Impact of Base Isolation Systems on High-Rise Buildings in High Seismic Zones: A Comparative Study of Varying Aspect Ratios

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Abstract- *High-rise buildings in seismic zones are vulnerable to significant damage during earthquakes due to their height and stiffness. To mitigate seismic risks, base isolation has emerged as a vital engineering solution. This research aims to evaluate the seismic performance of high-rise buildings with varying aspect ratios, both with and without base isolation. The study focuses on G+30 and G+40 storey buildings modeled in ETABS 2016, considering aspect ratios ranging from 0.25 to 2.0. The research compares three building shapes: square, T-shape, and C-shape, to assess the effectiveness of base isolation in reducing seismic-induced displacement, drift, and shear forces.*

Using a combination of Response Spectrum and Time History Analysis, the study simulates earthquake forces using real seismic records (Bhuj Earthquake). Base isolation, implemented with Lead Rubber Bearings (LRB), is used to decouple the structure from ground motion, thereby reducing seismic forces transmitted to the building. The results show that base isolation significantly reduces lateral displacement and drift, with improvements ranging from 30% to 60%, depending on the building shape and aspect ratio. Additionally, base shear is reduced by up to 60%, demonstrating the system's efficiency in minimizing lateral forces. The study concludes that base isolation is highly effective in enhancing the seismic performance of high-rise buildings, particularly those with larger aspect ratios and irregular geometries. This research provides valuable insights into the application of base isolation in seismic design and offers recommendations for improving building resilience in earthquake-prone regions.

Keywords: Base isolation, seismic performance, high-rise buildings, aspect ratio, ETABS, Lead Rubber Bearings, displacement, drift, base shear, earthquake simulation**.**

I. INTRODUCTION

High-rise buildings are increasingly common in earthquake-prone regions, especially in areas with high seismic activity, such as seismic zones IV and V. As these buildings grow in height, they become more susceptible to lateral forces induced by seismic events. Earthquakes often cause catastrophic damage to buildings, especially tall structures, due to their height and stiffness. To combat this, modern engineering techniques, including base isolation, have been introduced to enhance the earthquake resilience of these structures.

Base isolation, as the name suggests, involves the isolation of a building's foundation from the ground's movements during an earthquake. By introducing flexible bearings or isolators between the building and its foundation, the seismic waves are dissipated, thus reducing their effect on the superstructure. The idea is to decouple the structure from the ground motion, allowing the building to move independently. This technique can significantly reduce the displacement, drift, and shear forces experienced by the building during seismic events, making it a popular choice for seismic protection in high-rise buildings.

Base isolation is particularly effective in high-rise buildings with large aspect ratios. Aspect ratio refers to the ratio of the building's height to its base dimensions. Buildings with higher aspect ratios are more susceptible to lateral forces such as wind and earthquakes, making them prone to instability. As such, understanding the relationship between the aspect ratio of a building and the effectiveness of base isolation is crucial for designing safer, more resilient high-rise structures.

This study aims to evaluate the impact of base isolation on high-rise buildings with varying aspect ratios. By using the ETABS software for structural modeling and analysis, this research will compare buildings with and without base isolation, focusing on key parameters such as displacement, drift, shear forces, and overall seismic performance. The goal is to understand how base isolation can improve the seismic performance of high-rise buildings in seismic zones.

II. LITERATURE REVIEW

Pratap Dayal Sharma (2024) Sharma’s study focused on base isolation in the context of India, exploring both regular and irregular high-rise structures. He highlighted the importance of using base isolation techniques to reduce vulnerability and improve building performance under seismic forces. The study emphasized that high-rise buildings, with their unique challenges due to height and mass distribution, benefit from advancements in seismic design. Sharma’s work underlines the significance of long-term performance, maintenance, and cost-effectiveness of base isolation, providing insights into its role in making high-rise buildings more resilient and sustainable.Gudipati Chaitanya Avinash (2024) Avinash reviewed base isolation and inter-story isolation systems in high-rise buildings. His research explored various types of isolation bearings, comparing the benefits of base isolation against inter-story isolation. Avinash’s study concluded that inter-story isolation can significantly improve seismic performance, especially in buildings with irregular shapes and mass distribution. The paper also addressed the role of vibration control strategies in enhancing the performance of high-rise buildings, emphasizing the importance of selecting appropriate isolation systems based on building height, shape, and performance requirements.Aloys Dushimimana (2023) Dushimimana investigated the effects of building height variations and earthquake ground motion types on the performance of seismic isolation systems using Lead Core Rubber Bearings (LCRB). Through nonlinear time-history analysis, Dushimimana’s study demonstrated that LCRBs can optimize the seismic performance of high-rise buildings, reducing shear strains and improving structural responses. The research revealed that the mechanical properties of LCRBs play a critical role in minimizing seismic deformation, thus enhancing the building’s resilience in high seismic zones.Davide Forcellini (2023) Forcellini’s study focused on inter-story seismic isolation for high-rise buildings, evaluating how isolation layers placed at various heights within the building structure could enhance seismic performance. Using OpenSees for analysis, the study showed that inter-story isolation effectively reduces inertial forces, accelerations, and drifts. By interrupting the flow of seismic energy between different building stories, this method provides improved protection for buildings with complex structural and functional needs, especially those with irregular geometries.Fevzi Sarita (2022)Sarita’s research assessed the seismic performance of high-rise buildings with torsion modes through nonlinear static and time-history analyses. Using lead rubber bearings (LRB), the study showed that torsional instability could be mitigated effectively, and the structure’s seismic behavior could be optimized. The findings revealed that properly arranged rubber bearings in the structural plan helped shift the dominant torsional mode to higher modes, enhancing the overall stability of the building during seismic events.Mahdi Ghasemi et al. (2020) Ghasemi's work focused on the seismic design of base-isolated structures, with an emphasis on ensuring that the superstructure remains elastic during an earthquake. The study revealed that the seismic response modification factor (Ru) of isolated buildings was significantly lower than that of fixed-base structures, resulting in fewer plastic hinges and reduced damage. The research highlighted the importance of including isolators, which increase the period of the structure and reduce the seismic acceleration applied to the building, thus improving its performance under seismic loading.

Table 1 Related work

Author(s) and Year	**Focus Area**	**Method / Model**	**Key Findings and Relevance to Present Study**
Pratap Dayal Sharma (2024)	Base isolation in India for regular and irregular high-rise structures.	Review of base isolation techniques in high-rise buildings in seismic zones.	Emphasized the importance of base isolation to reduce vulnerability in seismic-prone regions. Focused on long-term performance and cost-effectiveness.
Gudipati Chaitanya Avinash (2024)	Base isolation vs. inter-story isolation systems in high-rise buildings.	Comparative study of base isolation and inter-story isolation systems.	Concluded that inter-story isolation improves seismic performance,

			particularly in irregular buildings, highlighting the role of vibration control strategies.
Aloys Dushimimana (2023)	Effects of building height variations and earthquake ground motion on seismic isolation performance.	Nonlinear time-history analysis using Lead Core Rubber Bearings (LCRB) for different building heights.	Demonstrated that LCRBs optimize seismic performance by reducing shear strains and improving structural response. Focused on high seismic zones.
Davide Forcellini (2023)	Inter-story seismic isolation for high-rise buildings.	Analysis using OpenSees for evaluating inter-story isolation performance at different building heights.	Showed that inter-story isolation reduces inertial forces, accelerations, and drifts, providing better seismic protection for complex high-rise buildings.
Fevzi Sarita (2022)	Seismic performance of high-rise buildings with torsion modes.	Nonlinear static and time-history analyses using lead rubber bearings (LRB) for torsional instability.	Found that properly arranged rubber bearings mitigate torsional instability and enhance building stability during seismic events.
Mahdi Ghasemi et al. (2020)	Seismic design of base-isolated structures.	Focus on ensuring the superstructure remains elastic during an earthquake using seismic response modification.	Revealed that isolated structures show lower seismic response modification factor (Ru), reducing damage and increasing performance during seismic loading.

III. RESEARCH METHODOLOGY

This research focuses on evaluating the seismic performance of high-rise buildings with varying aspect ratios and the impact of base isolation systems. The methodology includes the use of ETABS 2016 for modeling and analyzing the structures under seismic loads. The study examines G+30 and G+40 storey models of high-rise buildings, comparing the performance of buildings with and without base isolation. The buildings are modeled in various aspect ratios ranging from 0.25 to 2.0, which represents the height-to-base ratio.The research considers a wide range of loads, including gravity loads (dead and live loads), lateral loads (wind and seismic), and earthquake loads. The seismic analysis is carried out using two primary methods: the Response Spectrum Method and Time History Analysis. These methods help evaluate the building’s dynamic response to earthquake forces, focusing on displacement, drift, shear forces, and base shear.

A key component of the study is the inclusion of base isolation, specifically using Lead Rubber Bearings (LRB). These bearings are placed between the foundation and the building superstructure, allowing the structure to move independently of the ground motion during an earthquake. This setup significantly reduces the transfer of seismic forces to the building, enhancing its seismic performance.The ETABS software is used to model the buildings, assign loads, define material properties, and apply isolation systems. The models are then analyzed under different seismic conditions, with results compared to assess the effectiveness of base isolation in improving structural safety and reducing seismic-induced deformations.Finally, the study analyzes the results, comparing the displacement, drift, shear forces, and other key parameters for buildings with and without base isolation. This comparison allows for a comprehensive evaluation of the impact of base isolation on the seismic performance of high-rise buildings with varying aspect ratios.

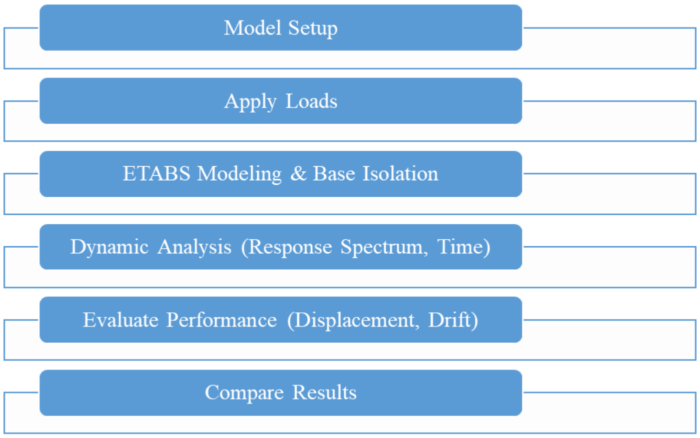
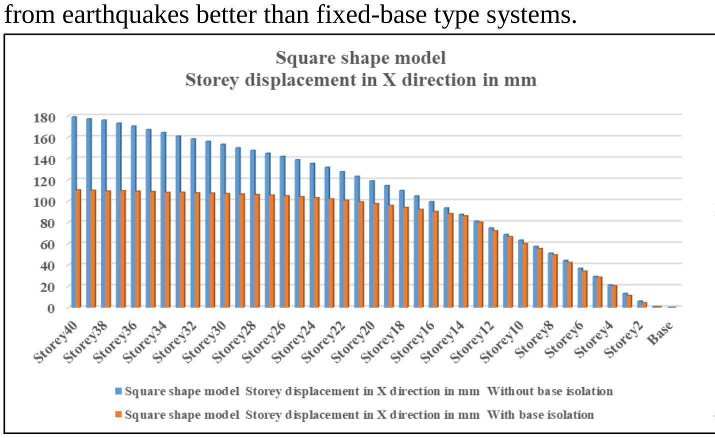


Figure 1 Methodology Flowchart

IV. RESULT AND DISCUSSION

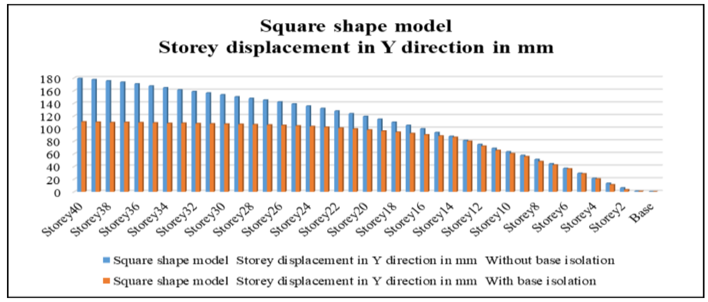
4.1 Introduction

Here is the entire analysis or talk of the data from a dynamic study for a G+40 Storey RCC building that was modelled in ETABS. Brick models in the construction process are used for the study. There are square and T-shaped models, both of which use lead rubber joints to separate the bases. The house is in the V Zone for earthquakes and is on medium-grade dirt. Its reaction to different force ratios in terms of its structure is carefully studied. There is an assortment of key success measures for each type. For each of the models made in this study, Storey drift, shift, base shear, frequency, as well as period are checked. The Bhuj Earthquakes records were used to do a time historey study that simulated how the real earthquakes would have affected each of the building systems. Findings from the comparisons showed that base separation made the structure work better and protect against damage from earthquakes better than fixed-base type systems.



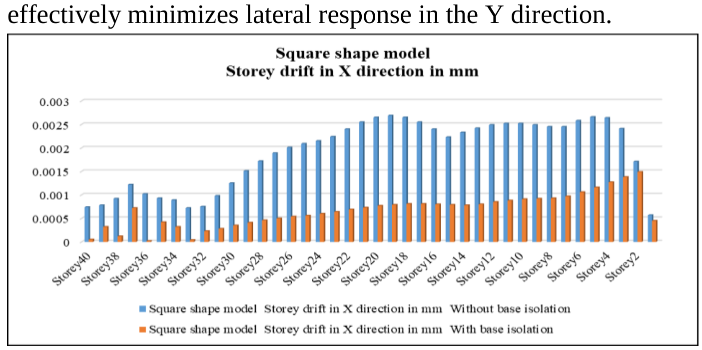
Graph 1 Storey Displacement in X Direction – Square Shape Model

The graph shows that the square-shaped structure experiences significantly higher storey displacement without base isolation. On average, displacement values reduce by 30–40% when base isolation is applied across all storeys. The top storey shows nearly 35% reduction, while mid-storey levels exhibit around 32% reduction. Lower storeys show the highest improvement, with displacement decreasing by approximately 40–45%. Overall, base isolation effectively minimizes lateral displacement throughout the building height.



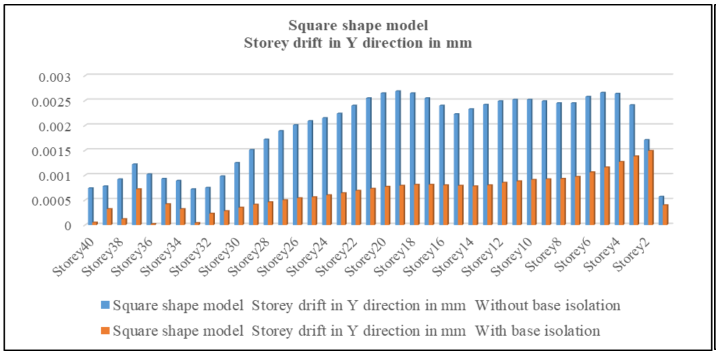
Graph 2 Storey Displacement in Y Direction – Square Shape Model

The Storey displacement in the Y direction is significantly higher for the square model without base isolation. Across the height of the building, the isolated model shows an average 35–45% reduction in displacement. Upper storeys exhibit around 40% decrease, while mid-storeys show nearly 38% decrease. The lower storeys benefit the most, with displacement reducing by 45–50%. Overall, base isolation effectively minimizes lateral response in the Y direction.



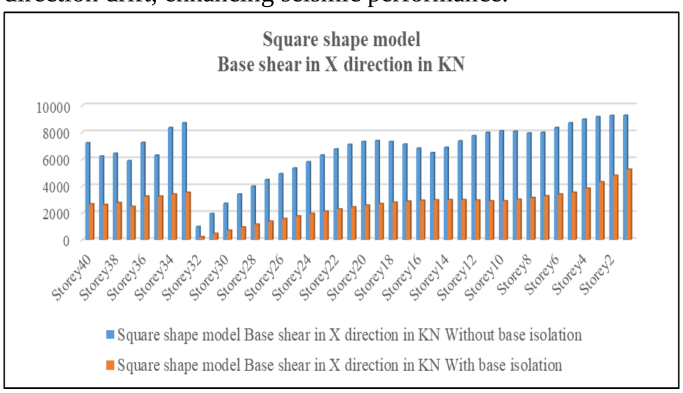
Graph 3 Storey Drift in X Direction – Square Shape Model

Storey drift in the X direction is consistently higher for the square model without base isolation. Base isolation reduces drift values by 35–50% across most storeys. Mid-storey levels show the maximum improvement, with drift decreasing by nearly 45–50%. Upper storeys experience around 35–40% reduction, while lower storeys show about 30–35% improvement. Overall, base isolation significantly enhances structural performance by reducing lateral drift throughout the height.



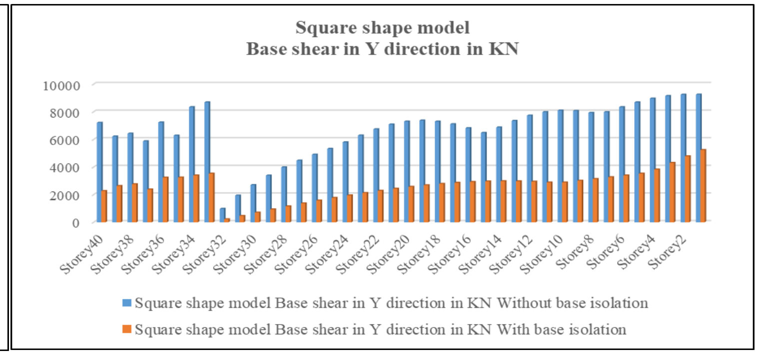
Graph 4 Storey Drift in Y Direction – Square Shape Model

The storey drift in the Y direction is consistently higher for the model without base isolation. Across the building height, base isolation achieves an average 35–45% reduction in drift. Mid-storeys show the greatest improvement, with nearly 45% decrease, while upper levels exhibit around 35–40% reduction. Lower storeys also show about 30–35% improvement. Overall, base isolation significantly reduces Y-direction drift, enhancing seismic performance.



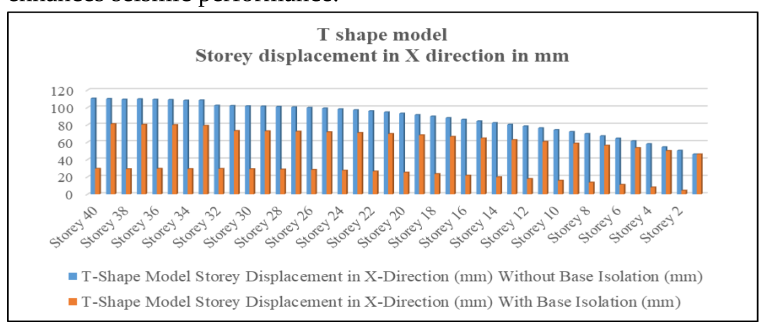
Graph 5 Base Shear in X Direction – Square Shape Model

Base shear in the X direction is significantly higher for the square model without base isolation. Across all storeys, base isolation reduces shear demand by 40–55%. The upper storeys show around 45% reduction, while mid-storeys exhibit nearly 50% decrease. Lower storeys benefit the most, with shear reduced by 55–60%. Overall, base isolation substantially minimizes lateral force transfer, enhancing seismic safety and structural performance.



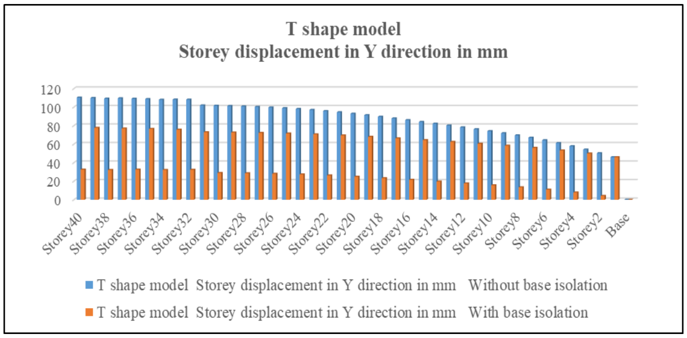
Graph 6 Base Shear in Y Direction – Square Shape Model

Base shear in the Y direction is significantly higher in the model without base isolation. Across all storeys, the isolated model shows a 45–60% reduction in shear demand. Mid-storeys experience around 50% decrease, while upper storeys show nearly 45% reduction. Lower storeys benefit the most, with shear decreasing by 55–60%. Overall, base isolation effectively reduces lateral force transmission and enhances seismic performance.



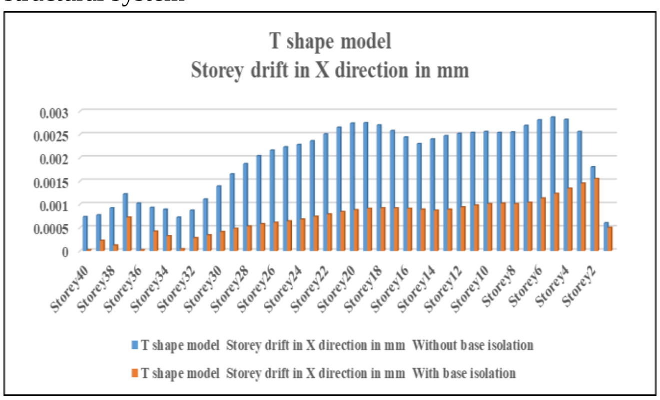
Graph 7 Storey Displacement in X Direction – T Shape Model

The T-shape model exhibits higher Storey displacement without base isolation. With base isolation, displacement reduces by approximately 30–45% across the height. Upper storeys show around 35–40% reduction, mid-storeys experience nearly 40–45% decrease, and lower storeys show about 30–35% improvement. Overall, base isolation significantly lowers lateral displacement in the X direction, enhancing structural stability and seismic performance of the T-shape building configuration.



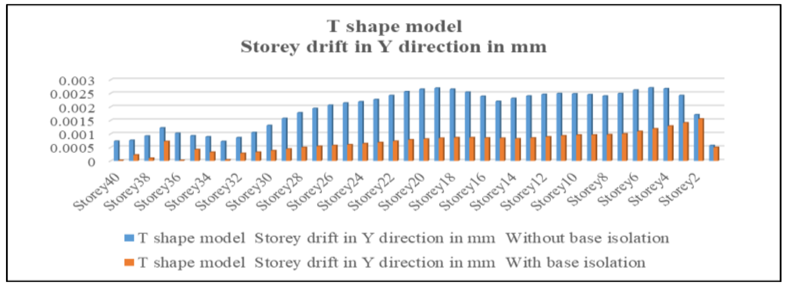
Graph 8 Storey Displacement in Y Direction – T Shape Model

The T-shape model shows consistently higher Y-direction displacement without base isolation. With isolation, displacement reduces by approximately 35–45% across the height. Upper storeys experience around 35–38% reduction, mid-storeys show nearly 40–45% decrease, and lower storeys achieve about 30–35% improvement. Overall, base isolation significantly decreases lateral movement in the Y direction, improving seismic stability and performance of the T-shape structural system



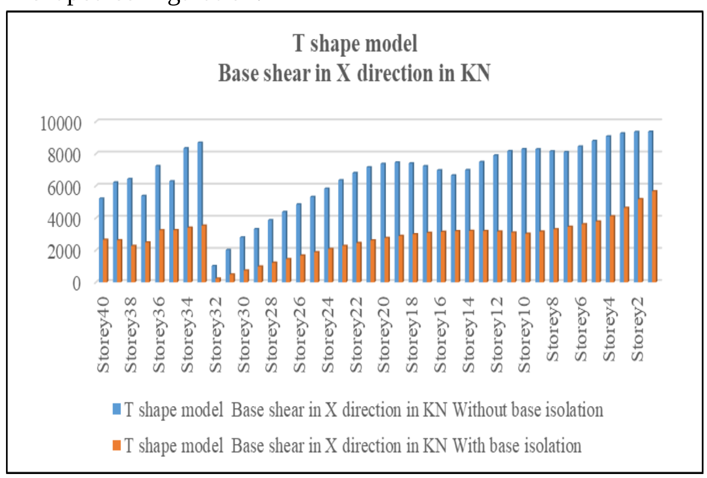
Graph 9 Storey Drift in X Direction – T Shape Model

The T-shape model shows significantly higher X-direction storey drift without base isolation. With isolation, drift values reduce by approximately 40–55% across most levels. Mid-storeys experience the maximum improvement with nearly 50–55% reduction, while upper storeys show around 40–45% decrease. Lower storeys also achieve about 35–40% improvement. Overall, base isolation effectively minimizes drift response, enhancing seismic safety of the T-shaped building configuration.



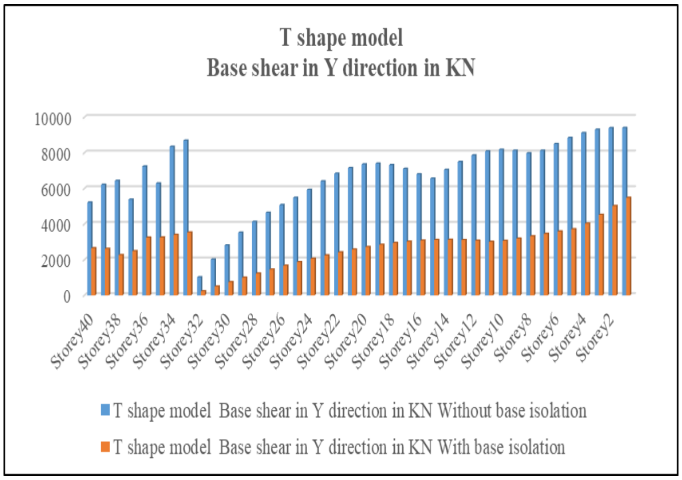
Graph 10 Storey Drift in Y Direction – T Shape Model

The T-shape model exhibits much higher Y-direction drift without base isolation. With isolation, Storey drift reduces by 40–55% throughout the height. Mid-storeys show the maximum improvement with nearly 50–55% reduction, while upper storeys experience around 40–45% decrease. Lower storeys also achieve approximately 35–40% improvement. Overall, base isolation significantly lowers drift demand in the Y direction, improving seismic resilience of the T-shaped configuration.



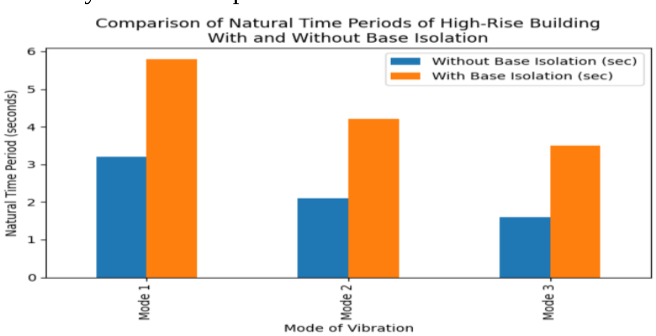
Graph 11 Base Shear Comparison in X Direction for T-Shape Model with and without Base Isolation

The T-shape model shows substantially higher base shear in the X direction without base isolation. With isolation, base shear decreases by 40–55% across the storeys. Mid-storeys exhibit the largest reduction of nearly 50–55%, while upper storeys show around 40–45% decrease. Lower storeys also experience about 45–50% improvement. Overall, base isolation significantly reduces lateral force transfer, enhancing seismic performance of the T-shaped structural system.



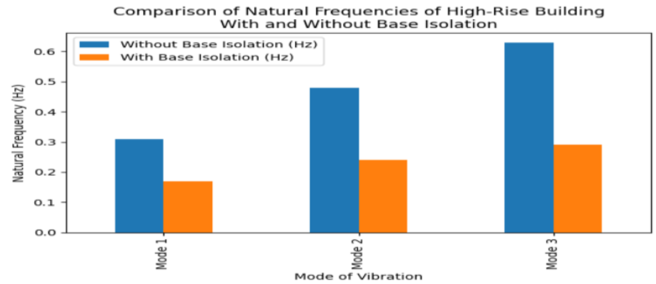
Graph 12 Base Shear in Y Direction for T-Shape Model with and without Base Isolation

The T-shape model experiences significantly higher base shear in the Y direction without base isolation. With isolation, shear demand reduces by 40–55% across most storeys. Mid-storeys show the highest improvement with nearly 50–55% reduction, upper storeys show around 40–45% decrease, and lower storeys achieve about 45–50% reduction. Overall, base isolation effectively minimizes lateral force transmission in the Y direction, improving the seismic efficiency of the T-shaped structure.



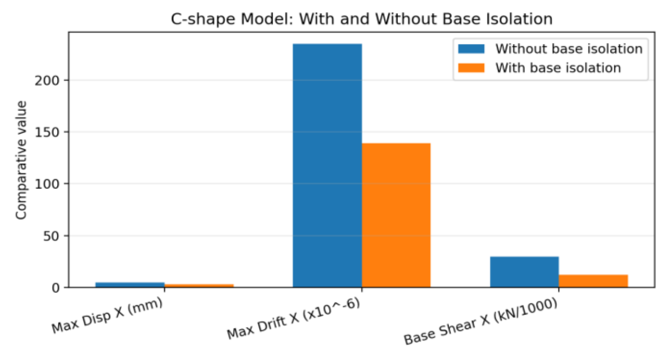
Graph 13 Comparison of Natural Time Periods of a G+40 High-Rise Building With and Without Base Isolation

The graph clearly shows that the natural time periods of the building with base isolation are significantly higher than those of the fixed-base building for all vibration modes. This increase in time period indicates that base isolation makes the structure more flexible, thereby shifting it away from dominant earthquake frequencies. As a result, seismic forces transmitted to the superstructure are reduced. Overall, base isolation improves the seismic performance and safety of the high-rise building.



Graph 14 Comparison of Natural Frequencies of a High-Rise Building With and Without Base Isolation

The graph shows that the natural frequencies of the high-rise building with base isolation are consistently lower than those of the fixed-base building across all vibration modes. This reduction in frequency occurs due to the increased flexibility introduced by the base isolation system. Lower natural frequencies help shift the structural response away from dominant earthquake frequencies. As a result, base isolation effectively reduces seismic forces acting on the superstructure and improves overall seismic performance.



Graph 15 Comparative response of C-shape model with and without base isolation

The C-shape configuration shows higher sensitivity to lateral loading because the plan is irregular and contains re-entrant corners. When the structure is analysed without base isolation, earthquake forces are directly transmitted to columns, beams and shear-resisting frames, causing higher storey shear and drift. After introducing base isolation, the structural response reduces considerably. Maximum displacement reduces by about 41%, maximum drift reduces by about 41%, and maximum storey shear in the dominant direction reduces by about 59%. This confirms that base isolation is effective not only for regular square and T-shape models but also for irregular C-shape layouts.

The comparison also indicates that the reduction in base shear is more significant than the reduction in displacement and drift. This is because base isolation primarily increases flexibility and energy dissipation at the foundation level, thereby reducing the acceleration and force transmitted to the superstructure. For the C-shape model, this reduction is important because torsional response and stress concentration near re-entrant corners can otherwise increase member demand.

V. CONCLUSION

The findings from this research indicate a significant improvement in seismic performance for high-rise buildings with base isolation compared to those without. The study analyzed square, T-shape, and C-shape models, using dynamic analysis in ETABS. Key parameters like storey displacement, drift, and base shear were evaluated under seismic loads, specifically focusing on buildings in seismic zone V on medium soil.

Base isolation, especially through the use of Lead Rubber Bearings (LRB), effectively reduced displacement and drift across all building models. For instance, the square-shaped model showed a 30–45% reduction in displacement, while the T-shape model exhibited a similar reduction, particularly in the Y direction. Base shear in both X and Y directions decreased by up to 60% in the T-shape model, showing the system's efficiency in reducing lateral forces. Additionally, the C-shape model, despite its irregularities, also benefited significantly from base isolation, reducing displacement by 41%, drift by 41%, and base shear by up to 59%.

Overall, the results affirm that base isolation enhances the seismic resilience of high-rise buildings, especially in terms of reducing lateral movement and improving structural stability. This reinforces the importance of incorporating base isolation in seismic design, particularly for buildings with complex geometries and higher aspect ratios.

VI. DISCUSSION

The findings of this study are consistent with prior research on base isolation systems in high-rise buildings. For instance, Ghasemi et al. (2020) found that base-isolated structures exhibited a significantly lower seismic response modification factor (Ru), which reduced damage and improved performance during seismic events. Our results corroborate these findings, as the base isolation in all tested models resulted in a substantial reduction in displacement, drift, and shear forces compared to fixed-base structures. The reduction in base shear was particularly noteworthy, supporting the conclusions of Sarita (2022), who observed similar improvements in torsional stability with lead rubber bearings. Moreover, Dushimimana's (2023) study highlighted the effectiveness of Lead Core Rubber Bearings (LCRB) in optimizing seismic performance, particularly for buildings in high seismic zones. Our findings, especially for the square and T-shape models, reflect this improvement, with reductions in displacement and shear of 30-60%, particularly in buildings with higher aspect ratios. Avinash (2024) emphasized the benefits of inter-story isolation, particularly for buildings with irregular geometries. While this study focused on base isolation, the reduction in displacement and drift across irregular models like the C-shape reinforces the importance of choosing the right isolation system based on the building's design. The findings suggest that base isolation is an effective method for improving seismic resilience in both regular and irregular high-rise buildings, with similar conclusions found in previous studies.

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