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Engineering for Tomorrow: Themes and Reflections from NCE 2024

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The National Civil Engineering Symposium (NCE 2024), held in Kyrenia, North Cyprus, has once again brought together a diverse and vibrant community of civil engineering professionals, researchers, and academics. This biennial event continues to serve as a critical forum for the exchange of ideas, dissemination of research findings, and the fostering of collaboration across the many sub-disciplines of civil engineering. The proceedings presented in this volume represent the collective effort of hundreds of contributors who are actively shaping the future of the built environment.

Civil engineering, as a discipline, stands at a pivotal intersection of technological advancement and societal need. In a time marked by the escalating effects of climate change, rapid urbanization, and the urgent demand for sustainable development, civil engineers are increasingly called upon to rethink conventional paradigms and adopt more adaptive, innovative, and resilient solutions. The research contributions in this volume reflect this transformation, offering both depth and breadth across traditional and emerging areas of civil engineering.

The contents of this proceedings volume are organized to reflect the comprehensive nature of the symposium. Contributions span across structural engineering, geotechnical engineering, construction materials, hydraulics and water resources engineering, traffic and transportation engineering, and construction management. In addition, a growing number of papers address interdisciplinary themes such as smart infrastructure systems, digital twins, disaster resilience, and sustainability in design and construction practices.

Many of the studies presented here highlight innovative approaches to long-standing challenges—such as seismic retrofitting of aging infrastructure, the reuse of industrial by-products in concrete production, or optimization of transportation systems through data-driven methods. Others explore frontier areas, such as machine learning applications in structural health monitoring, climate-adaptive urban drainage systems, or the role of life-cycle assessment in infrastructure investment decisions. This blend of traditional engineering principles and forward-looking research reflects the evolving responsibilities and expanding toolbox of the modern civil engineer.

Of particular note is the high level of engagement by early-career researchers and graduate students, whose energy and creativity are evident throughout the contributions. Their presence, alongside the work of seasoned academics and industry experts, creates a rich and multigenerational dialogue that is essential for progress in any engineering field.

This volume also underscores the increasing importance of multidisciplinary collaboration. Several papers result from partnerships between academia, industry, and public agencies, and demonstrate how real-world impact can be amplified through cooperative efforts. Equally,

many submissions reflect a conscious awareness of engineering's broader responsibilities—toward environmental stewardship, public safety, and social equity.

The editorial team is grateful to all authors who submitted their work, to the reviewers for their invaluable input, and to the organizing committee for curating a technically rigorous and thematically diverse symposium program. We believe this compilation of research represents not only the state of the art in civil engineering today, but also offers a glimpse into the profession's future—a future that is more integrative, responsive, and committed to building a more resilient and sustainable world.

We invite readers to explore the contributions within these pages with curiosity and critical thought. May the work presented here inspire further inquiry, cross-disciplinary dialogue, and meaningful innovation in both academic and practical realms of civil engineering.

TABLE OF CONTENTS

Observed Damages in Turkiye Due to the Kahramanmaras Earthquakes of February 6, 2023, and Recommendations for TRNC

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1. INTRODUCTION

On February 6, 2023, at about 4:17 am local time, an earthquake occurred at a depth of 17.9 km (Mw 7.8) and with an epicenter near the city of Nurdağı, in the province of Gaziantep, in the South of Turkey (coordinates 37.174°N, 37.032°E). Approximately 9 hours later, a second earthquake induced by the previous one occurred on the Sürgü-Çardak fault at a depth of 10 km (Mw 7.5) with an epicenter near Ekinözü, in the province of Kahramanmaraş (coordinates 38.024°N, 37.203°E). The earthquakes were followed by many aftershocks, including several larger than Mw 6.0. Nevertheless, under the Kahramanmaraş earthquake demands, several buildings partially or completely collapsed, and several others were severely damaged in Turkey and Syria. The high vulnerability in the region had previously been identified due to the rapid construction that responded to the need for residential housing, coupled with questionable control and poor code enforcement (Abrahamczyk et al. 2013).
As a result of the earthquakes and aftershocks, around 28,500 buildings partially or completely collapsed, while another 66,000 buildings were severely damaged in Turkey (Dilsiz et al., 2023). To exemplify, the statistics of the damaged buildings in the province of Hatay are shown in Fig. 1.

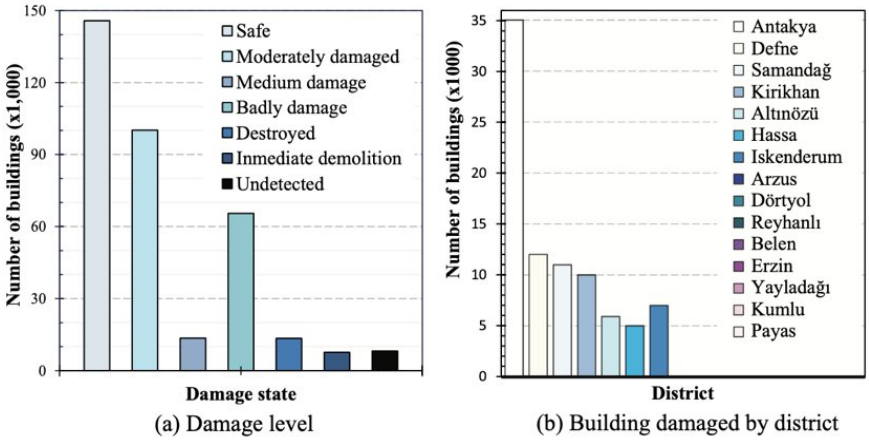

Figure 1. Statistics of damaged buildings in the province of Hatay (AFAD 2023).

The locations visited at the post-earthquake inspection included cities and towns in the provinces of Gaziantep, Kahramanmaraş, Adiyaman, Osmaniye, and Hatay. This paper examines the structural response of buildings under imposed seismic demands. Furthermore, the study aims to spread the acquired knowledge to provide significant insight into the

performance of structures and show the lessons to improve the current design practices in seismic-prone countries such as TRNC.

2. MATERIALS AND METHODS

2.1. Recorded Ground Motions

The earthquake demands were recorded by several accelerometric stations from the Turkiye's Disaster and Emergency Management Authority of the Ministry of Interior (AFAD). Twelve records were selected from the Turkish Accelerometric Network to underline the magnitude of the imposed demands. Although the ground motions were not exactly recorded at the buildings' locations, the magnitudes, fault distance, and source mechanisms are consistent with those controlling the maximum demand. Therefore, they might contribute to understanding the damage evolution and collapse mechanisms.

2.2. Structural Configuration

According to the field inspection, the most frequent structural system in urban areas considered for buildings was the moment-resisting reinforced concrete frames. For example, in Antakya, it represents more than 67% of the entire building stock (Abrahamczyk et al., 2013). The moment-resisting frame system typically consists of rectangular columns or concrete shear walls with rectangular beams. The second most used system was simple stone masonry, and unreinforced masonry, usually with multi-perforated clay bricks, representing 28%. Fig. 2 presents the distribution of the damaged buildings in the province of Hatay. Except for three locations, it is clear that most of the damages occurred in urban areas. This suggests that there was much damage in urban buildings even when they are supposed to be designed and built following the stricter requirements of specialized codes.

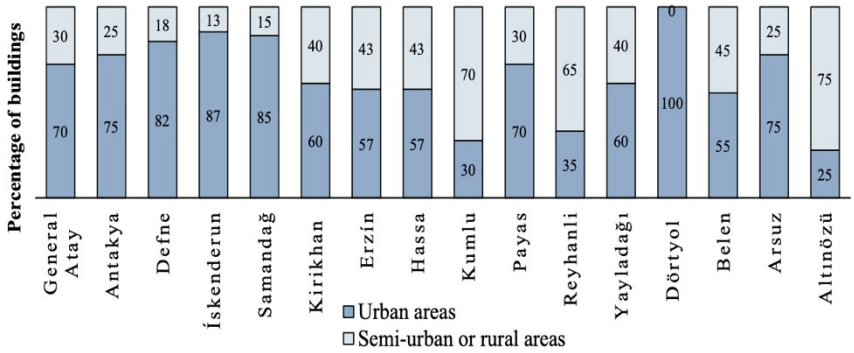

Figure 2. Distribution of the damaged buildings in the province of Hatay

Soft story buildings are vertically irregular structures that frequently become damaged or collapse after a strong earthquake because the weak stories are less stiff and resistant. The first soft-story was one of the most commonly used structural configurations in collapsed buildings in other earthquakes.

The reinforced concrete frames often have columns (or walls) oriented with greater cross-sectional dimension in one direction, creating weaker frames in the orthogonal direction (Fig. 8). In some cases, beams are only laid in one direction, while the connection between parallel frames relies upon the concrete slab forming the floor.

2.3. Collapse modes

Although specific damage was often influenced by factors related to the particularities of each building, a typical pattern might be identified in the collapse mechanism. As discussed ibelow, the main identified mechanisms were pancake collapse, first-story collapse, upper story failures, shear cracks on iAnfill masonry walls, bending and shear failure in reinforced concrete elements, and foundation failure associated with subsidence or liquefaction.

3. CONCLUSION

The damages happened due to the combination of different factors, including the large magnitudes of the earthquakes, unequal distribution of structural members and their dimensions regarding stiffness and strength, lack of reinforced concrete shear walls, inappropriate design and construction practices, poor detailing, damage, and effects of infill walls, amongst others, which resulted in insufficient ductility elements or connections and, consequently, in severe affectations.

Reinforced concrete frames were the most commonly used structural systems for residential buildings in the affected areas. The majority of the buildings had infill walls with multi-perforated clay bricks. Upon the post-earthquake inspection, it was evident that the practice knowledge associated with the local seismic code's requirements was lacking and that provisions for detailing. Common identified mistakes are i) absence, amount, and distribution of transverse ties; ii) stirrups spacing and formation of 135-degree hooks; iii) the quality of the concrete was usually poor, contributing to the brittle behavior of structural elements, which includes the use of river rocks as aggregated and sand obtained from the sea, insufficient vibration and curing of concrete, and production of concrete on the site by workers with high water/cement ratios for workability.

The most common failure mechanism was the soft-story collapse of the first or two stories, which was related to the inappropriate behavior of vertical reinforced concrete elements. In areas of higher shaking, the proportion of multi-story collapse was more significant. Architectural project deficiencies were also identified such as the short column effect; overloaded cantilevers; unsymmetrical buildings; and placement of vertical elements (columns and walls) with orientation of strong axis in the same direction.

As conclusion, the building stock of TRNC has similar building typologies and construction tecnologies to Turkiye. There are many faults during the design and construction of new buildings. During the design and construction of newly constructed buildings, it is necessary to enact the necessary legislation to be inspected by experienced and certified design and implementation supervisors. In addition, it is necessary to quickly scan the existing buildings and to make the necessary structural improvements to eliminate the irregularities and performance deficiencies by performing detailed performance analyses of reinforced concrete buildings, especially with five or more stories.

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Evaluation of the effectiveness of various retrofitting methods

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1. INTRODUCTION

After the February 6, 2023 Kahramanmaraş Earthquakes, it has been observed that retrofitting of damaged structures in the earthquake zone was carried out under the name of retrofitting by using fibrous polymer without static analysis. These and similar situations, which are carried out without examining the needs and requirements of the structure, cause loss of national wealth by failing to provide the necessary strength despite the expenditures made or by being applied although it is not necessary.
This study has been prepared to evaluate the effectiveness of element-based and system-based retrofitting methods used in buildings and is expected to be useful in preventing faulty applications. The structures were retrofitted using fibrous polymer wrapping and shear wall addition methods and the outputs of the retrofitting methods were examined.

2. MATERIALS AND METHODS

TS500, TBDY-2018 and ACI-440 regulations were used for static analyses and the models were prepared using SI unit system according to linear and non-linear methods using programs widely used in the sector such as ETABS-SAP2000.
The structures selected for the study were chosen to represent the existing building stock in Turkey, which has problems in terms of compressive strength, ductility, regular structural system configuration and shear strength.
First, a linear model of the selected structures was established. Based on the data obtained from the linear model, the nonlinear analysis method was selected according to TBDY-2018. The effective section stiffness of the elements of the structure was calculated and then the displacement demand of the structure was determined by performing nonlinear analysis. For the determined displacement demand, the condition of the structural elements was evaluated according to TBDY-2018 and the structural performance was determined.
Based on the insufficient strength of the structures in the current situation, the structures were reanalyzed by using methods such as reinforcement with fibrous polymer and shear wall addition.

3. CONCLUSION

In the analysis results, it was observed that the retrofitting method with fibrous polymer, which is an element-based retrofitting method, increased the displacement capacity of the structure by providing ductility to the structure, reduced the number of collapsed elements, increased the compressive strength of concrete with the wrapping effect depending on the section geometry and provided significant increases in shear strength depending on the element shear capacity, but since there was no change in the stiffness of the structure, it was observed that it could not prevent the formation of collapsed structural elements in structures that do not have sufficient stiffness.
In the shear wall addition method, which is a system-based retrofitting method, it was observed that the displacement demand of the structure decreased due to the increased stiffness in the structure by adding shear walls to the structure, and in response to this, the rotations in the

structural elements decreased. In some structures, it was observed that the addition of shear walls due to reduced rotations prevented collapse, while in some structures, it was observed that collapse could only be prevented if the structural elements were reinforced with fibrous polymer after the addition of shear walls. Especially the structure with low concrete compressive strength and insufficient stiffness required the use of both methods.

In addition, the earthquake force on the structure increased with the increase in stiffness. Even if a large part of the increased seismic force is absorbed by shear walls, it is observed that inadequacy occurs due to the increased shear force, especially in structural elements with small cross-sections and low compressive strength, and in such cases, jacketing is needed because the shear capacity of the elements is insufficient. It is seen that fibrous polymer will be very useful in elements whose cross-sectional dimensions and concrete compressive strength are sufficient but collapse is observed due to insufficient stirrups.

As a result, it was observed that the deficiencies of the structure should be well evaluated in the selection of the retrofitting method to be used, stiffness increasing methods such as shear wall addition should be used in structures with insufficient stiffness, but the method should be supported by using element-based retrofitting methods for the deficiencies that may occur in the elements while using these methods.

It is predicted that the retrofitting method with fibrous polymer will not provide the desired performance in structures with insufficient stiffness, but it is thought that it will be a very useful retrofitting method for increasing element ductility, normal compressive strength and shear strength in structures that do not have problems in terms of stiffness.

Performance Level of Reinforced Concrete Buildings Using Neural Network and Multi-Regression Analysis

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1. INTRODUCTION

During past earthquakes, many reinforced concrete (RC) buildings have either collapsed or suffered distinct degrees of damage. Earthquake safety of our structures is one of the most important considerations which should be taken before any construction project gets underway. If the structure is strong enough then the people who are using that structure are in a safe position.

2. MATERIALS AND METHODS

This study consists of a calculation of the performance level of reinforced concrete buildings using an Artificial Neural Network and Multi-Regression Analysis. To determine the performance level of building stock, 377 RC buildings were designed according to the 1975, 1997, 2007, and 2018 Turkish Earthquake Codes. Then, the performance level of 377 RC structures was checked according to the 2018 Turkish Earthquake Code using modal pushover analysis. Finally, Artificial Neural Network and Multi-Regression Analysis models were prepared using these data and selecting 12 input parameters. The input parameters used in this study are 1-The area of the building, 2-Class of concrete, 3-Story number in the building, 4-Class of Steel, 5-Column Ratio in the structure, 6-Shear Wall Ratio, 7-Earthquake zone, 8-Earthquake Code, 9-Soil Type, 10-Stirrup Spacing, 11-Torsional Irregularity and 12-Soft Story. The output parameter for the study is the performance level of the structures.

3. CONCLUSION

As a result, 97% accuracy has been found for ANN and 95% accuracy for the MRA. From the performance level results, it can be indicated that the structures with low concrete compressive strength, low shear-wall ratio and not enough stirrup spacing have collapse and collapse prevention performance levels. Also, the structures that have irregularities and consist of soft stories also have low performance.

Keywords: Artificial Neural Network (ANN), Multi-Regression Analysis (MRA) Earthquake, 2018 Code, Performance.

Comparative Analysis of Seismic Code Requirements (Tec 2007, Tec 2018, and Eurocode 8) for Reinforced Concrete Buildings with Emphasis on Material Efficiency and Environmental Impact.

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1. INTRODUCTION

Earthquake-resistant design codes play a crucial role in ensuring the safety and resilience of reinforced concrete (RC) buildings in seismic-prone regions. Turkey, being situated in a highly seismic area, has recently updated its earthquake code from TEC 2007 (*2007-Turkish-Earthquake-Code.Pdf*, n.d.) to TEC 2018 (*TEC2018-Sadece Ana Text.Pdf*, n.d.), while Eurocode 8 (EC 8) (*En.1998.1.2004.Pdf*, n.d.) serves as a widely adopted standard in Europe (Lagha, n.d.). The purpose of this study is to compare the minimal design specifications for RC buildings as outlined by EC 8 (EN 1998-1:2004), TEC 2007, and TEC 2018. This study evaluates the impact of the codes on structural material requirements for low- to mid-rise superstructure frames (4, 7, and 10 stories) with three bay configurations (6m spacing in both directions) and 3.5m uniform story heights. The analysis calculates the bare minimum of steel and concrete needed for every design code using MS Excel calculations, revealing how each code's provisions impact material efficiency. According to recent studies on the evolution of seismic codes, TEC2018 and EC8 introduced stricter material performance standards and safety enhancements in response to the increased seismic safety requirements for urban areas (Ricci et al., 2023). To further assess the environmental effects of various seismic codes, this study quantifies the embodied energy (EE) and carbon (EC) related to the construction of the RC frames designed in accordance with each code.
This is in line with contemporary sustainable construction trends that place a high priority on lowering resource consumption and carbon emissions in the building industry. The EE and EC findings contribute valuable insights, especially given recent calls for seismic codes to consider not only structural safety but also sustainability. The significance of this research lies in its potential to guide the development and refinement of earthquake design codes that strike a balance between ensuring the structural integrity of RC buildings and promoting sustainable construction practices. The comparison of Eurocode 8, TEC 2018, and TEC 2007 offers important insights into how design requirements have changed over time and how they affect material consumption and environmental sustainability. The study contributes to the expanding body of knowledge on the environmental performance of seismic-resistant structures by quantifying the carbon and embodied energy associated with each code's design outcomes (Atmaca & Atmaca, 2015) hence informing decision-makers, and engineers about the trade-offs between structural safety and environmental sustainability when adopting different earthquake design codes (Hossain & Ng, 2018).

2. MATERIALS AND METHODS

The methodology for this research will be structured in several key phases, encompassing the selection of building models, detailed calculations based on the specified codes, and the assessment of embodied energy and carbon emissions. These calculations will be done using spreadsheet software (MS Excel) by taking into account the minimum requirements suggested by the codes to be applied to the proposed RC frames shown in **Figure 1**.

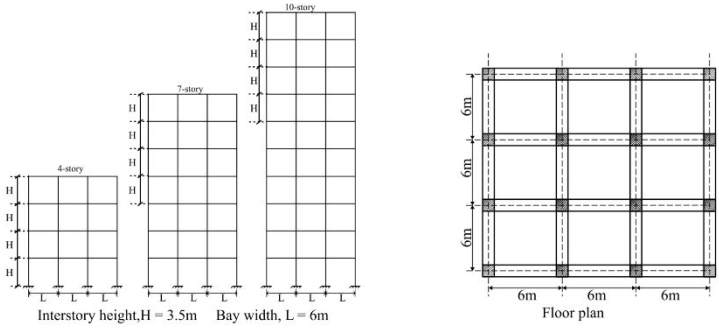

Figure 1. Proposed RC frames and floor plan.

The construction embodied energy and carbon estimations will be determined by considering the coefficients suggested using the ICE database("Embodied Carbon Footprint Database," n.d.).

$$EE = \sum Material\ quantities * EEcoeff \quad [1]$$

$$EC = \sum Material\ quantities * ECcoeff \quad [2]$$

3. RESULTS AND DISCUSSION

The RC-frames material, EE, and EC quanties are determined for the different building codes in **Figure 2**. These results provided a basis for discussing the similarities, differences, and trends based on the codes' minimum requirements.

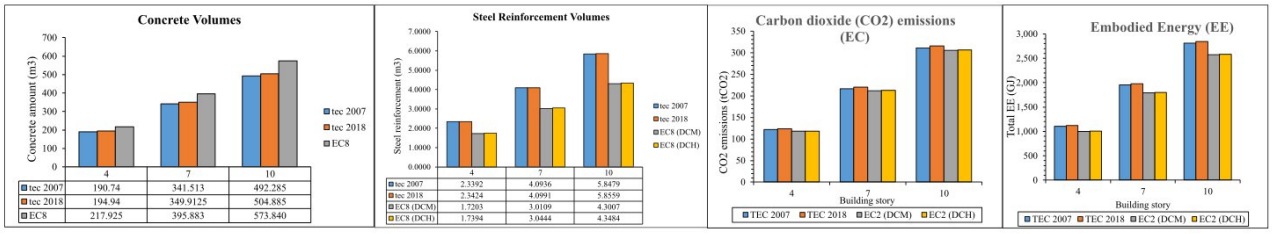

Figure 2. Material quantities as well as EC and EE results

4. CONCLUSION

The study gives insight to the evolution of seismic design codes, their implications for material efficiency and environmental sustainability, and potential trade-offs between structural safety and environmental impact. By quantifying the material consumption and embodied energy and carbon associated with each code's design outcomes, the study highlights the importance of considering environmental metrics in the evaluation of seismic design codes.

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Seismic Evaluation of RC Sports Facilities Buildings in Lefkoşa Using Rapid Visual Assessment Methods

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1. INTRODUCTION

In recent years, the significance of earthquake preventive measures has greatly increased, particularly due to the latest earthquakes. One of the most important prevention measures that should be carried out is the evaluation of buildings in earthquake-prone areas. Evaluating the performance of a building requires time and resource, however, due to these limitations, several screening techniques have been developed that can help in the rapid assessment of the vulnerability of a wide range of building types globally. Many earthquake-prone nations already employ pre-earthquake screening of structures to determine which ones are most likely to be seismically dangerous and to rank the ones that need further investigation. The methods used in this review will focus on four methods, and the comparison between the scores obtained. Yakut et. al, 2014, Albayrak et. al., 2015, FEMA 154, 2002, and KTIMO 2023. The KTIMO 2023 method was developed by the chamber of civil engineers, based on the Yakut et al., 2015 method, as a response to the earthquake which devastated Türkiye in February 2023.

2. METHODS

In this project, an evaluation of six sports facilities buildings in Lefkoşa (Atatürk Kapalı Yüzme Havuzu, Atatürk Spor Salonu, Atatürk Stadyumu, Sporcu Kamp ve Eğitim Merkezi, Küçük Antreman Salonu and Necati Taşkın İlkokulu Spor Salonu) was carried out by visually assessing the structures using Yakut et. al, 2014, Albayrak et. al., 2015, FEMA 154, 2002, and KTIMO 2023 methods. This section will present a summary of the data collection and analysis using rapid visual assessment methods to evaluate the seismic risk level of sports facilities buildings. Through the assessment of building vulnerability and categorize their risk level through visual inspection. Thus, results were obtained and used to make a comparison between the methods used in the visual assessment of the buildings. Parameters used to carry out the rapid visual assessment include building age, structural system, number of floors, vertical and plan irregularities, presence of short columns, heavy overhangs, and potential pounding effects from adjacent buildings.

3. CRACKS AND OTHER PROBLEMS OBSERVED IN BUILDINGS

There are several important observations that should be noted, as:

- Cracks were observed due to the seeping of water in the concrete, resulting into the growth of vegetation, which accelerate the deterioration of concrete by exerting pressure on the building.
- Spalling was seen at several locations throughout the buildings visited. That is surface cracking, which in this case is a direct result of the corrosion of the rebar, resulting into the detachment of the concrete, or due to insufficient concrete cover.
- Efflorescence was observed as well, it is a white deposit at the concrete surface, as a result of moisture movement.

4. RESULTS AND DISCUSSIONS

The difference in the scores obtained from four methods slightly differed, depending on the regional applicability, and the criteria used in the scoring.

Table 1. Comparison of the results obtained from the four methods

Method	B1	B2	B3	B4	B5	B6
Albayrak et al., 2015	No risk	No risk	No risk	No risk	No risk	No risk
Yakut et al. 2014	Low	Low	Low	Low	Low	Low
KTIMO 2023	Low	High	High	Low	Low	Low
FEMA 154 2002	Low	High	High	Low	High	Low

When comparing the varying risk scores obtained using the four methods, it is important to note that each method was developed with specific regional considerations, through the evaluation of structural characteristics and seismic vulnerabilities typical of the area in which it is intended to be used. Hence, the applicability and sensitivity of each method may differ when applied to the same building in a different region.

The relative importance of the considered factors varies across the methods, with each method weighting certain vulnerabilities differently. This difference in parameter weighting affects the overall risk score.

5. CONCLUSIONS

The rapid visual assessment methods serve as efficient tools for the qualitative analysis of the seismic risk of buildings. However, selecting an appropriate method should take into account its alignment with regional factors, such as the specific country or region, soil conditions, building typologies, seismic zoning, and the historical characteristics of local buildings. Since more parameters are taken into account in the KTIMO 2023 method, it is thought that it allows for a more extensive examination of the buildings examined. The results also emphasized the importance of scheduling regular structural inspection and preventive maintenance to ensure the safety and durability of sports facilities buildings in regions susceptible to earthquakes.

6. ACKNOWLEDGMENT

The authors would like to extend appreciation to the relevant authorities in the TRNC for providing the necessary authorization. We would like to give thanks to Assoc. Prof. Dr. Abdullah Ekinci, President of the Chamber of Civil Engineers, and the 46th term of board directors. Lastly, we would like to acknowledge the 3rd National Civil Engineering Symposium for the opportunity to present this work.

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Seismic Rehabilitation and Nonlinear Analysis of a Reinforced Concrete School in Nicosia Following the 2023 Kahramanmaraş Earthquake Sequences

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1. INTRODUCTION

Seismic hazards have consistently led to significant destruction, particularly in densely populated urban areas. The 2023 Turkish earthquake is one of the most devastating disasters to have occurred in recent years, severely impacting the Turkish economy and causing widespread destruction. This earthquake damaged residential buildings and had a severe impact on hospitals, schools, and other public facilities. (Ihsan Turan et al., 2024; Altunsu et al., 2024)

Public facilities like hospitals and schools play a crucial role during and after seismic events. Hospitals must remain operational to provide immediate care to the injured, while schools, beyond their role in protecting students during school hours, can serve as shelters for displaced individuals in the aftermath of a disaster. Given these critical functions, the construction and maintenance of such buildings must adhere to high safety standards. (Qu et al., 2023; Vuran et al., 2024; Yu et al., 2024)

In response to this earthquake, the government of North Cyprus initiated a program to rehabilitate essential facilities, including schools, in several cities. An effective assessment, beyond conventional gravitational and seismic analysis, should consider the nonlinearity of element behaviors, the frequency content and duration of seismic excitation, and uncertainties in material properties, geometry, and loads within the analysis environment. (Onat et al., 2024)

This case study focuses on the rehabilitation process for Atatürk Technical High School, located in the city of Nicosia. The rehabilitation aimed to enhance the safety and resilience of the building, ensuring they can effectively serve their community during and after seismic events.

The time-history analysis of the building in both directions aligns with the pushover analysis and clearly indicates the need for additional lateral resistance and rehabilitation. The rehabilitated buildings, which are either reinforced with 25 cm shear walls or hollow steel tube sections, were analyzed using sequential time-history analysis. The results demonstrate that the case study buildings maintain immediate occupancy status even after the second ground motion sequence, and the residual deformations in the structures are significantly reduced.

2. MATERIALS AND METHODS

The analysis focuses on two buildings: a one-story kindergarten constructed over 20 years ago and a newer structure, Ek Derse, with two blocks (Block A and Block B). The kindergarten is made of C16 concrete and features columns (25 cm by 40 cm) weaker than its beams (25 cm by 60 cm), making it vulnerable to shear failures. In contrast, Ek Derse is built with higher-quality C30 concrete, with columns measuring 30 cm by 60 cm and beams between 30 cm by 60 cm and 30 cm by 80 cm. Images of the investigated buildings are provided in Figure 1.

Figure 1. Atatürk Technical High School; a) Kindergarten, b) Ek Derse

The seismic response of the structure was evaluated using the 2023 Turkey earthquake ground motion sequence. ASCE 41-17 guidelines (Tables 10-7 to 10-9) were applied for defining plastic deformations and hinge formations, using SAP2000 for analysis.

3. RESULTS AND DISCUSSION

Time history analysis revealed that most hinges formed in the first story, with 17% of columns reaching collapse after the main shock and 48% following the second shock (Figure 2). Shear walls and steel-braced frames were added to the system in both the x and y directions (Figure 3), which reduced the maximum roof drift to one-third of the initial value. Additionally, residual drift became negligible after the rehabilitation (Figure 4).

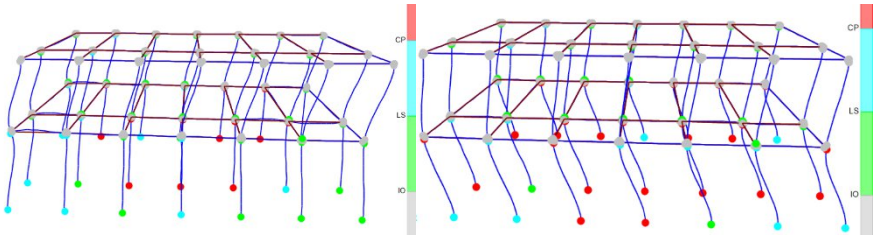

Figure 2. Hinge formations in the frames at X direction at the end of the; a) Mainshock, b) Second shock

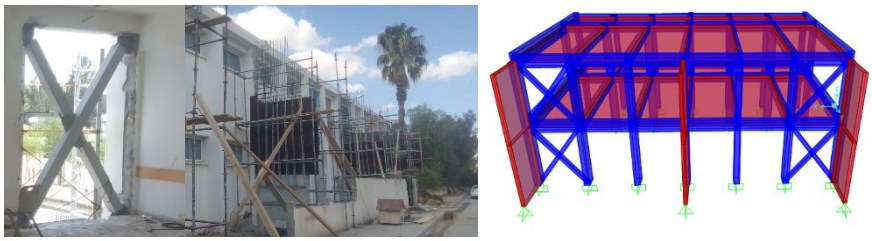

Figure 3. a) Tube 200x200x12.5 X-braced frames, b) 25 cm shear wall, c) Rehabilitated building (Block A)

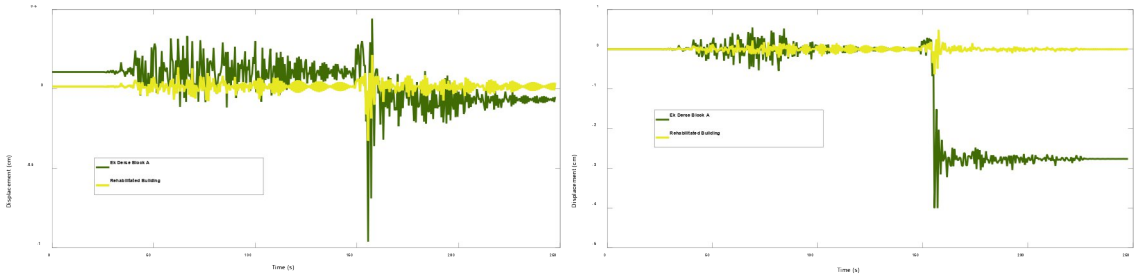

Figure 4. Time history analysis of the Ek Derse Block A at a) X direction, b) Y direction

4. CONCLUSION

Time history analysis shows that non-rehabilitated buildings face life safety concerns, hinge formation, and potential collapse by the second shock. In contrast, rehabilitated buildings achieve immediate occupancy, and exhibit minimal residual deformation, whereas non-rehabilitated ones undergo up to three centimeters of roof displacement.

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Finite Element Modelling of Reinforced Concrete Beam-Column Joints' Shear N-M Interaction Hinge: Applications at a Structural System Level

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1. INTRODUCTION

In reinforced concrete (RC) buildings, beam-column joints serve primarily in correctly distributing the lateral forces across the connecting frame elements to the ground via a continuous load path. This function makes the joints critical to the structure's overall seismic performance. As a result, it is critical to properly design these joints for seismic loads. The significance of poorly designed beam-column joints in resisting lateral forces during the design of RC structures is underscored by studies from earthquake incidences, which contribute to the sudden collapse of these structures. As seismic design codes have evolved, the strong column-weak beam (SCWB) capacity design approach is used to design buildings. This approach prevents collapse of columns and beam-column joints by providing joint shear reinforcement and guarantees that seismic energy is dissipated to the beams (forming beam plastic hinges). Despite this, beam-column joint failures are still observed in RC structures, highlighting the need for a method to properly design/model these connection. Several models (Birely et al., 2012; Unal & Burak, 2013; YOUSSEF & GHOBARAH, 2008) have been developed to represent the behaviour of beam-column joints to be used during seismic analyses. However, the complexity of these models makes it impractical for everyday engineers to incorporate to real life engineering applications. These models' inability to consider axial load variations makes them undesirable. Thus in this research, we are proposing the application of a model at a structural system level which represents the beam-column joint shear capacity as an N-M interaction envelope. This study seeks to investigate the joint shear failures of RC beam-column joints in the behaviour of reinforced concrete frame structures (modern and old). This study focuses on the numerical use of beam-column joint shear N-M interaction hinges to represent the RC beam-column joints' shear capacity in a main stream finite element software (SAP2000) widely used by the practicing structural engineers. Through the use of this modelling approach in nonlinear static analyses for RC frames whose experimental tests have been conducted, investigations concentrate on its application at the structural system level (i.e. 2D RC frame tests) to demonstrate and highlight its accuracy, practicality, and validity for real-world engineering applications. The research's outcomes aim to significantly contribute to the current body of knowledge regarding joint shear failures in reinforced concrete structures, ultimately leading to the development of improved RC beam-column joint shear modelling approaches for structural/seismic assessment applications in RC structures.

2. MATERIALS AND METHODS

The methodology to be used is that proposed by (Tasligedik, 2020) where the joint shear capacity is expressed as an N-M interaction envelope to account for both principal compression and principal tension stresses due to changes in axial load levels that determine which of the two stresses are critical. This methodology is a development from the application of strength hierarchy assessment at RC beam column joints (Tasligedik et al., 2016). A summary of the RC beam-column joint N-M interaction envelope to be used in the model is shown in **Figure 3**.

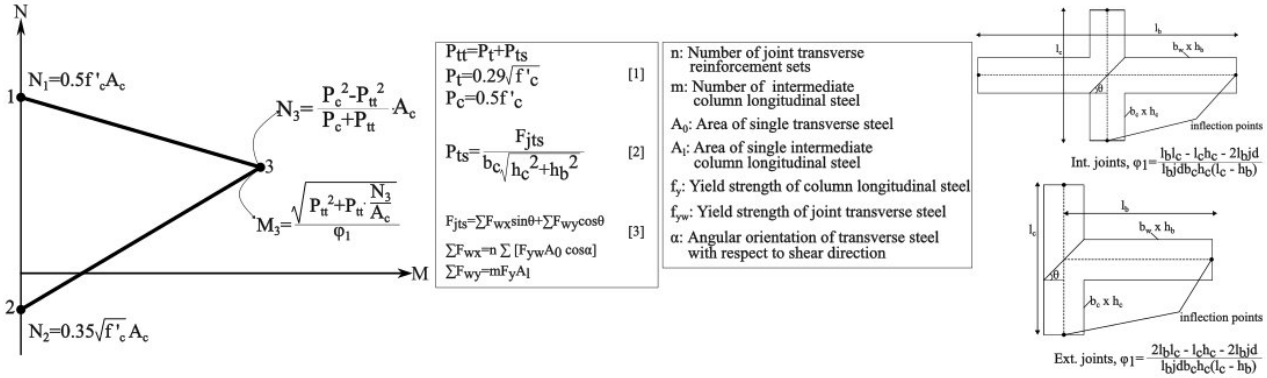

Figure 3. RC beam-column joint N-M interaction envelope (Tasligedik, 2020).

The three points on the proposed model are similar to N-M interaction diagram for columns with the first point (N1), second point (N2), and third point (N3, M3) similar to the uniaxial compression, uniaxial tension, and balanced case respectively. The RC beam-column joints' shear capacity will be represented with beam-column joint shear N-M interaction hinges modelled as force controlled interacting P-M2-M3 hinges below the joint in SAP 2000 together with the respective beam and column hinges.

3. CONCLUSION

Although the results are not yet available, it is anticipated that the findings will contribute significantly to the existing body of knowledge in structural engineering. The expected outcomes include enhanced modeling accuracy, improved design recommendations for RC beam-column joints, and a deeper understanding of their behavior in both modern and older structures. Ultimately, this research intend to contribute best practices in seismic design and assessment, leading to safer and more resilient infrastructure.

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Deep Neural Network to Predict the Compressive Strength of Rubberized Concrete Containing Silica Fume

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1. INTRODUCTION

In the recent years, researchers have used different methods to predict and evaluate different properties of concrete based on Artificial intelligence (AI) algorithms, among the AI algorithms neural network has been successfully used in civil engineering field (Siam et al., 2019; Naderpour et al., 2018). Neural network (NN) model possesses the capability of learning and modeling the complexity and nonlinearity between the inputs and the output (Basheer et al., 2000). The effectiveness of NN models in prediction of the mechanical properties of concrete could potentially lead to the reduction in the experimental cost and time. This research offers an approach to understanding the complex binary impact of Silica fume (SF) and rubber on concrete's strength using Deep neural network (DNN)

2. DEVELOPMENT AND EVALUATION OF THE MODEL

The research process included several steps. Data was collected, followed by a descriptive analysis to select features for the prediction model. The data was then preprocessed to remove outliers, normalize it, and ensure it was ready for training and testing. Normalization addressed scale differences between variables and reduced the impact of outliers (Ma et al., 2022). After preprocessing, the data was randomized and split into a training set (80%) and a testing set (20%) to ensure a fair distribution. The testing set was reserved for evaluating the model's performance on unseen data. Next, the DNN was trained using a 10-fold cross-validation procedure to tune the hyperparameters. This involved adjusting key parameters like learning rate, number of neurons, and activation function to find the optimal configuration. The best model was selected based on the average mean squared error (MSE) from the validation subsets.

3. RESULTS AND DISCUSSION

The performance of the DNN was evaluated using the test set. Hyperparameter optimization was done through "Nested loops" and 10-fold cross-validation, with mean squared error (MSE) as the main metric. The goal was to find the best hyperparameter combination. The final evaluation was based on the minimum average MSE from 10-fold cross-validation. The optimized hyperparameters for the DNN are shown in Table 1.

Table 1: Hyperparameter tuning ranges and optimal parameters of the DNN

Model	Hyperparameter	Tuning Range	Optimal Parameter
DNN	Neurons in the hidden layer 1	5-50	16
	Neurons in the hidden layer 2	5-50	14
	Activation Function	'relu', 'elu', 'sigmoid', 'tanh'	'elu'
	L1 Regularization	0-0.5	0
	L2 Regularization	0-0.5	0.001
	Learning rate	0.001-0.8	0.005

To evaluate the generalizability of the developed DNN model, its performance was tested on a held-out subset, simulating real-world conditions outside the controlled training environment. Performance metrics for this test subset are presented in Table 2, and Figure 1 visually compares predicted versus actual results. Additionally, the DNN model's performance is compared with linear and lasso regression models. The DNN achieved the highest R^2 value of 0.95, demonstrating superior performance compared to the other models.

Table 2: Performance evaluation of the models on training and testing subset

Base Learner	Training		Testing	
	R^2	MSE	R^2	MSE
DNN	0.9	14.9	0.92	9
LR	0.76	36.44	0.7	36.06
Lasso	0.68	44.75	0.7	35.6

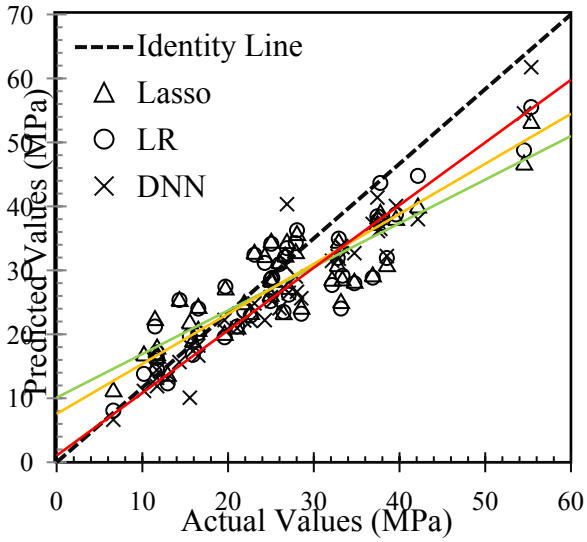

Figure 1: Correlation between actual and predicted outputs of models on testing data

4. CONCLUSION

This paper investigates the application of Deep Neural Networks (DNN) for predicting the compressive strength of rubberized concrete, which includes rubber and silica fume (SF) as components of sustainable construction materials. Hyperparameter tuning was performed using 10-fold cross-validation, optimizing for Mean Squared Error (MSE). The DNN model demonstrated strong performance during training, achieving an MSE of 14.9 MPa, while the Linear Regression (LR) model and lasso Regression recorded a much higher MSE of 36.44 and 44.75 respectively, indicating weaker performance. The models' ability to generalize to unseen data was evaluated on a test set. The DNN model again outperformed, with an R^2 of 0.92, compared to the LR and Lasso which both R^2 of 0.7, consistent with the training results.

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Sustainability enhancement by ai-based recycling processes of composite materials, a review

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1. INTRODUCTION

Composite materials, characterized by their heterogeneous structure and durability, pose unique challenges in recycling. Traditional recycling methods often fall short in handling the complexity of these materials (Jagadeesh et al., 2022). The increasing use of composite materials, including carbon fiber-reinforced plastics (CFRP) and glass fiber-reinforced plastics (GFRP), has created significant sustainability challenges in terms of recycling and waste management. Composite materials consist of multiple distinct components (fibers and matrices) that are chemically or physically bonded, making it difficult to separate and recycle them efficiently. Current methods, such as mechanical shredding, thermal recycling, and chemical dissolution, often degrade the quality of recovered fibers, reducing their potential for reuse in high-performance applications (Qureshi, 2022). The increasing global demand for sustainable solutions in material science has drawn significant attention to the recycling of composite materials, which are integral to industries such as aerospace, automotive, and construction. Traditional recycling approaches struggle with the complexity of composite materials, often leading to inefficient recovery, material complexity, contamination and high energy consumption. However, Arterial Intelligence (AI) and Machine Learning (ML) have emerged as transformative tools that can potentially address these challenges. With global emphasis on reducing carbon footprints and transitioning towards a circular economy, there is a growing need for advanced recycling processes (Essamlali, Nhaila, & El Khaili, 2024).

AI-based solutions can address these inefficiencies by optimizing processes, reducing energy consumption, and improving material recovery. AI technologies, including ML, computer vision, and optimization algorithms, offer innovative solutions to overcome the challenges associated with recycling composite materials. AI-based recycling processes offer transformative potential for enhancing the sustainability of composite materials. Arterial intelligence and machine learning can play significant roles in improving composite materials recycling processes. The efficiency gains provided by AI can lower operational costs for recycling facilities. This can make composite recycling economically viable on a larger scale, encouraging wider adoption of recycling practices across industries. AI-based predictive models are helping construction companies recover and repurpose composite materials from demolition waste (Ali et al., 2023). These models predict the condition and performance of recycled fibers, ensuring their safe reuse in new construction projects. AI-enhanced recycling processes contribute significantly to sustainability by reducing waste, conserving resources, and minimizing the carbon footprint associated with composite material disposal. Through efficient material recovery, AI-based systems can close the loop in composite manufacturing, transforming waste into high-quality raw materials that can be reintegrated into production cycles (Xu et al., 2023).

Karimi Ghaleh Jough and Şensoy (Karimi Ghaleh Jough & Şensoy, 2016) improved risk management in concrete moment frames by introducing meta-heuristic techniques to assess the bursting threat of mid-rise steel tension frame structures. Using models of finite elements, Karimi Ghaleh Jough and Golhashem (Karimi Ghaleh Jough & Golhashem, 2020) examined the out-of-plane motion of ad hoc brick constructions and discovered that walls constructed using the lightest masonry materials available today exhibited reduced self-weight axial distortion. Karimi Ghaleh Jough and Beheshti Aval (Karimi Ghaleh Jough & Beheshti Aval, 2018) created a fuzzy C-means fuzzy adaptive neuro-fuzzy inference framework to build the seismic sensitivity curve for an SMRF structure. In order to lower environmental pollution

throughout the production process, sustainable CNC machining procedures are being researched (Soori et al., 2024b). Soori and Karimi Ghaleh Jough (Soori & Karimi Ghaleh Jough, 2024) evaluate the use of AI in steel moment frame structure optimization to improve the operating performance of these structures. Applications of blockchains for the industrial internet of things are evaluated (Soori et al., 2024a) in order to improve the performance of industry 4.0's sustainable supply chain management. To increase performances of industrial robots in working conditions, applications of AI and ML is studied (Soori, Arezoo, & Dastres, 2023a). To increase productivity in industry 4.0, applications of internet of things is studied (Soori, Arezoo, & Dastres, 2023b).

This paper reviews recent developments in these fields and their implications for composite materials recycling. It discusses the current state of AI-based recycling techniques, focusing on their potential to enhance sustainability. The paper outlines the current challenges in composite recycling, AI's role in improving recycling methods, and future opportunities for research and industrial applications. Table 1 summarizing key aspects of sustainability enhancement through AI-based recycling processes of composite materials.

Table 1. Key aspects of sustainability enhancement through AI-based recycling processes of composite materials.

Aspect	Traditional Approach	AI-Based Approach	Sustainability Impact
Material Separation	Manual sorting, low accuracy	Automated sorting using AI-based computer vision	Higher material recovery rates and reduced contamination
Material Quality	Fiber degradation during recycling	AI predicts and controls recycling conditions	Improved quality of recycled fibers, suitable for reuse
Economic Feasibility	High costs, limiting widespread adoption	AI lowers operational costs by optimizing processes	More economically viable recycling, increasing adoption rates
Aspect	Traditional Approach	AI-Based Approach	Sustainability Impact
Process Efficiency	Manual and semi-automated, energy-intensive	Optimized using machine learning algorithms	Reduced energy consumption and improved recycling efficiency

2. OPTIMIZATION OF RECYCLING PROCESSES

Intelligent systems can be implemented to optimize various stages of recycling, such as sorting, shredding, and separation of composite materials. As AI technology evolves, more advanced algorithms can be developed to handle increasingly complex composite materials and optimize new recycling techniques (Kuusisto, 2024). AI's role in creating closed-loop systems where composite materials can be continuously recycled without material degradation is a key area for future research (Türker, Öztürk, & Öz, 2024). Applications of optimization of recycling processes is presented in figure 1.

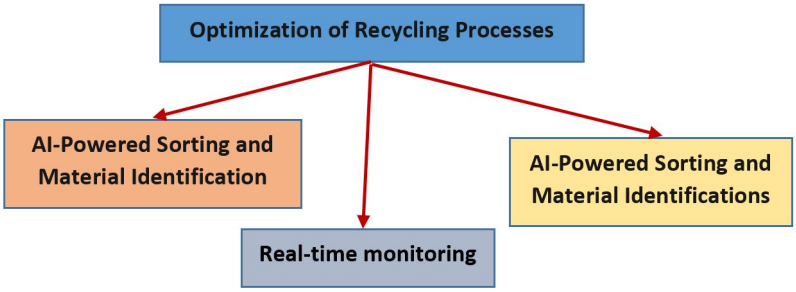

Figure 1. Applications of optimization of recycling processes.

3. PROCESS MONITORING AND CONTROL BY ROBOTS

Utilizing intelligent systems to monitor and control the recycling processes in real-time, ensuring efficiency and quality of the recycled materials. AI can monitor the performance of recycling machinery in real time, adjusting operational parameters for maximum efficiency (Gondal et al., 2021). AI can integrate data from multiple sensor sources such as X-ray

fluorescence, infrared, and optical cameras to identify materials. AI can enable robot vision in order to accurately disassemble complex composite components, preserving valuable materials for recycling (Baduge et al., 2022). By analyzing visual and spectral data, AI can differentiate between composite types, identify defects, and guide robotic systems in sorting materials with high precision. This reduces contamination and improves the purity of recovered materials (Peršak et al., 2020).

4. PREDICTIVE MAINTENANCE

AI can detect equipment problems before they happen, minimizing downtime and increasing recycling throughput, by evaluating machine sensor data (Jambol et al., 2024). Intelligent technologies can be used to anticipate and stop machine malfunctions, cut down on downtime, and boost recycling operations' dependability (Shahin et al., 2023). AI has the potential to assist in the design of recycling procedures and the creation of novel materials by predicting the behavior and performance of recycled composites (Nguyen et al. 2023).

5. SORTING AND CLASSIFICATION

AI algorithms can improve the sorting and classification of different types of composite materials. Machine learning models can be trained to improve sorting accuracy over time, learning from past sorting tasks to better recognize different composite structures (Kroell et al., 2024). For example, image recognition systems can identify and sort materials based on their type and composition. By improving the precision and effectiveness of recycling, AI can reduce the amount of composite waste sent to landfills or incineration, thus decreasing environmental pollution (Fang et al., 2023).

6. OPTIMIZATION OF PROCESS PARAMETERS

AI models can analyze data from recycling processes to identify optimal parameters for shredding, separation, and other steps, leading to improved efficiency and material quality (Fang et al. 2023). AI-driven algorithms can be used to control the temperature and time settings in pyrolysis or chemical recycling processes, minimizing energy consumption and maximizing material recovery (Balakrishnan et al., 2024). These models can also predict the mechanical properties of recovered fibers, ensuring their reuse in high-performance applications (Rani et al., 2021).

7. LOWER ENERGY CONSUMPTION AND CARBON EMISSIONS

High energy requirements for processes like pyrolysis and mechanical grinding make traditional recycling methods costly and environmentally unsustainable (Pandey et al. 2023). AI can significantly lower the energy required for recycling, particularly in mechanical and thermal processes. Enhanced material recovery rates enabled by AI reduce the demand for virgin composite materials, leading to lower carbon emissions associated with material production (Arun, Barik, & Chandran, 2024). By optimizing operating parameters and reducing material losses, AI contributes to reduced carbon emissions from recycling facilities (Fang et al., 2023). Also, by minimizing energy usage and improving recycling efficiency, AI systems can contribute for lowering the overall carbon footprint of composite material production and disposal (Lodhi, Gill, & Hussain, 2024).

8. QUALITY CONTROL

AI algorithms can analyze data from sensors and testing equipment to monitor the quality of recycled materials and ensure they meet required standards (Perera et al., 2023). The process is for ensuring that recycled composites maintain sufficient quality for reuse in high-value applications (Heng et al. 2024). ML algorithms can assess the condition and integrity of composite materials, predicting defects or potential quality degradation during recycling (Machello et al., 2023).

9. COST REDUCTION

The cost of recycling is high compared to manufacturing new composite materials, limiting the adoption of sustainable practices (Shehab et al., 2022). By analyzing historical data and optimizing processes, AI can help reduce costs associated with recycling by improving efficiency and reducing waste (Reza & Hassan, 2023). By integrating AI into the recycling workflow, companies can reduce manual labor, decrease energy consumption, and minimize operational costs. AI can help in minimizing waste production by accurately estimating and utilizing material inputs in the recycling process (Abdallah et al., 2020).

10. CONCLUSION

AI-based recycling processes offer a transformative solution to the challenges posed by composite material waste, significantly enhancing sustainability. By improving material recovery rates, reducing energy consumption, and enabling predictive maintenance, AI can drive the transition to a circular economy for composites. As industries increasingly focus on sustainable practices, AI will play a crucial role in advancing recycling technologies that promote environmental preservation and economic efficiency. By improving material identification, sorting, mechanical and thermal recycling, and robotic disassembly, AI can overcome many of the challenges associated with conventional recycling methods. As industries increasingly adopt composite materials, the integration of AI into recycling processes will be critical to achieving environmental sustainability and promoting a circular economy. The adoption of AI in composite recycling will require supportive regulatory frameworks and industry collaboration. Governments and industry players must work together to implement standards for AI-driven recycling systems, ensuring scalability and widespread adoption. By improving material classification, optimizing recycling processes, and predicting end-of-life, AI can help reduce the environmental impact of composite materials and move industries closer to a circular economy.

As AI technology evolves, more advanced algorithms can be developed to handle increasingly complex composite materials and optimize new recycling techniques. AI's role in creating closed-loop systems where composite materials can be continuously recycled without material degradation is a key area for future research. Future recycling plants may incorporate Internet of Things (IoT) sensors and robotic systems powered by AI to automate and monitor the entire recycling process. This will allow real-time adjustments based on material flow and equipment performance, further enhancing sustainability. Future recycling plants can incorporate IoT sensors and robotic systems powered by AI to automate and monitor the entire recycling process. This will allow real-time adjustments based on material flow and equipment performance, further enhancing sustainability. AI models can be developed to capable of handling composite materials with multiple phases, such as hybrid composites.

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Artificial intelligence-driven optimization of ready-mix concrete for enhanced strength, cost efficiency, and carbon dioxide emission reduction

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Abstract
This study builds upon the evolving landscape of sustainable construction practices, where optimizing ready-mix concrete for strength, cost-efficiency, and reduced CO2 emissions is crucial in aligning with global environmental sustainability targets. Through an extensive analysis of diverse input parameters, including water-cement ratio, aggregate characteristics, additives, and their interactions with critical output parameters, this research has unveiled a substantial dependence on concrete performance, cost-efficiency, and environmental impact on cement selection and proportioning. This research emphasizes the pivotal role of cement in determining both the cost and CO2 emissions of concrete production, highlighting a notable positive correlation between cement content and compressive strength (R2 = 0.4946), and an even more pronounced correlation with CO2 emissions (R2 = 0.9529). This underlines the importance of optimizing cement use for balanced performance. Furthermore, the study reveals that while admixtures play a limited role in enhancing compressive strength (R2 = 0.0426), their impact on other concrete properties like workability and durability is significant. The optimization of concrete components, including a strategic reduction in admixture use, can lead to considerable cost and CO2 emission reductions, exemplified by a 5% cost decrease and a 7% drop in emissions with a 20% admixture reduction. Overall, these findings highlight the transformative impact of AI in concrete mix design, paving the way for more sustainable construction methods and contributing to global efforts to reduce the infrastructure sector's carbon footprint.
Keywords: ready mix concrete, multi-objective optimization, artificial neural network; Machine Learning; CO2 emissions; Sustainability; Sustainable Construction; Low-Carbon Concrete.

1. INTRODUCTION

Adopting ready-mixed concrete (RMC) has significantly transformed the construction industry, enhancing the efficiency and consistency of various projects. Yet, the widespread use of Ordinary Portland Cement (OPC) in concrete, as noted by Neville (ACI-Committee-311), raises environmental concerns, particularly with its high energy consumption and Carbon Dioxide (CO_2) emissions. This situation has brought the critical need to optimize concrete mix designs to mitigate these environmental impacts.
In construction, concrete quality is a paramount concern, rigorously regulated by assessing characteristics like workability, compressive strength, and durability (Juenger et al., 2019; Sharma et al., 2023; Gill et al., 2023). Artificial Intelligence (AI) application shows promise in predicting these properties (ACI-Committee-311). However, there still needs to be an unmet need for comprehensive AI models that optimize concrete mixes, not only in terms of strength but also considering CO_2 emissions and cost (Gill et al., 2023). The literature detailed in Table 1 demonstrates the effectiveness of AI models in modeling concrete properties. Yet, this research aims to address a gap in using AI to achieve a holistic balance in concrete mixes, optimizing for strength, emissions, and cost.

Table 1. Existing literature on AI application of ready-mix concrete

No.	Year	Author	Method	Output Variable			
				Strength	Workability	Durability	Cost
1	1998	Yeh (Yeh, 1998)	ANN	P			
2	2000	Dias and Pooliyadda (Dias & Pooliyadda, 2001)	ANN	P	P		
3	2002	Amalraj and Rajasekaran (Rajasekaran & Amalraj, 2002)	ANN	P	P		
4	2003	Lee (Lee, 2003)	ANN	P			
5	2005	Öztaş et al. (Baykasoğlu et al., 2009)	ANN	P	P		
6	2006	T Ji (Ji et al., 2006)	GA-based ANN	P	P		P
7	2009	Chindaprasirt, et al. (Chindaprasirt et al., 2009)	ANN			P	
8	2009	IC Yeh (Yeh, 2009)	ANN	P			
9	2010	J Sobhani (Sobhani et al., 2010)	ANN		P		
10	2011	Muthupriya (Sobhani et al., 2010)	ANN	P		P	
11	2011	JS Chou, CK Chiu, M Farfoura (Chou et al., 2011)	ANN MR SVM Ensemble Models	P			
12	2012	Seyyed, Aminian, Gandomi, Alavi, and Bolandi (Mousavi et al., 2012)	GEP	P			
13	2013	T Kim, S Tae, S Roh (Kim et al., 2013)	GA-based ANN	P			
14	2013	Cheng et al. (Cheng et al., 2012)	Time-Weighted EFSVM	P			
15	2014	Cheng et al. (Cheng et al., 2014)	GA-based SVM	P			P
16	2015	Ghafari et al. (Ghafari et al., 2015)	ANN	P	P		
17	2015	Chandwani, Agrawal, and Nagar (Chandwani et al., 2015)	GA-based ANN		P		
18	2016	Chopra, et al. (Chopra et al., 2016)	ANN & GP	P			
19	2016	Hoang and Pham (Hoang & Pham, 2016)	LSSVR		P		
20	2017	Prayogo and Cheng (Prayogo et al., 2017)	SOS-LSSVM	P			
21	2017	Behnood, et al. (Behnood et al., 2017)	M5 Model	P			
22	2017	Gou et al. (Gou et al., 2016)	PSO based- LSSVM	P	P		
23	2017	Khashman and Akpinar (Khashman & Akpinar, 2017)	ANN	P			
24	2018	Liang, Qian, Chen, and Kang (Liang et al., 2018)	ANN	P			
25	2018	Yu, Li, Li, and Nguyen (Yu et al., 2018)	CSO based-LSSVM	P			
26	2019	D da Costa Reis, et al. (da Costa Reis et al., 2019)	ANN			P	
27	2020	JK Chow, et al (Chow et al., 2020)	AI-empowered inspection pipeline			P	
28	2021	D Fan, et al (Fan et al., 2021)	ANN	P			
29	2022	MN Amin, et al (Amin et al., 2022)	machine learning	P	P	P	
30	2023	H Rezk, et al. (Rezk et al., 2023)	Marine Predators Algorithm (MPA)			P	

Note: CSO = Cat swarm optimization; EFSVM = evolutionary fuzzy support vector machine; GP = Generic programming; GEP = gene expression programming; MR = multiple regression.

Innovative approaches to sustainable concrete production: a comprehensive study on the utilization of silica fume and coal bottom ash as dual replacements for cement and recycled plastic as a substitute for fine aggregate.

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ABSTRACT

In recent times, the engineering and construction industry has effectively engaged in incorporating sustainable, environmentally friendly, and reused materials in the production of concrete. Environmental degradation and health risks result from the majority of waste products being thrown into landfills and open spaces. The use of industrial wastes in place of building materials is another important consideration. It is necessary to investigate the engineering characteristics as well as the environmental effects of concrete that contains these waste components.

This study looked at how the durability, mechanical strength, and fresh characteristics of concrete are affected when silica fume, coal bottom ash, and recycled plastic are added. Various combinations were utilized, including SF 15%, CBA 20%, and a ternary mix of SF 15%, CBA 20%, and RP 20%, all while keeping a constant water-to-cement (w/c) ratio of 0.5. In the slump test, RP 20 demonstrated improved workability compared to the control mix. SF 15, when contrasted with the control mix, showcased the highest compressive strength, while the ternary mix exhibited the highest tensile strength and the lowest rate of water absorption in comparison to the control mix.

Keywords: Cementitious Material, Cement Replacement, Coal Bottom Ash, Concrete, Pozzolanic Materials, Durability, Silica Fume, Recycled Plastic.

Flexural Performance of Cement Pastes Reinforced With 3d Printed Reinforcement

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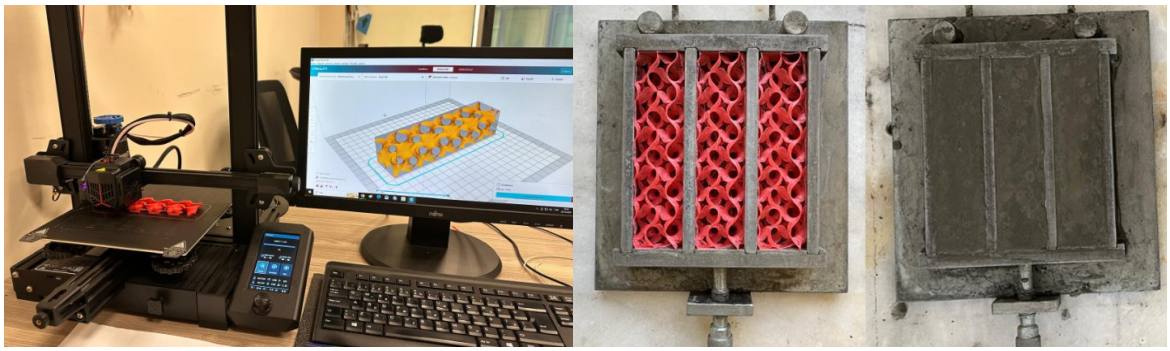
1. INTRODUCTION

3D printing is a popular production method developed and used in many areas today. In 3D printing technology, multiple layers with a definite height are superimposed, and various types of products designed by various CAD software can be easily produced (Kun, 2016). Cost-effectiveness of resources, automated production with fewer defects, use of recyclable raw materials such as metals or polymers, easy preparation and sharing of designs are the main advantages of 3D printing (Berman, 2012). In the construction sector, 3D printing of complete concrete structures has recently attracted great attention (De Schutter et al., 2018; Asprone et al., 2018). In addition, there are several studies on producing 3D printed reinforcements for cement-based materials. In a study, 3D printed reinforcements based on acrylonitrile butadiene styrene (ABS) were produced and used as a reinforcement element in cement-based composites, and significant improvements were obtained in both flexural and tensile performances (Xu and Šavija, 2019). Salazar et al. (2020) investigated the use of 3D octet lattice structures made of PLA and ABS materials instead of steel reinforcement and showed that 3D reinforced cement-based composites exhibited strain hardening up to peak load. They also reported that multiple cracking and controlled crack expansion were observed in the samples during flexural loading up to peak load.

This study evaluated the usability of 3D-printed reinforcements as an alternative reinforcement element in cement-based composites. For this purpose, polyethylene terephthalate glycol (PETG) and polylactic acid (PLA) based reinforcements were prepared in gyroid form. Their mechanical performances were investigated under three-point flexural tests.

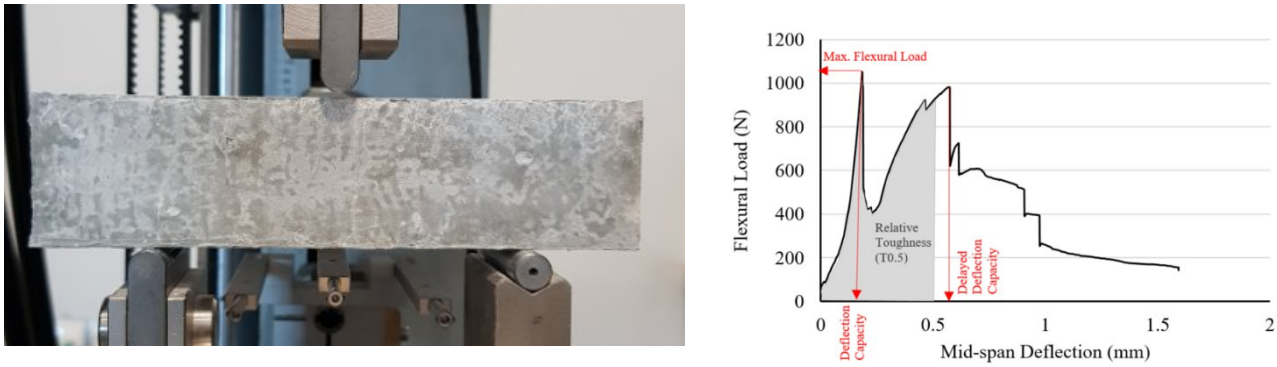
2. MATERIALS AND METHODS

Cement paste with a cement-to-water ratio of 0.50 was prepared by using CEM I 42.5R type cement as the matrix phase of the composites. The product idea of reinforcements is transformed into digital data employing TINKERCAD software. The shapes are transformed into a CAD-guided 3D product via CrealitySlicer software and digitally sliced. The layered data is transferred to a Creality Ender 3 v2 Neo brand 3D printer (Figure 1a). In the production of 3D printed reinforcements, polyethylene terephthalate glycol (PETG) and polylactic acid (PLA) filaments were used. Three reinforcements from each filament were printed and placed into 40x40x160 mm^3 molds. Then, the prepared cement paste was poured into molds (Figure 1b). One day after pouring, specimens were taken from the molds and cured in water for 27 days. Flexural performances of specimens were determined under deflection-controlled three-point flexural tests with a loading rate of 0.5 mm/min. Load and deflection values were saved, and flexural load-mid span deflection curves were drawn for three specimens for each series. The maximum load value was determined and flexural strengths were calculated using these values. Corresponding deflection values to the peak loads were determined as deflection capacities. Since a remarkable regain of strength was achieved in some of the curves, the deflection data corresponding to the second peak on the load-deformation curve was also investigated and determined as the delayed deflection capacity. Finally, the area under the curve up to 0.5 mm deflection was calculated and named as the relative toughness (T0.5).



(a) (b)

Figure 1. a) Preperation of 3D printed reinforcements, b) Molding of specimens

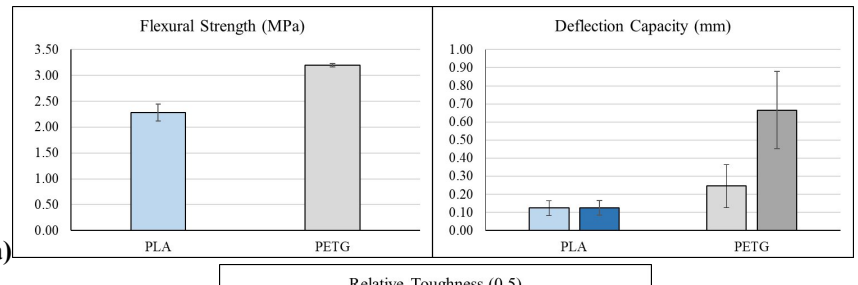


(a) (b)

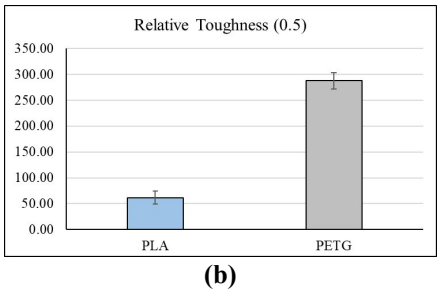
Figure 2. a) Flexural test setup, b) Determination of mechanical parameters

3. RESULTS AND DISCUSSION

The mechanical properties obtained from the curves were given in Figure 3. The flexural strengths were calculated as 2.28±0.16 MPa and 3.20±0.03 MPa for PLA and PETG reinforcements, respectively (Figure 3a). In the Figure 3b, lighter colors present the deflection capacity and darker colors represent the delayed deflection capacity. In both cases, PETG reinforcements performed higher deflection capacity than the PLA reinforcements. The deflection capacities of PLA and PETG reinforced specimens were determined as 0.12±0.04% and 0.12±0.04%, respectively. The delayed deflection capacity was not obtained from the PLA reinforced specimens. However, PETG reinforced specimens performed an average delayed deflection capacity of 0.66±0.22%. In the case of relative toughness, PLA reinforced specimens achieved a relative toughness of 61.78±12.16 N.mm while the PETG reinforced specimens achieved 287.88±15.51 N.mm.



(a) (c)



(b)

Figure 3. a) Flexural strength, b) Deflection capacity, c) Relative toughness

4. CONCLUSION

This study showed that the 3D printed reinforcements have the opportunity to be used for reinforcing the cement based composites. PETG reinforcement was found more appropriate to be used in the cement based matrix. The flexural strength, deflection capacity and the relative toughness of PETG reinforced specimens were approximately 40%, 433% and 365% higher compared to the PLA reinforcement. By adopting 3D printing technology to reinforcement industry, pre-designed reinforcements may have the chance to be used in 3D printing concrete technology. Besides, environmental sustainability can be increased when the case of using recycled PET wastes in the production of 3D printed reinforcements. Researchers should note that the mechanical properties can be enhanced using different filaments or 3D reinforcement designs which may be a key parameter for producing high performance and sustainable cement-based composites.

5. ACKNOWLEDGMENT

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Effect of Waste Glass Powder and Limestone Powder in Concrete

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ABSTRACT

This study examined the effects of incorporating waste glass powder and limestone powder at various proportions (5%, 10%, 15%, and 20%) into concrete mixtures, while keeping a constant water-binder ratio of 0.375 and a superplasticizer dosage of 0.5%. The research compared the performance of glass powder from different sources, such as clear and brown glass, finding similar results in terms of rheological properties, mechanical performance, and durability. Key metrics analyzed included flowability, compressive strength, flexural strength, fire resistance, water absorption, and density. The addition of waste glass powder (WGP) improved flowability more effectively than the control mix, with increased glass powder content enhancing this property further. Although limestone powder (LSP) also contributed to flowability, it did not match the performance of WGP. The highest compressive strength was observed with a 20% LSP addition compared to the control mix, and the binary blends showed comparable strength levels. The mix with 15% WGP and 5% LSP achieved the highest flexural strength, with most blends performing similarly to the control in this regard. For fire resistance, the blend with 5% WGP and 15% LSP exhibited the best resistance at 200^0C.

Keywords: Cement replacement, Durability, Limestone powder, Sustainability, Waste Glass Powder, Waste materials

Developing Adequate Lunar Construction Materials for Facilitating Lunar Missions and Settlemets: An Overview

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1. INTRODUCTION

Besides being an indicator of level of advancements in science and technology, the capability of countries to succeed in lunar missions and initiating settlements certainly provides significant advantages. Outposts to be established on Moon's surface, including landing pads, investigation laboratories, equipment storage facilities and habitations for researchers are of vital importance in order to facilitate longer term investigations and missions to be delivered in deeper parts of space in a near future.

Building adequate constructions for the mentioned facilities safely under harsh environmental conditions of Moon has become an important task for researchers from all around the world. It is known that carrying high quantities of materials having considerable weights to the Moon would certainly pose complications on the mission, both technically and economically. Lunar regolith (i.e. lunar soil) is the key in-situ resource that could be used in mentioned lunar constructions. This study aims to provide a brief overview on the studies done on lunar regolith simulants, as well as the performance studies done on construction materials manufactured from these simulants.

2. COMPARATIVE EVALUATION OF DIFFERENT LUNAR CONSTRUCTION MATERIALS

2.1 Lunar Regolith Simulants Used to Produce Lunar Construction Materials

To ensure the success and the safety of the lunar missions, several scientific experiments should be carried out by using lunar soil beforehand in the world. As the real lunar soil that has been brought to Earth is only around 380kg and is definitely not adequate for all studies, more than fifty different simulants of lunar soils have been produced around the world (Toklu & Akpinar, 2022). Türkiye has become the 10th country in the world producing lunar soil simulant that meets the research needs successfully (Toklu et al. 2023).

2.2 Different Types of Lunar Construction Materials

Sulfur-based lunar concrete, polymer-based lunar concrete, geopolymer concrete, 3D-printed construction elements and sintered/cast building blocks are the main types of lunar construction materials that have been proposed in the related literature. Maximum reported compressive and flexural strength values of these types of lunar construction materials that have been reported by related literature are presented in Figure 1 a and b, respectively. One must keep in mind that these values are obtained as a result of literature survey and the values can only be qualitatively compared due to different test conditions. Pros and cons of each type of material, different manufacturing procedures and final performance results should be considered in detail for making the ultimate decisions on material selection.

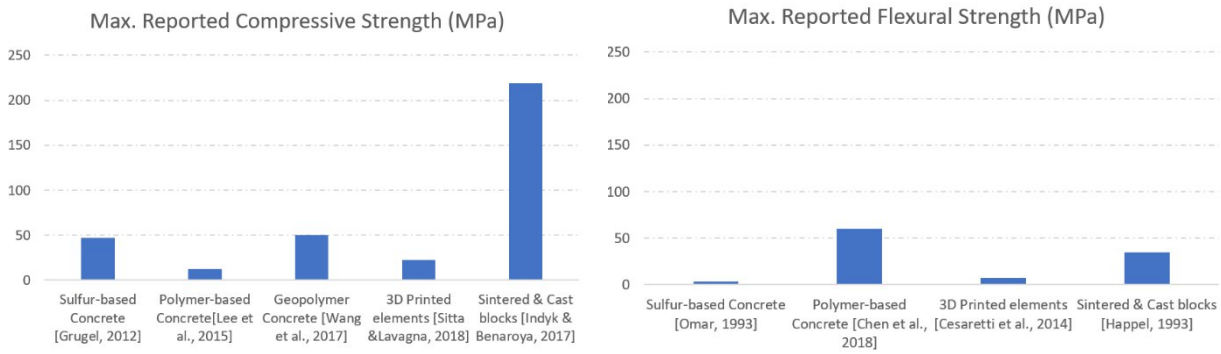

Figure 1 a. (Left) Maximum reported compressive strength values of lunar construction materials. b. (Right)Maximum reported flexural strength values of lunar construction materials.

3. DISCUSSIONS AND CONCLUSIVE REMARKS

Results of the literature study have shown that every type of lunar construction material has their own pros and cons; some of them being not resistant enough under harsh temperature or vacuum conditions of moon, some others having relatively difficult procedures of manufacture. High compressive and flexural strength values obtained in some material types makes them eligible for being further focused on. As these already yield promising performance results, their manufacture procedures can be further developed, and eventually, their strength values can be improved along with other performance criteria that would be necessary for each specific function that they would be employed for. It is recommended that future studies should be extended to include more comparable test procedures, with more realistic lunar exposure conditions as well, that will enable researchers to gain more precise insights on the real performance of each type of lunar construction materials. It is expected that such studies done for Lunar missions will also contribute to similar works on other space bodies, such as Mars.

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Utilizing tea waste ash as a sustainable construction material

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1. INTRODUCTION

In the face of the global climate crisis and the imperative to reduce our carbon footprint, the pursuit of sustainable and eco-friendly building materials has gained paramount importance (Lim, A. L. (2018)) [1]. The construction industry is a major contributor to environmental degradation, consuming vast quantities of resources and emitting substantial greenhouse gases (Istoan, et. al. (2022, July)) [2]. To address this challenge, there is a growing interest in the utilization of unconventional, renewable, and waste materials to develop innovative and sustainable alternatives.

Tea, a beverage revered for its rich history and cultural significance, generates a substantial amount of waste in the form of spent tea leaves. These discarded leaves, often seen as a byproduct, hold an untapped potential that extends beyond the teacup. Worldwide, tea consumption has experienced a significant upsurge, now totaling approximately five million tons annually. In Turkey, a prominent player in tea production, black tea stands as one of the country's most vital manufacturing products. In the year 2003, the country cultivated 552 tons of green tea, while only 94 tons of black tea were produced, as indicated in Table 1. Green tea was grown on 76,653 hectares of Turkish land, tended to by a substantial number of 204,112 farmers. The transformation of green tea into black dry tea is accomplished by Caykur across 46 processing plants, with approximately 10 percent of the refined black tea turning into waste (Klasra, et. al. (2007)) [3]. Unfortunately, these residues are not subject to local recycling and ultimately find their way into landfills. This issue has contributed to the growing concern of landfills being one of the most pressing challenges for the Turkish government. Consequently, repurposing these waste materials as an alternative to cement within the construction industry is considered both environmentally and economically beneficial (Gupta, et. al.) [4].

2. MATERIALS AND METHODS

Ordinary Portland cement (42.5 grade), conforming to the ASTM C150M-12 [9] standard, was used. The chemical composition of cement is presented in Table 2. The specific gravity of cement was 3.12, and its fineness was 2928 cm^2 /g. Tea waste is likely to be rich in potassium, calcium, and magnesium, with trace amounts of other elements such as phosphorus, sodium, iron, and zinc, and water content in the mix was adjusted. Tap water was used for tests and preparation of the mixtures.

Five samples for each curing age (7, 28, and 56 days) and for each mixture group were cast for compressive strength tests. Cubic molds of 50 mm3 in size were used for the compressive strength tests. Six samples for each curing age (7, 28, and 56 days) were prepared and tested for flexural strength tests. Mortar prisms of 40 mm × 40 mm × 160 mm in size were used for flexural strength tests. The ASTM C109M-20 [10] standard for compressive strength and ASTM C348-19 [11] standard for flexural strength tests were used. Three samples were cast for each testing age (7, 28, and 56 days) to evaluate the physical properties of the composites. The apparent specific gravity and water absorption experiments were performed according to

the ASTM C127-15 [12] procedure. The consistency of prepared mixtures was determined using a flow table test according to the ASTM C230M-14 [13] procedures. Twelve samples were prepared for each curing age (28 and 56 days) and for each mixture group to evaluate the sulfate and seawater resistance. The sulfate tests of all prepared mixtures were determined according to the ASTM C88-18 [14] procedure. The specimens were subjected to a sulfate solution until cracked. At the end of each cycle, the samples were removed from the sulfate solution and dried in an oven at 105 ◦C. The mass changes were recorded in each cycle. For seawater tests, the samples were immersed in seawater for one week, and the same procedure was applied for sulfate tests. The tests were continued until the first visible crack. The mass changes were then recorded.

3. RESULTS AND DISCUSSION

Based on the experimental test results the composites are classified as lightweight and can be used for various civil engineering applications such as manufacturing eco-friendly building materials, stabilization, and road base works. The water absorption and porosity values range from 8-15%, and 32-40 %, respectively. The unconfined compressive strength and flexural strength values range from 5 MPa-30 MPa and 0.7 MPa to 3.9 MPa, respectively.
Figure 1 shows the sample composites prepared at the laboratory (tea ash- cement paste composites)

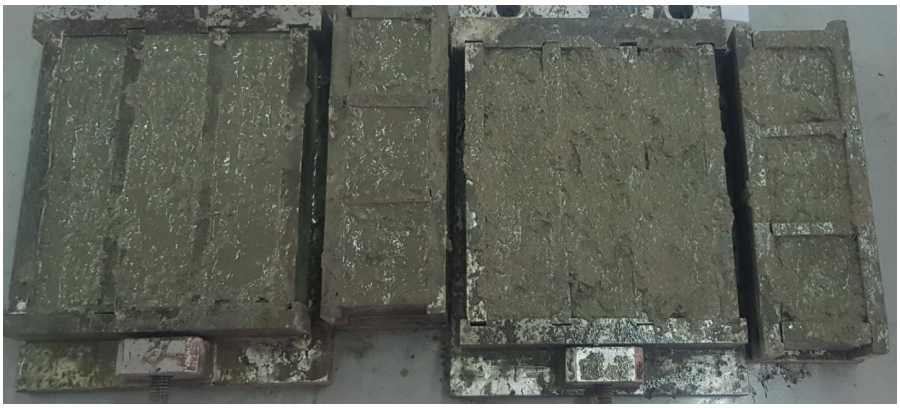

Figure 1. Tea waste-enriched cement composites

4. CONCLUSION

The current research promotes the sustainable utilization of tea waste in the construction sector as a new binder for concrete alternatives to traditional building materials. Incorporating tea waste as a replacement for cement in building construction, not only can waste reduction be attained but also significant advances in promoting sustainable building practices and decreasing the carbon footprint of construction projects. The 15% tea waste was found optimum for strength and durability.

5. ACKNOWLEDGMENT

The authors would like to express appreciation for the support of Birol Karaman who provided the materials for the present study.

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Assessment of Concrete Strength, Cost, and Environmental Footprint with Marble Dust and Metakaolin as Partial Cement Replacements

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1. INTRODUCTION

Supplementary cementitious materials (SCMs) like calcined clays are of significant interest. Kaolinitic clays, widely available in the Earth's crust, undergo dehydroxylation between 600 and 800 °C to form metakaolin (Sabir et al., 2001), which exhibits excellent pozzolanic properties. The reactivity of metakaolin is linked to its content of penta-coordinated aluminum ions formed during dihydroxylation. Fine limestone is also commonly added to cement. Limestone additions up to about 5% can react with cement and enhance various properties (Lothenbach et al., 2008). This reaction forms calcium monocarboaluminate and hemicarboaluminate instead of monosulfoaluminate, leaving more sulfate to form ettringite. (Damidot et al. 2011) have shown through thermodynamic calculations that the increase in solid volume in a ternary blend of cement, limestone, and pozzolan—when replacing limestone with pozzolan—is related to the reactive aluminous content of the pozzolan. Therefore, metakaolin is particularly interesting due to its high reactive aluminate content.
This study aims to evaluate the effectiveness of partially replacing Portland cement with a combined blend of metakaolin and waste marble dust in concrete. The extra alumina from metakaolin is expected to react with more limestone from waste marble dust, maintaining good properties even at higher levels of substitutions.

2. MATERIALS AND METHODS

2.1 Materials

The experiment used Type II/B-S 42.5N cement (60.88% CaO, 19% SiO_2). Metakaolin with 86%–90% particles smaller than 2 μm and Waste marble dust, obtained from the mining and sawing processes of marble products, was also used. Limestone coarse and fine aggregates were used.

2.2 Methods

Metakaolin (MK) and marble dust (MD) were used together to substitute cement in the concrete at a ratio of 2:1. The percentages of substitution were 15%, 22.5%, 30%, 37.5%, and 45% by weight of cement. For comparison purposes, two mixes were cast with only 12.5% MD and 25% MK, respectively. Workability was adjusted using superplasticizer, with an increment of 0.5 kg/m3 in each mix. Ultrasonic pulse velocity tests were carried out on 150 mm cubic samples, taking the average of three samples. The samples were then tested for compressive strength. Flexural strength tests were conducted using three prisms of dimensions 500 × 100 × 100 mm. Then economic and ecological analyses were performed on each mix through evaluating the cost per strength ratio (Cp) and the embodied CO_2 per strength ratio (Tp) .

3. RESULTS AND DISCUSSION

Mix with 10% marble dust and 20% metakaolin shows the best balance, with peak values in pulse velocity, compressive strength, and flexural strength as shown in table 1, suggesting an optimal ratio of MD and MK where enhancements in density and matrix cohesion are maximized. For each mix, the cost per strength ratio (Cp) and the embodied CO_2 per strength (Tp) were estimated to evaluate the economic and environmental impacts (figure 1). The results indicate that the mix containing 10% marble dust and 20% metakaolin has the lowest Cp ratio. Additionally, the mix with 15% marble dust and 30% metakaolin achieves the lowest Tp ratio, although it exhibits the highest Cp ratio. In contrast, the control mix shows the highest Tp.

Table 1: pulse velocity, compressive strength and flexural strength for each mix

Mix	Pulse Velocity (Km/s)	Compressive Strength (Mpa)	Flexural Strength (Mpa)
Control	4.73	52.2	6.23
MD5MK10	4.64	55.4	6.79
MD7.5MK15	4.62	59.03	6.43
MD10MK20	5.23	61.1	7.31
MD12.5MK25	5.18	56.2	6.94
MD15MD30	5.14	54.53	6.53

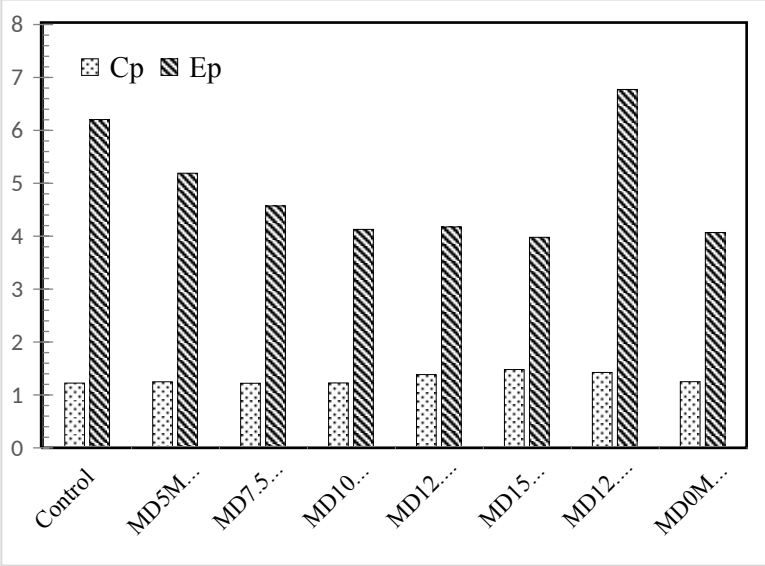

Figure 4: Economic and ecological factors for each mix

4. CONCLUSION

This study demonstrates that combining metakaolin and marble dust as substitutes for Portland cement results in excellent 28-day strength performance. A 2:1 blend of metakaolin and waste marble dust, with substitutions up to 45%, delivers superior mechanical properties compared to a 100% Portland cement reference. Notably, the mix containing 10% marble dust and 20% metakaolin exhibits outstanding compressive and flexural strengths and shows excellent concrete quality based on ultrasonic pulse velocity measurements. Economic and environmental analyses were conducted by evaluating the cost per strength ratio (Cp) and the embodied CO_2 per strength ratio (Tp) for each mix. The results indicate that the mix with 10% marble dust and 20% metakaolin has the lowest Cp and Tp values, making it the most optimal choice in terms of strength, cost-effectiveness, and environmental impact. Therefore, this specific blend offers the best balance of mechanical performance, economic viability, and ecological sustainability.

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Properties of limestone as a supplementary cementitious material on Ultra-High Performance Concrete

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1. INTRODUCTION

Ultra-High-Performance Concrete (UHPC) is a modern cementitious material with superior mechanical and durability properties, which can enhance the sustainability of buildings and infrastructure [1], [2]. It is composed of a blend of fine aggregate, steel fibers, silica fume, Portland cement, and high-range water-reducing admixture (HRWR) [3], [4], [5]. UHPC has a compressive strength range of 150 to 810 MPa, making it 3-16 times stronger and 300 times more ductile than ordinary concrete [3], [6]. Its global market was estimated at USD 488.8 million in 2022 and is expected to grow to USD 844.1 million by 2030 (Fig. 1), increasing at a 7.1% compound annual growth rate (CAGR) during 2022 and 2030 [7].

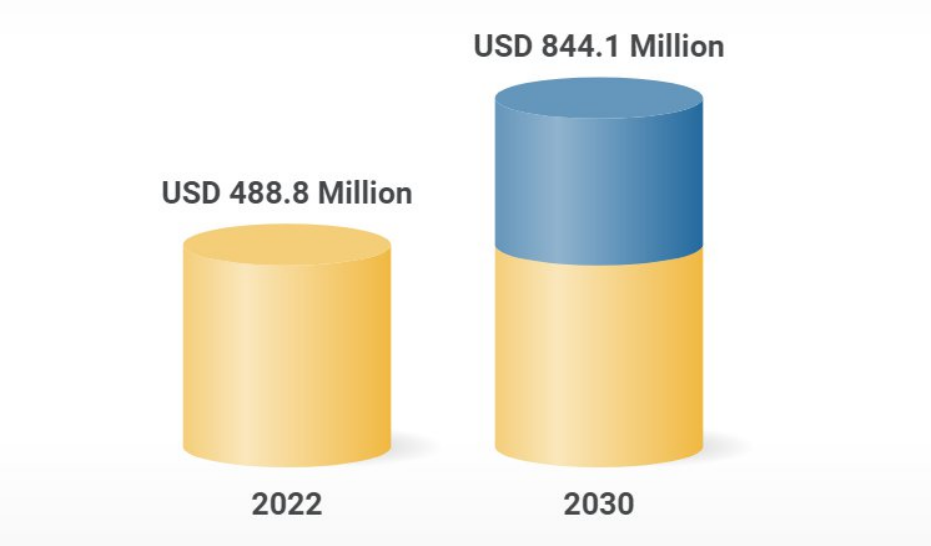

Fig. 1. Global UHPC market [7]

Global warming and climate change are major problems caused by CO2 emissions [8] and improving cement technology can help decrease global CO2 emissions by up to 50% until 2050 [9]. Ordinary Portland cement (OPC) has the highest utilization in concrete, with its production process involving carbonates decomposing like limestone and coal burning at higher temperatures. Cement manufacturing emits 5-7% of all world CO2 emissions [10], [11], [12], with yearly cement production predicted to increase to over 5 billion metric tons by 2050 [13].

Limestone powder (LP) is a mineral powder generated by crushing limestone or calcium carbonate rock that is used as a substitute micro filler for UHPC [16] due to simple quality control, low cost, and comfort access [15], [14]. LP fills voids, improves packing density, develops strength and accelerates cement hydration [17], [18], and improves fresh properties of concrete [19], [20]. The global limestone market is projected to

expand at a CAGR of 7.3% from its 2022 estimation of USD 72.31 billion [22].

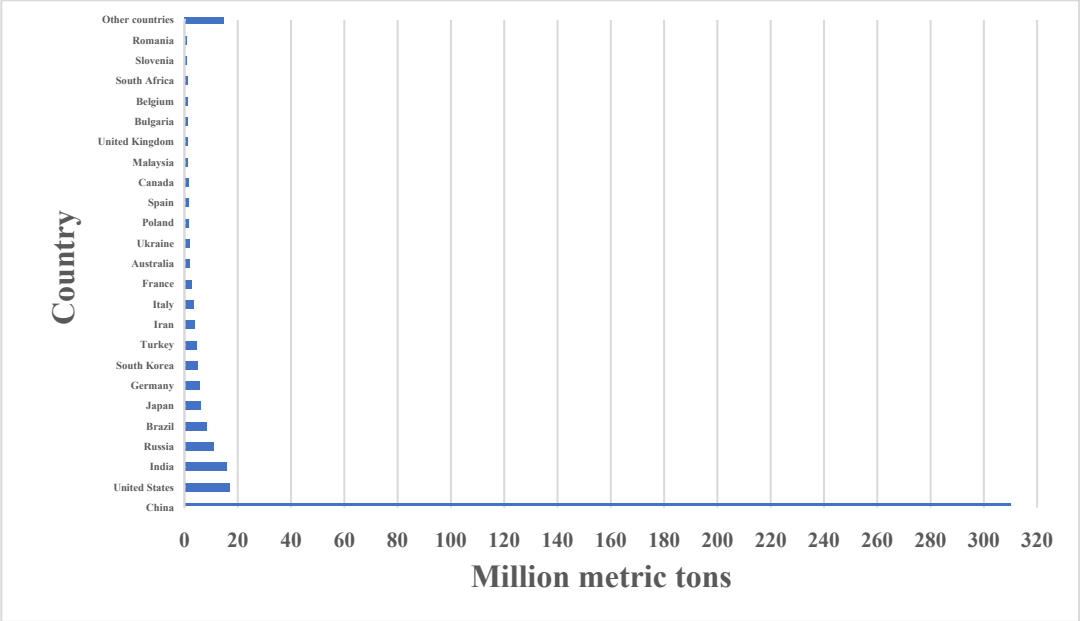

Fig. 2. Worldwide lime production in 2023

2. MATERIALS AND METHODS

Crushed limestone or calcium carbonate rock is used to make limestone powder, which is often used in place of cement or silica powder. Its costs reliable quality, and easy accessibility are contributing to its rising popularity [21][24][14][15].

The purpose of this study is to focus on the qualities of UHPC that has been changed using limestone as a cement alternative. The evaluation will include a comparison to applicable standards such as ASTM C1856 and ASTM C2002. Limestone powder can be used as a partial mass substitution for cement and silica powder, optimizing the composite's fresh qualities like mixing time and workability. Small cement substitutes have shown beneficial features. In addition, this study will discuss the ideal percentages and procedures for using UHPC in cementitious composites to improve performance as a cement replacement material[23].

the research will focus on developing UHPC mix designs that incorporate limestone as a partial cement replacement. The performance of limestone-modified UHPC will be compared to ordinary UHPC, High Performance Concrete (HPC), and conventional Concrete (CC). To further understand the influence of limestone incorporation, many characteristics of UHPC will be evaluated, including mechanical qualities, durability, shrinkage, and thermal properties. Continuously assessing the performance of limestone-modified UHPC in real-world applications will be critical. Any necessary enhancements or adjustments based on comments and observations will be implemented, ensuring an iterative process for continuous improvement of the methodology and application of limestone in UHPC manufacturing.

3. RESULTS AND DISCUSSION

Recent research shows that substituting parts of cement with limestone in UHPC enhances both environmental friendliness and mechanical characteristics. This substitution reduces carbon emissions while maintaining or improving the material's strength and durability. Furthermore, micro- and nano-sized limestone particles increase early-age strength by accelerating the hydration process and strengthening the microstructure, making UHPC an attractive alternative for environmentally friendly construction without harming performance.

4. CONCLUSION

Limestone decreases the the compressive strength of UHPC (the limestone functions like a filling material), the limestone decreased the flexural strength, reduced the shrinkage, increases the hydration degree, generates more C-S-H and CH at early ages, but it has little effect on the hydration products at later age, reduces the porosity of cement-based materials due to filler and nucleation effects and effectively reduce the CO2 emissions per unit volume of UHPC, and simultaneously guarantee the advanced performances of UHPC.

5. ACKNOWLEDGMENT

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Investigating the Durability and Mechanical Properties of a Mechanically Activated Clay-Based Geopolymer for Road Construction: A Review

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1. INTRODUCTION

To effectively utilize clay and reduce the environmental impact of road construction, large-scale utilization of a thermally treated clay-based material as a road construction building material has been reported. However, the thermally treated clay geopolymer exhibits properties unsuitable for road construction. Greenhouse gas emissions are deeply connected to numerous human-induced activities. Transport and industrial production sectors carry the heaviest burden and generate more than two-thirds of the world's anthropogenic CO_2 emissions. The construction industry represents a significant part with high involvement of cement production, a typical manufacturing material. Geopolymeric materials arise as very promising replacements. Geopolymeric materials are indeed extremely low carbon footprint, high-performance construction materials with very low greenhouse gas emissions that can be activated even at room temperature. In addition to inert materials, waste is consumed as raw materials, further supporting the role of environmentally friendly materials within the construction industry (Sambucci et al., 2021; Hamad et al., 2021; Elmesalami & Celik, 2022).

2. MATERIALS AND METHODS

Material selection: A proper site is selected, soil excavated and clay extracted. Key seps are used to ensure that the clay is properly isolated from other materials.
Material preparation: Clay samples are mechanically activated through high-energy ball milling to increase reactivity.
Geopolymer synthesis: The activated clay is blended with the alkaline activators which include Calcium Hydroxide (Ca(OH)2) and lime (CaO) and silica fume as precursor in preparation of the geopolymer pastes and mortars.
Durability testing: It consists of freeze-thaw cycles, wet-dry cycles as well as de-icing salt exposure situations in order to mimic real life conditions.
Mechanical testing: Curing ages are mostly taken to evaluate the following mechanical properties; Compressive strength, flexural strength and the elastic modulus.
Microstructural analysis: To investigate the geopolymerization process and its impact on material characteristics SEM, XRD, and FTIR are used.

3. RESULTS AND DISCUSSION

The result section provides a tabulation and analysis of the XRD, SEM, and mechanical strength tests of the geopolymer carbonated samples. Uncompressed samples of MAC-geopolymer were prepared for this reason and their 28-day compressive strength is 10.6, 25.4, 30.7 and 30.7 MPa respectively after 1, 7, 14 and 28 days. The average compressive strength was determined after one-month curing at 32.7 MPa, higher than the minimum specified strength of 25 MPa for road base materials. The geopolymer matrix also had a relatively low bulk process dimensional change compared to OPC, which is favorable in reducing shrinkage cracking particularly in road base applications. CO2 saturated samples containing carbonated were immersed in a 1000 ppm pure CO2 solution at atmospheric pressure and room temperature for 14 and 28 days

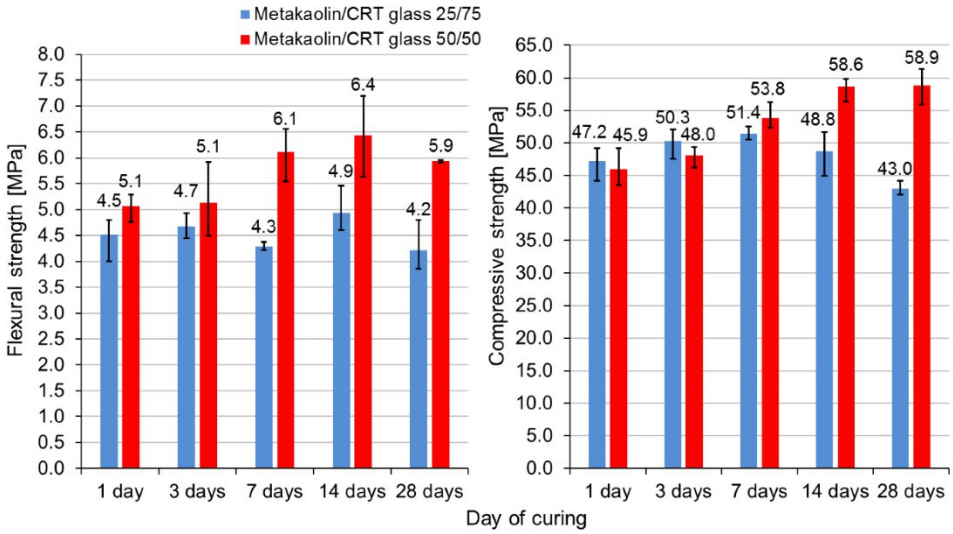

Figure 1. Flexural and compressive strengths of geopolymer cured for 1, 3, 7, 14, and 28 days.
(Górski et al., 2021.)

4. CONCLUSION

This research shows, the prospect of using mechanically activated clay based geopolymers in road construction as a sustainable option is viable. Some of the developed contents possess or may possess mechanical properties and durability that are at par or even better than those of conventional cementious materials in roads with added advantage of minimizing the hazards of the environment when constructing roads. More studies have to be done in order to refine the mix designs for certain uses and to conduct more extensive field testing. This research adds to the existing literature on sustainable construction materials and opens up possibilities of the effective utilisation of clay-based geopolymers in road construction projects.

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Animal Fiber Utilization in Low Carbon Cement Paste Production

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1. INTRODUCTION

The construction industry has been under intense pressure to reduce the use of natural resources. Due to resource depletion and increasingly serious environmental problems, experts have begun to study sustainable construction options (Govindan et al., 2016). The construction industry consumes a lot of materials and generates a lot of waste (Hoffmann et al., 2006). It regards for more than one third of global carbon emissions (Samani et al., 2015). the marble trash generated by the masonry industry cannot be ignored in the solid waste (Rana et al., 2015). Marble waste can be used to improve the quality of concrete in a cost-effective manner (Ulubeyli et al., 2015). For the fibers reinforced, hair can contribute to the concrete's increased tensile strength and toughness, which reduces cracking and increases its capacity to handle severe loads (Azimi., 2017).

2. MATERIALS AND METHODS

MATERIALS

Portland Cement: PC CEM I (42.5R) in conformity with TS EN 197-1 is used in this work.

Marble Powder (MP): With a particle size of 150 μm, the MP chosen for these experiments was white colored. It is directly obtained from deposits of marble factories during shaping.

Dog Hair (DH): The DH used in this experiment was precured from a local pet shop and it was obtained from a husky dog.

METHODS

In this study, MP is used as a cement replacement in specific proportions, alongside DH, which is used as fiber reinforcement in the modified cement pastes. The performance of the modified mixes is evaluated by comparison with a control mix C. Four mixes were prepared:

- The first mix is the control mix.
- The second mix was replaced with 5% MP.
- The third mix was replaced with 5% MP and contained 0.25% DH.
- The fourth mix was replaced with 5% MP and contained 0.50% DH.
- The tests were conducted at 7, 28, and 56 days.

Below are the tests that were performed:

- **Mini Slump Test:** (ASTM C143).
- **Flow Test:** (ASTM C230).
- **Fresh Density:** (ASTM C138).
- **Compressive Strength:** (ASTM C109).
- **Flexural Strength:** (ASTM C490).
- **Sea Water and Porosity Test:** (ASTM C1585).
- **Sustainability Performance:** (CO_2 emissions, cost).

3. RESULTS AND DISCUSSION

The workability assessment of the developed samples, incorporating MP and DH, indicated reduced fresh state properties relative to the control sample C. The fresh density of the

modified samples was higher than the C sample. The compressive and flexural strengths of the MP - and DH-modified samples were higher than those of the C sample. The incorporation of DH into the cement paste improves its durability, bonding strength, and resistance to cracking. The seawater resistance and porosity test results indicate that the porosity of the modified mixes reduced with age. The sustainability assessment of the C and the modified mixes was carried out for both environmental and economic aspects. The sustainability assessment which is quite crucial for wastes utilization in cement mixes exhibited promising results. Environmental sustainability in which CO_2 emission was calculated for C sample and developed samples exhibited that total CO_2 emission for the developed samples were lower than that of C sample. Also the economic sustainability results indicated that the cost for developed samples was lower than the C sample. These results indicated that the use of MP and DH is sustainable both environmentally and economically.

4. CONCLUSION

The study illustrates the possible advantages of adding MP and DH to cement paste in order to create a low-carbon sustainable building material. The findings reveal that while the modified mixes show reduced fresh-state workability compared to the C mix, they exhibit superior compressive and flexural strengths, enhanced bonding strength, and durability due to DH reinforcement. Additionally, these blends' resistance to cracking and seawater improves as their porosity diminishes over time. Crucially, the altered cement pastes exhibit fewer CO_2 emissions and lower cost, demonstrating the economic and environmental viability of employing MP and DH. Thus, this approach aligns with sustainable construction goals by reducing waste, lowering emissions, and minimizing reliance on traditional resources, providing a viable pathway for eco-friendly infrastructure development.

5. ACKNOWLEDGEMENT

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Evaluation of Mechanical Properties and Durability of Polypropylene Fiber-Reinforced Geopolymer Concrete with Recycled Concrete Aggregates

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1. INTRODUCTION

This construction sector contributes significantly to global carbon emissions and is a large user of natural resources. Conventional Portland cement concrete, the most popular building material, has significant negative effects on the environment due to its high energy consumption and greenhouse gas emissions during manufacturing. Alternative, more environmentally friendly building materials are becoming more and more popular as a reaction to these difficulties. As an environmentally sustainable substitute for traditional concrete, geopolymer concrete (GPC) has gained traction. Geopolymer concrete, in contrast to Portland cement, uses binders that are activated by alkaline solutions made from industrial byproducts like fly ash and slag. This significantly decreases carbon emissions while also lessening the need for natural resources. Among the many benefits of geopolymer concrete are its great mechanical strength, exceptional durability, and resistance to chemical degradation. Adding recycled concrete aggregates (RCA) to concrete mixtures is an additional strategy to improve sustainability in the building industry.

2. MATERIALS AND METHODS

Materials

1. Alkali Activator Solution:
    - Sodium Hydroxide (NaOH) Solution: Prepared to a concentration of 12 Molar.
    - Sodium Silicate Solution: With a SiO_2/Na_2O ratio of 2.5.
2. Binder:
    - Fly Ash: Class F fly ash was used as the primary binder material.
3. Aggregates:
    - Natural Fine Aggregates: River sand conforming to ASTM standards.
    - Coarse Aggregates: Natural coarse aggregates with a maximum size of 20 mm.
    - Recycled Concrete Aggregates (RCA): Sourced from demolished concrete structures, with replacement levels of 50% and 100%.
4. Fibers: Polypropylene Fibers: With an average length of 12 mm and a diameter of 0.02 mm, added at 0.5%, 1%, and 1.5% by volume of the concrete mix.

Mix Design

A total of 5 different mixes were prepared for this study. The mix proportions were designed to evaluate the effects of varying levels of RCA and polypropylene fibers on the mechanical properties of geopolymer concrete under different curing conditions.

Mix No.	Description
Control	Pure geopolymer concrete without RCA and fibers
1	Geopolymer concrete with 50% RCA
2	Geopolymer concrete with 100% RCA
3	Geopolymer concrete with 0.5% polypropylene fibers
4	Geopolymer concrete with 1% polypropylene fibers
5	Geopolymer concrete with 1.5% polypropylene fibers

Mixing Procedure

1. Preparation of Alkali Activator Solution:
    - Sodium hydroxide solution was prepared 24 hours in advance to ensure complete dissolution.
    - Sodium silicate solution was mixed with sodium hydroxide solution just before adding to the dry materials.
2. Dry Mixing: Fly ash and aggregates (both natural and RCA as per the mix design) were dry-mixed in a concrete mixer for 2 minutes.
3. Addition of Alkali Activator: The alkali activator solution was gradually added to the dry mix while the mixer was in operation.
4. Incorporation of Fibers: Polypropylene fibers were added to the wet mix and mixed for an additional 3 minutes to ensure uniform distribution.
5. Final Mixing: The complete mix was mixed for another 2 minutes to achieve a homogeneous consistency.

Casting and Curing

1. **Mold Preparation:** Standard cube molds (100 mm x 100 mm x 100 mm) and cylindrical molds (100 mm diameter x 200 mm height) were prepared for casting.
2. **Casting:** The prepared mixes were poured into molds in two layers, with each layer compacted using a table vibrator.

Testing Procedures

1. **Compressive Strength:** Tested on 100 mm cube specimens at 7, 28, and 56 days as per ASTM C109.
2. **Tensile Strength:** Splitting tensile strength tests conducted on cylindrical specimens as per ASTM C496.
3. **Flexural Strength:** Tested on beam specimens (100 mm x 100 mm x 500 mm) as per ASTM C78.
4. **Durability Tests:**
    - **Water Permeability:** Tested as per DIN 1048.
    - **Shrinkage:** Measured as per ASTM C157.
    - **Sulfate Attack Resistance:** Evaluated by immersing specimens in a 5% Na_2SO_4 solution and measuring mass loss and strength reduction after 28 days.

3. RESULTS AND DISCUSSION

The aim of this study is to investigate the mechanical properties of fiber-reinforced geopolymer concrete incorporating recycled concrete aggregates (RCA). Specifically, the study examines the effects of varying levels of RCA and polypropylene fibers on the compressive strength, tensile strength, flexural strength, and durability of geopolymer concrete. By exploring the synergy between RCA and polypropylene fibers, the research aims to develop a sustainable and

high-performance construction material that reduces environmental impact and promotes the broader adoption of geopolymer concrete in the construction industry.

4. CONCLUSION

This study successfully explored the mechanical properties of fiber-reinforced geopolymer concrete (GPC) incorporating recycled concrete aggregates (RCA) and polypropylene fibers. The findings indicate that the use of RCA, particularly at levels of 50% and 100%, affects the mechanical performance of GPC, but the incorporation of polypropylene fibers can mitigate some of these challenges.

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Implementation of cementitious composites containing Posidonaia oceanica leaf-based Biochar for a Sustainable Mortar Production

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Abstract

The ongoing pace of industrialization continues to contribute to a yearly rise in carbon dioxide (CO_2) emissions from both cement production and developed urban environments. In response to this environmental challenge, there is a growing interest in utilizing biochar, a byproduct of biomass pyrolysis, as a partial replacement for cement in concrete. The increasing popularity of biochar can be attributed to its ecological and economic benefits, serving as a carbon sink or capture agent, demonstrating low thermal conductivity, exhibiting chemical resistance, and featuring advantageous thermal properties. Among various sources of biochar, *Posidonia oceanica* leaf-based biochar has emerged as a promising alternative. Derived from the Mediterranean seagrass *Posidonia* oceanica, this biochar not only contributes to carbon sequestration but also enhances the performance of concrete due to its unique physical and chemical characteristics. The integration of *Posidonia* oceanica leaf-based biochar from pyrolysis processes into concrete formulations represents a sustainable approach to mitigating CO_2 emissions and improving the environmental footprint of construction materials.

Keywords: Biochar, Carbon Sequestration, Carbon sink, Durability, Posidonia oceanica Leaf, Pyrolysis.

Upgrading Sustainability of RC Multi-Story Buildings by Using FHRC Material in Walls and Partitions

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1. INTRODUCTION AND BACKGROUND

The construction industry is increasingly seeking sustainable alternatives to high-consumption raw materials with minimum environmental impact. The use of lightweight fiber-reinforced innate materials seems to be a promising response to this need. The use of fiber reinforcement for earthen materials goes back to decades ago, however, it is still a hot research topic. Akinmusuru and Adebayo (1981) are among the first scholars who worked on fiber-reinforced earth blocks. Mesbah et al (2004) conducted some direct tensile tests on compacted earth blocks reinforced with natural fibers. Butt et al. (2016) studied strength behavior of clayey soil reinforced with human hair as a natural fiber. Also, Patil and Harini (2016) proposed a method of improving subgrade strength of soft soil using human hair fibers as reinforcement. Abou Diab et al. (2016) studied the undrained shear strength characteristics of compacted clay reinforced with natural hemp fibers.

From sustainability point of view almost all of previously proposed materials suffer from one or more of the following shortcomings: (1) being not resilient against all disastrous events, (2) having high production cost, (3) needing high technology for production, (4) not being quite eco-friendly, and finally (5) not being fully recyclable. As such, Zaryoun and Hosseini (2019a, 2019b) introduced Foamed Hair-Reinforced Clay (FHRC), as a sustainable material incorporating human hair fibers as reinforcement, which does not have any of the mentioned shortcomings, and is therefore very helpful for architectural sustainability and increasing the disaster resilience of buildings; and discussed its usage in walls and false ceilings instead of conventional materials.

In this paper the effect of using FHRC, as a somehow new material, in walls and partitions of new and existing buildings for increasing their sustainability and disaster resilience is discussed. Economic and environmental sustainability, thermal insulation efficiency, and structural seismic mass are the matters discussed in the paper in detail, by using FHRC in comparison to conventional hollow concrete blocks.

2. MATERIALS AND METHODS

Three RC buildings with 4, 7, and 10 stories, shown in Figure 1, were considered for the comparative study.

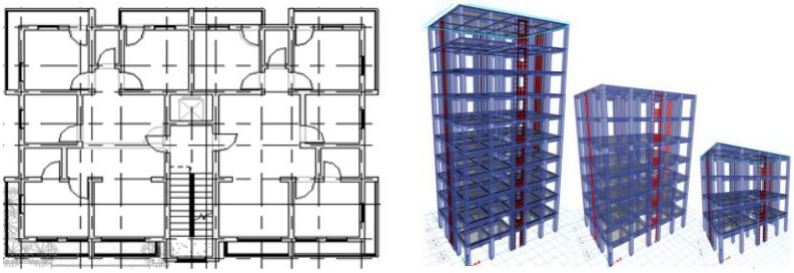

Figure 1. The typical floor plan and the 3D views of the buildings considered in this study

The buildings were designed once assuming walls and partitions made of conventional hollow concrete blocks, and once more made of FHRC material. The research used U-value for the heat loss or gain, and advanced structural analysis tools like Revit and ETABS to model and evaluate the performance of the two wall types mentioned. Figures 1 and 2

3. RESULTS AND DISCUSSION

According to the performed investigations and analyses, the thermal transmittance or U-value of FHRC walls is 0.244 W/m²K, while for the conventional hollow concrete block wall is 1.780 and for fiberglass wall is 0.250 W/m²K. Furthermore, Table 1 presents the comparative results from the amount required steel bars, seismic mass and construction costs viewpoints.

Table 1. Comparison of buildings with conventional and FHRC walls

No. of stories	Required steel bars' weight (tonf)		Seismic mass (ton)		Wall construction costs (USD)	
	Conventional	FHRC	Conventional	FHRC	Conventional	FHRC
4	26.5	23.80	688	599	41000	14000
7	39.65	34.98	973	849	67000	25000
10	56.10	44.97	1460	1274	95000	35000

4. CONCLUSIONS

The findings showed that thermally, FHRC walls have superior insulation properties with a U-value of 0.244 W/m²K, significantly lower than 1.780 of the conventional concrete block walls. Furthermore, using FHRC in walls and partitions lowers the building's seismic mass by approximately 13% on average. Finally, using FHRC materials results in approximately 64% cost reduction, on average, in construction of walls and partitions of the buildings.

5. ACKNOWLEDGMENT

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Impact Of Extreme Emissions on Future Precipitation Variability in Northern Cyprus

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1. INTRODUCTION

A majority of scientists agree that greenhouse gas emissions from human activities play a pivotal role in driving recent climate changes, particularly contributing to global warming (Wyser et al., 2020). However, the resulting increase in global surface temperatures is not evenly distributed across the globe, which cause distinct climatic variations among different regions. The Mediterranean basin, in particular, is projected to experience significant changes in its typical weather patterns due to evolving climate conditions. Current literature indicates a steady increase in mean temperature coupled with a reduction in precipitation rates throughout the Mediterranean region (Giorgi and Lionello, 2008). These fluctuations in precipitation demonstrate significant temporal and spatial disparities, making it essential to conduct localized assessments of precipitation characteristics for each country within the region.

In light of these considerations, this study aims to investigate the impact of a high-emission, worst-case scenario (RCP 8.5) on annual and seasonal precipitation totals using EURO-CORDEX model projections. The analysis focuses on both the near future (2025–2062) and the far future (2063–2100) to evaluate how extreme emissions may influence precipitation dynamics across the northern part of the island. By providing localized insights into these potential changes, this study contributes to a deeper understanding of future climate impacts in this critical region.

2. MATERIALS AND METHODS

The study area focuses on the northern part of Cyprus. To accurately capture the local climate conditions, seven precipitation stations (Lefkosa, Girne, Guzelyurt, Magusa, Kantara, Bogaz, and Karpaz) from strategically critical locations were selected. The daily observed precipitation data for these stations, covering the historical period from 1978 to 2005, were obtained from the meteorological office. For model data, five EURO-CORDEX climate models, comprising combinations of Global Climate Models (GCMs) and Regional Climate Models (RCMs), were used. The specific GCM-RCM pairs used in this study include: ICHEC-EC-EARTH with KNMI-RACMO22E_v1 (Model 1), IPSL-IPSL-CM5A-MR with SMHI-RCA4_v1 (Model 2), MOHC-HadGEM2-ES with both DMI-HIRHAM5_v1 (Model 3) and KNMI-RACMO22E_v2 (Model 4), and NCC-NorESM1-M with DMI-HIRHAM5_v2 (Model 5). These models serve both to evaluate the historical period and to project future climate conditions for the years 2025–2100 under the RCP 8.5 scenario.

The methodology of this study proceeds as follows: initially, historical simulations from the models are compared with observed data using performance metrics including mean bias (MB), modified index of agreement (MIA), normalized root mean square error (nRMSE), and Kling-Gupta efficiency (KGE) to assess the accuracy of the raw models. Subsequently, the Quantile Delta Mapping (QDM) bias correction method (Cannon et al., 2015) is applied to both historical and projected model simulations to refine the data. The effectiveness of this correction is then evaluated through the same performance metrics.

Following this correction process, the projections are combined into a multi-model ensemble average (MMEA) to minimize model uncertainties. The MMEA series are then used to assess projected changes in precipitation. Finally, these aggregated series are analyzed to investigate the anomaly changes of precipitation on annual and seasonal scales over the near-future (2025–2062) and far-future (2063–2100) periods.

3. RESULTS AND DISCUSSION

Model 2 demonstrated the strongest performance across most metrics, achieving the highest KGE, highest MIA, and a relatively low MB, which made it the most reliable model for representing observed precipitation patterns. Model 4 showed balanced performance, particularly in MB and KGE, suggesting it as a strong alternative. In contrast, Model 5 exhibited weaker performance, especially in KGE and nRMSE, which implied its limitations in capturing observed data effectively. Besides, Models 1 and 2 generally tended to underestimate observations, while Model 3 overestimated them. Furthermore, the performances of the models varied from station to station and even from season to season. Magusa and Karpaz stood out as the stations, where the models performed best with high KGE values, moderate to high MIA values, and balanced MB values. In contrast, Guzelyurt and Lefkosa exhibited relatively weaker model performance.

The application of QDM bias correction significantly improved model performances by effectively minimizing systematic biases, bringing MB values close to zero across all models. This correction led to a marked increase in KGE, which increased overall model reliability by balancing bias and variability, with an average KGE rise from 0.26 to 0.40. While MIA remained largely unchanged, which indicated preserved temporal structure and agreement with observed data, a slight increase in nRMSE was observed.

The results indicate significant variability in precipitation patterns, with positive anomalies observed in the near future, particularly during the summer months. However, a marked shift occurs in the far future, with most stations experiencing negative anomalies, particularly in annual averages, where Magusa and Kantara show decreases of -32.2% and -37.5%. Particularly, winter and spring precipitation is projected to decline across all stations, suggesting a potential shift toward drier conditions during these seasons. Moreover, the findings indicates that while summer precipitation may increase significantly, winter and spring precipitation may decrease, which highlights the potential shifts in seasonal precipitation patterns due to climate change.

4. CONCLUSION

In conclusion, this study examined the impact of extreme emissions on future precipitation variability in Northern Cyprus. Model 2 offered the most reliable representation of observed precipitation patterns. The application of QDM significantly improved model performance. Results showed positive anomalies in summer precipitation contrasted by negative anomalies in winter and spring, which indicates the potential shifts toward drier conditions in these seasons. These findings highlight the need for effective climate adaptation strategies to address the localized impacts of climate variability under extreme emissions scenarios.

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Water Resources Pollution Analysis in TRNC

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1. INTRODUCTION

Due to reasons such as rapid population growth, unplanned urbanization, and excessive use of natural resources, increasing environmental pollution problems are observed in Northern Cyprus, as in the rest of the world. Cyprus, the third largest island of the Mediterranean, is effected by pollution to a great extent due to the limitations in its natural resources and the conditions of being an island country. Regarding the problems experienced from the macro scale to micro pollutants, limited number of studies reveal the necessity of urgent measures. Many problems are experienced on the island, such as the Solid Waste problem, the waste of old mining sites and polluted groundwater and insufficient capacity of wastewater treatment plants. There is not enough data on many of the pollution sources.

2. MATERIALS AND METHODS

Some research studies and scientific reports have been reviewed and also some results from analytical studies in Cyprus International University has been demonstrated in this conference.

3. RESULTS AND DISCUSSION

3.1 Wastewater Problem:

Treatment of domestic wastewater has gained importance in Northern Cyprus due to tourism and the increasing population. While the use of septic tanks is common in villages, wastewater goes to treatment plants in large districts. Approximately 10% of the domestic wastewater, estimated to be around 100 million m^3/year, reaches treatment facilities.

Especially in Kyrenia, the existing domestic wastewater treatment facility is insufficient for the wastewater potential of the rapidly increasing resident population, and it is observed that domestic wastewater is discharged into the sea without secondary treatment. It is essential to eliminate this situation in terms of tourism and health.

Table 1. Wastewater Treatment Plants and Their Capacities

	Capacity (m^3/day)	Actual Case (m^3/day)
Mağusa Wastewater Treatment Plant	8.883	4.100
Haspolat Wastewater Treatment Plant	30.000	9.000
Girne Wastewater Treatment Plant	1.800	1.800
Güzelyurt Wastewater Treatment Plant	3.179	500
Bafra Wastewater Treatment Plant	6.000	1.500
Lapta Wastewater Treatment Plant	500	500
Total (m^3/day)	29.362	17.400
Total (m^3/year)	**10.717.130**	**6.351.000**

3.2 Groundwater Problem:

According to the Falkenmark index, the Turkish Republic of Northern Cyprus (TRNC) is within the border range of countries suffering from absolute water scarcity, with the amount of renewable water per capita of 328 m^3 / year (Yılmaz, 2020). There are no rivers with permanent flow in the TRNC (Kutoğlu, 2010). It is highly dependent on groundwater (Koday, 1995; Şenol, 2020). Considering the recharge area of the Güzelyurt aquifer, which constitutes 50% of the TRNC groundwater potential, it has the status of a transboundary aquifer that is fed largely by the rainfall falling on the foothills of Karlıdağ (Phillips Agboola and Egelioglu, 2012). It is relatively dependent on the south, considering the inflow characteristics of renewable water resources.

Morphological features together with high evaporation and low precipitation do not allow high amounts of water to be stored in dams (Maden, 2013). TRNC, which is highly dependent on groundwater, experiences salinization problems in its coastal aquifers (Ergil, 2000). The salinization problem, which develops with the intrusion of seawater into the aquifer system as a result of excessive water withdrawal without taking into account the recharge characteristics of the aquifer system, currently causes both quantity and quality problems on TRNC potable water resources (Ergil, 2000; Maden, 2013). TRNC had difficulties in meeting domestic use demand and sectoral water needs until 2017, when the project of transportation of Turkish Water to TRNC by under-marine pipelines had been realized. Half of the 75 million m^3 of water to be transmitted to the TRNC annually is being used as drinking and utility water, and the remaining half will be used as irrigation water.

3.3. Irrigation Ponds

The natural surface water resources have completely dried up due to excessive extraction, excessive eucalyptus tree planting and the dry period that has prevailed in recent years.

There are 29 ponds in total, some of these ponds are old irrigation ponds with an open channel system and some of them serve as flood traps. All surface storage facilities in the country are used for groundwater recharge or irrigation purposes. 10 of these facilities were built before 1974 and 18 afterwards. The total 304 million m^3 of operational storage facilities is quite low, when compared to the South. However, this difference is caused by the fact that the amount of precipitation falling within the borders of TRNC is less than in the south.

3.4. Micropollutants found in TRNC Water Resources

Like all around the world, TRNC is also facing pollution problem in all water resources. The conventional pollutants can be easily removed by conventional treatment techniques, but micropollutants (at mg or ng levels) are remaining as immense problems. A bunch of studies have been carried out in Cyprus International University, which focus on micropollutants.

Especially when the pesticides were considered, 5 banned pesticides (alachlor, atrazine, diuron, isoproturon and pentachlorophenol) were investigated with advanced analysis techniques in various samples taken from the Güzelyurt aquifer, and 1 of them (isopuroturon) was detected in the groundwater. A broader survey should be applied to observe the pesticides in aquifers.

Another class of micropollutants is Endocrine disruptors; They are industrial pollutants and by-products that have entered every aspect of our daily lives as an inevitable result of industrialization. They are an exogenous chemical or mixture of chemicals that has the potential to interact with the organism at different hormonal levels. They may interact with the production, secretion, transport, metabolism, receptor binding function and removal process of hormones necessary for the balance of reproductive and developmental processes. With epigenetic effect; they can disrupt the expression of genes that regulate DNA processing functions. They can mimic natural steroid hormones and bind to steroid hormone receptors. However, there is still confusion and lack of advice on this subject.

It is seen that the treatment of endocrine disruptors and micropollutants at high percentages is possible with advanced oxidation methods when they are integrated into treatment plants (Kidak, 2013). Advanced oxidation techniques are namely, ozonation, UV/H_2O_2, sonication and other processes that provide production of chemical radical species. Removal of pesticides, bisphenol-A (BPA) and Bis(2-ethylhexyl) phthalate (DEHP), various pesticidal residuals were achieved with high efficiency.

4. CONCLUSION

As in the rest of the world, environmental pollution in the TRNC causes widespread effects from macro to micro levels. Considering the importance of the issue, solutions on local and global scale are gaining urgency day by day. The optimized reaction to this issue should be the cooperation of the governmental and institutional authorities to focus on permanent solutions from engineering point of view. As the academical studies try to guide scientific methods for the official people, we would like to see them showing effort to overcome problems which effect the lives of people. Academicians are discouraged when the work-shops or reports are not taken into account by the authorities.

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Planning Water-Secure and Water Sensitive Urban Areas in North Cyprus

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1. INTRODUCTION

As a result of global warming, more water evaporates from the earth's surface compare to past, and when it finds a suitable environment in the atmosphere, it falls on the earth as a heavy rainfall. In fact, the occasional occurance of heavy rainfall events is a normal natural phenomenon. However, the frequent occurrence of these events is considered as an evidence that the climate is changing.

More frequent heavy storm events cause more frequent urban floods. As in other countries, after heavy storm events, frequently urban floods occur in Northern Cyprus. However, the increased rainfall intensity as a result of global warming is not the only cause of urban floods in Northern Cyprus. In general, there are two main reasons of urban flooding in Northern Cyprus. The first one happens when the agricultural lands are converted into residential areas. In this kind of project, some of the streams that are not shown on the maps are missed. The second reason is that there are no legal requirements for the design and construction of stormwater drainage networks and many stormwater drainage pipes and channels are not built based on any hydraulic design. Although stormwater design methods were developed a hundred years ago, most of the stormwater drainage networks built in Northern Cyprus were not designed according to any method. Many hydraulic structures such as rainwater pipes and culverts are designed and constructed based on predictions.
In this study, the causes of floods in the urban areas in Northern Cyprus, where urbanization is rapidly progressing, were examined and suggestions for solution were presented.

2. FLOODING IN RIVERS AND STREAMS PASSING THROUGH URBAN AREAS

As in other parts of the world, rivers and streams pass through many urban areas in Northern Cyprus. However, the fact that these streams did not flow for a certain period of time, created the perception that these streams would no longer flow and in some urban areas, streams with open channel cross-section are replaced with pipes. However, the increasing rainfall intensity in recent years creates flood and inundation problems in places where these structures are located.

In the past, the water flowing in streams in many places throughout Northern Cyprus was used to irrigate agricultural areas. However, while urbanization are being built, unfortunately the land slopes in these areas are not controlled and the routes of the streams are not protected. In this case, even a normal rainfall event may cause an urban flooding.

While streams are visible on the old maps, in some regions, these streams are not seen on the new maps. Therefore, while the necessary opinions and construction permits are being obtained, it is not known if there is a flood risk or not. Unfortunately, the flood risk of these regions arise after a flood event is observed in these regions.

3. EXISTING CONDRITION IN THE DESIGN OF STORMWATER NETWORKS

One of the reasons of flooding in residential areas is the absence or inadequate stormwater infrastructure. Generally, local governments such as municipalities own the stormwater networks in the urban areas. For this reason, regulations and standards regarding stormwater design are generally

determined by local governments. However, in some countries, these regulations and standards have been determined by the relevant ministry of the country. For example, in Turkey, the "Regulation on Rainwater Collection, Storage and Drainage Systems" was prepared by the Ministry of Environment and Urbanization and was announced in the Official Gazette on June 23, 2017. (TC Resmi Gazeter, 2017). Unfortunately, there is no any regulation regarding stormwater design in Northern Cyprus. In infrastructure projects such as land subdivision, architects and engineers who prepare the project must obtain a visa from some chambers affiliated with the Union of the Chambers of Cyprus Turkish Engineeers and Architects. However, in this process, a visa regarding stormwater design is not requested. Within their borders, some municipalities require the construction of rainwater pipes when granting construction permits of the buildings, but do not request any reports regarding their stormwater design. An Environmental Impact Assessment (EIA) Report must be prepared for a condominium with 60 or more residences. The prepared EIA Report states that a stormwater drainage system should be designed and built on the site. However, as metioned before, any regulation regarding the desing of stormwater is not available in Northern Cyprus. Unfortunately, stormwater pipelines with diameter and elevation are shown in the drawings without any stormwater design and only according to the predictions.

4. DISCUSSION AND CONCLUSION

Changing climate conditions and increasing rainfall intensities necessitate water-sensitive urban planning designs and practices in developed countries. While sustainable stormwater design and management is implemented in these countries, the legal regulations that would make classical stormwater design mandatory is not even available in Northern Cyprus. Civil and Environmental Engineers and relevant non-governmental organizations should take the necessary steps in order to make stormwater design mandatory in Northern Cyprus. In changing climate conditions, water-secure and water-sensitive urban planning is becoming more and more essential every year.

On the other hand, the European Union Regulation on the Assessment and Management of Flood Risks (Directive 2007/60/EU; Floods Directive –FD) requires that, in member countries, a flood risk analysis of urban areas, where rivers or streams are crossing, be carried out and updated every six years. Therefore, flood risk analyzes of urban areas, where a river or stream are coming from montains and crossing them, must be prioritized. It should not be forgotten that water that we do not manage and direct will harm us in the future as it did in the past.

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Assessing Water Resources, Demands, and Sustainable Management Strategies in the Gulf Cooperation Council (GCC) Countries

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1. INTRODUCTION

The Gulf Cooperation Council (GCC) countries, namely Saudi Arabia, UAE, Oman, Bahrain, Kuwait, and Qatar, are challenged by severe water scarcity due to arid climates, minimal rainfall, and reliance on non-renewable water sources (Al-Rashed & Sherif, 2000). Water demands are escalating with population growth, industrialization, and high water usage in agriculture, which collectively contribute to groundwater depletion and environmental degradation (H. Hashemi, 2013). This study evaluates current water resources and management practices within the GCC and proposes strategies for enhancing water sustainability amid growing environmental pressures.

2. MATERIALS AND METHODS

This research examines quantitative data on water resources, including shallow and deep aquifers, desalination, and treated wastewater capacities. Key references include regional government reports and climate models assessing water demands, renewable resource potential, and the impact of climate variability on water availability (Sherif et al., 2023). The study also reviews renewable energy applications in desalination and efficiency in irrigation systems, aiming to identify sustainable management options suitable for GCC's climate and economic conditions.

3. RESULTS AND DISCUSSION

Groundwater serves as a critical but diminishing resource, particularly in Saudi Arabia and Oman, where overextraction has led to severe aquifer depletion and seawater intrusion along coastal zones (Al-Zubari, 2014). Estimated annual recharge of GCC's shallow aquifers is limited to 3.5 billion cubic meters, whereas fossil aquifers provide non-renewable reserves that are unsuitable for sustained use (UN-ESCWA, 2013). Desalination has emerged as a primary solution for freshwater supply, covering up to 87% of Qatar's water needs, and 50% in Saudi Arabia (Sherif, 2010). However, the high energy costs associated with desalination contribute significantly to greenhouse gas emissions. Renewable energy, particularly solar, is being integrated into desalination processes to curb these emissions and reduce dependence on fossil fuels (A. Zapata-Sierra, 2021).

Treated wastewater also plays a growing role in non-potable uses, such as irrigation and landscaping. In Saudi Arabia, over 4,000 million cubic meters of wastewater is treated annually, though current utilization remains below its full potential. Advanced treatment technologies like ultrafiltration and reverse osmosis in countries such as Kuwait are helping to improve water quality for agricultural and industrial applications (Aleisa, Al-Jadi, & Al-Sabah, 2015)

To address water scarcity, GCC countries are implementing several key strategies. These include tariff revisions to encourage conservation, advanced irrigation techniques, and public education on

water efficiency (Sharma, 2022). Given that over 80% of water consumption in the GCC is attributed to agriculture, improved water management in this sector is crucial. Precision agriculture, efficient irrigation systems, and crop selection suited to arid climates could significantly reduce water demand (Bani, 2019). Managed aquifer recharge (MAR) projects, as demonstrated in Bahrain, are promising for restoring groundwater levels and enhancing resilience to droughts (Ghadeer M. Kadhem, 2020)

Expanding renewable energy usage in desalination remains a priority. The UAE's Ghantoot desalination pilot, powered by solar energy, and Saudi Arabia's King Abdullah Economic City solar desalination plant exemplify how clean energy can contribute to more sustainable water solutions (Mohsen Sherif, 2023). These projects support broader GCC goals for sustainable infrastructure and a reduced environmental footprint.

4. CONCLUSION

The findings emphasize the urgent need for an integrated, multi-pronged approach to water management in the GCC. Policies prioritizing efficient water use, renewable energy in desalination, and wastewater recycling are essential for sustainability. Public education campaigns, efficient irrigation in agriculture, and investment in innovative technologies are critical for long-term water security. Through collaboration, the GCC can mitigate the impacts of water scarcity and move towards a sustainable and resilient future.

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Analyzing Self-Aeration on Step Spillway: An Improved Numerical Model

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1. INTRODUCTION

Air entrainment in high velocity free surface flow is crucial for several technical applications, including ecological, mechanical, environmental, and hydraulic systems (Masouminia & Türker, 2022; Wei et al., 2017). Flow aeration presents complex challenges impacting drag force, morphology of flow, and cavitation, which has been effectively examined by numerical analyses (Chanson et al., 2021; Zabaleta et al., 2020). This has led to the creation of numerical models that can predict and simulate self-aerated flow with greater accuracy, reduced costs, and shorter timeframes (Masouminia & Türker, 2024). This paper introduces a numerical model that employs drag coefficient in the presence of bubbles and droplets in flow on stepped spillway. This numerical model is applied over a stepped spillway, a recognized construction that induces aeration, to verify its accuracy and enhance comprehension of flow velocity variations, pressure distribution, and aeration.

2. MATERIALS AND METHODS

2.1 Governing equations

To address air-water penetration in high turbulence flow, the Eulerian model is employed to characterize the flow morphology (Colombo et al., 2021). The Eulerian model offers advantages and flexibility over the phase interface mechanism, enhancing the precision and validity of numerical calculations (Cheng et al., 2006; Gualtieri & Chanson, 2021).

$$\frac{\partial}{\partial t}\left(\alpha_j \rho_j\right) + \nabla.\left(\alpha_j \rho_j \mathbf{V}_j\right) = 0 \quad [1]$$

$$\frac{\partial}{\partial t}\left(\alpha_j \rho_j \mathbf{V}_j\right) + \nabla.\left(\alpha_j \rho_j \mathbf{V}_j \mathbf{V}_j\right) = -\alpha_j \nabla P + \nabla.\bar{\bar{\tau}}_j + \alpha_j \rho_j \mathbf{G} + \mathbf{F}_{drag} \quad [2]$$

$$\mathbf{F}_{drag} = C_D A_i \frac{\rho_m}{8} |\mathbf{V}_r| \mathbf{V}_r \quad [3]$$

where t denotes time; α and ρ signify void fraction and density, respectively; V is velocity; P signifies pressure; τ represents the stress-strain tensor; G indicates gravitational acceleration; F_{drag} and C_D refer to the drag force between phases and drag coefficient, respectively. Relative velocity is defined as $\mathbf{V}_r = \mathbf{V}_g - \mathbf{V}_l$; A_i denotes the interfacial area concentration; and $\rho_m = \alpha_g\rho_g + (1-\alpha_g)\rho_l$ is the mixture density. Subscript j phase is g as gas or l as liquid.

3. RESULTS AND DISCUSSION

The initial flow parameters for this numerical model (Table 1), are based on the experimental values of Carosi and Chanson (2006), where a stepped spillway with 10 steps were examined. The length and height of each steps were 25 and 10 cm, respectively. In table 1, d_c signifies critical depth, while relative critical depth is expressed as d_c/h_{st}.

Table 1. Initial data of step spillway (Carosi & Chanson, 2006)**.**

Case	q_w (m^2/s)	d_c (cm)	d_c/h_{st}	Inception Step
Q1	0.1164	11.5	1.15	6-7
Q2	0.1431	13.3	1.33	6-7
Q3	0.1612	14.5	1.45	7-8

Figure 1 illustrates a close correlation in velocity comparison with experimental data from the literature, so validating the enhanced numerical model and confirming the accuracy of the proposed

model. Figure 2 demonstrates a strong link between the experimental void fraction data and the suggested enhanced numerical model. A divergence is evident near to each step edge due to the boundary effect in numerical values. Furthermore, a significant reduction is achieved based on calculated RMSE of Cheng and Chen (2013) and the Improved numerical model, reportedly decreasing from 77% to 29%. The same trend is detected for the maximum deviation, with total improvement ranging from 79% to 12%.

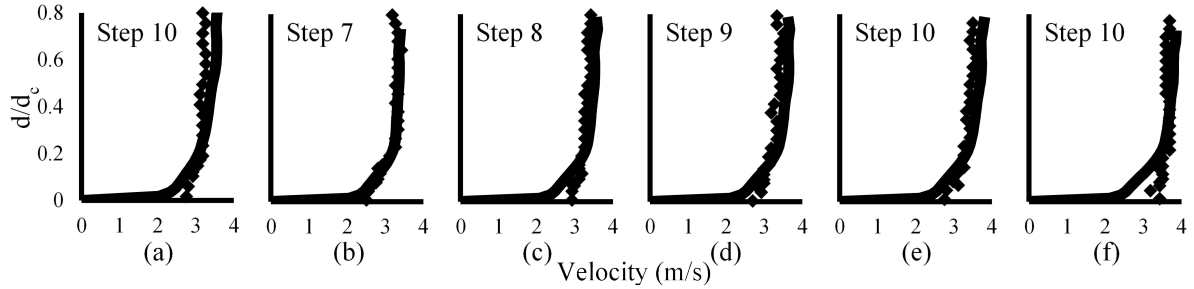


Figure 1. Velocity comparison of experimental and improved numerical model (a) Q1, (b, c, d, e) Q2, and (f) Q3.

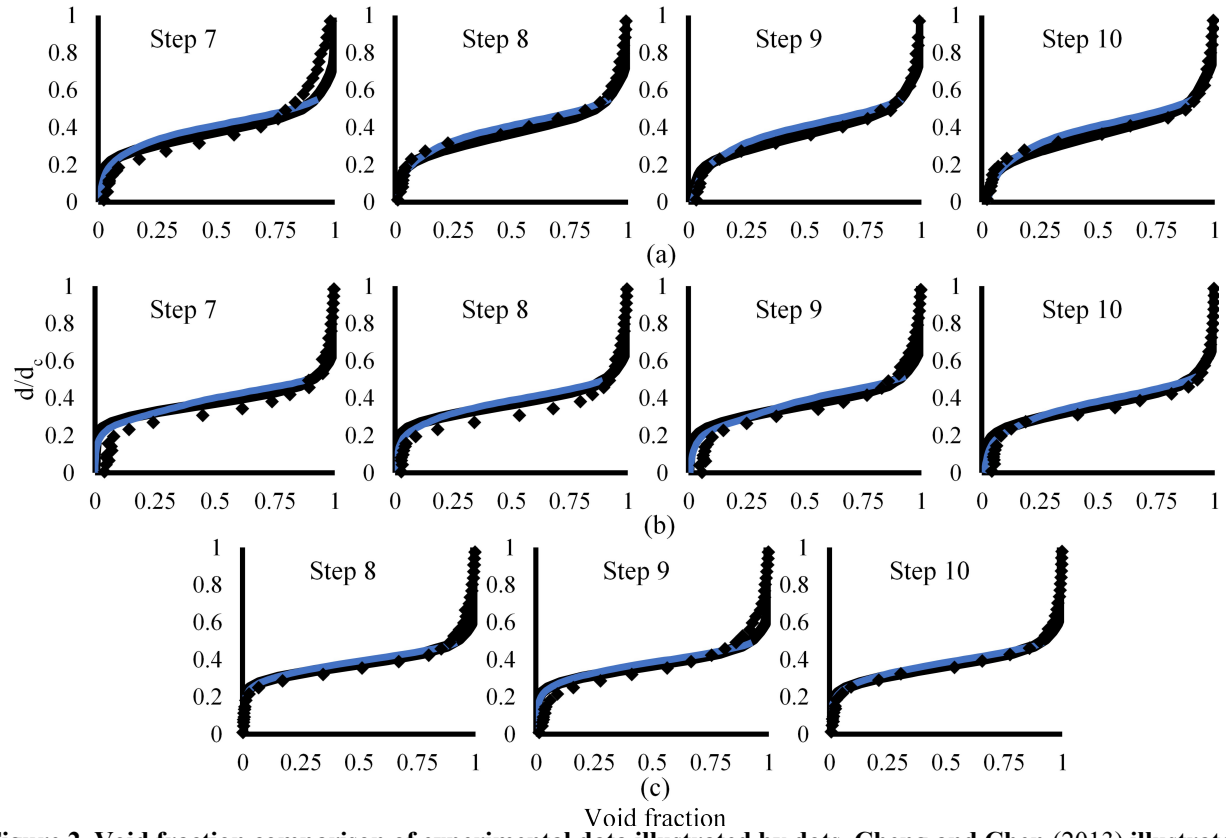


Figure 2. Void fraction comparison of experimental data illustrated by dots, Cheng and Chen (2013) **illustrated by dash-line, and improved numerical model illustrated by line, over relative depth (a) Q1, (b) Q2, (g) Q3.**

Carosi and Chanson's (2006) experimental data supports the prediction of the inception step in aeration, indicating that increased flowrate can relocate the inception point downstream, reducing overall aeration and causing concentrated void fraction distribution in the step cavity (Figure 3).

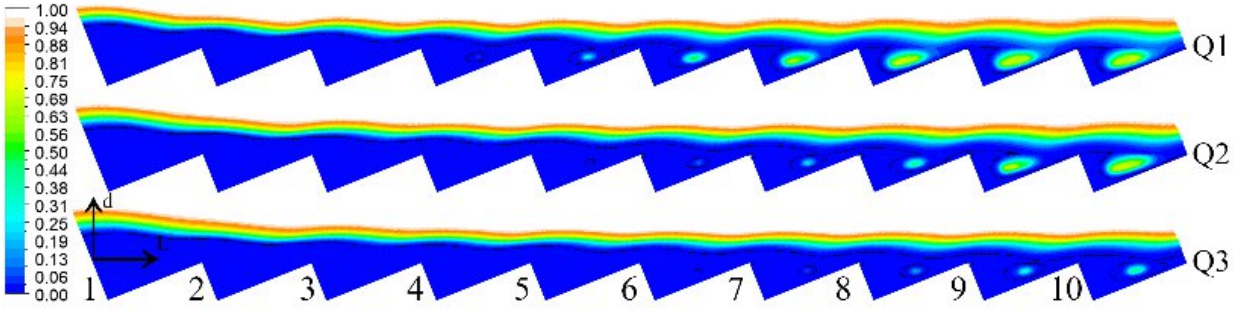
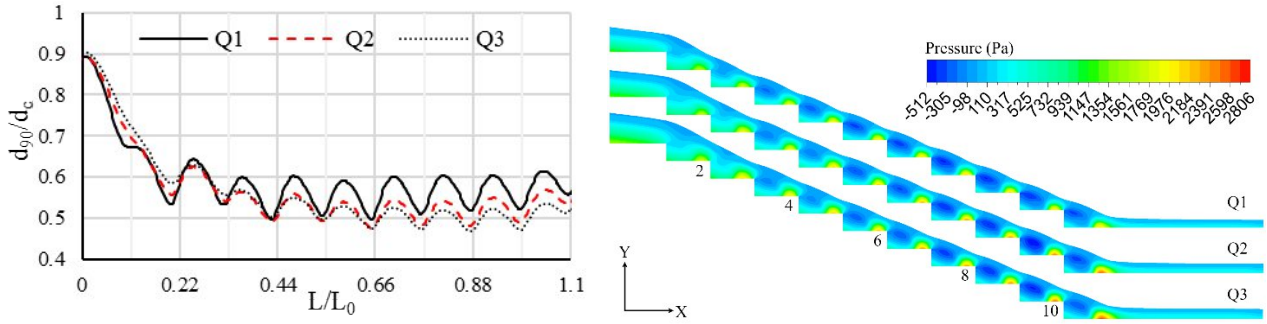


Figure 3. Void fraction and inception point location.

The fluctuation of the water surface is affected by the relative depth of the steps, with greater amplitude fluctuations noted in Q1 (Figure 4a). The reduced critical depth emphasizes step height, resulting in surface rupture and instability. The impact of steps on water surface fluctuation is negligible until the third step, except for Q1. The minimum relative depth values are observed immediately prior to the step edge, whilst elevated values diminish. The convergence of relative depth can be related by step spillway geometries. Same as Zhou et al. (2021), the relative critical depth of a stepped spillway profoundly influences aeration, with diminished depths signifying enhanced aeration. When the relative critical depth above 30%, aeration significantly diminishes from 0.74% down to 0.38%, indicating completely skimming flow (Figures 3, 4a).

The pressure distribution along the stepped spillway reveals the occurrence of cavitation. Low-pressure zone after step edge, migrating downstream with flowrate increases (Figure 4b). The minimum pressure for each flowrate occurs over the final step, where the resistance force inhibits pressure reduction in the last step cavity.



(a) (b)

Figure 4. (a) Water surface profile, (b) Pressure distribution.

4. CONCLUSION

The improved numerical model, precisely forecasts flow properties, especially self-aeration, across stepped spillways. This paradigm, corroborated by a 2D model, and is applicable to 3D models. The step roughness and turbulence Froude numbers encompass macro properties of flow, including free surface location, rotating area, and inception point location, in addition to micro qualities such as void fraction. The model also mitigates under-prediction outcomes in areas with high void fraction, yielding more accurate simulations. The model additionally recognizes cavitation indications, suggesting a reduced relative critical depth for self-aeration flow. This model is pertinent for constructing economical hydraulic structures and is essential for analyzing cavitation and destructive forces in spillways with irregular step lengths, heights, and configurations.

5. ACKNOWLEDGMENT

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Urban flood Simulation in Mashhad city with SWMM with emphasis on urban resilience and SDG 11

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1. INTRODUCTION

Climate change alters rainfall patterns, leading to flooding. Also, human activities, such as increasing urbanization, exacerbate surface runoff and flood risks (Soleymani, 2014). Flooding in cities, damages infrastructures, threatens public safety, and results in economic losses (Soleymani, 2014; Agarwal & Kumar, 2019). According to UN-Habitat's definition for urban resilience, cities face a range of natural and human-made shocks and stresses, from earthquakes, floods, and rapid migration to cyberattacks. Today, cities and their residents face additional and intensified challenges due to rapid urbanization, climate change, political instability, and similar issues (UN-Habitat, 2021). Therefore, in this research, together with flood modeling in the city of Mashhad (Iran), suggestions are provided for the resilience of the city where flood is one of its main threats based on sustainable development goals (SDGs) especially SDG 11 which is about making cities and human settlements inclusive, safe, resilient and sustainable.

2. MATERIALS AND METHODS

2.1 Study Area

Geographical Location

In Iran, some megacities, like Mashhad have encountered numerous floods in recent years. Table 1 demonstrates the physiographic and climate patterns of Mashhad watershed (Memari et al., 2020).

Table 1. Climate and physiographic pattern of the city (Memari et al., 2020).

Climate	Evaporation and transpiration (mm)	Average Slope (%)	Perimeter (km)	Area (ha)
Semi-dry	1316.7	16.28	33.9	2472

2.2 Methods

One widely used software to simulate urban flooding and management is the Storm Water Management Model (SWMM) (Rai et al. 2017) (Niazi et al. 2017). This is a public software developed by the U.S Environmental Protection Agency (USEPA) in 1971 to simulate rainfall-runoff quantity and quality in urban environments (Niazi et al. 2017). The data on topography, land use and land cover, hydrology, and the drainage network are required for simulation. The data were collected from online and government resources. For conducting the simulation, data of area, average slope, equivalent rectangular width, percentage of impervious areas, Manning's roughness coefficient for impervious and pervious surfaces and channels, infiltration and storage height for different surfaces, and curve number is needed. The area was divided into sub-catchments and averaged precipitation, and slop were assigned to them.

3. RESULTS AND DISCUSSION

The simulation identified flood-prone areas, water depth, and velocity, and analyzed different strategies, such as permeable pavements and detention basins. Flood-prone areas are regions with inadequate drainage systems or low-lying regions where surface water accumulates during high-intensity storms. Impervious surfaces, like impermeable pavements, generate higher runoff, which

highlights the need for urban planning and green infrastructures. Improving the drainage network's performance and combining it with other measures enhance flood resilience. Also, the concentration-time is another key factor influencing peak run-off. With increasing urbanization, fewer green areas are available and more impervious surfaces are erected which results in less concentration time. So, some strategies were needed to increase the concentration time and decrease the flood-prone areas.

4. CONCLUSION

Results showed that some strategies were needed in these regions, such as building green areas and rain barrels to collect rainfall to recharge the watershed or utilize it in different ways. These strategies result in reducing flood volume, preventing peak run-off, recharging watershed, and increasing the quality of flood. By implementing the suggested solutions, urban vulnerability can be reduced and as a result, urban resilience can be increased.

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Hydrological Patterns and Ecological Balance: Insights from Five Climatically Diverse Locations

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1. INTRODUCTION

Climate change is mostly caused by greenhouse gas emissions from human activity (Trenberth, 2018). It poses major challenges to the global water supply and hydrological systems. The effects of this phenomenon are most apparent in semi-arid regions. One such region is Cyprus in the Eastern Mediterranean (Pascual et al., 2015). Water resources in Northern Cyprus are limited and fragile. It's important to understand how climate change affects key hydrological variables (Elkiran et al., 2019).

Hydrological patterns are crucial for maintaining ecological balance. This is particularly important in regions with diverse climatic conditions. This study looks at the relationships between water systems and ecosystems. It focuses on five different locations, each with its own unique climatic characteristics.

2. METHODOLOGY

This study uses a detailed dataset of hydrological variables. The data is obtained from the Meteorology Department of Norther Cyprus for five main locations in Northern Cyprus. These locations are Lefkoşa, Mağusa, Girne, Güzelyurt, and Ercan. The data mainly covers the periods from 2008 to 2012.

2.1. Hydrological Variables

Mean Air Temperature (°C), Mean Precipitation (mm), Mean Relative Humidity (%), Mean Evaporation (mm), Mean Cloud Cover (oktas), Mean Wind Speed (m/s), Mean Grass Temperature (°C), Mean Sunshine Duration (hours/day), Mean Solar Radiation (W/m²), Mean Soil Temperature at 50 cm Depth (°C), Mean Soil Temperature at 100 cm Depth (°C), Mean Air Pressure (hPa).

2.2. Data Collection and Sources

The dataset was thoroughly assessed using quantitative approaches. A variety of statistical methods were applied. The data was organized in Microsoft Excel. This improved computing performance. Pivot tables and built-in statistical methods were effective for identifying patterns. Descriptive statistics and time series analysis were used to investigate climate factors. Excel's advanced algorithms simplified the calculation of critical parameters. For further research, Python was chosen because of its extensive data science libraries. Python analysed temporal patterns and trends across the years. The data was modelled both mathematically and visually. Built-in Python functionality was used, while data processing was done with Pandas. This combination enabled a thorough analysis and visualization of the dataset.

3. RESULTS AND DISCUSSION

Figure 1 displays temperature and precipitation in a single graph. This format facilitates easy comparison for Lefkoşa, the capital city of Northern Cyprus.

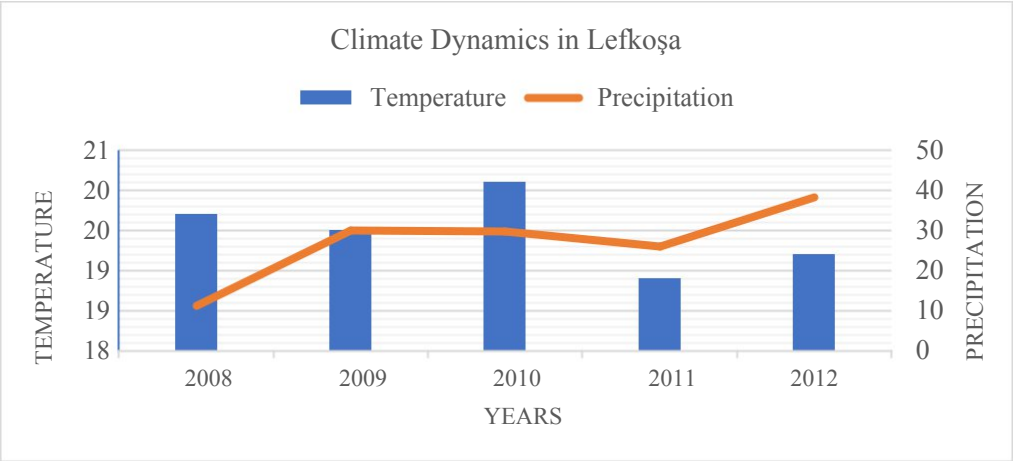

Figure 1. A Combined Graph of Temperature and Precipitation Trends in Lefkoşa

Precipitation tends to increase in Girne and Mağusa in response to higher temperatures. Higher temperatures are often followed by rising humidity levels. Girne and other areas that receive a lot of precipitation are known for their high humidity. In regions like Mağusa, stronger winds are often linked to slightly lower temperatures. This implies that strong winds may moderate local temperatures. Increased cloud cover is correlated with higher humidity levels, as demonstrated by Güzelyurt. This occurs as a result of moisture being trapped during cloud formation. Higher air pressure is related to less cloud cover in Mağusa. This condition leads to clearer skies that allow for more sunlight. Notably, higher evaporation happens even with moderate humidity, as seen in Lefkoşa. Grass temperatures in Girne are closely related to air temperatures. Additionally, soil temperatures stay stable despite changes in air pressure. In areas like Lefkoşa and Ercan, higher wind speeds are linked to lower humidity levels. As a result, increased airflow can lead to drier conditions. The relationship among temperature, humidity, and precipitation shows that moderate temperatures can support significant humidity and rainfall.

4. CONCLUSIONS

Analysis of climatic data reveals some correlations between meteorological factors. Higher temperatures frequently correspond with higher levels of precipitation. This is especially noticeable in Girne and Mağusa. Elevated humidity is typically associated with higher levels of precipitation, particularly in Girne. In Mağusa, increased wind speeds appear to reduce temperatures. They also have an impact on humidity levels. Lefkoşa with significant solar radiation, experiences high temperatures and elevated grass temperatures. Furthermore, higher cloud cover is frequently associated with increased humidity, especially in Güzelyurt. In contrast, areas with high air pressure tend to have clearer skies. This demonstrates the connection between atmospheric conditions and cloud formation. These insights clarify how climatic factors interact and influence local weather. Recognizing the effects of these variables can guide practical applications. This knowledge is important for climate management and urban planning.

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General Overview on Water Existence in LUNAR REGOLITH

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1. INTRODUCTION

Human being, those who are eager about discovering something new in particular, have always dreamt about settlement opportunities and building up lives outside the world. However, considering the "WATER" being the major source of life has always been the major challenge! Existence of water on the Moon has been an interest for SOME engineers and scientists for the last few decades. Studies conducted in recent years have changed the view that there is no water on the Moon. Latest researches have shown that water on the lunar surface is present in either hydroxyl (OH) or water ice forms. Under the insight of its presence, studies have focused on the amount, location and extraction methods of water on the Moon. The scope of this study is to scrutinize studies those were carried out about aforementioned focused points and to summarize for further studies.

2. EXISTENCE OF LUNAR WATER

Studies have shown that water ice has been found in permanently shadowed region of the moon, especially at and/or near the lunar poles (Feldman et al., 2001). Permanently shadowed regions never receive direct sunlight thus causing these locations to be extremely cold and allowing formation of water ice and exist in a stable state. NASA's Moon Mineralogy Mapper (M3) and the Lunar Reconnaissance Orbiter (LRO) have provided evidence for the presence of water ice (Piters et al., 2009).

3. SOURCES OF WATER

Jessica et al. (2014) published a paper about hydrous-mineral apatite in lunar highland samples. Also, the analysis of some most primordial in lunar samples show that the water these samples contain is characterised by H isotopic composition similar to that of the Earth and some carbonaceous chondrites. Simulation for the impacts of comets and asteroids on the lunar surface have been done by Svetsov and Shuvalov (2015). Study conclude that the impacts of water-bearing carbonaceous asteroids could produce deposits of free and chemically bound water inside some lunar craters. Solar winds; streams of charged particles emanating from the Sun, can interact with lunar surface materials. Some hydrogen from the solar wind can be implanted into the lunar soil (regolith), and over time, it can react with oxygen-bearing minerals to form water. A chemical kinetics model that simulates the long-term evolution of OH/H_2O on the Moon has been developed by Jones et al. in 2018.

4. DETECTION OF LUNAR WATER

Scientists use a variety of instruments and techniques to detect and study lunar water. These methods are designed to identify water in different forms, including ice, hydrated minerals, and adsorbed water. Detection methods used so far to investigate lunar water can be listed as:

Reflectance Spectroscopy, Neutron Spectroscopy, Radar Mapping, Thermal Analysis, Mass Spectrometry, Direct Impacts and Sampling. These methods have been used covering the period from 1979 to 2021 where each of these have pros and cons over each other and some only can be used under specific conditions for special purposes.

5. LOCATION OF LUNAR WATER

Lunar water have been found in various locations on the Moon, and its distribution are not uniform. Following, Table 1, shows that references for locations of lunar water including their investigation time.

Table 1 – Years and References for locations of lunar water investigations

Year	Reference	Subject
1976	Head	Volcanic Deposits
1991	McKay et al.	Lunar Regolith
2007	Ethridge and Kaukler	Lunar Regolith
2010	Anand	Volcanic Deposits
2012	Gladstone et al.	Permanently Shadowed Regions
2018	Li et al.	Sunlit Regions
2019	Benna et al.	Exosphere and Surface Layers
2021	Schörghofer et al.	Exosphere and Surface Layers
2023	Schörghofer and Rufu	Permanently Shadowed Regions

6. CONCLUSIONS

This study was targeting to bring all investigations and published sources together as a compilation to shape future researches about lunar water. More than 60 published studies have been summarized within this study. Authors are intending to explore current research to be used as a guide for further space investigations.

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Strategic Level Transport System Analysis

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1. INTRODUCTION

The importance of an efficient transport system in any region is directly linked to population growth, lifestyle changes, and economic development. As the population and level of technology of a country increase, so does the demand on the transport system. There is an inherent two-way link with economic improvement and transport systems development. Efficient transport systems can be catalyst in improving local and international trade through accessing to wider markets, impact traveler behavior, and facilitates access to resources needed for daily necessities, fundamental to a functioning society and emergencies. In the absence, results in several problems and disruptions that can affect the users. Therefore, an efficient transportation network will impact positively. Influenced with the international transport systems agenda which linked to development, a study on Democratic Republic of Congo (DRC) has been the focus of this study to gather baseline information, analyse, compare to developed nations and provide a framework with an action plan to improve Economic growth, access to services and making an impact on Country's future. This study presents the framework adopted for the situational data on transport performance, gaps in the infrastructure and a methodological approach to determine the primary key performance indicators and how these meets the objectives set out.

2. AIM AND OBJECTIVES

This paper presents the aim of this research, development of a common evaluation framework for the performance analysis of transport systems, by setting key performance indicators.
These are:

- Develop a methodology to identify transport system performance indicators
- Set a benchmark for transport performance indicator analysis
- Investigate the positive effects of a well set up transport system
- Present guidelines to the application of the established framework with an action plan

.

3. LITERATURE REVIEW

The progress of technology, the increase in urbanization and the change in the lifestyle of habitants exert an important pressure on the infrastructure of several countries that face common transport challenges. In this regard, underdeveloped nations face issues such as inadequate infrastructure connectivity, poor road condition with exceeding traffic conditions, and severe disruptions resulting in fatalities (Mattsson & Jenelius,2015). Therefore, the implementations of different solutions have raised interest on setting some performance measure as a benchmark to analysis the effectiveness of the different transport system in a particular region. Numerous studies have identified indicators of transport infrastructure performance using accessible open-source data from various countries. By comparing these indicators across different regions, it is possible to evaluate the effectiveness of various transport policies. Shah *et al* (2013) study established a list of performance indicators based on a review of practice and research from different countries. Furthermore, they propose some criteria regarding the selection of these indicators, based on a qualitative analysis of different transportations

plans and policy research. On the other hand, Kaparias, Bell and Tomassini (2011) emphasize on the need of these indicators, by providing details explanations on the objectives of each of them. They also explain the data requirements for the performance measurement, notifying that data requirement depends on the spatial concern and level of responsibility. Firstly, ideal measures related to a specific goal should be identified, and data should be selected depending on their availability. In this regard, Skorobogatova and Kuzmina-Merlino (2017) conducted a strategic analysis of transport infrastructure performance and its positive effect on the region development, by highlighting the need of a methodology that can be applied systematically and generally. This will be helpful for transportation-related policy makers. To establish a framework for performance analysis, a case study of a specific region can be conducted. As an example, an exploration of the factors affecting the road infrastructures effectiveness in Western Australia using network-level high resolutions road defects data, and a survey on different groups, was conducted to identify and analyze the contribution of different factors of the performance of transport infrastructure. The results appear to be critical in the determination of reasonable approaches for decision making (Wu *et al* 2022). An approach presented by Faturechi and Miller-Hooks (2015) focused on some factors that indicates the performance of a transport system in case of disruptions, as mentioned in the following table.

Table 3.performance indicators of a transport system

Performance indicators	Comment
Risk	Combination of probability of an event and its consequences in terms of performance.
Safety	Ability to ensure the well-being of individuals and prevent accidents in transportation sector
vulnerability	Susceptibility of the system to threats and incidents causing operational degradation
reliability	Probability that a system remains operative at a satisfactory level post-disaster
robustness	Ability to withstand or absorb disturbances and remain intact when exposed to disruptions
flexibility	Ability to adapt and adjust to changes through contingency planning in the aftermath of disruptions
Sustainability	Ability to withstand sudden disturbances to functionality while meeting original demand
resilience	Ability to recover from a disruption to an operational level that is similar to the period preceding the disruption in a timely manner.

The analysis of the effectiveness of a transport system will be dependent on the objectives to attain, but are also dependent on the region priorities, policies, and data availability.

4. NEED FOR DATA TO ANALYSE AGAINST OBJECTIVES

The following table summarizes the primary data necessary for a transport system performance analysis. They are adapted to the analysis of key performance indicators.

5. APPROACH TO DATA ANALYSIS

Different approaches exist for the analysis of key performance indicators. However, they are greatly dependent on the data availability and are adapted to these. The following table presents some major approaches for the research.

Table 4.required data for analysis

Required data for analysis			
Reliability and resilience indicators	**Risk and safety indicators**	**Traffic efficiency and pollution reduction indicators**	**Economic indicators**
Origin-destination travel time	Nodes and links matrices	Origin-destination matrices	Gross domestic product

Table 2. required data for analysis (continued)

Average speed	Route choice map	Daily traffic volume	Road's lengths
Road's lengths	Traffic flow	Congestion duration	Road's density
Average trips per links	Accidents statistics	Route choices	Daily traffic
Nodes and link capacities			

Table 5.data analysis approaches

Data analysis approaches	
Reliability and resilience indicators	Travel time variations and travel delay analysis, GIS, simulations
Risk and safety indicators	Statistical and descriptive analysis
Traffic efficiency and pollution reduction	Qualitative analysis, case studies analysis
Economic indicators	Regression and thematic analysis

6. MAPPING ANALYSIS RESULTS TO OBJECTVIES

The following figure describes the methodology to be carried for the required objectives.

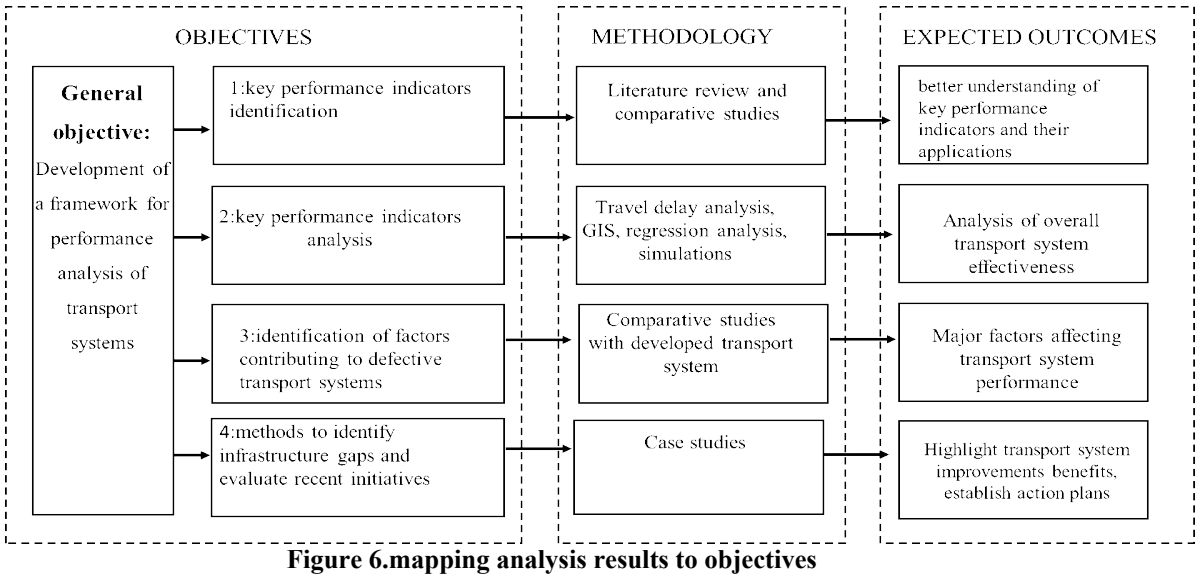

Figure 6.mapping analysis results to objectives

7. EXPECTED OUTCOMES

The aim of this study is to set a common evaluation framework to analyze the performance of transport systems in different regions. In the form of key performance indicators, and to provide guidelines to its application. Therefore, fundamental performance indicators will be established for the area of study. Then, each performance indicator will be analyze depending on the data availability.

A comparative study will be conducted between the selected region and different efficient transport system plans, to set out a framework for the performance evaluation of the transport system in a particular region.

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Weather Impacts on Urban Bike-Sharing: A Multi-Year Analysis of Chicago's Divvy System

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1. INTRODUCTION

Bike-sharing systems have emerged as a sustainable urban transportation solution, but their effectiveness is influenced by climate conditions. As cities face increasing challenges from climate change, understanding the relationship between weather patterns and bike-sharing usage becomes crucial for system optimization and planning. Previous research has shown that bike-sharing can reduce greenhouse gas emissions and improve public health, while weather conditions significantly impact system usage.

2. MATERIALS AND METHODS

We analyzed operational data from Chicago's Divvy bike-sharing system (2014-2017), including:

- Trip-related data (trip ID, temporal factors, user type, gender, duration)
- Weather-related data (temperature, weather events)
- Station-related data (location information)

The analysis employed Python for data processing and statistical analysis, focusing on:

1. Descriptive statistics and visualization of weather-dependent bicycle utilization
2. Regression analysis of temperature-usage relationships
3. Analysis of weather impacts on trip duration
4. Investigation of weather effects on user behavior by gender and membership type
5. Assessment of weather impacts on station capacity and system operations

3. RESULTS AND DISCUSSION

3.1 Weather Conditions and Usage Patterns

- Optimal riding conditions occur between 60-80°F
- Trip volume decreases above 80°F
- Average trip duration decreases by 0.5-1 minute during rain or snow
- Highest ridership occurs during cloudy conditions, followed by clear weather
- Thunderstorms show the strongest negative impact on rental volume (>100 rentals/hour decrease)

3.2 Regression Analysis

Key findings from multiple linear regression analysis (R-squared: 0.798):

- Temperature shows positive correlation with trip duration (coefficient: 0.039)
- Clear weather events show positive correlation (coefficient: 2.050)

- Cloudy conditions show positive correlation (coefficient: 1.855)
- Rain/snow events show positive but lower correlation (coefficient: 1.398)
- Thunderstorms show negative correlation (coefficient: -0.745)

Table 1. Weather Impact Coefficients on Trip Duration.

Weather Condition	Coefficient
Temperature	0.039
Clear Weather	2.050
Cloudy	1.855
Rain/Snow	1.398
Thunderstorms	-0.745

4. CONCLUSION

1. Weather conditions significantly impact bike-sharing system performance and demand
2. Favorable weather (clear skies, mild temperatures) correlates with higher ridership
3. Extreme weather events (rain, snow, extreme heat) reduce system usage
4. Weather patterns affect different user groups (members vs. non-members) differently
5. System operators can use weather forecasts to optimize resource allocation

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Analysis of Building Construction Sector in TRNC

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1.ABSTRACT

It was well established that, basic locomotives of economy in Turkish Republic of Northern Cyprus (TRNC) are Tourism, Higher Education and Construction sector. It was believed that, if this triple managed well, the economy in TRNC will be well. Unfortunately, the economy in TRNC has not been performing well recently. However, in this paper, only the building construction sector will be focused on. Why is the economy not performing well and what is the effect of building construction industry for ill performance of economy?

2.METHODOLOGY

In this study, the building construction sector in TRNC will be analyzed. In the last two decades immovable property actions have become highly apparent. Local and foreign investors invested in immovable property to a great extent. This caused to a misunderstanding, and a disinformation that propagated as, Turkish Cypriots are going to lose all their properties soon. At this stage a big mistake was made by the government which extremely affected the construction sector negatively. Instead of limiting selling large Turkish Cypriot lands to foreigners, the government limited the foreigner's buying apartments. So, building construction sector immediately affected negatively and unfortunately approached to stop.

In this study, having defining the construction sector in TRNC, a SWOT analysis was realized. In this analysis, the strength, the weaknesses, the opportunities, and the threats of the sector are summarized. The results of recent investigations of Cyprus Turkish Building Contractors Union on the "construct and sell" sector was given and its coherence with the SWOT analysis results were studied.

3.CONCLUSION

In the conclusion, currently there is crisis in both the immovable property sector and building construction sector. The crisis requires it to be managed promptly and by the contribution of all the stakeholders. The major stakeholders of the sector are the government, local authorities, Cyprus Turkish Building Contractors Union, Union of the Chambers of Cyprus Turkish Engineers and Architects. The seriousness of the crises lay burden on all of those parties. Those parties are required to come together and consider precautions urgently for the economy of TRNC.

The government will stop the discouraging of foreigners to come and to invest in TRNC by purchasing buildings and must find the ways to fight against the damaging propagandas of Greek Cypriot.

The local authorities working with government legally will improve themselves to enforce the investors to contribute to the major infrastructure of the region, without which, the investors will not be able to get the final approval for their projects.

The Cyprus Turkish Building Contractors Union needs to find ways to improve the financial structure of their members.

The Union of the Chambers of Cyprus Turkish Engineers and Architects working with government still has not succeeded to bringing “charter engineering” system to improve the quality of designing of the project and controlling them on the construction sites as many countries succeeded.

So, as it is obvious, the most responsible party of the recent crises in the building sector is the government.

Sustainable Practices and Embodied Carbon Reduction in Building Construction Projects

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1. INTRODUCTION

Structural engineering plays a crucial role in promoting sustainable construction and reducing embodied carbon emissions. By conserving materials and energy in existing structures, it is possible to minimize environmental consequences and reduce resource consumption. This research aims to shed light on the process of lowering embodied carbon and improving the environmental friendliness of modern construction projects, particularly in the United Kingdom. The study examines both historic and contemporary houses, focusing on greenhouse gas emissions, energy efficiency, and operational efficiency. Structural engineers must increasingly incorporate sustainability and sustainable construction practices into their work to reduce embodied carbon emissions. The research hypothesizes that sustainability and its development in modern construction are necessary and continuously achievable, and that structural engineering has a number of impacts on reducing embodied carbon. The study's findings will be valuable for structural engineers and other stakeholders in the construction sector, contributing to worldwide efforts to reduce embodied carbon and greenhouse gas emissions.

2. LITERATURE REVIEW

Effective human progress depends on the ability to anticipate and predict future developments, especially in relation to climate change. Sustainability in construction refers to the careful design of buildings to minimize any adverse effects on the community, environment, and financial resources. The primary objectives of sustainable buildings are energy efficiency, well-being, and preservation of natural resources. Key future developments in structural engineering encompass the development of self-healing materials, the implementation of progressive designs, and the utilization of computer tools for design optimization. These technologies strive to enhance function performance while taking into account existing limitations and restrictions.

3. METHODOLOGY

This systematic review (SLR) examined ten empirical studies published between 2015 and 2022 on Structural Engineering and Embodied Carbon. The search used Elsevier, Scopus, and Google Scholar to find literature related to sustainable practices, embodied carbon, and building construction projects. The study aimed to understand contemporary research on structural engineering and its future applications, as well as approaches to reducing carbon emissions. The SLR identified the most frequent references to research on potential applications of structural engineering, sustainability practices, and carbon emissions reduction. The review also highlighted the need for longer-term investigations and a greater diversity of mixed-method techniques.

This research reviews seven research works on the potential of structural engineering, sustainable practices, and the reduction of embodied carbon. Amin Ghafooripour's (2020) essay on the future of structural engineering provides a historical perspective on its evolution. Moncaster et al. (2022) emphasize the need for carbon reduction in buildings for sustainability. Rodriguez et al. (2014) highlight the challenges in implementing sustainable design practices in the construction industry. Esau et al. (2021) suggest strategies to achieve low embodied carbon in buildings, including reducing on-site construction, utilizing reusable materials, and reducing precast concrete use. Roy Aisha (2021)

emphasizes the need for quick action to reduce the carbon footprint of industrial activities. Lisa Aukeman (nd) suggests performance-based design can reduce earthquake damage. Jannik et al. (2015) highlight the barriers to sustainable construction, such as high pricing, lack of knowledge, and insufficient design time.

4. FINDINGS

The analysis of existing literature demonstrates that sustainable construction methods are both essential and attainable in contemporary construction. These practices encompass the use of reduced-carbon materials, sustainable energy sources, and environmentally-friendly architectural designs. Implementing these methods can decrease the amount of carbon stored in the constructed environment, enhance environmental efficiency, and encourage the development of a more sustainable built environment. Nevertheless, obstacles such as inadequate education, governmental regulations, and reluctance to embrace change persist. Furthermore, the use of low-carbon materials, the optimization of structural design, and the implementation of modern analysis techniques can greatly decrease embodied carbon in structural engineering. Nevertheless, obstacles such as the availability of low-carbon materials and the expenses associated with incorporating new technology can impede the adoption of sustainable practices in the construction sector.

Structural engineering is fundamental in minimizing embodied carbon in construction projects by optimizing structural design and utilizing low-carbon materials. Through the promotion of low-carbon materials and the encouragement of resource conservation, construction technology and management also help to reduce carbon emissions. Maximizing sustainable performance requires the implementation of an integrated approach that encompasses structural engineering, construction technology, and management. Life-cycle assessment (LCA) is an essential element of this strategy, mapping out the key phases of a building's lifespan and identifying the most efficient measures to reduce its impact. The impact of structural engineering on the reduction of embodied carbon is contingent upon the specific location, stage of construction, and the materials employed. The implementation of many sustainable techniques is crucial for the attainment of sustainability in modern construction. To attain sustainable practices in the building sector, it is imperative to adopt a comprehensive approach that takes into account structural engineering, construction technology, and management.

5. CONCLUSION

Key conclusions from this literature analysis are: Green building design, careful material selection, and renewable energy sources are essential to today's construction projects and easily accessible. Other examples include green building design. There are several challenges to overcome to implement sustainable construction practises. Lack of information and training, lack of government regulation and incentives, and firm resistance to change are examples.

Structures can permanently store less carbon thanks to structural engineering advances. These developments can boost these efforts. This goal can be achieved in several ways. These methods include using low-carbon materials, improving structural design, and using cutting-edge analytical methodologies. The availability of low-carbon materials and the cost of incorporating current technologies are two more barriers to reducing structural engineering carbon.

Structural engineering, construction technology, and management can reduce "embodied" carbon in buildings. An integrated strategy that considers structural engineering, construction technology, and management is needed to maximize building sustainability.

Investigation Of Frequency of Construction Accidents in Metro Construction Projects

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1. INTRODUCTION

In the context of accelerating urbanization in developing countries, there has been a significant increase in the number of metro construction projects in recent years to deal with land consolidation, traffic congestion, and environmental contamination (Yu et al., 2014). For example, as of 2024, Istanbul is overseeing eleven active metro construction projects. However, urban underground construction is characterized by high-risk factors and complexities, including substantial financial investments, prolonged project timelines, numerous interrelated subprojects, as well as intricate geological and hydrological conditions (Ramlee & Masrom, 2018; Seo & Choi, 2008). The extensive and intensive nature of underground construction within densely populated urban areas markedly elevates safety risks to critical infrastructure, including gas pipelines, water supply systems, and adjacent drainage networks (Choi et al., 2004; Liu et al., 2018). Consequently, metro construction projects are often classified among the most hazardous in the construction industry. Data from China's construction sector reveals that the fatality rate associated with metro construction is approximately twenty times higher than that of other construction types. This statistic highlights the necessity for robust safety management strategies developed to mitigate accidents within these high-risk projects.

2. MATERIALS AND METHODS

This study aims to investigate the predominant types of accidents occurring in metro construction by employing a questionnaire survey complemented by descriptive statistical analysis. A comprehensive literature review was conducted to identify the most prevalent construction accidents. Tözer et al. (2018) examined construction accidents in Northern Cyprus between 1994 and 2004, proposing 14 distinct accident types. Similarly, Winge and Albrechtsen (2018) analyzed 176 construction accidents in Norway and categorized them into nine major groups. Furthermore, Deng et al. (2024) explored metro construction accidents, categorizing them into 13 essential groups. An extensive literature review ultimately identified 41 commonly occurring construction accidents, which were subsequently organized into ten categories. Based on these findings, a questionnaire was developed, consisting of two distinct sections: the first section elicits demographic information from the participants and their respective organizations, while the second section addresses the 41 identified construction accidents. Participants were requested to assess the likelihood of these accidents occurring using a 5-point Likert scale, with a score of 1 indicating "rarely" and a score of 5 denoting "usually." The questionnaires were distributed face-to-face to 71 experts to ensure clarity regarding the questionnaire's details and to mitigate misunderstandings and inconsistencies. Ultimately, 55 completed questionnaires were returned, although five were excluded due to incomplete data. Despite the increase in the number of metro projects in recent years, the number of experts on the safety management in metro construction projects remains relatively limited, thus the data size was considered appropriate for this study. Initially, the demographic structure of the participants was revealed to gauge their levels of experience. Subsequently, the gathered data set was subjected to descriptive analysis, yielding the mean and standard deviations regarding the probability of occurrence of the identified construction activities.

3. RESULTS AND DISCUSSION

The demographic composition of the participants, as well as the respective organizations involved, indicates that both possess substantial experience levels, with means calculated at 3.72 and 3.96. Consequently, the dataset is deemed appropriate for the objectives of this study. A subsequent descriptive analysis was conducted to ascertain the mean and standard deviation of likelihood of the metro construction accidents. The findings from this analysis revealed that the most prevalent types of accidents included: cuts resulting from knives and hand tools (mean = 3.84), cuts from sharp materials (mean = 3.80), electric shocks occurring in wet environments (mean = 3.54), and eye injuries arising from debris produced by hand tools (mean = 3.52). The data indicates that the cut accidents are the most significant concern in these projects, which may be attributed to inadequate lighting conditions. Given that these projects are typically situated underground, the absence of natural sunlight necessitates reliance on artificial illumination. The literature further substantiates the connection between accidents and insufficient lighting in environments devoid of natural daylight (Li et al., 2024). An additional noteworthy observation from this study is that while "fall-from-height" incidents are frequently cited as the predominant accident type within the general construction industry, this assertion does not hold true in this study. This discrepancy can be elucidated by the utilization of tunnel boring machines.

4. CONCLUSION

This study provides valuable insights into the most commonly encountered accidents in metro projects, which can assist in prioritizing the allocation of limited resources toward eliminating these hazards, thereby maximizing safety in these endeavors.

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Investigation on design change root causes in Afghanistan construction projects

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ABSTRACT

One of the most significant sectors that contributes to global economic expansion, social advancement, and environmental improvement is the construction industry. In Afghanistan, time overruns are a significant concern in the construction industry that cause substantial problems for projects. Design changes are one of the most significant adverse issues that lead to time overruns. Delays are best reduced by finding and evaluating the underlying causes of problems and their effects. Consequently, a review of the literature was conducted in order to identify the underlying reasons for design changes. A Likert scale questionnaire was then administered to Afghan experts in order to evaluate these causes in the country's construction sector. The most detrimental causes were identified and ranked using the Relative Importance Index (RII) technique. The purpose of this study is to evaluate the variables that influence design changes in Afghanistan's construction sector. By addressing these important factors, the study aims to enhance industry practices for the efficient, timely, and trouble-free completion of construction projects. According to results, the top three reasons why designs are altered in Afghanistan's construction sector are: a lack of technical understanding; poor communication within the design team; and the application of unsuitable design standards.

Keywords: Construction Projects, Design Changes, Project Delay, Root Causes

1. INTRODUCTION

The construction industry is a critical and dynamic sector that shapes our world. The construction industry in Afghanistan has expanded dramatically since 2000, focusing on the urgent needs of the country's development and the restoration of essential infrastructure.

On several times, a number of factors, chief among them time overruns, have significantly impacted the execution of building projects in Afghanistan. Time overruns can be caused by a variety of circumstances, including insufficient contractor experience, severe weather issues, design revisions, weak owner decision-making, poor project management, and contractor mobilization delays.

In examined articles, design change was highlighted as the most repeated and vital element. This illustrates how widely design changes affect construction projects' delay [1] , [2]. The term "changes" in the construction industry refers to the addition, deletion, or modification of preexisting construction plans or implementation strategies. These modifications, which typically take place during the building phase, pose a significant risk to the timely and budgetary completion of construction projects. [3]

The causes of design changes have been the subject of numerous regional and international studies. However, no research has specifically addressed this issue in relation to Afghanistan. Thus, there is an urgent need to investigate this significant gap and provide specialized knowledge to address the challenges associated with construction projects in Afghanistan. Investigating and identifying the primary causes of construction project delays was the aim of this study. Investigating the crucial underlying causes of design changes, which are one of the primary detrimental factors contributing to construction project delays in Afghanistan, was the secondary objective of this study. The second goal was to identify and rank the most important reasons using the Relative Importance Index (RII).

2. LITERATURE REVIEW

Common negative factors that affect the time and cost management of building projects were found in a study by [1] that used quantitative and qualitative methodologies. Therefore, five primary factors influencing time and cost management were identified: design changes; risks and uncertainties; inaccurate evaluation of project time/duration; complexity of works; and non-performance of subcontractors

According to a related study [4], determined the causes of building project delays in Turkey. In this study, 83 negative factors were found. Poor site management and supervision, inadequate contractor expertise, inefficient project planning and scheduling, owner or agent design changes during construction, and delayed material delivery were identified as the top five major reasons for construction project delays.

A questionnaire survey was used in another study [2] to investigate the reasons behind the Dr. Iskak's Hospital Pavilion project's delay in Indonesia. The findings show that the design change factor was the most significant contributor to project completion delays across worker and work environment components.According to a recent study by Sharma et al., a larger percentage of highway development projects are falling behind schedule. The primary five major causes of delays in highway construction in Northern India are described as the land acquisition process, utility shifting, constructability under traffic, lack of project planning and design changes. [5]

In another study authors claim that design modifications are a frequent and harmful element that causes construction projects to go over budget and schedule. [6]. According to a different study by [7], design changes are unavoidable in construction projects. They find the activities or circumstances that caused these changes and look into how design changes affect project expenses.

In 2021, [8]. demonstrate that changes are one of the most common reasons for concern during a construction project. Using owners, consultants, and contractors from North Cyprus, Turkey, and the United States of America as their bases, they sought to investigate the riskiest change variables.

The reasons and relationships of design modifications in the Iranian building construction industry were also thoroughly examined by [9], Critical factors such scope uncertainty, errors in design, change orders, and unfamiliarity with new building methods were highlighted in their approach, highlighting their impact on causing design changes. According to a study by [10], design is the foundation of all building since it is a technical and strategic procedure required for competitiveness. The motivations driving design changes are the main focus of the study. According to the findings, the most common consequences of design modifications are cost and time overruns as well as the requirement for more personnel, tools, or experts.

3. METHODOLOGY

An extensive literature review was the first step in this study, which aimed to identify the time overrun causes. According to the statistics, there are roughly 99 significant causes. The data collection toke place through using Google Scholar, Science Direct and Web of Science databases. The second phase was an extensive literature review that identified, retrieved, and summarized the top 5 prevalent causes of time overrun. Design changes were chosen for a thorough investigation after this stage.

The study then identified the factors that contribute to design changes in construction projects by conducting a thorough literature review. 70 reasons that require design changes for the project were identified as a consequence of this study section. These causes arise from various parties and sources inside an engineering construction project. Therefore, it has been determined to divide the causes for the design changes into six groups: owner, contractor, consultant, regulation and contract, labor and equipment and external causes.

The 23 primary associated causes of the design-related category, as indicated in Table 2, were chosen for a detailed examination and included in a Likert scale questionnaire. The purpose of the questions was to gauge the respondents' perceived frequency and the effect of each reason on the construction project's timeline. A questionnaire was then given to Afghan construction specialists.

The findings of a 5-point Likert scale were converted into a relative importance index for each aspect in order to determine the ranks of the 23 design-related adverse reasons that were inquired about and their impact on the timeliness of construction projects in Afghanistan. The relative significance index (RII) was calculated using the formula:

$$RII = \frac{\sum W}{A \times N} \quad [1]$$

W is the weighting that respondents assigned to each Cause. A is the greatest weight in this questionnaire, which is 5, and N is the total number of participants [11].

A function of the frequency and severity index [12] was used to generate the relevant index for each case as follows:

$$\text{Importance Index} = \frac{F.I \times S.I}{100} \quad [2]$$

Where, F.I – is Frequency Index and S.I – Severity Index.

4. RESULTS AND DISCUSSIONS

The findings and analysis of a questionnaire survey that took into account the frequency and severity of causes from the viewpoints of design consultants, contractors, and owners/clients are presented in this section. The results of the questionnaires were statistically analyzed using Microsoft Excel.

The study looked into the root causes of construction project delays in Afghanistan. Top 5 most common causes are: poor planning and scheduling, design changes, material, Labor and equipment shortage in construction site, contractual disputes and severe weather problems. More research was done on design changes and 70 causes were identified as the reason behind the design changes. Design-related variables are listed in Table 1. Twenty-three design-related factors were selected from among these to be thoroughly examined in order to ascertain their impact on project timelines within the framework of Afghan construction.

Table 1 Causes that related to design phase

ID	Design Related Factors
C1	Complexity in Design
C2	Design Errors and omissions
C3	Limited Involvement of Stakeholders in the Design Phase
C4	Insufficient Design Experience
C5	Use Inappropriate Standards
C6	Difficulty in Understanding Client's Needs
C7	Inadequate Resources
C8	Unstructured Design Process
C9	Absence of Design Checking
C10	Time Constraints in design
C11	Poor Communication and Coordination Within the design Team
C12	Inadequate Information Provided
C13	Lack of Familiarity with Modern Design methods
C14	Lack of Adequate Documentation
C15	Late Approvals of Design
C16	Underutilization on Innovative Design Software
C17	Limited Site Investigation
C18	Conflictual Relationship Between Designer and Client
C19	Design Inaccuracies by Consultant
C20	Lack of Technical understanding
C21	Lack of Effective Supervision During Design

C22	Suggesting alternative designing methods by designer
C23	Slow Decision-making

To ascertain the importance of these factors, surveys using a Likert scale were conducted with important stakeholders in the following phase. The respondents evaluated each factor based on how frequently it occurred and how it affected the project's duration. In statistical analysis, the 23 design-related adverse causes were ranked using the Relative Importance Index (RII). The formula (1) accounted for the weighting respondents given to each cause relative to the total number of participants. The RII results are displayed in Table 2 according to the frequency and severity of the causes.

Table 2 Frequency and Severity ranking according to RII

	Frequency		Severity	
Rank	**Cause ID**	**RII**	**Cause ID**	**RII**
1	C20	0.753	C20	0.757
2	C9	0.723	C23	0.734
3	C5	0.719	C11	0.723
4	C11	0.715	C5	0.715
5	C19	0.7	C21	0.715
6	C17	0.696	C17	0.707
7	C2	0.684	C19	0.707
8	C7	0.669	C7	0.696
9	C6	0.661	C4	0.692
10	C12	0.661	C15	0.692

In order to determine the most significant factors affecting the construction projects in Afghanistan, the importance index approach (IMPI) was employed in the second stage of the calculations. The (IMPI) method analysis's results and ranking are displayed in Table 3.

Table 3 Ranking of Important Index Method for 23 investigated causes.

Rank	ID	RII F	RII S	(IMPI) Importance
1	C20	0.7538	0.7576	0.5711
2	C11	0.7153	0.723	0.5172
3	C5	0.7192	0.7153	0.5145
4	C19	0.7	0.7076	0.4953
5	C17	0.6961	0.7076	0.4926
6	C9	0.723	0.6576	0.4755
7	C21	0.6615	0.7153	0.4732
8	C23	0.6384	0.7346	0.469
9	C7	0.6692	0.6961	0.4658
10	C2	0.6846	0.673	0.4607

The most significant negative factors influencing the project's design changes, according to IMPI calculations, are inadequate technical knowledge, poor team communication, the use of inappropriate standards, consultant design errors, and insufficient site investigation.

5. DISCUSSIONS

The significance of the reasons is assessed using the RII approach. Lack of technical understanding is the most important factor affecting design revisions in engineering projects, according to the research. Afghanistan might have trouble offering top-notch engineering education because of its antiquated curricula, shortage of qualified instructors, and financial constraints. Because of this, graduates could enter the workforce lacking the thorough technical understanding and real-world skills necessary to tackle engineering difficulties.

Furthermore, there may not be many opportunities for specialized education and professional progression in Afghanistan, particularly in specialized or developing technological occupations that

require training and expertise. The contract awarding procedure itself is a significant problem in Afghanistan, particularly in relation to the selection criteria and adherence to relevant rules and regulations. Contracts are thought to occasionally be influenced by personal relationships or preferences, which may lead to the selection of less qualified applicants. Projects could not end up in the best hands as a result, which could unintentionally impact their effectiveness and success.

According to the findings, poor communication within the design team is the second most significant reason that causes design changes in the project. Ineffective leadership and personality conflicts are the main causes of bad communication. Poor team communication can be caused by a variety of communication challenges, including language barriers, cultural differences, and occasionally disparate communication styles among design team members. Project design teams find it challenging to communicate successfully due to Afghanistan's many ethnic groups, each of which has its own languages and customs. Due to misunderstandings, misinterpretations, and communication obstacles, this linguistic and cultural variety can make coordination and collaboration efforts more difficult.

The absence of clear project objectives in engineering projects greatly hinders design team communication, leading to uncertainty, inefficiency, and conflict. Team members may view work differently if goals are not stated clearly, which could cause misunderstanding and discontent. This misunderstanding results in overlaps or missed obligations and exacerbates the issue of unclear roles by leaving people unsure of their positions. Furthermore, the absence of a well-structured feedback approach impedes the team's progress by denying them important insights for enhancement. Project objectives must be clearly stated in order to ensure that efforts are concentrated on common objectives and to facilitate effective communication, collaboration, and progress.

Using unsuitable design standards is ranked third and is commonly seen in Afghan engineering projects. Lack of awareness, out-of-date knowledge, misunderstandings or poor communication, and budgetary constraints are the causes of this problem. Design teams can struggle to figure out and adhere to extensive regulatory requirements, leaving them uncertain about which design standards to follow. Afghan customs, social norms, and cultural preferences may have an impact on design decisions. While ensuring that designs are both acceptable and effective requires cultural awareness, it is also crucial to integrate cultural issues with industry best practices and functional requirements. Afghanistan has primarily relied on foreign consultants or contractors over the last 20 years to supply design expertise, particularly for complex or specialized projects. In these situations, a lack of local understanding of oversight or competence may lead to the adoption of designs that are inappropriate for local engineering needs or conditions.

6. CONCLUSION

In construction projects, delay is a pervasive problem that leads to disappointing outcomes globally. There are several negative factors for this issue. Due of the heavy monitoring loads that delays place on owners, contractors, and governments, it is imperative to investigate the underlying reasons of time overruns.

This study examined and determined the factors of time overrun following a thorough review of the literature. Consequently, design change was chosen for more research. After that, the fundamental reasons and origins of design modifications in construction projects were examined. In construction projects, the reasons for design changes have been divided into six major categories. The 23 adverse causes that comprise the design-related category have been selected for further examination.

A Likert scale questionnaire survey was then administered to engineers who were actively employed in Afghanistan's construction sector. The Relative Importance Index (RII) analysis was then used to rank these underlying causes according to the frequency and severity of the data. The most crucial

components particular to Afghanistan's construction industry were then determined and ranked using the Importance Index.

It is determined that employing qualified engineers, offering suitable and enhanced technical training, creating comprehensive guidelines to address the root causes of design modifications, and promoting greater cooperation and coordination are all essential to resolving these core issues and significantly improving the results of construction projects. The study's conclusions provide helpful information that construction industry professionals may use to enhance project performance and reduce delays. It is important to emphasize that the findings of this study are restricted to Afghan construction projects and the negative factors that lead to design changes.

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Innovative Pavement Management System for EMU Campus: Integrating Smartphone Technology and Traditional Methods for Enhanced Road Maintenance

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1. INTRODUCTION

The pavement network in the Eastern Mediterranean University EMU camp is unquestionably one of its most valuable infrastructure assets. It is essential to a thriving community. To protect the economy in the transportation sector, it will be beneficial to maintain and preserve these significant transportation assets. One of the most valuable resources in the financial community is roads, which have enormous positive social effects. However, numerous road networks face the risk of deterioration due to asset mismanagement (UN Economic and Social Council, 2009). The campus of EMU is currently experiencing poor road maintenance. The roadways and parking lots on campus were constructed between thirty and thirty-five years ago, and they are crucial to the effective and secure flow of people and things. The EMU campus is a town due to its size and population. Pavement ages, weather, and heavy traffic all cause it to deteriorate over time. Therefore, it must be carefully and quickly maintained. When maintenance is not done on time, the level of distress increases. For instance, little potholes quickly enlarge from cracks, which may eventually grow into larger ones. The parking lots and paved roads on the EMU campus are currently experiencing some problems. In this study, the utilization of a smartphone application to measure acceleration data for road assessment will be discussed. The objective is to calculate the Pavement Condition Index (PCI) of the road, an essential parameter for evaluating road quality and maintenance needs. By leveraging the capabilities of modern smartphone sensors, this method offers an accessible and free solution for gathering precise acceleration data, which can be analyzed to determine the condition and performance of road surfaces.

2. MATERIALS AND METHODS

2.1 PAVEMENT CONDITION SURVEY PROCEDURES

Manual visual inspections have been performed by two persons walking through the entire pavement section or driving slow sections and stopping periodically. Walking is a more accurate way to collect data than driving, but it also requires more time and money. The PCI method, which was created by the U.S. Army Corps of Engineers and outlined in ASTM D6433, “Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys,” is used for the distress surveys.

2.2 EMU-PMS Database

At last, the gathered and computed data are entered into a database; Microsoft Excel is used for this task. This straightforward database can be updated at any crucial moment or while maintenance is being performed.

2.3 TYPICAL TREATMENT REQUIREMENTS

The recommended yearly Treatment work level for each pavement segment throughout the network optimization is contained in the ASTM. The following are these treatment works:

• Discrete stop-gap (filling potholes).
• Regional preventive (crack filling).
• Worldwide preemptive (surface treatment).
• Significant (overlay or reconstruction).

Utilizing the crucial PCI approach, the network optimization is completed. The critical PCI is defined as "the PCI value at which the cost of applying targeted preventive maintenance increases significantly or the rate of PCI loss increases with time." Our treatment choices are based on the PCI level in the section that is comparable to the crucial PCI level. The worst route, with the lowest PCI value, will be prioritized for treatment if the section's PCI is significantly low. The PCI value is determined based on acceleration data collected from smartphone apps.

2.4 VEHICLES USED IN THE SURVEY

In this section, the vehicles employed in our road condition survey will be outlined, with a specific focus on the use of bicycles. For the EMU Camp road survey, bicycles were selected as the primary mode of transportation for data collection. This decision was driven by the need for a flexible, cost-effective, and environmentally friendly method to gather acceleration data. Bicycles offer several advantages for such surveys, including their ability to navigate various types of road surfaces and conditions with ease. By equipping bicycles with smartphones capable of recording acceleration data, the road conditions at EMU Camp were efficiently and accurately assessed. This innovative approach not only underscores the versatility of using bicycles for road surveys but also highlights the practicality of integrating modern technology with sustainable transportation methods.

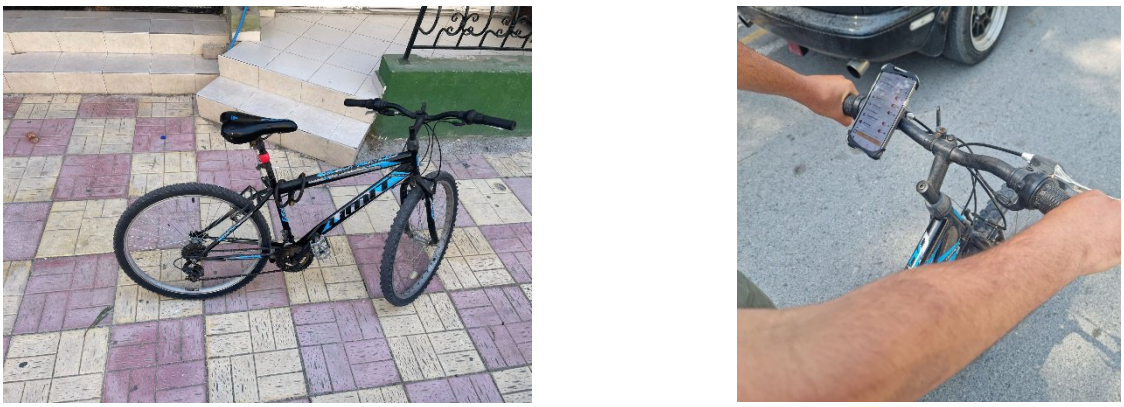

Figure1. Survey Bicycle

2.5 SENSOR LOGGER APPLICATION

The Sensor Logger application was employed, utilizing the advanced sensors in modern smartphones to record acceleration data. This application is particularly effective for capturing the dynamic responses of bicycles as they traverse various road surfaces. By analyzing the acceleration data, the types of stress exerted on the road were classified, providing valuable insights into its condition. The Sensor Logger application records data from multiple sensors, including the accelerometer, gyroscope, and magnetometer, allowing for comprehensive analysis. The recorded data is then processed to identify different stress types, such as vibrations caused by rough patches, potholes, and other surface irregularities. This method not only enhances the accuracy of road condition assessments but also offers a cost-effective and scalable solution for continuous monitoring and maintenance planning.

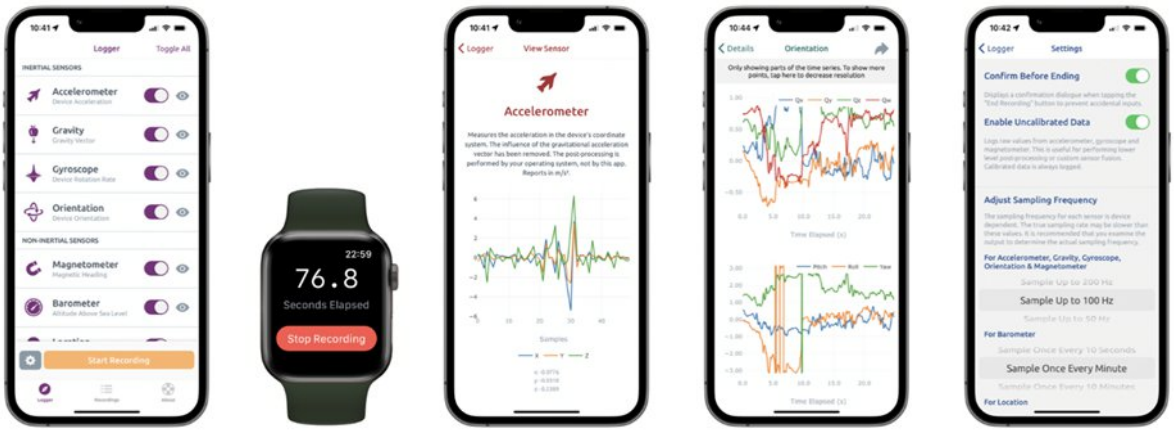

Figure2. Sensor Logger Application

2.6 COLLECT DATA

In this subsection, the data collection process using a bicycle equipped with a smartphone running the Sensor Logger application is detailed. For the EMU Camp road survey, a single bicycle was used, with the smartphone securely mounted to ensure accurate data capture. Before starting the survey, the device was calibrated to ensure that the x, y, and z axes were set to zero, thereby eliminating any initial bias in the readings. The primary focus was on collecting the z-axis acceleration data, as this vertical component is critical for identifying different types of road surface cracks and stress points. To maintain consistency and reliability in our data, the bicycle was driven at a constant speed throughout the survey.

2.7 UPLOAD DATA

Following the data collection phase, the next step involved uploading the collected data to a centralized database for further analysis. The Sensor Logger application facilitated this process by providing a user-friendly interface for data transfer. A seamless and secure upload process was ensured, preserving the integrity of the acceleration data and making it readily accessible for subsequent analysis. This step is crucial for enabling collaborative review and ensuring that the data can be effectively utilized to assess road conditions and identify maintenance needs.

2.8 DATA VISUALIZATION

The final step in our methodology involved viewing and analyzing the data using the visualization tools provided by the Sensor Logger application. The application enables real-time viewing of the collected data, offering immediate insights into road conditions as the survey progresses. By focusing on the z-axis acceleration values, the types of cracks and surface irregularities encountered during the survey were classified. This visualization capability not only facilitates immediate assessment but also supports the systematic documentation of road conditions for further analysis and reporting. In summary, the use of the Sensor Logger application on a bicycle for the EMU Camp road survey provided a robust and efficient method for collecting, uploading, and visualizing acceleration data. This approach enabled us to accurately identify and classify road surface cracks, ensuring a comprehensive assessment of the road's condition.

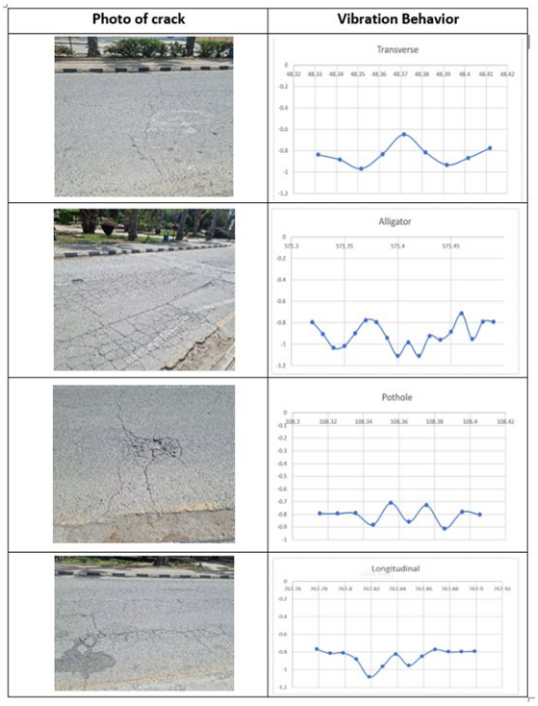

Figure3: Cracks behavior according to the Z acceleration rate

2.9 DATA ANALYSIS AND MAPPING

2.9.1 DATA ANALYSIS

To process and analyze the collected data, Python and its data processing libraries were employed. The workflow included several key steps:

- Loading the Data: The smoothed accelerometer data was imported from a CSV file using the Pandas library.
- Defining Thresholds: Specific threshold values were set to classify different types of cracks based on the z-axis acceleration data. These thresholds were determined through a detailed analysis of the data patterns.
- Identifying Cracks: An iterative loop was used to scan the z-axis acceleration data, counting and classifying the occurrences of each crack type based on the defined thresholds.

Through this coding process, different types of cracks present in the surveyed road sections were accurately classified and counted.

2.9.2 MAPPING CRACK LOCATIONS

Once the types of cracks were identified, the next step involved mapping their locations using GIS tools. The visualization of crack locations provides valuable insights into the distribution and severity of road damage, which is crucial for maintenance planning.

- Data Preparation: The crack location data, along with the identified crack types, was organized into a structured format suitable for mapping.
- Creating the Map: Using the Folium library, a map was created, and markers for each crack location were added. These markers were color-coded based on the type of crack.

This map provided a visual representation of the road conditions, allowing for easy identification of areas requiring maintenance. The integration of Python coding with GIS tools facilitated the efficient analysis and visualization of road surface conditions, enhancing our ability to monitor and address road maintenance needs effectively.

Figure4: Cracks behavior according to the Z acceleration rate

2.10 PAVEMENT CONDITION SURVEY MANUALLY

Following the initial identification and mapping of road cracks using smartphone accelerometer data and coding, a manual survey was conducted to obtain precise measurements of the cracks. This phase involved traditional methods to assess the area and severity of the cracks, ensuring a comprehensive evaluation of the pavement condition. Once the locations of the cracks were pinpointed on the map, the next step was to manually measure each crack using standard tools and techniques. The manual survey involved the following steps:

- Preparation of Standard Sheets: Standard measurement sheets, each covering a 100-meter section of the road, were prepared. These sheets were used to systematically document the locations and measurements of the cracks.
- Using a Measuring Wheel: A measuring wheel was employed to accurately measure the length and width of each crack. This tool ensured that the dimensions of the cracks were recorded with high precision.
- Photographic Documentation: For each crack, photographs were taken to provide visual evidence of the pavement condition. These images were essential for cross-referencing and validating the recorded measurements.
- Recording the Area of Cracks: The area of each crack was calculated based on the measurements taken with the measuring wheel. This data was then noted on the standard sheets along with the corresponding photographs.
- Systematic Surveying: The survey was conducted systematically, moving from one 100-meter section to the next. This approach ensured that all cracks within the surveyed area were documented comprehensively.

By combining the precise location data obtained from the initial mapping with detailed manual measurements, a thorough record of the pavement condition was created. This integrated method allowed us to cross-verify the automated data with manual observations, enhancing the accuracy and reliability of the survey results.

2.11 Integrating Coding With Crack Area Data To Calculate The Pavement Condition Index (PCI)

The integration of coding with manual measurements of crack areas enables a comprehensive and accurate calculation of the Pavement Condition Index (PCI). The PCI is a crucial metric used to evaluate the overall condition of pavement surfaces. By combining the precise location and type of

cracks obtained from the initial automated survey with detailed area measurements, and employing coding to process this data, the PCI value can be effectively computed, providing a clear assessment of road quality. After identifying the locations and types of cracks using the Sensor Logger application and mapping these with GIS tools, the next step involved manually measuring the area of each crack. This was achieved using standard measurement techniques and tools, including measuring wheels and standard measurement sheets.

2.12 Pci Calculation Using Python

- Density Calculation: The script calculated the density of each crack type using the Eq[1]:

$$\text{Density} = (\text{Crack Area}/\ \text{Total Area}) \times 100 \quad [1]$$

- Severity and Deduct Values: Each crack was classified according to its severity (Low, Medium, High) and assigned a deducted value based on ASTM D6433 standards.
- Corrected Deduct Value (CDV): The total deduct values were computed and used to calculate the Corrected Deduct Value (CDV) using the Eq[2]:

$$\text{CDV} = 0.1 \times (\sum \text{Deduct Values})2 \quad [2]$$

- PCI Value: Finally, the script calculated the PCI value using the Eq[3]:

$$\text{PCI} = 100 - \text{CDV} \quad [3]$$

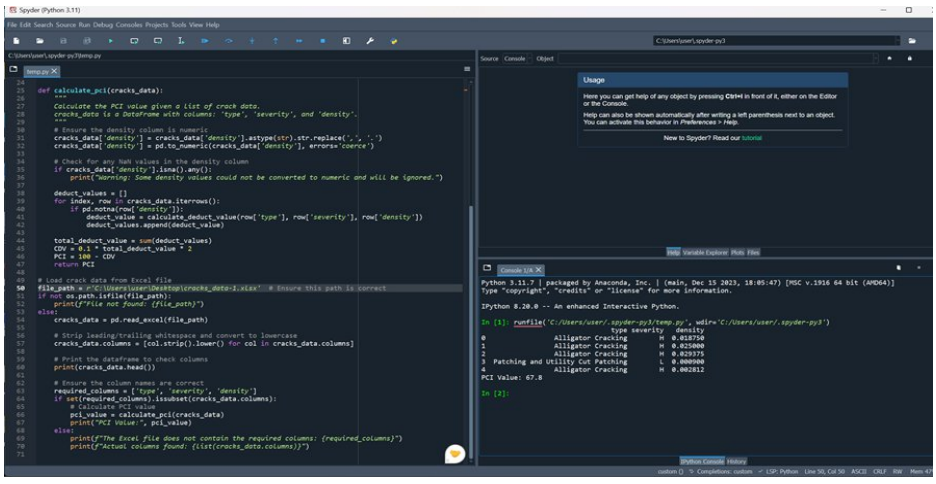

Figure5 PCI calculation code

As shown in Figure 5 above, the integrated data was processed by the Python code to calculate the PCI. The code ensured that the density column was numeric, handled any potential missing values, and iterated through the data to apply the thresholds for each crack type. The results were then used to compute the total deduct value and subsequently the PCI value, providing a quantitative assessment of the pavement condition.

3. RESULTS AND DISCUSSION

The assessment of the pavement condition for three roads (A, B, and C) was conducted using a combination of manual measurements and Python coding to calculate the Pavement Condition Index (PCI). The process involved two primary steps: manually measuring the area of cracks and then applying Python coding to compute the PCI values based on these measurements. The results are summarized in Figure5.

Table 1 PCI value for roads A, B, and C

PCI Value	Section ID	Section Length
66	A1	100 m
92	A2	100 m
81	B1	100 m
92	B2	100 m
70	B3	100 m
77	B4	100 m
84	B5	100 m
89	B6	100 m
85	C1	100 m
67	C2	100 m
67	C3	100 m
82	C4	100 m
90	C5	100 m
87	C6	100 m

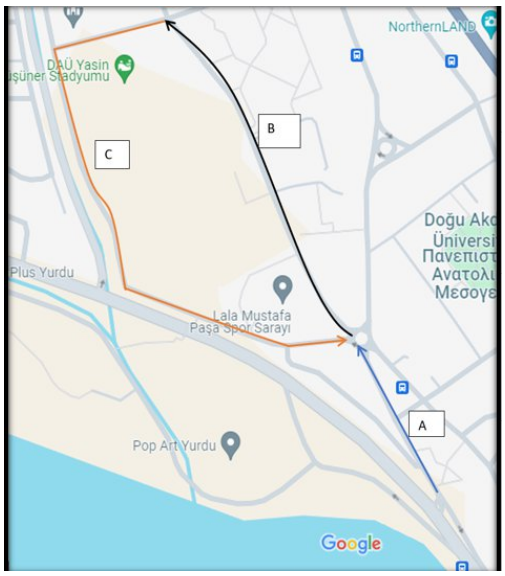

Figure6 PCI Road map calculation

According to the result, it can be said that road A1 with PCI 66 is the worst part which needs Treatment first as soon as possible. then road C2 and C3

4. CONCLUSION

In conclusion, the integration of modern technology with traditional pavement condition survey methods offers a comprehensive and efficient approach to road maintenance. By utilizing smartphone

applications such as the Sensor Logger for initial data collection and GIS tools for mapping, the locations and types of road cracks were pinpointed accurately. The subsequent manual measurements provided precise data on the dimensions of these cracks, ensuring a thorough evaluation. The calculated Pavement Condition Index (PCI) values, derived through a combination of manual data collection and Python coding, provided a clear and quantitative assessment of the pavement condition for roads A, B, and C at the EMU Campus. This innovative methodology not only enhanced the accuracy of the survey but also demonstrated the practicality of integrating low-cost technology for ongoing road maintenance and management. Furthermore, the treatment and repair methods were tailored to the specific types and severities of cracks identified. By addressing the different distress types—longitudinal cracks, transverse cracks, alligator cracks, and potholes—through appropriate treatment options such as seal coating, crack filling, milling, and asphalt overlay, the overall durability and functionality of the pavement can be significantly improved. This study underscores the importance of combining advanced data collection techniques with traditional maintenance methods to ensure the longevity and safety of road infrastructures. Implementing a robust Pavement Management System (PMS) that leverages these integrated approaches can greatly enhance the management and preservation of valuable transportation assets, ultimately contributing to a safer and more efficient transportation network.

5. ACKNOWLEDGMENT

we would like to thank the Sensor Logger Application for giving us the chance to measure the acceleration data of the road in the X, Y, and Z directions without any cost. Our project would never have been so successful without the help of this valuable tool.

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Performance of cementitious composites containing Posidonia Oceanica leaf-based Biochar and Waste Glass Powder for a Sustainable Mortar Production

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1. INTRODUCTION

The production of cement involves high temperatures and chemical reactions that release CO_2 into the atmosphere, and the widespread use of concrete in construction further exacerbates the carbon footprint of the sector (Zeidabadi et al 2018). Huge efforts are made towards finding proper replacement materials that could replace cement at least partially and are more environmentally friendly options that would not decrease the properties and the performance of concrete mixes overall. Presently, the world faces two significant challenges: the generation of substantial amounts of diverse waste necessitating proper disposal or strategies to mitigate potential environmental impact (Eggleston et al 2006).

Biochar, is a sustainable carbon-rich solid by-product, which is generated by subjecting organic material to high-temperature pyrolysis or degasification in an environment with low or no oxygen. This method prevents combustion and yields a substance with significant carbon content (Gabhane et al 2020). Biochar has garnered attention as a desirable supplementary material in the realm of cement replacement (Gupta, S., & Kua, H. W. 2019; Maljaee et al 2021). The primary method for producing biochar, known as pyrolysis, involves heating biomass in the absence or with minimal oxygen.

Posidonia oceanica is a crucial marine plant native to the Mediterranean Sea, particularly along coastal shores. It plays an essential role in coastal ecosystems by producing significant amounts of oxygen and serving as a vital resource for various fish species and other aquatic animals, offering them protection, food, and shelter (De Sanctis et al 2019). Additionally, it helps reduce wave energy, acting as a natural barrier against coastal erosion.

Hamdaoui et al (2021) examined the thermal and mechanical properties of hardened cement paste reinforced with Posidiona oceanicia seed weed fibers, varying the fiber volume fraction from 0% to 20%. They estimated thermal conductivity, tensile and compressive strength, and tenacity variation using simplified models, finding that PO fiber addition improved the material's insulating properties.

The explored in the hazards of waste glass (WG) would emphasize the importance of economically and environmentally friendly recycling technique. They investigate the physical and chemical properties of WG and review the existing literature on its use as a substitute for aggregates in concrete (Qaidi et al 2022). Glass is a hundred percent renewable source that can be reprocessed permanently without reduction in quality (Babajide Olabimtan, S., & Mosaberpanah, M. A. (2023). The variances in chemical levels of various types of glasses, as well as the challenges in categorizing multiple-color glasses, make reuse problematic.

The outcomes of this study are expected to serve as a practical way for fine-tuning Posidonia Oceanica leaf-based biochar and glass powder characteristics to meet real world applications. Furthermore, this research is anticipated to stimulate novel ideas and approaches in the utilization of Posidonia Oceanica leaf-based biochar and glass powder within the realm of construction materials.

2. MATERIALS AND METHODS

Throughout the course of this experimental investigation, an array of materials was utilized, includes necessities like portable water, superplasticizer, fine aggregate, and ordinary cement. Two distinct cementitious material are Posidonia Oceania leaf-based biochar and glass powder were methodically prepared at different percentages and processed with precision, acting as substitutes for cement in the experimental mixes.

Biochar was produced from Posidonia oceanica seagrass was collected from the Mediterranean coast Iskele in North Cyprus. The leaves were washed, air-dried, and then heated at 600°C following ASTM D3174-12 standards. After cooling, the char was ground and sieved to particles below 75 µm. Glass was collected from trash bins.

Table 1: Description of the Mortar mixes

Mix Id	Description
CM	Control Mix
PBC_1	Posidonia Biochar 1%
PBC_2	Posidonia Biochar 2%
PBC_3	Posidonia Biochar 3%
PBC_4	Posidonia Biochar 4%
PBC_5	Posidonia Biochar 5%
PBC_6	Posidonia Biochar 6%
WGP_{15}	Waste glass powder 15%
WGP_{20}	Waste glass powder 20%
PBC_1WGP_{15}	Posidonia Biochar 1% and Waste glass powder 15%
PBC_1WGP_{20}	Posidonia Biochar 1% and Waste glass powder 20%
PBC_2WGP_{15}	Posidonia Biochar 2% and Waste glass powder 15%
PBC_2WGP_{20}	Posidonia Biochar 2% and Waste glass powder 20%
PBC_3WGP_{15}	Posidonia Biochar 3% and Waste glass powder 15%
PBC_3WGP_{20}	Posidonia Biochar 3% and Waste glass powder 20%
PBC_4WGP_{15}	Posidonia Biochar 4% and Waste glass powder 15%
PBC_4WGP_{20}	Posidonia Biochar 4% and Waste glass powder 20%
PBC_5WGP_{15}	Posidonia Biochar 5% and Waste glass powder 15%
PBC_5WGP_{20}	Posidonia Biochar 5% and Waste glass powder 20%
PBC_6WGP_{15}	Posidonia Biochar 6% and Waste glass powder 15%
PBC_6WGP_{20}	Posidonia Biochar 6% and Waste glass powder 20%

Table 2: Mix proportion of mortar specimens for 75µm particle size

Mix ID	**C**	**PBC**	**WGP**	**W/B**	**Cement (g)**	**PBC (g)**	**WGP (g)**	**Sand (g)**	**Water (g)**	**SP (wt % of binder)**
CM	100	0	0	0.35	684.00	0	0	1538	239	1.05
PBC_1	99	1	0	0.35	677.16	6.84	0	1538	239	1.05
PBC_2	98	2	0	0.35	670.32	13.68	0	1538	239	1.05
PBC_3	97	3	0	0.35	663.48	20.52	0	1538	239	1.05
PBC_4	96	4	0	0.35	656.64	27.36	0	1538	239	1.05
PBC_5	95	5	0	0.35	649.8	34.2	0	1538	239	1.05
PBC_6	94	6	0	0.35	642.96	41.04	0	1538	239	1.05
WGP_{15}	85	0	15	0.35	581.4	0	102.6	1538	239	1.05
WGP_{20}	80	0	20	0.35	547.2	0	136.8	1538	239	1.05

PBC_1WGP_{15}	84	1	15	0.35	574.56	6.84	102.6	1538	239	1.05
PBC_1WGP_{20}	79	1	20	0.35	540.36	6.84	136.8	1538	239	1.05
PBC_2WGP_{15}	83	2	15	0.35	567.72	13.68	102.6	1538	239	1.05
PBC_2WGP_{20}	78	2	20	0.35	533.52	13.68	136.8	1538	239	1.05
PBC_3WGP_{15}	82	3	15	0.35	560.88	20.52	102.6	1538	239	1.05
PBC_3WGP_{20}	87	3	20	0.35	526.68	20.52	136.8	1538	239	1.05
PBC_4WGP_{15}	81	4	15	0.35	554.04	27.36	102.6	1538	239	1.05
PBC_4WGP_{20}	76	4	20	0.35	519.84	27.36	136.8	1538	239	1.05
PBC_5WGP_{15}	80	5	15	0.35	547.2	34.2	102.6	1538	239	1.05
PBC_5WGP_{20}	75	5	20	0.35	513	34.2	136.8	1538	239	1.05
PBC_6WGP_{15}	79	6	15	0.35	540.36	41.04	102.6	1538	239	1.05
PBC_6WGP_{20}	74	6	20	0.35	506.16	41.04	136.8	1538	239	1.05

3. RESULTS AND DISCUSSION

3.1 Fresh Density

This ranges from 2300- 3989kg/m^3. The decline in fresh properties as PBC percentage increases in mortar mixes corresponds to biochar's high porosity, low density, and variable particle sizes. These traits affect biochar's distribution and interaction within the mix, ultimately impacting its fresh properties.

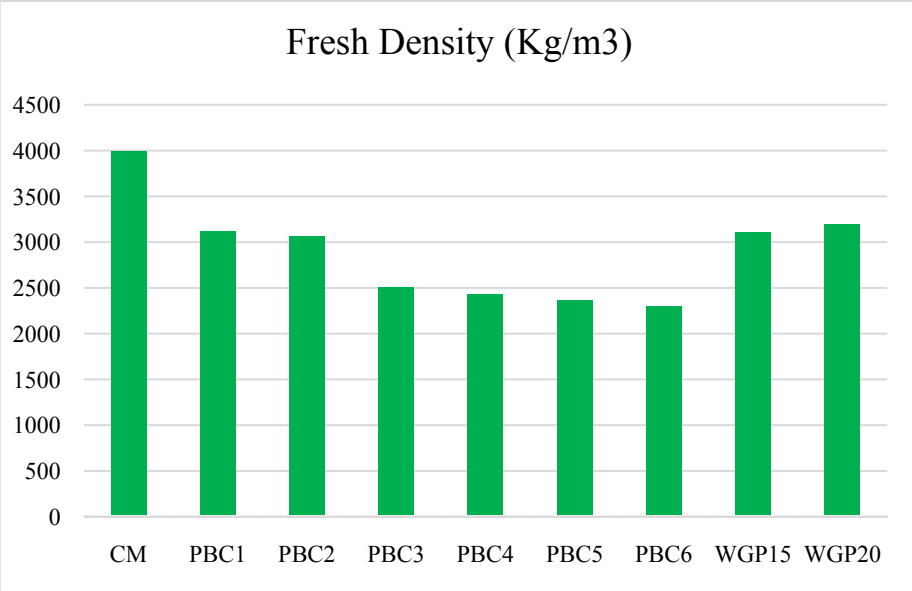

Figure 1: Fresh Density of the Mixtures

3.2 Flow Test

Mixes incorporating waste glass powder (WGP20 and WGP15) enhanced performance can a be as a result of WGP's low water absorption rate and smooth surface, which increase mixtures' flowability. Waste Glass Powder (WGP)'s tiny particles are useful because they fill the fine aggregates' pores efficiently, increasing their porosity.

On the other hand, PBC6 show decrease in flowability observed in the mixtures, as compared to the control mix This can be attributed to the increased surface area of the materials. This greater surface area led to the absorption of some of the mixing water by the BC, ultimately leading to a reduction in flowability.

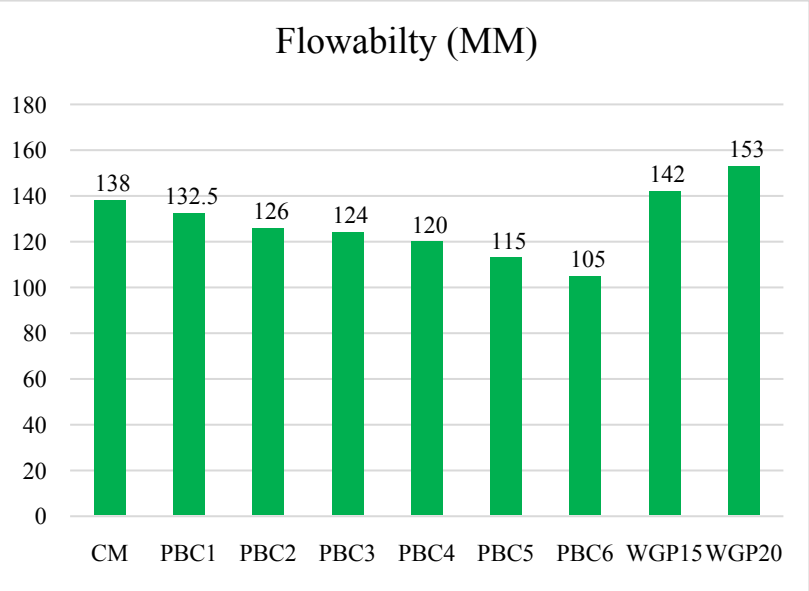

Figure 2: Flow Table

3.3 Compressive Strength (7days)

PBC2% exhibits a 4.5% rise in compressive strength compared to the control mix, indicating a positive effect from adding Posidonia Biochar (PBC). similar view was denoted by (Akhtar, A. 2020; Masmoudi, G., & Dhaouadi, H. 2024) the use of biochar source has an attracting increased interest in compressive strength since its results from heating of biomass in a limited oxygen environment.
This improvement may stem from PBC's filler effect, enhancing particle bonding within the mortar. However, at 6% PBC concentration, there's a significant decrease of 38.9% in strength.
This adverse effect could be attributed to diminishing pozzolanic reaction at higher PBC concentrations, negatively impacting strength. On the other hand, the waste glass powder exhibits a low strength in 7days compared to control mix. This occurrence is due to the slow pozzolanic reaction of silica oxide in glass (Radwan et al 2021).

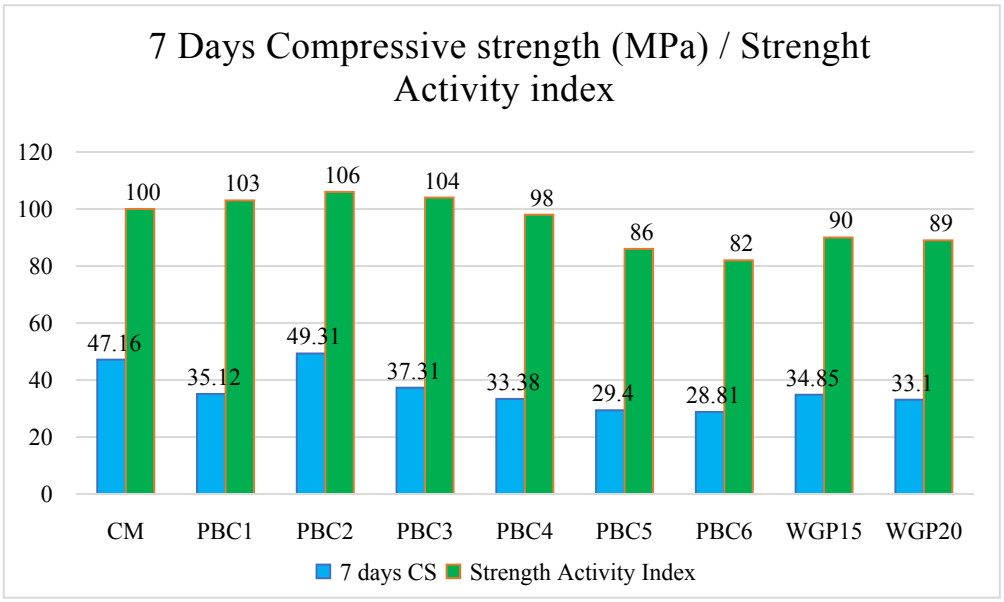

Figure 3: Days Compressive Strength

3.4 Flexural Strength

The flexural strength values range from 2.1 to 2.5, with all values lower than that of the control mix (CM) at 2.9. This decline in flexural strength in PBC 1-6 could be attributed to the presence of air spaces created due to the too much inclusion of PBC particles in the cement matrix. Tan et al (2018) have similar suggestion air entrapment within the hardened concrete, resulting in the formation of voids and subsequently impacting the flexural strength The waste glass powder mixes (WGP15 and WGP20), the flexural strength values are also lower than that of the control mix, ranging from 2.6 to 2.8. This reduction in flexural strength may result from the irregular shapes and sizes of the glass powder particles, which could hinder proper compaction of the concrete mix and weaken the interfacial bond between the cement matrix and aggregates

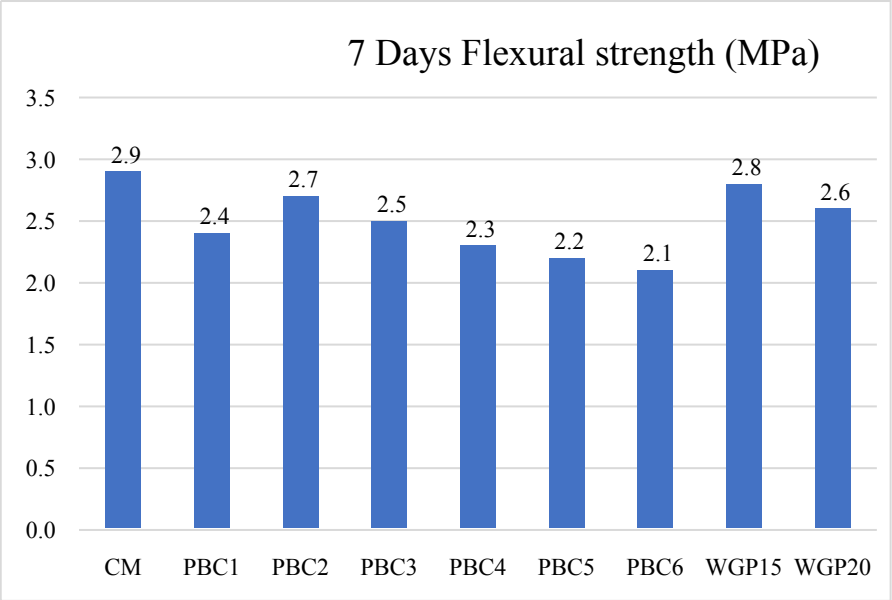

Figure 4: Flexural Strength

3.5 Xray diffraction

The analysis, depicted in Figure 5, identified coesite in the glass powder, while Figure 6 showed the presence of calcite in the Posidonia seaweed.

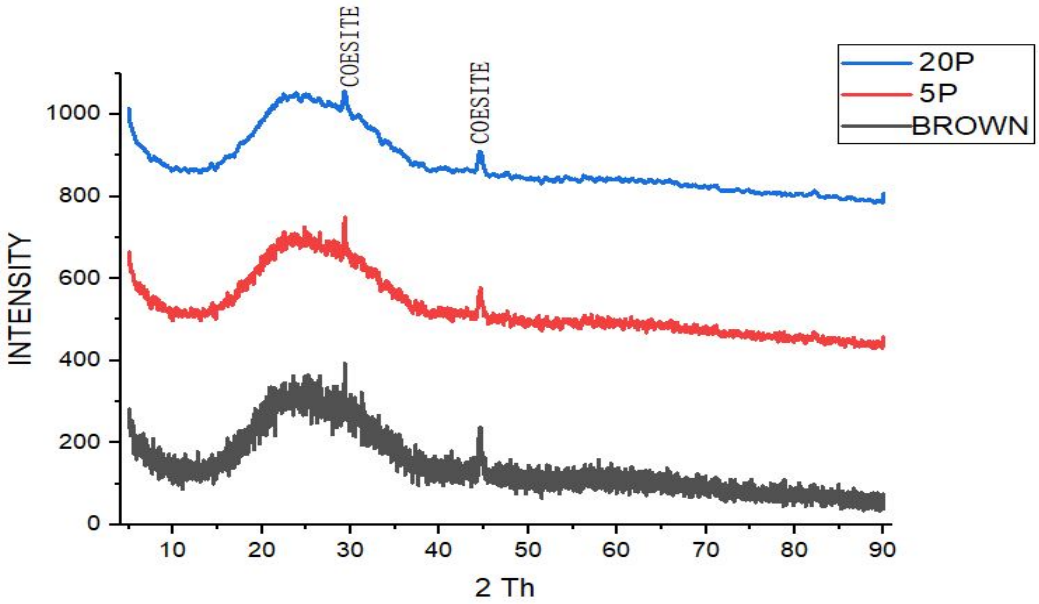

Figure 5: Xray diffraction for Glass powder

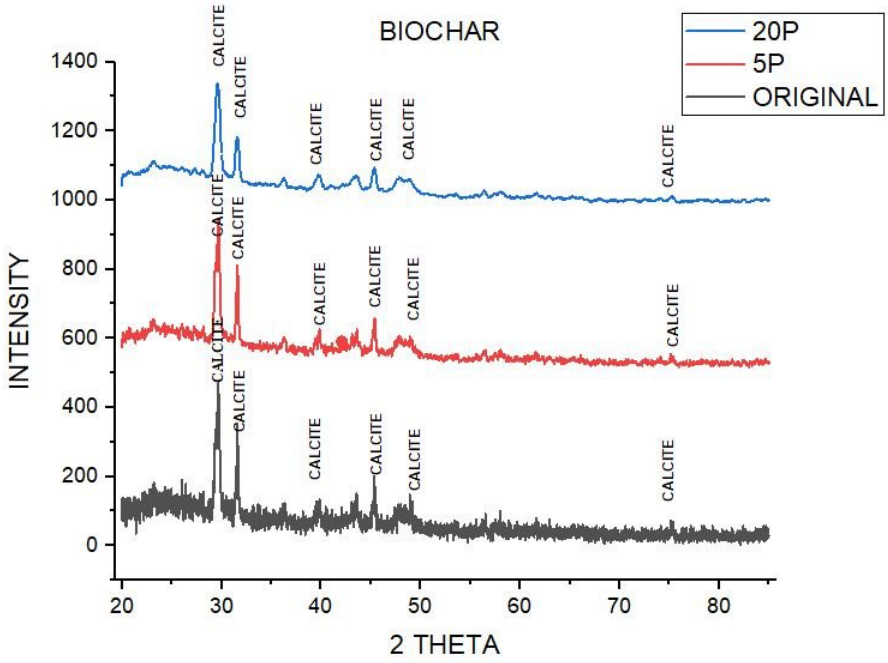

Figure 6: Xray diffraction for Posidonia Oceania seawed

4. CONCLUSION

In summary, after 7 days, the analysis of mortar mixes reveals the following conclusion

1. There is an increased compressive strength of 2% PBC by 4.5% compared to the control mix. This improvement is likely due to enhanced particle bonding from the filler effect.
2. Significant decrease in compressive strength of 6% PBC: by 38.9%. This reduction is attributed to decreased pozzolanic reaction efficiency at higher PBC concentrations.
3. WGP15 and WGP20 exhbit a lower compressive strengths compared to the control mix. This is due to the slow pozzolanic reaction of silica oxide in the glass powder and irregular particle shapes affecting compaction and bonding.
4. There is a Reduced flexural strength PBC Mixes (PBC1-6) compared to the control mix, likely due to air entrapment and void formation from excessive PBC particles.
5. Lower flexural strength also was exhibited in WGP Mixes (WGP15 and WGP20) than the control mix, attributed to irregular particle shapes of glass powder affecting compaction and the bond between the cement matrix and aggregates.

Overall, while PBC and WGP may show improved performance with extended curing duration, making it essential to monitor their effects over time to optimize strength and durability.

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Sustainable Water Utilization and Wastewater reuse in Pakistan's Dairy industry: A Review

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ABSTRACT. The dairy industry in Pakistan plays a significant role in the nation's economy and contributes to food security. Similar to dairy sectors in other nations, the dairy industry in Pakistan is known for placing a significant burden on natural resources, with a particular focus on water. This review paper aims to examine the water consumption patterns within the Pakistani dairy industry. It will also explore the challenges it faces and assess innovative practices and technologies designed to mitigate water usage while ensuring the industry's growth. To address this issue, a case study has been conducted on one of Pakistan's largest dairy industry, Friesland Campina Engro Foods Pakistan. This paper also aims to assess the environmental consequences resulting from the excessive water consumption within Pakistan's dairy industry. Additionally, the paper explores sustainable water management practices, such as wastewater treatment, water recycling, and efficient technologies. It also proposes strategies and recommendations to reduce water consumption in the country's dairy sector.
Keywords: Sustainability, Dairy industry, Environmental impact, Water recycling, Natural resources

1. INTRODUCTION

Sustainable water consumption is critical to achieving global food security, especially in regions where agriculture places significant stress on water resources **[1]**. Pakistan's dairy industry, the fifth-largest globally, exemplifies this challenge. With annual milk production exceeding 67.9 million tonnes **[2]**, the sector's water usage is substantial, spanning cattle hydration, cleaning, milk processing, and product formulation.

1.1 Literature Review & Problem Background

Sustainable water management in the dairy industry has been explored in various countries. For instance, **[3]** found that Amul Dairy in India could reclaim 5% of daily water consumption through reuse. **[4]** used life cycle assessment (LCA) to show that producing 1 kg of fat- and protein-corrected milk in northwest Spain depletes 0.52 m^3 of water. **[5]** estimated annual water use by the food and beverage industries in England and Wales at 157 million m^3. Comparative studies reveal Australia's dairy sector as a leader in minimizing water consumption through wastewater treatment and reuse **[6].** Figures 1 illustrate water use per kilogram of processed milk globally, highlighting the effectiveness of Australian practices.

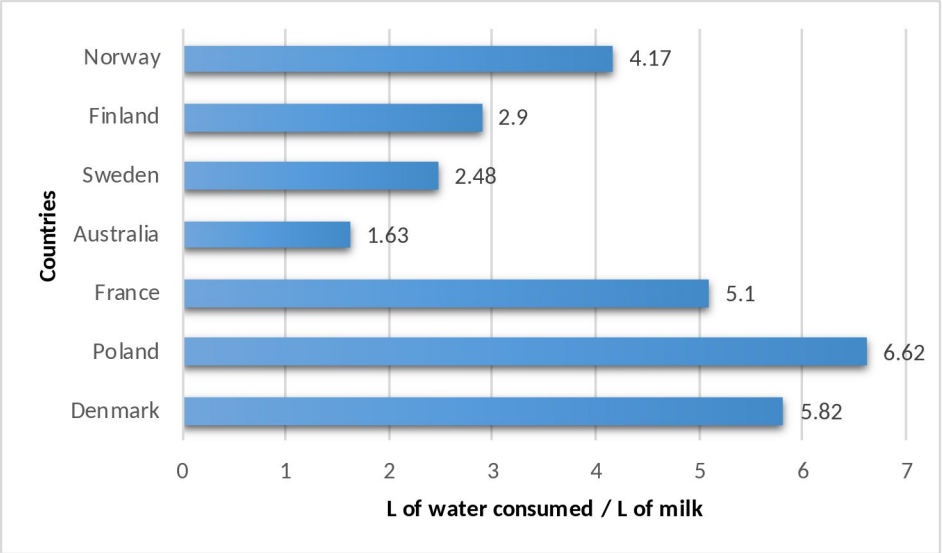

Figure 1: Average water consumption of different countries for milk processing [6]

In Pakistan, water scarcity presents a significant challenge, exacerbated by unsustainable groundwater usage across domestic and industrial sectors. From 1961 to 2020, Pakistan's per capita groundwater reserves declined from 1,168.69 m³ to 242.08 m³, far below the global average (figure 2). Meanwhile, milk production surged from 30.34 million tons in 1998 to 67.87 million tons in 2022, driving water consumption from 45.51 to 101.81 billion m³ (Figure 3) **[7, 8]**. Additionally, dairy processing generates approximately 17.8 m³ of wastewater per cubic meter of processed milk daily, with tanker and equipment washing as major contributors **[7].** To address these issues, Pakistan's dairy sector urgently requires sustainable policies and practices to conserve water and secure resources for future generations.

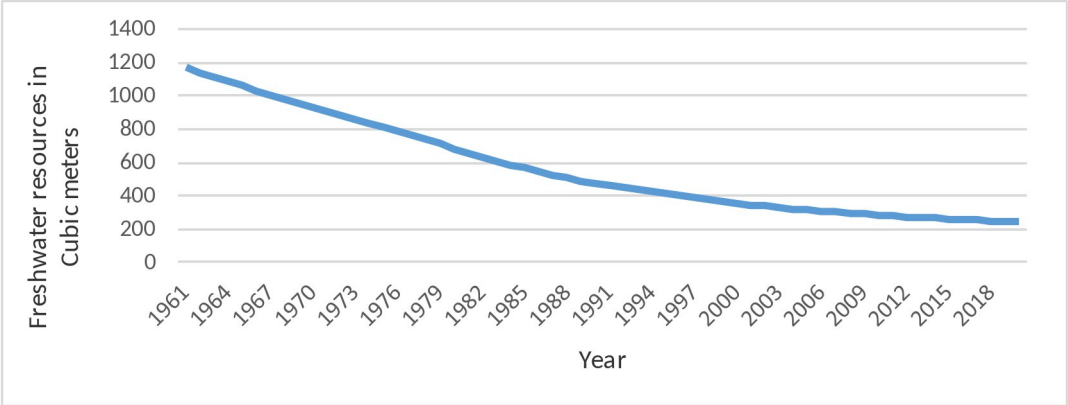

Figure 2: Per capita internal freshwater resources in Pakistan [9]

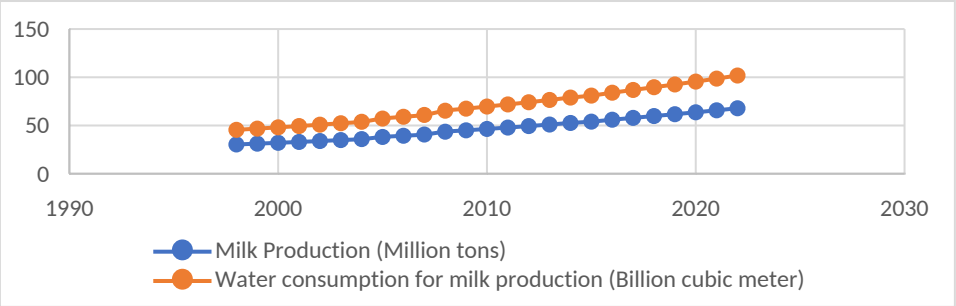

Figure 3: Annual Milk Production & Water Consumption for milk production in Pakistan [7, 8]

1.2 Knowledge gap & Objectives

The lack of a comprehensive review on water consumption patterns, challenges, and sustainable practices in Pakistan's dairy industry highlights a significant research gap. While the environmental impact of water use in this sector is acknowledged globally, a detailed examination specific to Pakistan's context remains absent. This paper aims to address this gap by:

1. Identifying key factors contributing to excessive water use in the dairy industry.
2. Assessing the environmental consequences of such practices.
3. Exploring sustainable water management strategies adopted by advanced dairy industries.

2. WATER UTILIZATION IN PAKISTAN'S DAIRY SECTOR

2.1. Cattle Hydration

Water is vital for the health and productivity of dairy cows and buffaloes, directly influencing their milk yield. Ensuring a consistent supply of clean and pure drinking water is crucial for maintaining their well-being and optimizing milk production **[10, 11].** Providing such an environment underscores the fundamental role of water purity in the success of dairy operations **[12].**

2.2. Cleaning and Sanitation

Water is essential for the sanitation of milk processing equipment, including milking machines, tanks, pipes, and containers. Maintaining hygiene is paramount to ensuring milk purity and safety, with water playing a critical role in removing impurities, bacteria, and harmful substances.

2.3. Milk cooling and chilling

To prevent bacterial growth and maintain milk quality, it is essential to cool raw milk quickly after collection. Water plays a key role in cooling systems, such as plate heat exchangers and cooling tanks, where it acts as a heat transfer medium. This efficient process rapidly reduces milk temperature, minimizing bacterial growth and preserving both freshness and nutritional properties **[13].**

2.4. Cleaning-in-Place (CIP) Systems

Clean-in-Place (CIP) systems in the dairy industry offer efficient cleaning without disassembling equipment. These systems use a combination of water, detergents, and sanitizers to thoroughly cleanse machinery. Water plays a vital role in removing milk residues and cleaning agents, ensuring high cleanliness standards and preparing equipment for the next production cycle **[14]**. This strategic use of water enhances both the effectiveness and efficiency of the cleaning process **[15].**

3. ENVIRONMENTAL CONSEQUENCES OF EXCESS WATER USE BY DAIRY SECTOR

3.1. Water Scarcity

Excessive water use in dairy processing contributes significantly to water scarcity, depleting resources and negatively affecting ecosystems, communities, and sustainable water management **[16]**. Dairy processing requires substantial water for cleaning, cooling, and production of milk-based products, which can be particularly problematic in water-scarce regions like Pakistan **[17]**. As shown in Figure 4, Pakistan is in the "extremely high" water scarcity zone, highlighted in red, reflecting the country's

excessive water consumption across various sectors, including dairy processing. This underscores the urgent need for sustainable water management practices in Pakistan.

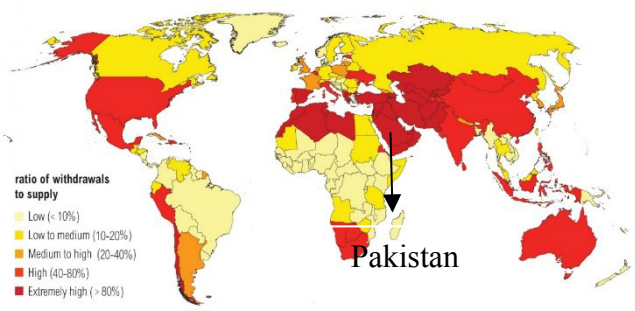

Figure 4: Water stress across the globe [18]

3.2. Depletion of Aquifers and Groundwater Resources:

Excessive water use by the dairy processing industry significantly contributes to the depletion of aquifers and groundwater resources, leading to long-term environmental consequences **[19].** Aquifers, which are essential for supplying water for drinking, irrigation, and industrial processes, are at risk when excessive groundwater extraction occurs. The dairy industry, which requires substantial water for cleaning, processing, and cooling, can exacerbate this problem through inefficient water management **[20].** Over-extraction reduces the natural recharge rates of aquifers, leading to depletion and reduced water availability **[21].**

Figure 5 illustrates fresh groundwater withdrawals in Pakistan from 1975 to 2020, highlighting the strain placed on groundwater resources by sectors like dairy processing and agriculture. The significant decline in water table levels, with depths ranging from 6 to 30 meters below the surface in various regions of Pakistan, emphasizes the urgent need for effective water resource management strategies to ensure long-term sustainability **[22, 23].**

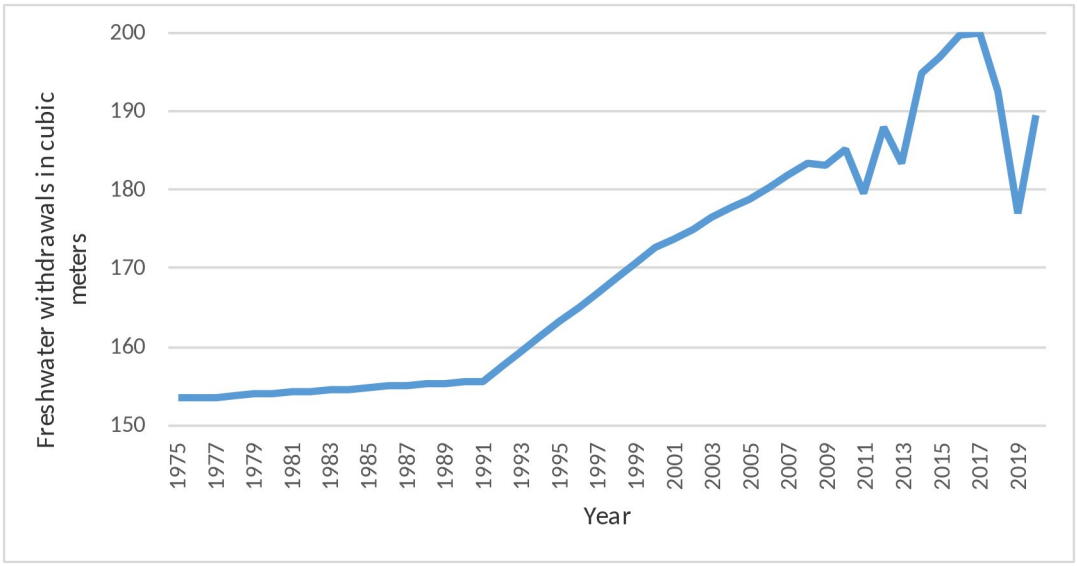

Figure 5: Fresh groundwater withdrawals in Pakistan [22]

3.3. Climate Change Impacts

Excessive water use in dairy processing contributes to water scarcity, water quality degradation, and indirectly impacts greenhouse gas emissions, which can exacerbate climate change **[24]**. The discharge of wastewater from dairy operations, containing pollutants like nutrients and chemicals, can lead to eutrophication, harmful algal blooms, and the degradation of aquatic ecosystems, negatively impacting both water quality and human health **[6, 25].**

Climate change can also affect dairy farming by altering precipitation patterns, temperatures, and water availability, impacting feed quality and milk production. Adaptation strategies, such as more efficient water use, improved recycling, and sustainable practices, are essential for mitigating these challenges **[26].**

4. POSSIBLE APPROACHES TO MINIMIZE WATER USAGE

4.1. Water Reuse

Implementing a robust water reuse strategy is key to minimizing water usage in the dairy industry **[27]**. The dairy sector, vital to Pakistan's economy, can significantly reduce water consumption through effective water reuse practices, contributing to sustainable water management. A study by **[3]** on Amul Dairy in India showed that 5% of daily water use could be reclaimed for processing. **[28]** found that effluent regeneration using membrane technologies could reduce freshwater consumption by up to 95.4% in general processes and 66.7% for CIP processes. Similarly, research by **[29]** demonstrated that applying pinch analysis and mixed-integer linear programming (MILP) to water networks in batch processes could result in a 30% water savings.

4.2. Air Cooling as an Alternative

To promote sustainable water use in the dairy industry, air-based cooling systems are being explored as alternatives to traditional water-based methods. This approach not only reduces water consumption but also supports broader sustainability goals **[30]**. A study by **[31]** demonstrated that using air as a cooling agent, with its low heat film coefficient and specific heat capacity, reduced water consumption in a cheese factory from 280 to 50 m^3/h during a 10-hour operational day, processing 100,000 tons of milk annually.

4.3. Reverse Osmosis

Reverse osmosis (RO) is a highly efficient technology in the dairy industry for water recovery and reuse, helping to address water scarcity. By treating wastewater from dairy processing, RO enables the recovery of high-quality water for various production stages. **[32]** reported that using nanofiltration (NF) and RO to treat rinse water significantly enhanced the environmental sustainability of the dairy sector. For a dairy industry processing 1,000 m^3 of milk daily, this strategy could potentially yield annual profits of US$349,000, according to an economic evaluation.

5. ADVANTAGES FOR PAKISTAN'S DAIRY SECTOR AND COMPANIES THROUGH THE IMPLEMENTATION OF RECOMMENDED SOLUTIONS

- **Reduced Water Consumption** (Water Reuse, Air Cooling can significantly reduce water consumption patterns)
- **Environmental Sustainability** (Can lead to reduce water stress on natural resources which can eventually benefit environment.)
- **Cost Efficiency** (Reduction in water consumption patterns and promoting water reuse can be cost efficient in long terms.)
- **Improved water quality** (RO effectively removes impurities, Bacteria & other contaminants from wastewater.)

6. CASE STUDY: FRIESLANDCAMPINA ENGRO PAKISTAN LIMITED (FCEPL)

In December 2016, FrieslandCampina Engro Pakistan Limited (FCEPL), a leading milk producer in Pakistan, launched a water conservation initiative within its dairy sector to manage water usage efficiently. It was discovered that 5.5 to 6 liters of water were being used to produce 1 liter of milk. To address this issue, the company began evaluating its water extraction and disposal processes by closely monitoring pumping heads. This was necessary due to a lack of continuous data availability from the absence of flow meters.

6.1. Water Usage Breakdown (2016)

A thorough measurement of water extraction and disposal allowed FCEPL to create detailed equipment specification sheets that outlined optimal water consumption levels for each machine. These sheets gave insights into water usage in areas like cleaning, cooling, ceiling water, and general operations. By measuring the total water inlet and outlet for various equipment (e.g., pasteurizers,

UHT machines, filling machines, and reception units), the company calculated the water consumption per liter of milk produced.

6.2. Efforts to Reduce Water Consumption

To decrease water consumption, the company implemented several measures:

- Modifying the inlet ceiling water pressure and cooling water pressure of pumps.
- Reducing the primary header water pressure by up to 30%.

These measures resulted in a 20% reduction in water consumption, bringing the water usage range to 4.5 to 4.9 liters per liter of milk produced.

6.3. Further Improvements

In an ongoing effort to address higher temperatures during the summer, FCEPL:

- Installed safety showers as per OSHA standards.
- Implemented a chilled water circulation system to maintain desired temperatures.
- Insulated water lines to prevent temperature fluctuations and reduce water waste.

6.4. Water Recycling Initiatives

A physicochemical analysis of the ceiling and rinsing water used in Clean-in-Place (CIP) processes revealed that about 90% of this water could be repurposed. Consequently, the company reused this water for activities like gardening and housekeeping. It was also used in cooling towers and condensers. Additionally, Shut-Off Valves (SOV) were added to ceiling water lines to prevent unnecessary water flow when the cooling tower was not operational.

6.5. Results Over Three Years (2016-2022)

These efforts led to a 50% reduction in water consumption in FCEPL's dairy operations. In 2015, it took 6 liters of water to produce 1 liter of milk, but by 2022, this was reduced to 3.7 liters per liter of milk produced, achieving significant progress in water conservation.

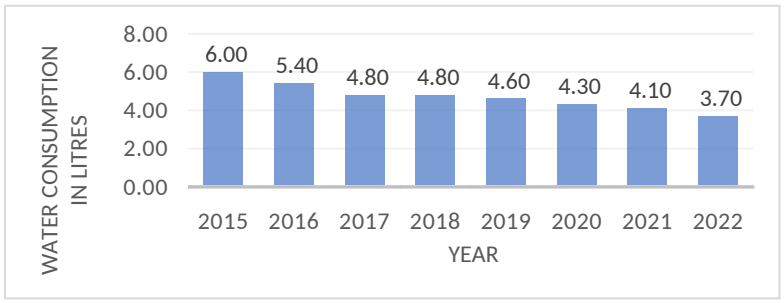

Figure 6: Water consumption by FCEPL per litre production of milk [33]

Figure 11 gives us the border view of FCEPL dedication to achieve sustainability in water consumption for the production of each litre of milk. It can be seen from the figure that water used per litre of milk production in 2015 was 6 litres and in 2022 in has been decreased almost 50% of what was company consumption in 2015 which is 3.7 litre per litre of milk production **[33].** To secure the long-term sustainability of water resources, the company has devised a plan to methodically incorporate flow meters on all water lines within their operations. This strategic undertaking anticipates several advantages. Mainly, it is poised to bring about a substantial decrease in water pumping expenses, potentially reaching up to 25%. This cost reduction in pumping will subsequently lead to noteworthy savings in electricity consumption. Additionally, the installation of flow meters will facilitate improved monitoring and control of water usage, empowering the identification of areas for additional optimization and efficiency enhancements.

7. CONCLUSIONS

In conclusion, the substantial demand for water in Pakistan's dairy sector raises a pressing environmental issue, contributing to water resource depletion and pollution. Effectively addressing these challenges necessitates a proactive and comprehensive strategy. This paper has explored key areas contributing to excessive water use in Pakistan's dairy sector, examined the environmental impacts of this excess water consumption, and proposed potential approaches for reducing water consumption in the dairy processing industry. Finally, it presents a case study on FrieslandCampina Engro Foods Pakistan Limited (FCEPL) and its water conservation program. The success of these initiatives not only preserves valuable water resources but also ensures the long-term sustainability of the dairy sector, fostering a harmonious balance between Pakistan's dairy development and environmental preservation.

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