkiye'de yeşil bina kullanımı [Importance of green building use and green building use in Turkey]. http://www.adjournal.net/articles/93/9320.pdf
[12] Ogundairo, T. O., Adegoke, D. D., Akinwumi, I. I., & Olofinnade, O. M. (2019, November).
[13] Sustainable use of recycled waste glass as an alternative material for building construction–A review. In IOP Conference Series: Materials Science and Engineering (Vol. 640, No. 1, p. 012073). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/640/1/012073/meta
[14] Özçuhadar, T. (2007). Sürdürülebilir çevre için enerji etkin tasarımın yaşam döngüsü sürecinde incelenmesi [Investigation of Energy Efficient Design for Sustainable Environment in the Life Cycle Process]. https://polen.itu.edu.tr/items/1b51ebc5-11e9-4982-852f-d02afdf95f9e
[15] Selim, C. & Sever, M. (2015). Kentsel alanlarda biyolojik çeşitliliğin sürdürülebilirliği ve koruma yaklaşımları [Sustainability of Biological Diversity in Urban Areas and Conservation Approaches]. https://www.google.com/url?sa=t&source=web&rct=j&url=https://derleme.gen.tr/index.php/derleme/article/download/267/265&ved=2ahUKEwip_eel35v5AhXKQPEHbDJCvM4HhAWegQIHRAB&usg=AOvVaw0kg3m-PGvJQuG_zw9Srs2H

Sustainable Solutions
Exploring Eco-Friendly Building Materials

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As our planet faces environmental challenges, it's important to find ways to build homes and buildings without harming the Earth. Traditional materials like concrete and steel are harmful because they use a lot of energy and resources to make. In contrast, eco-friendly alternatives involve a wide array of materials, including recycled, renewable, and low-impact options. Recycled materials, like r wood, steel, and glass, offer the benefits of waste reduction and resource protection. Renewable materials, such as bamboo, straw bales, and cork, are sourced from renewable natural sources, reducing dependence on non-renewable resources. Additionally, low-impact materials prioritize energy efficiency and minimal environmental impact throughout their lifecycle. To make eco-friendly materials more popular, architects, builders, and governments need to collaborate. They can implement rules and promote the use of these materials in construction. Additionally, educating people about the benefits of eco-friendly buildings can help generate demand for them. In conclusion, using eco-friendly building materials is a big step forward in protecting the environment. By making smart choices, we can build a greener future for everyone.

Keywords: *Environment, Eco-friendly materials, Recycle, Renewable, Construction.*

1. INTRODUCTION

In this paper, we're diving into the world of environmentally friendly materials used for building. Imagine a world where buildings not only serve our needs but also protect our planet. That's what we're exploring—how to construct homes, offices, and structures in a way that's kind to the environment. As previously known the challenges for building a safe and sustainable environment are constantly rising due to the consequences of climate change.[1] The growing frequency and severity of natural disasters call for smart solutions. Future-proof construction is therefore no longer a decision, but a necessity. High-performance material solutions are essential for the construction of long-lasting and safe structures. In the contemporary landscape of construction and infrastructure development, the importance of sustainability has emerged as a central guiding principle. With environmental concerns mounting and the need for responsible resource management becoming increasingly apparent, the quest for eco-friendly building materials has gained unprecedented traction. In 2019 alone, the building construction industry was responsible for 38% of global $CO2$ emissions, recording almost 10 gigatonnes. [2] As if that has not caused enough damage, the construction industry has relied on non-renewable resources for products that are also environmentally toxic. Through this exploration, we aim to present sustainable solutions that not only minimize ecological footprints but also promote, harmonious built environments.

2. MATERIALS AND METHODS

2.1 The environmental impact of construction

First of all, to find a solution and promote eco-friendly building materials, we need to discuss about the condition in which our planet is because of construction and its importance nowadays. Construction is an essential part of human development, providing infrastructure for communities, homes for individuals, and spaces for commerce.

However, this progress comes at a cost, because as we all know the construction sector is considered worldwide as one of the main sources of environmental pollution, as it produces enormous negative effects on the environment either directly or indirectly throughout the life cycle of development. These impacts occur from initial work on-site through the construction period, operational period and to the final demolition when a building comes to an end of its life. [1] During construction, significant energy consumption occurs, primarily from machinery operation and building material production. This energy often comes from non-renewable sources, leading to greenhouse gas emissions and climate change. [3]

Additionally, Construction is expected to cause damage to the fragile environment due to adverse impacts of construction, including resource depletion, loss of biological diversity due to extraction of raw materials, waste dumping, lower productivity work, adverse effects on human health due to poor indoor air quality, global warming, acid rain and smog caused by emissions generated by the manufacturing of energy-consuming construction and transportation products. [4]

Moreover, the transportation of these materials to construction sites contributes to carbon emissions, air pollution, and traffic congestion. According to some studies, construction is responsible for up to 50% of climate change. It also impacts landfills and air, water, and noise pollution. [5] The construction sector contributes to 23% of air pollution, 50% of the climatic change, 40% of drinking water pollution, and 50% of landfill wastes. In separate research, the construction industry accounts for 40% of worldwide energy usage, with estimations that by 2030 emissions from commercial buildings will grow by 1.8%.[6] in the different climatic and geological conditions, animal species are established that adapt to the specific conditions of the different sites where construction projects are developed.

Also, in thinking about how construction impacts fauna, the most representative phenomenon is, precisely, the migration of animal species and therefore, the impact on the ecosystem. [7] Likewise, the operation and transit of vehicles and heavy machinery, by generating significant levels of noise, scare away some species such as mammals and birds. It means, then, that the fauna, as well as the flora, is susceptible to modifications that can alter its life partially or totally. [7]

In discussion of environmental impact of construction, we can not leave without mentioning the materials that are the "cell" of construction. Materials used in construction projects have a huge importance because they determine the characteristics of the project, requirements and type of maintenance required. The variety of raw materials used is quite extensive and with the passage of time and technological advances, compounds have been developed that respond to the changing needs of the industry. They serve as the very fabric upon which construction projects are built, providing structural support, insulation, and aesthetic appeal. Wood, cement, aggregates, metals, bricks, concrete, clay are the most common type of building material used in construction. The choice of these are based on their cost effectiveness for building projects. [8] Depending on the fact that building materials are used in large quantities, so they must come from abundant, inexpensive raw materials. Many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings.

Generally, stone and brush are used as basic structural components in these buildings, while mud is used to fill the space between them to act as a type of concrete and insulation. [9] Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. [10] The manufacture of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades. Moreover, construction materials can be generally categorized into two sources, natural and synthetic. Mixing these materials together are created other building materials that are used in construction, such as concrete that is a material widely used in composite construction projects made from the combination of aggregate and a binder such as cement. [11]

2.2 How was the necessity for eco-friendly building materials born?

Faced with the need to give society greater spaces for housing, commerce and recreation, the construction industry showed considerable growth. However, negative effects also appeared such as the emission of toxic substances and the indiscriminate use of natural resources. The above began to raise red flags in society in the 1970s, especially when the oil crisis of 1973 made people think about how necessary it was to save energy through the moderate use of fossil fuels such as gas and coal. [12]
A decade later the term "Going Green" and "Sustainability" appeared and became new buzzwords in most industries, which establishes the need to think about the resources that future generations would need to survive.[13] The necessity for eco-friendly building materials emerged due to increasing awareness of environmental issues, such as climate change, pollution, and resource depletion.
As societies realized the negative impact of traditional construction materials and practices on the environment, there was a growing demand for sustainable alternatives that reduce carbon emissions, conserve natural resources, and promote healthier living environments. This began a gradual change that currently involves not only architecture and urban planning, but also civil society and governments. This led to the development of eco-friendly building materials that prioritize renewable resources, energy efficiency, and minimal environmental impact throughout their lifecycle and promote biodiversity.
As consumers, developers, and policymakers, we all have a role to play in promoting the use of sustainable materials in construction and creating a more sustainable future. [13]

2.3 But how do we define a 'sustainable' material, and which are their benefits?

Sustainable materials are described as items that are produced and used by humans in an environmentally responsible way. They can be produced in the necessary quantities throughout consumer and industrial economies without depleting non-renewable resources or upsetting the environments and major natural resource systems established steady-state balance.[14] To put it simply, sustainable materials are typically made from renewable resources and can be recycled into other items, thus reducing waste processes and preserving the environment.

1.Cork

Often associated with wine stoppers and bulletin boards, cork can actually be used as a construction material. Its many sustainable features are still unknown to many. The cork we use comes from cork oak trees, which can survive for around 200 years. During its lifespan, a tree can produce some hundred kilograms of cork, making it one of the most renewable sources. Stripped from the tree barks, it is then processed to produce the cork to be made into boards or stoppers. Nowadays, architects are showing interest in this material as it is recyclable, water resistant, lightweight and thermally efficient. [2]

2.Recycled steel

Steel, one of the most widely recycled materials, plays a crucial role in reducing environmental impact. processing discarded steel products and scrap and melting them down to create new steel. This process consumes significantly less energy and reduces the need for mining and refining iron ore. Recycled steel not only saves resources but also decreases greenhouse gas emissions and other pollutants associated with steel production. [15]

3.Recycled or Reclaimed wood

You can't go wrong with wood; it is easy to use, especially with proper care, and with the right aesthetic can make for some rather pleasing architectural elements. But how do we make its use sustainable? With proper management, wood can be a renewable resource. However, we must ensure not to rely on new wood or our usage can overtake its growth rate. One easy solution is to recycle reclaimed wood. We can already see this practice with upcycled furniture. By recycling wood, we can lower deforestation and indirectly promote biodiversity and carbon capture. [2]

4.Bamboo

A popular material for both architecture and industrial design, bamboo has been used for construction as a sustainable building material by many architects.Its fast growth rate and abundance make it an environmentally and economically sustainable material. In fact, bamboo is known to be one of the fastest-growing plants in the world. It is also lightweight and flexible to shape with the proper technique. Combined with computational means, bamboo can be used to construct strong and stunning structures.

5.Hempcrete

Hempcrete stands as a remarkable bio-composite building material that embodies sustainability, performance, and environmental responsibility. With its exceptional insulating properties, breathability, and carbon-sequestering capabilities, hempcrete is a game-changer in the world of green construction. Thus hempcrete indirectly further reduces the need for energy consumption for heating or cooling. [16]

6.Mycelium

Mycelium has been explored as a potential sustainable construction material in the recent few years. It is a fungal material, more specifically made from the root-like fibres of the fungi. If developed and used the right way, it can become one of the most innovative green materials due to its organic and environment-friendly as well as it being insulating and non-toxic to both users and the environment. [2] That's not all – it is lightweight and resistant to fire and water. Mycelium is now being used in several industries including packaging and fabrication.

7.Rammed earth

Buildings in rammed earth, dating back centuries, can be found in many parts of the world. To this day, it is considered an plentiful , and sustainable resource for building material. With the right type of earth for such constructions, rammed earth buildings can have a low carbon footprint since the earth excavated from the site can be used, leaving little or no need for transportation. Using low carbon materials such as rammed earth can decarbonise the environment. A similar material is mud, which many modern architects have experimented with.

8.Biocomposite cement

Technology has become so advanced that we can now produce masonry blocks with materials grown from algae! Certain kinds of algae are able to naturally produce cement-like material. The result is a low-carbon material with similar properties to cement used in construction. This is still largely in the testing processes and not widely used in the industry yet but could soon be one of the leading materials to help achieve net-zero buildings.

9.Recycled plastic

Plastic material is a pressing environmental threat polluting much of the earth and the oceans, owing to high usage and low recycling rates. Many artists and designers have taken up the challenge of using recycled plastic in their products. Although this may just be a small collective effort, as the recycling reaches industrial level, this practice may soon prove effective along with reduced reliance on plastic, of course.

10.Terrazzo

Terrazzo is a recycled material used commonly as floor tiles. Not only is it aesthetic with colourful fragments, but also sustainable as it is made from scraps of marble and glass chips in cement. This material is nothing new; it has been used since the ancient Roman times but was popularised in the 18th century. The terrazzo we use now is an upgrade of the old with better resistance to scratches and cracks. Ecological recycling is what makes terrazzo a sustainable material – even pieces of plastics can be recycled to become terrazzo.

11.Mud bricks

Mud bricks are an ecological material as they are usually made on site, or at least with the mud from the site. Thus, it reduces the need for more materials and transportation for them to be carried to the site. They are rarely made only with mud and water; other materials such as straw or even cement can be mixed in to reinforce its strength. As they are produced from mud on site, they are recyclable and non-toxic to the environment. They also have high thermal mass (the ability of a material to absorb and store heat), making it a good option in hot and dry locations. The only downside is that mud bricks need good insulation against water.

2.3 What are their benefits?

The use of ecological construction materials translates into a series of benefits both for the environment and for the people who will inhabit the buildings:

Reduced carbon footprint: [14] Eco-friendly building materials typically have a lower carbon footprint over their life cycle. Being produced in a more sustainable and efficient way, they generate fewer greenhouse gas emissions, which contributes to the fight against global warming.

Saving natural resources: The use of renewable and recycled materials allows us to reduce the extraction of non-renewable natural resources, such as wood, oil or minerals. Furthermore, by promoting recycling and reuse of materials, the amount of waste is reduced and a more efficient circular economy is promoted. [12]

Improved energy efficiency: By using materials that have insulating properties, such as rock wool, hemp or cellulose, greater energy efficiency is achieved in buildings. This translates into lower energy consumption for heating and cooling, thus reducing polluting gas emissions associated with the use of air conditioning systems.[17]

Indoor air quality: Green materials are generally less toxic and release fewer volatile organic compounds (VOCs) than conventional materials, improving indoor air quality in buildings and protecting the health of their occupants. [12]

Promoting biodiversity: The selection of sustainable materials can have a positive impact on biodiversity by promoting more responsible agricultural and forestry practices, avoiding the destruction of ecosystems and preserving local fauna and flora.

Long-term value: Buildings constructed with green materials typically have a longer lifespan and greater resistance to adverse weather conditions, which in turn reduces long-term maintenance and repair costs.

Corporate responsibility: The use of ecological materials in construction also has an impact on the perception of companies and organizations, demonstrating their commitment to caring for the environment and sustainability. [17]

2.4 Countries that prioritize the use of eco-friendly building materials in construction

There are several countries that prioritize the use of eco-friendly materials in construction, but some of the leaders in this regard include:

Germany: Known for its rigorous environmental standards, Germany promotes the use of sustainable materials such as recycled concrete, timber, and energy-efficient insulation.

Denmark: With a focus on sustainable urban development, Denmark emphasizes green building practices and materials such as wood, bamboo, and recycled materials.

Sweden: Sweden is committed to reducing carbon emissions in construction by promoting the use of wood, which is renewable and has a lower carbon footprint compared to traditional building materials like concrete and steel.

Norway: Norway has stringent regulations promoting environmentally friendly construction practices, including the use of recycled materials, energy-efficient designs, and sustainable building techniques.

Netherlands: The Netherlands is renowned for its innovative approach to sustainable architecture and promotes the use of eco-friendly materials such as reclaimed wood, recycled glass, and energy-efficient technologies. [18]

3. CONCLUSION

In conclusion, the journey towards change commences with us, underscoring the necessity to disseminate information and educate individuals about the essential role of sustainable building materials. There are several effective strategies to educate people about using more eco-friendly materials for building such as Awareness Campaigns, Demonstration Projects, School Curriculum Integration etc. Exploring Eco-Friendly Building Materials" urges us to go beyond the usual ways of thinking and embrace a future where being sustainable isn't just a choice but a must-do.

REFERENCES

[1] Carlos Maur´ıcio Fontes Vieira, Gustavo de Castro Xavier, Henry Alonso Colorado Lopera, Sergio Neves Monteiro (2023) Eco-Friendly Materials for Civil Construction: Utilization and Advantages.

[2] https://www.novatr.com/blog/sustainable-building-materials

[3] https://archdesk.com/blog/how-does-construction-affect-the-environment/

[4] https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-50732014000300002#:~:text=Adem%C3%A1s%2C%20los%20impactos%20de%20la,crea%20condiciones%20inseguras%20de%20trabajo.

[5] https://www.goconstruct.org/why-choose-construction/whats-happening-in-construction/construction-and-the-6-6-6-environment/#:~:text=Does%20construction%20impact%20the%20environment,%2C%20water%2C%20and%20noise%20pollution

[6] How Does Construction Impact the Environment? | GoContractor

[7] https://360enconcreto.com/blog/detalle/impactos-ambientales-en-la-industria-de-la-construccion/

[8] https://theconstructor.org/building/types-of-building-materials-construction/699/

[9] https://www.ferrovial.com/en/resources/building-materials/

[10] https://structuralengineeringbasics.com/what-types-of-construction-building-materials/

[11] Building Materials: Construction Materials for House Building | UltraTech Cement

[12] https://puertasasturmex.com/blog/construcciones-ecologicas/

[13] https://www.aranca.com/knowledge-library/articles/business-research/the-need-for-sustainable-building-material

[14] https://bluestandardinc.com/blogs/news/what-are-sustainable-materials-and-its-characteristics

[15] https://logic-bespoke.com/how-sustainable-is-recycled-steel/

[16] https://www.hempitecture.com/post/hempcrete-an-eco-friendly-building-material/#:~:text=Hempcrete%20stands%20as%20a%20remarkable,the%20world%20of%20green%20construction.

[17] https://hcarchitects.co.uk/sustainable-materials/

[18] https://www.linkedin.com/pulse/eco-friendly-construction-role-sustainable-building-materials

Deforestation In Pakistan: An Overview of Causes & Impacts

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Pakistan is a country characterized by an extremely high rate of deforestation. This paper is a review and attempts to analyze the trends of deforestation and their impacts using statistical information about the amount of deforestation, the loss of important vegetation, and the ecological consequences of these events. This review paper consolidates and analyzes existing research on deforestation in Pakistan, drawing insights from two distinct case studies. One case study, conducted by (Waseem & Khayyam, 2019) explores the deforestation dynamics within the capital city, Islamabad, while the other, by (Qamer et al., 2016) scrutinizes the Northern Himalayan region of Pakistan which is a significant contributor about 67% of Pakistan's total forest cover. The primary objective of this review is to synthesize and critically assess the findings from these studies. Special attention is given to quantifying the rate of forest cover loss specifically in Islamabad and the northern regions of Pakistan Additionally, the research aims to quantify the rate of forest cover loss specifically in Islamabad and the northern regions of Pakistan. The methodology involves a thorough examination of various research papers to construct a comprehensive review, offering insights into the state of deforestation and environmental degradation in Pakistan using six reputable academic databases, namely Scopus, Web of Science, Google Scholar, Science Direct, PubMed, and Springer Nature. In conclusion, the study reveals alarming trends of deforestation in Pakistan, as evidenced by the intricate examination of the distinct cases of Islamabad and the Northern Himalayan region. These findings underscore the imperative for immediate attention and the formulation of sustainable forest management policies to counteract the identified impacts leading to environmental degradation.

Keywords*: Deforestation, Climate Change, Urbanization, NDVI, Remote Sensing.*

1. INTRODUCTION

Forests cover one third of the global land area and they are among the most biologically rich and diverse ecosystems of our planet [1]. Forests are also an important source of livelihood for millions of people. The elements present in a forest e.g., microorganisms, soil, vegetation canopy interact to provide different ecosystems services and play a vital role in regulating the climate [2]. However, humans have not valued this blessing of nature and they have continuously exploited this resource and ultimately destroyed the forests to meet their needs. In 2015 world forests were spanning over an area of 3999 M ha which is equal to 31 % of global land area or a 0.6 hectare of forest land for every inhabitant of earth [3]. There has been a net decrease of 3% of the world's forests from 1990 to 2015 reducing the global forest area from 4128 M ha to 3999 M ha [4]. The impacts of deforestation have caused irreversible damages to the world at large and Pakistan is one of the countries affected by this phenomenon. Pakistan is a developing country located in South Asia and it is the world's fifth most populous nation with a population of about 241.5 million people as of 2023 [5].

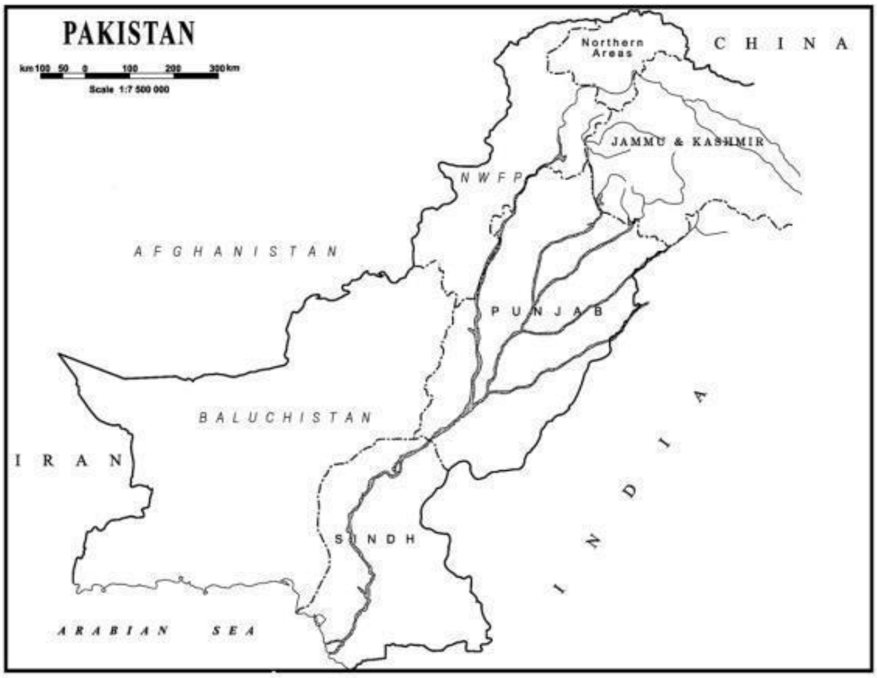


Figure 1. Geographical Location of Pakistan

Geographically Pakistan lies in the North- western region of the Indo-Pak subcontinent, is located between 24° and 37° North latitudinally and between 61° and 76° East longitudinally in the northern hemisphere indicated in Figure. 1 [6]. Pakistan has emerged as an independent country in 1947. The major forest reserves of the country consist of 1.96 million hectares of hill coniferous forests (43% of total forests), 1.72 million hectares of scrub or foothill forests (37.2 % of total forests), 0.234 million hectares of irrigated plantations, 0.297 million hectares of riverine forests, and 0.35 million hectares of mangroves in the Indus River delta [7]. In Pakistan the primary use of forest resources is to meet daily household energy needs, construction sector, furniture industry and as fuel in brick kilns. Due to huge consumption of forest wood and poor and unsustainable management, forests are depleting on an unbelievable rapid pace. Population increase and urbanization are among one of the biggest problems for Pakistan which have a significant role in deforestation. The amount of forest cover was 2.5 million hectares, 2.1 million hectares, and 1.7 million hectares in 1990, 2000, and 2010, respectively [8].

On average Pakistan lost its 41,000 hectares of forest per annum from 1990 to 2000 which is equal to a deforestation rate of 1.63 percent per year [6]. According to a measure of total rate of "Habitat conversion" which is defined as the sum of change in forest and woodland area minus the net plantation expansion, as a whole Pakistan has lost 14.7% of its forest reserves between year 1990 and 2005 [10]. It is anticipated that Pakistan is on the verge of losing its forest cover within next 30 to 40 years if the deforestation keeps up at the current rate. So, it is very crucial for Pakistan to preserve its forest land being already a forest poor country and then struggling with worst deforestation problems. Additionally, the population living near to woods exploit them to meet their domestic needs and use them in an unsustainable way [9].

1.1. Causes of Deforestation in Pakistan

Pakistan's Economy is heavily dependent on agriculture and the increasing urbanization is pressurizing the need for more agricultural land which is consequently a major cause of deforestation. For that reason, Pakistan has the highest annual deforestation rate in Asia of 2.1 % [11]. The Federal Bureau of Statistics reports that only within a span of 3 years from 2000 to 2005, the amount of forest land decreased by 3%. Between 2005 and 2010 the deforestation rate was 2.26% per annum with a total loss of 215,000 hectares of forests land. Until January 2015, the highest deforestation rate is found to be 2.54% per annum at an average annual deforestation of 42,800 hectares as summarized in Table 1 [26].

Table 1. Statistics of Forest Cover and Annual Deforestation rate of Pakistan

	1995 -2000	2000 -2005	2005 -2010	2010 -2015
Total Forest Area in the base Year (Ha)	2,321,000	2,116,000	1,902,000	1,687,000
Annual Forest Loss (Ha)	41,100	42,800	43,000	42,800
Annual Rate of Deforestation (%)	1.63	2.02	2.26	2.54

In the last two decades Pakistan has lost 8.852% (1995 to 2005) and 22.55% (2005 to 2015) of its forest cover, which is 205,000 and 429,000 hectares, respectively. Urbanization, excessive grazing, farming practices, global warming, and the use of wood as a primary energy source in rural regions are among the various causes [12]. Forests are responsible for regulating the climate, weather patterns and serve as carbon sinks. Rapid and continuous deforestation has led to the worst disasters in previous decades. At present Deforestation induced climate change is also one of the greatest concerns as forests influence climate through exchanges of water, carbon dioxide, energy, and other chemical species with the atmosphere [13].

Removal of forest cover alters global and regional climate patterns and results in catastrophic rainfall spells followed by prolonged dry periods [14]. The exploitation of forest resources is frequently attributed to people who live in or near woods [15]. To meet their livelihood farmers encroaches on steep slopes and forests areas ultimately bringing marginal lands under cultivation [16]. This clearing of the forests by inhabitants in order to grow crops, urbanization, roads construction, illegal timber mafias, overgrazing by cattle and rural population reliance on wood for fuel and domestic purposes are the factors that contributed to the depletion to of forests in KPK province of Pakistan [17].

Apart from the above-mentioned issues, the inefficient and unsustainable forest management policies, which have prioritized financial interests over environmental benefits, is another principal cause of increased deforestation [18]. After independence, Pakistan released its first forest policy in 1955 through the Central Board of Forestry. Subsequently, the country released forest policies in 1962, 1975, 1980, 1988, 1991, 2005, and 2010, along with provincial plans [18]. Although these policy measures aimed at conserving the environment however they disregarded the local people whose means of subsistence depends on the forests. Also, the policies and practices pertaining to forest management were strongly biased towards generating revenue and failed to take the social and economic circumstances of the local communities into account [19]. As result these policies were never implemented effectively even for the environmental conservation aspect.

Apart from human induced deforestation, the interplay of natural calamities such as wildfires and the frequent overgrazing that may stunt the growth of young trees. Arid climates, a high reliance on irrigation water, vulnerable watersheds and rangelands, and lengthy growth periods are among the natural elements affecting forests [20]. Deforestation also triggers soil erosion. Because the tree roots anchor the soil and keep it from washing away providing a natural barrier to the flow of water and thus stabilization the ground [21]. Pakistan is acknowledged as the seventh most affected country by climate change, despite its ranking of 135th on the Global Greenhouse Gases(GHS) index [22]. Because ofenvironmental degradation, Pakistan has faced severe natural disasters in the past. DestructiveFloods were seen in 2010 and 2011, and it isanticipated that these types of natural disasterswould occur more frequently in the years to come.

2. MATERIALS AND METHODS

For selecting and extracting the relevant papers for the research work a systematic approach was adopted. Initially, I employed specific keywords such as deforestation, environmental degradation, 'loss of forests' and 'forests Statistics in Pakistan' to search six reputable academic databases, namely Scopus, Web of Science, Google Scholar, Science Direct, PubMed, and Springer Nature. , I applied a time filter, focusing on articles published within the last 25 years to ensure relevance and accuracy. The initial search yielded 30 papers from the above-mentioned academic databases, mainly consisting of 16 peer reviewed research papers, 3 governmental reports and 1 thesis. These papers were interesting because of the fact that they encompassed different deforestation related aspects apart from the causes and the impacts. Noteworthy contributions include [12] investigation into the linkages between deforestation, energy, and economic growth, as well as [22] evaluation of environmental degradation as a threat to human security. Additionally, reports such as the Living Planet Report by Worldwide Fund [11] and data from [27] offer valuable insights about forest dynamics and statistics globally and specially about Pakistan. Furthermore, the study by [9,17] delve into the specific challenges and failures in forest management in Pakistan. The inclusion of international studies, such as [1] and [4], enriches the review by providing a global overview of changes in forest dynamics and biomass. This selection of papers laid a solid foundation for a nuanced exploration of the multifaceted issues surrounding deforestation in Pakistan, integrating both regional and global perspectives, and providing a thorough insight of the drives beyond the alarming deforestation in Pakistan. Overall, the adopted methodology was a calculated mix of database searches, screening methods, and iterative improvement.

2.1.Snowballing Technique

In addition to the above-mentioned procedures, the Snowballing technique was utilized to uncover more relevant and useful sources. Through this technique, the reference lists of selected publications were reviewed and utilized. Iteratively, the search was broadened by looking through the citations and similar articles that selected papers recommended. After gathering all the required papers and information and thoroughly reviewing them, essential information was extracted such as deforestation statistics, methodologies employed by the authors to assess loss of forests, the results of their studies. I collected a total of 19 articles and 1 book through this technique. This data was then systematically arranged and combined to create a coherent study that addressed the relationship between deforestation, its causes and impacts in context of Pakistan. I used Mendeley Reference Manager, an open- source software, for managing, citing, and referencing published papers in the manuscript. The heading levels should not be more than 4 levels. The font of heading and subheadings should be 12-point normal Times New Roman. The first letter of headings and subheadings should be capitalized.

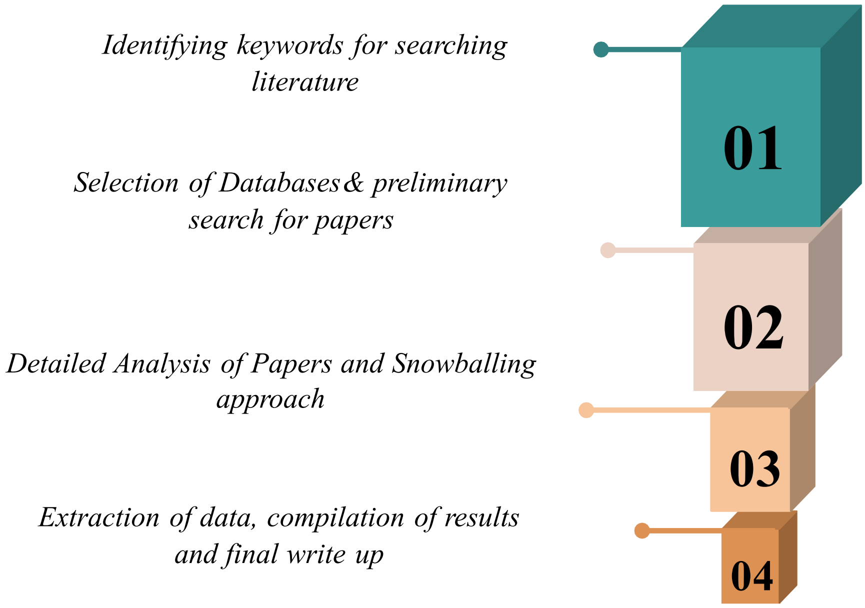


Figure 2. Mapping the Research Journey: General Overview of Methodology

3. RESULTS AND DISCUSSION

3.1. Deforestation Assessment in Islamabad

Islamabad is the capital city of Pakistan spanning over an area of 906 square kilometers, or 90,650 hectares. It is located at 33.738045° N and 73.084488° E. [23] assessed the forest loss in Islamabad using GIS and Remote Sensing techniques. The study made use of 4 Landsat images from United States geological survey (USGS) for the years 1992, 2000, 2008 and 2017 whereas the months of September as a study point was selected for all the four study years. These images were then classified into six IPCC1 land use classes. The conversion of one Land Use class into the other during all these respective study years was determined using Tabulation in ArcGIS. In this way forestland change was calculated. To evaluate the amount of vegetation cover, Landsat pictures were subjected to the Normalized Differential Vegetation Index (NDVI). NDVI has a range of values between +1 and -1. The values close to +1 indicates dense vegetation, while values near to -1 indicates poor vegetation. NDVI values of the images ranging between 0.72-0.92 are classified as very good, 0.42-0.72 as good while <0.1 as no vegetation of barren land as represented in table 2 [23].

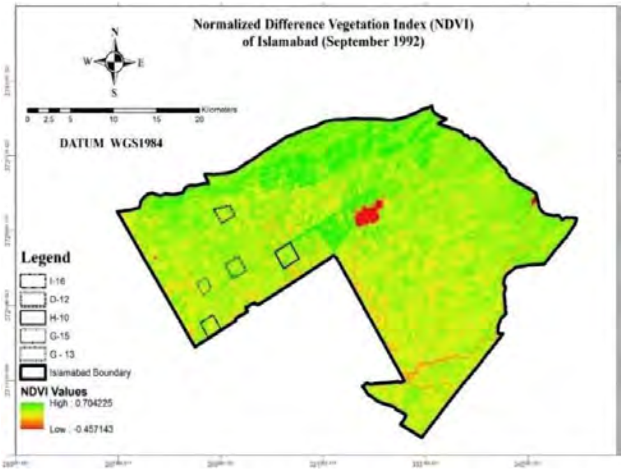
Table 2. NDVI values representing the vegetation characteristics of Islamabad.

S.No	Vegetation (Physical Charcteristics)	NDVI Values
1.	Very Good	0.72-0.92
2.	Good	0.42-0.72
3.	Normal	0.20-0.42
4.	Poor	0.10-0.20
5.	Very Poor	-0.10-0.12
6.	No Vegetation	≤ 0.1

These results were then compared with standard NDVI values to calculate the amount of vegetation that has been lost in Islamabad over the course of 25 years, from 1992 to 2017.

The study revealed that NDVI values for 1992 images falls in a range of 0.704225. This high value indicates the vegetation cover of Islamabad in 1992 was in “Very good” classification category representing the presence of dense vegetation within the study area (Fig). In the year 2000. NDVI values for the year 2000 showed variation of 0.0485-0.2297 Based on this range of values, physical attributes of vegetation covers were designated as "good to normal”. However, the investigation showed that September 2008

NDVI values were in the negative range, i.e., 0.128 to 0.375 lying in poor to very poor" classification (Fig. 6). This validated that there was a reduction in the vegetative cover of Islamabad in 2008. However, the situation becomes extremely intensified when the values for last study period i.e. September 2017 were found to be -0.0198 identifying “No vegetation cover” in the certain areas of Islamabad as indicated in fig 7. In conclusion, the study verified that, for 25 years, the vegetation intensity in the Islamabad had reduced. And urbanization being the primary cause of this extensive deforestation. Fig 3,4,5,6 represents the NDVI maps of Islamabad city for the year 1992, 2000, 2008 and 2017 respectively [23].



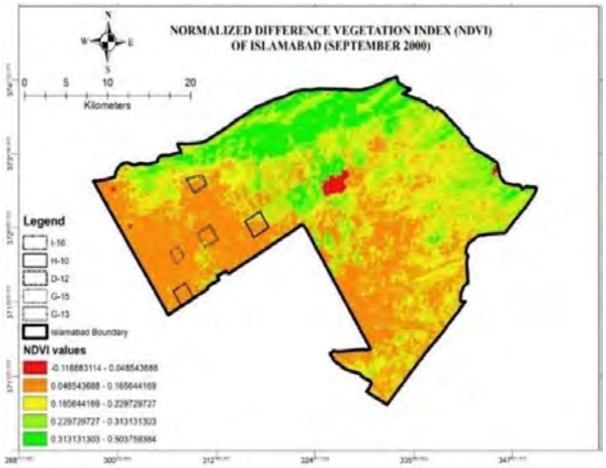
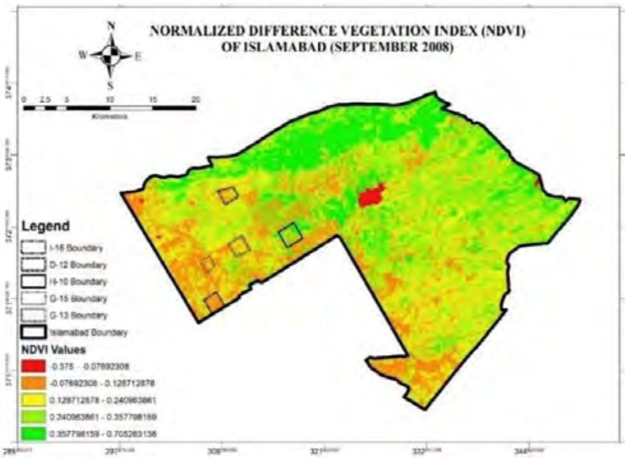


Figure 3. NDVI Map of Islamabad (September 1992) **Figure 4.** NDVI Map of Islamabad (September 2000)



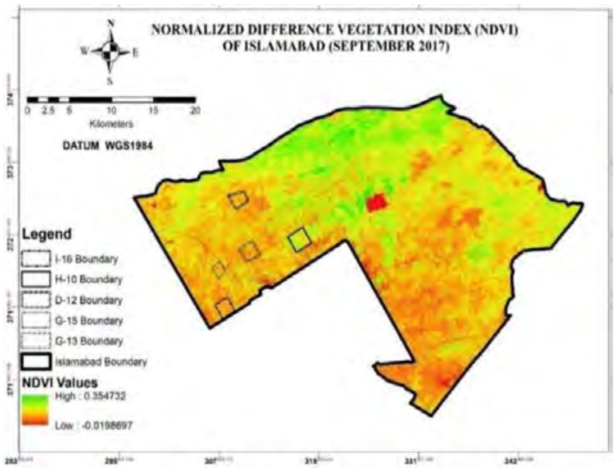


Figure 5. NDVI Map of Islamabad (September 2008 **Figure 6.** NDVI Map of Islamabad (September 2017)

3.2. Assessment of Deforestation in Western Himalayan Region of Pakistan

Forests of Western Himalaya stretching across KPK Province of Pakistan, federally administrated area of Gilgit Baltistan and the state of Azad Jammu and Kashmir accounts for 67% of the total forest cover of Pakistan. . Massive forest degradation started in this region during the early British Government's rule (1850s), when forest timber was utilized for infrastructure construction and commercial usage [24]. The changes in forest cover of western Himalayan region was analysed by [25] within a time series of 1990 to 2010. The study began with collection of Level 1 terrain corrected (L1T) temporal Landsat data from 1990, 2000, and 2010. The satellite data was acquired for the month of august to October to minimize cloud and snow cover. These temporal records make it possible to observe changes across time, which is essential for monitoring trends of deforestation. This data was then processed to account for the errors related to geometric inaccuracies and reducing the influence of atmospheric phenomena. The specific corrections applied were top of atmosphere reflectance conversion, BRDF normalization and cloud masking. The image classification process involves training a computer algorithm to recognize different land cover types based on spectral signatures. This process is guided by 14 predefined land cover classes and uses training data collected from ground observations and high-resolution imagery. The resulting classified map provides a detailed representation of the distribution of land cover types, allowing for the analysis of changes over time, specifically focusing on deforestation and forest degradation in the Western Himalayas as indicated in figure 7 [25].

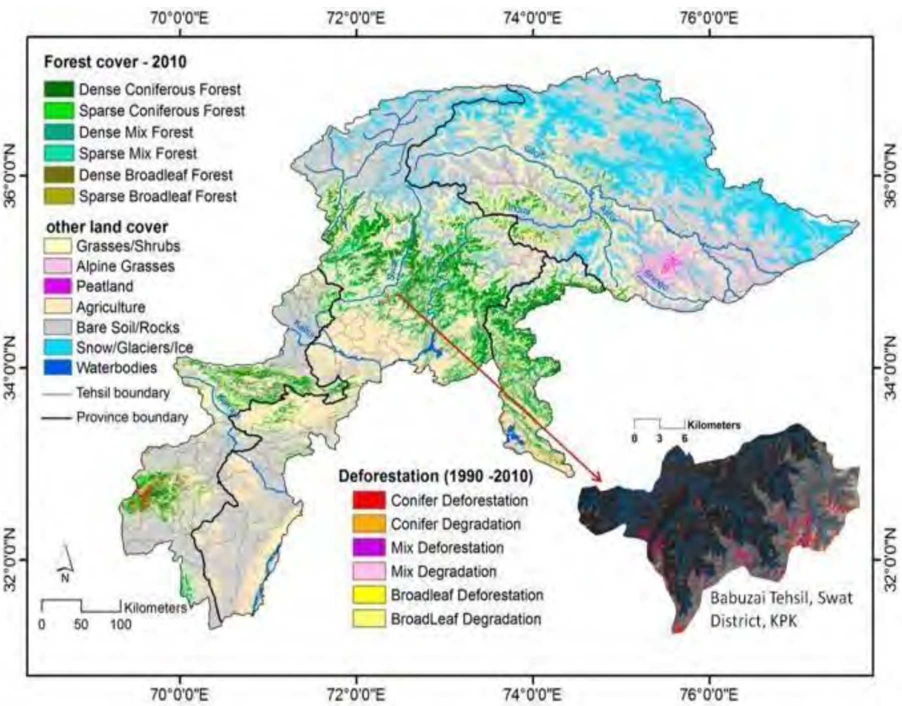


Figure 7. Landcover Classes Distribution and Deforestation

The land cover was mainly divided into 14 classes which included eight non-forest cover classes (such as grassland/shrubs, alpine grassland, agriculture, bare soil/rocks, snow/glaciers/ice, and water bodies) and six forest cover classes (dense coniferous forest, sparse coniferous forest, dense mixed forest, sparse mixed forest, and sparse broadleaved forest). Deforestation was defined as the change from dense to sparse forest, and degradation as the change from dense to non-forest. The definition of deforestation used by the FAO does not discriminate between forest loss resulting from natural processes and that caused by human activity. To quantify changes of the forest cover spatial analysis tool of ArcGIS was used.

Based on the analysis of land cover photos taken in 2010, the study area's forest cover amounts to about 12% (2,152,173 ha). Of the entire amount of forest cover, 57% is made up of coniferous forest, 14% is made up of broadleaf forest, and 29% is made up of mix forest in the transition zone. The study revealed changes in forest for 137 sub-districts of Pakistan across two time periods: 1990–2000 and 2000–2010. It was found out that Between 1990 and 2000, there was a total forest loss of 74,613 hectares, while between 2000 and 2010 there was a bigger total forest loss of 95,598 hectares due to deforestation. The deforestation hotspots have been identified figure 8 [25], based on the area of forest cover and the corresponding deforestation rates in each sub-district.

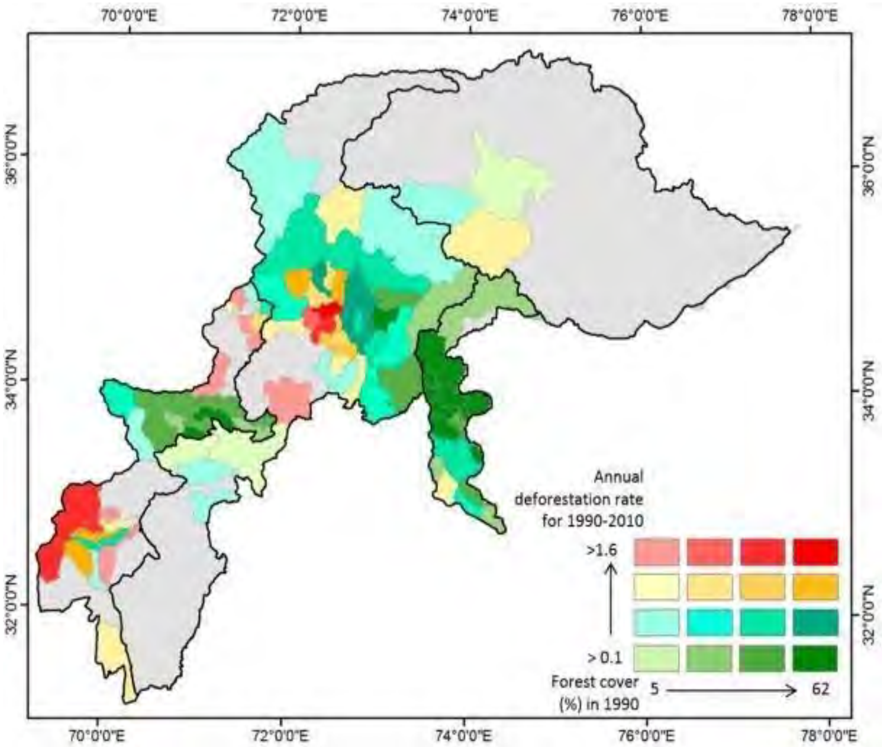


Figure 8. Map identifying hotspots of Deforestation across the study area

3. CONCLUSION

This study attempted to summarize intricate issue of deforestation in Pakistan, shedding light on the alarming trends through the examination of two distinct case studies. The first case delves into the deforestation scenario in the capital city, Islamabad, while the second case focused on the Northern Himalayan region of Pakistan. The results of the study reveal that, since 1992, Islamabad has continuously seen a loss of vegetative cover, especially in the urbanized areas. It has been found that Islamabad had a 22% decrease in vegetative cover between 1992 and 2000. Another period of ongoing decline in said cover, extending up to 27% between 2000 and 2008, follows this trend. Even more concerning, the data showed a 51% decrease in the vegetative cover between 2008 and 2017.

The forests in the Northern Himalayan region accounts for about 67% of the total forest cover of Pakistan. The Northern Region constitutes Khyber Pakhtunkhwa province, the administrative unit of Gilgit Baltistan and the state of Azad Jammu & Kashmir spanning over a total area of 18,260,000 ha, which is about 23% of the total area of Pakistan. The deforestation studies in this region revealed that a total forest loss of 74,613 has occurred during 1990-2000 and a 95,598 ha of forest area was destroyed during 2000-2010. So, within a period of 20 years 170,684 ha of forest has been lost which amounts to be 0.38% cut per

year. The study also identified the hotspots of deforestation. In terms of forest types, it was found that dry temperate forests in the area of Malakand and subtropical forest in Waziristan area are under severe threat.
In addition, the study also unveiled the causes of deforestation identifying the key factors that contribute to this silent disaster. Urbanization, excessive grazing, farming practices, global warming, and the use of wood as a primary energy source, human practices and poor forest management policies are identified as the main reasons behind the massive forest loss in these regions of Pakistan.

REFERENCES

[1] Köhl, M., Lasco, R., Cifuentes, M., Jonsson, Ö., Korhonen, K. T., Mundhenk, P., de Jesus Navar, J., & Stinson, G. (2015). Changes in forest production, biomass and carbon: Results from the 2015 UN

[2] Krieger, D. J. (n.d.). Economic Value of Forest Ecosystem Services: A Review THE WILDERNESS SOCIETY THE ECONOMIC VALUE OF FOREST ECOSYSTEM SERVICES: A REVIEW.

[3] FAO Global Forest Resource Assessment. Forest Ecology and Management, 352, 21–34. https://doi.org/10.1016/j.foreco.2015.05.036

[4] Keenan, R. J., Reams, G. A., Achard, F., de Freitas,J. V., Grainger, A., & Lindquist, E. (2015). Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. In Forest Ecology and Management (Vol. 352, pp. 9–20). Elsevier B.V. https://doi.org/10.1016/j.foreco.2015.06.014

[5] Pakistan Bureau of Statistics (www.pbs.gov.pk). (Pakistan Bureau of Statistics,2023) 5 August 2023. Retrieved 15 August 2023.

[6] Tahir, S. N. A., Rafique, M., & Alaamer, A. S. (2010). Biomass fuel burning and its implications: Deforestation and greenhouse gases emissions in Pakistan. Environmental Pollution, 158(7), 2490– 2495. https://doi.org/10.1016/j.envpol.2010.03.017

[7] Qazi, I.A., 1994. Pakistan: country and forests. In: Ashraf M.M. and Ahmad, I. (eds.) *Handbook of Forestry. p. 253.Pakistan Agric. Research Council, Islamabad. Pakistan.*

[8] Løyche, M., & Senior, W. (2010). Forestry Department Food and Agriculture Organization of the United Nations GLOBAL FOREST RESOURCES ASSESSMENT 2010 COUNTRY REPORT PAKISTAN 2 The Forest Resources Assessment Programme. www.fao.org/forestry/fra

[9] Hasan, L. (2007). An Anatomy of State Failures in Forest Management in Pakistan (Vol. 46, Issue

[10] Pakistan deforestation Rates and related forestry figures (PDRRFF), 2000. Available at. http://rainforests.mongabay.com/deforestation/20 00/Pakistan.htm (PDRRFF,2000) (accessed on 3.7.2009).

[11] Worldwide Fund (WWF). *'Living Planet Report(2010)*.http://www.footprintnetwork.org/pr ess LPR2010.pdf.

[12] Ahmed, K., Shahbaz, M., Qasim, A., & Long, W. (2015). The linkages between deforestation, energy and growth for environmental degradation in Pakistan. *Ecological Indicators*, *49*, 95–103. https://doi.org/10.1016/j.ecolind.2014.09.040

[13] Schuldenrein, J., Wright, R. P., Mughal, M. R., & Khan, M. A. (2004). Landscapes, soils, and mound histories of the Upper Indus Valley, Pakistan: New insights on the Holocene environments near ancient Harappa. Journal of Archaeological Science, 31(6), 777–797. https://doi.org/10.1016/j.jas.2003.10.015Announcement of Results of 7th Population and Housing Census-2023 'The Digital Census'" (PDF).

[14] Strasser, U., Vilsmaier, U., Prettenhaler, F., Marke, T., Steiger, R., Damm, A., Hanzer, F., Wilcke, R.A. I., & Stötter, J. (2014). Coupled component modelling for inter- and transdisciplinary climate change impact research: Dimensions of integration and examples of interface design. Environmental Modelling and Software, 60, 180–187. https://doi.org/10.1016/j.envsoft.2014.06.014.

[15] Steimann, B. (2007). Livelihood Strategies in North-West Pakistan Results from the Sustainable Livelihoods Survey 2004, North-West Frontier Province (Pakistan). http://www.north- south.unibe.ch

[16] Hussain, S.S., 2003. Mountain ecosystems: emerging challenges and opportunities for agriculture in Northern Pakistan. In: Mufti, S.A., S.S. Hussain and A.M. Khan (eds.). Mountains of Pakistan: Protection, Potential and Prospects. pp. 180–91. Global Change Impact Studies Centre, Jinnah Avenue, Islamabad, Pakistan.

[17] Mahmood, I., 2003. Deforestation in NWFP. National Institute for Public Administration, Karachi (Pakistan). The J., 8: 75–101 (Mahmood et al 2003)

[18] Shahbaz, B., Ali, T., & Suleri, A. Q. (2007). A critical analysis of forest policies of Pakistan: Implications for sustainable livelihoods. Mitigation and Adaptation Strategies for Global Change, 12(4), 441–453. https://doi.org/10.1007/s11027-006-9050-9

[19] Khan, A. R., and O. R. G. Asian Prod (1990). Pakistan - forestry resources management in apo member countries (khan et al,1990).

[20] Yu, L., Zhang, S., Tang, J., Liu, T., Bu, K., Yan, F., Yang, C., & Yang, J. (2015). The effect of deforestation on the regional temperature in Northeastern China. Theoretical and Applied Climatology, 120(3–4), 761–771. https://doi.org/10.1007/s00704-014-1186-z

[21] Treydte, K. S., Schleser, G. H., Helle, G., Frank, D. C., Winiger, M., Haug, G. H., & Esper, J. (2006). The twentieth century was the wettest period in northern Pakistan over the past millennium. Nature, 440(7088), 1179–1182. https://doi.org/10.1038/nature04743

[22] Aslam, B., Gul, S., & Asghar, M. F. (2021). Evaluation of environmental degradation as an unprecedented threat to human security in Pakistan. *Liberal Arts and Social Sciences International Journal (LASSIJ)*, *5*(1), 197–211. https://doi.org/10.47264/idea.lassij/5.1.14

[23] Waseem, S., & Khayyam, U. (2019). Loss of vegetative cover and increased land surface temperature: A case study of Islamabad, Journal of Cleaner Production , 234, 972-983.

[24] Tucker, R. P. (1987). Dimensions of Deforestation in the Himalaya: The Historical Setting. In Source: Mountain Research and Development (Vol. 7, Issue 3).

[25] Qamer, F. M., Shehzad, K., Abbas, S., Murthy, , M.S. R., Xi, C., Gilani, H., & Bajracharya, B. (2016). Mapping deforestation and forest degradation patterns in Western Himalaya, Pakistan. Remote Sensing, 8(5). https:/doi.org/10.3390/rs8050385.

[26] Faiza, N., Weiguo, J., Aijun, Y., & Wenxing, S. (n.d.). Giant deforestation leads to drastic eco- environmental devastating effects since 2000; a case study of pakistan. In *The J. Anim. Plant Sci* (Vol. 27, Issue 4).

Integrated Network of Collection and Transportation of Construction and Demolition Waste

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Over the last three decades, urban development within the Republic of Albania has led to an increase in the volume of solid waste produced by the construction sector due to its operational activities. Legal requirements aimed at protecting the environment as a whole have established obligations to ensure proper waste management. To facilitate the integrated management of solid waste from construction and demolition generated by this sector, it is mandatory for waste collection and transportation from the source to disposal/recovery facilities to be conducted by licensed operators. These operators must be registered through the National Business Center and hold a subcategory III.2.B license titled "Other professional activities related to environmental impact. "Waste classification is done based on the Albanian and European waste catalogs, identifying the construction sector's waste under code 17, which pertains to construction and demolition waste. This classification is further detailed with a six-digit code to precisely identify the type of waste. According to records from the national register of licenses, authorizations, and permits managed by the QKB from 2012 to 2023, 500 operators have been licensed to collect and transport various types of waste. The majority of these operators are located in the Tirana district, followed by the Durrës district. Out of the total number of operators licensed under III.2.B, 202 are involved in collecting and transporting waste associated with at least one of the codes from the construction sector. This has enabled the development of an integrated network for the collection and transportation of waste from construction and demolition.

Keywords: *Waste from construction and demolition, waste code, construction sector, license III.2.B, collection, transportation.*

1. INTRODUCTION

Economic operators who, as a result of their operational activities in the construction sector, are the main generators of solid waste from construction and demolition, are obligated by current environmental protection legislation, environmental impact assessment and integrated waste management requirements to collect and transport the generated waste with a subcategory III.2.B license towards disposal/recovery facilities.
According to data published by INSTAT, from 2017 to 2023, a total of 8,436 construction permits were approved throughout the territory of the Republic of Albania, with a total area of 12,936,272 square meters.
Furthermore, according to data from the National Registry of Authorizations, Licenses, and Permits issued through the NBC, it appears that from 2012 to 2023, a total of 500 operators have been licensed with a subcategory III.2.B license, out of which 202 of them conduct collection and transportation operations in the field of waste from construction and demolition.

The Albanian Waste Catalog, approved by Decision of the Council of Ministers no. 402, dated 30.6.2021, allows for the classification of waste according to type, specified with a 6-digit code, while the economic sectors and respective subcategories generating these wastes are

designated with 2-digit and 4-digit codes, respectively. Waste from construction and demolition generated by the construction sector falls under code 17, which is further divided into subcategories to identify the exact type of waste.
The aim of this study is to contribute to the development of strategies, national and local waste management plans in the Republic of Albania, by establishing clear objectives for the integrated management of construction and demolition waste through the construction of an integrated collection and transportation network. This will be achieved by identifying specific waste streams from the construction sector at both national and county levels for the period 2012-2023.

The objectives of this study are:

- To analyze the trends in the construction sector at national and county levels.
- To analyze the licensing trends of economic operators conducting collection and transportation operations of construction and demolition waste at national and county levels.
- To analyze and identify the types of waste for each respective subdivision of the construction sector at national and county levels.

The methodology used and the results obtained from this study in the field of environmental research and management are based on both qualitative and quantitative analysis methods.
In line with its title, aim, and objectives, this study focuses on 5 (five) main issues treated as research questions, as follows:

1. What is the number of construction permits and the total area of approved construction space at national and county levels for the period 2017-2023?
2. What is the number of operators licensed with a III.2.B license for the collection and transportation of various types of waste at national and county levels for the period 2012-2023?
3. What is the number of operators licensed with a III.2.B license for the collection and transportation of construction and demolition waste at national and county levels for the period 2012-2023?
4. How is the licensing trend of operators for "collection and transportation of construction and demolition waste" progressing by county and year?
5. What is the number of operators licensed for the 6-digit waste codes belonging to the economic sector of construction and demolition, and how are these operators distributed at the county level?

2. MATERIALS AND METHODS

The methodology used for the preparation of this study and the achieved results are based on contemporary methods, namely qualitative and quantitative analysis.

The qualitative method employed allows for the collected and processed information to be systematically reflected in the material and ordered according to the importance of application, providing readers with accurate, coherent, accessible, and easily understandable information with well-defined references. Meanwhile, the quantitative method enables us to process data and present them in statistical form.
To achieve the study objectives, several steps have been followed, as outlined below:

2.1 Data collection

For data collection, initially, the scope of activity was determined, and the waste-generating sector was identified, focusing on the construction sector for the purposes of this study. Firstly, data were gathered from INSTAT[xvii] regarding the number of construction permits and approved areas in square meters for residential and non-residential buildings at both national and county levels from 2017 to 2023. Subsequently, information from the National Registry of Licenses, Authorizations, and Permits issued through the NBC was collected regarding subcategory III.2.B licenses titled "Other professional activities related to environmental impact". All collected information was compiled and processed in Excel, including data such as: 1- Serial number; 2- Subject name; 3- NUIS (National Unique Identification Number); 4- Codes for non-hazardous waste; 5- Codes for hazardous waste; 6- Subject activity; 7- Location of activity; 8- County; and 9- Year of license approval. For each code of waste from construction and demolition, the number of licensed operators at both national and county levels was identified.

2.2 Data analysis

For data processing and analysis, a model was constructed in Excel where all collected information was entered. Data processing involved verifying each economic operator holding a III.2.B subcategory license through the official QKB website, conducting advanced searches in the national registry of licenses, authorizations, and permits issued through the NBC using the serial number (month/year). Then, relevant data for each operator were entered into the Excel database, including: 1- Serial number; 2- Subject name; 3- NUIS; 4- Codes for non-hazardous waste; 5- Codes for hazardous waste; 6- Subject activity; 7- Location of activity; 8- County; and 9- Year of license approval. Data analysis for the period 2012-2023 was conducted using filtering options provided by Excel, focusing on waste code, county, and year. From the data processing for the period 2012-2023, identification and division of each 6-digit waste code belonging to the economic sector of construction and demolition were carried out, as presented in the table below.

Table 1. The classification of the types of waste generated by the construction and demolition sector, according to the waste catalogue approved by Decision of the Council of Ministers no. 402, dated June 30, 2021.

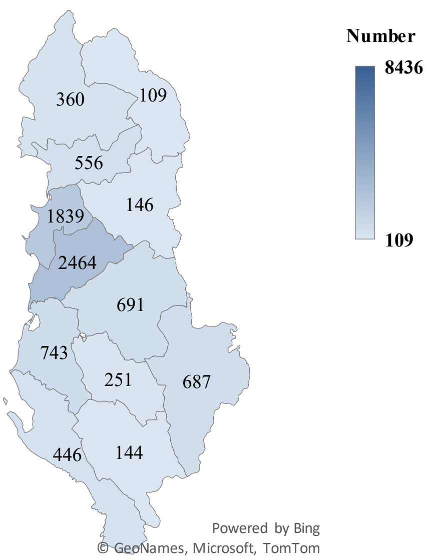
Code	Label
17 01 01	Concrete
17 01 02	Bricks
17 01 03	Tiles and Ceramics
17 01 06*	Mixtures or separate fractions of concrete, bricks, tiles and ceramics containing hazardous substances
17 01 07	Concrete, brick, tile and ceramic mixtures, other than those mentioned in 17 01 06
17 02 01	Wood
17 02 02	Glassware
17 02 03	Plastic
17 02 04*	Wood, glass and plastic containing hazardous substances
17 03 01*	Bituminous mixtures containing coal tar
17 03 02	Bituminous mixtures, other than those mentioned in 17 03 01
17 03 03*	Coal pitch and tar
17 04 01	Copper, bronze, brass
17 04 02	Aluminum
17 04 03	Lead
17 04 04	Zink

17 04 05	Iron and Steel
17 04 06	Tin
17 04 07	Mixed Metals
17 04 09*	Metal waste contaminated with hazardous substances
17 04 10*	Cables containing petroleum, bitumen or other hazardous substances
17 04 11	Cables other than those mentioned in 17 04 10
17 05 03*	Soils and stones containing dangerous substances
17 05 04	Soils and stone, other than those mentioned in 17 05 03
17 05 05*	Clay containing hazardous substances
17 05 06	Clay, other than those mentioned in 17 05 05
17 05 07*	Gravel containing hazardous substances
17 05 08	Gravel, other than those mentioned in 17 05 07
17 06 01*	Insulation material containing asbestos
17 06 03*	Insulation material consisting of or containing hazardous substances
17 06 04	Insulation materials other than those mentioned in 17 06 01 and 17 06 03
17 06 05*	Building materials containing asbestos
17 08 01*	Gypsum building materials that are contaminated with hazardous substances
17 08 02	Gypsum building materials, other than those mentioned in 17 08 01
17 09 01*	Construction and demolition waste containing mercury
17 09 02*	Construction and demolition waste containing mercury
17 09 03*	Construction and demolition waste, including mixed waste containing hazardous substances
17 09 04	Mixed construction and demolition waste, other than those mentioned in 17 09 01, 17 09 02 and 17 09 03

3. RESULTS AND DISCUSSION

In the following figure (Fig.1), the number of approved construction permits at the national and county levels for the period 2017 – 2023 is presented. In total, for the analyzed period at the national level, 8436 construction permits have been approved for both residential and non-residential buildings. At the county level, the highest number of approved construction permits is held by Tirana County with 2464 construction permits, followed by Durrës County with 1839 construction permits, while the lowest number is held by Kukës County with 109 construction permits.

The number of construction permits approved in the territory of Albania (year 2017-2023)



The area of contruction space in m² approved in the territory of Albania (year 2017 - 2023)

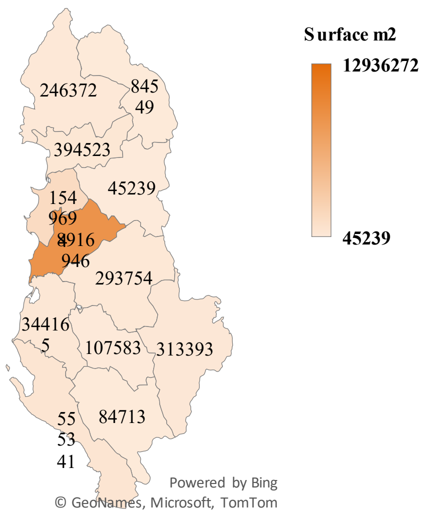


Figure 1. The numer of contruction permits approved in the territory of Albania (year 2017-2023)

Figure 2. The area of construction space in m2 approved in the territory of Albania (year 2017 – 2023)

From the analysis and processing of the data presented in the following figure (Fig. 2) for the period 2017 – 2023, the total area of approved construction space (m^2) at the national and county levels is shown. In total, the area of approved construction space (m^2) at the national level is 12,936,272 m^2. Tirana County leads with 8,916,946 m^2 of approved construction area, followed by Durrës County with 1,549,694 m^2 of approved construction area, while the lowest number is held by Dibër County with 45,239 m^2 of approved construction area.

The data from figures 1 and 2, through the indicators of the number of approved construction permits and the area of approved construction space, help us identify that the highest volume of solid waste generated by the construction sector for the period 2017-2023 is concentrated in Tirana and Durrës counties.

The data from the following figure (Fig.3) for the period 2012-2023 show us that at the national level, we have 500 licensed operators with a subcategory III.2.B license in the field of collection and transportation of various types of waste. At the county level, Tirana county has the highest number of operators with a III.2.B license, with 193 operators, followed by Durrës county with 87 operators and Elbasan county with 45 operators, while Kukës county has the smallest number with 1 operator licensed with a III.2.B license.

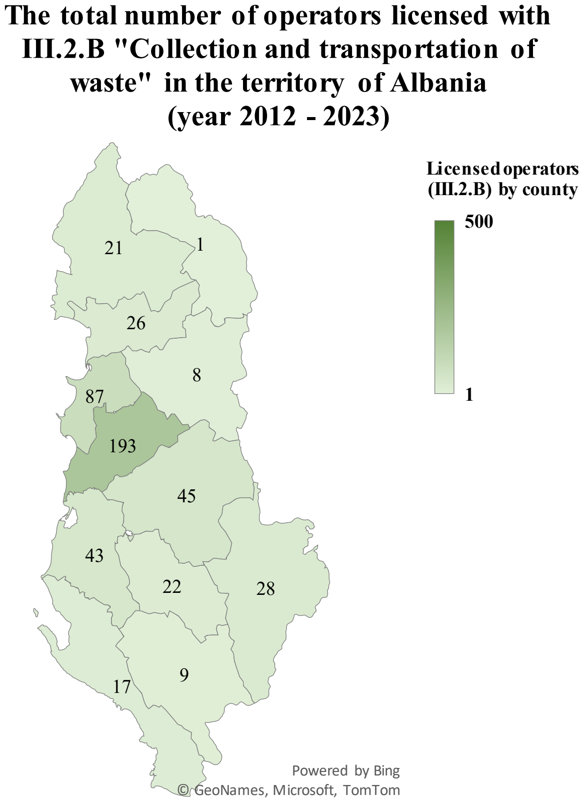


Figure 3. The total number of operators licensed with III.2.B “Collection and transportation of waste” in the territory of Albania (year 2012 – 2023)

In the following figure (Fig.4) for the period 2012 - 2023, the data analyzed at the national level shows that we have 202 licensed operators with a subcategory III.2.B license in the field of collection and transportation of waste from construction and demolition. The district with the highest number of III.2.B licensed operators for construction and demolition waste is

Tirana district with 98 operators, followed by Durrës district with 36 operators, while the lowest number is held by Kukës district with 0 operators licensed under III.2.B.

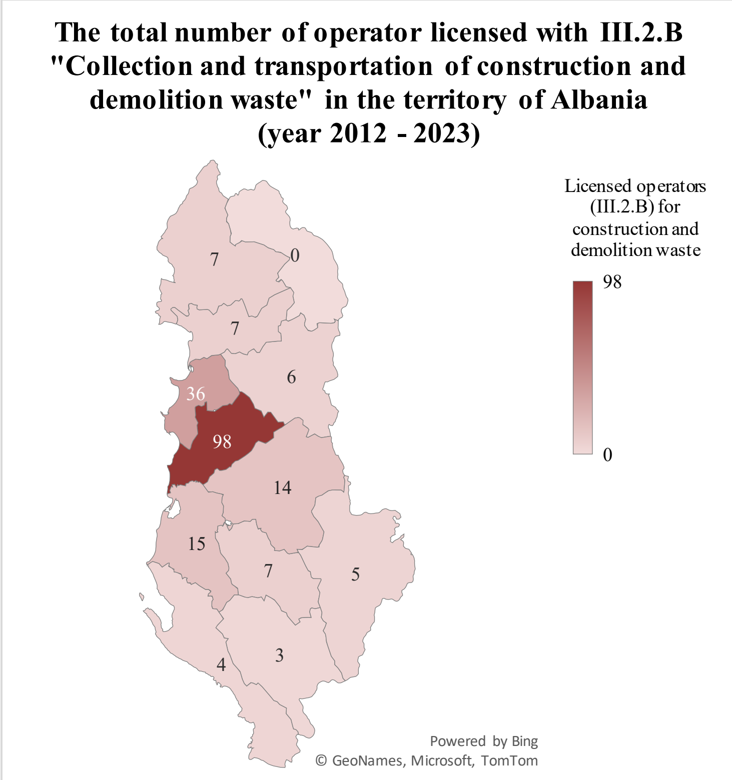


Figure 4. The total number of operator licensed with III.2.B "Collection and transportation of construction and demolition waste" in the territory of Albania (year 2012 – 2023)

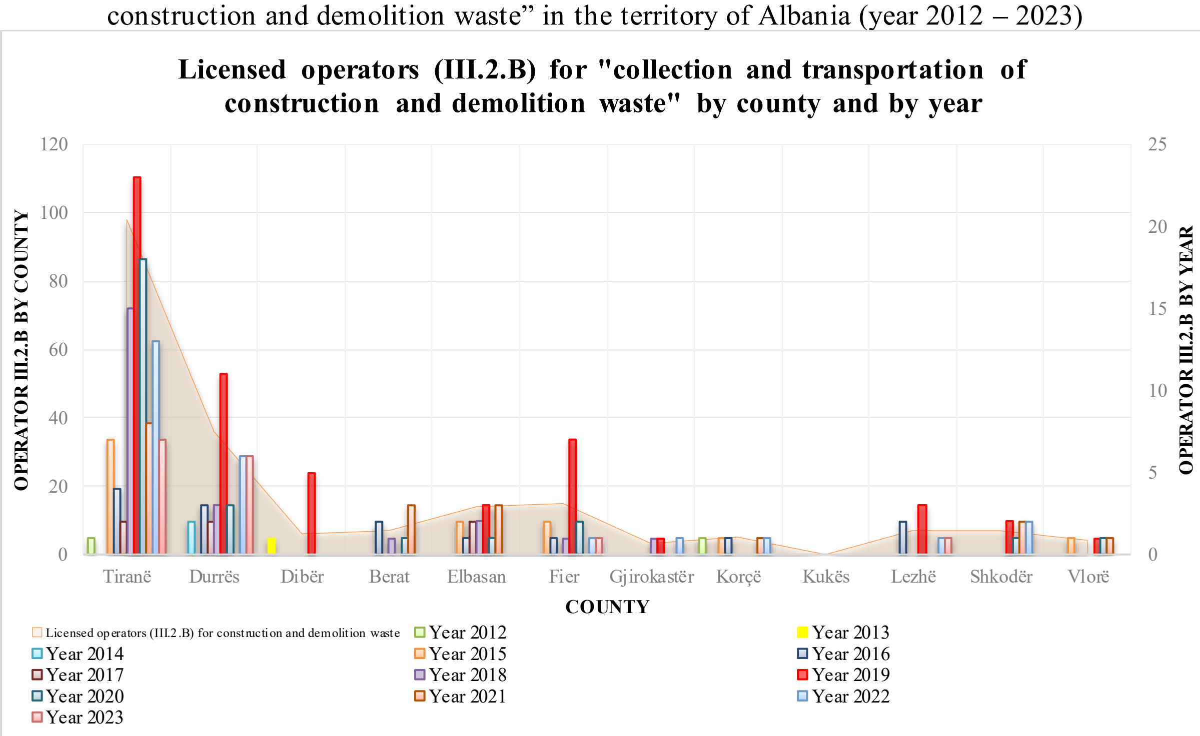


Figure 5. Licensed operators (III.2.B) for "collection and transportation of construction and demolition waste" by county and by year

In the above graph (Fig.5), the number of operators equipped with a III.2.B license for the collection and transportation of waste from construction and demolition is provided, divided by district and by year. The analyzed data show that in 2019 we have the highest number of licenses, with Tirana, Durrës, and Fier districts leading. The processed data also include changes made to the III.2.B subcategory licenses, but the reference year is taken as the year when the license was first issued through the National Licensing Center. For the years 2012 and 2013, the processed data show a low number of operators collecting and transporting waste from construction and demolition, due to the fact that the III.2.B licenses did not have an approved 6-digit code, which identifies the economic sector of waste.

While analyzing the data from the graph below (Fig.6), it is found that the highest number of operators licensed with a III.2.B license is for code 17 05 04 (concrete, bricks, tiles, and ceramics) with 144 operators, followed by code 17 09 04 (mixed construction and demolition wastes) with 118 operators. Out of 38 waste codes generated by the construction and demolition sector, we have licensed operators for 37 waste codes, meaning that we do not have licensed operators only for waste code 17 09 02* (construction and demolition wastes containing PCBs).

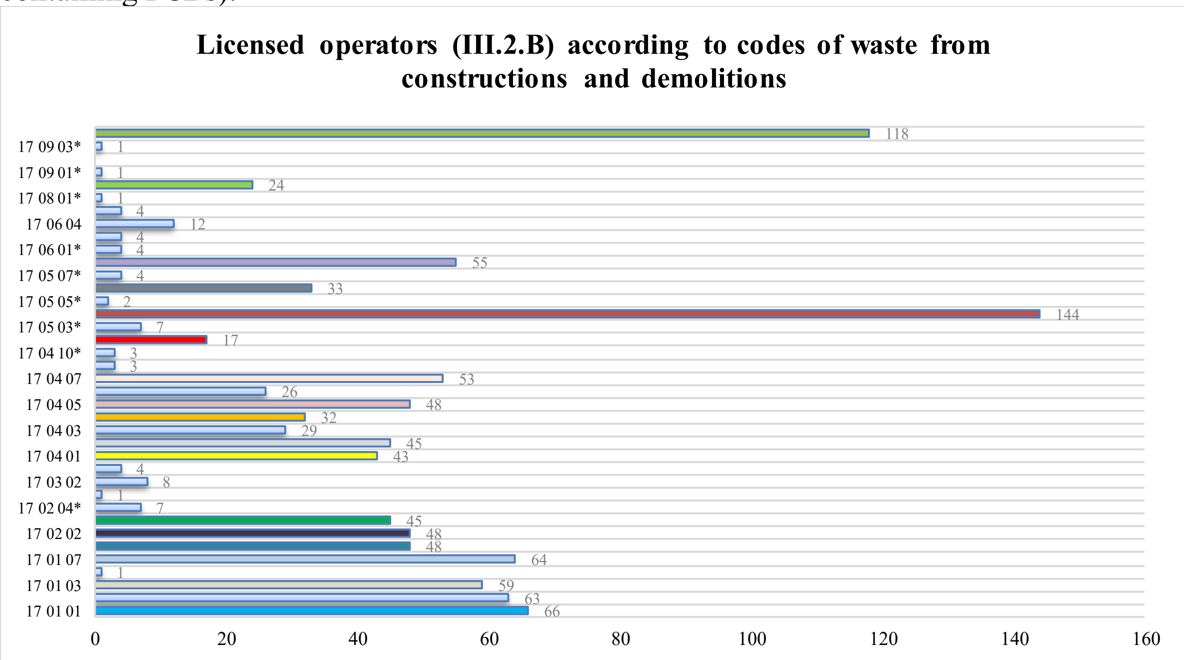


Figure 6. Licensed operators (III.2.B) according to codes of waste from constructions and demolitions

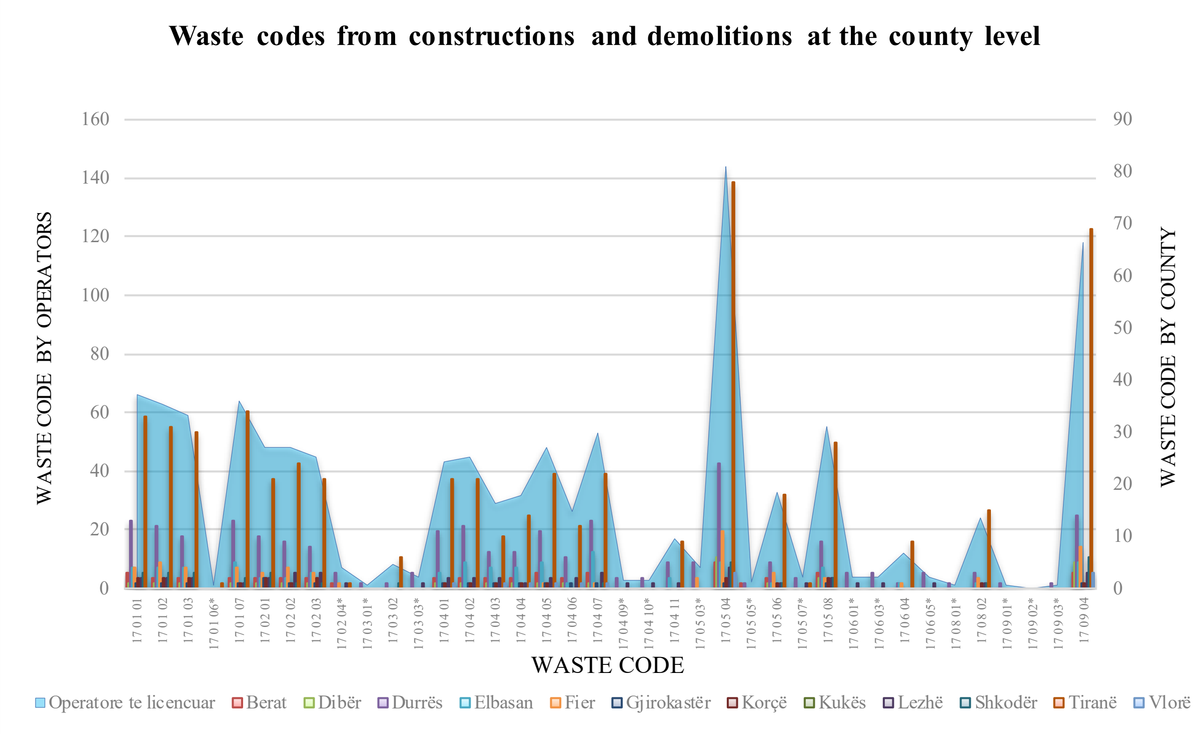


Figure 7. Waste codes from constructions and demolitions at the county level

In the above graph (Fig. 8), the data shows that the highest number of licensed operators with a greater number of waste codes from construction and demolition is held by Tirana district, followed by Durrës district. Meanwhile, the district that does not have any licensed operators for any of the waste codes from construction and demolition is Kukës district.

4. CONCLUSIONS

From this study on the "Integrated Network for Collection and Transportation of Construction and Demolition Waste" in the field of research on environmental quality and management, we conclude that:

- At the national level for the period 2017 - 2023, the highest number of approved construction permits and construction area surfaces is held by Tirana district with 2464 construction permits and 8,916,946 m^2 of approved construction area, followed by Durrës district with 1839 construction permits and 1,549,694 m^2 of approved construction area.
- The increase in the number of construction permits and construction area surfaces has led to an increase in the volume of waste generated by the construction sector.
- The high number of approved construction permits and construction area surfaces has resulted in a concentration of the highest number of licensed operators with subcategory III.2.B licenses for "collection and transportation of waste from construction and demolition" in Tirana and Durrës districts.
- At the national level for the period 2012 - 2023, construction and demolition waste occupy the highest number of licensed operators for economic sectors, where out of 500 operators in total for all economic sectors (20 economic sectors), 202 operators are licensed for the economic sector in the field of construction and demolition, identified with code 17.
- The highest number of licensed operators at the national level for the collection and transportation of waste from construction and demolition is in the year 2019.

- Construction and demolition waste with codes 17 05 04 (concrete, bricks, tiles, and ceramics) and 17 09 04 (mixed construction and demolition wastes) have the highest number of licensed operators for their collection and transportation at the national level.
- At the national level for the period 2012 - 2023, almost for all waste codes belonging to the construction and demolition sector, Tirana district holds the highest number, followed by Durrës and Elbasan districts. Meanwhile, Kukës district does not have any licensed operators for any of the waste codes from the construction and demolition sector.
- Policies, strategies, national and local waste management plans that will be adopted, reviewed, or modified in the future for integrated waste management should be based on this study to assess the possibility of establishing a network of facilities for recovery/recycling and/or treatment of each waste stream from construction and demolition.
- Economic operators operating in the construction sector who apply or seek to apply circular economy concepts during their activities should rely on this study to identify and collaborate with licensed economic operators for waste codes in the field of construction and demolition.
- Central and local institutions should promote policies for the protection of natural resources, mainly minerals (exploitation of quarries and mines), by taking concrete measures for the reuse of waste from demolition/construction as primary materials for infrastructural products (construction material) or the reuse of ferrous and non-ferrous metal waste as primary materials for the metal production and processing industry.

REFERENCES

[1] Law no. 10431, dated 9.6.2011 "On Environmental Protection", as amended, article 25 [Page 9], article 33 [Page 12]
[2] Law no. 10440, dated 7.7.2011 "On Environmental Impact Assessment", as amended, Appendices I and II [Pages 14-20]
[3] Law no. 10463, dated 22.9.2011 "On Integrated Waste Management", as amended, articles 57 - 59 [Pages 25-26]
[4] Council of Ministers Decision no. 538, dated 26.5.2009 "On licenses and permits processed by or through the national business center (NBC) and some other common sub-legal
[5] Law no. 10081, dated 23.2.2009 "On Licenses, Authorizations and Permits in the Republic of Albania", as amended, article 14 [Page 7]
[6] Council of Ministers Decision no. 402, dated 30.6.2021 "On Approval of the Waste Catalog, Appendix 1, point 3, code 17"
[7] Institute of Statistics of the Republic of Albania

Formaldehyde as an Indoor Pollutant: Origins, Impacts, and Remedial Strategies. A case study of Kosovo

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This papert delves into the issue of formaldehyde as an indoor pollutant shedding light on its origins, impacts, and potential solutions. Kosovo specifically faces challenges in maintaining indoor air quality due to industrial activities, household practices, and vehicular emissions. The combustion of fossil fuels, suboptimal waste management, and the prevalent use of solid fuels for heating contribute significantly to elevated levels of formaldehyde, exacerbating health risks. The ramifications of indoor formaldehyde pollution extend beyond environmental concerns, profoundly affecting public health, agriculture, and societal well-being. Prolonged exposure to formaldehyde-laden air poses significant threats to respiratory and cardiovascular health, particularly impacting vulnerable populations. Furthermore, the repercussions extend to ecosystems, agricultural yields, and the broader issue of climate change, necessitating a comprehensive approach for effective resolution. This paper studies the importance of strict indoor air quality monitoring, and preventive and mitigation measures involving institutions, industries, and local communities. Through the drafting and implementation of strategies aimed at formaldehyde emission reduction, advocacy for sustainable practices, and awareness raising on usage, presence and effects of Formaldehyde, Kosovo can ensure that attention is paid to indoor air quality and the creation of a healthier living environment for its populace.

Keywords: *Air Pollution, Kosovo, Formaldehyde, Impacts, Awareness Raising, Public Health*

1. INTRODUCTION

Formaldehyde is a colorless, and highly toxic gas, flammable at room temperature and a strong-smelling chemical that is commonly used in research and medical laboratories as an aquatic solution, in addition to being used in building materials. Formaldehyde is a known human carcinogen linked to nose cancer and lung cancer[1], [2], [3], [4]. Formaldehyde is a known gaseous indoor air polluter. In recent years, organizations have developed multiple concepts for assessing indoor air quality, and therefore the concentrations of formaldehyde in the indoor environment have decreased. In the air outside many metropolitan areas, formaldehyde concentrations are steadily increasing and sometimes exceeding the limits. Formaldehyde has been discussed as a typical indoor polluter for decades. Legal requirements and ever-lower allowed limits for formaldehyde in the indoor air have led to a steady reduction in the amount of formaldehyde delivered from furniture, the materials of construction and household products over many years[1], [5], [6], [7], [8], [9]. Today, the concentrations of formaldehyde in the air outdoors, especially in polluted urban areas, sometimes reach indoor levels. It is mainly the result of photochemical processes and the use of biofuels [10]. The main sources of indoor formaldehyde are wood-printed products, insulation materials, paints, lacquers, household cleaning products and cigarettes, among others[8]. Although this chemical is a known indoor pollutant, data on formaldehyde concentrations in the indoor environment are still scarce in some places. The results of many studies confirm that the indoor level of formaldehyde is a worrying health issue, which should be considered by policymakers and regulatory bodies [3], [4].

2. MATERIALS AND METHODS

The Materials and Methods section involved a comprehensive literature review and analytical investigation on Formaldehyde as an indoor air pollutant with a focus on understanding the current state of formaldehyde pollution and general indoor air quality in Kosovo. A systematic search was conducted across various academic databases, including Google Scholar, PubMed, and Web of Science, as well as national reports from the Kosovo Environment Protection Agency and other relevant institutions. Relevant articles, reports, and official documents, including any existing historical data, were identified, and thoroughly examined to gather insights into the key trends, challenges, and opportunities pertaining to the topic within the context of Kosovo. Additionally, data analysis techniques such as content analysis and thematic coding were employed to categorize and synthesize the information extracted from the literature, enabling a structured assessment of the existing knowledge landscape, and facilitating the identification of gaps and areas warranting further investigation.

3. RESULTS

3.1. Impact of formaldehyde on the environment, human and animal health

Formaldehyde is a carcinogenic substance for humans. The health effects of formaldehyde exposure can range from mild irritation of the eyes, nose, and throat to more severe respiratory issues and allergic reactions, especially in sensitive individuals. Prolonged or high-level exposure to formaldehyde has been associated with increased risks of respiratory diseases and certain cancers. Formaldehyde also damages the nervous system, and causes asthma [2], [3]. Formaldehyde usually breaks down quickly to create formic acid and carbon monoxide, which can also be harmful substances. When animals are exposed to formaldehyde, they can make them sick, affect their ability to breed and to reduce their life expectancy [3], [5].

Formaldehyde is a colorless, and highly toxic gas, flammable at room temperature. Acute exposure to it is very irritating to the respiratory system and can cause headaches and irritation of the eyes and throat at very high concentrations[5].

3.2. Formaldehyde as an indoor pollutant in Kosovo

In Kosovo, like in many other regions, formaldehyde exposure indoors is a concern due to its potential health effects. Common sources of formaldehyde indoors in Kosovo include:

- Building Materials: Many building materials, such as plywood, particleboard, and some insulation materials, contain formaldehyde-based resins. These materials can emit formaldehyde into indoor air, especially when they are newly installed or during renovation activities.
- Furniture and Furnishings: Some furniture items, including pressed-wood products like cabinets, shelving, and desks, may also emit formaldehyde. Additionally, certain textiles, carpets, and upholstery treatments can release formaldehyde over time.

- Consumer Products: Various household products such as cleaning agents, air fresheners, and personal care items may contain formaldehyde or formaldehyde-releasing compounds. These products can contribute to indoor formaldehyde levels, particularly in poorly ventilated spaces.
- Tobacco Smoke: Smoking tobacco indoors is a significant source of formaldehyde and other harmful chemicals. In households where smoking occurs, indoor formaldehyde concentrations can be elevated, posing health risks to occupants.

At present, Kosovo still legaly allows the importing of Formaldehyde for the needs of the Kosovo Energy Company (mainly heating and energy production) [11], and Formaldehyde is regularly a recognised hazardous waste in Kosovo [12]. Due to its history and decades of unregulated expolitation of resources and industry, Kosovo is facing significant environmental challenges, made worse by increased traffic in the later years. The outdoor air quality, sanitation and the state of buildings severely impacts the quality of indoor air. Older and dilapidated buildings especially, of which Kosovo has many, are riskier. According to research conducted in 2023 in Kosovo schools, Formaldehyde concentrations of 5.4 – 21.0 μg/m3 were found in the classrooms and halls, and 1.9 to 6.8 μg/m3 concentrations were detected in the schoolyards [13].

3.3. Prevention and Mitigation Measures

Mitigation and prevention strategies for formaldehyde exposure in Kosovo can be implemented at various levels, including policy, building codes, public awareness campaigns, and individual actions. Individual actions could include buying building materials and furniture that have little, or no formaldehyde added and/or being careful in the use of products and sources of heat (including cooking) that can release formaldehyde. Beware of personal care products, including cosmetics, soap, shampoo, and body washers, especially aerosols that can release formaldehyde into the air. Check product labels for these compounds that can release formaldehyde[1], [5], [8]:

- Hydantoin DMDM
- Imidazolidine urea
- Diazolidine urea
- Quaternium-15
- Bronopole (2-bromo-2-nitropropane-1,3-diol)
- 5-Bromo-5-nitro-1,3-dioxane
- Hydroxymimethyl glycine

To mitigate formaldehyde exposure indoors in Kosovo but also worldwide, several strategies can be implemented:

- Ventilation: Proper ventilation, such as using exhaust fans and opening windows, helps to dilute indoor air pollutants, including formaldehyde. Increasing ventilation rates, especially during activities that can release formaldehyde (e.g., painting, renovation), is crucial.
- Air Purification: Using air purifiers equipped with activated carbon or HEPA filters can help remove formaldehyde and other VOCs from indoor air, improving overall air quality.

- Smoking Policies: Implementing strict no-smoking policies indoors can significantly reduce formaldehyde concentrations, as tobacco smoke is a major contributor to indoor pollution.

At the policy and regulatory level, there are several strategies that can be implemented to ensure mitigation or prevention of formaldehyde pollution, such as:

- Emission Standards: Enforce stringent emission standards for building materials, furniture, and consumer products to limit formaldehyde content. Implement regulations that require manufacturers to label products with formaldehyde emissions levels.
- Building Codes: Include provisions in building codes that promote the use of low-emission or formaldehyde-free materials in construction and renovation projects. Encourage the adoption of green building practices that prioritize indoor air quality.
- Import Controls: Monitor and regulate the importation of products containing formaldehyde to ensure compliance with national emission standards. Conduct regular inspections and testing of imported goods.
- Health Campaigns: Launch public health campaigns to raise awareness about the health risks associated with formaldehyde exposure and the importance of indoor air quality. Provide information on sources of formaldehyde and practical tips for reducing exposure.
- Occupant Training: Educate building occupants, homeowners, and tenants about indoor air quality management strategies, including proper ventilation practices, use of air purifiers, and selection of low-emission products.
- School Programs: Incorporate indoor air quality education into school curricula to educate students about the impacts of indoor pollutants like formaldehyde and promote healthy habits both at home and in educational facilities.
- Smoking Policies: Implement and enforce no-smoking policies indoors to eliminate tobacco smoke, a significant source of formaldehyde and other harmful chemicals.

By implementing these multi-faceted strategies at the policy, awareness, building design, and individual levels, Kosovo can effectively mitigate formaldehyde exposure indoors and create healthier living and working environments for its residents.

4. CONCLUSION

In conclusion, formaldehyde emerges as a significant indoor air pollutant in Kosovo, posing potential health risks to its inhabitants. Our research based on literature review and analytical assessment, shows the widespread presence of formaldehyde in indoor environments, primarily from sources such as building materials, furniture, consumer products, and tobacco smoke. The proposed measures and strategies provide a roadmap for addressing this pressing issue. At the individual level, careful selection of building materials, furniture, and household products with minimal formaldehyde content is crucial. Moreover, adopting ventilation practices, using air purifiers, and implementing no-smoking policies indoors can significantly reduce formaldehyde concentrations. Policy interventions play a pivotal role in curbing formaldehyde pollution. Stringent emission standards, incorporation of green building practices, and effective import controls are essential measures. Public awareness campaigns, occupant training programs, and educational initiatives in schools further contribute to fostering a culture of indoor air quality management. Considering these findings and recommendations, it is imperative for policymakers, regulatory bodies, and stakeholders in Kosovo to prioritize formaldehyde mitigation efforts. By collectively embracing these strategies, Kosovo can pave the way for healthier indoor environments and safeguard the well-being of its populace.

REFERENCES

[1] C. B. Cheng and F. H. Lin, *Formaldehyde: Chemistry, Applications, and Role in Polymerization*, 1st ed., vol. 1. Nova Science Publishers Inc. , 2012.

[2] A. Patton, *Formaldehyde: Synthesis, Applications and Potential Health Effects*. Nova Science Publishers Inc. , 2015.

[3] L. Zhang, *Formaldehyde: Exposure, Toxicity and Health Effects*, 1st ed. Royal Society of Chemistry, 2018.

[4] M. N. M. S. Joaquim Rovira Neus Roig and J. L. Domingo, “Human health risks of formaldehyde indoor levels: An issue of concern,” *Journal of Environmental Science and Health, Part A*, vol. 51, no. 4, pp. 357–363, 2016, doi: 10.1080/10934529.2015.1109411.

[5] H. Knöppel and P. Wolkoff, *Chemical, Microbiological, Health and Comfort Aspects of Indoor Air Quality - State of the Art in SBS*. Springer Netherlands, 2013.

[6] L. Morawska and T. Salthammer, *Indoor Environment: Airborne Particles and Settled Dust*. Wiley, 2006.

[7] J. Spengler, J. Samet, and J. McCarthy, *Indoor Air Quality Handbook*. McGraw - Hill, 2001.

[8] A. T. Hodgson, D. Beal, and J. E. R. McIlcaine, “Sources of Formaldehyde, Other Aldehydes and Terpenes in a New Manufactured House,” *Indoor Air*, vol. 4, no. 12, pp. 235–242, Feb. 2002, doi: https://doi.org/10.1034/j.1600-0668.2002.01129.x.

[9] T. Salthammer, “Formaldehyde in the Ambient Atmosphere: From an Indoor Pollutant to an Outdoor Pollutant?,” *Angewandte Chemie International Edition*, vol. 52, no. 12, pp. 3320–3327, 2013, doi: https://doi.org/10.1002/anie.201205984.

[10] Prof. Dr. Tunga Salthammer, “Formaldehyde in the Ambient Atmosphere: From an Indoor Pollutant to an Outdoor Pollutant?”

[11] T. Veselaj *et al.*, “The state of waste and chemicals report,” Prishtina, 2014.

[12] T. Veselaj, P. Gashi, A. Agushi, V. Makolli, and I. Dervari, “Report on Industrial Hazardous Wastes in Kosovo,” Prishtina, 2019.

[13] A. Ukëhaxhaj, N. Ramadani, H. Moshammer, and D. Zogaj, “Sources of Indoor Air Pollution in Schools in Kosovo,” *Buildings*, vol. 13, no. 3, Mar. 2023, doi: 10.3390/buildings13030668.

Tackling Indoor Air Pollution in Kosovo: Sources, Impacts, and Mitigation Strategies for Lead

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This paper offers an overview of internal air pollution in Kosovo, specifically on lead, focusing on its sources, impacts, and potential mitigation strategies. As a developing nation in Southeast Europe, Kosovo grapples with the challenges of maintaining air quality due to a combination of industrial activities, domestic practices, and vehicular emissions. Combustion of fossil fuels for energy production, inadequate waste management, and the prevalent use of solid fuels for heating contribute to heightened levels of particulate matter, nitrogen oxides, and sulfur dioxide. The consequences of internal air pollution in Kosovo extend beyond environmental concerns, impacting public health, agriculture, and overall well-being. Respiratory illnesses, cardiovascular problems and adverse effects on vulnerable populations are notable health risks associated with prolonged exposure to polluted air. Additionally, the repercussions extend to ecosystems, agricultural productivity, and climate change, necessitating comprehensive efforts to address the issue. This paper underscores the importance of thorough air quality monitoring, policy development and collaborative initiatives involving government agencies, industries, and local communities. By implementing effective strategies to reduce emissions, promoting sustainable practices, and fostering awareness, Kosovo can work towards improving air quality and ensuring a healthier environment for its citizens.

Keywords: *Air Pollution, Kosovo, Sources, Impacts, Mitigation Strategies, Public Health*

1. INTRODUCTION

Lead is a heavy metal that can be found in various forms in the environment. It has been widely used in industrial processes, paint, gasoline, and plumbing materials. When it comes to indoor pollution, lead can enter homes through various sources and pose serious health risks, particularly to young children and pregnant women[1], [2].

Lead can enter homes through lead-based paints in older buildings (usually before 1978), lead-contaminated dust from deteriorated paint or soil, lead pipes or plumbing fixtures, some imported ceramics or pottery, certain toys or jewelry, and traditional remedies or cosmetics from other countries[1], [2], [3], [4], [5], [6]. Exposure to lead can cause serious health issues, especially in children. It can affect the brain, nervous system, kidneys, and red blood cells. Even low levels of lead exposure can lead to developmental delays, learning difficulties, behavioral problems, and lowered IQ[7]. Preventing lead exposure involves identifying and removing potential sources of lead in the home, such as lead-based paint or contaminated soil. Regular cleaning and dusting can also help reduce lead dust levels. Remediation may involve professional lead abatement services for significant lead hazards.

Lead is a very important metal. However, it also has its advantages and weaknesses in special cases of complex situations, in terms of damages that can be caused. It means that as in any metal, we must be careful to find a way to get from lead as a metal. The human factor must be careful and avoid damage or consequences that could be caused by the bullet. Lead is a metal that has been known for 7000 years. The name lead comes from the Latin word [plumbum - lead]. Lead is a chemical element found in the 14th group of the periodic system, with symbol pb and atomic number 82. Lead is found in many different elemental states. Most often we find it in the form of natural compounds [8]. The most important ones of all of them are lead galena Pbs and cerussite $PbCO_3$.

In Kosovo, the main lead minerals are found in Trepçë, Artanë, Kishnica, Hajvali, Badoc. There is a lead smelter in Zveçan [9]. It is a heavy metal that is stronger than most common materials. Lead is soft and malleable and has a low melting point. When freshly cut, lead is a shiny gray with a blue tint. It stains to a dull gray color when exposed to air. Lead has the highest atomic number of any stable element, and three of its isotopes are the endpoints of the main decay chains of the heavier elements. Lead is toxic, not a small thing, but also for many things. Everyone can make an analysis and interpret the results found from the findings made regarding lead and the care that will take place from the damages that have been brought to the environment and our lives in a dramatic way [6], [8].

Lead is highly toxic and has been a significant concern due to lead pollution from operations like the Trepçë smelter in Mitrovica, leading to serious health issues, especially among children, and necessitating cleanup efforts, soil remediation, public health interventions, and ongoing environmental management to mitigate risks and address the broader challenges of heavy metal pollution, including those from the mining sector in areas like Artana and Trepça impacting agriculture and local communities[10].

2. MATERIALS AND METHODS

This study employed a comprehensive approach to investigate the state of lead pollution in Kosovo, focusing on the environmental and health impacts, particularly in areas affected by industrial activities such as mining and smelting. The methodology involved a thorough literature review of scientific publications, government reports, and relevant documents pertaining to lead contamination in Kosovo, including data on historical industrial operations, pollution sources, exposure pathways, and health outcomes associated with lead exposure. Special emphasis was placed on evaluating the impacts of lead pollution on vulnerable populations, including children, pregnant women, and communities residing near industrial sites or areas with legacy contamination.

3. RESULTS AND DISCUSSION

3.1. Sources of Lead

Lead can be found in multiple household and industrial use products and materials, in different shapes and forms such as [1], [3], [4]:

1. Lead Ore: Natural mineral deposits containing lead, such as galena (lead sulfide) and cerussite (lead carbonate), are mined as primary sources of lead.
2. Lead Ingot: Refined lead metal is often cast into ingots for storage, transportation, and further processing.
3. Lead-acid Batteries: Lead is a key component in lead-acid batteries, which are commonly used in automobiles, backup power systems, and industrial applications.
4. Lead-based Paint: Lead was historically used as a pigment in paint to provide color and durability, although its use has been restricted due to health concerns.
5. Lead Shielding: Lead is utilized as a shielding material to block radiation in various applications, including medical imaging equipment, nuclear facilities, and aerospace.
6. Lead Solder: Lead-tin alloys are commonly used in soldering electronic components and plumbing joints due to their low melting point and excellent wetting properties.
7. Lead Bullets: Lead is a dense and malleable metal used in the production of ammunition for firearms.
8. Lead Glass: Lead oxide is added to glass formulations to increase its refractive index, making it suitable for lenses, decorative items, and radiation shielding.

9. Lead Sheet: Thin sheets of lead are used in construction for roofing, flashing, soundproofing, and radiation protection.
10. Lead Alloys: Lead is alloyed with other metals to enhance specific properties, such as hardness, machinability, and corrosion resistance. Common alloys include lead-calcium for batteries and lead-tin for soldering.

These materials highlight the diverse applications of lead across various industries, although it's important to handle and dispose of lead-containing materials responsibly to mitigate health and environmental risks.

Heavy metals are released into the biosphere by natural processes and human activities. They are mainly transferred as molecules or particles through the atmosphere, mostly on a large scale. The number of heavy metals of anthropogenic origin has increased continuously since the beginning of the industrial revolution, and the awareness and concern about the environmental and health risks associated with them has increased significantly during the last decades. The main points of metal emissions are congested urban areas with high density of industry and traffic. Lead is one of the prominent examples of anthropogenic metal pollution of the environment. In addition to industry, lead emissions were associated for several decades with the use of lead compounds as antiknock additives in gasoline. Its toxic effect is mainly the inactivation of enzymes and proteins through binding to sulfhydryl groups[2], [3], [4], [8].

Studies from research on sources of lead exposure at different sites within different regional areas are reviewed. The results showed that in Nigeria, the sources of electronic photo exposure, ink and batteries. In Mexico, the exposed sources are glazed ceramics, lead-contaminated utensils and lead-contaminated water, for India, the sources of lead are cosmetics and traditional medicines. English and electronic sources of lead exposure, traditional medicines industrial emissions. In France, the sources of exposure attention to the old house, imported ceramics and cosmetics and industrial emissions. Australia's exhibition sources in paint, powder, imported toys and traditional medicines. bottom, in the environment of pooling resources and imitation of this paint, all industrial exposure to lead and batteries. In the high-income country (HIC) Lead exposure to it keeps the exposed populations high. Low-income countries and LMICs), there are no regulation or the inability to implement population exposure regulations[1].

Homes built before 1978 (when lead-based paint was banned) probably contain lead-based paint. When paint peels and cracks, it creates lead dust. Children can be exposed to lead when they swallow or inhale lead dust. Some water pipes may contain lead. Lead can be found in some products such as toys and jewelry. Lead is sometimes found in candy or traditional home remedies. Some jobs and hobbies involve working with lead-based products, such as stained glass, and may cause parents to bring lead into the home. Children who live near airports can be exposed to lead in the air and in the ground from aviation gas used in piston-engine aircraft[1], [2], [4], [7].

Kosovo has faced challenges related to lead pollution, particularly in the town of Mitrovica, where a lead smelting plant operated for decades. The Trepçë smelter in Mitrovica was a major source of lead emissions, contaminating the surrounding environment and exposing residents to high levels of lead and other pollutants into the air, soil, and water. This contamination has affected not only Mitrovica but also nearby areas and communities. High levels of lead exposure have led to serious health consequences for residents, particularly children. Lead poisoning cases, including elevated blood lead levels, have been documented, leading to concerns about developmental issues and long-term health effects. Efforts have been made to address the lead pollution in Mitrovica. These include cleanup initiatives, soil remediation projects, public health interventions such as blood lead level screenings, and awareness campaigns to educate residents about the risks of lead exposure[10].

Despite remediation efforts, challenges remain in fully addressing the lead pollution legacy in Mitrovica and other affected areas of Kosovo. Continued monitoring, public health interventions, and environmental management are essential to mitigate the ongoing risks associated with lead exposure. The mining sector, particularly in areas like Artana and Trepça, has contributed to environmental pollution through the release of heavy metals, acids, and other contaminants into the soil and water. This has affected agricultural lands, water resources, and local communities relying on these resources for livelihoods[10].

3.2. Effects on the environment and human health

Lead-contaminated soil continues to be a dangerous source of childhood exposure for other children in the United States. Deposits from leaded gasoline, lead-based exterior paints, and industrial sources have contributed to these levels of lead in the soil. This is common in urban areas and their pre-1978 homes.

Protecting humans from lead exposure is important for lifelong good health. No safe blood lead level in children is something. Although they are low in lead, some negative levels have been shown in intelligence, the ability to devote your academic attention. While the effects of lead poisoning can damage their body permanently, if caught early, when those who want to can do to expose their children's health. Lead exposure occurs when a child comes into contact with lead by touching, swallowing, or inhaling lead or lead dust. A young Asian boy sitting on the carpet in a day care center is about to put one in his mouth. Exposure to lead can seriously harm children's health and negative effects have been documented such as[7]:

- Damage to the brain and nervous system,
- Poor growth and development,
- Learning and skill problems,
- Hearing problems,
- Lower IQ.

Lead exposure in children is difficult to see. Most children have no immediate symptoms. If you suspect that a child may have been exposed to lead, parents should talk to their child's caregiver to do a blood lead test.

Lead in water can come from homes with lead service lines connecting the home to the main water line. Some drinking water sources with lead-lined tanks and other plumbing fixtures that are not intended for drinking water (e.g., laboratory faucets, pipes, hand-washing sinks) may also have lead in the water. Lead can enter drinking water when a chemical reaction occurs in plumbing materials containing lead. This is known as corrosion - the breaking down or wearing away of metal from pipes and fittings. This reaction is more severe when the water has high acidity or low mineral content. How much lead gets into the water is related to the acidity or alkalinity of the water, the types and amounts of minerals in the water, the amount of lead the water comes into contact with, the temperature of the water, the amount of wear in the pipes, and the presence of protective steps or coatings in pipes[7].

You cannot see, taste or smell lead in drinking water. The best way to know your risk of exposure to lead in drinking water is to identify potential sources of lead in your service line and household plumbing. Your local water authority is always your first source for testing and identifying lead contamination in your tap water. Many public water systems will test drinking water for residents upon request. There are also laboratories that are certified to test for lead in water. Understand that water sample results may vary depending on time of day, season, sampling method, water flow, and other factors. Risk from Lead in Water Because no safe blood level has been identified for young children, all sources of lead exposure for children should be controlled or eliminated. EPA has set the maximum contaminant level goal for lead in drinking water at zero because lead can be harmful to human health even at low levels of exposure. Lead is a toxic metal that is persistent in the environment and can accumulate in the body over time[1], [2], [4], [7].

The risk will vary depending on the individual, the chemical conditions of the water and the amount consumed. For example, infants who drink formula prepared with lead-contaminated tap water may be at a higher risk of exposure because of the large volume of water they consume relative to their body size. Bathing and showering should be safe for you and your children because human skin does not absorb lead in water[7].

3.3. Measures for minimization

The first step is to identify potential sources of lead in your home, such as lead-based paint, dust from lead-containing materials, lead pipes or plumbing fixtures, and certain household items like imported ceramics or pottery. Remove or replace these sources wherever possible to reduce lead exposure. Keep your home clean and dust-free, especially in areas where lead may be present. Use wet mopping, wiping, and vacuuming with a HEPA filter vacuum cleaner to effectively remove lead dust and prevent it from becoming airborne.

If your home has lead-based paint, keep it in good condition by addressing any peeling, chipping, or deteriorating paint immediately. Encapsulate or seal lead-based paint surfaces to prevent the release of lead dust into the air. Ensure good ventilation in your home, particularly in areas where lead sources are present or during activities that may generate lead dust (e.g., renovation or remodeling projects). Use exhaust fans, open windows, and air purifiers with HEPA filters to improve indoor air quality.

Practice good personal hygiene, especially for young children, to reduce ingestion of lead-contaminated dust. Wash hands, toys, and surfaces regularly, and avoid eating or drinking in areas where lead exposure is possible. Conduct regular lead testing in your home, especially if it was built before 1978 when lead-based paint was commonly used. Test drinking water for lead contamination if you have older plumbing or suspect lead pipes.

For significant lead hazards or remediation needs, seek professional assistance from lead abatement contractors or environmental consultants. They can safely remove lead-based paint, address lead-contaminated soil or dust, and provide guidance on reducing lead exposure risks. Educate yourself, family members, and household occupants about the risks of lead exposure and the importance of preventive measures. Raise awareness in your community about lead pollution and advocate for policies that promote lead-safe environments.

4. CONCLUSION

In conclusion, the text provides a comprehensive overview of the issue of lead pollution, particularly focusing on Kosovo but with broader implications for global understanding and action. Lead, a heavy metal with numerous industrial applications, poses significant health and environmental risks, especially in older homes and areas with industrial activities like mining and smelting. The text highlights various sources of lead exposure, ranging from lead-based paints to contaminated soil, water, and consumer products.

Efforts to mitigate lead exposure include identifying and removing sources of lead, implementing remediation measures, conducting regular testing, and raising awareness among communities. However, challenges persist, especially in addressing historical legacies of lead pollution and protecting vulnerable populations such as children and pregnant women.

The importance of ongoing monitoring, public health interventions, and environmental management cannot be overstated in safeguarding human health and ecosystems from the detrimental effects of lead contamination. Collaborative efforts at local, national, and international levels are essential to create and enforce regulations, promote lead-safe practices, and support research and innovation for sustainable solutions to lead pollution.

REFERENCES

[1] E. Obeng-Gyasi, "Sources of lead exposure in various countries," vol. 34, no. 1, pp. 25–34, 2019, doi: doi:10.1515/reveh-2018-0037.

[2] G. J. K. Komarnicki, "Lead and cadmium in indoor air and the urban environment," *Environmental Pollution*, vol. 136, no. 1, pp. 47–61, 2005, doi: https://doi.org/10.1016/j.envpol.2004.12.006.

[3] L. H. Malcoe, R. A. Lynch, M. C. Keger, and V. J. Skaggs, "Lead sources, behaviors, and socioeconomic factors in relation to blood lead of native american and white children: a community-based assessment of a former mining area.," *Environ Health Perspect*, vol. 110, no. suppl 2, pp. 221–231, 2002, doi: 10.1289/ehp.02110s2221.

[4] A. K. Mackay, M. P. Taylor, N. C. Munksgaard, K. A. Hudson-Edwards, and L. Burn-Nunes, "Identification of environmental lead sources and pathways in a mining and smelting town: Mount Isa, Australia," *Environmental Pollution*, vol. 180, pp. 304–311, 2013, doi: https://doi.org/10.1016/j.envpol.2013.05.007.

[5] G. Sérafin, P. Blondeau, and C. Mandin, "Indoor air pollutant health prioritization in office buildings," *Indoor Air*, vol. 31, no. 3, pp. 646–659, 2021, doi: https://doi.org/10.1111/ina.12776.

[6] J. Spengler, J. Samet, and J. McCarthy, *Indoor Air Quality Handbook*. McGraw - Hill, 2001.

[7] M. Markowitz, "Lead Poisoning: An Update," *Pediatr Rev*, vol. 42, no. 6, pp. 302–315, Jun. 2021, doi: 10.1542/pir.2020-0026.

[8] H. Knöppel and P. Wolkoff, *Chemical, Microbiological, Health and Comfort Aspects of Indoor Air Quality - State of the Art in SBS*. Springer Netherlands, 2013.

[9] T. Veselaj, P. Gashi, A. Agushi, V. Makolli, and I. Dervari, "Report on Industrial Hazardous Wastes in Kosovo," Prishtina, 2019.

[10] "Organization for Security and Co-operation in Europe OSCE Mission in Kosovo Background Report Lead contamination in Mitrovicë/Mitrovica affecting the Roma community," 2009.

Water and Wastewater Treatment

Membrane Bioreactor in Wastewater Treatment- Case study: WWTP in the Cement Factory "Antea Titan "

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Membrane bioreactor (MBR) technology is an efficient technology for municipal and industrial wastewater treatment. It is a novel technology due to its divergent advantages over conventional bioreactors. With significant removal rates of contaminants, MBR has been considered as a simple, reliable and cost-effective process for wastewater treatment. However, the major drawback hindering wider application of MBRs is membrane fouling, which significantly reduces membrane performance and lifespan, resulting in a significant increase in maintenance and operating costs. In Albania it seems to be a rare technology. Only one cement fabric uses this technology which is taken as a case study in this paper.

Keywords: *Environmental education, wastewater, Albania, sustainable future, membranes.*

1. INTRODUCTION

Wastewater treatment is an important phase in the overall management of wastewater water resources. European directives, the water law, as well as the text sand recent decrees oblige to practice a thorough depollution, institute ambitious performance obligation and impose deadlines. The most common method fortreating all types of pollution is based on the concept of activated sludge process. This is composed of a ventilation tank followed by a decanter. Since a few yearsnew technique associating a bioreactor with an emerge membrane system, this is themembrane bioreactor.
A first part will be dedicated to a technical study of this process which will lead us todetermine the advantages and disadvantages.

2. PRINCIPLE OF THE TECHNIQUES

2.1. Definition-Origin

The membrane bioreactor (MBR) is a water purification plant continuous two dissociated functions:

- Purification function (the bioreactor)

- A separation function (the membranes)

This concept was born simultaneously in France (Rhône Poulenc patent) and in the United States (patent Dorr Oliver) in the 1970s. The breakthrough for the MBR came in 1989 with Yamamoto and co-workers idea of submerging the membranes in the bioreactor. Until then, MBRs were designed with a separation device located external to the reactor (sidestream MBR) and relied on high transmembrane pressure (TMP) to maintain filtration. With the membrane directly immersed in the bioreactor, submerged MBR systems are usually preferred to sidestream configuration, especially for domestic wastewater treatment.

This process applies to both urban wastewater and industrial wastewater. Indeed, there are MBR in dairy industry,pharmaceutical, petrochemical ...

This purification plant is also used in some hospitals, big hotels and even the "Queen Mary 2" cruise ship.

2.2. Types Of Membrane Bioreactors

There are two types of MBR: external membrane bioreactors (type a) and submerged membrane bioreactors (type b).

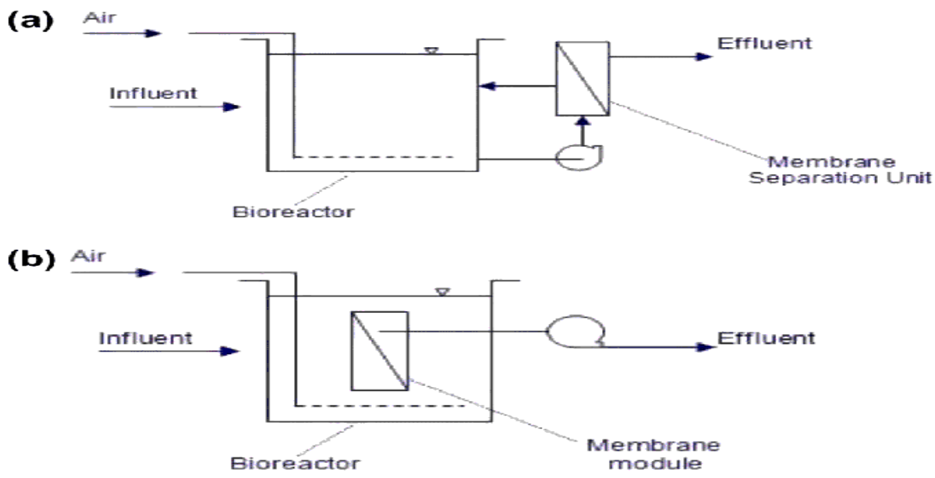

Figure 1 Types of MBRs

The first generations of MBR implement organic tubular membranes or inorganic compounds placed in external recirculation loops. This filtration module is biomass fueled by a circulation pump which also ensures a pressurization of the system. Biomass circulates at high speed in these loops to limit clogging membranes and reduce the frequency of chemical washes. But the circulation induces a energy consumption which leads these processes to high energy costs (from 10 to50 kWh / m^3) and who are not eligible when it comes to wastewater treatment. This constraint is one of the reasons for developing new configurations of MBR.(Type a: External membrane bioreactor).

The submerged membrane bioreactors have therefore appeared with the aim of simplifying implementation of the systems and reduce their operating costs. In this news configuration, the membranes are directly immersed in the ponds containing the biological sludge. The permeate is drawn off by suction using a suction pump. The work is therefore carried out in depression and does not exceed, in general, 0.5 bar against 1 bar or more for external loop processes. As a result, the associated energy expenditure not exceed 0.2-0.4 kWh / m3.

This process is therefore the most used today although it's treatment capacity is lower than for the external membrane bioreactor.(Type b: submerged membrane bioreactors).

2.3. THE BIOREACTOR

The bioreactor is the place of biological degradation of pollution. There develops a adapted biomass of microorganisms. This is composed of heterotrophic bacteria that treat biodegradable organic matter and autotrophic bacteria that metabolize ammoniacal nitrogen. The number of bacteria of each type depends on the composition of the effluent. The interest of membranes is to keep all of these microorganisms in the biological basin. In addition, they retain high-molecular weight organic molecules which prolongs their contact time with bacteria and facilitates thus their biodegradation. With regard to the hydraulic residence time and the age of the mud, they are perfectly controlled and can be chosen independently. The sludge, produced in very small quantities, is the only residue that is extracted.

2.4. THE MEMBRANES

A membrane is a barrier of a few hundred nanometers to a few millimetersthick, selective, which under the effect of a transfer force, will allow or prohibit thepassage of certain components between two media that it separates. The transfer forcecovers the gradient of pressure, concentration, activity or electrical potential. From thismade membranes include a wide variety of materials and structures.

With regard toMBR membranes, the transfer force corresponds to a difference pressure on both sides of the membrane and the most commonly used filtering microfiltration and ultrafiltration. In addition, filtration is generally tangential to the membrane.

3. BENEFITS AND LIMITATIONS OF MBR

In this section we are going to analisethe most often advantages and disadvantages listed by builders and MBR users.

3.1. THE BENEFITS

Performances

The purification efficiencies of the MBR are high allowing discharges in sensitive zones. The treated water will have undergone a strong abatement of carbonated and nitrogen pollutants. Retention SS will be almost total and the elimination of bacteria and viruses will be very advanced. To obtain the same results (in SS and COD) as the MBR, the equivalent classical station multiplies the positions (primary settling + clarification + disinfection) and therefore the sources of problem all along the chain.

Sludge

The high sludge age and prolonged contact between bacteria and organic molecules at high molecular weight facilitate biodegradation. In addition, sludge production is relatively low, up to 50% lower than conventional methods.

Compactness and adaptability

The MBR installations are very compact and modular. In addition, performance remains the same when they are subject to peaks of pollution or large variations in flow.

Economics of water resources

The treated water can be recycled into utility water for example as boiler water and in different processes.

3.2. THE LIMITATIONS

Clogging/ Fouling

Small particles and macromolecules can be retained within the membrane and block certain pores, be adsorbed on the outer surface of the micropores or to deposit there forming a gel or a deposit. This results in a clogging phenomenon that translated by a decrease in the permeate flow.

This clogging is fortunately not irreversible. Particles accumulated in front of membrane can be removed by backwashing while absorbed solutes can only be removed by chemical washing. The cleaning station which allows the washing and rinsing of the membranes is automated.

Membrane protection

Membranes are very sensitive to abrasive materials. These damage strongly the membranes then rendering them ineffective. Pretreatment is therefore generally recommended so that at the level of the membranes only a dirty water but without materials abrasive. This pretreatment depends on the characteristics of the water to be treated, it can for example be composed of screening and sandblasting.

The cost

The cost of installing brm is relatively high and they require an energy supply superior to a conventional biological process with activated sludge.

4. CASE STUDY 'TITAN' CEMENT FACTORY ALBANIA

The wastewater treatment plant at Antea Titan Cement Plant serves for sanitary water purification and processes. It is a biological type with aeration basin and biomembranes. The stages of treatment include:

- Pretreatment (rounding, grating);
- Primary treatment: decantor with a volume of 80 m^3;
- Aeration Basin (Reactor) 2 x 18 m^3;
- Sludge collection reservoir with a volume of 7.0 m^3;
- Tertiary treatment: chlorine disinfection, reservoir volume 8.5 m^3.

The average computational flow is 50 m^3/d. In the water line the flow of the influent, after gravity arrives from the main collector, inside the plant is realized by three pumps.The pumping system in the regulating tank is duplicated (service pump + stand-by pump). Reactor ventilation is accomplished by two HC-801S type blowers, each with a capacity of 198 m^3/h

and an installed power of 5.5 kW. Operating them is done automatically with a timer installed in the blower compartment. One of the bellows stands in stand-by mode.

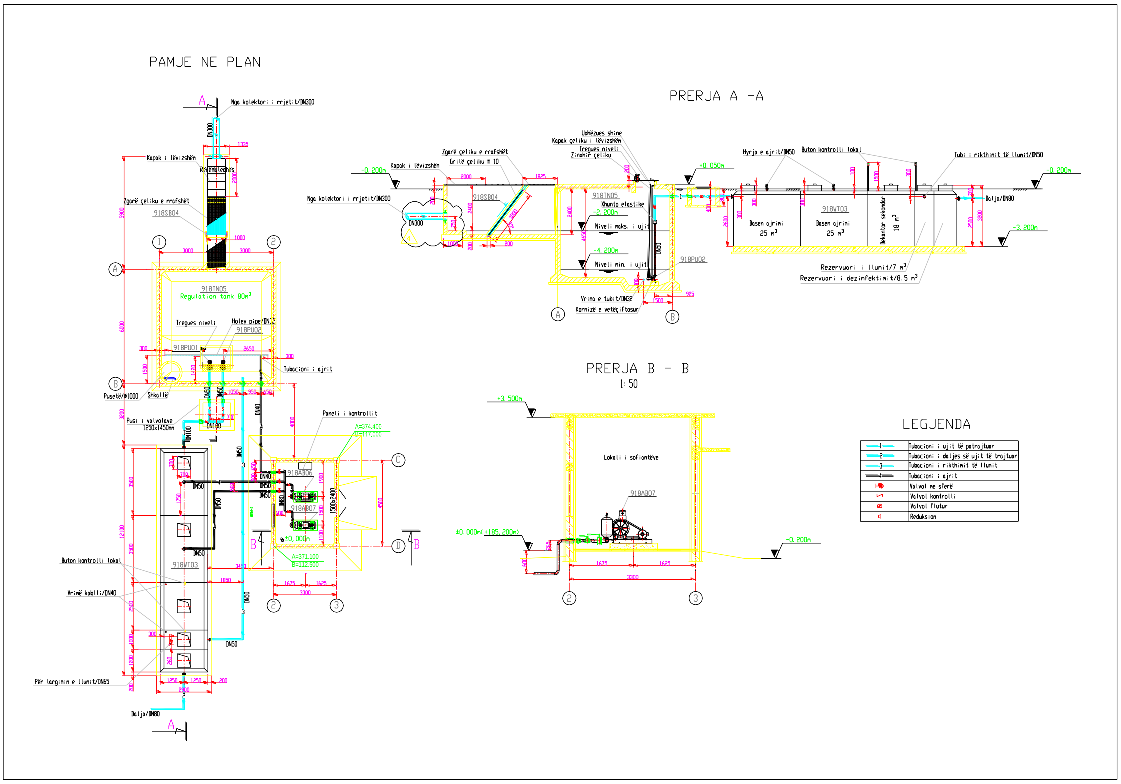

Figure 2: 'Titan' factory MBR treatment plant.

In this table we will look at and compare contaminant components and water quality indicator components. The analyzes undertaken in the study were conducted in January and February 2016 and some of them will be compared with the legal norms adopted by the decision of the Council of Ministers dated 31.03.2005. Based on the results of the analyzes and comparing them with the legal norms we see that the level of technological water treatment is quite qualitative and the final results are quite satisfactory. This shows once again the quality of this travertine technology.

Table 1. Water quality indicator components

Naming analyzes	Results for January	Results fo February	Legal Norms
pH	8.35	8.08	
Electrical Conductivity EC	935 µS/cm	735 µS/cm	
Total Suspended Solids TSS	<2 mg/L	<2 mg/L	< 35 mg/L
Turbidity	20.3 NTU	17.7 NTU	
Biochemical Oxygen Demand BOD5	10 mg/L	10 mg/L	< 25 mg/L
Chemical Oxygen Demand COD	25 mg/L	27 mg/L	< 125 mg/L
Oil & Grease	8.2 mg/L	8.4 mg/L	
Total Nitrogen N-TOTAL	13.95 mg/L	12.6 mg/L	< 15 mg/L
Total Phosphorus P-TOTAL	1.69 mg/L	1.39 mg/L	< 2 mg/L
Total Colliforms 100 ml	0 Cfu	>300 Cfu	
E-Coli 100 ml	0Cfu	3 Cfu	
Intestinal Enterococ 100 ml	0Cfu	120 Cfu	

5. CONCLUSION

The membrane bioreactor seems to be a technique in the making but still needs improvements. Its today timid development should therefore be activated in the future especially at the industrial level. Indeed, the treatment of industrial wastewater byMBR is an interesting technical solution for reducing the volume of sludge. In addition, treated water can be reused for other processes. MBR can therefore be included in a zero-rejection environmental policy.

REFERENCES

[1] Environmental interviews 2002, Water: global issues and local solutions

[2] The books of the CFM n ° 2, Micro and Ultrafiltration: conducting pilot tests,Water treatment and effluents.

[3] Implementation of functional indicators in WWTP of cement factory in Albania.

Energy Production Through Treating Wastewater

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In addition to their primary function of ensuring public health and safety through the treatment of wastewater, as well as protecting the environment, wastewater treatment plants (WWTPs) can be considered essential cells of energy resources. The paper treats the corresponding topic with detailed descriptions of processes from wastewater treatment to energy production. Flow pumping, mechanical pretreatment, digestion, sludge thickening, drainage, and energy extraction are some of the processes addressed throughout this research. Biogas obtained from the sludge of wastewater is the main product of these plants for energy production, and so are solar panels and wind turbines too. An example of using this methodfor energy production is the WWTP in Austria. Austrian institutes conclude that the heat potential in WWTPs from the digester gas and the extraction from the wastewater effluent canbe estimated at 3375 GWh/a and the potential for energy production at a dimension of 115.5 GWh/a. This production turned out to be sufficient for the plant's own requirements; furthermore, it managed to supply the surrounding area, not small areas in Austria, which proves the great capacities that this "industry" has in itself. The last part of this paperintroduces recommendations and conclusions for this form of energy production in Kosovo that are crucial for the energy transition in our country.

Keywords: *Wastewater treatment plant, energy, potential, sewage, sludge, biogas.*

1. INTRODUCTION

Wastewater treatment plants (WWTPs) serve a critical role in society by not only purifying domestic and industrial wastewater but also by potentially harnessing energy from the treatment processes. This dual functionality underscores the importance of exploring the feasibility and effectiveness of energy production within WWTPs. In recent years, there has been growing interest in utilizing various sources of energy inherent in these facilities, ranging from the combustion of solid matter derived from wastewater to the utilization of heat generated during treatment processes. Additionally, the spatial layout of WWTPs presents opportunities for the integration of renewable energy technologies such as solar panels and turbines, further enhancing their energy production potential. While several methods exist for energy production within WWTPs, this paper primarily focuses on the utilization of biogas, a byproduct of anaerobic digestion processes, as a viable source of renewable energy. The study is based on data collected from a wastewater treatment plant in Austria that employs biogas production as part of its energy generation strategy. [1] By analyzing the efficiency, sustainability, and economic viability of this energy production method, valuable insights can be gained into its applicability and potential for wider adoption within the wastewater treatment sector. It is important to note that similar energy production methods are employed in other wastewater treatment facilities around the world nowadays, including the water treatment plant in Peja, Kosovo. However, due to data limitations, this paper focuses solely on the Austrian case study. Nevertheless, the overarching goal of this research is to contribute to the broader understanding of energy production in WWTPs and its implications for sustainable development. Moreover, the energy generated within WWTPs serves primarily for internal consumption, fulfilling the operational needs of the facilities themselves. In instances where excess energy is produced, there exists the possibility of feeding it into the electrical grid, thereby contributing to local energy supplies and potentially offsetting external energy demands. Through a comprehensive examination of energy production in WWTPs, this paper seeks to shed light on the feasibility, challenges, and opportunities associated with integrating renewable energy technologies into essential infrastructure systems, ultimately advancing the transition towards a more sustainable and energy-efficient future. [2]

2. MATERIALS AND METHODS

According to Austrian researchers (Authors of "Mapping Thermal Energy Resource Potentials from Wastewater Treatment Plants", Sep 2015), the main factors to evaluate the potential of energy production in plants are the amount of water for treatment and the temperature level. For the calculation of such values, we need to have available the values of "Velocity of the volume of wastewater (***Vww***)", "Specific heat capacity of wastewater (c)" and "Change of temperature" (ΔT)". The calculation of the main factors is done through Equation (1) presented below:

$$Pww = Vww \times c \times \Delta T \qquad \text{Equation (1)}$$

***Pww** – Thermal extraction from wastewater

"The assessment of thermal energy potential is based on the following assumptions:

- The specific thermal capacity of wastewater is calculated with the appropriate water value (1.16 kWh/m^3 × K).
- The average wastewater temperature in the heating period is estimated at 10 °C.
- The wastewater in the effluent will be cooled to 5 °C so that 5 K can be extracted.

According to these assumptions, a total heat capacity of about 533 MW can be provided by wastewater in several types of WWTPs, reaching about 700 MW of the total heat capacity that includes the electricity demand of heats pumps with a performance factor equal to 4 according to Equation (2)."

$$P_{HP} = Pww \times {}^{COP}{}_{(COP-1)} \qquad \text{Equation (2)}$$

In the Austrian case, in addition to the thermal energy obtained from wastewater in the treatment plants, the production of thermal energy recovered from the solvent gas has also been applied. This type of energy is possible to produce only in the cases of WWTPs, which are equipped with solvents, which means they provide solvent gas that is considered an aid or additional source for energy production. How much is the thermal energy supply capacity from the solvent gas in the plant can be calculated through Equation (3) below:

$$ES_{th} = LE \times BEF_{th} \qquad \text{Equation (3)}$$

ES$_{th}$ – Thermal energy supply from solvent gas;

LE – Current load entering the WWTP;

PE – Population equivalent;

BEF$_{th}$ – Thermal energy factor of biogas;

The heat potential in WWTP from the digester gas and extraction from the wastewater effluent can be estimated at 3375 GWh/a, and the potential for energy production is 115.5 GWh/a. This production turned out to be sufficient for the plant's requirements, but not only that, the surplus remaining after the supply inside the plant is managed to supply the surrounding area, not small areas in Austria, which proves the great capacities that this "industry" has in itself. [1]

When we talk about treating contaminated water that contains numerous microorganisms and living matter, this process also involves recovering chemical energy. This energy can be partially retrieved in WWTPs through the process of anaerobic digestion of sludge, which produces biogas. Biogas is an energy source that can be used to generate electricity and heat. Although hydraulic energy in wastewater is low, there is technology available that can convert it into electricity through turbines or kinetic devices with a recovery efficiency of up to 90%. To explain the procedure of energy production from renewable sources, we understand that when organic waste manages to decompose in an environment without oxygen, it manages to release gases from the decomposition of one of them, methane. A case of such release is the breakdown or decomposition of waste in landfills at great depths, and this methane, instead of being released into the atmosphere and contaminating the environment, can be collected and used for energy production.

Collection of Solid Sludge: The energy production process begins with the collection of solid sludge from sewage. This sludge contains organic matter, such as food waste, fecal matter, and other biodegradable materials, which can serve as a valuable resource for energy production.

Thermal Hydrolysis: The collected sludge undergoes a pretreatment process known as thermal hydrolysis. In this step, the sludge is subjected to high temperature and pressure conditions, which break down complex organic compounds into simpler molecules. This process maximizes the amount of methane that can be produced during subsequent stages, enhancing the overall efficiency of biogas production.

Anaerobic Digestion: After thermal hydrolysis, the treated sludge is introduced into an anaerobic digester that is a biological process in which microorganisms break down organic matter in the absence of oxygen. As the organic material decomposes, methane-rich biogas is produced as a byproduct. This biogas typically consists of methane (CH_4), carbon dioxide (CO_2), and trace amounts of other gases.

Biogas Utilization: The methane-rich biogas produced in the anaerobic digester can be utilized for various energy needs. Biogas can be combusted to generate heat and electricity, which can be used to power equipment within the WWTP or supplied to the local grid for broader energy distribution. Additionally, biogas can be processed further to remove impurities and upgrade its quality, making it suitable for use as a renewable natural gas (RNG) substitute for fossil fuels.

Resource Recovery: The energy production process from organic waste not only yields biogas but also results in a nutrient-rich solid residue known as digestate. This digestate can be further processed and utilized as a valuable soil amendment or fertilizer. By returning nutrients to the soil, digestate promotes plant growth and enhances soil health, closing the nutrient loop and contributing to a circular economy approach.

Electricity Generation and Grid Integration: The electricity generated from biogas-powered generators can be integrated into the local electrical grid to meet the energy needs of surrounding communities. Depending on the scale of electricity production and the regulatory framework, excess electricity can be sold back to the grid, providing additional revenue streams for the wastewater treatment plant and promoting renewable energy integration into the broader energy infrastructure. Electricity production from biogas offers numerous sustainability benefits, including reducing greenhouse gas emissions, mitigating odors from

organic waste, and providing a renewable energy source. By converting organic waste into electricity, wastewater treatment plants contribute to resource recovery, waste management, and environmental stewardship goals, aligning with broader sustainability objectives.
Overall, the energy production process from renewable sources in WWTPs represents a sustainable and resource-efficient approach to managing organic waste while simultaneously generating renewable energy and valuable byproducts. Through the integration of advanced technologies and innovative strategies, WWTPs can play a significant role in addressing environmental challenges, reducing greenhouse gas emissions, and advancing the transition towards a more sustainable energy future.

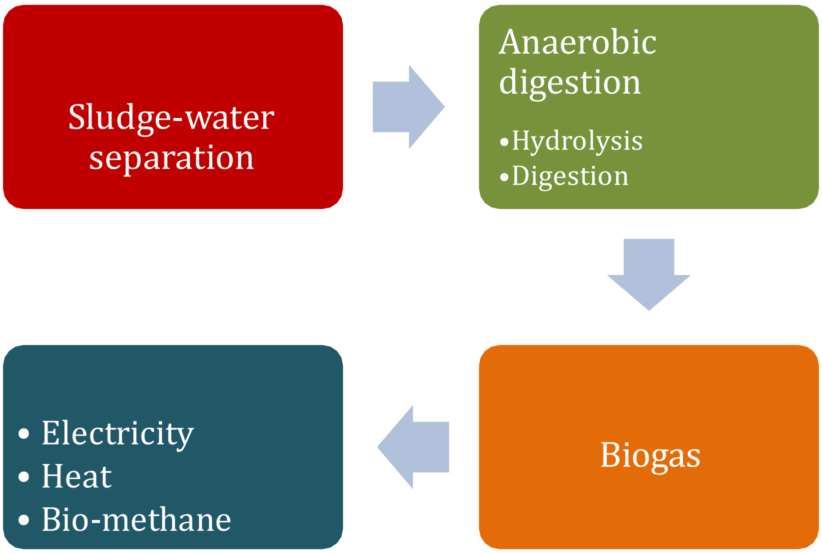

Figure 1. Main steps of anaerobic digestion in WWTP

2.1 Biogas utilization methods

To utilize the biogas from WWTPs, we need specific equipment to apply various methods. Below are listed some of the biogas utilization methods.

Table 1. Conventional use of digester biogas

Biogas utilization methods	**Equipment for the application of methods**
Digestion tank heating	Boiler, heat recovery equipment
Power generation	Biogas purification equipment, biogas generator
Facility heating	Heat recovery equipment
Conditioners	Heat recovery equipment
Sludge drying	Dryers, heat recovery equipment
Sludge pasteurization	Boiler, heat recovery equipment
Thermal hydrolysis	Boiler, heat recovery equipment

Methane sales	Biogas treatment equipment
Driven pump and fan	Biogas generator set
Burn	Fuel

2.2 Energy conservation methods in WWTPs

As a plentiful resource, the energy generated in WWTPs can be used to generate energy even when it is not needed. Researchers have been exploring methods to preserve or convert this energy for future use. Their analysis has shown that conserving energy through consumption is one of the best ways to save it. Over nearly 50 years of research, several optimization techniques and decision-making theories have been developed, and some of these techniques have been adopted by manufacturers. These techniques have proven to be effective in resolving a wide range of real-world issues in all WWTPs.

Table 2. Assessment methods for energy conservation in WWTPs [3]

Evaluation methodology	**Description**
Analytic Hierarchy Process (AHP)	AHP is a methodology used for evaluation and decision-making in systems engineering. It involves breaking down the factors involved in decision-making into goals, criteria, programs, and other levels. The method relies on subjective judgments of people to be expressed and calculated in the form of quantity. Based on this, qualitative and quantitative analysis is performed.
Life Cycle Assessment (LCA)	The structured system development method, commonly known as LCA, is a widely used approach for developing information systems. LCA is an all-encompassing tool that evaluates the entire life cycle of a product, from the extraction and processing of raw materials to its production, packaging, marketing, use, and maintenance, all the way to its eventual reuse or disposal.
Fuzzy Comprehensive Evaluation (FCE) method	The fuzzy comprehensive evaluation method is a technique used to comprehensively evaluate something using the fundamental principles of fuzzy mathematics.
	This method can convert qualitative evaluations into quantitative ones by applying the membership degree theory of fuzzy mathematics.

Specific method of energy consumption analysis	The specific energy analysis method refers to the energy consumption of a wastewater treatment plant per unit volume of wastewater. This energy is then converted into electricity (kWh/m^3).
Analysis of energy consumption per unit	The method for analyzing unit energy consumption is based on the functions and energy consumption characteristics of each sewage treatment facility within the sewage treatment plant. The plant is divided into three primary units for energy analysis, with energy consumption analysis and calculation performed separately for each processing unit. Each analysis is performed independently to determine the energy consumption per unit, the primary energy-consuming equipment, the pattern of energy consumption and the main factors that contribute to energy consumption. The energy consumption units are compared and analyzed to find the processing unit with the highest energy consumption and the devices with the largest energy consumption per unit.

3. RESULTS AND DISCUSSIONS

The data below are also confirmed by the WERF (Water Environment Research Foundation) report (Crawford and Sandino, 2010).
Energy consumption in WWTPs is classified as follows:

- Aeration of sludge liquids (55-70%).

Aeration is a critical process in biological wastewater treatment, where microorganisms break down organic matter in the presence of oxygen. The high energy consumption associated with aeration is primarily due to the need to supply oxygen to support microbial activity. Some of optimization strategies for aeration are: “fine-tuning aeration systems”: implementing advanced control systems and optimizing aeration rates based on real-time monitoring of oxygen levels and microbial activity can help minimize energy wastage while maintaining treatment efficiency; “retrofitting with energy-efficient equipment”: upgrading aeration systems with energy-efficient blowers, diffusers, and mixing technologies can significantly reduce energy consumption without compromising treatment performance; “utilizing renewable energy sources”: integrating renewable energy sources such as solar or wind power to supplement aeration energy requirements can help offset electricity consumption and promote sustainability.

- Primary and secondary placement in sludge pumping: 15.6%.

Pumping is necessary for transporting sludge between different treatment units within the WWTP, such as from primary settling tanks to secondary treatment processes or from treatment units to sludge digestion facilities. Some optimization strategies are: “hydraulic system optimization”: proper design and sizing of pumping systems, along with optimization of piping networks, can minimize friction losses and reduce energy consumption during sludge transfer; “variable frequency drives (VFDs)”: installing VFDs on pumps allows for adjusting pump speed based on varying flow demands, leading to energy savings compared to fixed-speed pumps; “sludge dewatering optimization”: implementing efficient dewatering technologies such as centrifuges or belt filter presses can reduce the volume of sludge to be pumped, thereby lowering energy requirements for sludge handling.

- Removal of liquid from the slurry: 7%.

Dewatering processes are employed to remove excess water from sludge, reducing its volume and weight for further processing and disposal. Optimization strategies: ”energy-efficient dewatering technologies”: investing in modern dewatering equipment with higher efficiency and lower energy consumption per unit of water removed can lead to significant energy savings; “heat recovery systems”: utilizing waste heat from dewatering processes for space heating or preheating influent wastewater can improve overall energy efficiency within the WWTP; “process optimization”: fine-tuning dewatering parameters such as polymer dosage, solids concentration, and dewatering duration can optimize performance and minimize energy consumption.

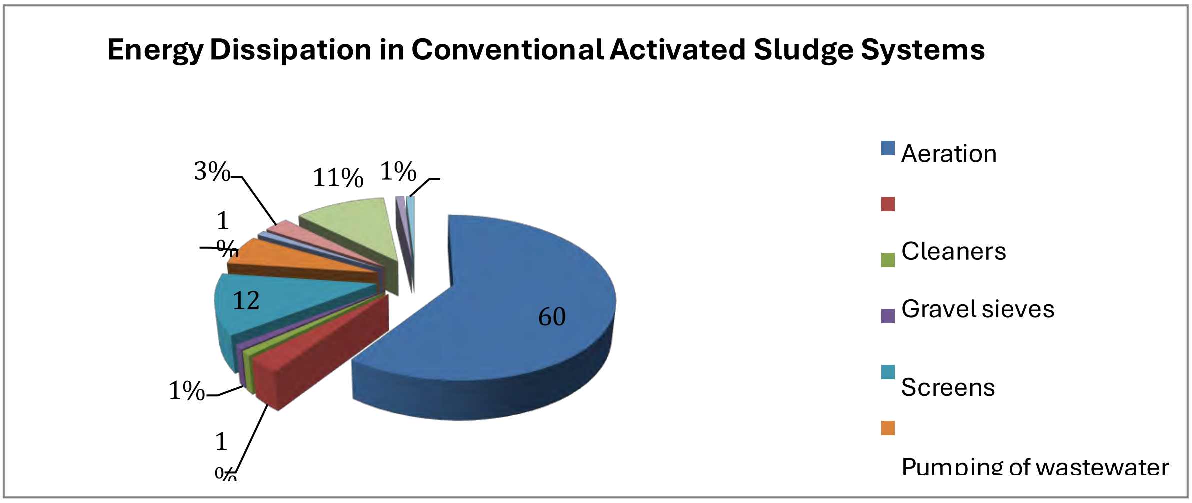

Figure 2. Energy dissipation in conventional activated sludge systems

4. CONCLUSIONS AND RECOMMENDATIONS

The main byproduct of wastewater treatment plants (WWTPs), biogas, contains methane which can be used to generate energy instead of being released into the atmosphere. Although carbon dioxide is also released during the energy production process, its net emissions are relatively insignificant when compared to methane's contribution to greenhouse gas emissions (which is 16%). Additionally, we can derive the benefits of water treatment without burdening the energy system that serves the same consumers by utilizing the energy produced by these plants.

- It is important to consider the production and conservation of energy within wastewater treatment plants right from the planning stages. This will ensure that the spaces are appropriately arranged to facilitate the application of energy production methods. The plant's internal energy should also be taken into account during the planning stages. This will ensure that the processes for preventing the spread of bacteria, viruses, parasites, and other microorganisms in the water can continue operating even in the event of an electricity supply loss.

- After processing the sludge for gas recovery to create energy, the leftover dry digest should be sold. It finds useful application in agricultural companies while gas serves as a fossil fuel.

REFERENCES

[1] Georg Neugebaue, Florian Kretschmer, René Kollmann, Michael Narodoslawsky, Thomas Ertl and Gernot Stoeglehner, "Mapping Thermal Energy Resource Potentials from Wastewater Treatment Plants," *ResearchGate,* pp. 13001, 13002, 2015.

[2] Xiaotian Fu, Leah Schleifer and Lijin Zhong,, "Wastewater: The Best Hidden Energy Source You've Never Heard Of," World Resources Institute, 17 March 2017. [Online].

[3] Ziyang Guo, Yongjun Sun, Shu-Yuan Pan and Pen-Chi Chiang, "Integration of Green Energy and Advanced Energy-Efficient Technologies for Municipal Wastewater Treatment Plants," *International Journal of Environmental Research and Public Health,* p. 16, 2019.

Comprehensive Analysis of Wastewater Treatment Processes and Environmental Impacts: A Case Study of Tirana Water Treatment Plant

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This paper offers a comprehensive exploration of the wastewater treatment processes employed at the Water Treatment Plant in Tirana, focusing on technical intricacies, environmental ramifications, and societal implications. The study delves into the treatment procedures implemented at the plant, scrutinizes both adverse and beneficial environmental and social effects encountered during project development and operation phases, examines physicochemical parameters, and anticipates enhancements in water quality within the project's ambit. The discharge of untreated wastewater into aquatic ecosystems constitutes a severe threat to water quality and public health, manifesting in recurring instances of water pollution and subsequent health hazards. To address this pressing issue, wastewater treatment plants are being established not only in Tirana but across the nation. These facilities, utilizing biological pathways, aim to elevate water treatment to a secondary level, thereby mitigating the detrimental effects of wastewater discharge. The Tirana Water Treatment Plant employs trickling filters for wastewater treatment and employs mechanical dehydration for sludge management post-thickening and digestion processes. Strategically located in Kashar, southwest of Tirana, the plant serves a populace of 850,000 individuals. The chosen site offers optimal conditions for construction and operation, including proximity to infrastructure networks and water bodies for treated water discharge. The collection and treatment of untreated sewage prior to discharge can substantially enhance river water quality and ecosystem health. Secondly, appropriate sewage handling and disposal practices are pivotal in averting contamination of ground and surface water sources. Thirdly, ensuring quality control of construction materials is imperative for the longevity and efficacy of plant operations. Lastly, while acknowledging the temporary negative environmental and social impacts during the construction phase, the long-term benefits of improved water quality outweigh these concerns.

Keywords: *Wastewater treatment, Environmental impacts, Water quality, Tirana, Sustainability, Infrastructure networks.*

1. INTRODUCTION

The purpose of this study is to know the treatment processes in the plant, the negative and positive environmental and social effects that the development of this project in the construction and operation phase, the study of the physicochemical parameters and the expectations of improving quality in the waters which are part of the project [1].
Wastewater that discharges into seas, rivers and lakes is one of the most serious problems for both water pollution and public health. The evidence is found year after year in environmental monitoring reports, which measure water quality in all basins of the country. These discharges are a source of infection and disease directly or indirectly for humans. They are the cause of the phenomenon of eutrophication, the blooming of algae, often poisonous, and with serious consequences for the living world to change this situation, not only in Tirana but throughout the country are implementing water treatment plants. The plants will treat water up to secondary level with biological pathways [2].
Water treatment plant applies the process of trickling filters for the treatment of polluted waters to

dry beds or mechanical dehydration for sludge that comes after the thickening and digestive process. The location of this plant is located in Kashar, southwest of the city of Tirana, which benefits 850,000 people. This plant will enable the treatment of according to the required standards including the sludge treatment process. The selected area is not questioned as it has optimal parameters for the construction of this plant, as it is a strategic area, reduces the costs of operation by using the transport with the gravity of polluted waters, has a flat surface area, is located near infrastructure networks, as well as near the water body for discharging treated waters [2-4].

2. MATERIAL AND STUDY METHOD

The designed technology contains pretreatment units such as: mechanical and automatic grate, collector and pumping station that sends the water to the primary level of treatment, designed as a primary decanter from which the reduction of matter in a suspended state is expected to the extent of 60% and of the need chemical for oxygen to the extent of 30%.

The secondary treatment level is designed as a trickling filter and secondary decanter. After the treated water comes out of the secondary level, it is planned to pass into a disinfection unit before it is poured to the nearest water body. The sludge treatment unit is designed with these components: sludge thickener, sludge digester and sludge drying beds or mechanical dehydrator (depending on the season).
The trickling filter technology is used for the following reasons:
• For energy saving
• Simplicity in operation and maintenance
• Technology that has been implemented in the plants of other cities in Albania
• Availability of large spaces
• Satisfactory quality is obtained.

2.1. Geomorphological indicators of the study area

In the southeast of the area, a very low-flow channel passes through the construction site, which will be used to discharge effluents from the urban wastewater treatment plant towards the Lana River. Planning the removal of water within the wastewater treatment plant is done by determining the water catchment areas and calculating the runoff water flow.
The construction of the wastewater treatment plant in Kashar is part of the project for permitting the sewerage network in Tirana, which consists in the installation of the main and secondary sewerage network in the areas defined in the map below, in area A, B and 7 and the construction of the main collector using the microtunneling technique that will send the polluted water to the plant[1-4].

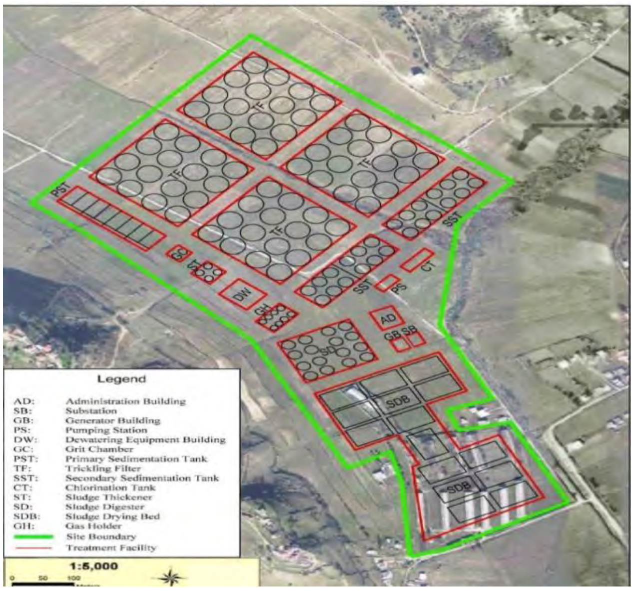

Figure 1. Aerial view and schematics of the study area

2.2. Study methodology.

Prior to the actual treatment process itself, raw waters generally undergo a pre-treatment that involves a series of physical and mechanical steps designed to decant from the wastewater the largest possible number of materials whose nature or size would cause problems in subsequent treatment processes.

The problems associated with the deficient quality of the raw water (septicity, large variations in flow and/or load, industrial effluents, etc.) inform the need for the pre-treatment to include other mechanical or chemical steps designed to improve the quality of those waters to ensure a better performance by downstream processes or avoid environmental issues. The use of a compact plant in small premises may be the most versatile solution, and significantly reduce the building work required[2][4].

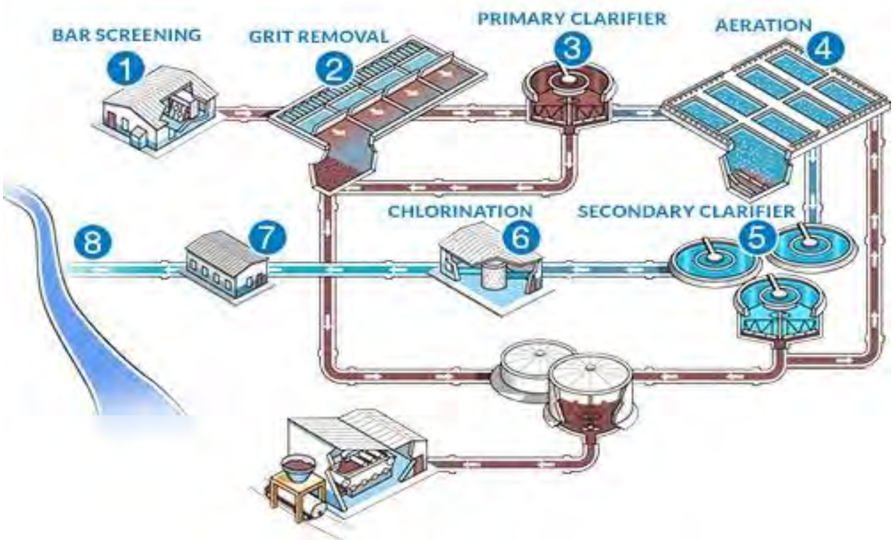

Figure 2. Eight Stages of the Wastewater Process

- Stage One — Bar Screening

Removal of large items from the influent to prevent damage to the facility's pumps, valves and other equipment. The process of treating and reclaiming water from wastewater (any water that has been used in homes, such as flushing toilets, washing dishes, or bathing, and some water from industrial use and storm sewers) starts with the expectation that after it is treated it will be clean enough to reenter the environment.

The quality of the water is dictated by the Environmental Protection Agency (EPA) and the Clean Water Act, and wastewater facilities operate to specified permits by National Pollutant Discharge Elimination System (NPDES). According to the EPA, The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. Under the CWA, EPA sets wastewater standards for industry. The EPA has also developed national water quality criteria recommendations for pollutants in surface waters. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges.

As an example of expected standards, the Biochemical Oxygen Demand (BOD) of average wastewater effluent is 200 mg/L and the effluent after treatment is expected to be >30 mg/L. It is crucial a wastewater facility meets these expectations or risk stiff penalty. The physical process of wastewater treatment begins with screening out large items that have found their way into the sewer system, and if not removed, can damage pumps and impede water flow. A bar screen is usually used to remove large items from the influent and ultimately taken to a landfill[2].

- Stage Two — Screening

Removal of grit by flowing the influent over/through a grit chamber. Fine grit that finds its way into the influent needs to be removed to prevent the damage of pumps and equipment downstream (or impact water flow). Too small to be screened out, this grit needs to be removed from the grit chamber. There are several types of grit chambers (horizontal, aerated or vortex) which control the flow of water, allowing the heavier grit to fall to the bottom of the chamber; the water and organic material continue to flow to the next stage in the process. The grit is physically removed from the bottom of the chamber and discarded[2].

- Stage Three — Primary Clarifier

Initial separation of solid organic matter from wastewater. Solids known as organics/sludge sink to the bottom of the tank and are pumped to a sludge digestor or sludge processing area, dried and hauled away. Proper settling rates are a key indicator for how well the clarifier is operating. Adjusting flow rate into the clarifier can help the operator adjust the settling rates and efficiency.

After grit removal, the influent enters large primary clarifiers that separate out between 25% and 50% of the solids in the influent. These large clarifiers (75 feet in diameter, 7½ inches at the edges and 10½ feet in the center as an example) allow for the heavy solids to sink to the bottom and the cleaner influent to flow. The effectiveness of the primary clarification is a matter of appropriate water flow. If the water flow is too fast, the solids don't have time to sink to the bottom resulting in negative impact on water quality downstream. If the water flow is too slow, it impacts the process up stream.

The solids that fall to the bottom of the clarifier are known as sludge and pumped out regularly to ensure it doesn't impact the process of separation. The sludge is then discarded after any water is removed and commonly used as fertilizer[2].

- Stage Four — Aeration

Air is pumped into the aeration tank/basin to encourage conversion of NH3 to NO3 and provide oxygen for bacteria to continue to propagate and grow.

Once converted to NO_3, the bacteria remove/strip oxygen molecules from the nitrate molecules and the nitrogen (N) are given off as $N_2\uparrow$ (nitrogen gas).

At the heart of the wastewater treatment process is the encouragement and acceleration of the natural process of bacteria, breaking down organic material. This begins in the aeration tank. The primary function of the aeration tank is to pump oxygen into the tank to encourage the breakdown of any organic material (and the growth of the bacteria), as well as ensure there is enough time for the organic material to be broken down. Aeration can be accomplished by pumping and defusing air into the tank or through aggressive agitation that adds air to the water. This process is managed to offer the best conditions for bacterial growth. Oxygen gas [O_2] levels below 2 ppm will kill off the bacteria, reducing efficiency of the plant. Dissolved oxygen monitoring at this stage of the plant is critical. Ammonia and nitrate measurements are common to measure how efficient the bacteria are in converting NH_3 to $N_2\uparrow$. A key parameter to measure in wastewater treatment is Biochemical Oxygen Demand (BOD). BOD is a surrogate indicator for the amount of organic material present and is used to determine the effectiveness of organic material breakdown. There are a number of other tests used to ensure optimal organic material breakdown (and BOD reduction) such as measuring pH, temperature, Dissolved Oxygen (DO), Total Suspended Solids (TSS), Hydraulic Retention Time (flow rate), Solids Retention Time (amount of time the bacteria are in the aeration chamber) and Mixed Liquor Suspended Solids. Ongoing and accurate monitoring is crucial to ensure the final required effluent BOD[2].

- Stage Five — Secondary Clarifier

Treated wastewater is pumped into a secondary clarifier to allow any remaining organic sediment to settle out of treated water flow.

As the influent exits the aeration process, it flows into a secondary clarifier where, like the primary clarifier, any very small solids (or fines) sink to the bottom of the tank. These small solids are called activated sludge and consist mostly of active bacteria. Part of this activated sludge is returned to the aeration tank to increase the bacterial concentration, help in propagation, and accelerate the breakdown of organic material. The excess is discarded.

The water that flows from the secondary clarifier has substantially reduced organic material and should be approaching expected effluent specifications[2].

- Stage Six — Chlorination (Disinfection)

Chlorine is added to kill any remaining bacteria in the contact chamber. With the enhanced concentration of bacteria as part of the aeration stage, there is a need to test the outgoing effluent for bacteria presence or absence and to disinfect the water. This ensures that higher than specified concentrations of bacteria are not released into the environment. Chlorination is the most common and inexpensive type of disinfection, but ozone and UV disinfection are also increasing in popularity. If chlorine is used, it is important to test for free-chlorine levels to ensure they are acceptable levels before being released into the environment[2].

- Stage Seven — Water Analysis & Testing

Testing for proper pH level, ammonia, nitrates, phosphates, dissolved oxygen, and residual chlorine levels to conform to the plant's NPDES permit are critical to the plant's performance.
Although testing is continuous throughout the wastewater treatment process to ensure optimal water flow, clarification and aeration, final testing is done to make sure the effluent leaving the plant meets permit specifications. Plants that don`t meet permit discharge levels are subject to fines and possible incarceration of the operator in charge [2][4].

- Stage Eight — Effluent Disposal

After meeting all permit specifications, clean water is reintroduced into the environment. Although testing is continuous throughout the wastewater treatment process to ensure optimal water flow, clarification and aeration, final testing is done to make sure the effluent leaving the plant meets permit specifications. Plants that don't meet permit discharge levels are subject to fines and possible incarceration of the operator in charge [2].

3. RESULTS AND DISCUSSION

The objective of the implementation of the project for Tirana is to improve the sanitary conditions of the city and stop the flow of untreated sewage into the Lana River and improve water quality. Such a goal is associated with positive influences. The project as a whole has positive impacts.

In the aquatic environment and public health through the improvement of water quality in the operational phase:

• Collection and treatment of untreated wastewater before discharge into rivers will improve water quality in rivers and improve the river environment.

• A proper sewage collection, treatment and disposal system will reduce the risk of parasites, infections and the prevalence of various diseases.

• Proper treatment of wastewater will minimize the chances of soil and surface water contamination.

• The ecological environment will be preserved by minimizing damage to flora and fauna.

• Beneficial reuse of wastewater and sludge eg. for agricultural activities, green belt developments, cement.

In the social environment through increased employment opportunities both in the construction and operation phases:

• Reducing road congestion and improving aesthetics.

• Increasing economic activities (both commercial and industrial), improving employment opportunities and economic growth.

• Improvements in public health, which will then result in higher economic activity and productivity.

• Local employment opportunities during the construction phase of the project, either as direct construction labor or to provide services at construction camps.

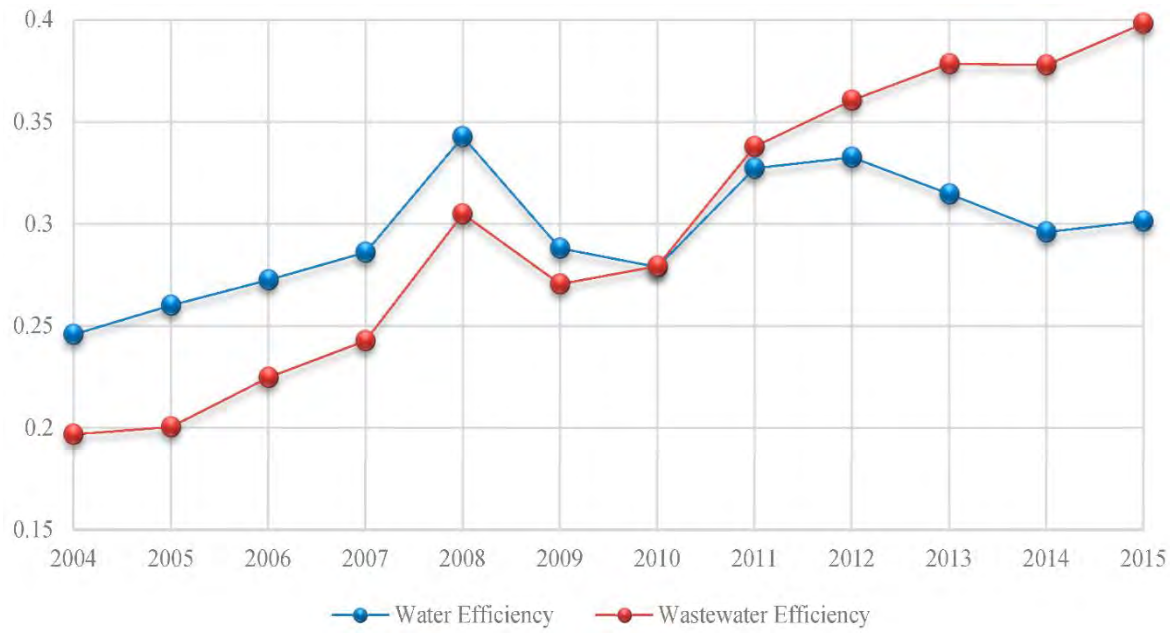

Figure 3. Effect of Sewage Treatment Plant Effluent on Water Efficiency

4.CONCLUSIONS

- Putting the polluted water treatment plant into operation will enable the improvement of the quality of Tirana rivers and the achievement of the physico-chemical parameters of the water after treatment set according to the EU.
- The implementation of this project has a negative environmental and social impact, but this impact is temporary during the construction phase.
- The plant during the operation phase will have positive environmental and social impacts.
- The technology used in the plant is a simple technology in monitoring and operation and has found application in other plants in Albania.
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REFERENCES

[1] Hoxha, V Study of physico-chemical parameters of surface waters in the Lana river, Albania. Zastita Mater.

[2] Imai, S Water Treatment Plants: Technology and Approaches

[3] YAMADA, S., IMAI, S., Lushaj, B., 2015. Study on environmental and social considerations for sewerage system and sewage treatment plant for greater Tirana.

[4] Surface water quality AKM 2021

Use of Activated Carbon for Drinking Water Treatment
Case study: Bovilla Water Supply and Purification Plant

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Bovilla Reservoir is a significant hydro-technical project in Albania. The study examines water treatment procedures at the Bovilla Plant, emphasizing the use of activated carbon. The plant can process up to 1800 l/s of surface water, meeting European quality standards. Water treatment involves various stages such as coagulation, flocculation, sedimentation, and filtration, including rapid sand filters. Chemical dosing pumps ensure precise chemical dosing, with a dedicated department for chemical storage. Treated water undergoes rapid sand filtration and automatic backwashing to maintain filter efficiency. Electronic monitoring systems track pH, temperature, turbidity, and free chlorine for optimal treatment. Upgrades in 2010-2011 improved efficiency in the chemical department, filters, flocculates, control systems, and laboratory.
The Bovilla Reservoir, created by damming the Tërkuzë River, collects water for treatment, with varying levels throughout the year. The study also addresses taste and odour concerns in drinking water, highlighting the identification of problematic compounds. Microorganisms, algae, and treatment methods are discussed in relation to taste and odour issues, focusing on the challenges of using powdered activated carbon.
In conclusion, the research offers a detailed look at water treatment processes, quality monitoring, reservoir features, taste and odour concerns, and the use of activated carbon at the Bovilla Plant. It demonstrates the plant's dedication to providing safe, high-quality drinking water to the local community. This thorough analysis highlights the plant's unwavering commitment to delivering superior drinking water to the region.

Keywords: *Bovilla Plant, drinking water treatment, activated carbon*.

1. INTRODUCTION

Taste and odour control is a significant concern for drinking water suppliers globally. Consumer complaints often revolve around unpleasant taste or odour in the drinking water [1]. Consumers are highly sensitive to changes in the taste and smell of their drinking water due to the low perception threshold of odour compounds (10–20 mg/L). While there are no specific mandates for taste and odour levels in drinking water, the World Health Organization guidelines [2] that these qualities be acceptable to prevent consumer dissatisfaction.
The Bovilla reservoir, situated 15 km North-East of Tirana, the capital of Albania, is a vital hydro-technical structure in the country that provides drinking water to Tirana. The water utility in the investigated area treats water from Bovilla reservoir and supplies 60% of Tirana city. Since autumn 2001, the reservoir has faced an unpleasant musty-earthy taste and odour problem, which is the second most common cause of odour issues after chlorine [3]. Geosmin (GSM) and 2-methylisoborneol (MIB) are the main off-flavour compounds responsible for this problem, produced by cyanobacteria [4] and actinomycetes [5]. Actinomycetes have long been linked with musty-earthy odours in water [6], but their actual role to odour in freshwater was unknown. Geosmin and other earthy–musty compounds produced in the terrestrial environment may be transported into water by runoff. [7, 8, 9]. In a study done in 2010-2013 Kullaj et al. 2013 [10] show that maximum level of actinomycetes count is associated with maximum levels of FTN (Flavour threshold number). Actinomycetes are very resistant to

treatment processes, they can colonize the structures of the drinking water plant through the spores favouring the production of odour-causing compounds in finished water [11] so traditional treatment processes are usually inadequate in removing many of these micro pollutants and more advanced processes such as ozonation and activated carbon treatment are required.
This reservoir is a warm monomictic water body and stratifies higher in the summer season. The predominant trophic state of Bovilla reservoir is oligotrophic. The reservoir has a hydraulic residence time 1.5 years [12]. The plant treats 1800 L/s raw water using oxidation, coagulation and flocculation, sedimentation, filtration and disinfection. Figure 1 gives a simplified overview of the treatment process.

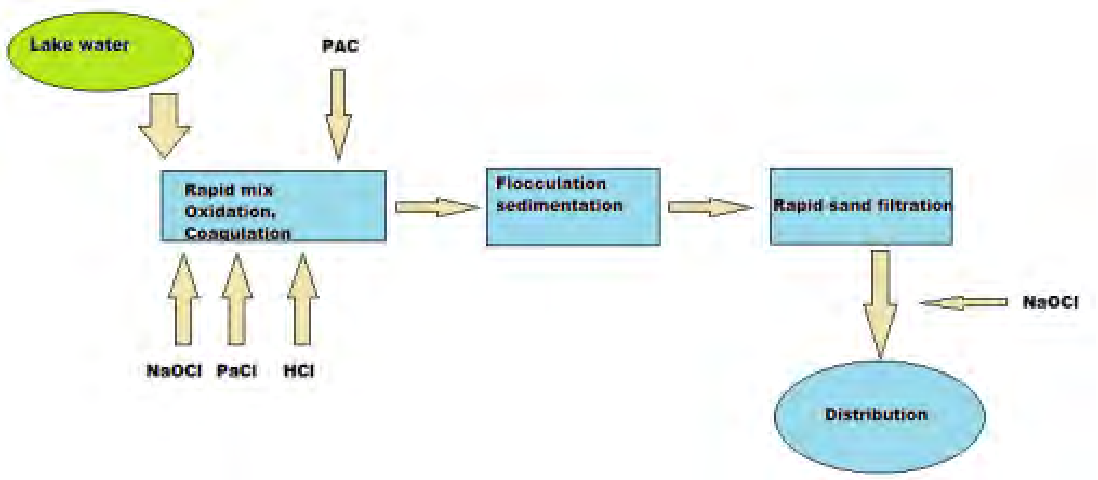

Figure 1. Treatment scheme of raw water in Bovilla plant

The Boville water treatment plant employs advanced methods such as powdered activated carbon (PAC) treatment to address seasonal taste and odor incidents. Challenges in predicting the required PAC doses can lead to under dosing, resulting in consumer complaints, or overdosing, leading to high treatment costs [13]. Factors affecting adsorption capacity include the presence of competing compounds for adsorption sites on activated carbon, disinfectants that can oxidize the carbon surface, contact time, mixing conditions, point of dosing, and coagulant presence.

The main goal of this study is to predict the necessary PAC doses for treating water from the Bovilla reservoir with taste and odor issues. The study aimed to evaluate the impact of NaOCl and other chemicals in the treatment process on removing actinomycetes and to determine the taste and odor removal efficiency of three types of activated carbons with varying iodine numbers.

2. MATERIALS AND METHODS

2.1 Sampling sites and experiments

Three were the sampling sites in WTP (water treatment plant). Site 1 represents raw water taken in the inlet of the plant. Site 2 represents water taken after coagulation, flocculation and sedimentation. Site 3 represents finished water. In the table below are shown the chronology of events and investigations.

Table 1. Chronology of events and investigations

Chronology of events and investigations	Event
Date Event May 2021-May 2023	Quality and Sensory analysis of raw water on a weekly frequency.
May 2021-May 2023	PAC adsorption experiments.
September 2023- November 2023	Laboratory scale experiments using different doses of chemicals and applying optimized doses in full scale.
September 2023- December 2023	PAC adsorption experiments using three types of PAC.

2.2 Analyses

Water samples were taken in sterile conditions and were analysed in the sampling day. The values of turbidity were measured using a turbid meter (WTW Turb 430IR model). pH values were measured with a pH meter (WTW ino Lab multi 740 model). Other parameters analysed in the laboratory of Bovilla WTP: Water temperature, ammonium, permanganate index, faecal streptococci and actinomycetes. Physical and chemical parameters were analysed according to Standard Procedures [14]. Faecal streptococci were identified by membrane filtration and was used AZIDE-NPS nutrient media. For the determination of actinomycetes 100 ml of raw water, was used. The water was filtered on a sterile green membrane filter with a pore size of 0.45 µm (Whatman). The medium used was actinomycetes NPS (DR. MÖLLER & SCHMELZ GmbH).

2.3 Flavour threshold test

Flavour threshold test (FTT) were determined by the dilution method [14]. Samples for determination of FTN (flavour threshold number) were collected from the intake of Bovilla WTP. These samples represented the 20-25 m depth waters of the lake and were analysed as soon as possible to avoid chemical and biological reactions which may possibly be able to modify the taste of water. A series of eight glass beakers was used. The water sample judged to be with taste was diluted with taste free water to a volume of 200 ml. The water was tested by a panel of six testers. To each tester was presented first the reference water, followed by the most dilute sample. From one to three additional blanks were inserted in the series. The flavour threshold number is the dilution ratio at which flavour is just detectable.

2.4 PAC adsorption experiments

In this study three commercially available PACs were employed. The PACs were dried in an oven at 105 o C for 24 h, then cooled and stored in a desiccator prior to use. Table 2 lists some characteristics of the PACs tested.

Table 2. Characteristics of powdered activated carbons (PACs) used in this study.

PAC	Iodine number m/g	Density Kg/m^3	Ash content %m/m	Granulometry <150 µm % m/m
1	850	480	7.8	98
2	1000	450	6.2	95
3	1190	415	5	100

The removal efficiency of taste and odour of PAC was determined using a jar test procedure. Six 2000- ml square jar test beakers were used and filled with 1000 ml of raw water. A PAC stock solution was prepared (1% = 10000 ppm) and concentrations of 4, 7, 10, 13 and 15 mg/L added to raw water which had taste and odour. The carbon was added to the water while mixing at 300 revolutions per minute for 30 seconds prior to the addition of other chemicals .A control containing no carbon was also prepared. The same coagulant and dose as being used at the plant was added to each jar and the same dose of chlorine and acid at the same concentrations as being used on the plant. Stirring at 300 rpm continued for 5 minutes after the addition of other chemicals. Thereafter the mixing speed was reduced to 60 rpm and stirring continued for 2 hours. The samples were left to settle for another 30 minutes. The water was then filtered through a filter paper (Whatman No. 1 equivalent) and analysed for taste.

3. RESULTS AND DISCUSSION

3.1 Quality and Sensory analysis of raw water

In the table 3 are show quality and sensory parameters of water analysed in three sites during the monitoring period. This monitoring period implicates two situation of the water quality: One situation with no taste (normal period) and the other situation with earthy taste (taste period). A study have shown that maximum levels of flavour threshold number (FTN) are observed in the same period where actinomycetes are frequent, suggesting an important role on the production of musty-earthy odour. And in fact in our study during the beginning of the bad taste are observed differences in water parameters after coagulation in comparison with the period with no taste. In site 2 of monitoring actinomycetes and faecal streptococci begins to appear. These parameters, when the taste begins have an incensement in the raw water. They survive in flocculates because of low concentration of chlorine. Chlorine is added in the rapid mix section of the WTP. In this section after problems of earthy odour occurs, PAC is added. PAC adsorbs the chlorine favouring the development of microorganisms in flocculates.

Table 3. Characteristics of water in three sites of monitoring.

Parameter	**Unit**	**Normal period**			**Taste period**		
		Raw water	Water after coagulation	Finished water	Raw water	Water after coagulation	Finished water
Water temperature	°C	10.8	10.3	10.9	10.92	10.2	11.0
pH		8.08	7.68	7.88	8.03	7.65	7.85
Turbidity	NTU	5.42	0.55	0.01	7.55	1.23	0.01
Permanganate index	mg/LO2	.95	0.57	0.57	.98	0.61	0.60
Ammonia	mg/L NH4 +	.025	0	0	.032	0	0
Free residual chlorine	Mg/L Cl	0	0.73	0.88	0	0.09	0.94
Fecal streptococci	Cfu/100 ml	54.27	0	0	120.16	0.32	0
Actinomycetes	Cfu/100 ml	16.27	0	0	89.78	0.15	0

FTN			0	0	0	13.18	0.031	0.025

3.2 PAC adsorption experiments

PAC adsorption experiments have been carried out during the taste season (September 2013- November 2013). During this period the raw water had a flavour threshold number average 20 FTN. The powdered activated carbon used for that experiment had an iodine number 1000 mg/L. The jar test procedure was used with the same chemical and doses as being used on the plant in normal conditions. In table 4 are shown results of jar test, using different doses of PAC in order to remove the earthy taste.

Table 4. Jar test results using different PAC doses.

Data	Coagulant mg/L	HCl mg/L	Chlorine mg/L	PAC mg/L	B
Jar 1 control	10	10	3	0	0
Jar 2	10	10	3	4	47
Jar 3	10	10	3	7	78
Jar 4	10	10	3	10	95
Jar 5	10	10	3	13	100
Jar 6	10	10	3	15	100
Raw water: pH=8.15 Turbidity = 13 NTU Water temperature: 11.9 °C FTN=24					

Results have shown that for the removal of taste from the water of Bovilla is needed a PAC dose between 10 and 13 mg/L. The control jar demonstrates that classical method of the water treatment is inadequate in removing earthy taste from water.

3.3 Laboratory scale experiments using different doses of chemicals

During the taste season bacterial load in the flocculates is present and the flavour threshold number is higher in comparison with raw water (when the PAC begins to be dosed), for this reason , laboratory scale experiments were done with different doses of chemical in order to remove better the taste. In table 5 are given the results of jar test. In these experiments the dose of PAC was kept 10 mg/L, a value take out from PAC adsorption experiments. Results have shown that increasing the doses of chemical, the odour is removed with e PAC dosage 10 mg/L with 100 % removal efficiency.

Table 5. Jar test results using different doses of chemicals.

Data	Coagulant mg/L	HCl mg/L	Chlorine mg/L	PAC mg/L	pH	Turbidity NTU	% Removal
Jar 1	10	10	3	0	7.73	1.53	0
Jar 2	10	10	5	7	7.75	1.51	83
Jar 3	10	13	5	7	7.63	1.51	90
Jar 4	15	13	5	7	7.54	0.94	93
Jar 5	15	12	5	10	7.51	0.86	100

**Raw water:
pH=8.18 Turbidity = 10 NTU Water temperature: 11.4 °C
FTN=24**

3.4 Applying optimized doses in full scale

Optimized dosages are been applied in full scale. Results shown in table 6 are referred to parameters measured after a week treatment with optimized chemicals doses. Results have shown that during the taste season is necessarily applying higher doses of chemical than in normal period. As the PAC adsorbs the chlorine, higher dose is need for the oxidation and disinfection to occur properly. A higher dose of coagulant and acid is needed to form more flocks to bind the microorganisms. So actinomycetes and faecal streptococci are removed from flocculates, from the bottom by a mechanical sludge removal. The presence of coagulants or chlorine or both enhanced the removal of taste.

Table 6. Water parameters after applying optimized doses of chemicals.

Parameter	Unit	Raw water	Water after coagulation	Finished water
Water temperature	°C	11.0	10.8	11.1
pH		8.17	7.58	7.83
Turbidity	NTU	10.3	0.88	0.01
Permanganate index	mg/LO_2	.96	0.51	0.50
Ammonia	mg/L NH4 +	.032	0	0
Free residual chlorine	Mg/L Cl	0	0.20	0.98
Fecal streptococci	Cfu/100 ml	230	0	0
Actinomycetes	Cfu/100 ml	84	0	0
FTN		23	0	0

3.5 PAC adsorption experiments using three types of PACs.

The AWWA standard for PAC specifies a minimum iodine number of 500 mg/g [15]. WTP of Bovilla uses an activated carbon with an iodine number minimally 900 mg /L. In our study a jar test procedure is done to establish the removal efficiency of taste and odour by three types of activated carbons with different iodine number. Results have shown that a PAC with high iodine number removes better the earthy taste from water (Table 7). However, a high iodine number is not necessarily an indication that a PAC will be effective in adsorbing the target compounds. A study has shown [16] that a high iodine number is not a guarantee of effective geosmin removal. In case of Bovilla water, taste removal efficiency was related with the iodine number of powdered activated carbon.

Table 7. Effective removal dose and with iodine number.

PAC	Iodine number mg/g	Effective removal dose mg/l
1	850	13
2	1000	10
3	1190	7

4. CONCLUSION

This study provided important information in optimizing water treatment practices for the effective removal of earthy taste from water. Results from this study indicate that:

The document highlights the inadequacy of traditional water treatment practices in effectively removing bad taste from water, particularly in the case of the Bovilla Water Supply and Purification Plant. It mentions that during the taste period, characterized by earthy taste issues, the traditional methods employed at the plant, such as coagulation, flocculation, sedimentation, and filtration, were insufficient in addressing taste and odor concerns.

During the taste season, it is indeed necessary for the Water Treatment Plant (WTP) to apply higher doses of chemicals than during the normal period in order to effectively remove the undesirable taste from the water. This is due to several factors outlined in the document. Firstly, during the taste season, there is an increased bacterial load in the flocculates, which contributes to the heightened flavor threshold number (FTN) and the presence of taste and odor compounds in the water. To combat this, higher doses of chemicals are required to ensure thorough removal of these compounds. Secondly, the presence of powdered activated carbon (PAC), which is added to address taste and odor issues, can adsorb chlorine, thus necessitating higher doses of chlorine and other chemicals for proper oxidation and disinfection to occur. Lastly, higher doses of coagulant and acid are needed during the taste season to form more flocks, which help bind microorganisms like actinomycetes and faecal streptococci, aiding in their removal from the water.

Powdered activated carbon (PAC) can indeed effectively remove taste and odor compounds from water when the correct dose is applied. The document highlights that PAC adsorption experiments were conducted to determine the optimal dosage for removing earthy taste from water at the Bovilla Water Treatment Plant. The jar test results presented in the document demonstrate that a PAC dose between 10 and 13 mg/L was effective in removing the earthy taste from the water. These experiments were carried out during the taste season, when the water had a higher flavor threshold number (FTN), indicating the presence of taste and odor compounds. Furthermore, the results show that the control jar, which did not contain any PAC, was unable to adequately remove the earthy taste from the water, emphasizing the importance of PAC in taste and odor control. Therefore, when applied at the correct dosage, PAC can be a valuable tool in water treatment processes for effectively removing taste and odor compounds, ultimately improving the quality and palatability of drinking water

REFERENCES

[1] Khiari D; Bruchet A; Gittelman T; Matia L; Barrett S; Suffett I.H; Hund R: Distribution generated taste-and-odor phenomena, Water Sci. Technol. 1999, 40 (6), 129-133

[2] World Health Organization: Guidelines for drinking-water quality, vol.1. Recommendations, 2nd ed. World Health Organization, Geneva, Switzerland. 2004.

[3] Suffett I.H, Corado A, Chou D, McGuire M.J.M, Butterworth S: AWWA taste and odor survey. J. Am. Water Works Assoc. 1996, 88 (4), 168–180.

[4] Persson P.E: Cyanobacteria and off-flavours. Phycology. 1996. 35 (6): 168-171.

[5] Klausen C, Nicolaisen M.H, Strobel B.W, Warnecke F, Nielsen J.L and Jorgensen N.O.G: Abundance of actinobacteria and production of geosmin and 2-methylisoborneol in Danish streams and fish ponds. FEMS Microbiology Ecology. 2005, 52 (2): 265-278.

[6] Silvey J.K.G, Roach A.W: Actinomycetes in the Oklahoma City water supply. J. Am. Water Works Assoc. 1953, 45, 409–416.\

[7] Raschke R.L, Carroll B, Tebo L.B: The relationship between substrate content, water quality, actinomycetes and musty odors in the broad River basin. J. Appl.Ecol. 1975, 12 (2), 535-560.

[8] Hrudey S.E, Rector D, Motkoski N: Characterization of drinking water odor arising from spring thaw for an ice-covered upland river source. Water Sci. Technol.

[9] Jensen S.E, Anders C.L, Goatcher L.J, Perley T, Kenefick S.E, Hrudey S.E: Actinomycetes as a factor in odor problems affecting drinking water from the North Saskatchewan River. Water Res. 1994, 28:1393-1401.

[10] Kullaj A, Hysko M.: Taste and odor episodes in water of bovilla reservoir used for the water supply of tirana . 5th International Symposium of Ecologist of Montenegro (ISEM5). Tivat 2-5 October 2013.

[11] Bao M.L, Barbieri K, Burrini D, and Griffini O & Pantani F: Determination of trace levels of taste and odor compounds in water by micro extraction gas chromatography-ion trap detection-mass spectrometry. Wat. Res. 1997, 31(7), 1719–1727.

[12] Miho A, Çullaj A, Bachofen R: Bovilla (Albania) Studim Limnologjik. SCOPES program 2005- 2008 (Scientific Cooperation between Eastern Europe and Switzerland). 2009.

[13] Cook D, Newcombe, G, Sztajnbok P: The application of powdered activated carbon for MIB and geosmin removal: predicting PAC doses in four raw waters.

[14] APHA (Ed.): Standard Methods for the Examination of Water and Wastewater. 20th Edition. American Public Health Association, Washington, DC. 1998

[15] American Water Works Association (AWWA), Standard for Powdered Activated Carbon ANSI/AWWA B600-90, USA, 1991.

[16] Linde J.J, Freese S.D, S Pieterse: Evaluation of powdered activated carbon (PAC) for the removal of taste and odor causing compounds from water and the relationship between this phenomenon and the physico-chemical properties of the PAC and the role of water quality. WRC Report No. 1124/1/03

Efficiency and Renewable Energy

Structural Facades. Case of "Forever Green Tower" in Tirana

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The modern construction field has seen significant advancements in city design and city skyline with the facade playing a crucial role in both aesthetics and functionality. The relationship between facade and tall buildings is conditioned by several factors such as climatic conditions, construction material, structural stability, and architectural aesthetics. Tirana as the capital of Albania, has undergone rapid growth in recent years which has influenced its vertical development, aiming to efficiently utilize the territory for various functions and facilitating the accommodation of people migrating within the territory of the Albanian state towards the capital city, Tirana. The aforementioned factors will play a key role in achieving the aim of this study, which will identify issues in the design of external cladding of tall buildings. Given that, the facade is a structural element that faces external forces, earthquakes, building movements, sudden temperature changes, the impact force of rain, atmospheric pollution, and corrosion. This paper provides a general overview of the literature on this topic and offers a thorough analysis of the factors that need to be considered during the selection of the facade typology to be used. The objective of this study will be achieved through the collection and analysis of various factors that are primary in the behavior of facades. Through modeling and extracting results from computer programs such as ETABS, the influence of the structural facade on the structure of the "4 Ever Green Tower' located in Tirana will be analyzed. This object is one of the tallest in the Balkans. Comparative analysis of the modeled building without facade load and with its load will provide us with the results we expect from this study. The results of this study are particularly important in terms of the design and construction of tall buildings with very good structural, architectural performance, and comfort that the facade offers to the buildings.

Keywords: *Structural facade, tall buildings, external forces, structural stability, architectural aesthetics, comparative analysis.*

1. INTRODUCTION

The chosen case study of Tirana Forever Green Tower is considered as one of the tallest buildings in the Balkans. The tower is 95 meters tall and serves as a multifunctional building. The total building occupies an area of more than 12,400 square meters. The building has 26 above-ground floors and 6 underground floors, specifically divided as follows: 6 floors for offices; 15 floors for a hotel; 2 floors for a restaurant on the terrace; and 3 floors for technical rooms. In the 6 underground floors, 5 floors are designated for parking, and on the -1 floor, there is a commercial space.

The building consists exclusively of an external reinforced concrete structure, constructed with cast-in-place concrete walls (which form the facade of the building). The facade is clad with precast panels with a double-layer of concrete, colored from the outside, composed of marble dust and river gravel, with the addition of oxides and necessary additives to achieve the desired colors and textured surface. In total, there are 1200m² of precast panels and 1300 linear meters of corner panels. The structural calculation scheme involves reinforced concrete shear walls, and the floor slabs in both directions are Cobiax slabs, 25cm thick, with lightweight fillers in the form of hollow blocks (composite material).

Figure 1. The external core of the building - Cast-in-place walls.

2. Determination of loads acting on the structure

The load analysis has been conducted taking into account the technical condition in force and Eurocode. Referring to the main loads acting on the first layer of the façade consists of windows. The windows are realized as open spaces left during the concrete phase and are made of W4750 type aluminium and Larson composite panels.

Regarding the windows, there have been identified the following specifications: W4750 Aluminium is an advanced aluminium system that provides elegant design and maximum safety with the highest thermal insulation requirements. This element provides four unparalleled advantages: i) Use of reinforced polyamides reinforced with glass and foam insulation material, providing high insulation level; ii) High-performance water resistance EPDM central gasket; iii) Advanced perimeter closure mechanism in a system offers an exceptional thermal insulation that constitutes an ideal solution for high-level residential and commercial projects that require high-energy efficiency performance with high design scale along with high functionality and iv) Visible aluminium with a width of 102 mm with the advanced ALU16 closing mechanism which provides more security and higher protection. [1] [2]

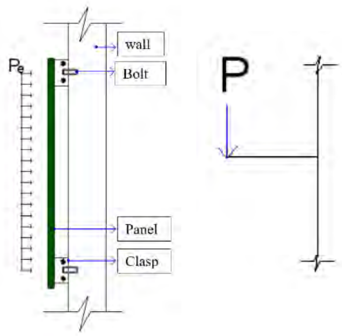
Regarding the panels, there have been identified the following specifications: It is being used a Larson composite panel which is considered a high-tech product for architectural cladding of facades. It is formed with two aluminium sheets, alloy 5005, bonded by a mineral core. The panel thickness is 6mm and the corresponded panel weight is 11.06 kg/m2. The standard width is 1500mm and the rigidity (EI) is calculated as 6 041 kNcm2/m where the moment of inertia (I) is 8630 mm4/m. [1] [2]

3. LINEAR ANALYSIS OF THE STRUCTURE

The structure will be modeled in the ETABS program based on the structural plan. Initially, a linear analysis of the structure without façade load will be performed to observe its behavior. Subsequently, the façade of the structure will be added to the model, and a second analysis will be conducted to assess the influence of the façade on the structural characteristics, including periods, displacements, and drifts. Upon completion of the analyses, it can be possible to review the results to understand how the addition of the facade affects the performance of the structure. In the figure below it can be noticed the overall structural plan of the building and also there have been given several data considerations for the linear analysis of the building without considering the façade load.

The considered calculated model of the considered load from the panel acting on the building façade is given below and the respective calculations required.

3.1 The influence of the facade on the internal stresses of the wall where it is attached



$$P = P_e + P_{panel}$$

$$P_{panel} = 11.06\ \text{kg/m}^2 * \frac{365}{2} = 20\ \text{kg/m}$$

Figure 2. The idealized scheme in the ETABS program

The force of wind acting on the structure depends on the wind pressure, the shape and height of the structure, and is calculated using the formula:

$$P_e = k * k_a * P_0 \text{ in kg/m}^2$$

Table 1. The value of coefficient K_a.[4]

The height of the object from the construction site to m.	**10**	**20**	**40**	**100**
K_a	**1.0**	**1.3**	**1.7**	**2.2**
For intermediate values, the coefficient Ka is calculated using interpolation.				

Where:

k – aerodynamic coefficient considering the shape of the structure
k_a – coefficient considering the height of the object
P_0 – wind pressure
k = +0.8; -0.6 (table 3 KTP 7-78)
k_a = 2.2 (table 1 KTP 7 -78) [4]

$$P_e = 0.8 * 2.2 * 40 = 70.4\ \text{kg/m}^2 * \frac{3.65}{2} = 128\ \text{kg/m}$$

Referring the calculation in Ultimate Limit State (ULS):

$$P = 1.35\ (D) + 1.5\ (W_p) = 1.35 * P_{panel} + 1.5\ P_e = 1.35 * 20 + 1.5 * 128 = 219\ \text{kg}.$$

Therefore, the worst case loading for the bolt will be 219 kg.

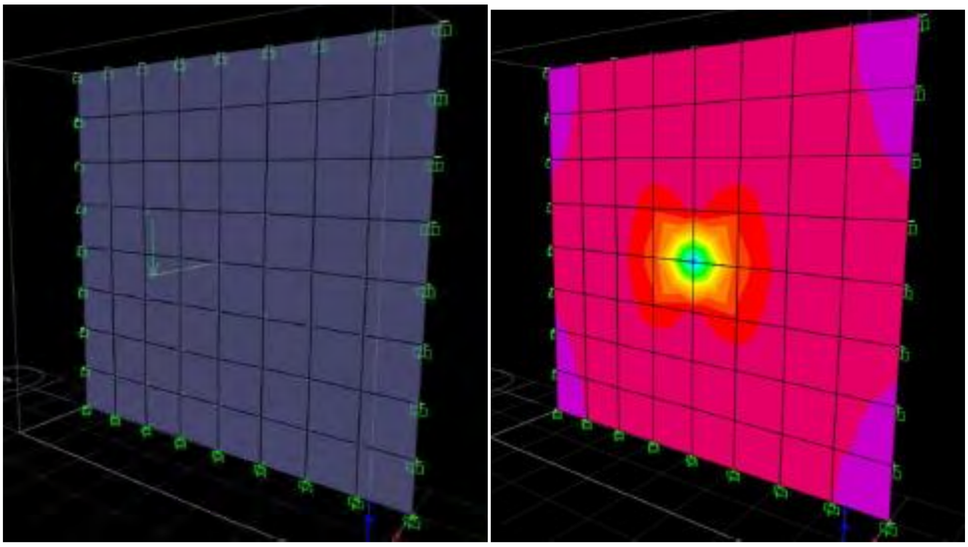


Figure 3. The idealized scheme in the ETABS program

Verification of stresses for Ultimate Limit State (ULS):

$$\frac{\sigma\ Ed}{\sigma\ Rd} = 1$$

$\boldsymbol{\sigma\ Ed}$ The stress at the edge of the concrete due to external load (Tensile stresses)

$\boldsymbol{\sigma\ Rd}$ The stress at the edge of the concrete

$$\boldsymbol{\sigma\ Ed = 1.3\,\frac{dan}{cm\ 2}}$$

$\boldsymbol{\sigma\ Rd}$ = $\boldsymbol{fctd}$ the design tensile strength of concrete

$$\boldsymbol{fctd\ =\ fctd\,\frac{fctk\ 0.05}{\gamma\ c} = 1 * \frac{20}{1.5} = 13.33\ Mpa\ \left(\frac{daN}{cm2}\right)}$$

$\frac{1.3}{13.33} = \boldsymbol{0.1 \leq 1}$ The tensile stresses induced in concrete by the bolt are very small

In order to best consider the effect of the panels loads to the rest of the building structure there have been analyzed two main cases; the first case is referred to the building façade without considering the loads coming from the panels and the second case is referred to building analyses while also considering the façade loads acting on the structure. A comparison is done in this regard and the main results are presenting below.

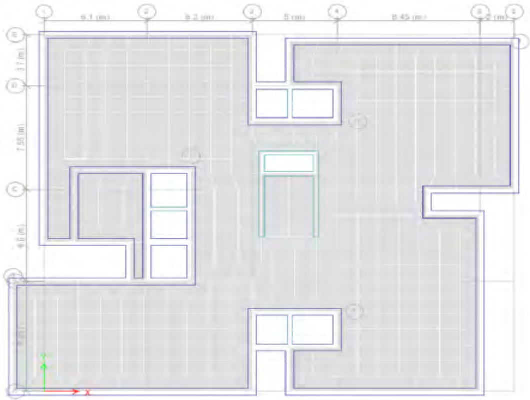


Figure 4. Building structural plan (source: authors 2024)

Useful general data on building:
Floor height → 3.65 m;
Number of floors → 26 floors;
Maximum ground acceleration → ag=0.3g;
Seismic Category (according to EC-8) → C;
Response Spectrum → Type 1;
Ductility Class → DCM (medium ductility class)
Materials: Concrete → C40/50; fck = 40 MPa; Ec = 35 Gpa;
Loads:
Permanent load on the slab → 150 daN/m2;
Distributed load of the walls on the slab → 200 daN/m2;
Temporary load on the slab → 200 daN/m2;
Seismic loads:
The response spectrum is constructed based on Eurocode-8.
From Table 3.2 in Eurocode 8, there have been derived the following values depending on the soil category: S=1.15 (soil factor)
TB= 0.2s
TC= 0.6s
TD= 2s [3]

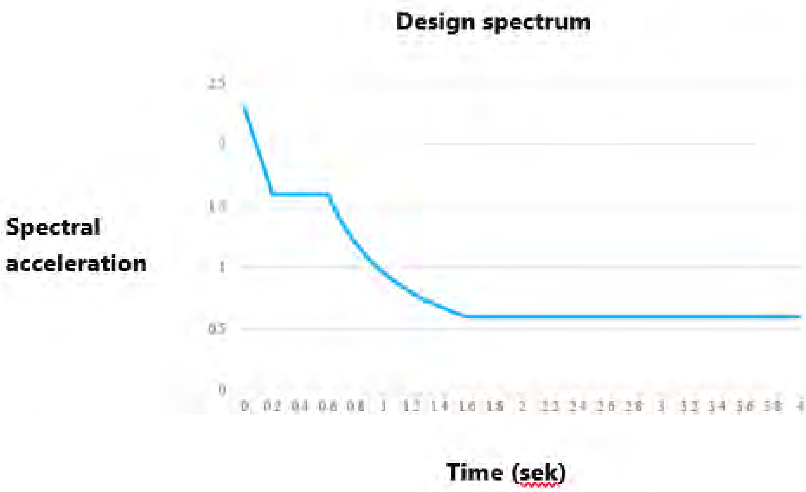


Figure 5. Design spectrum (source: authors 2024).

In addition to the above information, the determination of the behavior factor "q" value [3] is also very important. According to Eurocode 8: The behavior factor "q" needs to be determined => $q = q0kw = 3$. Based on the formulas from Eurocode 8, it can be easily constructing the spectrum. [3]

On the other hands the combination of loads and actions is based on Eurocode 1, 2, and 8. The following table provides the combinations used: [3]

Table 1. The combination of loads (source: authors 2024).

Combination Coefficient						
Combination	**Permanent Load**	**Temporary Load**	**Seismic Load in the X direction**	**Seismic Load in the Y direction**	**Wind Load in the X direction**	**Wind Load in the Y direction**
DCON1	1.35	-	-	-	-	-
DCON2	1.35	1.5	-	-	-	-
DCON3	1	0.45	1	0.3	-	-
DCON4	1	0.45	0.3	1	-	-
DCON5	1	0.45	-	-	1	0.3
DCON6	1	0.45	-	-	0.3	1

3.1 Structural analysis and presentation of results of the first case study without façade loads

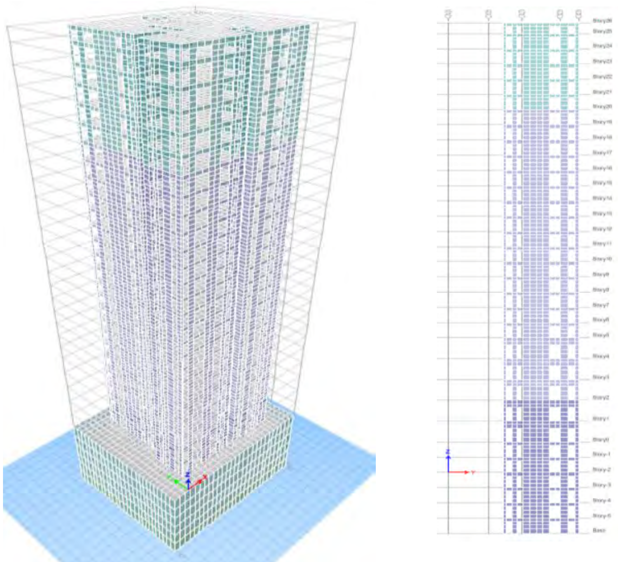


Figure 6. The model in ETABS, 3D-view, and sections

The main results regarding the modal analysis for the first mode of vibrations is been given below. There are no torsional coupling phenomena observed in this case. As it can been clearly seen the structure is moving in xy direction showing translative movement.

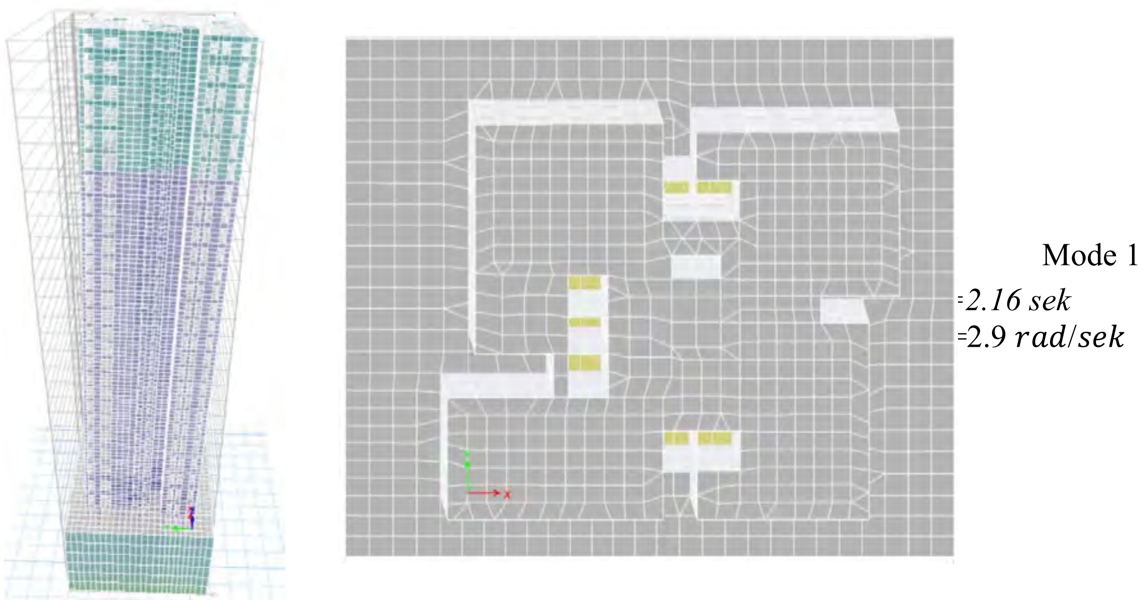
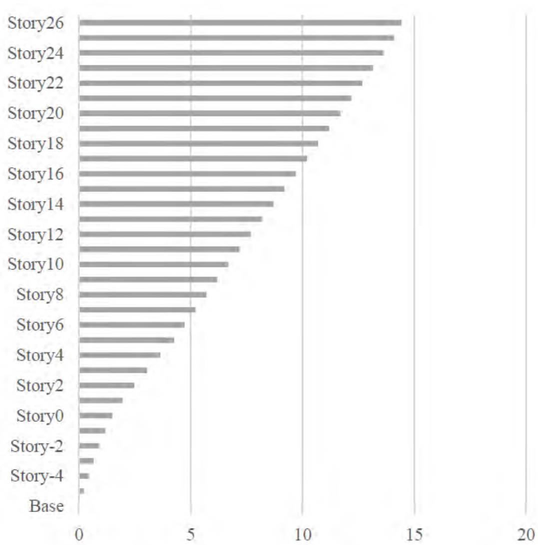


Figure 7. Results of modal analysis for the first mode of vibrations

Also, regarding the displacements and drifts results from the modal analysis according to Load Combination 4, they are been given in the table below.

Table 2. Displacements and drifts according to Load Combination 4

Zhvendosjet dhe driftet sipas Komb-4						
Kati	**Lartësi**	**Zhvendosje**	**Drifti**	**Drifti lejuar**	**q**	**Zhvendosja**
	m	**cm**				**elasto-plastike**
Story26	**107.8**	**14.4298**	**0.3204**	**<1.217**	**3**	**43.2894**
Story25	105.3	14.1094	0.4739	<1.217	3	42.3282
Story24	101.65	13.6355	0.4785	<1.217	3	40.9065
Story23	98	13.157	0.4844	<1.217	3	39.471
Story22	94.35	12.6726	0.4896	<1.217	3	38.0178
Story21	90.7	12.183	0.4935	<1.217	3	36.549
Story20	87.05	11.6895	0.4929	<1.217	3	35.0685
Story19	83.4	11.1966	0.4956	<1.217	3	33.5898
Story18	79.75	10.701	0.4984	<1.217	3	32.103
Story17	76.1	10.2026	0.5007	<1.217	3	30.6078
Story16	72.45	9.7019	0.5024	<1.217	3	29.1057
Story15	68.8	9.1995	0.5034	<1.217	3	27.5985
Story14	65.15	8.6961	0.5038	<1.217	3	26.0883
Story13	61.5	8.1923	0.5034	<1.217	3	24.5769
Story12	57.85	7.6889	0.5021	<1.217	3	23.0667
Story11	54.2	7.1868	0.4999	<1.217	3	21.5604
Story10	50.55	6.6869	0.4969	<1.217	3	20.0607
Story9	46.9	6.19	0.493	<1.217	3	18.57
Story8	43.25	5.697	0.4876	<1.217	3	17.091
Story7	39.6	5.2094	0.4814	<1.217	3	15.6282
Story6	35.95	4.728	0.4671	<1.217	3	14.184
Story5	32.3	4.2609	0.6135	<1.217	3	12.7827
Story4	27.3	3.6474	0.5983	<1.217	3	10.9422
Story3	22.3	3.0491	0.5692	<1.217	3	9.1473
Story2	17.3	2.4799	0.5185	<1.217	3	7.4397
Story1	12.3	1.9614	0.4757	<1.217	3	5.8842
Story0	7.3	1.4857	0.3059	<1.217	3	4.4571
Story-1	3.65	1.1798	0.279	<1.217	3	3.5394
Story-2	0	0.9008	0.2384	<1.217	3	2.7024
Story-3	-3.65	0.6624	0.2246	<1.217	3	1.9872
Story-4	-7.3	0.4378	0.2205	<1.217	3	1.3134
Story-5	-10.95	0.2173	0.2173	<1.217	3	0.6519
Base	-14.6	0	0	<1.217	3	0



The displacements are taken according to Load Combination 4 for reasons of the highest value. The allowable displacement at the peak is: $\Delta r = \Delta e \cdot q \leq 1200 \cdot H$ (from the Eurocode EC-8)

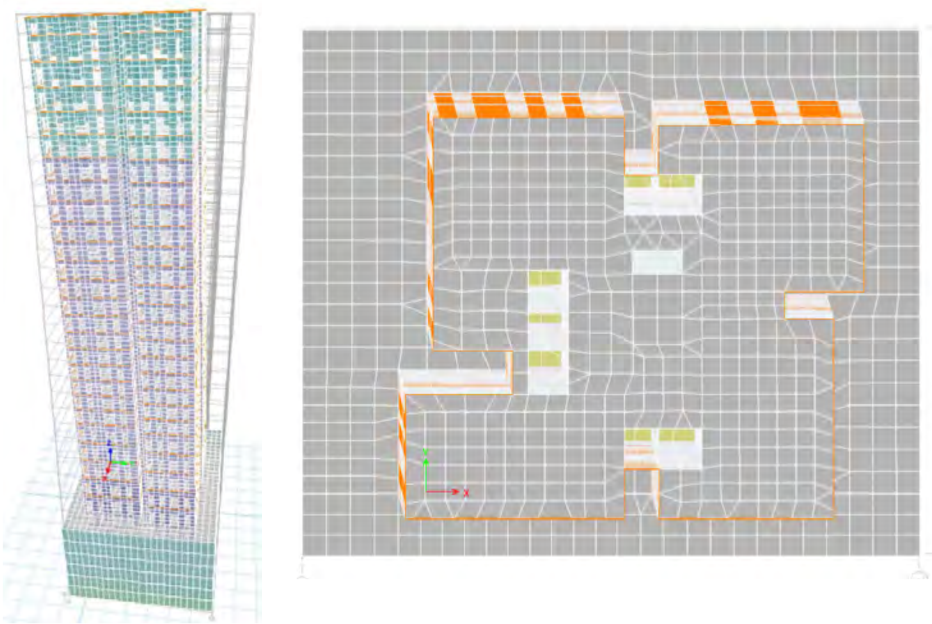
Then: $\Delta e \leq 1200 \cdot q \cdot H = 1200 * 3 * 10780 = 17.9 cm$

The maximum allowable elastic displacement at the peak of the building is 17.9 cm. The maximum elastic-plastic displacement is "q" times greater, thus 53.7 cm. The absolute displacement at the peak from the elastic analysis results in $\Delta \boldsymbol{e}$ =14.43 cm, which is the smallest value allowed. While the full elastic-plastic displacement at the peak of the building is: $\Delta r = \Delta e \cdot q = 14.43 * 3 = 43.29 cm$.

3.2 Structural analysis and presentation of results of the first case study with façade loads

In the following case study, it was added the façade load. The façade load on the structure will be placed around the perimeter as a distributed load on each floor. Since the structure is modeled entirely with wall elements (Wall) as there are no columns and beams but only walls, then on the perimeter, it was placed beams but with zero stiffness, meaning the elasticity modulus for the beam is set to zero, and on these beams, we place the façade load. The façade load on the beam will be equivalent to the panel load we have determined above multiplied by a safety coefficient. So, on the perimeter beam, it was added a load of 60kg/m.

1



Mode

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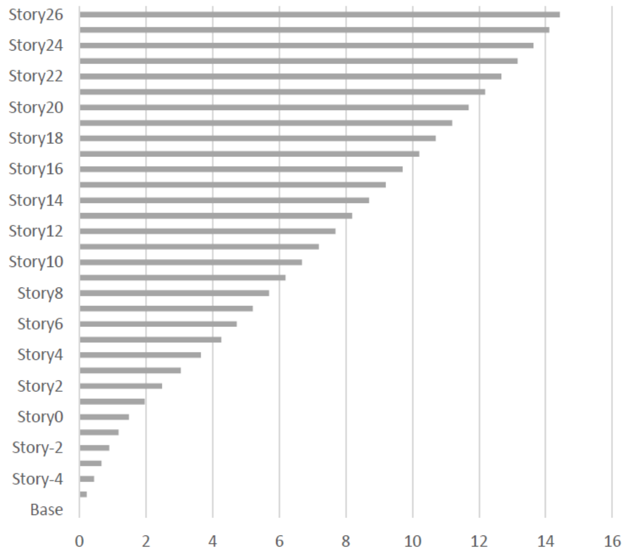
Figure 8. Results of modal analysis for the first mode of vibrations

Regarding the main displacements and drifts values there are given below.

Table 3. Displacements and drifts

Zhvendosjet dhe driftet sipas Komb-4						
Kati	Lartësi	Zhvendosje	Drifti	Drifti lejuar	q	Zhvendosja
m		cm				elasto-plastike
Story26	**107.8**	**14.3851**	**0.3196**	**<1.217**	**3**	**43.1553**
Story25	105.3	14.0655	0.4725	<1.217	3	42.1965
Story24	101.65	13.593	0.477	<1.217	3	40.779
Story23	98	13.116	0.4826	<1.217	3	39.348
Story22	94.35	12.6334	0.4878	<1.217	3	37.9002
Story21	90.7	12.1456	0.4918	<1.217	3	36.4368
Story20	87.05	11.6538	0.4909	<1.217	3	34.9614
Story19	83.4	11.1629	0.4936	<1.217	3	33.4887
Story18	79.75	10.6693	0.4964	<1.217	3	32.0079
Story17	76.1	10.1729	0.4985	<1.217	3	30.5187
Story16	72.45	9.6744	0.5002	<1.217	3	29.0232
Story15	68.8	9.1742	0.5012	<1.217	3	27.5226
Story14	65.15	8.673	0.5016	<1.217	3	26.019
Story13	61.5	8.1714	0.5012	<1.217	3	24.5142
Story12	57.85	7.6702	0.4997	<1.217	3	23.0106
Story11	54.2	7.1705	0.4977	<1.217	3	21.5115
Story10	50.55	6.6728	0.4947	<1.217	3	20.0184
Story9	46.9	6.1781	0.4907	<1.217	3	18.5343
Story8	43.25	5.6874	0.485	<1.217	3	17.0622
Story7	39.6	5.2024	0.479	<1.217	3	15.6072
Story6	35.95	4.7234	0.4652	<1.217	3	14.1702
Story5	32.3	4.2582	0.6123	<1.217	3	12.7746
Story4	27.3	3.6459	0.5971	<1.217	3	10.9377
Story3	22.3	3.0488	0.5683	<1.217	3	9.1464
Story2	17.3	2.4805	0.5179	<1.217	3	7.4415
Story1	12.3	1.9626	0.4755	<1.217	3	5.8878
Story0	7.3	1.4871	0.3059	<1.217	3	4.4613
Story-1	3.65	1.1812	0.2792	<1.217	3	3.5436
Story-2	0	0.902	0.2386	<1.217	3	2.706
Story-3	-3.65	0.6634	0.225	<1.217	3	1.9902
Story-4	-7.3	0.4384	0.2208	<1.217	3	1.3152
Story-5	-10.95	0.2176	0.2176	<1.217	3	0.6528
Base	-14.6	0	0	<1.217	3	0



4. Comparison of Two Models

From the results of modal analysis, it can be observed that:

Mode 1 (Without façade load): **Mode 1 (With façade load):**

T=**2.161** sek $\omega = \mathbf{2.9079}\ rad/sek$ T=**2.156** sek $\omega = \mathbf{2.9148}\ rad/sek$

According to the displacement table, combination 4 shows that:

The value of drift at the 26th floor:

Without façade load: With façade load:

0.3204 **0.3196**

The value of elastic-plastic displacements at the 26th floor:

Without façade load: With façade load:

42.2894	**43.1553**

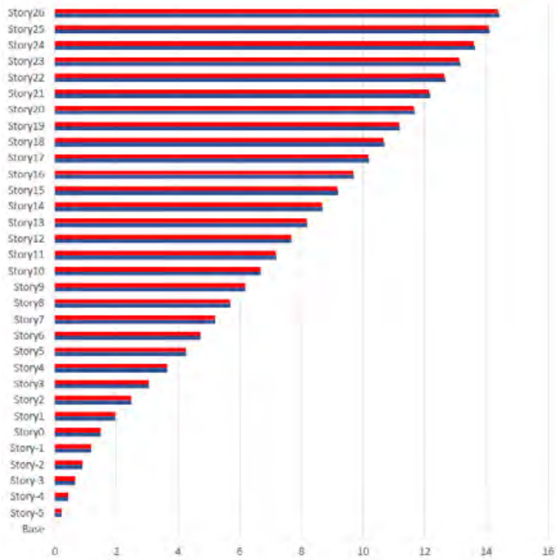


Figure 9. Comparison of displacements with load and without load.

Red- Displacements with facade load   Blue- Displacements without facade load

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the comparison of the two analyses and the results of the structure with façade load and without façade load, as well as the influence of the façade on the internal stresses of the wall where it is attached, the following conclusions have been reached:

1. The facade in this case study hardly affects the intrinsic characteristics of the structure, as evidenced by the comparison of results concluded from graphs and tables processed by the ETABS program. This can be explained by the fact that the structure, regardless of its height, has a high stiffness because it consists solely of walls, which are good systems against displacements and drifts.
2. The structure is not very tall to exhibit problems against wind loading, which would require a more comprehensive treatment later on.
3. The country of Albania is characterized by high seismicity, and for this reason, structures are designed for seismic loads, comparing the seismic load with the facade load in the structure, the latter being much smaller. This results in a structure designed for a much larger load in which the façade, along with the wind load, does not pose significant problems.
4. The installation of the facade seems to not impact the internal stresses of the wall. Anyway, it is recommended that the tensile/compressive stresses induced by the bolt should be much smaller than those allowed.

REFERENCES

[1] Aksamija, A. 2013. Sustainable Facades: Design Methods for High-Performance Building Envelopes. United States: John Wiley & Sons.
[2] EN 1998-1: Eurocode 8: Design of structures for earthquake resistance

[3] Guglielmetti, R., D. Macumber, and N. Long. 2011. OpenStudio: An Open-Source Integrated Analysis Platform. United States: National Renewable Energy Lab. (NREL), Golden, CO.
[4] KTP 7-78 Kushtet Teknike të Projektimit
[5] Manuali Teknik i Alumil për sistemin M1 (2016).
[6] Manuali teknik i Alumil për sistemin M50 Energy (2017).
[7] Rivka, O., (2008) "Performance-Based design: Current Practices and Research Issues." International Journal of Architectural Computing 6 (1): 1–17.

Analysis and Design of 5-MW Onshore Wind Turbine Under Wind Load

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As the world struggles with the pressing need for sustainable energy solutions, renewable sources like wind energy have emerged as promising alternatives to fossil fuels. Using wind energy to create clean electricity, onshore wind turbines are an important component of the renewable energy industry. In this regard, careful consideration must be given to the design and analysis of wind turbines to ensure both structural integrity and maximum performance. One of the most important elements in the functionality of wind turbines is foundation design, as it transfers and distributes structural loads safely to the ground. From blade design to tower construction, every element must be finely tuned to withstand environmental forces while maximizing energy output. With careful planning and innovation, these turbines can continue to play a pivotal role in meeting the world's growing energy needs while advancing towards a cleaner, more sustainable future. Investigating the performance of onshore wind turbine structures, this study aims to understand their response to various environmental and operational factors. Throughout their lifespan, wind turbine structures are subjected to dead load itself, seismic loads, aerodynamic loads, and operational loads. Understanding the loads is crucial for effective design, construction, and ongoing performance. Hence, this study focuses on the analysis of onshore wind turbine structures by using FAST (Fatigue, Aerodynamics, Structures, and Turbulence), an open-source software developed by the National Renewable Energy Laboratory (NREL). By integrating various physical domains such as aerodynamics, and structural dynamics into a comprehensive simulation by using FAST, it aims to gain insights into the dynamic behavior of a 5 MW onshore wind turbine structure by incorporating the effects of wind turbulence on the structure.

Keywords: *Wind turbine, Renewable energy, FAST.*

1. INTRODUCTION

Despite it being one of the oldest sources of clean energy, wind energy is still considered one of the rapidly developing sources in the field, with room for further development. A major key in wind turbines' performance and stability is understanding the different loads it is subjected to. These loads mainly include structural and environmental loads. Structural loads are the loads resulting from the mass of the structure which plays an important role in its stability. On the other hand, environmental loads include seismic, wind, and aerodynamic loads which could also be classified as dynamic loads. For environmental loads, a primary concern is that they behave in a cyclic pattern, meaning that they are applied to the structure over repeated cycles. An example of this behaviour is the wind loads which could lead to fatigue failure. Secondly, they are unpredictable, varying in load being applied. For instance, seismic loads and extreme wind conditions.[1] Therefore, when designing wind turbine structures, the ultimate strength and fatigue limits need to be investigated. In recent years the dynamic response of wind turbine structures, specifically the one caused by the wind loads, has been studied. In this study, however, the aim is to better understand the dynamic response by comparing different wind load effects on fatigue limit in normal operating conditions and Ultimate limit in extreme conditions.

Wind loads are one of the most crucial environmental loads in the wind turbine. Although it is key in determining the design aspects of wind turbines, wind load is a variant that can't be controlled or predicted easily. Wind speed changes in both magnitude and direction over time. Therefore, different mathematical representations are used to better showcase this variation. For its variation over shorter periods, power energy spectral density models are used. It represents the varying wind energy over a frequency domain, instead of a time domain. The two most used models are Von Karman and the Kaimal spectrum. In this study, the Kaimal spectrum is used as it is better at representing variation over small frequencies [1]. On the other hand, The Weibull probability distribution functions are used for long-period representation which is key in fatigue. A 10-minute mean wind speed is used with different return periods. For normal conditions, a 10 minute return period is used. For extreme events, however, a 50-year return period is more suitable. [1-3]

Furthermore, based on these analytical representations, wind speed could be quantified using different parameters. The value of wind speed variations over a short period is defined as turbulence. A parameter that is used to describe it is the intensity. Which is the standard deviation obtained from the distribution function divided by the mean wind speed. Mean wind speed also varies over height, an effect that is known as wind shear. Due to the earth's rough surface, friction is induced on wind leading to a decrease in its speed. [3] In other words, the wind mean speed increases as the height from the surface increases. Wind profile functions could represent this effect. The most accurate ones are the logarithmic function and power function. This study will use the power function. According to the IEC standards [4], the power function is defined as

$$V(z) = V_{hub}\left(\frac{z}{z_{hub}}\right)^{\alpha} \qquad ; \alpha = 0.2$$

Where the alpha represents the shear power coefficient which relates to the surface roughness.

2. MATERIALS AND METHODS

2.1. Wind Load Analysis

Wind load analysis forms the basis for assessing the structural performance of onshore wind turbines. The OpenFAST (Fatigue, Aerodynamics, Structures, and Turbulence) software, an advanced aero-elasto-servo simulator developed by the National Renewable Energy Laboratory (NREL), facilitates comprehensive simulations integrating aerodynamics and structural dynamics. The analysis considers wind turbulence effects to accurately capture the dynamic behaviour of the turbine structure.

In conducting the wind load analysis, simulations are performed for a duration of 660 seconds, ensuring a comprehensive assessment of the turbine's response to varying wind conditions. To minimize the impact of start-up transients, each simulation's time span is extended by an additional 60 seconds, with the initial 60 seconds of results discounted. This approach allows for a more accurate representation of the turbine's steady-state behavior under different wind scenarios. Additionally, it is generally recommended to initialize the rotor speed and blade-pitch angle based on their expected (mean) value conditioned on the mean hub-height wind speed being simulated. Furthermore, the turbulent wind field generated by TurbSim is characterized with a grid size set to 31x31 points covering an area of 145x145 m². Table 1 provides a concise summary of the wind turbine properties utilized in this study, based on the

Definition of 5-MW Wind Turbine by the National Renewable Energy Laboratory (NREL).[5]

Table 1

Definition	Value
Rated Power	5 MW
Orientation Rotor	Upwind
Number of Blades	3
Rotor Diameter	126 m
Height of Tower Above Ground	87.6 m
Cut-In Wind Speed	3 m/s
Cut-Out Wind Speed	25 m/s
Rated Rotor Speed	12.1 rpm

2.1.1. Load Cases

In this study, the wind load analysis is conducted under both power production and parked load cases, specifically examining the structural responses such as the overturning moment, and the blade-root in-plane and out-of-plane moments. These metrics are crucial for evaluating the turbine's performance and stability across different scenarios. Using OpenFAST, the dynamic behavior of a 5-MW wind turbine IEC class 3A and 2B is thoroughly simulated and analyzed._The classification into wind class 3A indicates suitability for moderate wind conditions, while class 2B turbines are designed for slightly stronger wind conditions. Each classification aligns the turbine design with expected wind profiles to optimize performance, reliability, and safety. This approach is particularly advantageous for installations in regions prone to extreme wind conditions, ensuring that the turbine's design effectively mitigates risks while maximizing energy production. Notably, the analysis includes both normal turbulence model (NTM) and extreme turbulence model (ETM) for comprehensive assessment under varying wind conditions, with additional consideration given to extreme wind model (EWM) to account for the most demanding scenarios.

Table 2. Definition of design load cases

Load Case	Description	Wind Speed	Yaw	Turbulence	Shear	Time	Seed
DLC12	Normal Production	3:2:25	0±8	NTM	0.2	660	1
DLC 13	Normal Production	3:2:25	0±8	ETM	0.2	660	1
DLC 62	Parked Grid Loss	V50	5:10:355	EWM	0.11	660	1

2.1.1.1. Fatigue Load Analysis

To assess the fatigue loads, the DLC 1.2 load case is carried out under normal wind conditions. In this case, the performance and power production of the wind turbine under fatigue loads will be evaluated. As discussed before fatigue failure is caused not necessarily by huge loads but by moderate repetitive loads. Therefore, the Normal Turbine Model, NTM, which is defined as turbulence loads that affect the wind turbine structure while operating in normal conditions during its lifetime, is used. The turbulence intensity values for each class are used according to [table or formula](IEC-16400). The pitch angle is also adjusted to match the wind speed range. To take into consideration the yaw controller delay, a small yaw error of -8, 0, and 8 are added. A time series will be carried out to analyse each yaw error over the wind range mentioned earlier. Random turbulence seeds were used per wind speed which makes the analysis length 36. For this case, overturning moments are important. Using the obtained overturning moments a long-term distribution graph could be generated. In this part, however, we will just draw the comparison from the overturning moment graph of 2B and 3A which are plotted below.

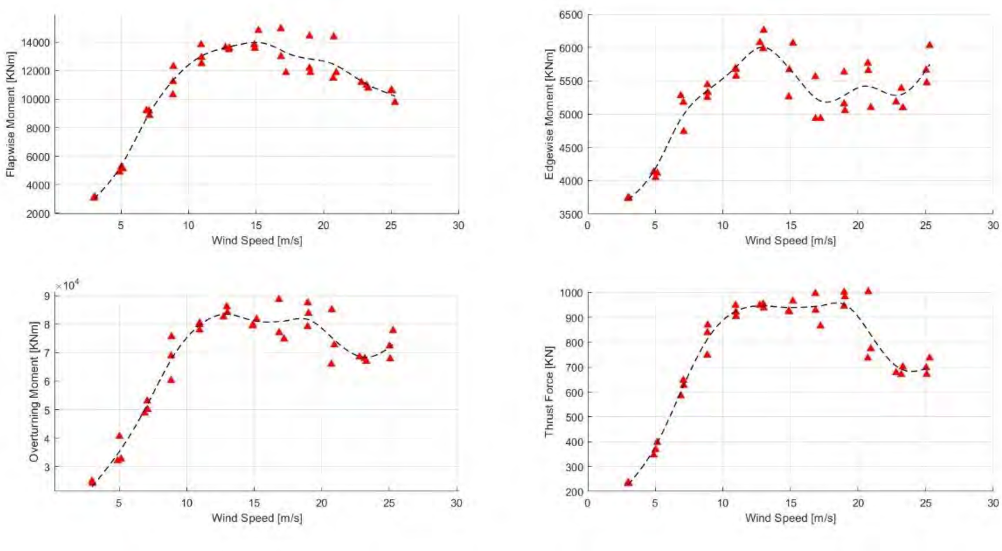

Figure 1. Maximum values of flapwise, edgewise, overturning moment and thrust force for DLC 1.2

2.1.1.2. Ultimate Load Analysis

In order to assess the performance under extreme conditions, this load case is carried out. It has the same values as the previous case however this time Extreme turbulence Model was used to determine the turbulence parameter. According to the IEC-16400 standards, equation 20 is used to describe the standard deviation of extreme turbulence conditions. The wind reference intensity depends on the wind class, A or B. The average velocity is the annual average wind speed. A partial safety factor of 1.35 is also used in the design. The graphs of overturning moment, edgewise and flapwise moments will be taken into consideration during. Tower bottom moments are also important to take into consideration.

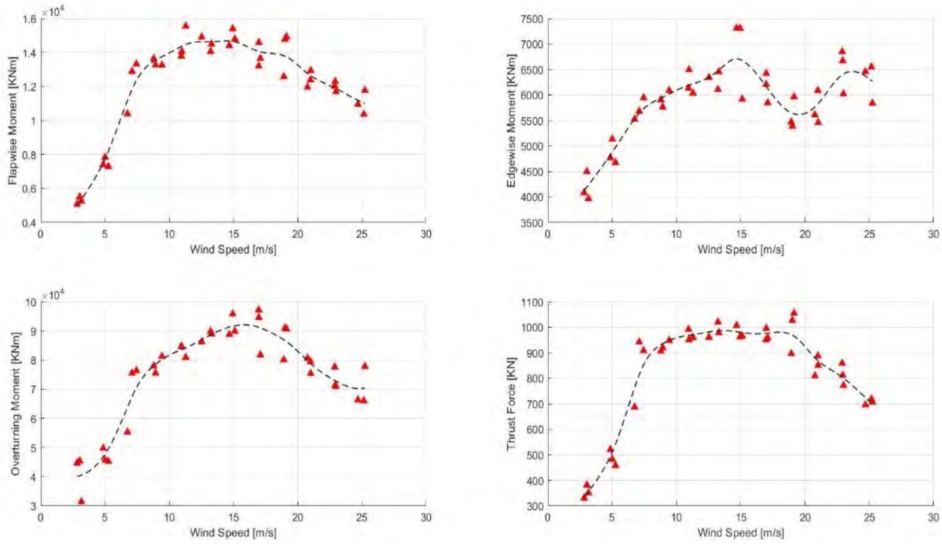

Figure 2. Maximum values of flapwise, edgewise, overturning moment and thrust force for DLC 1.3, IEC Class 3A

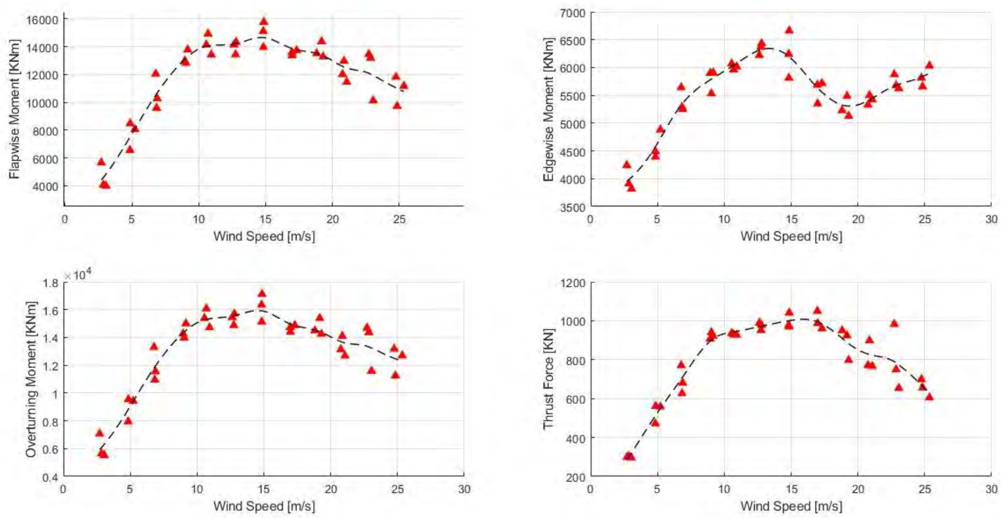

Figure 3. Maximum values of flapwise, edgewise, overturning moment and thrust force for DLC 1.3, IEC Class 2B

2.1.2. Parked Condition

In the parked condition simulation, a specific scenario is targeted: the loss of network connection, resulting in the wind turbine losing control over its yaw drive mechanism. To model this condition accurately, simulations are run for a comprehensive range of possible yaw misalignment angles, spanning from -175° to +175°, resulting in a total of 36 simulations (1 seed per yaw angle). This DLC simulates a parked wind turbine and experiencing an unusually large yaw misalignment due to grid loss. The wind speed selected for this simulation corresponds to a 50-year recurrence period, ensuring a realistic representation of extreme conditions. Additionally, a turbulence intensity of 11% is applied to capture the dynamic response of the turbine under turbulent conditions and the blade pitch is adjusted to a feathered position, optimising the turbine's performance under simulated conditions.

Through these simulations, the behavior of the wind turbine under loss of network condition can be thoroughly analyzed, providing valuable insights for enhancing the turbine's operational reliability and resilience in real-world scenarios. To further enhance stability, strategies such as bypassing yaw errors that lead to instability or increasing structural damping in the blade edge and tower side-to-side modes are considered. Specifically, in cases where particular yaw misalignments cause instabilities, these could be strategically ignored, such as potentially omitting the 35-degree case, thereby refining the reliability of the operational assessments.

2.2. Foundation Design

The foundation design of onshore wind turbines is critical for transferring and distributing structural loads to the ground. Various factors, including soil characteristics, environmental conditions, and turbine specifications, influence foundation design. Proper foundation design ensures stability and minimizes the risk of structural failure during operation.

The design of onshore wind turbine foundations, often constructed in octagonal or circular gravity forms, must withstand various mechanical stresses. These include horizontal wind loads, the resultant overturning moments, and vertical loads from the turbine and foundation's own weight, alongside twisting moments.

In accordance with the IEC61400-6, the geotechnical design process involves iterating between Ultimate Limit State (ULS) and Serviceability Limit State (SLS) considerations. The ULS addresses potential overturning, bearing capacity, or sliding failures, and structural integrity, while the SLS focuses on ensuring adequate lateral and rotational stiffness, preventing excessive long-term tilt, settlement, and avoiding long-term degradation that could lead to failures. This iterative checking is essential for maintaining the foundation’s structural integrity and functionality under both normal and extreme conditions.

Following a similar procedure as outlined in the referenced study [5], this analysis adopts a systematic approach to the preliminary geotechnical design of onshore wind turbine foundations, ensuring a reliable foundation design.

3. RESULTS AND DISCUSSION

The data in Table 3 represents the different best and worst scenarios for the 2B and 3A wind classes for DLC 13. Firstly, it's noticeable that the maximum values in the 3A class are generally higher than those in the 2B class. For instance, for TwrBsMrt (tower base moment), the maximum value in the 3A class is 131157.6 KNm, which is higher compared to the maximum value in the 2B class, which is 104107.0 KNm. This suggests that the 3A class may be able to withstand more severe wind conditions and cope with larger moments.

Moreover, the range of values, from minimum to maximum, highlights the variability and stresses that the turbine foundations must be engineered to endure, particularly under the more demanding conditions associated with the 3A wind class. These insights into the fluctuating load conditions emphasize the need for robust design and material selection to ensure structural integrity and long-term performance.

In conclusion, this table can be used to compare how the 3A and 2B wind classes respond to different load conditions. Providing a higher capacity for maximum moments but lower resistance to minimum forces, the 3A class offers a crucial reference for design and durability decisions.

Table 3. Maximum and minimum moments for DLC 1.3

DLC 13		TwrBsFxt	TwrBsFyt	TwrBsFzt	TwrBsMxt	TwrBsMyt	TwrBsMzt	TwrBsFrt	TwrBsMrt
2B	Max	1204.1	317.1	-7272.5	34285.3	101578.9	9410.5	1212.1	104107.0
	Min	-358.7	-416.0	-7744.5	-14868.7	-27574.0	-10090.8	0.2	0.8
3A	Max	1629.6	482.7	-8837.8	46804.0	129616.9	13343.4	1656.8	131157.6
	Min	-692.2	-541.6	-9522.6	-29634.3	-60428.1	-15693.2	0.1	1.2

Incorporating the data from the provided table into the foundation design of onshore wind turbines is essential for ensuring structural integrity and stability under varying load conditions. By considering the maximum and minimum loads experienced by the wind turbine structure, engineers can design foundations capable of withstanding extreme forces while maintaining stability during normal operation. This involves evaluating load combinations, iteratively refining the design based on Ultimate Limit State (ULS) and Serviceability Limit State (SLS) considerations and incorporating appropriate safety margins. Additionally, site-specific factors such as soil characteristics and environmental conditions should be taken into account to tailor the foundation design to local conditions. Overall, leveraging the insights provided by the load data enables the development of robust foundation designs that enhance the reliability and longevity of onshore wind turbine installations.

4. CONCLUSION

In this study, the aim was to be able to gain an insight into how the wind turbine structure performs under different wind conditions. This was done by conducting a time series analysis of two different wind turbine classes under three main cases. In the first case, DLC 1.2, the analysis was done under normal wind conditions which was important for fatigue assessment. In the second case, DLC 1.3, Extreme wind conditions were used to account for the extreme wind fluctuations and examine the ultimate strength. In the last case, the turbine was in parked condition, meaning no power was being produced. The wind loads were examined with a return period of 50 years. However, in extreme wind conditions, there is an evident increase in the moment and force applied to the structure in the case of the 3A class. This needs to be accounted for in the design steps of the wind turbine.

REFERENCES

[1] Leite, O. B. (2015). *Review of Design Procedures for Monopile Offshore Wind Structures* (Master 's thesis, Faculdade de Engenharia da Universidade do Porto).

[2] Van Der Tempel, J.(2006).*Design of Support Structures for Offshore Wind Turbines*(Unpublished doctoral dissertation). Delft University of Technology.

[3] Løken, I. B. (2017). *Dynamic Response and Fatigue of Offshore Wind Turbines: Effect of Foundation Type and Modelling Method Using Software FAST* (Master's thesis, Norwegian University of Science and Technology).

[4] IEC, (2005). *IEC 61400-1: Wind Turbines–Part 1: Design Requirements*, International Electrotechnical 557 Commission, Geneva.

[5] Jonkman, J., Butterfield, S., Musial, W., Scott, G. (2009). *Definition of a 5-MW Reference Wind Turbine for Offshore System Development*. National Renewable Energy Laboratory (NREL).

[6] Demirci, H. E. (2023). "*Geotechnical Preliminary Design of Onshore Wind Turbine Foundations*." Erzincan University Journal of Science and Technology, 16(3), 756-781. DOI: 10.18185/erzifbed.1306867.

[7] Morató, A., Sriramula, S., Krishnan, N., & Nichols, J. (Date). *Ultimate loads and response analysis of a monopile supported offshore wind turbine using fully coupled*

Embracing energy efficiency processes for a neighborhood building

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The building sector is ranked as the highest energy demand and consumable sectors followed by the public lightening in a classic dwelling neighborhood. High energy consumption in these sectors is related to their poor performance and lack of constant interventions to the updated technology in place. Buildings account for nearly 40% of global CO_2 emissions, with operational emissions (from energy used to heat, cool, and light buildings) comprising the majority. The trend towards carbon neutrality in the building sector is gaining momentum, driven by technological advancements, shifting policy landscapes, and a growing recognition of the urgent need for sustainability in the face of climate change. Concrete buildings in Albania are one of the worst energy performance ones, where dwellers should deal with a too hot inner environment during the summertime and a too cold environment during wintertime. Most concrete buildings are completely not plastered, and apart from the extra heat and cold, the presence of humidity is a constant disturbance for the community living in them. This is translated into building facade not being thermo-insulated, with poor windows frames, and not adequately oriented by lacking natural ventilation, and a public lightening system in place that consumes high energy to provide very few hours of proper lightening in the neighborhoods. Energy-efficient buildings provide healthier and more comfortable. Better insulation reduces the number of pollutants and allergens that can come into the home, which can result in better indoor air quality. Adopting energy-efficient practices and technology is essential to reduce energy use, prevent climate change, and guarantee a cleaner, healthier future as societies work toward sustainable development. This article seeks to understand the energy performance of concrete buildings that go under a process of façade refurbishment through analyzing the construction of the building and the possible insulation technology that would improve the energy performance.

Keywords*: Energy usage, insulation, energy efficiency, refurbishment of the building, energy savings, energy auditing.*

1. INTRODUCTION

Albania is a country with a considerable building stock inherited before the ’90, typically conventional buildings, where the common building materials used were bricks or concrete pallets. They had no protection layers, which resulted in a very bad energy performance of the buildings. In some cases, buildings had a coated layer that helped in protecting them from the atmospheric conditions.

The concrete buildings are one of the worst energy performance building, where dwellers should deal with a too hot inner environment during the summer time and a too cold inner environment during winter time.

Addressing the energy performance of concrete buildings in Albania is crucial for reducing energy consumption, lowering utility bills, and mitigating the environmental impact of building operations. Retrofitting measures such as improving insulation, upgrading windows, installing energy-efficient heating and cooling systems, and enhancing ventilation can significantly improve the energy efficiency of these buildings while also enhancing comfort and indoor air quality for occupants.

Nowadays, Albania as a developing country is focusing on the energy efficiency in residential sector. Energy efficiency is one of the biggest challenges that energy sector is actually facing

in Albania. Continuous developments and ever-increasing demand for energy on the one hand, both in public and private buildings, in industry and in many other fields, and on the other hand, the constant increase in energy prices is pushing every day the different sectors that to invest in increasing energy efficiency by reducing the cost of energy they pay each month, reducing energy consumption and consequently reducing greenhouse gases.
Based on it, this paper will briefly analyze an apartment which is in the area of Tirana. Albanian legislation, normative and European directives have been considered for analysis of energy audit in residential buildings. The results during the analysing of this paper will be given in accordance with the Albanian legislation as well as with the European Norms for the energy performance of the buildings.

Figure 1. A brick building in Tirana

2. MATERIALS AND METHODS

2.1. Legal background

The concept of energy auditing and energy efficiency in Albania are new ones by law and by practice. Albanian legislation for energy efficiency and auditing has been renewed and amended, reaching the background it has today which consists of these main laws:

Table 1. Albanian legislation for energy efficiency

1	**Law no. 116, dated 10.11.2016**	**" On energy performance in buildings "**
2	DCM no. 480, dated 31.07.2018	" National Energy Strategy (2028-2030) "
3	DCM no. 958, dated 02.12.2020	" On the approval of the procedures and conditions for certification of the apartment."
4	Law no. 124, dated 12.11.2015 (amended 2019, 2021)	"On the efficiency of of energy"
5	DCM no. 342, dated 22.05.2019	"On the approval of categories, of the conditions and requirements of the manager's qualification energy"

6	DCM No. 256, dated 27.3.2020	“For the approval of the methodology for calculating the levels of optimum cost for minimum performance requirements of energy of buildings, units and elements building”
7	DCM No. 537, dated 8.7.2020	“For the approval of the minimum performance requirements of energy of the buildings and elements of the building”

Energy auditing process

Based on order no.5 dated 12.01.2021 “For the format of the energy audit process” , must be followed by these main steps:

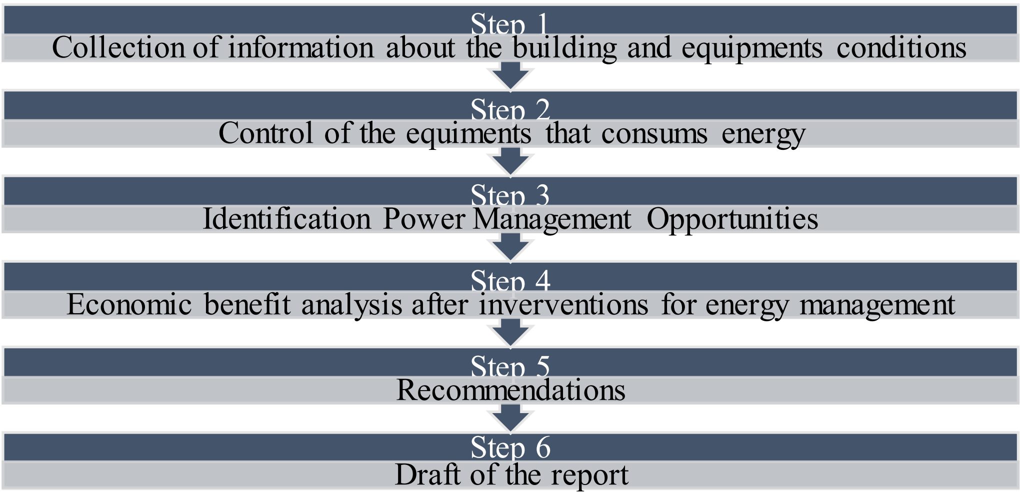


Figure 2. Energy auditing process steps

During the first phase, the energy auditor should collect all the information available on the existing situation of the building physical conditions (construction materials), geographical position and the equipment using energy from different sources, including lighting too. After the first evaluation, the energy auditor will use the relevant equipment to measure energy consumption of the appliances and control all the energy consumption from electrical energy bills of each of the family in the building. These evaluations will help the auditor to identify possible remediation to the energy consumption of the building, which would be translated in reduction of the electrical energy bills at the end of the year. For each energy audit conducted in a specific unit, the energy auditor should provide specific recommendations that would complete the whole report of the energy audit.

3. PERFORMANCE OF THE BUILDING

In 2009, for the first time it was approved the new law on the ownership, which enabled the concept of condominium in apartment buildings. It is safe to say that it was quite a new concept for the dwellers and, it was hardly understood or in the best case implemented. As stated in the law, municipalities are the state institutions, which are in charge to lead this process by engaging and making aware the dwellers about the condominium law and the tasks and responsibilities they might have.

Residential apartment that is taken in consideration in this research work is located in the area of Tirana city. The apartment is located on the second floor of a three-stores building. The living area of the apartment is 84.2 m^2 and consists of two bedrooms, living room, kitchen/ dining room, bathroom and two balconies. The building in which the apartment is located, in 2021 had a structure with brick retaining walls, a cover made of concrete and a layer of bitumen.

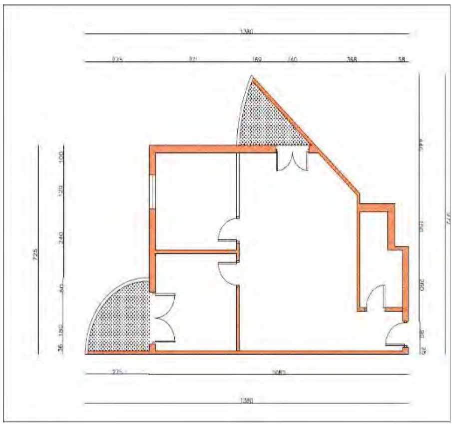


Figure 3. The plan of the apartment

The degradation of the facades due to the lack of thermal insulation was a serious problem in the structure of the building. Non-thermally insulated facades negatively affected the energy consumption, the thermal comfort of the apartments in this building and brought large costs for heating and cooling.
Another disadvantage of non-insulated facades is the presence of significant amounts of moisture, causing problems for the residents of these apartments.
Based on this situation, with the approval of the residents, the municipality of Tirana decided to implement the project for this building.
Given the above situation, the Municipality of Tirana in 2021, started to implement the project "The Community Fund". The project proposed community participation and engagement of local authorities to increase community awareness regarding the possibility to save energy in their dwellings through implementing energy efficient measures, based on the guidance of the law "On ownership administration in domestic buildings".
Based on the condition of the building, the first step of this intervention is taking measures to improve the conditions for the residents, as well as saving energy through the thermal insulation of the facades of the building, using the envelope system.
The necessary measures were taken to improve the thermal insulation of the building's facade using quality materials and contemporary technology. An effective solution is the use of thermal insulation with polystyrene panels, which provides an improvement excellent in the thermal performance of the object.
The combination of this material with glass fiber nets provides not only thermal insulation, but also additional stability for the facade of the building. This helps to maintain the structural integrity of the facade, making it more stable against the effects of different atmospheric conditions.

3.1 First monitoring phase

After a year of the project implementation the building envelope was completely renovated, as the façade, the windows frame, the entrances, and the roof. It was undertaken a monitoring process to understand the energy improvements gained under the new condition of the building. The objectives of the auditing process consisted on:

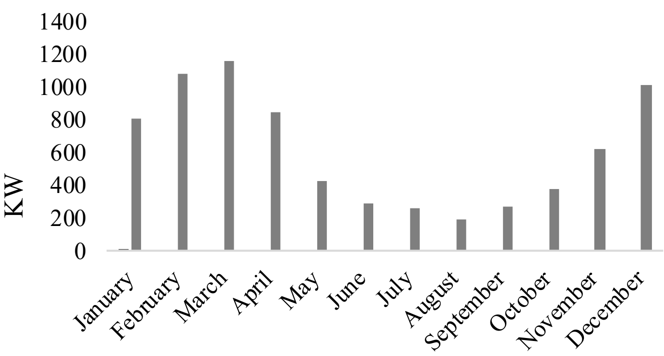
1. Monitoring of the electrical energy consumption of the building in the first phase (without insulation);
2. Monitoring of the electrical energy consumption of the building in the second phase (with insulation): considering its energetic behaviour during summer and winter time;
3. Comparison of both results from the monitoring phases to conclude in figures that showed the energetic benefits of the prefabricated building after being insulated.

The first monitoring process started from January 2021 till December 2022 (January 2021-December of 2021 the building was not insulated, after December 2021 the building was insulated), based on the kw consumption from the electrical bills of the apartment.

From the data we could obtain from the electrical energy bills, we generated tables and graphs to understand, first the tendency of the energy consumption after the building has been insulated, and second to try to derive results regarding their energetic benefits.

Table 2. Energy consumption in 2021-2022

Nr.	Months/Years	2021 (KWh)	2022 (KWh)
1	January	807	1032
2	February	1082	1035
3	March	1158	1104
4	April	843	912
5	May	421	353
6	June	291	280
7	July	263	302
8	August	191	183
9	September	273	368
10	October	380	321
11	November	619	377
12	December	1016	647
	Kw/Year	7344	6914



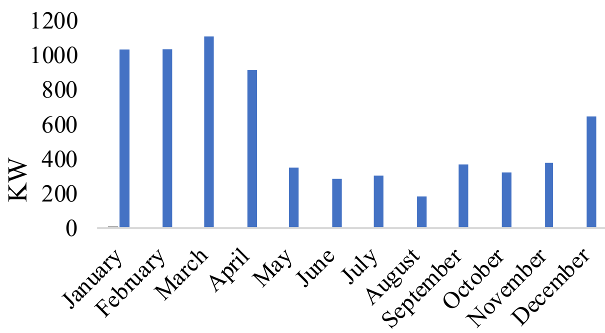


Figure 4. Energy consumption in 2021

From the results of the first phase of monitoring, a slight decrease in the energy consumption values in this apartment is observed. This decrease is expected since the building was thermally insulated in 2021 and the building needs a certain time to get inertia to start performing under the new conditions.

$$kW\ benefits\ from\ insulation = \frac{7344-6914}{7344} * 100\% = 6\% \qquad (1)$$

The results from the first monitoring, just after the building was insulated, showed that the whole building envelope performance improved with 6% during the first year of the renovation.

3.2 Second monitoring phase

The second phase of the building monitoring continued from January 2023 up to December 2023, based on the kW consumption from the electrical bills of the apartment. The results from this monitoring phase are shown in the graph and table below:

Table 3. Energy consumption in 2023

	Months/Years	2023 (KWh)
1	January	662
2	February	817
3	March	593
4	April	481
5	May	335
6	June	294
7	July	271
8	August	257
9	September	272
10	October	384
11	November	604
12	December	843
	Kw/Year	5813

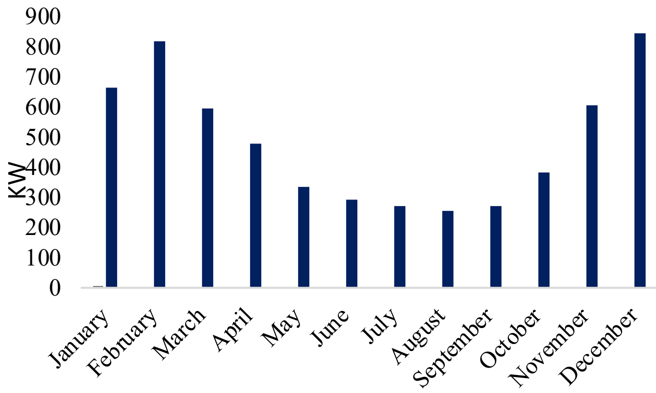


Figure 5. Energy consumption in 2023

$$kW\ benefits\ from\ insulation = \frac{7344-5813}{7344} * 100\% = 21\% \qquad (2)$$

As we can see from the graph the building energy performance during the last year has made moderate improvements from the renovation undertaken, but still the data from the electrical bills do not show only the energy consumption from heating or cooling. Most of the energy consumption goes for hot water, cooking and lighting. However, we understand that the building has the tendency to perform better under new conditions.

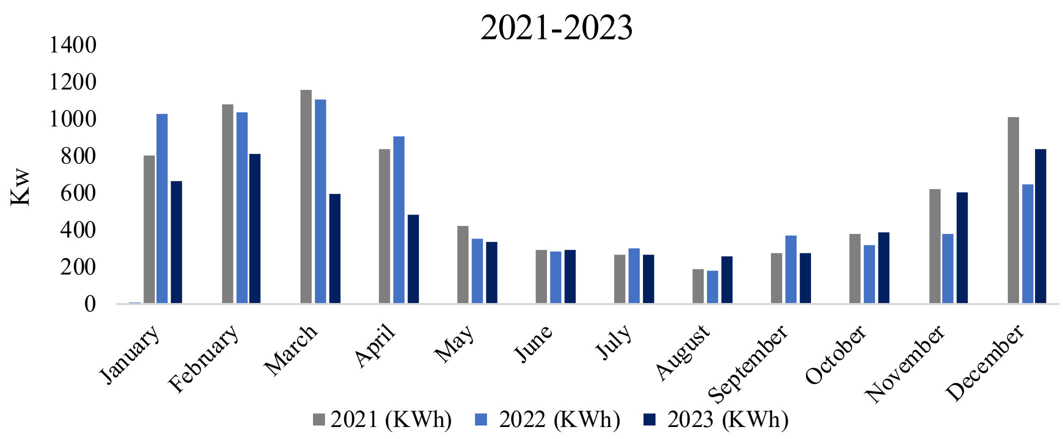


Figure 6. Energy auditing (2021-2023)

4. RESULTS AND DISCUSSION

Based on the data collected and the analysis carried out for three years, a summary table is presented, through which we can make a comparison of energy consumption during these three years.

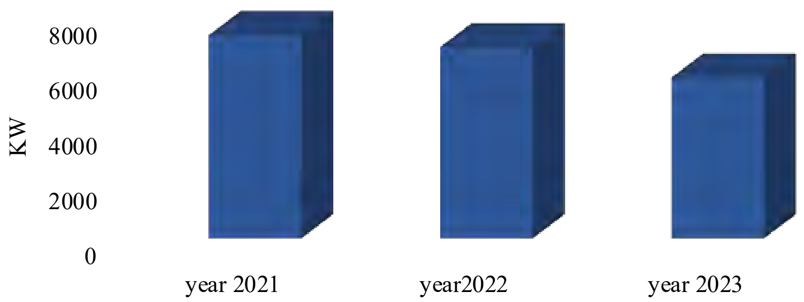


Figure 7. Energy consumption of the apartment (2021-2023)

From the graph above, it is clear that each year the performance of the building is improving, starting from 2022 with 6% to 21% in 2023.
Also, if we convert the amount of energy consumed (kw) into costs (ALL), knowing that the price for 1 kwh during these three years is 9.5 ALL /kwh, it turns out that the costs of energy bills are also reduced.

Table 4. Energy consumption costs (2021-2023)

Months/Years	2021 Costs (ALL)	2022 Costs (ALL)	2023 Costs (ALL)
January	7666.5	9804	6289
February	10279	9832.5	7761.5
March	11001	10488	5633.5
April	8008.5	8664	4569.5
May	3999.5	3353.5	3182.5
June	2764.5	2660	2793
July	2498.5	2869	2574.5

August	1814.5	1738.5	2441.5
September	2593.5	3496	2584
October	3610	3049.5	3648
November	5880.5	3581.5	5738
December	9652	6146.5	8008.5
ALL/Year	69768	65683	55223.5

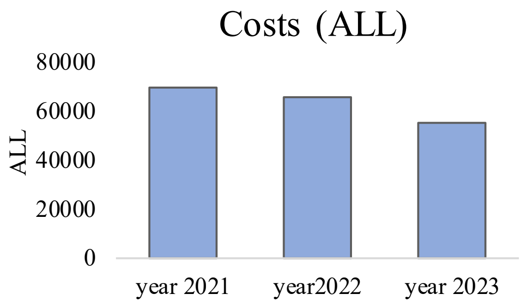


Figure 8. Energy consumption costs (2021-2023)

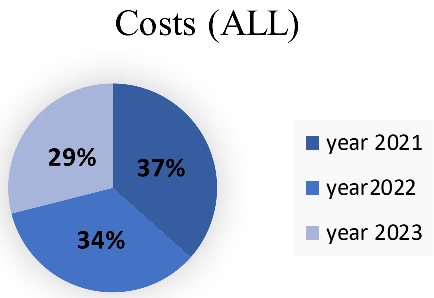


Figure 9. Energy consumption costs in 2021-2023

5. CONCLUSION

The implementation of thermal insulation measures, particularly using polystyrene panels, has led to a substantial improvement in the energy performance of the residential building in Tirana. Over the course of two monitoring phases, there was a noticeable reduction in energy consumption, indicating enhanced thermal efficiency and reduced reliance on heating and cooling systems.
The insulation of the building's facade not only contributed to energy savings but also positively impacted the comfort and well-being of occupants. By mitigating temperature fluctuations and reducing moisture ingress, the insulation measures have enhanced indoor thermal comfort and reduced the risk of structural damage due to adverse weather conditions.
In addition to environmental and social benefits, there are significant financial advantages associated with energy efficiency improvements. The reduction in energy consumption translates directly into lower utility bills for residents, contributing to increased affordability and economic well-being.
Overall, the results demonstrate the effectiveness of retrofitting measures in enhancing the energy performance, comfort, and sustainability of residential buildings in Albania.

REFERENCES

[1] Gjoka K., Shehi T. (2017) How refurbishment of buildings envelope can reduce energy usage in concrete buildings. International Conference of Civil Engineering. Books of proceedings

[2] Co-PLAN, Institute for Habitat Development, Udhëzues praktik për të arritur eficiencën termike në ndërtesat e banimit (2011)

[3] Bebi E., Dhoska K., Alcani M., Sakaj E., Qosja S. (2022) Energy audit analysis in private residential apartment in Tirana city. International Scientific Journal "Industry 4.0"

[4] Gorishti A., Dhoska K., Tyxhari G. (2023) Energy audit evaluation in private residential building. International Journal on “Technical and Physical Problems of Engineering”

[5] Zeneli E., Shira A., Bidaj F., Hoxha A., (2021) An assessment of energy efficiency measures in a public building in Albania in the prospect of cost and emissions reduction. International Scientific Journal "Science. Business. Society"

Moving toward a Circular and Sustainable Energy Paradigm

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The 21st century climatic development has driven the initiation of the new transition era toward a circular and sustainable energy paradigm, which will direct the shifting from a linear model of energy production and consumption to the one that prioritizes and promotes the usage of renewable sources, energy efficiency, and waste reduction. Practically, this movement would require the embracement of technologies embrace technologies like solar, wind, and hydroelectric power, promoting energy conservation, and implementing policies to support a circular economy where resources are used more efficiently, and waste is minimized through recycling and reuse initiatives. This article will try to bring a holistic overview of the main instruments that have started and will drive this transition toward a carbon neutrality future. One of the leading instruments that has found strong grounds of implementation in many western countries is the investment in promoting the application of low-carbon, and nuclear-free energy system by increasing the share of renewable energy sources like wind and solar power. On the other hand, another driver that has spread its effects in different areas and lifestyles is the implementation of policies and practices to improve energy efficiency in buildings, transportation, and industry. Moreover, the study will try to tackle other drivers as developing smart grid infrastructure and energy storage technologies to integrate renewable energy sources efficiently into the grid, and adaptation of circular economy principles to minimize resource consumption, promote recycling and reuse of materials, and reduce waste generation throughout the energy value chain. This article will try analyzing at the end, which are the concrete steps that may ensure this transition toward a circular and sustainable energy paradigm through a multi-dimensional approach and ongoing evaluation.

Key words: *Low carbon economy, carbon neutrality, sustainable and circular energy paradigm, circular economy, renewable energy sources, energy efficiency.*

1. INTRODUCTION

The world is facing unprecedented energy, environmental, climate, and sustainability challenges, such as biodiversity loss, resource use, and pollution. During the last decade, extreme weather events due to the increase in the temperature of the Earth's surface have progressively created a fact-based conviction among the scientific and common community, that they are a direct consequence of global warming. It is recognized as a problem that has a high priority throughout the world and the impact of global warming is getting worse [1][2]. Human activities, mainly from burning fossil fuels, are the main cause to increase of greenhouse gas emissions. According to the IPCC report of 2007, there is strong evidence that over the last 50 years, 90% of global warming effects come from fossil fuel combustion of human activities.

The UN, driven by the fast economic and industrial sector development after the Second World War, initiated a process of developing the concept of sustainable development at the Global Level. This process has gone through different steps since 1972 with an environmental conference in Stockholm, Sweden until the adoption of the 2030 Agenda for Sustainable Development in September 2015. The agenda tackles 4 key areas for urgent action starting

with climate and the planet. Later that year the adoption of the Paris Agreement at the Paris Climate Conference marked the first ever universal, legally binding global climate change agreement in 2015. [1]
Since 2005, the non-governmental organizations Germanwatch, the New Climate Institute, and the Climate Action Network (CAN) have published annual data on the climate change performance index (CCPI) for 63 countries and the EU (that count for 90% of the greenhouse gas emissions emitted throughout the atmosphere). The organization ranks the countries due to their yearly efforts on achieving the goal of limiting global warming to just 1.5 degrees, compared to the pre-industrial period. As the target is set to be met by 2030, experts do praise the countries' new policy measures to accelerate the expansion of renewable energy as positive but still, they think that serious attention should be paid to transportation policy, as very little is happening [2].
Although almost all major economies now rely on wind, solar, and hydropower, the expansion of renewable sources will have to increase exponentially to quickly reduce CO_2 emissions and replace fossil fuels, so harmful to the climate. The world has "now entered a very decisive phase": Greenhouse gas emissions must be halved by 2030, otherwise the escalation of the climate crisis cannot be avoided, and, in the meantime, we need a binding resolution to triple renewable energy capacity worldwide by 2030, said Höhne & Burck, at COP28 in Dubai 2023). [2]
Since 1988, when the Brundtland Report burst the bubble of climate change existence, countries around the world have started to recognize the actual impact on the economy, environment, and society of climate change effects. As the trend, from accepting that global warming is happening to the upgraded steps of bringing it as the main discussion point, to drafting global policies on climate change adaptation and mitigation and providing concrete paths on how to transpose them to local policies, it is a fact that the concept of green investments is seen widely as a step toward Circular and Sustainable Energy Paradigm.
As the International Monetary Fund (IMF) phrases it, a green investment is an investment required to adapt to climate change by reducing greenhouse gas emissions without reducing the production and consumption of non-energy significantly. Studies have shown that, at a large scale, the use of green investment schemes in the housing sector, in the frame of energy efficiency target achievement, has contributed to the reduction of 30% of carbon emissions and becoming a major force in the energy sector. Other studies and research have started to dig a little deeper in this regard by attaching the influence of green investment towards adaptation to climate change to reduce greenhouse gas emissions through disclosure of carbon emissions.
Meanwhile, as global efforts have shown, energy production is shifting toward a new paradigm that patterns after the closed-loop circular systems of natural ecosystems. Among all sectors, the new paradigm aims to offer a new model for critical electricity provision for most emerging countries, by avoiding fossil fuels and thus less pollution and reducing the throughput of matter and energy. Examples in the merging economy countries revealed the efficacy of renewable power created through cooperative, cross-sector initiatives that also yield economic and social benefits for the communities.

2. SUSTAINABILITY AND CIRCULARITY AND THE NEW ENERGY TRANSITION FUTURE PATH

2.1. Sustainability and the New Energy Transition Future Path

The concept of sustainability is attracting great attention as societies become increasingly aware of the environmental consequences of their actions. One of the most critical challenges that humankind is facing is the scarcity of resources, which are expected to reach their limits in the foreseeable future. Associated with this, there is increasing waste generated because of rapid growth in the world population (particularly in urban areas) and a parallel rise in global income.

To cope with these problems, a linear strategy has been applied to increase efficiency by reducing the use of materials and energy to lessen environmental impacts. However, this cradle-to-grave approach has proven inadequate, due to a lack of attention to several economic and social aspects. A paradigm shift is thus required to re-think and innovate processes (as early as in the design phase) in such a way that materials and energy are used more effectively within a closed-loop system.

The integration of sustainable energy sources reduces reliance on non-renewable energy. The utilization of sustainable energy resources such as solar, wind, hydro, and geothermal power forms the foundation of a smart energy system. These resources decrease reliance on fossil fuels, decrease pollution, and promote environmental sustainability. The Venn diagram illustrates perfectly that economic, environmental, and social aspects of sustainability, are interconnected and in perfect harmony represent the coexistence of these three pillars. [3]

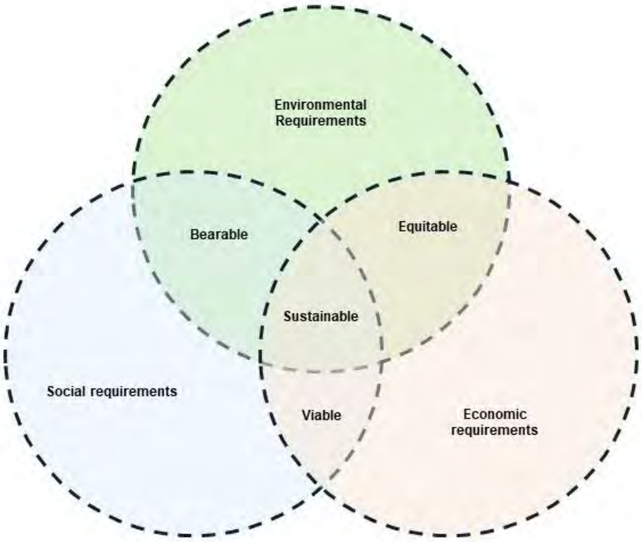

Figure 42. Venn diagram on sustainable development pillar relation

Green issues, including climate change mitigation and environmental conservation, are integral to the SDGs. The transition to sustainable energy systems aligns with these goals and fosters innovation, competitiveness, and regional diversification.

Addressing climate change entails balancing environmental policies with economic considerations. Green technologies drive regional diversification and economic growth, particularly in sectors related to renewable energy and environmental sustainability.

Investing in green activities fosters a culture of innovation and adaptation to ecological challenges. In this regard, as nowadays has become a common thing, all this revolution in technology and industry (the industry 4.0 paradigm and related technologies) are proving more and more to be a reliable instrument for facilitating knowledge and information diffusion, driving innovation, and creating new employment opportunities. By leveraging advancements in connectivity, automation, and data analytics, I4.0 enables efficient energy production, distribution, and consumption. In the meantime, the introduction of green environmental technologies within the frame of the Fourth Industrial Revolution is crucial for the diversification of local, sustainable activities to protect the environment against negative climate changes. [4]

2.2.Circularity and the New Energy Transition Future Path

The strategy cradle-to-cradle approach relies on the assumption that everything is a resource for something else since no waste is ever generated in nature. In line with the cradle-to-cradle approach, the bio-inspired circular economy concept aims at eco-effectiveness, rather than eco-efficiency. It carries significant importance since it "is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value always, distinguishing between technical and biological cycles.

It is a fact that society's political, economic, and environmental actors foresee the circular economy as a crucial pathway for decoupling finite resource consumption from economic growth. The challenge consists of applying the circular economy's high-level operating principles to the critical infrastructural services that underpin economic growth — the resource- and energy-intensive provision of energy, sanitation, water, waste management, communications, transport, and other sectors of the economy. One opportunity for humanity would be to foster the embrace of circular planning in the provision of new and extended infrastructural services in both the rural and urban developing world where the growth of and demand for infrastructural services are rapidly escalating, specifically the energy demand.

Given the definition of the circular economy principles, the instrument role of circularity in the transition to sustainable energy consists of improving energy efficiency and renewable energy.

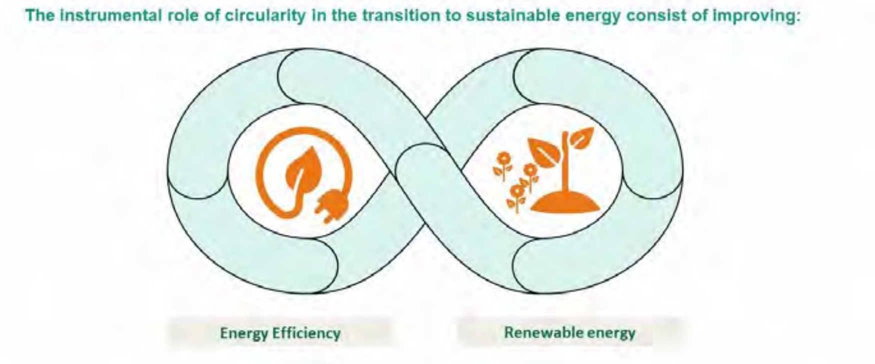

Figure 2. Circularity in the transition to sustainable energy

Energy Efficiency policy is focused on securing affordable energy supplies, sustainable energy consumption, improving energy efficiency, increasing renewable energy, and lowering fossil fuel dependence to help reach climate objectives and decarbonize of energy system by 2050, known as carbon neutrality. On the other hand, renewable energy sources, such as sustainable energy, are practically inexhaustible or able to be renewed within a human lifetime. They have an essential role in preserving and enhancing natural capital and decarbonizing the energy system. The renewable energy system is also viewed as a sustainable mechanism to address rising temperatures, climate change, and environmental issues, so it has been established as a mainstream contributor to the global electricity generation mix, becoming much cheaper and competitive.

Figure 3. Energy Efficiency policy

The energy sector plays a crucial role in steering the world toward a low-carbon future. Despite efforts, there has been little progress in meeting the EU's commitment to its SDG objective over the past five years. This slightly negative result is due to increases in the EU's energy consumption between 2014 and 2019. It does therefore not yet reflect, at least temporarily, the reductions expected for 2020 following measures taken in response to the COVID-19 pandemic.

3. RESULTS AND DISCUSSION

At the basis of this new energy transition phase that aims at the end to build a society that tends to be sustainable and circular for a carbon-low economy, the introduction, and implementation of policy instruments for Smart Energy Systems can enable and incentivize consumer engagement in adopting sustainable practices and foster local green culture. In summary, designing a smart energy system entail integrating sustainable technologies, fostering innovation, balancing economic and environmental considerations, and promoting international collaboration.[5]
Exemplary cases in emerging economy countries reveal the efficacy of renewable power created through cooperative, cross-sector initiatives that also yield economic and social benefits. These alternatives, in the frame of a circular economy strategy for power production, moving beyond conventional, mono-sectoral approaches to energy delivery, have constantly proven to be solid solutions for energy poverty.
Case I - Methane recovery illustrating the potential for closed-loop use of an otherwise wasted energy source in rapidly urbanizing settlements: Landfill, conventionally filled with municipal solid waste (MSW - a mix of inorganic and organic material 46% global average), release harmful methane (CH_4) into the atmosphere. Landfill gas alone leads to the worldwide release of between 19.99 million and 59.99 million tons (approximately 22 million to 66 million tons) of methane annually. [6]
Recovering and utilizing gas from the decomposing organic matter in sanitary landfills for energy generation represents a closed-loop bio cycle and is considered a transitional, carbon-neutral energy solution. Understanding and replicating this approach is extremely relevant for low-income countries that can only spend a fraction of their solid waste management budgets on waste disposal, with most MSW going simply to waste collection and not to appropriate treatment.

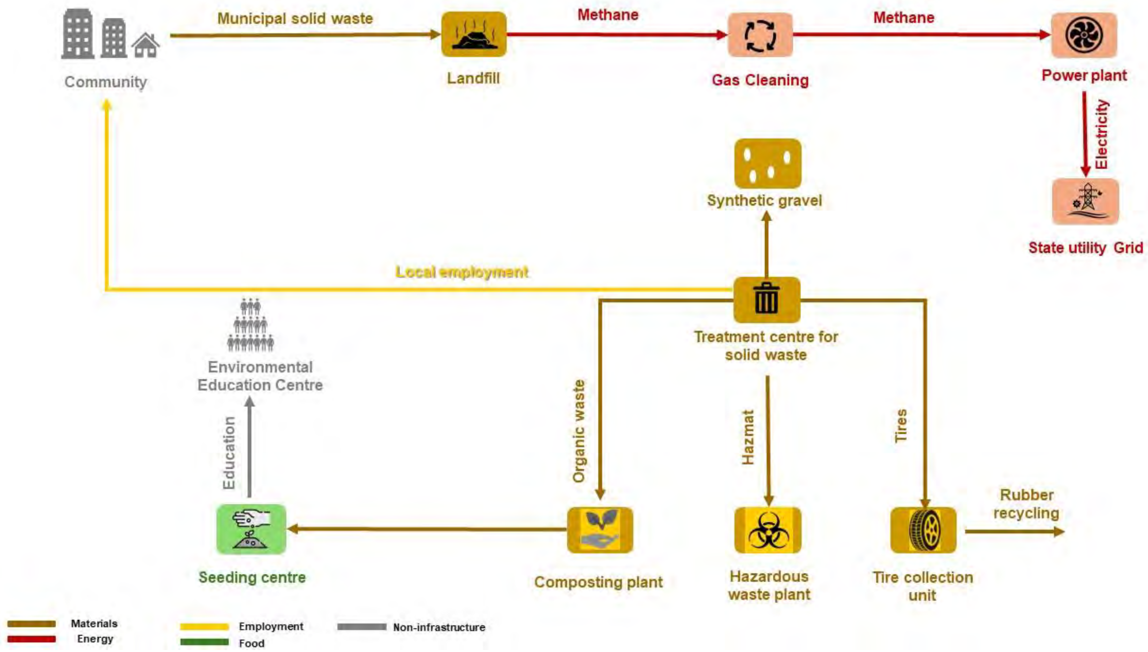

Figure 4. Infrastructural Ecologies: Alternative Development Models for Emerging Economies (Brown & Stigge) – adapted by the author. [7]

Case II - Provision of affordable electricity for poor rural settlements by combining the electricity demand from the telecommunications sector to support the economical construction of small to mid-size solar power plants: Another aspect of the circular energy economy is the optimization of asset usage through sharing, as the cases of Uber, Zipcar, Airbnb. These platforms are revolutionizing the transport and hospitality sectors by extending the deployment of a particular asset. Similarly, the combined use of a single infrastructure facility through co-location means fewer resources consumed and less waste produced. [8] This is the case of using a single solar power plant to serve two different kinds of clients, as a shared-used arrangement that makes the business model financially viable – selling electricity to the rural poor – without necessitating government subsidies.
Case III - Development of a generator of renewable power, to address the pollution of the reservoir from agricultural waste by establishing a rural waste-to-energy program that electrified more than 2,200 households: In this case, a significant feature of the program is related to the capitalization of a closed-loop bio cycle supplemented by biogas to generate electricity, utilizing biomethane produced by local anaerobic biodigesters which feed on agricultural, animal, and human waste. The micropower plants can also readily be supplemented by wind energy and equipped with battery banks and/or diesel-fired backup generators to guard against low solar insolation levels during monsoon seasons.

4. CONCLUSIONS

In the wake of the COVID-19 crisis, there is a growing need for a green recovery that involves advanced and emerging economies. This requires a long-term commitment to sustainable policies and investment strategies aimed at promoting a more sustainable paradigm. To achieve this, there is a need to prioritize the development of a green culture, sustainable infrastructure, and a green recovery.

The current situation highlights the urgent need for action to combat climate change, which continues to impact different parts of the world in different ways. Climate change will have a significant impact on built environments, energy demand, and the design of infrastructure. To achieve the goal of zero emissions by 2050, we can no longer postpone the transition to a more sustainable economy. While circular thinking is one way to reduce the global carbon footprint, renewable technologies are also becoming increasingly cost-competitive with conventional generation. This is leading to the installation of new distributed renewable installations at a meaningful pace, with total global capacity increasing by 9% over 2015, to nearly 2,017 GW globally in 2016.

The development of sustainable infrastructure has the potential to help redress environmental degradation while also addressing the economic and political instability that plagues many emerging economies. By working together, public, and private gas and electrical utilities can find synergistic opportunities to build closed-loop, circular energy systems that make use of untapped or underused local resources. This can create sustainable energy access for remote and impoverished populations with multiple benefits.

Recent events, such as the War in Ukraine, have impacted the international energy market, leading to a significant increase in the prices of electricity and energy raw materials. In October 2021, due to the high volatility of these sectors, gas prices rose by 400% compared to April, also pushing up electricity prices (+200%). Despite this, some countries are testing and implementing new strategies to finance new gas-fired power plants that will be in operation for the next 30 years.

Designing intelligent energy systems that make use of smart meters (SMs) is expected to provide relevant benefits in the I4.0 paradigm. SMs can lead to energy savings and increased efficiency for both network operators and final users. Smart grids for energy are relatively recent, and there is a lack of detailed statistical information to support the proposed theoretical model. [9]

Nonetheless, this approach could be useful in driving governmental institutions towards a shared managerial sustainable vision, there is still a lack of knowledge and maturity among households and firms in many countries when it comes to the energy market structure and its operability. Policymakers can support SMs through regulation and education, which can help to install new green cultural skills through hourly rates, complete information on supplier change, and strong legislation on privacy and data protection, thus favouring social acceptance.

In the end, ensuring that we move towards a sustainable and circular energy paradigm, it requires the embracement of a multilayer approach and ongoing evaluation, mainly following these steps:

1. Set clear goals and targets.
2. Monitor progress and performance.
3. Align and integrate policies.
4. Engage stakeholders.
5. Build capacity and share knowledge.
6. Promote innovation and technology adoption.
7. Foster behavioural change and awareness.
8. Remain flexible and adaptable.

By following these steps and fostering a collaborative approach, we can move closer to a sustainable and circular energy future. Innovative financing mechanisms such as green bonds, carbon pricing, and feed-in tariffs can help mobilize investment in renewable energy projects and support the transition to a sustainable energy paradigm.

REFERENCES

[1] Cuentas V.K. (2022-2023). Driving Circularity - The Role of Energy Policy and Legislation. C.E.A. CIRCULAR ECONOMY ALLIANCE

[2] Burck J., Uhlich T., Bals C., Höhne N., Nascimento L. (2023) Results - Monitoring Climate Mitigation Efforts of 63 Countries plus the EU – covering more than 90% of the Global Greenhouse Gas Emissions. Germanwatch, NewClimate Institute, and CAN Climate Action Network International.

[3] [Lozano, R. Envisioning sustainability three-dimensionally. J. Clean. Prod. 2008, 16, 1838–1846.

[4] Lopes Sousa Jabbour, A.B.; Jabbour, C.J.C.; Foropon, C.; Godinho Filho, M. When titans meet—Can Industry 4.0 revolutionize the environmentally-sustainable manufacturing wave? The role of critical success factors. Technol. For. Soc. Chan. **2018**, 132, 18–25.

[5] Morelli, G.; Magazzino, C.; Rosa Gurrieri, A.; Pozzi, C.; Mele, M. (2022) Designing Smart Energy Systems in an Industry 4.0 Paradigm towards Sustainable Environment. MDPI, Basel, Switzerland.

[6] A. Robinson, G. Sewell, N. Damdaran, E. David, and N. Kalas-Adams, "Landfills in Developing Countries and Global Warming," in *Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium*, Cagliari, Italy, CISA, Environmental Sanitary Engineering Centre, October 6–10, 2003, 2.

[7] Brown, H. (2017) Towards A Circular Energy Economy: Cross-Sector Successes in Brazil and India. MIT Press 2017

[8] Almqvist, P., Cutting the cord for a better energy future," *The Solutions Journal* 4(2) June 2013,
http://www.thesolutionsjournal.org/node/22511?page=31%2C0%2C0%2nC0%2C.

[9] Berger, S.; Ebeling, F.; Feldhaus, C.; Loschel, A.;Wyss, A.M. What motivates smart meter adoption? Evidence from an experimental advertising campaign in Germany. Energy Res. Soc. Sci. **2022**, 85, 1–5.

Integration of Renewable Energy in Urban Environments

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At a time when environmental challenges and pollution are becoming increasingly concerning for modern cities, the integration of renewable energy resources becomes a fundamental challenge and a great opportunity to address these issues. This study aims to explore the importance and advantages of integrating renewable energy in urban environments, focusing on the analysis of various renewable energy technologies and their potential to contribute to a cleaner environment and more sustainable development of cities. Through an in-depth literature review and a critical examination of previous research in the field of renewable energy in cities, this study will identify the key advantages of using renewable energy resources, including reducing air pollution, improving air quality, and enhancing energy supply security at the local level. At the same time, a wide range of challenges that may arise during the integration process of these technologies in the urban environment will be examined, including technical limitations, infrastructure challenges, and administrative barriers. To illustrate the potential benefits of renewable energy integration in modern cities, the study will include the analysis of several case studies and practical examples of this process on a global scale. Through these cases, successful applications of renewable energy technologies in current urbanization and their role in improving urban life quality will be examined. Finally, the study will propose recommendations and guidelines for policymakers, urban planners, and other stakeholders to facilitate and promote the integration of renewable energy resources in modern cities, thus creating a more sustainable environment and greater progress towards future cities.

Keywords: *Renewable Energy, Benefits, Environmental Challenges, Urban Development, Pollution.*

1. INTRODUCTION

In an era marked by escalating environmental concerns and the urgent need for sustainable solutions, the integration of renewable energy sources within urban environments emerges as a critical imperative. Rapid urbanization, coupled with the proliferation of pollution and greenhouse gas emissions, underscores the pressing need to transition towards cleaner and more sustainable energy systems. This study embarks on a comprehensive exploration of the significance, advantages, challenges, and potential pathways for integrating renewable energy in urban environments, aiming to elucidate its transformative potential in shaping the cities of tomorrow. Urbanization is a defining characteristic of the modern era, with more than half of the world's population residing in urban areas. However, this rapid urban growth has been accompanied by a host of environmental challenges, including air pollution, resource depletion, and climate change [1-2]. At the heart of these challenges lies the energy sector, which remains heavily reliant on fossil fuels, contributing significantly to urban pollution and carbon emissions. In this context, the integration of renewable energy sources offers a promising pathway towards mitigating environmental degradation, enhancing energy security, and fostering sustainable urban development. The primary objective of this study is to explore the importance and advantages of integrating renewable energy in urban environments. Through a systematic examination of existing literature and empirical evidence, this research seeks to delineate the environmental, economic, and social benefits of renewable energy integration. Additionally, the study aims to identify and analyze the key challenges and barriers that may impede the widespread adoption of renewable energy technologies in urban settings. By synthesizing insights from theory, case studies, and practical experiences, this study endeavors to provide actionable recommendations and guidelines for policymakers, urban planners, and other stakeholders to facilitate the transition towards renewable energy-driven urban systems [3-4].

The integration of renewable energy in urban environments offers a myriad of benefits across multiple dimensions. Environmental advantages include the reduction of air pollution, improvement of air quality, and mitigation of climate change impacts. Renewable energy technologies, such as solar photovoltaics (PV), wind turbines, and biomass, produce electricity with minimal or zero emissions, thereby reducing the carbon footprint of urban energy systems. Moreover, the decentralization of energy production through distributed renewable energy systems can enhance energy resilience and reduce dependence on centralized fossil fuel-based power plants.From an economic standpoint, renewable energy integration presents opportunities for job creation, local economic development, and cost savings. The renewable energy sector has emerged as a significant source of employment, with jobs in solar and wind energy surpassing those in the coal and oil industries. Furthermore, renewable energy technologies are becoming increasingly cost-competitive with conventional energy sources, leading to lower electricity prices and long-term savings for consumers and businesses alike [5].

Social benefits of renewable energy integration include improved public health outcomes, increased energy access, and community empowerment. By reducing air pollution and harmful emissions, renewable energy deployment can mitigate the adverse health effects associated with fossil fuel combustion, such as respiratory illnesses and cardiovascular diseases. Additionally, decentralized renewable energy systems can enhance energy access and resilience in underserved urban communities, empowering residents to take control of their energy future [6].

Administrative barriers, such as regulatory uncertainty, policy fragmentation, and lack of stakeholder coordination, also present formidable obstacles to renewable energy integration. Inconsistent or outdated regulatory frameworks may impede the development of renewable energy projects, while bureaucratic hurdles can delay project implementation and increase costs. Moreover, limited public awareness and stakeholder engagement can undermine community support for renewable energy initiatives, hindering their successful adoption and implementation [7].

Figure 1. Urban Skyline with Renewable Energy Infrastructure

2. ENERGY LANDSCAPE OF URBAN ENVIRONMENTS

2.1 Analysis of energy consumption patterns in urban areas

Analyzing energy consumption patterns in urban areas is crucial for understanding the dynamics of energy demand, identifying trends, and informing strategic decision-making in energy planning and management [5-7].

Data Collection and Sources

Collecting comprehensive and accurate data is the foundation of analyzing energy consumption patterns in urban areas. Data sources may include:

- Utility billing records: Providing detailed information on electricity, natural gas, and water consumption at the household, commercial, and industrial levels.
- Transportation data: Including fuel consumption statistics, vehicle miles traveled (VMT), and modal shares for different transportation modes.
- Census data: Offering demographic information, household characteristics, and socio-economic indicators that influence energy consumption patterns.
- Energy surveys: Conducted at regular intervals to gather data on energy use behaviors, appliance ownership, and building characteristics.

Segmentation Analysis

Segmenting energy consumption data by sector, end-use, and demographic variables allows for a deeper understanding of consumption patterns:

- Residential sector: Analyzing energy use for heating, cooling, lighting, appliances, and electronics in households of varying sizes and income levels.
- Commercial sector: Examining energy consumption in office buildings, retail stores, hotels, and other commercial establishments, considering factors such as operating hours, occupancy rates, and equipment types.
- Industrial sector: Assessing energy usage in manufacturing facilities, warehouses, and industrial processes, focusing on energy-intensive operations and production cycles.
- Transportation sector: Analyzing fuel consumption patterns for private vehicles, public transit, freight transportation, and other modes of transportation, accounting for travel distances, vehicle types, and trip purposes.
- Socio-economic factors: Investigating how income levels, housing characteristics, lifestyle choices, and cultural preferences influence energy consumption behaviors and demand profiles.

Figure 2. Segmentation, Forecast

Temporal Analysis

Temporal analysis reveals variations in energy consumption patterns over time, including:
Seasonal trends: Identifying peak demand periods for heating and cooling in residential and commercial buildings, as well as fluctuations in energy use due to weather conditions and climate variations [3-5].

- Daily patterns: Examining diurnal energy consumption profiles, including peak demand hours, off-peak periods, and overnight baseload requirements, influenced by human activity patterns and daily routines.
- Long-term trends: Tracking changes in energy consumption patterns over years or decades, reflecting shifts in population growth, economic development, technological advancements, and policy interventions.

Spatial Analysis

Spatial analysis explores geographical variations in energy consumption patterns within urban areas:

- Neighborhood-level analysis: Identifying disparities in energy consumption between different neighborhoods, influenced by factors such as building age, housing density, land use mix, and socio-economic characteristics.
- Urban-rural divide: Contrasting energy consumption patterns between urban, suburban, and rural areas, highlighting differences in transportation modes, housing types, and access to services and amenities.
- Hotspot identification: Identifying areas of high energy consumption, such as commercial centers, industrial zones, and transportation hubs, to target energy efficiency and conservation efforts more effectively.

Figure 3. Spatial analysis of renewable energy potential

2.2.Role of renewable energy in addressing urban energy needs

Renewable energy plays a pivotal role in addressing the complex energy needs of urban areas, offering a sustainable and low-carbon solution to meet growing demand. Here's an exploration of its multifaceted role [6-7]:

Decarbonizing Urban Energy:

- Renewable energy sources such as solar, wind, and hydroelectric power produce electricity with minimal greenhouse gas emissions, helping cities reduce their carbon footprint and combat climate change. By transitioning away from fossil fuels for electricity generation, heating, and transportation, urban areas can significantly mitigate their contribution to global warming and air pollution.

Diversifying Energy Sources:

- Incorporating renewable energy into the urban energy mix diversifies energy sources, reducing dependence on finite fossil fuels and volatile energy markets. This diversification enhances energy security and resilience by minimizing the risk of supply disruptions and price fluctuations associated with traditional fossil fuel imports.

Localized Energy Production:

- Renewable energy systems can be deployed at various scales, from rooftop solar panels to community wind farms, enabling decentralized and localized energy production within urban areas. This distributed energy generation model reduces transmission losses and grid congestion, enhancing grid reliability and stability while empowering communities to take control of their energy supply.

Reducing Energy Costs:

- Renewable energy technologies have witnessed significant cost reductions in recent years, making them increasingly competitive with conventional energy sources. By harnessing abundant natural resources such as sunlight and wind, urban areas can generate electricity at lower costs over the long term, providing economic benefits to residents, businesses, and local governments through reduced energy bills and job creation in the renewable energy sector.

Promoting Energy Efficiency:

- Renewable energy deployment often goes hand in hand with energy efficiency measures, as cities seek to optimize energy use and minimize waste. Integrated solutions such as smart grids, energy storage systems, and demand-side management technologies complement renewable energy generation, enabling more efficient energy distribution, utilization, and conservation within urban environments.

3. TECHNOLOGY SELECTION AND DESIGN

Selecting appropriate renewable energy technologies and designing efficient systems are crucial steps in integrating renewable power into urban environments [4-7].

3.1. Overview of renewable energy technologies suitable for urban environments

Solar Energy

– Rooftop Solar: Utilizes available roof space on residential, commercial, and industrial buildings for solar panel installation, maximizing energy generation without additional land use.

– Building-Integrated Photovoltaics (BIPV): Integrates solar panels directly into building materials such as glass facades, windows, and roofing tiles, providing both structural and energy benefits.

– Solar Parks: Develops larger-scale solar installations on vacant urban land or brownfield sites, providing clean energy to urban communities and supporting local grid infrastructure.

Wind Energy

Wind energy systems harness wind power to generate electricity using horizontal or vertical-axis wind turbines.

– Rooftop Turbines: Small-scale vertical-axis wind turbines installed on rooftops or in urban gardens can capture wind energy in densely populated areas with limited space.

– Urban Wind Farms: Larger horizontal-axis wind turbines located in urban fringe areas or offshore wind farms near coastal cities can supplement urban electricity supply and contribute to renewable energy goals.

– Wind-Responsive Architecture: Innovative building designs incorporate wind-capturing features such as vents, chimneys, and turbines to harness natural ventilation and generate on-site electricity.

Micro-Hydro Systems:

Micro-hydro systems utilize small-scale turbines or waterwheels to generate electricity from flowing water in urban waterways or stormwater management systems.

– Urban Streams and Rivers: Low-head micro-hydro turbines installed in urban waterways or wastewater treatment plants can capture kinetic energy from flowing water, providing renewable electricity to nearby communities.
– Stormwater Harvesting: Small-scale hydroelectric generators integrated into stormwater management infrastructure can utilize runoff from heavy rainfall events to produce clean energy and reduce urban flooding risks.

Biomass Energy:

Biomass energy technologies convert organic materials such as agricultural residues, forestry waste, and urban biomass into heat, electricity, or biofuels.
– Anaerobic Digestion: Organic waste from urban sources such as food scraps, yard trimmings, and sewage sludge can be processed in anaerobic digesters to produce biogas for heat, electricity, or vehicle fuel.
– Combined Heat and Power (CHP): Biomass-fired CHP systems installed in urban district heating networks or industrial facilities utilize biomass feedstocks to generate both heat and electricity, maximizing energy efficiency and resource utilization.
– Waste-to-Energy (WtE): Incineration or gasification of municipal solid waste (MSW) in modern waste-to-energy plants can generate electricity and heat while reducing landfill volumes and greenhouse gas emissions.

Geothermal Energy:

Geothermal energy systems extract heat from the Earth's subsurface to provide space heating, cooling, and electricity generation.
– Ground-Source Heat Pumps (GSHP): Closed-loop or open-loop GSHP systems installed beneath urban buildings utilize stable ground temperatures for space heating and cooling, offering energy-efficient climate control solutions in urban areas.
– Geothermal District Heating: District heating networks in urban neighborhoods can be powered by geothermal energy, supplying renewable heat to multiple buildings and reducing reliance on fossil fuels for heating purposes.
– Tidal and Wave Energy:
– Description: Tidal and wave energy technologies capture kinetic energy from ocean currents and waves to generate electricity.
– Coastal Cities: Offshore tidal turbines and wave energy converters located near coastal cities can tap into predictable tidal flows and wave patterns, providing renewable electricity to coastal communities and supporting marine renewable energy development.

4.COMMUNITY ENGAGEMENT AND PUBLIC PARTICIPATION

4.1. Examples of successful community-led renewable energy initiatives

Community-led renewable energy initiatives have demonstrated the power of grassroots efforts to drive sustainable energy transition and empower local communities [3-6].
SolarShare is a community solar cooperative based in Ontario, Canada, that enables residents to collectively invest in solar energy projects and receive financial returns through clean energy generation. SolarShare allows individuals and organizations to become members of the cooperative by purchasing shares, making them co-owners of solar energy installations across Ontario. It develops and operates solar photovoltaic (PV) projects on rooftops, parking lots, and brownfield sites, leveraging economies of scale to maximize energy production and cost-effectiveness. SolarShare projects contribute to Ontario's clean energy transition by displacing fossil fuel-based electricity generation, reducing greenhouse gas emissions, and supporting the growth of renewable energy capacity in the province, and fosters community engagement and education through outreach events, workshops, and tours of solar

installations, raising awareness about the benefits of renewable energy and empowering residents to take action on climate change.

Repower Shoalhaven is a grassroots community organization based in the Shoalhaven region of New South Wales, Australia, dedicated to promoting renewable energy adoption and community-owned energy projects. Repower Shoalhaven engages with residents, businesses, and local organizations through outreach events, workshops, and educational campaigns to raise awareness about renewable energy and empower community action. Shoalhaven facilitates solar bulk-buy programs, negotiating discounted rates with local solar installers to make solar photovoltaic (PV) installations more accessible and affordable for residents and businesses.Repower Shoalhaven collaborates with community members to develop and finance community-owned solar projects on public buildings, schools, and community facilities, allowing local residents to invest in and benefit from clean energy generation .It promotes energy efficiency measures and sustainability practices, encouraging residents to reduce energy consumption, improve home insulation, and adopt energy-saving technologies to complement renewable energy generation.

5. FUTURE TRENDS AND OPPORTUNITIES

As urban areas continue to seek sustainable energy solutions, emerging technologies and innovations are playing a crucial role in transforming the renewable energy landscape [2][3-6].

- Building-Integrated Photovoltaics (BIPV):

BIPV integrates solar photovoltaic modules into building materials such as windows, facades, and roofing, turning buildings into power-generating assets.

- Urban Wind Turbines:

Urban wind turbines are compact, low-profile wind turbines designed for installation in urban environments, capturing wind energy in densely populated areas.

- Solar-Tracking Systems:

Solar-tracking systems optimize the orientation of solar panels to track the sun's movement throughout the day, maximizing energy generation efficiency.

- Energy Harvesting from Urban Infrastructure:

Energy harvesting technologies capture wasted energy from urban infrastructure and convert it into usable electricity, reducing energy consumption and enhancing sustainability.

- Hybrid Renewable Energy Systems:

Hybrid renewable energy systems combine multiple renewable energy sources, energy storage, and grid connectivity to provide reliable and resilient power solutions for urban environments.

6. CONCLUSION

In conclusion, the integration of renewable power in urban environments represents a critical pathway towards sustainable and resilient cities in the face of urbanization and climate change challenges. Throughout this discourse, we've explored the multifaceted implications, challenges, and opportunities associated with this endeavor.

Urbanization brings about intensified energy demands, driven by population growth, infrastructure expansion, and changing lifestyles. Simultaneously, climate change exacerbates

these challenges, amplifying energy needs for cooling amidst rising temperatures and posing risks to energy infrastructure through extreme weather events.
However, amidst these challenges lies a transformative potential. The adoption of renewable energy technologies, such as solar, wind, and hydroelectric power, offers a viable pathway to address urban energy needs while mitigating greenhouse gas emissions. Innovative solutions, including building-integrated photovoltaics, urban wind turbines, and energy-efficient systems, are reshaping urban landscapes and driving the transition towards sustainable energy systems.
The integration of renewable power in urban environments is not merely about decarbonizing energy sources but also about fostering resilience, equity, and economic development. Community-led initiatives, smart city technologies, and policy frameworks play crucial roles in advancing this transition, empowering local communities, enhancing energy efficiency, and promoting social inclusion.
In embracing renewable energy integration, urban environments can reap multiple benefits, including reduced air pollution, enhanced energy security, and job creation, while simultaneously contributing to global efforts to mitigate climate change and build a sustainable future.
As we move forward, collaboration, innovation, and commitment are paramount. By working together across sectors and disciplines, we can harness the power of renewable energy to create cities that are not only vibrant and prosperous but also sustainable, resilient, and equitable for generations to come. The journey towards renewable power integration in urban environments is not without its challenges, but it is a journey worth undertaking for the well-being of our cities and the planet.

REFERENCES

[1] Energy landscapes and urban trajectories towards sustainability – ScienceDirect. www.sciencedirect.com
[2] Confronting the energy crisis: Changing behaviours to reduce energy consumption. www.oecd.org
[3] Rise of renewables in cities – Energy solutions for the urban future. www.irena.org
[4] Technology Readiness | The Power of Renewables: Opportunities and Challenges. https://nap.nationalacademies.org/
[5] Sustainability | Free Full-Text | A Review of Renewable Energy Communities. https://www.mdpi.com/
[6] Shaping the Future: Emerging Technologies in Renewable Energy Projects. www.enerdatics.com
[7] (PDF) IMPACTS OF URBANIZATION AND ENERGY CONSUMPTION ON CLIMATE CHANGE. https://www.researchgate.net/

Climate Changes, Adaptation & Mitigation

Integrating Adaptation and Mitigation Strategies for Climate Resilience and Development: Challenges and Opportunities

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Climate change is a global challenge with profound implications for ecosystems, economies, and human well-being. Addressing this challenge requires a combination of adaptation and mitigation strategies. Adaptation focuses on reducing vulnerability and building resilience to the impacts of climate change, while mitigation aims to reduce greenhouse gas emissions to limit future climate change. Adaptation strategies encompass a range of actions aimed at reducing the adverse effects of climate change on communities and ecosystems. Nature-based solutions, such as restoring mangroves and wetlands, can help protect coastal areas from sea-level rise and storm surges while providing habitats for biodiversity. Infrastructure improvements, such as building resilient water management systems and designing heat-resilient buildings, can enhance urban resilience to climate change impacts. Additionally, promoting sustainable agricultural practices, such as crop diversification and agroforestry, can help farmers adapt to changing climate conditions while reducing emissions. Mitigation strategies focus on reducing greenhouse gas emissions to mitigate the severity of climate change. Transitioning to renewable energy sources, such as solar and wind power, can reduce reliance on fossil fuels and lower emissions. Improving energy efficiency in buildings, transportation, and industry can also contribute to emission reductions. Furthermore, reducing emissions from deforestation and forest degradation through sustainable forest management and conservation efforts can help sequester carbon and mitigate climate change. Additionally, uncertainties in climate projections and the complex interactions between social, economic, and environmental factors can pose challenges to effective decision-making. To address these challenges, a holistic approach is needed that integrates adaptation and mitigation strategies into broader sustainable development goals. By implementing effective adaptation and mitigation strategies, we can build more resilient and sustainable communities and contribute to global efforts to address climate change.

Keywords: *Mitigation / adaptation strategies, environmental impacts, climate change, resiliency.*

1. INTRODUCTION

Albania, nestled in the heart of the Balkans, boasts a rich tapestry of history, culture, and natural beauty. However, like many nations around the globe, Albania faces the pressing challenge of climate change. As a country situated on the Adriatic and Ionian Seas, Albania's climate is influenced by its proximity to the Mediterranean. However, in recent years, the effects of climate change have become increasingly evident, posing significant threats to the nation's environment, economy, and society.

From rising temperatures to changing precipitation patterns, Albania is experiencing a range of climate-related impacts. Coastal areas are particularly vulnerable to sea-level rise and erosion, while inland regions face challenges such as droughts and floods. These changes not only endanger ecosystems and biodiversity but also jeopardize vital sectors like agriculture, tourism, and infrastructure.

In response to these challenges, Albania has been actively engaged in both national and international efforts to mitigate and adapt to climate change. Through policy initiatives, investment in renewable energy, and collaboration with global partners, Albania is striving to reduce its greenhouse gas emissions and build resilience to climate impacts.

Despite these efforts, much work remains to be done. As Albania navigates the complex intersection of development, environmental conservation, and climate action, fostering awareness, collaboration, and innovation will be essential in shaping a sustainable and resilient future for this diverse and vibrant nation.

2. RESULTS AND DISCUSSION

There is an increasing trend in temperature in Albania. Farmers also observed an increasing trend in extreme heat events. Analysis indicates this trend will accelerate in Albania in the near future, as indicated in Figure 1. Although uncertainty remains as to the degree of warming that will occur in Albania, the overall warming trend is clear and evident in all four agro-ecological zones (AEZs), with average warming over the next 40 years of about 1.5ºC, much greater than the increase of less than 0.5ºC observed over the last 50 years. Changes in precipitation are much more uncertain than temperature changes, as demonstrated in Figure 2. The medium impact forecast indicates a decline in average annual precipitation for Albania of about 50 mm by 2050, most of this decline occurring in the lowlands AEZ. The range of outcomes across the low and high impact alternative scenarios, however, encompasses an increase in annual precipitation of 30 mm for low impact and a decrease of 90 mm for high impact. Uncertainty at the regional level is even higher: annual precipitation declines in the lowlands and intermediate AEZs, including areas around Lushnje, Vlores, Fushe-Kruje, and Shkodra, could be as large as 150 mm per year. Most models show that the mountainous areas of Albania, particularly around Korce, should experience only modest declines in annual precipitation.

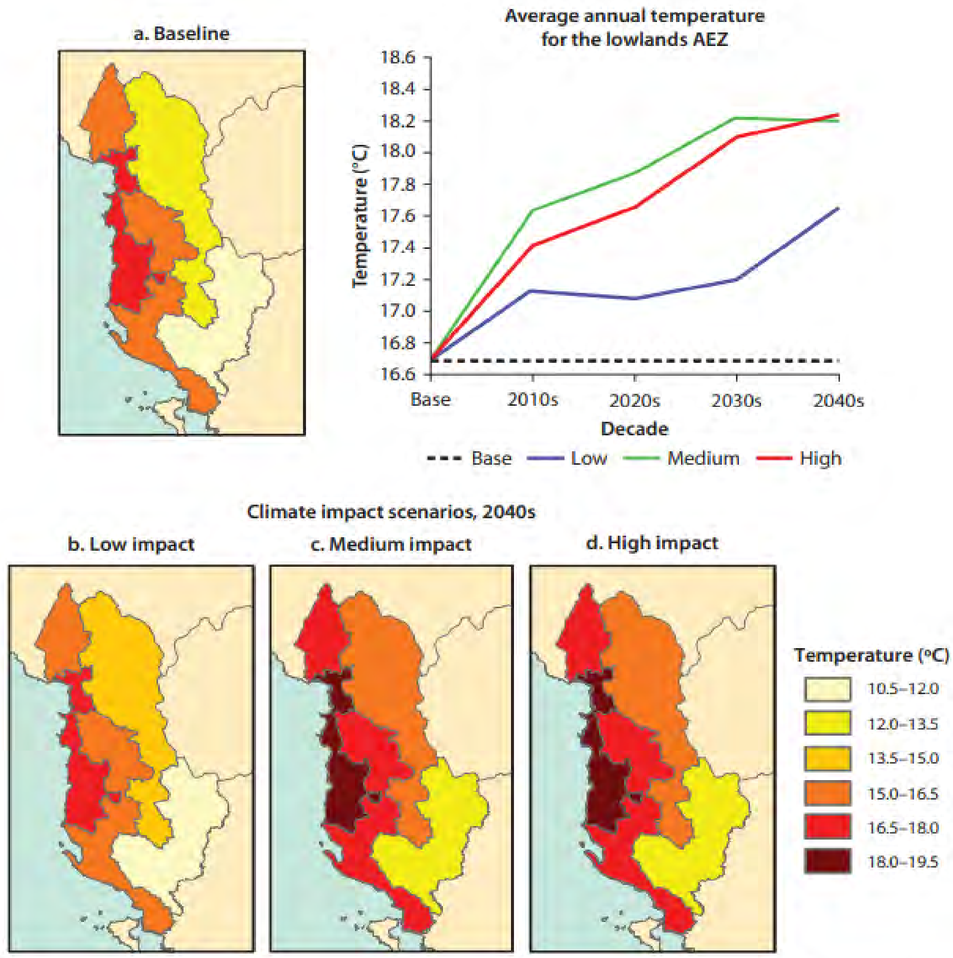

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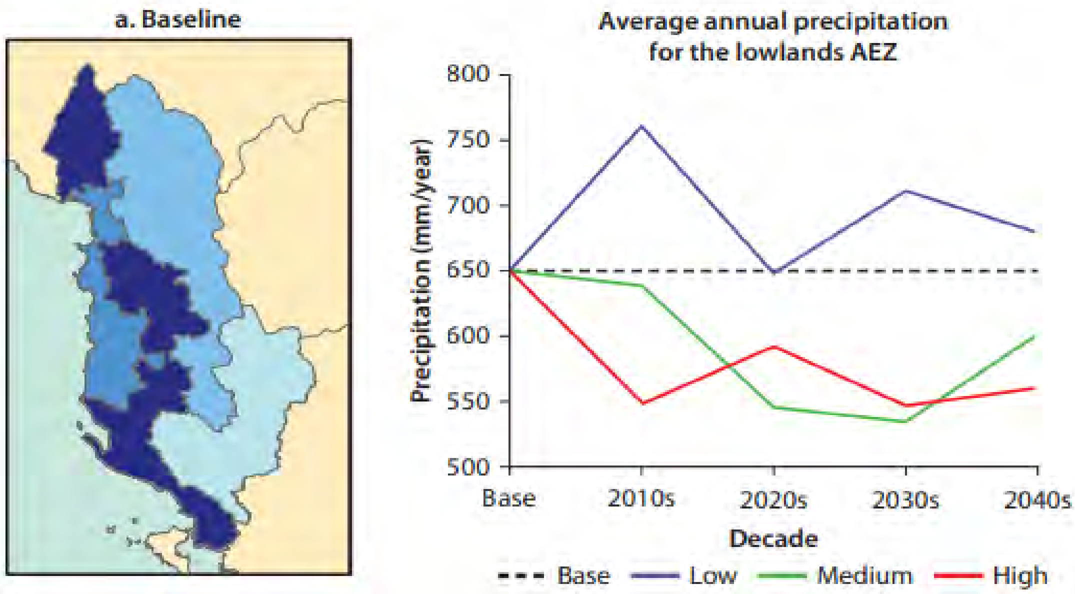
Figure 1. Albania: Effect of Climate Change on Temperature through 2050 for the Three Climate Impact Scenarios



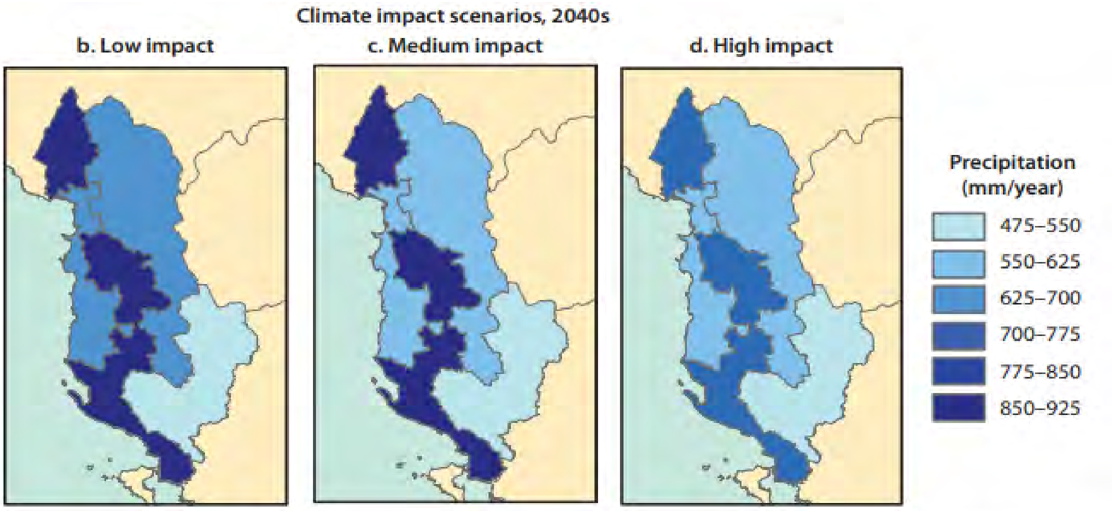


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Figure 2. Albania: Effect of Climate Change on Precipitation through 2050 for the Three Climate Impact Scenarios

Albania also has a history of relatively frequent flooding, especially in the last two decades. Flood events occur on a daily to weekly timescale, so the monthly data presented above does not reflect the risk that climate change can lead to more extreme precipitation and flooding events. During a large flood in December 2010, 14,000 hectares of Shkodra were submerged due to heavy rains and high-water levels of the river Drin. Flooding is a particular problem in the northwest, a region with minimal watershed management and poor infrastructure. Most prevalent in May–December, the floods have worsened in recent decades most likely due to deforestation, overgrazing, and erosion, combined with a lack of maintenance of drainage canals and pumping stations. In addition, river control programs were discontinued and reservoirs became silted. These disruptions led to a worsening of the hydroelectric and irrigation systems. Climate change could potentially increase the frequency and magnitude of flooding. While precipitation is only expected to increase in the low impact scenario by the 2040s (see Figure 2), rainfall events in all scenarios are likely to be larger and less frequent. Additionally, increasing sea level rise and storm surges are expected to increase flooding in coastal areas. For the agriculture sector in Albania, floods are particularly problematic in the spring, when flooding can delay or prevent planting of summer crops, and during late summer, when flooding can destroy the entire year's growth and prevent timely harvesting. Less serious flood events can reduce productivity through water logging of roots. The seasonal pattern of changes in climate are, however, more important for crop and livestock production than annual averages, particularly if no adaptation measures are adopted beyond those that farmers already employ (such as changing planting dates in response to temperature changes). The graphs provide the monthly temperature and precipitation results for Albania, showing that temperature increases are higher and precipitation declines greater in July and August relative to current conditions. The summer temperature increase can be as much as 4–5ºC in the northern mountains of Albania. In addition, forecast precipitation declines are greatest in the key May–September period when precipitation is already lowest, particularly in the southern and northern mountains

3.1. Impact Assessment Results for Albania

The monthly projections are further translated to daily projections for use in the crop models. These models provide results for climate change impacts to crops if no adaptation is implemented. The results show that grapes and olives will be most affected by climate change, with declining grape yield in all AEZs and with olives particularly affected in the lowlands AEZ. Winter wheat yields could increase, however, as climate change will likely result in an extended growing season, more moderate fall and winter temperatures, and greater precipitation and water availability during the wheat growing season. Alfalfa production should also increase in most regions. The expected effects on maize vary by region, with yield increases in the southern highlands and decreases in other regions, probably because current temperatures are quite moderate in the mountainous southern highlands and a temperature increase could enhance yields. The other crops analyzed in this study should experience relatively modest crop yield changes compared with current yields. The study team also conducted a water availability analysis in Albania at the river basin level. They modeled the effect of climate change on water runoff in rivers for each basin and then used a second model to compare water supply results with forecasts of water demand for all sectors, including agriculture. Agricultural water demand for irrigation is derived from the crop model results.

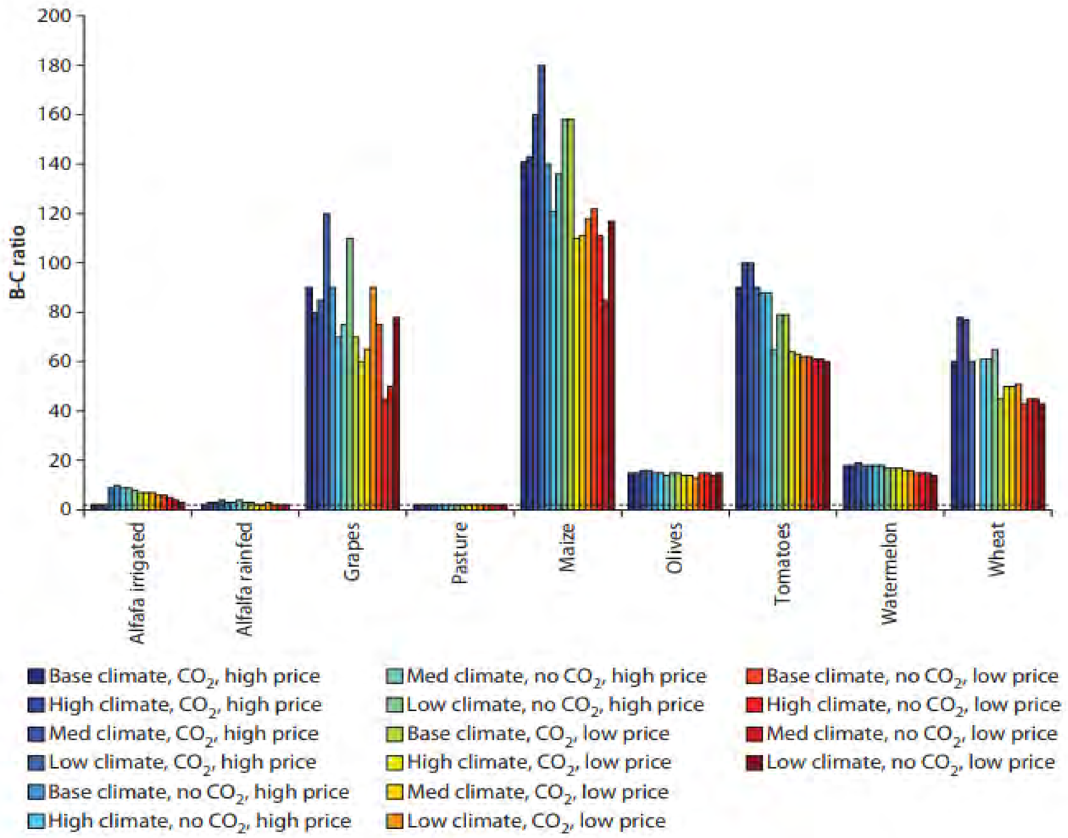

Figure 3. Benefit-Cost Analysis Results for Improved Drainage in Albania's Lowlands AEZ—Rehabilitated Drainage Infrastructure

3. CONCLUSION

In Albania, overall results suggest that water supply will decrease under the high and medium impact scenarios, and increase under the low impact scenario. Irrigation water demand is higher for all scenarios, particularly in the summer months. Nonetheless, in each of the four river basins of the country, because the baseline supply of water is so high, the analysis indicates there is no unmet water demand through 2050, indicating there will continue to be ample water available for both current levels of irrigation and expansion of irrigated areas, as necessary. Effects on alfalfa and rainfed pasture crops summarized in the previous section present one type of climate change risk to livestock, an indirect effect. Effects of climate change on maize yields may also be linked to effects on livestock. As noted, for the medium scenario alfalfa and grassland yields are expected to increase in the northern mountains and southern highlands AEZs, where livestock makes up a larger percentage of overall agricultural productivity. Even under the high impact scenario, the effects on these crops in the higher elevation regions of Albania are relatively modest, with the temperature effects providing a boost to yield that generally balances or outweighs the negative effects of less precipitation. As a result, the indirect effects of climate change in areas where livestock are most important would range from relatively modest in the worst case to beneficial in the best case. The direct effect of climate change on livestock is also important and is linked to higher than optimal temperatures for livestock, where heat can affect animal productivity and, in the case of extreme events, can lead to elevated mortality rates related to extreme heat stress. As noted previously, there is very limited information to characterize the direct effects of climate on livestock because the currently available methodologies are far less sophisticated than the crop modeling techniques or the water resource modeling techniques.

It was conducted in the form of a detailed quantitative benefit-cost (B-C) analysis of adaptation options selected from this list to address seven adaptation issues in Albania, including the following:

1. adding new drainage capacity;
2. rehabilitating existing drainage infrastructure;
3. adding new irrigation capacity;
4. rehabilitating existing irrigation infrastructure;
5. improving water use efficiency in fields;
6. changing crop varieties; and
7. optimizing fertilizer use.

Some of these options included costs for extension programs, as appropriate, if enhanced extension was determined to be necessary to achieve the full benefits of the adaptation option. This is true for two of the selected options—improving water use efficiency and changing crop varieties. In addition, less detailed analyses were conducted of two other options: improving the hydrometeorological network and installing hail nets for selected crops. The assessments were conducted at the farm level on a per hectare basis and considered available estimates of the incremental cash costs for implementing the option as well as the revenue implications of increasing crop yields.

REFERENCES

[1] IPCC (2018) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. https://www. ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf.

[2] PBES (2019) Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat. https://ipbes.net/sites/default/fles/inline/fles/ipbes_global_assessment_report_summary_for_policymakers.pdf.

[3] RP (2019) Global Resources Outlook 2019: Natural resources for the future we want.

In Report of the International Resource Panel. United Nations Environment Programme. fle:///C:/Users/PC/AppData/Local/Temp/ GRO_2019.pdf. Accessed 25 June 2021

[4] EEA (2019) The European environment—state and outlook 2020. Publications Office of the European Union. https://d2ouvy59p0dg6k.cloudfront. net/downloads/soer_2020_executive_summary_embargoed_4_decem ber.pdf.

[5] The European Green Deal (2019) Communication from the commission to the European parliament, the European council, the council, the European economic and social committee and the committee of the regions. https://ec.europa.eu/info/sites/default/fles/european-greendeal-communication_en.pdf.

Carbon Footprint and Carbon Emission Reduction of Higher Education Institution Buildings: Case of Faculty of Civil Engineering Building, Tirana

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Climate change is one of the most serious global environmental problems. Due to this concern, the assessment of emissions and the calculation of a carbon footprint have continuously gained attention, especially as a starting point for reduction of environmental impact and eventually achieving carbon neutrality. Reducing the carbon footprint helps to meet the targets of the sustainable development goals (SDGs), with an emphasis on SDG13, which seeks urgent measures to combat climate change and its consequences. The objective of this paper is to calculate the carbon footprint of the Civil Engineering Faculty in Tirana. The calculation includes direct and indirect emissions of scope. This means that the data will refer to water and energy consumption, transportation mode and waste production in regard to the total number of students and professors. All the data mentioned here will be used in ClearPath software program that will do the calculation of the carbon footprint. This paper will show the importance of higher education institutions in undertaking research towards a sustainable future and to present different approaches to reducing carbon emissions.

Keywords: *Climate change, carbon footprint, carbon neutrality, emissions.*

1. INTRODUCTION

Climate change refers to the steady and ongoing increase in the Earth's atmospheric temperature, primarily attributed to the release of vast amounts of greenhouse gases such as carbon dioxide, methane, fluorocarbons or chlorofluorocarbon, nitrous oxides or also known as greenhouse gases. [1]

In September 2015, nations from across the globe came together to endorse Agenda 2030, a comprehensive framework committed to achieving sustainable development. The goal is to enable present generations to develop without compromising the opportunity of future generations to meet their own. [2]

The carbon footprint is defined as a measure of the impact human activities have on the environment quantified in terms of the greenhouse gases emitted, primarily measured in carbon dioxide (CO2) units. [3] These emissions are measured using carbon dioxide equivalent. GHGs are gases that raise the earth's temperature through infrared absorption. Carbon dioxide and methane, which are carbon containing gases, are among the GHGs emitted through specific activities such as the burning of fossil fuels, land clearance, material production, wood usage, transportation, services, and construction. Addressing the challenge of reducing our carbon footprint requires efforts and increased emphasis on sustainable development initiatives and research.[4]

A sustainable university can be defined as a higher educational institution that comprises and encourages the minimization of hostile environmental, economic, and societal impacts generated by use of their resources. While the environmental impact of universities may be relatively small compared to other sectors, the education sector delivers poignant knowledge to all segments of society and act as anchors in the local and global communities as they serve as pioneers in scientific and technological advancements through research and the education of professionals.[5] Universities prioritizing sustainability will cultivate engineers engaged in seeking sustainable practice. Hence, it should be essential to develop sustainable universities from every point of view.[6]

When calculating the carbon footprint, emissions are typically categorized into scopes and categories. A popular classification is presented by the GHG Protocol Corporate Standard. Their guideline proposed the division of the emitted greenhouse gases into three scopes. [7] Whilst Scope 1 (direct emissions from sources owned or controlled by the reporting organization) and Scope 2 (from purchased electricity) are the simplest to assign and calculate, Scope 3 emissions (the remaining indirect emissions from purchased and sold goods and services) are seldom quantified in their entirety [8].

The aim of this study is to calculate the carbon footprint of the Civil Engineering Faculty in Tirana using ClearPath software program. Considering direct and indirect emissions we will be able to identify the biggest contributors to the carbon footprint of the Civil Engineering Faculty building. Based on the results of our study we will be able to present different approaches to reducing carbon emissions and show the importance of higher education institutions in undertaking research towards a sustainable future.

2. MATERIALS AND METHODS

2.1. Study area.

This study was carried out at the Faculty of Civil Engineering, Polytechnic University of Tirana. The building was constructed in 2010 and has a surface area of 4881.9 m^2. Figure 1 shows the location of the building whereas space utilization is presented in the following Table 1.

Figure 1. Location of Civil Engineering Faculty building (Source: Google Maps 2024)

Table 1. Space utilization of the Civil Engineering Faculty building

Space utilization used for the faculty and staff	Quantity	Surface area
Lecture hall	9	158.3 m^2
Seminar classroom	7	455.6m^2
Laboratory	9	780 m^2
Offices for the academic staff of the departments	4	58 m^2
Offices for faculty's departments	4	152 m^2
Dean/ Vice dean's office and dean's secretary	3	117 m^2
Secretary	1	60.3 m^2
Offices for administrator and finance	2	38 m^2

2.2. Data analyzing

2.2.1 Data collection

To calculate the carbon footprint of the Civil Engineering Faculty building, the dataset secured from the administrative staff ensured that all three scopes of emissions were included. The dataset spans from 2022 to 2023 and comprises water and energy consumption data, waste production and transportation mode data in regard to the total number of students in the faculty (2535 students) and professors (64 professors).

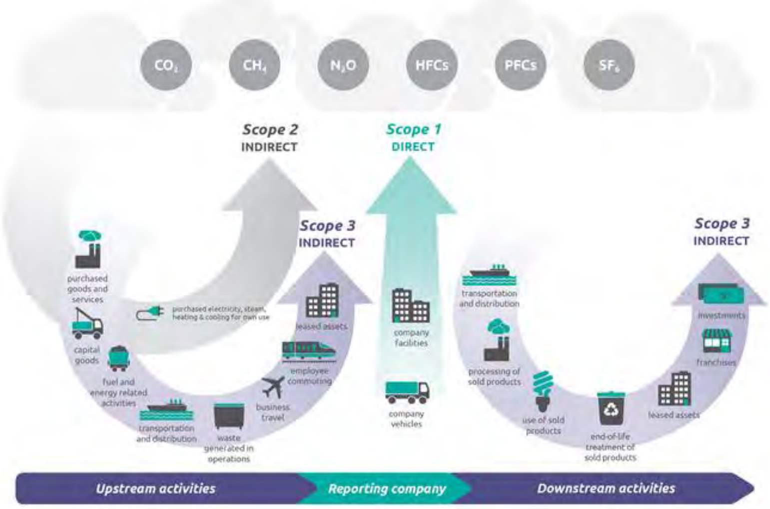

Figure 2. Scope's introduction (Source: EPA Center for Corporate Climate Leadership)

2.2.2 Methodology

ClearPath, developed by the organization ICLEI, has emerged as a widely adopted emissions calculation tool utilized by cities worldwide. It has garnered significant attention, particularly within the United States. ClearPath is an online cloud-based emissions calculation tool that helps quantify and manage greenhouse gas emissions.[9]

3. RESULTS AND DISCUSSION

3.1 Results

Table 2 shows the data used as input to calculate the carbon emissions from transport activity.

Table 2. Transport data.

	Vehicles/day	Traveled distance (km)	Fossil fuel consumption (liters)
	40	8	
Diesel			3449.6
Petrol			1478.4
Total			4928

For every 100 km kilometers traveled, diesel vehicles consume approximately 7 liters of fossil fuel, while petrol vehicles consume approximately the same amount. This means that for a traveled distance of 8 km, a vehicle consumes 0.56 liter of fossil fuel. Considering that 70% of the vehicles use diesel, according to the administrative sources, and the remaining ones use petrol as a fuel, we were able to estimate the total fossil fuel consumption.

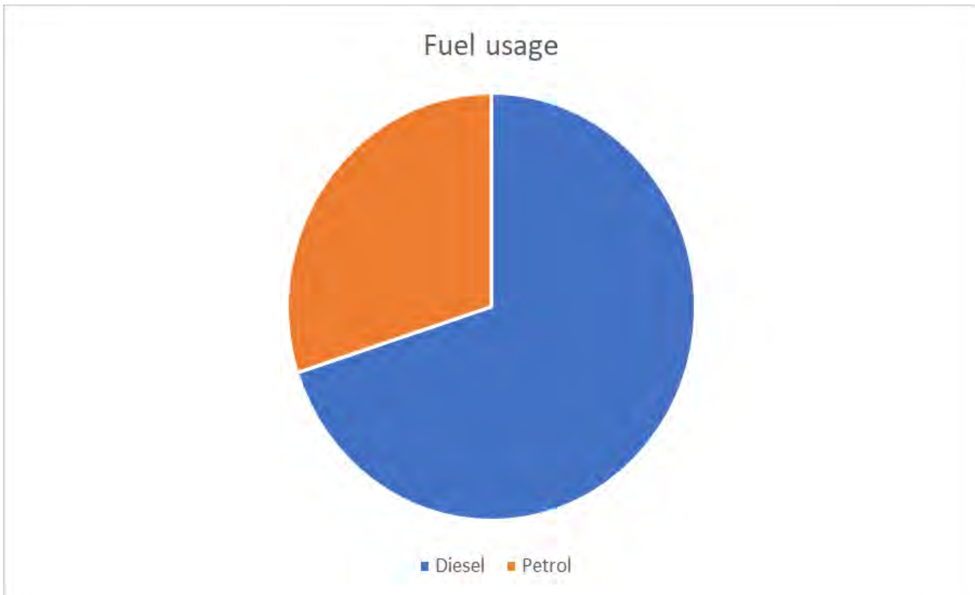

Figure 4. Fuel usage distribution

The amount of water consumption according to the secured data is 6198.8 m^3 water for both drinking water and wastewater as well in 2023 and 8677.4 m^3 in 2022. Taking into consideration the total number of students we can estimate that the two-year average water consumption per student is 0.35 m^3 water.

Table 3 shows the data used as input to calculate carbon emissions from waste production in the faculty building.

Table 3. Waste production data.

Students	Waste generation norm/year (kg/year)
2535	22

Utilizing this data, we were able to estimate the total amount of generated waste per year in the building which is 55 m^3 waste/year ($1m^3$ per waste can).

Table 4 shows the data used as input to calculate carbon emissions from electricity consumption in the faculty building.

Table 4. Electricity consumption data.

	Year 2022 (kW/h)	Year 2023 (kW/h)
Electricity consumption	124,324	86,891

3.2. Discussion

Applying the dataset in the ClearPath software program to calculate the carbon footprint of the Civil Engineering Faculty building, we were able identify the major contributor to carbon levels of emissions.

Table 5. Carbon emissions per activity

	Activity	TCO_2 / year
	Transport	14.2
	Electricity	126
	Waste	0.36
Total :		**140.56**

Based on the results shown in Table 5 we estimate that the total value of the carbon footprint of the Civil Engineering faculty is **140.56 TCO_2 / year**, and the activity that generated the most carbon emissions is electricity consumption with the value of 126 **TCO_2 / year**.

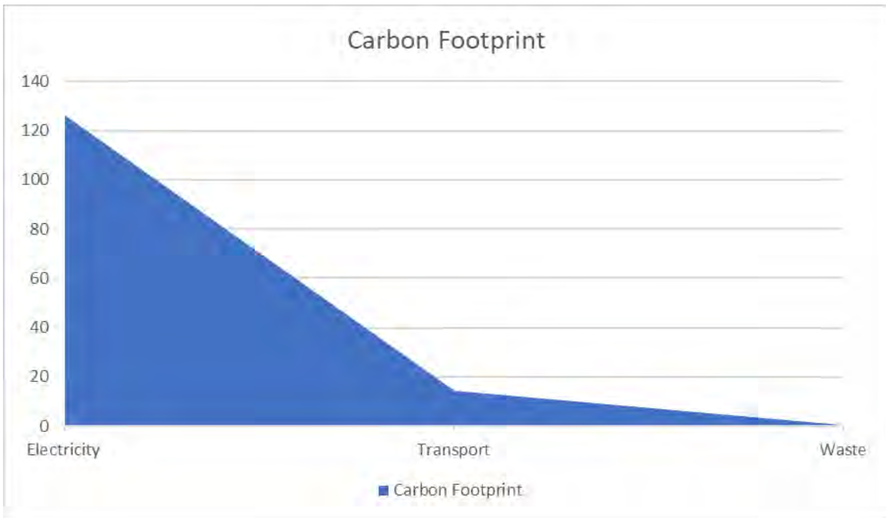

Figure 3. Carbon footprint of the Civil Engineering Faculty

Since it is evident that electricity consumption plays a major role in the quantity of the carbon footprint of the Civil Engineering Faculty building, we need to apply a mitigation measure. Referring to our administrative sources, the faculty's building lacks thermal insulation, making it difficult to mitigate heat transfer. By proper installation of insulation using energy-efficient materials that would reduce the heat loss or heat gain, we would be able to reduce the energy cost as the result.[10]

Additionally, we evaluated the carbon emissions resulting from fossil fuels utilized by these vehicles which resulted in the total value of **14.2 TCO_2 / year** and the amount of carbon emissions from generated waste which was estimated to be **0.36 TCO_2 / year.**

4. CONCLUSIONS AND RECOMMENDATIONS

Climate change is one of the most pressing global challenges. The increased amount of greenhouse gases makes reducing carbon emissions an important goal. Higher education institutions are responsible for cultivating an environment that ensures that students will lead the future by providing sustainable solutions.
The aim of this paper was to calculate the carbon footprint of the Civil Engineering Faculty building using the ClearPath software program. The total amount of the carbon footprint was **140.56 TCO_2 / year**. The activity that generated the most carbon emissions was electricity consumption with the estimated value of **126 TCO_2 / year**.

To reduce the impact of carbon emissions here are recommendations proposed. Encouraging the use of public transport and switching to low emissions vehicles will have an impact on the carbon footprint. Furthermore, one of the most effective forms to reduce carbon emissions is educational campaigns, informative lectures, sustainability training programs and workshops around the faculty. These should aim to educate students and faculty on how to reduce their annual consumption of utilities such as electricity, water, and paper. [11]

REFERENCES

[1] Adanza J.R., (2016), Barriers to Mitigate Carbon Footprint in a Selected Academic Institution in Bacoor City, Cavite, Philippines. *International journal of environmental & science education* 11 (12): 5653-5661.

[2] Jarillo M.P., Pedraza L., Ger P.M., Bocos E., (2019), Challenges of Online Higher Education in the Face of the Sustainability Objectives of the United Nations: Carbon Footprint, Accessibility and Social Inclusion. *Sustainability* (11) :5580.
[3] Misni A., Buyadi S.N.A., Kamaruddin S.M., Ahmad P., (2019), Quantifying Carbon Footprint Review in University Campus. *Environment behaviour proceedings journal* 4 (12): 133-138.
[4] Maulidevi N.U., Aji1 B.S.K., Hikmawati E., Surendro K., (2023), Modelling Integrated Sustainability Monitoring System for Carbon Footprint in Higher Education Buildings.*IEEE Access* 11: 135365 - 135376.
[5] Mustafa A., Kazmi M., Khan H.R., Qazi S.A., Lodi S.H., (2022), Towards a Carbon Neutral and Sustainable Campus: Case Study of NED University of Engineering and Technology. *Sustainability* (14) :5580.
[6] Helmers E., Chang C.C., Dauwels J.,(2021), Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. *Environmental sciences Europe* 33:30.
[7] Kiehle J., Kopsakangas-Savolainen M., Hilli M., Pongracz E., (2023), Carbon footprint at institutions of higher education: The case of the University of Oulu. *Journal of Environmental Management* 329.
[8] Robinson O.J., Tewkesbury A., Kemp S., Williams I.D., (2018), Towards a universal carbon footprint standard: A case study of carbon management at universities. *Journal of Environmental Management* 172: 4435-4455.
[9] Dhanens E., (2020), Analysis of emissions inventory challenges across the U.S. Supported by the case study of Dekalb, Illinois, using clearpath. *Master's thesis*, Northern Illinois University.
[10] Aditya L., Mahlia T.M.I., Rismanchi B., Ng H.M., Hasan M.H., Metselaar H.S.C., Muraza O.,Aditya H.B., (2017), A review on insulation materials for energy conservation in buildings.
Renewable and Sustainable Energy Reviews 73: (1352-1365).
[11] Samara F., Ibrahim S., Yousuf M.E., Armour R.,(2022), Carbon Footprint at a United Arab Emirates University: GHG Protocol. *Sustainability* 14(5):2522.

Building the Resilience of Protected Areas to Climate Change, Case Study Protected Area Baks Rrjoll, Shkoder

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Human activities have had a huge impact on climate change, which has become one of the most important phenomena in the last decades. Because of its negative effects in the sustainable development on our planet, taking effective measures to protect the planet has become one of the main goals for many countries. In the last year, the Agenda for Sustainable Development 2023 painted an alarming picture for the future of the planet, where the measurements of its 17 goals showed a decrease in many of the targets which are directly connected to climate change. That is why the need to take quick measures has become very important. The aim of this paper is to show the importance of taking actions and applying effective measures in an area where the human impact should be on a smaller scale. The case study of this paper is Baks Rrjoll, a protected area near Shkoder, which has a great potential to transform it into the next popular tourist spot. The main goal of this transformation of Baks Rrjoll is to become an example for other protected areas or areas that have the potential to become one. In this paper the focus will be on measures that affect the fields of water conservation, water efficiency, energy efficiency, waste management and most importantly protecting the biodiversity of species.

Keywords: *Climate change, sustainable development, protected area.*

1. INTRODUCTION

Climate change refers to long-term shifts in temperatures and weather patterns. Even though these temperature changes can be natural, since the 1800s human activities have had the most important role in climate change, the main cause being burning of fossil fuels, which generate greenhouse gas emissions that trap the sun's heat and raise temperatures. [1] The Earth's surface now registers an average temperature approximately 1.1°C higher than in the late 1800s, preceding the industrial revolution, surpassing warmth levels observed in the past 100,000 years. Since the Earth is a system, rising of temperatures aren't the only concern. [1] Climate change repercussions encompass a spectrum of impacts, including intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms and declining biodiversity. [1]

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs. The cornerstone of global collaboration lies in sustainability, epitomized by the 2030 Agenda for Sustainable Development and its' Sustainable Development Goals (SDGs). [2] The Global Sustainable Development Report (GSDR) was created in "The Future We Want," the outcome of the Rio+20 conference on sustainable development, where the groundwork for the 2030 Agenda for Sustainable Development and the 17 associated Sustainable Development Goals (SDGs) were being layed. [3]

In the last year, the Agenda for Sustainable Development 2023 painted an alarming picture for the future of the planet, where the measurements of its 17 goals showed a decrease in many of the targets which are directly connected to climate change. [4] The aim of this paper is to show the importance of taking actions and applying effective measures in an area where the human impact should be on a smaller scale, such as a protected area, in this case Baks Rrjoll, a protected area near Shkoder, which has a great potential to transform it into the next popular tourist spot. [5] This transformation will help the environment and the economic aspects of the state. [5]

2. MATERIALS AND METHODS

2.1.SDG Evaluation

The Sustainable Development Goals (SDGs), also known as the Global Goals that The United Nations adopted in 2015, aiming to universally address poverty, safeguard the planet, and strive for global peace and prosperity by 2030. [6] The 17 SDGs recognize that action in one area will affect outcomes in others; therefore the development must balance social, economic and environmental sustainability. Achieving the Sustainable Development Goals (SDGs) in any setting requires harnessing the creativity, expertise, technology, and financial resources of all sectors of society. [6]

2.1.1. SDG Goals

From the 17 SDGs that are set in the Sustainable Development Report, 7 are the ones that are closely tied to environmental problems. [6]

1. Good health and well-being→the main goal of this indicator is to substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination by 2030. Also part of this goal is to strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction, and management of both national and global health hazards. [6]

2. Clean water and sanitation→many countries are experiencing water stress, and increasing drought and desertification is worsening water shortening. By 2050, it is projected that at least one in four people will suffer recurring water shortages. [6]

3. Affordable and clean energy→ as the population expands, the demand for affordable energy escalates, but relying on fossil fuels exacerbates climate change. To attain SDG 7 by 2030, it's crucial to invest in solar, wind, and thermal power, enhance energy efficiency, and ensure universal access to energy. [6]

4. Sustainable cities and communities→ the swift expansion of cities due to rising populations and migration has sparked a surge in mega-cities, particularly in the developing world, where slums are becoming a more significant feature of urban life. [6] Making cities sustainable means creating career and business opportunities, safe and affordable housing, and building resilient societies and economies. [6]

5. Climate action→ the main purpose of this goal it to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries;

also to integrate climate change measures into national policies, strategies and planning

6. Life below water→ this SDG strives to sustainably preserve and safeguard marine and coastal ecosystems from pollution, while also tackling the consequences of ocean acidification. Strengthening conservation efforts and promoting the sustainable utilization of ocean resources through international legal frameworks will aid in addressing the various challenges confronting our oceans. [6]

7. Life on land→ the main purpose is to ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements. [6]

2.1.2. SDG Report for Albania

According to continuous monitoring, Albania ranks 54th out of 166 countries that have signed the agenda. Most of the indicators show an overview of problems that are aggravating in some areas of life. [7] In figure 1 are shown the trends of SDGs in Albania, highlighting the main 7 SDGs:

Figure 1. SDG parameters for Albania

As noted above, apart from indicator 13 for climate change, most of the indicators related to the environment have numerous problems, where underwater life is the most endangered. [7]

2.1.3 Report of 2023-Special Edition

The 2023 report on sustainable development underscores the urgent need for decisive and stringent action due to the lack of significant progress. Progress on over 50 percent of the targets remains weak and insufficient, with 30 percent either stagnant or regressing, particularly in critical areas such as poverty, hunger, and climate change. [4]

The compounding crises of the COVID-19 pandemic alongside climate change, biodiversity loss, and pollution are inflicting severe and enduring consequences. These challenges are further exacerbated by conflicts, leading to heightened food and energy costs, and triggering a global cost-of-living crisis that affects billions. [4] Moreover, the planet is experiencing its highest extinction rate since the age of dinosaurs, while plastic pollution in the oceans exceeded 17 million metric tons in 2021, with projections indicating a potential doubling or tripling by 2040. [4]

2.2 Strategic Plan for Baks Rrjoll development

The village of Baks-Rrjoll is nestled in the southeastern region of Velipoja town, approximately 30 km (19 miles) from Shkodra. It resides within a diverse coastal ecosystem, boasting natural dunes, alluvial forests, temporary ponds, wetlands, agricultural fields, and a sandy beach. [8]

The lands and wetlands of Baks-Rrjoll represent a crucial habitat for waterflow. The town stands on a rich European bird migration route. As such, it is also a RAMSAR zone with key regional bio centers and bio corridors. [8]

The Strategic Plan considers Baks Rrjoll as a new potential touristic spot, which will encourage sustainable development of other protected areas; also will bring many economical contributions to the country. [8] Even though Baks Rrjoll is near other touristic places, the main problems which it faces are the lack of basic infrastructure, such as roads, sewer systems, accommodation structures, etc. [8]

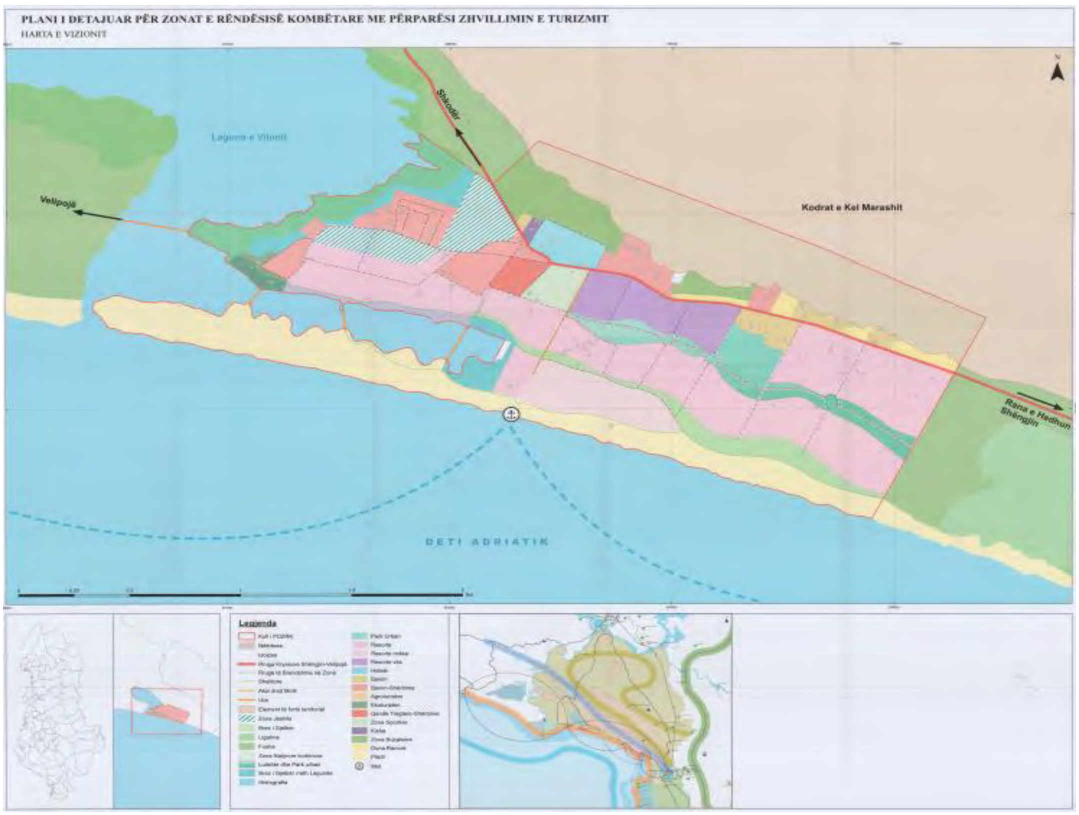

Figure 2. Vision plan of Baks Rrjoll

4. RESULTS AND DISCUSSION

To turn Baks Rrjoll is a sustainable tourist spot there are measures that have to be taken in different aspects of environmental issues. [5]

1) Alternative energy source

To maximize energy production and solar energy, there will be three different ways to use solar panels; one being energy production, 2nd for water warming and the last usage for lighting. [5]

2) Efficient water usage

Because of a regular rainfall regime in Baks Rrjoll, collecting and using rainwater for sanitation purposes, plant watering and for any non-drinking purposes, it will become one of the main resources to be used in this place. [5] The RWH system's elements are catchment area, transportation, flushing and filter media (Sand gravel filter/Charcoal filter). [5]

Figure 3. Elements and purpose of RWH

3) Waste water management

Wastewater will be collected in a main manhole that will be connected with a pumping station, which will send the collected water at Velipoje Wastewater Treatment Plant. [5]

Figure 4. Sewer system of collecting wastewater

4) Protecting the natural view

The main measures to help the view of the lagoon are to build lower buildings that should be hidden to the species, especially the migratory birds; another one is planting autochthonous species of plants. [5]

5) Protecting the wildlife

To protect the wildlife it is needed to restore their natural habitats by stopping deforestation and illegal hunting. Another way that can be used to help wildlife is to create green corridors, mainly alongside the sea shore. [5]

6) Air pollution

Even though air monitoring evaluated the air as the perfect condition, still there are measures to be taken so this evaluation doesn't digress, some of which are promoting bicycle use, improving road infrastructure and public transportation. [5]

5. CONCLUSION

The 2023 report on sustainable development underscores the urgent need for decisive and stringent action due to the lack of significant progress. Human activity has had significant impact on climate change evidently in protected areas as well. The aim of this paper is to show the importance of taking actions and applying effective measures in the protected area of Baks Rrjoll, near Shkoder. This protected area is classified as a RAMSAR zone with a potential to become a touristic spot; nonetheless there are several issues present here.

Some proposed measures to ensure the future sustainability development of this area include:

1- Utilization of alternative energies, specifically solar panels to maximize energy production and usage.

2- Efficient water usage to turn the regular rainfall regime as a great useful resource.

Taking these measures in a protected area, can hopefully become a model of sustainability and speed up the progress towards achieving SDG goals in other protected areas as well.

REFERENCES

[1] https://www.un.org/en/climatechange/what-is-climate-change

[2] https://www.iisd.org/mission-and-goals/sustainable development#:~:text=Sustainable%20development%20is%20development%20that,to%20meet%20their%20own%20needs

[3] https://sdgs.un.org/gsdr/gsdr2023

[4] The 2023 Report- Special Edition

[5] Baks Rrjoll Strategic Plan

[6] https://www.undp.org/sustainable-development-goals

[7] SDG Albania profile

[8] https://www.albanopedia.com/travel/baks-rrjoll-village#google_vignette

Climate Change Effects, Contributors and Measures: A Case Study of India and Kosovo

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This paper aims to provide an essential analysis on climate change, including its impact at the global level and the main causes that influence this phenomenon. Climate change has declared a serious challenge for the international community, bringing great consequences for the environment, economy and society. To understand this challenge, the main causes of climate change will be examined, including the impact of human activity and natural processes. In addition, we will analyze sea level rise, changes in rainfall patterns, global warming and droughts. These changes have a direct impact on terrestrial and marine ecosystems, with consequences for biodiversity and human life. Through a sustainable approach and international cooperation, it is possible to reduce pollution, promote renewable energy, and take effective actions to adapt and mitigate the negative impacts of climate change. It then focuses on the analysis of climate change in the context of India and the country's efforts to address its challenges. India, as a country with a large population and a growing economy, is experiencing major impacts from this global crisis. In this part of the paper, we will examine the main causes of climate change in India and their impact. Also, we will analyze the impact of these changes on key sectors of the Indian economy, including agriculture, the energy sector and public health. We will then focus on India's efforts and strategies to cope with climate change. For this reason, we will analyze India's current plans and policies related to reducing emissions, increasing public awareness and improving adaptation capacities. Finally, we will draw conclusions and recommendations to improve India's current efforts in the fight against these changes and the comparison of India with the Republic of Kosovo.

Keywords: *Climate Change, Impacts, India, Measures, Effects.*

1. INTRODUCTION

Climate change refers to long-term shifts in temperatures and weather patterns. These changes may be natural, such as those arising from variations in the solar cycle, but since the 1800s, human activities have become the primary drivers, notably the combustion of fossil fuels like coal, oil, and gas. This combustion releases significant quantities of greenhouse gases, including carbon dioxide and methane, intensifying the greenhouse effect and increasing global temperatures. Consequently, the world faces diverse climate change consequences, including rising sea levels, more severe droughts, more intense storms, and significant biodiversity loss. To mitigate these challenges, it is critical to reduce emissions, adapt to the impacts of climate change, and finance necessary mitigation measures. These measures include keeping fossil fuels in the ground, investing in renewable energy sources, and transitioning to sustainable transportation systems. The effects of climate change are evident worldwide, with India being particularly affected. In India, climate change manifests through irregular weather patterns, rising sea levels, and melting glaciers, which broadly impact human health, economic stability, and access to natural resources like clean water [1][4-5].

Figure 1. The State of the World as a Result of Climate Change United Nations.

Figure 2. Nagaon, Assam, India - May 19, 2022: Heavy water flow washed away a significant section of the Nagaon Road in Kampur at Kathiatoli village in the Nagaon district of Assam.

Despite having a population that constitutes 17% of the global total, India only emits 7% of the world's greenhouse gases, amounting to about 3 gigatons of carbon dioxide annually. This places India under significant pressure to enhance its emission reduction goals and to adopt clean energy technologies. Effective management of water resources and protection against frequent floods and droughts are unique challenges that India faces. The country's response to these issues will play a crucial role in shaping the global climate policy landscape [2-4].

1.1.Effects of climate change in India.

The Main Effects of Climate Change in India Include:

Extreme Heat: India experiences temperature rises that cover large areas, predicting new climatic regimes with high temperatures that will heavily impact agriculture. *Changes in Precipitation Patterns*: Monsoon rains have decreased since the 1950s, and the summer monsoon is expected to become very unpredictable. Global warming will make wet years wetter and dry years drier.

Droughts: In areas like northwest India and the regions of Jharkhand, Orissa, and Chhattisgarh, droughts are expected to become more frequent and severe, causing significant drops in crop yields [7][11].

Figure 3. New Delhi, India: People walk through a dried-up riverbed on a hot summer day in New Delhi.

Groundwater: Overuse and declining groundwater levels due to high demand from a growing population and lifestyle changes, particularly in the service and industrial sectors.

Glacial Melt: Melting of the Himalayan glaciers and loss of snow cover could affect the stability of North India's rivers like the Indus, Ganges, and Brahmaputra, impacting irrigation and food production.

Sea Level Rise: Significant increases in sea levels and storm intensity will lead to the intrusion of saltwater into coastal areas, degrading the quality of groundwater and causing health problems such as diarrhea and cholera [4][7][11-12].

Figure 4. Assam, India: In 2022, devastating floods and landslides in Assam have resulted in the tragic loss of 197 lives.

Food and Energy Security: Water scarcity and increased health risks are expected to drive migration, political conflicts, and heighten food and energy insecurity.

Global Effects: *Increased Global Average Temperature*-The global average temperature has risen significantly, characterized by ocean warming and the reduction of ice sheets in both hemispheres. This warming has led to the decline of Arctic Sea ice and the intensification of extreme weather events such as heavy rainfall and heatwaves.

Figure 5. Implications of Global Warming for India

Ocean Acidification- The acidification of the oceans has increased due to the large amounts of carbon dioxide absorbed by ocean waters. This has created significant risks for marine ecosystems, affecting the health and sustainability of marine life, which depend on stable pH levels to thrive. The ongoing acidification poses a threat not only to species that rely on calcareous structures, such as corals and shellfish, but also to the broader ecological balance of the oceans. These effects present a serious challenge for India in managing the consequences of climate change, requiring coordinated actions for adaptation and mitigation [11-16].

2. CONFRONTING CLIMATE CHANGE IN INDIA

To cope with the effects of climate change, India should focus more on adaptation strategies than on mitigation, which are more critical for developed countries. Here are two main steps India could take to address climate change:

I. Interlinking of Rivers (ILR): The ILR aims to utilize water resources more efficiently through the construction of new dams and canals that would allow the transfer of water from flood-prone areas to water-scarce regions. This would help combat frequent floods and droughts in various parts of India.The project involves building 3,000 new dams and 15,000 km of new canals, potentially adding 35 million hectares of land under cultivation and generating 34,000 MW of hydroelectric power.
II. Genetically Modified (GM) Crops: The use of GM crops can be a critical part of "climate-smart agriculture," where drought-resistant crops and those that produce high yields under specific climatic conditions can minimize environmental impact and improve food security. Despite resistance to GM technology in India, a review of policies to include these globally proven technologies is necessary, as they can play a significant role in adapting agriculture to climate changes.

Adaptation strategies are essential for managing the current and inevitable consequences of climate change, such as storms, floods, and droughts that continuously challenge India's

Figure 6. Floods in Assam because of Climate Change. A typical submerged house is an innovative way to keep floodwaters at bay as it is built on an elevated platform supported by bamboo stilts.

infrastructure and economy. While mitigation remains important for slowing future changes, adaptation is crucial for ensuring that India and other developing countries survive and thrive under new climatic conditions. In addition to these steps, it is vital that new policies and initiatives are supported by further studies and sustainable funding to ensure they are effective and sustainable in the long term [15-17].

3. FACTORS INFLUENCING THE EMERGENCE OF SUCH CHANGES

To effectively tackle climate change, recognizing the factors that influence a region's climate is crucial. In India's case, these factors are divided into two main categories: natural and anthropogenic [14].

Natural Factors

- Continental Drift: The movement of tectonic plates changes the positions of continents and bodies of water, influencing ocean currents and winds, which bring long-term climate changes.

- Volcanism: Volcanic eruptions release gases and particles into the atmosphere, block solar rays, and can lead to temporary global cooling.
- Changes in Earth's Orbit: Variations in Earth's orbit, such as eccentricity, axial tilt, and axial precession, affect the distribution of solar radiation on Earth, causing Milankovitch cycles associated with ice ages and interglacial periods.

Anthropogenic Factors

- Greenhouse Gases: Gases like CO_2 absorb infrared radiation emitted by Earth, causing global warming through the greenhouse effect.
- Atmospheric Aerosols: These particles directly affect the climate by absorbing and scattering solar radiation. They indirectly influence by altering cloud formation and properties.
- Land Use Changes: Replacing forests with agricultural land or urban infrastructure increases the absorption of solar radiation and the amount of moisture evaporated, affecting the climate.
- Albedo:Changes in the Earth's surface reflectivity affect how much solar radiation is absorbed or reflected back into space, impacting global temperatures.

India-Specific Climate Factors

- Geographic Latitude:The impact of sunlight varies from the equator towards the poles, affecting temperature.
- Altitude:Temperature decreases with an increase in altitude above sea level.
- Pressure and Wind Systems:Influence temperature depending on geographic latitude and altitude.
- Proximity to the Sea (Continentality):Areas close to seas have milder climates compared to more remote areas that experience more extreme conditions.
- Ocean Currents:Warm or cold currents affect local temperatures.
- Relief Features:Mountains can block cold or warm winds, affecting local climate.

4. COMPARATIVE ANALYSIS OF CLIMATE CHANGE IMPACT: INDIA VS. REPUBLIC OF KOSOVO

Since the conclusion of the armed conflict in 1999, Kosovo has embarked on significant reconstruction and strengthening of its physical and legislative infrastructure. Despite these efforts, adapting to climate change remains a formidable challenge, exacerbated by a lack of sufficient country-specific studies addressing climate trends, forecasts, and impacts. Kosovo's economy has steadily grown since its unilateral declaration of independence in 2008. However, the rates of unemployment and poverty remain among the highest in Europe. While the large service sector (67% of GDP) is less vulnerable to climate impacts, agriculture (14%) and industry (19%) are critical economic drivers that are highly susceptible to water shortages, heatwaves, droughts, and floods. Rapid construction since 1999, combined with poorly regulated land use and disregard for building codes, has rapidly increased the population's exposure to risks. The mild winter and dry February of 2014, followed by a record wet April, led to extraordinary rainfall, causing rapid flooding and severe damage to infrastructure, particularly in northern Kosovo. The extraction of lignite (low-energy, high-pollution coal) and mineral deposits, inadequate wastewater treatment, and a lack of public environmental awareness contribute to serious air and water pollution and environmental degradation challenges that Kosovo is striving to manage; these will complicate the impacts of climate change. Between 2004 and 2008, 80% of Kosovo's municipalities suffered from water shortages due to hydrological droughts and mismanagement of water resources. In the winter of 2014, following the depletion of reservoirs due to low snow and rain levels, the state and water company-imposed water rationing in Pristina, the capital. Kosovo also faces risks from flooding in lowlands, floods in mountainous areas, and dam breaches. The risk of flooding and potential damage costs is exacerbated by poorly maintained river channels, gravel extraction from embankments (flood protection barriers), and construction in flood-prone areas [6][8].

In India, a noticeable decline in monsoon rainfall has been observed since the 1950s, along with an increased frequency of heavy rainfall events. A sudden change in the monsoon could precipitate a major crisis, causing more frequent droughts and greater flooding across large parts of India. Analyzing a trend of rising temperatures and declining rainfall from 1970-2015, the 2018/19 economic survey noted that in years when rainfall levels drop 100 mm below average, farmers' incomes fall by 15% during the seasons. The survey highlighted that climate change could reduce annual agricultural incomes by an average of 15% to 18%, and up to 20-25% in rainfed areas. It emphasized that climate change will increase farmers' insecurity and called for effective crop insurance and the use of technology to make agriculture more efficient. The frequency of extreme weather events such as floods and heatwaves is predicted to increase significantly in India in the future due to climate changes, according to a study by researchers at the Indian Institute of Technology, Gandhinagar [9].

The challenges faced by Kosovo highlight the urgent need for coordinated action to build resilience and reduce vulnerability to climate change. Similarly, India's experience underlines the importance of integrating climate adaptation strategies into national development policies to safeguard and enhance the livelihoods of vulnerable populations [6] [8-9].

5. RECOMMENDATIONS FOR ENHANCING CLIMATE CHANGE RESILIENCE AND SUSTAINABILITY IN INDIA&KOSOVO

- Emission Intensity Reduction Goal: Aim to reduce greenhouse gas emission intensity by 45% below the 2005 levels by the year 2030. This target reflects India's commitment to reducing its carbon footprint through efficiency improvements and renewable energy investments.
- Renewable Energy Capacity Goal: Target to achieve 50% of cumulative installed electric power capacity from non-fossil fuel sources by 2030. This includes expansions in solar, wind, hydro, and nuclear energy sectors, bolstering India's shift towards a sustainable energy future.
- Carbon Sequestration Initiative: Establishment of a carbon sink that will capture and store between 2.5 to 3 gigatonnes (Gt) of CO_2 by 2030. This will be achieved through the enhancement of forest cover and other natural or artificial reservoirs, including potential use of underground formations and oceans for long-term CO_2 storage.
- Low-Carbon Rural Development: Approximately two-thirds of the Indian population resides in rural areas, often on small farms with minimal access to electricity. These areas are particularly vulnerable to the adverse effects of climate changes such as droughts and pollution, which threaten their agricultural bases and livelihoods.
- Clean Cooking Solutions: About 70% of the population uses traditional stoves that burn biomass such as wood and dung. The promotion of biogas units in households

and communities aims to replace these with clean-burning methane stoves, reducing indoor air pollution and associated health risks.

- Efficient Stove Replacement: Replace conventional wood-burning stoves with more efficient models to decrease smoke emissions and improve air quality within homes.
- Solar-Powered Lighting: Expand access to solar-powered lighting solutions in rural areas to reduce reliance on kerosene lamps, thereby cutting down emissions and improving household safety.
- Promotion of Climate-Smart Agricultural Practices: Foster scientific and economic promotion of climate-smart agricultural techniques using information technology platforms, including smartphone applications. These tools can help farmers make informed decisions that optimize resource use and enhance crop resilience against climate variability.
- Clean Transport Options: Use public transportation, carpooling, or bicycles to reduce emissions.
- Minimize and Recycle Waste: Use recyclable products and reduce waste generation by choosing products with minimal packaging.
- Reduce Water Usage: Implement water-saving measures at home and maintain high water quality.
- Support Conservation Efforts: Participate in and support local and international projects aimed at environmental conservation and restoration.

6. CONCLUSION

India's response to climate change is a complex interplay of economic growth, technological advancement, and policy initiatives aimed at sustainable development. With a large and diverse geographical area, India faces significant challenges from extreme weather events, including cyclones, floods, and droughts. The government's ambitious targets to reduce emission intensity by 45% by 2030 and achieve 50% of its energy capacity from non-fossil fuels are commendable steps toward mitigating climate impacts. Furthermore, initiatives like massive afforestation programs and the promotion of renewable energy sources reflect a robust commitment to environmental sustainability. However, vast segments of the rural population still suffer from inadequate access to clean energy and water resources, highlighting a critical area for ongoing focus and improvement. The adaptation measures, while extensive, need continuous strengthening to align with the escalating frequency and severity of climate phenomena due to global warming.

Since the end of its armed conflict in 1999, Kosovo has made significant strides in rebuilding its infrastructure and legislative frameworks. However, climate change adaptation remains a nascent field with considerable challenges ahead. The lack of comprehensive climate studies specific to Kosovo hampers effective planning and response strategies. Vulnerabilities in agriculture and industry due to erratic weather patterns, such as increased precipitation variability and rising temperatures, are acute concerns that threaten economic stability and livelihoods. Kosovo's efforts to manage environmental issues, particularly regarding air and water quality affected by lignite mining, are critical in shaping its environmental future. The country's focus on enhancing rural resilience through sustainable practices and clean energy access is essential but requires substantial international support and technological transfer to achieve significant impacts.

Both India and Kosovo are at pivotal stages in their climate change adaptation journeys. While India's scale and scope of initiatives are vast and integrated into its national development agenda, Kosovo's smaller scale efforts are equally vital for its environmental and economic health. Both nations exemplify the urgent need for global cooperation in climate technology, finance, and policy innovation to combat the adverse effects of climate change effectively. Moving forward, enhancing local capacities, investing in sustainable technologies, and fostering international partnerships will be crucial for both countries to meet their environmental and economic goals in the face of global climate challenges.

REFERENCES

[1] United Nations, (UN). What Is Climate Change? https://www.un.org/en/climatechange/what-is-climate-change ("Climate action tracker", n.d.).https://climateactiontracker.org/countries/india/

[2] Extreme weather events to rise manifold in india due to climate change: iit gandhinagar study. (2022 , November 21) https://www.preventionweb.net/news/extreme-weather-events-rise-manifold-india-due-climate-change-iit gandhinagarstudy#:~:text=The%20frequency%20of%20extreme%20weather,Indian%20Institute%20of%20Technology%2C%20Gandhinagar.

[3] ("India: Development while fighting climate change", n.d.). https://www.edf.org/climate/india-development-while-fighting-climate-change

[4] Lahiry, (Dr S.C.). (2018, April 8). Climate change and its impact on water resources. https://www.indiawaterportal.org/articles/climate-change-and-its-impact-water-resources

[5] ("Climate Change Programme" , n.d.). https://dst.gov.in/climate-change-programme

[6] United States Agency for International Development, (USAID). (2017, January 31). Climate Risk Profile: Kosovo. https://www.climatelinks.org/resources/climate-risk-profile-kosovo

[7] Government of India, (myGov). (2022,08 July). How does India take a leadership role in tackling climate change? https://blog.mygov.in/editorial/how-does-india-taken-a-leadership-role-in-tackling-climate-change 3/#: ~:text=India%20is%20the%20third%20largest, in%20the%20last%20five%20years.

[8] United Nations Office for Disaster Risk Reduction, (UNDRR). (2014). Kosovo: strategy on climate change 2014-2024. https://www.preventionweb.net/publication/kosovo-strategy-climate-change-2014-2024

[9] Crown Science.org. (n.d). Comparing India with Kosovo. https://www.crownscience.org/places/india/kosovo

[10] ("Climate Change", n.d.). https://web.worldbank.org/archive/website01291/WEB/0__CO-78.HTM

[11] Down to earth. (2022, 03 November). Extreme Weather Events Occurred for Most of 2022 in India, Killed Over 2,700: Report. https://thewire.in/environment/extreme-weather-events-occurred-for-most-of-2022-in-india-killed-over-2700-report

[12] Le Monde. (Wednesday, December 21, 2022). For India, 2022 has brought daily climate disasters. https://www.lemonde.fr/en/climate-change/article/2022/11/10/in-india-one-climate-disaster-every-day_6003631_152.html

[13] ("Factors that Influence Climate" , n.d.). https://nittygrittyscience.com/textbooks/weather-climate/section-4-factors-that-influenceclimate/

[14] ("What are the Factors Affecting the Climate of India" , n.d.). https://byjusexamprep.com/what-are-the-factors-affecting-the-climate-of-india-i

[15] Sanchita Paul, (S.P). (January 31, 2015). Global Warming and Its Implications for India.https://www.mapsofindia.com/my-india/subcontinent/global-warming-and-its-implications-for-india

[16] United Nations Office for Disaster Risk Reduction, (UNDRR). (21 September 2021). India's Mising community seeks to expand its indigenous adaptation practices in response to climate change. https://www.undrr.org/news/indias-mising-community-seeks-expand-its-indigenous-adaptation-practices-response-climate

[17] ("What are the solutions to climate change" , n.d.). https://www.greenpeace.org.uk/challenges/climate-change/solutions-climate-change/

Climate change impacts on different stages of waste management system

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Global warming is becoming one of the greatest challenges of the century, bringing significant impacts on all aspects of human life and the environment. The waste management system emerges as one of the most affected and sensitive aspects to global temperature rise, changes in precipitation patterns, and extreme weather events. The increase in temperature complicates the waste collection processes, causing equipment to overheat and increasing the risk of fires in landfills. Additionally, it also increases energy consumption for recycling processes, making it more difficult to control carbon emissions. Furthermore, the sea level rise also poses significant challenges too. Coastal flooding impacts waste collection routes inaccessible, hindering the movement and transportation of waste, which consequently may damage the recycling facilities and generate large volumes of household waste in affected areas. Extreme precipitation events and extreme droughts seasons have caused low stability in land structures by massive flooding events and unexpected land erosion, which may affect waste collection routes. The escalation of risk also comes from strong winds, cyclones, and hurricanes, which can cause considerable damage to waste management infrastructure and pose the risk of dispersing hazardous objects or toxic materials into the environment. This article tries to analyze the complex relationship between climate change and waste management, highlighting their interaction and explaining the challenges and opportunities to address how the climate change effects as temperature increase, sea level rise and extreme precipitation. The study tries to present several measures beyond the effects of climate change that can be taken to improve and prevent negative effects into the waste management system, followed by the development of risk management plans to prevent damage and ensure safety at waste landfill sites.

Key words: *Climate change, waste management, temperature rise, precipitation, extreme weather, sea level rise.*

1. INTRODUCTION

The Earth's surface temperature has increased over the last decades, with global temperatures rising by 0.7 to 0.9 degrees Celsius every century since early 1900. In addition, since the 1980s, the rate of worldwide surface temperature warming has almost doubled, from 1.5 to 1.8 degrees per century.

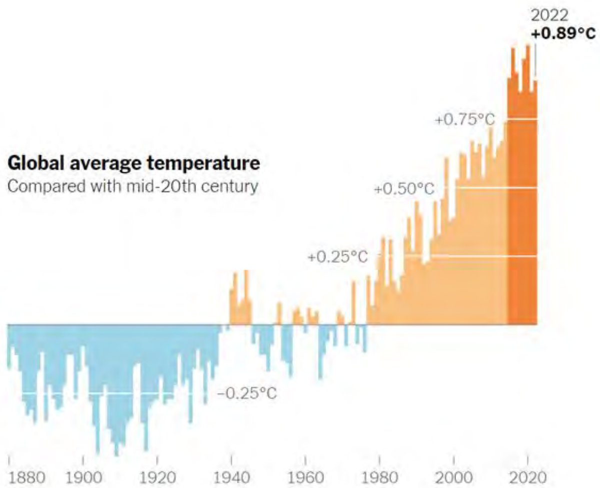

Figure 1. Global average temperature compared with mid-20 century

Climate change caused by global warming affects both the atmosphere and human life and is causing frightening changes in our biological system and the natural environment. Extreme weather, increased fire risk, environmental destruction, and the spread of contagious diseases are all illustrations of environmental dangers to human health that are becoming more prevalent.

2. CLIMATE CHANGE IMPACTS ON DIFERENT STAGES OF WASTE MANAGEMENT SYSTEM

2.1.Waste generation process.

Waste generation is influenced by socio-economic factors, population growth, urbanization, and consumption patterns, all of which are interconnected with climate change. Here's how climate change affects waste generation:

- Rising temperature

Increased Consumption: As temperatures rise, energy demands for cooling systems escalate, leading to higher energy consumption and consequently increased waste generation from packaging materials, electronic devices, and appliances.

Changes in Food Habits: Climate change affects agricultural productivity, leading to shifts in food habits. This can influence the types and amounts of food waste generated, impacting the overall waste stream.

- Changes in Precipitation

Infrastructure Damage: Increased generation of waste from damaged equipment and infrastructure because of flooding from increased precipitation.

- Extreme Weather

Natural Disasters: Climate change is associated with an increase in the frequency and intensity of extreme weather events like hurricanes, floods, and wildfires. These events generate large quantities of waste, including debris, hazardous materials, and damaged infrastructure.

- Sea – Level Rise

Flood: Sea level rise leads to the production of larger volumes of waste in flood prone areas, bringing large quantities of mud, clay, and gravel.

2.2.Waste Collection process.

Waste collection is a crucial stage in the waste management system, responsible for gathering waste from households, businesses, and public spaces for transportation to treatment or disposal facilities. Climate change impacts waste collection in various ways:

- Rising temperature

Worker Exposure Risks: Waste collection workers are often exposed to outdoor conditions for extended periods, increasing their vulnerability to heat stress and other weather-related hazards. Heatwaves associated with climate change can exacerbate these risks, leading to adverse health effects among workers.

Vector-Borne Diseases: Changes in temperature and precipitation patterns can affect the distribution and abundance of disease vectors such as mosquitoes and rodents.

Changes in collection process: Increased frequency of collection due to decomposition of waste, deterioration of odor requiring more frequent collection of waste. Overheating of collection vehicles requiring cooling capacity, including extending motor life.

- Changes in Precipitation

Access Challenges: Changes in precipitation patterns and the occurrence of landslides, floods or mudslides can obstruct access to certain areas, particularly in rural or remote regions. This can pose challenges for waste collection in these communities.

- Extreme Weather

Disruption of Collection Services: Extreme weather events such as hurricanes, floods, and heavy snowfall can disrupt waste collection schedules and operations. Flooding may render roads impassable, while high winds can damage collection vehicles and infrastructure.

Increased Frequency of Events: Climate change is associated with an increase in the frequency and intensity of extreme weather events, leading to more frequent disruptions in waste collection services and challenges in maintaining regular schedules.

- Sea – Level Rise

Damage to Collection Infrastructure: Climate-related phenomena such as sea-level rise and coastal erosion can threaten waste collection infrastructure located in coastal areas. Damage to transfer stations, sorting facilities, and storage depots can hinder the efficiency and reliability of waste collection services.

2.3.Recycling and treatment

Recycling and treatment are essential components of the waste management system, aimed at diverting waste from landfills, recovering valuable materials, and minimizing environmental impacts. Climate change influences recycling and treatment processes in several ways:

- Rising temperature

Scarcity of Resources: Climate-related events such as droughts or wildfires can exacerbate resource scarcity, affecting the availability of materials for recycling and treatment processes.

Equipment: Damaged recycling and treatment equipment, reduced worker productivity, and increased demand for space – cooling and overheating of sorting equipment due to the increase in temperature.

Energy: Rising temperatures put a strain on energy usage during recycling and production, leading to higher energy consumption.

- Changes in Precipitation

Infrastructure: Damaged recycling and treatment infrastructure and equipment because of flooding from increased precipitation.

- Extreme Weather

Infrastructure damage: Damaged recycling and treatment infrastructure and equipment because of strong winds, heavy rainfall, or heat waves

- Sea – Level Rise

Infrastructure: Damaged coastal recycling and treatment infrastructure and equipment.

2.4.Waste Disposal

Waste disposal is the final stage in the waste management process, involving the safe and environmentally sound disposal of residual waste that cannot be recycled or treated. Climate change influences waste disposal practices and facilities in several ways:

- Rising temperature

Fires: The rise in temperature can alter the chemical reactions between different materials in landfills, potentially resulting in materials that are more prone to combustion.

Gases: Higher temperatures can affect the production process of methane gas from decomposition of organic materials in landfills.

- Changes in Precipitation

Landfill Operations: Climate change can impact landfill operations through changes in precipitation patterns, leading to variations in leachate generation and landfill gas production. Proper landfill management practices are essential to mitigate potential environmental risks.

- Extreme Weather

Extreme Weather Risks: Climate-related hazards such as hurricanes, floods, and wildfires can pose risks to hazardous waste storage and disposal facilities. Enhanced risk management and preparedness measures are crucial to minimize the potential for environmental contamination and human health impacts.

- Sea – Level Rise

Land Use Planning: The rise in sea levels and heightened flood hazards linked to climate change might require alterations in landfill location and layout to mitigate contamination risks and ensure sustained stability over time.

3. MEASURES

Summarizing the mentioned impacts, we have identified several key areas for enhancement.

Table 16. Climate changes' impacts on waste management processes

	Rising temperature	**Changes in precipitation**	**Extreme weather**	**Sea – level rise**
Generation	Increased Consumption Changes in Food Habits	Infrastructure Damage	Natural Disasters	Flood
Collection	Worker Exposure Risks Vector-Borne Diseases Changes in collection process	Access Challenges	Disruption of Collection Services Increased Frequency of Events	Damage to Collection Infrastructure
Recycling and treatment	Scarcity of Resources Equipment Energy	Infrastructure	Infrastructure damage	Infrastructure

Disposal	Fires Gases	Landfill Operations	Extreme Risks	Weather	Land Use Planning

3.1 Waste generation process.

- Rising temperature

Educational Campaigns: Launching public awareness campaigns to educate individuals and communities about the environmental impacts of excessive consumption and the importance of reducing waste generation, particularly during periods of high temperatures.
Heat-Resilient Packaging: Encouraging the use of heat-resistant and eco-friendly packaging materials to reduce the generation of waste from packaging items that may degrade or become damaged due to high temperatures.
Efficient Cooling Systems: Implementing energy-efficient cooling systems in commercial and residential buildings to reduce energy consumption and minimize the generation of waste from cooling-related appliances and equipment.
Installing water fountains across the city to reduce consumption of disposable bottles that steeply increase during heat waves.

- Changes in Precipitation

Water Conservation Measures: Promoting water conservation practices, such as rainwater harvesting and efficient irrigation methods, to mitigate the impacts of changing precipitation patterns on water availability and reduce water-related waste generation.
Flood-Resilient Infrastructure: Implementing flood-resistant building designs and drainage systems to minimize water damage to properties and infrastructure during heavy rainfall events, thereby reducing the generation of flood-related waste.

- Extreme Weather

Disaster Preparedness Education: Providing education and training programs to businesses and communities on disaster preparedness and response measures to minimize waste generation and environmental damage during extreme weather events.
Extreme weather events generate a lot of waste from single use emergency equipment (water bottles, tents, plastic sheets, etc.). *Adapting these materials to be biodegradable or easily reusable and recyclable* means lowering the impact of such disasters in a city's systems.

- Sea – Level Rise

Erosion Control: Implementing erosion control measures, such as beach nourishment and dune restoration, to protect coastal waste generation facilities from erosion and shoreline retreat associated with sea level rise.
Emergency Response Planning: Developing and implementing emergency response plans for coastal waste generation facilities to mitigate the impacts of sea level rise-related hazards, such as flooding and storm surge, and ensure the safety of workers and surrounding communities.

3.2 Waste Collection process.

- Rising temperature

Worker Safety Protocols: Implement heat stress management protocols to ensure the safety and well-being of waste collection workers during periods of high temperatures, including providing adequate hydration, rest breaks, and access to shaded areas.
Vehicle Maintenance: Conduct regular maintenance checks on waste collection vehicles to ensure proper functioning of cooling systems and prevent breakdowns or malfunctions in hot weather conditions.

Route Optimization: Optimize waste collection routes to minimize travel time and exposure to heat for collection crews, thereby reducing fuel consumption and greenhouse gas emissions from collection vehicles.
Community Outreach: Educate residents about proper waste management practices during hot weather, such as sealing waste containers tightly to prevent odors and attracting pests and avoiding overloading bins to prevent spillage.

- Changes in Precipitation

Flood Preparedness Plans: Develop flood preparedness plans for waste collection operations, including identifying alternate collection routes and temporary storage areas to minimize disruptions during heavy rainfall and flooding events.
Equipment Protection: Implement measures to protect waste collection equipment, such as waterproof covers and storage facilities, to prevent damage from exposure to rain and moisture during precipitation events.

- Extreme Weather

Communication Systems: Establish reliable communication systems between waste collection crews and emergency response agencies to coordinate response efforts and disseminate important information during extreme weather events.
Equipment Resilience: Invest in resilient waste collection equipment, such as reinforced collection vehicles and heavy-duty containers, to withstand the impacts of extreme weather events and minimize downtime due to damage or breakdowns.

- Sea – Level Rise

Coastal Collection Infrastructure: Assess the vulnerability of waste collection infrastructure in coastal areas to sea level rise and implement measures to protect facilities from inundation and erosion, such as elevating critical equipment and infrastructure above projected sea level rise levels.

3.3 Recycling and treatment

- Rising temperature

Energy Efficiency Upgrades: Implementing energy-efficient technologies and practices in recycling and treatment facilities to reduce energy consumption and minimize greenhouse gas emissions, thereby mitigating the contribution to further temperature rise.
Heat Stress Management: Ensuring the safety and well-being of workers in recycling and treatment facilities by implementing heat stress management protocols, providing adequate hydration, rest breaks, and access to shaded areas during hot weather.

- Changes in Precipitation

Flood Preparedness: Developing flood preparedness plans for recycling and treatment facilities, including measures to protect equipment and infrastructure from water damage, such as raising critical equipment above flood levels and installing flood barriers.

- Extreme Weather

Emergency Response Plans: Developing and implementing emergency response plans for recycling and treatment facilities to ensure the safety of workers and minimize environmental damage during extreme weather events, such as hurricanes, floods, and wildfires.
Backup Power Systems: Installing backup power systems, such as generators and battery backups, to maintain essential operations in recycling and treatment facilities during power outages caused by extreme weather events.
Material Stockpiling: Stockpiling critical materials and supplies needed for recycling and treatment processes to ensure continuity of operations during disruptions caused by extreme weather events, such as supply chain disruptions or transportation delays.

- Sea – Level Rise

Coastal Infrastructure Protection: Implementing measures to protect coastal recycling and treatment facilities from sea level rise impacts, such as elevating critical equipment and infrastructure above projected sea level rise levels or relocating facilities to higher ground.

3.4 Waste Disposal

- Rising temperature

Landfill Gas Management: Implement landfill gas management systems to mitigate methane emissions, a potent greenhouse gas, from landfills under higher temperatures.
Cover Material Selection: Use heat-resistant cover materials for landfill caps to prevent degradation and minimize the risk of fire outbreaks caused by increased temperatures.

- Changes in Precipitation

Stormwater Management: Improve stormwater management systems at landfill sites to handle increased precipitation and prevent runoff pollution, erosion, and flooding.
Leachate Treatment: Upgrade leachate treatment facilities to handle larger volumes of leachate generated during heavy precipitation events and ensure compliance with regulatory standards.

- Extreme Weather

Disaster Preparedness Plans: Develop and implement disaster preparedness plans for landfill facilities to mitigate the impacts of extreme weather events, such as hurricanes, floods, and wildfires, including emergency response protocols and infrastructure reinforcement.
Emergency Response Training: Provide training for landfill personnel on emergency response procedures to ensure the safety of workers and minimize environmental damage during extreme weather events.

- Sea – Level Rise

Coastal Landfill Management: Assess the vulnerability of coastal landfill facilities to sea level rise and implement protective measures, such as raising critical infrastructure and implementing coastal defences.
Leachate Containment: Strengthen leachate containment systems at coastal landfills to prevent saltwater intrusion and protect groundwater quality from the impacts of sea level rise.

Figure 2. Measures to mitigate the impacts of climate change on various phases of waste management.

4. CONCLUSION

The relationship between waste management and climate change is intricate and multifaceted, with each influencing the other in significant ways. Climate change impacts various stages of waste management, from generation to disposal, exacerbating existing challenges and introducing new complexities.

Consequently, addressing the interplay between waste management and climate change is crucial for building resilient and sustainable systems capable of mitigating environmental impacts and adapting to future challenges.

REFERENCES

[1] EPA (2023) Best Practises for Solid Waste Management. A Guide for Decision-Makers in Developing Countries. Solid Waste Management and Climate Change.

[2] Engility corporation, Washington, DC (2012) ADDRESSING CLIMATE CHANGE IMPACTS ON INFRASTRUCTURE

[3] Climate Smart Governance. (2017 - 2020) Climate change and solid waste management

[4] Bebb, J. and Kersey, J. (2003). Potential Impacts of Climate Change on Waste Management

[5] Castro, P. et al. (2021). Waste Management Strategies to Mitigate the Effects of Fluorinated Greenhouse Gases on Climate Change

[6] Gichamo, T. and Gokcekus, H. (2019). Interrelation between Climate Change and Solid Waste

[7] U.S. EPA. 2022c. Waste Management Benefits, Planning and Mitigation Activities for Homeland Security Incidents

Climate Change: Effects, Contributors and Actions Taken - Case Studies of Kosovo and Germany

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Climate change is a global challenge that affects all spheres of our lives, including the countries of Germany and Kosovo. In this paper, we will examine the effects of climate change in these two countries and make a comparison between them in the main aspects of their impact. First, we will analyze the current climate situation in Germany and Kosovo, including average temperatures, precipitation levels and changes in natural ecosystems. After that, we will examine the causes of climate change in each of these countries, including greenhouse gas emissions, energy resource use, and agricultural practices. Next, we will analyze the consequences of climate change in Germany and Kosovo in social, economic and environmental aspects. We will discuss the effects of escalating global warming on public health, food security, the economy and their natural biodiversity. Finally, we will include a detailed analysis of the policies and measures that have been taken in each of these countries to address climate change and mitigate its negative impact. In comparison, we will assess the effectiveness and variability of these policies and measures, identifying best practices and common challenges through which Germany and Kosovo can collaborate to improve their response to the climate crisis.

Keywords: *Environment, Germany, Kosovo, climate changes, pollution, biodiversity.*

1. INTRODUCTION

Climate change can be a natural process where temperature, precipitation, wind and other elements change over decades or more. In millions of years, our world has been warmer and colder than it is now. But today we are experiencing rapid warming from human activities, mainly due to the burning of fossil fuels that generate greenhouse gas emissions. Increased greenhouse gas emissions from human activity act like a blanket wrapped around the earth, blocking the sun's heat and raising temperatures. Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane. These come from burning fossil fuels such as petrol to run a car or coal to heat a building. Clearing land and forests can also release carbon dioxide. Landfills are another source. Energy, industry, agriculture and waste disposal are among the main emitters [1][2].

Climate change is a big challenge, but we already know many solutions. These can bring economic benefits by improving our lives and protecting the environment. We also have global agreements to guide progress, such as the UN Framework Convention on Climate Change and the Paris Agreement. The three broad categories of action are: cutting, emissions, adapting to climate impacts and financing the necessary adjustments. Switching energy systems from fossil fuels to renewable sources such as solar will reduce em issions that drive climate change. But we have to start now. While a growing coalition of countries is committing to net zero emissions by 2050, around half of emissions cuts need to be in place by 2030 to keep warming below 1.5°C Climate adaptation protects people, homes, businesses, tools of livelihood, infrastructure and natural ecosystems. It covers current and potential future impacts. Adaptation will be required everywhere, but priority should be given now to the most willing people with the fewest resources to cope with climate risks. Fever rates may be high. Disaster early warning systems, for example, save lives and property, and can deliver benefits up to 10 times the initial cost [1-4].

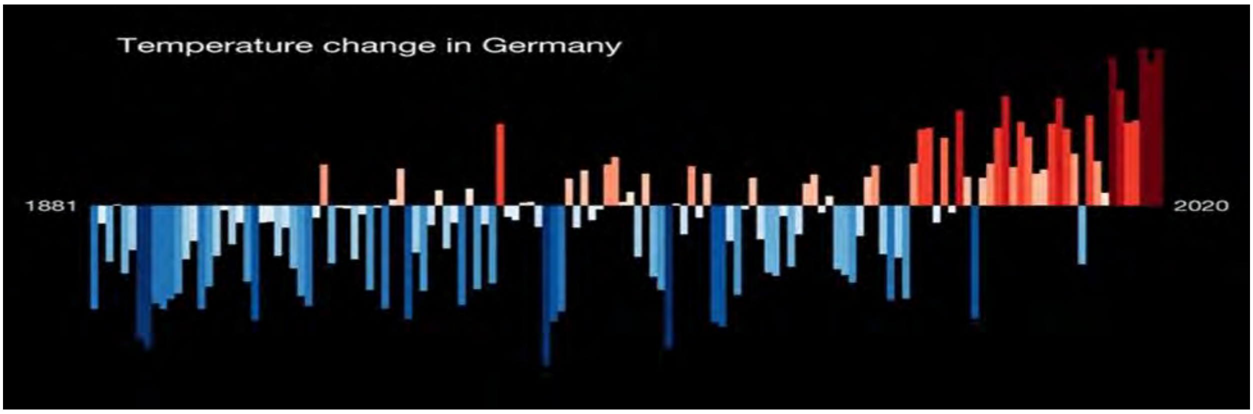

Figure 1. Climate changes in Germany from 1881-2020

1.1.Influencing factors

The Climate Change Act sets annual declines in annual emissions volumes for various sectors until 2030. Projected emissions will not fall fast enough if current climate policies remain unchanged, which means that according to current estimates the gap between targets and emissions current will continue to grow until 2030. Also, if we continue to miss the targets, annual deficits will accumulate. This means that, between 2021 and 2030, the established emission limits will be exceeded by a cumulative amount of more than one gigatonne (1000 million tons) of CO_2 equivalent - i.e. with more than an entire year's actual emissions [5][6].

Time is running out for effective mitigation of the climate crisis. The rise in average global temperature should, if possible, be kept to 1.5ºC to avoid serious consequences for life on Earth – this is what has been agreed in the Paris climate agreement. It can only be achieved if greenhouse gas emissions are curbed as soon as possible worldwide. The goal is global carbon neutrality by the middle of this century. Climate change poses a threat to the foundations that support our life and economic activity in Germany: the increase in extreme weather events and climate change not only endanger life, health and biodiversity - they also cause significant economic damage. For this reason, we want to make Germany greenhouse gas neutral in less than 25 years - no later than 2045. More and more countries are facing this task. The whole European Union and all The G7 partners – I some of Germany's main trading partners – want to achieve this target by 2050; China has 2060 on the horizon. An ambitious and rapid restructuring of our economy towards greenhouse gas neutrality is not only a contribution to mitigating climate change: it will also help maintain our global competitiveness in many economic sectors. The global race for the best strategy for this has begun. The situation we find ourselves in could hardly be more challenging: given the insufficient emissions trends seen in the past and the likelihood that we will not reach our targets in the coming years, there is an urgent need for action by all sectors. The new federal government will respond to this. This status report forms the platform for specific actions. The Federal Government is now starting its work on the Immediate Climate Action Programmer, which will be completed in several stages with all the necessary acts, ordinances and measures by the end of 2022[1][5-7].

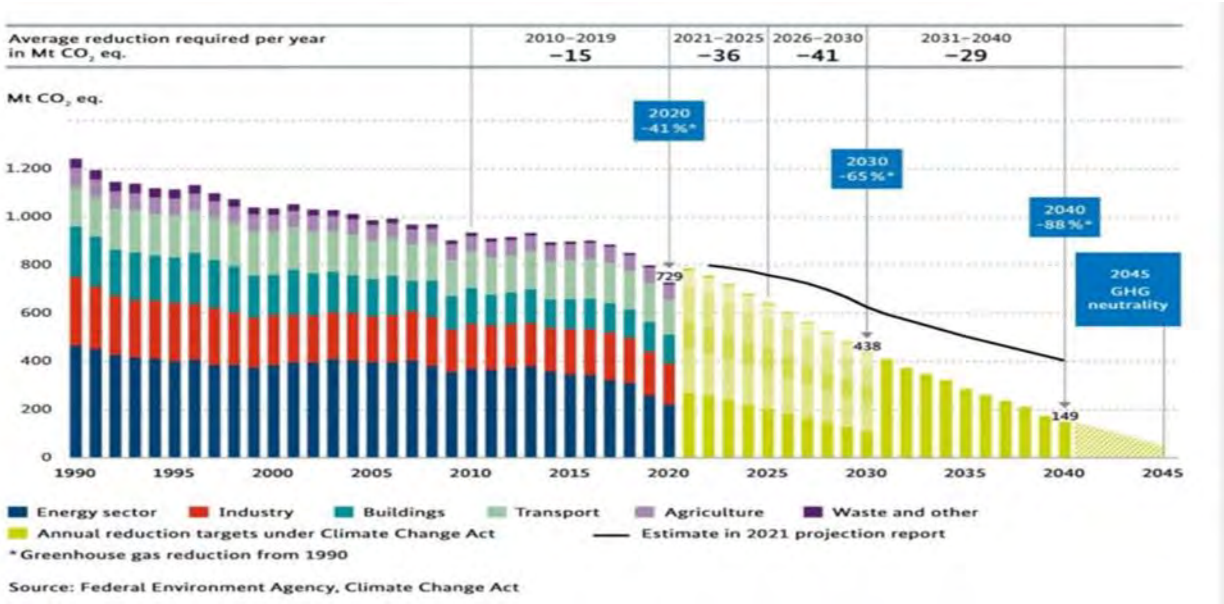

Figure 2. Development of greenhouse gas emissions in Germany

2. FLOOD AND DROUGHT

So, while heat itself is a concern for the EU nation, this problem is in many ways dwarfed by the resulting changes in precipitation. A study by the German Climate Service Center (GERICS) found, according to Phys.org, that "precipitation in Germany have increased by 11 percent since 1881 – and the trend is predicted to continue. It now rains much more in winter almost everywhere in Germany; in some cases, rainfall volumes have increased by up to 30 percent in the cold season. In contrast, summers in many federal states have become drier." These drying summers—especially at a time of general warming—can be a major concern because below-average rainfall naturally increases the likelihood and duration of wildfires. in the woods[1-3].

This is a particular concern for areas like the Alps, where snow is melting earlier, and earlier as unreasonably warm temperatures begin earlier in the spring and creep deeper into the fall. Given that forests are considered flammable about a month after snowmelt ends, the result is a much longer period than usual when forests are vulnerable to fire. And, with less predictable rains, it's harder to stop these fires once they start. It's no wonder that climate change-driven drought and all that comes with it has led to an increased risk of fires in the Alps. However, at other times of the year, Germany has suffered from the other side of what we have just described. This was especially true just last year: "So far, the summer has been, at least in terms of weather, one thing above all else: extremes. As a result, the German Meteorological Service (DWD) declared July 2017 the wettest month Germany has seen since records began in 1881[2-5].

Elsewhere, rising sea levels and increased storm surge height could cause flooding along the country's North Sea and Baltic Sea coasts, allowing salt water to seep inland, potentially contaminating freshwater. Terres trial and surface. The result: Without adaptation, by the 2080s, total losses due to sea level rise in Germany could reach 2.6 billion euros per year.

3. PUBLIC HEALTH

Extreme heat increases the death rate from diseases such as heart attack, heat stroke, organ failure and more. But in Germany, a more pressing concern will come from diseases that spread as insects travel farther and farther as our climate changes. "As temperatures rise, disease carriers (vectors) can migrate to new habitats and thus expand the regional reach of the diseases they transmit," writes the country's federal environment agency, the Um welt bundesamt. "This includes, among others, vectors such as mosquitoes, ticks or insects. … In Germany, especially the generally rising temperatures favor the growth and spread of vectors. Mild winters increase the survival rate of many disease vectors. They cause accelerated successions of generation and extended periods of annual activity." [1][3][6].

In some regions in southern Germany, even true tropical vectors such as the Asian tiger mosquito are spreading - and they are bringing serious diseases such as malaria or dengue fever with them. Due to the climate crisis, Germans must also expect an increase in asthma and allergies. The science here is true in many places around the globe: as temperatures rise, pollen seasons will start earlier and last longer, and concentrations of ozone and particulate matter in the air will increase. "Direct health effects caused from the higher ozone concentration include irritation of the mucous membranes, respiratory reactions such as reduced lung functions, cardiovascular diseases, as well as an impaired physical performance," according to the Um welt bundesamt [2][7].

4. FOOD AND WATER SECURITY

If we continue to burn fossil fuels at our current rates, food may become increasingly difficult to grow in many countries. Fresh drinking water may become increasingly scarce as runoff from polluted floods pollutes rivers, lakes and reservoirs — or drought and warming combine to dry them all up. Like much of the climate change story, the threat to food and water security in Germany is a tale of the impact of rising temperatures on the water cycle – something well understood by the country's government: "In the context of changes climate, the amount of precipitation and its distribution is changing in Germany. This has a direct effect on the temporal and regional availability of water." Altered rainfall leads to fluctuations in soil and groundwater levels. Thus, soil quality and agricultural land productivity are affected. If temperatures rise at the same time, the consequences for agricultural production will be even more severe. Decreases in summer rainfall of up to 30 percent are expected across Germany by 2080, potentially leading to problematic heat and drought conditions. in some areas and resulting in reduced crop yields and poor harvest quality[1-4].

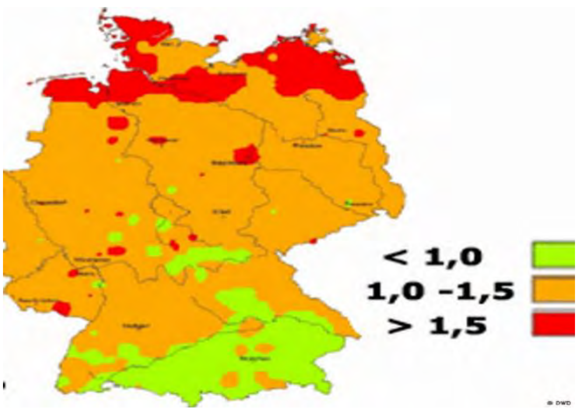

Figure 3. Climate change to increase heat in Germany

5. MEASURES TAKEN

The point is that climate change affects every aspect of our lives – in Germany and around the world. But there's also plenty of good news: With clean energy solutions like wind and solar becoming more affordable, batteries getting better, and buildings getting more efficient every year, the solutions to this crisis are available to us now.

We're working to accelerate the global shift from dirty, climate-changing fossil fuels to renewable energy so we can power our lives and economies without destroying our planet [1].

5.1.Comparison with the Republic of Kosovo

5.1.1. Maximum daily temperatures

The highest daytime temperatures in Germany are reached in July with an average of 23.9 °C. The coldest month, on the other hand, is January, with an average of only 3.4 °C. In Kosovo, August is the warmest month, with 32.9 °C. There, it is coolest in January with an average of 4.7 °C [1][5].

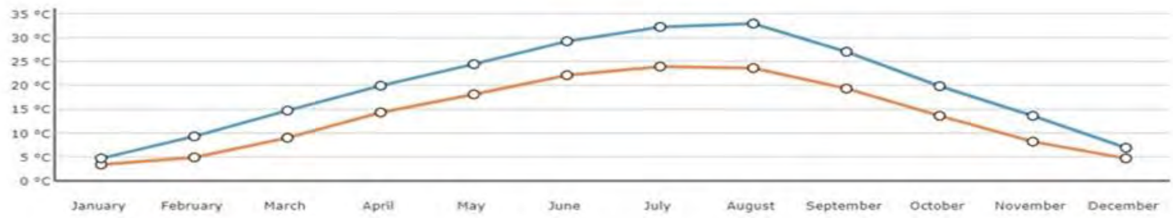

Figure 4. Diagram of Maximum Temperatures [5]

5.1.2. Amount of precipitation per day

Depending on the season and the location of a place, the wind brings a different amount of water with it. As a rule, water that evaporates in the oceans is absorbed and then transported inland.

The highest amount of rain (hail or dew are also forms of precipitation) in Germany occurs in July, when about 2.6 liters fall per square meter per day. In Kosovo, the average amount of precipitation varies from 0.9 liters per day in July to 1.7 in May. However, these are average values. If you consider that in Germany there are only 10.6 rainy days in July, each of them amounts to about 7.3 liters [5].

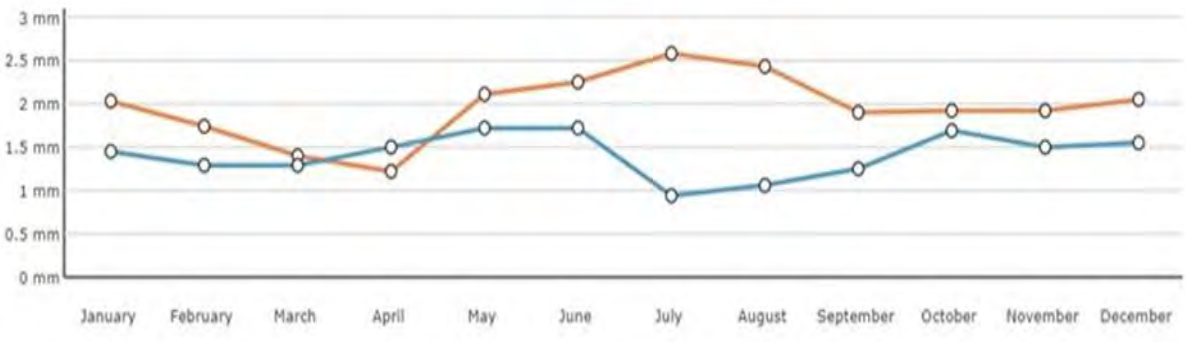

Figure 5. Diagram of the amount of precipitation during the day [5]

5.1.3. Rainy days per month

By definition, a rainy day is a day in which at least 0.1 liters of precipitation fall per m². This corresponds to a 1 square meter pond in which the water stands 0.1 mm high - as long as the water does not seep through or evaporate. So, it shouldn't rain all day. January brings the rainiest days (12.3) in Germany. With an average of just 7.2 days, April is friendlier. In Kosovo, it rains most often in January with 9.6 days [5].

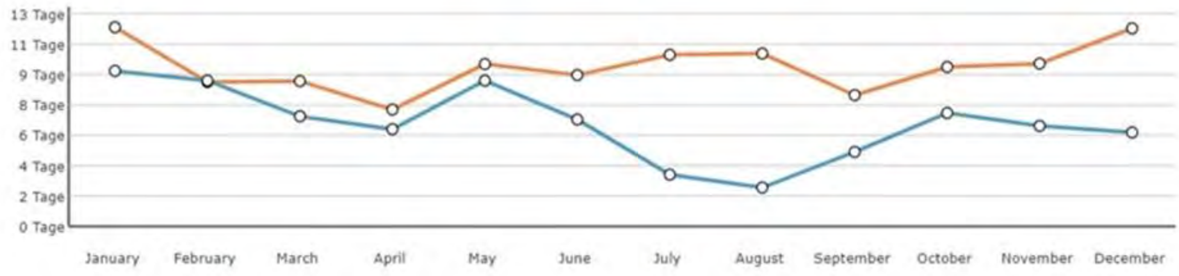

Figure 6. Diagram for rainy days during the months [5]

5.1.4. Germany's policy recommendations

Among 196 other countries, Germany agreed to the Paris Agreement in 2015. It was ratified in the country on October 6, 2016. Below is a projection from the Climate Action Tracker of the level of emissions that EU countries need to achieve in order to ' became 1.5 in line with degrees Celsius by 2030. All countries within the European Union have agreed to work towards achieving this target to guarantee a sustainable future for future generations. (Score card, recommendations, 2019)

6. CONCLUSIONS

In conclusion, the case studies of Germany and Kosovo vividly illustrate the multifaceted challenges posed by climate change and the diverse strategies employed to address them. The comparison between these countries highlights the global nature of the climate crisis and the urgent need for collective action. Germany, as a developed nation, faces significant pressures from rising temperatures, changing precipitation patterns, and heightened risks of extreme weather events. The country's proactive approach, including ambitious emissions reduction targets and robust adaptation measures, serves as a model for others to follow. On the other hand, Kosovo, as a developing nation, grapples with its unique set of challenges, balancing economic development with environmental sustainability. Despite facing constraints, Kosovo has taken steps towards environmental protection and climate resilience, albeit with limited resources. The comparative analysis underscores the importance of tailored solutions that consider each country's specific circumstances and capacities. Both Germany and Kosovo are signatories to international agreements like the Paris Agreement, signaling their commitment to global climate action. However, the gap between targets and actual emissions remains a pressing concern, emphasizing the need for accelerated efforts across sectors and regions. Moving forward, collaboration and knowledge exchange between nations, especially between developed and developing economies, are crucial in advancing climate solutions. By sharing best practices, leveraging technological innovations, and enhancing policy coherence, countries can collectively mitigate the impacts of climate change and build a sustainable future for all.

REFERENCES

[1] "What is climate change?" NASA. [Online]. Available: https://climatekids.nasa.gov/climate-change-meaning/. [Accessed: 12-Apr-2024]

[2] “How is climate change affecting Germany?” The Climate Reality Project, 25-Jan-2021. [Online]. Available: https://www.climaterealityproject.org/blog/how-climate-change-affecting-germany. [Accessed: 12-Apr-2024]

[3] BMWK - Federal Ministry for Economic Affairs and Climate Action, “National climate action policy,” BMWK. [Online]. Available: https://www.bmwk.de/Redaktion/EN/Dossier/national-climate-action-policy.html. [Accessed: 12-Apr-2024]

[4] Deutsche Welle, “Climate change to turn up the heat in Germany – DW – 09/03/2008,” dw.com, 03-Sep-2008. [Online]. Available: https://www.dw.com/en/climate-change-to-turn-up-the-heat-in-germany/a-3615754. [Accessed: 12-Apr-2024]

[5] “Climate comparison: Germany / Kosovo,” Worlddata.info. [Online]. Available: https://www.worlddata.info/climate-comparison.php?r1=germany&r2=kosovo. [Accessed: 12-Apr-2024]

[6] “World Bank Climate Change Knowledge Portal,” Summary | Climate Change Knowledge Portal. [Online]. Available: https://climateknowledgeportal.worldbank.org/country/germany. [Accessed: 12-Apr-2024]

[7] B. Mohr, “Germany policy recommendations,” Climate Scorecard, 20-Jul-2019. [Online]. Available: https://www.climatescorecard.org/2019/07/germany-policy-recommendations/. [Accessed: 12-Apr-2024]

Strategies for mitigation and adaptation of climate change

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Human-induced climate change poses a growing threat to life on Earth, primarily fueled by increasing greenhouse gas emissions, notably from burning fossil fuels. This perilous shift in Earth's climate, driven by rising carbon dioxide and greenhouse gas (GHG) levels, foresees a worsening impact of climate change over the next two to three decades. Heatwaves, wildfires, droughts, storms, and floods are expected to rise, posing greater risks to both human health and global stability. This paper explores different perspectives, presenting evidence of climate change across Earth's spheres, from altering emission pathways to understanding the drivers of climate change. It critically examines the current and future state of global climate change, emphasizing mitigation and adaptation strategies. Urgent action is needed to combat the acceleration of climate change, highlighting the crucial shift to renewable energy sources and enhancing carbon sinks. These steps are identified as vital measures to mitigate the adverse impacts of climate change and align with the global imperative to reduce greenhouse gas emissions. The report emphasizes the significance of advancements in carbon quantification, modeling, and pricing as essential tools for effective climate change mitigation. Adaptation strategies, fostering resilience in local communities and ecosystems, emerge as essential components of a comprehensive response. To pave the way for a sustainable future, the report delves into a detailed analysis of the impacts of climate change on environmental and human health. It explores evolving strategies for mitigation and adaptation, underscoring the critical need to confront and overcome key challenges in reversing and adapting to global climate change. This comprehensive exploration acts as a call to action, urging collaborative efforts on a global scale to safeguard the future of our planet and its diverse life forms.

Keywords: *Climate change, GHG emissions, Sustainability, Mitigation, Adaptation.*

1. INTRODUCTION

Climate change is accelerated by anthropogenic greenhouse gas emissions and its effects are increasingly felt globally. Addressing this crisis requires both adaptation and mitigation strategies. Adapting involves developing resilience to climate impacts through infrastructure, technology and awareness-raising, while mitigation demands urgent reductions in greenhouse gas emissions. The Paris Agreement outlines targets for emissions reduction, requiring a shift to low-carbon energy and sustainable development practices, so collaboration among citizens, researchers and policymakers is essential to enact effective measures. Immediate global action is necessary to combat climate change and ensure a sustainable future for our planet.

2. MATERIALS AND METHODS

2.1 Drivers of climate change

Climate change has been a natural occurrence throughout Earth's history, with fluctuations in temperature and atmospheric composition occurring over millions of years. Natural factors such as volcanic activity, changes in solar radiation and variations in Earth’s orbit and tilt have all played a role in these changes. Human activities through land use changes such as deforestation and urbanization have led to an increase of the greenhouse effect and global warming.

More importantly, burning fossil fuels for energy, release large amounts of CO_2. Also, human activities produce a significant quantity of GHGs such as methane (CH_4), nitrous oxide (N_2O), Ozone (O_3), chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) into the atmosphere. These gases trap outgoing longwave radiation from the Earth that would otherwise be emitted into space, leading to a warming effect on the planet.

2.2 Evidence of climate change on Earth's spheres

2.2.1 Atmosphere

Human activities since the Industrial Revolution have significantly increased greenhouse gases like CO_2, CH_4, and N_2O, that along with atmospheric transport, impact the planet's climate patterns. Based on current measurements an increase in atmospheric CO_2 results in a temperature increases of ~1 °C per 100 ppm CO_2. Human-made chemicals like chlorofluorocarbons (CFCs) have depleted the stratospheric ozone layer and have affected atmospheric temperatures and circulation patterns, ocean currents, and the Earth's carbon cycle. It also affects tropospheric ozone and particulate matter levels, influencing air quality and environmental health.

2.2.2 Pedosphere

Soil carbon cycling: Soil stores lots of carbon, crucial for the carbon cycle. Climate change affects soil carbon levels, speeding up decomposition and releasing more carbon into the air, worsening global warming.

Soil nutrient cycling: Climate change impacts soil nutrient levels, boosting plant growth but potentially causing shortages of nutrients like phosphorus. Increased precipitation can wash away nutrients, harming ecosystems.

Soil diversity: Changes in temperature and moisture affect soil organisms, vital for ecosystems, by disrupting their distribution. Soil diversity is crucial, because different organisms contribute to processes like nutrient cycling, decomposition of organic matter, soil structure formation and plant health.

2.2.3 Hydrosphere

Climate change affects the water cycle system by increasing evaporation rates, altering precipitation patterns, impacting surface water runoff, and influencing groundwater recharge. The globe is experiencing smaller ice coverage, and the average annual global lake evaporation rate is expected to increase by 16% by 2100.

By the late 21st century, it is projected that 67% of the land area will experience a decline in water reserves.

2.2.4 Biosphere

Two of the most widely discussed changes in the biosphere are shifts of biomes towards the pole regions or higher elevations and changes in plant, microbial, and animal phenology. Other evidence includes the die-off of plants and animals due to heat waves, drought, fire, or outbreak of insects and diseases.

2.2.5 Cryosphere

Glaciers worldwide have been shrinking since the second half of the 19th century. In addition, glacier decline can accelerate the release of long-stored legacy pollutants with potential risks on ecology and human systems. On the one hand, snow cover and glacier changes have altered soil moisture in river catchments, increasing plant productivity and expanding species habitats. But on the other side, the rapid shrinking of the cryosphere has led to the loss or disappearance of habitats that depend on snow and ice cover.

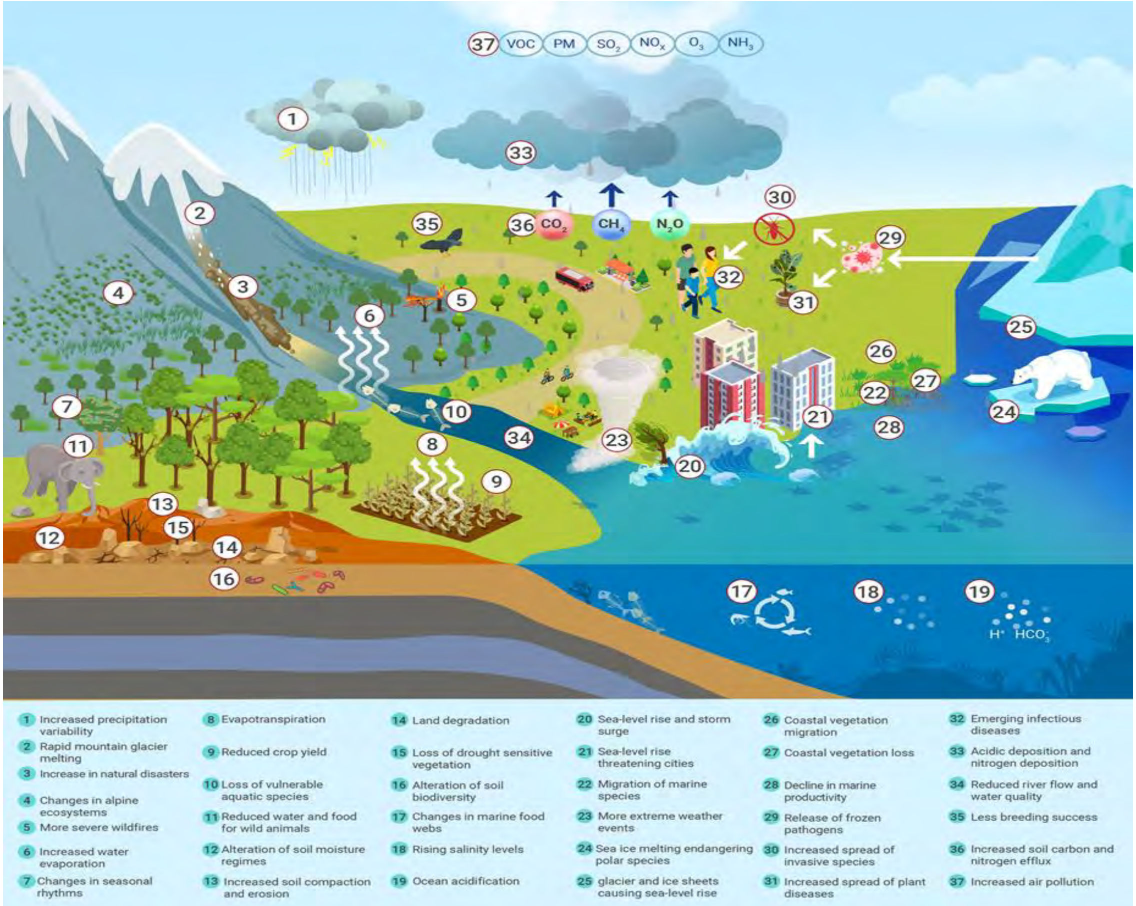

Figure 1. Evidence of global climate change and its effects on the environment

2.3 Impacts on human health

Climate change has emerged as a significant threat to global public health. Extreme weather events, including heatwaves, wildfires, hurricanes, droughts, and floods, have led to a series of adverse health impacts from excess mortality and morbidity to negative birth outcomes and mental health issues. A 1°C temperature rise was associated with a significant increase in morbidity due to arrhythmias, cardiac arrest, and coronary heart disease. Furthermore, heat waves have been linked to adverse birth outcomes. A recent meta-analysis showed that for every 1°C rise in temperature, there was a 2.2% increase in mental health-related mortality and a 0.9% increase in mental health-related morbidity.236 A global study found that for every 10 μg/m3 increase in wildfire-related $PM_{2.5}$ exposure, there was a 1.9, 1.7, and 1.9 higher risk of all-cause, cardiovascular, and respiratory mortality, respectively.

3. RESULTS AND DISCUSSIONS

3.1. Strategies for mitigation of climate change

3.1.1 Nature-based solutions for climate change mitigation

- **Protection of natural carbon-sink resources**
  Natural carbon sinks are ecosystems that trap and store carbon dioxide from the atmosphere, such as forests, wetlands, and oceans. By protecting these carbon sinks from human-induced

activities such as deforestation, land-use change, and drainage, we can prevent the release of large amounts of carbon dioxide into the atmosphere. For example, reforestation projects can help to reestablish forests that have been lost due to deforestation or land use change, while wetland restoration can help to enhance carbon sequestration in coastal ecosystem.

- **Afforestation and forest ecosystem restoration**
  Afforestation and forest ecosystem restoration are vital strategies for mitigating climate change and achieving the goals outlined in the Paris Climate Agreement. Over the past ten years, terrestrial ecosystems have removed ~30% of human carbon emissions each year and forests account for most of this uptake.
  Afforestation and reforestation, considered natural climate solutions (NCSs), have the potential to contribute significantly to climate change mitigation, with estimates suggesting they could remove up to 7 Pg CO_2e annually by 2030.
- **N_2O emission reduction**
  By increasing the activity of N_2O reducing organisms or N_2O-consuming microbes in soils through bioaugmentation or bio stimulation, N_2O emissions can be reduced. Furthermore, research has shown that some types of fungi can reduce N_2O emissions by promoting the growth of plants that have a high affinity for nitrogen uptake. These plants can take up excess nitrogen from the soil, thereby reducing the availability of nitrogen for microbial processes that produce N_2O.

- **Adopting and developing organic farming**
  Organic farming offers a sustainable approach to food production, aiming to supply high-quality food, while positively responding to the climate crisis. Key practices include extended crop rotations, herbaceous cover, reduced tillage and the limited use of synthetic inputs like chemical fertilizers and pesticides. Additionally, organic farming has the potential to increase soil organic carbon (SOC) levels, that can reduce greenhouse gases through processes like carbon sequestration.

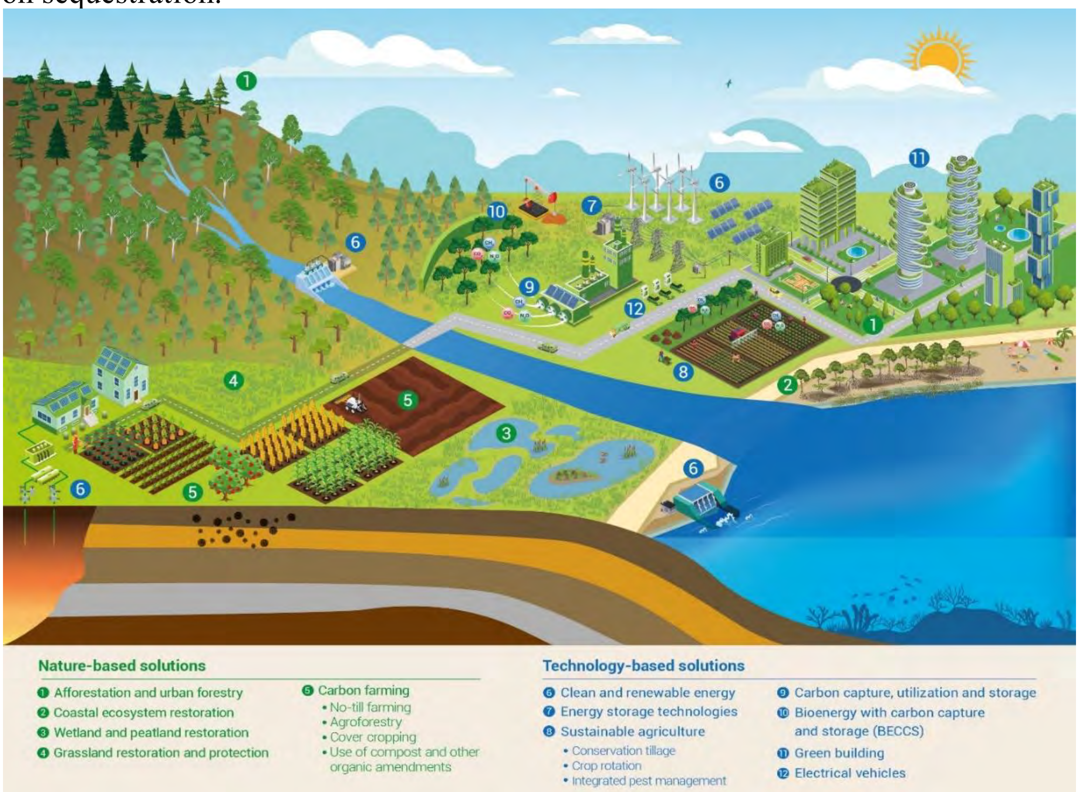

Figure 2. Nature- and technology-based solutions for climate change mitigation

3.1.2. Technology-based solutions for climate change mitigation

- **Developing and adopting renewable and clean energy technologies.**
Renewable energy sources include biomass, geothermal resources, solar, water, and wind. It is estimated that renewables will transform the global power mix through 2027, becoming the largest source of electricity. Hydropower accounts for more than 90% of all grid-scale capacity, however, it is restricted by the availability of suitable locations and multibillion-dollar capital costs. Solar photovoltaic (PV) and wind account for almost 90% of all new renewable energy installations in 2022.

- **Potential and impact of carbon capture, utilization, and storage on global change.**
Carbon capture, utilization, and storage (CCUS) is a process that involves capturing CO_2 emissions from industrial processes or power generation, utilizing the captured CO_2 for various purposes, and storing the remaining CO_2 in geological formations or other long-term storage facilities. IPCC (Intergovernmental Panel on Climate Change) reported that CCUS can reduce CO_2 emissions by 3.0-6.8 billion tons per year in 2050, and in International Energy Agency (IEA)'s sustainable development scenario, CCUS can contribute to 15% of the accumulated CO_2 emission reduction to realize net zero emission in 2070.

- **Smart management of agri-food systems in the face of climate change**
The need to smartly implement mitigation technologies and improve the structure of agri-food systems, comes from it being responsible for one-third of anthropogenic GHG emissions. Crucial steps are identifying and replacing high-emission food products, along with spatial redistribution to areas with ample water supply and high productivity, transitioning towards sustainable diets and adopting more efficient farming practices, such as: Conservation tillage Crop rotation and Integrated pest management (IPM).

3.2 Strategies for adaptation of climate change

- Terrestrial and freshwater ecosystem-based management
Terrestrial and freshwater ecosystems are also significantly threatened by climate change. One way to significantly increase the resilience of vulnerable terrestrial ecosystems is Ecosystem-Based Management or (EMB) - a recently recognized new approach for effective measures to provide co-benefits related to climate change adaptation and ecosystem environmental conservation. Progress has been made in implementing EMB measures worldwide, particularly in forests and lakes and they include conservation, diversification, and reducing nutrient inputs.

- Coastline protection and combating sea level rise
Coastline protection and sea level rise are a very important issue that affects many communities and coastal ecosystems. According to the National Climate Change Report, sea level has risen by 0.24m since 1880 and is projected to rise by 0.3-1.2m by 2100. There are different strategies to protect coasts from sea level rises, such as hard engineering (e.g., concrete seawalls, levees, and dikes) or soft engineering (e.g., nature-based solutions, living shorelines, and beach nourishment). The nature-based solutions for sea level rise and coastal protection include:

1) Conservation of coastal wetlands: Coastal wetlands and mangroves are periodically flooded by salt water. They can store wave energy, trap sediment, reduce erosion, and provide habitat for wildlife.

2) Beach restoration: Beaches are sandy shores that can prevent wave action, flooding and support recreation and tourism. They can be restored by doing so or vegetation to replenish eroded areas.

3) Creating oyster reefs: Oysters are bivalve mollusks that form reefs by attaching to hard substrates. They can reduce tidal surges, stabilize shorelines, filter water and support fisheries.

4) Mangrove restoration: Mangroves are trees and shrubs found in tropical and subtropical coastal areas. They can protect coastlines from storms, sequester CO_2, prevent saltwater intrusion and host different species. increasing biodiversity conservation, etc.

- Climate-smart agricultural practices and regenerative agriculture as instruments in a carbon economy
  Climate-smart practices such as crop history management, reduced tillage, soil amendments such as biochar and cover crops aim to sequester soil carbon and reduce GHG emissions. Research indicates that biochar application is particularly effective in increasing soil organic carbon, followed by cover crops and conservation tillage. In addition, developing climate-resilient crop varieties is critical to ensuring food security in the face of climate change-induced extreme weather events. Breeding efforts focus on traits like heat tolerance, drought, and flood resistance, alongside improving soil and water management techniques.
- Address and plan for environmental change.
  Combining climate change adaptation plans with urgent actions to reduce environmental pollution is crucial for achieving sustainability goals. This includes managing global warming, soil health, air, water, and food security, as well as waste management and alternative energy sources. Meeting these challenges aligns with the zero-pollution vision for 2050 and targets for 2030 to improve air, water, and soil quality. Controlling emissions, reducing particulate matter, and enhancing soil carbon sink capacity are key strategies.
- Efficient risk management of extreme weather events
  Climate change has brought major problems such as tornadoes, hurricanes, floods and fires causing damage. The use of technology existing to track weather is extreme for reducing the effects of climate change. Satellite platforms are a tool for monitoring global weather patterns and ground-based monitoring stations also play a critical role in observing local weather conditions.
- Urban soil for adaptation to climate change
  The population that lives in cities is likely to increase between 60% and 92% by the end of the 21st century, so protecting soil is crucial. Urban green infrastructure (UGI), such as parks, green walls and roofs, street trees, rain gardens, and other vegetated spaces within urban areas, contributing to the swamp cities' concept for retaining water in the cities for irrigation purposes and cooling. They help reduce the potential for flooding through water infiltration and capture and store carbon.
- From traditional infrastructure to climate-resilient infrastructure.
  Cities produce more than 70% of the global CO_2 emissions. Urban infrastructure, crucial for future development, needs to be made resilient to climate change impacts, through strategic planning and adaptation measures. The future planning to design and develop regenerative infrastructure should consider protecting key biodiversity regions, maintaining ecological connectivity and considering holistic benefits to human and environmental health.

Figure 3. Ecosystem-based management options for the adaptation to climate change in global systems

4. CONCLUSIONS

Over the past 150 years, global systems have evolved rapidly in response to the needs of a growing world population, resulting in overexploitation of natural resources. Thus, action is needed to transform local and global food and socio-ecological systems to better mitigate and adapt to climate change.

- First, there is a persistent and critical challenge of achieving a higher quality of life and economic growth while reducing the negative impact of energy consumption on the environment. In 2022, fossil fuels provided 81% of the world's energy and energy related CO_2 emissions continue to rise, so additional efforts are needed to increase the share of clean and renewable energy sources.
- Second, to effectively feed the growing population, agriculture is developing rapidly and its contribution to global GHG emissions is also increasing, currently accounting for 19-29% of total GHG emissions globally. This calls for effective management of soils and crop-livestock production systems, recycling the agricultural waste in agroecosystems, and improving the features of bio/organic fertilizers, to achieve carbon-neutral agriculture.
- Third, the ongoing loss of ecosystem carbon, its sequestration potential, and ecosystem services leave an unnecessary debt to future generations. In this regard, collaborative efforts centered on our current and future demands are needed, for a sustainable future irrespective of global political or economic tensions.

REFERENCES

[1] HERRING, D., and LINDSEY, R. (2020). Hasn't earth warmed and cooled naturally throughout history? NOAA Climate.gov.

[2] EPA (2023). Causes of climate change. United States Environmental Protection Agency.

[3] Friedlingstein, P., O'Sullivan, M., Jones, M.W., et al. (2022). Global carbon budget 2022. Earth Syst. Sci. Data ***14***, 4811−4900.

[4] Berner, L.T., and Goetz, S.J. (2022). Satellite observations document trends consistent with a boreal forest biome shift. Global Change Biol. ***28***, 3275−3292.

[5] Allen, C.D., Macalady, A.K., Chenchouni, H., et al. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. For. Ecol. Manage. ***259***, 660−684.

[6] Hodson, A.J. (2014). Understanding the dynamics of black carbon and associated contaminants in glacial systems. WIREs. Water ***1***, 141−149.

[7] You, J., Qin, X., Ranjitkar, S., et al. (2018). Response to climate change of montane herbaceous plants in the genus Rhodiola predicted by ecological niche modelling. Sci. Rep. ***8***, 5879.

[8] Guo, Y., Gasparrini, A., Armstrong, B.G., et al. (2017). Heat wave and mortality: a multicountry, multicommunity study. Environ. Health Perspect. ***125***, 087006.

[9] Pan, Y.D., Birdsey, R.A., Fang, J.Y., et al. (2011). A large and persistent carbon sink in the world's forests. Science ***333***, 988−993.

[10] Bakken, L.R., and Frostegård, Å. (2020). Emerging options for mitigating N2O emissions from food production by manipulating the soil microbiota. Curr. Opin. Environ. Sustain. ***47***, 89−94.

[11] Gibb, D., Ledanois, N., Ranalder, L., et al. (2022). Renewables 2022 global status report+ Renewable energy data in perspective+ Press releases+ Regional fact sheets+ Country fact sheets.

[12] Wang F., Harindintwali J.-D., Wei K., et al., (2023). Climate change: Strategies for mitigation and adaptation. The Innovation Geoscience **1(1)**, 100015.

[13] IEA (2022). Carbon capture, utilisation and storage - fuels & technologies. Int. J. Energy Res.

[14] Schuerch, M., Spencer, T., Temmerman, S., et al. (2018). Future response of global coastal wetlands to sea-level rise. Nature ***561***, 231−234.

[15] Jiang, L.W., and O'Neill, B.C. (2017). Global urbanization projections for the Shared Socioeconomic Pathways. Global Environ. Change-Human Policy Dim. ***42***, 193−199.

[16] De la Sota, C., Ruffato-Ferreira, V.J., Ruiz-Garcia, L., and Alvarez, S. (2019). Urban green infrastructure as a strategy of climate change mitigation. A case study in northern Spain. Urban For. Urban Gree. ***40***, 145−151.

Geodesy, Cartography, Photogrammetry and RS

Creation of a tourist map using GIS applications for the municipality of Gjakova

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This paper outlines the methodology and data required to create a tourist map of a municipality using GIS software. While the main purpose of creating a tourist map is to provide an accessible and informative guide to the city's attractions, amenities, and points of interest, the procedure includes various key steps such as collecting data and selecting only the data that is useful and should be featured in our map, map designing and user testing. The collected data used in creating the tourist map for the municipality of Gjakova belongs to different resources including topographic maps for said location, orthophotos, and basemaps provided by the software. The map also includes additional information about each official tourist location featured on the map, with the simple intention of making the map as informative as possible. Map designing and user testing are two components closely intertwined because while designing the map we should always aim to keep the content as simple and as easy to understand as we can. This is when user testing comes in handy. Doing as many user tests as we could helped us understand how helpful and effective our map design to different groups of people with different professional backgrounds is. The contents of this map are designed in both languages: Albanian and English. This speaks of its bilingual character, which makes it very useful for both local and international tourists.

Keywords: *Tourist map, GIS software, Municipality, Data collection, Orthophoto, Map design.*

1. INTRODUCTION

An important element for every tourist destination is a tourist map. A tourist map should be able to give the tourist an answer for every landmark and interest point that they may have. It should provide the tourists with information regarding the unknown and make it so that they can navigate themselves in that area [1].

A great deal of cartographic publications are represented by tourist city maps, this is due to the fact that cities are a major attraction for a variety of tourists. Taking into consideration the size of the city, it should also proportionally allocate the amount of information that is demanded by the tourists, in return, this brings changes to the scale of the map where the average scale for city-scaled maps is 1:25 000 or larger. Every tourist map should have basic orientation features such as street names and interest points (usually) in numerical order. Furthermore, a majority of the information should be regarding tourist attractions. Bridges, mosques, cathedrals, museums, and more should be marked on the map with additional information at the bottom of the map [2].

Based on the previously mentioned information, we created this tourist map for the municipality of Gjakova using ArcMap, which is a GIS application. During the process, we followed a series of steps by first, determining the optimal scale of the map. An essential step is also selecting the required data from different open sources. Developing a comprehensive tourist map for a city can help boost local tourism by highlighting hidden gems and showcasing the unique culture and history of the destination.

2. MATERIALS AND METHODS

2.1. Map scale selection.

Map scale selection depends on three main factors: our map destination, the territory dimension to be mapped, and the possibility of mapping the main content. Depending on these three factors, the first thing we did was to determine our map paper format, based on the map's destination. Through various analyses, it was determined that the A2 paper format (42.0 x 59.4 cm) is the most appropriate format for tourist maps. This format allows for practical use and easy identification of the map's features from a distance of 60 centimeters from the user's eye.

To select the optimal map scale, we used two methods based on two different conditions: one being our paper and territory dimensions, and the other being the minimal distance between two tourist spots [3].

2.1.1. Selection of the map scale based on the paper's format and the territory's dimensions.

Knowing Gjakova municipality's dimensions and the paper's format allows us to determine the most appropriate map scale for our map. Such mathematical dependence is expressed using these formulas:

$$F_1 = D_Y : d_y \tag{1}$$

$$F_2 = D_X : d_y \tag{2}$$

where: F – is the scale factor of the map,
D_Y – the width of the territory getting mapped,
d_y – the width of the paper format,
D_X – the length of the territory getting mapped,
d_x – the length of the paper format.

In this case, we obtain two scale factor values and then select the higher scale factor value, which corresponds to the smaller scale. This implies that the scale should be determined based on both the length of the area to be mapped and the length of the paper format, as well as the width of the area and the width of the paper format [3].

2.1.2. Selection of the map scale based on minimal distance.

The second method we used to determine the map's optimal scale is the minimal distance formula. Map designing is a very important step in the map-making process, hence the reason we used this method. This method allows us to locate the two features in nature that are closest to each other, and make sure these features do not overlap when mapped. Overlapping features in maps can confuse the user and might lead to misinterpretation of the map, which directly affects the quality of the map.
For our map, we decided on a 0.5-centimeter minimal distance between mapped features. The minimal real distance between the two closest identified tourist spots was measured using GIS Software, ArcMap. The connection between these two elements is shown by the following formula:

$$F = \frac{L}{l_{min.}} \quad (3)$$

where: F – is the scale factor of the map,
L – the smallest distance between two tourist spots in nature,
$l_{min.}$ – the smallest distance allowed on the map.

In cases where multiple conditions must be met, we select the scale that satisfies all other conditions. In this particular case, the scale factor that met all the conditions was F=8 000, respectively the 1:8 000 map scale [3].

2.2.Collecting the necessary data

In order to create our map, we had to gather the required data. We found it appropriate to use online free open-source data for this purpose.
When designing a tourist map, it's crucial to collect data based on the information we want to incorporate into the map. The main focus of our map is the tourist attractions, so we had to make sure to include those as the primary content. One important feature of a tourist map is to include roads and transportation options, helping tourists navigate from one point of interest to another. A good tourist map should include other important locations such as hotels, hospitals, and police stations so that visitors can easily find accommodation, medical assistance, and law enforcement in case of an emergency. This provides tourists with the necessary information to navigate on their own and feel safe during their travels.
After considering these key points, we have determined that utilizing the topographic maps, orthophotos, and basemaps provided by the software is the appropriate method for gathering the necessary data [3].

2.3. Creating the map's symbology

When it comes to creating a map, several important steps need to be taken before the final product can be produced. One of the most important steps in this process is the creation of the symbology for the features that have been digitized for presentation on the map. This step involves carefully designing the visual representation of the various features on the map, including roads, bodies of water, landmarks, and more [4].
Creating symbology for a map involves choosing the appropriate symbols, colors, and styles to represent each feature on the map. This can be a complex task, as the symbols used must be both visually appealing and easy to understand for the map's intended audience.
Ultimately, the goal of creating the symbology for a map is to make it as clear and easy to read as possible for the intended audience. This requires careful consideration of every feature on the map and a deep understanding of the audience's needs and preferences. By taking the time to carefully design the symbology for a map, it is possible to create a final product that is not only visually appealing but also highly functional and easy to use.

2.4.The importance of map toponyms and tourist attractions' names

Tourist maps are designed with the user in mind. They are usually published in a language that is familiar to the target audience, or at least in a language that is commonly understood by the group. As a result, many place names mentioned in travel publications, leaflets, and catalogs may not match the actual name used at the destination [4].

Many toponyms are of little interest to tourists beyond their use within wayfinding strategies in an unfamiliar destination. However, in some cases, a place name can be a sight in its own right, that's why proper displaying of toponyms is very important in tourist maps [5].
Taking these things into consideration we decided to create a bilingual map, that displays the information in two languages: Albanian and English. The reason why it's important to create a bilingual map lies in the fact that tourist maps can be.

3. RESULTS AND DISCUSSION

User testing is a crucial phase in the development of our tourist map. It helps us understand how usable and effective the map is. To make sure that the map is easy to use, we conducted a series of user testing sessions with different groups of people, including tourists and locals. By watching how people interacted with the map and listening to their feedback, we were able to identify areas that needed improvement and address any challenges they faced while using it. This helped us refine the map's design, layout, and content, making it easy and intuitive for people to use. By taking into account the feedback we received, we created a tourist map that not only meets but exceeds the needs and expectations of its users, making it easier for them to explore and enjoy the destination with confidence and ease. The final product is shown in Figure 1.
During our discussion on the usability and effectiveness of the map, we came to the conclusion that although the map is helpful in guiding tourists around Gjakova and highlighting various attractions, it does not contribute much to the promotion of tourism in the area. For the very same reason, we decided to make this map a little more informative and at the same time more attractive for tourists while adding images of the tourist attractions and also text that contains some basic information, such as a brief historical background or construction detail. The second page of the map containing these changes is shown in Figure 2.

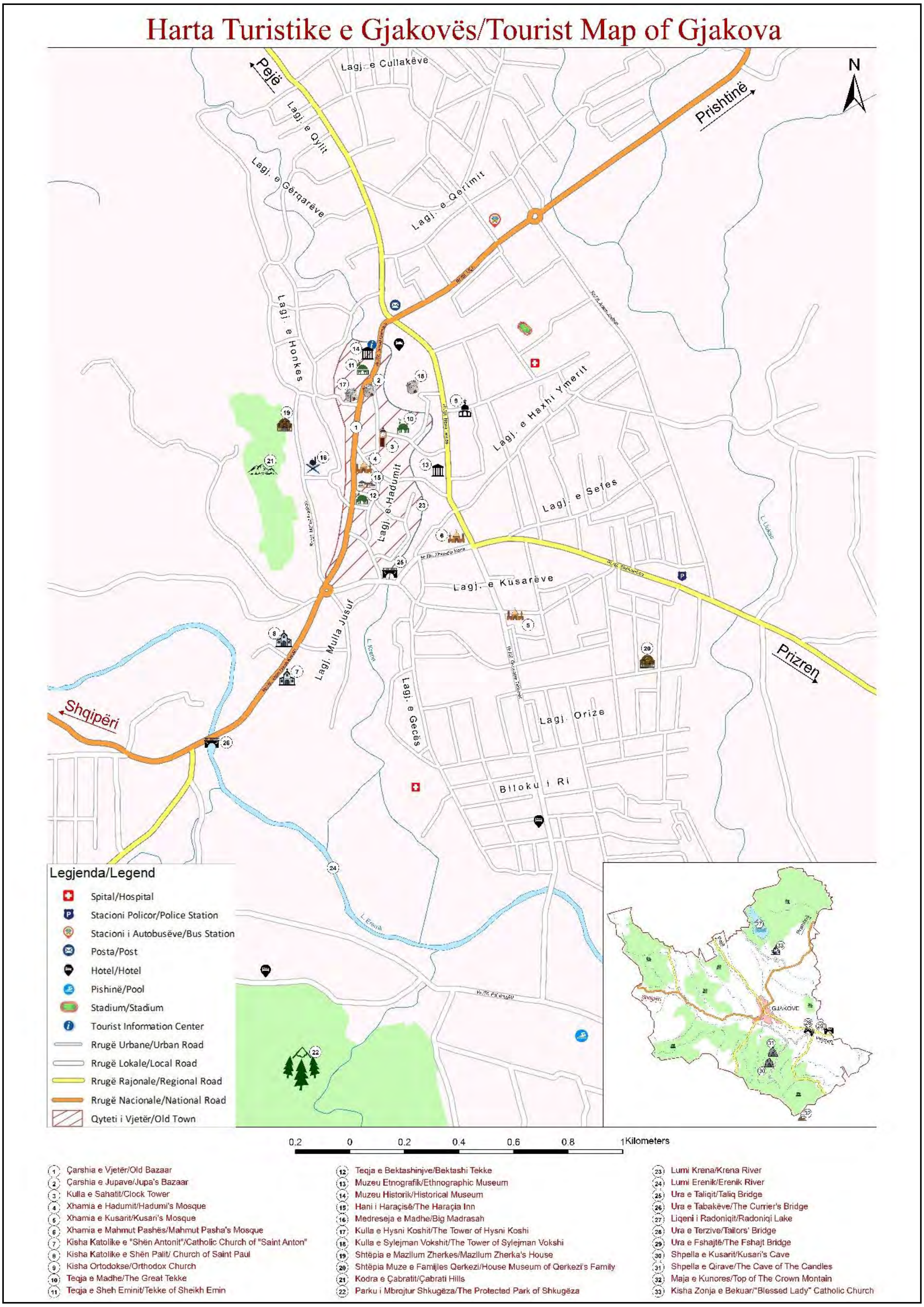

Figure 1. The tourist map of Gjakova municipality.

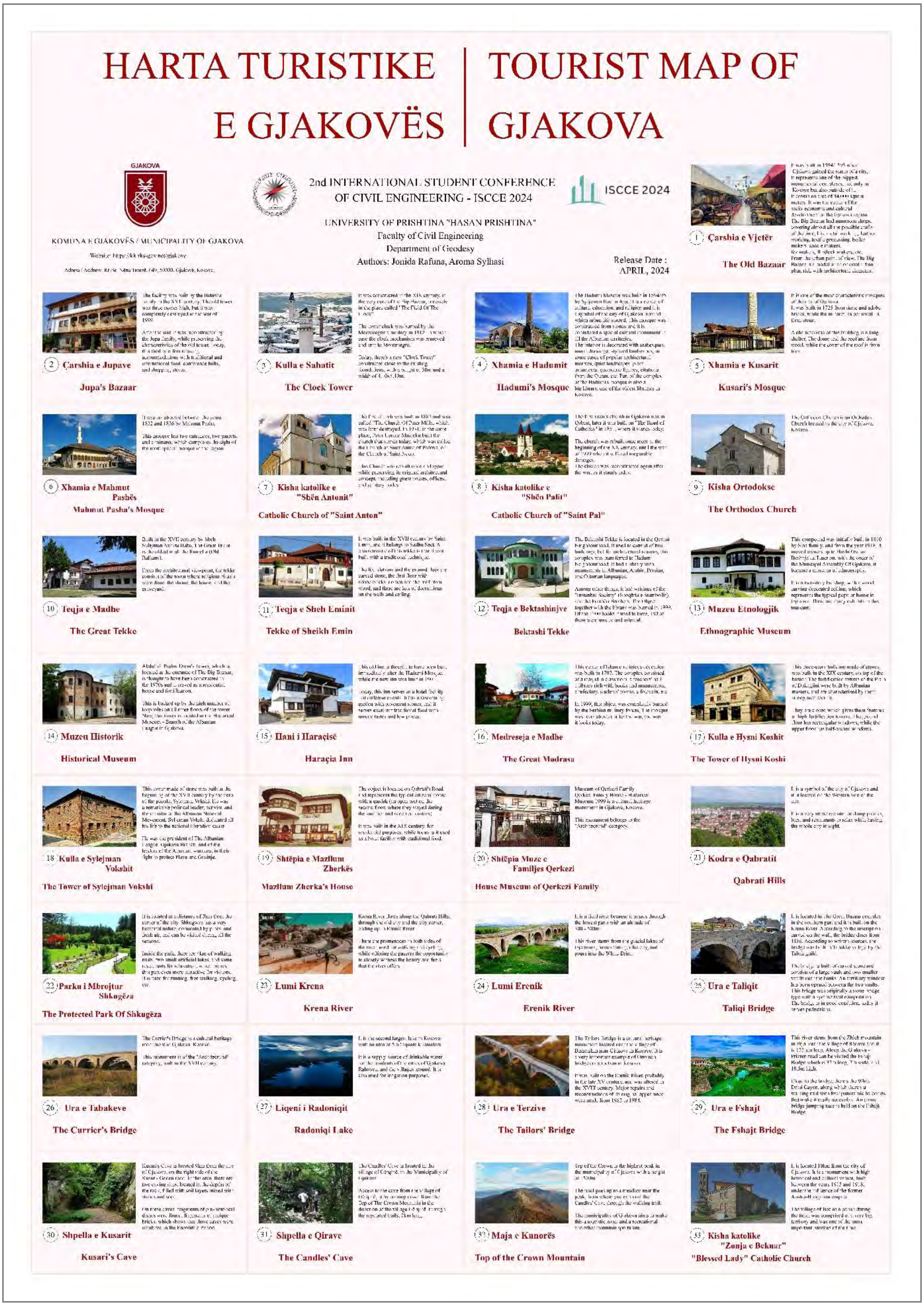

Figure 2. The second page of the map.

4. CONCLUSION

The creation of tourist maps is crucial in promoting destination exploration, facilitating visitor navigation, and supporting local tourism economies. Using GIS software for this purpose is a strategic decision as it offers various benefits, including precise spatial data management, customizable design capabilities, and opportunities for ongoing updates. By using GIS technology, destinations can ensure the production of accurate and informative maps that tend to the needs of diverse visitors or tourists. This approach not only enhances the overall visitor experience but also contributes to sustainable tourism development and the preservation of cultural heritage.

Our aim in producing this tourist map is to encourage and promote tourism in our municipality, intending to make it more welcoming and attractive to visitors. This is of utmost importance for the prosperity and future development of Gjakova's economy. Tourist maps are not only an essential feature of any municipality, but they also serve as a vital tool for attracting new visitors and ensuring the continued growth of the tourism industry. We believe that this map will play a significant role in helping our municipality achieve its full potential as a popular tourist destination.

REFERENCES

[1] Grabler, Floraine, et al. "Automatic Generation of Tourist Maps." ACM Transactions on Graphics, vol. 27, no. 3, 2008, pp. 1-11.

[2] Jancewicz, Kacper, and Dorota Borowicz. "Tourist Maps – Definition, Types and Contents." Polish Cartographical Review, vol. 49, no. 1, 2017, pp. 27-41.

[3] Idrizi, Bashkim. “Përpilimi i hartave & Përgjithësimi hartografik.” Shkup, FineArt Multimedia, 2006, pp. 17-21.

[4] Stani-Fertl, Roman. Section 3 Regional Activities and Different Applications Chapter 6 Geographical Names for Tourist Maps, pp. 1-2.

[5] Tourism and toponymy: commodifying and consuming place names, Journal: Tourism Geographies, : 2013, ISSN: 1470-1340.

Land coverage and the changes occurred between years 2006 and 2018 - case study Gjakova Municipality

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The main purpose of this paper is to present the ways in which we can analyze the data from open sources on land coverage for certain surfaces and in different periods of time using GIS software. In this case study, we used QGIS software and land cover data from CORINE Land Cover with 100m resolution. Land cover is defined as the observed physical cover on the earth's surface, including vegetation (natural or planted) and human constructions. The data from CORINE Land Cover is classified into 44 different land cover classes, which we received in raster format. Using the tools and functions provided by the software, we have analyzed this data for the municipality of Gjakova, producing coverage maps for the years 2006 and 2018, accompanied by diagrams and tables that present the area and the percentage of coverage of each type, compared to the total area of the municipality. Also, with the help of geoprocessing tools, we have extracted the surfaces where there was a change in the type of coverage to obtain a map of the changes that occurred during these time periods. To make a comparison of the results, we also analyzed the land cover from satellite images by means of supervised classification based on the colors of the features, in a smaller number of classes but at a higher resolution. The products obtained from this study will be able to be used by different municipal, state or private institutions for different purposes, analysis, and planning.

Keywords: *Land Cover, GIS, QGIS, Map, Raster, Municipality.*

1. INTRODUCTION

Land cover and land use are two terms that are often used interchangeably, but they have distinct meanings. Land cover refers to the surface cover of the earth, which includes vegetation, urban infrastructure, water, bare soil, and so on. Identifying land cover provides the baseline information for various activities such as thematic mapping and change detection analysis. Land use, on the other hand, refers to the purpose for which the land is used, such as recreation, wildlife habitat, or agriculture. [1,2]
When used together, the phrase Land Use / Land Cover (LULC) generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials. [1]
The world we live in has been constantly changing since the emergence of humanity. One of the most noticeable changes is the coverage of the land surface. Over the years, many parts of the land have experienced changes in the physical material that covers them. While some changes have had a positive effect, others have had negative consequences.
In the short term, natural disturbances such as storms, floods, fires, volcanic eruptions, insects, and landslides, as well as human activities such as population growth, industrial and urban development, deforestation or reforestation, water diversion, and road construction, can affect land cover. These changes can be perceived as either improvements or degradations of the land cover condition, depending on the perspectives. [3]
The growth of a society is dependent on its social and economic development, which is why socio-economic surveys are conducted. These surveys include both spatial and non-spatial

data sets, where LULC (Land Use/Land Cover) maps play an important role in planning, management, and monitoring programs at the local, regional, and national levels. The information provided by these maps helps in understanding land utilization and developing policies and programs for development planning. To ensure sustainable development, monitoring of land use/land cover patterns over time is necessary. Authorities involved in urban development must generate planning models to use available land rationally and optimally, and to prevent haphazard development of towns and cities. This requires current and past land use/land cover information. LULC maps are also useful in studying changes in the ecosystem and environment. Detailed information about land use/land cover of a study unit helps in formulating policies and launching programs to save the environment. [1]
From what we said, it is evident that land coverage is crucial in determining the most effective use of land and preventing its deterioration. In the upcoming section, we will explore different techniques utilized for processing and analyzing land cover data, alongside the products that emerge from these processes.

2. MATERIALS AND METHODS

2.1.Study area

The study area for this project is the municipality of Gjakova, located in the southwestern part of Kosovo. With a total area of 587 km² and a population of around 94,556 inhabitants, Gjakova is situated between 42° 15′ and 42° 34′ north latitude, and 20° 09′ and 20° 37′ east longitude. The municipality has a favorable geographical location, placed in the Dukagjin region between the municipalities of Peja and Prizren, and on its western side, it shares a border with Albania.

Figure 1. Study area

2.2.Methodology

The project methodology involves the creation of land cover maps, change maps, and statistical tables for the study area using data acquired from various open sources through GIS software. The data includes raster data provided by CORINE Land Cover and satellite images from different sources.

2.2.1. GIS in land coverage analysis

GIS is an acronym for Geographic Information System, which is a technology that enables you to capture, store, manipulate, analyze, and present spatial data. GIS can assist you in visualizing land data on maps, graphs, and reports, as well as performing intricate calculations and queries. GIS has the capability to combine data from various sources, such as satellite imagery, census data, zoning regulations, environmental assessments, and market trends. [4] The use of Geographic Information System (GIS) has significantly contributed to the evolution of land cover and land use data, leading to their widespread application in society. GIS technology has made it easier to collect, process, and analyze these data, resulting in higher-quality outputs. The relationship between GIS and land coverage is therefore very close, and this connection will be further explored in the remainder of this paper.

2.2.2. Maps creation from CORINE Land Cover data

Based on the data obtained from CORINE Land Cover for the study area, we have created two coverage maps for the years 2006 and 2018. Additionally, we have created a map of changes between these two periods.
CORINE Land Cover (CLC) product offers a pan-European land cover and land use inventory with 44 thematic classes, ranging from broad forested areas to individual vineyards. The product is updated with new status and change layers every six years—with the most recent update made in 2018. CLC serves a multitude of users and has nearly limitless potential and actual applications, including environmental monitoring, land use planning, climate change assessments, and emergency management. The product has a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100m for linear phenomena.
We've downloaded raster data for the entire territory of Kosovo for the years 2006 and 2018. However, as we are only interested in the municipality of Gjakova territory, we have clipped the irrelevant parts of the rasters using tools for manipulating raster data. This was done based on the shapefile of the borders of the municipality of Gjakova so that we only have the necessary data for our study area. [2]
The CORINE Land Cover data comes with symbology and labels for all 44 possible cover classes. We've applied this symbology to the rasters of the two periods to obtain land coverage maps for the municipality of Gjakova. Using the Semi-Automatic Classification Plugin and post-processing tools, we've generated classification reports for the coverage in the two years. These reports contain information on the number of pixels covered by each class, the percentage of the territory they occupy, and the total area. We've also created column graphs to visually track changes along the surfaces occupied by each class.

2.2.3. Change analysis in land coverage

When analyzing land cover, it is essential to examine the changes that have taken place over a specific period of time. The analysis of these changes is crucial in creating rules, making decisions, and planning for the most sustainable and rational use of the earth's surface.
One of the ways to analyze changes in land cover over time is through pre-created maps from CLC data. The primary tool for this analysis is geoprocessing, which provides a framework for managing and analyzing geographic data. However, geoprocessing tools can only be used for data in vector format. Therefore, the first step is to convert the data from raster to vector format using the Polygonize (Raster to Vector) tool. The resulting layers are then dissolved based on the classification codes to obtain an object for each coverage class, which may have more than one polygon. Finally, to identify areas where there is a change in coverage class from 2006 to 2018, we use the intersection tool to identify areas where polygons overlap. This process automatically identifies areas where there is a change in coverage class.
The results obtained from the analysis have been displayed in a coverage change map, with different colors representing the various changes detected. To avoid overloading the map with

too much information, we only included changes with a total area greater than $1cm^2$. The remaining changes can be viewed in a separate file accompanied by graphics for better understanding.

2.2.4. Land cover analysis from satellite images

Another way to obtain data on land cover is through satellite imagery. Nowadays, there are numerous companies and organizations that provide satellite images for either a fee or for free. In our case, we used the ESRI Satellite image with a resolution of 0.6m, which is available for free and can be found as a base map in various software. This image for our territory was captured on 28.11.2021.

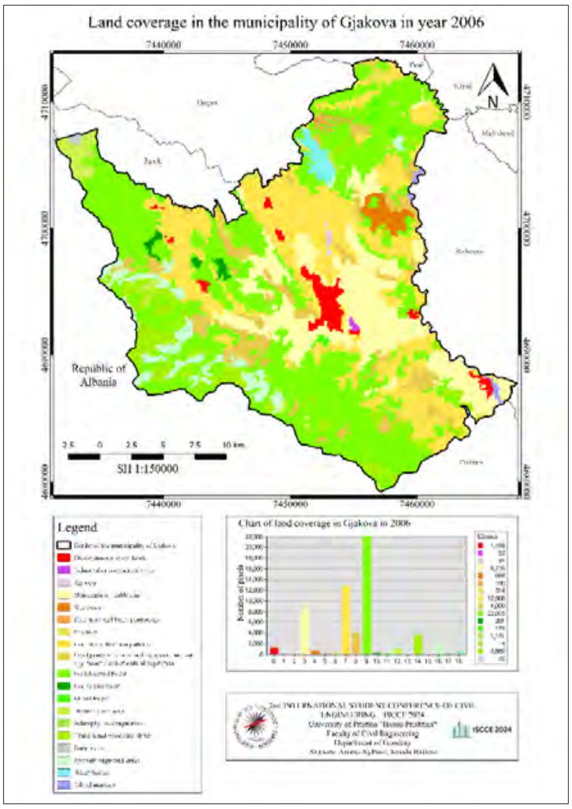
Land cover data can be extracted from satellite images by classifying image pixels based on the colors associated with the corresponding features. Although satellite images provide higher resolution coverage than the CLC data, the number of features that we can classify is smaller compared to the 44 classes of CLC. This is because the classification is carried out by detecting colors, and in nature, different phenomena and objects can be characterized by the same color.

Pixel classification in satellite imagery can be achieved through automatic or supervised classification. Unsupervised classification is calculated by software that analyzes an image without the input of user-provided sample classes. This involves grouping pixels with common characteristics. The computer uses techniques to determine which pixels are related and groups them into classes. The user can specify which algorithm the software will use and the desired number of output classes, but is otherwise not involved in the classification process. However, it is important for the user to have knowledge of the area being classified. On the other hand, supervised classification is based on the idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. The user selects training sites based on their knowledge of the area being classified. They also determine the bounds for how similar other pixels must be to group them together. These bounds are often based on the spectral characteristics of the training area and may include a certain increment based on the "brightness" or strength of reflection in specific spectral bands. The user also designates the number of classes into which the image is classified. [2]

In our research paper, we conducted a supervised classification by creating training samples and dividing the features into seven categories. For each feature, we attempted to capture all shades of colors to achieve a more precise classification. This classification was realized in a 30m resolution.

3. RESULTS AND DISCUSSION

From the data provided by CORINE Land Cover, as a result, we obtained two maps of land coverage for the territory of the municipality of Gjakova for the years 2006 and 2018, accompanied by reports on land coverage for these periods.



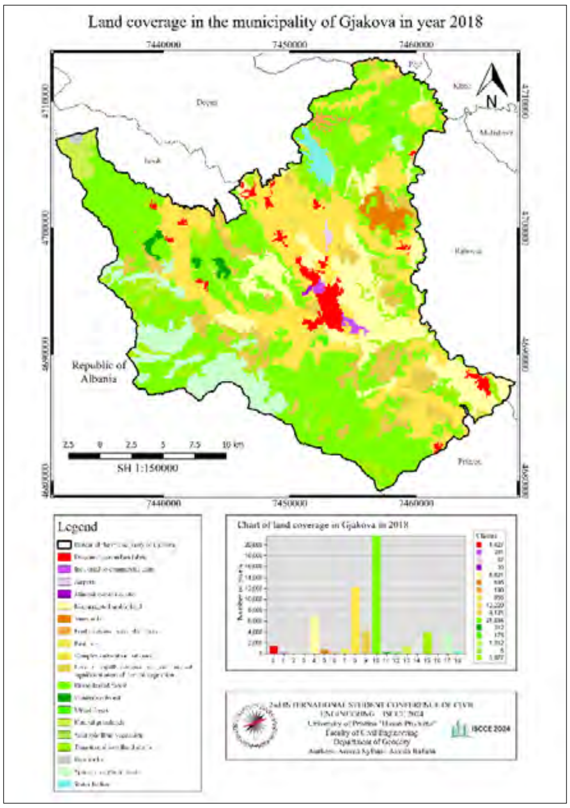


Figure 2. Land coverage map in 2006 **Figure 3.** Land coverage map in 2018

In the maps above, we can observe the changes in land coverage over a 12-year period. Also, in addition to the legend, the maps also have attached graphs about the area of the features. The attached coverage reports indicate the number of pixels covered by each class, the coverage percentage, and the total coverage area. According to the 2006 report, the three classes that have the highest percentage of land coverage in the municipality of Gjakova are Broad-leaved forest (37.78%), Complex cultivation patterns (21.94%), and Non-irrigated arable land (14.96%).

Class	Number of pixels	Percentage %	Area [m^2]
Discontinuous urban fabric	1169	2	11745057.48
Industrial or commercial units	53	0.09	532496.19
Airports	91	0.16	914285.91
Non-irrigated arable land	8735	14.96	87761400.41
Vineyards	668	1.14	6711461.42
Fruit trees and berry plantations	190	0.33	1908948.61
Pastures	314	0.54	3154788.75
Complex cultivation patterns	12808	21.94	128683230.3
Land principally occupied by agriculture with significant areas of natural vegetation	4000	6.85	40188391.71
Broad-leaved forest	22055	37.78	221588744.8
Coniferous forest	301	0.52	3024176.48
Mixed forest	175	0.3	1758242.14
Natural grasslands	1151	1.97	11564209.72
Sclerophyllous vegetation	4	0.01	40188.39
Transitional woodland-shrub	3669	6.29	36862802.3
Bare rocks	82	0.14	823862.03
Sparsely vegetated areas	2162	3.7	21721825.72
Inland marshes	184	0.32	1848666.02
Water bodies	559	0.96	5616327.74

Figure 4. Land Coverage Report 2006

Even in 2018, the three classes with the highest coverage continue to remain the same, but the percentage of their coverage changes as follows: Broad-leaved forest (37.12%), Complex cultivation patterns (20.92%), and Non-irrigated arable land (11.68%).

Class	Number of pixels	Percentage %	Area [m²]
Discontinuous urban fabric	1427	2.44	14325299.3
Industrial or commercial units	201	0.34	2017789.18
Airports	87	0.15	873371.44
Mineral extraction sites	30	0.05	301162.56
Non-irrigated arable land	6821	11.68	68474328.32
Vineyards	695	1.19	6976932.73
Fruit trees and berry plantations	190	0.33	1907362.91
Pastures	856	1.47	8593171.83
Complex cultivation patterns	12220	20.92	122673551.1
Land principally occupied by agriculture with significant areas of natural vegetation	4131	7.07	41470085.08
Broad-leaved forest	21684	37.12	217680301.3
Coniferous forest	312	0.53	3132090.67
Mixed forest	175	0.3	1756781.62
Natural grasslands	1312	2.25	13170842.8
Sclerophyllous vegetation	6	0.01	60232.51
Transitional woodland-shrub	3877	6.64	38920242.03
Bare rocks	81	0.14	813138.92
Sparsely vegetated areas	3754	6.43	37685475.52
Water bodies	561	0.96	5631739.95

Figure 5. Land Coverage Report 2018

As a result of our analysis and comparisons, we have not only obtained coverage maps but also a map that displays changes in land coverage classes during the years 2006 and 2018. This map presents the changes that occurred through feature codes and colors, making it easier to understand the changes in a visual format.

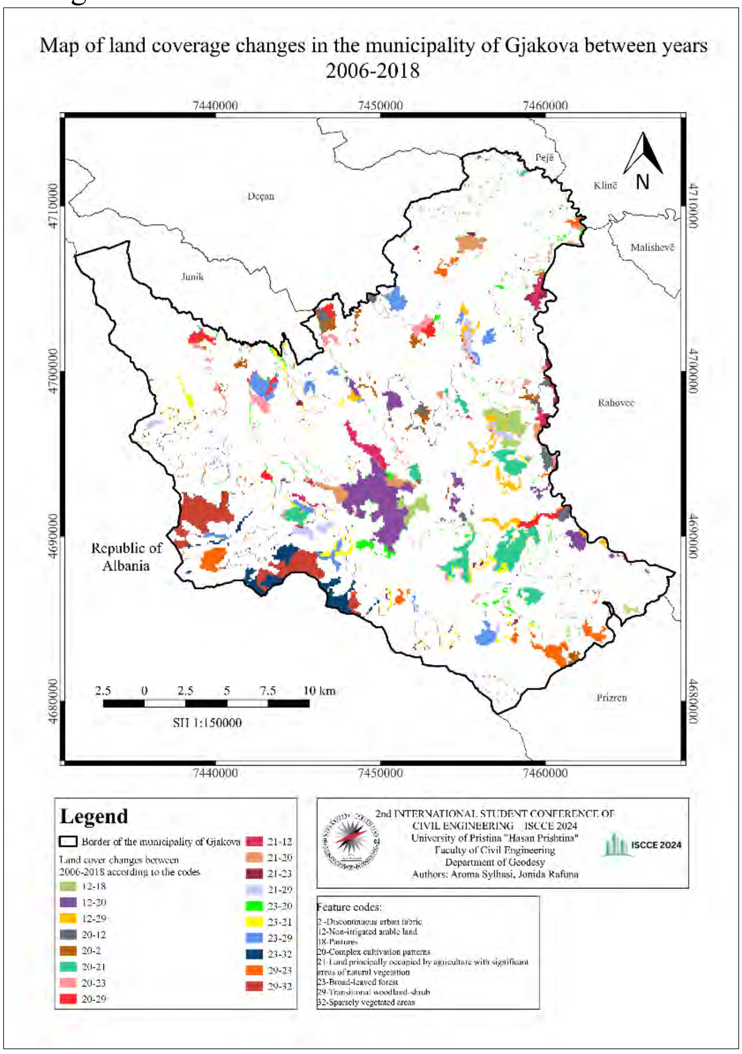


Figure 6. Land coverage changes map 2006-2018

Between the years 2006 and 2018, the land coverage in the area has undergone several changes. The most significant change was the conversion of 1412.08 hectares of non-irrigated arable land to complex cultivation patterns. This was followed by the conversion of 1051.37 hectares of land from complex cultivation patterns to land principally occupied by agriculture with significant areas of natural vegetation. The third most significant change was the transformation of 1009.87 hectares of transitional woodland-shrub into sparsely vegetated areas. Other changes in land coverage are depicted in the chart below.

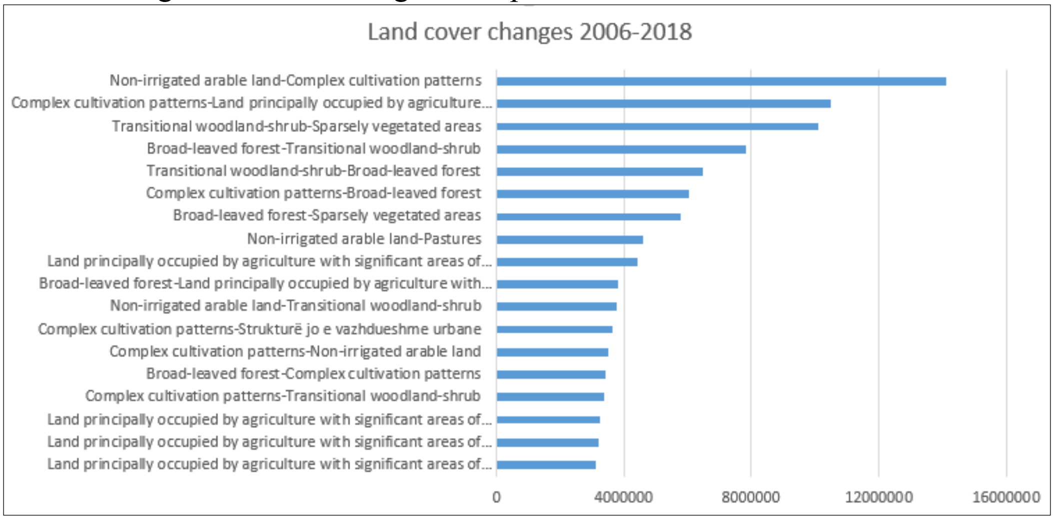


Figure 7. Chart of land cover changes

The results presented above are based on CLC data. Regarding the coverage data obtained from satellite images, as a result, we have obtained the coverage map of 2021 and the coverage report.

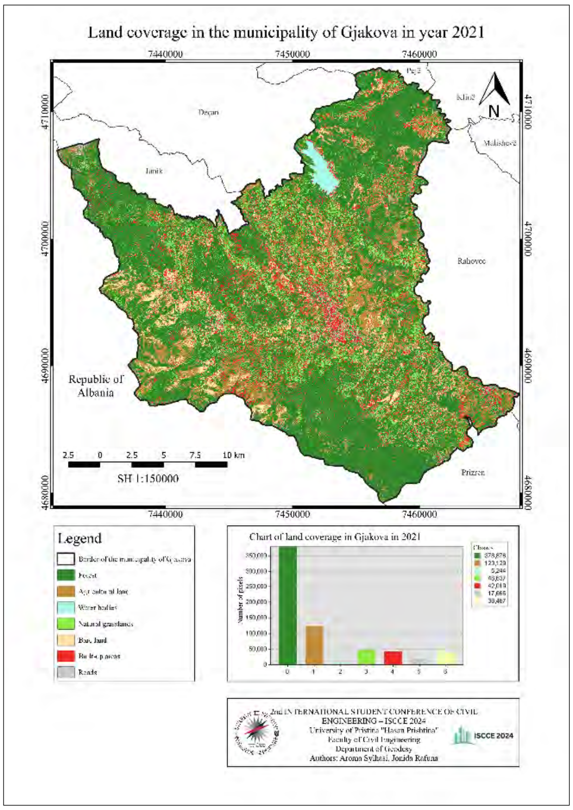


Figure 8. Land coverage map in 2021 from satellite images

Class	Number of pixels	Percentage %	Area [m^2]
Forest	378876	58.11	340944715.1
Agricultural land	123129	18.88	110801903.1
Water bodies	5244	0.80	4718995.4
Natural grassland	46637	7.15	41967922.7
Bare land	42019	6.44	37812255.2
Built-up areas	17666	2.71	15897363.1
Roads	38467	5.90	34615864.7

Figure 9. Land Coverage Report 2021

4. CONCLUSION

This study highlights the significant importance of land cover data for humanity, especially in managing natural resources and ensuring proper economic development. Therefore, the data on land coverage should be of the highest quality and as safe as possible. Comparing the data used by us, we can see that data provided by CLC has a lower spatial resolution but is classified in a higher number of classes. On the other hand, data extracted from satellite images has a higher spatial resolution, but the classification can be done in a lower number of classes, as we base it on the color of the features, and in nature, we may encounter phenomena of the same color, leading to false classifications that are challenging to eliminate. We also understand that the data analysis process is crucial to obtain accurate information, and GIS software and geoprocessing tools significantly facilitate this process. It is essential to model and style the results obtained on different maps with great care to avoid any confusion when reading them.

REFERENCES

[1] SATPALDA. Available online: https://satpalda.com/blogs/significance-of-land-use-land-cover-lulc-maps/ (accessed on 08 April 2024)

[2] Rujoiu-Mare, M., & Mihai, B. (2015). Mapping Land Cover Using Remote Sensing Data and GIS Techniques: A Case Study of Prahova Subcarpathians. Procedia Environmental Sciences, 32, 244-255. https://doi.org/10.1016/j.proenv.2016.03.029

[3] United States Environmental Protection Agency. Available online: https://www.epa.gov/report-environment/land-cover (accessed on 08 April 2024)

[4] Centers for Disease Control and Prevention. Available online: https://www.cdc.gov/gis/what-is-gis (accessed on 08 April 2024)

Types of Mobile Mapping Approaches Compared to Static Terrestrial Scanning

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This article evaluates and compares two modern spatial data acquisition technologies, mobile mapping, and static terrestrial scanning, in terms of data collection and processing effort, accuracy, and integrity of the resulting point clouds. Mobile mapping contains a group of tools that use moving media such as vehicles or pedestrian surveys to collect data. Three types of mobile mapping devices were tested: spherical imaging followed by reconstruction using SfM (Structure from Motion) to create point clouds; the Faro Orbis mobile laser scanner that rapidly collects data indoors and outdoors using a combination of laser scanning, an inertial unit (INS), and SLAM (Simultaneous Localization and Mapping); and the VMX-2HA vehicle-mounted mobile mapping system using the Global Navigation Satellite System (GNSS), INS, and SLAM for mass data collection in exterior. A Trimble X7 scanning system was used for static scanning, and the resulting reference point clouds were created by combining several survey stations. The results show the differences between the types of mobile mapping methods and their advantages, also compared to static scanning. SfM from spherical imagery is suitable for creating models with lower accuracy and density requirements for point clouds, while Faro Orbis and VMX-2HA provide the flexibility to collect data with varying levels of accuracy and detail in interiors and exteriors. The choice between these methods depends on the specific requirements of the project. This paper provides an overview and comparison of key parameters to facilitate the selection of the appropriate technology for a given application.

Keywords: *Mobile mapping, SfM, SLAM, GNSS/INS*

1. INTRODUCTION

Spatial data acquisition plays a key role in various fields, including urban planning [1], architecture, heritage conservation, and territorial area management. For this purpose, various methods are commonly used. This paper deals with a comparison analysis of terrestrial laser scanning and mobile mapping methods, focusing on the difficulty of data collection and processing, accuracy and integrity of the resulting point clouds.

Mobile mapping uses a variety of tools as dynamic platforms, e.g. vehicles or persons. The device can include a digital camera, a laser scan head, an INS system, an odometer, and a GNSS system that is used for data collection [2]. In this article, three types of mobile mapping devices were tested: spherical imagery in conjunction with structure-from-motion (SfM) [3] reconstruction, a Faro Orbis mobile laser scanner integrating laser scanning, an inertial unit (INS) and simultaneous localization and mapping (SLAM), and a vehicle-mounted mobile mapping system VMX-2HA [4] using global navigation satellite system (GNSS), INS and SLAM [5] technologies.

In contrast to these mobile methods, static scanning using the Trimble X7 [6] scanning system, which generated point clouds of reference points using a combination of measurement stations, served as a benchmark. By carefully comparing these methodologies, this research highlights the applicability of each approach and allows surveyors to discern the most appropriate technology for their specific project requirements.

2. MATERIALS AND METHODS

2.1. Materials

Four devices were used for this project: a static scanner, a 360 ° camera, and two mobile laser scanners.

2.1.1. Static scanning device

The first, the static scanner, was used to create reference point clouds. It was measured with Trimble X7, which enables fast scanning, transfer of the device during measurement is very simple and fast and enables automatic connection of survey stations. Its measuring range is 0.6-80 m with an accuracy of 2 mm.

Figure 1. Trimble X7 with controller.

2.1.2. Mobile scanning devices

A 360-degree commercial Insta360 X3 is the first device in this project used for mobile mapping. The camera consists of two fisheye lenses – the equivalent 35mm focal length is 6.7 mm, and the sensor size is ½". The camera can take 360 videos with 5.7K resolution (5760x2880).
The second mobile mapping device used in this project is Faro Orbis. This handheld scanner was released in October 2023. It is a combination of a mobile scanner (GeoSLAM) with a stationary flash scanning feature. The accuracy given by the manufacturer is 5 mm. The scanner captures 640,000 points per second.
And the last mobile device is the Riegl VMX-2HA. This mobile scanner is placed on the roof of the car. It includes two laser heads with a speed of 1 million points per second, a LadyBug panoramic camera for cloud coloration, positionable cameras, IMU and GNSS unit. Vehicle speed during scanning is typically around 50 km/h, point density is around 8000 pts/m2. The accuracy claimed by the manufacturer using IMU and GNSS is in the range of 2-3 cm.

Figure 2. Mobile mapping devices (Insta360 X3, Faro Orbis, Riegl VMX-2HA).

(

1)

2.2. Case Study

The devices were tested in three different places, each place was measured with the terrestrial static scanner but only with one type of mobile mapping device.
The first test object was the interior of an ordinary family house with 6 rooms. This object was measured with the Insta360 camera. A total of 12 code targets were placed in pairs and the length between each pair was measured. These targets were used as control points. The accuracy of the reference point cloud is 2.1 mm.
Data collection with Faro Orbis was carried out in the historic administration building, in the basement. The reference clouds were measured with a deviation of 1.3 mm.
Compared to previous devices, the Riegl VMX-2HA is designed for outdoor measurements. The measurements were carried out in Pilsen, North Suburbs, where a test base for this device was built. The base contains the high-precision control points to which both mobile scanner and static scanner measurements were tied. The accuracy of the reference cloud is 1.9 mm.

2.3. Measurement methods

To reconstruct a 3D model of an area using SfM, it is necessary to have multiple overlapping images taken from different angles. The other condition is to measure in a heterogeneous environment. SfM identifies significant points and then uses these points to reconstruct the interior and exterior camera orientation elements and to reconstruct 3D points of interest area.
The first test area was measured with an Insta360 camera mounted on a selfie stick. The rooms were then walked with the camera at eye level and the data was recorded via video.
SLAM technology works on a similar principle to SfM, but, in addition, INS and often GNSS data are measured to locate the position of the device.
After a basic initialization of the mobile systems, the area was surveyed. To increase the accuracy of SLAM technology, measurement was started and finished at the same location.
Measuring with the Trimble X7 terrestrial static scanner is very easy. After placing the device on the first survey station, it is not necessary to accurately level the device, the measurement can be started. This procedure is repeated throughout the object of interest. The spacing of the

measuring stations was about 30 m. The linking of points to clouds is done automatically 'cloud to cloud' immediately after measurement.
The steps of each method and their difference are shown in Figure 3.

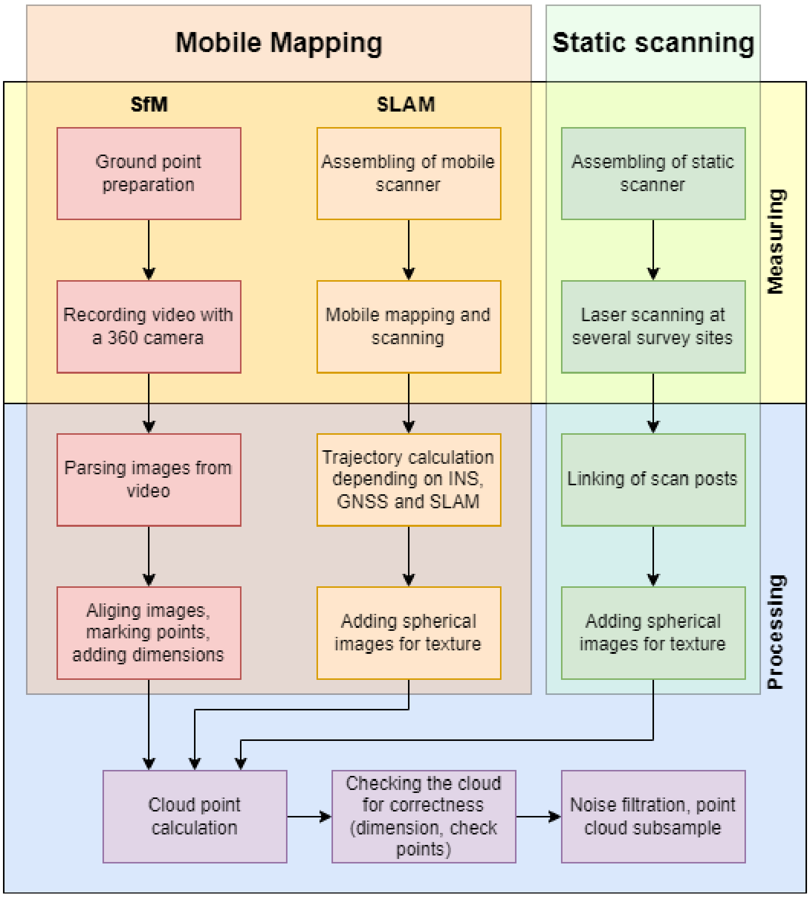

Figure 3. Steps of mobile mapping and static scanning processing.

2.4. Processing

3D reconstructions of areas are processed using two different methods, SfM and SLAM. Softwares were used for this purpose: Agisoft Metashape, Faro Connect, and Riegl RiPROCESS.
Firstly, the recorded INSV video from Insta360 X3 has to be edited in Insta360 Studio, frames using INS data from the camera are stabilised, videos from two lenses are stitched in one, and the video is exported to mp4 format. The export is followed by frame separation; frames with one-second spacing are extracted and saved as individual images. Photos then proceed in the software Agisoft Metashape; an important note is to set in this software these images as spherical and create a clipping mask (remove surveyor). The process then proceeds like any other photogrammetric project. The photos are aligned, the measured distances between control points are entered, the points are adjusted, and the point cloud is calculated (Figure 5).
For the remaining mobile devices, the basic processes are similar to each other. In the Faro Connect and Riegl RiPROCESS software, the SLAM and GNSS/INS technologies first determine the basic measurement trajectory. Depending on this trajectory, 3D points of the surrounding environment are then calculated. After this process, the ground control points can be inserted, and the adjustment is performed.

A comparison of mobile mapping with static scanning was performed in CloudCompare software, clouds were linked via ground control points, and cloud distances were calculated.

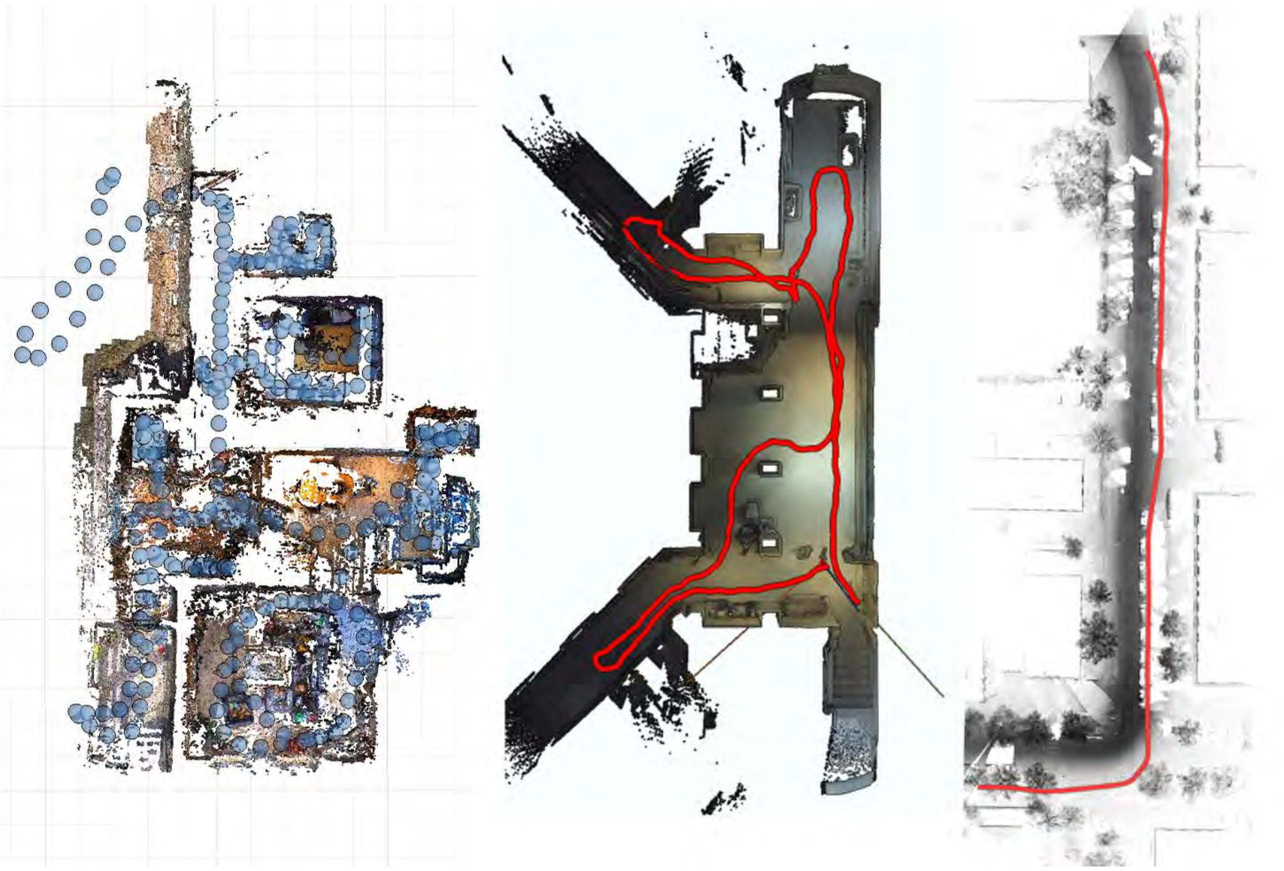

Figure 5. Point clouds with Insta360 camera position (left) and trajectories (middle Faro Orbis, right VMX-2HA)

3. RESULTS AND DISCUSSION

This section is dedicated to comparing mobile methods with a static method and with each other. The values compared are the cost of the device, measuring time, processing time, and cloud accuracy. The values are shown in Table 1. Calculations were performed on a PC consisting of an Intel Core i9-7900, RAM 128 GB RAM, and a Nvidia GeForce RTX 2080 Ti.

Table 1. Comparison of mobile mapping methods with terrestrial static scanning

	Measurement time	Manual processing + calculation time	3D standard deviation	Static scanner measurement + time calculation	Price of device
Insta360 X3 (Fig. 6)	10 min	15 min + 3 h	35 mm	2 + 1 h	470 €
Faro Orbis (Fig. 7)	8 min	5 min + 1 h	4 mm	1 + 0.75 h	47 000 €
Riegl VMX-2HA (Fig. 8)	2 min	10 min + 1 h	17 mm	2 + 1 h	590 000 €
Trimble X7	6 min/station	1 min + 0.15 h/st.	-	-	28 000 €

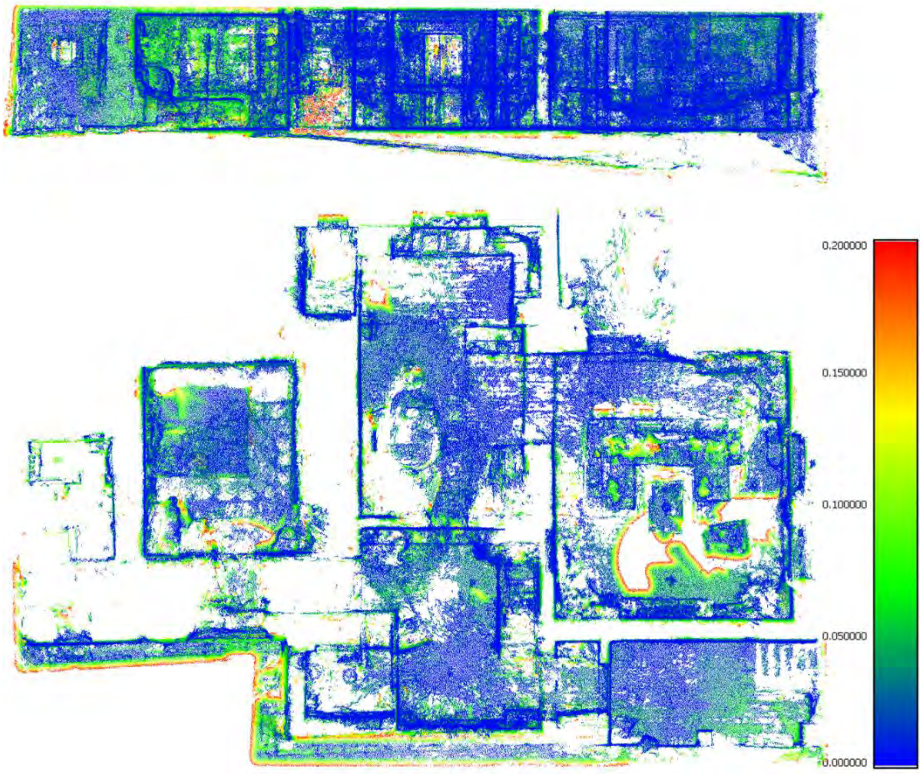

Figure 6. Comparison of the SfM method using Insta360 X3 and static scanning

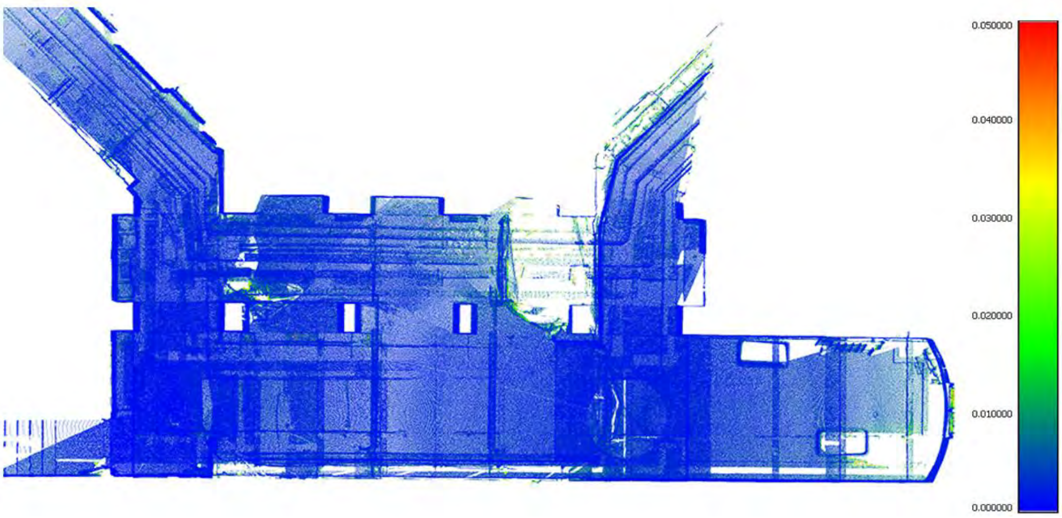

Figure 7. Comparison of the SLAM method using Faro Orbis and static scanning

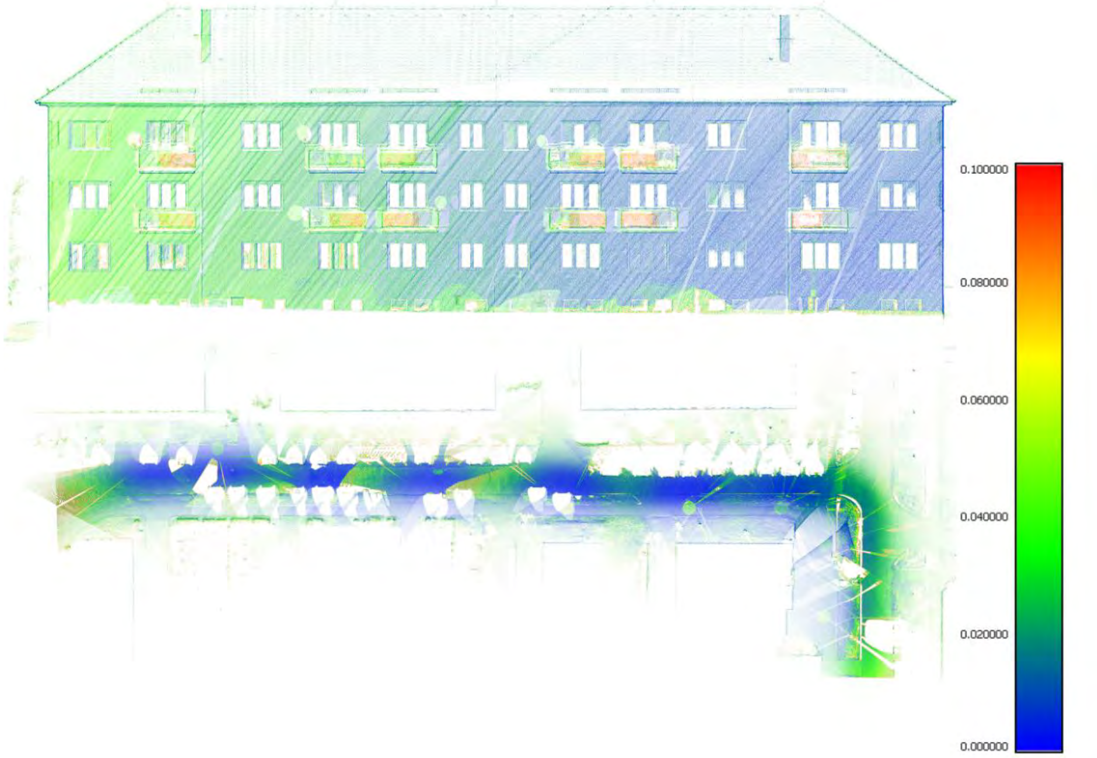

Figure 8. Comparison of the SLAM method using Riegl VMX-2HA and static scanning

The quality and accuracy of SfM depend very much on image quality. In this case, in the family house, light conditions were not ideal. The frames extracted from the video are very poor and this was reflected in the overall quality of the point cloud (Figure 6). Moreover, this method requires high attention in processing and the experience of the operator. Outputs from 3D point reconstruction can often be deformed, and it may be appropriate to divide the object into several parts.

As can be seen, using mobile laser scanning with the SLAM method is more accurate. In the first case of this method, using Faro Orbis in the interior, the deviations are very close to zero (Figure 7), and the quality of the data is very good.

The accuracy is slightly worse when using the Riegl VMX-2HA mobile mapping system, but in this case, long distances are measured, and the system uses GNSS measurements to adjust the trajectory. The error from the GNSS measurement is then reflected in the overall cloud point accuracy. Figure 8 then shows the systematic deviation caused by this error.

4. CONCLUSION

The study compared mobile mapping methods (SfM and SLAM) with static terrestrial scanning. The key factors considered were equipment cost, measurement time, processing time, and cloud accuracy.

SfM using a spherical camera (Insta360 X3) offers a low-cost solution but provides lower accuracy and requires significant processing experience. On the contrary, mobile laser scanning with SLAM (Faro Orbis and Riegl VMX-2HA) provides higher accuracy but is associated with higher costs.

However, in general, mobile mapping offers a faster measurement method than terrestrial static scanning, resulting in a large cost reduction.

The optimal choice ultimately depends on the project requirements. This article provides valuable insights and comparisons of key parameters to help select the most appropriate technology for a given application.

REFERENCES

[1] Wang, Chen, Zhu, Liu, Li, & Zheng. (2019). A Survey of Mobile Laser Scanning Applications and Key Techniques over Urban Areas. *Remote Sensing*, 11(13). https://doi.org/10.3390/rs11131540

[2] Schwarz, K. P., & El-Sheimy, N. (2004). Mobile Mapping Systems -- State Of The Art And Future Trends. Int. Arch. *Photogramm. Remote Sens.* Spat. Inf. Sci., 35. https://www.researchgate.net/publication/2945448_Mobile_Mapping_Systems_--_State_Of_The_Art_And_Future_Trends

[3] Zahradník, D., & Vynikal, J. (2023). Possible approaches for processing of spherical images using SfM. *Stavební obzor - Civil Engineering Journal,* 32(1), 1-12. https://doi.org/10.14311/CEJ.2023.01.0001

[4] Grešla, O., & Jašek, P. (2023). MEASURING ROAD STRUCTURES USING A MOBILE MAPPING SYSTEM. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-5/W2-2023, 43-48. https://doi.org/10.5194/isprs-archives-XLVIII-5-W2-2023-43-2023

[5] Cole, D. M., & Newman, P. M. (2006). Using laser range data for 3D SLAM in outdoor environments. Proceedings 2006 IEEE International Conference on Robotics and Automation, 2006. ICRA 2006, 1556-1563. https://doi.org/10.1109/ROBOT.2006.1641929

[6] Jang, A., Jeong, S., Park, M. J., & Ju, Y. K. (2023). Structural evaluation by reverse engineering with 3D laser scanner. Ce/papers, 6(5), 308-314. https://doi.org/10.1002/cepa.1989

Automatic transformation of map projection with QGIS. Case study: RKS's borders in different Map Projections

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The cartographic representation of country borders is the most crucial aspect of mapping, decision making processes and spatial understanding. With the Republic of Kosova's rather complex geopolitical history, it provides a compelling plane of study for examining the transformation of the border across different map projections. This study tends to analyze the different variations of Kosovo's border when portrayed on diverse map projections and evaluating the implications for special perception. While utilizing Quantum Geographic Information Systems (QGIS) software, this research compares Kosova's borders, their Municipalities and their Cadastral Zones within, undergone different map projections. The study elucidates linear distortions, angular deformations and area distortions that arise from each projection's background mathematical framework. The findings of this research contribute to cartographic theory and practical use for applications, filling the need for critical engagement with map projections in spatial analysis and decision-making processes.

Keywords: *Republic of Kosovo, Map projections, QGIS, automatic transformation.*

1. INTRODUCTION

Map projections are systematic representations of all or part of the surface of a round body, especially the Earth, on a plane. Since features of the earth can't be displayed without distortion, the cartographer's job is to choose which characteristic is to be shown accurately at the expense of others, or a compromise of several characteristics. Distortions can be apparent based on the surface area in question. For small areas such as countries/cities, distortions might not be visible but if the surface area in question is a large amount such as continents/the earth, the distortions are apparent. So based on which feature we want to preserve, cartographic projections based on the way of presentation of the cartographic grid are classified as:

- Conical,
- Pseudo Conical,
- Cylindrical,
- Pseudo Cylindrical,
- Azimuthal,
- Pseudo Azimuthal
- Poly Conical and
- Axonometric.

1.1. Kosovo's Geographical position

Kosovo has a central geographical position in the Balkan Peninsula that has a connecting role between the northern and southern, western and eastern parts, but also of Central Europe. Its natural conditions are quite favorable. They make Kosovo a crossroads between the Adriatic, the Pannonian Plain and the Aegean Sea. Kosovo lies between 41°50'58" and 43°51'42" north latitude and 20°01'30" and 21°48'02" east longitude with a surface area of 10,887 km².

1.2. Kosovo's State Coordinate Reference System (CRS) - KOSOVAREF01 (*EPSG 9141*)

The Republic of Kosova has adopted its national CRS entitled "KOSOVAREF01" on year 2001, which is based on the ETRS89 geodetic datum. based on ETRS89 datum and Gauss-Krüger projection with -1dm/km distortion (scale factor 0.9999) along the central meridian (21°E), equator as origin of latitude, Greenwich as origin of longitudes, as well 7500000m false easting and 0m false northing values (Idrizi et all 2009). CRS "KOSOVAREF01" is the legal and technical base for all official geodetic, topographic, cartographic, and cadastral data in Kosova. The state CRS of Kosova "KOSOVAREF01" was officially recognized and registered in EPSG database with its own code 9141. (Figure 1.1)

2. USING DIFFERENT MAP PROJECTIONS ON THE RKS'S BORDERS

In this chapter the Republic of Kosova's Municipal borders will undergo the main categories of projections previously mentioned in the first chapter. For each category there will be two different types of Map Projections.

2.1. Conical Projections

Conical map projections are a category of map projections that project data from a three-dimensional spherical surface onto a two-dimensional conical surface. The cone is then unwrapped onto a flat plane to create a map. Normal conic projections are distinguishable from the use of concentric circles centered at the apex of the cone for parallels of latitude and proportionally spaced straight radii of these circles that are interrupted at the apex of the cone for meridians.

2.1.1 Albers Equal-Area Conic Projection (*ESRI:102013*)

Is a conic, equal-area projection. Parallels are unequally spaced arcs of concentric circles, more closely spaced at the north and south edges of the map. Meridians are equally spaced radii of the same circles, cutting parallels at right angles. There is no distortion in scale or shape along two standard parallels, or along just one. Poles are arcs of circles. Was presented by Albers in 1805. (*Figure 2.1.*)

2.1.2. Lambert Conformal Conic Projection (*ESRI:102014*)

Is a conic, conformal projection. Parallels are unequally spaced arcs of concentric circles, more closely spaced near the center of the map. Meridians are equally spaced radii of the same circles, thereby cutting parallels at right angles. Scale is true along two standard parallels, normally, or along just one. Pole in same hemisphere as standard parallels is a point; other pole is at infinity. Used for maps of countries and regions with predominant east-west expanse. Was presented by Lambert in 1772. (Figure 2.2.)

2.2.Cylindric Projections

The regular cylindrical projections consist of meridians which are equidistant parallel straight lines, crossed at right angles by straight parallel lines of latitude, generally not equidistant. Geometrically, cylindrical projections can be partially developed by unrolling a cylinder which has been wrapped around a globe representing the Earth, touching at the Equator, and on which meridians have been projected from the center of the globe.

2.2.1. Cylindrical Equal-Area Projection (*ESRI:54034*)

Is a cylindrical, equal-area projection. Meridians on normal aspect are equally spaced straight lines. Parallels on normal aspect are unequally spaced straight lines, closest near the poles, cutting meridians at right angles. On normal aspect, scale is true along Equator, or along two parallels equidistant from the Equator. Is an orthographic projection of sphere onto cylinder. There is substantial shape and scale distortion near points 90° from central line. Normal and transverse aspects were presented by Lambert in 1772. (Figure 2.3.)

2.2.2. Equidistant Cylindrical Projection (*ESRI:54002*)

Is a cylindrical, neither equal-area nor conformal projection. Meridians and parallels are equidistant straight lines, intersecting at right angles. Poles are shown as lines.
Used for world or regional maps due to its very simple construction and used only in spherical form. Was presented by Eratosthenes (B.C.) or Marinus (A.D. 100). (Figure 2.4.)

2.3.Azimuthal Projections

The azimuthal projections are formed onto a plane which is usually tangent to the globe at either pole, the Equator, or any intermediate point. Azimuthal projections are characterized by the fact that the direction, or azimuth, from the center of the projection to every other point on the map is shown correctly. In regular azimuthal projections, parallels are represented as concentric circles from the projection center, at different distances between them depending on the mode design. As you move away from the pole, the distance between the parallels may increase, decrease, or remain constant. Unlike parallels, meridians are represented as lines rights that start-stop at the pole of projection and continue to the equator.

2.3.1. Lambert Azimuthal Equal-Area Projection (*ESRI:102017*)

Lambert azimuthal is an azimuthal, equal-area projection. Not a perspective projection. All meridians in the polar aspect, the central meridian in other aspects, and the Equator in the equatorial aspect are straight lines. The outer meridian of a hemisphere in the equatorial aspect (for the sphere) and the parallels in the polar aspect (sphere or ellipsoid) are circles. All other meridians and parallels are complex curves. Scale decreases radially as the distance increases from the center, the only point without distortion. Scale increases in the direction perpendicular to radii as the distance increases from the center. Directions from the center are true for the sphere and the polar ellipsoidal forms. Point opposite the center is shown as a circle surrounding the map. Used for maps of continents and hemispheres. Was presented by Lambert in 1772. (Figure 2.5.)

2.3.2. Azimuthal Equidistant Projection (*ESRI:54032*)

Is an azimuthal, neither equal-area, conformal or a perspective projection. Distances measured from the center are true. Distances not measured along radii from the center are not correct. The center of projection is the only point without distortion. Directions from the center are true. All meridians on the polar aspect, the central meridian on other aspects, and the Equator on the equatorial aspect are straight lines. Parallels on the polar projection are circles spaced at true intervals (equidistant for the sphere). The outer meridian of a hemisphere on the equatorial aspect (for the sphere) is a circle. All other meridians and parallels are complex curves. Point opposite the center is shown as a circle (for the sphere) surrounding the map. Used in the polar aspect for world maps and maps of polar hemispheres. Used in the oblique aspect for atlas maps of continents and world maps for aviation and radio use. Known for many centuries in the polar aspect. (Figure 2.6.)

2.4.Pseudo Conical Projections

Pseudo conic projections showcase parallels as concentric circles like in the case of straight conical projections, while the meridians are presented as symmetrical curves against the central meridian, which is the only line of the cartographic network that is presented as right. Characteristic of these projections is that the poles are presented as points.

2.4.1. Bonne Projection (*ESRI:54024*)

Bonne's is a pseudo conic projection. Central meridian is a straight line. Other meridians are complex curves. Parallels are concentric circular arcs, but the poles are points. Scale is true along the central meridian and along all parallels. No distortion along the central meridian and along the standard parallel. Used for atlas maps of continents and for topographic mapping of some countries. Sinusoidal projection is equatorial limiting form of Bonne projection. Used considerably by Bonne in mid-18th century but developed by others during the early 16th century. (Figure 2.7)

2.5.Pseudo Cylindrical Projections

Pseudo-cylindrical map projections are a category of map projections that aim to balance the preservation of certain properties, such as shape, area, distance, or direction, across a map. Unlike true cylindrical projections, which have straight meridians and parallels, pseudo-cylindrical projections often feature curved meridians to minimize distortion.

2.5.1 Mollweide Projection (*ESRI:54009*)

Mollweide is a pseudo cylindrical, equal-area projection. Central meridian is a straight line; 90th meridians are circular arcs; all other meridians are equally spaced elliptical arcs. Parallels are unequally spaced straight lines, parallel to each other. Poles are points. Scale is true along latitudes 40°44' N. and S. Used for world maps with single central meridian or in interrupted form with several central meridians. Inspiration for several other projections. Presented by Mollweide in 1805. (Figure 2.8)

2.6.Polyconic Projection (*ESRI:54021*)

The polyconic projection is neither conformal nor equal area. Its scale is true along each parallel and along the central meridian, but no parallel is "standard". Parallels of latitude (except for Equator) are arcs of circles but are not concentric. Central meridian and Equator are straight lines, all other meridians are complex curves. Free of distortion only along the central meridian. Was apparently originated about 1820 by Hassler. (Figure 2.9)

3. RESULTS AND DISCUSSION

After performing each projection individually, we are presented with these maps. In each projection, the respected municipal area is extracted along with its border perimeter for further analysis. The following maps are corresponded to each projection mentioned previously based on Figure Numbers.

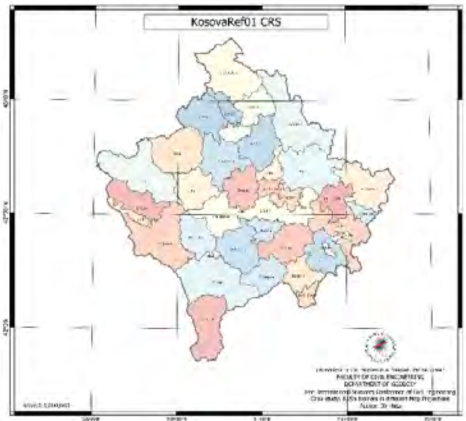

Figure 1. KosovaRef01 CRS.

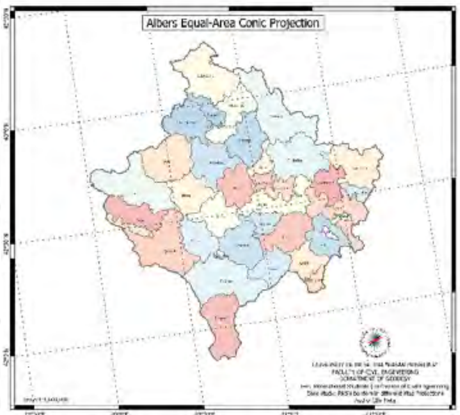

Figure 2. Albers Equal-Area.

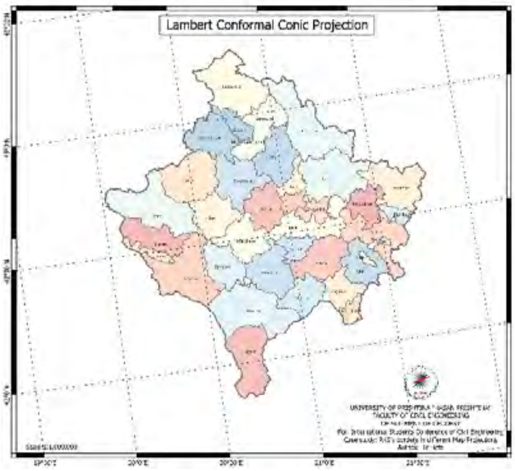

Figure 3. Lambert Conformal

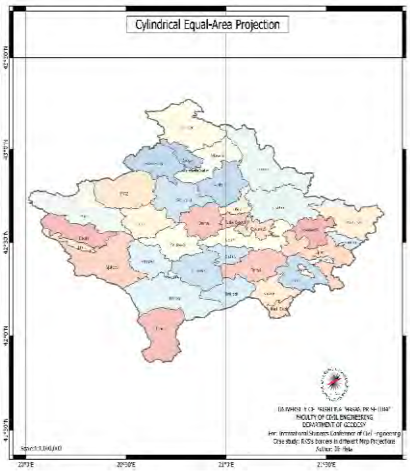

Figure 4 Cylindrical Equal-Area.

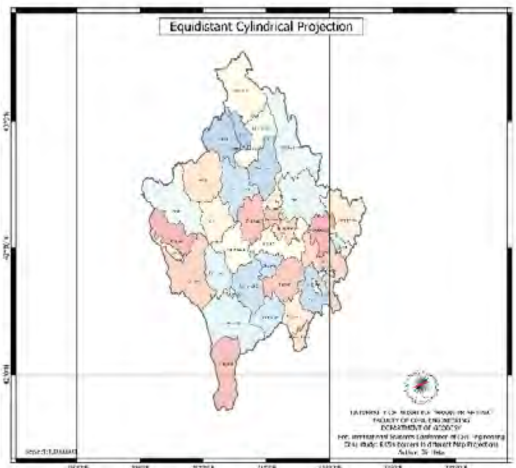

Figure 5. Equidistant Cylindrical.

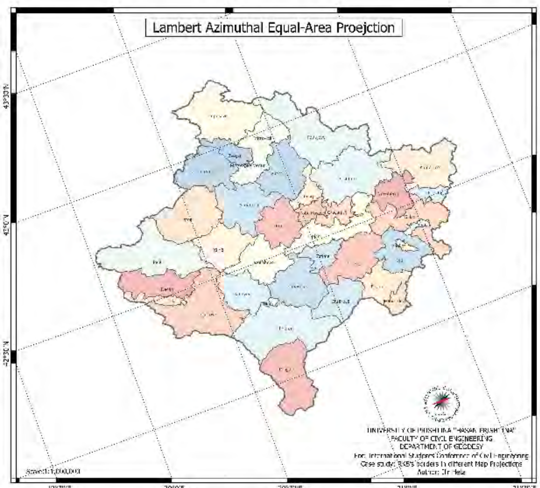

Figure 6 Lambert Azimuthal Equal-Area.

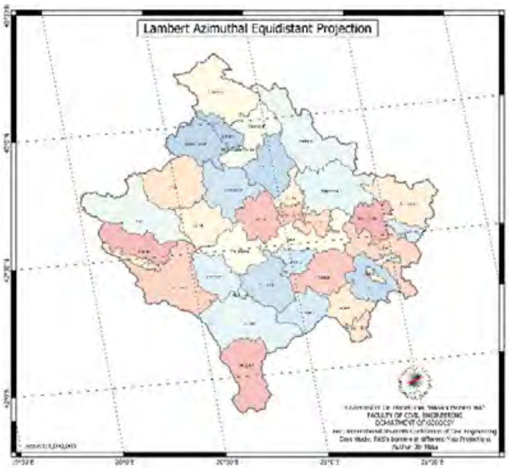

Figure 7. Lambert Azimuthal Equidistant.

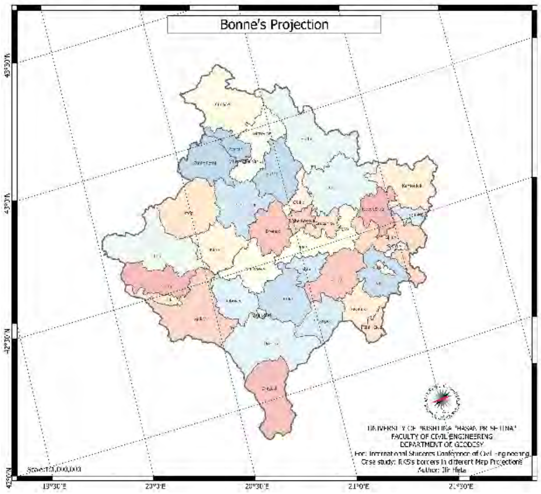

Figure 8 Bonnes.

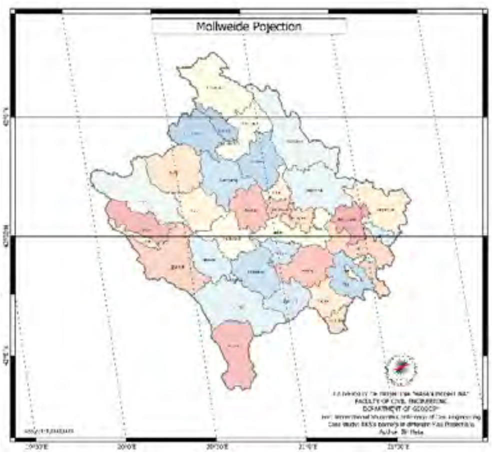

Figure 9. Mollweide.

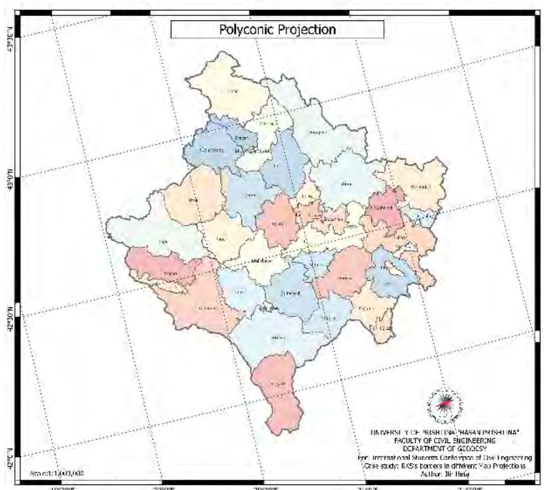

Figure 10. Polyconic

The extraction of the Municipality properties such as Area and Perimeter in the previously mentioned projections, gave its distortions between them. To find its distortions, the areas and perimeters in the default CRS of Kosovo were extracted and compared them with the results from each projection. The following values are the differences between areas referred to State Map Projection of the Republic of Kosova KOSOVAREF01 (*EPSG 9141*) expressed in ***m²/km²*** for areas and ***m/km*** for the border lines of municipalities (**Table 1a and Table 1b).**

4. CONCLUSION

In conclusion, map projections play a crucial role in representing the Earth on a flat surface. Each map projection preserves certain characteristics based on the surface area in question so understanding the trade-offs between them is essential for task completion, whether it's spatial analysis, thematic mapping, or a nation-wide project. As technology is advancing, cartographic representation evolves, and new techniques emerge that offer improved flexibility and accuracy. However, no known projection can perfectly represent the Earth's surface without distortion, so the goal is the choice of a map projection that suits the specific task's needs.

REFERENCES

[1] Bandrova T. 2008. Kartografia 1, Kartni Proekcii. Sofia. Bugaria.
[2] Grafarend E., Krumm F. 2006. Map projections. Cartographic information systems. Springer. https://www.springer.com/gp/book/9783540367024
[3] Idrizi B. 2009 Most common state map projections for the Republic of Kosova. ICA conference proceedings. Chile. https://icaci.org/files/documents/ICC_proceedings/ICC2009/html/nonref/10_2.pdf
[4] Idrizi B. 2010. Hartografia Matematike, Prishtinë, Kosovë.
[5] Idrizi B. 2022. International EPSG coding of the state coordinate reference system of the Republic of Kosova. ICC&GIS 2022. Nessebar. Bulgaria. https://iccgis2020.cartography-gis.com/8ICCGIS-Vol1/8ICCGIS_Proceedings_Vol1_(49).pdf
[6] Idrizi B. 2023. State Coordinate Reference Systems of the Republic of Kosova and the Republic of North Macedonia in international EPSG and PROJ databases. Proceedings of the international scientific conference. Tirana. Albania. Full paper in PDF
[7] Idrizi B., Meha M., Ismaili F., Nikolli P. 2012. Calculation of the national area of the Republic of Kosova. FIG WW 2012. Rome. Italy. https://www.fig.net/resources/proceedings/fig_proceedings/fig2012/papers/ts02m/TS02M_idrizi_meha_et_al_6050.pdf
[8] Idrizi B., et all. 2018. Study of Length Differences from Topography to Map Projection within the State Coordinate Systems for some Countries on the Balkan Peninsula. FIG conference. Istanbul. Turkey. https://www.fig.net/resources/proceedings/fig_proceedings/fig2018/papers/ts08e/TS08E_idrizi_pashova_et_al_9602.pdf
[9] Institute for Environment and Sustainability. 2001. Map projections for Europe. Joint Research Centre. European Comission. https://op.europa.eu/en/publication-detail/-/publication/96743011-0b4f-11ea-8c1f-01aa75ed71a1
[10] Kennedy M., Kopp S. 2000. Understanding map projections. USA. https://giscourses.cfans.umn.edu/sites/giscourses.cfans.umn.edu/files/understanding_map_projections.pdf
[11] Salomon D. 2006. Transformations and projections in computer graphics. Springer. https://www.springer.com/gp/book/9781846283925
[12] Shehu A., Samimi E. 1980. Hartografia (hartografi matematike). Tirane. Shqiperi.
[13] SNYDER J. (1987) Map Projections-A Working Manual, *Washington DC*, U.S.A.

Annex 1: **Table 1a.** Differences of Areas (A) and Border lines (B) of each used map projection compared to Kosovaref01 CRS (EPSG 9141)

Municipalities	Kosovaref01 *EPSG: 9141*		Albers Equal-Area Conic *ESRI:102013* to EPSG9141		Lambert Conformal Conic *ESRI:102014* to EPSG9141		Cylindrical Equal-Area *ESRI:54034* to EPSG9141		Equidistan Cylindrical *ESRI:54002* to EPSG9141	
	Area *(km²)*	**B**order *(km)*	A *(m²/km²)*	B *(m/km)*	A *(m²/km²)*	B *(m/km)*	A *(m²/km²)*	B *(m/km)*	A *(m²/km²)*	B *(m/km)*
Deçan	293.97	121.25	118.24	0.18	2567.87	1.29	104.90	103.71	320695.76	169.18
Pejë	602.58	173.46	124.40	0.12	1894.72	0.96	111.27	82.99	319402.99	159.25
Gjakovë	586.62	175.48	152.53	0.12	3541.00	1.72	139.21	76.13	322411.51	156.68
Dragash	433.84	106.37	195.68	0.35	5860.46	2.94	182.50	11.59	326438.40	124.61
Prizren	626.86	158.43	198.21	0.11	4703.71	2.33	184.89	69.03	324401.02	154.58
Gjilan	391.84	229.82	175.02	0.00	3386.86	1.71	161.98	50.13	322071.26	142.41

Viti	269.69	143.36	189.75	0.04	3991.46	1.98	176.62	57.22	323141.39	147.37
Istog	454.36	107.73	171.07	0.09	1392.17	0.71	157.16	78.76	318315.53	154.46
Zubin Potok	334.38	111.16	192.21	0.08	564.25	0.31	179.23	55.58	316635.64	141.23
Prishtinë	523.14	181.28	198.45	0.03	1858.57	0.95	185.49	46.19	319142.37	139.26
Kaçanik	211.28	101.71	203.73	0.07	4529.65	2.25	190.53	63.10	324077.46	150.76
Shtërpcë	247.70	79.63	212.57	0.17	4551.18	2.27	199.30	75.58	324094.16	159.41
Zveçan	123.01	77.34	205.24	0.10	356.09	0.16	192.30	67.96	316186.87	145.95
Leposaviq	539.05	149.36	205.46	0.07	479.98	0.23	192.60	93.67	314495.78	159.14
Podujevë	632.59	192.13	205.39	0.08	619.85	0.31	192.54	18.59	316704.62	124.17
Lipjan	338.41	189.07	207.97	0.17	2884.85	1.43	194.88	84.90	321059.84	161.51
Ferizaj	344.61	112.47	208.42	0.13	3734.87	1.87	195.25	73.51	322627.92	156.04
Shtime	134.42	83.32	212.73	0.35	3377.33	1.69	199.57	123.01	321961.76	180.90
F. Kosova	84.09	65.54	212.54	0.08	2328.30	1.16	199.54	56.62	320002.48	148.72
Kastriot	104.84	82.66	212.16	0.05	1855.74	0.91	199.17	44.20	319102.16	138.18
Drenas	275.63	98.51	210.39	0.00	2345.11	1.17	197.31	33.86	320038.42	132.42
Skenderaj	374.37	135.07	202.46	0.03	1635.27	0.82	189.41	32.81	318702.56	130.87
Klinë	309.02	110.68	186.05	0.10	2338.15	1.16	172.88	67.58	320088.33	150.16
Junik	77.76	83.88	110.28	0.17	2886.65	1.44	97.06	99.02	321312.48	167.55
Vushtrri	344.85	118.09	212.42	0.07	1243.64	0.59	199.46	40.03	317916.84	134.09
Therandë	361.04	115.23	209.63	0.12	3849.83	1.88	196.36	70.90	322833.83	155.19
Mitrovicë	330.72	144.66	210.94	0.10	540.19	0.29	198.05	53.26	316536.23	140.63
Artanë	203.98	111.23	180.95	0.06	2619.67	1.31	167.96	23.32	320631.98	128.50
Rahovec	275.90	103.16	187.69	0.03	3526.07	1.77	174.40	43.94	322297.41	138.59
Malishevë	306.42	121.40	201.48	0.10	3010.04	1.50	188.31	68.97	321309.25	152.31
Kamenicë	416.61	166.97	149.14	0.08	2225.79	1.15	136.24	69.51	319969.61	151.92
Hani i Elezit	83.11	57.80	200.90	0.11	5072.79	2.52	187.63	35.48	325051.18	136.79
Graçanicë	122.41	108.15	208.90	0.06	2584.17	1.29	195.81	53.69	320494.56	145.97
Partesh	28.67	44.79	175.14	0.17	3531.18	1.76	162.08	86.44	322339.98	160.97
Mamushë	10.94	20.98	200.92	0.10	4009.33	2.01	187.59	72.95	323147.78	151.89
Kllokot	23.39	35.10	187.10	0.01	3887.38	1.94	173.95	53.07	322960.47	143.78
Ranillug	77.62	60.04	154.17	0.10	2903.22	1.45	141.16	74.73	321231.78	155.39
Mitrovica V.	5.46	18.42	209.08	0.12	782.14	0.39	196.16	97.75	317023.47	163.53

Table 1b. Differences of Areas (A) and Border lines (B) of each used map projection compared to Kosovaref01 CRS (EPSG 9141)

Municipalities	Lambert Azimuthal Equal-Area *ESRI:102017* to EPSG9141		Azimuthal Equidistant *ESRI:54032* to EPSG9141		Bonne *ESRI:54024* to EPSG9141		Mollweide *ESRI:54009* to EPSG9141		Polyconic *ESRI:54021* to EPSG9141	
	A (m^2/km^2)	B (m/km)	A (m^2/km^2)	B (m/km)	A (m^2/km^2)	B (m/km)	A (m^2/km^2)	B (m/km)	A (m^2/km^2)	B (m/km)
Deçan	104.98	15.49	117313.62	63.15	104.96	0.39	687.43	5.39	33950.47	15.24
Pejë	111.17	9.70	117951.07	65.35	111.20	1.71	665.81	11.33	33919.54	16.19
Gjakovë	139.20	8.15	116875.72	64.43	139.20	1.87	759.79	11.53	34683.93	16.86
Dragash	182.14	10.31	115643.57	50.98	182.21	2.27	892.87	1.38	36103.79	21.49
Prizren	184.84	6.58	116652.66	60.31	184.86	0.15	850.04	6.44	36035.75	17.95
Gjilan	161.97	0.47	119195.59	62.95	161.97	1.71	775.45	11.86	38348.48	20.34
Viti	176.61	2.86	118524.08	64.55	176.62	2.39	813.82	13.60	38138.38	19.68
Istog	158.10	7.80	118912.45	59.82	158.00	1.30	689.33	3.13	34604.74	17.04

Zubin Potok	179.24	0.93	119973.04	66.41	179.24	3.35	675.24	16.10	34956.92	18.34
Prishtinë	185.50	1.01	120134.97	58.07	185.50	1.13	735.53	4.20	37383.87	20.23
Kaçanik	190.51	4.67	117831.87	57.09	190.51	2.03	848.60	1.77	37775.00	19.35
Shtërpcë	199.30	8.84	117398.91	57.00	199.30	2.78	857.89	0.16	37043.43	18.11
Zveçan	192.33	3.96	120456.51	70.94	192.32	5.14	678.91	21.25	35386.74	17.85
Leposaviq	192.63	10.99	121236.34	67.05	192.62	1.30	643.26	11.05	35263.88	16.53
Podujevë	192.54	8.92	121030.80	62.69	192.54	2.64	690.26	14.49	36798.59	21.36
Lipjan	194.89	10.66	118964.86	59.91	194.89	1.94	786.72	2.01	37058.82	17.69
Ferizaj	195.26	7.59	118316.64	62.41	195.26	0.36	821.44	8.10	37325.39	18.35
Shtime	199.56	21.64	118350.79	64.01	199.57	1.30	811.20	3.41	36797.96	15.31
F. Kosova	199.48	2.90	119274.66	57.17	199.50	2.32	768.41	1.27	36664.61	19.03
Kastriot	199.16	1.57	119713.88	53.26	199.17	3.60	748.54	2.81	36630.78	20.07
Drenas	197.30	4.58	118937.38	55.06	197.29	1.73	766.94	2.16	36122.79	20.33
Skenderaj	189.41	5.12	119272.43	60.96	189.41	1.66	729.99	11.32	35539.71	19.95
Klinë	172.89	5.13	118331.43	57.56	172.89	1.91	743.23	1.51	35141.08	17.87
Junik	96.92	14.38	116967.42	69.02	96.97	3.25	692.90	15.20	33895.63	15.24
Vushtrri	199.46	3.20	120097.95	58.32	199.46	0.47	723.26	5.55	36259.66	20.07
Therandë	196.39	6.98	117652.82	61.19	196.39	0.07	827.12	6.86	36369.39	18.00
Mitrovicë	198.04	0.42	120578.35	59.96	198.04	0.36	692.22	5.98	35888.46	19.09
Artanë	167.96	7.27	119779.04	54.77	167.96	1.82	750.06	2.45	38079.56	22.00
Rahovec	174.41	1.46	117367.00	59.00	174.41	0.47	793.01	7.99	35415.77	19.24
Malishevë	188.28	5.92	118082.57	59.23	188.28	1.07	785.48	3.98	35772.89	18.00
Kamenicë	136.23	5.81	120418.79	62.98	136.23	0.36	703.44	8.38	38597.76	19.32
Hani i Elezit	187.64	3.25	117469.74	52.81	187.64	3.07	867.26	0.67	38017.58	21.19
Graçanicë	195.86	1.82	119275.66	56.94	195.84	2.12	775.34	1.64	37095.29	19.49
Partesh	162.07	10.93	119091.72	69.32	162.07	3.59	781.42	16.66	38406.57	18.04
Mamushë	187.63	6.52	117227.03	59.38	187.63	0.60	825.12	4.83	35917.18	18.03
Kllokot	173.99	1.31	118654.93	67.07	173.97	4.15	807.12	18.18	38203.23	19.97
Ranillug	141.20	7.53	119814.65	62.70	141.19	0.06	735.92	7.52	38672.13	19.02
Mitrovica V.	196.12	12.89	120204.72	69.14	196.12	2.43	700.69	14.06	35674.60	16.31

Geo-information and NSDI

Utilization of the QGIS Platform with OSGEO for Publishing and Analyzing Geospatial Data of River and Road Networks in the Municipality of Vushtrri

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In this paper will be shown how has been established a Web GIS (Geography Information System) platform for publication and analysis of river and road networks in the municipality of Vushtrri. The main aim of this project is to enable a sustainable source of geospatial information, including important details on the characteristics of rivers and roads networks, as well as to make an easy working environment for performing spatial analysis by all stakeholders as an integrated database for the river and road network analysis. Developed platform could facilitate local administration for monitoring, management and maintenance of geospatial data which are under responsibilities. This platform will be able to assist not only the municipality but also other responsible institutions such as MESPI (Ministry of Environment, Spatial Planning, and Infrastructure), which are involved in the analysis and planning of road and hydrographic networks, also all stakeholders.
The presentation and paper will present the developed platform and its usage by various user levels, as well as its updates and maintenance.

Keywords: *Web GIS, geospatial data, river, road, spatial analysis.*

1. INTRODUCTION

Web GIS is the combination of the Web and GIS. The integration of the Web with GIS allows people the freedom to interact with GIS applications globally and access information almost instantly, creating a system that enables users to analyze and visualize geographic information through a Web browser, which we call a Geoportal.
The Geoportal plays a crucial role in the availability of geospatial data for a wide range of users, including the general public and municipal institutions. To create a Geoportal, first we need to establish a geodatabase for storing geospatial data, such as PostgreSQL. Then, leveraging GeoServer, which is a server based on Java that enables the creation of maps and facilitates data sharing. It operates entirely under open-source principles and adheres to OGC standards. This platform enables the display and sharing of spatial data worldwide via the web. GeoServer includes a WMS component that seamlessly integrates with other Java applications such as OpenLayers, enabling the creation of maps in various formats. In this case, GeoServer acts as an intermediary between PostgreSQL and the Heron MC (Mapping Client) library, which provides ready-made code for Geoportal creation.
This Geoportal aims to provide a conducive environment for distributing, analyzing, and visualizing geographic information, thereby enhancing the efficiency and capacity of road and river network planning and management at the local level for the municipality of Vushtrri. The use of this Web GIS serves to improve the community's needs and facilitates the exchange of geoinformation and collaboration for the mapping and implementation of projects for the municipality's development.

2. MATERIALS AND METHODS

2.1 Theme, territory and utilization of Ueb GIS for municipality of Vushtrri

The road and river network is fundamental to the overall functioning of a municipality. The accessibility and readiness of roads have a direct impact on the local economy and the daily lives of citizens, while the selection of territory has been made based on a deeper understanding of this municipality compared to others, which has influenced decisions such as settlement placement, gathering data on residents in cadastral areas, etc. The connection of the topic with the state of rivers also serves to identify flood-prone areas, enabling planning and preventive measures.
By focusing on the road and river network in the municipality of Vushtrri, the Geoportal aims to provide a significant source of information for all involved stakeholders. This strategic choice of theme and territory will contribute to improving the quality of life and sustainable development of the community.

The main objectives of the Geoportal are:

• Improving road infrastructure by identifying areas for regulation and construction of new roads,
• Managing water resources to prevent floods and preserve the environment,
• Informing citizens and local authorities about the condition of roads and rivers, and
• Assisting in urban planning and the development of the municipality in the area of road and river networks.

2.2 Content and structure of database

Initially, we utilized QGIS and GeoServer. Through QGIS, we defined the projection, coordinate system, and stylization of features, while GeoServer facilitated the publication of this data as OpenLayers, allowing us to utilize it in Heron's JavaScript library, which serves for the creation of various Geoportals such as Kosovo's, Hungary's, and Italy's.
Next, we will describe some of the personal layer data and the reasons for their visualization, as presented in (Fig 2.2.1).
Vushtrri Municipality border - was used as a Web Map Service (WMS) but simultaneously possesses the characteristics of a Web Feature Service (WFS) because we configured the services through GeoServer. This implies that it is local and stylized through QGIS software, from which we exported it. Below, we will demonstrate the JavaScript code and configuration in GeoServer, including the projection definition, publication, and connection with stylization (SLD).

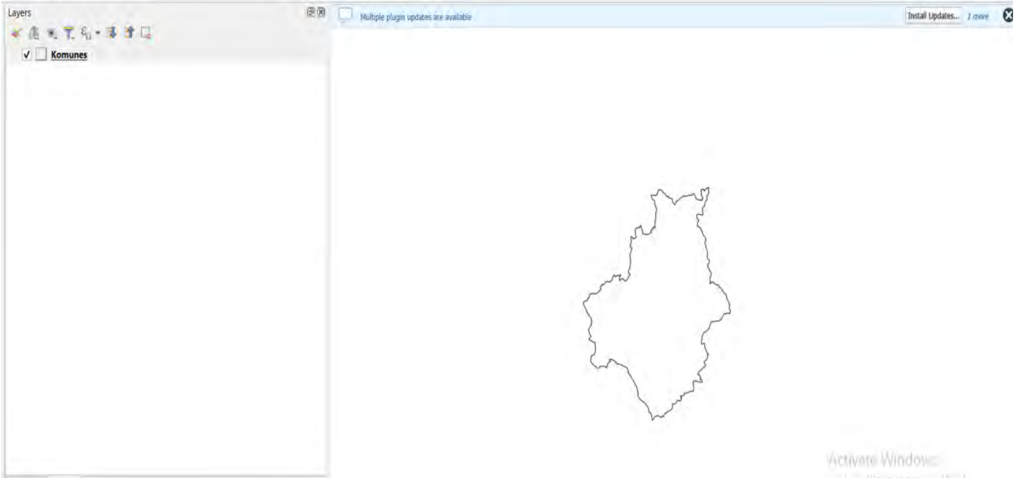

Figure 1 The "Municipality Boundary" layer in QGIS prior to stylization.

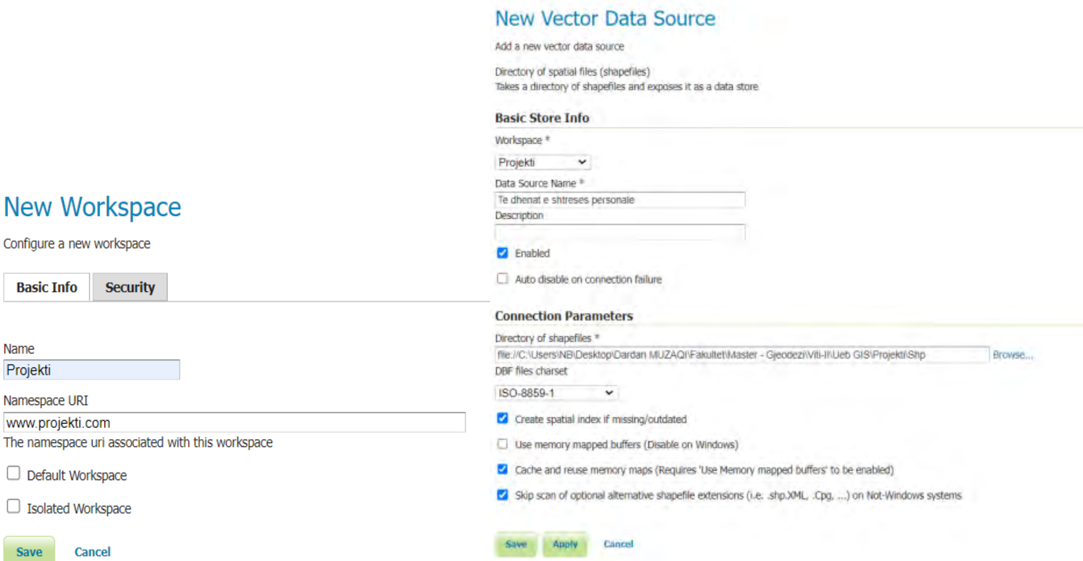

Figure 2 Setting up the workspace and inserting data.

2.2.1 Publishing data on GeoServer

After inserting the data, we will proceed with their publication, where we will explain a case of how the publication is done: Firstly, we navigate to the “Layers menu”, then select “Add New Layers”, and subsequently, a window opens as shown below, where by clicking “Publish”, we continue the process of data publication.

<< < 1 > >> Results 0 to 0 (out of 0 items) Search

Published	Layer name	Action
✔	0derine500	Publish again
✔	1001derine1500	Publish again
✔	1501derine2000	Publish again
✔	501derine1000	Publish again
✔	Dytesore te qytetit	Publish again
✔	Hekurudhe	Publish again
✔	Komunave fqinje	Publish again
✔	Komunes	Publish again
✔	Kryesore te qytetit	Publish again
✔	Lokale	Publish again
✔	Lum	Publish again
✔	Lumenjte	Publish again
✔	Nacionale	Publish again
✔	Qender komunale	Publish again
✔	QenderKVendbanim	Publish again
✔	Rajonale	Publish again
✔	Rrjedhë	Publish again
✔	Rruget_Vushtrri	Publish again
✔	Vendbanim	Publish again
✔	Zonat kadastrale	Publish again
✔	mbi 2001	Publish again

Figure 3 Publishing data from personal database.

2.3 The link between GeoServer and the Geoportal

First, we define the type as OpenLayers and then through the link of GeoServer "localhost:8080/geoserver," which functions as a local network, meaning it is installed on our device.
Next, we specify the layers where the Project represents the workspace while the Municipality is the layer to be published on the Geoportal. Other parameters like visibility are used for presentation; this parameter determines whether the layer should be automatically displayed on the Geoportal or manually activated through the button. Feature Info Format implies the format of information we desire to receive when clicking on a layer. Then, there are parameters of WFS (Web Feature Service) such as protocol, layer prefix, and workspace link (featureNS). Below, we have the data download formats that we defined at the beginning of the JavaScript.

```
new OpenLayers.Layer.WMS(
    "Komunes",
    Heron.GISWS.urls.GEOSERVER,
    {layers: "  Projekti:Komunes", format: "image/png", transparent: true},
    {isBaseLayer: true, singleTile: true, visibility: false, alpha: true,
        featureInfoFormat: "application/vnd.ogc.gml", transitionEffect: 'resize',
        metadata: {
            wfs: {
                protocol: 'fromWMSLayer',
                featurePrefix: 'Projekti',
                featureNS: 'www.projekti.com',
                downloadFormats: Heron.options.wfs.downloadFormats,
                maxQueryArea: 100000,
                maxQueryLength: 1000
            }
        }
    }
),
```

```
Ext.namespace("Heron.options.wfs");
Heron.options.wfs.downloadFormats = [
    {
        name: 'CSV',
        outputFormat: 'csv',
        fileExt: '.csv'
    },
    {
        name: 'GML (version 2.1.2)',
        outputFormat: 'text/xml; subtype=gml/2.1.2',
        fileExt: '.gml'
    },
    {
        name: 'ESRI Shapefile (zipped)',
        outputFormat: 'SHAPE-ZIP',
        fileExt: '.zip'
    },
    {
        name: 'GeoJSON',
        outputFormat: 'json',
        fileExt: '.json'
    }
];
```

Figure 4 Publishing data on the Geoportal and data download formats.

3. RESULTS AND DISCUSSION

3.1 Application development

The application has been developed solely for the web, but there is the possibility of using it as a mobile version, which leaves much to be desired in terms of usability, as utilizing an application for a mobile version requires styling through CSS (Cascading Style Sheets).

3.1.1 Web version

The web version has been developed using the Heron library, which is utilized by the AKK of Kosova and other European states for the development of Geoportals.

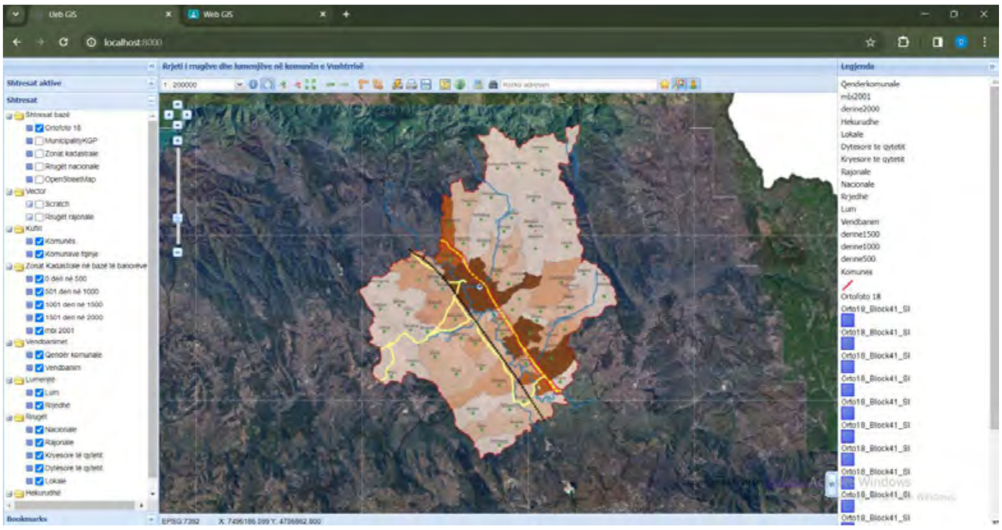

Figure 5. Web version.

3.1.2 Mobile version

We will use the mobile version through the iPad or Nest Hub.

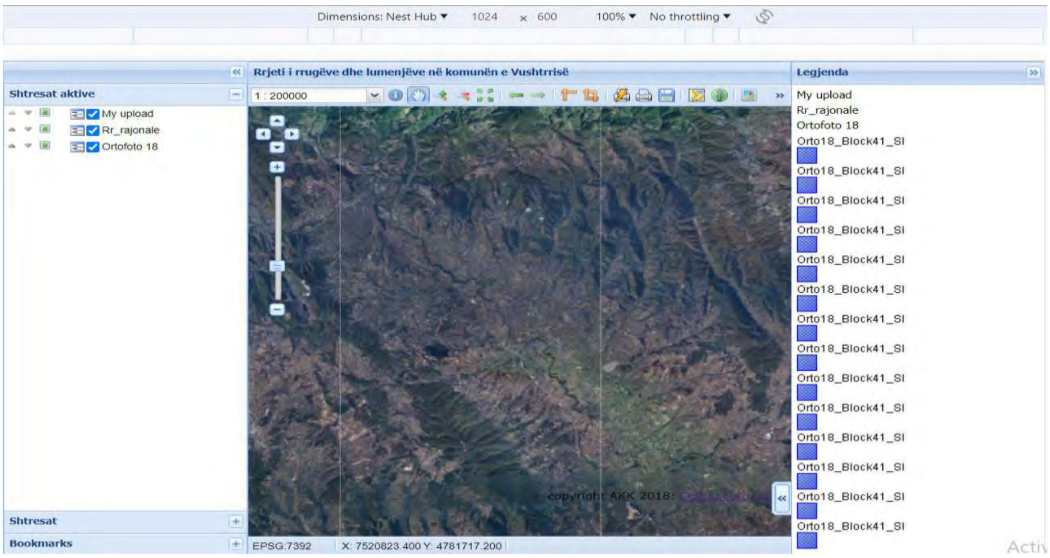

Figure 6 Mobile version.

3.2 The publication/distribution of created applications

The publication of the web application was done through the local WiFi IP address, through which we can access it directly via the real IP address. Firstly, we navigate to cmd >> ipconfig to obtain the local IPs of our PC.

However, initially, to gain access and connect via the IP address, we need to disable "Firewall Network Protection.

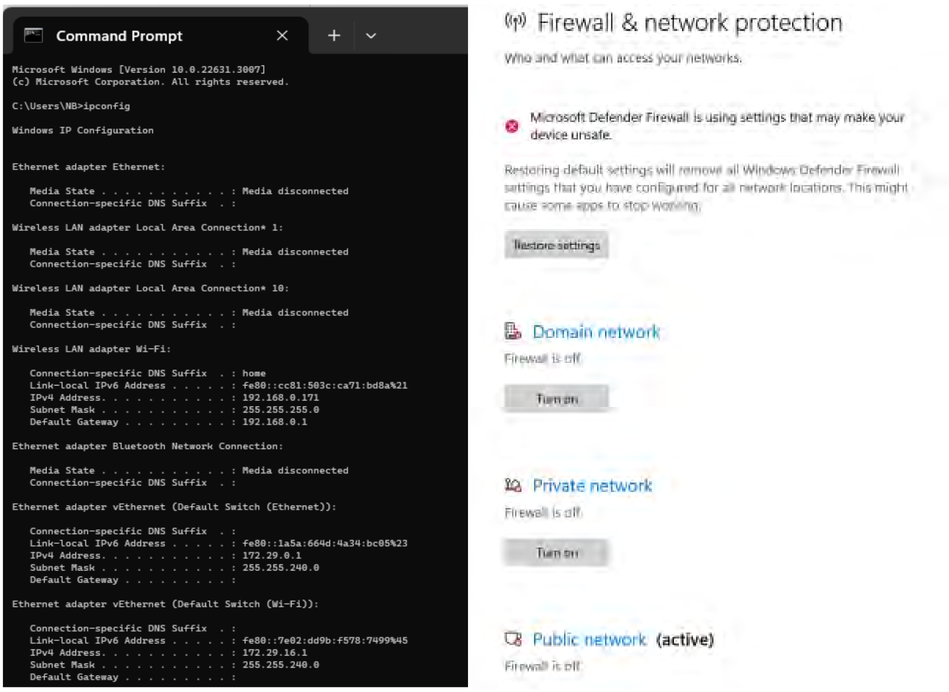

Figure 7 The PC's IP address and disabling Firewall & Network Protection.

3.3 The creation of web services for third-party use

In this subchapter, we will present the usage of web services such as WFS through QGIS, demonstrating how this method functions and is highly suitable for remote usage in the era of the internet, meaning the utilization of services from a distance.

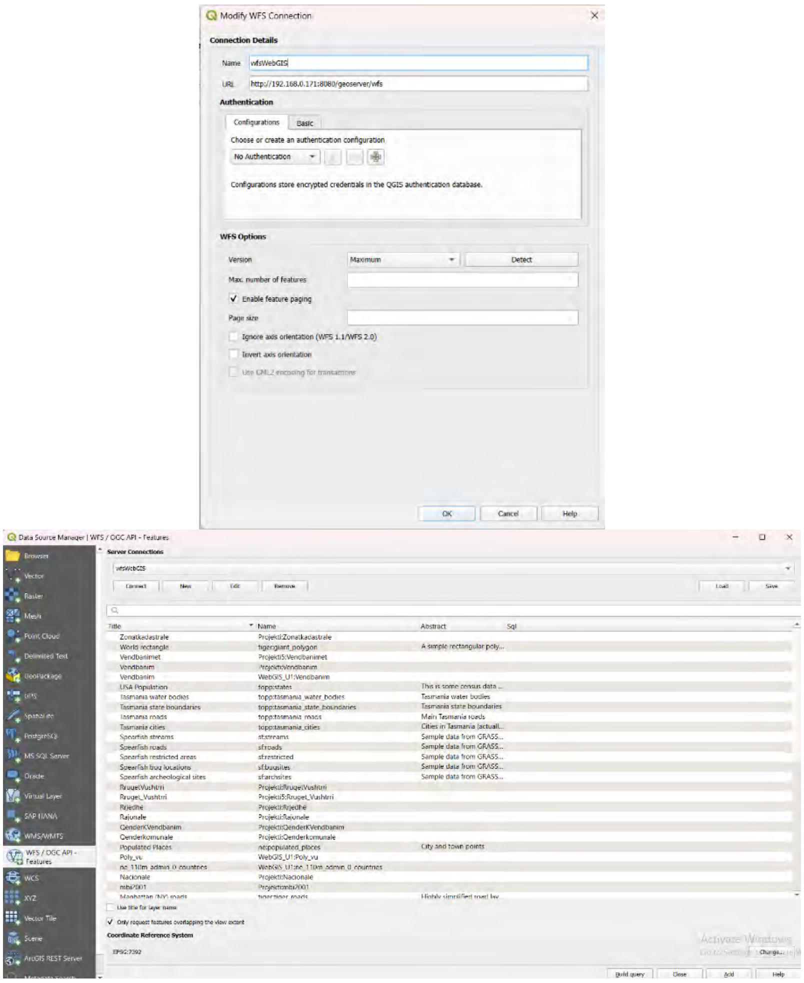

Figure 8 The creation of WFS (Web Feature Service) and linking it to the local GeoServer database.

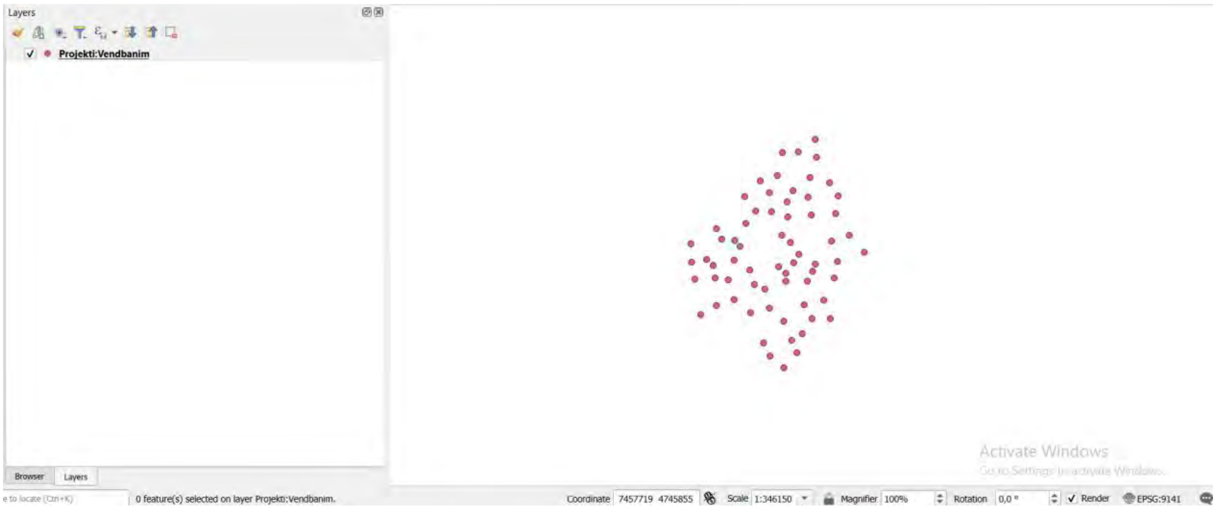

Figure 9 Enabling WFS for the layer "Settlements.

4. CONCLUSION

In our research work, we have established the utilization of the QGIS platform in collaboration with OSGEO for publishing and analyzing geospatial data of river and road networks in the

Municipality of Vushtrri represents a valuable framework for enhancing spatial analyses and decision-making processes. Through the integration of various geospatial technologies such as GeoServer and OpenLayers, we have successfully developed a comprehensive web-based Geoportal that facilitates the dissemination of geographic information to stakeholders and the general public.

By using QGIS and OSGEO, we have been able to define the projection, coordinate system, and stylization, enabling efficient management and visualization of spatial data. Furthermore, the implementation of internet services such as WMS, WFS, and WCS has facilitated remote access to geospatial data, fostering collaboration and information exchange among users.

REFERENCES

[1] Fu, P (2018). Getting to Know Web GIS Third Edition, 16-17.

[2] Kommana, K. (2013). Implementation of a Geoserver Application for GIS Data Distribution and Manipulation, 12-15.

[3] Li, S & Dragicevic, S & Veenendaal, B (2011). Advances in Web-based GIS, Mapping Services and Applications, 109-112.

[4] Fu, P & Sun, J. (2010). Web GIS: Principles and Applications, 35-39.

Developing and usage of Mobile GIS Applications

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The presentation completes an application of how mobile GIS applications make geography knowledge in everyday life and in special projects. Through them, users can have immediate access to geographic information from anywhere, adding a dimension of understanding of awareness about products and the environment around them. Mobile GIS applications are platforms that allow users to explore, analyze and share geographic information through mobile devices, such as smartphones and tablets. These applications are built based on geographic information systems and use Internet technologies to provide quick and easy access to maps and geographic data. The content of these applications may include interactive maps, location information, and interaction with geographic data. Users can browse geographic space, perform various analyses, and share geographic information with others from their mobile devices. This also brings a new dimension to everyday life, integrating geographic information into daily activities and making it a valuable tool for many different fields, including urbanism, environment, territorial development, and many others. In this paper, contents such improving mobility, suitable functionalities for mobile devices, information sharing, security and integrity, built-in functions, intuitiveness of usage, filtering, and analyses, using of social links, application development process, technologies and programming languages, mobile application design, as well as core technologies for developing and using of mobile GIS applications will be presented in conference presentation and described in full manuscript.

Keywords: *Mobile GIS, graphical user interface, user interface, user experience, virtual reality, security certificates SSL&TLS.*

1. INTRODUCTION

The presentation completes an application of how mobile GIS applications make geography knowledge in everyday life and in special projects. Through them, users can have immediate access to geographic information from anywhere, adding a dimension of understanding of awareness about products and the environment around them.

2. WEBGIS MOBILE APPLICATIONS

Web GIS Mobile applications are platforms that allow users to explore, analyze and share geographic information through mobile devices, such as smartphones and tablets. These applications are built on the basis of geographic information systems and use Internet technologies to provide quick and easy access to maps and geographic data.

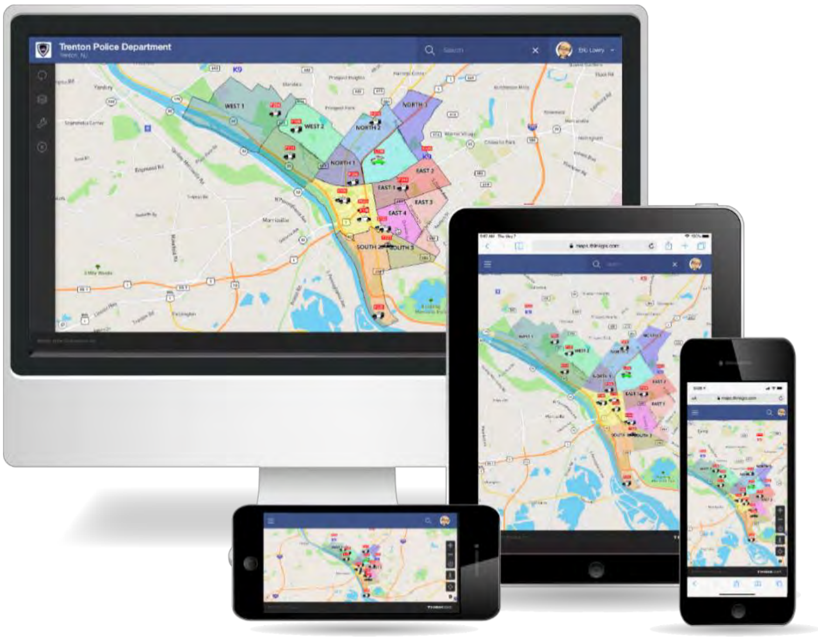

Figure 1. Mobile devices

The content of these applications may include interactive maps, location information, and interaction with geographic data. Users have the ability to browse geographic space, perform various analyses, and share geographic information with others from their mobile devices.

This also brings a new dimension to everyday life, integrating geographic information into daily activities and making it a valuable tool for many different fields, including urbanism, environment, territorial development, and many others.

2.1. Advantages of WebGIS Mobile Applications

2.1.1. Ease of use and easy access

a) Web GIS Mobile applications have a simple and easy work for users.

b) Enables access to geographic information from mobile devices such as smartphones and tablets.

Figure 2. Easy and engaging experience

2.1.2. Improving mobility

a) Allows users to access geographic information anytime and anywhere.
b) It enables users to be aware of the location and environment around them, adding a new dimension of understanding and awareness.

2.1.3. Functionality suitable for mobile devices

a) Web GIS Mobile applications are designed with functionalities that are optimized for the small screen and characteristics of mobile devices.
b) Users can explore maps, perform analysis and share geographic information with easy and intuitive use.

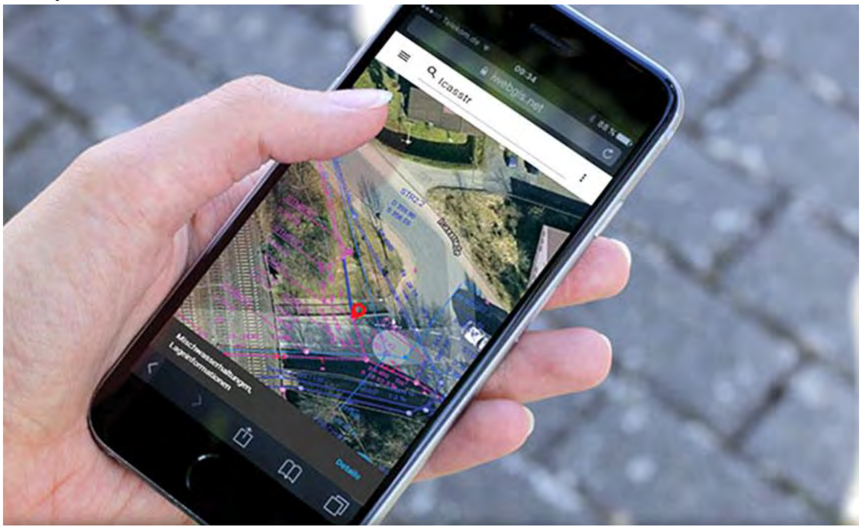

Figure 3. Functionality suitable for mobile devices

2.1.4. Information sharing

It enables users to easily share geographic information with others, using links and shared social platforms from their mobile devices.

2.1.5. Security and integrity

The advantages of data security and integrity are essential supports of Web GIS Mobile applications, guaranteeing users that information is safe and reliable.

2.2.Content of WebGIS Mobile Applications

2.2.1. Examples of geographic information

a) Base map with various geographic annotations, including roads, schools, and other key objects.
b) Different layers of the map that present specialized information, such as temperature, water flow, or new constructions.

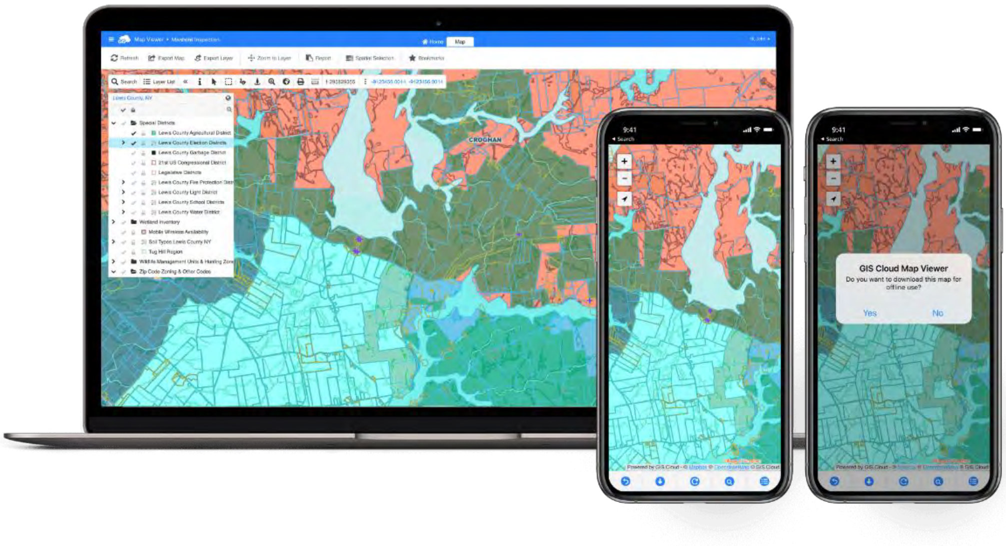

Figure 4. Content of applications

2.2.2. Built-in functions

a) Location search: Use GPS technology to find your current location and find nearby objects or geographic information.
b) Photo Enhancement: Ability to upload and share geo-linked photos.
c) Using Virtual Reality (VR): The ability to explore the environment using virtual reality technology.

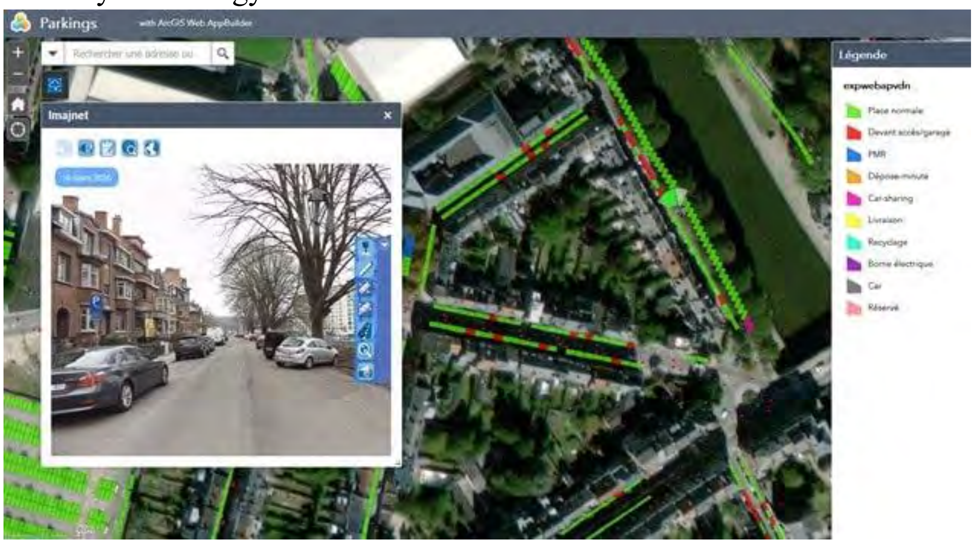

Figure 5. Virtual reality (VR) technology

2.2.3. Intuitiveness of use

a) Simple and understandable menus and icons to make use intuitive and easy.
b) Use distributed controls to zoom and move around the map.

2.2.4. Filtering and analysis

a) The possibility to filter and analyze the data on the map based on criteria defined by the user.

b) Using graphs and diagrams to present map information more easily.

2.2.5. Using social links

a) Distribution of location and geographic information via social media platforms.
b) Connecting with the community and other users to transmit and receive geographic information.

Figure 6. Using social links

2.2.6. Application Development Process

a) Research and planning: Identifying user needs, designing an appropriate strategy, and planning the development phase.
b) User Design (UI/UX): Creating an engaging and functional user experience through mobile-friendly design.
c) UI – User interface is the visual aspect and user interface of an application, website, or digital product.
d) UX – User experience is the user's total experience with a product or service, including all their feelings, thoughts and perceptions.

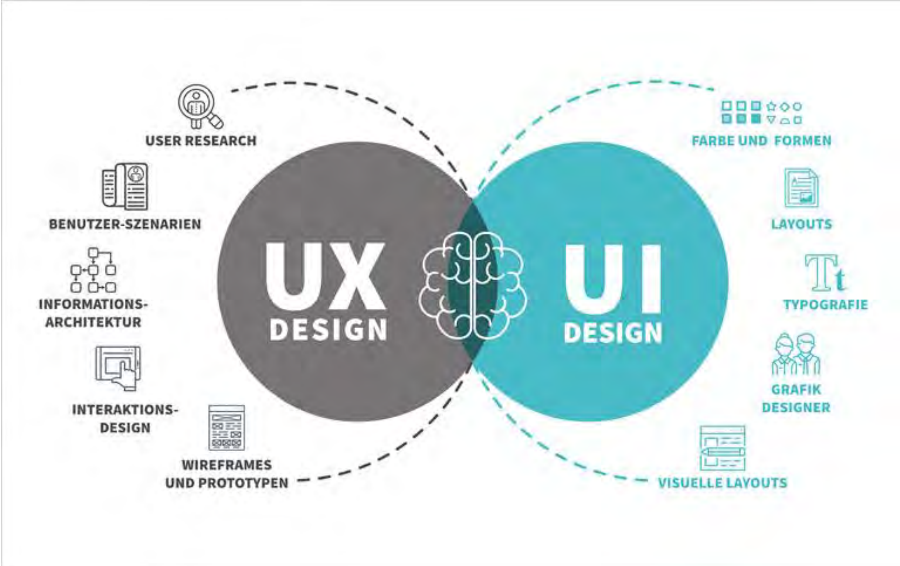

Figure 6. GUI (Graphical User Interface)

e) Application Development: Creating code and implementing various functionalities, including connecting to databases and using map APIs.

2.2.7. Technologies and programming languages

a) HTML5, CSS, and JavaScript: Web page basics and the use of modern technologies for displaying and styling information.
b) JavaScript frameworks (eg, React Native, Angular, Vue): Using frameworks to facilitate the development and sustainability of mobile applications.
c) Programming languages (eg, Java, Kotlin for Android; Swift, Objective-C for iOS): Using specialized languages to develop applications for specific platforms.
d) GIS Libraries (eg, Leaflet, Mapbox SDK): Integration of specialized libraries for manipulating and presenting geographic information.

Figure 7. HTML5, CSS3 and JavaScript

2.2.8. Testing and improvement

a) Performance testing: Ensuring that the application works with high performance across different mobile devices.
b) Security Testing: Verifying the security and privacy of user data.

c) Feedback and improvements: Accepting feedback from users and implementing improvements to improve the user experience.

2.2.9. Launch and ongoing support

a) Launch: Implementation of the application in the application stores (App Store, Google Play).
b) Ongoing Support: Providing ongoing support to users, including possible changes and improvements.

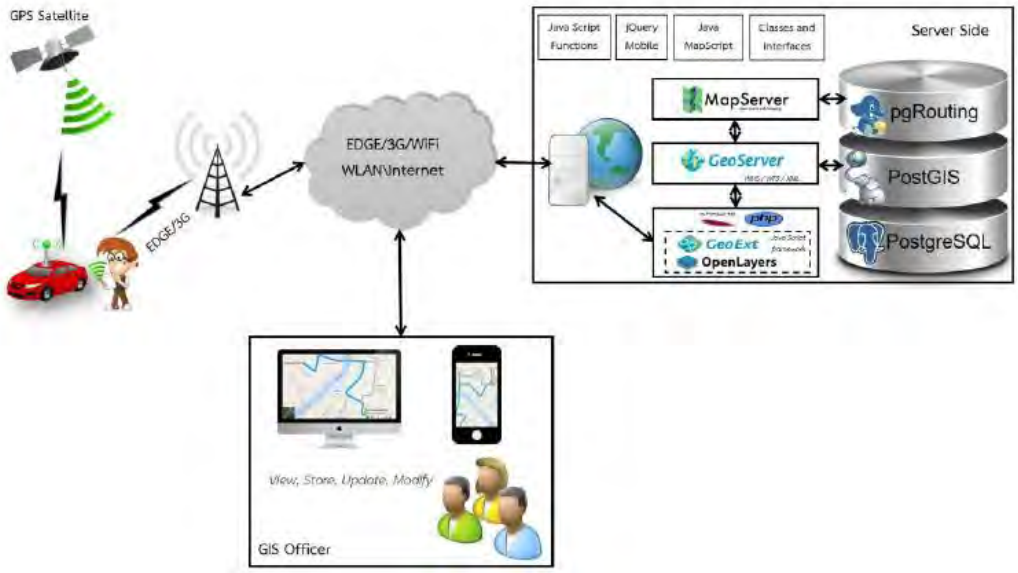

Figure 8. Launch and ongoing support

2.3.Most important technologies

2.3.1. HTML5, CSS, and JavaScript

a) HTML5: The latest Hypertext Markup Language (HTML) standard for web page structure and its adaptability to mobile devices.
b) CSS (Cascading Style Sheets): Used to style and adapt the appearance of the website across mobile devices.
c) JavaScript: The programming language used to make web pages interactive and to connect applications to the user.

2.3.2. JavaScript Framework

React Native, Angular, Vue: Specialized frameworks for developing mobile applications via JavaScript. Their use facilitates adaptation and speed of development.

2.3.3. Programming Languages

Java, Kotlin for Android; Swift, Objective-C for iOS: Specialized languages for developing applications for certain platforms (Android and iOS).

2.3.4. GIS Libraries

a) Leaflet: Open and easy-to-use library for displaying interactive maps on web pages.

b) Mapbox SDK: Powerful and lightweight app development platform with rich visuals and advanced map functionality.

2.3.5. Using the Maps APIs

Google Maps API, Mapbox API: Using these APIs allows the integration of rich maps and their functionalities in mobile applications.

2.3.6. Fingers and User Gestures

Touch Events: Using touch events to make interactivity and map exploration easier on mobile devices.
The combination of these technologies provides a strong foundation for the development of Web GIS Mobile applications, ensuring an attractive and functional user experience.

2.4.Responsiveness and mobile appropriate design

2.4.1. The importance of appropriate design

a) Mobile-friendly design is critical to ensuring an engaging and functional user experience.
b) Mobile devices have small screens, and a suitable design ensures that information is clear and easy to understand.

2.4.2 Key elements of mobile design

a) Clear menus and buttons: Use icons and short text to make menus and buttons clear and easy to touch.
b) Appropriate fonts: Choosing fonts suitable for the small screen.
c) Appropriate Images: Use images optimized for loading speed and to ensure high quality.

2.4.3. Site structure and navigation

a) Information Hierarchy: Placing information in a logical hierarchy to facilitate navigation.
b) Simple navigation: Using simple and intuitive navigation to facilitate users in finding information.

2.4.2. Illustrations and examples

a) Map design using clear colors: Use of contrasting and clean colors to make geographic information clear.
b) Use of intuitive icons: Choosing clear and intuitive icons to convey functions and actions.
c) Illustration of page with convenient search: Examples of a page with an easy to find and use search box.

2.4.4. Orientation adaptation (Landscape/Portrait)

Adapting the design for device orientation and portrait: Ensuring that the app works well in both orientations, using the screen real estate effectively.

Figure 9. Adaptation and orientation

Appropriate and careful design for mobile devices increases usability and positively affects the perception of the application by users.

2.5.Security and privacy

2.5.1 Security and Privacy Measures in Web GIS Mobile Applications

a) Security certificates (SSL/TLS):

Use of SSL/TLS certificates to ensure secure connections between the application and the server.

Improves integrity and confidentiality of transmitted data.

b) Encryption methods:

Using encryption protocols to protect user data from unauthorized users.

End-to-end encryption ensures that data is secure from start to finish of transmission.

c) Privacy policies:

Defining and clearly announcing privacy policies to inform users of how their data will be handled and stored.

Allowing users to choose what information they want to share and what not.

d) Authentication and authorization

Use of secure methods for user authentication and their respective authorization.

Allows access and manipulation of information only for authorized users.

Figure 10. Security certificates

e) Management of vulnerabilities (risks)

Security Monitoring: Using tools and technologies to monitor activity and identify unauthorized attempts.

Using the latest software versions: Ensuring that all software components are up-to-date and protected against known vulnerabilities.

f) User education

Providing limited access to users: Making security configurations easier to use for ordinary users.

Advice and education: Providing advice and information to users about safe behaviors and using the app with care.

Security and privacy are critical elements of the design and development of Mobile GIS Web Applications to ensure a reliable user experience.

2.6. Implementation and Testing

2.6.1. Implementation

a) Application Coding: Developing code based on previously defined specifications and design.
b) Component integration: Linking all application components to ensure proper functionality and correctness.

2.6.2. Testing

a) Unit Testing (Unit Testing): Verifying the correctness of individual code functionalities.
b) Integration Testing: Ensuring that all parts of the application work together smoothly.
c) Performance testing: Using testing tools to evaluate the speed and efficiency of the application under different conditions.
d) Security testing: Identifying and correcting any potential security issues using various testing techniques.

2.6.3. Testing Tools

a) Jest & Mocha: For automated code testing through units.
b) Selenium: For automated testing of various usability and functionality on web pages.
c) JMeter: For performance evaluation, simulating high user loads.
d) OWASP Zap: For security testing and identifying potential security vulnerabilities.

2.6.4. Optimization and debugging

a) Performance Optimization: Using techniques to improve application loading speed and responsiveness.
b) Fixing Identified Issues: Addressing any issues discovered during the testing phase.

2.6.5. Release and ongoing monitoring

a) App Release: Publishing the finished version to app stores.
b) Usage and performance monitoring: Using monitoring tools to evaluate usage and identify any emerging issues.

The implementation and testing phase are critical for ensuring a Web GIS Mobile application of stability, performance and security.

2.7.Use and continuous improvement

2.7.1. Strategies of continuous use

a) User Feedback: Encouraging users to share comments and feedback about their experience.
b) Usage Monitoring: Using tools to analyze how users authenticate and use the Application.
c) Surveys and Analytics: Creating surveys and analytics to get user perspective on performance and functionality.

2.7.2. Continuous improvement

a) Using feedback: Analyzing feedback to identify issues and needs for improvement.
b) Regular Updates: Releasing regular updates to add new functionality and fix any emergent issues.
c) Innovation and new development: Creating innovations and adding new functionalities to keep the app fresh and competitive in the market.

2.7.3. Communication with users

a) Notifications and communication of updates: Informing users about changes and improvements through notifications and informational materials.
b) Social Media Platforms: Using social media platforms to connect the community and get faster feedback.

2.7.4. Usage analysis tools

a) Google Analytics, Mixpanel: Using these tools to measure app usage, interaction and performance.
b) A/B Testing: Conducting different tests to evaluate which changes are most effective and preferred by users.

2.7.5. Community and user growth

a) Forums and Discussions: Creating forums and other discussion spaces to facilitate interaction between users.
b) Rewards programs and games: Encouraging users for continued use through rewards and game activities.

Continuous use and improvement through close communication with users and the use of analysis tools help keep a Web GIS Mobile application relevant and advanced.

REFERENCES

[1] Mobile Design Pattern Gallery: UI Patterns for Smartphone Apps" nga Theresa Neil
[2] Don't Make Me Think, Revisited: A Common Sense Approach to Web Usability
[3] Nielsen Norman Group
[4] Lean UX: Designing Great Products with Agile Teams" nga Jeff Gothelf dhe Josh Seiden

Historical and Monumental Buildings

The Restoration and Preservation of Albania's Mati Bridge

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The Mati Bridge, also known as the Zogu Bridge, is one of the first works in Europe to have applied precast concrete technology. Built in May 1927, this engineering marvel features six arches and is the only bridge of its kind in Albania and one of the most important Albanian engineers Gjovalin Gjadri following the design of Prof. Emil Mörsch, and together with Eng. Erwin Schnitter, applied innovative techniques as the pre-method of prestressed concrete. With a span of 54 meters, the bridge employs a unique arch supporting structure with two hinges, while the tie-beam acts as a horizontal spin absorber. Today, faced with decay due to corrosion and theft, restoring the Mati Bridge presents both technical and economic challenges. However, preserving this historic landmark not only safeguards its architectural significance but also honors the ingenuity of past generations and ensures a legacy for future ones. In January 2021, leg number 5 of the bridge experienced a sudden decrease in height, causing damage to adjacent arch spans and raising concerns about the stability of leg number 6. Despite this, the bridge maintained its structural integrity but displayed noticeable movement. Until July of the same year, the bridge continued to exhibit movement until leg number 5 stabilized without external intervention, despite a total subsidence of 201 cm over six months. However, in December 2022, the subsidence of leg number 5 doubled, reaching a settlement of 384 cm, resulting in substantial damage to the superstructure. Despite growing concerns, the bridge, this special monument of our cultural heritage, faces every day the high risk of collapse, but what are the measures expected to be taken for its restoration and preservation?

Keywords: *Mati Bridge, Prestressed Concrete, Structural Integrity, Restoration, Risk of Collapse.*

1. INTRODUCTION

Prior to the construction of the Zog Bridge spanning the Mat River and alongside the road leading to Mirdita, two previous bridges stood but were obliterated during the tumult of the First World War, between 1916 and 1918. The imperative need for a fresh, resilient bridge became paramount to facilitate connectivity between the southern and northern regions of the country. The bridge stands out for its remarkable structure, boasting distinctive arches that lend it significant museum-worthy appeal and in the nation's collective memory, symbolizing a period when Albania looked westward, seeking refuge and inspiration, however, now is considered a monumental heritage [1]. Designed by the well-known Italian studio Mazorana & Co. Triest and an Italian-German construction firm entrusted to undertake this significant project. Additionally, Swiss engineer Erwin Schnitter and with German engineer Emil Morsch played a pivotal role in the implementation phase. With much of the material supplied by Italians, the bridge's execution was carried out by Albanian engineer Gjovalin Gjadri, renowned for designing the Milot-Burrel highway and over 75 other notable projects to his name, including iconic structures like the Lana Bridge and the Rubik Power Plant, his portfolio reflects his creativity and engineering prowess.

Construction commenced at the end of May 1926 and culminated with the inauguration on May 25, 1927. By late January 1927, the concreting of arches and corresponding floors had been completed. Both Gjovalin Gjadri and Erwin Schnitter corroborated that volumetric work spanning nine months, from May 1926 to January 1927, was successfully accomplished, completing the construction within just one year. This notably brief timeframe is particularly impressive given the significant engineering challenges faced during the project's implementation, as well as Albania's limited technical resources in the mid-1920s.To honor the king and his interest, this bridge was named after him, the Bridge of King Zog. The construction of the arch bridge of Milot, over the Mat River, stands out as one of the most graceful and accomplished engineering endeavors ever undertaken in our nation.

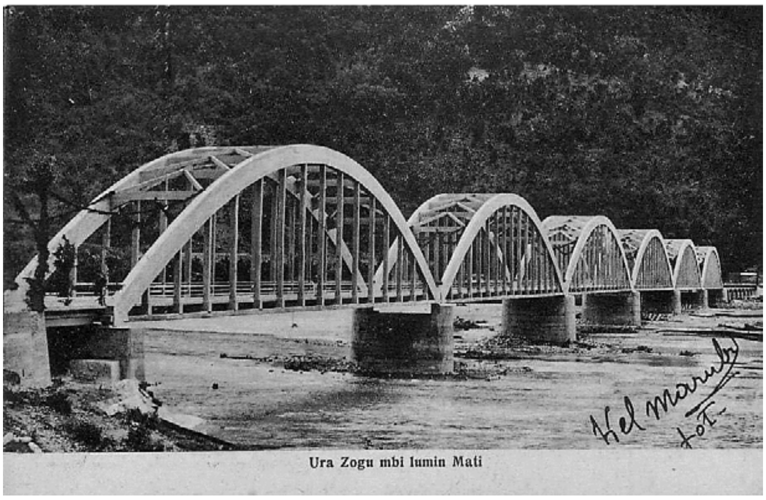

Figure 1 Bridge “Zogu” on the river Mat, 1927- Kel Marubi

What sets this bridge apart is not only its striking design but also the distinguished reputation of its structural designer, a prominent figure in the global arena of reinforced concrete constructions. This picturesque bridge with its graceful arches stands as one of the pioneering reinforced concrete structures in both Europe. It is remarkable that, even with the limited methods at hand at the time, it took an innovative approach to preventing the cracking of its hinges and tie beams by partially utilizing the prestressing technique.

This unique feature has not only earned the Mat Bridge recognition in Albanian technical literature but also in publications from other countries. Presently, the bridge spans five arches, each spanning 54 meters. However, historical records indicate that prior to the end of the Second World War (1944), it featured six arches. Sadly, one arch was destroyed during the war and subsequently replaced with a beam structure following its conclusion and five arches remained. It was thanks to an Italian engineer's merit that, fortunately, he managed to save it.

Now, nearing a century since its construction, one section of the bridge has collapsed, demanding urgent intervention to stabilize and preserve its structure. Thanks to the efforts of impassioned youth activists, this endangered cultural monument gained recognition from the "Europa Nostra" organization, listed among the seven most threatened monuments of 2022.

2. MATERIALS AND METHODS

2.1.Construction Plan

Developed a comprehensive restoration plan based on the findings of structural assessment and historical research, outlining specific interventions required to address structural deficiencies, stabilize the bridge, and preserve its historical integrity, The National Council of Material Cultural Heritage approved the emergency intervention project at Mat Bridge. This project, titled "Technical Implementation Project for Emergency Intervention in the Cultural Monument, Mat Bridge" [2] is the collaborative effort of esteemed professors and experts from the Faculty of Civil Engineering at the Polytechnic University and the National Institute of Cultural Heritage, these experts have worked diligently to design the project within a short timeframe. In addition, the recent approval of the monitoring equipment installation project will provide crucial technical and scientific data necessary for the implementation project's design.

2.2.Documentaries

There are incorporated various documentaries [3], TV shows, and news reports as key materials. These sources provided diverse perspectives and in-depth insights into the bridge's construction, historical significance, and its impact on the local community and infrastructure development. Integrating multimedia sources enriched our analysis and offered a comprehensive understanding of the subject matter and provided valuable visual and narrative insights into its historical significance, architectural features, and restoration journey.

2.3. On-Site Visit

In the course of research, we recognized the significance of first-hand observation in understanding the deteriorating conditions of bridges. As a group of students committed to thorough investigation, we organized an on-site visit to observe these conditions directly. By visiting the bridge, we aimed to leverage our collective insights and experiences to enrich our research findings. This facilitated a deeper understanding of the challenges faced by the infrastructure in question, enabling close examination of its architectural details, structural elements, and damaged areas. Interacting with local residents during on visit, offered a valuable perspective on the bridge's historical and cultural importance, as well as the social and economic context of the surrounding area. Conversations with locals provide insights into traditional construction techniques, folklore, and community memories associated with the bridge. Such interactions enrich researchers' understanding of the bridge's heritage value and contribute to a more holistic approach to restoration.

3. RESULTS AND DISCUSSION

The bridge was built with a hinge-supported arch structure. It featured a spandrel as a horizontal thrust member, and the arch spans measured 54 meters. Apart from the nine arch spaces, there were also 17.4-meter-wide openings without arches, creating a continuous girder-like structure rather than a Gerber girder, aiming to economize on steel usage.

In total, it consisted of 15 piles with an overall length of 480.5 meters, of which 324 meters were with arches. Currently, it spans approximately 270 meters with arches, as a section of the arch has been damaged.

The concrete used in the bridge was composed of inert materials sourced from the Mat River, comprising calcium carbonate from the Mat River and silicates from the Fan River. This combination provided excellent properties, making it an ideal filler material for concrete. Cement and steel were imported from Italy. The unique application of tie rods initially involved the casting of concrete as a primary phase, followed by their load application with a rear strain, resulting in the tensioning of the tie rods. Subsequently, their concrete casting was carried out in a prestressed state, essentially constituting a form of pre-tensioning of the tie rods. The infrastructure was frail, with limited means for concrete production and modest transportation compared to contemporary standards. Despite the river Mat's minor sedimentation during rainfall, it carried substantial sediment deposits, leading to area inundation and project damage. Undertaking such an ambitious project, constructing sustaining piers reaching a height of 21 meters to support the girders to be cast in concrete, posed a significant engineering feat, both for the state of that time and for the present. Building such a bridge was truly a challenge for the state at that time, and even for the present-day state, it remains an entrepreneurial endeavor of such magnitude.

The bridge is not merely utilitarian structure that span the river, valleys, and ravines. The Mat Bridge, a testament to engineering prowess and a symbol of societal progress, held profound significance across social, cultural, and economic realms, extending well beyond its sturdy steel and concrete structure.

Culturally, is a masterpiece of early 20th-century engineering in the Balkans. It's celebrated for being one of the first to utilize prestressed concrete technology and its striking steel architectural design. This innovative approach influenced metal construction across Southern Europe.

Socially, the bridge was essential in bringing communities together. It functioned as an essential conduit, promoting communication and cooperation amongst individuals with various backgrounds. Beyond its practical use, it developed into a symbol of solidarity that enriched the social fabric and bolstered ties between the areas it connected.

In terms of the economy, Zogu's Bridge sparked growth and trade. It increased trade, the movement of products, and economic activity by offering a dependable transit link between locations. Its advantageous position combined with a strong infrastructure made it a center of economic activity that attracted investment and promoted growth both locally and globally. So, in addition to being a feat of engineering, Zogu's Bridge serves as an important foundation of economic, social, and cultural progress.

Figure 2. Bridge “Zogu” on the river Mat, 1927- Kel Marubi

Over the years, the bridge, has undergone various maintenance interventions to ensure its continued functionality and safety, with many proving successful in preserving its structural integrity. In 1938, a significant overhaul took place, involving the replacement of all movable hinges, a crucial step in maintaining the bridge's operability. Transitioning from reinforced concrete to reinforced concrete clad with steel sheets, a transformation that endures to this day, further fortified its resilience against wear and tear. Throughout its history, several reinforcement approaches have been proposed and implemented, demonstrating a commitment to adapting to evolving engineering standards and challenges [4]. These included reinforcing the "Herbert" superstructure, substituting it with a "Bailey" superstructure, and adding two new intermediate legs to reduce the clear space from 26m to 13m. Eng. Gjovalin Gjadri played a pivotal role in implementing these enhancements, ensuring the bridge's adaptability to modern demands. In the early 2000s, a new wave of maintenance interventions rejuvenated the bridge, focusing on cleaning and plastering its main elements. These efforts not only revitalized the aesthetic appeal of the structure but also contributed to its longevity and functionality. Through meticulous care and strategic interventions, Zogu's Bridge has withstood the test of time, remaining a vital link for communities and a testament to enduring engineering excellence.

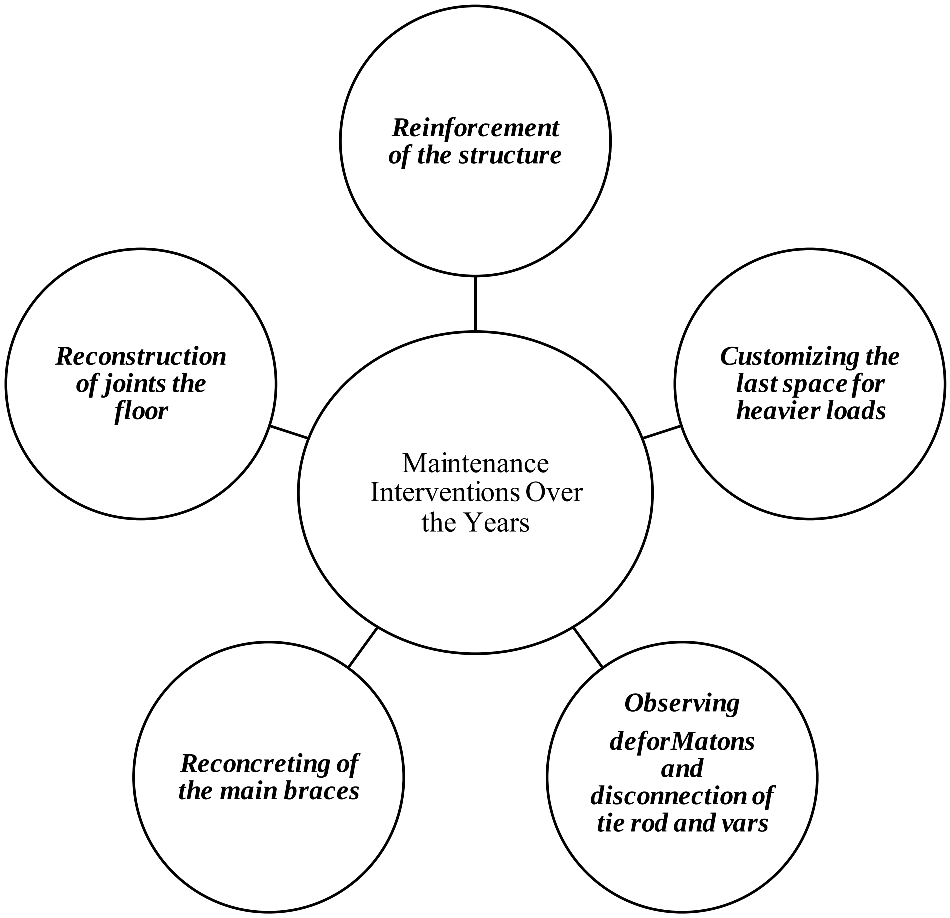

Figure 3. Diagram - Bridge maintenance interventions over the years until the beginning of the 2000s

Continuing from the events documented, the unfolding saga of the Zogu Bridge reveals a narrative that intertwines infrastructure, governance, and public awareness. On January 11, 2021, a significant event unfolded on leg no. 5 of the south-north direction of the bridge, resulting in a substantial decrease of approximately 170 cm. This incident immediately inflicted damage on the adjacent arch spans, prompting concerns about the stability of leg no. 6 as well. Despite the damage, the bridge managed to endure, albeit with noticeable movement. Engineering assessments accurately forecasted subsequent developments. The bridge continued to shift until July of the same year when, remarkably, leg no. 5 stabilized on its own, despite subsiding by a total of 201 cm over the six-month period. Fortunately, the superstructure remained intact, adhering to the established plan.

This precarious state persisted until December 14-15, 2022, spanning a total of 702 days. Throughout this period, the Ministry of Culture remained uninvolved, despite mounting reactions, even within engineering circles. However, on December 14-15, the subsidence on leg no. 5 doubled, reaching 384 cm. This dramatic increase not only confirmed earlier warnings but also led to a deviation from the original plan, resulting in significant damage to the superstructure. [5]

Figure 4. The Bridge 2024- M.Qyra

Apart from the 4-meter subsidence, the pier exhibits two distinct modes of behavior: one more pronounced along the axis of the bridge and the other softer transversely. The vertical load exerted, exceeding 600 tons, coupled with the condition of the steel pile cap, has resulted in the deterioration of the stability of the supporting pier. The settlement of the pier has also caused critical conditions in two other adjacent supports. The critical condition is evident in the northern neighboring pier, where the support has been damaged, leading to a fragile equilibrium state.

Furthermore, the settlement has induced differential settlements in the abutments, consequently resulting in a critical condition in the tie elements connecting the abutments. Due to the lowering of the topographic elevation of the riverbed, the approach embankment for water conveyance has subsided approximately 30 meters beyond the bridge, affecting the upstream flow of the river.

Preserving a bridge involves a combination of proactive maintenance, regular inspections, and strategic interventions to ensure its longevity and structural integrity. The Mat Bridge's single span comprises several structural elements: (1) arch, (2) brace beam, (3) tie beam, (4) hangers, (5) pier, (6) pile cap, and (7) pile group. It features a thrustless arch with a tie beam, supported by four bearings. While the bridge system can be analyzed statically due to external determinacy, any settlement of bearings, whether differential or not, can induce additional forces and stresses in the superstructure due to its inherent static indeterminacy.

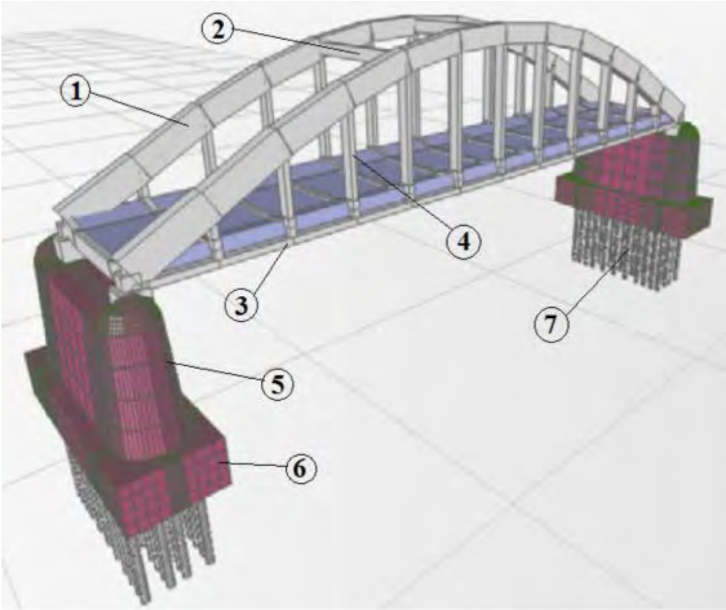

Figure 5. Schematics of Mati Bridge (By: Erion Periku)

3. CONCLUSION

In conclusion, the restoration and preservation of Albania's Mat Bridge present a formidable challenge yet a crucial opportunity to safeguard a landmark of historical, cultural, and engineering significance. As a principal infrastructural work in Albania, its unparalleled quality, unmatched even after a century, underscores the urgency of addressing its current state of disrepair. However, the continued neglect of this iconic structure jeopardizes its integrity and risks the loss of an invaluable piece of Albania's national heritage. It is imperative that action be taken swiftly to initiate comprehensive restoration efforts, incorporating modern engineering techniques while preserving the bridge's architectural integrity. Furthermore, raising public awareness about the significance of the Mati Bridge is essential in garnering support for its restoration and ensuring its long-term preservation. By engaging the public in discussions about the bridge's historical importance and cultural value, we can foster a sense of ownership and responsibility towards its upkeep. In essence, the restoration and preservation of the Mati Bridge are not merely technical endeavors but represent a collective commitment to honoring Albania's past and shaping its future. It is our duty to act decisively and ensure that this iconic structure continues to stand as a symbol of resilience and cultural pride for generations to come.

REFERENCES

[1] Cultural monuments in Albania (Monumente të kulturës ne Shqipëri) S.Adhami (1995)

[2] Public competition: "Emergency Intervention in the Cultural Monument "Mat Bridge" (Konkurrim publik: “Ndërhyrje Emergjente në objektin Monument Kulture “Ura e Matit”) (2023) https://www.kultura.gov.al/konkurrim-publik-nderhyrje-emergjente-ne-objektin-monument-kulture-ura-e-matit/

[3] ZOGU BRIDGE ON THE MAT RIVER | DOCUMENTARY (URA E ZOGUT NE LUMIN MAT | DOKUMENTAR) (2021) https://youtu.be/wDKd7hlDoHU

[4] ZOGU Bridge over the Mat River and features of rehabilitation interventions in different periods of time (Ura e Zogut mbi lumin Mat dhe veçori të ndërhyrjeve riaftësuese në periudha të ndryshme kohore) M. Baballëku, R.Luka (2024) https://www.researchgate.net/publication/379154801_Ura_e_Zogut_mbi_lumin_Mat_dhe_vecori_te_nderhyrjeve_riaftesuese_ne_periudha_te_ndryshme_kohore

[5] Zogu Bridge – The project with more signatories than the Declaration of Independence E.Periku(2024) https://www.linkedin.com/feed/update/urn:li:activity:7150986428586360833?updateEntityUrn=urn%3Ali%3Afs_feedUpdate%3A%28V2%2Curn%3Ali%3Aactivity%3A7150986428586360833%29

Gjirokastra: A Heritage Preservation Perspective.

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The historic town of Gjirokastra in southern Albania is a rare example of a well-preserved Ottoman town, built by farmers of large estates. Gjirokastra was declared "Museum City" in 1961. It is noted that this concept could best be translated as "urban 176 conservation area". This presentation aims to bring into light aspects of architecture and engineering that have impacted adding this city to the UNESCO World Heritage Site list in 2005. Gjirokastra's buildings occupy a special place in the housing typology of Albanian popular dwellings in the feudal period. The heritage of the city is at risk for a wide variety of reasons and strategies must be designed to safeguard the role of its historic areas in the ongoing economic activity of the town whilst ensuring this does not dilute the worth of the underlying heritage asset. This necessitates the identification, protection, conservation, and restoration of buildings that are considered part of the museum system of Gjirokastra. The purpose of this part of the article is to identify the existing depreciated situation, the problems, and unauthorized interventions, and to present the best possible solution for improving conditions and infrastructure. These changes are expected to significantly improve the conditions in which the facilities are and positively impact the increase in visitor numbers. In conclusion, we think that creating all the institutions and associated mechanisms needed to support the renewal of this city is a massive task. Schemes need to be undertaken that support the process of renewal and establish good practice. Gjirokastra is one of the most important assets of our Albania and we must treat it as such.

Keywords: *UNESCO, aspects of architecture and engineering, conservation area, protection, restoration.*

1. INTRODUCTION

The city of Gjirokastër is located in southern Albania, situated in a valley between the Mali i Gjerë mountain and Drino river, at 300 metres above sea level. Known also as the Stone City, in 2005, Gjirokastër was announced a UNESCO (The United Nations Educational, Scientific and Cultural Organization) protected site defined as "a unique example of a well-preserved Ottoman town with a building stock mostly dating from the 17th and 18th centuries.
Gjirokastra was built by major landowners. Around the ancient 13th century citadel, the town has houses with turrets (the Turkish *kule*) which are characteristic of the Balkans region. Gjirokastra contains several remarkable examples of houses of this type, which date from the 17th century, but also more elaborate examples dating from the early 19th century.

1.1 Typical Othoman style of building.

The interest in the protection of Gjirokastra's heritage arose in 1961 when it was proclaimed a "museum city". On that occasion 616 out of 1220 traditional buildings were declared protected monuments (Torresi, 2001; Riza, 2015). Nowadays, in Gjirokastër there are 590 monuments, which can be grouped into two main categories according to their importance. In the 1st category, there are about 56 monuments while at the 2nd category 540. Overall, near the city around 1200 stone buildings are found.

The Ottoman detached tower-houses, (in Turkish and Albanian *kullë*), which served a dual, living and defensive purpose, mark the urban vernacular landscape. They are the evidence of Gjirokastra's wealth and regional status in the time of Ottoman Empire, when generations of skilled craftsmen arrived at this town from neighbouring areas to carry out their construction. Local stone is the main building material of the town: the walls, the roofs, the paving of the streets and the courtyards are made of blocks or slabs of local limestone and slate. Wood also plays an important role: the masonry reinforcement elements, the structures of the floors and the roofs and the uppermost walls are made of timber. The uppermost floors, with a timber structure (called çatma), a wooden lath and plaster, a row of windows and terraces are typical of Ottoman residential houses.

Stone has not only been used for the construction of some of the most important monuments and structures but, at the same time, all the old streets are made of stone because of its strength, hardness, abrasion resistance, and durability. In general, in the whole range of constructions, there have been involved native highly skilled stonemasons, with the intent of preserving the characteristic architecture and building technology of the old town. Moreover, being so abundant in this region, stone has always been an affordable and cost-effective building material.

1.1.1 The çatma technique

Çatma Walls, or "Overhanging Walls," are a distinctive feature of the architecture in Gjirokastra.Çatma is the building technique used for the walls of the upper floors, characterised by wide windows and reduced thickness. The çatma technique consists of a structure of vertical posts and horizontal battens, on which wooden boards are nailed. The filling of this frame is made of waste material and stones.

The purpose of çatma walls was both functional and aesthetic.

Functionally, they provided stability to the structure by distributing the weight of the upper floors evenly and also served to deflect rainwater away from the building.

Aesthetically, they contributed to the unique appearance of Gjirokastra's skyline, adding to its architectural charm.

They reflect the region's traditional building techniques and have become an integral part of its cultural heritage.Today, these çatma walls continue to be a defining characteristic of Gjirokastra's architectural landscape, attracting tourists and researchers interested in Albania's cultural and historical heritage.

2. CIVIL ENGINEERING CHALLENGES IN HERITAGE PRESERVATION

The morphology of the slopes of the Drino valley where the traditional ancient stone houses with grey slate roofs were built, the climate and the socio-economic conditions of their inhabitants influenced the morphology of the buildings. The choice of the place of foundation on rocky, steep and uneven mountain slopes overlooking the Drino valley, met a defensive need but created a number of severe limitations to the builders.

2.1 Structural challenges

1. Structural Degradation: Many of Gjirokastra's historic buildings suffer from structural degradation due to age, weathering, and lack of maintenance. Civil engineers must assess and address these issues to prevent collapse and ensure longevity.
2. Foundation Stability: The rocky terrain upon which Gjirokastra is built presents challenges for ensuring the stability of building foundations. Engineers must employ innovative techniques to stabilise foundations while preserving the integrity of historical structures.

3. Seismic Vulnerability: Albania is prone to seismic activity, posing a significant risk to Gjirokastra's historic buildings. Civil engineers must retrofit structures to withstand earthquakes without compromising their architectural authenticity.
4. Water Damage: Moisture infiltration and water damage threaten the structural integrity of Gjirokastra's buildings, particularly those constructed with traditional materials such as stone and mudbrick. Engineering solutions involving waterproofing and drainage are essential for preservation efforts.

2.1.1 Some solution methods

1. Structural Reinforcement: Civil engineers utilise techniques such as reinforcing existing masonry with steel, carbon fibre, or other materials to strengthen historic buildings while maintaining their original appearance.
2. Foundation Underpinning: Underpinning techniques, including micropiles and grouting, are employed to stabilise foundations and mitigate settlement issues without disturbing the historic fabric of Gjirokastra's structures.
3. Seismic Retrofitting: Engineers implement retrofitting measures such as installing steel bracing, base isolators, and dampers to enhance the seismic resilience of historic buildings without compromising their architectural significance.
4. Waterproofing and Drainage Systems: Innovative waterproofing membranes and drainage systems are installed to protect Gjirokastra's buildings from water infiltration and mitigate the risk of moisture-related damage.

Preserving the cultural heritage of Gjirokastra requires a delicate balance between conservation and engineering innovation. Civil engineers play a crucial role in addressing the unique challenges associated with heritage preservation, ensuring that future generations can continue to appreciate the architectural wonders of this historic city.

3. ENGINEERING AND ARCHITECTURAL CASES THAT REPRESENTS GJIROKASTRA HERITAGE

3.1 Tower houses (*kullat)*

A fortified house or tower-house is a type of building which developed in Europe during the Middle Ages, generally with significant fortifications added. Likewise, the urban vernacular landscape of Gjirokastra is marked by these Ottoman detached tower-houses (kullë). The building served a living and defensive purposes, being at the same time a symbol of power and wealth. The interiors reflect the hospitable character of Gjirokastra people, as well as their propensity to display their status through opulent furnishings. The basic unit of the house is the residential room (oda), which maintains the same dimensions but presents different decorative elements in accordance with the people, family members or guests who used it.

3.1.1. Architectural aspects and construction methodology

Fortified dwelling in Gjirokastra, is mainly built on a sloping terrain. This dwelling almost always has its own yard. The size of land that forms the courtyard is different for different types of buildings. The housing relationship with courtyard and street configuration is generally conditioned by the configuration of the lot.

Three variations of the kullë can be identified considering the planimetric and volume composition as the basic criterion for its classification: the perpendicular type, the one-wing type, and the two-wing type. The perpendicular variation, dating back to the late eighteenth century, is the simplest one: it consists of a prismatic block with a rectangular base, with two or three storeys, linked by outer stairs. The one-wing variation, consisting of two blocks perpendicular to each other, is the most common kind of the Gjirokastra house. The two-wing variation, dating from the nineteenth century, has two parallelepiped blocks connected together by a central distribution volume.

The functional organization follows a vertical hierarchy. The ground floor, always built in stone, housed the service spaces: livestock (katoi), a space to store food reserves (qilari), big water cisterns to collect rainwater from the roof for the dry months of summer (stera), sometimes a mill and cereals (kube). The upper floors, more protected and safe, accommodated the living areas: the living room, called 'fire room' (oda e zjarrit), and the 'guest room', named 'good room' (oda e miqve or oda e mirë). The main rooms (oda) have low couches (sofa) and small ornate niches around three sides. Generally, the guest room is richly decorated, with floral paintings on the walls, ceilings, and on the fireplace, wardrobes with mouldings and notches.

The two residential floors usually have different uses depending on the seasons. The second floor, with small windows and thick stone walls, was used in winter (it is called dimerore, which means the wintry floor). The third and last floor (generally higher than the first), was used in summer (it is called beharore, which means Summer floor). It presents larger windows on the façades and thin walls with timber structure.

3.1.2 Preservation perspective

The logical connection between the historical values of the buildings should be present in the modern design process, as part of the historic core of the city of Gjirokastra. The modern design process should be inspired by the historical values, the use of the traditional materials, the construction techniques, the operation mode and people's lifestyle. The next generation of architects and engineers should be aware of the historical architectural values, should be well informed and respect the history of their own country. The historical dwellings are part of the living memory of a place at a given time frame and they should never be neglected.

3.2 Restoration proposal

A jewel of cultural heritage nestled in the heart of Gjirokaster, Albania - The Ethnographic Museum. This museum stands as a testament to the rich history and vibrant traditions of the region, encapsulating the essence of Gjirokaster's cultural identity.

From traditional clothing and household items to artisanal tools and musical instruments, every artifact tells a story of resilience, creativity, and community spirit.

However, despite its invaluable cultural significance, the Ethnographic Museum is in dire need of restoration. Years of neglect, environmental factors, and insufficient maintenance have taken their toll on this historic landmark. Cracks mar its walls, roofs leak, and delicate exhibits suffer from deterioration.

The building is declared as a first category monument and as such the intervention will totally respect the elements and try to preserve in maximum the values the building is caring for.

- Every authentic element will be preserved and only if it is considered very necessary will be replaced by new elements using the same material and techniques.
- The museological proposal also will respect the structure and elements of the building.
- All the elements will be cleaned and their condition will be checked carefully.
- Only the elements that are completely damaged will be replaced with new ones using the same type of material and dimensions.

The material used for the restoration of the elements needs to be of the same specifications of the existing ones: type, density, humidity, strength need to be analysed and the data will be used for the new elements.

More in particular:

1. Drainage in the back part of the building was to avoid the humidity in the ground floor and first floor on the south west walls.
2. Restoration works in the roof
   -All the stone slates must be removed to allow for the hydro isolation membrane to be installed.
   -Where there are structural problems: rotten, damaged, missing or wrongly positioned elements the roof needs to be dismantled carefully and elements need to be restored and correctly positioned.

- New elements, like beams, rafters and props will be installed where needed. Beams will be installed in parallel to the damaged or missing ones.
- Joints of different elements need to be checked and elements reconnected properly.

3. Restoration of the damaged stone walls.
   Repointing the loose joints. The joints will be checked in the lower part of the walls where humidity has affected and in the North West and south west facades. Test pits for the composition of the joints plaster will be done initially. The new plaster will have the same composition as the existing one verified from the tests. Internal stone walls, where the hanging exhibition boxes are positioned, will have minimal interventions. At the upper level of the exhibition boxes there will be installed metallic elements in the joints of the stone walls for hanging. Small openings of plaster on the stone walls to see where the joints are will be done, so that anchors can be installed. The mortar will be then restored with a new one having the same composition as the existing one. The joints will be first cleaned thoroughly with pressured water and after refilled with the new mortar. Additional non correct repointing with cement mortar will be mechanically removed carefully not to damage the stones, the joints cleaned and restored in the same process as mentioned above.
4. Test-pits to check the wooden wall structures of the building for their condition. Restoration of "çatma" walls if necessary.
5. Restoration of the windows/doors/wooden floors/ceilings/staircases of the building. Every element will be checked carefully and only the damaged ones will be replaced with new ones.Test pits should be done to evaluate the condition of the main structure.The stability of their structure should be secured.
6. Cleaning the walls from the vegetation
7. Graffiti cleaning walls
8. Treatment of ceilings, windows, doors and all other wooden elements with linseed oil

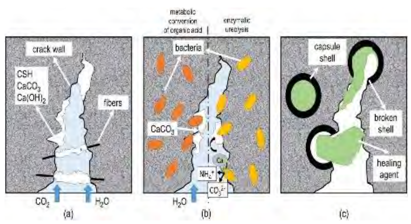
4. FUTURE DIRECTION IN HERITAGE ENGINEERING

The utilization of advanced restoration techniques can stimulate economic growth by attracting tourism, fostering local pride, and revitalizing historic neighborhoods, thus creating a ripple effect of positive social and economic benefits for surrounding communities.
Investing money into the newest technology to repair old buildings is more than just spending; it's a wise investment in our history. These ancient structures are a physical connection to our shared history, giving us a glimpse into the architecture, social life, and culture from the past. With the latest tech, we can help these precious landmarks last longer and protect them from wear and tear, natural disasters, and harm from the environment.

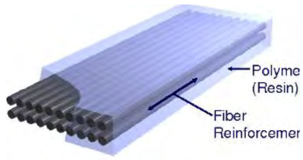
These innovations aim to ensure longevity, structural integrity, and aesthetic fidelity. Here's a look at some of the advanced materials and techniques used in restoration:

4.1. Advanced Materials that can be used in restoration

- Self-Healing Concrete: This concrete contains bacteria that produce limestone when exposed to water and air. It's used to fill cracks and improve the durability of structures.



- Fiber-Reinforced Polymers (FRP): These materials are used to strengthen structural elements without significantly increasing their weight or altering their appearance.



-Nanomaterials: Nanotechnology offers solutions for enhancing the mechanical properties of materials, providing self-cleaning surfaces (through photocatalytic coatings), and improving thermal and moisture insulation.
-Shape Memory Alloys (SMAs): SMAs can return to their original shapes after being deformed, making them useful for reinforcing structures against seismic activity.

-Geopolymer Concrete: This is a more sustainable alternative to traditional concrete, with better resistance to chemicals and fire. It's used for repairs and in areas requiring enhanced durability.
-Bioactive Glass for Conservation: In the conservation of stone and murals, bioactive glass can be used for its properties of chemically bonding with the existing material, facilitating better preservation.

4.2. Advanced Techniques suggested in restoration

-Digital Twins: Creating a digital twin (a virtual model) of a structure allows engineers to simulate effects of different restoration methods and environmental conditions on the building.
-Structural Health Monitoring (SHM): SHM systems use sensors to continuously monitor the condition of a structure, detecting issues like cracks or deformations early on.
-Laser Cleaning: Laser techniques are used for cleaning surfaces, removing contaminants, and uncovering original details without physical contact or the use of chemicals.

-Electrochemical Techniques: For metal restoration, electrochemical methods can be used to remove corrosion without damaging the original material.
-Biological Methods: For stone and masonry, certain biological treatments involve microorganisms that can remove pollutants or consolidate the material, preserving it without harsh chemicals.

5. CONCLUSION

Preserving the heritage and restoring buildings in Gjirokastra is not just about maintaining architectural beauty; it's a profound commitment to safeguarding a unique cultural identity and historical narrative for future generations. Gjirokastra, with its distinctive stone houses and rich history, stands as a testament to the artistic and cultural achievements of its people over centuries. The restoration efforts in this UNESCO World Heritage Site embody a delicate balance between honouring the past and embracing the present. By investing in the preservation of Gjirokastra's buildings, we are not only protecting physical structures but also ensuring the continuation of stories, traditions, and a sense of community that define this historic city. Thus, the restoration and preservation of Gjirokastra is a critical endeavour that bridges generations, fostering an appreciation for cultural heritage while contributing to sustainable tourism and economic development in the region.

REFERENCES:

[1]Lamprakos, M., 2010: Conservation of Gjirokastra, Albania. Onsite Review Report, edited by Aga Khan Award for Architecture.

[1.1] ICOMOS article, April 2005: Gjirokastra (Albania) .

[1.1.1] L. Dipasquale 1, M. Carta 1, S. Galassi 1, A. Merlo 1, * 1 Department of Architecture, DAR|MED Lab, University of Florence, Italy-THE VERNACULAR HERITAGE OF GJIROKASTRA (ALBANIA): ANALYSIS OF URBAN AND CONSTRUCTIVE FEATURES, THREATS AND CONSERVATION STRATEGIES

[3.1] [3.1.1] [3.1.2] Klodjan Xhexhi Research Paper 2021: Fortified Historcial Dwelling Reevaluated
In Modern Context, Gjirokaster, Albania.

[3.2] Casanova and Hernandez architects Cultural Heritage without Borders 2020: Design and supervision Gjirokastra system of Museums

[4.1] Michele B., Giovanna P., David C., Piero B, 2021: Advanced Materials in Cultural Heritage Conservation

[4.2] Maria A., Emiro D., Jorge E., 2023: Technologies for the Preservation of Cultural Heritage—A Systematic Review of the Literature

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