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# MITIGATING SEISMIC HAZARD BY BASE ISOLATION

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**Abstract:** Base isolation has been used as one of the most wildly accepted seismic protection systems that should significantly separate a superstructure from substructure on which it is resting on a shaking ground, there by sustainably saving entire structures against earthquake forces as well as inside non-structural failures. The main purpose of earthquake engineering is to design the structure in such a way that the damage in the structures and its other components during an earthquake is minimized. In the present study lead rubber base isolator (LRB) has been designed for a general low rise building. The building is then analyzed with ETABS software. The comparison has been made between the fixed base building and base isolated building to check the performance of the base isolated building. The seismic responses with respect to base shears and inter-story drifts have been compared before and after the installation of LRB isolation systems in the framed building. The main function of the LRB isolator is to extend the time period of structural vibration by increasing lateral flexibility in the framed structure, and ground accelerations transferred into the superstructure can dramatically decrease.

**Keywords: earthquake, design, seismic, drift, shear, displacement, rubber, isolator, bearing, analysis, ETABS and LRB**

## I. INTRODUCTION

The structures which have been constructed even with the good techniques have suffered a great loss during the earthquakes and have lead to the loss of the property and human lives which has compelled the scientists and engineers to think, analyze and create innovative techniques and methods to protect the buildings and other structures from the destructive forces of the earthquakes. Many earthquakes which occurred in the recent past have given much evidences of the performance of distinct type of structures under various earthquake conditions and at various foundation conditions as a good instinct to the engineers. This has lead to different type of techniques and innovations in earthquake engineering to save the structures from the earthquakes.

Base isolation concept was termed by the engineers and scientists in the year of 1923 and after then different methods of isolations for the building structures from earthquakes have been developed in many countries of the world. There are many countries like like United States, New Zealand, China, Japan and European countries which have adopted the new techniques in the field of construction as their new normal for the building construction of public buildings as well as residential buildings. Number of buildings are designed every year with the provision of base isolation technique in many countries. This research also describes the advancements in the base isolation technology and other techniques which are utilized around the world. Till now there is limited use of base isolation technology in India, in India. The use of base isolation technique has been utilized at few locations like Bhuj hospital building, experimental building at IIT Guwahati, the general structures which are in safe zones are built without base isolation techniques.

### Principle of Base Isolation

The basic objective of seismic base isolation is to introduce horizontally flexible but vertically stiff components (base isolators) at the interface of base and superstructure of a building to significantly uncouple the superstructure from ground of high-recurrence seismic tremor shaking. The fundamental idea of base isolation framework is to stretch the normal time-frame of the fixed base structure. The benefits of adding a lateral flexible system of seismic isolation at foundation level of a building can be understood from the acceleration response spectrum. If time period of a structure is increased it reduces the frequency of shaking of the structure and also the acceleration is decreased.

The structures with base isolation have more displacements and the researchers are trying to increase the energy dissipation or damping in the seismic isolated structures in order to reduce displacements.. If the additional damping in the building systems is achieved it means there would be fewer displacements in the seismic isolators and thus we can reduce the size of isolators.

## II. LITERATURE REVIEW

**Jung Han Kim, Min Kyu Kim, In Kil Choi**(2019) tested lead–rubber bearings (LRBs) to verify their behavior and performance under seismic loadings. Numerous experimental studies have been conducted on the horizontal behavior of seismic isolation bearings. However, the bulk of these tests were unidirectional or with small-scale specimens. This test focused on bidirectional behavior with full- scale specimens. In addition, this test aimed to derive the test protocol to obtain mechanical properties under dynamic behavior and to the failure limit under more realistic seismic input motions.

**Nailiang Xiang, Jianzhong Li**(2019) carried out an experimental program to investigate the sliding behavior of laminated rubber bearings with typical configurations. The bearing was placed directly on a steel plate representing the embedded steel plate at the bottom of bridge girders, to create an elastomer-steel sliding surface. Experiment results showed that the behavior of bearings before obvious sliding could be approximated as a linear response, with an effective shear modulus in the range of 610–1100 kPa. The sliding coefficient of friction was observed to be inversely related to normal force, and positively related to the sliding velocity.

**Ingrid. Madera Sierra, Daniele Losanno, Salvatore Strano, Peter Thomson**(2019) presented a thorough investigation on unbounded rubber isolators which, based on the satisfactory behavior shown during experimental tests, could be a viable alternative to conventional isolators. Rubber and reinforcing materials used in the manufacture of the isolator prototypes were obtained locally to reduce the cost of the new devices. The different isolator configurations, steel versus nylon/carbon fiber reinforcement (FREI) and bolted versus unbounded connections were investigated to assess the technological competitiveness.

**Aparma Verma** and **Ashutosh Gupta**(2017) In this paper, Aparma Verma and Ashutosh Gupta concluded that exhibition of fixed base and isolated base construction relies upon the kind of underlying soil on which the design rests. For hard soil layers soil the reaction is good yet the soft soil expands the speeding up ground acceleration, so there is decrease in energy dissemination of the design and the recurrence increments. For low to medium rise structures, the proficiency of isolators has been acceptable.

**RESEARCH OBJECTIVE**

The objectives of my research are listed below:

1. Increasing the safety of the structure and after earthquake the structure should be operational.
2. Reducing the effects of horizontal forces or design lateral forces on structure.
3. Isolating ground accelerations from super structure.

## III. RESEARCH METHODOLOGY

The adopted method of approach consists of using response spectrum concept to evaluate the effectiveness of seismic isolation for long-period structures subjected to far field and near field excitations.

**Ground Response Spectrum Concept**

Inelastic response spectra have been widely used to understand and analyze the effect of the inelastic behavior of structures which are subjected to ground excitations. Ground response spectra tell about maximum seismic demands (e.g., displacement, force, ductility, etc.) on a single-degree-of-freedom (SDOF) systems with predefined damping ratios, initial periods, and force-displacement relationships subject to a given ground excitation. Many studies in the past have developed inelastic spectra for near field and far field ground motions.

**Design Procedure**

A G+5 building of medium rise has been used for the analysis and subsequently designing of base isolator. Building structure is symmetrical in x and y directions in plan and is also regular in geometry, it is being done to reduce the complicated efforts in calculations. Figure 3.1 & Figure 3.2 show the plan of the chosen building and 3D view of same G+5 building respectively. It is having 3 bays in X-direction & also 3 bays in the Y-direction, bays are having a span of 4m. The thickness of all floor slabs was taken as 150mm. The building is located in Zone V that's the most severe zone. The frame of the building is special moment resisting frame. The soil site is chosen to be medium soil but the interaction of the soil is not taken into account. The building is taken as general building rather than important buildings like hospital and school.

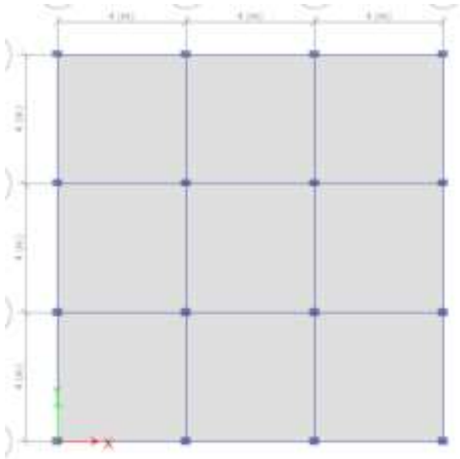

Figure 3.1 Plan

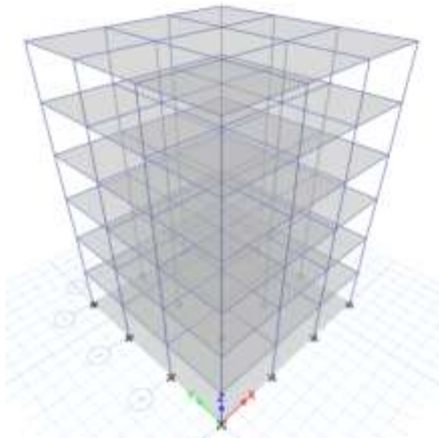

Figure 3.2 3D View

In order to create the genuine effects in the structure a building was simulated with the ETABS 19.0.0 in order to meet the real practice of construction for G+5 building. As moving upwards the load is decreasing on the building components so the section sizes of columns and beams were reduced from ground floor to the top floor. The beams and columns used in the building at various floors have been tabulated below in table 3.1 along with the sections of beams and columns. All members of the frame are made of M30 grade concrete and reinforcement used is Fe500 steel. The slabs at the various floors have been designed as rigid floor diaphragm to minimize the torsional effects. The two models of the building have been analyzed which are fixed base and base isolated model.

**Table 3.1: Sectional properties of Columns, Beams and Slab loading**

| Floor | Column size (m) | Beam size (m) | Live load on slab ($kN/m^2$) |
|---|---|---|---|
| GF | 0.30 × 0.45 | 0.30 × 0.35 | 3 |
| 1st floor | 0.30 × 0.45 | 0.30 × 0.35 | 3 |
| 2nd floor | 0.30 × 0.45 | 0.30 × 0.35 | 3 |
| 3rd floor | 0.30 × 0.35 | 0.30 × 0.30 | 3 |
| 4th floor | 0.30 × 0.35 | 0.30 × 0.30 | 3 |
| 5th floor | 0.23 × 0.30 | 0.23 × 0.30 | 1.5 |

The analysis was free vibration under response Spectrum a type of dynamic analysis. The fundamental time period of building structure and various mode shapes of the building were obtained by using number of modes to achieve 90% mass participation. In addition to this the total seismic weight (DL + LL) of the same structure was calculated for the entire building as per IS 1893-2002, which comes out to be 11050.55kN and same was reported by ETABS as well. For symmetric building there are more vertical loads in columns which are near or at the core of the building as compared to the columns which are present at the periphery. The maximum gravity load (DL + LL) taken to derive the size of an isolator was 1200kN as the reaction of the column.

**Design of seismic base Isolators**

The bearings are constructed by placing un-vulcanized rubber sheets and steel shims in a mould, then subjecting this mould to subjected elevated temperature and pressure in order to simultaneously vulcanize and bond the rubber. A rubber cover is provided to protect the internal rubber layers and steel plates from environmental degradation due to ozone attack and corrosion, respectively. Typically used for seismic applications elastomeric bearings have a shear modulus ($G$) that ranges from 0.65 MPa to 0.9 MPa. A practically applicable seismic isolation system should meet these requirements.

1. To provide a horizontal degree of freedom to the structural system in order to increase the structural time period.
2. The isolation system should have the sufficient energy dissipation capacity so that there are no greater displacements across the isolators to a practical level.
3. There must be enough rigidity in the structure to make the isolated buildings similar to

fixed base buildings for the general loading.

On the basis of mentioned requirements as well as codal procedures IBC 2000 and UBC 1997 Volume 2, Lead Rubber Bearing (LRB) was designed. As per the formulations, the effective stiffness required to provide the lateral stability for lead rubber bearing was calculated. The properties like damping, stiffness, modulus of rigidity, modulus of elasticity and poisons ratio, for the lead rubber bearing were calculated in accordance with Section 1623 of IBC 2000 and UBC 1997 Volume 2. However, wherever there was requirement of Indian Seismic code IS 1893-2002(part 1) considerations were taken from that code as well. The final design of the isolators is represented in the table 2.

**Table 2: Design parameters for Lead rubber bearing**

| Items | Design Values |
|---|---|
| Rubber bearing diameter(m) | 0.600 |
| Total rubber layer thickness(m) | 0.250 |
| one rubber layer thickness (m) | 0.0167 |
| Diameter of lead core(m) | 0.100 |
| Total layers required | 15 |
| Isolator height (m) | 0.328 |
| Thickness of shim plates (m) | 0.002 |
| Thickness of cover plate (m) | 0.025 |
| Diameter of steel plate (m) | 0.590 |
| Vertical stiffness (linear) (For $U_1$ direction) (kN/m) | 582391.25 |
| Horizontal stiffness (linear) (For $U_2$ $and$ $U_3$ direction) (kN/m) | 1012 |
| Horizontal stiffness (Nonlinear) (For $U_2$ $and$ $U_3$ direction)(kN/m) | 11020 |
| Effective damping(For U2 and U3) | 0.05 |
| Yield Displacement (Distance from End-J), $D_y$ (m) | 0.0031 |

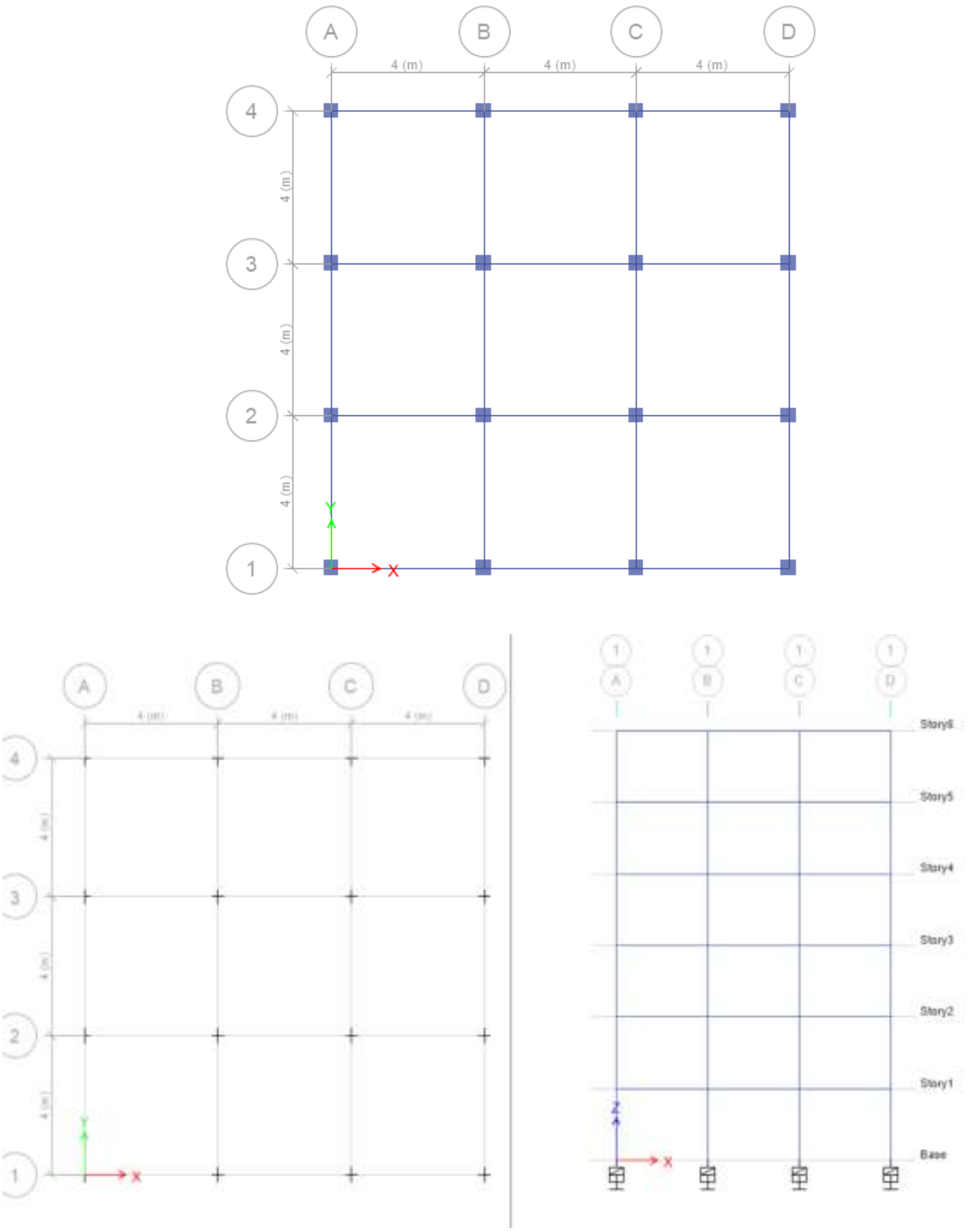


Figure 3.4 Fixed base Building

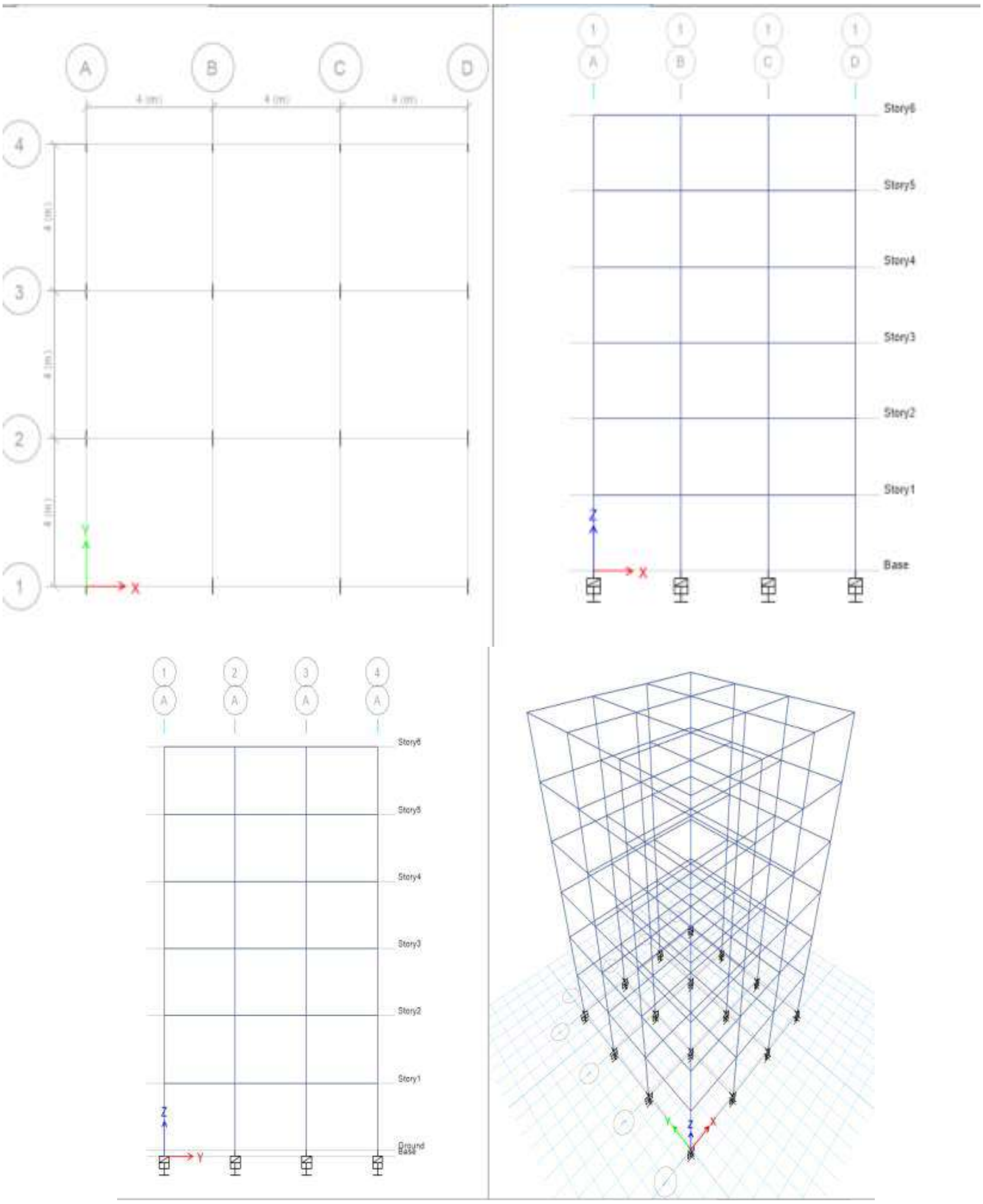


Figure 3.5 Base isolated building

**Modelling and simulation**

**. Types of Models**

- Model 1 = RCC Building with Fixed Base
- Model 2 = RCC Building having Base isolated (LRB)

**Building details**

- Structural frame made of RCC (SMRF)
- Structure Type is having Plan Regular Structure
- Plan Dimensions of 12mx12m
- Height of Building is 18m (G+5)

- Height of each Storey is 3m
- In X-direction there are 3 bays of 4m length of each bay
- In Y-direction there are 3 bays of 4m length of each bay

**Material Properties**

- Grade of concrete used is M30
- Grade of steel used is Fe500
- Density of concrete is taken as 25 KN/m3
- Density of brick infill wall is taken as 19 KN/m3

**Section Properties**

- Beam size
  - i. 300mm x 350mm for G, I, II, III floors
  - ii. 230mm x 300mm for IV, V floors
- Column size
  - i. 300mmx450mm for G, I, II floors
  - ii. 300mmx350mm for III, IV floors
  - iii. 230mmx300mm for V floor
- Slab Thickness is taken as 0.15m
- Wall Thickness is taken as 0.23m

**Load Considerations**

**Gravity Load:**

- Dead load is the load of Columns, Beams and Slabs
- Live load is taken as 3KN/m2 on floor
- Live load is taken as 1.5kN/m2 on roof slab

**Lateral Load of Response Spectrum Analysis:**

- Soil Profile type is taken as Medium soft
- Seismic Zone Factor is taken very severe i.e Zone 5
- Response Reduction Factor is 5.0 for SMRF
- Importance Factor is 1.0 for general building
- Effective Damping is 5 %
- Damping coefficient 1.0 as per Table 3 cl. 6.4.2 of IS 1893-2002(part 1)

## IV. RESULTS

The response spectrum analysis was done for the fixed base building. The fundamental time period of the building and also the mode of shape were determined. This result is an input for deciding the target fundamental time period of a base isolated building, which is nearly three times the period of fixed base building. The fixed base modeled building was subjected to gravity loads (DL + LL) along with earthquake forces as per IS: 1893-2002 (Part I) using equivalent static procedure. The combined effect of DL + LL + EQ was obtained.

**. Storey displacement**

The storey displacements of the various storeys of fixed building and building with LRB are shown in the table:

**Table 4.3 Displacements at the Storey Level**

| Displacement | Fixed Base(in mm) | LRB (in mm) |
|---|---|---|
| Ground Floor | 0 | 36.66 |
| Floor I | 6.84 | 52.11 |
| Floor II | 15.69 | 58.55 |
| Floor III | 23.60 | 63.05 |
| Floor IV | 31.34 | 67.09 |
| Floor V | 37.51 | 70.10 |

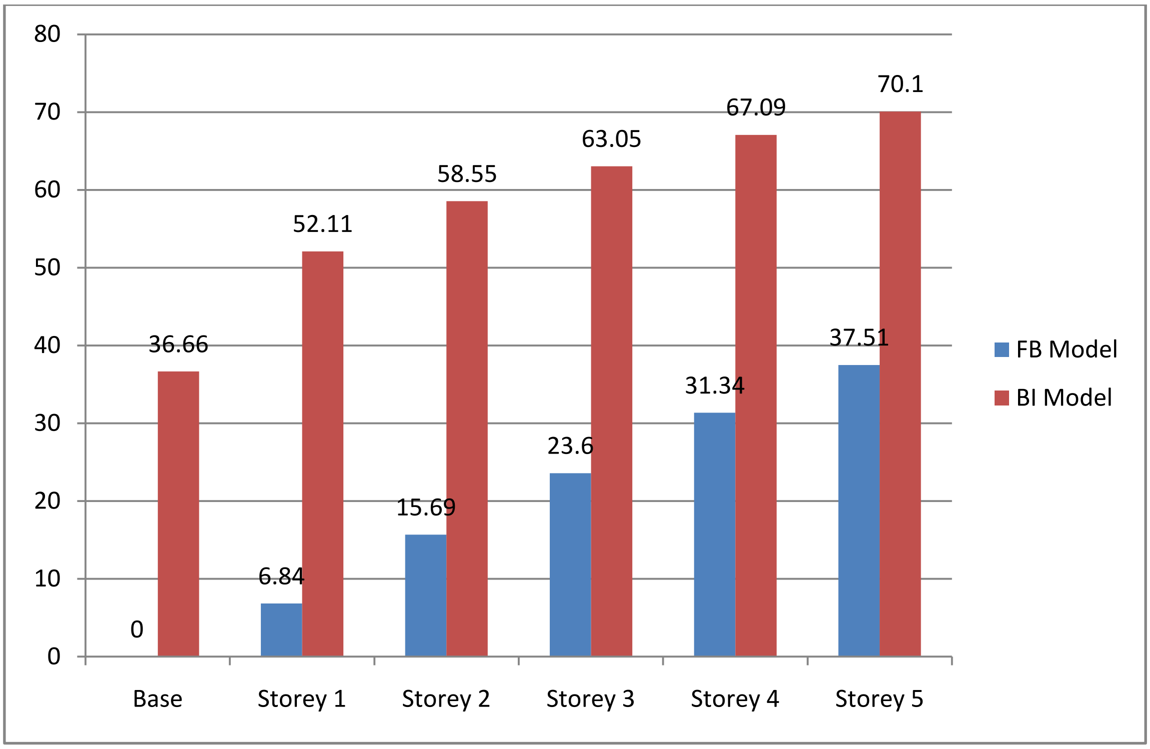


Figure 4.3 Displacements at the Storey Level

The displacement of various stories in base isolated model when compared with fixed base model is more because of the flexibility provided by the LRB.

**4.2. Storey Drift**

The storey drifts of the various storeys of fixed building and building with LRB are shown in the table:

**Table 4.4 Storey Drifts of Various Storeys**

| Drift | Fixed Base(in mm) | LRB (in mm) |
|---|---|---|
| **Ground Floor** | 6.85 | 18.13 |
| **Floor I** | 8.88 | 6.46 |
| **Floor II** | 8.07 | 4.58 |
| **Floor III** | 8.19 | 4.21 |
| **Floor IV** | 6.88 | 5.11 |
| **Floor V** | 7.34 | 2.96 |

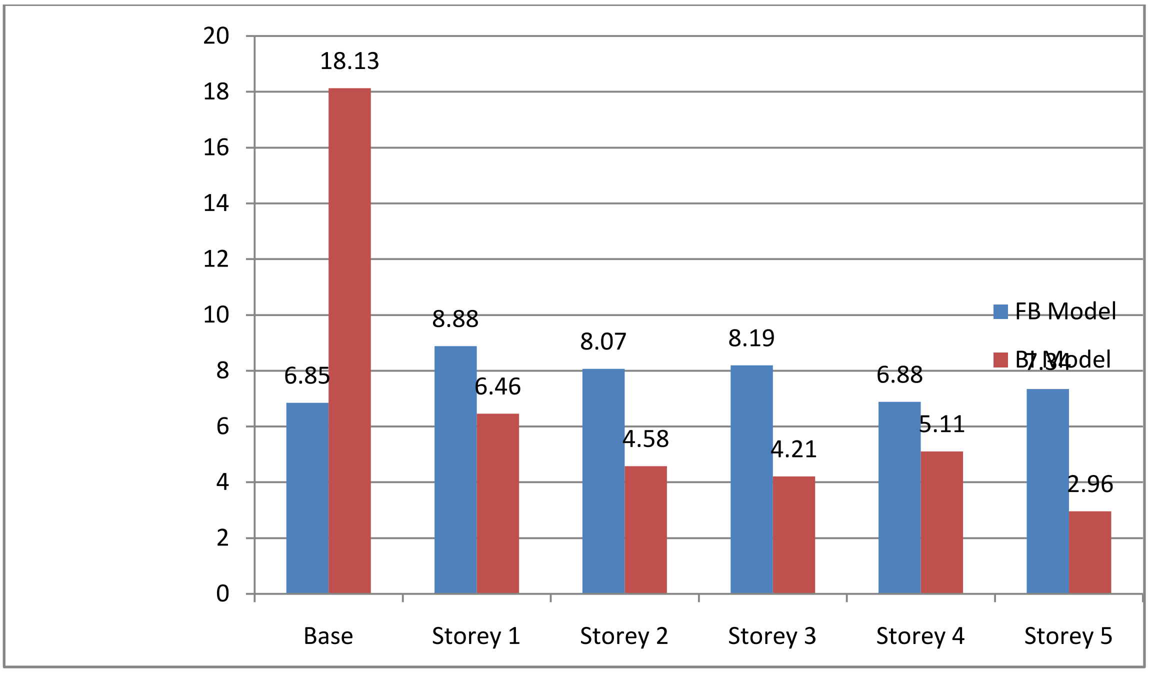


Figure 4.4 Drift of Various Storeys

**Storey Shear**

The storey shear of the various storeys of fixed building and building with LRB are shown in the table:

V. CONSCLUSION

The two models of fixed base and the base isolated model using the lead rubber bearing were analyzed by the response spectrum analysis which is a dynamic analysis. After the analysis of these building models following conclusions were drawn out:

1. Natural time period is increased reducing the frequency of susceptibility of the earthquake tremors to the structure which minimizes the earthquake forces acting on the structure during shaking. The natural time period increases by 1.615 sec for lead rubber isolator when compared to fixed base building, that's first objective of isolating a structure from the ground motions and it is called "Period Shift".
2. Story shear reduction is achieved by using the lead rubber bearing (LRB) as base isolating device which increases the seismic resistance of building.
3. Story drift is also gets reduced in as we move to upper stories which also make the structure safe against earthquake hazard.
4. There has been an increase in storey displacements in every storey by the use of LRB which is required to make the structure flexible and transfer less earthquake forces to super structure.
5. The story drifts were more for the base isolated building with LRB isolators compared to the story drift of fixed base building.

REFERENCES

1. Kim, Jung Han, Min Kyu Kim, and In-Kil Choi "Experimental study on seismic behavior of lead-rubber bearing considering bi-directional horizontal input motions." Engineering Structures 198 (2019): 109529.
2. Nailiang Xiang, Jianzhong Li "Experimental and numerical study on seismic sliding mechanism of laminated-rubber bearings." Engineering Structures 141 (2017) 159–174.
3. Ingrid. Madera Sierra, Daniele Losanno, Salvatore Strano, Peter Thomson "Development and experimental behavior of HDR seismic isolators for low rise residential buildings." Engineering Structures 183 (2019) 894-906.
4. Swapnil Ambasta "Analysis of the base isolated building(Lead Rubber Bearing) in ETABS" International Research Journal of Engineering and Technology (IRJET) (2018) Volume:05

5. Aparma Verma and Ashutosh Gupta "Base Isolation System: A Review" International Journal of Engineering Science Invention (2017) Volume 6, 43-46
6. Sunil Shirol "Seismic Base Isolation of RC Frame Structures With and Without Infill" International Research Journal of Engineering and Technology (2017) Volume: 04
7. M.K. Shrimali, S.D. Bharti, S.M. Dumne and Arumairaj, (2015), "Seismic response analysis of coupled building involving MR damper and elastomeric base isolation", J. Ain Shams Engineering, 6, 457–470.
8. J. Enrique Luco, (2014), "Effects of soil–structure interaction on seismic base isolation", "ELSEVIER, Soil Dynamics and Earthquake Engineering, 166-167
9. ETABS 19.0.0, Computer & Structures Inc., Berkeley, California.
10. UBC 1997 Volume 2, Structural Engineering Design Provisions.
11. IS 1893-1 (2002): Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings.