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Innovative Seismic Design for Resilient Civil Structures

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Introduction

This paper investigates the seismic performance of long-span suspension bridges, critically accounting for soil-structure interaction. It proposes an integrated design approach that moves beyond traditional fixed-base assumptions. The research uses advanced numerical models to evaluate seismic responses, demonstrating how proper consideration of soil characteristics can lead to more resilient bridge designs, especially under severe earthquake scenarios [1].

This study examines the seismic vulnerability and resilience of high-rise concrete buildings, focusing on different design methodologies. It develops fragility curves to quantify the probability of damage at various earthquake intensities and assesses the buildings capacity to recover post-event. The findings offer valuable insights into enhancing urban resilience by identifying design practices that lead to more robust structures capable of minimizing downtime and repair costs after seismic events [2].

The research investigates the effectiveness of combining base isolation with tuned mass dampers (TMDs) in enhancing the seismic performance of structures. Specifically, it analyzes systems employing lead rubber bearings (LRBs) for isolation. The study demonstrates that this hybrid approach can significantly reduce structural response and improve safety margins during earthquakes, offering a compelling strategy for designing critical facilities in seismically active regions [3].

This article explores innovative methods for retrofitting existing reinforced concrete (RC) columns that dont meet current seismic standards. It specifically focuses on the application of advanced fiber-reinforced polymer (FRP) composites. The research highlights how FRP wrapping can substantially enhance the strength and ductility of columns, thereby improving their overall seismic resistance and extending the lifespan of vital infrastructure [4].

This study presents an optimization framework for the performance-based seismic design of steel moment-resisting frames. It integrates lifecycle cost and environmental impact considerations, offering a holistic approach beyond just structural safety. The methodology aims to achieve designs that are not only resilient to earthquakes but also economically viable and environmentally responsible throughout their service life, promoting sustainable construction practices [5].

This paper provides a comparative analysis of seismic design provisions for multistory steel frame buildings as mandated by various international building codes. It identifies key differences and commonalities in design philosophies and detailing requirements. The insights gained are crucial for engineers working on projects with global implications, helping them navigate complex regulatory landscapes and ensure consistent safety standards across different jurisdictions [6].

This research presents an experimental and numerical study on improving the seismic resistance of unreinforced masonry (URM) walls, a common vulnerability in older structures. It investigates the effectiveness of strengthening URM walls using Textile-Reinforced Mortar (TRM). The findings confirm that TRM significantly enhances the in-plane and out-of-plane capacity of these walls, offering a viable and less intrusive retrofitting solution for historical or vulnerable masonry buildings [7].

This study evaluates the seismic performance of multi-span bridges equipped with triple friction pendulum (TFP) bearings, analyzing their response to a range of ground motions. It highlights the benefits of TFP bearings in decoupling the bridge superstructure from ground shaking, effectively reducing seismic forces transmitted to the piers. The research provides critical data for designers considering advanced isolation systems for bridges in high seismic zones [8].

This paper focuses on the critical aspect of achieving immediate functional recovery for hospitals through performance-based seismic design. It outlines methodologies that ensure these essential facilities remain operational post-earthquake, a crucial consideration for disaster response and public health. The work emphasizes designing for resilience, not just structural integrity, offering pathways to minimize downtime and ensure continuous healthcare services [9].

This study presents experimental results on the seismic performance of a five-story cross-laminated timber (CLT) building, demonstrating the potential of mass timber in earthquake-resistant construction. The findings indicate that properly designed CLT structures exhibit excellent seismic behavior, including good energy dissipation and minimal damage under strong ground motions. This research contributes significantly to the adoption of sustainable timber solutions in seismically active regions [10].

Description

This paper investigates the seismic performance of long-span suspension bridges, critically accounting for soil-structure interaction. It proposes an integrated design approach that moves beyond traditional fixed-base assumptions [1]. The research uses advanced numerical models to evaluate seismic responses, demonstrating how proper consideration of soil characteristics can lead to more resilient bridge designs, especially under severe earthquake scenarios. In a related vein, another study evaluates the seismic performance of multi-span bridges equipped with triple friction pendulum (TFP) bearings, analyzing their response to a range of ground motions [8]. This analysis highlights the benefits of TFP bearings in effectively decoupling the bridge superstructure from ground shaking, which significantly reduces seismic forces transmitted to the piers. This research provides critical data for designers considering advanced isolation systems for bridges located in high seismic zones.

Turning to buildings, one significant study examines the seismic vulnerability and resilience of high-rise concrete buildings, focusing on different design methodologies [2]. It meticulously develops fragility curves to quantify the probability of damage at various earthquake intensities and rigorously assesses the buildings capacity to recover post-event. The findings from this work offer valuable insights into enhancing urban resilience by identifying specific design practices that lead to more robust structures, capable of minimizing downtime and repair costs after seismic events. Furthermore, an optimization framework for the performance-based seismic design of steel moment-resisting frames is presented, integrating lifecycle cost and environmental impact considerations [5]. This offers a holistic approach beyond just structural safety, aiming for designs that are not only resilient but also economically viable and environmentally responsible throughout their service life. This promotes sustainable construction practices. Another important area of investigation involves a comparative analysis of seismic design provisions for multi-story steel frame buildings as mandated by various international building codes [6]. This work identifies key differences and commonalities in design philosophies and detailing requirements, providing crucial insights for engineers working on projects with global implications, helping them navigate complex regulatory landscapes and ensure consistent safety standards across different jurisdictions.

Regarding structural enhancement, the research investigates innovative methods for retrofitting existing reinforced concrete (RC) columns that do not meet current seismic standards [4]. It specifically focuses on the application of advanced fiber-reinforced polymer (FRP) composites. This research highlights how FRP wrapping can substantially enhance the strength and ductility of columns, thereby significantly improving their overall seismic resistance and extending the lifespan of vital infrastructure. Concurrently, another study presents an experimental and numerical investigation into improving the seismic resistance of unreinforced masonry (URM) walls, which represent a common vulnerability in older structures [7]. This study rigorously investigates the effectiveness of strengthening URM walls using Textile-Reinforced Mortar (TRM). The findings confirm that TRM significantly enhances both the in-plane and out-of-plane capacity of these walls, offering a viable and less intrusive retrofitting solution particularly suitable for historical or vulnerable masonry buildings.

In the realm of advanced seismic control, the effectiveness of combining base isolation with tuned mass dampers (TMDs) in enhancing the seismic performance of structures is thoroughly investigated [3]. Specifically, this analysis focuses on systems employing lead rubber bearings (LRBs) for isolation. The study conclusively demonstrates that this hybrid approach can significantly reduce structural response and measurably improve safety margins during earthquakes, thus offering a compelling and advanced strategy for designing critical facilities located in seismically active regions.

Finally, practical applications for critical infrastructure are explored. One paper focuses on the critical aspect of achieving immediate functional recovery for hospitals through performance-based seismic design [9]. It meticulously outlines methodologies that ensure these essential facilities remain operational post-earthquake, which is a crucial consideration for effective disaster response and public health. This work emphasizes designing for resilience, extending beyond mere structural integrity, offering clear pathways to minimize downtime and ensure continuous healthcare services. In a separate but equally important study, experimental results are presented on the seismic performance of a five-story cross-laminated timber (CLT) building, demonstrating the considerable potential of mass timber in earthquake-resistant construction [10]. The findings indicate that properly designed CLT structures exhibit excellent seismic behavior, including good energy dissipation and minimal damage even under strong ground motions. This research contributes significantly to the broader adoption of sustainable timber solutions within seismically active regions.

Conclusion

This collection of research explores various aspects of enhancing seismic performance and resilience across diverse civil engineering structures. The studies investigate seismic performance-based design for long-span suspension bridges, critically considering soil-structure interaction to foster more resilient designs. Research also assesses the seismic vulnerability and resilience of high-rise concrete buildings, developing fragility curves and identifying design practices that minimize post-earthquake damage and recovery costs. Innovative seismic protection systems, such as combining base isolation with tuned mass dampers using lead rubber bearings, are examined for their effectiveness in reducing structural responses. Furthermore, the papers delve into advanced retrofitting methods for reinforced concrete columns utilizing fiber-reinforced polymer composites to enhance strength and ductility. An optimization framework for performance-based seismic design of steel moment-resisting frames integrates lifecycle cost and environmental impact, advocating for sustainable construction. Comparative analyses of international seismic design codes for multi-story steel frames provide crucial insights for global projects. Additional studies present findings on strengthening unreinforced masonry walls with Textile-Reinforced Mortar and evaluating triple friction pendulum bearings for multi-span bridge performance. The research also highlights achieving immediate functional recovery for hospitals through specialized performance-based design and validates the excellent seismic behavior of Cross-Laminated Timber buildings, promoting sustainable earthquake-resistant solutions.

Acknowledgement

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Conflict of Interest

None.

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