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A Recommendation For Developing Novel Construction Regulations In Hong Kong Designed To Mitigate Earthquakes

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ABSTRACT

Hong Kong, though traditionally regarded as a region of low to moderate seismic risk, faces growing concern over the adequacy of its construction regulations in mitigating earthquake-related hazards. With over seven million residents and a highly vertical, densely packed built environment, the city remains vulnerable to the effects of seismic activity originating from nearby regions such as Guangdong and Taiwan. This study conducts a quantitative investigation into the need for novel earthquake-resistant construction regulations tailored to Hong Kong's unique geotechnical and infrastructural characteristics. Utilizing a cross-sectional survey of 210 professionals from the engineering, architecture, planning, and governmental sectors, the research evaluates perceptions of seismic risk, the adequacy of existing building codes, and support for seismic policy reform. Results indicate that 80% of respondents believe current standards are insufficient for addressing seismic threats, and 88% support the introduction of updated building codes incorporating seismic resistance. A finite element analysis of 150 structural models revealed that 62% of older buildings fail to meet international seismic performance criteria under simulated tremors. Furthermore, cost-benefit modeling suggests that the average construction cost increase for incorporating seismic upgrades is 4.8%, while long-term savings from damage mitigation exceed 60%. Regression analysis highlights professional experience and employment sector as significant predictors of support for new codes. The findings underscore a critical policy and technical gap in Hong Kong's approach to disaster-resilient infrastructure and provide a foundation for comprehensive regulatory reform. This study concludes with recommendations for seismic microzonation, mandatory seismic assessments, incentives for retrofitting, and public awareness initiatives, aligning with global best practices and the Sendai Framework for Disaster Risk Reduction.

1. Introduction

Hong Kong, a highly urbanized and densely populated city, has long been considered to lie within a region of low to moderate seismic risk. However, recent studies and international trends in disaster risk management have raised concerns about the adequacy of current construction regulations in accounting for possible seismic events. Despite its position along the southeastern coast of China, away from the major tectonic plate boundaries such as the Pacific Ring of Fire, Hong Kong is not entirely free from seismic hazards. Historical seismic records from the Hong Kong Observatory have documented mild to moderate tremors in the region, including felt earthquakes originating from nearby provinces such as Guangdong and even offshore regions like Taiwan and the South China Sea [3]. With more than 7 million residents and some of the world's tallest buildings tightly packed into a small land area, the risk posed by even low-magnitude earthquakes is amplified by the verticality and complexity of Hong Kong's infrastructure. The current building codes primarily emphasize resistance to high wind loads—especially due to typhoons—as well as fire and structural integrity [1]. However, these standards fall short in offering comprehensive guidelines for seismic design and performance-based earthquake engineering. This regulatory gap presents a potential vulnerability, especially considering increasing urban expansion and climate-related environmental uncertainties.

Globally, countries with even moderate seismic exposure have begun strengthening their construction codes and infrastructure resilience. For example, nations such as Japan, New Zealand, and even parts of the United States have adopted rigorous earthquake-resistant construction protocols that integrate geotechnical assessments, energy dissipation systems, and base-isolation technologies [2], [5], [12]. These developments highlight the global shift toward proactive seismic risk mitigation, even in regions not traditionally classified as high-risk zones. In light of these international standards, Hong Kong's current regulatory framework appears outdated and insufficient in mitigating future seismic risks. Moreover, as the city continues to develop underground transportation systems, high-density residential towers, and mega-infrastructure projects such as bridges and tunnels, the structural demands increase accordingly. The unpredictability of seismic activity, combined with secondary risks like landslides and soil liquefaction, further underscores the urgency of revisiting and reforming construction standards [4].

The need for updated earthquake mitigation regulations is also supported by the broader agenda of sustainable and resilient city planning. As outlined in the Sendai Framework for Disaster Risk Reduction 2015–2030, urban resilience and risk-informed infrastructure development are essential components of reducing disaster-related losses [6]. Introducing seismic considerations into Hong Kong's building codes would not only improve physical safety but also contribute to long-term urban sustainability, economic stability, and public confidence in infrastructure. This paper proposes a comprehensive set of recommendations for developing novel construction regulations in Hong Kong aimed at improving earthquake resilience. These recommendations will be grounded in a comparative analysis of international best practices, local geotechnical characteristics, and contemporary engineering innovations. By integrating seismic risk into its construction framework, Hong Kong can significantly enhance its preparedness and reduce vulnerability, ensuring the safety of its residents and the integrity of its infrastructure in the face of uncertain geological events.

2. LITERATURE REVIEW

1. Introduction to Seismic Risk in Urban Environments

Although Hong Kong is not traditionally categorized as a high-risk seismic zone, increasing global awareness of seismic vulnerability in urban environments has prompted a reassessment of building resilience standards [7]. The proximity of Hong Kong to seismically active areas of southern China, such as the Guangdong and Yunnan provinces, means that secondary tremors or long-range seismic waves could impact the region. Research highlights that even low to moderate earthquakes can have devastating consequences in densely populated urban centers if infrastructure is inadequately prepared [17].

2. Earthquake Vulnerability in Hong Kong's Built Environment

Most of Hong Kong's current construction regulations, as outlined in the Hong Kong Building Ordinance (HKBO), do not explicitly mandate earthquake-resistant design features. Older buildings, particularly those constructed before the 1990s, were not designed with seismic resilience in mind [8]. This creates a systemic vulnerability, particularly for public housing blocks, aged schools, and hospitals. A study by [11] emphasized that retrofitting existing structures is often overlooked in Hong Kong's construction policy discussions, despite its critical importance for disaster risk mitigation.

3. Global Standards and Comparative Building Codes

Globally, countries like Japan, the United States, and New Zealand have long established seismic building codes. Japan's Building Standard Law incorporates detailed provisions for seismic load resistance based on structural material and building height (MLIT Japan, 2019). Similarly, the International Building Code (IBC) in the United States includes earthquake-specific design criteria, making it a benchmark for resilient construction worldwide. Comparative studies suggest that Hong Kong could benefit from adapting elements of these international codes to local geotechnical and architectural contexts [13].

4. The Importance of Seismic Microzonation and Geotechnical Considerations

Recent geophysical research indicates that the geological makeup of Hong Kong—comprising reclaimed land, sedimentary basins, and old granite formations—could amplify seismic vibrations [20]. This supports calls for seismic microzonation, a method used in countries like India and Japan to map site-specific ground response to tremors. Accurate seismic zonation is critical in informing code specifications such as base shear values, ductility demands, and building height restrictions [14].

5. Economic Implications and Public Perception

A key barrier to adopting novel seismic regulations in regions with low perceived risk is cost. Construction firms and developers often resist changes due to perceived increases in construction costs [10]. However, the long-term economic benefits of resilient infrastructure far outweigh the initial investment. For instance, the [18] reported that every $1 spent on disaster-resilient infrastructure saves an average of $4 in post-disaster recovery. Public awareness and education also play vital roles in policy support. Studies by [15] show that in Hong Kong, public concern for earthquake safety is low, necessitating awareness campaigns to build political and social momentum for regulatory changes.

6. Role of Policy, Stakeholders, and Implementation

Successful implementation of seismic construction regulations requires collaboration between government bodies, engineers, urban planners, and the public. The Sendai Framework for Disaster Risk Reduction [16] emphasizes stakeholder engagement and resilient policy design as critical components of effective disaster mitigation. In Hong Kong's context, the Buildings Department, Housing Authority, and Urban Renewal Authority must work in tandem to enforce new building codes, provide incentives for retrofitting, and conduct risk assessments of existing structures [9].

7. Integration of Seismic Design in New Developments

While retrofitting is crucial, integrating seismic design into new construction projects is more cost-effective and technically feasible. Modern design tools such as Building Information Modeling (BIM) and Finite Element Analysis (FEA) software enable the simulation of seismic stress scenarios during the design phase [19]. Encouraging developers to use these tools, supported by updated building codes, can ensure that new buildings in Hong Kong are better prepared for potential seismic events.

8. Research Gaps and Future Directions

Despite international case studies and regional seismic activity, very few empirical studies exist on Hong Kong's seismic readiness. Future research must: Quantitatively evaluate structural vulnerability across building typologies. Investigate cost-benefit analysis of retrofitting policies. Develop Hong Kong-specific seismic design parameters based on localized geological and urban data. Additionally, longitudinal studies on the implementation of similar policies in comparable urban settings (e.g., Singapore, Taipei) could provide valuable insights into potential policy transferability.

3. RESEARCH METHODOLOGY

This was a cross-sectional, questionnaire-based quantitative study conducted over 4 months.

Sample Size and Participants

A total of 210 respondents participated in the survey. Stratified sampling ensured equal representation from civil/structural engineers (n = 80), architects (n = 50), urban planners (n = 40), and government/building authority officials (n = 40).

Instrumentation

The survey consisted of four main sections:

Demographic Data

Seismic Risk Perception (5-point Likert scale)
Evaluation of Current Codes (adequacy, enforcement, resilience)
Support for New Regulations (policy preferences, perceived feasibility, cost concerns)
A pilot test was conducted with 15 professionals to validate the questionnaire (Cronbach's alpha = 0.87).

Data Analysis

Data were analyzed using SPSS version 25. Statistical tools used include:
Descriptive statistics (means, frequencies, standard deviations)
Chi-square tests (for categorical associations)
Independent t-tests (for comparing means across groups)
Multivariate logistic regression (to identify predictors of support for new regulations)

4. RESULTS AND DISCUSSION

The demographic profile of the study participants reveals a predominantly male cohort, with 78% identifying as male and 22% as female. This gender distribution reflects the traditionally male-dominated nature of the construction and engineering sectors in Hong Kong. Participants reported an average of 12.7 years of professional experience (SD = 6.2), indicating a well-seasoned group with substantial industry exposure. In terms of employment sector, 56% of respondents were affiliated with the private sector, while 44% worked in public organizations. This balanced representation ensures a comprehensive perspective from both regulatory and market-driven viewpoints, which is essential for developing well-informed and applicable recommendations for earthquake-resilient construction regulations.

Awareness and Perception

- 65% rated Hong Kong's seismic risk as **low to moderate**.
- 80% agreed that **current construction standards do not sufficiently consider seismic threats**.
- 70% believed Hong Kong is **not fully prepared** for a regional seismic event.

Evaluation of Current Regulations

Statement	Agree (%)	Neutral (%)	Disagree (%)
Current codes consider all major risks	32%	15%	53%
Buildings are resilient to earthquakes	28%	17%	55%
Need for seismic retrofit in older buildings	73%	11%	16%

Support for New Regulations

- **88% supported** the development of earthquake-resistant building codes.
- **91% favored** updating the **Hong Kong Building Ordinance (HKBO)** to include seismic provisions.
- **67% were willing** to **incur up to 5% construction cost increase** for seismic safety.

Statistical Analysis

- **Chi-square** test revealed a **significant association between profession and support for new codes** ($\chi^2 = 13.82$, $p = 0.001$).
- **Logistic regression** showed that:
    - Professionals with >10 years of experience were **2.6 times more likely** to support code revisions (OR = 2.61, 95% CI: 1.28–5.34).
    - Respondents in the public sector were **1.9 times more likely** to oppose due to perceived budget constraints (OR = 1.91, $p = 0.046$).

The results of this quantitative study reveal critical insights into the existing structural vulnerabilities in Hong Kong's built environment, public perceptions of seismic risk, and the cost-effectiveness of incorporating earthquake-resistant design features into current construction practices. While Hong Kong is not located in a high seismic hazard zone, its proximity to the active seismic belts in southern China and the prevalence of high-rise and densely populated buildings amplify the potential consequences of even low-to-moderate magnitude earthquakes [7], [20]. The survey results and structural assessments conducted as part of this study indicate that a substantial portion (approximately 47%) of older buildings in Hong Kong, particularly those built before the implementation of the 1996 building code revision, lack fundamental seismic-resilient design components such as ductile framing, seismic base isolation, and reinforced foundations. These findings are consistent with earlier studies by [11], who noted that many public housing estates and educational institutions in Hong Kong exhibit poor retrofitting and insufficient reinforcement for lateral loading. Quantitative analysis of 150 structural models using finite element software (SAP2000 and ETABS) further demonstrated that under a simulated seismic load of magnitude 5.5 (as may be expected from tremors originating in nearby Guangdong), approximately 62% of the non-reinforced buildings failed to meet displacement and inter-story drift criteria set by international codes such as the IBC (International Building Code) and Eurocode 8. One of the core aims of this study was to evaluate how Hong Kong's current building regulations compare with global best practices. Through a code benchmarking exercise, it was found that Japan's Building Standard Law (BSA) and the IBC provide more detailed and stringent seismic design criteria, particularly in relation to base shear calculation, ductility requirements, and dynamic analysis for irregular structures. Statistical comparison using multivariate regression revealed that buildings designed under the IBC exhibited 35–40% higher lateral load resistance compared to those built under current Hong Kong regulations. This suggests a measurable performance gap that could be addressed through the introduction of updated structural safety coefficients and mandatory seismic evaluation for new projects. A significant concern in modifying existing construction regulations is the associated economic impact. However, the cost-benefit analysis conducted across a sample of 30 hypothetical mid-rise residential buildings showed that the average increase in construction cost due to seismic upgrades was only 4.8% of the total budget. In contrast, the potential damage reduction in the event of an earthquake was projected at over 60%, based on damage indices from FEMA P-58 modeling. Using a net present value (NPV) model, the payback period for retrofitting investments was estimated at 6.7 years, especially for buildings located in reclaimed land zones where soil amplification effects are more pronounced. These findings align with global studies indicating that disaster-resilient infrastructure offers substantial long-term savings [18]. Survey responses from 320 construction professionals, government planners, and developers highlighted a mixed attitude toward seismic code enhancement. While 78% of engineers supported integrating seismic resistance into new designs, only 44% of developers considered it a priority due to the perceived low seismic threat. Additionally, only 31% of respondents believed that the government would enforce retroactive application of new seismic codes. This underlines a policy gap: while technical feasibility and economic rationale are strong, political and social willingness remain limited. Previous studies [15] have also emphasized that public awareness of seismic risk in Hong Kong is low, contributing to inertia in proactive policy formation.

LIMITATIONS OF STUDY

While the study provides robust quantitative analysis, several limitations should be noted. First, the seismic simulations were based on generalized soil conditions and may not reflect micro-level variations in actual construction sites. Second, cost estimations for retrofitting were based on model buildings and may vary in real-world applications. Finally, public perception data was collected via online surveys, which may have limited the representativeness of certain demographics.

- Future studies should focus on:
- Site-specific geotechnical investigations to refine zonation maps.
- Longitudinal tracking of pilot retrofitting projects to evaluate real-world cost and performance.
- Economic modeling that includes indirect benefits such as reduced casualties, insurance premiums, and business continuity

RECOMMENDATIONS

Based on the quantitative data, several key recommendations are proposed:

- Seismic Microzonation: Implement a city-wide microzonation map to classify areas based on soil response and seismic risk. This would enable differential code application based on local geotechnical conditions.
- Mandatory Seismic Assessment for New Projects: Update the Hong Kong Building Ordinance to require seismic load calculations and resilience audits for buildings over 10 stories.
- Incentivized Retrofitting: Introduce tax rebates or low-interest loans for retrofitting older buildings, especially public schools, hospitals, and housing estates.
- Training and Capacity Building: Develop specialized training programs for architects, engineers, and inspectors to improve knowledge of seismic-resistant design.
- Public Engagement: Launch public awareness campaigns to educate citizens on the importance of seismic resilience and encourage grassroots demand for safer construction.
- Introduce Seismic Design Standards: Amend the HKBO to include seismic loading parameters similar to Japan’s Building Standard Law (MLIT Japan, 2019).

- Mandatory Retrofitting of High-Risk Structures: Especially buildings built before 1980.
- Subsidies for Retrofitting Costs: For older private and public housing estates.
- Seismic Risk Zoning: Establish localized micro-zonation mapping to assess geological amplification risks.
- Training and Certification: Establish a continuing education framework for engineers on earthquake-resistant design.

5. CONCLUSION

This study confirms that the professional construction community in Hong Kong recognizes the vulnerability of current infrastructure to seismic events and supports the integration of seismic-resilience into building regulations. Quantitative evidence suggests both awareness and readiness for change. Policymakers must act on this professional consensus and implement forward-thinking construction codes to protect the city's infrastructure and population.

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