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SEISMIC ANALYSIS OF RC STRUCTURES USING BASE ISOLATION TECHNIQUE

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Abstract - *The base isolation is technique that has been used to protect the structures from the damaging effects of earthquake. The installation of isolators at the base increases the flexibility of the building structures. In present study Modeling and analysis of 10 storey RC building is done in ETBS 15.1 version software for two cases. The first one is fixed base and the second one is base isolated. Two vertical irregular and Two plan irregular models are considered and analysis is done by equivalent static and response spectrum method. The Lead rubber bearing (LRB) is designed as per UBC 97 code and the same was used for analysis of base isolation system. The results obtained from analysis were Storey displacement. Storey shear, storey acceleration, and Inter storey drift. Due to the presence of isolators the inter storey drift, storey accelerations and storey shear is greatly reduced and storey displacement is increased in both X and Y directions compared to fixed base structures.*

Key Words: Base isolation, Lead rubber bearing, Equivalent static method, Response spectrum method, Irregular building, storey displacement, storey shear, storey acceleration, Inter storey drift.

1. INTRODUCTION

A natural calamity like an earthquake cause significant loss of life and destruction to property every year. A disturbance that causes shaking of earth surface due to movement at underground along fault plane or from volcanic activity is called earthquake. The seismic forces produced are harmful and lasts only for a small duration of time. Yet, humans are confused with uncertainty in terms of its time of occurrence and its nature. However with advances made in varies areas of sciences it has been learned how to pinpoint the locations of earthquake and how to accurately measure their sizes, however, this solves only one part of the problem to protect a structure. The other part is seismic design of the structures. Since from the last century, this part of problem has taken various forms, and improvements in design philosophy and methods have been done. There are two types of methods for the seismic design of structures,

1) Conventional method: This is the traditional method to resist lateral force is by increasing the design capacity and stiffness. Ex- shear wall, Braced frames or Moment resisting frames.
2) Non conventional method: Based on reduction of seismic demands instead of increasing capacity. Ex- Base isolation, Dampers.

2. BASE ISOLATION

In base isolation technology during earthquake, separating the superstructure or reducing the lateral movements of building superstructure from the movement of ground or foundation. The bearings of base isolation are designed in such a way that they are stiff vertically and flexible horizontally to allow for the difference in lateral movement while still supporting the superstructure. The base isolated structures are different than that of fixed base structure, in which the connection between the superstructure and the foundation are rigid and the superstructure translation in all direction is constrained.

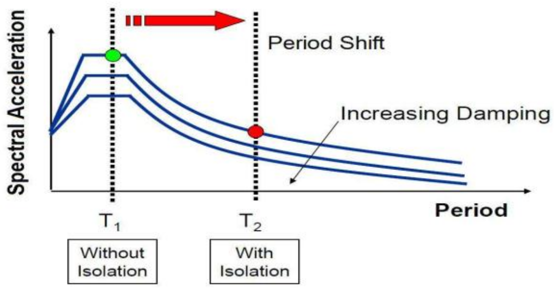


Figure-1: Effect of Seismic Isolation on Spectral Acceleration

The main aim of base isolation is to reduce the earthquake force produced on building superstructure. To some extent by reducing the superstructure's spectral acceleration, the reduction in seismic force at superstructure is achieved. By increasing the base isolated structure fundamental period and through damping caused by dissipation energy within bearing the accelerations are reduced.

2.1 Lead Rubber Bearing

A variety of isolation devices including elastomeric bearings (with and without lead core), frictional/sliding bearings and roller bearings have been developed and used practically for a seismic design of buildings during the last 25 years. Among the various base isolation system, the lead rubber bearing had been used extensively. It consist of alternate layers of rubber and steel plates with one or more lead plugs that are inserted into the holes. Due to lateral forces the lead core deforms, yields at low level of shear stresses approximately 8 to10 Mpa at normal (20^{0}c) temperature, so the lead bearing lateral stiffness is significantly reduced. Due to this period of structure increases. One of the feature of lead core is that it can recrystalize at normal temperature and will not encounter the problems of fatigue failure under cyclic loadings.

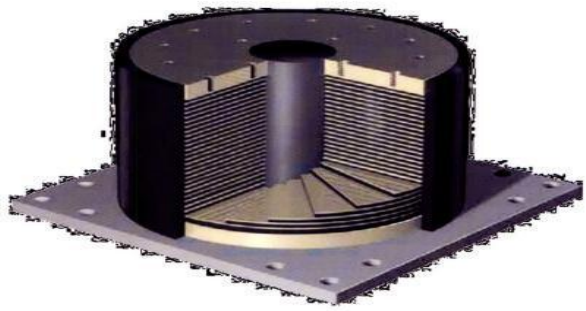


Fig-2: Lead Rubber Bearing with Layers of Rubber and Steel and Lead Core

Basic functions of LRB's:

- Load supporting function: Rubber reinforced with steel plates provides stable support for structures. Multilayer construction rather than single layer rubber pads provides better vertical rigidity for supporting a building.
- Horizontal elasticity function: With the help of LRB, earthquake motion is converted to low speed motion. As horizontal stiffness of multilayer rubber bearing is low, strong earthquake vibration is lightened and the oscillation period of the building is increased.
- Restoration function: Horizontal elasticity of LRB returns the building to its original position. In LRB, elasticity mainly comes from restoring force of the rubber layers. After an earthquake this restoring force returns the building to the original position.
- Damping Function: Provides required amount of damping that is necessary.

3. OBJECTIVES OF THE STUDY

In the present study, the work includes the analysis of a 10 storey reinforced concrete plan geometric irregular and vertical geometric irregular buildings in accordance with IS1893-2002 provisions; one with fixed base and other with base isolated.
The objectives of the study are as follows;

- To carry out modeling and analysis of fixed base and base isolated building by using ETABS 15.1 version software and study the effect of seismic forces on these models.
- To design and study the effectiveness of lead rubber bearing used as a base isolation system.
- To carry out comparison between fixed base and base isolated building by equivalent static method and dynamic method on the bases of response properties like storey displacement, inter storey drift, storey shear and storey acceleration.
- To study the behavior of plan irregular and vertical irregular RC building under higher seismic zone area.

4. METHODOLOGY

In the present study 10 storied reinforced concrete building having plan geometric irregularity and vertical geometric irregularity is considered. Two different plan geometric irregular models are considered. Tow vertical geometric irregular models are considered. The RC frame without infill panels situated in zone IV of India having medium stiff soil is considered.

- **Loadings**
  - Live load on floors = 3 kN/m^2
  - Live load on roof = 1.5 kN/m^2
- **Geometric Properties**
  - Column size = 350mm x 450mm
  - Beam size = 250mm x 300 mm
  - Slab thickness = 125mm
- **Material Properties**
  - Grade of concrete = M25
  - Grade of Steel = Fe415
- Soil type : Medium (Type II)
- Zone factor : Z = 0.24
- Importance factor : I = 1
- Special Moment Resisting Frame : R = 5

The work started with modeling and analysis of RC building for two cases. The first one is fixed base and the second is base isolated. In the present study Lead Rubber Bearing is used as a base isolator. After analysis of fixed base regular or rectangular model using E-TABS 15.1 version software, maximum vertical reaction is obtained. By using this vertical reaction lead rubber bearing is designed manually and the same is used as a base isolator for all the models considered.

Table -1: Isolator properties

Required stiffness (k_{eff})	2602.71kN/m
Bearing horizontal stiffness	509.79kN/m
Vertical stiffness	292 x 10^3 kN/3
Yield force (F)	39.01Kn
Stiffness ratio	0.1
Damping	0.05

After the modeling, the analysis is done by equivalent static method and linear dynamic method for fixed base and base isolated conditions and the results are compared.

4. MODELLING AND ANALYSIS

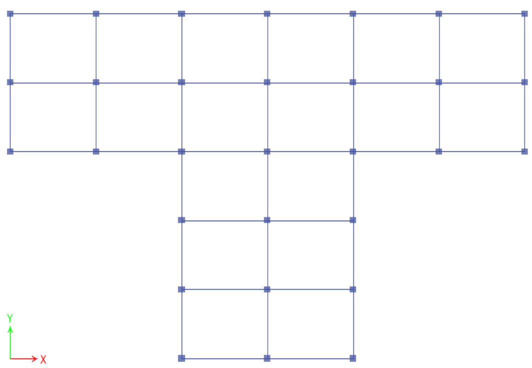


Fig -3: Plan view of T shaped model

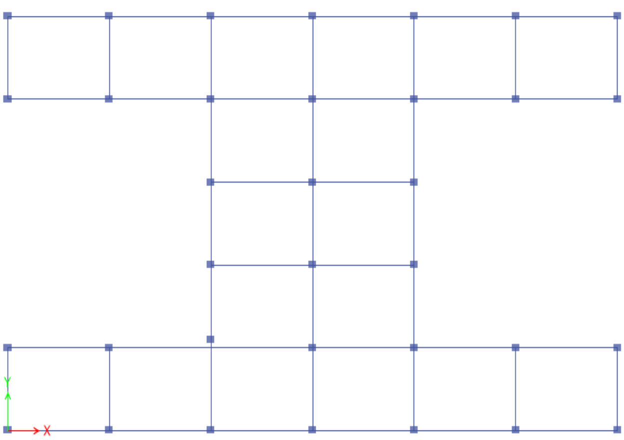


Fig -4: Plan view of I shaped model

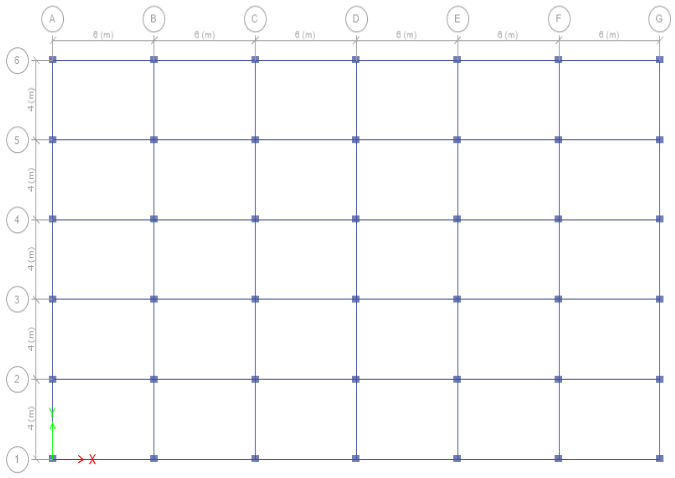


Fig -5: Plan view of Vertical Irregular model

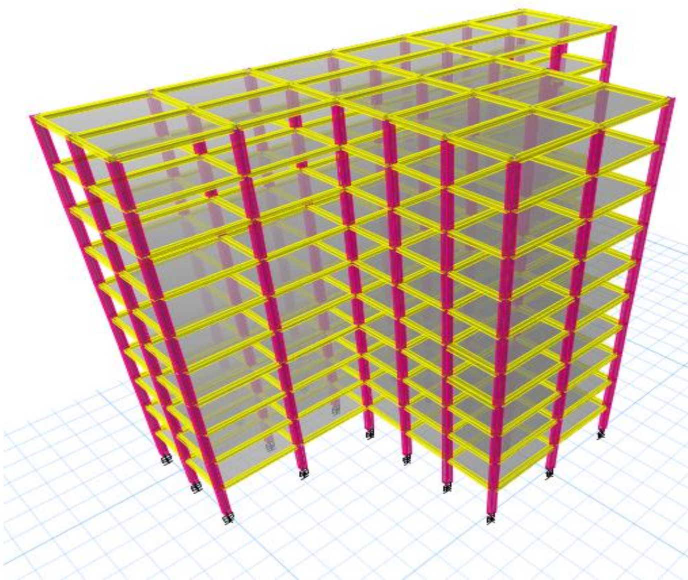


Fig -6: 3D view of T shaped base isolated building

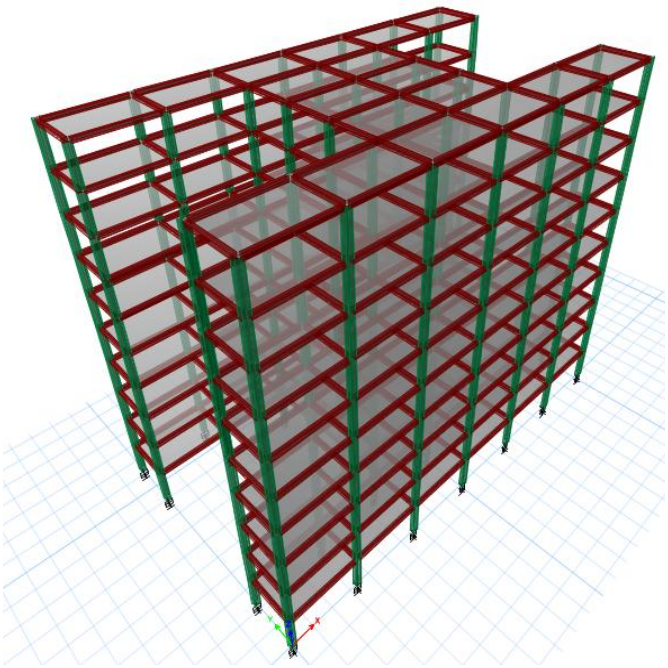


Fig -7: 3D view of I shaped base isolated building

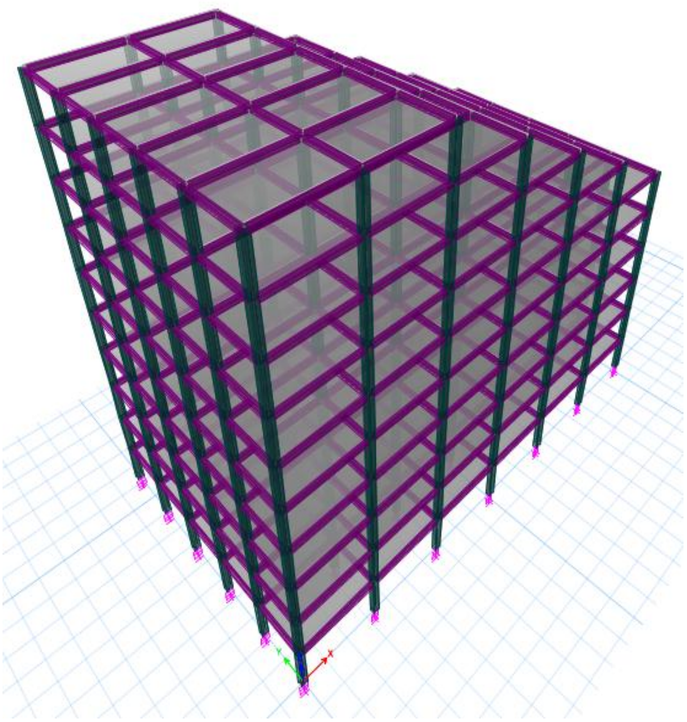
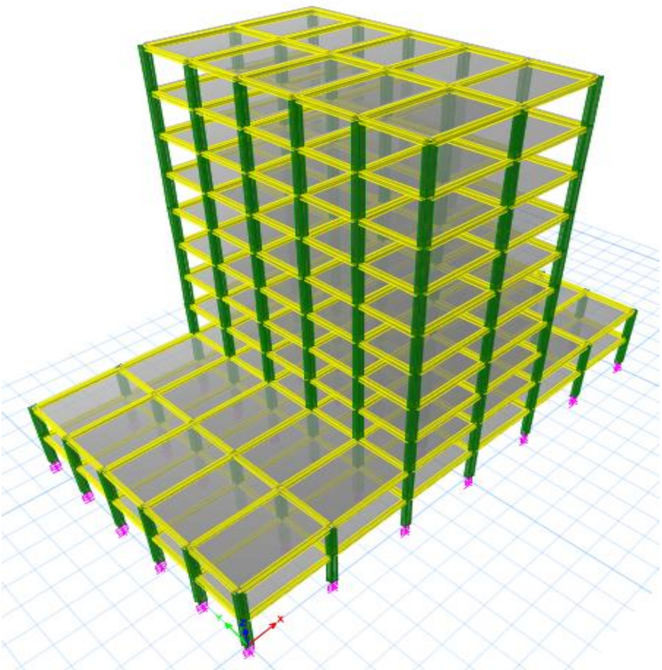


Fig -8: 3D view of Vertical irregular base isolated building



. **Fig -9:** 3D view of Vertical irregular base isolated building

After modeling the analysis is done and the results are compared between fixed base and base isolated building both in X and Y direction by equivalent static method and linear dynamic method on the bases of response properties like storey displacement, Inter storey drift, storey acceleration, and storey shear.

5. RESULTS AND DISCUSSIONS

Case 1 (1A): Fixed base RC building in X direction by equivalent static method.

Case 2 (1B): Base isolated RC building in X direction by equivalent static method.

Case 3 (1C): Fixed base RC building in Y direction by equivalent static method.

Case 4 (1D): Base isolated RC building in Y direction by equivalent static method.

Case 5(2A): Fixed base RC building in X direction by response spectrum method.

Case 6 (2B): Base isolated RC building in X direction by response spectrum method.

Case 7(2C): Fixed Base RC building in Y direction by response spectrum method.

Case 8(2D): Base isolated RC building in Y direction by response spectrum method.

1) Plan Irregular Model:

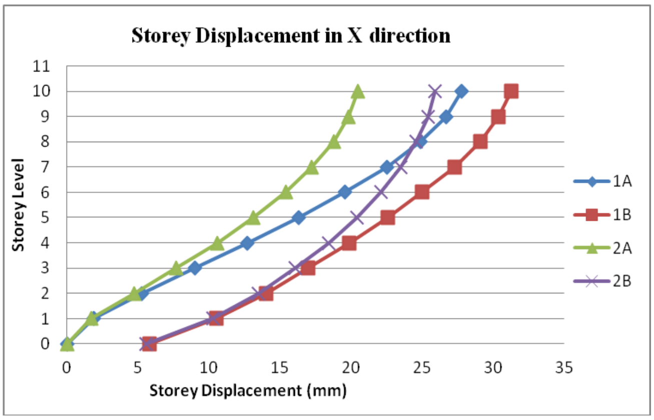


Fig -10: Storey Displacement in X direction

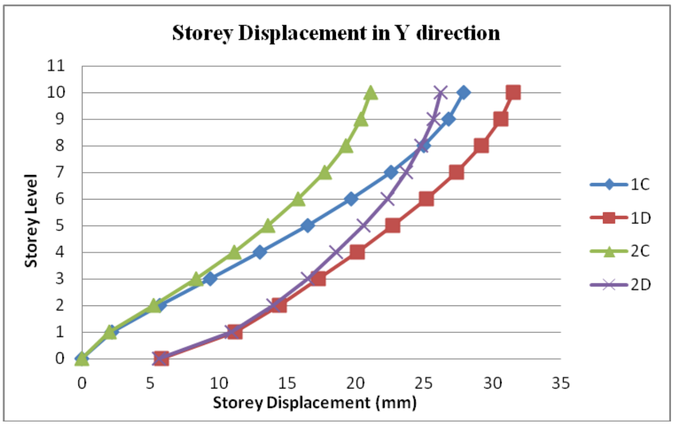


Fig -11: Storey Displacement in y direction

From figure 10 and 11 it is observed that, in case of RC building analyzed by the equivalent static method storey displacement in the base isolated structures increased by 12.578% in X direction 12.9% in Y direction compared to fixed base structures. Similarly to the same building analyzed by response spectrum method storey displacement in base isolated structure is increased by 26.34% in X direction and 24.17% in Y direction compared to fixed base structure.

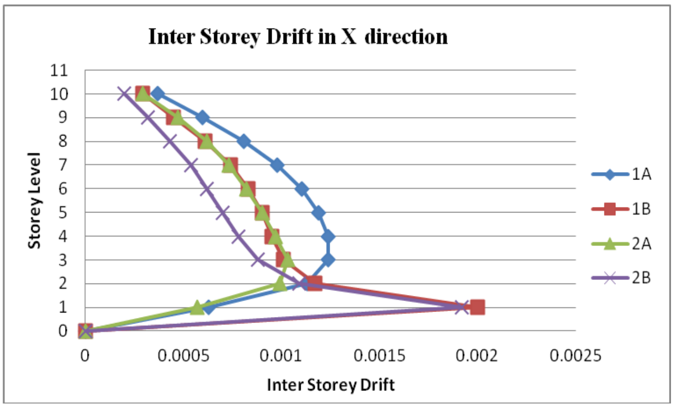


Fig -12: Inter Storey Drift in X direction

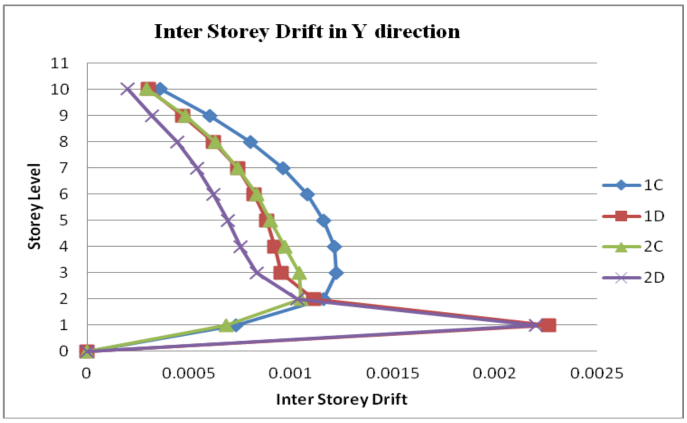


Fig -13: Inter Storey Drift in Y direction

From the figure 12 and 13, it is observed that in case of RC building analyzed by response spectrum method in the base isolated structure the inter storey drift significantly reduces as compared to fixed base structure than that of same building analyzed by equivalent static method in both X and Y directions.

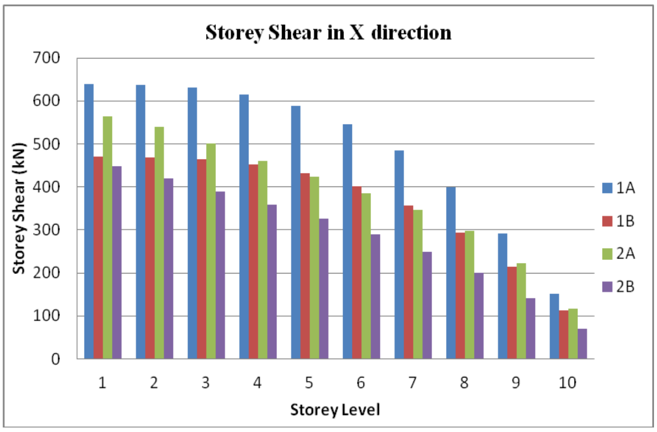


Fig -14: Storey Shear Drift in X direction

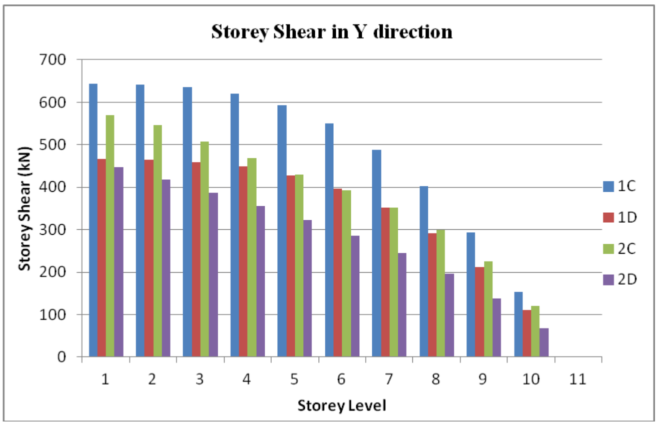


Fig -15: Storey Shear Drift in Y direction

From the figure 5.1.5 and 5.1.6 it is observed that in case of RC building analyzes by equivalent static method the storey shear in case of base isolated structures reduced by 26.43% in X direction and 27.66% in Y direction compared to fixed base structure. Similarly the same building analyzed by the response spectrum method in base isolated structures it is reduced by 20.27% in X direction and 21.47% in Y direction compared to fixed base structure.

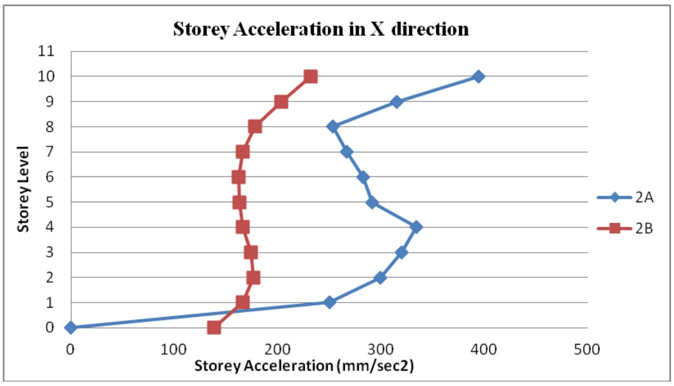


Fig -16: Storey Acceleration in X direction

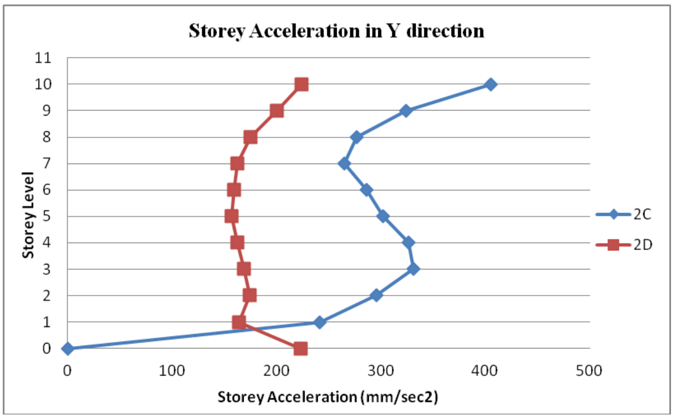


Fig -17: Storey Acceleration in Y direction

From figure 16 and 17 it is observed that, the storey acceleration in case of base isolated structures decreased by 41.25% in X direction and 44.76% in Y direction as compared to fixed base building for the same storey level. The storey accelerations are nearly same in base isolated building from bottom to top of storey. Where as in fixed base building there is large difference in storey acceleration from bottom to top of storey.

2) Vertical Irregular Model:

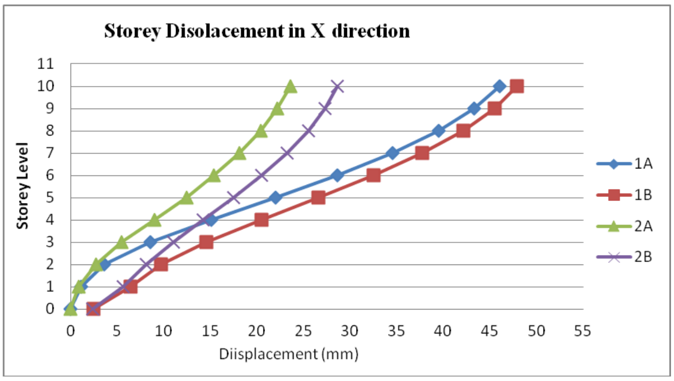


Fig -18: Storey Displacement in X direction

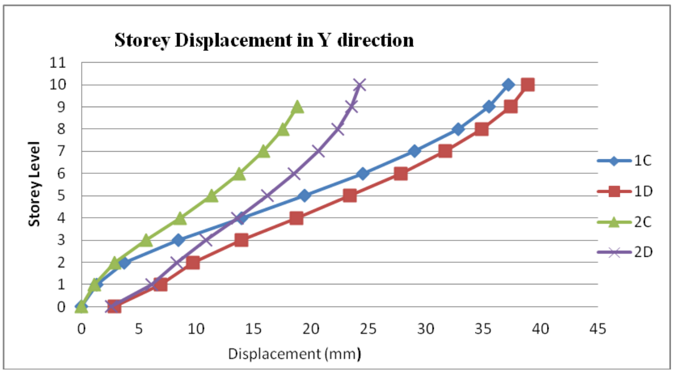


Fig -19: Storey Displacement in Y direction

From figure 18 and 19 it is observed that, in case of RC building analyzed by the equivalent static method storey displacement in the base isolated structures increased by 4.130% in X direction 4.560% in Y direction compared to fixed base structures. Similarly to the same building analyzed by response spectrum method storey displacement in base isolated structure is increased by 21.18% in X direction and 23.46% in Y direction compared to fixed base structure.

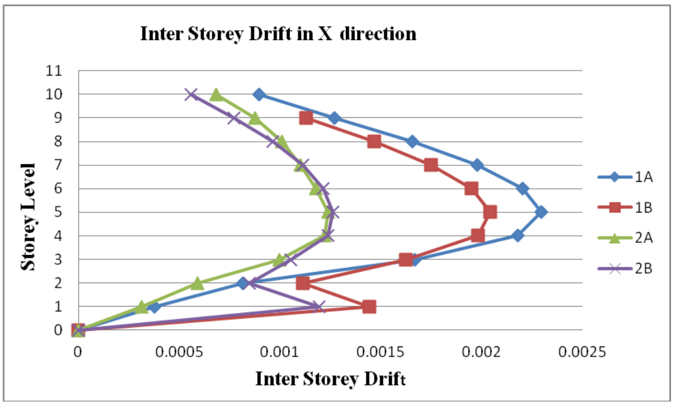


Fig -20: Inter Storey Drift in X direction

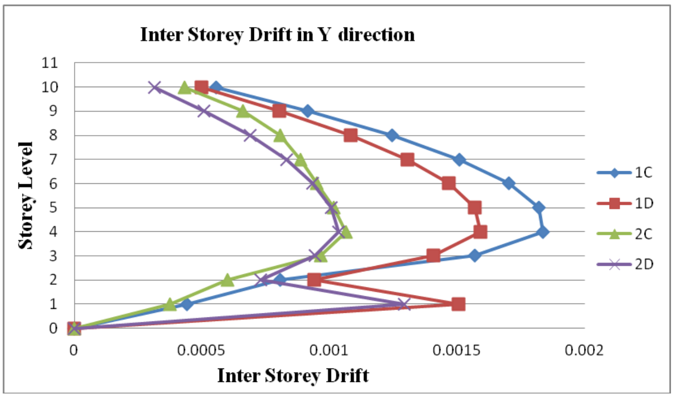


Fig -21: Inter Storey Drift in Y direction

From the figure 20 and 21, it is observed that in case of RC building analyzed by response spectrum method in the base isolated structure the inter storey drift significantly reduces as compared to fixed base structure than that of same building analyzed by equivalent static method in both X and Y directions.

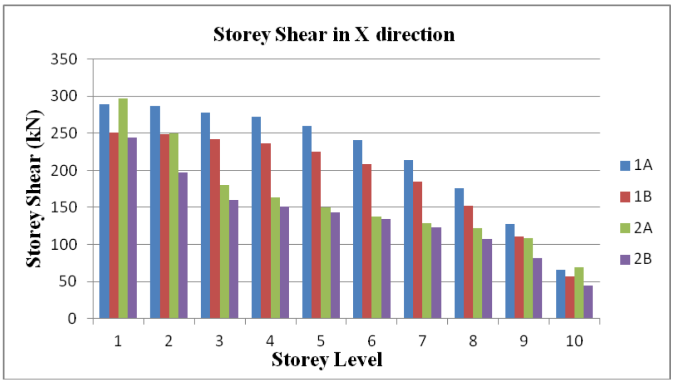


Fig -22: Storey Shear Drift in X direction

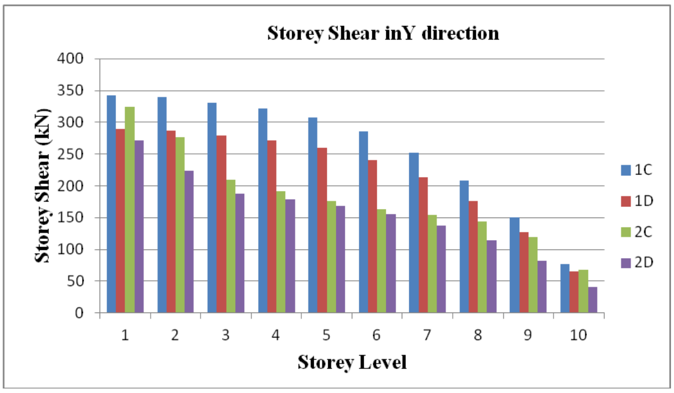


Fig -23: Storey Shear Drift in Y direction

From the figure 22 and 23 it is observed that in case of RC building analyzes by equivalent static method the storey shear in case of base isolated structures reduced by 13.32% in X direction and 15.59% in Y direction compared to fixed base structure. Similarly the same building analyzed by the response spectrum method in base isolated structures it is reduced by 35.89% in X direction and 39.35% in Y direction compared to fixed base structure.

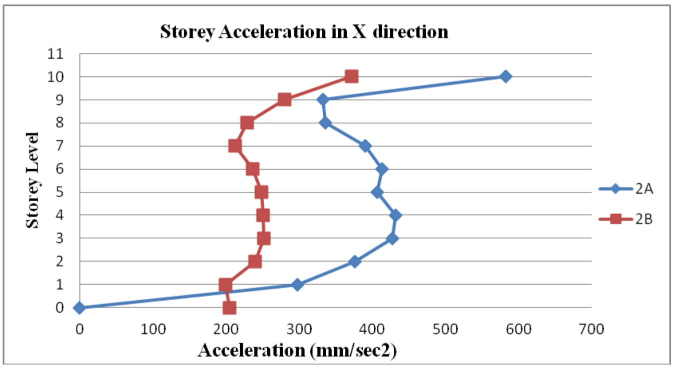


Fig -24: Storey Acceleration in X direction

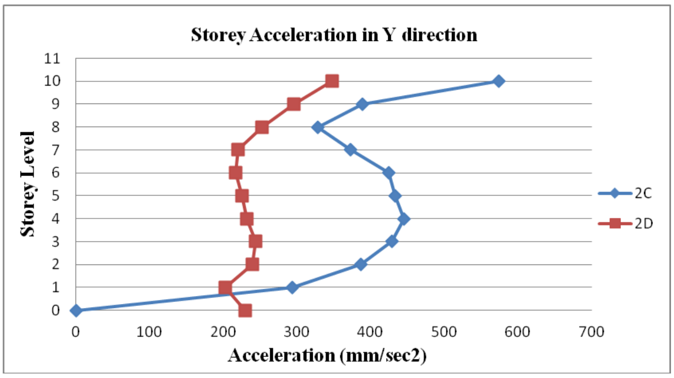


Fig -25: Storey Acceleration in Y direction

From figure 24 and 25 it is observed that, the storey acceleration in case of base isolated structures decreased by 36.09% in X direction and 39.49% in Y direction as compared to fixed base building for the same storey level.

The storey accelerations are nearly same in base isolated building from bottom to top of storey. Where as in fixed base building there is large difference in storey acceleration from bottom to top of storey.

6. CONCLUSION

From analysis results it is observed that base isolation technique is very significant in order to reduce seismic response of both plan irregular and vertical irregular models as compared to fixed base fixed base building and control damages in building during seismic action. By comparing response properties of structure following conclusions are made:

1) Fixed base plan irregular as well as vertical irregular models have zero displacement at the base of building where as, base isolated building model shows considerable amount of lateral displacement at base. Also it has been observed that as floor height increases, lateral displacement increases extremely in fixed base building as compared to base isolated building. During earthquake due to this reduction in lateral displacement damages of structural as well as nonstructural is reduced.
2) In base isolated models at the base more inter storey drift was observed as compared to models of fixed base building. As storey height increases, the inter storey drift in base isolated models extremely decreases as compared to models of fixed base building.
3) Compared to equivalent static method the analysis results obtained by response spectrum method are very significant.
4) At the base fixed base models have zero storey acceleration whereas, in case of base isolated building models shows considerable amount of storey acceleration. Also it has been observed that as floor height increases, storey acceleration increase extremely in fixed base building as compared to base isolated building where it is almost constant.
5) As compared to fixed base building the storey shear is reduced considerably in case of base isolated building.
6) Reduction in base shear is more in case of plan irregular base isolated building as compared to vertical irregular base isolated building.
7) From the study it has been concluded that, by using the isolators at the base of building plan irregular building gives better performance as compared to vertical irregular building at higher seismic zone area.

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