iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: VI Month of publication: June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72778

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

# 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.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

## 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.

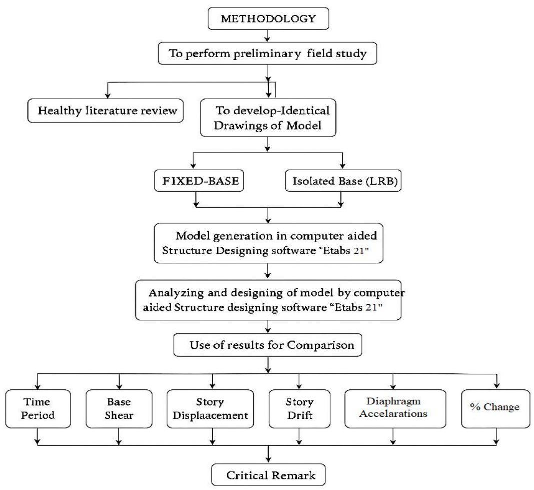



Fig. 1 Methodology

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

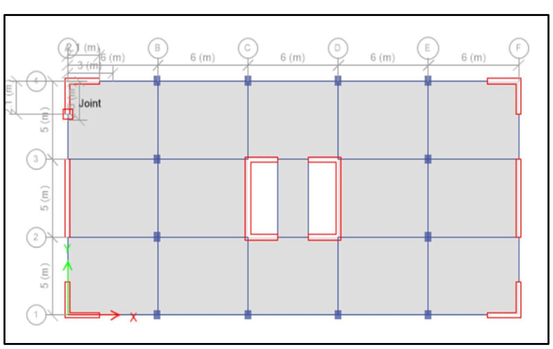



Fig 2 Plan View of Building

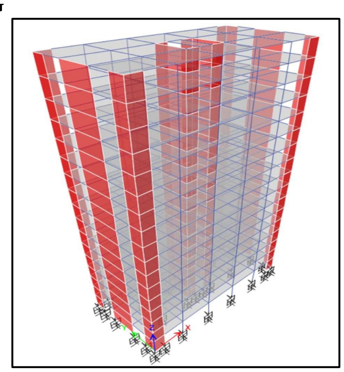


Fig 3 3D view of G+15 BUILDING

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

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.

## 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)*(2π/2.5)$^2$ $K_{eff\_min}$ = (79918/9.81)*(2π/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,

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

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

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

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

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)
$\beta$ = damping multiplier, is given by:

$$\frac{S_a}{g} = 0.242$$

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

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:

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

$$V_b = 51.458 * 1000 * 0.159 = 8186.14 \text{ Kn}$$

  - 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:

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

Hence,

$$V_s = 8186.14/2 = 4091 \text{ Kn}$$

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.

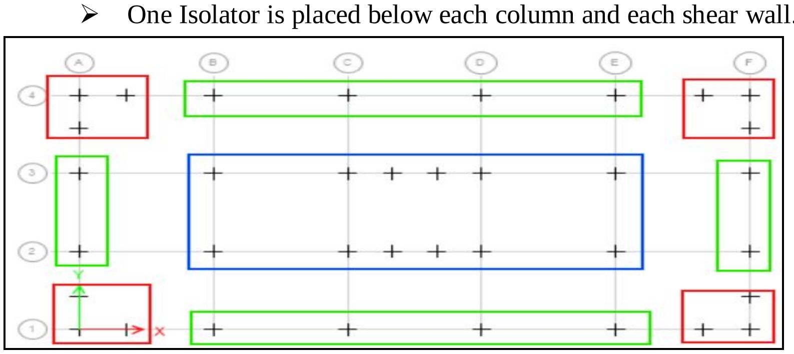



Fig 4 Grouping of Isolators

- 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 | - | - |

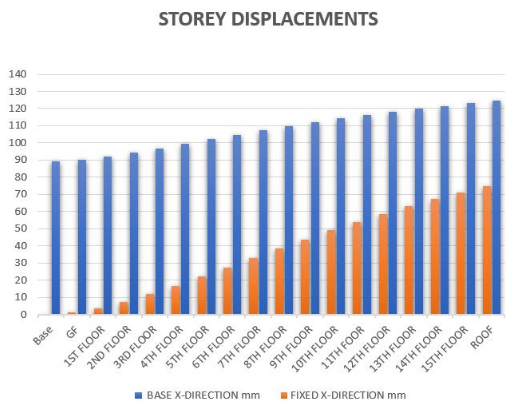



Fig. 5 Storey Displacements X Direction.


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 | - | - |

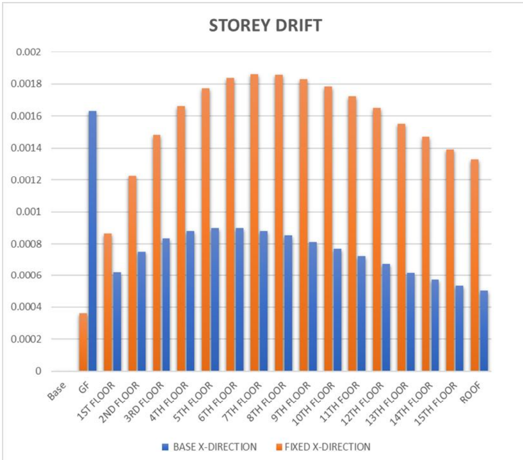



Fig. 7 Storey Drift X Direction.

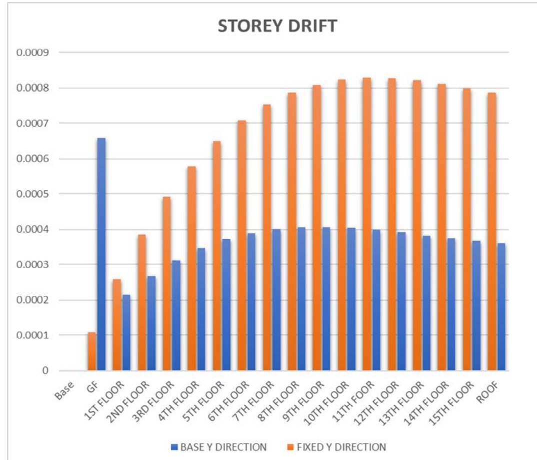



Fig. 8 Storey Drift Y Direction.

### 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 | - | - |

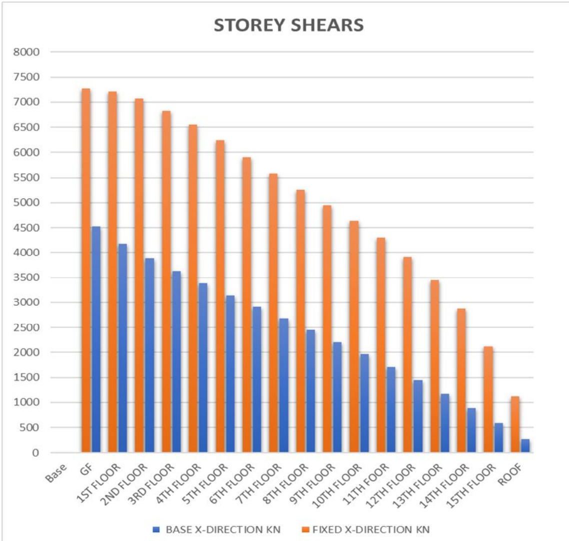



Fig. 9 Storey Shears X Direction.

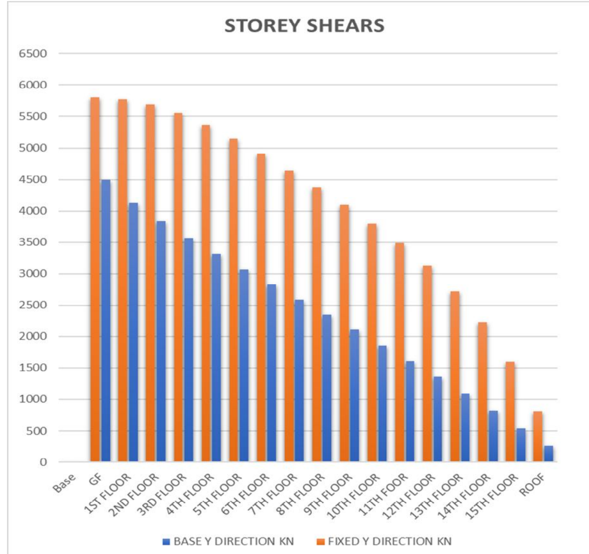



Fig. 10 Storey Shears Y Direction.

### *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 |

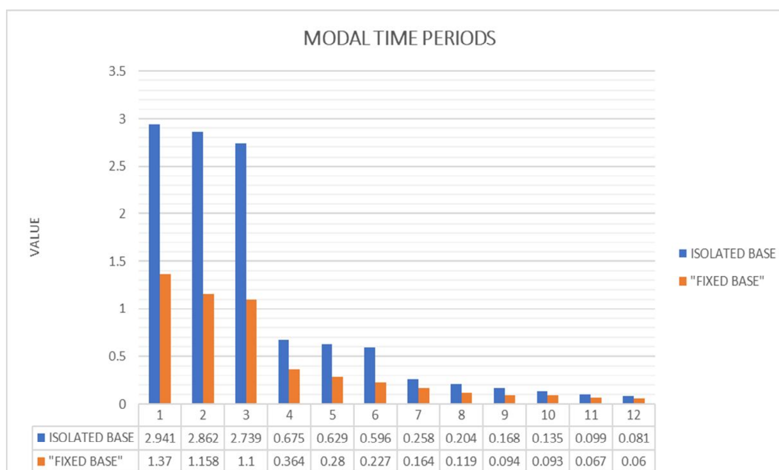



Fig. 11 Modal Time Periods Comparison

### *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.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

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 |
| $15^{TH}$ FLOOR | 48 | TOP | 632.14 | 587.82 | 2148.73 | 1671.28 | 239.9136267 | 184.3183287 |
| $14^{TH}$ FLOOR | 45 | TOP | 602.19 | 564.46 | 1755.49 | 1387.88 | 191.5176273 | 145.8774758 |
| $13^{TH}$ LOOR | 42 | TOP | 575.06 | 543.59 | 1621.69 | 1242.66 | 182.003617 | 128.6024393 |
| $12^{TH}$ FLOOR | 39 | TOP | 551.35 | 525.68 | 1587.99 | 1189.22 | 188.0185 | 126.2250799 |
| $11^{TH}$ FOOR | 36 | TOP | 531.33 | 511.14 | 1555.53 | 1160.15 | 192.7615606 | 126.9730407 |
| $10^{TH}$ FLOOR | 33 | TOP | 515.99 | 500.23 | 1594.17 | 1152.9 | 208.9536619 | 130.473982 |
| $9^{TH}$ FLOOR | 30 | TOP | 505.75 | 493.03 | 1660.04 | 1175.37 | 228.2333169 | 138.3972578 |
| $8^{TH}$ FLOOR | 27 | TOP | 500.7 | 489.4 | 1706.45 | 1201.39 | 240.812862 | 145.4822231 |
| $7^{TH}$ FLOOR | 24 | TOP | 500.65 | 489 | 1739.73 | 1192.14 | 247.4942575 | 143.791411 |
| $6^{TH}$ FLOOR | 21 | TOP | 505.3 | 491.3 | 1742.57 | 1141.46 | 244.8584999 | 132.3346224 |
| $5^{TH}$ FLOOR | 18 | TOP | 513.69 | 495.64 | 1687.8 | 1077.5 | 228.5639199 | 117.3956904 |
| $4^{TH}$ FLOOR | 15 | TOP | 524.73 | 501.26 | 1601.56 | 1015.62 | 205.2160159 | 102.6134142 |
| $3^{RD}$ FLOOR | 12 | TOP | 537.1 | 507.34 | 1499.85 | 922.68 | 179.2496742 | 81.86620412 |
| $2^{ND}$ FLOOR | 9 | TOP | 549.37 | 513.26 | 1285.92 | 749.88 | 134.0717549 | 46.10139111 |
| $1^{ST}$ 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 | - | - |

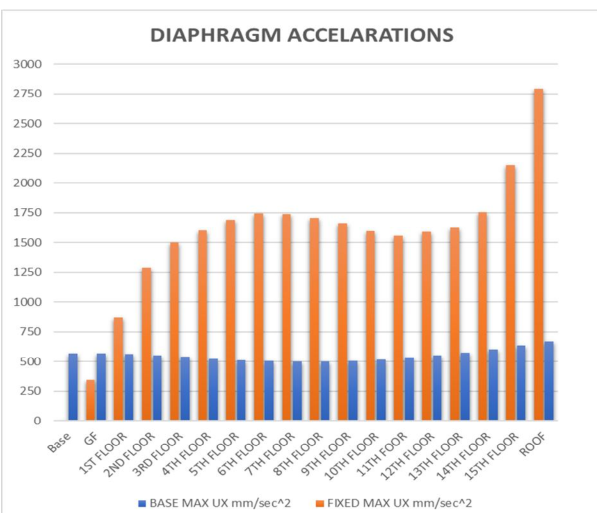



Fig. 12 Diaphragm Accelerations X Direction.

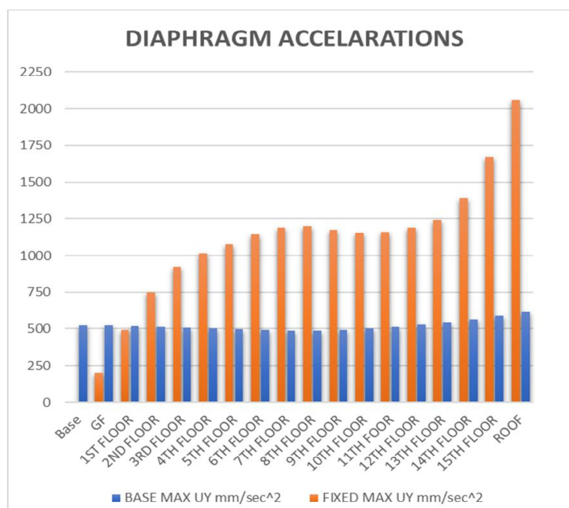



Fig. 13 Diaphragm Accelerations Y Direction.

## 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.

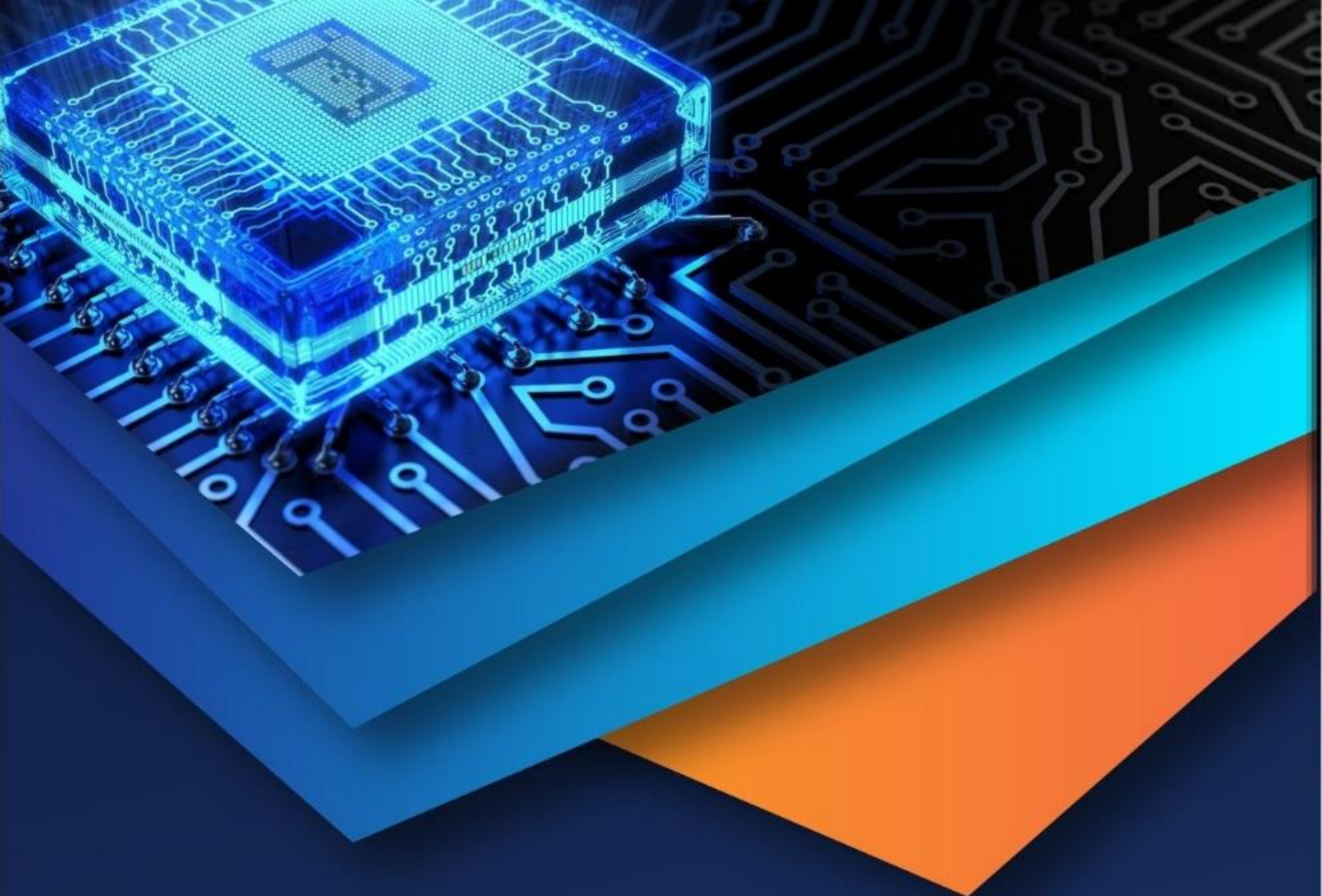
A key finding is the reduction in storey accelerations above the isolation layer, where values decreased by 38–41% in both directions. This drop plays a critical role in safeguarding internal contents, sensitive equipment, and ensuring post-earthquake functionality—vital for hospitals, heritage buildings,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

## REFERENCES

[1] R.S. Jangid, Optimum lead–rubber isolation bearings for near-fault motions, Engineering Structures 29 (2007) 2503–2513,ELSEVIER PUBLICATION-2007.
[2] Mrudula Madhukumara, Helen Santhi M, Vasugi V, Performance analysis of lead rubber bearing isolation system for low, medium and high- rise RC buildings, Research on Engineering Structures & Materials 9(1) (2023) 263-276.
[3] Pradeep Kumar Pandey, Comparision of Fixed Base and Base Isolation Reinforced Concrete Structure for Seismic Response, Volume 4, Issue 4, April -2017, International Journal of Advance Engineering and Research Development.
[4] Sarvesh K. JAIN and Shashi K. THAKKAR, APPLICATION OF BASE ISOLATION FOR FLEXIBLE BUILDINGS, 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 1924.
[5] M. Tamim Tanwer, Prof. Dr. Tanveer Ahmed Kazi, Prof. Dr. Mayank Desai, COMPARATIVE STUDY ON LEAD RUBBER BEARING (LRB) BASE ISOLATION SYSTEM ON G+12 & G+22 STORY RCC STRUCTURE OVER FIXED BASED FOR INDIAN SUBCONTINENT, Volume 10, Issue 11, November 2019, pp. 423-433, Article ID: IJCIET_10_11_043. International Journal of Civil Engineering and Technology (IJCIET) .
[6] Anas M. Fares, Comparison between fixed base and isolated base in seismic response of high-rise buildings: a case study, CHALLENGE JOURNAL OF STRUCTURAL MECHANICS 6 (4) (2020) 204–214, 3 June 2020.
[7] Swapnil Ambasta, Dushyant sahu, G.P. Khare, ANALYSIS OF THE BASE ISOLATED BUILDING (LEAD PLUG BEARING) IN ETABS, Volume: 05 Issue: 01 | Jan-2018, International Research Journal of Engineering and Technology (IRJET).
[8] SANKET VIJAY MUNOT, P.B.AUTADE, Design of Lead Rubber Bearing Base Isolator system for High Rise Structure, ISSN: 2320-2882 Volume 9, Issue 7, International Journal of Creative Research Thoughts (IJCRT)-JULY 2021.
[9] Dhruv V. Jain, Dr.(Major). Chaitanya S. Sanghvi, Comparative study of IS: 1893 part-6 (draft code) Base Isolated buildings with International codes, Volume 8, Issue 5, Journal of Emerging Technologies and Innovative Research (JETIR)-MAY 2021.
[10] A. Paul, “Base Isolation System: Outline on Principles, Types, Advantages & Applications,” [Online]. Available: https://civildigital.com/base-isolation-system-outline-on-principles-types-advantages-applications/.
[11] M. N. a. M. Ziyaeifar, “Vertical Seismic Isolation of structures,” Journal of Applied Sciences, p. 7, 2008.
[12] Z. Q. L. F. I. T. Yun-Peng Zhu, “Analysis and design of non-linear seismic isolation systems for building structures—An overview,” Front. Built Environ, p. 14, 2023.
[13] “Different Types of Base Isolators Used in Buildings,” [Online]. Available: https://theconstructor.org/earthquake/different-types-base-isolators-structures/36177/#google_vignette.
[14] F. N. a. J. M. Kelly, “Code Provisions For Seismic Isolation,” John Wiley & Sons, Inc., p. 30, 1999.
[15] I. Systems, “Dynamic Isolation Systems,” 2010. [Online]. Available: https://dis-inc.com/pdf_files/DIS_Terms_Symbols.pdf.
[16] FipMec, “fipmec.it,” [Online]. Available: https://www.fipmec.it/en/download-area/catalogues/#category-53.
[17] Major Sandeep Shah (Retd) FIAStructE, ETABs Commands/Procedure for Defining Dampers , Taylor Devices inc.
[18] “What are the Effects of Earthquake on Structures?,” [Online]. Available: https://theconstructor.org/structural-engg/earthquake-effects-structures/2704/.
[19] C.V.R.Murty, “IITK- Earthquake Tip 5,” [Online]. Available: https://www.iitk.ac.in/nicee/EQTips/EQTip05.pdf.
[20] “Seismic Dampers – Types, Working Mechanism, and Components,” [Online]. Available: https://theconstructor.org/earthquake/seismic-dampers/8332/.
[21] E. I. M. &. C. Ozer, “Seismic Performance Comparison of Fixed and Base-Isolated Models,” Iranian Journal of Science and Technology, Transactions of Civil Engineering, vol. 47, p. 16, 2022.
[22] IS 456:2000 – Plain and Reinforced Concrete – Code of Practice

[23] IS 875:1987 – Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures
[24] Part 1: Dead Loads
[25] Part 2: Imposed Loads
[26] Part 3: Wind Loads
[27] IS 1893:2016 (Part 1) – Criteria for Earthquake Resistant Design of Structures – General Provisions and Buildings
[28] IS 1893:2022 (Part 6) – Criteria for Earthquake Resistant Design of Structures – Base-Isolated Buildings
[29] IS 16700:2017 – Criteria for Structural Safety of Tall Concrete Buildings
[30] NBC 2016 – National Building Code of India 2016



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY