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Comparison of Different Bearing Types Performance in Multistoried Building

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Abstract*-As the earthquake prone areas are increasing so the need of its resistance structures and their safety has become a prime importance on counter part the need of multi storied building to face the increasing demand of the housing and make the shock proof is a challenge in front of a structural engineer. The paper deals with the comparison of different types of bearing and their performance, the mathematical equation have tried to analyzed the multi storied building with different cases.

I. INTRODUCTION

During the last two decades considerable advances have been accomplished in the area of seismic protection of structures, furthermore new promising systems have been developed which can be incorporated in structures to improve their response when exited by earthquakes. These systems, also known as earthquake-protection systems, consisting of passive, active, semi-active or hybrid devices and can considerably minimize the seismic demand of buildings and structures Seismic base-isolation, which is now recognized as a mature and efficient technology, can be adopted to improve the seismic performance of strategically important buildings such as schools, hospitals, industrial structures, elevated water tanks, residential houses etc. in addition to places where sensitive equipments are intended to protect from the hazardous effects during earthquake. Based on the extent of control to be achieved over the seismic response, the choice of the isolation system varies and there upon its design is done to suite the requirement of use of the structure. In the seismic design approach of base-isolated structures, the superstructure is decoupled from earthquake ground motion by introducing flexible interface between the foundation and the base of the structure. Thereby, these isolation systems shift the fundamental time-period of the structure to a large value and dissipate the energy in damping, limiting the amount of force that can be transferred to the superstructure such that inter-story drift and floor accelerations are reduced drastically. The dominant time-period of typical earthquake accelerations are in the range of 0.1 – 1.0 sec. and maximum acceleration usefully occurs in the range of 0.2 – 0.6 sec. Therefore, when the vibration time-period of the structure is increased beyond these limits the matching of fundamental frequencies of base-isolated structures and the predominant frequency contents of earthquake is avoided thereby the preventing the near-resonance response, resulting in dramatic reduction in structural response. The resulting flexible structural system which is more suitable from earthquake resistance viewpoint is obtained by adopting the two most common types of base-isolation systems in practice utilizing either rubber bearings or sliding systems between the foundation and superstructure for the purpose of isolation become an active approach to safeguard the structures against earthquakes without any requirement of modification in the superstructure. Base Isolation System When a structure is subjected to a strong earthquake, the system energy of the structure can be conceptually expressed as

$$KE + DE + SE = IE$$

Where KE denotes the kinetic energy, DE the dissipated energy, which equals the sum of VE and HE , with VE denoting the viscous energy and HE the hysteretic energy; SE is the strain energy and IE the seismic input energy. Elastomeric rubber bearing (EMB)

The rubber layers constituting the high damping rubber bearing are usually made of materials that are highly nonlinear in terms of shear strains. Effective damping in the range of 0.10~0.20 of critical can easily be exhibited by the HDR, which is achieved through addition of special chemical compounds that can change the material properties of the rubber. As was stated previously, the stiffness and damping of the HDR are required to be large enough to resist wind and minor earthquakes. In practice, the stiffness and damping properties of the HDR remain quite stable under one or more design earthquakes. Thus, similar to what has been undertaken in most previous studies, the HDR is assumed to be linear elastic and isotropic in this chapter, for the purpose of preliminary design.

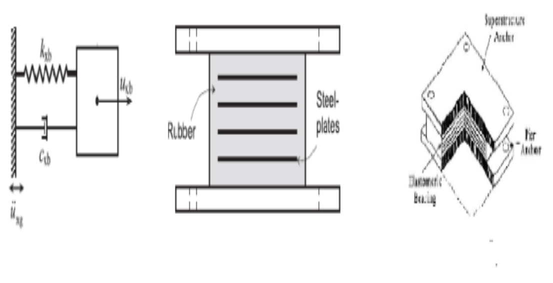

Fig 1: Elastomeric bearing Lead rubber bearing (LRB)

If substantial damping can be introduced into the bearings or the isolation system, then this large displacement problem can be alleviated. It is for this reason that the laminated rubber bearing with inclusion of a central lead plug has been devised, as shown in Figure 1. Other forms of supplemental dampers, such as hydraulic dampers, steel coils, and viscous dampers, also serve to increase the damping of the isolated structure

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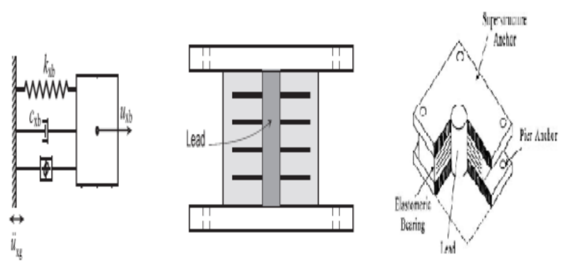

Fig 2: Lead rubber bearing Friction pendulum system (FPS)

The other approach for increasing flexibility in a structure is to provide a Sliding or friction surface between the foundation and the base of the structure. The shear force transmitted to the superstructure across the isolation interface is limited by the static friction force, which equals the product of the coefficient of friction and the weight of the superstructure.

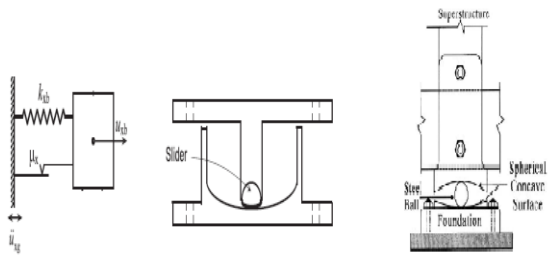

Fig 3: Friction Pendulum System

II. MODELING OF STRUCTURE

Structural model of base-isolated building fig. shows the idealized mathematical model of the 3 story base-isolated building considered for the present study. The base-isolated building is modelled as a shear type structure mounted on isolation systems with one lateral degree-of-freedom at each floor. Mathematical model of Building figure 4 shows the idealized mathematical model of the 3-storey base-isolated building considered for the present study. for the system under consideration, the governing equations of motion are obtained by considering the equilibrium of forces at the location of each degrees of- freedom. The equations of motion for the superstructure under earthquake ground acceleration are expressed in the matrix form as

$$[M_s]\{\ddot{x}_s\}+[C_s]\{\dot{x}_s\}+[K_s]\{x_s\}=-[M_s]\{r\}(\ddot{x}_b+\ddot{x}_g)$$

where ***[Ms], [Cs]*** and ***[Ks]*** are the mass, damping and stiffness matrices of the superstructure, respectively; **(*x*)= (*x*$_1$, *x*$_2$, …… *x*$_N$), *x*.$_s$, *x*..$_s$** the unknown relative floor displacement, velocity and acceleration vectors, respectively; , $\ddot{x}_b$ and $\ddot{x}_g$ are the relative acceleration of base mass and earthquake ground acceleration, respectively; and {r} is the vector of influence coefficients.

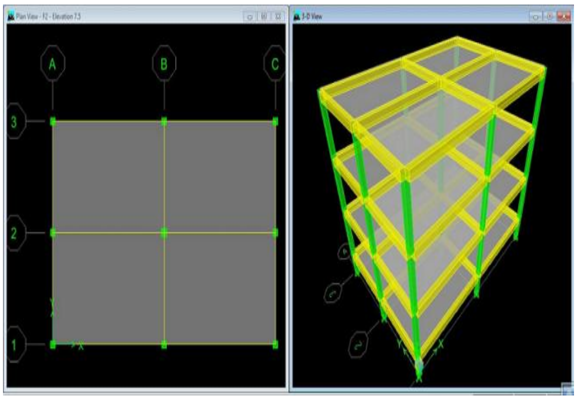

Fig 4: Mathematical model of 3-storey Building

The corresponding equation of motion for the base mass under earthquake ground acceleration is expressed by

$$m_b\ddot{x}_b+F_b-k_1x_1-c_1\dot{x}_1=-m_b\ddot{x}_g$$

force developed in the isolation system, respectively; ***k*$_1$** is the story stiffness of first floor; and ***c*$_1$** is the first story damping. The restoring force developed in the isolation system, ***F*$_b$** depends upon the type of isolation system considered and approximate numerical models shall be used. as per Uniform Building Code and International Building Code, the non-linear force-deformation characteristic of the isolator can be replaced by an equivalent linear model through effective elastic stiffness and effective viscous damping. The linear force developed in the isolation system can be expressed as.

$$F_b=k_{eff}x_b+c_{eff}\dot{x}_b$$

Where *Keff* is the effective stiffness; $c_{eff}=2\beta_{eff}M\omega_{eff}$ is the effective viscous damping constant; is the effective viscous damping ratio $\omega_{eff}=2\pi/T_{eff}$ is the effective isolation frequency and $T_{eff}=2\pi\sqrt{M/k_{eff}}$ is the effective isolation period. A three-story reinforced concrete office building is located on a rock site are away from active faults. The story heights are 5 m for the first story and 4 m for the second and third stories. The sizes of the columns, beams, walls, and slabs are given as follows Interior column C_1: 0.30 × 0.30 m ,Exterior column C_2 0.25 × 0.25 m ,Beams B, G: 0.25 × 0.40 m, Equivalent wall W1 thickness: 0.08 m , Slab thickness S: 0.15 m. The story loads on the building are: dead load = 10 kN/m^2 and live load = 2.5 kN/m^2.The building has a regular plan with three columns spaced at 6 m along the *x* direction, and also three columns at 4 m apart along the *y* direction, as shown in Figure 4 The total weight *WT* of the building is 5,209 kN, Density of concrete is 25 kN/m^3, modulus of elasticity *E*=25000 N/mm^2 · f_{ck}= 25 N/mm^2 ,*fe*=415 N/mm^2 .By a static analysis using the

ETABS program , the loads computed for all the columns at their base, where the bearings are to be installed are shown in figure 4 Seismic response of a base-isolated building is investigated under various real earthquake ground motions for linear isolator characteristics. The earthquake motions selected for the study is N00S component of 1995 Kobe earthquake recorded at JMA. This implies that the selected ground motions are recorded on stations having firm soil or rocky terrain.

The response quantities of interest are the top floor absolute acceleration and relative bearing displacement. The above response quantities are of importance because floor accelerations developed in the superstructure are proportional to the forces exerted because of earthquake ground motion. On the other hand, the bearing displacements are crucial in the design of isolation systems. For the present study, the mass matrix of the superstructure [Ms] is a diagonal matrix and characterized by the mass of each floor, which is kept constant (i.e. $m_j = m$ for j = 1, 2 . . .N). Further, the base raft of the isolated structure is considered such that the mass ratio, m_b/m = 1. The damping matrix of the superstructure, [Cs], is not known explicitly. It is constructed by assuming the modal damping ratio in each mode of vibration for superstructure, which is kept constant. The damping ratio of the superstructure ξ_s, is taken as 0.02 and kept constant for all modes of vibration. The inter-story stiffness of the superstructure is adjusted such that a specified fundamental time period of the superstructure *Ts* is achieved. The number of story in the superstructure is considered as 1 and 3. For the three-story building, the inter-story stiffness k_1, k_2, k_3 are taken constant. The value of k is selected to provide the fundamental time period of fixed base superstructure as 0.4 sec. The natural frequencies of the superstructure with fixed base measured in rad/sec are 15.71. The equivalent linear behaviour is considered by selecting the appropriate values of the effective isolation time period, *Teff* =2.5 s .The effective stiffness k_b and effective viscous damping ratio ξ_{eff} of elastomeric bearing, lead rubber bearing and friction pendulum system are 868 KN/m and 1363.702 (0.2), 868 kN/m and 681.59 (0.1), 560kN/m and 1363.702(0.2) respectively and coefficient of friction of friction pendulum system is μ =0.05. The weight of elastomeric bearing, lead rubber bearing and friction pendulum system are 0.654 kN, 11.922 kN and 0.426 kN respectively. Density of rubber, lead and steel are 960 kg/ m^3, 11340 kg/ m^3 and 7800 kg/m^3 respectively.

Bearing details of Building

Table 1: Bearing details of Building

Sr. No.	Dimension of bearing	Lead Isolated Base	Elastomeric Isolated Base	FPS
1.	Diameter of the bearing	700mm	700 mm	450 mm
2.	Total height of bearing/depth	552 mm	192 mm	170 mm
3.	Numbers of rubber layer	42	12	-
4.	Thickness of individual rubber layer	10 mm	10 mm	-
5.	Numbers of steel plates	41	11	-
6.	Thickness of individual plates	2 mm	2 mm	-
7.	Thickness of bottom and top plates	25 mm	25 mm	-
8.	Radius of curvature of spherical surface	-	-	1500 mm
9.	Diameter of lead core	130 mm	-	-

Displacement of building at top:

Table 2: Displacement of building with types of base isolator and w/o base isolator

Time (sec)	w/o base isolator (mm)	Deflection in isolator (mm)		
		EMB	LRB	FPS
0	0	0	0	0
5	0.0040 7	0.0030 2	0.0033 9	0.0033
10	-0.0033	- 0.00265	-0.0024	- 0.00277
15	- 0.00343	-0.0013	- 0.00131	- 0.00155
20	- 0.00306	-3.36E- 04	-3.96E- 05	-4.23E- 04
25	- 0.00238	-1.24E- 05	5.59E- 04	1.45E- 04

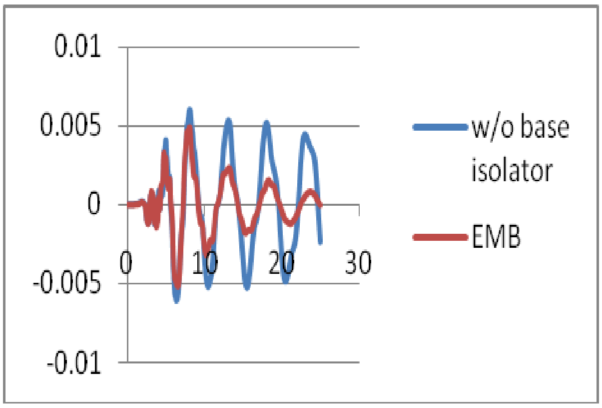

Fig 5: Displacement –Time graph for w/o base isolator and Elastomeric bearing of building at top

X axis – Time (sec)

Y axis – Displacement in m

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From figure: 5. Displacement-time graph, it is observed that displacement of the building is more in case of without isolator as compare to elastomeric bearing. The maximum displacement of building is nearly 5 mm for without isolator and nearly 2 mm for elastomeric bearing between 10 to 15 second.

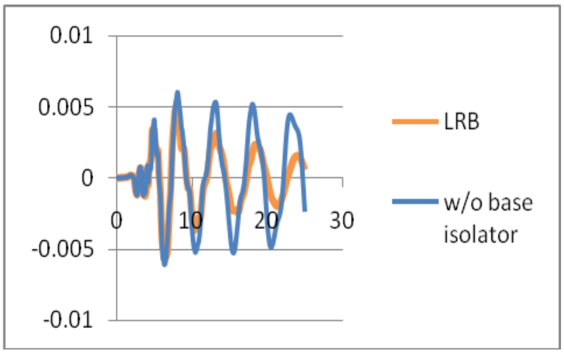

Fig 6: Displacement –Time graph for w/o base isolator and Lead rubber bearing of building at top

From figure 6. Displacement-time graph, it is observed that displacement of the building is more in case of without isolator as compare to lead rubber bearing. The maximum displacement of building is nearly 5 mm for without isolator and nearly 3 mm for lead rubber bearing between 10 to 15 second.

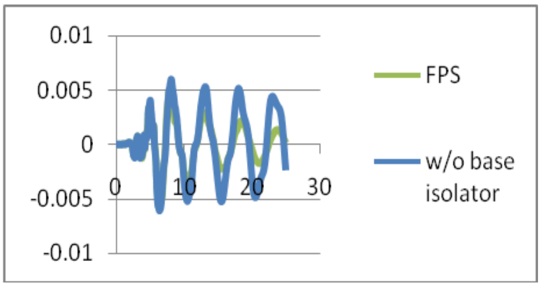

Fig 7 Displacement –Time graph for w/o base isolator and Friction pendulum system of building at top

From Figure: 7 Displacement-time graph, it is observed that displacement of the building is more in case of without isolator as compare to friction pendulum system. The maximum displacement of building is nearly 5 mm for without isolator and nearly 3 mm for friction pendulum system between 10 to 15 second.

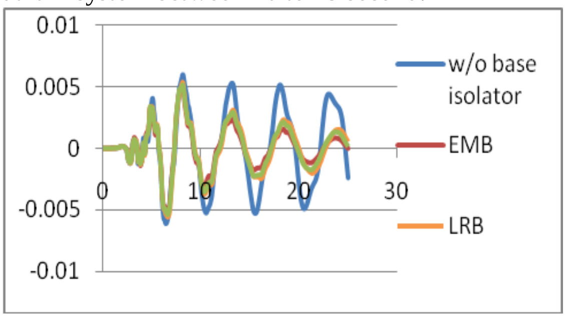

Fig 8 Displacement –Time graph for w/o base isolator Elastomeric Bearing, Lead Rubber Bearing, Friction pendulum Displacements of Building at top

From Figure 8 It is obvious that building displacement is more in without base isolator. The maximum displacement of building is 5 mm for without isolator and nearly 3 mm for all types of isolator between 10 to 15 second, further the displacement is reduces with time and elastomeric bearing shows better performance compare to LRB and FPS.

Table -3 Mode shape of building for w/o base isolator and with base isolator.

Storey height (m)	w/o base isolator (mm)	Deflection in base isolator (mm)		
		EMB	LRB	FPS
0	0	1.167	1.246	1.105
0.5	5.438	1.212	1.286	1.166
5.5	3.479	2.817	2.680	2.703
9.5	4.694	4.407	4.411	4.453
13.5	6.019	4.933	5.383	5.17

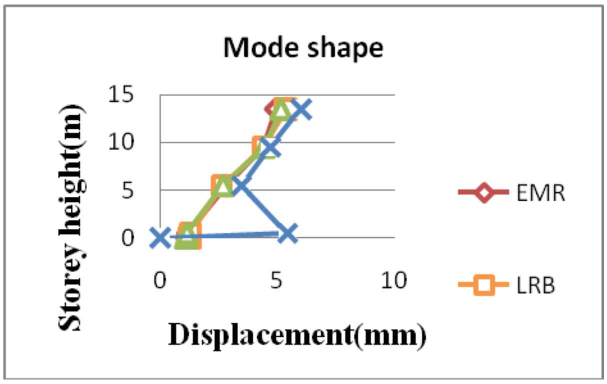

Fig: 9 Mode shape of building for w/o base isolator and with base isolator.

Figure: 9 shows, storey displacement of building without base isolator is increase according to the building height and difference in storey drift is more. Storey displacement of building with base isolator is decrease according to the building height and difference in displacement of storey drift is less, The building top level displacement is influenced by the bearing displacement. . Difference between displacement at base and at top level is less in with base isolator as compare to w/o base isolator.

Acceleration of building at top

From figure:10 acceleration-time graph, it is observed that acceleration of the building is more in case of without isolator as compare to elastomeric bearing. The maximum and of building is 0.4822 m/s^2 for without isolator and nearly 0. 46942 m/s^2 for elastomeric bearing at 3.55 and 3.6 second.

X axis – Time (s)

Y axis - Acceleration

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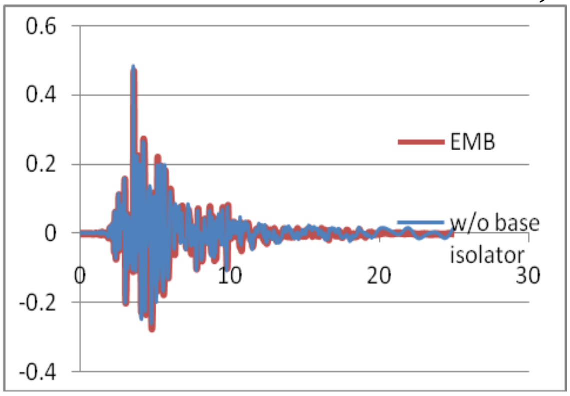

Fig 10: Acceleration –Time graph for w/o base isolator and Elastomeric bearing of building at top

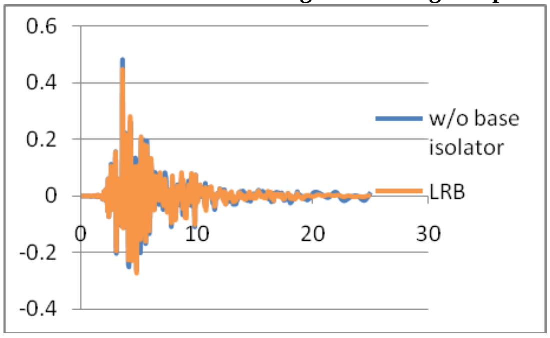

Fig 11: Acceleration –Time graph for w/o base isolator and Lead rubber bearing of building

from figure:11 acceleration-time graph, it is observed that acceleration of the building is more in case of without isolator as compare to lead rubber bearing. The maximum and of building is 0.4822 m/s^2 for without isolator and nearly 0.44711 m/ s^2 for to lead rubber bearing at 3.55 and 3.6 second.

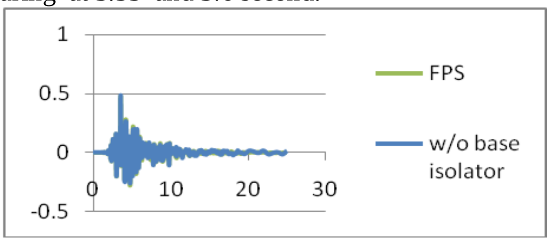

Fig 12: Acceleration –Time graph for w/o base isolator and Friction pendulum system of building at top

from figure:12 acceleration-time graph, it is observed that acceleration of the building is more in case of without isolator as compare to Friction pendulum system. The maximum and of building is 0.4822 m/s^2 for without isolator and nearly 0. 47631 m/ s^2 for to Friction pendulum system at 3.55 and 3.6 second.

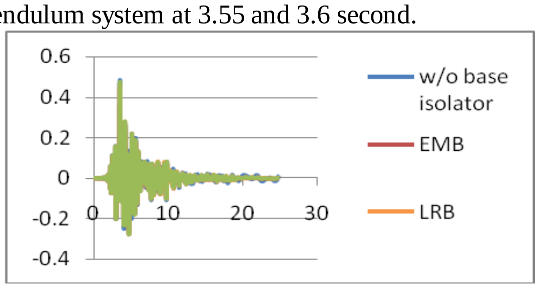

Fig: 13: Acceleration –Time graph for w/obase isolator Elastomeric Bearing, Lead Rubber Bearing and friction pendulum Building at top

From Figure: 13 Time acceleration graph shows the expected result i.e. the structure without base isolator accelerate more compare to with bearing , same as deflection case acceleration in case of elastomeric bearing is less.

Table -5 Mode shape of building for w/o base isolator and with base isolator.

Storey height (m)	w/o base isolator (mm/s^2)	Deflection in base isolator (mm/s^2)		
		EMB	LRB	FPS
0	0	4.206	4.358	4.213
0.5	1.259	4.395	4.544	4.469
5.5	4.987	5.124	4.991	5.160
9.5	4.753	4.934	5.052	4.739
13.5	4.822	4.694	4.471	4.763

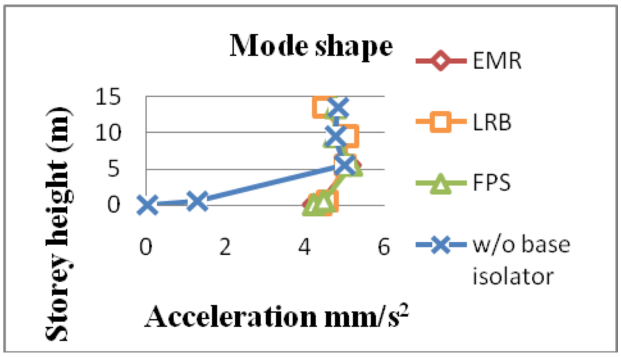

Fig: 14 Mode shape of building for w/o base isolator and with base isolator.

Figure 14 shows, storey acceleration of building without base isolator is increase according to the building height and difference in storey drift is more. Storey acceleration of building with base isolator is decrease according to the building height and difference in acceleration of storey drift is less, The building top level displacement is influenced by the bearing displacement. Difference between acceleration at base and at top level is less in with base isolator as compare to w/o base isolator.

III CONCLUSION

From result and discussion it concludes that the performance of base isolated structure is good compare with non base isolated structure. Elastomeric bearing giving less displacement in case of building because the stiffness of elastomeric bearing is enough to sustain vertical. Loads Maximum acceleration is observed at 3.55-3.6 sec for all types of bearings. The acceleration of

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building is marginally less in case of load bearing as compared to other two types of bearings.

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