ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Impact Factor: 8.206

Volume 8, Issue 5, May 2025

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

© 2025 IJMRSET | Volume 8, Issue 5, May 2025| DOI:10.15680/IJMRSET.2025.0805046

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Review On the Role of Base Isolation in Modern Earthquake Engineering

Maaz Ahmed Khan, Prof. Hemant Dahake

Student M. Tech, Dept. of Civil Engineering, G.H. Raisoni University, Amaravati, India

Head, Dept. of Civil Engineering, G.H. Raisoni University, Amaravati, India

ABSTRACT: Base isolation has become one of the most prominent and effective methods for protecting structures from earthquake-induced damage, particularly through its ability to decouple buildings from seismic forces. Earthquakes pose significant risks due to the destructive nature of ground shaking, often leading to the collapse of buildings and infrastructure. The extent of the damage depends on various factors, including the intensity and frequency of the ground motion, soil conditions, the characteristics of the building, and the quality of its construction. Therefore, it is vital to reinforce buildings before earthquakes occur by assessing their structural integrity and reinforcing weak points. Base isolation addresses these challenges by incorporating a flexible layer of isolators, such as rubber bearings or friction bearings, between the building's foundation and superstructure. In addition to design, proper construction methods and materials are essential to ensuring the effectiveness of earthquake-resistant buildings. Poor construction practices, such as improper concrete mixing, insufficient curing, or substandard materials, can lead to failures in buildings during earthquakes. In regions with less developed construction standards or enforcement, the implementation of local building codes and quality control measures is critical for reducing earthquake risks.

I. INTRODUCTION

Earthquakes are one of the most devastating natural disasters, capable of causing massive destruction to infrastructure, significant loss of life, and substantial economic damage. The unpredictable nature of earthquakes, with their varying magnitudes, frequencies, and durations, makes it extremely challenging to design structures that can effectively withstand seismic forces. The seismic forces generated during an earthquake are transmitted to buildings and other structures, resulting in damage that can range from minor cracks to complete structural collapse. This presents a significant challenge, especially in earthquake-prone regions where high-density populations and critical infrastructure are at risk.

In response to the increasing frequency and severity of seismic events, researchers and engineers have developed a variety of mitigation techniques aimed at reducing the impact of earthquakes on buildings, bridges, water tanks, and other civil structures. One such technique that has proven to be particularly effective is base isolation. Base isolation is a seismic protection strategy that decouples the superstructure (the building or infrastructure above ground level) from the foundation, allowing the structure to move independently of the ground motion. This decoupling process reduces the amount of seismic energy transmitted to the structure, thus mitigating the potential for damage during an earthquake. Base isolation systems work by introducing flexible, energy-dissipating elements—typically bearings or isolators—between the foundation and the building. These isolators allow for controlled movement, enabling the superstructure to absorb and dissipate seismic energy, while preventing excessive lateral displacements or accelerations that could lead to structural failure.

II. LITERATURE REVIEW

Lin Su et al. (2018) [1], introduced a novel Sliding Resilient Base Isolation System (SR-F) by combining the characteristics of the EDF (Electricity de France) base isolator and the resilient base isolator (R-FB1). This study compared the performance of the SR-F isolator with traditional systems, such as EDF and R-FB1, under different earthquake conditions.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

The research demonstrated that the SR-F system offered significant improvements in reducing peak responses, maintaining lower displacement without amplifying the frequency or amplitude content of the vibrations, making it an effective choice for earthquake mitigation.

A.N. Lin et al. (2017) [2] investigated base-isolated concentrically braced and moment-resistant steel frames, emphasizing the performance of rigid base and base-isolated steel frames. This study relied on the SEAOC (Structural Engineering Association of California) guidelines for designing base-isolated and fixed-base frames, using a variety of ground motion records to assess seismic responses. The analysis revealed that reducing the lateral force by 50% of SEAOC's recommendation provided superior performance compared to other configurations, showcasing the benefits of base isolation in enhancing structural resilience.

Furthering the analysis of seismic isolation systems, H.W. Shenton III [3] compared fixed-base and base-isolated structures, utilizing different lateral force levels based on SEAOC recommendations (25% and 50%). By performing nonlinear dynamic analysis with post-earthquake records, the study observed improvements in the base-isolated structure's performance, such as reduced lateral displacements and improved overall seismic response, compared to fixed-base systems under specified lateral forces.

In the domain of industrial applications, Todd W. Erickson [4] analyzed the seismic response of industrial buildings designed according to the IBC (International Building Code). The study highlighted the importance of base isolation in large industrial structures, where the unique challenges of design, analysis, and isolator placement must be addressed. The results showed that base isolation offers significant benefits in protecting these structures from seismic forces.

J. Enrique Luco (2017) [5] expanded on the effect of soil-structure interaction (SSI) on base-isolated buildings, emphasizing that the deformation of inelastic structures increases when SSI is accounted for. The study found that neglecting SSI could lead to undamped vibrations and resonance, ultimately affecting the isolator and structure's performance. This finding underscores the importance of including soil behavior in isolation system designs for optimal results.

The research of Donato Concellara et al. (2017) [6] introduced a High Damping Hybrid Seismic Isolator (HDHSI), which combined Lead Rubber Bearings (LRBs) with friction sliders. The study demonstrated that the HDHSI system outperformed traditional LRB-based systems by offering better protection during severe seismic events. Nonlinear time history analysis was employed to compare the seismic response, revealing that the hybrid system provided more effective isolation and reduced base shear and displacement during intense seismic activity.

Boya Yin [7] investigated the effect of soil-structure interaction on base isolation systems, particularly focusing on the nonlinear frictional forces and the substantial displacements at the story levels. The study used various soil models, including a liquefied soil model, to simulate the effect of different soil conditions on the performance of base-isolated buildings. The research indicated that while large hysteretic friction forces were less effective in achieving isolation, SSI had a significant impact on the overall response of base-isolated structures.

In another groundbreaking study, Y. Li and J. Li [8] proposed a smart base isolator with variable stiffness and damping properties to handle severe seismic forces. The passive nature of conventional isolators might not suffice during extreme earthquakes, and this smart system addressed this limitation by adjusting its stiffness and damping properties dynamically based on the seismic conditions. The study presented dynamic modeling, design, and experimental testing, indicating that this adaptive isolation system could significantly improve earthquake resistance compared to traditional passive systems.

Further reinforcing the importance of soil-structure interaction, J. Enrique Luco (2017) [9] presented another study highlighting the role of SSI in increasing the resonant response of both isolators and superstructures. The study demonstrated that the damping properties of the isolator were critical in mitigating the amplified vibrations due to SSI, further proving that understanding the interaction between soil and structure is essential for effective seismic isolation.

M.K. Shrimali et al. (2017) [10] emphasized the growing need for seismic control devices, particularly in mitigating pounding effects between adjacent buildings during an earthquake. The study focused on comparing damper-based systems

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

and base-isolated systems, finding that hybrid systems combining passive and semi-active control methods offered superior performance. This research underscores the evolving need for integrated control technologies to address the complexity of seismic hazards.

The research by A. Swetha and Dr. H. Sudarsana Rao [11] explored dynamic analysis of a G+4 story building using El Centro earthquake records for input ground motion. The study compared base-isolated and fixed-base scenarios, revealing that base isolation systems reduced base shear, displacement, and lateral forces, leading to a more stable and resilient structure during seismic events. This demonstrated the advantages of base isolation in mitigating earthquake-induced forces.

Sekar and Kadappan [12] investigated the effect of base isolation on multi-story reinforced concrete buildings situated on sloping and normal ground. The study showed that base isolation increased the natural time period of the structure, resulting in reduced base shear but increased inter-story drift. The effects were more pronounced on sloping grounds, highlighting the importance of terrain conditions in designing base-isolated buildings.

Shu-lu Wang et al. (2017) [13] presented a metal rubber isolator, which aimed to address vibration problems associated with traditional isolators. The study outlined the history, dynamic modeling, and experimental behavior of metal rubber materials used in isolators, demonstrating their potential for improving isolation system performance, particularly in mitigating vibrations and improving long-term reliability.

In a practical case study, Farzad Hatami et al. (2017) [14] examined a ten-story base-isolated structure and the influence of soil-structure interaction (SSI). The study used nonlinear dynamic time history analysis to evaluate the effects of various soil types (soft, medium, and stiff) on the building's seismic performance. The results highlighted that the structure's response was significantly influenced by the underlying soil, particularly in the case of soft soils, which affected the time period and seismic response of the structure.

Finally, Donato Concellara et al. (2017) [15] compared the performance of high damping rubber bearings (HDRBs) and friction bearings in seismic base isolation systems. The study showed that HDRBs provided superior protection, particularly during severe seismic events, by better controlling base shear and reducing displacement. This reinforced the idea that hybrid isolation systems, which combine multiple types of bearings, offer enhanced performance in high-intensity earthquakes.

In summary, these studies collectively highlight the significant advancements in base isolation technology, from traditional isolators like lead rubber bearings to hybrid systems and smart isolators with adjustable properties. Additionally, the role of soil-structure interaction (SSI), damping, and seismic control devices is critical in optimizing the performance of base-isolated structures. These innovations are continuously evolving to address the complex challenges posed by seismic events, ensuring the safety and resilience of buildings in earthquake-prone regions.

Base isolation is a technique used to protect structures from seismic forces by decoupling the building from the ground motion. This method has gained significant attention over the past few decades due to its ability to reduce damage to structures during earthquakes. The concept of base isolation dates back to the early 20th century, but significant advancements have been made in its design and application in recent years. Below is a review of relevant studies in the field of base isolation, which will serve as a foundation for this research.

2.1 Historical Development of Base Isolation

Early studies on seismic protection through base isolation can be traced back to the 1970s when the idea of isolating a structure from seismic forces was first explored. Kelly (1986) and Robinson (1990) contributed significantly to the understanding of elastomeric bearings and lead-rubber bearings, which became the most common types of base isolators. Their work demonstrated that these systems could reduce the seismic forces transmitted to the superstructure and thus protect the building from extensive damage.

2.2 Types of Base Isolation Systems

Several base isolation systems have been developed and applied in practice, each with distinct advantages and limitations. According to Naeim and Kelly (1999), elastomeric bearings, which combine rubber and steel, are the most commonly used due to their flexibility, cost-effectiveness, and durability. Lead-rubber bearings, which include a lead core inside the elastomeric layer, provide higher energy dissipation, making them effective for mitigating seismic forces in large structures (Skinner et al., 1993). Additionally, the Friction Pendulum System (FPS), first proposed by Zayas (1987), is another widely studied isolator. FPS bearings use the principle of sliding friction to absorb seismic energy and are particularly suitable for large-scale structures, such as bridges (Ryan & Chopra, 2004).

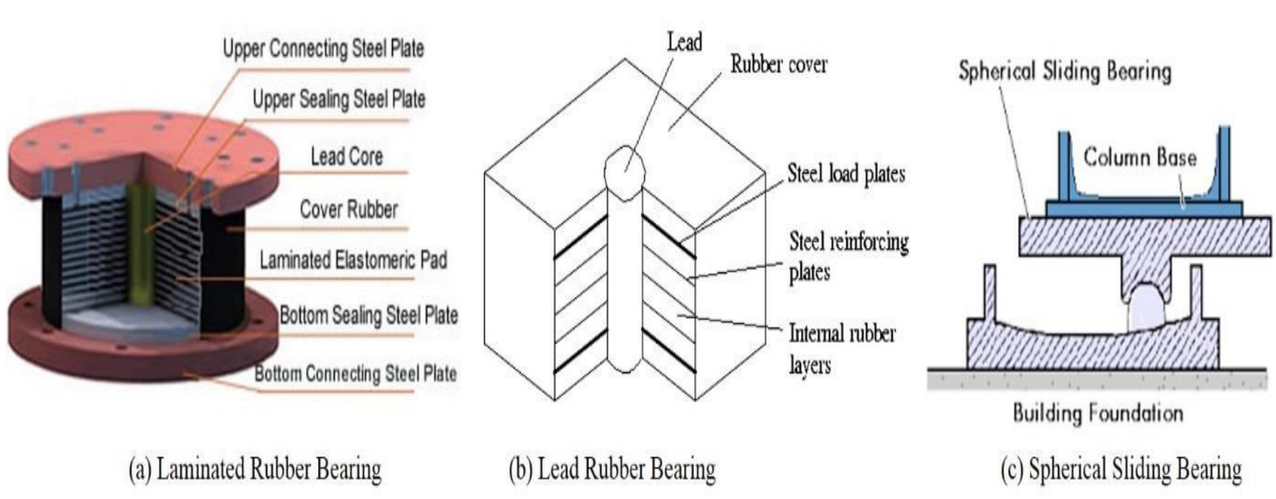

Figure: Types of Base Isolators: Elastomeric, Lead-Rubber, and Friction Pendulum Bearings

III. OBJECTIVES

1. To analyse the performance of base isolation systems under different seismic conditions using computational simulations.
Detail: Base isolation systems are designed to decouple a building from the ground motion during an earthquake, thereby reducing the seismic forces transmitted to the structure. To understand their performance fully, computational simulations will be employed to model various seismic conditions (e.g., ground shaking, fault displacement, and vibration frequencies) and their effects on isolated structures.

2. To evaluate the effectiveness of various isolator types, such as elastomeric and friction pendulum systems.
Detail: Different base isolation systems are designed to offer varying levels of seismic protection depending on the nature of the earthquake and the building's design. This objective focuses on comparing the performance of two major types of isolators:

- Elastomeric Isolators: These are typically made from layered rubber and steel, offering flexibility and energy dissipation. They are widely used in seismic design due to their ability to reduce lateral displacements while maintaining structural stability.
- Friction Pendulum Systems (FPS): These systems rely on the principle of friction and pendulum motion to absorb seismic energy and reduce lateral movement. FPS is advantageous for taller buildings as it allows large horizontal displacements with minimal deformation of the isolator itself.

3. To study real-world case examples of base-isolated buildings and their performance during past earthquakes.

Detail: To validate the theoretical and computational findings, this objective will involve examining real-world examples of buildings that have implemented base isolation systems. The performance of these buildings during past earthquakes will be analysed to understand how well the isolators performed in actual seismic events. Case studies might include buildings from earthquake-prone regions like Japan, New Zealand, and California. Specific case examples can focus on the response of these structures to earthquake magnitudes, building types (e.g., hospitals, schools, or residential buildings), and the role of isolation in preventing structural damage and reducing building downtime. The goal is to gather empirical data on the effectiveness of base isolation systems and to identify potential improvements based on real-world performance.

4. To assess the economic feasibility and practical challenges of implementing base isolation in new and existing buildings.
Detail: While base isolation has been proven to be effective in improving seismic resilience, its adoption in both new construction and retrofitting of existing buildings must be economically feasible and practical. This objective will evaluate the cost implications of implementing base isolation systems, including the upfront costs of installation, maintenance, and potential retrofitting. Additionally, the research will consider the logistical challenges involved, such as the need for specialized materials, labor, and construction techniques, as well as regulatory hurdles. Cost-benefit analyses will help determine the economic justification for base isolation, considering factors such as the reduction in damage, downtime, and insurance costs during seismic events.
5. To recommend advancements in base isolation technology for improving seismic resilience.
Detail: This objective aims to push the boundaries of base isolation technology by recommending advancements that can enhance its performance, cost-effectiveness, and applicability. Potential advancements may include:
Material Innovations: Exploring new materials that offer better energy dissipation, durability, and resistance to environmental degradation (e.g., advanced polymers or composite materials).
Hybrid Systems: Developing hybrid isolation systems that combine multiple types of isolators (e.g., elastomeric with friction or viscous dampers) to provide superior performance across a wider range of seismic events.

REFERENCES

1. Chopra, A. K. (2012). Dynamics of Structures: Theory and Applications to Earthquake Engineering. 4th Edition, Pearson Education.
2. Huang, Y., & Boulanger, R. W. (2017). "Seismic Response of Base-Isolated Buildings: A Review of Recent Advances and Future Directions." Engineering Structures, 140, 261–272. https://doi.org/10.1016/j.engstruct.2017.02.010
3. Moehle, J. P., & Lowes, L. N. (2011). "Base Isolation: A Proven Technology for Seismic Protection." Journal of Structural Engineering, 137(6), 853–860. https://doi.org/10.1061/(ASCE)ST.1943-541X.0000377
4. Newmark, N. M., & Rosenblueth, E. (1971). Fundamentals of Earthquake Engineering. Prentice Hall.
5. Kelly, J. M. (1999). "Earthquake-Resistant Design with Rubber." Springer-Verlag, Berlin, Heidelberg.
6. Baker, J. W., & Cornell, C. A. (2004). "Seismic Hazard and Risk Analysis." Earthquake Engineering Research Institute, Monograph 10.
7. Fang, L., & Zheng, S. (2014). "Comparative Study of Different Base Isolation Systems." Journal of Earthquake Engineering, 18(5), 697–711. https://doi.org/10.1080/13632469.2014.880484
8. Eurocode 8 (2004). Design of Structures for Earthquake Resistance, Part 1: General Rules, Seismic Actions and Rules for Buildings. European Committee for Standardization (CEN).
9. ASCE/SEI 7-16 (2016). Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers (ASCE).
10. Naeim, F., & Kelly, J. M. (1999). Design of Seismic Isolated Structures: From Theory to Practice. Wiley-Interscience.
11. Jangid, R. S., & Datta, T. K. (2001). "Seismic Response of Base-Isolated Buildings Under Near-Field Earthquake Motions." Journal of Earthquake Engineering, 5(4), 515–536. https://doi.org/10.1080/13632460109350535
12. Ohta, M., & Tazawa, K. (2014). "Performance of Base-Isolated Buildings during the 2011 Great East Japan Earthquake." Earthquake Engineering & Structural Dynamics, 43(3), 419–437. https://doi.org/10.1002/eqe.2387
13. Lam, N. T. K., & Goda, K. (2006). "Base Isolation for Seismic Protection of Buildings: A Review." Progress in Structural Engineering and Materials, 8(3), 167–175. https://doi.org/10.1002/pse.176

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

14. Priestley, M. J. N., & McKellar, M. (2005). "Seismic Isolation of Building Structures." NZSEE Conference Proceedings, 2005, 1–12.
15. Sokolov, S., & Tizani, W. (2017). "Base Isolation: Performance under Extreme Seismic Loading." Earthquake Engineering and Engineering Vibration, 16(2), 359–370. https://doi.org/10.1007/s11803-017-0412-4
16. Agarwal, P., & Shrikhande, M. (2006). Earthquake Resistant Design of Structures. Prentice Hall India.
17. FEMA 273 (1997). NEHRP Guidelines for the Seismic Rehabilitation of Buildings. Federal Emergency Management Agency.
18. Jain, S. C., & Sinha, S. K. (1995). "Seismic Behavior of Buildings with Base Isolation: A State-of-the-Art Review." Journal of Structural Engineering, 121(4), 551–560. https://doi.org/10.1061/(ASCE)0733-9445(1995)121:4(551)
19. Sakata, S., & Wada, A. (2012). "Lessons from the 2011 Japan Earthquake: Performance of Base-Isolated Structures." Proceedings of the 15th World Conference on Earthquake Engineering, Lisbon, Portugal, 1–6.
20. Zhang, L., & Lou, W. (2009). "Base Isolation and Seismic Design: A Comparative Review." International Journal of Earthquake Engineering, 8(1), 44–59.

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY