Analysis And Retrofitting of RCC Building in Seismic Zone III

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Abstract: - *Devastating earthquakes have historically occurred on the Indian subcontinent. The Indian plate is moving into Asia at a pace of about 47 mm/year, which is the main cause of the earthquakes' high frequency and intensity. Nearly 58% of the area in India is earthquake-prone, according to geographic statistics. During the course of their design life, structures must endure loads such as gravity, seismic activity, wind, and others. However, a lot of existing structures might deteriorate or require an upgrade for any of the reasons listed below: 1. A structure that is not code compliant 2. Later code and design practise updates 3. Subsequent seismic zone upgrades 4. Regression of age and fitness 5. Altering an existing structure 6. Modification of the building's use in accordance with the needs of the client, etc. The modelling and analysis of the RC frame buildings has been done by using structure analysis tool ETAB and results found is validated by performing linear static analysis, response spectrum analyses as per IS:1893 (part 1): 2002 After a comparison of the structures with and without bracing, it becomes clear that the structures with lateral force resisting systems are more suited and safe The primary goal of this project is to safeguard both new and old structures by creating an earthquake-resistant framework. Retrofitting is the process of upgrading that makes it possible for an older structure to withstand pressure in situations where Seismic Retrofitting is an upgrade to older structures that makes them more resistant to seismic activity.*

Key Words: - Response Spectrum Analysis (RSA), Lead Rubber Bearing, Indian Seismic Zone 3, ETABS, Retrofitting of Structures.

1. **Introduction: -** Many older structures that were built in conformity with earlier design norms and regulations are frequently found to be vulnerable to earthquake damage due to inadequate detailing, incorrect seismic loads, material deterioration with time, and other issues. Because new construction is expensive and older structures have historical value, building owners have opted to renovate them rather than build new ones. In response, governmental bodies passed legislation requiring seismic fortification. This means that methods to seismic building rehabilitation must take into account both an evaluation of the building's existing lateral-force-resisting characteristics and, if necessary, the installation of new parts. Zone III, a zone of moderate intensity Kerala, Goa, the Lakshadweep Islands, portions of Uttar Pradesh and Haryana, the remaining portions of Gujarat and Punjab, West Bengal, portions of western Rajasthan, Madhya Pradesh, the remaining portion of Bihar, portions of northern Jharkhand and Chhattisgarh, and portions of Maharashtra, Odisha, Andhra Pradesh, Telangana, Tamil Nadu, and Karnataka. (Refer figure A) The primary objective of earthquake resistant design is to prevent building collapse in order to lower the danger of human death or injury during earthquakes. Over the course of a structure's existence, there is incredibly little chance that a catastrophic earthquake will strike. Traditional structural designs prevent stresses and strains from getting close to the elastic limit for the vast majority of loads. However, in earthquake design, structures are permitted to stretch over their elastic limit in response to ground motion. If a structure had to endure such earthquakes elastically, a pricey lateral load resisting system would be necessary. The structure is anticipated to endure inelastic deformation during a major earthquake; thus, the building must rely on its ductility and capacity to release hysteric energy to prevent collapse.

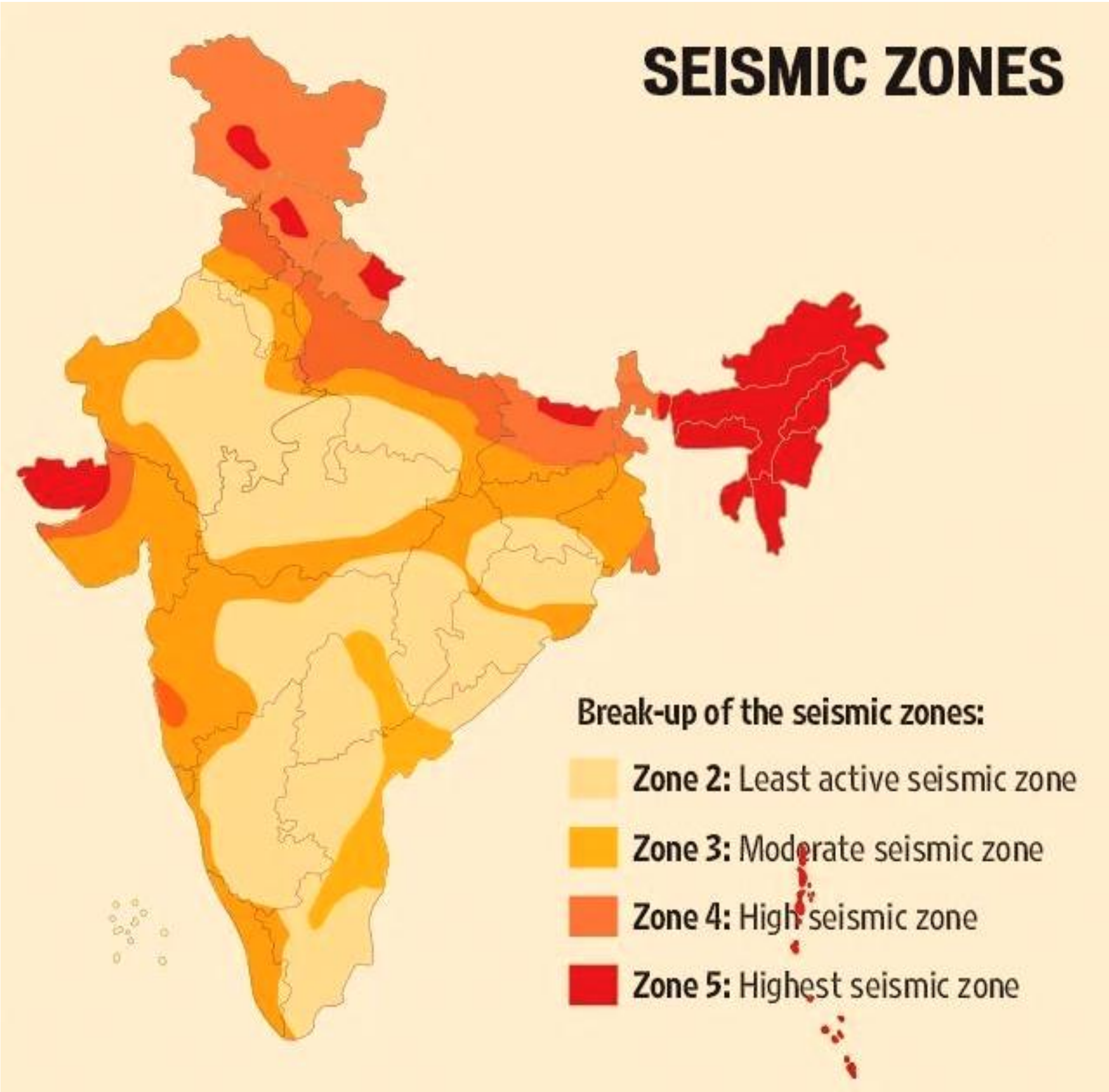

Fig: -1.1 MAP SHOWING VARIOUS SEISMIC ZONES IN INDIA

2. INTRODUCTION TO RETROFITTING OF BUILDINGS: -

2.1 Moment Frame Seismic Resisting Systems:

- Steel Moment-Resisting Frames
- Reinforced Concrete Moment-Resisting Frames

2.2 Base Isolation Systems:

- High Damping Bearings
- Lead Rubber Bearings
- Flat Slider Bearings
- Ball & Roller Bearings
- Elastomeric Bearings
- Curved Slider Bearings or Pendulum Bearings

2.3 Diaphragms:

- Reinforced Concrete Diaphragms
- Wood Diaphragms

2.4 Shear Wall Seismic Resisting Systems:

- Reinforced Masonry Shear Walls
- Steel Shear Walls
- Wood Shear Walls
- reinforced Concrete Shear Walls

2.5 Braced-Frame Seismic Resistance Systems:

- Eccentrically Braced Frames
- Buckling-Restrained Braced Frames (BRBFs)
- Wood Braced Frames
- Concentric Steel Braced Frames

2.6 Seismic Isolation and Energy Dissipation Systems

3. MORE ABOUT BASE ISOLATION SYSTEM: -

A base isolation system separates the structure from the base (foundation or substructure) as a means of earthquake protection. The amount of energy that is transferred to the superstructure during an earthquake is greatly reduced by separating the building from its base.

To support the weight of the structure, these base isolation systems frequently feature one or more types of bearings. These parts include things like elastomeric pads, sliding plates, and inverted pendulums. All of these parts can dissipate energy to some extent, although usually only by hysteretic damping. Hysteretic damping can occasionally trigger higher modes but has some restrictions on how much energy it can absorb.

3.1 There are Six major types of base isolation devices: -

- Elastomeric Bearings
- High Damping Bearings
- Lead Rubber Bearings
- Flat Slider Bearings
- Curved Slider Bearings or Pendulum Bearings
- Ball & Roller Bearings

3.2 Advantages:

1.Less severe earthquake displacements.

2. Reduced the structural cost by lowering the seismic demand on the structure.

3. Lessened the harm caused by earthquakes. This aids in keeping the structure operating well after an event.

4. Increases the security of structures

5. Property preservation

6. Improves a structure's performance under seismic loads.

4. INTRODUCTION: LEAD RUBBER BEARING:

In the event of an earthquake, LRB lead rubber bearings' base isolation principle restricts the amount of energy that is transferred from the ground to the structure. The Base Isolation A laminated rubber and steel bearing with steel flange plates for installation to the structure makes up Lead Rubber Bearings (LRB). Every isolator has a lead core that dissipates energy. The isolator's rubber serves as a spring. Although quite rigid vertically, it is very soft laterally. Thin rubber layers strengthened by steel shims are used to create the high vertical stiffness.

How does a lead-rubber bear function? The un-isolated building will vibrate back and forth in different directions during the earthquake as a result of inertial forces, which will cause the building to deform and sustain damage. The lead rubber bearing effectively dissipates the inertial force upon the building, lengthens the period of vibration, and reduces the acceleration of the building. In contrast, the base isolated building will also move but maintain its original shapes and avoid damages. During an earthquake, the lead plug will slide along the laminated rubber, but it will transform this energy of movement into heat instead, which will effectively lessen the inertial force acting on the building and reduce vibration. Due to its great elasticity, the rubber component will continue to maintain its original shape.

Fig 4.1 (LRB)

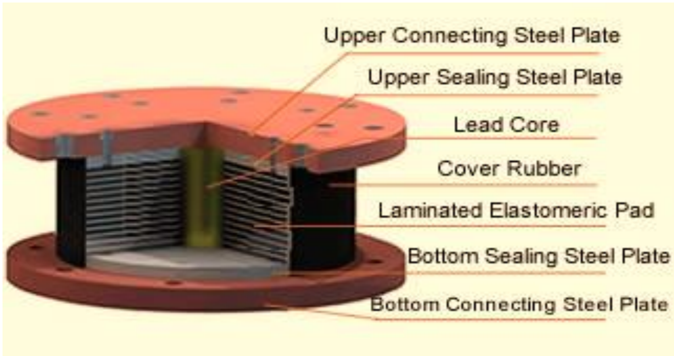

Fig 4.2 (Details of LRB)

5. OBJECTIVES: -

a. to enhance the displacement of the base isolated structure relative to the conventional structure in all stories, including the bottom stories. if time history analysis is used.
b. To develop the Lead rubber bearing utilising E-TABS data and to investigate the effectiveness of providing Lead rubber bearing (LRB) in the building.
c. Using the comparable static analysis, response spectrum analysis, and time history analysis methods, determine the storey displacements, storey drift, and storey shear at each storey.
d. When compared to a normal building with the same conditions, the G+7 storey RC bare frame is separated utilising Lead rubber bearing (LRB) to prevent storey drifts, which will aid in the development of earthquake-resistant structures.

6. METHODOLOGY: -

a. ETABS v 21.0.0 is the programme used for structure analysis.
b. For structural analysis, dynamic analysis is used.
c. IS 1893 (PART I) 2016, UBC 1997, UBC Isolated 1997, IS 875 (PART 1, 2, and 5 for dead load, live load, and combination load, respectively) are the codes utilised.
d. In this project, there are several sorts of dynamic analyses. Time-history analysis utilising Tukey Earthquake 2023 earthquake data was primarily done as the IS code suggests Response Spectrum study only over the 30m hight buildings.
e. For Time- History Analysis Tukey Earthquake 2023 earthquake data is used
f. The loads are applied in accordance with IS 875 (PART I and II) code rules after the building has been modelled. Reaffirmed for both live and dead loads in 2008

g. The maximum axial load is indicated from support response results for both internal and external supports after the analysis of a fixed base construction is completed.
h. Following the identification of the axial load, the Lead core rubber bearing (LRB) is then created for each internal and exterior column independently in order to support the maximum axial load.
i. As link properties for the base isolation structure in E-TABS, the properties of the lead core rubber bearing are then determined.
j. Then the Base Isolation Structure is analysed for similar condition at different support.

7. ANALYSIS (TIME- HISTORY): -

An analytical technique called time-history analysis is based on historical ground motion data from previous earthquakes. In this kind of analysis, the previous earthquake is applied to the structure. The software receives historical earthquake data and generates waves for a specific amount of time. The graph between acceleration and time shows historical data for the period of time. With the aid of Time History Analysis, different graph and tabular figures may be created, and we can also examine the building's response spectrum. A response spectrum is a curve that is drawn between the maximum response of a single-degree-of-freedom system and the frequency (or time period) of the seismic motion.

7.1 Details of Building: -

- The analysis was performed using ETABS version 21.0.0
- units were "KN-m"
- code provisions were UBC 1997 and IS 1893 (Part 1)
- Time history analysis is the type of study performed on 2016 and UBC Isolated 1997.
- Structure: RCC
- Structure Type: Plan Irregular structure
- Plan Dimension: 25.5m×16m
- Height of Building: G+7 (24.432m)
- Height of Each Storey: 3.05 (10.1 feet)
- Building Type: residential

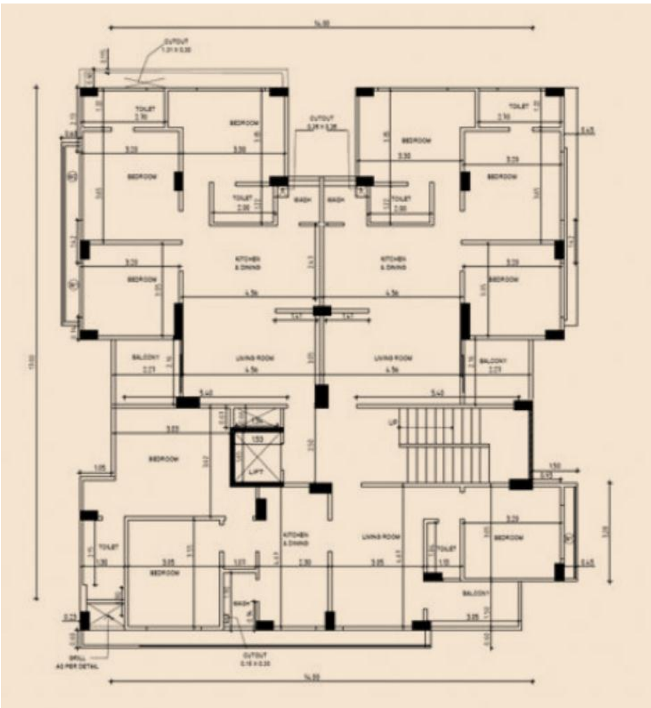

Fig 7.1.1 Architectural plan

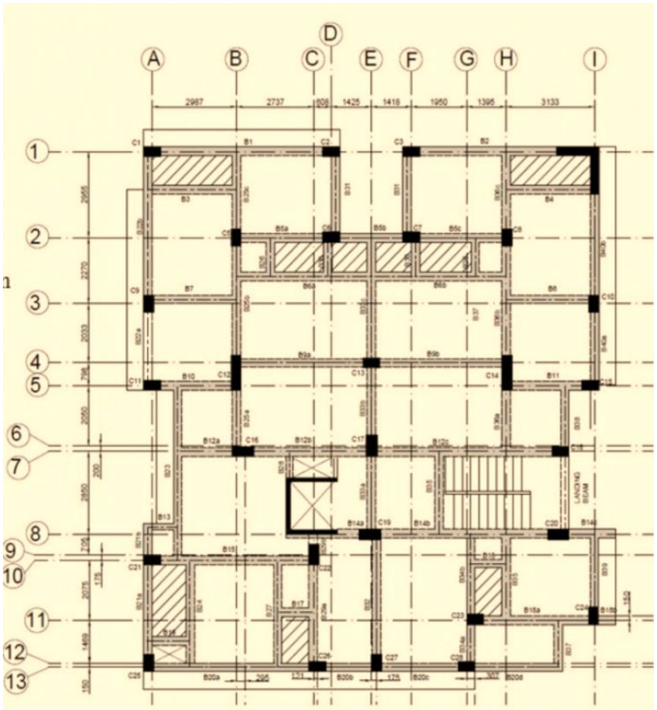

Fig 7.1.2 Structural Layout

7.2 Materials Details:

- Grade of Concrete: M25 (For Beams and column)
- M25 (For Slab and shear wall in lift area)
- Grade of Steel: Fe415

7.3 Section Details:

- lab Thickness: 150mm
- Wall thickness: 230mm
- Beam and columns dimensions shown in fig

7.4 Loads

- DL: Column, Beam, Slab (constant)
- LL for Floors= 3.0 kN/m2
- LL for Roof=1.5 kN/m2
- FF= 1.0 kN/m2
- Wall Load: T× density ×H = 0.23×18×2.9 = 12.006 kN/m
- Parapet Load: = 0.23×18×0.9 = 3.726 kN/m

7.5 Lateral Load for Response Spectrum Analysis (according to UBC 1997)

- Seismic Zone Factor (Z) – Zone 3
- Seismic Source Type – B
- Near Source Factor Na – 1
- Near Source Factor Nv – 1
- Damping coefficient (βD or βM) – 1
- Damping (βeff) – 5% (for Concrete structure)
- Soil Profile Type – Sc
- Seismic Coefficient Ca - 0.36
- Seismic Coefficient Cv (CVD) - 0.54
- Importance Factor (I) – 1.25
- Response Reduction Factor (R) – 8.5(For SMRF)

7.6 Detailing of Models

- Model 1: Time- History Analysis with Lead Rubber Bearing (LRB) isolated.
- Model 2: Time- History Analysis with Fixed Base

7.7 For Internal and External Columns Design of Base Isolator (LRB)

Lead rubber bearing isolators are the kind of base isolators that are used for analysis, and they are designed as is shown below in order to determine their qualities. Make a note of the largest support reaction (W). After Model 2's study, the greatest support reaction is noted.
Max support reaction (W) Ext. Colm = 9750kN, Max support reaction (W) Int. Colm = 11300kN
Design Formulas for LRB calculations: -

1 Design Displacement, $\mathrm{D_D} = \frac{\mathrm{G} C_{VD} T_D}{4\pi^2\,\mathrm{B_D}}$

Int. Colm $\mathrm{D_D} = \frac{9.81\times0.54\times2.5}{4\pi^2\times1} = 0.3355$ Ext. Colm $\mathrm{D_D} = \frac{9.81\times0.54\times2.5}{4\pi^2\times1} = 0.3355$

2 Bearing Effective Stiffness, $\mathrm{K_{eff}} = \frac{W}{g} X \left(\frac{2\pi}{T_D}\right)^2$

Int. Colm $K_{\text{eff}} = \frac{11300}{9.81} X \left(\frac{2\pi}{2.5}\right)^2 = 7275.94$ Ext.Colm $K_{\text{eff}} = \frac{9750}{9.81} X \left(\frac{2\pi}{2.5}\right)^2 = 6277.91$

3 Energy dissipated per cycle, $W_D = 2\pi k_{\text{eff}} D_o 2\beta_{\text{eff}}$

Int. Colm $W_D = 2\pi \times 7275.94 \times 0.3355^2 X 0.05 = 257.290$ Ext. Colm $W_D = 2\pi \times 6277.91 \times 0.3355^2 X 0.05 = 221.99$

4 Force at design displacement of characteristics strength, $Q = \frac{W_D}{4D_D}$

Int. Colm $Q = \frac{257.290}{4\times 0.3355} = 191.72$ Ext. Colm $Q = \frac{221.99}{4\times 0.3355} = 165.35$

5 Pre yield in rubber, $K_2 = k_{eff} - \frac{Q}{D_0}$

Int. Colm $K_2 = 7275.94 - \frac{191.72}{0.3355} = 6704.49$ Ext. Colm $K_2 = 6277.91 - \frac{165.35}{0.3355} = 5785.06$

6 Post yielding stiffness to pre yield stiffness ratio (n) for rubber, $n = \frac{k_2}{k_1}$

Int. Colm $n = \frac{k_2}{k_1} = 0.1$ Ext. Colm $n = \frac{k_2}{k_1} = 0.1$

7 Yield displacement, $D_Y = \frac{Q}{k_1 - k_2}$

Int. Colm $D_Y = \frac{191.72}{67044.9 - 6704.49} = 0.003177 \approx 0.0032$ Ext. Colm $D_Y = \frac{165.32}{57850.6 - 5785.06} = 0.003177 \approx 0.0032$

8 Recalculation of force Q to Q_R, $Q_R = \frac{W_D}{4\times(D_0 - D_r)}$

Int. Colm $D_Y = \frac{257.290}{4(0.3355 - 0.0032)} = 193.56$ Ext. Colm $D_Y = \frac{221.99}{4(0.3355 - 0.0032)} = 167.01$

9 Area of lead plug, $A_{PE} = \frac{Q_R}{10\times 10^3}$

Int. Colm $A_{PE} = \frac{193.56}{10\times 10^3} = 0.019656$ Ext. Colm $A_{PE} = \frac{167.01}{10\times 10^3} = 0.016701$

10 Diameter of Lead plug, $\phi_{\text{PB}} = \sqrt{\frac{4A}{\pi}}$

Int. Colm $\phi_{PB} = \sqrt{\frac{4X0.019656}{\pi}} = 0.50026 \text{ m} \approx 500.26 \text{ mm}$ Ext. Colm $\phi_{PB} = \sqrt{\frac{4\times 0.16701}{\pi}} = 0.4611\text{m} \approx 461.13\text{mm}$

11 Recalculation of rubber stiffness k_{eff} to $k_{eff(R)}$, $k_{eff(R)} = k_{eff} - \frac{Q_R}{D_0}$

Int. Colm $k_{\text{effifR}} = 6704.49 - \frac{193.56}{0.3355} = 6127.56$ Ext. Colm $k_{\text{eff((R)}} = 5785.06 - \frac{167.01}{0.3355} = 5287.26$

12 Total thickness of rubber, $t_r = \frac{D_D}{\gamma}$

Int. Colm $t_r = \frac{0.3355}{1} = 0.3355$ Ext. Colm $t_r = \frac{0.3355}{1} = 0.3355$

13. Area of bearing, $A_{\text{LRB}} = \frac{k_{\text{eff(R)}} \times t_r}{G}$

Int. Colm $A_{\text{LRB}} = \frac{6127.56\times 0.3355}{0.7X100} = 2.93 \text{ m}^2$ Ext. Colm $A_{\text{LRB}} = \frac{5287.26\times 0.3355}{0.7\times 100} = 2.53 \text{ m}^2$

14. Dia of bearing, $\phi_{\text{LRB}} = \sqrt{\frac{4A}{\pi}}$

Int. Colm $\phi_{LRB} = \sqrt{\frac{4X2.93}{\pi}} = 1.93$ m Ext. Colm $\phi_{LRB} = \sqrt{\frac{4\times 2.53}{\pi}} = 1.79$ m

15. Horizontal Frequency,

$F_n = \frac{1}{2} = 0.5$ Hz for both cases

16. Shape factor, $S = \frac{f_v}{f_H} \times \frac{1}{2.4}$

Int. Colm $S = \frac{10}{0.5} \times \frac{1}{2.4} = 8.3$ Ext. Colm $\text{S} = \frac{10}{0.5} \times \frac{1}{2.4} = 8.3$

17. Single layer of rubber, $\text{T} = \frac{Q_{LRB}}{4S}$

Int. Colm $\text{t} = \frac{1.93}{4X8.33} = 0.0579 \text{ m} \approx 57.9 \text{ mm}$ Ext. Colm $\text{t} = \frac{1.79}{4X8.33} = 0.0537 \text{ m} \approx 53.7 \text{ mm}$

18. Compression Modulus, $\text{Ec} = 6GS^2\left(1 - \frac{6GS^2}{K}\right)$

Int. Colm $\text{Ec} = 6\text{X}0.7 \times 100 \times 8.33^2 \left(1 - \frac{6\times 0.7\times 100\times 8.33^2}{2000\times 1000}\right)$, $\text{Ec} = 248.96 \times 10^3 \text{kN/m}^2$

Ext. Colm $Ec = 6 \times 0.7 \times 100 \times 8.33^2 \left(1 - \frac{6\times 0.7\times 100X8.33^2}{2000\times 1000}\right)$ $\text{Ec} = 248.96 \times 10^3 \text{kN/m}^2$

19. Horizontal stiffness, $(K_h) = \frac{GA_{LRB}}{t_r}$

Int. Colm $\text{K}_\text{h} = \frac{0.7\times 1000\times 2.93}{0.3355} = 6113.26 \text{ kN/m}$ Ext. Colm $\text{K}_\text{h} = \frac{0.7\times 1000\times 2.53}{0.3355} = 5278.68 \text{ kN/m}$

20. Moment of inertia circulation, $I = \frac{\pi B^4}{64}$

Int. Colm $\text{I} = \frac{\pi\times 1.93^4}{64} = 0.68108 \text{ m}^4$ Ext. Colm $\text{I} = \frac{\pi\times 1.79^4}{64} = 0.503943 \text{ m}^4$

21. Area of Hysteresis loop, $A_h = 4Q(D_D - D_Y)$

Int. Colm $A_h = 4 \times 191.72(0.3355 - 0.0032\,) = 254.83$ Ext. Colm $A_\text{h} = 4 \times 165.35(0.3355 - 0.0032\,) = 219.78$

22. Yield strength $F_Y = Q + k_2 \times D_Y$

Int. Colm $\text{A}_\text{h} = 191.72 + 6704.49 \times 0.0032 \;=\; 213.174$ Ext. Colm $\text{A}_\text{h} = 165.35 + 5785.06 \times 0.00332 = \text{c}$

23. Numbers of rubber layers $\frac{t_r}{t}$

Int. Colm numbers of rubber layers $\frac{0.335!}{0.0585} = 5.70$ Ext. Colm numbers of rubber layers $\frac{0.335!}{0.0548} = 6.14$

24. Vertical Stiffness $k_v = \frac{E_c A_{LRB}}{t_r}$

Int. Colm $k_v = \frac{248.96\times10^2\times3.02}{0.3355}$ =2233.59x10^3 $\frac{kN}{m} = \frac{1929.35MN}{m}$ Ext. Colm $k_v = \frac{248.96\times10^2\times2.60}{0.3355} = 2241.01$ MN/m

7.8 Placing of Lead Rubber Bearing

- There are base isolators at base level and isolators above every footing. The tables below list the calculated properties of LRB.
- input values for the LRB Isolator for internal columns in ETABS in TABLE No.7.8.1
- input values for the LRB Isolator for external columns in ETABS in TABLE No.7.8.2

TABLE No.7.8.1

Rotational Inertia1	**0.68108 m⁴**
For U1 Effective Stiffness	7275940 kN/m
For U2 & U3 Effective Stiffness	7275.94 kN-m
For U2 & U3 Effective Damping	0.05
For U2 & U3 Distance from End-J	0.0032 m
For U2 & U3 Stiffness	6704.49kN/m
For U2 & U3 Yield Strength	213.174 kN

TABLE No.7.8.2

Rotational Inertia1	**0.503943 m⁴**
For U1 Effective Stiffness	6277910 kN/m
For U2 & U3 Effective Stiffness	6277.91 kN-m
For U2 & U3 Effective Damping	0.05
For U2 & U3 Distance from End-J	0.0032 m
For U2 & U3 Stiffness	5785.06 kN/m
For U2 & U3 Yield Strength	213.174 kN

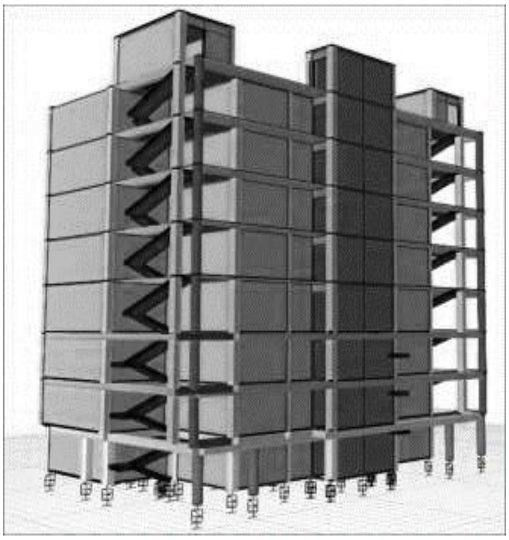

Fig 7.8.1 (LRB isolated building)

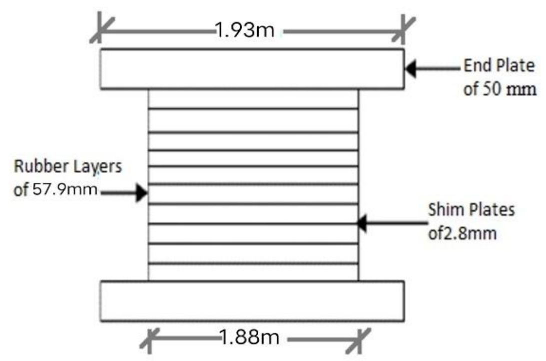

Fig 7.8.2 (Cross section of internal column LRB)

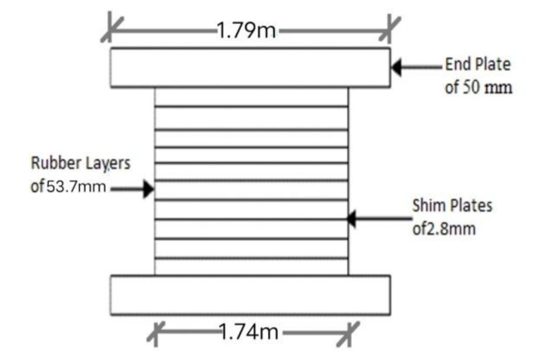

Fig 7.8.3 (Cross section of external column LRB)

8. RESULTS: -

The base shear is the amount of reactive shear force needed to fully stabilise the structure during seismic action, whereas story shear is the shear generated at each storey during seismic action. earthquake movement. As can be observed, compared to a fixed base building, the storey shear in the x-x direction was dramatically reduced at each storey in the base separated building. This indicates that the base isolator's base shear, base shear, lateral load at each floor, etc. are reduced after the introduction of Lead rubber bearing. When compared to a fixed base building, the story shears in the x-x direction at the top story of the base isolated building are reduced by 89.725%. Overall base shear decreased by 41.288%.

Table No 8.1 Floor shear

Floor shear in (KN)		
Floor numbers	Base isolated	Fixed Supported
Base Floor	0	0
1st Floor	122.1181	144.0628
2nd Floor	247.6766	291.2779
3rd Floor	374.0705	439.4724
4th Floor	500.4644	587.6668
5th Floor	626.8582	735.8613
6th Floor	753.2004	883.9952
7th Floor	792.9405	930.5898
Base Shear	3252.9089	5759.6789

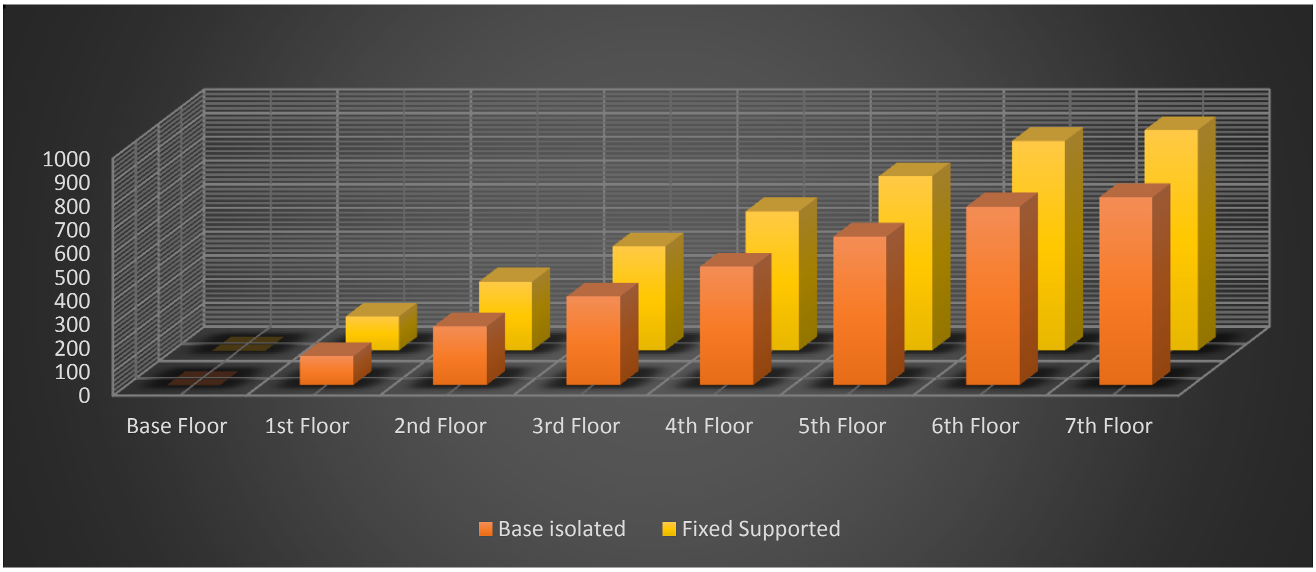

Chart NO 8.1 FLOOR SHEAR

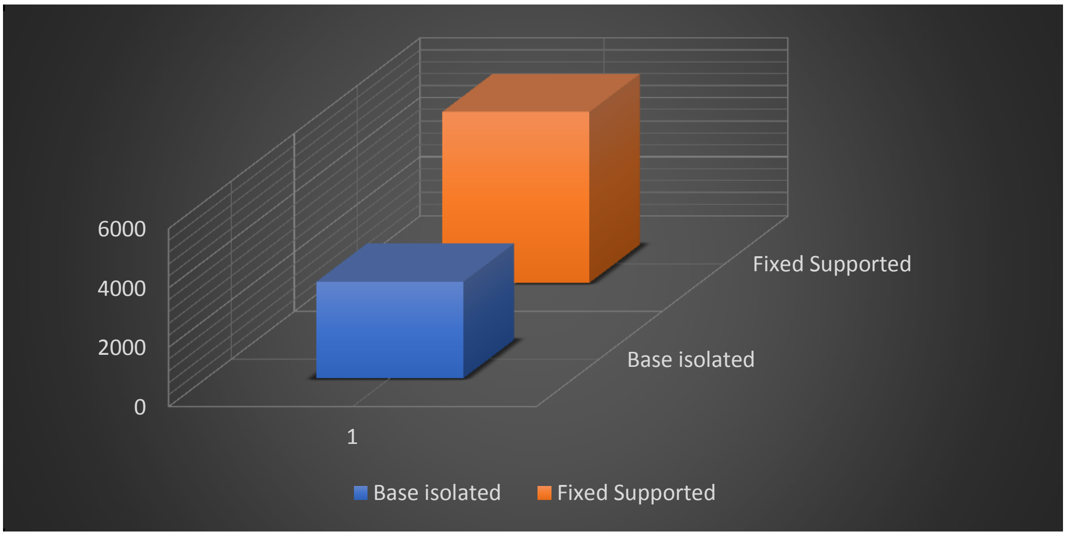

Chart NO 8.2 BASE SHEAR

9. CONCLUSION: -

The following findings can be drawn from these construction models after doing a time history study on the base isolated by providing lead rubber bearing.

- After the lead rubber bearing (LRB) is given as a base isolation system, the influence of earthquakes on the building is decreased, resulting in a reduction in storey shear for each level.
- After supplying LRB, base shear is also decreased, which stabilises the structure during earthquakes.
- Additionally, each storey's storey drift is decreased, especially in higher levels, making the structure earthquake-safe.
- After implementing LRB, point displacements in every story increased, which is crucial for making a building flexible during an earthquake.
- When there is an earthquake, mode periods are lengthened, which lengthens a structure's response time.

- Base shear decreased for base isolated structures up to 3252.9089 KN as opposed to 5759.6789 KN for fixed base supported structures.
- Finally, it can be said that when LRB is used as a base isolation system, the structure is more earthquake-resistant and requires less reinforcing, making it more cost-effective.

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