Sustainable Design in the Long Beach Region of North Cyprus: A Qualitative Research Approach

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Abstract: Cyprus, the third largest island in the Mediterranean, is located in a seismically active zone, making it vulnerable to earthquakes and associated risks such as soil liquefaction. The Long Beach region of Northern Cyprus, in particular, faces significant challenges due to its ground conditions, which exacerbate structural vulnerabilities during seismic events. This research aims to address seismic risks and promote sustainable architectural practices through earthquake-resistant design strategies. By adopting a qualitative research methodology, this study examines resilience design factors specific to the Long Beach area. Data was collected through field investigations, document analysis, and semi-structured interviews with ten experts specializing in geotechnical, civil, and urban fields. The research further employed MAXQDA software to systematically analyze qualitative data, identify recurring themes, and derive key insights related to soil conditions, structural requirements, and infrastructure needs.

The findings highlight the importance of implementing earthquake-resistant design techniques, including soil stabilization, reinforced foundations, and suitable construction practices, to reduce seismic risks. Additionally, the study identifies the role of regulatory frameworks, monitoring processes, and sustainable building strategies in enhancing resilience within the Long Beach region. Solutions such as stricter adherence to construction codes, integration of landscape design principles, and collaboration between urban planners, engineers, and policymakers are proposed to mitigate the impacts of seismic events. This study underscores the need for targeted interventions and interdisciplinary approaches to promote sustainable development and ensure the safety and durability of urban infrastructure in earthquake-prone areas.

Keywords: Earthquake, Resilience design, Sustainable architecture, Soil liquefaction, Qualitative research, MAXQDA, Long Beach, Cyprus.

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1. Introduction

The pursuit of sustainable design has become increasingly important in the context of global environmental challenges. In North Cyprus, particularly in the Long Beach region, researchers have undertaken a qualitative research study to explore sustainable design practices. Geologically, Cyprus is located in the southern place where the Eurasian and African plates meet [1]. Due to the earthquake-proneness of Cyprus, there is a problem of the soil liquefaction in the Long Beach area [2].

The Long Beach region in Northern Cyprus presents a unique case for addressing seismic risks due to a combination of rapid development and significant geotechnical challenges. As a growing center for residential and tourism-related construction, this area has experienced increased development activity over the past decade. However, its underlying soil conditions, particularly the liquefaction susceptibility, amplify the risks associated with seismic events. These combined factors, high construction activity, and fragile ground conditions— create an urgent need for targeted resilience strategies. Addressing these challenges through sustainable architectural practices is essential to ensure structural safety, economic viability, and long-term sustainability of the region.

According to the Liquefaction Potential Determination and Hazard Mapping Based on Standard Penetration Tests in Long Beach and Tuzla Regions of Cyprus, earthquake-resistant design is important. So, examining the issue of soil and the level of earthquake susceptibility in this area is important.

While existing studies have examined the geotechnical and structural aspects of seismic risks in Cyprus, they often lack a qualitative exploration of resilience-focused architectural solutions. Specifically, there is a research gap in understanding how sustainable design principles can be applied to mitigate seismic risks in rapidly developing areas like Long Beach. This study aims to fill that gap by conducting a detailed qualitative analysis of earthquake-resistant architectural factors, combining field investigations, expert interviews, and case study analyses to propose actionable solutions for resilient and sustainable development.

This article provides an overview of the research methodology, which involved reviewing existing documents, conducting interviews, and studying case resorts like Long Beach Resort, Ceasar Resort, Royal Life Poseidon, and Courtyard. The aim was to address seismicity concerns in the area and develop earthquake-resistant designs. The research included the preparation of a questionnaire for interviews, which was administered to experts in the geotechnical, civil, and urban fields. The article highlights the main findings derived from the interviews and presents them in a tabular form.

2. Theoretical Framework

2.1 Seismic History and Impacts in Cyprus

Cyprus has a long history of seismic activity due to its location at the convergence of the Eurasian and African tectonic plates. Historical records indicate destructive earthquakes in the region, including events in 1953 and 1996, both of which reached magnitudes of 6.5 [1, 3]. These earthquakes caused significant damage, particularly in areas with weak soil composition, leading to soil liquefaction. Soil liquefaction, a phenomenon where saturated soil loses its strength and behaves like a liquid under seismic stress, exacerbates structural vulnerabilities [2, 4].

In comparison, regions like California and Japan— both highly seismic— have adopted advanced monitoring technologies and resilient design frameworks to mitigate such risks. For instance, seismic micro-zonation techniques and soil improvement strategies have been successfully implemented in the Kobe region of Japan post-1995 earthquake, reducing liquefaction risks [5, 6]. Lessons from such regions can offer valuable insights into addressing similar challenges in Cyprus, particularly in the Long Beach area.

2.2 Soil Challenges in the Long Beach Region

The Long Beach region is characterized by its susceptibility to soil liquefaction, which poses significant risks during seismic events. Soil investigations have shown that weak, water-saturated layers in the area reduce bearing capacity and lead to structural instability under seismic loads [2]. Moreover, the increasing rate of development in Long Beach—

driven by its growing tourism industry— heightens the urgency to address these challenges. Similar concerns have been observed in areas like Turkey's Marmara Region, where liquefaction caused devastating damages during the 1999 Kocaeli earthquake [7, 8].

Modern soil stabilization techniques, such as compaction, soil replacement, and pore water pressure relief methods, are widely used in earthquake-prone regions to mitigate liquefaction risks [9]. Incorporating these strategies in Long Beach, alongside strict regulatory enforcement, could significantly enhance resilience.

2.3 Resilient Design Concepts

Resilient design focuses on creating structures capable of withstanding and recovering from seismic events, ensuring durability, safety, and functionality. According to Martin (2021), resilience integrates structural stability, energy efficiency, and long-term sustainability. Regions like California and New Zealand have embraced resilient design principles by incorporating base isolation systems, energy-dissipating devices, and reinforced materials into construction practices [10, 11].

However, in the context of Northern Cyprus, there remains a gap in adopting advanced seismic technologies and sustainable construction methods. For example, building with reinforced concrete structures is common in Long Beach, but limited attention is given to integrating ecofriendly materials or seismic-resistant innovations such as flexible foundations and dampers [12].

2.4 Sustainable Design and Economic Considerations

The integration of sustainable design practices in seismically active regions not only improves resilience but also offers long-term economic benefits. Sustainable construction methods, such as using renewable energy sources, green materials, and efficient water management systems, reduce operational costs while enhancing environmental performance [13].

A cost-benefit analysis of implementing sustainable design in earthquake prone areas reveals that the initial investment is often offset by long-term savings in maintenance, energy efficiency, and reduced disaster recovery costs [9]. For instance, post-earthquake rebuilding costs in Kobe, Japan, were significantly reduced where preemptive resilient design strategies had been implemented. A similar approach in Long Beach would not only minimize seismic risks but also attract investment by promoting the area's safety and sustainability for future developments.

2.5 Research Gap and Justification

While existing studies have examined the geotechnical and structural challenges in Northern Cyprus [2], there is a lack of qualitative research exploring resilience-focused architectural solutions within the region. Moreover, comparisons with other seismically active areas remain limited, which restricts the generalizability of findings. This study aims to bridge this gap by conducting an in-depth qualitative analysis of sustainable architectural practices, drawing insights from expert interviews, case studies, and global best practices. By addressing the Long Beach region's unique challenges, this research contributes to a broader discourse on seismic resilience and sustainable design (Figs. 1-7).

Figure 1. Iskele, Cyprus [14]

Figure 2. Long Beach area, Cyprus [15]

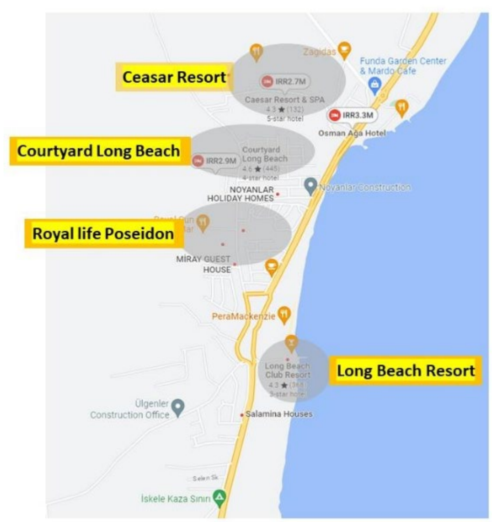

Figure 3. Some resorts in the Long Beach area [15]

Figure 4. Long Beach Resort, Long Beach, Cyprus [16]

Figure 5. Courtyard, Long Beach, Cyprus [17]

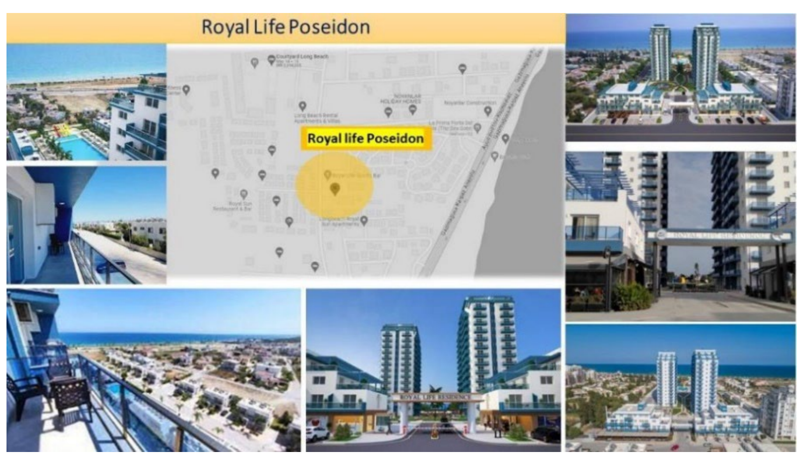

Figure 6. Royal Life Poseidon, Long Beach, Cyprus [18]

Figure 7. Ceasar Resort, Long Beach, Cyprus [19]

3. Methodology

The research employs a qualitative methodology to explore sustainable architectural practices and resilience design in the earthquake-prone Long Beach region of Northern Cyprus. The approach focuses on analyzing existing documents, conducting case studies, and interviewing experts to extract valuable insights. Additionally, the study integrates quantitative data where applicable to provide a more holistic understanding of the topic.

3.1 Data Collection Process

The study utilized multiple methods to ensure comprehensive data collection:

Document and Literature Review: Relevant studies, reports, and technical documents on seismic risks, soil liquefaction, and sustainable design were analyzed to establish a theoretical foundation.

Case Studies: A detailed examination of key resorts in the Long Beach area, Long Beach Resort, Ceasar Resort, Royal Life Poseidon, and Courtyard— was conducted. This included on-site observations, photography, and surveys of physical attributes such as building forms, heights, materials, and construction techniques.

Expert Interviews: Semi-structured interviews were conducted with ten experts specializing in geotechnical engineering, civil engineering, and urban design. The interviews were guided by a structured questionnaire divided into two parts:

Part 1: Broader themes exploring the importance of resilience design, construction issues, and structural challenges.

Part 2: Focused sub-questions addressing specific technical factors like soil stabilization, infrastructure improvements, and construction quality in the Long Beach area.

3.2 Data Analysis Using MAXQDA Software

The qualitative data from expert interviews were analyzed using MAXQDA software, a tool designed for coding, categorizing, and visualizing qualitative findings [20].

Coding Process: Transcriptions from the interviews were imported into MAXQDA. A systematic coding process was applied, starting with open coding to identify recurring themes, followed by axial coding to establish relationships between key concepts.

Criteria for Categorization: The categorization process focused on identifying patterns related to seismic challenges, soil conditions, resilience design strategies, and regulatory gaps. Keywords such as "resilience", "liquefaction", "sustainable infrastructure", and "regulatory enforcement" were used to refine the analysis.

The software facilitated the organization of responses into thematic categories, which were then summarized into charts and tables. For example, MAXQDA was used to map expert recommendations regarding soil improvement techniques, construction strategies, and sustainable design principles.

3.3 Incorporation of Quantitative Data

To strengthen the analysis, the study incorporates quantitative data where applicable:

Construction Costs: Data on the cost of implementing earthquake-resistant and sustainable design strategies were gathered from industry reports and expert feedback. This includes initial investment costs for reinforced materials, soil stabilization techniques, and energy-efficient infrastructure.

Energy Consumption: Comparative metrics on energy usage in sustainable versus conventional buildings were reviewed to highlight long-term benefits of sustainable practices.

Seismic Risk Metrics: Quantitative data from previous seismic studies, such as liquefaction potential indices and soil strength values for the Long Beach area, were included to contextualize the region's vulnerabilities. By integrating both qualitative and quantitative insights, the study provides a more comprehensive understanding of the economic and practical implications of sustainable design in seismically active regions.

3.4 Integration of Methods

To enhance clarity and avoid redundancy, the "Materials and Methods" section is combined with the broader "Methodology" section. The combined structure ensures a cohesive narrative, detailing the research process from data collection to analysis.

4. Results and Findings

4.1 Resilience design requirement and Importance of earthquake in Cyprus

Concerning to the importance of sustainable design in Cyprus, it is possible to mention the creation of appropriate regulations, design in fewer floors and the adoption of appropriate laws for landscape construction.

The importance of earthquake-resistant design in Cyprus is examined in this study, and in this regard, we can mention the medium risk of earthquakes in this country, soil liquefaction, especially in the Long Beach region, and the importance of earthquake-resistant design (Fig. 8).

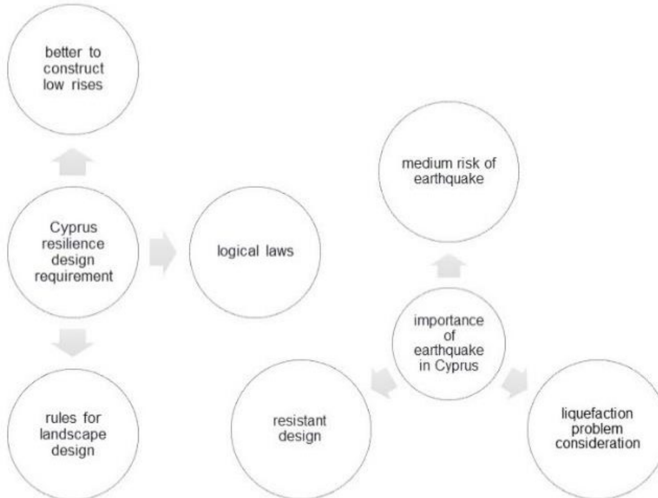

Figure 8. MAXQDA analysis, Resilience design requirement and importance of earthquake in Cyprus

4.2 Proper structures

There are several items like suitable insulation, stability, infrastructure, foundation, compacting soil, suitable drains, proper depth of excavation, proper columns, proper height considering the distance from the sea, proper height, proper piles are important in the case of the proper structure (Fig. 9).

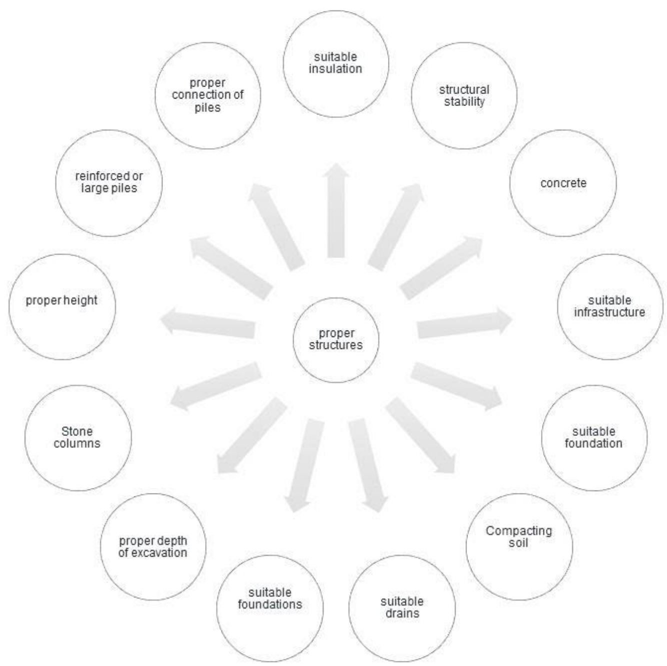

Figure 9. Proper structures

4.3 Requirements, Long Beach and the Location

In examining the needs, geophysical testing and resistant design are important. And the proper location should be done according to the rules and the distance from the sea in the Long Beach area. Also, in Long Beach, he reviewed the rules of this area, proper distance, proper supervision, and strict rules (Fig. 10).

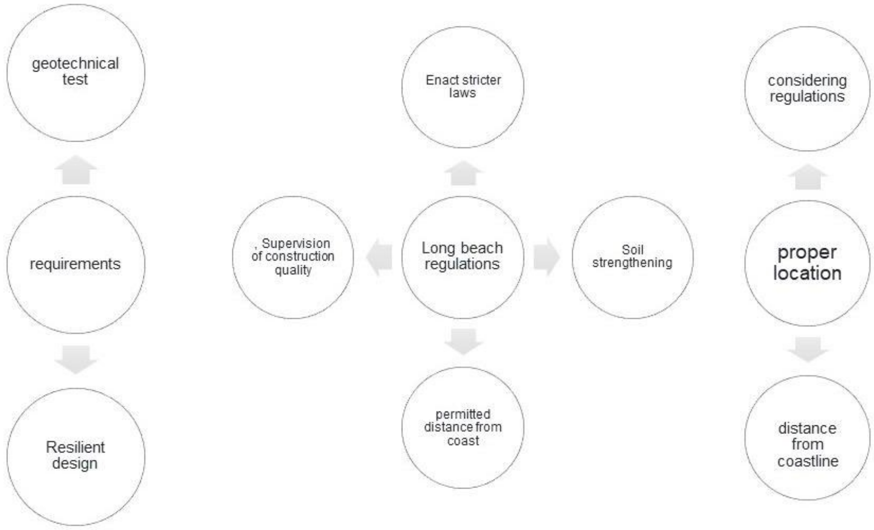

Figure 10. Requirements, Long Beach and the Location

4.4 Encourage private construction and Landscape construction

In the field of encouraging construction, solutions such as participation, various organizational programs and land participation through the government can be mentioned. Also, in the construction of the landscape, it should be noted about proper isolation, proper and correct drainage, and soil improvement (Fig. 11).

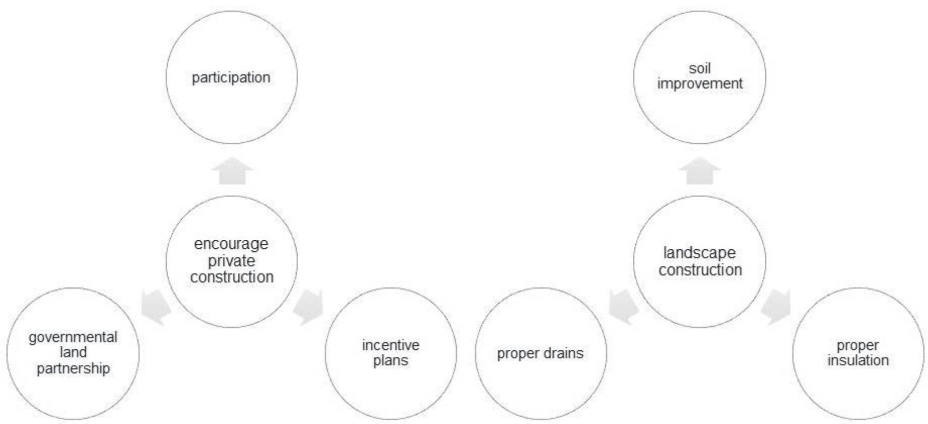

Figure 11. Encourage private construction and Landscape Construction

4.5 Proper infrastructure and earthquake risk reduction

In the field of construction of suitable infrastructure, we can mention things such as improvement and replacement and compaction of soil, physical modification, use of drainage and construction of suitable foundation. To reduce the risk of earthquakes, it mentioned proper piles and connections, strengthened foundations, proper distance and other things (Fig. 12)

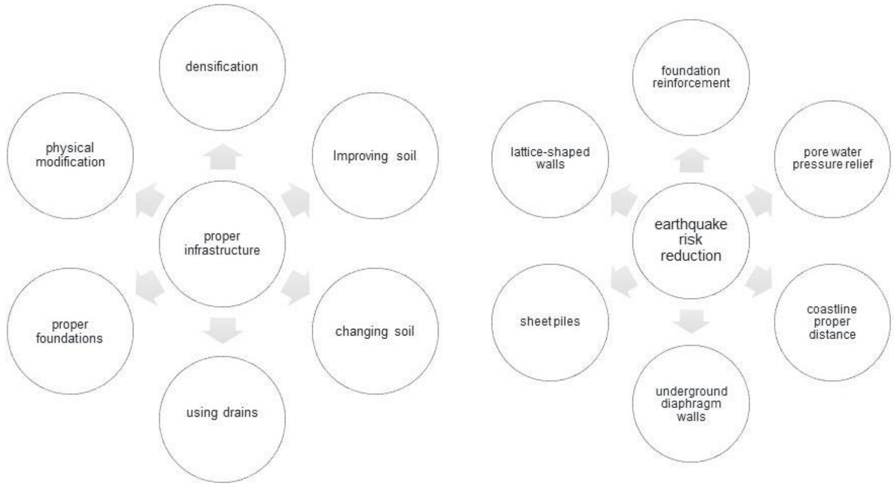

Figure 12. Proper Infrastructure and earthquake risk reduction

The interview was done with experts of different fields related to the construction of Long Beach area. A conclusion of their opinions or solutions and points have been collected in the following tables (Tables 1-2).

Table1. Technical interviews

Technical factors	Solutions suggested
Infrastructures requirements	Increasing compactness - Drain of gravel, sand, or synthetic materials - adding proper soil – soil improvement
Foundation requirements	Proper foundation - good insulation - piles of larger dimensions - connecting piles to the cap in a the ductile manner that allows some rotation
Structure requirements Reinforcement solutions	reinforced concrete-stone columns Reinforcement in concrete reinforcement piles
Height allowed	It depends on the distance from the sea - from one floor to the nearest ones to the sea to the high rises

Table2. Summary of Interviews

Factors noticed in interviews	Opinions	Solutions
Requirement to have resilience design in Cyprus	Mostly said needed	—
Importance of earthquake issue in Cyprus construction	Famagusta is the high-risk part, the Long Beach part with the medium risk	Improve the strengthening plan of existing buildings according to the earthquake is seen in Cyprus up to 6.5 Richter
Common structures used in the Long Beach area	Reinforced concrete structure	—
The problem in the construction of the Long Beach area	Second zone of earthquake - Liquefaction can cause major damage during earthquakes	Revision of laws with the help of structural and geophysical engineers
Earthquake prevention measures for the Long beach area	Some buildings have been considered but others do not	Stricter review of existing regulations and improve them
Earthquake-resistant building arrangements are mandatory in North Cyprus, especially in the Long Beach area	Earthquake construction requirements are partly mandatory in new construction	It must be more detailed and specified
The construction quality of Long Beach	Mostly acceptable implementation quality	—
Soil liquefaction infrastructure urban design of Long Beach	Lack of enough attention	Paying more attention to the adoption of appropriate infrastructure regulations, their implementation, and durability
Distance of construction from the coast	Different in different parts	Near the coastline, almost 1st-floor height exists and as far it goes in the height going far it goes in the height
Earthquake risk reduction solutions	—	Replacement or physical modification, densification, pore water pressure relief, foundation reinforcement
Supervision during the construction of Long Beach Resort	Mostly said good	Monitoring after construction is required for durability and resistance after construction.
Ways to encourage the improvement of private construction	—	Providing an incentive plan by implementing the most suitable infrastructure

The research findings were summarized in a tabular format to present a clear overview of the main points derived from the expert interviews. The tabular presentation allowed for a concise and structured representation of the data. The results highlighted the following key findings:

1. *Seismicity and Soil Issues:* Given the history of seismic activity in Cyprus, earthquake-resistant design is crucial. The Long Beach area faces specific challenges due to soil-related issues, which further emphasize the need for robust seismic design strategies.

2. *Sustainable Design Practices:* Experts identified various sustainable design practices that can be implemented in the Long Beach region. These include the use of renewable energy sources, efficient water management systems, green building materials, and the integration of natural elements into the design.

3. Collaboration and Knowledge Exchange: The research emphasized the importance of collaboration among experts from different fields to address the complex challenges associated with sustainable design. Knowledge exchange and interdisciplinary approaches were deemed crucial for achieving sustainable and resilient solutions.

4.6 Implications for Resilience Design in Long Beach

The findings presented in tables and charts reveal several critical aspects of resilience design specific to the Long Beach region. Technical solutions, such as reinforced foundations, soil stabilization methods, and appropriate structural systems, have direct implications for mitigating the risks of earthquakes and soil liquefaction. For instance, the recommendation to implement piles with ductile connections and compacted soil infrastructure highlights practical approaches to improving the region's structural resilience. These techniques not only ensure durability but also enhance safety in a region where weak soil composition amplifies seismic impacts.

Furthermore, the adoption of low-rise construction near the coastline aligns with international best practices for seismically active zones, as it reduces the structural load on unstable soil. This strategy emphasizes the importance of tailoring construction practices to site-specific conditions, which is a fundamental principle in resilience design. By addressing both structural and geotechnical challenges, the proposed solutions contribute to a more comprehensive framework for sustainable and earthquake-resistant development in Long Beach.

4.7 Generalizability of the Findings

While the study's findings are specific to the Long Beach region, they offer broader insights into resilience design in other seismically active areas with similar geotechnical challenges. For example, lessons learned from soil stabilization techniques and low-rise construction can be applied to regions experiencing rapid urban development on liquefaction-prone land, such as parts of Japan, Turkey, and California. However, it is important to note that the unique environmental, regulatory, and economic context of Northern Cyprus may limit direct applicability. Future research can adapt these findings to other contexts by considering local geological conditions, building regulations, and economic priorities.

4.8 Cost Implications of Sustainable Design

A key challenge identified in implementing sustainable design practices is the higher initial cost associated with advanced materials, energy-efficient systems, and soil stabilization techniques. For instance, constructing reinforced foundations and implementing soil improvement measures require significant upfront investment. However, a cost-benefit analysis reveals that these initial costs are offset by substantial long-term benefits, including reduced maintenance expenses, lower energy consumption, and minimized structural damage during seismic events.

For example, studies from similar contexts, such as post-earthquake regions in Japan and California, demonstrate that earthquake-resistant infrastructure can reduce recovery costs by up to 50% [5]. Moreover, energy-efficient buildings can lower operational costs by 20-30% over their lifecycle [8]. In the case of Long Beach, promoting investment in sustainable and resilient design can attract developers and stakeholders by ensuring the longevity and economic viability of urban developments.

4.9 Policy Recommendations and Strategies for Implementation

The findings highlight the need for stricter regulations, improved supervision, and policy interventions to promote sustainable and earthquake-resistant design in Long Beach. To address these gaps, the following actionable policy recommendations are proposed:

Strengthen Building Regulations

Enforce mandatory compliance with seismic design codes, including requirements for soil stabilization, reinforced foundations, and low-rise construction in high-risk areas.

Introduce periodic inspections to ensure the durability and safety of existing and new structures.

Incentivize Sustainable Design

Provide financial incentives, such as tax breaks or subsidies, for developers who adopt sustainable materials and energy-efficient systems.

Introduce low-interest loans for construction projects that integrate earthquake-resistant technologies and sustainable practices.

Public Awareness and Education

Launch educational campaigns to inform stakeholders, including developers, policymakers, and residents, about the long-term benefits of resilience-focused construction.
Offer training programs for engineers, architects, and urban planners on advanced sustainable design techniques.

Integrate Cost-Benefit Analysis in Policy Development

Require a cost-benefit analysis for all major construction projects to evaluate the economic viability of sustainable and resilient practices. Promote research and development to explore innovative, cost-effective materials and construction methods tailored to the Long Beach region's challenges.

By implementing these strategies, policymakers can create a regulatory and economic framework that encourages sustainable growth while enhancing the region's resilience to seismic events.

5. Conclusion

This study provides valuable insights into the resilience design factors necessary for earthquake-resistant construction in the Long Beach region of Northern Cyprus, addressing a critical gap in the literature. By combining qualitative analysis with quantitative data on construction costs, energy consumption, and seismic risk metrics, the research offers a comprehensive understanding of the challenges and solutions for creating resilient, sustainable urban environments in seismically active areas.

One of the novel contributions of this research is the use of MAXQDA software to systematically analyze and categorize expert interviews. This tool facilitated nuanced exploration of the technical, geotechnical, and regulatory factors influencing resilience design, providing a detailed mapping of expert recommendations on soil stabilization, reinforced foundations, and low-rise construction practices. The use of MAXQDA enabled a robust qualitative analysis that helped identify key themes and emerging patterns, contributing to a deeper understanding of how sustainability and seismic resilience can be integrated into urban development.

In addressing the research gap, this study expands on existing literature by offering a qualitative analysis of resilience-focused architectural practices in Cyprus, an area where such research has been limited. Unlike previous studies that have primarily focused on the technical or geotechnical aspects of seismic risks, this research emphasizes the need for a holistic approach to resilient design, which incorporates both sustainable building practices and regulatory improvements. By examining specific case studies in the Long Beach region, the study provides actionable insights into how design solutions can be tailored to local conditions, while also making a broader contribution to resilience design strategies that can be adapted to other earthquake-prone regions.

The findings not only underscore the importance of earthquake-resistant design but also highlight the economic and policy implications of implementing such strategies. While the initial costs of sustainable and resilient construction can be high, the long-term benefits—such as reduced repair costs, energy savings, and minimized disaster recovery expenses—demonstrate the value of proactive investment. Policy recommendations, including stricter regulations, financial incentives for sustainable construction, and public awareness campaigns provide a framework for encouraging more widespread adoption of resilience focused design practices.

In conclusion, this research advances the understanding of resilience design in Northern Cyprus and lays the groundwork for future studies that explore the integration of sustainability and seismic resilience in other regions. The study's findings and policy recommendations provide a foundation for creating safer, more sustainable urban environments that can withstand the challenges posed by seismic activity and promote long term, resilient development.

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