"Enhancing The Seismic Response of Residential RC Buildings with an Innovative Base Isolation Technique"

Mr. Sandesh Wani[1], Dr. Shilpa Kewate[2]

[1] *PG Student, Department of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani, Maharashtra, India.*

[2] *Associate Professor, Department of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani, Maharashtra, India.*

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Abstract-*Base isolation is an effective seismic protection technique in which isolation devices are introduced between the foundation and the superstructure to reduce the transmission of earthquake-induced vibrations. Among the commonly adopted isolation systems are elastomeric and sliding-type bearings. In the present study, a twenty-three-storey reinforced concrete building is considered for seismic analysis. The structural responses of a conventional Fixed Base Structure and a Lead Rubber Bearing (LRB/N-Z bearing) isolated structure are evaluated and compared. The performance of the two structural configurations is assessed using important seismic response parameters, including maximum storey displacement, maximum storey drift, storey shear, and base shear. The study focuses on evaluating the effectiveness of Lead Rubber Bearings in reducing earthquake-induced structural responses in a high-rise reinforced concrete building.*

Keywords: Base isolation, Lead Rubber Bearing, Laminated Rubber Bearing, N-Z Bearing, storey displacement, storey drift, storey shear, base shear.

1. INTRODUCTION

Base isolation is a seismic design approach intended to reduce the transfer of earthquake-induced ground motion to a building. In this technique, an isolation layer consisting of flexible and energy-dissipating devices is provided between the foundation and the superstructure. The isolation system allows controlled horizontal movement of the structure during an earthquake, thereby reducing the seismic forces transmitted to the upper portion of the building. By increasing the effective fundamental period and providing additional energy dissipation, base isolation can reduce the acceleration and deformation demands imposed on structural and non-structural components. Base isolation is primarily implemented using elastomeric and sliding-type isolation systems. Elastomeric isolation bearings are generally composed of alternating layers of rubber and steel plates and may incorporate a lead core for additional energy dissipation. Sliding isolation systems, in contrast, utilize controlled relative movement between contacting surfaces to reduce the transmission of seismic forces. Both systems are intended to permit lateral movement during an earthquake while maintaining adequate vertical load-carrying capacity.

Lead Rubber Bearings (LRBs) are one of the widely used elastomeric isolation devices. The development of modern lead-rubber isolation technology is associated with New Zealand during the 1970s. An LRB generally consists of alternating layers of elastomer and steel plates, together with a central lead plug and end plates that facilitate connection to the structure. The laminated rubber provides flexibility in the horizontal direction while the steel reinforcement layers contribute to the vertical load-carrying capacity of the bearing. The principal function of an LRB is to provide relatively low horizontal stiffness while maintaining high vertical stiffness. During an earthquake, the bearing undergoes controlled lateral deformation, which increases the effective period of the isolated structure and consequently reduces the seismic acceleration transmitted to the superstructure. At the same time, deformation of the lead core provides hysteretic energy dissipation, thereby reducing the amount of seismic energy transferred to the building. The present study investigates the seismic response of a twenty-three-storey reinforced concrete building using two structural configurations: a conventional fixed-base system and a Lead Rubber Bearing isolation system. The responses of both models are compared using maximum storey displacement, maximum storey drift, storey shear, and base shear as the principal performance parameters. The comparison is intended to demonstrate the influence of Lead Rubber Bearings on the seismic behaviour of a high-rise reinforced concrete structure.

2. TYPES OF ISOLATION BEARINGS

2.1 Elastomeric Devices

These bearings are composed of alternating layers of natural or synthetic rubber and steel plates. They are highly stiff in the vertical direction but horizontally flexible. The common elastomeric devices include: natural rubber bearings, lead rubber bearings and high damping natural rubber bearings.

2.1.1 Natural Rubber Bearing

Natural rubber bearings, commonly referred to as laminated rubber bearings, are isolation devices manufactured using natural rubber or synthetic elastomers such as neoprene. These materials are selected because of their flexibility, durability, and ability to withstand repeated cyclic deformation. A typical laminated rubber bearing consists of multiple alternating layers of elastomeric rubber and thin steel shims. The rubber layers provide the required horizontal flexibility, while the steel shims enhance the bearing's vertical load-carrying capacity and Stability.

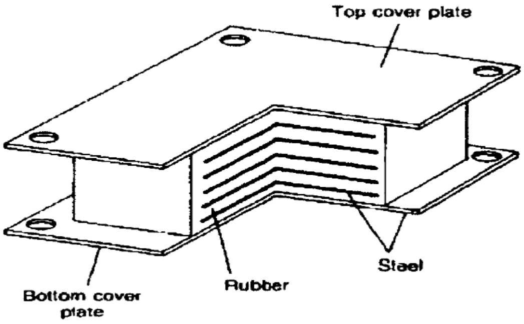


Fig-1: Natural Rubber Bearings

2.1.2 Lead Rubber Bearings

Compared with conventional natural rubber bearings, Lead Rubber Bearings (LRBs) provide greater resistance to lateral loads such as wind loads and offer enhanced energy-dissipation capacity due to the presence of the lead core. The basic construction of an LRB is similar to that of a laminated natural rubber bearing. However, it incorporates one or more cylindrical lead cores positioned within the central portion of the bearing, as illustrated in Figure 2. These lead cores undergo controlled deformation during seismic loading and contribute significantly.

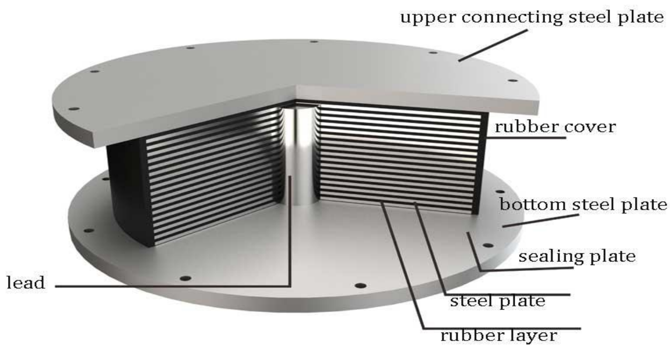


Fig 2-Lead Rubber Bearing

2.1.3 High Damping Natural Rubber Bearings

High-damping natural rubber bearings can provide the required energy dissipation without the need for additional damping mechanisms. Their enhanced damping performance is obtained by incorporating suitable additives, such as carbon-based fillers, oils, and resins, into the rubber compound. These additives can increase the damping capacity of the bearing to approximately 20–30% of critical damping. At shear strain levels below about 20%, high-damping natural rubber bearings generally exhibit relatively high stiffness along with significant damping capacity, making them suitable for seismic isolation applications.

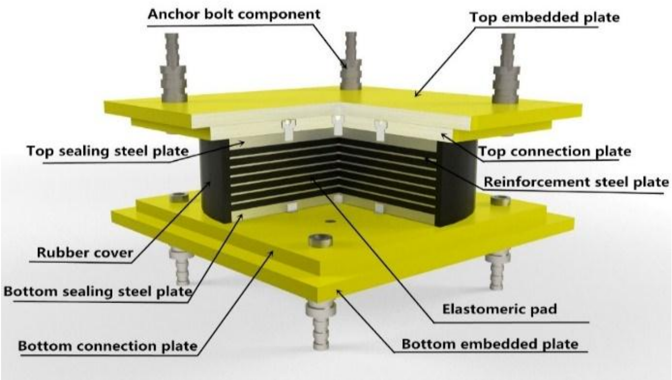


Fig 3-High Damping Natural Rubber Bearings

2.1.4 Friction Pendulum Bearings

Friction Pendulum Bearings (FPBs) utilize a combination of sliding and pendulum mechanisms to provide seismic isolation. As illustrated schematically in Figure 4, the system consists of a curved slider that moves along a spherical concave surface, which is generally fabricated with a highly polished surface. The sliding element is typically provided with a low-friction material, such as PTFE (Teflon), to facilitate controlled movement. Depending on the sliding velocity and bearing characteristics, the coefficient of friction is typically around 0.1 at higher sliding velocities and approximately 0.05 at lower velocities. Consequently, the lateral resisting force developed by the friction pendulum system is governed by the combined effects of frictional resistance and the restoring force generated by the spherical geometry.

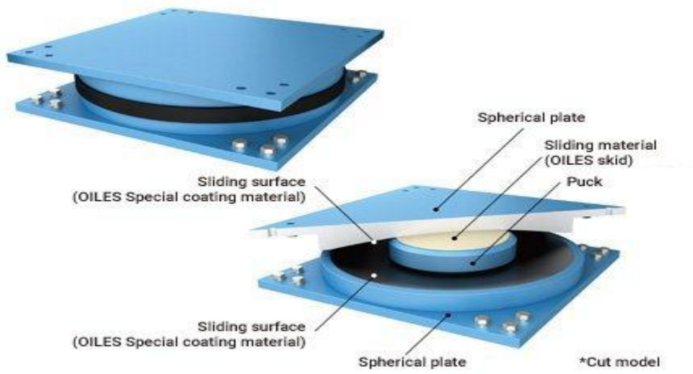


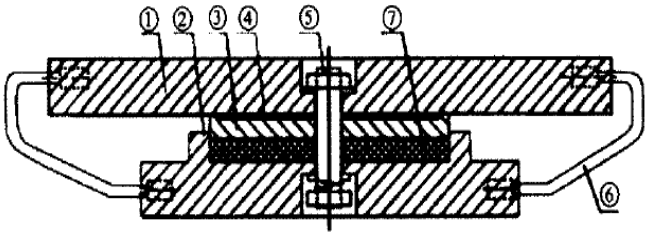
Fig 4-Friction Pendulum Bearings

2.2 Sliding Devices

One of the important benefits of sliding isolation devices is their ability to reduce torsional response in structures with asymmetric configurations. The frictional resistance developed by a sliding bearing is primarily dependent on the vertical load acting on the bearing. Consequently, the lateral resisting forces are distributed in accordance with the gravity loads carried by the individual isolators. This characteristic helps maintain a closer relationship between the center of gravity of the superstructure and the effective center of resistance of the isolation system, thereby reducing the tendency for torsional movement during seismic excitation.

2.2.1 Cable Friction Bearings

The isolation system comprises a conventional sliding bearing supplemented with high-strength restraining cables and, where required, a centrally positioned shear bolt. During an exceptionally severe earthquake, the restraining cables act as displacement-limiting components, preventing excessive lateral movement of the superstructure and helping maintain the stability of the isolated structure.



(1) upper plate (2) lower plate (3) stainless steel plate (4) teflon plate (5) shear bolt (6) cable (7) elastomeric pad

Fig 5-Cable Friction Bearing

2.2.2 Resilient Friction Base Isolators

Resilient friction-base isolators consist of several flat metallic plates arranged to permit relative sliding, along with a central rubber core and, in some configurations, additional rubber cores positioned around the perimeter. The metallic components are enclosed within a flexible rubber casing, which protects the internal elements from environmental effects such as moisture, dust, and corrosion. The contact surfaces of the sliding plates are generally coated with low-friction materials such as PTFE (Teflon) to facilitate smooth sliding motion. The rubber cores contribute to the overall flexibility of the isolator by accommodating and distributing lateral displacement and deformation over the height of the device.

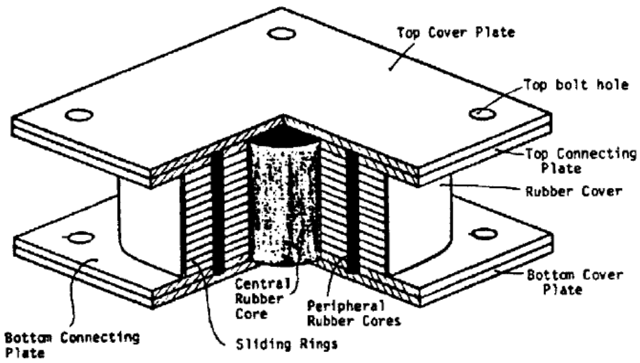


Fig-6 Resilient Friction Base Isolators

1. Comparison of Lead Rubber Bearing (LRB) verses Fixed Base Structure

Parameter	Lead Base Isolation (LRB)	Fixed Base Structure
Seismic performance	Excellent seismic performance; significantly reduces earthquake forces transmitted to the superstructure	Earthquake forces are directly transferred to the structure
Base shear	Generally lower due to isolation and energy dissipation	Generally higher
Inter-storey drift	Generally reduced, especially in the superstructure	Usually higher during strong earthquakes
Natural time period	Increases significantly, moving the structure away from the dominant earthquake period	Generally shorter
Earthquake damage	Potentially much lower damage to structural and non-structural components	Greater possibility of structural and non-structural damage
Construction complexity	More complicated; requires isolation bearings, seismic gaps and detailing	Simpler conventional construction

2. Review of Previous Studies

Amol Chirde, Yashraj Malvatkar, Sanket Madhwai, Ganesh Gavale, Prof. Manisha Surve et al. (2022) investigated the seismic behaviour of reinforced concrete buildings with different heights, namely G+2, G+4, G+6, and G+8 storeys. The buildings had a plan dimension of 25 m × 25 m and were subjected to dead load, live load, and seismic loading corresponding to Seismic Zone V, with a zone factor of 0.36 and an importance factor of 1.0. Three structural configurations were considered: a conventional fixed-base model, a base-isolated model, and a model incorporating high-damping rubber isolation. The analysis considered a live load of 3 kN/m^2 and floor finish load of 1 kN/m^2. The structural responses were compared in terms of maximum displacement, maximum storey drift, fundamental time period, and base shear.

Sarvesh K. Jain and Sashi K. Thakkar (2020) studied the seismic response of ten-, fourteen-, and twenty-storey buildings by comparing fixed-base and base-isolated configurations. The researchers introduced an Effectiveness Ratio (ER), defined using the ratio of the corresponding response parameters of fixed-base and isolated structures, to assess the influence of seismic isolation. A higher ER indicates a greater reduction in the considered response due to isolation. The study particularly examined the applicability of base isolation for structures having fundamental time periods in the range of approximately 1 to 3 seconds and investigated conditions under which isolation can provide improved seismic performance.

Pallavi Wamanrao Taywade and Madhuri Narayan Savale (2017) examined the seismic performance of buildings incorporating base isolation systems. The study highlighted the importance of protecting structures against dynamic loads that may occur throughout their service life. Such loads include earthquakes, wind, waves, traffic-induced vibrations, and blast effects. The researchers discussed seismic base isolation as an effective approach for reducing the transmission of earthquake-induced forces to the superstructure and improving the overall seismic resistance of buildings.

R. B. Ghodke and S. B. Admane (2016) investigated the application of base isolation for reducing earthquake-induced damage in buildings. A comparative analysis between fixed-base and base-isolated structures was performed using SAP2000. The study considered a five-storey building located in Seismic Zone IV and subjected the models to recorded earthquake ground motions from different locations in India. The results indicated that the displacement response of the base-isolated structure was lower compared with the corresponding fixed-base structure under the considered conditions. The study demonstrated the potential of base isolation as a means of reducing seismic demand and improving the earthquake performance of buildings.

Tejas Jitendra Chordiya and Vaishnavi Yogesh Totla (2018) investigated the effectiveness of base isolation in reducing earthquake-induced structural damage. The fundamental principle considered in the study was to increase the effective vibration period of the structure and provide additional energy dissipation through the isolation system. Fixed-base and Lead Rubber Bearing (LRB) isolated models were analysed using the response spectrum method. The comparative results demonstrated that incorporating LRBs modifies the seismic response of the structure and can improve its performance under earthquake excitation.

Sushma G. Sawadatkar (2020) carried out a comparative study of different seismic isolation techniques, including Lead Rubber Bearings, high-damping rubber bearings, and friction pendulum systems. The study described the basic principle of base isolation, in which an isolation interface is introduced between the foundation and the superstructure to reduce the transfer of ground motion. The seismic responses obtained using the different isolation systems were compared to evaluate their relative performance. The study reported differences in the effectiveness of Lead Rubber Bearings, high-damping rubber bearings, and friction pendulum systems in controlling structural response under earthquake loading.

3. Modeling of the Structure

Planning of G+23 RCC structure using AutoCAD 2018. Software used for analysis and design of structure is ETABS. The analysis carried out by using Response Spectrum Analysis. Structure is modelled, after that loads are applied as per code provisions. Calculation of a Dead load for different members using IS:875(Part I). Calculation of Live load using IS: 875(Part II). For response spectrum analysis method, spectrum used from IS 1893:2016. Firstly, analysis of fixed support building is done; from that maximum vertical reaction is noted from support reactions results. Once maximum vertical reaction is taken, and then LRB is designed. Properties of LRB is calculated. For base isolation structure, the LRB properties are used as link properties. Then analysis of isolated base structure. Checking behaviour after analysis. Then results are tabulated and represented in terms of table and using graphical representation.

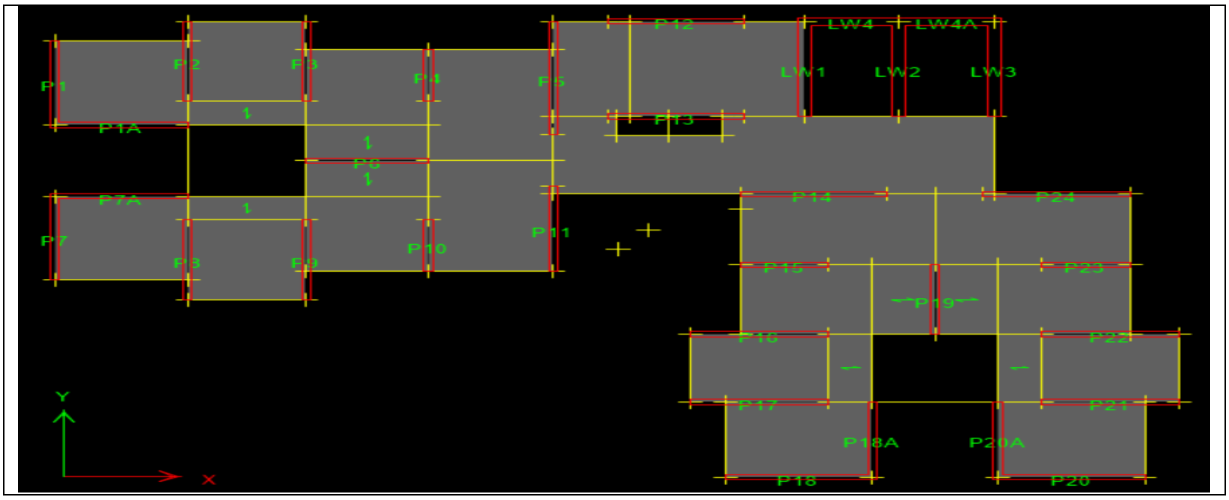
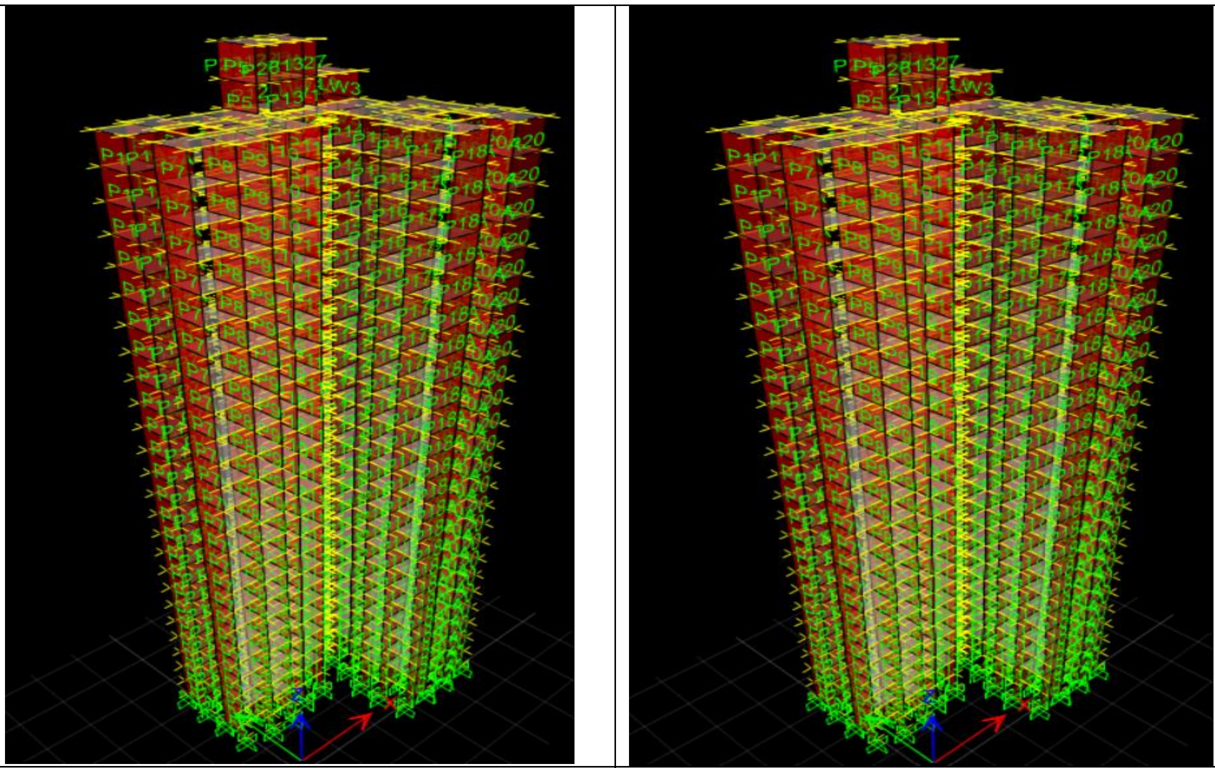


Fig. 7 Plan View of Structure



3D-Fixed Base Model	**3D-Lead Rubber Base Isolation Model**

Fig-8 ETABS Fixed Base & Rubber Base 3D Model

5.1 Modelling and Analysis

5.1.1 Material Properties

Grade of Concrete = M35
Grade of Steel = Fe500

5.1.2 Properties of Building Elements

1. Beam = 0.2 X 0.75m
2. Shear wall thikness =0.2 m thk

3. Slab thickness =0.125 m
4. Main wall thickness =0.2 m
5. Partition wall thickness =0.15m
6. Shear wall thickness (Lift) =0.3m
7.Live load=2kn/m^2
8.Floor finish=1.5kn/m^2
9.RCC design code=IS 456:2000

5.1.3 Earthquake parameters for structure according to IS 1893:2016

1. Seismic zone (Z) =Zone III
2. Soil profile type =Type 2
3. Importance factor(I) =1.2
4. Response reduction factor(R) =4 (SMRF)
5.Damping ratio =0.5%
6.Type of soil=medium soil

5.1.4 Wind design parameters for structure according to IS 875:2007

1.Baseic wind speed=44 m/s
2. Risk Coefficient(K1) =1
3. Terrain size coefficient (K2) =1
4. Topography Factor(K3) =1
5.Damping ratio =0.5%

5.1.5 Input values in ETABS after the Design of the LRB

Rotational inertia I =0.367664 kN/m
For U1 effective stiffness (Linear) =1694260 kN/m
For U2 and U3 effective stiffness (Linear) =5170.425 kN/m
For U1 and U2 effective damping =5%
For U1 and U3 distance from end-J =0.003177 m
For U2 and U3 stiffness (Non-linear) =47643.41 kN/m
For U2 and U3 yield strength =152.6644 Kn

4. RESULT

a) **Storey Displacement due to Seismic loading: -** (IS Code-1893:2016)
- Permissible Storey displacement due to seismic loading = H/250= 74400/250

Permissible Story displacement due to seismic loading = 297.6 mm.

Table No.1 - Storey displacement for earthquake along "X"

Storey	RC Frame Structure with Fixed Base (mm)	RC Frame Structure with Lead Base Rubber Base Isolation (mm)
3rd	5.586	2.595
6th	11.277	6.818
9th	18.146	12.06
12th	25.389	17.743
15th	32.582	23.451
18th	39.416	28.883
21th	45.751	33.898

23rd	49.753	37.052
Terrace	51.744	38.62
	51.744 < 297.6	**38.62 < 297.6**
	OK	**OK**

b) Storey drift limitation: - (IS Code 1893:2016, Clause- 7.11.1)

- The permissible Storey drift (Δ) in any Storey **= 0.004 × H= 0.004 × 2900**

Permissible Storey drift (Δ) in any Storey = 11.6mm

Table No.2- Maximum Story Drift for Response Spectrum along "X"

Storey	RC Frame Structure with Fixed Base (mm)	RC Frame Structure with Lead Base Rubber Base Isolation (mm)
3rd	0.000502	0.000301
6th	0.000612	0.000403
9th	0.000655	0.000436
12th	0.000665	0.000449
15th	0.000658	0.000459
18th	0.000634	0.000461
21th	0.000597	0.000446
23rd	0.00058	0.000435
Terrace	0.000577	0.000433
	0.000433 < 11.6	**0.000433 < 11.6**
	OK	**OK**

c) Storey shears: -

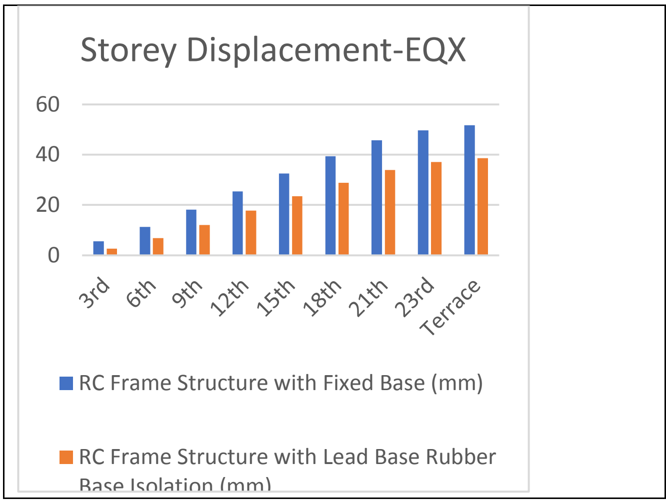
- Storey shears comparison for load cases "SX" and "SY" for the three models are given below both graphically and in the tabular format.

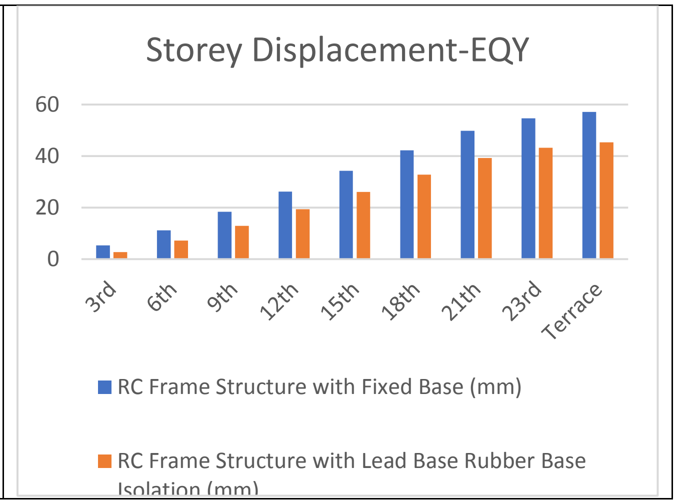
Table No.3 - Storey shears for response spectrum along "X"

Storey	RC Frame Structure with Fixed Base (KN)	RC Frame Structure with Lead Base Rubber Base Isolation (KN)
3rd	983.7768	949.9701
6th	858.0225	816.6611
9th	753.0921	686.3934
12th	684.728	600.1795
15th	642.4047	580.9142
18th	592.1957	560.4521
21th	481.1581	476.5628
23rd	316.2456	325.5745
Terrace	196.3481	206.8564

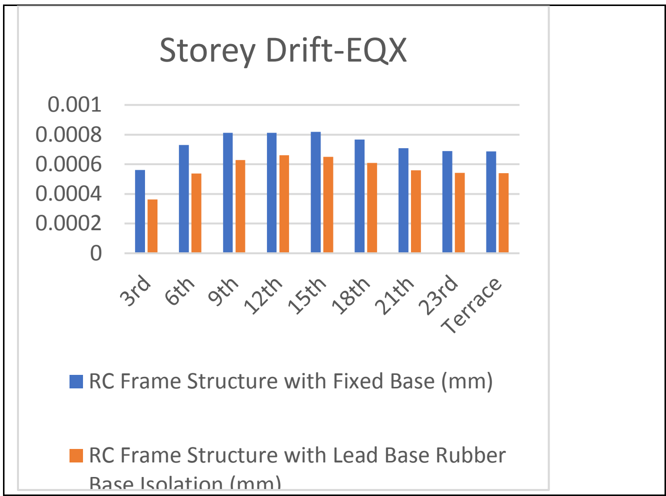
Graph Representing Result-

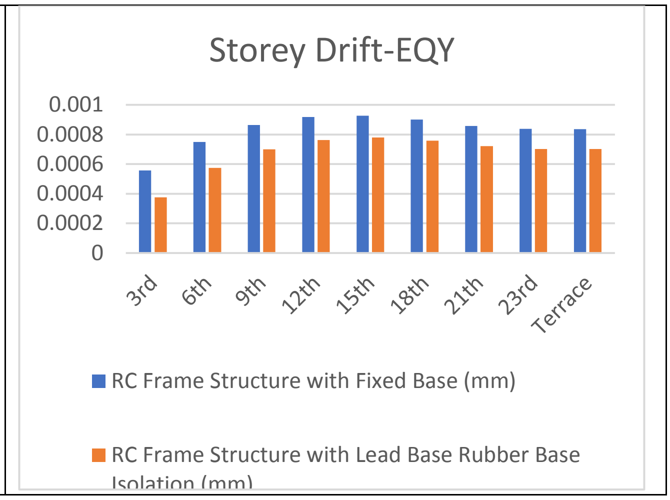
6.1 Storey Displacement



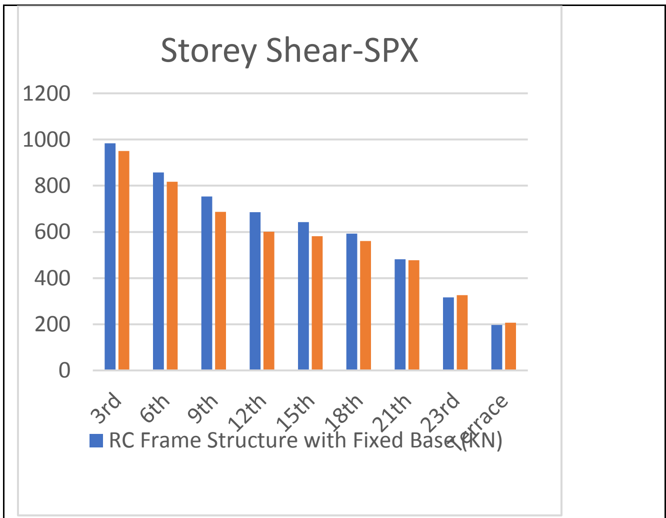


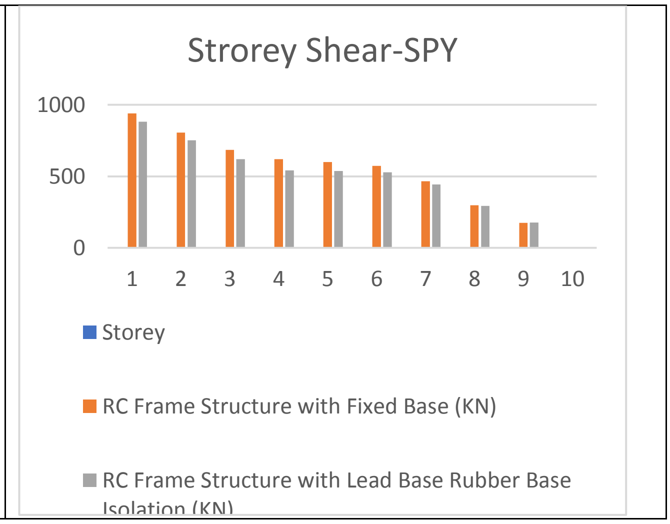
6.2 Storey Drift





6.3 Storey Shear-





5. CONCLUSIONS

Storey Displacement: In the fixed-base configuration, the lateral displacement generally increases with the elevation of the building, with the upper storeys experiencing greater displacement. In the base-isolated configuration, a significant portion of the lateral movement is accommodated by the isolation system at the base. Consequently, the relative displacement demand on the superstructure is reduced compared with the fixed-base structure.

Storey Drift: The base-isolated structure exhibits considerably lower inter-storey drift than the corresponding fixed-base structure. The results indicate that the storey drift at the top level is reduced by approximately **72%** with the incorporation of Lead Rubber Bearings. The difference in drift response between the two structural configurations is clearly observed in the corresponding storey-drift plots.

Storey Shear: The introduction of Lead Rubber Bearings results in a reduction in storey shear throughout the height of the isolated building compared with the fixed-base model. The increased horizontal flexibility provided by the isolation system allows a portion of the earthquake-induced energy to be dissipated through the bearings. As a result, lower seismic forces are transmitted to the superstructure, leading to a reduction in storey shear. This reduction can also be observed clearly from the storey-shear response plots.

Modal Period and Frequency: For the fixed-base structure, the higher modes generally exhibit shorter modal periods and consequently higher natural frequencies. In contrast, the introduction of the base isolation system increases the fundamental modal period and reduces the corresponding frequency. The longer period of the isolated structure shifts its dynamic response away from the dominant range of earthquake excitation and provides greater time for the structure to respond to ground motion.From the above results it is concluded that. Base isolation is good technology to protect structures like buildings, bridges, airport terminals and nuclear power plants etc. from tremor effect

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