

Seismic Performance of Regular and Irregular Buildings with Fixed Base and Lead Rubber Bearing Base Isolator

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Abstract - The implementation of Lead Rubber Bearing (LRB) base isolation systems significantly optimizes the seismic performance of multistory reinforced concrete moment-resisting frames, particularly for G+10 structures where plan irregularities—such as L-shaped configurations—induce complex torsional effects and non-uniform stiffness distribution. While fixed-base irregular structures exhibit amplified inter-story drift demands and localized force concentrations under seismic excitation, the integration of LRB isolators serves as an advanced passive control strategy that extends the fundamental natural period and enhances energy dissipation. Response Spectrum Analysis demonstrates that base isolation effectively decouples the superstructure from ground-induced inertia forces, resulting in a substantial reduction in base shear and lateral displacement profiles compared to conventional fixed-base systems. Ultimately, this seismic isolation technique mitigates the adverse dynamic response associated with structural asymmetry, ensuring superior structural integrity and serviceability in high-risk seismic zones.

Key Words: Lead Rubber Bearing (LRB), Structural Plan Irregularity, Seismic Base Isolation, Response Spectrum Analysis, Inter-storey Drift Ratio, Torsional Effect Mitigation

1. INTRODUCTION

Base isolation represents a paradigm shift in performance-based seismic engineering, evolving from early patented concepts into a primary strategy for ensuring the operational continuity of critical infrastructure. While conventional seismic design relies on the ductility of structural members to prevent collapse—often resulting in significant residual damage—base isolation prioritizes the protection of both structural integrity and sensitive non-structural components, such as medical equipment and electrical systems. By integrating flexible interfaces like Lead Rubber Bearings (LRB) or Friction Pendulum Systems at the foundation, the superstructure is effectively decoupled from horizontal ground motion.

This decoupling shifts the building's fundamental natural period away from the high-energy range of earthquake ground motions, leading to a marked reduction in transmitted floor accelerations, base shear, and inter-storey drift. Unlike internal damping systems that manage energy within the building frame, base isolation mitigates seismic

demand at the source. This ensures that regular and irregular reinforced concrete structures remain not only stable but fully functional, preserving safety and serviceability in the immediate aftermath of major seismic events.

1.1 Concept of Base isolation system

Base isolation is a sophisticated structural control strategy that introduces a flexible or sliding interface between a building's superstructure and its foundation to decouple it from horizontal ground motion. By extending the fundamental natural period, this system significantly limits the transmission of earthquake-induced inertia forces, protecting both the structural frame and sensitive non-structural components.

To be effective, isolation devices must maintain high vertical load-bearing capacity and service-level lateral stiffness (for wind and minor tremors) while exhibiting high lateral flexibility and energy dissipation during major seismic events. Furthermore, an ideal system incorporates self-centring capabilities to minimize residual displacement post-earthquake. This approach is particularly critical for facilities requiring immediate occupancy—such as hospitals and data centers—as it prioritizes operational continuity and reduces long-term life-cycle costs by minimizing structural damage and repair requirements.

1.2 Lead Rubber Bearing system

Lead Rubber Bearings (LRBs) have become a predominant solution in seismic-resistant design due to their integrated mechanical efficiency. Structurally, an LRB consists of alternating layers of vulcanized rubber and steel reinforcement shims, which provide high vertical axial stiffness to support gravity loads while preventing lateral bulging.

The defining component is the centrally located lead plug, which undergoes plastic shear deformation during seismic events. This creates a stable bilinear hysteretic response, providing the necessary energy dissipation and damping to control the building's lateral excursions. Because lead recrystallizes at room temperature, it exhibits excellent fatigue resistance and microstructural recovery, ensuring consistent performance over multiple cycles. By combining vertical load support, service-level wind resistance, and high seismic flexibility within a single compact unit, LRBs offer a technically robust and cost-effective method for decoupling structures from damaging ground motions.

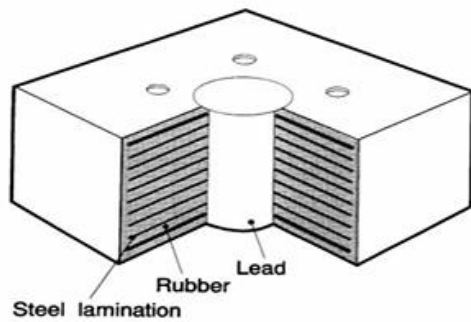


Fig -1: Section of Lead Rubber Bearing

Table -1: Data assumed for ETABS modelling

Building shape	Ordinary (Regular) & L-Shaped (Irregular)
Building Height	33m
Overall Story's	G+10
Floor Height	3m
Line load Considered	6.9 kN/m, 9.0 kN/m, 3.0 kN/m
Area load Considered	LL = 3.0 kN/m ² SDL = 1.5 kN/m ²
Beas Size assumed	300 x 500
Column Size assumed	450 x 50
Slab thickness	125

2. AIM AND OBJECTIVE

2.1 Aim:

The primary aim of this research is to investigate and compare the seismic performance of regular and irregular multistorey reinforced concrete buildings under fixed-base and Lead Rubber Bearing base-isolated conditions, in order to evaluate the effectiveness of base isolation in reducing earthquake-induced forces, controlling structural deformations, and improving overall safety and functional performance of buildings subjected to seismic excitation.

2.2 Objective:

1. To evaluate the seismic performance of multistorey reinforced concrete buildings with regular and irregular plan configurations.
2. To investigate the influence of plan irregularity on dynamic response parameters such as fundamental time period, base shear, storey displacement, inter-storey drift, and floor acceleration.
3. To analyse and compare the seismic behaviour of fixed-base structures with base-isolated structures using Lead Rubber Bearing (LRB) isolators.
4. To study the effectiveness of Lead Rubber Bearing base isolation system in reducing seismic force transmission and enhancing overall structural response.
5. To determine the improvement in global seismic performance and structural safety achieved through the adoption of base isolation technique.

3. METHODOLOGY

For this research work, ETABS software was used. ETABS is a structural engineering software used for modelling, analysis, and design of multistorey buildings under gravity and lateral loads such as wind and earthquake. It provides advanced analysis features including response spectrum and time history analysis, making it suitable for evaluating the seismic behavior and performance of regular and irregular building systems.

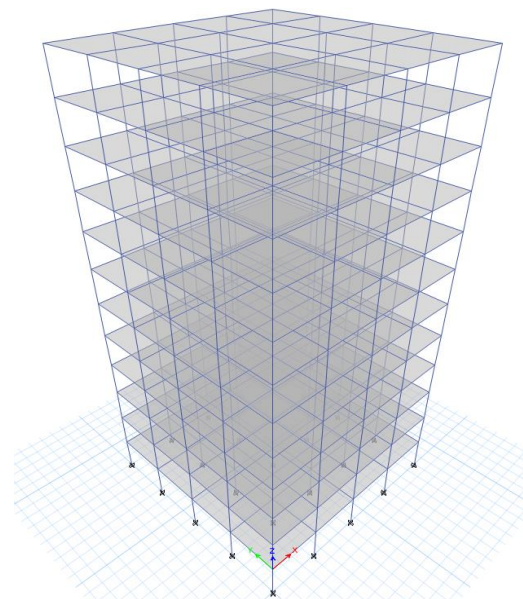


Fig -2: Regular Building with fixed base (Restrained against displacement and rotation)

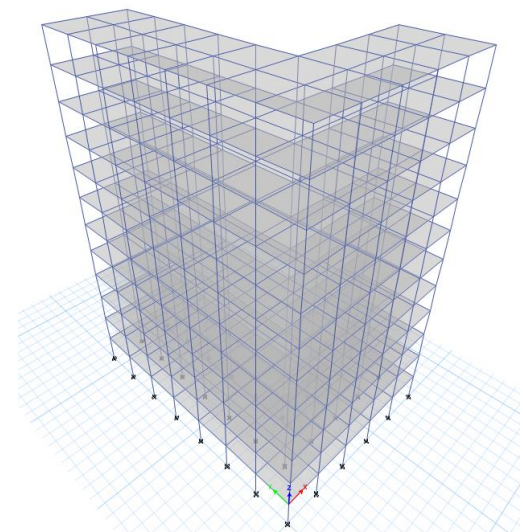


Fig -3: Irregular Building with fixed base (Restrained against displacement and rotation)

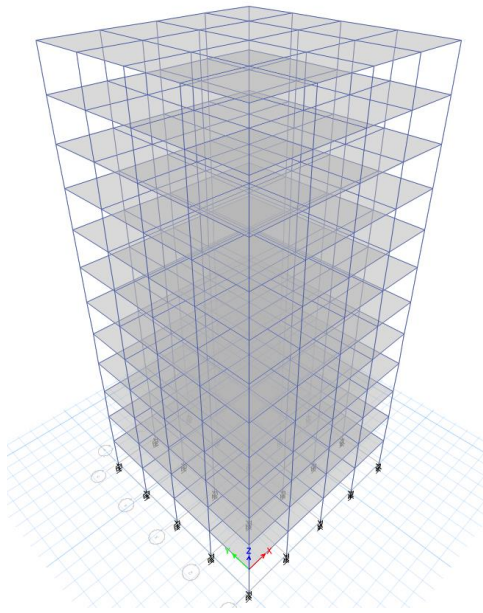


Fig -4: Regular Building with LRB

For U2 & U3 Effective Damping	0.05000
For U2 & U3 Distance from End-J	0.00254
For U2 & U3 Stiffness	28664.66017
For U2 & U3 Yield Strength	72.85353

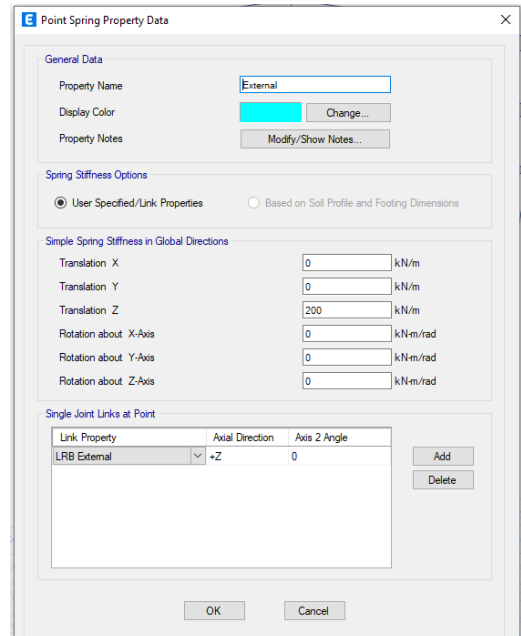


Fig -5: External LRB used

Table -2: Seismic data consideration

Seismic zone	III
Zone Factor	0.16
Importance Factor, I	1.2
Line load Considered	6.9 kN/m, 9.0 kN/m, 3.0 kN/m
Soil type	II
Response Reduction factor, R	5

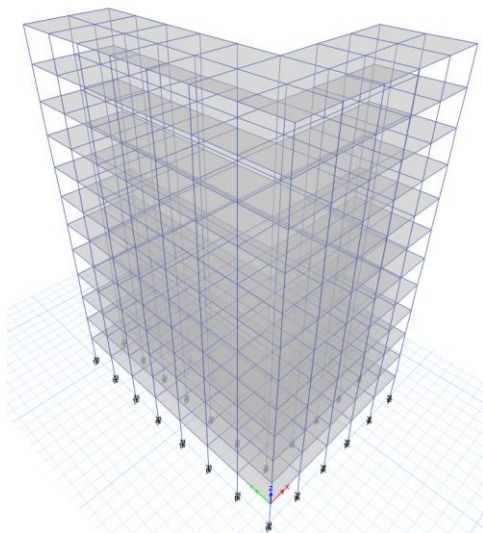


Fig -5: Irregular Building with LRB

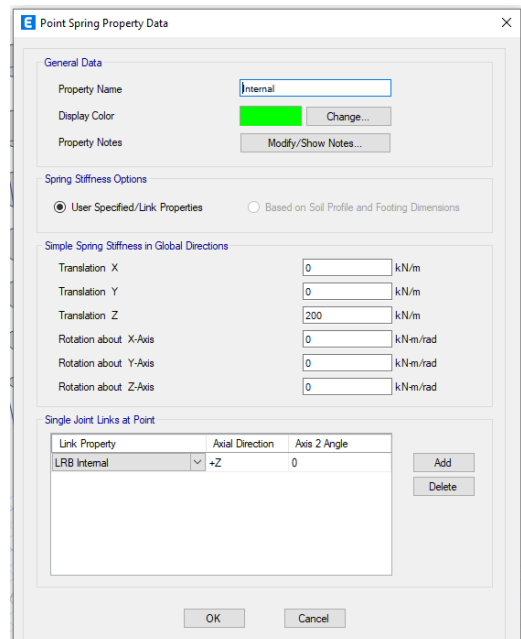


Fig -6: Internal LRB used

Table -3: LRB (Lead Rubber Base) Data consideration

Rotational Inertia 1	0.00972
For U1 Effective Stiffness	3110786.62754
For U2 & U3 Effective Stiffness	3110.78663

4. RESULTS

4.1 Modal Participation

Table -4: Modal Participating Mass Ratio (Regular Building)

TABLE: Modal Participating Mass Ratios (Regular Building)					
Case	Mode	Period	UX	UY	RZ
Modal	1	1.647	78%	3%	0%
Modal	2	1.647	3%	78%	0%
Modal	3	1.448	0%	0%	82%

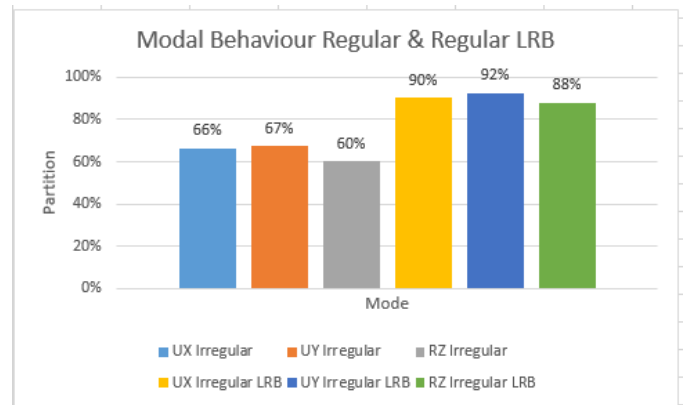


Chart -2: Modal Behavior irregular vs irregular LRB

Table -5: Modal Participating Mass Ratio (Regular LRB)

TABLE: Modal Participating Mass Ratios (Regular LRB)					
Case	Mode	Period	UX	UY	RZ
Modal	1	2.361	15%	80%	0%
Modal	2	2.361	80%	15%	0%
Modal	3	2.145	0%	0%	96%

4.2 Story Drift

Table -8: Story Drift regular vs regular LRB building

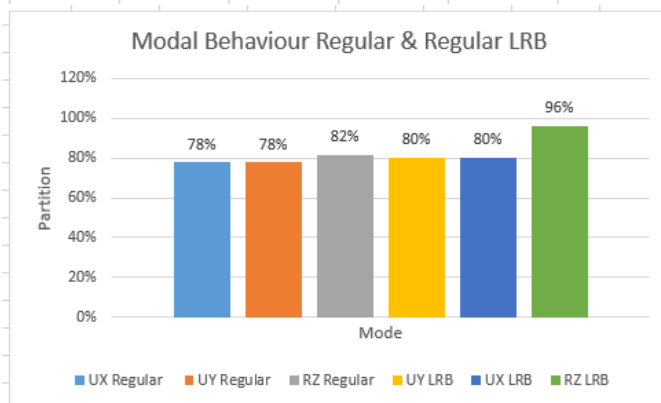


Chart -1: Modal Behavior regular vs regular LRB

Story	Drift Regular Building	Drift Regular Building with LRB
TENTH FLOOR	0.000222	0.000161
NINETH FLOOR	0.000339	0.000243
EIGHTH FLOOR	0.000443	0.000316
SEVENTH FLOOR	0.000527	0.000374
SIXTH FLOOR	0.000592	0.00042
FIFTH FLOOR	0.00064	0.000453
FOURTH FLOOR	0.000673	0.000476
THIRD FLOOR	0.000693	0.00049
SECOND FLOOR	0.000701	0.000498
FIRST FLOOR	0.000698	0.000505
GROUND FLOOR	0.000666	0.000569
PLINTH LEVEL	0.000443	0.001182

Table -6: Modal Participating Mass Ratio(Irregular Building)

TABLE: Modal Participating Mass Ratios (Irregular Bulding)					
Case	Mode	Period	UX	UY	RZ
Modal	1	2.361	66%	1%	12%
Modal	2	2.361	5%	67%	8%
Modal	3	2.145	9%	13%	60%

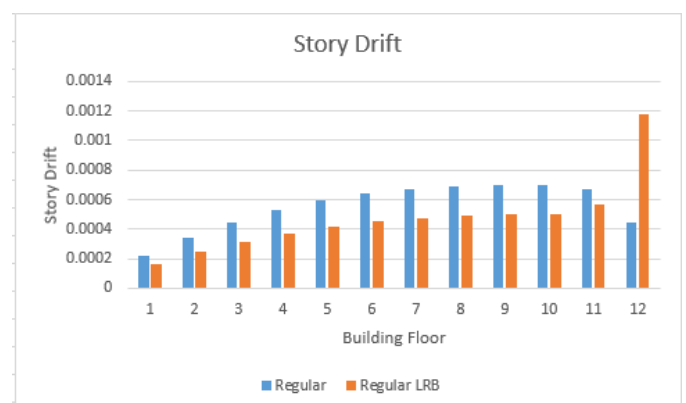


Chart -3: Story Drift regular vs regular LRB

Table -7: Modal Participating Mass Ratio(Irregular LRB)

TABLE: Modal Participating Mass Ratios (Irregular LRB)					
Case	Mode	Period	UX	UY	RZ
Modal	1	2.361	90%	0%	5%
Modal	2	2.361	1%	92%	3%
Modal	3	2.145	5%	4%	88%

Table -9: Story Drift irregular vs irregular LRB building

Story	Drift Irregular Building	Drift Irregular Building with LRB
TENTH FLOOR	0.000207	0.000149
NINETH FLOOR	0.000315	0.000222
EIGHTH FLOOR	0.000415	0.000289
SEVENTH FLOOR	0.000495	0.000344
SIXTH FLOOR	0.000557	0.000386
FIFTH FLOOR	0.000601	0.000416
FOURTH FLOOR	0.000631	0.000436
THIRD FLOOR	0.000647	0.000447
SECOND FLOOR	0.000652	0.000452
FIRST FLOOR	0.000644	0.000455
GROUND FLOOR	0.000611	0.000509
PLINTH LEVEL	0.000406	0.001079

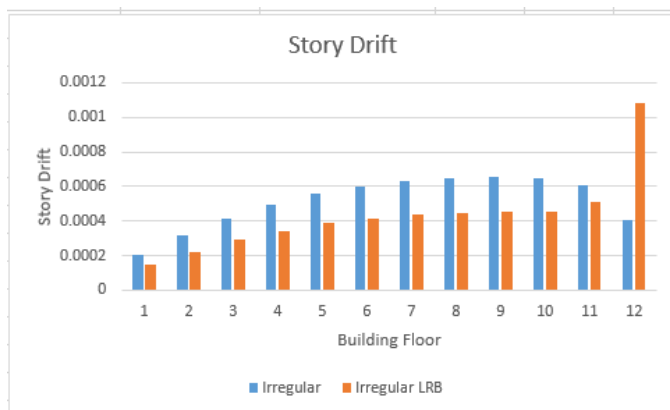


Chart -4: Story Drift irregular vs irregular LRB

4.3 Story Displacement

Table -10: Story displacement regular vs regular LRB building

Story Displacement				
Type	Case	Displacement (mm)	Case	Displacement (mm)
Regular	EQX	20	EQY	20
Regular LRB	EQX	23	EQY	23

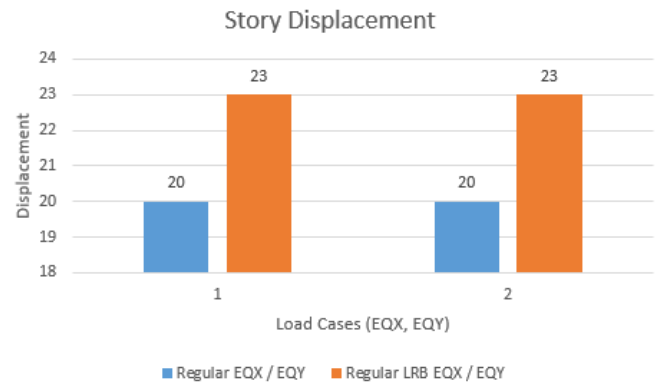


Chart -5: Story displacement regular vs regular LRB

Table -11: Story displacement irregular vs irregular LRB building

Story Displacement				
Type	Case	Displacement (mm)	Case	Displacement (mm)
Irregular	EQX	28	EQY	29
Irregular LRB	EQX	24	EQY	23

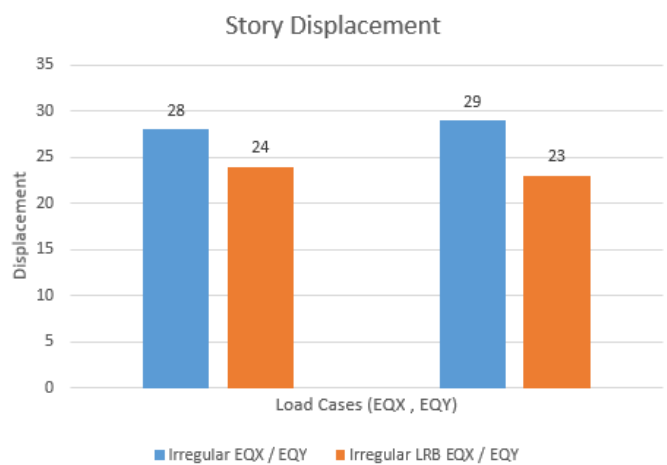


Chart -6: Story displacement irregular vs irregular LRB

3. CONCLUSIONS

1. The integration of Lead Rubber Bearing (LRB) isolators significantly optimizes the seismic performance of G+10 reinforced concrete frames by mitigating the complex torsional effects and non-uniform stiffness distribution associated with plan irregularities.
2. Base isolation effectively decouples the superstructure from ground-induced inertia forces, resulting in a marked extension of the fundamental natural period and a substantial reduction in base shear and lateral displacement.

3. The bilinear hysteretic response provided by the LRB's lead core enables stable energy dissipation and damping, which limits the transfer of seismic forces and protects both structural and sensitive non-structural components.
4. Comparative analysis using Response Spectrum Analysis in ETABS confirms that isolated irregular structures exhibit significantly lower inter-storey drift demands and floor accelerations than their fixed-base counterparts.
5. The system's self-centring capability and the microstructural recovery of the lead plug ensure consistent mechanical performance and minimal residual displacement across multiple seismic cycles.
6. By reducing seismic demand at the source, base isolation ensures that regular and irregular buildings remain fully functional, prioritizing operational continuity and reducing long-term repair costs.

REFERENCES

- [1] Nafisa Anjum, "Seismic Performance Evaluation of a 10-story RC Building Using Pushover Analysis & Response Spectrum Analysis", January 2026.
- [2] Md. Saniul Haque Mahi, "Seismic Performance Assessment of Regular and Irregular RC Buildings Under BNBC 2020 Using ETABS", July 2025.
- [3] Vinod vawadra, "Pushover analysis of G+20 RCC Structure with Horizontal Irregularity", June 2024.
- [4] Walid A. Al-Kutti, "Potential Design of Seismic Vulnerable Buildings Incorporating Lead Rubber Bearing", February 2019.