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Seismic Analysis of High-Rise Building Using Different Base Isolators

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Abstract

Base isolation is a proven technique that decouples the superstructure from ground motion, thereby enhancing seismic resilience by increasing the fundamental time period and dissipating energy through isolator deformationThis study presents a comparative seismic analysis of a high-rise reinforced concrete (RC) building using different base isolators: Lead Rubber Bearings (LRB) and High Damping Rubber Bearings (HDRB) to evaluate their effectiveness in reducing seismic responses.. In this research, a G+10 storey RC building located in Seismic Zone III with medium soil conditions was modelled and analyzed using SAP2000 software as per IS 1893: 2016 (Part 1). Two analytical models—fixed-base and base-isolated were developed and subjected to nonlinear time history analysis using the Kobe (1995) and Superstition Hills (1987) earthquake records. The study analyzed key seismic parameters such as storey displacement, inter-storey drift, and base shear. Results indicated that both LRB and HDRB systems significantly reduced seismic demands compared to the fixed-base structure. The findings demonstrate that base isolation effectively enhances structural performance under seismic excitation. LRB provided greater flexibility and energy dissipation due to the yielding of its lead core, whereas HDRB offered higher inherent damping and temperature stability. The choice between the two systems depends on design priorities, cost, and environmental considerations. Overall, this study confirms the efficiency of seismic base isolation in improving the safety and sustainability of high-rise buildings in moderate seismic zones.

Keywords: *Base Isolator; High Damping Rubber Bearing; High-Rise building; Lead Rubber Bearing; Seismic Analysis.*

1. Introduction

Earthquakes are one of the most dangerous natural disasters that can cause serious damage to buildings and loss of life. The safety of buildings during earthquakes is a major concern in modern civil engineering. In recent years, the number of high-rise buildings has increased rapidly in urban areas, even in regions that experience frequent earthquakes. Because of their height and flexibility, high-rise buildings behave differently from low-rise structures during earthquakes and are more likely to experience large swaying and structural stress. In traditional buildings, the base of the structure is fixed directly to the ground. When an earthquake occurs, the shaking of the ground is transferred straight to the building. This increases the forces acting on the structure and can lead to severe damage or even collapse. To reduce this problem, engineers use a modern technique called base isolation. Base isolation works by placing special flexible devices between the building and its foundation. These devices absorb and reduce the earthquake energy that enters into the building. As a result, the building shakes less, the internal forces are reduced, and both structural and non-structural damage are minimized. Base isolation is now considered one of the most effective methods for earthquake-resistant design. Following are the

Earthquake protection systems. There are various types of base isolation devices used in earthquake-resistant structures shown in Figure 1, such as lead rubber bearings (LRB), high-damping rubber bearings (HDRB), friction pendulum systems (FPS), and sliding bearings. These devices decouple the structure from ground motion, reducing seismic forces and enhancing building safety and performance during earthquakes. There are different materials used for manufacturing of an isolator'ssuch as 1. Rubber 2. Lead 3. Steel layers.

1. Rubber has very low stiffness in horizontal direction but is almost incompressible in the vertical compression. So it is good for vertical load transfer from structure to the ground and at the same time provides isolation from horizontal ground motion by having very low shear stiffness. However, rubber does not perform adequately in tension. Modern day rubber bearings, with good quality control, have been able to provide some tension capacity up to a pressure of 3G, where G is the shear modulus of the rubber.
2. Lead was chosen because of its plastic property while it may deform with the movement of the earthquake, it will revert to its original shape, and it is capable of deforming many times without losing strength. During an earthquake, the kinetic energy of the earthquake is absorbed into heat energy as the lead is deformed.
3. Use of steel layers with the rubber means the bearing can move in a horizontal direction but is stiff in a vertical direction.

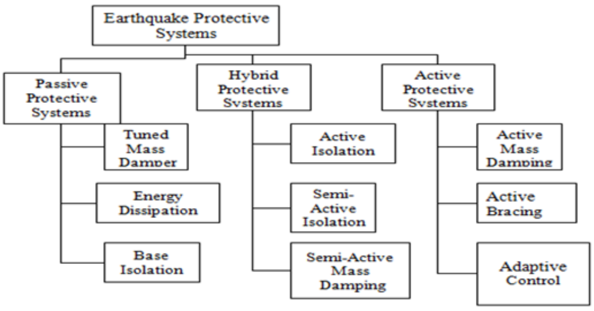

Figure 1 **Earthquake Protection Systems**

1.1 Base Isolator's

The Lead Rubber Bearing (LRB) consists of alternating layers of rubber and steel plates with a solid lead core at the centre as shown in figure 2. During an earthquake, the rubber layers provide horizontal flexibility, allowing the building to move smoothly rather than shaking intensely. At the same time, the lead core undergoes plastic deformation, absorbing and dissipating a significant portion of the seismic energy as heat. After the ground motion stops, the lead core and rubber layers help bring the structure back to its original position due to their re-centering properties. Hence, the LRB mechanism combines flexibility from the rubber and energy dissipation from the lead core, providing excellent seismic perform.

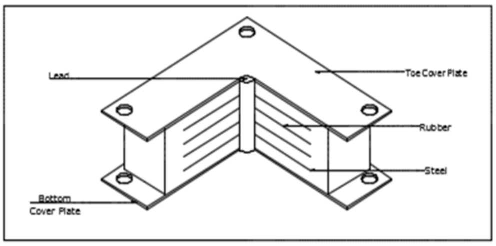

Figure 2 **Lead Rubber Bearing**

The High Damping Rubber Bearing (HDRB), on the other hand, is made up of rubber layers with high internal damping properties and steel shims to provide vertical stiffness shown in figure 3. When the ground moves, these rubber layers deform in shear, allowing horizontal displacement and absorbing energy through the internal friction of the rubber material, known as viscoelastic damping. Unlike the LRB, HDRB does not have a lead core; instead, it relies entirely on the damping characteristics of the special rubber compound for energy dissipation.

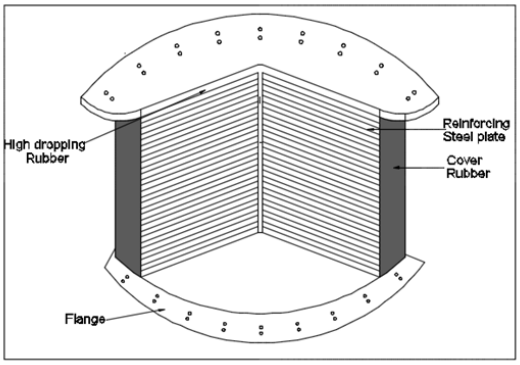

Figure 3 High Damping Rubber Bearing(HDRB)

Past researchers focused on Experimental tests, finite element modelling, time-history and response spectrum analyses, analytical modelling, and comparative studies. Both LRB and HDRB systems elongate structural periods, reduce seismic demands, and improve damping. LRBs provide higher energy dissipation via lead yielding, while HDRBs offer maintenance-free operation and better temperature stability. LRBs are preferred for high seismic regions needing strong energy dissipation, whereas HDRBs are suitable for moderate seismic zones and eco-sensitive applications. Continuous advancements in materials and modelling are enhancing the reliability and applicability of both systems. This paper include study of LRB and HDRB for G + 10 building located in zone III and responses of building compared in terms of displacement, story drift and Base Shear.

1.2 Scope of work

Although several studies have been carried out on base isolation systems, most of them have focused either on single isolation types or on low-rise structures located in high seismic zones. There is limited comparative research on the performance of Lead Rubber Bearings (LRB)andHigh Damping Rubber Bearings (HDRB) specifically for medium-to high-rise RC buildings (like G+10) situated in moderate seismic zones (Zone III) as per IS 1893 (Part 1): 2016. Moreover, past studies have not sufficiently explored the comparative effect of LRB and HDRBon key seismic parameters such as storey displacement, drift, and base shear through software-based analysis using SAP2000. Hence, there exists a need for a detailed analytical study to evaluate and compare the efficiency of LRB and HDRB isolators and to identify the most suitable base isolation system for improving the seismic performance of multi-storey buildings in moderate seismic regions

1.3 Objectives

- To study the working mechanism of LRB and HDRB.
- To model and analyze a G+10 RC building using SAP2000 as per IS 1893: 2016 (Part 1).
- To design suitable LRB and HDRB isolators for Zone III.
- To compare results in terms of displacement, storey drift, and base shear.
- To identify the more effective isolation system for moderate seismic regions.

1.4 Literature Review

Base isolation is one of the most effective seismic protection techniques for buildings and bridges. It decouples the superstructure from ground motion, primarily by increasing the fundamental period and adding damping through isolation devices. Among various isolation systems, Lead Rubber Bearings (LRB)andHigh Damping Rubber Bearings (HDRB) are the most widely used due to their efficiency, reliability, and cost-effectiveness. The following literature review summarizes key studies on the development, analysis, and performance of these systems. Radmila B. Salić et al. [1] investigated a G+7 storey shear wall residential tower isolated with LRBs to evaluate seismic performance. Using GPS-synchronized ambient vibration measurements and ARTMIS software, they derived mode shapes and damping ratios, validating the analytical model. Thirty-two LRBs were designed per UBC-97, and time-history analysis using four earthquake records revealed elongation of the fundamental period and significant reduction in base shear, inter-storey drift, and acceleration.Pan Wen and Sun Baifeng [2] proposed a two-stage base isolation design methodology following the Chinese Seismic Code (2001). The simplified design of the isolation layer followed by detailed nonlinear analysis enhanced computational efficiency and ensured compliance with code provisions. K. Sab and S. K. Thakkar [3] examined the feasibility of base isolation for structures with higher natural periods (1–3 s). They concluded that isolation effectiveness improves by increasing isolation system flexibility or superstructure damping, confirming that isolation is most beneficial for short-period structures (< 1 s).

S. A. Kabeer and S. K. Kumar [4] compared fixed-base and isolated RC structures using equivalent lateral force and response spectrum analyses. LRBs were found to significantly reduce displacements, bending moments, and shear forces.T. Subraman et al. [5] investigated LRB performance on soft soils and near-fault zones, concluding that base isolation reduces structural accelerations by decoupling the superstructure from ground motions, with additional damping further improving response reduction. Fazilali K. [6] analyzed the response of base-isolated and fixed-base buildings in ETABS, observing improved seismic performance for LRB-isolated structures. S. Keerthana et al. [7] designed laminated rubber bearings and performed dynamic analysis, confirming that base isolation enhances overall structural performancethrough period elongation.Sameer S. Shaikh and P. B. Murnal [8] studied isolator placement using SAP2000, showing that optimum isolator location significantly affects seismic response parameters. Mital N. Desai and Roshni John [9] compared HDRB, LDRB, and LRB systems for an 8-storey building and concluded that LRBs provided the greatest energy dissipation, while HDRBs offered enhanced temperature stability.JainSaksham and GangwalSambha [10] conducted response-spectrum and time-history analyses for 4- and 12-storey RC buildings in seismic zone V, revealing that increased isolation period (up to 3 s) reduces storey accelerations and drifts but increases base displacements. Faraaz and A. S. Patil [11] compared fixed-base, shear-wall, and LRB-isolated models under the Bhuj earthquake record, demonstrating that LRBs minimize base shear and lateral deflections.Venkatesh and Arunkumar H. R. [12] emphasized the reliability of LRB systems for multi-storey buildings and their practical importance in earthquake-resistant design. Kishan Bhojani et al. [13] studied laminated rubber bearings under various damping conditions and observed that optimum damping reduces acceleration and base shear. Recent studies have extended LRB research into rate-dependent hysteretic modeling and near-fault performance. Aghaeidoostet al. [14] developed an advanced rate-dependent analytical model capturing velocity effects and cyclic degradation. Ren et al. [15] analyzed nonlinear responses of LRBs under near-fault excitations, highlighting large displacement demands. Whittaker (2023) summarized the global adoption of LRBs and discussed aging and temperature sensitivity of the lead core as key durability concerns.Overall, LRB systems have proven effective in increasing flexibility, dissipating energy through lead yielding, and achieving substantial seismic response reductions in low- and mid-rise structures. Pianese et al. (2024) [16] introduced fiber-reinforced HDRBs, achieving improved shear strength and reduced bulging.

2. Methodology

The G+10 reinforced concrete building was modelled in SAP2000 as a three-dimensional space frame structure. The model consisted of beam, column, and slab elements defined using the respective geometric and material properties (M30 concrete and Fe 500 steel). Rigid diaphragm constraints were assigned at each floor level to simulate in-plane floor rigidity. Time History Analysis was performed in SAP2000 to study the seismic performance of the structure of.

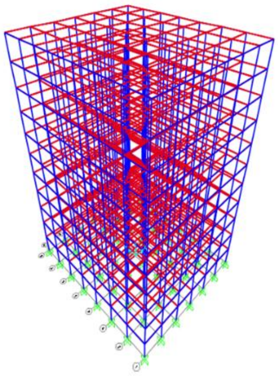

Figure 4 **3D Model G+10 Story Building**

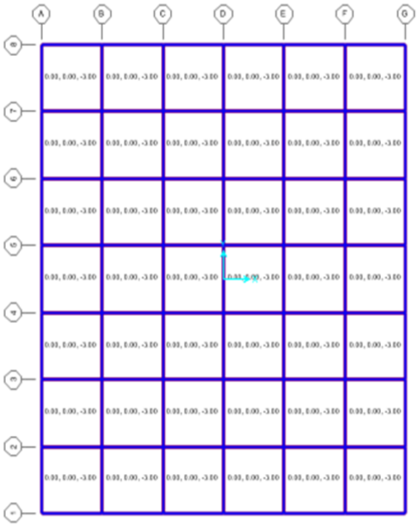

Figure 5 **Plan G+10 Story Building**

Figure 4 and 5 shows the 3D model and plan of the G + 10 building. The inputs such as building dimension, materials are shown in the table 1.

Table 1 **Model Details of G+10 Building**

S.No	Particulars	Description
1	Type Of Frame	SMRF
2	Area	27 x 31.5 sq.m
3	No. of Storey's	G+10
4	Height of storey	4 m
5	Height of building	44 m (class B)
6	No. of flexural members / floor	97
7	No. Of Compression members / floor	56
8	No. of slabs / floor	42
9	slab thickness	200 mm
10	Size of column	300 x 1000 mm
11	Size of Beam	300 x 600 mm
12	Wall thickness	230 mm
13	Concrete grade	M30
14	Rebar grade	Fe 500

SAP2000 isone of the most widely used structural analysis and design software programs in civil and structural engineering The Time history analysis was carried out using SAP2000. It has in-build Isolator properties such as Rubber Isolator, friction Isolator etc. To incorporate base isolation, the fixed supports at the foundation level were replaced with Lead Rubber Bearing (LRB) isolators using SAP2000's in-built isolator link properties. The isolator parameters such as vertical stiffness, lateral stiffness, yield strength, and damping ratio were defined as per the design data or standard reference values. Two models were developed for comparison:

Fixed Base Model: the building was assumed to be directly connected to the ground.

Base-Isolated Model: isolator elements were assigned at the column base level to evaluate the seismic response reduction. Time History Analysis was then carried out for both models under identical ground motion inputs to assess the effectiveness of the base isolation system in reducing acceleration, story drift, and base shear. Following are the loads considered for the analysis of building.

Dead load: the dead load of columns, beams, and slabs is taken into account in accordance with IS: 875 (Part-1)-1987.

Live load: chosen building models are commercial in the current project; the live load for these models is 3 KN/m2 as per IS: 875 (Part-2)-1987. Floor finish a floor finish load of 1 KN/m2 is considered.

Wall load (super dead load): The wall load is considered a super dead load, the total height of each storey is 4m, and the beam depth is 0.6. The wall load is calculated as = thickness of wall x density x height. Wall load = 0.23 X 20 X 3.4 = 15.64 KN/m. After the analysis of fixed base structure, analyses the building for seismic loads as shown in the table2

Table 2 **Seismic details for modelling**

S. No	Particulars	Description
1	Seismic Zone	III
2	zone factor	0.16
3	Soil type	Type II (Medium)

4	Importance Factors	1.5
5	Response reduction Factor	5
6	Damping of the structure	5%
7	Response Spectra	As per IS 1893 Part I 2016
8	Time History	Kobe And Superstition

As building is modelled as a base isolated structure following inputs are required for LRB and HDRB as a link element shown in Table 3.

Table 3 Boundary conditions (LRB/HDRB)

Particulars	**Values**	
	LRB	**HDRB**
	G+10	**G+10**
Linear Effective Stiffness	9×10^9N/m	1.2×10^9N/m
U2 & U3 Linear Effective Stiffness	1.47×10^6 N/m	1.92×10^6 N/m
U2 & U3 Nonlinear Stiffness	13.54×10^6 N/m	14.69×10^6 N/m
U2 & U3 Yield strength	34.41×10^3 N	91.39×10^3 N
U2 & U3 Post Yield stiffness ratio	0.1	0.1
Rotational inertia	104.42×10^3 KN/m2	924.27×10^3 N/m
Damping	5%	20%

The IS 1893 (Part 1): 2016 standard serves as the primary code for the seismic analysis and design of buildings in India. It outlines the procedures for evaluating design seismic loads, developing response spectra, and conducting dynamic analysis methods such as time history analysis.

2.1 Numerical Analysis

Time History Analysis is a dynamic method used to study how a structure responds to an actual or simulated earthquake ground motion over time. It involves applying recorded acceleration data to the structure and calculating its response at each time step, including displacement, velocity, and acceleration. This method gives a detailed and realistic picture of how the structure behaves during an earthquake and is especially useful for nonlinear analysis of complex buildings. It is one of the most accurate methods recommended in earthquake engineering for performance-based design. This study presents a comparative analysis of fixed-base and base-isolated structures utilizing Lead Rubber Bearings (LRB) and High Damping Rubber Bearings (HDRB). The finite element software SAP2000was employed for modeling and analysis. AG+10 storey building located in Seismic Zone III with medium soil conditions was considered. To evaluate seismic performance, nonlinear time history analysis was performed using ground motion records from the Superstition Hills (1987) earthquake at the Parachute Test Site with a PGA of 0.2g, and the Kobe (1995) earthquake at Takatori with a PGA of 0.105g.
The base isolators were designed considering a support reaction of 1461.92 kN, an effective isolator period of 2 seconds, and damping ratios of 5% for LRB and 20% for HDRB. The structural responses were compared in terms of roof displacement, storey drift, and base shear. The dimensions and configuration details of the isolators are illustrated in Figure 6 and 7 for LRB and HDRB.

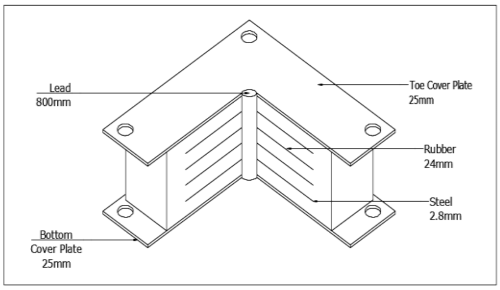

Figure 6 Details of lead rubber bearing for G+10 building

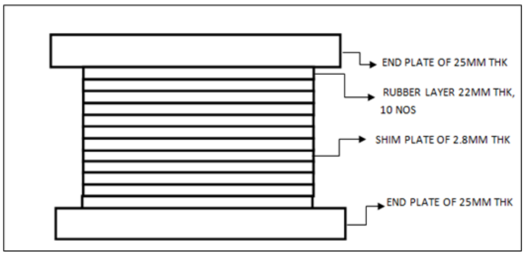

Figure 7 Details of High damping rubber bearing for G+10 building

3. Results And Discussion

The comparative study of fixed-base and base-isolated (LRB and HDRB) building models was carried out to evaluate their dynamic behavior under seismic loading. The fundamental time period, fundamental frequency, and base shear responses were analyzed and compared. It was observed that the incorporation of base isolation significantly increased the fundamental time period of the structure. For the fixed-base model, the fundamental time period in the first and second modes was1.92 sec and 1.10 sec, respectively. When lead rubber bearings (LRB) were used, these values increased to 4.47 sec and 3.55 sec, while for high damping rubber bearings (HDRB), they were 3.38 sec and 2.07 sec, respectively. This increase in time period indicates that the base-isolated structures have a longer period of vibration, which effectively shifts the building response away from the predominant energy range of ground motion, thereby reducing seismic forces. A corresponding decrease in fundamental frequency was noted for the isolated models. The fundamental frequency of the fixed-base structure was 0.52 Hz and 0.91 Hzfor modes 1 and 2, respectively. For the LRB model, these values reduced to 0.22 Hz and 0.28 Hz, and for the HDRB model, to 0.30 Hz and 0.48Hz. The reduction in frequency confirms that base isolation lengthens the structural period, leading to a more flexible system that can dissipate seismic energy effectively. Figure 8 shows Displacement profiles of LRB for Kobe Ground motion

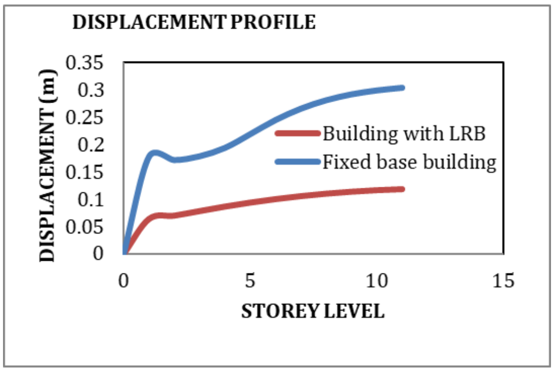

Figure 8 Displacement profiles of LRB for Kobe Ground motion

For G+10 storey building displacement profile is shown in Fig.8. It is observed that displacement of fixed base building model at top storey is 0.305m and for building model with lead rubber bearing is 0.07m for Kobe Ground motion data.

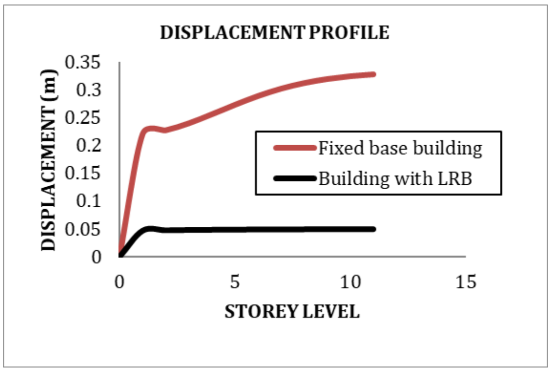

Figure 9 Displacement profiles of LRB for superstition Ground motion

Figure 9 shows displacement profile for G+10 storey building. it is observed that displacement of fixed base building model at top storey is 0.335 m and for building model with lead rubber bearing is 0.05m for superstition ground motion data.

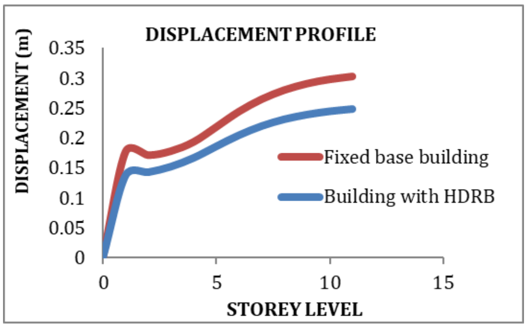

Figure 10 **Displacement profiles of HDRB for Kobe Ground motion data.**

Figure10 shows displacement profile for G+10 storey building model. It is observed that displacement of fixed base building model at top storey is 0.301 m and for building model with high damping rubber bearing is 0.25 m for Kobe ground motion data. Figure 11 Displacement profiles of HDRB for superstition Ground motion. Fig.11shows displacement profile for G+10 storey building model. It is observed that displacement of fixed base building model at top storey is 0.34 m and for building model with high damping rubber bearing is 0.06 m for superstition ground motion data. A substantial reduction in base shear was achieved with both isolation systems. The use of lead rubber bearings (LRB) resulted in a 61.53% reduction in base shear compared to the fixed-base building, while high damping rubber bearings (HDRB) achieved a 42.85%reduction. This decrease in base shear demonstrates the efficiency of base isolators in minimizing seismic forces transmitted to the superstructure, thereby enhancing the overall seismic performance and safety of the building. From the comparative results, it is evident that both isolation systems effectively improve the seismic performance of the G+10 storey building. LRB shows slightly better performance in terms of period elongation and base shear reduction due to the additional energy dissipation capacity of the lead core. However, HDRB provides a more stable response with higher damping and reduced displacement demand.Hence, the selection between LRB and HDRB depends on performance objectives, design constraints, and cost considerations.

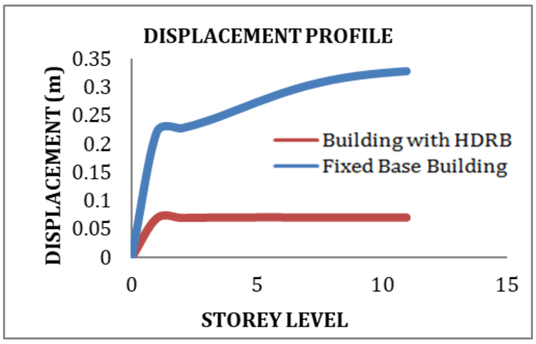

Figure 11 **Displacement profiles of HDRB for superstition Ground motion**

The LRB system increased the natural period from 1.0 s to 2.5 s, resulting in a 60% reduction in base shear. HDRB provided higher damping but slightly higher displacement. Following graphs shows comparison of inter story drift, for fixed base building model with base isolated building model by using lead rubber bearing and high damping rubber bearing for Kobe ground motion data and superstition ground motion data.

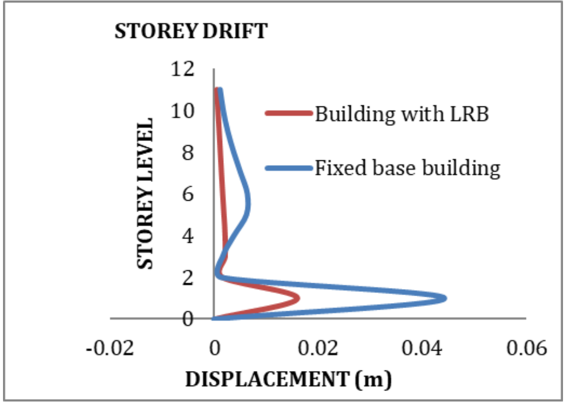

Figure 12 **Inter Storey Drift of LRB for Kobe Ground motion**

Fig.12 shows storey drift of G+10 storey building model for Kobe ground motion data, it is observed that fixed base building model has reached maximum displacement of 0.045m and building model with lead rubber bearing reached maximum displacement of 0.016m.

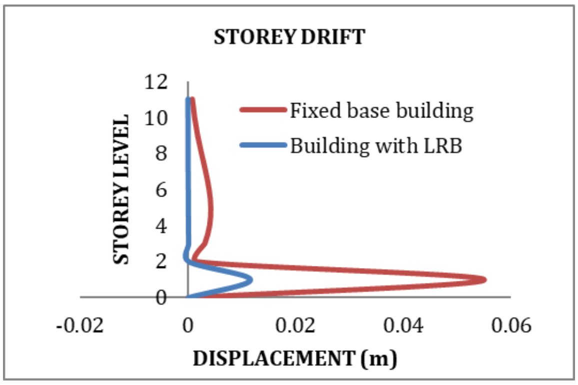

Figure 13 Inter Storey Drift of LRB superstition for Ground motion

Figure 13 shows storey drift of G+10 storey building model for superstition ground motion data, it is observed that fixed base building model has reached maximum displacement of 0.058m and building model with lead rubber bearing reached maximum displacement of 0.01m. Figure 14 shows storey drift of G+10 storey building model for superstition ground motion data, it is observed that fixed base building model has reached maximum displacement of 0.058m and building model with high damping rubber bearing reached maximum displacement of 0.019m.

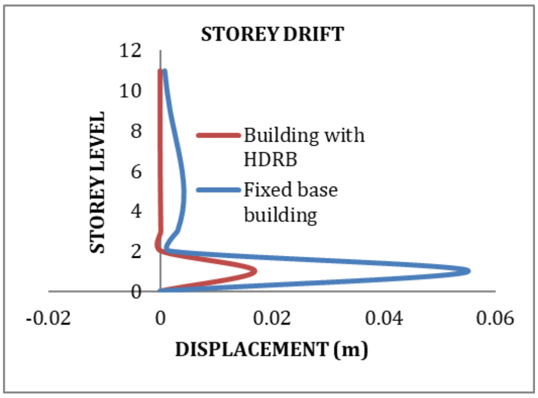

Figure 14 Inter Storey Drift of HDRB for superstition Ground motion

4. Conclusions

From the present study it is concluded that:
Base isolation significantly reduces seismic forces.
LRB and HDRB both enhance structural safety.
HDRB offers superior energy dissipation, while LRB provides higher flexibility.
Suitable choice depends on soil type, importance factor, and design level.
SAP2000 provides reliable simulation for seismic isolation systems.

5. Future Scope

It Include nonlinear isolator modeling.
Validate analytical results with experimental data.
Study hybrid isolation systems (e.g., FPS + HDRB).
Calibration of isolation design with updated Indian seismic code provisions (IS 1893:2024).

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