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Self Centering Seismic Resistant Structures

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A B S T R A C T

This paper presents an overview of high-performance seismic structural systems, including innovative designs like Resilient Steel Eccentric (RSE), Reinforced Concrete Rocking Core (RCRC), and Seismically Controlled Rocking Steel Frame Systems (SCSRS). These systems aim to enhance earthquake resilience by sustaining minimal to no damage and featuring self-centering mechanisms for post- earthquake recovery. The review delves into self-centering steel frame systems, highlighting post-tensioned connections, self-centering braces, and energy dissipating devices. Additionally, it discusses a novel self-centering column base for earthquake restoration, along with quasi-static tests on group specimens and investigations into replacing stiffener angle steels with re-tensioning post-tensioned strands. Furthermore, recent research on seismic resilience enhancement through SC mass timber structures is covered, encompassing experimental, analytical, and numerical studies, showcasing technological advancements.

1. INTRODUCTION

This paper undertakes a review of high-performance DRSRS (Displacement Responsive Seismic Systems) geared towards fostering resilient cities, with a particular emphasis on seismic behaviors and energy dissipation within structural systems. It delves into the realm of self-centering seismic systems, geared towards fostering resilience and sustainability in urban environments, with a focus on minimizing structural damage and lowering repair costs following seismic events. The paper highlights self-centering steel frame systems designed to withstand seismic forces, with a specific focus on post-tensioned connections, self-centering braces, and mechanisms for energy dissipation. Moreover, it directs attention towards seismic resilient structures engineered for rapid post-earthquake recovery, introducing a novel self-centering column base equipped with replaceable stiffener angle steels. Lastly, it examines the recent advancements in SC (Self-Centering) mass timber structures, offering insights into progress made since 2019 through experimental, analytical, and numerical studies, elucidating key design considerations for seismic resilience.

2. REVIEW OF LITERATURES

2.1 Junhua Wang and Hua Zhao.

This literature study conducts an in-depth analysis of Displacement Responsive Seismic Resistant Systems (DRSRS), thoroughly examining their seismic behaviors, energy dissipation mechanisms, and the multifaceted research challenges they entail. It meticulously summarizes the existing landscape of DRSRS systems, elucidating their methodologies, structural intricacies, and persistent challenges impeding their widespread adoption. Moreover, it delves into the current research status surrounding DRSRS, outlining pressing challenges and offering insightful recommendations to propel future advancements. Through its comprehensive approach, this study aims to foster innovation and resilience in seismic-prone regions, contributing to the development of more effective and sustainable structural solutions. In essence, it stands as a beacon of knowledge, guiding researchers and practitioners toward a better understanding of seismic-resistant structures and paving the way for a more resilient built environment in the face of seismic hazards.

2.2 Nathan Brent Chancellor,Matthew Eatherton,David Roke,Tuğçe Akbaş

This study provides a comprehensive overview of self-centering seismic systems, delving into their fundamental principles, research challenges, and the underlying motivations driving their development. It meticulously summarizes the key aspects of self-centering seismic systems, elucidating their innovative mechanisms designed to mitigate structural damage during seismic events. Additionally, it sheds light on the formidable research challenges inherent in the development and implementation of such systems, ranging from technical complexities to practical limitations. Furthermore, the study explores the intrinsic motivations fueling the development of self-centering seismic systems, emphasizing the urgent need for resilient infrastructure capable of withstanding seismic hazards while minimizing damage and ensuring occupant safety. Through its nuanced analysis, this study seeks to inspire further research and innovation in the field, ultimately advancing the state-of-the-art in seismic-resistant structural engineering.

2.3 Lihua Zhu,Cheng Zhao

This review meticulously examines self-centering steel frame systems tailored for seismic-resistant structures, with a specific emphasis on their self-centering connections, braces, and full frames. It provides an in-depth analysis of the structural details, test results, and pivotal conclusions drawn from empirical studies, offering valuable insights into the efficacy and practical implications of these systems. Moreover, the review offers critical commentary on existing studies, highlighting their strengths and limitations, and provides suggestions for further research avenues to address unresolved challenges. It underscores the importance of addressing critical issues such as structural performance under extreme loading conditions and the optimization of design parameters to enhance the resilience and functionality of self-centering steel frame systems. Through its comprehensive approach, this review serves as a valuable resource for researchers and practitioners in the field, guiding future developments and advancements in seismic-resistant structural engineering.

2.4 Dongde Sun, Yong Yang, Yinke Ma, Yicong Xue, Yunlong Yu, Shiqiang Feng

This study directs its focus towards seismic-resilient structures, advocating for a replaceable philosophy in structural design that prioritizes the rapid recovery of building functions post-earthquake with minimal interruption. It underscores the critical importance of designing structures that can swiftly rebound from seismic events, ensuring the continuity of essential functions and minimizing the socio-economic impact of disasters. Through its emphasis on resilience, the study highlights the need for innovative design approaches that integrate replaceable components and resilient materials, enabling structures to withstand seismic forces while facilitating prompt restoration. By championing this replaceable philosophy, the study aims to foster a paradigm shift in structural engineering towards proactive risk mitigation and enhanced disaster preparedness, ultimately contributing to safer and more resilient built environments in seismic-prone regions.

2.5 Fei Chen

The study introduces the Monotonic Beam Analogy (MBA) method as a novel approach for analyzing self-centering (SC) concrete structures, providing a robust framework for evaluating their seismic performance and behavior. It explores various modeling techniques, including distributed spring models, fiber element models, and lumped spring models, which are integral components of the MBA method. Through the utilization of these modeling approaches, the study aims to enhance the understanding of the structural response of SC concrete structures under seismic loading conditions. By employing distributed spring models, fiber element models, and lumped spring models within the MBA method, researchers can accurately simulate the behavior of SC concrete structures, enabling engineers to optimize design parameters and improve overall seismic resilience. Through its innovative methodology and comprehensive modeling techniques, this study contributes to advancing the field of seismic-resistant structural engineering, paving the way for the development of more resilient and sustainable concrete structures.

3. METHODS UTILIZED

Various innovative methods have been employed in seismic-resistant structural engineering to enhance resilience against earthquakes. These methods include implementing rocking wall systems and slip-friction connectors, utilizing ultrahigh strength rebar, and integrating base isolation techniques. Additionally, gap opening mechanisms have been employed to facilitate nonlinear elastic behavior, while post-tensioning techniques are utilized to restore structures to their upright position after seismic events.

A comprehensive review of self-centering steel frame systems has been conducted, encompassing both experimental and theoretical investigations into self- centering systems with integrated energy dissipation mechanisms. Furthermore, methods such as secant stiffness calculation, moment calculation verification, and the implementation of loading protocols have been employed to assess structural performance and validate analytical predictions.

Moreover, the Monotonic Beam Analogy (MBA) method has been introduced for the analysis of self-centering concrete structures. This method incorporates distributed spring models, fiber element models, and lumped spring models to accurately simulate the behavior of self-centering systems and evaluate their seismic performance. Through the utilization of these diverse methods, researchers aim to advance the field of seismic-resistant structural engineering and develop more resilient and sustainable infrastructure.

4. FUTURE STUDY

The forthcoming research endeavors in seismic-resistant structural engineering are poised to address critical areas for further advancement and innovation. One avenue of study involves investigating residual deformation under reversed cyclic seismic loading for Displacement Responsive Seismic Resistant Systems (DRSRS), aiming to deepen our understanding of their long-term performance and durability. Additionally, there is a focus on analyzing the seismic behaviors of concrete columns reinforced by Super Relastic Shape Memory Alloy (SBPDN) bars, with the aim of enhancing structural resilience and performance.

Furthermore, ongoing research endeavors seek to quantify the life-cycle costs of self-centering systems compared to conventional systems, with a particular emphasis on addressing performance goals aimed at reducing repair costs and minimizing business downtime following seismic events.

Moreover, investigations into the impact of prestress loss on seismic performance in self-centering structures are underway, alongside the development of design guidelines for integrating Shape Memory Alloy (SMA) and prepressed springs in connections to optimize structural performance.

Future studies are anticipated to explore the self-centering properties of structures under diverse seismic conditions, facilitating the development of adaptive and resilient structural systems. Additionally, research efforts will investigate the impact of various materials on friction column-base joints, aiming to optimize their performance and durability in seismic events.

Moreover, the exploration of Shape Memory Alloy (SMA) materials in Self-Centering (SC) timber structures presents a promising avenue for enhancing resilience in timber constructions. Further investigations will delve into the utilization of SMA wires for reinforcing mortise-tenon joints in timber structures, paving the way for innovative solutions to bolster seismic resilience in timber-based constructions. These future studies hold immense potential to revolutionize seismic-resistant structural engineering and contribute to the development of safer and more resilient built environments.

5. CONCLUSION

In conclusion, seismic-resistant structural systems like RSRS and SCSS, along with shear walls featuring replaceable coupling beams, offer promising solutions for limiting post-earthquake damage. While numerical modeling has advanced understanding, challenges persist in floor diaphragm connections and collapse safety. Self-centering systems, complemented by post-tensioning, show reduced damage and drift post-earthquake, with lower life-cycle costs. Further research is imperative for developing comprehensive design guidelines, especially for self-centering steel frames. Column bases exhibit seismic redundancy and recoverability, with cost-effective improvements through stiffener angle steel replacements and post-tensioned strand re-tensioning. SC technology holds potential for enhancing resilience in mass timber structures, though challenges in achieving high composite actions remain. Continued interdisciplinary collaboration is essential for advancing seismic-resistant structural engineering and ensuring safer, more resilient built environments in seismic-prone regions

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