

Effectiveness of Base Isolation and Energy Dissipation Devices on the Seismic Performance of Mid-Rise RC Buildings – An ETABS Study

Bibek Biswas¹, Chitrnanjan Kumar², Praveen Verma³, Mayank Chauhan⁴, Abhishek Rana⁵

^{1,2,3,4,5} Department of Civil Engineering, Shri Venkateshwara University, Gajraula(UP), 244236

Abstract - Mid-rise reinforced concrete (RC) buildings exhibit significant vulnerability to seismic forces, often experiencing substantial structural and non-structural damage during earthquakes. This dissertation presents a comprehensive comparative analysis of two advanced seismic protection strategies: base isolation systems and supplemental energy dissipation devices, aimed at enhancing the performance of these structures.

The study utilizes ETABS, a state-of-the-art structural analysis software, to conduct detailed three-dimensional modelling and analysis of representative mid-rise RC frame buildings. The research methodology involves developing models for a fixed-base building, a base-isolated building, and a building equipped with energy dissipation devices. The effectiveness of Lead Rubber Bearings (LRB) is evaluated as base isolation techniques. The seismic performance of these models is assessed through nonlinear dynamic time-history analysis using a suite of ground motion records and nonlinear static (pushover) analysis. Key performance parameters, including base shear, inter-story drift, floor accelerations, and displacement demands, are systematically evaluated to quantify the effectiveness of each protection strategy. The results demonstrate that base isolation significantly lengthens the structure's fundamental period, leading to a substantial reduction in floor accelerations and inter-story drifts, thereby protecting both structural and non-structural components. Energy dissipation devices are also shown to effectively reduce displacement and dissipate seismic energy, offering a viable solution for seismic retrofitting. This study provides a quantitative comparison of these systems, offering critical insights into their respective advantages and limitations for mid-rise RC buildings. The findings will aid structural engineers in selecting the most appropriate seismic protection system to achieve desired performance objectives, such as Immediate Occupancy or Life Safety, contributing to the development of more resilient urban infrastructure.

Key Words: Reinforced Concrete, Lead Rubber Bearings, Moment Resisting Frame, Base Shear, Fundamental Natural Time Period, Dead Load, Live Load.

1. INTRODUCTION

1.1 Background & Motivation

Seismic vulnerability remains one of the most significant challenges facing structural engineering, particularly in earthquake-prone regions where mid-rise reinforced concrete (RC) buildings constitute a substantial portion of the built environment. Conventional seismic design philosophy relies primarily on structural ductility and energy dissipation through

inelastic deformation of structural members, often resulting in significant damage during severe earthquakes despite preventing total collapse. This approach, while life-saving, frequently leads to substantial economic losses, displacement of occupants, and prolonged recovery periods.

The limitations of traditional fixed-base design have prompted researchers and practitioners to explore alternative strategies that fundamentally alter how structures respond to seismic excitations. Two prominent approaches have emerged: base isolation systems and energy dissipation devices, both representing paradigm shifts in seismic protection philosophy. Base isolation decouples the superstructure from ground motion by introducing flexible elements at the foundation level, effectively lengthening the fundamental period and reducing transmitted forces. Energy dissipation devices, conversely, absorb seismic energy through various mechanisms including metallic yielding, friction, or viscous damping, thereby reducing structural response without necessarily altering the fundamental period significantly.

Mid-rise RC buildings, typically ranging from 5 to 15 stories, occupy a critical position in this discussion as they represent the predominant building typology in urban areas worldwide. Their fundamental periods (approximately 0.5 to 2.0 seconds) often coincide with peak spectral accelerations in design response spectra, making them particularly vulnerable to seismic damage. The effectiveness of protective systems for these structures requires careful evaluation considering structural dynamics, soil-structure interaction, construction feasibility, and economic viability.

1.2 Problem Statement

Conventional seismic design for mid-rise reinforced concrete (RC) buildings, particularly in developing nations like India, relies on the structure's ability to dissipate energy through inelastic deformation. While this approach is intended to prevent collapse, it often results in significant structural damage, rendering the building non-functional, economically unviable to repair, and posing a risk to occupants during aftershocks. This leads to substantial economic losses, prolonged business interruption, and displacement of communities. The fundamental periods of these mid-rise structures often align with the peak spectral acceleration of typical earthquake ground motions, making them disproportionately vulnerable to seismic events.

Existing research has established the effectiveness of advanced protective technologies like base isolation and energy dissipation devices. However, there is a lack of comprehensive, comparative research that directly evaluates the performance and cost-effectiveness of these different systems specifically for the mid-rise RC building typology prevalent in the Indian seismic context. Engineers and stakeholders lack clear, data-driven guidance on which

system—or combination of systems—provides the most effective protection for achieving specific performance objectives, such as Immediate Occupancy versus Life Safety. Therefore, this research addresses the critical problem of mitigating seismic risk in mid-rise RC buildings by conducting a rigorous comparative analysis. The study will quantify the effectiveness of various base isolation and energy dissipation systems in reducing seismic demand and damage. The goal is to develop clear engineering guidelines that will enable the selection of the most appropriate and economically viable seismic protection strategy, thereby enhancing the resilience of critical urban infrastructure and safeguarding communities against the devastating impact of earthquakes.

1.3 Scope of Work

The scope of this study is delineated to ensure focused and achievable outcomes within the academic timeline:

Building Typology: A symmetric G+5 Reinforced Concrete building with a typical floor plan, representative of urban residential towers in India.

- **Seismic Zone:** Zone V ($Z = 0.36$), the most severe seismic zone in India, to test the limits of the protection systems.
- **Soil Condition:** Medium Soil (Type II) as per IS 1893, which is the most common soil classification encountered in the Indo-Gangetic plains.
- **Software:** CSI ETABS (v22) will be used for all modeling and analysis.

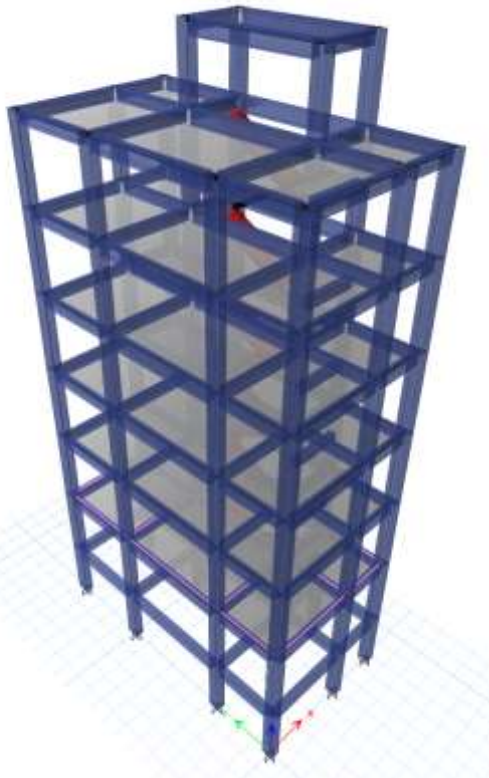


Fig-1.1 3D Model

Analysis Types:

- Phase 1: Equivalent Static, Response Spectrum, and Modal Analysis.
- Phase 2 : Fast Nonlinear Analysis (FNA) and Nonlinear Time History Analysis (NLTHA).

2. LITERATURE REVIEW

2.1 Overview of Previous Work

Research on seismic protection of structures has long recognized the importance of energy dissipation as a means to mitigate earthquake effects. Early foundational studies in structural dynamics emphasized that seismic damage correlates with the cumulative energy input into a structure rather than merely peak forces, motivating the development of devices that absorb and dissipate this energy before it damages structural elements. Passive dampers, such as viscous, friction, yielding, and fluid viscous dampers, have been extensively researched for their ability to reduce inter-story drift, base shear, and floor accelerations by converting seismic input into heat through hysteresis or fluid motion. These devices are widely used in both retrofit and new construction to enhance seismic performance without the need for external power sources.

Parallel to this, base isolation techniques evolved as a distinct but related seismic control strategy. Pioneering work by Kelly, Naeim, and others in the late 20th century formalized the theory of isolators—such as lead-rubber bearings, high-damping rubber bearings, and friction pendulum systems—which decouple the superstructure from ground motion by increasing the structure's natural period and introducing damping at the foundation level. These isolators significantly reduce the seismic demand transmitted into the structure, lowering base shear and floor accelerations.

In recent decades, research has increasingly focused on hybrid systems that combine base isolation with supplemental energy dissipation devices. Studies demonstrate that adding dampers to isolated structures can control excessive isolator displacements, improve overall damping, and enhance resilience under severe earthquakes beyond what isolation alone can achieve. Semi-active and hybrid control strategies (e.g., magneto-rheological dampers) have also been explored for adaptive performance.

Overall, the literature reflects a progression from individual passive damping devices and isolation systems toward integrated seismic protection schemes, where energy dissipation and isolation work synergistically to optimize structural performance under earthquake loading. The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

2.1 Critical Analysis and Research Gaps

Despite this extensive research, certain gaps remain. Many prior studies focus on particular devices or specific building types (often high-rise or archetype cases) rather than systematically examining a mid-rise concrete frame. For example, Liu et al. note that although base isolation and inter-story isolation have been individually well studied, comparative analyses of their effectiveness in multi-story RC frames are relatively scarce. Likewise, few investigations have explored how variations in device properties (bearing stiffness, damping coefficients, etc.) affect performance in practice. Most analyses assume idealized (often linearized) device behavior under code spectra, but the real seismic benefit can depend sensitively on the isolator's bilinear properties and on damper tuning. Studies of viscous dampers

have generally demonstrated their benefits, but optimal placement and parameter selection in mid-rise frames (especially in conjunction with isolation) are not well quantified. Moreover, the recent introduction of IS 1893 Part 6 (2022) means there is limited published work applying these updated criteria with modern software tools. In particular, there is a need for detailed ETABS-based parametric studies that combine base isolation with supplemental damping. In short, while it is clear that isolators and dampers help, comprehensive comparisons of different isolation schemes, damper configurations, and device settings for typical mid-rise RC buildings are lacking. Filling these gaps will improve our understanding of how best to design and tune these systems for a given structure and seismic zone.

2.3 Summary

In summary, the literature shows that both base isolation (especially LRBs) and energy-dissipating devices (such as FVDs) can substantially reduce seismic responses in RC buildings. Base isolators typically yield the largest reductions by lengthening the period, while dampers add robustness by absorbing energy. However, most existing studies treat these strategies separately or use limited parametric scenarios. There is a clear research need to quantitatively compare the effectiveness of different isolation and damping schemes for mid-rise RC frames, using consistent modeling approaches. This motivates the present work, which will use ETABS simulations to systematically evaluate LRB isolators in a prototypical mid-rise concrete frame, under the guidelines of current seismic codes.

3. OBJECTIVE AND METHODOLOGY

3.1 Aim of Research

The primary aim is to evaluate how base-isolation bearings and supplemental viscous dampers affect the seismic performance of a typical mid-rise reinforced-concrete moment-resisting frame. Specifically, the study will quantify reductions in key response parameters (roof and story displacements, inter-story drifts, base shear, and floor accelerations) when devices like lead-rubber bearings (LRBs) are installed. The focus on a mid-rise structure is motivated by the fact that such buildings often have natural periods near the peak of earthquake spectra, so lengthening the period via isolation can yield large benefits. The research will also explore how varying the mechanical properties of the devices (e.g. bearing stiffness, damping coefficients) influences performance, thereby identifying design guidelines for optimal device selection and tuning.

3.2 Research Question

The central question is: How effectively can base isolation and supplemental damping improve the seismic resilience of a mid-rise RC frame? Sub-questions include: (1) To what extent do LRB isolators reduce drifts, accelerations, and shear in the frame compared to a fixed-base model? (2) How much additional benefit can fluid viscous dampers provide, and under what configurations? (3) How sensitive are the performance improvements to the isolator stiffness and damper damping values? Answers to these will inform whether a given isolation or damping system is justified for a mid-rise design and how to optimize it.

3.3 Proposed Methodology

The study will use a detailed finite-element model of a mid-rise RC building in ETABS. Key steps include:

Structural Model Setup: Define a representative building with typical RC column-beam framing (moment-resisting frame) as per IS 456 and IS 1893 provisions. Assign material properties and geometric dimensions. Model the unretrofitted building first (fixed-base) to establish a baseline response.

Base-Isolated Model: Introduce base isolation by inserting LRB elements at the foundation level. Model the LRBs with appropriate bilinear (pinned) behavior or equivalent linearized properties. Parameters (elastic stiffness, yield force, post-yield stiffness, damping ratio) will be chosen based on IS 1893 (Part 6):2022 recommendations and literature values. An example of this approach is seen in Bokey & Patel, who modelled a 15-storey RC building in ETABS with LRB base isolation and conducted response-spectrum analysis.

Seismic Loading and Analysis: Apply seismic loading using the Response Spectrum Method per IS 1893 (Part 1 and Part 6) with appropriate zone factors and spectra. Dynamic properties of the isolated structure (extended period, added damping) will be captured automatically by ETABS. Time-history analysis may also be performed for verification.

Parameter Variations: Systematically vary device parameters across cases. For LRBs, adjust the isolator stiffness and damping ratio within realistic ranges. Compare results for each case.

Performance Metrics: For each model (fixed-base, isolated, damped, and combinations), extract key results: roof displacement, maximum inter-story drift, floor accelerations, and base shear. Compute percentage improvements of each metric relative to the fixed-base case.

Code Compliance: Check that all models conform to the latest Indian standards. For example, ensure design accelerations and building code requirements follow IS 1893:2022 and IS 1893 (Part 6) where relevant.

Software Tools: Perform all structural modelling and analysis in ETABS (the current version). This methodology is consistent with prior studies; for instance, Bokey & Patel used ETABS for LRB-isolated building analysis.

Each analysis will be carefully validated (e.g. by checking the period shift and comparing with known results). By systematically comparing the results across models, the study will determine which device configurations give the greatest reduction in seismic demands for a mid-rise RC frame.

Seismic Analysis and Device Modeling Methodology with Governing Equations

In this study, the seismic response of the reinforced concrete moment-resisting frame was evaluated using the Response Spectrum Method in accordance with IS 1893 (Part 1): 2016 and IS 1893 (Part 6): 2022. ETABS computes the design horizontal seismic coefficient A_h using the expression

$$A_h = \frac{Z I S_a}{2 R g}$$

where Z is the seismic zone factor, I is the importance factor, R is the response reduction factor, and S_a/g is the spectral acceleration coefficient corresponding to the fundamental time period of the structure. The total design base shear acting on the structure is then obtained as

$$V_b = A_h W$$

where W_i is the seismic weight of the building. This base shear is vertically distributed along the height of the structure according to

$$Q_i = V_b \frac{W_i h_i^2}{\sum W_j h_j^2}$$

ensuring that higher storeys attract greater lateral forces. For base-isolated buildings, the response spectrum is further modified to account for increased damping using the damping correction factor

$$\eta = \sqrt{\frac{10}{5 + \xi}}$$

where ξ is the effective damping ratio of the isolated system. Lead Rubber Bearings (LRBs) were modeled in ETABS using nonlinear link elements with bilinear hysteretic behavior. The lateral force developed in an LRB is expressed as

$$F = Q_d + k_2 D$$

where Q_d is the characteristic yield strength of the lead core, k_2 is the post-yield stiffness, and D is the lateral displacement. The effective horizontal stiffness of the isolation system is defined as

$$k_{eff} = \frac{F_{max}}{D_{max}}$$

which governs the effective fundamental time period of the isolated structure given by

$$T_{eff} = 2\pi \sqrt{\frac{M}{k_{eff}}}$$

where M is the seismic mass of the superstructure. The enhanced energy dissipation capacity of LRBs is represented by the equivalent viscous damping ratio

$$\xi_{eff} = \frac{E_d}{4\pi k_{eff} D^2}$$

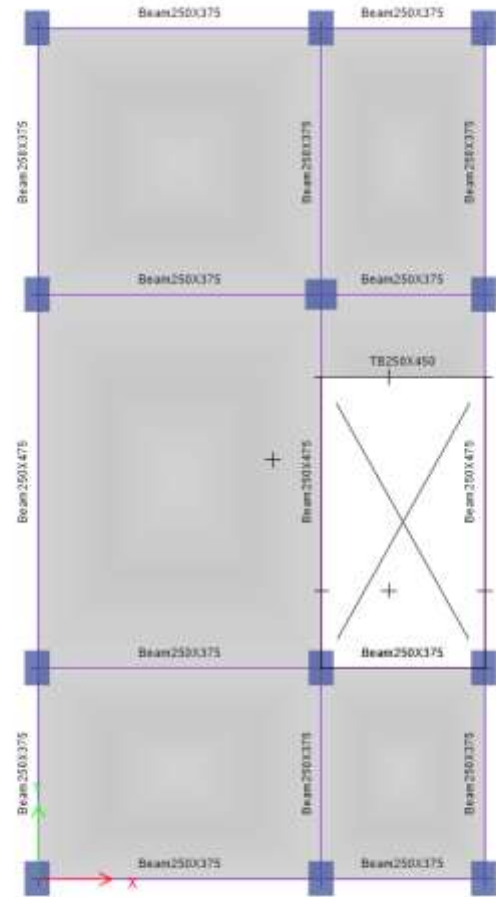
where E_d is the energy dissipated per cycle, corresponding to the area enclosed by the hysteresis loop. Period elongation combined with increased damping results in a substantial reduction of seismic force demand transmitted to the superstructure.

3.4 Expected Outcome

Based on the literature and preliminary modeling, the expected outcomes include:

- **Quantified Performance Gains:** The isolated building should exhibit much longer natural periods and correspondingly lower base shear and drifts. We anticipate reductions in story drift and roof displacement on the order of 50–60% for LRB isolation, as seen in prior analyses. Floor accelerations above the isolation layer should drop substantially, improving occupant safety and non-structural stability.
- **Device Parameter Effects:** By varying isolator stiffness and damper coefficients, the study will reveal how sensitive the building response is to these parameters. We expect to identify an optimal range: too soft an isolator could produce large base displacements, while too stiff an isolator gives less benefit. Similarly, increasing damper capacity should yield diminishing returns after a point. The outcomes will include recommendation curves or guidelines for selecting isolator and damper properties for mid-rise RC designs.
- **Design Recommendations:** The results will confirm that base isolation (LRBs) is highly effective for mid-rise RC frames in high-seismic zones, and will quantify the extent of

improvement as a function of isolator properties. In summary, the research is expected to demonstrate that modern isolation and damping systems, properly chosen, can dramatically improve seismic performance of mid-rise reinforced concrete buildings. These findings will provide engineering insights



directly applicable to design under IS 1893, potentially encouraging wider use of such systems in future construction.

4. DETAILED NUMERICAL MODELLING AND PARAMETRIC STUDY

4.1 Initial Work Done

The preliminary phase of the present research focused on establishing a reliable analytical framework for evaluating the seismic effectiveness of base isolation and energy dissipation devices in mid-rise reinforced concrete (RC) buildings. The initial work began with an extensive review of seismic design provisions of IS 1893 (Part 1): 2016 and IS 1893 (Part 6): 2022, with particular emphasis on dynamic analysis requirements, response spectrum parameters, and special considerations for base-isolated structures. Design guidelines from IS 456:2000 were also reviewed to ensure consistency in structural modeling.

A baseline fixed-base RC moment-resisting frame (MRF) model was developed in ETABS to represent a typical mid-rise building. The building geometry, material properties, member sizes, and load combinations were defined as per Indian Standard practice. Dead loads, live loads, and seismic loads were assigned, and response spectrum analysis was performed to obtain fundamental dynamic characteristics such as natural time period, mode shapes, base shear, storey displacement, and inter-storey drift.

Following the fixed-base model, a base-isolated model using Lead Rubber Bearings (LRBs) was created. Isolation elements were assigned at the foundation level using ETABS link properties. The LRBs were modeled using equivalent linear properties derived from literature and code recommendations, including effective stiffness, characteristic strength, and damping ratio. Multiple isolator property sets were defined to study the influence of varying isolator stiffness and damping on the overall structural response.

Base-isolated building with LRBs

Preliminary response spectrum analyses were conducted for all models under the same seismic input parameters to ensure consistency in comparison. Output results such as storey displacement, storey drift, base shear, and acceleration were extracted for initial assessment.

4.2 Description of Baseline Structural model

The baseline structural model considered in this study represents a typical mid-rise reinforced concrete (RC) moment-resisting frame commonly used for residential and commercial buildings in Indian urban regions. This model serves as the reference configuration against which the seismic performance of base-isolated, damped, and hybrid systems is evaluated in Phase-II.

The building consists of a G+5 storey RC frame, with a regular plan geometry and uniform storey height. Each storey has a height of 3.0 m, resulting in a total building height of 18.0 m above the foundation level. The structural layout comprises equally spaced bays in both orthogonal directions, ensuring plan and vertical regularity in accordance with seismic design recommendations.

Structural members are modeled using M25 grade concrete and Fe500 grade reinforcing steel, consistent with prevalent construction practices in India. Beams and columns are designed as per the provisions of IS 456:2000, and slab action is modeled using rigid diaphragm assumptions at each floor level. The floor system is assumed to act as a rigid diaphragm, distributing lateral loads uniformly among the vertical load-resisting elements.

Dead loads include the self-weight of structural components, along with floor finishes and wall loads applied as uniformly distributed loads on beams. Live loads are assigned in accordance with IS 875 (Part 2), and appropriate load reduction factors are applied for seismic mass calculation. The seismic mass of the structure is derived from dead load and a specified percentage of imposed load, as recommended by IS 1893 (Part 1).

The building is assumed to be located in Seismic Zone V, resting on medium soil, with a response reduction factor (R) corresponding to a special moment-resisting frame (SMRF). The importance factor (I) is taken as unity, representing a standard occupancy building. The seismic analysis is carried out using Response Spectrum Analysis (RSA) and, where applicable, nonlinear dynamic procedures in accordance with IS 1893 (Part 6):2022.

In the baseline configuration, the structure is modeled as a fixed-base system, with all column bases fully restrained against translation and rotation. This fixed-base model establishes the reference seismic demand in terms of base shear, storey displacement, inter-storey drift, acceleration

response, and member forces. All subsequent models incorporating Lead Rubber Bearings (LRBs) systems retain identical geometry, material properties, loading conditions, and seismic input parameters. Only the seismic control devices and their properties are varied during the parametric study.

The baseline model thus provides a consistent and reliable benchmark for evaluating the effectiveness of various seismic protection strategies, enabling meaningful comparison of response reduction and performance enhancement achieved through base isolation and energy dissipation mechanisms.

4.3 Definition of Performance Parameters

To assess the seismic performance of the mid-rise RC building and to compare the effectiveness of base isolation, energy dissipation, and hybrid systems, selected response parameters are evaluated from ETABS analyses. These parameters represent both global and local structural behavior under seismic loading. All results are compared with respect to the fixed-base model under identical seismic input conditions as per IS 1893 (Part 6):2022.

The fundamental natural time period is considered to evaluate changes in dynamic characteristics of the structure. Base isolation systems are expected to increase the natural period by introducing flexibility at the base, thereby reducing seismic forces acting on the structure.

Base shear is used as a key indicator of seismic demand transmitted to the structure. Reduction in base shear reflects the effectiveness of isolation and damping systems in limiting earthquake forces.

Storey displacement and inter-storey drift ratio are evaluated to assess lateral deformation and potential structural damage. Inter-storey drift is particularly important, as it directly relates to damage levels and code-prescribed performance limits.

The structural acceleration response at floor levels is examined to evaluate occupant comfort and the performance of acceleration-sensitive non-structural components. Energy dissipation devices are expected to reduce acceleration demands effectively.

Member forces, including axial force, bending moment, shear force, and torsion in beams and columns, are analyzed to understand the influence of seismic control systems on internal force distribution and structural safety.

For base-isolated models, isolator displacement is monitored to ensure that lateral movements at the isolation level remain within acceptable limits.

Finally, the energy dissipation capacity of LRBs is considered to evaluate their ability to absorb seismic input energy and reduce damage to structural members. All performance parameters are presented using tables and graphs, along with percentage reductions relative to the fixed-base model.

5. WORKFLOW FOR PARAMETRIC ANALYSIS AND EVALUATION

5.1 Development of Reference (Fixed-Base) Model

The fixed-base structural model is established as the baseline configuration with all supports fully restrained. This model provides the reference seismic response against which all modified models incorporating isolation and damping devices are compared.

Load Combination	(DL+LL) (FZ)	RSx	RSy
Overturning Moment $\frac{kN-m}{kN}$	36135.9	2322.58	3191.98
Base Shear $\frac{kN}{kN}$	6685.79	179.58	240.43
Max Story Displacement $\frac{mm}{mm}$	5.08mm	36.69mm	29.38mm
Max story Drift	0.00039	0.0026 1st floor	0.0021 1st floor

Mode Shape	Mode 1	Mode 2	Mode 3
Period $\frac{s}{s}$	1.590	1.376	1.149
Max Displacement $\frac{mm}{mm}$	84	112	84

Table -1: Result Fixed Base

5.2 Extraction of Baseline Seismic Response

Key response parameters such as time period, base shear, storey displacement, inter-storey drift, acceleration, and member forces are obtained from the fixed-base model. These values serve as benchmark data for subsequent comparison.

Case-1: LRB Properties – LRB 600

ETABS Input Field	Property Value
Total Mass	350 kg
Weight	3.43 kN
Rotational Inertia 1, 2, 3	0.015 ton-m ²
U1 Stiffness - Linear (Vertical)	1,800,000 kN/m
U2 & U3 Stiffness - Linear (Effective)	1,450 kN/m
U2 & U3 Stiffness - NonLinear (Initial K ₀)	12,500 kN/m
U2 & U3 Yield Strength (F _y)	180 kN
U2 & U3 Post-Yield Stiffness Ratio	0.1

Result

Load Combination	(DL+LL)	RSx	RSy
Overturning Moment $\frac{kN-m}{kN}$	36135.90	1855.84	1772.83
Base Shear $\frac{kN}{kN}$	6706	146.78	142.59
Max Story Displacement $\frac{mm}{mm}$	-5.93mm	47.85	35.44
Max story Drift	0.00043	0.0047 gr floor	0.0033 gr floor

Mode Shape	Mode 1	Mode 2	Mode 3
Period $\frac{s}{s}$	2.282	2.05	1.81
Max Displacement $\frac{mm}{mm}$	60	75	84

Table -2: LRB 600

Case-2: LRB Properties – LRB 800

ETABS Input Field	Property Value
Total Mass	680 kg
Weight	6.67 kN
Rotational Inertia 1, 2, 3	0.035 ton-m ²
U1 Stiffness - Linear (Vertical)	3,100,000 kN/m
U2 & U3 Stiffness - Linear (Effective)	2,800 kN/m
U2 & U3 Stiffness - NonLinear (Initial K ₀)	25,000 kN/m
U2 & U3 Yield Strength (F _y)	320 kN
U2 & U3 Post-Yield Stiffness Ratio	0.1

Result

Load Combination	(DL+LL)	RSx	RSy
Overturning Moment $\frac{kN-m}{kN}$	36135.90	1971.30	1872.81
Base Shear $\frac{kN}{kN}$	6725	154.75	170.49
Max Story Displacement $\frac{mm}{mm}$	5.6mm	45.79	32.04
Max story Drift	0.00042	0.0048 gr floor	0.0033 gr floor

Mode Shape	Mode 1	Mode 2	Mode 3
Period $\frac{s}{s}$	2.128	1.899	1.659
Max Displacement $\frac{mm}{mm}$	70	84	84

Table -3: Result LRB 800

Case-3: LRB Properties – LRB 500 Custom 1

ETABS Input Field	Property Value
Total Mass	500 kg
Weight	4.91 kN
Rotational Inertia 1, 2, 3	0.015 ton-m ² (2 & 3 are 0)
U1 Stiffness - Linear (Vertical)	2,100,000 kN/m
U2 & U3 Stiffness - Linear (Effective)	1,850 kN/m
U2 & U3 Stiffness - NonLinear (Initial K ₀)	18,500 kN/m
U2 & U3 Yield Strength (F _y)	340 kN

U2 & U3 Post-Yield Stiffness Ratio	0.08
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Result

Load Combination	(DL+LL)	RS _x	RS _y
Overturning Moment	36135.90	1907.81	1812.26
Base Shear kN	6715	150.36	144.91
Max Story Displacement mm	5.83mm	47.03	33.91
Max story Drift	0.00043	0.0048 gr mumpty floor	0.0033 gr floor

Mode Shape	Mode 1	Mode 2	Mode 3
Period s	2.21	1.98	1.75
Max Displacement mm	75	75	84

Table -4: Result LRB 500 Custom 1

Case-4: LRB Properties – LRB 800

ETABS Input Field	Property Value
Total Mass	500 kg
Weight	4.91 kN
Rotational Inertia 1, 2, 3	0.015 ton-m ² (2 & 3 are 0)
U1 Stiffness - Linear (Vertical)	1,750,000 kN/m
U2 & U3 Stiffness - Linear (Effective)	850 kN/m
U2 & U3 Stiffness - NonLinear (Initial K ₀)	10,500 kN/m
U2 & U3 Yield Strength (F _y)	85 kN
U2 & U3 Post-Yield Stiffness Ratio	0.06

Result

Load Combination	(DL+LL)	RS _x	RS _y
Overturning Moment $kN-m$	36135.90	1695.87	1664.89
Base Shear kN	6715	135.62	136.03
Max Story Displacement mm	5.94mm	49.783	39.69
Max story Drift	0.00043	0.0045 gr mumpty floor	0.00325 gr floor

Mode Shape	Mode 1	Mode 2	Mode 3
Period s	2.48	2.259	2.025
Max Displacement mm	64	68	84

Table -5: Result LRB 500 Custom 2

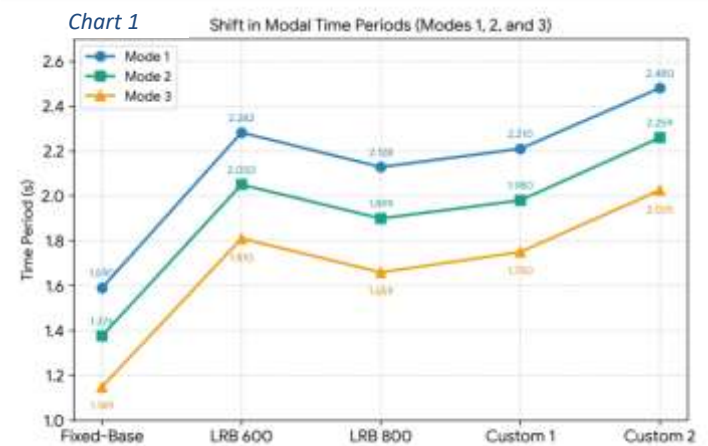
6. CONCLUSIONS

6.1 Summary

This study systematically evaluated the effectiveness of base isolation techniques, specifically Lead Rubber Bearings (LRB), on the seismic performance of a mid-rise reinforced concrete (RC) building. A comprehensive parametric analysis was conducted using ETABS to compare a conventional fixed-base model against four isolated configurations (LRB 600, LRB 800, Custom 1, and Custom 2), varying in stiffness and yield strength. The results establish that the strategic implementation of LRB systems significantly decouples the superstructure from ground-induced seismic excitations, thereby enhancing structural stability and serviceability.

6.2 Fundamental Period Elongation and Structural Decoupling

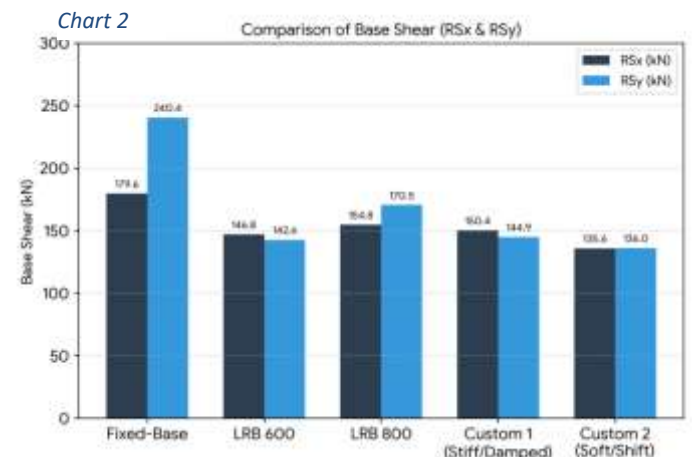
The primary mechanism of base isolation—shifting the fundamental time period of the structure was successfully



validated. The fixed-base RC frame exhibited a fundamental time period of 1.590 seconds. The introduction of LRB isolators shifted the period into the low-acceleration region of the design response spectrum, with values ranging from 2.128 seconds (LRB 800) to 2.480 seconds (Custom 2). The Custom 2 model, characterized by an exceptionally low effective stiffness ($K_{eff} = 850$ kN/m), demonstrated the most significant period elongation. Furthermore, the uniform shift across higher modes of vibration (Modes 2 and 3) confirms complete structural decoupling. superstructure from ground-induced seismic excitations, thereby enhancing structural stability and serviceability.

6.3 Mitigation of Base Shear

The elongation of the structural period resulted in a marked

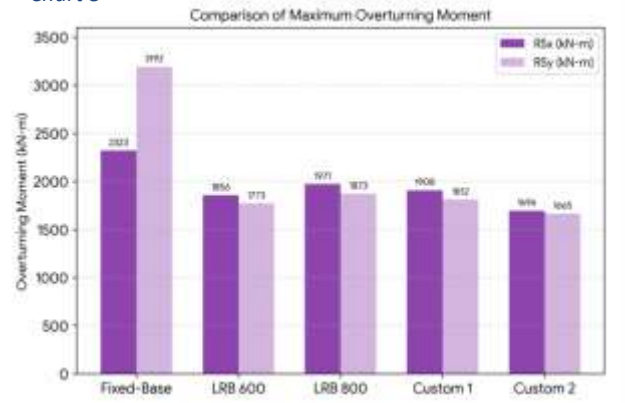


reduction in the spectral accelerations drawn from the design earthquake, directly translating into lower global base shears. The fixed-base model attracted a base shear of 179.58 kN (RSx) and 240.43 kN (RSy). Conversely, the Custom 2 isolation system reduced the base shear to 135.62 kN (RSx) and 136.03 kN (RSy), representing a substantial decrease in the lateral forces transferred to the RC framing.

6.4 Reduction of Overturning Moments

A critical objective of structural design is limiting the global overturning forces that dictate foundation sizing and column stress. The fixed-base model experienced severe overturning

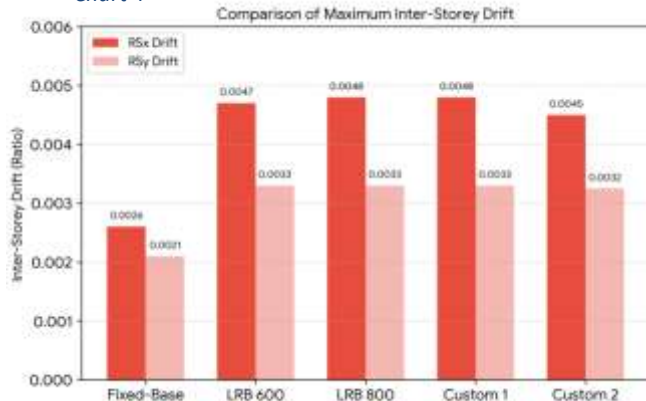
Chart 3



moments, particularly in the Y-direction (3192 kN-m). By isolating the base, the models significantly dissipated these internal forces. The Custom 2 LRB achieved the highest reduction, dropping the RSy overturning moment to 1664 kN-m. This massive reduction directly translates to a more stable structure with mitigated uplift forces on the foundation.

6.5 Displacement Profiles and Inter-Storey Drift Control

Chart 4



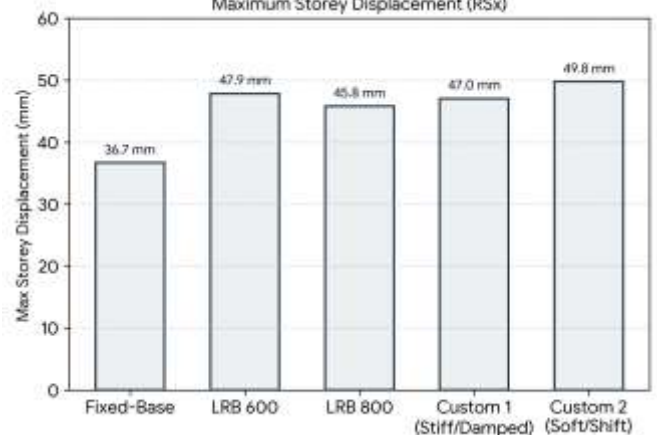
While base isolation reduces internal member forces, it intrinsically increases absolute lateral displacements at the base. The maximum storey displacement increased from 36.69 mm in the fixed-base model to 49.78 mm in the Custom 2 model. However, an analysis of the drift profiles indicates a critical structural benefit: the maximum inter-storey drift migrated from the 1st floor in the fixed model to the ground floor (isolation interface) in the LRB models. This confirms that the elastomeric bearings absorbed the majority of the lateral deformation, acting as a structural fuse that preserves the structural integrity of the upper stories.

6.6 Final Remarks

In conclusion, the implementation of Lead Rubber Bearings is a highly viable and effective strategy for designing mid-rise RC structures in seismically active regions. The study confirms that the selection of LRB parameters must be a

calibrated compromise between stiffness, damping, and allowable displacement. Bearings with softer rubber matrices (Custom 2) are preferable for maximizing shear and overturning moment reduction, provided the structural detailing can accommodate the requisite lateral clearances. Bearings with robust lead cores and higher stiffness (LRB 800) are recommended when site conditions strictly limit permissible lateral base drift, ensuring robust energy

Chart 6



dissipation within confined spatial bounds.

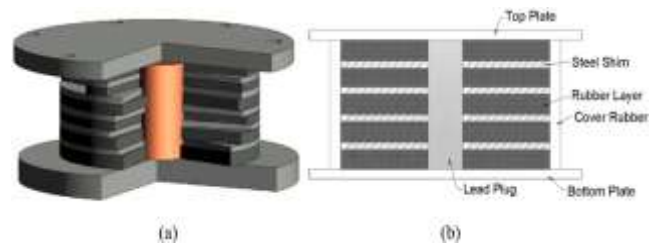


Figure 2- Sectional Details of LRB

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Robinson, W. H. – Inventor of the lead rubber bearing (LRB), widely referenced in base isolation research and applications. Bhandari et al. (2018)
Scientific studies on HDRB and LRB base isolation — comparisons of different isolation systems for multi-storey RC buildings exploring performance under seismic excitations.
Ozer et al. (2025) — compared fixed base vs. various base isolation models (LRB, friction bearings) and confirmed reduced seismic demands with base isolation.
Kazeminezhad et al. (2025) — presented design refinements and performance improvements for LRBs in reinforced concrete buildings, emphasizing reductions in drifts and forces.
Ras & Boumechra (2016) – Seismic energy dissipation using fluid viscous dampers — numerical analysis showing FVDs significantly improve seismic response without increasing stiffness.
Belbachir et al. (2023/2024) – explored the use of fluid viscous dampers combined with high-damping rubber bearings in base-isolated RC buildings, demonstrating energy

dissipation benefits and reductions in base shear and accelerations.

MDPI Applied Sciences (2025) – review article summarizing seismic behavior with supplementary dampers, covering fluid viscous, viscoelastic, friction and other damper types, useful for background on energy dissipation theories.

MDPI Enhancing Seismic Resilience... (2025) – quantified the improvements in drift and displacement due to non-linear viscous dampers in reinforced concrete buildings.

Seismic response of base-isolated buildings: exploring isolator properties - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Lead-rubber-bearing-a-3D-view-b-sectional-view_fig1_379835328

AUTHOR'S BIOGRAPHY



Bibek Biswas is a Civil engineer, holds B.Tech Degree from Maulana Abul Kalam Azad University of Technology, West Bengal. He is currently pursuing his M.Tech. degree from Shri Venkateshwara University, Gajraula (UP). His research focuses on advanced earthquake engineering, specifically evaluating the "Effectiveness of Base Isolation and Energy Dissipation Devices on the Seismic Performance of Mid-Rise RC Buildings". He specializes in structural modeling using CSI ETABS and shifting design philosophies from damage control to damage prevention in high-risk Indian seismic zones.