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TO CALCULATE BASE ISOLATION ON A MULTISTOREY BUILDING BY USING ETABS

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ABSTRACT

The present work attempts to study the effectiveness of base isolation using lead rubber bearings (LRB) over conventional construction, using a case study of identical conventional and isolated building constructed in the most seismically active region in India. Base isolator is a device which decouples a super structure from its substructure resting on a shaking ground thus protecting structural and non-structural components. This project deals with design, modelling and analysis of multistorey rigid jointed plane symmetrical RCC frames for two cases. First case is fixed base and second case is base isolated (LRB). Building's storey displacement, storey drift and storey shear are compared for that both cases. For designing of G+12 multistorey building IS 875:1987 (Part 1&2), IS 1893:2016 are used and for analysis ETABS 18.0.2 software is used and for designing of isolator IS 1893:2016 (part 1) is used.

Keywords: *Base Isolation, Base Isolator, Isolated building, Lead Rubber Bearings, Storey Displacement, Storey Drift, Storey Shear.*

1. Introduction

An earthquake in simple words is shaking of the earth. It is a natural event and caused due to release of energy, which generate waves that travel in all directions. Due to this release of energy, stress is produced on lithosphere due to collision between the plates when this stress is high the lithosphere breaks or shifts. The collision between plates may be of two types one is inter-plate and other is intra-plate. Most of the earthquakes occurred near Himalayan region are inter-plate earthquakes and earthquakes occurred near Peninsular region are intra-plate earthquakes. During an earthquake energy is released from fault, in the form of heat and seismic waves. These seismic waves radiate from focus (source) and shake the ground, these seismic waves travel 100's of km away from the source. The point exactly above the focus on the earth's surface is called the epicenter. The figure below shows faults, plates, focus, epicenter, seismic waves.

But, when the rocky material along the interface of the plates in the Earth's Crust reaches its strength, it fractures and a sudden movement takes place there the interface between the plates where the movement has taken place (called the fault) suddenly slips and releases the large elastic strain energy stored in the rocks at the interface. For example, the energy released during the 2001 Bhuj (India) earthquake is about 400 times (or more) that released by the 1945 Atom Bomb dropped on Hiroshima!!

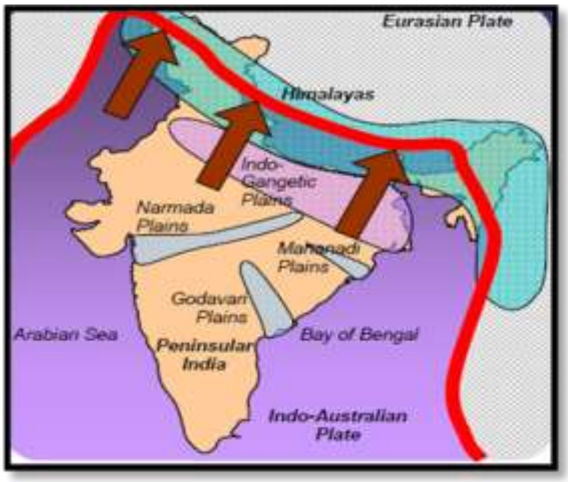

Fig 1: Map showing collision between different plates.

1.1 Introduction to base isolation system

The concept of base isolation represents a radical departure from the current seismic design practice. In this technique of base isolation, the building is detached or isolated from the ground in such a way that only a very small portion of seismic ground motions is transmitted up through the building. In other words, although the ground underneath it may vibrate violently, the building itself would remain relatively stable. This results in significant reduction in floor accelerations and inter-storey drifts, thereby providing protection to the building components and contents. The system decouples the structure from horizontal components of the ground motion by interpose structural elements with low horizontal stiffness between the structure and the foundation. Base Isolation falls into general category of Passive Energy Dissipation.

Base isolation of structures is one of the most desired means to protect it against earthquake forces. The term base isolation has two words first is 'base' its is a part that supports from underneath or perform as a foundation of a structure, and second is 'isolation' its of the state of being disparate. The effective reduction of inter storey drift in the floor of base isolation system can ensure the lowest damage to facilities and also human safety.

The fundamental principal of base isolation system is to rectify the response of the structure so that the ground can move below the structure without transferring these motions into the superstructure. In an ideal system for the supple this separation would be total. But In the existing world there is a need to have some contact between the superstructure and sub structure, so for this Lead Rubber Bearing is used as a base isolator.

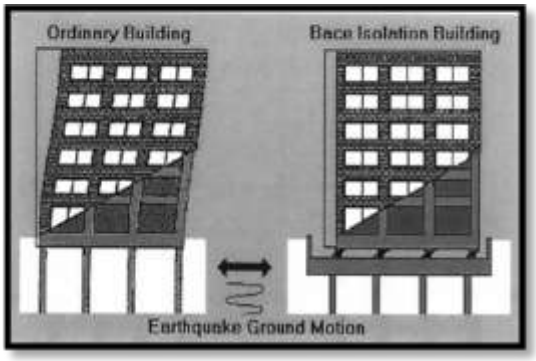

Fig 2: Difference between performance of fixed base and base isolated structure.

1.2 Lead-Plug Rubber Bearing

LRB was first invented in 1975 in New-Zealand. The components of the LRB are lead plug, endplates, steel shims and rubber layers. The steel shims provide vertical stiffness to the LRB and layers of rubber provide lateral flexibility or horizontal stiffness. Lead core of the LRB gives extra stiffness to the isolators and it also provides damping to the system. This base isolation system provides the combined features of vertical load support, horizontal flexibility, restoring force, and damping in a single unit.

The fundamental principal of base isolation system is to rectify the response of the structure so that the ground can move below the structure without transferring these motions into the superstructure. In an ideal system for the supple this separation would be total. But in the existing world there is a need to have some contact between the superstructure and sub structure and for this lead rubber bearing is used as a base isolator.

The LRB has following functions listed below: -

- Due to its property of vertical stiffness is functions as load supporter
- Provide elasticity in horizontal direction due to the property of horizontal stiffness
- It has energy restoring capability
- As it has lead core it provides damping to the structure by deforming plastically
- It reduces ground acceleration of a structure by increasing the time period of vibration.
- It can be easily installed since no separate damper is required
- It has low maintenance when compared to other types of isolators.

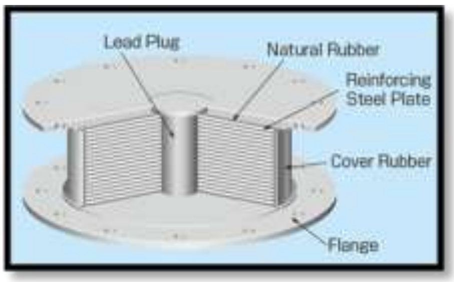

Fig 3: Components of lead rubber bearing

1.3 Objective of Project:

The main objective of project was to compare fixed base and base isolated structure by dynamic analysis. Response spectrum analysis method is used for analysis. The results were compared for Story drifts, Base shear, Story shear, and Point displacements.

The objective of the project is as explained below: -

- The G+12 storey RC bare frame is isolated using Lead core rubber bearing to reduce the story drifts when compared with conventional building.
- To make the structure earthquake resistant.
- To increase the displacement of base isolated structure in all stories when compared to conventional structure when analyzed by response spectrum analysis.
- To increase the displacement of bottom stories of base isolated structure when compared with conventional structure when analyzed using Nonlinear time history analysis.
- To decrease the story drift of a base isolated structure when compared with fixed base structure.
- To decrease the base shear of a base isolated structure when compared with fixed base structure.
- To study the effectiveness of providing Lead core rubber bearing.
- To know the method of response spectrum analysis using ETABS.
- To gain a knowledge in the base isolation systems.
- To know the design of earthquake resistant structure.

2. Modelling and Analysis

2.1 Description and Modelling of Building

- Software used for analysis is ETABS v18.0.2
- Units used are “kN-m”
- Code provisions as per IS 875 (Part 1 & 2), IS 1893:1986, IS 1893:2016 (Part-1) and UBC 1997
- Type of analysis performed are Response Spectrum Analysis

2.2 Building Details:

Structure: RCC (OMRF)

Structure Type: Plan Regular Structure

Plan Dimension: 28m x 9m

Height of Building: G+12 (42.2m)

Total No. of Storey: 14

Height of Each Storey: 3m

Height of Bottom Storey: 3.2m

Height of Plinth: 1.2m

Building Type: Residential

Blocks Used: AAC

2.3 Material Properties

Grade of Concrete: M35 (for Beams, Column and Slabs)

Grade of Steel: TMT 500

2.4 Sectional Properties

Column Size: 304.8mm x 457.2mm

Beam Size: 457.2mm x 304.8mm

Slab Thickness: 150mm

Outer Wall Thickness: 304.8mm

Inner Wall Thickness: 228.6mm

2.5 Load Consideration

2.5.1 Gravity Load

Dead Load: 0.52 kN/m^2

Live Load: 3 kN/m^2

Floor Finish: 1 kN/m^2

Frame Load Outer Wall: 4.59 kN/m

Frame Load Inner Wall: 3.519 kN/m

2.5.2 Lateral Load for Response Spectrum Analysis

Seismic Zone – IV

Zone Factor -0.24

Importance Factor – 1.2

Seismic Coefficient C_v – 0.54

Response Reduction Factor R – 3 (OMRF)

Damping Coefficient (B_D or B_M) – 1

Damping (β_{eff}) – 5%

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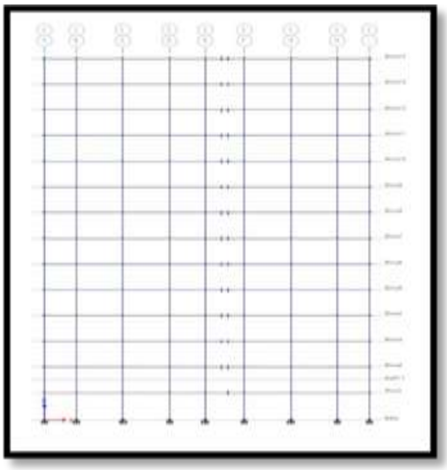
Site Type – II

2.6 Description of models

Model 1: Response Spectrum Analysis with Fixed Base.



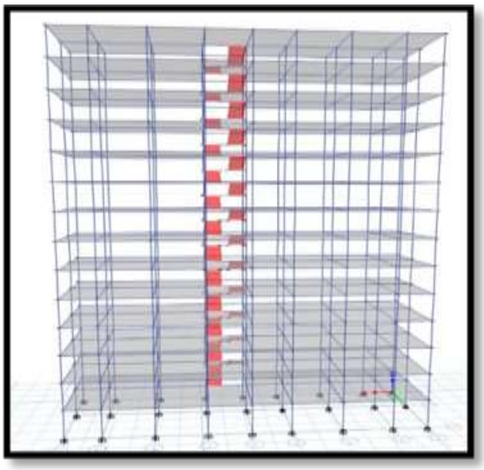
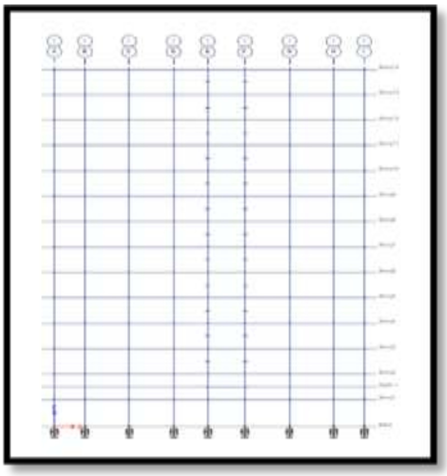


Fig 4: Elevation **Fig 5:** 3D View

Model 2: Response Spectrum Analysis with Lead Rubber Bearing.



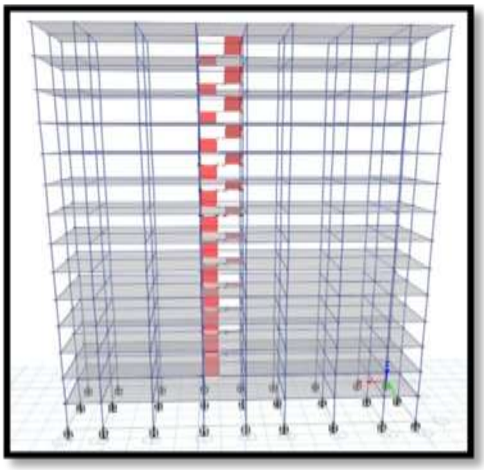


Fig 6: Elevation **Fig 7:** 3D View

2.7 Design of base isolator for model 2

The type of base isolator used for analysis is lead rubber bearing isolator, to get the properties of isolator its design is carried out as shown below.

(1) Write down the maximum support reaction

- After the analysis of Model 1 the Maximum support reaction is noted
- Display > Show-Tables > analysis reaction > reaction > support reaction

- Tabulated the support reaction result in the excel sheet and get the maximum support reaction
- Maximum support reaction (W) = 3753.22 kN

(2) Calculate Design Displacement (D_D)

Assume Design Time Period T_D = 2.5 sec

$$D_D = \frac{g}{4\pi^2} * \frac{C_v \times T_D}{B_D}$$

$$D_D = \frac{9.81}{4\pi^2} \times \frac{0.54 \times 2.5}{1} = 0.3355\ m$$

(3) Effective Stiffness (K_{eff})

$$K_{eff} = \frac{W}{g} \times [\frac{2\pi}{T_D}]^2$$

$$K_{eff} = \frac{3753.22}{9.81} \times [\frac{2\pi}{2.5}]^2 = 2416.65\ kN/m$$

(4) Energy dissipated per cycle (W_D)

$$W_D = 2\pi \times K_{eff} \times D_D^2 \times \beta_{eff}$$

$$W_D = 2\pi \times 2416.65 \times 0.3355 \times 0.05$$

$$W_D = 85.46\ kN\text{-}m$$

(5) Force at design displacement of characteristic strength (Q)

$$Q = \frac{W_D}{4D_D}$$

$$Q = \frac{85.46}{4 \times 0.3355}$$

$$Q = 63.68\ kN$$

(6) Stiffness in rubber (K_2)

$$K_2 = K_{eff} - \frac{Q}{D_D}$$

$$K_2 = 2416.65 - \frac{63.68}{0.3355}$$

$$K_2 = 2226.84\ kN/m$$

Where, $\frac{Q}{D_D}$ = Stiffness of lead core

(7) Yield Displacement (D_Y)

$D_Y = \frac{Q}{K_1 - K_2}$ we have $K_1 = 10K_2$

$D_Y = \frac{Q}{10K_2 - K_2}$

$D_Y = \frac{Q}{9K_2}$

$D_Y = \frac{63.68}{9 \times 2226.84}$

$D_Y = 0.003177$ m

(8) Recalculation of Q to Q_R

$Q_R = \frac{W_D}{4 \times (D_D - D_Y)}$

$Q_R = \frac{85.46}{4 \times (0.3355 - 0.003177)}$

$Q_R = 64.29$ kN

(9) Calculation of area and diameter of lead plug Yield strength of lead is around 10Mpa the area of lead plug needed is

$A_{PB} = \frac{Q_R}{10 \times 10^3}$

$A_{PB} = \frac{64.29}{10 \times 10^3}$

$A_{PB} = 0.006429$ m

Dia. of plug,

$d = \sqrt[2]{0.006429 \times \frac{4}{\pi}}$

$d = 0.90475$ m or 90.45 mm

(10) Revising Rubber Stiffness K_{eff} to $K_{eff\,(R)}$ (after revising Q to Q_R)

$K_{eff\,(R)} = K_{eff} - \frac{Q_R}{D_D}$

$K_{eff\,(R)} = 2416.65 - \frac{64.29}{0.3355}$

$K_{eff\,(R)} = 2225.025$ kN/m

(11) Total thickness of rubber layers (t_r)

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$t_r = \frac{D_D}{Y}$

where, $Y = 100\%$ (maximum shear strain of rubber)

$t_r = \frac{0.3355}{1}$

$t_r = 0.3355$ m

(12) Area of bearing

$A_{LRB} = \frac{K_{eff(R)} \times t_r}{G}$

$A_{LRB} = \frac{2225.025 \times 0.3355}{0.7 \times 1000}$

$A_{LRB} = 1.066\ m^2$

Where, G is Shear modulus which is 0.7 MPa

(13) Diameter of bearing

$d_b = \sqrt[2]{\frac{A \times 4}{\pi}}$

$d_b = \sqrt[2]{\frac{1.066 \times 4}{\pi}}$

$d_b = 1.1650$ m or 1165 mm

(14) Shape Factor

$S = \frac{1}{2.4} \times \frac{f_v}{f_h}$

Where, f_v = Vertical frequency

f_h = Horizontal frequency

Take horizontal period to be 2 sec

$f_h = 0.5\ H_z$

Consider, $f_v = 10\ H_z$

$S = \frac{1}{2.4} \times \frac{10}{0.5}$

$S = 8.33$

Also, we have

$S = \frac{d_b}{4t}$

Where, t is thickness of single rubber layer

Therefore,

$t = \frac{1.1650}{4 \times 8.33}$

$t = 0.0349\ m \quad or \ \ 34.96\ mm$

Number of rubber layers $N = \frac{t_r}{t}$

$N = \frac{0.3355}{0.0349}$

$N = 9.613 \quad \rightarrow 10\ No's$

Therefore,

Provide 35 mm thick 10 rubber layers

(15) Dimensions of Lead Rubber Bearing [LRB]

- Let thickness of shim plates be 2.8mm

  Number of shim plates = (10 – 1) = 9

- End plate thickness is between 19.05 to 38.10

  Adopt thickness of end plate as 25 mm

- Total height of LRB (h)

  $h = 10 \times 35 + 9 \times 2.8 + 2 \times 25$

  $h = 425.2\ mm \quad or \quad 0.4252\ m$

- Dia. Of rubber layer

  $d_b = N \times t$

  $d_b = 10 \times 35$

  $d_b = 350\ mm \quad or\ 0.35\ m$

- Area of rubber layer

  $A = \frac{\pi}{4} \times {d_b}^2$

  $A = \frac{\pi}{4} \times 0.35^2$

$A = 0.09621\ m^2$

(16) Compression Modulus E_c

$$E_c = 6GS^2\left(1 - \frac{6GS^2}{K}\right)$$

Where, K – Bulk modulus = 2000 MPa

G – Shear modulus = 0.7 MPa

$$E_c = 6 \times 0.7 \times 1000 \times 8.33^2\left(1 - \frac{6 \times 0.7 \times 1000 \times 8.33^2}{2000 \times 1000}\right)$$

$$E_c = 248960\ kN/m^2$$

(17) Horizontal Stiffness K_H

$$K_H = \frac{G \times A_{LRB}}{t_r}$$

$$K_H = \frac{0.7 \times 10^3 \times 1.066}{0.3355}$$

$$K_H = 2224.14\ kN/m$$

(18) Vertical Stiffness K_V

$$K_V = \frac{E_C \times A_{LRB}}{t_r}$$

$$K_V = \frac{248.96 \times 10^3 \times 1.066}{0.335}$$

$$K_V = 791032.37\ kN/m$$

$$K_V = 749.47\ MN/m$$

2.8 Placing Lead Rubber Bearing

- Base isolators are placed at 0.5m above base level.
- Isolators are provided above every footing.
- Properties of LRB Calculated are mentioned in the below table

Property Type	Response Spectrum Analysis
Effective Stiffness $K_{eff\,(R)}$	2225.025 kN/m
Horizontal Stiffness K_H	2224.149 kN/m
Vertical Stiffness K_V	791032.37 kN/ m
Yield strength Q_R	64.29 kN
Post Yield Stiffness ratio	0.1
Damping	5 %

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3 Result and Discussion

3.1 Storey Displacement

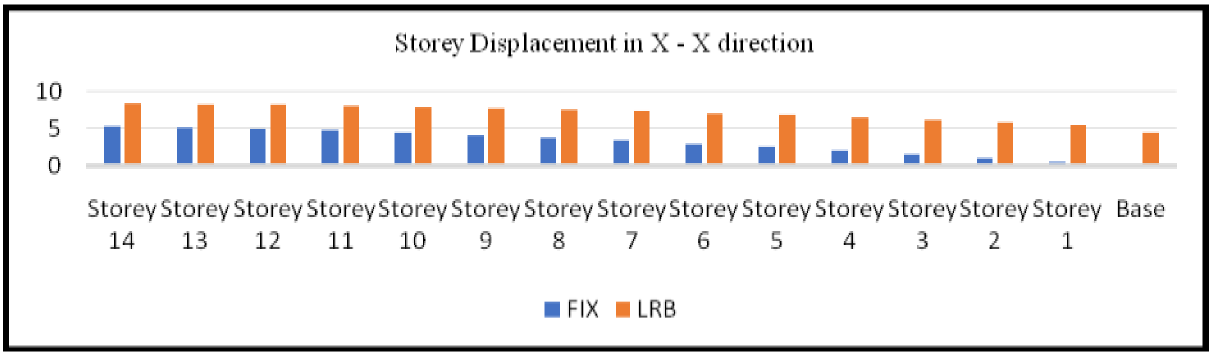

Fig 8: Graph showing Storey displacement results in X – X direction of Fixed Base and Base Isolated (LRB) Buildings.

The variation in maximum displacement of stories in base isolated model is very low while compared with fixed base model.

3.2 Storey Shear

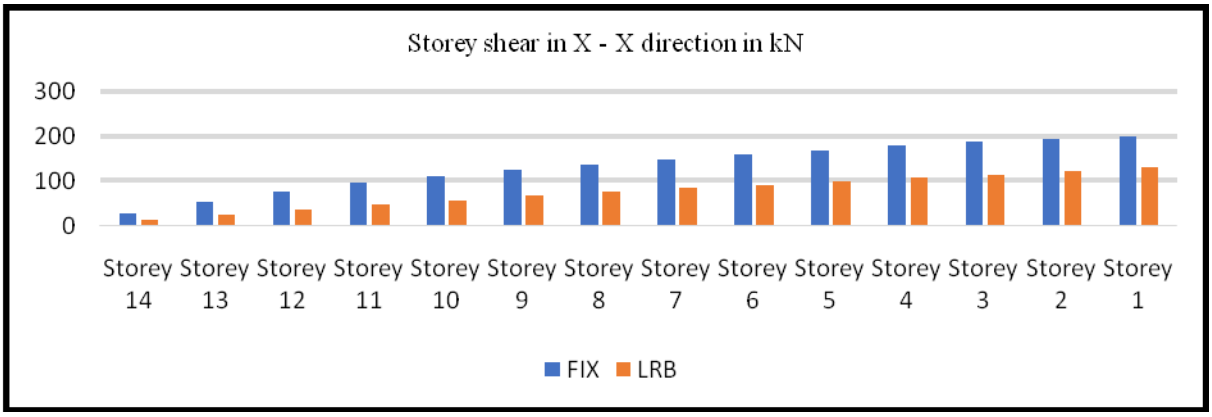

Fig 9: Graph showing Storey shear results in X-X direction of Fixed base and Base Isolated Buildings.

From above Graph which are response spectrum analysis results it can be seen in base isolated building story shear in x-x direction were reduced significantly at each story when compared to fixed base building. This means after the use of Lead rubber bearing as base isolator the story shear in x-x direction are reduced. The base isolated building story shears in x-x direction at top story reduced by 43% when compared with fixed base building.

3.3 Storey Drift

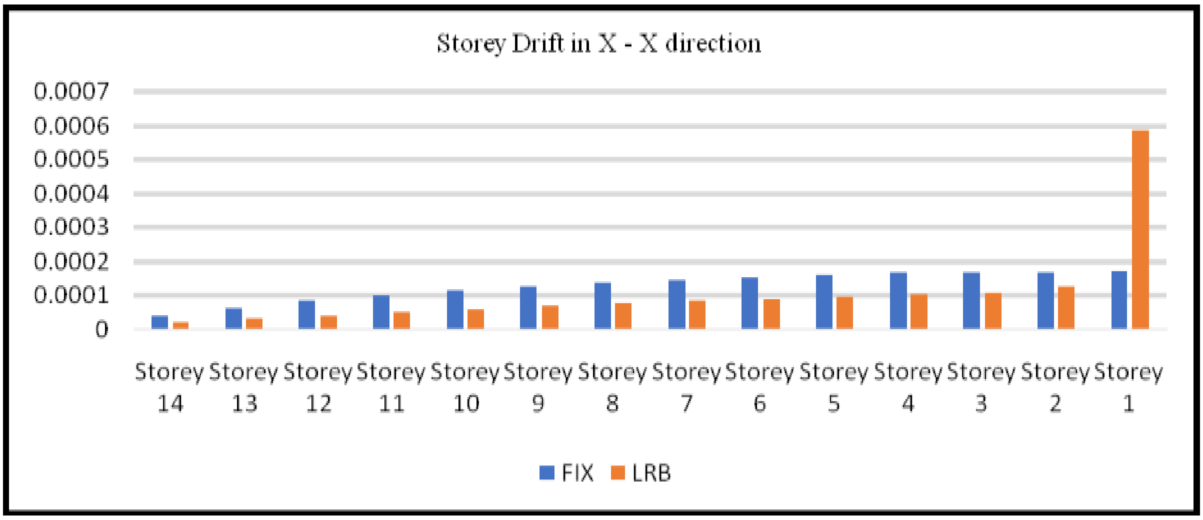

Fig 10: Graph showing Story drift in X-X direction comparison between Fixed Base and Base Isolated Buildings.

From above graph it is observed that story drifts in x-x direction are increased in story 1 and 2 of base isolated building when compared to fixed base building and in story 3 to story 14 the story drifts in x-x direction are reduced in base isolated building compared to fixed base building which is the effect of lead rubber bearing at base. It is important to reduce story drifts of top stories which damage structure during earthquake. In base isolated story drift in x-x direction at story 6 reduced by 26% when compared to fixed base and in base isolated story drift in x-x direction of story 14 reduced by 30.95% when compared to fixed base building.

4. Conclusion

After the analysis of fixed base and base isolated (LRB) building by response spectrum analysis following conclusions can be made.

- Story shear reduced after the lead rubber bearing (LRB) is provided as base isolation system which reduces the seismic effect on building.
- Base shear is also reduced after providing LRB which makes structure stable during earthquake.
- Story drift are reduced in higher stories which makes structure safe against earthquake.
- Modal displacements are increased in every story after providing LRB which is important to make a structure flexible during earthquake.
- Natural periods are increased which reduces earthquake forces on the shaking.
- Finally, it is concluded that after LRB is provided as base isolation system it increases the structures stability against earthquake and reduces reinforcement hence make structure economical.

- Fixed base model base isolated model by providing lead rubber bearing these two models were analyzed by response spectrum analysis from these building models following conclusions can be made.

5. References

[1] Duggle S.K., "Earthquake Resistant Design Structure", Tata McGraw Hill Publication.

[2] ETABS Three-Dimensional Analysis and Design of Building Systems Tutorial Computers and Structures, Inc. Berkeley, California, USA.

[3] IS 1893:1986 Criteria for earthquake resistant design of structures.

[4] IS 1893:2016 (Part-1) Criteria for earthquake resistant design of structures.

[5] IS 875:1987 (Part-1) [Dead Load] Code of practice for design loads (other than earthquake) for building and structures.

[6] IS 875:1987 (Part-2) [Imposed Load] Code of practice for design loads (other than earthquake) for building and structures.

[7] DESIGN OF SEISMIC ISOLATED STRUCTURE from theory of practice by JAMES M.KELLY and FARZAD NAELIM

[8] Earthquake Engineering Handbook by Wai-Fah Chen and Charles Scawthorn

[9] Pankaj Agarwal and Manish Shirkhande (2010) Textbook on "Earthquake Resistant Design of Structures", PHI Learning Private Limited, New Delhi