Comparative study of base isolated structural system for different aspect ratio of height to plan dimension

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Abstract- *Conventional seismic design attempts to make building that do not collapse under strong earthquake shaking, but may sustain severe damage to non-structural elements as well as some structural members. This may render the building non-functional after the earthquake, which is not acceptable for important buildings, like hospitals. Special techniques are required to design buildings such that they will not suffer damage even in a severe earthquake. One of the technologies used to protect buildings from damaging earthquake effect is "Base Isolation". The idea behind base isolation is to isolate the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least greatly reduced. This paper presents the seismic behaviour of G+3 R.C.C frame structure with different base isolators. Two types of base isolators are considered namely Lead Rubber Bearing (LRB) and Friction Pendulum System (FPS). Isolators are designed for different aspect ratio of height to plan dimension (h/a=0.4, h/a=0.7, h/a=1, h/a=1.3). Response quantities like time period, story displacement and story shear will be extracted for building with fixed base and building with isolated base by performing Response Spectrum Analysis (RSA) and final conclusion will be made on the bases of study.*

Keywords- Seismic Isolation, Comparative Study, lead Rubber Bearing, Friction Pendulum System, RC Building, Response Spectrum Analysis, Storey Displacement, Storey Drift, Base Shear.

I. INTRODUCTION

Safety is the major affair for civil structures in a seismic active zone. It has always been a challenge for structural engineers to protect structures from earthquake.

For many structure, earthquake load is the significant dynamic load. Response to the dynamic load play vital role in the overall design of structure. Structural designer's efforts are directed towards decreasing the dynamic response of the structure. There are two approaches of structure against seismic loads.

The first approach is enhancing capacity of structural components. In this approach, the seismic forces that could act on the structure in this case of earthquake are determined. The demand on the various components is calculated and the components are proportioned to have a capacity sufficiently higher than the demand. Conventional seismic design of framed structures uses this approach which depends on earthquake induced energy through inelastic response in selected components of structural frame.

The second approach is reducing the demand on the structural components. Seismic demand of a structure depends on certain characteristics of the structure. Some modification in these characteristics can decrease the seismic demand. In this approach, such modification is make, and the demand on the structure is ensures to be sufficiently lower than the capacity of the structure. Much research work has been done development of such devices which control the response of earthquake and seismic demand. Among the structural control system developed seismic isolation, which is a passive control system. This is the one of the most alternatives to reduce the demand on structure components. This is secondary device which is provided on the foundation below the main structure.

II. LITERATURE SURVEY

Yogesh P. Patel and Prof. P. G. Patel (IJSRD-2016) [1]:

In this paper studied an regular RC building of 4 storey, 8 storey, 12 storey and 16 storey is modelled and analysed with and without base isolators using Etabs 2015 software. The effect of two different types of seismic isolation systems and are compared with each other and with the fixed base structure in order to decrease the Storey shear and base shear of the structures. The experimental work planned in this project consists of carrying out the analysis in static way (Equivalent Static Analysis) and dynamic way taking the parameters of earthquake

Result from this analysis of maximum increment in time period, 3.55 times & 3.93 times are shown in 12 m structure with FPS and LRB with respect to fixed base structure. Structure with FPS gives lower response compared to structure with LRB in all cases.

M. K. Sharbatdar, S. R. Hoseini vaez, G Ghodrati amiri, H. Naderpour. (Elsevier- 2011) [2]:

This paper compares three systems of 15 story structure with five different seismic protection alternatives as fixed base, rubber bearing, friction pendulum bearing. The parametric study is concentrated on base shear, accelerations and displacements of isolated models. Three dimensional nonlinear time history analysis is performed on RC building model for fixed base case with respect to the seismic isolation and earthquake protection alternatives. In the analysis, total base shear forces, story shear forces, maximum absolute accelerations and relative story drifts are compared and results are compered.

Numerical results from the models fewer than 4 records of Imperial Valley earthquake show that the value of maximum base displacement can be differed up to 66% in a zone restricted within a distance of about 4km from the ruptured fault

Sarang M. Dhawade and Srikant M. Harle. (IJESRT-2014) [3]:

In this research paper the structural behaviour of (G+14) multi-Storey building with or without base isolation subjected to earthquake ground motion. Analytical seismic response of (G+14) storied building supported on base isolation system is investigated and compared with fixed base building. The modeling procedure of not only fixed base but also of base isolated building in ETAB software is carried out. This review of literature focuses on the design steps of isolators and linear static analysis for isolated building has been discussed. Also the results of various parameters such as the variation in maximum storey displacement, maximum storey drift, lateral loads to stories, and storey overturning moment and storey shear of isolated building is discussed

Arati Pokhrel, Jianchun Li, Yancheng Li. (Applied Mechanics and Materials-2016) [4]:

In their paper discussed the behaviour of the building with different seismic isolation systems in terms of roof acceleration, elastic base shear and inter-storey drift under four benchmark earthquakes, namely, El Centro, Northridge earthquakes. Firstly, the design of base isolation systems, i.e. lead rubber bearing (LRB) and friction pendulum bearing (FPB) for five storey RC building was introduced in detail. The nonlinear time history analysis was performed in order to determine the structural responses whereas Bouc-Wen Model of hysteresis was adopted for modelling the bilinear behaviour of the bearings.

Zaheer UI Hassan Samdani, Ravichandra, Banulatha G. N. (IJARET-2015) [5]:

In this paper studied an irregular RC building of G+10 storeys is modelled and analysed with and without base isolators using SAP 2000 software of version 14.2.4. The effect of two different types of seismic isolation systems and are compared with each other and with the fixed base structure in order to decrease the Storey shear and base shear of the structures. The experimental work planned in this project consists of carrying out the analysis in static way (Equivalent Static Analysis) and dynamic way (Time History Analysis) taking the parameters of El-Centro earthquake

Pawan S Gulhane, Anket P Shinagre, Niraj P Jaiswal, Harshankit Singh. (IJFEAT-2015) [6]:

In this paper by using friction pendulum bearing in structure which should substantially decouple a superstructure from its substructure resting on a shaking ground thus protecting a building or non-building structure's integrity. Base isolation method has proved to be a reliable method of earthquake resistant design. Time period of the base isolated structure i.e. FPS Increases as compared to the fixed base structure.

Case study shows that acceleration per unit time considerably reduced by using base isolation devices over the conventional structure

C. Pabha and Basil Sabu. (Transaction on Engineering and Sciences-2014) [7]:

In this paper studied the structural behaviour of multi-storey structure with or without base isolation subjected to earthquake ground motion. The performance of isolator is assessed from variation of base shear, acceleration, displacement, storey drift. Time history analysis has been carried out in the software "SAP2000" using the Imperial Valley Earthquake record of May 18, 1940 also known as the El-Centro earthquake of magnitude 7 is used for obtaining the various responses.

The reduction in displacement is 8.91% at the base for base isolated structure in comparison with fixed base building. Reduction in acceleration at top floor is 53.49% for LRB with 20% damping in comparison with fixed base structures. Reduction in base shear is 50.75% for LRB with

20% damping. Reduction of base shear when compared to fixed base buildings is very much effective when β=20% for 6 storied structure

III. MODEL DEVELOPMENT

In this Section presents the information for model development of R. C. frame building with Lead rubber bearing and Friction Pendulum System in ETABS 2015 Software. The response of RC frame structure in the form of Time period, Story displacement, Story Drift and Story Shear were determined.

The Method of analysis given in IS-1893(Part-1):2002. The modeling procedure of fixed base and base isolated building in ETABS 2015 is carried out.

For the comparison, a G+3 storey building was modelled in ETABS 2015 with different aspect ratio of height to plan dimension (h/a=0.4, h/a=0.7, h/a=1, h/a=1.3) and also compare with Lead rubber bearing and friction pendulum system.

Table 1. Structure Configuration for G+3 Building.

Aspect Ratio(h/a)	:-	0.7
Total height of building(h)	:-	16m
Plan dimension(a)	:-	24mX24m
Story Height	:-	4 m
Bay Width in X-Direction	:-	4 m
Bay Width in Y-Direction	:-	4 m
Column Size	:-	0.450 m X 0.450 m
Beam Size	:-	0.300 m X 0.450 m
Slab Thickness	:-	200 mm
Char. Strength of Concrete	:-	25 N/mm^2
Live Load on Typical Story	:-	3 kN/m^2
Type of Soil –IS 1893:2002	:-	Hard
Importance Factor	:-	1.5
Seismic Zone :IS 1893:2002	:-	V (Z = 0.36)
Response Reduction Factor	:-	5

IV. DESIGN OF ISOLATORS

A complete design for base isolation should ensure that the isolators can supports the maximum gravity service loads of the isolators can provide the dual function of period shift and energy dissipation to the isolated structure during earthquakes.

A. Design of Lead Rubber Bearing

Table 2. Characteristics of Lead Rubber Bearing

Characteristics	Sign	Value	Units
Total Height of Bearing	H	190.6667	mm
Thickness of top and bottom cover	b	3	mm
Overall diameter	B	350	mm
Bounded diameter	d_b	340	mm
Total rubber thickness	T_r	140	mm
Thickness of individual rubber layer	t_i	6	mm
No of rubber layer	N_r	24	Nos
Thickness of steel plates	t_s	2	mm
No of steel plates	N_s	23	Nos
Average Service Load	P_{DL+LL}	562.46	kN
Total Weight	W_T	27560.69	kN
Gravitational Acceleration	g	9.81	m/s^2
Yield Strength of Lead Core	F_{py}	8.82	MN/m^2
Rubber Hardness	-	IRHD 60	
Young's Modulus	E	445	N/cm^2
Shear Modulus,	G	106	N/cm^2
Modified Factor,	k	0.57	

Table 3. Hysteretic properties of Lead Rubber Bearing

Parameters	Sign	Value	Unit
Characteristic strength	Q_d	24.92532	N
Post yield stiffness	K_d	401.8751	kN/m
Initial stiffness	K_u	3588.37	kN/m
Yield displacement	D_y	0.007822	m

Table 4. Parameters of LRB different aspect ratio.

Parameters	h/a=0.4	h/a=0.7	h/a=1.0	h/a=1.3
Effective stiffness K_{eff}	809.41	843.65	886.30	925.97
Effective damping C_b	126.22	126.50	126.49	125.81
Yield strength F_y	28.07	28.07	28.07	28.07
Post yield stiff. ratio Y_r	0.11	0.11	0.11	0.11
Vertical stiffness K_v	8631637	7883717	7105661	6463426

B. Design of Friction Pendulum System

Table 5. Parameters of FPS with different aspect ratio.

Parameters	h/a=0.4	h/a=0.7	h/a=1.0	h/a=1.3
Effective Stiffness,K_{eff}	699.75	791.248	803.05	830.17
Effective damping,C_b	5.05	2.74	1.97	1.636

V. ANALYSIS RESULT

A. Time Period

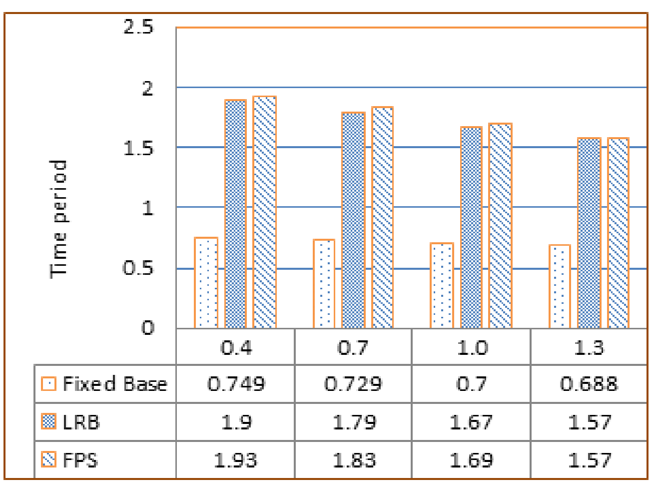


Figure 1. Comparison of Time Period (sec).

B. Maximum Story Displacement.

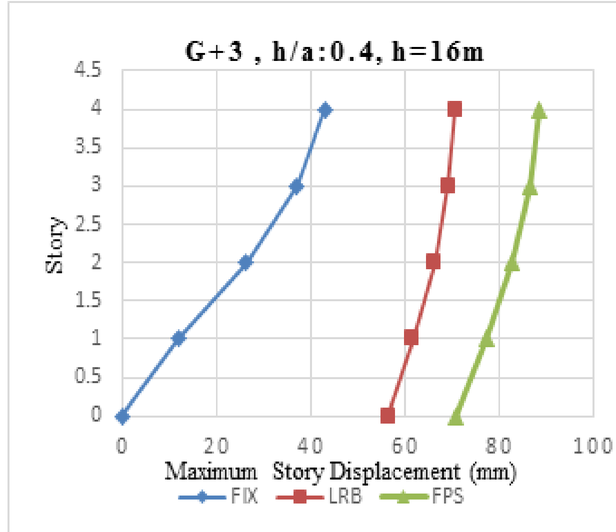


Figure 2.

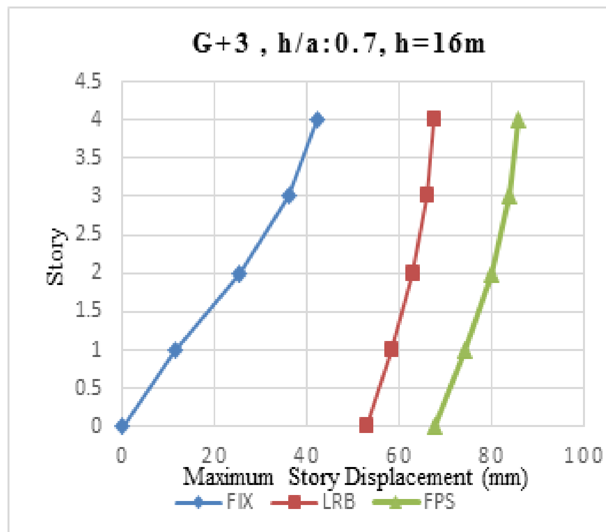


Figure 3.

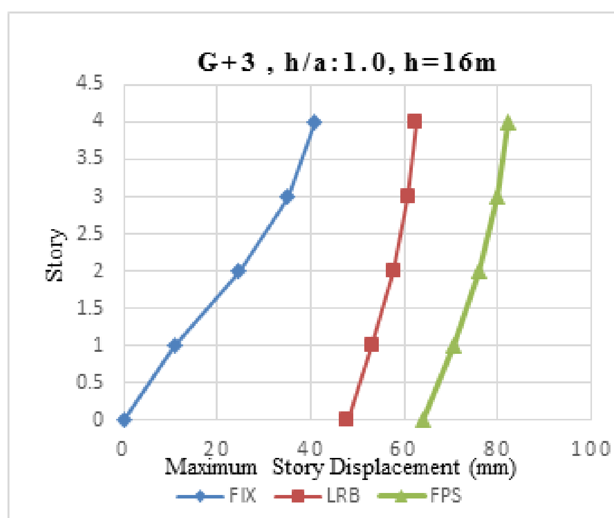


Figure 4.

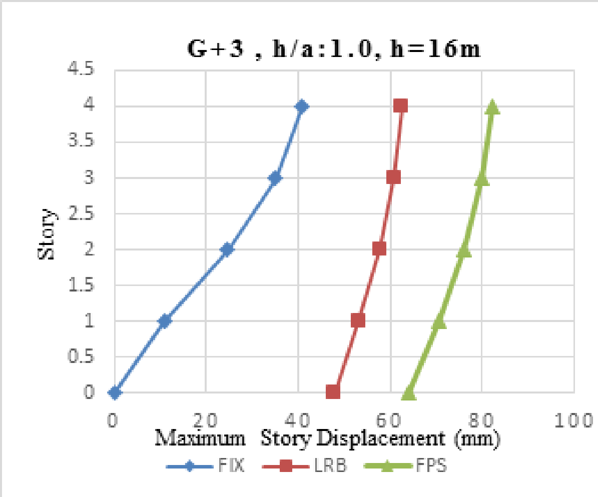
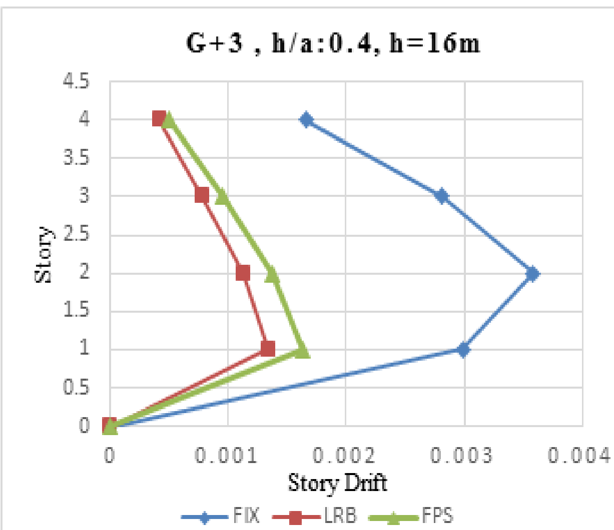


Figure 5.

C. Maximum Story Drift.



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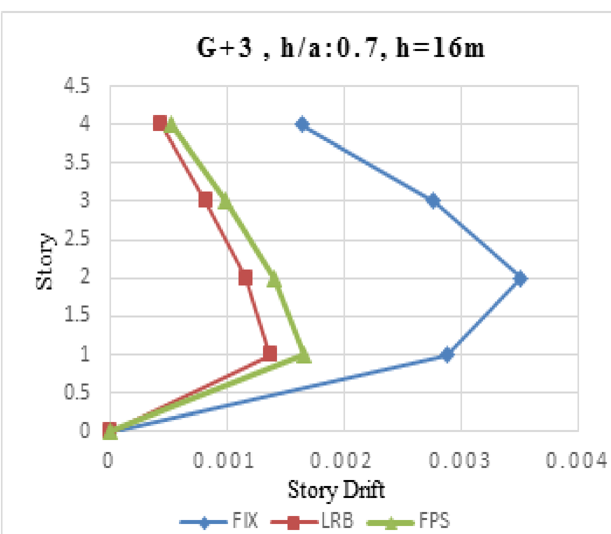

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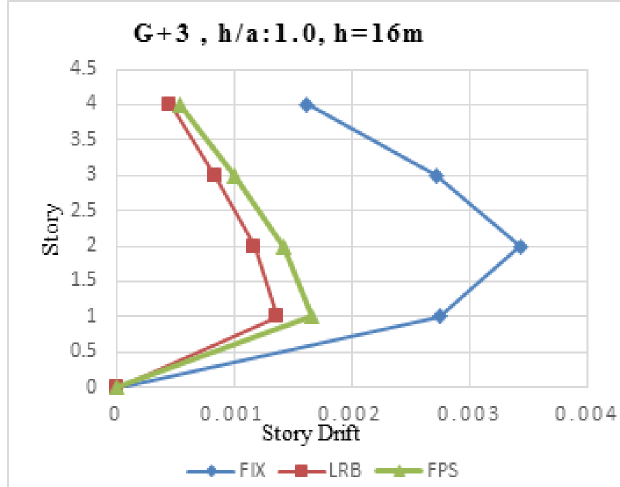

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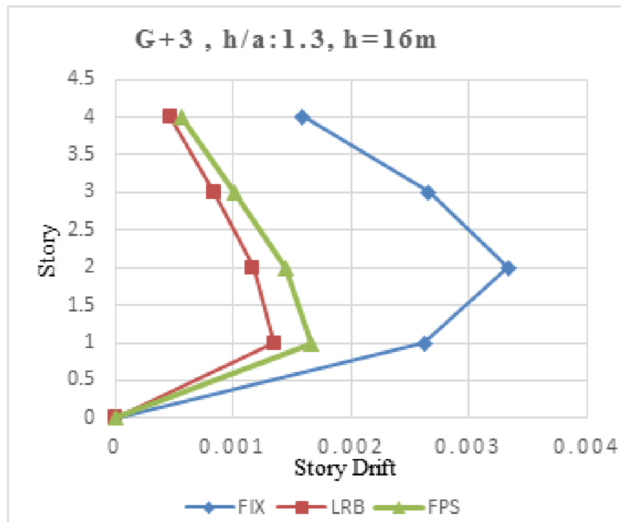
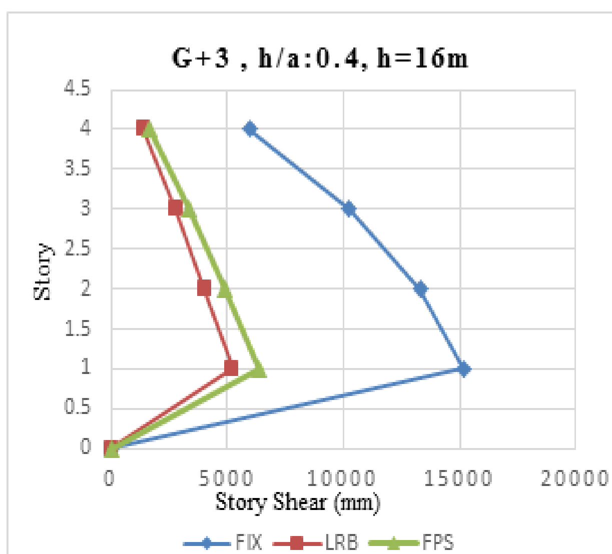


Figure 9.

D. Maximum Story Shear.



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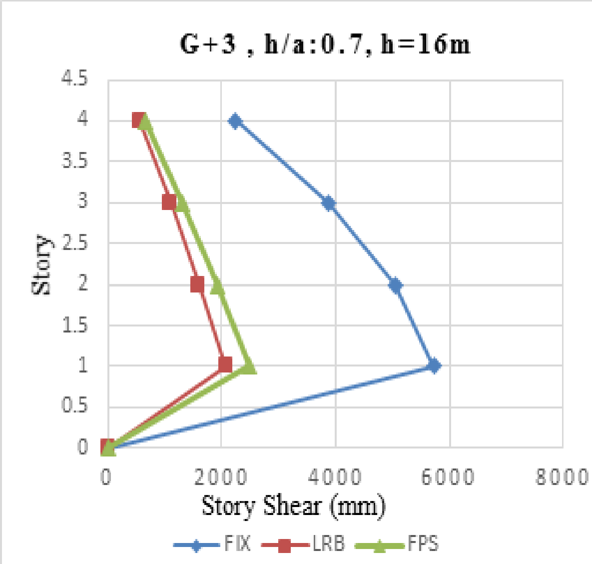

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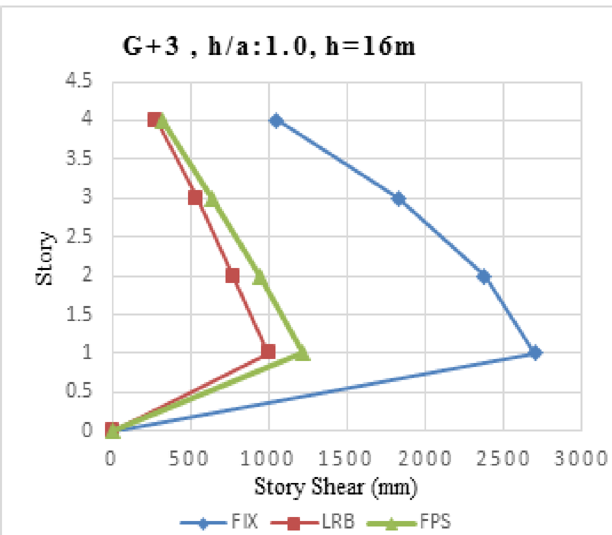

Figure 12.

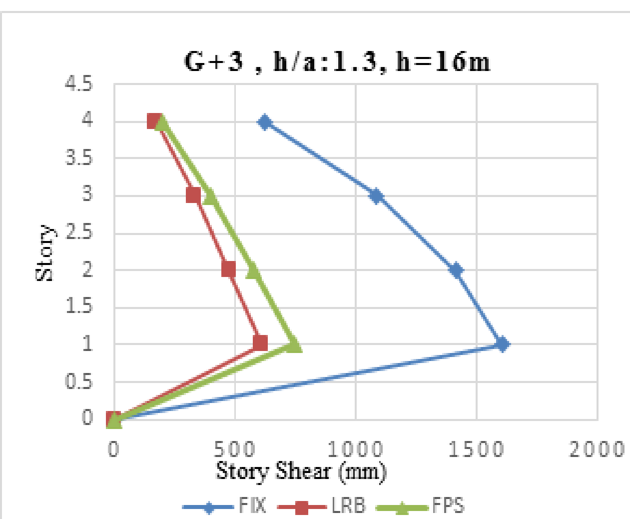

Figure 13.

VI. CONCLUSION

- The significant properties of base isolation system were affected the superstructure to have a rigid moment and a results shows the relative storey displacement and story drift of structural element will decreases and consequently the internal force of beam and column will be reduced.
- The variation in maximum displacement of stories in base isolated model is very low while compared with fixed base model.
- Time period of base isolated structure increases as compared to the fixed base structure.
- Maximum base shear reduction are 65.40% and 58.05% in aspect ratio of G+3 building with lead rubber bearing and friction pendulum system with respect to fixed base structure.
- In every cases base shear always decreased in both isolated structure compared to fixed base structure. But the height to plan dimension aspect ratio increases the rate of base shear also decreases.
- Maximum increment in time period is 1.9 sec and 1.92 sec shown in aspect ratio of 0.4 for G+3 building.
- In every cases time period are always decreased with increased of the height to plan dimension aspect ratio for the G+3 building.

REFERENCES

[1] Yogesh P. Patel and Prof. P. G. Patel (IJSRD-2016). “Comparative Study of Seismic Response of Structure with Different Base Isolators” IJSRD - International Journal for Scientific Research & Development

[2] M. K. Sharbatdar, S. R. Hoseini vaez, G Ghodrati amiri, H. Naderpour. (Elsevier- 2011). “Seismic Response of Base-Isolated Structures with LRB and FPS under near Fault Ground Motions” in Elsevier, ScienceDirect.

[3] Sarang M. Dhawade and Srikant M. Harle. (IJESRT-2014). “Seismic Performance of Base Isolated & Fixed Based RC Frame Structure using”.

[4] Arati Pokhrel, Jianchun Li, Yancheng Li. (Applied Mechanics and Materials-2016). ” Comparative Studies of Base Isolation Systems featured with Lead Rubber Bearings and Friction Pendulum Bearings” Applied Mechanics and Materials

[5] Zaheer UI Hassan Samdani, Ravichandra, Banulatha G. N. (IJARET-2015) “Comparative Study on Performance of Multi-Storey Structure Rubber Bearing and Friction Pendulum Base Isolation Systems” International Journal

of Advanced Research in Education Technology (IJARET).

[6] Pawan S Gulhane, Anket P Shinagre, Niraj P Jaiswal, Harshankit Singh. (IJFEAT-2015). “friction pendulum bearing for building base isolation” international journal for engineering applications and technology

[7] C. Pabha and Basil Sabu. (Transaction on Engineering and Sciences-2014). “Study of Base Isolation in Multi-Storeyed Buildings” Transactions on Engineering and Sciences.

[8] Is 1893(part1):2002,”Criteria for earthquake resistant design of structures, part 1 general provisions and building”.