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A Review of Base Isolation Technologies and Their Applications in Indian Seismic Zones

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ABSTRACT

Enhancing structural resilience in high-seismic regions like India is crucial. Earthquakes pose significant threats to buildings, necessitating innovative solutions like base isolation, which reduces structural damage by decoupling the superstructure from ground vibrations. This study highlights the importance of base isolators in India's diverse architectural landscape, focusing on both regular and irregular structures to improve performance, reduce vulnerability, and promote sustainable development. High-rise buildings, with their unique challenges due to height and mass distribution, benefit from advancements in seismic design and retrofitting. Implementing base isolation in high-rises requires careful consideration of stability and performance factors. This study reviews recent research on base isolation in high-rises, identifying key findings and gaps, including long-term performance, maintenance, and cost-effectiveness. Additionally, it examines the interaction between base isolators and other structural components, emphasizing the need for comprehensive design guidelines. By reviewing various seismic mitigation strategies, this research aims to enhance high-rise resilience and ensure safer urban environments.

Keywords —ETAB, Multi Earthquakes, Base Insolation, High Rise Buildings.

I. INTRODUCTION

In high-seismic regions like India, enhancing structural resilience against earthquakes is a critical endeavor. Seismic events pose significant threats to buildings and infrastructure, necessitating innovative engineering solutions to mitigate the potentially catastrophic consequences of such natural disasters. Among these solutions, base isolation has emerged as a promising strategy to minimize structural damage and ensure occupant safety during seismic events. Base isolation effectively isolates the superstructure from ground vibrations, reducing the transfer of damaging forces and displacements. This mechanism offers a unique solution to the dynamic forces generated by earthquakes, which often challenge conventional structural designs.

The significance of studying the efficacy of base isolators in high-seismic regions of India is underscored by the country's diverse architectural landscape and varying seismic hazards. India experiences seismic activity across different regions, each presenting unique challenges to structural engineers and designers. Regular and irregular structures, characterized by differences in geometry, mass distribution, and stiffness, demand tailored approaches to seismic mitigation. Understanding how base isolators influence both types of structures is essential for devising effective seismic retrofitting strategies and informing future construction practices.

Furthermore, the socio-economic implications of seismic events highlight the importance of robust structural design and risk reduction measures. In densely populated urban areas, the resilience of buildings and infrastructure directly impacts public safety, economic stability, and community well-being. By evaluating the impact of base isolators on regular and irregular structures, this research aims to contribute valuable insights into enhancing structural performance, reducing vulnerability, and fostering sustainable development in high-seismic regions of India.

The quest for enhancing the seismic resilience of high-rise structures has been a focal point in structural engineering, particularly in regions prone to significant seismic activity. As earthquakes continue to pose substantial threats to buildings and infrastructure, innovative solutions like base isolation have gained prominence for their potential to mitigate seismic-induced damage and ensure structural integrity. This introduction aims to provide an overview of recent research endeavors focused on the application of base isolators in high-rise structures, highlighting key findings and identifying existing research gaps.

Base isolation, a seismic retrofitting technique, involves decoupling the superstructure from the ground motion using specialized bearings or isolators. By isolating the building from seismic waves, base isolators effectively reduce the transmission of damaging forces and displacements, thereby enhancing the structure's ability to withstand earthquakes. While base isolation has been extensively studied and implemented in various structural typologies, including low-rise buildings and historical structures, its application in high-rise buildings presents unique challenges and opportunities.

High-rise buildings, due to their height and mass, interact with seismic forces differently compared to low-rise structures. The distribution of mass and stiffness along the height of the building, as well as the dynamic characteristics, play crucial roles in their seismic response. Implementing base isolation in high-rise buildings requires careful consideration of these factors to ensure that the isolators can effectively reduce seismic forces without compromising the stability and performance of the structure.

Recent research has explored various aspects of base isolation in high-rise buildings, including the design and optimization of isolators, the impact on structural dynamics, and the performance under different seismic scenarios. These studies have provided valuable insights into the benefits and limitations of base isolation for high-rise buildings. However, there are still gaps in understanding the long-term performance, maintenance requirements, and cost-effectiveness of base isolators in these structures.

Additionally, the interaction between base isolators and other structural and non-structural components in high-rise buildings needs further investigation. The behavior of elevators, staircases, utility lines, and other systems integrated within the building can significantly influence the overall performance during seismic events. Addressing these issues is crucial for developing comprehensive design guidelines and best practices for implementing base isolation in high-rise buildings.

II. IMPACT OF EARTHQUAKE LOAD ON STRUCTURE

The impact of earthquakes on high-rise structures is a critical concern due to their height and complex configurations, making them particularly vulnerable to dynamic seismic forces. Understanding these challenges is essential for designing resilient buildings, ensuring safety, and minimizing damage.

Seismic events cause ground motion that affects structures, with the impact on high-rises varying by shaking intensity, duration, proximity to the epicenter, and structural characteristics. A major concern is vertical amplification, where upper floors experience higher accelerations and displacements, leading to significant structural demands and potential damage.

The behavior of high-rise structures during earthquakes depends on mass distribution, stiffness, and damping properties. Irregularities in geometry and structural discontinuities can cause localized stress and uneven force distribution, increasing the risk of damage and collapse. Building codes set seismic design criteria, but compliance alone doesn't ensure absolute protection, especially in high-risk areas.

Advancements in seismic design and retrofitting, like base isolation, tuned mass dampers, and advanced damping systems, have improved high-rise resilience. Developments in structural analysis methods, such as finite element analysis and performance-based design, enhance predictions of building behavior under seismic loading.

Despite these advancements, earthquakes remain a significant challenge for high-rise structures, causing damage, infrastructure disruption, loss of life, and economic impact. As urbanization increases high-rise construction in seismic regions, prioritizing seismic resilience and adopting comprehensive mitigation strategies is imperative.

III. BASE ISOLATOR

A base isolator is a mechanical device used in structural engineering to reduce the impact of seismic forces on buildings and infrastructure. It works by separating the superstructure from ground movement during earthquakes, thereby minimizing the transmission of seismic energy and reducing structural damage. Typically, base isolators consist of resilient materials like rubber bearings or elastomeric pads, installed between the foundation and the structure's base. Their primary function is to provide flexibility and damping, allowing the superstructure to move independently of the ground motion during an earthquake. This isolation mechanism decreases the acceleration, velocity, and displacement experienced by the structure, enhancing its seismic resilience. By protecting the integrity of the building and ensuring occupant safety, base isolators reduce the likelihood of structural collapse or damage.

Base isolators are integrated into the foundation system of buildings or bridges during construction or retrofitting. They are carefully positioned at the base of the structure to form a strong connection between the ground and the superstructure. The selection and design of base isolators depend on various factors, including the structure's height, mass, stiffness, and the expected level of seismic activity in the area. Besides reducing structural damage, base isolators also minimize the transfer of seismic forces to non-structural components and building contents, such as utilities, equipment, and furnishings. This comprehensive approach to seismic mitigation helps preserve the functionality and usability of buildings after an earthquake, facilitating rapid recovery and minimizing downtime.

Base isolators play a crucial role in enhancing the seismic resilience of buildings and infrastructure by isolating them from ground motion and reducing the risk of damage or collapse during earthquakes. Their effectiveness in protecting structures and ensuring occupant safety has made them a widely used and proven seismic retrofitting strategy in earthquake-prone regions worldwide.

IV. LITERATURE REVIEW

Rodriguez et al. (2024) conducted a comprehensive comparative analysis of methods for assessing seismic responses in structures, focusing on maximum displacements and collapse evaluation. They applied modal spectral analysis, non-linear dynamic analysis, and incremental pushover analysis to a specific structure and compared the results. The study highlighted the importance of time step selection and ductility inclusion for accurate predictions. Non-linear dynamic analysis indicated that a seismic event similar to the 2011 Lorca earthquake would severely impact the studied structure, emphasizing the significance of finite element method modeling for predicting plastic hinge formation and assessing structural safety. The findings underscore the need for multiple analytical approaches and detailed modeling to understand seismic behavior and ensure resilience and stability during extreme events.

Campiche et al. (2024) presented key findings from the Ecclissa research project, introducing an innovative wall system engineered to withstand severe seismic events. The system features a Cold-Formed Steel (CFS) frame with pre-installed Ultra-High-Strength (UHS) bars arranged in a "V" configuration, enhancing horizontal resistance. The v-bracing system incorporates CFS walls and pre-reinforced UHS bars. Extensive design procedures and experimental operations evaluated the Light Frame-Reinforced Structure (LFR) wall system's overall and local performance. Tests assessed material properties and system performance under dynamic loading conditions, indicating that a properly designed LFRS system can effectively withstand seismic loads by preventing plastic deformations in UHS members and maintaining elastic behavior in other elements.

Gao et al. (2024) proposed a simplified simulation method for scaffold design and optimization, summarizing column placement rules. The scaffold consists of horizontal, vertical, and diagonal members, with the bracing system providing lateral rigidity. The study compared stiffness in concentric braced, eccentric braced, and knee braced designs using finite element simulations and theoretical formulas. The analysis showed that overall support arrangements exhibited greater stiffness compared to center-span central support, lateral center support, and low-height support arrangements. Guidelines for scaffold design emphasize consistent connections between levels and lower weak layers, facilitating reasonable calculations of scaffold lateral stiffness.

Evangelos et al. (2024) introduced a further vibration-controlled system (VCS) into isolated base (IB) structures to moderate seismic activity and reduce base displacement. The VCS used an improved k-damper principle, mechanically reinforcing the resultant force to align with the inertial force of the linked mass. This integrated optimization approach enhanced damping qualities, using customized acceleration data and real earthquake measurements to evaluate the VCS's efficacy. The k-damper-based VCS outperformed other tuned mass systems in enhancing dynamic behavior.

Li et al. (2024) recommended installing a concave barrier mechanism at the structure's base to limit rotations and capitalize on the egocentric nature of curling motion during earthquakes. Experimental studies showed that the proposed design reduced internal seismic waves by over 50%, improving seismic resistance and achieving effective seismic isolation for column structures. The study emphasized the importance of considering velocity spectrum constraints in seismic design.

Akhare et al. (2023) examined the effect of an inert fluid damper (FID) on high-rise structures with separate foundations and traditional brickwork. Using a multilayer shear structure model, the study evaluated the seismic response under various ground motion measurements. The FID effectively reduced base displacement and top floor acceleration, with greater effectiveness observed in flexible, base-isolated structures. The study found that increased FID inertance ratios led to decreased base displacement values, enhancing seismic resilience.

Jouneghani et al. (2023) analyzed the impact of lateral dampers on multi-floor steel structures, demonstrating that dampers and rigid cores effectively reduced lateral displacement in base isolation systems, particularly in low-rise buildings. The study proposed a precautionary approach for reducing lateral movement during nearby earthquakes.

Pilli et al. (2023) evaluated the performance of a G+9 warehouse with friction expansion and rubber pad isolation systems using SAP 2000 software. The analysis indicated that seismic isolation effectively controlled seismic parameters like connection displacement, shear force, and bending moment. The friction pendulum model and rubber-based model showed significant reductions in base shear force, highlighting their effectiveness as supplementary damping systems for managing seismic loads. The friction pendulum bearing system was identified as the optimal isolation system for the studied building.

V. CONCLUSIONS

The application of base isolation in high-rise structures holds great potential for enhancing seismic resilience and ensuring the safety and integrity of buildings in high-seismic regions like India. Continued research and innovation are essential to address the challenges and fully realize the benefits of this promising seismic mitigation strategy. This study aims to contribute to the growing body of knowledge by providing detailed analysis and evaluation of base isolator performance in regular and irregular high-rise buildings, ultimately contributing to safer and more resilient urban environments.

REFERENCES

[1] Cesar A. Rodriguez, Angel Mariano Rodriguez Perez, Raul Lopez, and Julio Jose Caparros Mancera, "Comparative Analysis and Evaluation of Seismic Response in Structures: Perspectives from Non-Linear Dynamic Analysis to Pushover Analysis", Applied Sciences, Special Issue Structural Analysis and Seismic Resilience in Civil Engineering, 2024.

[2] Cesar A. Rodriguez, Angel Mariano Rodriguez Perez, Raul Lopez, and Julio Jose Caparros Mancera, "Comparative Analysis and Evaluation of Seismic Response in Structures: Perspectives from Non-Linear Dynamic Analysis to Pushover Analysis", Applied Sciences, Special Issue Structural Analysis and Seismic Resilience in Civil Engineering, 2024.

[3] Alessia Campiche, Roberto Tartaglia, Luigi Fiorino, Raffaele Landolfo, "Experimental tests for the evaluation of the seismic performance of the innovative CFS wall", Thin-Walled Structures, Vol. 198, May 2024.

[4] Ruiqi Gao, Keqi Huang, Xiaomin Liu, Junlong Zhou, Qian Zhang, Yikang Li, Hao Xu, Buyuan Tian, Birun Ye and Yichao Zhao, "Analysis and optimization of brace system in scaffold", Journal of Physics: Conference Series, Vol. 2732, The 2nd International Conference on Algorithms, Network and Computer Technology, 2024.

[5] Sapountzakis, Evangelos, Georgios Florakis, and Konstantinos Kapasakalis. "Design and Performance Assessment of Base Isolated Structures Supplemented with Vibration Control Systems." Buildings 14.4: 955, 2024

[6] Sheng Li, Yao Hu, Zhicheng Lu, Bo Song and Guozhong Huang,"Seismic Isolation of Fragile Pole-Type Structures by Rocking with Base Restraints." Buildings 14.4: 1176, 2024.

[7] Surchandrajeet Kamble and P.S.Lande, "Evaluation of seismic performance of diagrid building with different arrangement of secondary bracing system", Journal of Emerging Technologies and Innovative Research (JETIR), Vol. 10, Issue. 7, pp. 123-129, 2023.

[8] Ashish R. Akhare, "Seismic response control of base-isolated structures with fluid inerter damper." International Journal of Structural Engineering 13.1, PP. 1-21, 2023.

[9] Kourosh Talebi Jouneghani, Mahmood Hosseını, Mohammad Sadegh Rohanımanesh, Morteza Raıssı, "Building's Controlled Seismic Isolation by Using Upper Horizontal Dampers and Stiff Core." Turkish Journal of Civil Engineering 34.3, pp. 1-42, 2023.

[10] Deepika, Pilli, and D. Surendra. "Base Isolation System and Energy Dissipating System in Earthquake Resistant Building Design." Journal of Engineering Sciences, 2023.

[11] Asma Belbachir, Abdelkader Benanane, Abderrahmane Ouazir, Zouaoui R. Harrat, Marijana Hadzima-Nyarko, Dorin Radu, Ercan Işık, Zouhir S. M. Louhibi and Sofiane Amziane,"Enhancing the Seismic Response of Residential RC Buildings with an Innovative Base Isolation Technique." Sustainability, 2023.

[12] Manoj Kumar Sharma, Hemant Kumar Sain, "Develop Approximate Analytical Models for Separated Seismic Analysis of Connected Buildings by SAP 2000", International Journal of Engineering Trends and Applications (IJETA), Vol. 11, Issue. 1, pp. 22-26, 2024.

[13] Hemant Kumar Sain, Krishana wadhwani, Rohit Vashishth, Vikash Siddh, "Experimental Study of Floating Concrete With Light Weight Aggregate", Third International Conference on Advances in Physical Sciences and Materials 2022, AIP Conference Proceedings, 2023.

[14] Sneha Mathew, Hemant Kumar Sain, "An Innovative Study on Utilisation of Pareva Dust and Quartz Sand in Concrete", Key Engineering Materials, Vol. 961, pp. 135-140, 2023.

[15] Manoj Kumar Sharma, Hemant Kumar Sain, "A Review on Seismic Analysis of Connected and High Rise Buildings", International Journal of Engineering Trends and Applications (IJETA), Vol. 11, Issue. 1, pp. 18-21, 2024.

[16] Dr. I.C.Sharma Mr Kshitij Gupta, "Structure Health Monitoring Using Vibration-Based Technique", International Journal for research in applied Science& Engineering Technology, Vol. 7, 2019.

[17] Ms Geetanajali Ganguly, Dr. I.C.Sharma, "Sustainable Solid Waste Management, Smart Cities and Swatch Bharat Initiative", Institute of Technology & Engineering Jaipur, 2017.

[18] Ishwar Chand Sharma & Dr. N.C. Saxena, "Engineering Utilization Of Marble Slurry", International journal of civil engineering and technology(IJCIET), Vol. 3, Issue. 2, pp. 1-6, 2012.

[19] Dr I .C.Sharma, Gori Shankar Soni, "Assessment of Limestone Dust and Chips as Eco-friendly Alternatives in Concrete Production", International Journal of Engineering Trends and Applications (IJETA), 2024.