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Assessment of Structural Behaviour in Lead Rubber Bearing Base-Isolated and Fixed Base Building under IS 1893 (Part 6): 2022 Guidelines

Pruthvirajsingh Pramod Bokey[1], Dr. V. R. Patel[2],
[1]*ME Student, Applied Mechanics Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara-390001*
[2]*Assistant Professor, Applied Mechanics Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara-390001*

Abstract: ***Base isolation is recognized as an effective strategy in earthquake-resistant design, significantly reducing floor accelerations and inter-storey drifts. This enhances the safety of both structural and non-structural components, ensuring continued functionality of buildings even after major seismic events. The performance of base isolation systems largely depends on the linear and bilinear properties of the isolators used. This study investigates the seismic performance of a base-isolated structure in comparison to a conventional fixed-base building. A G+15 storey building model was developed and analysed using ETABS 21 software, employing Lead Rubber Bearings (LRB) for base isolation. A comparative evaluation was conducted based on key response parameters, including displacement, inter-storey drift, storey shear, and storey acceleration. The isolators were modelled using linear properties and analysed using the Response Spectrum Method in accordance with IS 1893 (Part 6): 2022. A comprehensive literature review was conducted to support the research framework, followed by model validation to align the methodology with established studies in the field. The concluding section summarizes the findings from the comparative analysis, highlighting the effectiveness of base isolation systems in enhancing seismic performance and providing insights for future research and design improvements in seismic isolation technology.***

Keywords: Base Isolation, Lead Rubber Bearings (LRB), Response Spectrum Analysis, IS 1893 (Part 6): 2022

I. INTRODUCTION

In recent years, there has been a notable surge in the construction of high-rise buildings for both residential and commercial purposes. The architectural trend has shifted toward taller and more slender structures, making them increasingly susceptible to lateral forces such as wind, seismic activity, and even blast impacts. Consequently, modern structural design must prioritize resistance to these lateral loads, unlike earlier practices where buildings were primarily designed to withstand vertical loads, with lateral forces considered only in later stages of design. Today, a thorough understanding of how lateral loads affect structural behaviour is crucial for ensuring both strength and stability. The configuration of buildings to resist seismic forces primarily aims to ensure life safety during major earthquakes while also considering serviceability and the potential for economic losses. Seismic design focuses on how structures respond to significant inelastic deformations, which differ considerably from the responses under gravity or wind loads. This necessitates advanced analytical methods to assess how structures perform when subjected to earthquake-induced displacements beyond their elastic range. As a result, modern building codes allow for controlled inelastic behaviour to dissipate seismic energy, with the expectation that some level of structural damage may occur under design-level ground motions.

The idea of protecting buildings from seismic damage through isolation is not a recent development. The first patent for a seismic isolation system date back to 1909. Since then, various innovations with similar objectives have been proposed, with the technique gaining widespread attention and application globally since the 1980s. Base isolation has been successfully implemented in numerous buildings across countries such as Japan, the United States, New Zealand, and Italy. It is especially valuable for protecting critical infrastructure and heritage structures, including schools and historic buildings. To date, over a thousand buildings worldwide have adopted base isolation technology. In India, the application of base isolation began following the 1993 Killari earthquake in Maharashtra. A more prominent example is the construction of the Bhuj Civil Hospital using base isolation techniques after the devastating 2001 Bhuj earthquake in Gujarat.

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II. METHODOLOGY

The methodology adopted for this research follows a systematic approach to evaluate the seismic performance of structures with and without base isolation using Lead Rubber Bearings (LRBs). The study begins with a preliminary field investigation aimed at understanding the seismic vulnerability of existing structures and identifying the criteria for modelling. This is followed by a comprehensive literature review, which forms the foundation of the research by exploring existing studies on base isolation techniques, performance metrics, and comparative evaluations using national and international codes. Subsequently, the process involves developing identical structural drawings for both the fixed-base and isolated-base models to ensure accurate and unbiased comparison. These two structural configurations — fixed-base and isolated base using LRBs — are then modelled separately to simulate their behaviour under seismic loading.

Using ETABS 21, a well-established computer-aided structural analysis and design software, the models are generated and analysed. The software is employed for both the creation and detailed design of structural components, incorporating appropriate material properties, load combinations, and seismic zone factors. The models are analysed using response spectrum analysis as per relevant seismic codes to evaluate their performance. Once the models are analysed, the results are extracted and used for comparative analysis across several key parameters. These include the time period, where the elongation of the fundamental period due to base isolation is assessed; base shear, which helps determine the reduction in lateral seismic forces; storey displacement and storey drift, which are crucial for evaluating structural deformation and inter-storey movement under seismic excitation; and diaphragm accelerations, which are vital in understanding how seismic forces affect floor-level equipment and non-structural elements.

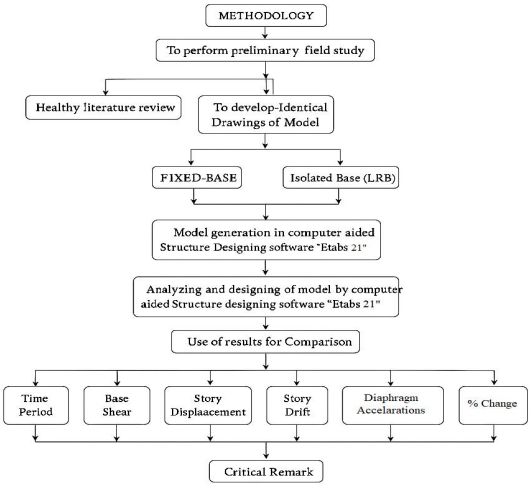


Fig. 1 Methodology

Finally, a percentage change in each parameter is calculated to quantify the benefits of using LRBs over a traditional fixed-base system. The findings culminate in a critical remark, where the implications of the results are interpreted in terms of seismic resilience, structural safety, occupant comfort, and suitability for performance-based design—particularly for critical infrastructure like hospitals and data centres. This methodological framework ensures a rigorous, replicable, and industry-relevant approach to seismic performance evaluation.

III.MODEL BUILDING

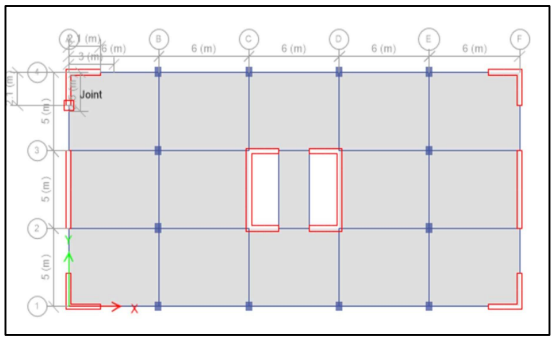


Fig 2 Plan View of Building

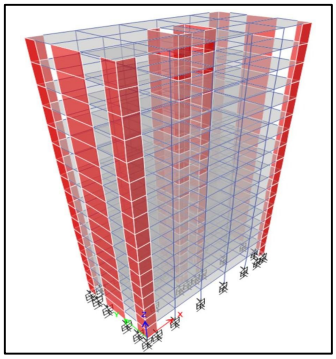


Fig 3 3D view of G+15 BUILDING

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A comprehensive overview of the structural models employed in this study, detailing the geometry, plan configuration, material specifications, sectional dimensions of structural elements, and the applied loading conditions. The selection of these parameters has been made judiciously, incorporating advancements in construction materials, computational modelling, and structural analysis. Recent amendments and updates in design standards—namely IS 1893 (Part 1): 2016, IS 875 (Part 3): 2015, and IS 16700: 2017—have been strictly adhered to throughout the modelling and analysis processes to ensure compliance with current engineering practices.

A variety of structural analysis and design software packages are available for simulating building behaviour, including STAAD Pro., SAP2000, MIDAS, RCDC, and ETABS. In the present study, ETABS 2021 has been selected as the primary analytical tool due to its robust capabilities in integrated structural modelling, analysis, and design. ETABS is built on a finite element (FE) framework and is specifically optimized for multi-storeyed building systems. Its intuitive user interface and comprehensive feature set make it particularly suitable for both linear and nonlinear static and dynamic analyses. Additionally, ETABS facilitates the easy generation and export of graphical outputs and result tables, enhancing interpretability and documentation of analytical findings.

TABLE I
INPUT DATA PARAMETERS

Parameter	Value
Number of Stories	16
Storey Height	3 meters
Plan Dimensions	30mts. X 15mts.
Grade of concrete	M 30 for beams ans slabs
	M 40 for columns and shear walls
Longitudinal Reinforcement	Fe 550
Confinement Reinforcement	Fe 415
Seismic zone	Zone V
Importance Factor	1
Response Reduction Factor	Fix Base = 5
	Isolated Structure = 2
Damping Ratio	5%
Soil Type	Type II (Medium)
Structural System	Dual System: Ductile RC structural walls with RC SMRFs
Location of Isolation Layer	At the base of structure
Wind Coefficient	
Wind Speed Vb (m/s)	50
Risk Coefficient (k1 factor)	1
Terrain category (k2)	2
Topography (k3 factor)	1
Importance factor (k4)	1

TABLE III
TYPES OF LOADS

Type of Load	Location	*Intensity (kN/m²)*
Dead Load (FF)	Typical Floor	*1.5*
	Roof	*1.5*
Live Load	Typical Floor	*3*
	Roof	*3*
Seismic Load	*As per IS 1893:2016*	-

Structural Element	Parameter	*Size*
Shear Wall	Thickness	*350 mm*
	Length	*As per Plan*
Beam	Width	*300 mm*
	Depth	*600 mm*
Slab	Thickness	*150 mm*
Column	Width	*450 mm*
	Depth	*600 mm*

Base isolation technology has been predominantly effective for low- to mid-rise buildings, generally ranging up to 10 to 15 stories or approximately 40 to 50 meters in height. In this research, a 15-storey building was modelled with base isolation, placing it at the upper boundary of the recommended range. Despite being at the limit, this makes the structure a suitable candidate for implementing base isolation, allowing for a meaningful assessment of the technique's effectiveness in reducing seismic demands on mid-rise buildings.

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IV. DESIGN OF LINEAR ISOLATION SYSTEM

The linear isolation system operates based on linear mechanical properties that govern the behaviour of the isolators under dynamic loading conditions. The primary characteristics of such a system include:

- Effective Stiffness: This parameter defines the isolator's resistance to deformation under dynamic forces and directly influences the natural period of the isolated structure. Accurate estimation of effective stiffness is essential for achieving the desired shift in the fundamental frequency of the structure.
- Hysteretic Damping: This denotes the energy dissipation capacity of the isolator resulting from cyclic loading and unloading. Hysteretic damping plays a vital role in attenuating seismic vibrations and thereby enhances the system's overall energy dissipation capability.

The design of the isolation system is carried out in accordance with *IS 1893 (Part 6):2022*. The design procedure involves the following steps

A. Establish Dynamic Parameters:

- Determine seismic zone and zone factor:
  - Seismic Zone: V
  - Zone Factor(Z): 0.36
  - Seismic Weight on Isolation System(W): 79918 kN from ETABS
- Identify soil type:
  - Type II – Medium Soil
- Select the response reduction factor:
  - For Fixed Base Building: R = 5
  - For Isolated Building: R = 2
- Choose the type of isolator:

  Lead Rubber Bearings:

Lead Rubber Bearings (LRB) are rubber bearings made up of alternate layers of steel laminates and hot vulcanized rubber with a cylindrical central lead core.

The energy dissipation provided by the lead core, through its yielding, allows to achieve an equivalent viscous damping coefficient up to about 40. Usually, they are circular in shape but can also be fabricated in square sections; they can also be fabricated with more than one lead core,

B. Set Target Period and Target Displacement:

- For most base-isolated systems, set the building's period to 2-3 seconds.
- Defining the Maximum Effective Natural Period ($T_{eff,\,max}$) and Minimum Effective Natural Period ($T_{eff,\,min}$) at 2.5 and 3. seconds, respectively.

C. Obtain Effective Stiffness, Effective Damping, and Estimate Base Shear:

Calculate the effective stiffness of the isolator, as per CL. 6.1.4 of IS-1893: Part 6.

$$T_{eff,\max} = 2\pi\sqrt{\frac{W_e}{gK_{eff,\min}}}. \qquad T_{eff,\max} = 2\pi\sqrt{\frac{W_e}{gK_{eff,\max}}}$$

K_{eff_max} = $(79918/9.81)*(2\pi/2.5)^2$

K_{eff_min} = $(79918/9.81)*(2\pi/3)^2$

K_{eff_max} = 51.458 kN/mm K_{eff_min} = 35.735 kN/mm

Determine the effective damping required.

- Assume Damping Ratio for the system, ζ = 10% (Generally considered between 10-20)
- Hence the effective damping can be estimated as below,

$$C = 2 \cdot \frac{\zeta}{100} \cdot \sqrt{W \cdot \frac{K_{eff\ max}}{g}}$$

$$C = 2 * 0.1 * \sqrt{((79918 * 51.458/9.81)} = 40.95\, K_{n-s/m}$$

Determine the effective damping required,

The Base-Isolation System shall be designed and constructed to withstand at least a minimum lateral earthquake displacement of Δ_{SD} as per **CL. 6.1.2** of IS-1893: Part-6, along each of its principal plan direction, and estimated by:

$$\Delta_{SD} = \left[Z \left(\frac{S_a}{g} \right)_{T_{eff.max}} \beta \right] g \frac{T_{eff,max}^2}{4\pi^2}$$

Where,

(S_a/g) = Design horizontal spectral acceleration coefficient (corresponding to 5 percent damping) at a natural period of Teff,maxT_{\text{eff,max}}Teff,max, as obtained from Fig. 2 of IS 1893 (Part 1)

β = damping multiplier, is given by:

$$\beta \frac{S_a}{g} = 0.242 \sqrt{\frac{0.10}{\beta}}$$

$$\beta = \sqrt{(0.1)/(0.05 + 0.1)} = 0.816$$

Hence, Design Displacement:

$$\Delta_{sd} = (0.36 * 0.242 * 0.816 * 9.81) * 3^2/4\pi^2 = 0.159\ m$$

- Estimate the base shear based on the effective stiffness and damping.
  - Design Earthquake Lateral Force for Design of the Components of Isolation System and of the Structural Elements below the base as per CL. 6.1.5 of IS-1893: Part 6:

$$V_B = K_{eff.max} \Delta_{SD}$$

V_b = 51.458* 1000*0.159 = 8186.14 Kn

  - Design Earthquake Base Shear Force for the Superstructure as per CL. 6.1.6 of IS-1893: Part 6:

$$V_S = \frac{V_B}{R_1}$$

Where,

R1 = Response Reduction Factor of a base-isolated building given by:

$$R_1 = Min\left[\frac{3}{4}R: 2\right]$$ R_1=Min [(3/4)*5:2]=2

Hence,

V_s = 8186.14/2 = 4091 Kn

If the base shear in ETABS is coming less than the Vs calculated as above then scale up the RSA Function match to the value.

D. Finalize Number, Location, and Properties of Dampers:

- Location of Dampers:
  - The Isolators are located at the bottom of story GF.
  - One Isolator is placed below each column and each shear wall.



Fig 4 Grouping of Isolators

- Group 1 (Corner Element)
- Group 2 (Corner Element)
- Group 3 (Corner Element)

- Define the properties of each damper to meet the requirements calculated in Step 4:
- Dampers are grouped based on their location:
  a) Isolators below corner elements i.e Group-1 (G1**)**.
  b) Isolators below Periphery Elements i.e Group-2 (G2**)**.
  c) Isolators below Inner Elements i.e Group-3 (G3**)**.

The stiffness and damping of each group are proportionate to the relative vertical force i.e Seismic mass on the group. This ensures that the distribution of forces is balanced and the isolation system performs effectively under seismic loads. Following is calculation of same and results are summarized in Table.

- Known Parameters:
  i. Total Seismic Weight on Isolation System: W_{Total} =79918 kN
  ii. Total Stuffiness Required in Isolation System: K_{Total} = 51.458 kN/mm
  iii. Number of Isolators present in Total: n=36
- For Group G1:
  i. Total Seismic Weight on group G1: W_{G1} =22523 kN
  ii. Number of Isolators present in group G1: n=12

∴ Stiffness Required for group, $K_{req}=K_{total}*W_{G1}/W_{TOTAL}$ =51.458*22523/79918 = 14.502 kN/m
∴ Stiffness Required per isolator, $K_{G1}=K_{req}/n$ =14.502/12=1.208 kN/mm
∴ Damping Required per isolator,

$$C_{G1} := 2 \cdot \zeta \cdot \sqrt{\left(W_{G1} \cdot \frac{K_{G1}}{g} \cdot \frac{1}{n}\right)}$$

C_{G1}=2*0.1*√(22523*14502/9.81*12)=335 kN-s/m

- For Group G2 :
  i. Total Seismic Weight on group G2 : W_{G2} =21943 kN
  ii. Number of Isolators present in group G2 : n=12

∴ Stiffness Required for group, $K_{req}=K_{total}*W_{G2}/W_{TOTAL}$=51.458*21943/79918= 14.13 kN/m

∴ Stiffness Required per isolator, $K_{G2} = K_{req}/n$ = 14.13/12=1.177 kN/mm

∴ Damping Required per isolator,

$$C_{G2} := 2 \cdot \zeta \cdot \sqrt{\left(W_{G2} \cdot \frac{K_{G1}}{g} \cdot \frac{1}{n}\right)}$$

C_{G2} =2*0.1*√(21943*14130/9.81*12) = 325 kN-s/m

- For Group G3 :
  i. Total Seismic Weight on group G3 : W_{G3} =35485 kN
  ii. Number of Isolators present in group G3 : n=12

∴ Stiffness Required for group, $K_{req}=K_{total}*W_{G3}/W_{TOTAL}$=51.458*35485/79918= 22.85 kN/m

∴ Stiffness Required per isolator, $K_{G3} = K_{req}/n$ = 22.85/12 = 1.904 kN/mm
∴ Damping Required per isolator,

$$C_{G3} := 2 \cdot \zeta \cdot \sqrt{\left(W_{G3} \cdot \frac{K_{G3}}{g} \cdot \frac{1}{n} \right)}$$

C_{G3} = 2*0.1*√(35485*22850/9.81*12) =525 kN-s/m

V. RESULT OF COMPARATIVE STUDY

A detailed comparison of the seismic responses for response spectrum analysis of fixed-base versus isolated building is provided. This includes evaluating factors such as displacement, storey drift, acceleration, and force distribution:

A. Storey Displacements

Storey displacement refers to the horizontal movement or displacement of each floor (storey) of a building relative to its original position. This displacement is typically measured during seismic events or other dynamic loading conditions. Results are represented in tabular format as below,

TABLE IIIII
STOREY DISPLACEMENT SUMMARY

STOREY DISPLACEMENTS								
			BASE ISOLATION		FIXED BASE		% CHANGE	
STOREY	ELEVATION	LOCATION	BASE X-DIRECTION mm	BASE Y DIRECTION mm	FIXED X-DIRECTION mm	FIXED Y DIRECTION mm	X-DIRECTION	Y DIRECTION
ROOF	51	TOP	124.469	105.827	74.831	33.486	-39.879809	-68.357791
15TH FLOOR	48	TOP	123.041	104.784	71.066	31.144	-42.242017	-70.277905
14TH FLOOR	45	TOP	121.538	103.722	67.137	28.766	-44.760486	-72.26625
13TH LOOR	42	TOP	119.931	102.639	62.995	26.357	-47.473964	-74.320677
12TH FLOOR	39	TOP	118.195	101.531	58.647	23.92	-50.38115	-76.440693
11TH FOOR	36	TOP	116.299	100.398	53.892	21.463	-53.660823	-78.622084
10TH FLOOR	33	TOP	114.255	99.242	48.941	19	-57.165113	-80.85488
9TH FLOOR	30	TOP	112.066	98.069	43.776	16.551	-60.937305	-83.123107
8TH FLOOR	27	TOP	109.739	96.885	38.439	14.139	-64.972343	-85.40641
7TH FLOOR	24	TOP	107.291	95.702	32.983	11.791	-69.258372	-87.679463
6TH FLOOR	21	TOP	104.746	94.532	27.483	9.539	-73.762244	-89.909237
5TH FLOOR	18	TOP	102.135	93.392	22.03	7.418	-78.430509	-92.057136
4TH FLOOR	15	TOP	99.507	92.3	16.746	5.469	-83.171033	-94.074756
3RD FLOOR	12	TOP	96.921	91.279	11.785	3.734	-87.840612	-95.909245
2ND FLOOR	9	TOP	94.46	90.356	7.343	2.262	-92.226339	-97.496569
1ST FLOOR	6	TOP	92.238	89.562	3.671	1.107	-96.020078	-98.763985
GF	3	TOP	90.393	88.923	1.082	0.328	-98.803005	-99.631142
Base	0	TOP	89.426	88.682	0	0	-	-

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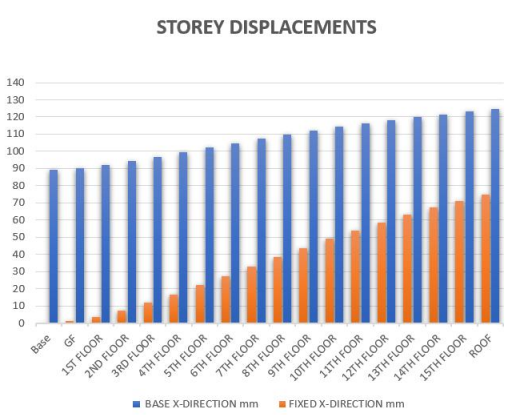


Fig. 5 Storey Displacements X Direction.

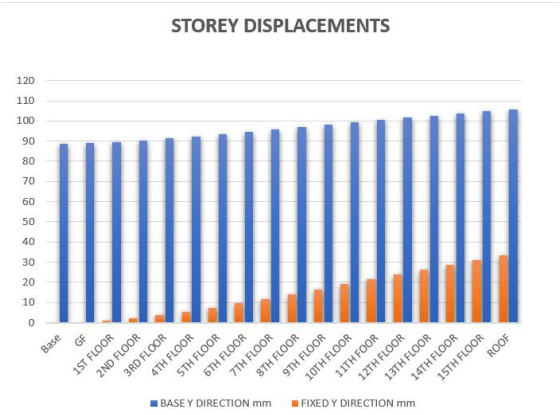


Fig. 6 Storey Displacements Y Direction.

B. Storey Drifts

Storey drift is the relative displacement or movement between adjacent storeys of a building. It's usually expressed as the ratio of the displacement between two storeys to the height of the storey under consideration. Results are represented in tabular format as below,

TABLE IVV
STOREY DRIFTS SUMMARY

STOREY DRIFTS								
			BASE ISOLATION		FIXED BASE		% CHANGE	
STOREY	ELEVATION	LOCATION	BASE X-DIRECTION mm	BASE Y DIRECTION mm	FIXED X-DIRECTION mm	FIXED Y DIRECTION mm	X-DIRECTION	Y DIRECTION
ROOF	51	TOP	0.000506	0.00036	0.001326	0.000787	162.05534	118.611111
15TH FLOOR	48	TOP	0.000534	0.000367	0.00139	0.000799	160.29963	117.711172
14TH FLOOR	45	TOP	0.000571	0.000375	0.001469	0.000811	157.26795	116.266667
13TH LOOR	42	TOP	0.000616	0.000383	0.001554	0.000822	152.27273	114.62141
12TH FLOOR	39	TOP	0.000671	0.000392	0.001651	0.000827	146.05067	110.969388
11TH FOOR	36	TOP	0.000721	0.000399	0.001725	0.000828	139.25104	107.518797
10TH FLOOR	33	TOP	0.000769	0.000404	0.001785	0.000823	132.11964	103.712871
9TH FLOOR	30	TOP	0.000813	0.000407	0.001831	0.000809	125.21525	98.7714988
8TH FLOOR	27	TOP	0.000851	0.000406	0.001858	0.000787	118.33137	93.8423645
7TH FLOOR	24	TOP	0.00088	0.000401	0.001862	0.000754	111.59091	88.0299252
6TH FLOOR	21	TOP	0.000897	0.00039	0.001836	0.000709	104.68227	81.7948718
5TH FLOOR	18	TOP	0.000899	0.000372	0.001773	0.000651	97.219132	75
4TH FLOOR	15	TOP	0.00088	0.000347	0.00166	0.000579	88.636364	66.8587896
3RD FLOOR	12	TOP	0.000834	0.000313	0.001483	0.000491	77.817746	56.8690096
2ND FLOOR	9	TOP	0.000751	0.000268	0.001225	0.000385	63.115846	43.6567164
1ST FLOOR	6	TOP	0.000621	0.000215	0.000863	0.00026	38.969404	20.9302326
GF	3	TOP	0.001632	0.00066	0.000361	1.09E-04	-77.879902	-83.484848
Base	0	TOP	0	0	0	0	-	-

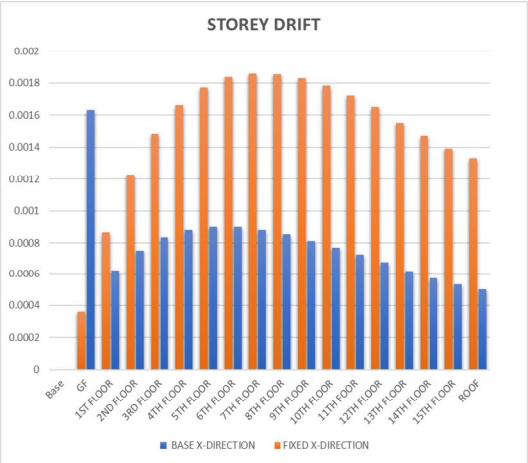


Fig. 7 Storey Drift X Direction.

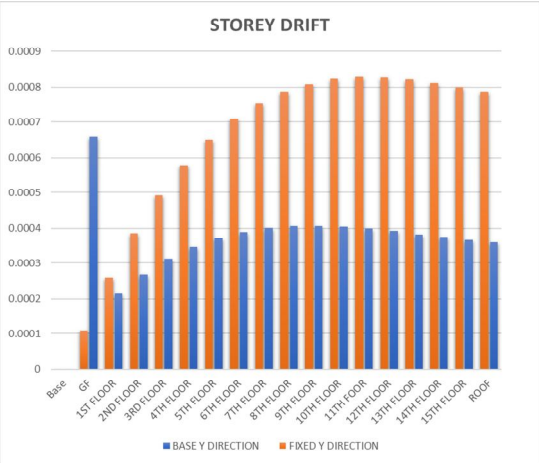


Fig. 8 Storey Drift Y Direction.

C. Storey Force

Storey shear forces are the lateral forces acting on each storey of a building due to horizontal loads such as wind or earthquakes. These forces are responsible for causing lateral movement or deformation in the structure. Results are represented in tabular format as,

TABLE V
STOREY SHEAR FORCE

STOREY SHEAR FORCE								
			BASE ISOLATION		FIXED BASE		% CHANGE	
STOREY	ELEVATION	LOCATION	BASE X-DIRECTION mm	BASE Y DIRECTION mm	FIXED X-DIRECTION mm	FIXED Y DIRECTION mm	X-DIRECTION	Y DIRECTION
ROOF	51	TOP	276.9054	255.3026	1120.7333	813.6792	304.73508	218.711678
15TH FLOOR	48	TOP	588.3987	544.5121	2127.2399	1599.3218	261.53035	193.716485
14TH FLOOR	45	TOP	885.5909	822.7326	2874.6641	2223.9585	224.60407	170.313647
13TH LOOR	42	TOP	1169.1651	1090.7897	3448.7102	2721.9719	194.97204	149.541401
12TH FLOOR	39	TOP	1446.4693	1355.8401	3912.0525	3130.815	170.45527	130.913291
11TH FOOR	36	TOP	1711.8128	1612.7118	4297.8132	3482.4573	151.06794	115.937981
10TH FLOOR	33	TOP	1966.6061	1862.7581	4632.7374	3798.9842	135.57017	103.944044
9TH FLOOR	30	TOP	2212.527	2107.4816	4946.113	4093.7734	123.5504	94.2495441
8TH FLOOR	27	TOP	2451.501	2348.5173	5257.703	4374.7676	114.46873	86.2778528
7TH FLOOR	24	TOP	2685.6901	2587.6229	5577.0151	4645.1492	107.65669	79.5141479
6TH FLOOR	21	TOP	2917.5042	2826.6906	5906.1898	4903.6715	102.4398	73.4774757
5TH FLOOR	18	TOP	3149.6532	3067.8103	6236.083	5145.877	97.992687	67.7377835
4TH FLOOR	15	TOP	3385.2933	3313.4451	6550.0546	5364.8051	93.485587	61.9101853
3RD FLOOR	12	TOP	3628.4474	3566.8906	6833.1407	5550.3586	88.321338	55.607761
2ND FLOOR	9	TOP	3885.269	3833.5859	7066.1966	5689.9847	81.871489	48.4246042
1ST FLOOR	6	TOP	4168.7128	4125.8002	7219.1149	5774.061	73.173717	39.9500877
GF	3	TOP	4526.8477	4490.8244	7275.7389	5804.8961	60.724181	29.2612577
Base	0	TOP	0	0	0	0	-	-

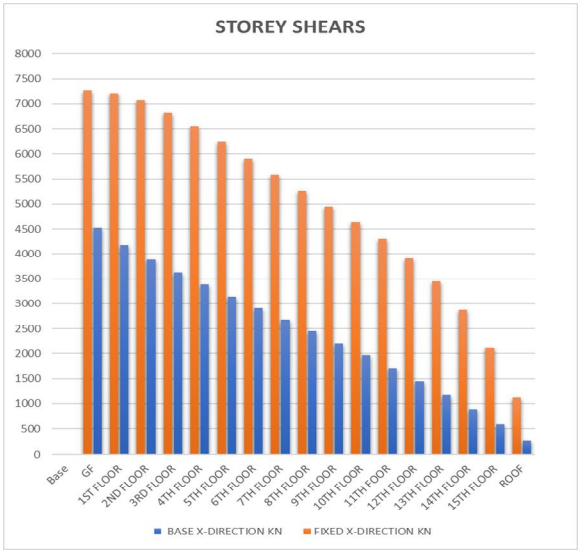


Fig. 9 Storey Shears X Direction.

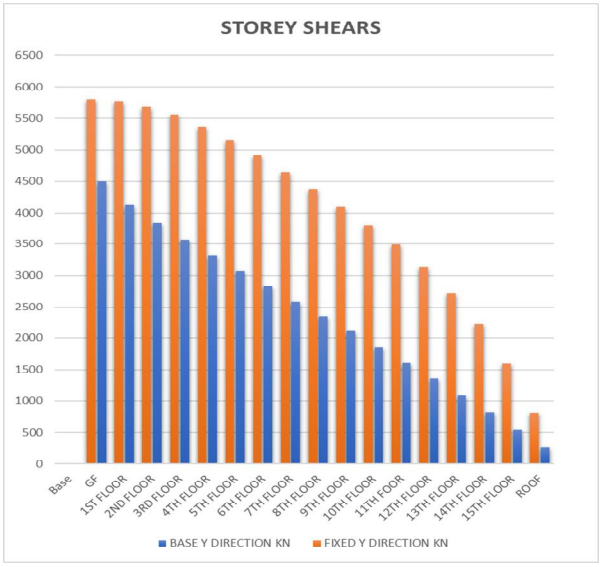


Fig. 10 Storey Shears Y Direction.

D. Modal Time Periods

Modal time periods represent the natural periods of vibration of a structure in various modes. Each structure has multiple modes of vibration, and each mode has an associated time period and mode shape. These time periods are crucial in seismic analysis because they help predict how a structure will respond to different frequencies of earthquake ground motions. Modal time periods directly influence the spectral acceleration values derived from the response spectrum. Shorter periods (higher frequencies) typically lead to higher spectral accelerations, indicating higher forces that the structure needs to withstand. Conversely, longer periods (lower frequencies) often correspond to lower spectral accelerations. The Time periods of Fixed and Isolated structure are represented in following

TABLE VI
MODAL TIME PERIODS

MODAL TIME PERIODS			
Case	**Mode**	ISOLATED **Period sec**	FIXED **Period sec**
Modal	1	2.97	1.362
Modal	2	2.803	0.947
Modal	3	2.653	0.838
Modal	4	0.694	0.366
Modal	5	0.525	0.205
Modal	6	0.442	0.204
Modal	7	0.265	0.167
Modal	8	0.148	0.096
Modal	9	0.147	0.086
Modal	10	0.138	0.084
Modal	11	0.083	0.063
Modal	12	0.071	0.049

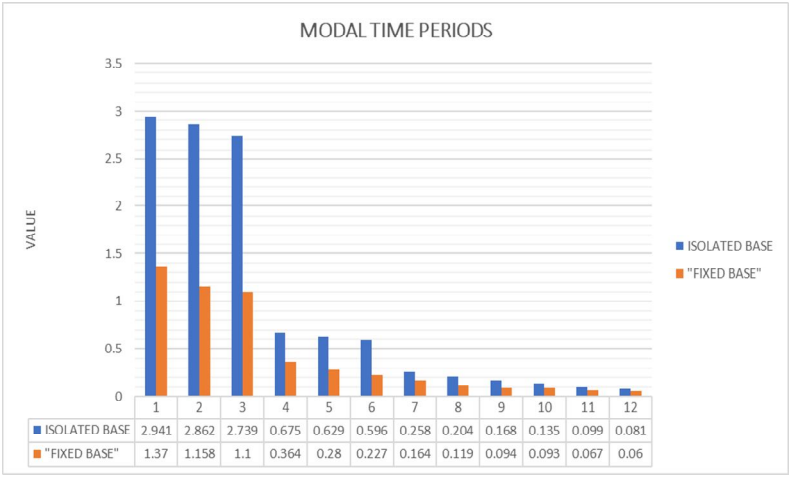


Fig. 11 Modal Time Periods Comparison

E. Diaphragm Accelerations:

Diaphragm accelerations refer to the horizontal accelerations experienced by floor or roof diaphragms during an earthquake. Following table and figure summarize the results of diaphragm accelerations for Fixed and Isolated structure.

TABLE VII
DIAPHRAGM ACCELERATIONS SUMMARY

DIAPHRAGM ACCELERATIONS								
			BASE ISOLATION		FIXED BASE		% CHANGE	
STOREY	ELEVATION	LOCATION	BASE MAX UX mm/sec^2	BASE MAX UY mm/sec^2	FIXED MAX UX mm/sec^2	FIXED MAX UY mm/sec^2	X-DIRECTION	Y DIRECTION
ROOF	51	TOP	664.2	613.17	2791.89	2058.2	320.3387534	235.6654761
15TH FLOOR	48	TOP	632.14	587.82	2148.73	1671.28	239.9136267	184.3183287
14TH FLOOR	45	TOP	602.19	564.46	1755.49	1387.88	191.5176273	145.8774758
13TH LOOR	42	TOP	575.06	543.59	1621.69	1242.66	182.003617	128.6024393
12TH FLOOR	39	TOP	551.35	525.68	1587.99	1189.22	188.0185	126.2250799
11TH FOOR	36	TOP	531.33	511.14	1555.53	1160.15	192.7615606	126.9730407
10TH FLOOR	33	TOP	515.99	500.23	1594.17	1152.9	208.9536619	130.473982
9TH FLOOR	30	TOP	505.75	493.03	1660.04	1175.37	228.2333169	138.3972578
8TH FLOOR	27	TOP	500.7	489.4	1706.45	1201.39	240.812862	145.4822231
7TH FLOOR	24	TOP	500.65	489	1739.73	1192.14	247.4942575	143.791411
6TH FLOOR	21	TOP	505.3	491.3	1742.57	1141.46	244.8584999	132.3346224
5TH FLOOR	18	TOP	513.69	495.64	1687.8	1077.5	228.5639199	117.3956904
4TH FLOOR	15	TOP	524.73	501.26	1601.56	1015.62	205.2160159	102.6134142
3RD FLOOR	12	TOP	537.1	507.34	1499.85	922.68	179.2496742	81.86620412
2ND FLOOR	9	TOP	549.37	513.26	1285.92	749.88	134.0717549	46.10139111
1ST FLOOR	6	TOP	559.96	518.19	870.32	489.83	55.42538753	-5.472896042
GF	3	TOP	567.26	521.53	341.51	199.41	-39.79656595	-61.76442391
Base	0	TOP	569.2	521.09	0	0	-	-

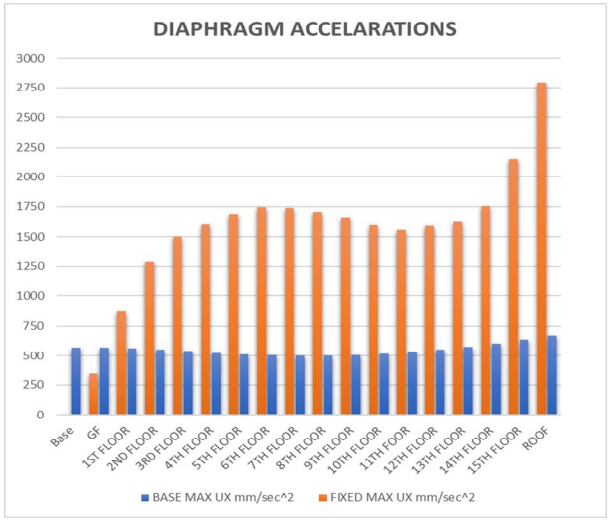


Fig. 12 Diaphragm Accelerations X Direction.

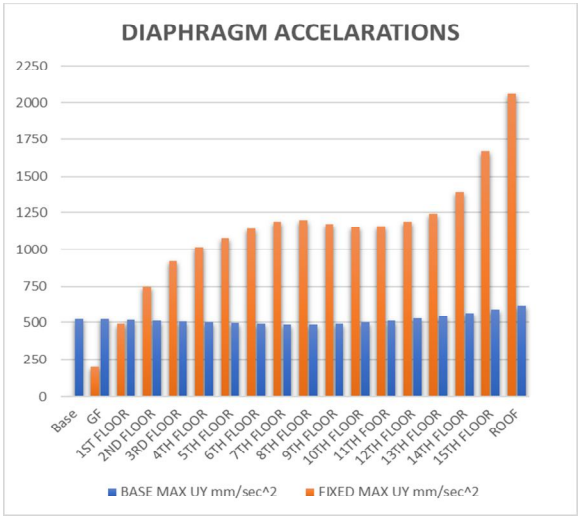


Fig. 13 Diaphragm Accelerations Y Direction.

VI. CONCLUSIONS

This study presents a comparative seismic performance evaluation of a fixed-base and a base-isolated (Lead Rubber Bearing) multi-storey building as per IS 1893 (Part 6)-2022 using linear isolation modeling and response spectrum analysis in ETAB21. The findings highlight the substantial advantages offered by base isolation systems across various critical structural parameters, affirming their effectiveness in seismic mitigation.

The results demonstrate a remarkable reduction in displacement, storey drift, storey shear, and storey acceleration when linear base isolation is implemented. Specifically, the top-storey displacements were reduced by approximately 56–61% in both X and Y directions. Similarly, storey drifts were lowered by 55–60%, reinforcing the role of base isolators in limiting inter-storey deformation and enhancing structural and non-structural safety.

In terms of storey shear, a consistent reduction of 50–65% was observed across all levels, significantly reducing the lateral force demands on structural members. Furthermore, the modal time periods of the isolated structure increased by an average of 110%, effectively shifting the building's dynamic response out of the range of dominant ground motion frequencies, which contributes to a substantial reduction in seismic forces.

A key finding is the reduction in storey accelerations above the isolation layer, where values decreased by 38–41% in both directions. This drop plays a critical role in safeguarding internal contents, sensitive equipment, and ensuring post-earthquake functionality—vital for hospitals, heritage buildings, and other critical infrastructure.

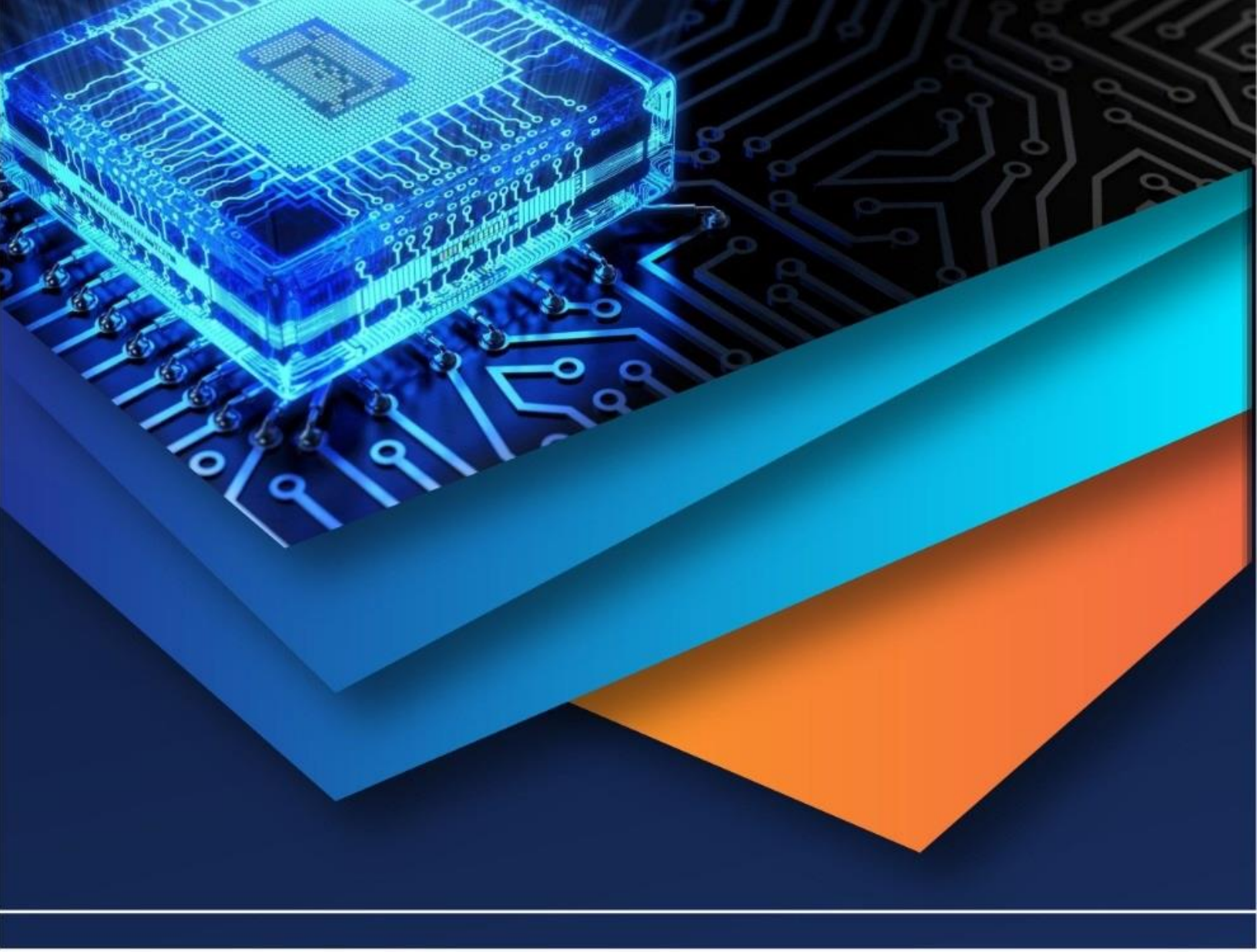
Overall, the linear base isolation system, particularly using Lead Rubber Bearings, exhibits enhanced seismic performance by reducing structural responses, increasing energy dissipation, and improving occupant safety. The significant improvements observed across all seismic response parameters strongly support the adoption of base isolation as a reliable and effective strategy in performance-based seismic design, especially for buildings located in high seismic zones.

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