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Response of High Rise Building With Lead Rubber Bearing, High Damping Rubber Bearing and Friction Pendulum System

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Abstract- *It has always been difficult for structural engineers to protect structures against earthquakes because safety is the primary concern for civil constructions in a seismically active zone. Base isolation technology, which may be used to retrofit both new and existing structures, has grown in popularity over the past few decades in the field of seismic protection. This study's goal is to assess how Delhi, which is in zone IV, will respond to various seismic isolation techniques when constructing a building. Firstly, the design of base isolation systems, i.e. lead rubber bearing (LRB) High Damping Rubber Bearing and friction pendulum bearing (FPB) by using UBC 97 and IBC 2000 Codes . The building was modelled and the analysis was carried out by using SAP2000 software is used for response spectrum analysis. This finite element analysis software is utilized to create model and to perform analyses. Five models of G+18 building i.e one model of fixed base building ,three models of base isolated building are used for this comparative study of base isolation system and one model of optimum base isolation and behavior of building studied by time history analysis on SAP2000 software. Time period, maximum displacement, base shear, and story drift are utilized to express the results. In contrast, the Friction Pendulum System offered the decrease in elastic base shear based on this comparative analysis carried out . Isolation systems increase the basic time period of structures and reduce base shear, which in turn reduces the lateral force imposed due to earthquakes in the structures. Low isolator displacement from LRB was supplied for the adopted bearing properties. By using time history analysis, the study of the best base isolation with FPS based on the linear dynamic analysis (response spectrum analysis).*

***Key Words*: safety, Lead Rubber Bearing (LRB), High Damping Rubber Bearing (HDRB), Friction Pendulum Bearing (FPB), SAP2000, response spectrum analysis , Time History Analysis.**

1. INTRODUCTION

Earthquake is a natural disaster which is experienced throughout the world According to an Indian earthquake zone map of 2002, 59 percent of the country's territory is vulnerable to seismically destruction. therefore civil engineer has come with solution for reducing the damage and made high rise structure earthquake resistant. Every year, earthquakes cause a huge number of fatalities and extensive property damage.. As an outcome, the seismic preservation of the structure has always placed a high priority on the earthquake resistant designs to ensure the safety of e4 the flexibility of the Structure and having adequate damping, constitutes base isolation, a well established seismic protection technique for buildings. The aspect of passive vibration control technology, it is one of the most effective earthquake engineering tools. The fundamental goal of base isolation became to safeguard the buildings by minimizing the effect of earthquakes rather than fighting them.

1.1 Types of base isolation system

1) Lead Rubber Bearing (LRB)

2) High Damping Rubber Bearing (HDRB)

3) Friction Pendulum System (FPS)

1.1.1 Lead Rubber Bearing:

The lead rubber bearings combine the roles of vertical support, stiffness at operating load levels, and horizontal flexibility at seismic loading to offer one of most cost-effective alternative for the base - isolated problems. LRB offers dampening in the ranges from 2% – 3%. Lead Rubber Bearings is rubber bearings with a central lead core that are composed of thin layer of steel laminates & hot vulcanized rubber. By yielding, the lead core's energy dissipation allows for the achievement of an equal viscous damping coefficient of up to about 30%.

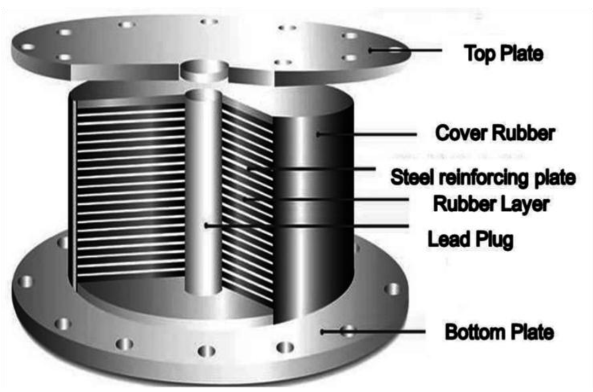

Fig-1: Lead rubber bearing system

1.1.2 High Damping Rubber Bearing:

An example of an elastomeric bearing is a rubber bearing, which offers horizontal flexibility through rubber and vertical rigidity with steel shim plates that are vulcanised inside the rubber. Layers of rubber and steel plates for reinforcement is provided in the HDRB isolators. Due to the interior steel plate, the bearing has a vertical stiffness that is 100 times more than the horizontal stiffness, although it is flexible in the normal direction. A 10 to 20 % damping range is given by HDRB.

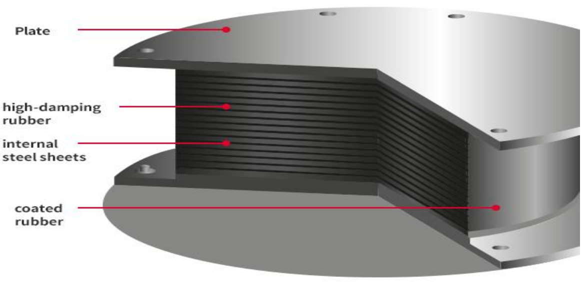

Fig-2: High Damping Rubber Bearing

1.1.3 Friction Pendulum System:

The bearing surface's curvature and diameter can be changed, and the FPS can be configured to fulfil a range of displacement magnitudes. The same theory underlies bearings as a simple pendulum. In the event of an earthquake, the A slider that is articulated Slides make modest, straightforward harmonic motions over a concave surface of the building. Using the bearings, the pendulum's speed, like a basic pendulum. buildings' natural deterioration by causing the building to slide down the concave inner surface of the bearing Deterioration by causing the building to slide down the concave inner surface of the bearing.

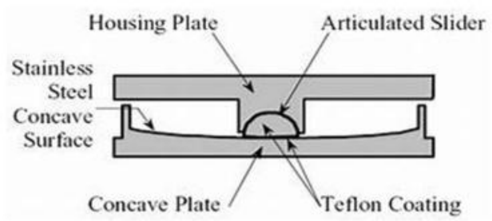

Fig-3: Friction Pendulum system

The three isolation systems for a 19-story reinforced concrete structure in Delhi that is perched on a class-B site are Lead Rubber Bearing (LRB), High Damping Rubber Bearing (HDRB), and Friction Pendulum System (FPS). The three isolation systems for a 19-story reinforced concrete structure in Delhi that is perched on a class-B site are Lead Rubber Bearing (LRB), High Damping Rubber Bearing (HDRB), and Friction Pendulum System (FPS). B are compared in this paper design comparison. The performance of LRB, HDRB, and FPB is demonstrated by a comparison of the findings in terms of duration, maximum isolator displacement, base shear, and story drift of the fixed base and isolated building. The best base isolation was chosen based on analysis of the response spectral data. Time history analysis is done for this best base isolation system.

1.2 Methods Of Analysis

1.2.1 Response Spectrum Analysis

The idealized single degree freedom systems' maximum response to earthquake ground motions when their basic time periods are different but their damping ration is the same. This analysis's method permits numerous modes of a building's reaction to be taken into consideration for the frequency response. Many building rules mandate this, with the exception of relatively straightforward or incredibly complicated structures. The "harmonics" in a vibrating string correlate to a variety of different kinds (modes) that make up a structure's reaction. These modes can be found for a structure through computer analysis Based on the modal mass and modal frequency, which are subsequently combined, the design spectrum responses to each mode.

1.2.2. Time History analysis

Nonlinear dynamic analysis can generate conclusions with relatively low uncertainty since it combines ground motion data with a thorough structural model. When the model is subjected to a ground motion, estimates of constituent deformations are made for each degree of freedom recording for nonlinear dynamic research. The modal responses are then integrated using methods like the sum of all square roots & dynamic nonlinear analysis includes a time history analysis that takes the structure's non-linear properties into consideration. Estimates of component deformations are created for each degree of freedom in the model when it is subjected to a ground motion recording for nonlinear dynamic research. The modal responses are then integrated using methods like the sum of squares at the square root. Dynamic nonlinear analysis includes a time history analysis that takes the structure's non-linear properties into consideration. For structures with unusual geometries or of particular significance, the toughest approach is required by some building regulations. The predicted response, however, may be highly dependent on the parameters of each ground motion employed as seismic input.

a) Modal time history analysis (Non-linear)

b) Direct integration time history analysis(non-linear)

In this paper time history analysis of base isolated building is carried out by modal time history analysis.

2. OBJECTIVES

The following are the objectives of the planned dissertation work:

1) Formulation of problem statement, developing of methodology and possible validation with high quality research article.

2) To examine the effect of various base isolation systems on seismic performance of high rise structures.

3) To compare seismic performance of fixed base and base isolated high rise structures.

4) To evaluate non-linear seismic performance of high rise structures with optimal base isolation system.

3. MODELLING OF BUILDING

For the study, In order to study the effect of the base isolation on high rise building, a building situated in Delhi region is considered. Three dimensional 19 story reinforced concrete (SMRF) residential building is considered. The building falls zone IV as per IS 1893:2002. The building has symmetrical plan in both two directions and number of bays considered in each direction is four. The thickness of wall is considered 0.230m for exterior and interior partitions .The plan for Square building is 12x12m The building is considered with the lift. Shear wall are used in the interior core region of lifts. The dead loads confirming IS 875 Part-1, 1987 and imposed loads confirming IS 875 Part 2 of the RC buildings are taken. Soil type B- medium or stiff soil. Time history analysis is done as a parameter to study the behavior of buildings by nonlinear dynamic analysis. The buildings square in plan are studied by Response spectrum analysis and Time history analysis to calculate the maximum storey drift, base shear and acceleration .Five building were modelled for the study of effect of base isolation as per the new version of

- IS 1893:2016 for zone IV, soil type II for fixed base the building.
- IS 1893:2016 for zone IV, soil type II And Use lead rubber isolation
- IS 1893:2016 for zone lV, soil type II and use high damping rubber isolation
- IS 1893:2016 for zone lV, soil type II and use friction Pendulum system
- IS 1893:2016 for zone IV, soil type II and use friction Pendulum System (Time History Analysis)

3.1 Preliminary Data:

Sr.No	Building Specifications	Type/size/weight
1	Structure	SMRF(Special Moment Resisting Frame)
2	No. of Stories	19
3	Floor to floor height	3m
4	Size Of Building	12m x 12m
	Member Properties	
1	Beam Size	250mm X 450mm
2	Grade of Beam	M25
3	Column Size	350mmX 750mm
4	Column Grade	M30
5	Slab Thickness	150mm
6	Slab Grade	M25
7	Thickness of wall	230mm
	Seismic Properties(As per 1893:2002)	
1	Zone factor	0.24
2	Importance factor	1
3	Response Reduction factor	5
4	Soil Type	II(Medium Soil)
5	Seismic Zone	IV
	Material Properties	
1	Grade of Concrete	M25 & M30
2	Grade of Steel	Fe415
3	Density Of Steel	78.5 KN/m3
4	Density of Reinforced Concrete	25 KN/m3
5	Brick Specific weight	19 KN/m3
6	Live load	3 KN/m2

6. STRUCTURE FIGURES

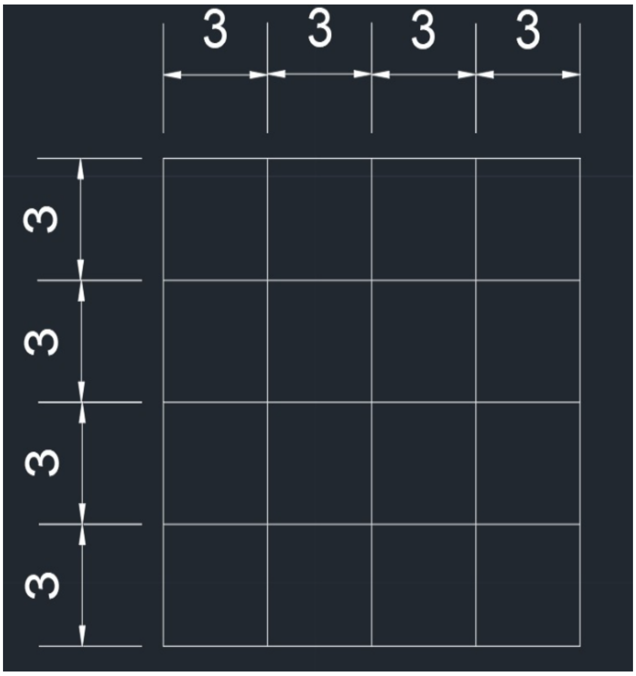

Fig-4: Plan (X-Y Plane)
(All Dimensions are in m)

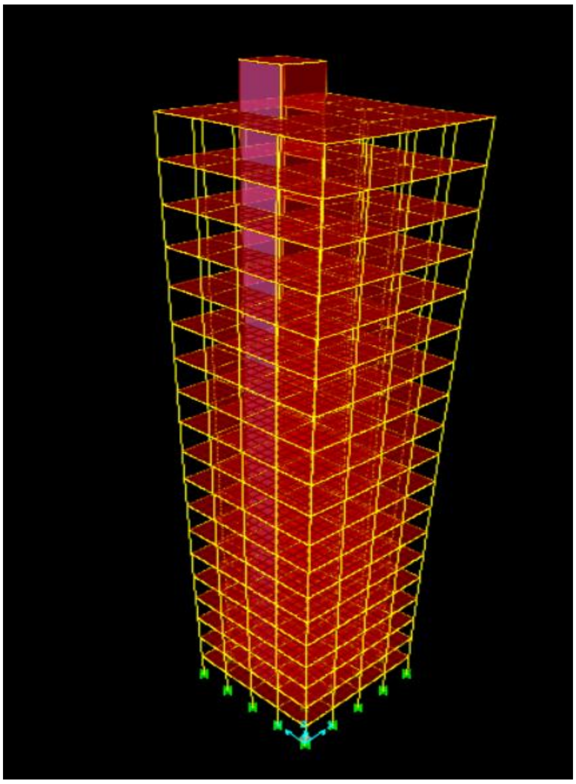

Fig-6: 3D View of structure

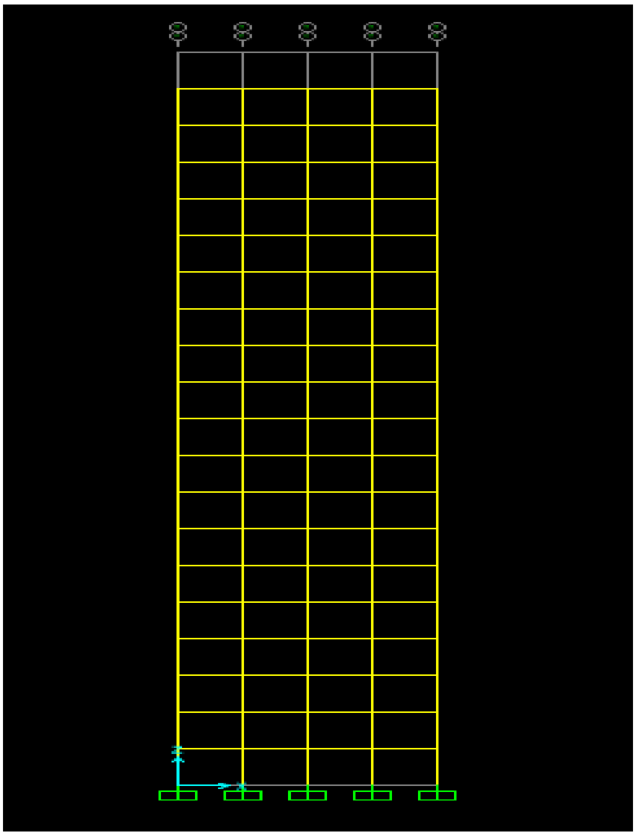

Fig-5: Elevation (X-Z Plane)

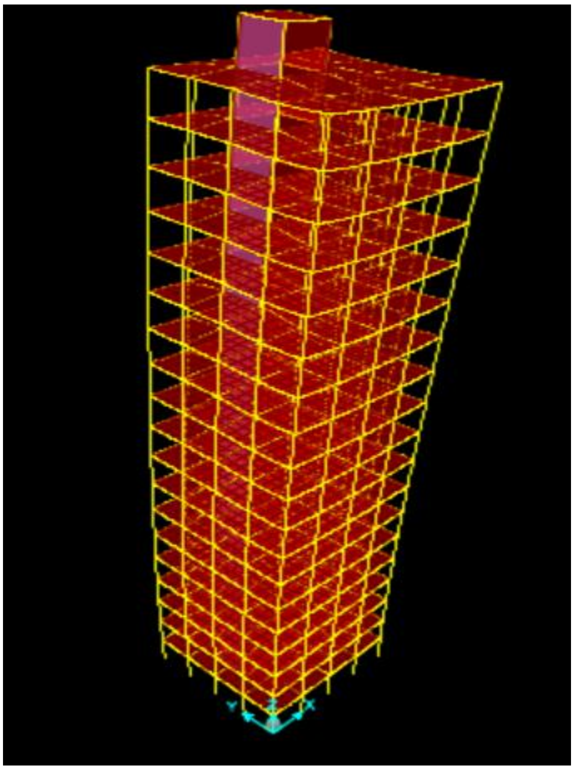

Fig-7: Deformed shape of building

From fixed base model maximum of base reaction force 3434KN which is in vertical direction. For a maximum base reaction , base isolation system is designed. According to Naeim and Kelly's documented Uniform Building Code (UBC 97) and International Building Code 2000 (IBC 2000), the design of new seismically isolated structures will likely be controlled by one of these two codes.. Based on this link Properties of the LRB, HDRB and FPB System are designed for the maximum base reaction .Maximizing the seismic performance of the building required designing and analyzing the stiffness parameters of the bearings.

Firstly, base isolator properties used for response spectrum method are linear properties only and for time history analysis non-linear link properties used. For time history analysis the earthquake of "Friuli_ Italy-01" in 1976 at station "Conegliano" chosen and The ground motion of this earthquake are matched by using 'SeismoMatch' software for given soil condition and seismic zone.

4. RESULTS AND DISCUSSION

4.1 Maximum Time Period

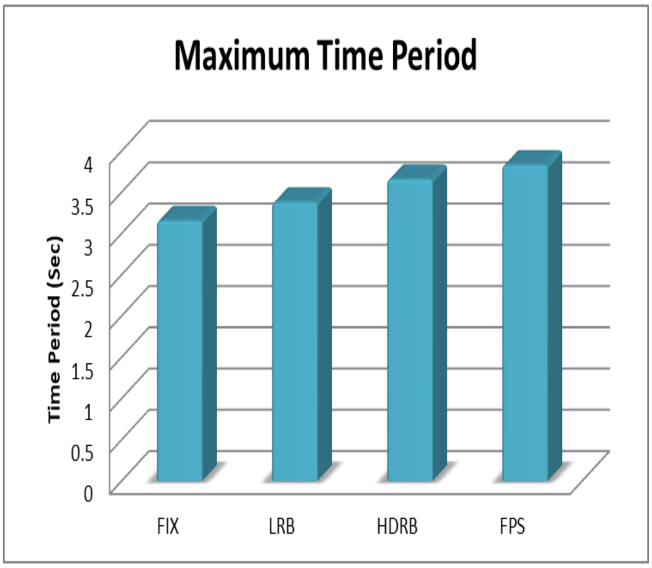

Fig-8: Maximum time period

The above Fig-8 for a 1st mode time period for a fixed base building is minimum(3.155 sec) and for FPS is maximum(3.828 sec).As mode changes from 1 to 12 time period for structure goes on decreasing and frequency increasing.

4.2 Maximum Base Shear:

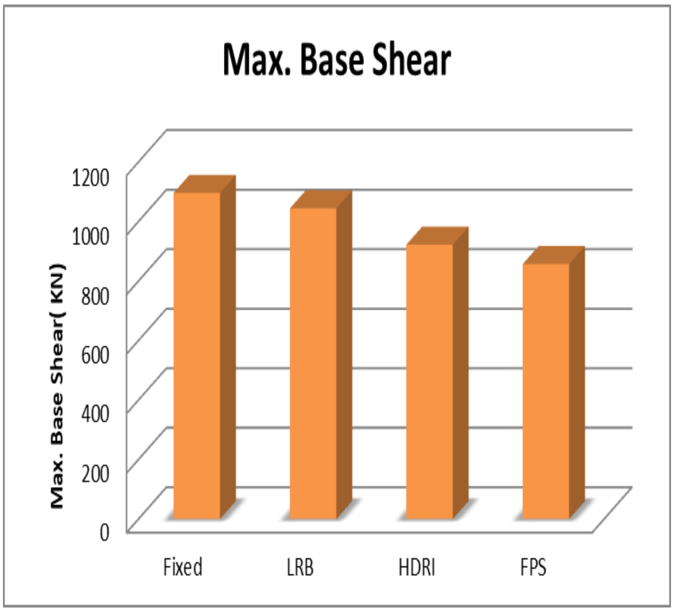

Fig-9: maximum Base Shear

The above Fig-9 shows that the maximum base shear for fixed base structure is maximum i.e 1095.4 KN and for FPS base isolated structure dreceses to 856.533 KN.

4.3 Maximum Displacement:

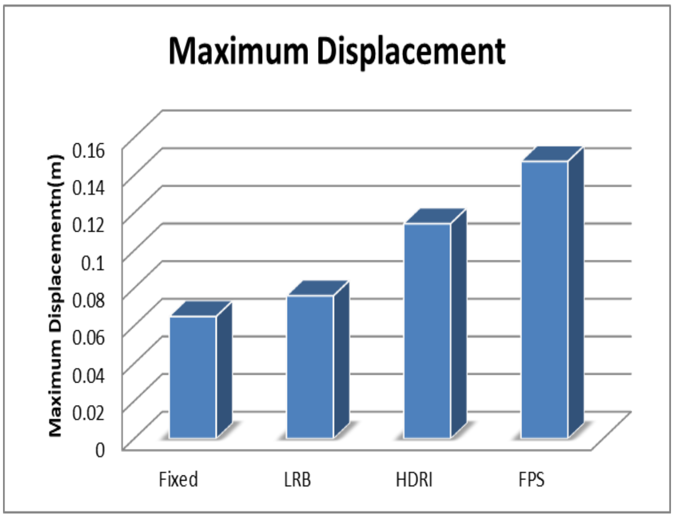

Fig-10: maximum Displacement

The maximum displacement for fixed base is minimum(0.0649m) as compared to LRB,HDRB and FPS base isolated structure as shown in above Fig-10. The displacement for base isolated with FPS structure is maximum(i.e.0.147m).

4.4 Story Drift

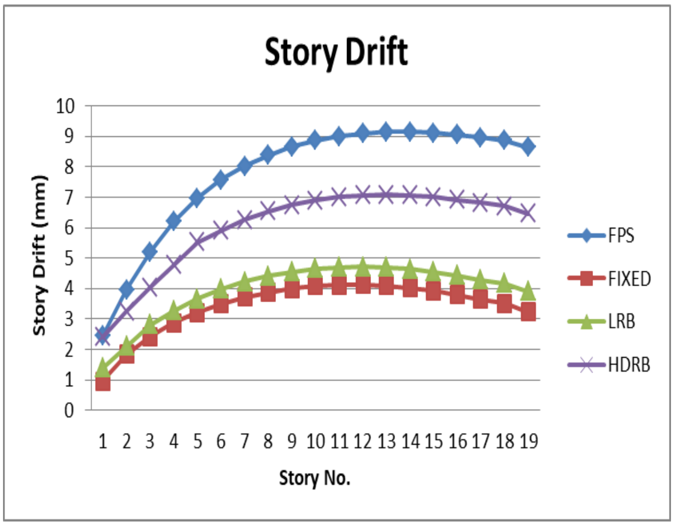

Fig-11: Story Drift

Above Fig-11 shows that the story drift for fixed base building is minimum as comapred to the base isolated building. In base isolated System,friction pendulum system has higher story drift as compared to building with LRB and HDRB isolator.

4.5 Response spectrum Curve :

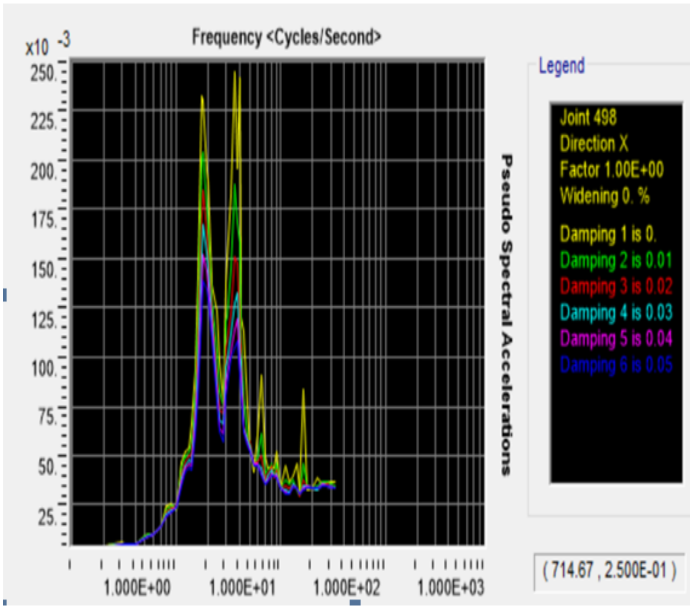

Fig-12: Response spectrum curve for FPS

The above graph gives the pseudo spectral acceleration in X direction for a damping upto 5% For sa friction pendulum Isolator.

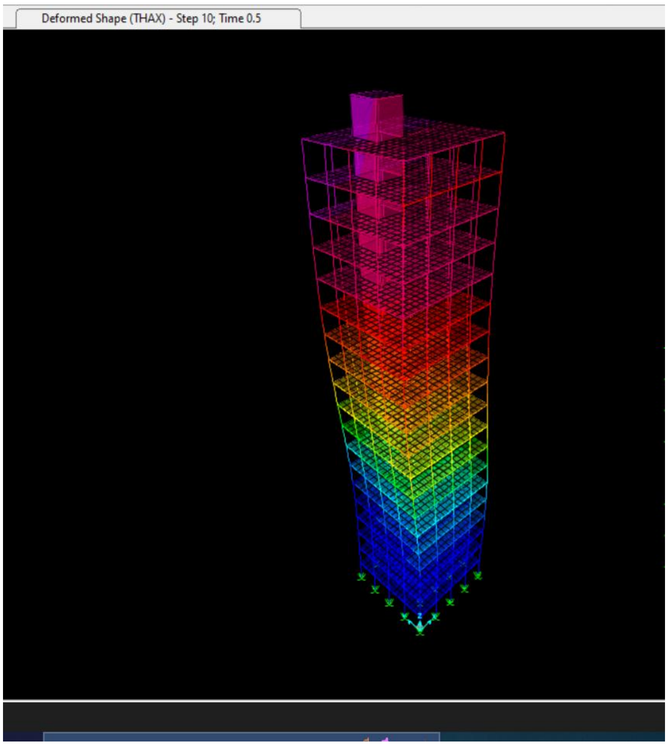

Fig-13: Deformed shape of building at 0.5 sec in X Drection.

The above Fig-13 shows that the building deformed in X-direction in time history analysis at the time of 0.5 second.

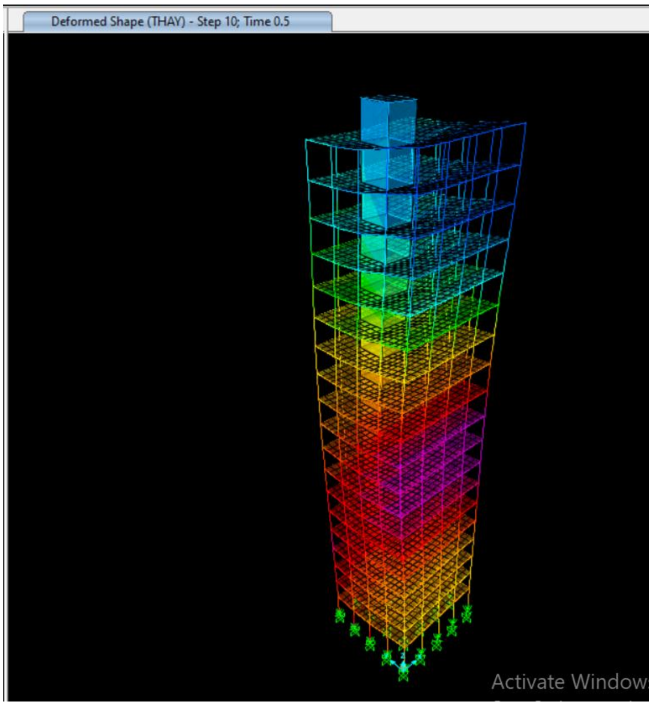

Fig-14: Deformed shape of building at 0.5 sec in Y Drection.

The above Fig-14 shows that the building deformed in y-direction in time history analysis at the time of 0.5 second.For the time history analysis, top story displacement is 204.6 mm in x direction at 5 sec and Bottom story displacement is 6.76mm in X direction at 4.85 sec. Base Shear in X direction is 698.90 KN and in Y direction is reduced to 589.64 KN. Acceleration at the top of story is 472.5mm/s2 and for the Y direction and Acceleration at the bottom story is 93.12 mm/s2.

5. CONCLUSIONS

i) For fixed base building time period is minimum as compared to base isolated structure i.e. due to base isolation time period of structure is increased . FPS isolation system provides more time period than HDRB and LRB isolation systems.

ii) All other buildings having a base isolation system exhibit an increase in lateral displacement at the base of building and displacement of fixed base buildings displays zero displacement at base Similarly, lateral displacement in base isolated buildings as compared to fixed base buildings buildings drastically rises with height. In comparison to LRB and HDRB isolators, the FPS base isolator provides higher displacement.

iii) For a fixed base building base shear is maximum as compared to base isolated buildings. A building with FPS isolator shows minimum base share as compared to LRB and HDRB isolator.

iv) The story Drift of Fixed base Building is minimum as compared to building with base isolator. For building with FPS isolator is maximum as compared to LRB and HDRB isolator. The maximum story drift of building with FPS isolator should be within a limit as per IBC 2000.

v) Based on the results, it was found that among three isolators, FPS base isolator give better performance compared to HDRB and LRB isolators.

vi) The non-linear time history analysis of building with FPS isolator shows that the higher displacement and base share also reduces as compared to response spectrum analysis and this method gives the actual behaviour of the building.

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