Seismic Behaviour of Base Isolated Structures With Various Distribution of Isolators

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Abstract- *From the beginning of ancient period, we know the Earthquake is the transfer mechanism which influences the seismic performance of the structural elements of building due to unnecessary and intense lateral displacements of the building. Due to the lack of space, there is a new trend to construct the multi storey building in the high seismic area. For the construction of the multi storey buildings in the high earthquake prone area required effective lateral load resisting mechanism which withstands against the seismic forces at the time of earthquake otherwise structure may be subjected to massive damage as well as collapse. After many experimental investigations it has shown that performance of the structure increased greatly because use of the base isolation system in the building configuration. Due to advancement in the construction industry and efforts of the various researchers, a number of base isolation systems like Lead rubber bearing, Friction pendulum system, New Zealand bearing, Ressilient bearimg are available. The choice of the particular isolated system depends on the two fundamental parameters like seismic risk of the zone and inexpensive for the construction. In present work the comparative study is carried out for the fix base structures and various base isolated structutes like Lead rubber braing and Friction pendulum bearing. The parametric study is carried out with the help of parameters like fundamental natural time period, storey drift, storey displacement, storey stiffness, and base shear. The linear dynamic analysis is performed by response spectrum method using SAP2000 software*

Keywords- Base isolation,Lead Rubber Bearing,Friction Pendulum Bearing , Response spectrum method.

I. INTRODUCTION

In recent years base isolation has become a progressively applied structural design technique for buildings and bridges in high seismicity regions. Many types of structures like residential, commercial, industrial and institutional have been built using this approach, and many others are in the planning and design phases. Most of the structures are constructed with the use of rubber and frictional pendulum bearings. Base isolation is the separation of the base or substructure from the superstructure. It is also called Seismic isolation.

Instinctively, the concept of extrication the superstructure from the ground to avoid earthquake damage is relatively simple to understanding. At the time of earthquake the ground moves and this ground movement which induces the inertial forces on the structures from both directions which causes most of the damage to structures. An airplane flying over an earthquake is not affected. So, the fundamental principle is quite simple. Separate the superstructure from the ground. The ground will move but the building will not move. Base Isolation falls into the general category of Passive Energy Dissipation. There are two fundamental approaches for an isolation system. Introduction of the low lateral stiffness between the structure and the foundation: Due to this layer, the fundamental natural time period increases for the isolated base structure than the fixed base structure. Increase in the fundamental time period may be reducing the pseudo-acceleration which results in the introduction of the earthquake forces in the structure. This method is widely used in the construction industry in recent years. The introduction of the isolation system for the characterization of the sliding system. This system work based on the transformation of the limiting shear across the isolation interface. In the construction industry, various sliding systems have been recommended and some have been used. In China, most of the buildings are constructed using the sliding system in which selected sand used at the sliding interface. In South Africa, nuclear power plant was constructed by introducing isolation system containing a lead-bronze plate sliding on the stainless steel with an elastomeric bearing. The friction-pendulum system is a sliding system using a special interfacial material sliding on stainless steel and has been used for several projects in the United States, both new and retrofit construction.

II. REASEARCH OBJECTIVES

To study the influence of the different base isolated system on the linear dynamic characteristics of the symmetrical and unsymmetrical structures subjected to the lateral earthquake by performing response spectrum analysis.

III. SCOPE OF WORK

The present study focuses on the analytical investigation of the influence of the different base isolated system on the seismic response of the structure subjected to a lateral seismic load.

1) Study of types of base isolators, their constituent elements
2) The present work is focused on the impact of different base isolated systems like Lead rubber bearing and friction pendulum bearing on the seismic performance of the symmetrical and unsymmetrical structure.
3) The comparative study between base isolated structures and fixed base structures is carried out.
4) The parametric analysis was carried out to study the linear dynamic characteristics considering different isolated systems used in the structure using Response spectrum method.
5) To design and study the effectiveness of lead rubber-bearing and friction pendulum bearing used as base isolation system.

IV. PROBLEM STATEMENT

The analytical investigation of the influence of the different base isolated system on the seismic response of the structure subjected to a lateral seismic load. The comparative study between base isolated structures and fixed base structures is carried out. The parametric analysis was carried out to study the linear dynamic characteristics considering different isolated systems used in the structure using Response spectrum method. The following data is used for analysis:-

a) RC frame details:

- No. of stories: Eleven
- Floor to floor Height: 3m
- Type of Building: Commercial
- Size of Beams: 230 X 450 mm
- Size of Columns: 600 X 600mm
- The thickness of Slab: 150mm
- The thickness of the wall: 230 mm
- The height of the Parapet wall: 1.2 m

b) Loading details

- Live load on floor: 3 KN/m^2
- Live load on roof: 1.5 KN/m^2
- Floor finish on floor: 1.5 KN/m^2
- Floor finish on roof: 2 KN/m^2

c) Seismic details

- Type of Frame: RC building with SMRF
- Earthquake zone: Zone V
- Type of soil: Hard [Type-I as per IS1893:2016]
- Importance factor: 1.5 [Table no. 8 IS1893:2016]
- Response reduction factor: 5
- Damping of structure: 5%
- Response spectra: As per IS1893:2016
- Time period: 0.075(H) 0.75 [MRF]

Figure1: Plan of the symmetrical building with fixed base

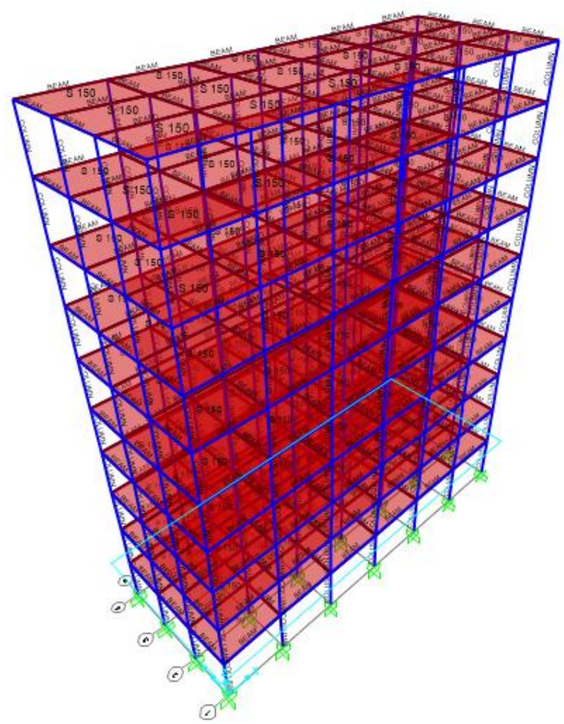

Figure2: 3D view of the symmetrical building with fixed base

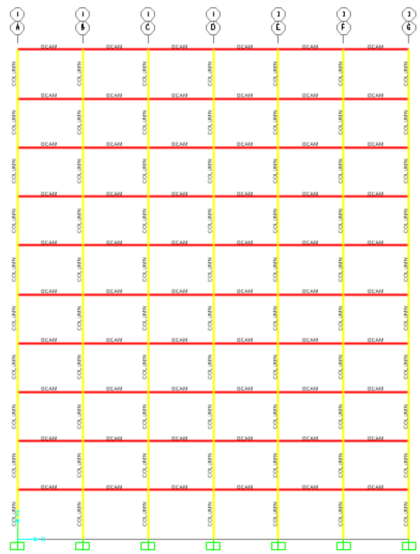

Figure3: Elevation of symmetrical building with fixed base

Figure4: Plan of the Unsymmetrical building with fixed base

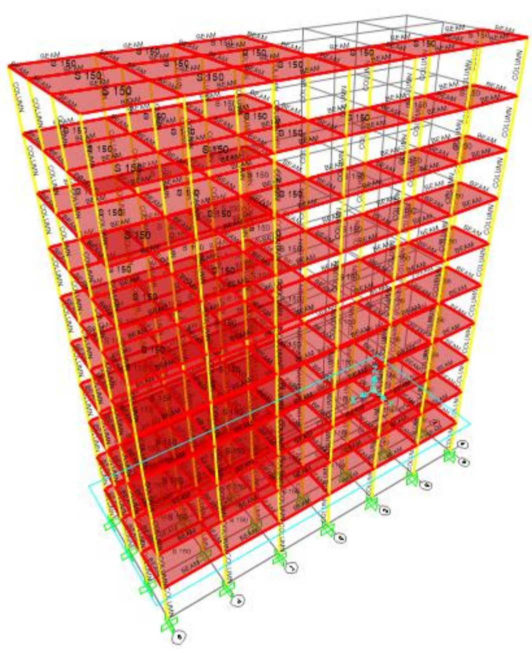

Figure5: 3D view of the Unsymmetrical building with fixed base

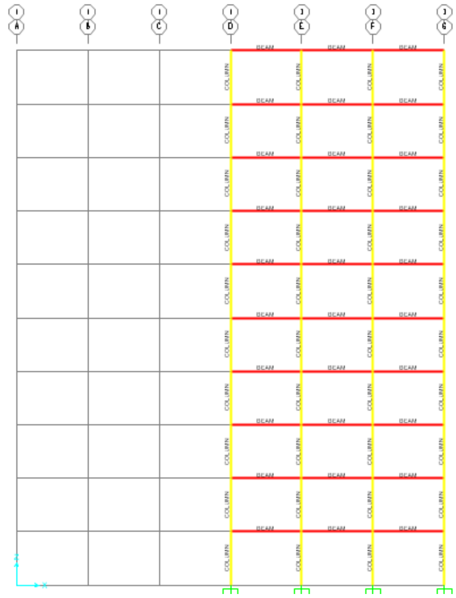

Figure6: Elevation of symmetrical building with fixed base

V. TYPES OF THE ISOLATORS USED

a) Lead Rubber Bearing :

It is formed of a lead plug force-fitted into a pre-formed hole in an elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads. Top and bottom steel plates, thicker than the internal shims, are used to accommodate mounting hardware. The entire bearing is encased in cover rubber to provide environmental protection.

When subjected to low lateral loads (such as a minor earthquake, wind or traffic loads) the lead-rubber bearing is stiff both laterally and vertically. The lateral stiffness results from the high elastic stiffness of the lead plug and the vertical rigidity (which remains at all load levels) result from the steel-rubber construction of the bearing. The period shift effect characteristic of base isolation system developed due to a higher load levels the lead yields and the lateral stiffness of the bearing is significantly reduced. As the bearing is cycled at large displacements, such as during moderate and large earthquakes, the plastic deformation of the lead absorbs energy as hysteretic damping. The equivalent viscous damping produced by this hysteresis is a function of displacement and usually ranges from 15% to 35%.

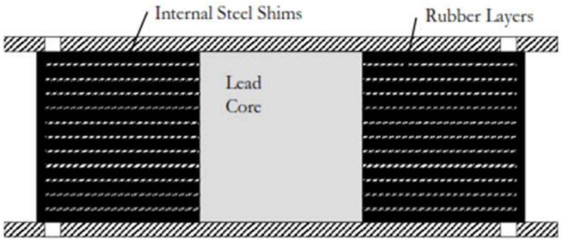

Figure7: Lead rubber bearing section (A.B. M. Saiful Islam et.al)

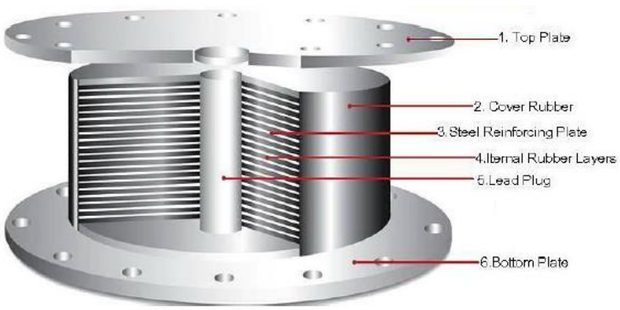

Figure8: Components of the L R B (A.B. M. Saiful Islam et.al)

A major advantage of the LRB system is it combines the functions of rigidity at service load levels, flexibility at earthquake load levels and damping into a single compact unit. These properties make the lead-rubber bearing the most common type of isolator used where high levels of damping are required (in high seismic zones) or for structures where rigidity under services loads is important (for example, bridges). As for HDR bearings, the elastomeric bearing formulas are also applicable for the design of LRBs.

Table 1: Parameters of the LRB system

Parameters in U_1 Direction	
Linear Effective Stiffness	376025.5 KN/m
Effective Damping	0.15
Parameters in U_1 and U_2 Direction	
Linear Effective Stiffness	752.051 KN/m
Effective Damping	0.15
Non Linear Effective Stiffness	5686.6621 KN/m
Yield Strength	156.9144 KN
Post Yield Stiffness Ratio	0.1

b) Friction Pendulum Bearing :

Although a large number of curved shapes are possible, only curved sliding bearing has been extensively used in the construction practice which the sliding surface is spherical in shape rather than flat, termed the Friction Pendulum System.

The isolator provides a resistance to service load by the coefficient of friction, as for a flat slider. Once the coefficient of friction is overcome the articulated slider moves and because of the spherical shape, a lateral movement is accompanied by a vertical movement of the mass. The total force resisted by a spherical slider bearing is directly proportional to the supported weight. If all isolators in a project are of the same geometry and friction properties and are subject to the same displacement then the total force in each individual bearing is a constant time the supported weight. Because of this, the center of stiffness and center of mass of the isolation system will coincide and there will be no torsion moment.

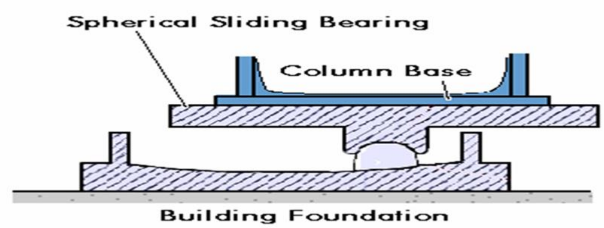

Figure9: Friction pendulum bearing section (A.B. M. Saiful Islam et.al)

Table 2: Parameters of the FPB system

Parameters in U_1 Direction	
Linear Effective Stiffness	1500000 KN/m
Effective Damping	0.15
Non Linear Effective Stiffness	1500000 KN/m
Damping coefficient	1.35
Parameters in U_1 and U_2 Direction	
Linear Effective Stiffness	752.051 KN/m
Effective Damping	0.15
Non Linear Effective Stiffness	12076.553 KN/m
Friction coefficient, slow	0.03
Friction coefficient, fast	0.06
Rate parameter	40
Radius of sliding surface	8.11m

VI. METHOD OF ANALYSIS

To know the linear dynamic behaviour of the different framing system response spectrum method is used.

Response spectrum method:

To know the topmost response of the building during the earthquake is obtained from the response spectrum method. This method gives earthquake response spectrum based on the type of soil condition. This method provides an approximate response but it is very beneficial for the structural design aspect. This method reflects the distribution of the forces up to the elastic range efficiently and also shows the effect of the higher modes of vibration. This method is applicable for the regular and irregular building without any height restrictions.

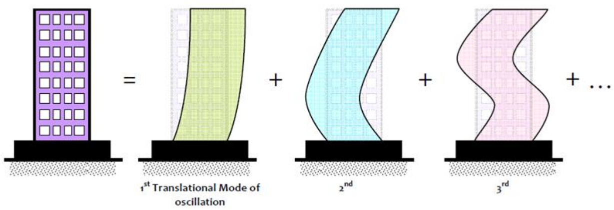

Figure10: Idealisation of Response spectrum method

VII. RESULTS AND DISCUSSION

The results obtained from the response spectrum method for the fix base structures and base isolated structures like Lead Rubber Bearing system and Friction Pendulum Bearing system are as follows

A. Symmetrical structure:

1. Fundamental natural time period:

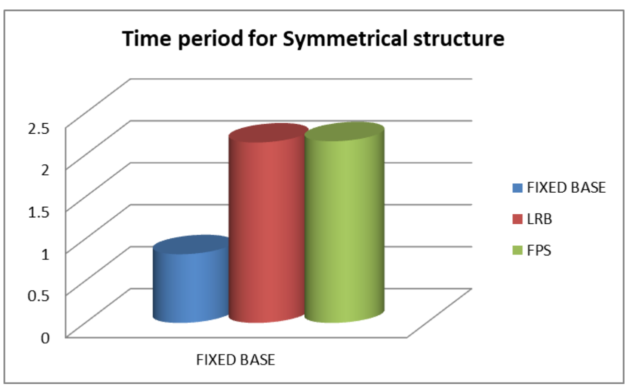

Figure11: Fundamental Natural Time Period

2. BASE SHEAR:

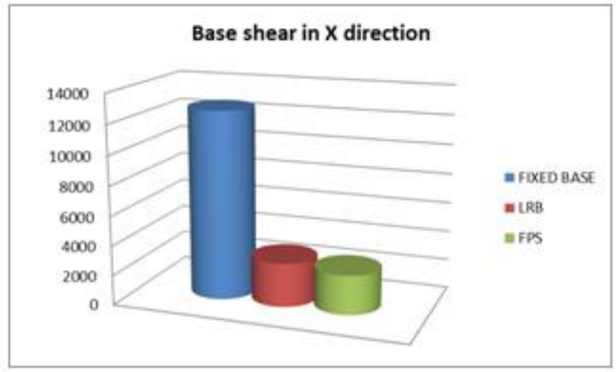

Figure12: Base Shear in X direction

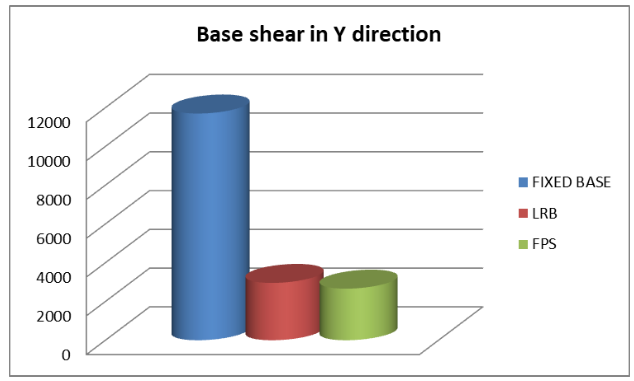

Figure13: Base Shear in Y direction

3. STOREY DRIFT:

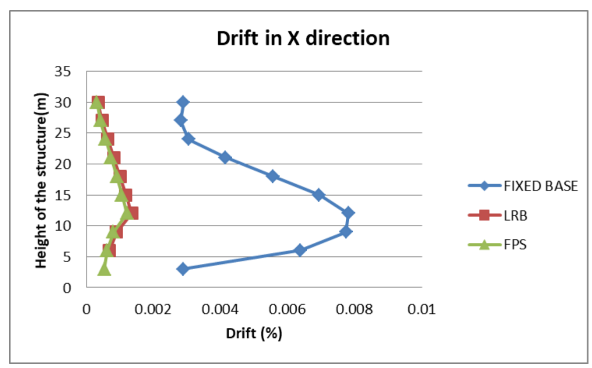

Figure14: Storey Drift in X direction

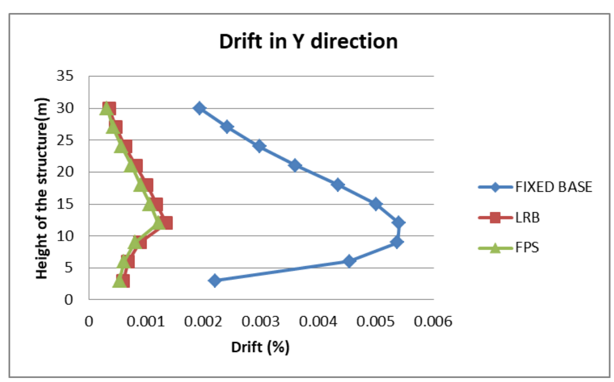

Figure15: Storey Drift in Y direction

4. STOREY DISPLACEMENT:

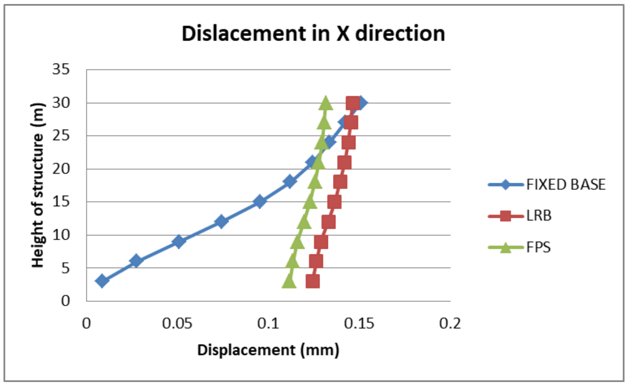

Figure16: Storey Displacement in X direction

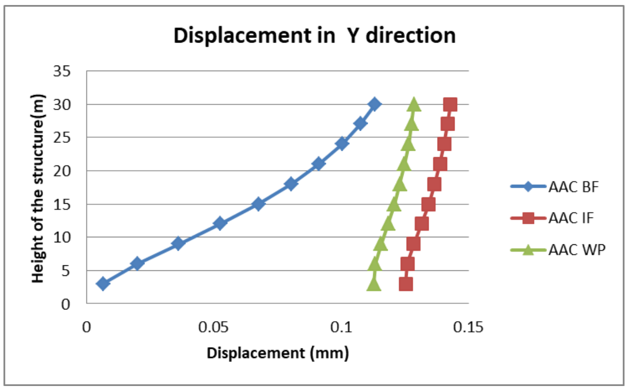

Figure17: Storey Displacement in Y direction

5. STOREY ACCELERATION:

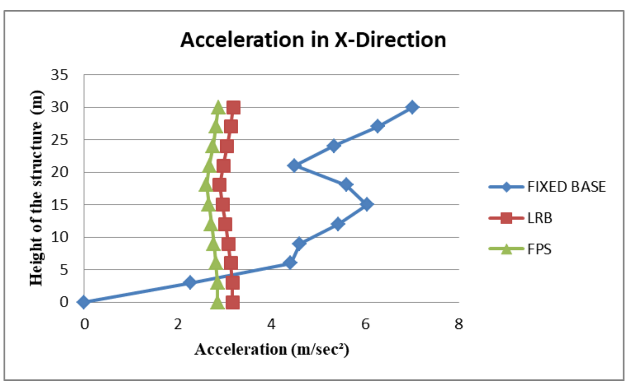

Figure18: Storey Acceleration in X direction

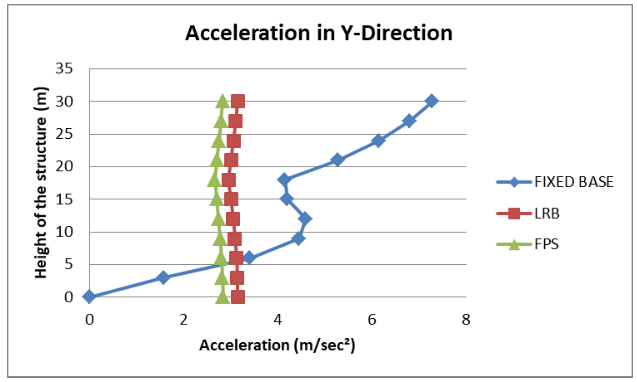

Figure19: Storey Acceleration in Y direction

B. UNSYMMETRICAL STRUCTURE:

1. FUNDAMENTAL NATURAL TIME PERIOD:

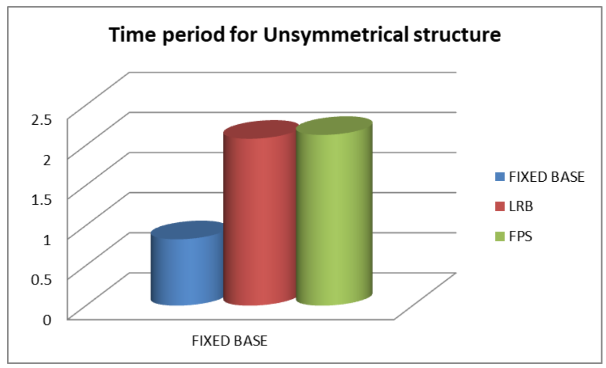

Figure20: Fundamental Natural Time Period

2. BASE SHEAR:

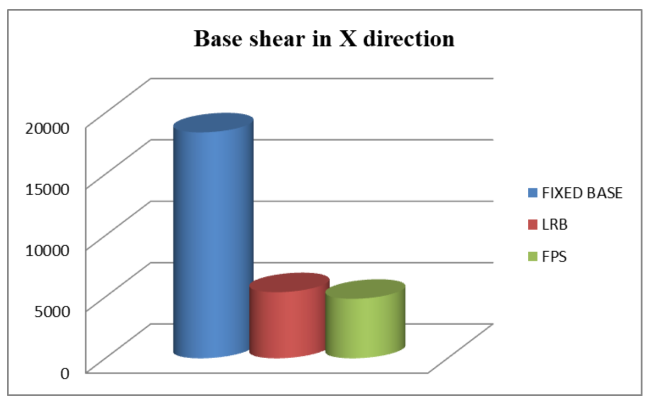

Figure21: Base Shear in X direction

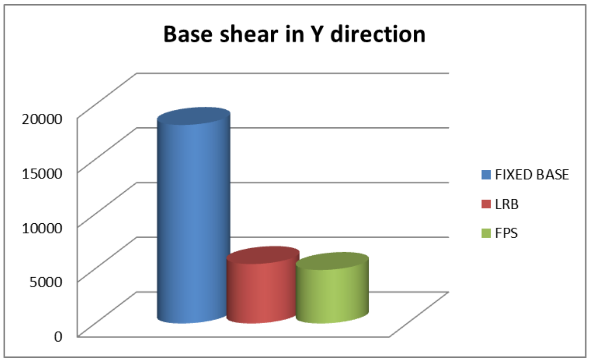

Figure22: Base Shear in Y direction

3. STOREY DRIFT:

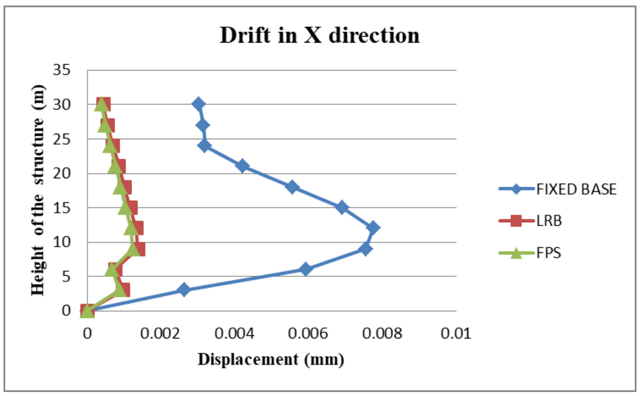

Figure23: Storey Drift in X direction

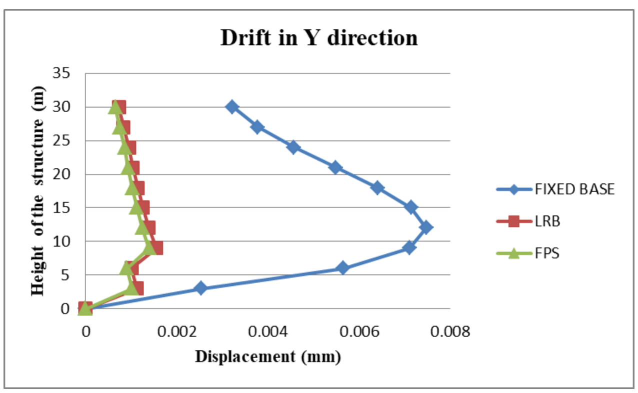

Figure24: Storey Drift in Y direction

4. STOREY DISPLACEMENT:

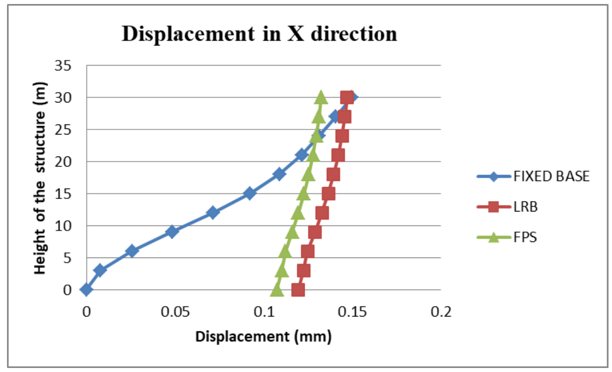

Figure25: Storey Displacement in X direction

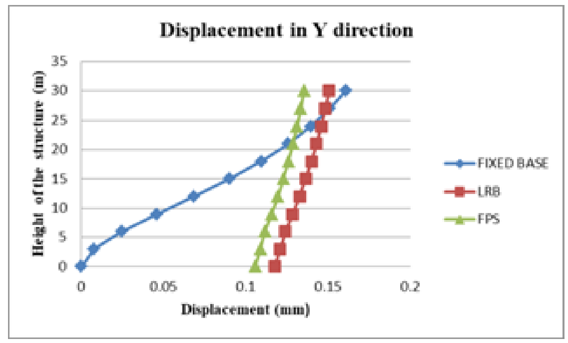

Figure26: Storey Displacement in Y direction

5. STOREY ACCELERATION:

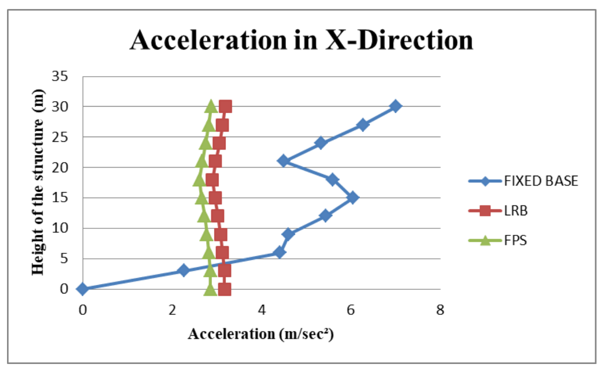

Figure27: Storey Acceleration in X direction

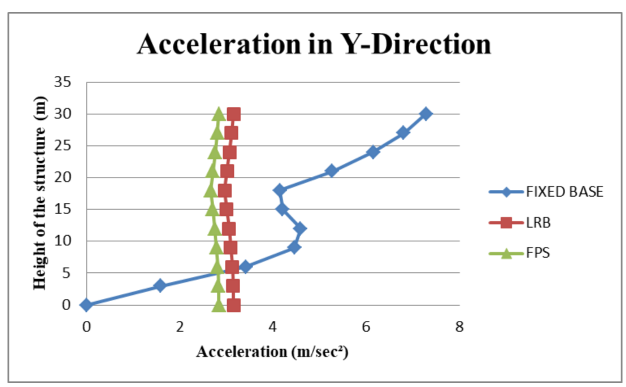

Figure28: Storey Acceleration in Y direction

The following observation can be drawn from the from the results obtained from the response spectrum method

1) Time period of the fixed base structure is found very less as compared to the isolated structures with LRB and FPS. This is because of the structure was separated from the ground in case of the isolator. The time period of the LRB is minutely greater than FPS system and both provides flexibility to the structure. All models have time period within permissible limit provided codal provisions of IS 1893:2016.
2) Base shear in fix base model is found much more as compared to LRB and FPS models. Base shear is a function of the fundamental natural time period and seismic zone. The base shear of the FPS is less than the LRB system.
3) The drift of the LRB and FPS models are less than fixed base models but are in permissible limit as prescribed by the codal provision of IS 1893:2016. It is again due to the flexibility of isolated structure when compared to fixed base structures. Hence introduction of base isolation system also reduces the drift of the building.
4) In all the systems, lateral displacement of the building is within the permissible limit as per codal provisions of IS1893:2016. The displacements of the LRB and FPS models are less than fixed base models. The displacement is reducing in case of the base isolated structure because the reduction in the lateral load due to provisions of the bearing at the base of the structure.
5) The fundamental principle of the base isolation system is to prevent entry of the ground acceleration in the structure. From the results obtained for acceleration it is observed that acceleration of fixed base structure is much higher than the fix isolated structure like FPS and LRB. The acceleration of the FPS is significantly less as compared to LRB bearing system.

VIII. CONCLUSION

1) Storey displacement, storey acceleration, base shear and drifts are reduced considerably in case of the base isolated structure than the fixed base structure for symmetrical and unsymmetrical building in both directions. In all the case storey displacement and drifts are within permissible limit as per codal provision of IS1893:2016.
2) From the linear dynamic analysis, the fundamental natural time period of the fix base is much less as compared base isolated system for all models considered. The time period obtained from the analysis is in comparison with the empirical expression given by the code.
3) The base shear is much greater for fix base structure as compared base isolated structure for all models in both x and y-direction.
4) From the linear dynamic analysis for multi storey symmetrical and unsymmetrical structures, the Storey displacement, storey acceleration, base shear and drifts are considerably less in case of the FPS models than the LRB models.
5) Finally it is concluded that base isolation system is significantly effective to protect the structures against moderate as well as strong earthquake ground motion.

IX. ACKNOWLEDGEMENT

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