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Comparative Seismic Analysis of a G+40 RCC High-Rise Building with and without Lead Rubber Bearing Base Isolation Using ETABS

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Abstract: This study presents a comparative seismic analysis of a G+40 reinforced concrete high-rise building with varying aspect ratios, analyzed with and without Lead Rubber Bearing (LRB) base isolation using ETABS. The structure is modeled under Seismic Zone V conditions with medium soil, as per IS 1893 (Part 1): 2002 provisions. Five different aspect ratios ranging from 0.25 to 2.0 are evaluated to investigate their influence on seismic performance. Response Spectrum analysis is performed to assess key structural parameters including storey displacement, storey drift, base shear, natural time period, and frequency.

The results demonstrate that the incorporation of LRB base isolation significantly enhances seismic performance. Storey displacement is reduced by approximately 35–45%, storey drift decreases by 35–50%, and base shear is lowered by 40–60% compared to the fixed-base models. Additionally, the natural time period increases while the natural frequency decreases, indicating improved flexibility and reduced seismic force transmission to the superstructure. The study confirms that LRB base isolation is highly effective for tall buildings in Zone V and that aspect ratio plays a critical role in seismic response behavior.

Keywords: Base Isolation, Lead Rubber Bearing, High-Rise Building, Seismic Analysis, ETABS, Aspect Ratio.

I. INTRODUCTION

Earthquakes are among the most destructive natural catastrophes, wreaking havoc on cities and people throughout the globe. Man-made structures are destroyed by earthquakes. Because earthquakes occur with little or no warning, earthquake engineering is vital. High overturning moments in high-rise structures, as well as torsion generated by eccentric ground motion, are two of the most critical structural issues posed by earthquakes. Recent earthquakes have supplied sufficient information on the performance of different kinds of structures under varied earthquake and foundation circumstances to provide engineers and scientists food for thought. As a consequence, numerous solutions have arisen to protect structures against earthquakes. Base isolation is also a tactic for earthquake protection. The base isolation approach was created in an effort to limit the impacts of earthquakes on structures, and it has proved to be one of the most successful in recent decades. One of the most common methods of protecting structures against seismic forces is base isolation. The phrase "base isolation" is derived from two words: "base," which refers to a segment that supports or serves as a foundation for a structure, and "isolation," which refers to the condition of being separated. The efficient control of interstorey drift in the base isolation system's floor may ensure that facilities suffer the least amount of damage while also protecting human safety. The basic idea behind the base isolation system is to prevent potentially damaging earthquake ground motions from entering a structure. This is accomplished by introducing horizontal flexibility at the structure's base and presenting some damping elements to counteract earthquake ground motions. However, limited studies have investigated the combined influence of aspect ratio variation and Lead Rubber Bearing isolation efficiency in G+40 high-rise buildings under Zone V conditions. This study aims to address this gap.

A. Aspect Ratio of High-Rise Buildings (ETABS)

The aspect ratio of a high-rise building plays a pivotal role in its seismic performance. This ratio is defined as the relationship between the height of the building and the width of its base. A thorough understanding of aspect ratio and its effects is essential for designing buildings that can withstand seismic forces effectively. The following subpoints elaborate on the various aspects of aspect ratio in the context of high-rise buildings:

B. Impact on Structural Dynamics

The aspect ratio directly affects the dynamic properties of a building, including its natural frequency, mode shapes, and period of vibration. Tall and slender buildings (high aspect ratio) tend to have longer periods and may be more prone to sway under seismic forces, while shorter and wider buildings (low aspect ratio) usually have shorter periods and are more rigid.

C. Seismic Performance and Stability

Buildings with different aspect ratios respond differently to seismic excitations. High aspect ratio buildings may experience significant lateral displacement and are more susceptible to overturning or excessive sway. In contrast, low aspect ratio buildings may experience higher base shear but generally exhibit less lateral movement. Understanding these differences is crucial for designing buildings with adequate seismic performance.

D. Role in Base Isolation Effectiveness

The effectiveness of base isolation in reducing seismic forces can vary depending on the building's aspect ratio. For instance, base isolation may significantly reduce lateral displacements in high aspect ratio buildings, but its impact on base shear and overall stability in low aspect ratio buildings must also be considered. ETABS can simulate these scenarios, providing valuable insights into how aspect ratio influences the performance of base-isolated structures.

E. Design Implications and Optimization

Aspect ratio is a critical factor in the design and optimization of high-rise buildings in seismic zones. Engineers must carefully consider the aspect ratio when selecting structural systems, materials, and seismic mitigation strategies like base isolation. By analyzing different aspect ratios using ETABS, this study aims to identify optimal design practices that enhance both safety and performance in high seismic regions.

F. Base Isolation

A base isolation system is a popular system implemented in a structure to protect it from the action of seismic forces. This system as base isolation bearings was developed by Dr. Bill Robinson in the 1970s in New Zealand. A base isolation system is used as a damage-resistant seismic design solution for both new and retrofitted buildings. This system is hence named as seismic base isolation system.

G. Behavior of Base Isolation in High-Rise Buildings

1) *Seismic Protection:* Base isolation is a structural technique used in high-rise buildings to protect them from seismic vibrations. It involves the installation of flexible or isolating materials between the building and its foundation.
2) *Vibration Reduction:* Base isolation effectively reduces the transmission of ground vibrations to the building. It helps dissipate and absorb the energy generated by seismic events, preventing it from causing significant damage to the structure.
3) *Increased Building Resilience:* Base isolation enhances the resilience of high-rise buildings by allowing them to move independently of the ground during an earthquake. This decoupling effect minimizes structural stress and prevents the building from experiencing the full impact of seismic forces.
4) *Improved Occupant Safety:* By reducing the intensity of vibrations transmitted to the building, base isolation significantly enhances occupant safety during seismic events. It helps prevent structural collapse and reduces the risk of injury or loss of life.
5) *Preservation of Building Contents:* Base isolation mitigates the damage to the contents of high-rise buildings during earthquakes. By minimizing the amplitude of vibrations, it helps protect sensitive equipment, furniture, and valuable assets from being damaged or displaced.

H. Components of Base Isolation System

A base isolation system mainly consists of two components:

1) *Isolation Units:* An isolation unit is the basic component of the isolation system that performs of decoupling effect to the building structure or the non-building structure.
2) *Isolation Components:* The isolation components are the connection units between the isolation units mentioned before. These components do not contribute to the decoupling process.

I. Features of Base Isolation System

The important features of a base isolation system are listed below:

1) Base isolation introduces horizontal flexibility at the foundation level of the structure.
2) The system increases the fundamental time period of the building, shifting the structural response away from the dominant frequencies of earthquake ground motion.
3) As the time period increases, the spectral acceleration demand on the structure reduces, thereby decreasing the seismic forces transmitted to the superstructure.
4) Base isolation significantly reduces base shear, storey drift, and floor acceleration compared to fixed-base buildings.
5) Incorporation of isolators provides additional energy dissipation through inherent damping (such as in Lead Rubber Bearings), further limiting seismic response.

J. Suitability of Base Isolation System in Buildings

Base isolation is suitable for the structures satisfying the following conditions:

1) The subsoil in the site does not possess a predominant long period during the ground motion.
2) The site has the ability to permit a horizontal displacement in the range of 200mm or greater.
3) The lateral loads experienced in the structure due to wind action is approximately lesser than ten percent by weight of the whole structure
4) For those structures that are fairly jointed by a sufficient high column load, this system is the best suitable.

II. LITERATURE REVIEW

Redwan-Ul-Islam et al. (2023) studied core and corner shear walls in buildings with varying aspect ratios under seismic loads, finding that strategic shear wall placement reduced building drift by 35-40%, enhancing lateral displacement control and structural safety. Davide Forcellini (2023) investigated inter-storey seismic isolation layers in high-rise buildings, revealing that these layers could reduce seismic forces by up to 50%, offering improved resilience by interrupting seismic force transfer between structural sections. Manish K. Dixit et al. (2022) explored how optimizing building aspect ratios reduces concrete use by 20-25%, lowering the carbon footprint and promoting sustainability while maintaining structural efficiency in modern building design.

Jin Wang et al. (2021) examined wind-induced gust effects on high-rise buildings with different aspect ratios, showing that Gaussian modeling accurately predicts wind pressure distribution and optimizing designs improves wind performance by 15-20%. Subrata Roy et al. (2021) analyzed horizontal and vertical aspect ratios on RCC buildings' seismic response, concluding that optimizing aspect ratios enhances seismic performance by 30-35%, reducing lateral displacement and improving building stability. Akshay Pankar et al. (2020) reviewed base isolation systems, highlighting their ability to provide horizontal flexibility and damping, which reduces seismic forces by 40-45%, making base isolation a cost-effective method for earthquake resilience. Anas M. Fares et al. (2020) compared seismic performance on different soil types, finding base-isolated buildings on soft soil reduced seismic demands by up to 50%, outperforming fixed-base structures in stability and displacement control.

Mahdi Ghasemi et al. (2020) studied base-isolated versus fixed-base buildings (8-24 stories), showing a 35-40% reduction in seismic demands on beams and columns, enhancing structural strength and minimizing earthquake damage in taller buildings. Md. Mohiuddin Ahmed et al. (2019) used ETABS to analyze seismic effects on buildings with varying vertical aspect ratios, demonstrating that optimizing ratios reduces base shear forces by around 30%, significantly improving seismic resilience. Budhi Ram Chaudhary (2019) compared seismic behavior of RC buildings with and without base isolation, revealing a 40% reduction in seismic forces with isolation, particularly effective for taller multi-storey buildings with basements. Mahendra Balasaheb Shelke et al. (2019) investigated aspect ratio influence on buildings under wind and seismic loads, finding optimized ratios could reduce forces by up to 30%, thus enhancing structural stability against environmental stresses.

Sanjay Kumar Sadh et al. (2016) analyzed vertical and horizontal aspect ratios using ETABS, concluding that optimized ratios reduce seismic damage by 25-30%, essential for maintaining strength and stiffness in earthquake-prone RCC buildings. Minal Ashok Somwanshi et al. (2015) introduced an advanced base isolation system for multi-storey RCC buildings, achieving reductions up to 45% in shear forces, bending moments, and storey drifts, significantly improving earthquake resistance. Vinodkumar Parma et al. (2015) evaluated base isolation in irregular multi-storey RC frames, showing 40-50% base shear reduction and increased natural periods, effectively enhancing seismic performance despite plan and vertical irregularities. Ms. Sarang M. Dhawade et al. (2014) studied base isolation in RCC buildings with varying vertical aspect ratios, demonstrating seismic response reductions up to 45%, proving isolation as an effective technique for managing seismic forces in challenging designs.

Takeshi Kikuchi et al. (2014) addressed seismic isolation challenges for high aspect-ratio steel buildings, proposing stepping-up systems and Mega-Bracing that improve seismic performance by 30-35%, offering practical solutions for tall, slender structures.

A. Research Gap

Previous studies on base isolation have mainly focused on low- to mid-rise buildings or on a single building configuration. Limited research is available on the seismic performance of very tall (G+40) RCC buildings with varying aspect ratios, especially in Seismic Zone V conditions. Moreover, comparative evaluation of fixed-base and Lead Rubber Bearing (LRB) base-isolated systems using response spectrum analysis in ETABS has not been sufficiently explored. Hence, a clear gap exists in understanding the effectiveness of LRB base isolation for high-rise RCC buildings under severe seismic conditions.

III. STRUCTURAL MODELING AND ANALYSIS PROCEDURE

In this study, a three-dimensional G+40 storey reinforced concrete (RCC) high-rise building was modeled using ETABS 2016 software to evaluate its seismic performance under earthquake loading. The building was analyzed under Seismic Zone V conditions, with a zone factor of 0.36 and medium soil classification.

Five different building configurations were considered by varying the plan aspect ratios from 0.25 to 2.0. For each aspect ratio, two structural systems were analyzed:

1) A fixed-base structure
2) A base-isolated structure incorporating Lead Rubber Bearings (LRB)

Gravity loads, including self-weight, floor finish, live load, and wall loads, were assigned in accordance with relevant Indian Standard codes. Lateral loads due to wind and earthquake were applied as per IS 875 (Part 3) and IS 1893 (Part 1): 2002, respectively.

Seismic analysis was carried out using both Equivalent Static Analysis and Response Spectrum Analysis methods to capture the dynamic behavior of the structure. The key structural response parameters evaluated included storey displacement, storey drift, base shear, natural time period, and natural frequency.

The overall analysis procedure involved a systematic workflow consisting of literature review, structural modeling, load assignment, seismic analysis, comparison of fixed-base and base-isolated systems, and evaluation of results to identify the most efficient structural configuration for high seismic conditions.

Table 1. Problem statement

SR.NO.	CONTENT	DESCRIPTION
	Number of storey	G+40
	Floor height	3 m
	Base floor height	1.5 m
	Wall thickness	230mm
	Size of column	750mm×750mm
	Size of beam	450mm×450mm
	Depth of slab	150mm
	Types of soil	Medium soil
	Seismic zone	V
	Zone factor	0.36
	L.L.	3 Kn/m²
	F.F.	1.5 KN/m2
	Wall load	13.8 KN/m
	Earthquake data	Bhuj

A. *Bhuj earthquake*

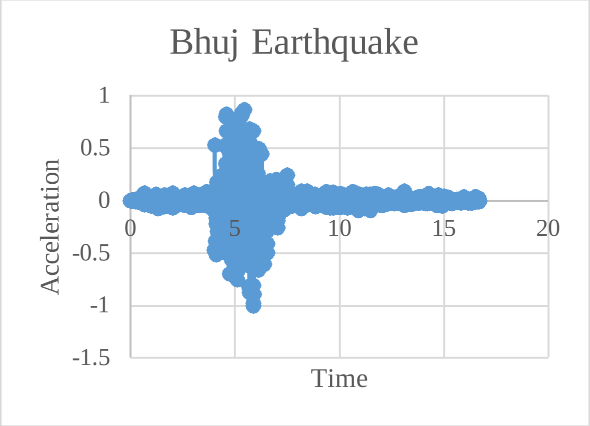


Fig. 1 Bhuj earthquake data

The 2001 Gujarat earthquake, also known as the Bhuj earthquake, occurred on 26 January at 08:46 am IST. The epicentre was about 9 km south-southwest of the village of Chobari in Bhachau Taluka of Kutch (Kachchh) District of Gujarat, India. The intraplate earthquake measured 7.6 on the moment magnitude scale and occurred at 17.4 km (10.8 mi) depth. It had a maximum felt intensity of X (Extreme) on the Mercalli intensity scale. The earthquake killed 13,805 to 20,023 people (including 18 in southeastern Pakistan), injured another 167,000 and destroyed nearly 340,000 buildings.

Table 2. Models

	No. of bays		Plan Dimension (m)		
Model	X-Direction	Y-Direction	X-Direction	Y-Direction	Aspect Ratio
Model 1 (M1)	4	13	15	60	0.25
Model 2 (M2)	5	9	20	40	0.5
Model 3 (M3)	7	7	30	30	1
Model 4 (M4)	10	7	45	30	1.5
Model 5 (M5)	9	5	40	20	2
Model 6 (M6)	11	5	50	20	2.5

Manual design of lead rubber bearing

B. *Modeling Images*

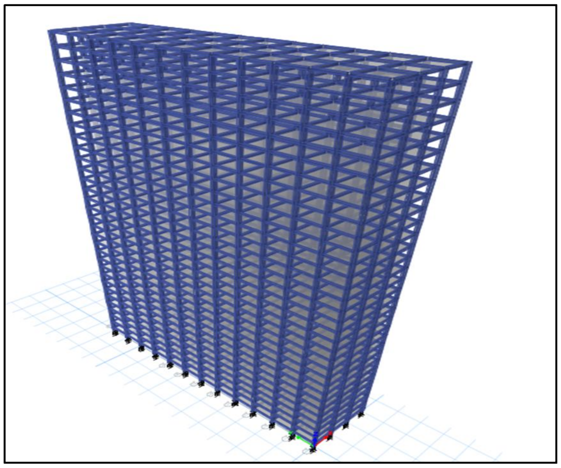


Fig 8. M1 3D view

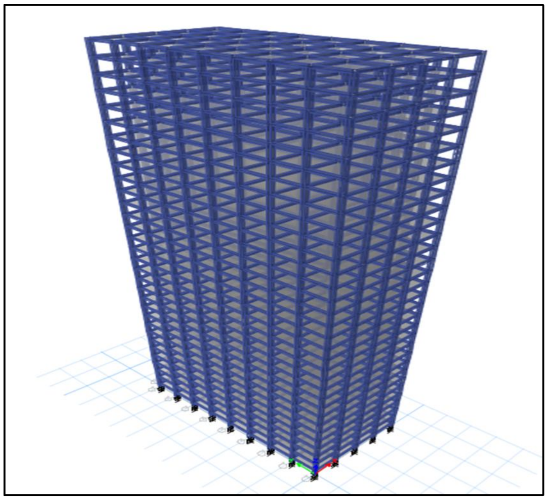


Fig 9. M2 3D view

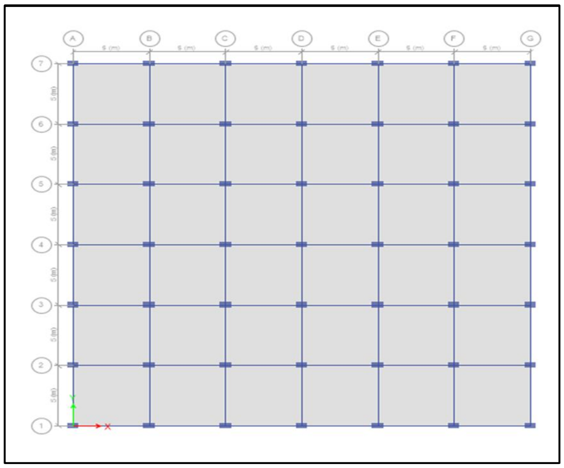


Fig 10. M3 plan view

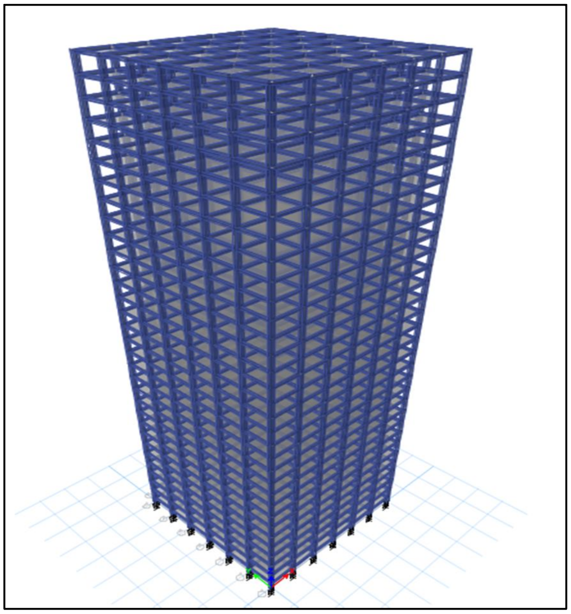


Fig 11. M3 3D view

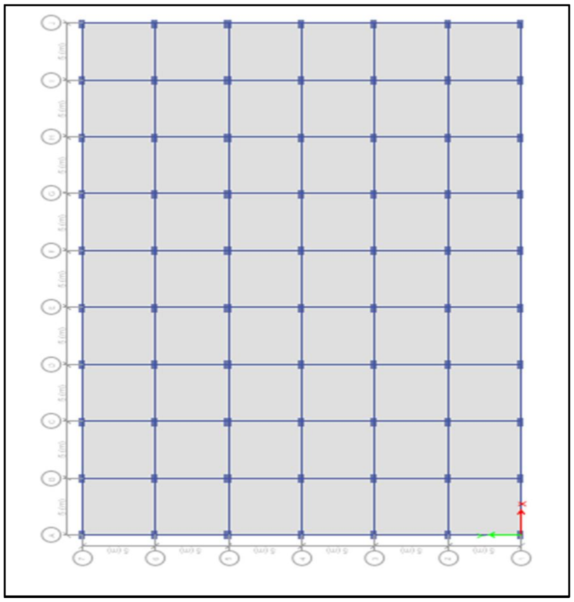
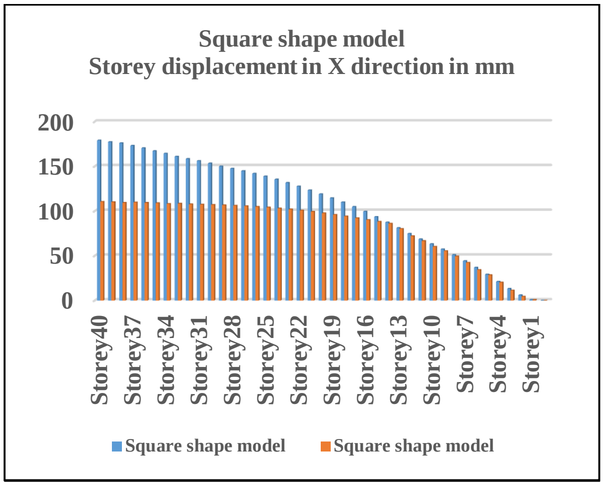


Fig 12. M4 plan view

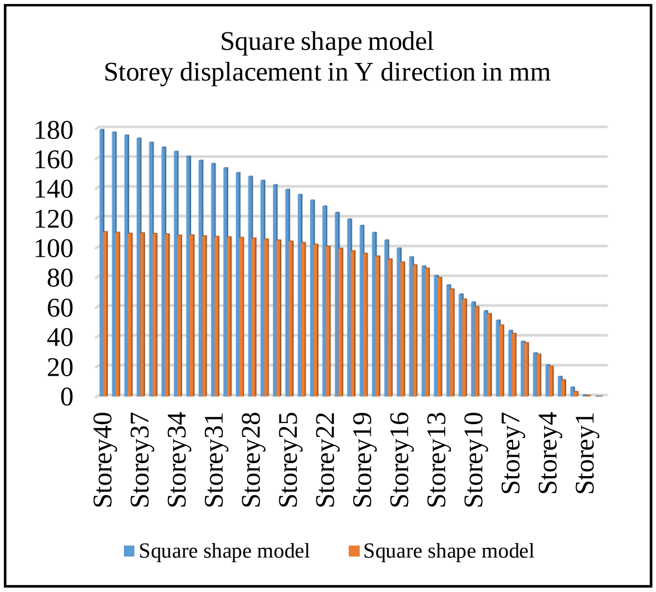
IV. RESULT AND DISCUSSION

The results chapter analyzes G+40 building models with different aspect ratios, focusing on the impact of Lead Rubber Bearing (LRB) base isolation under high seismic conditions using ETABS. Five models, with and without base isolation, were evaluated for displacement, storey drift, shear force, and bending moment. Results show maximum displacements consistently occur at the top storeys, with the lowest at the base. Base isolation effectively reduces storey displacements, enhancing seismic resilience across various building configurations.



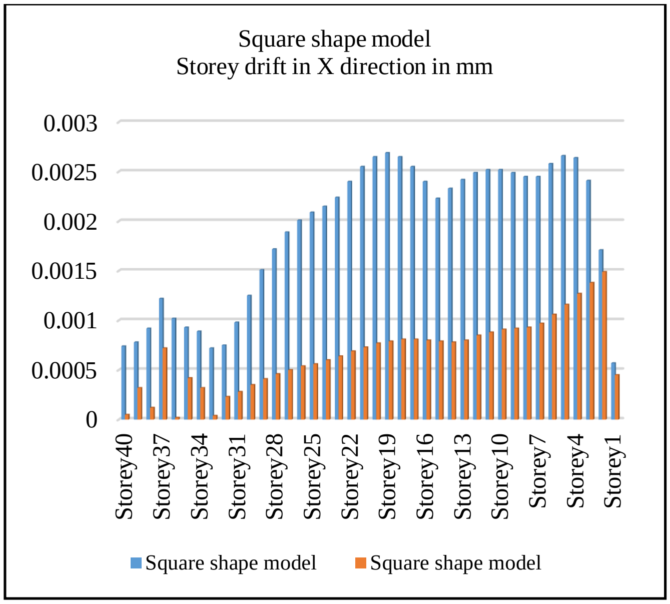
Graph 1.1 Storey Displacement in X Direction – Square Shape Model

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.



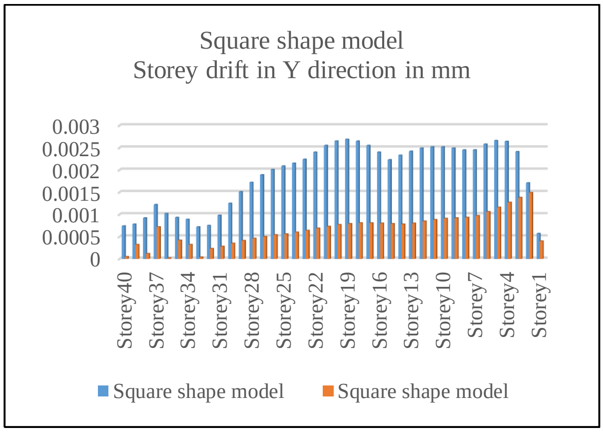
Graph 2. Storey Displacement in Y Direction – Square Shape Model

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.



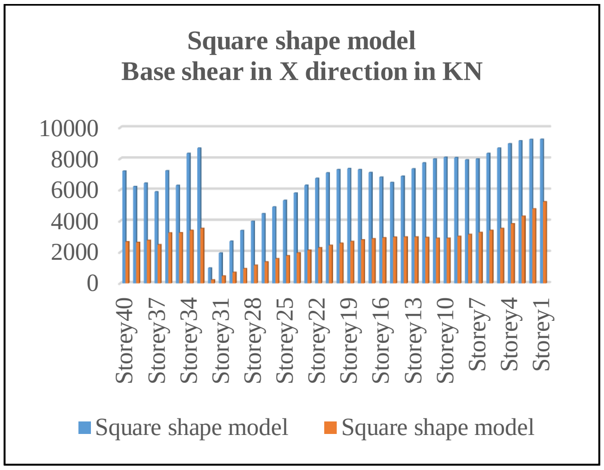
Graph 3. Storey Drift in X Direction – Square Shape Model

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.



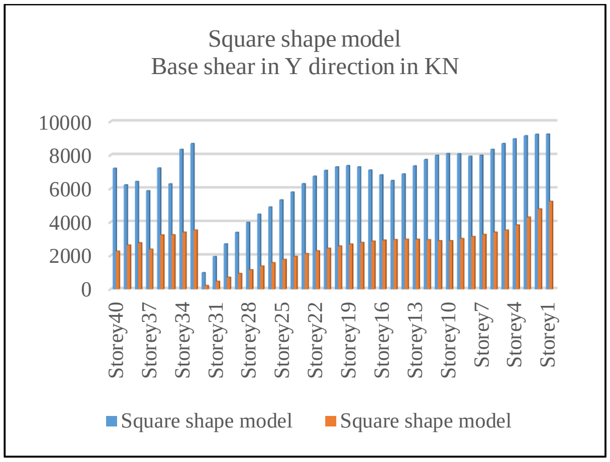
Graph 4. Storey Drift in Y Direction – Square Shape Model

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.



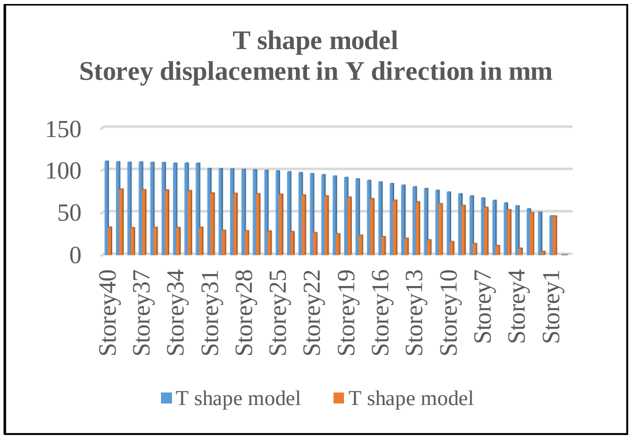
Graph 5. Base Shear in X Direction – Square Shape Model

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.



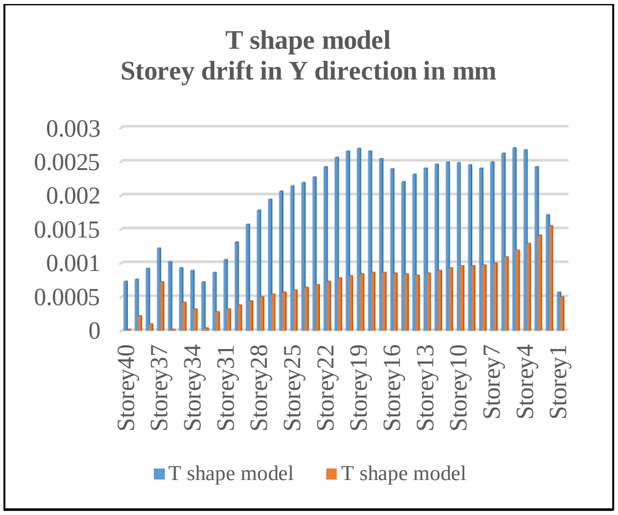
Graph 6. Base Shear in Y Direction – Square Shape Model

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.



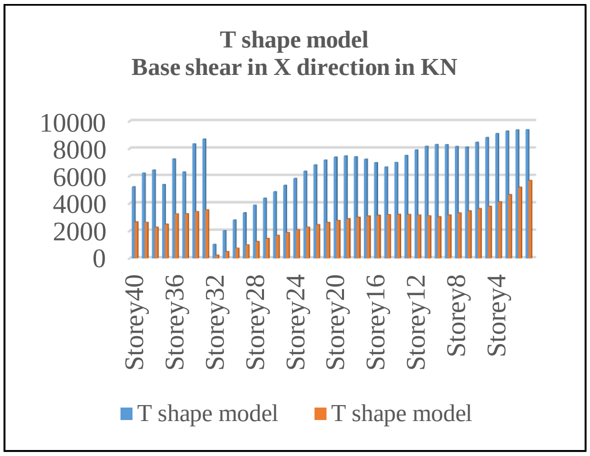
Graph 7. Storey Displacement in Y Direction – T Shape Model

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.

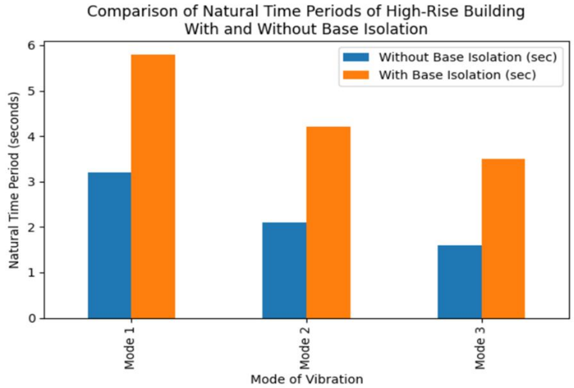


Graph 8. Storey Drift in Y Direction – T Shape Model

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.

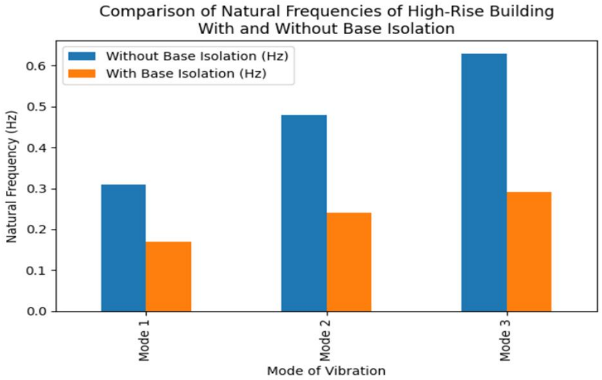


Graph 9. Base Shear Comparison in X Direction for T-Shape Model with and without Base Isolation



Graph 10. 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 11. 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.

V. CONCLUSION

The study concludes that the incorporation of Lead Rubber Bearing (LRB) base isolation in a G+40 high-rise RCC building significantly enhances seismic performance under Seismic Zone V conditions. The isolated models exhibited a reduction in lateral displacement of approximately 35–40%, indicating improved overall structural stability. Storey drift values decreased by nearly 40–45%, demonstrating effective control of inter-storey deformation during seismic excitation. Additionally, base shear forces were reduced by approximately 40–55%, confirming that base isolation substantially minimizes seismic force transmission to the superstructure.

The increase in fundamental time period and corresponding reduction in spectral acceleration demand contributed to improved damping behavior and reduced structural and non-structural damage potential. Due to the reduced seismic demand, the structural reliability and expected service life of the building are likely to improve, making base isolation a highly effective strategy for tall buildings in high seismic regions. However, one limitation of the present study is that the analysis is based on linear response spectrum methods and assumes idealized isolator behavior, which may not fully capture complex nonlinear seismic responses under severe ground motions.

Therefore, future research is recommended to incorporate nonlinear time history analysis and soil–structure interaction effects to obtain a more realistic assessment of isolated high-rise buildings. Further investigation into long-term performance and maintenance considerations of isolation systems may also enhance practical implementation strategies. Overall, the study establishes that LRB base isolation provides significantly improved seismic resilience compared to conventional fixed-base systems and is a viable solution for high-rise structures in severe seismic zones. The findings are particularly beneficial for tall buildings in high seismic zones where conventional fixed-base systems may experience excessive lateral demand.

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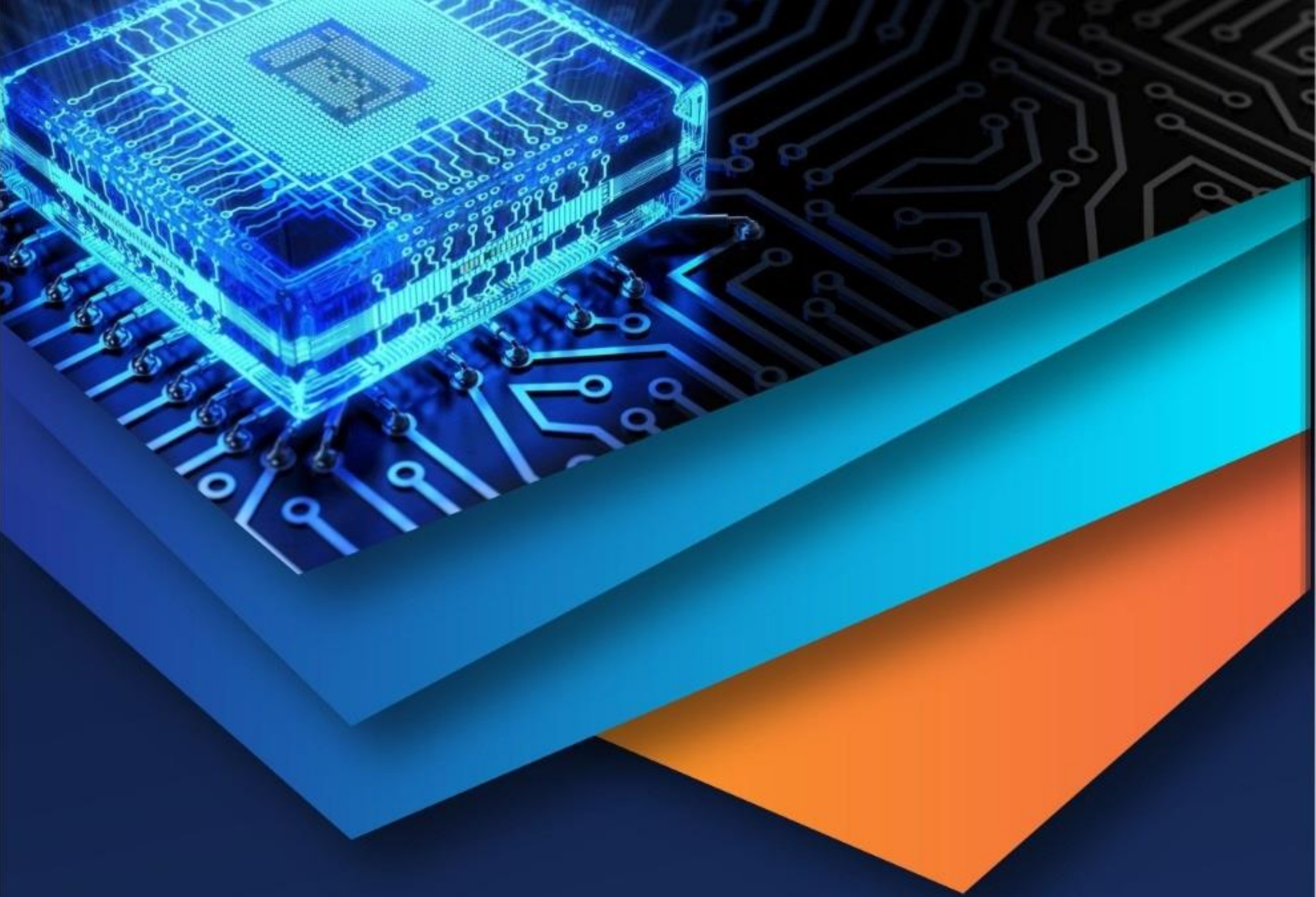

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