

Seismic Analysis of Fixed Base and Isolated Base Building Structure

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Abstract— The traditional method for seismic design of building structures i.e. strengthening the ductility, stiffness and strength of the structures has been in common use from a long time. The efficiency of the conventional methods is constrained. To resolve disadvantages associated with the conventional methods a number of vibration-control measures called structural control have been discovered and remarkable growth in this subject have been noticed over recent years. In this study a comparative seismic analysis of the multi-storey RC building is done with the variation in the base conditions. G+5, G+8 and G+10 building models are analysed with fixed base, natural rubber bearing, lead rubber bearing and high damping rubber bearing. The variation in the seismic zone is also considered for the analysis. Seismic parameter like time period, base shear and interstorey drift ratio are obtained and results are compared.

Keywords— Base Isolation systems, Natural rubber bearing, Lead rubber bearing, High damping rubber bearing, RC Moment resisting building, Seismic analysis,

Introduction

Civil Engineers are still unable to predict the loads which structures may have to withstand during their useful lifecycle. Recent destructive earthquakes in California and Japan have shown how vulnerable our structures remain to natural hazards. The enormous losses inflicted by such destruction have motivated ever more stringent requirements on the performance of structural systems, in an effort to reduce the cost of repair and disruption. In the field of Structural Control the performance and cost requirement is the motivation for both buildings and equipment which deals with methodologies for the protection of high performance structural systems. All structures are subjected to vibration the vibration isolator is a device that is designed to effectively isolate such structures from harmful vibrations. The primary motivation of the present study is to check the difference between the responses of a fixed-base building frame and the isolated-base building frame under seismic loading. The main purpose of using the seismic isolation is to reduce the base-shear of the structure. Large base shear due to strong horizontal ground accelerations is one of the main reasons of structural damages. Thus, to reduce the lateral acceleration of structure it is a basic principle. From the design point of view many seismic codes use the base shear as a control parameter for example, if the base shear of a building is reduced, then the upper story floor drifts and lateral forces are also reduced. In the case of a bridge, base shear reduction will minimize damage to the piers. The objective of the study is to check the seismic performance of R.C. structure before and after the application of base isolation technique. Also compare the performance of the natural rubber bearing, Lead rubber bearing and High damping rubber bearing over a conventional technique and optimize a better performance of the building during the earthquake.

Base Isolation System

The fundamental principle of base isolation is to modify the response of the building so that the ground below the building can move without transmitting its motions into the building. In an ideal system this separation would be total but in the real world, there is a need to be some contact between the ground and structure. Perfectly rigid buildings have a zero time period exhibits zero relative displacement between the ground and structure that means when the ground moves the acceleration induced in the structure will be equal to the ground acceleration. The ground and structure move with the same amount. Building that is perfectly flexible has an infinite time period this kind of structures exhibits equal relative displacement between the ground and structure. When the ground below the structure moves there is zero acceleration induced in the structure resulting the structure does not move. The response of the any structure to ground motions is between these two extremes discussed above because all real structures are neither perfectly rigid nor perfectly flexible as shown in Figure 1. For periods between zero and infinity, the relative displacements between the ground and the structure and the maximum accelerations are the function of the earthquake, as shown conceptually in Figure 1. For most earthquakes there be a range of periods at which the acceleration in the structure will be amplified beyond the maximum ground acceleration. The relative displacement should not exceeds the peak ground displacement, that is the displacement corresponds to infinite time period, but there are some exceptions to this particularly sites which are located close to the fault generating the earthquake and soft soil sites.

Natural rubber bearing: This bearing uses natural rubber, which inherently has a low damping factor (about 2-3% equivalent damping factor), a stable restoring force and excellent linearity. A separate damper is required, but the overall isolation design has much greater flexibility. Four different kinds of elastic moduli are available to support a wide range of column loads.

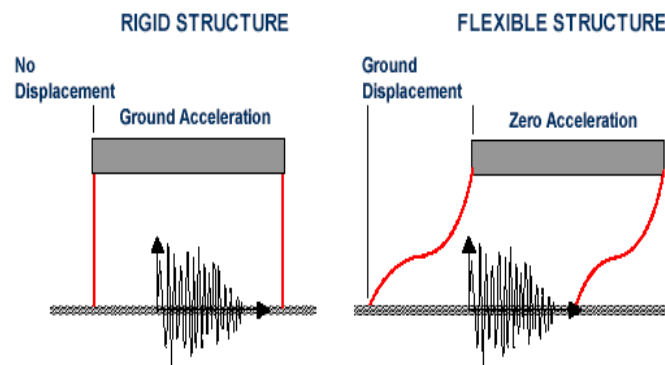


Fig. 1 Transmission of ground motions

Lead rubber bearing: Lead rubber bearing (LRB) is the laminated rubber bearing containing one or more lead plugs to deform in shear. Also It is a hysteresis resembles elastoplastic materials. This bearing includes a laminated natural rubber structure embedded with the lead plug at the center, where the lead plug provides the damping capability and the rubber incorporates the spring capability. The lead core provides energy dissipation under high seismic loads and rigidity under service loads. Top and bottom steel plates which is thicker than the internal shims are used to accommodate mounting hardware. The entire bearing system is encased in rubber cover which provides environmental protection. A major advantage of the lead-rubber bearing is that it combines the functions of flexibility at earthquake load levels, damping into a single compact unit and rigidity at service load levels. A separate damper is not required with LRB also it a good choice for areas with space constraints. These properties make the lead-rubber bearing the most common type of isolator used where rigidity under services loads is important (in bridges) or high levels of damping are required (in high seismic zones).

High damping rubber bearing: High damping rubber bearing (HDRB) is type of elastomeric bearing which consist of thin layers of high damping steel plates and rubber in alternate layers. Like lead rubber bearing this type of bearing does not contain lead plug at the centre of bearing. In the HDRB the used rubber is either synthetic rubber or natural rubber which provides a sufficient amount of damping. This high damping rubber includes both damping and spring characteristics together. Generally, in the HDR bearing separate damper is not required also it may be an excellent choice for areas with space constraints. Also two different elastic moduli are available and light column loads can also be accommodated. The high damping rubber bearing is elastomeric type bearings where the elastomer is used (either synthetic or natural) which provide a significant amount of damping, usually from 8% to 15% of critical damping as compare to the more usual rubber compounds which provide around 2% damping. The additional damping is produced by altering the cross link density of the molecules and modifying the compounding of the rubber to provide a hysteresis curve in the rubber. Since the damping provided is hysteretic in nature (displacement dependent) and its hysteresis curves are relatively smooth For most HDR compounds the viscous component of damping (velocity dependent) remains relatively small (about 2% to 5% of critical). By adopting the concept of "equivalent viscous damping", the damping provided by the rubber hysteresis can be used in design calculated from the measured hysteresis area, as in done for LRBs. For the most HDR bearings, used now days have effective damping is around 15% at low strains (between 25% to 50%) and reducing to 8% to 12% for strains above 100%. Some synthetic compounds may provide 15% or more damping at higher strains values. In design, for a particular elastomer compounds the amount of damping is obtained from tabulated equivalent viscous damping ratios.

Building Modelling

Analysis and design of multistory R.C. building on fixed base is to be performed using SAP2000 and analysis of the same proposed RC buildings after the application of base isolation technique. In this study total 36 cases of building models with different configurations are considered for the analysis. A fixed plan of 36m X 48m with variation in the height is considered. Total 3 building G+5, G+8 and G+10 with a height of 24.5m, 35m and 42m respectively are considered as illustrated in Figure 2 and from Figure 3 to Figure 5. Each building model is designed and analyzed for the seismic zone III, zone IV and zone V also with the variation in the base condition which are fixed base, natural rubber bearing type base, lead rubber bearing type base and high damping rubber bearing type base. Total 12 numbers of cases have been analyzed for each building model. Storey height of all buildings is kept constant which is 3.5m. The guidelines of IS 875 (Part I) and IS 875 (Part II) are used to consider the dead and live loads on the buildings and lateral loads are calculated as per the guidelines of IS 1893 (2002). For designed lateral load calculation zone factor is taken as 0.36, 0.24 and 0.16 for zone V, IV and III respectively. The value of s_a/g is taken for medium soil corresponding to time period of the structure.

The importance factor of study buildings are taken as 1 and each building model is designed as special moment resisting frame (SMRF) with response reduction factor value 5. The design of building models is done as per IS 456 (2000) and ductile detailing of frames is done conforming to IS 13920 (1993) guidelines. M-25 grade of concrete with unit weight of 25 KN/m³ and Fe-415 grade of steel is used for the all building models. 150mm thick slab is assigned to building models at all storey levels.

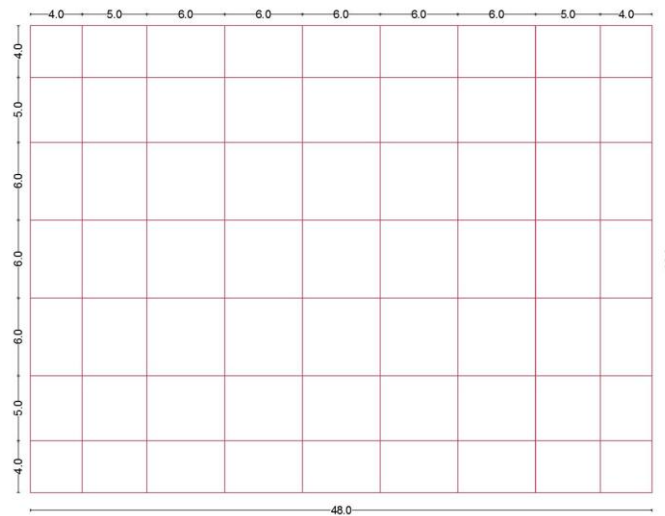


Fig. 2 Plan of building

Thickness of the internal wall is considered 100mm which is assumed on all the internal beams and 200mm thickness is considered for the exterior wall which is assigned on the outer periphery beams of the building at all floor level except roof level. Live load on the structure is assumed 2 KN/m² for all study cases. In G+5 building the required beam size is 300X400 for 4 & 5 m span and 300X500 for 6 m span and for columns up to ground floor 400X400 and from 3rd to 5th floor 300X300 is required. Similarly the member section requirement for the G+8 and G+10 building models are shown in Table 1.

Table 1: RC member size of the building models

Building Model	Beam Section (mm)		Column Section (mm)
	4 and 5m span	6 m span	
G+5	300X400	300X500	400X400 (0 to 2 nd Floor)
			300X300 (3 rd to 5 th Floor)
G+8	300X400	300X500	500X500 (0 to 2 nd Floor)
			400X400 (3 rd to 5 th Floor)
			300X300 (6 th to 8 th Floor)
G+10	300X400	300X500	600X600 (0 to 2 nd Floor)
			500X500 (3 rd to 5 th Floor)
			400X400 (6 th to 8 th Floor)
			300X300 (8 th to 10 th Floor)

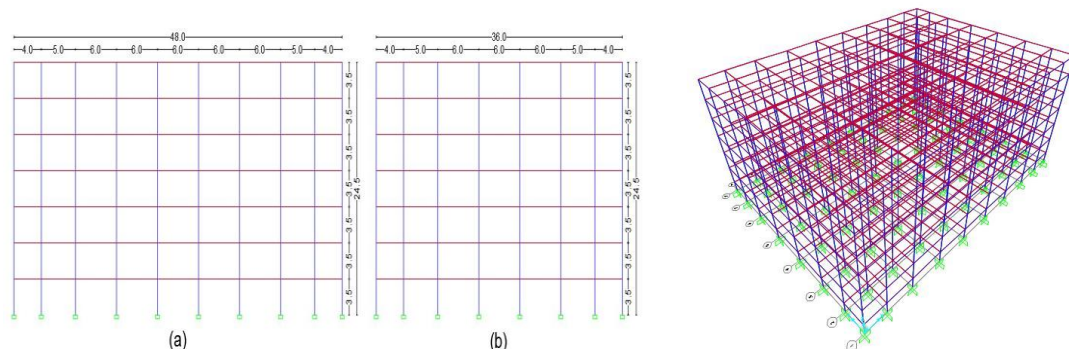


Fig. 3 Elevation of G+5 building (a) X-direction (b) Y-direction and 3D model

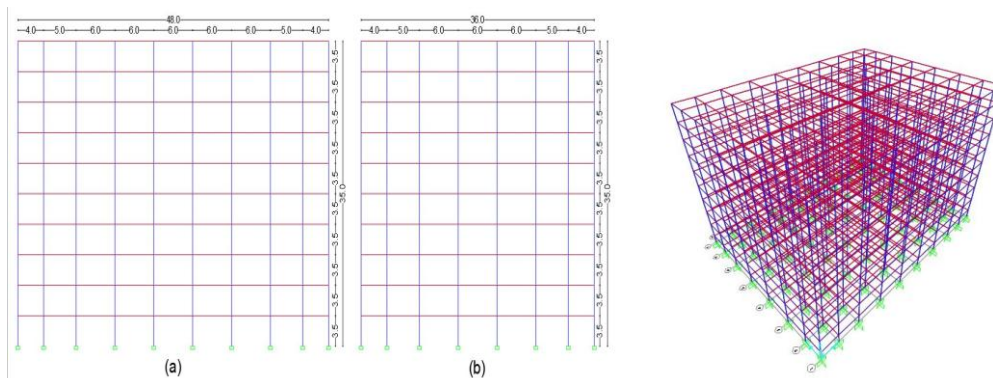


Fig. 4 Elevation of G+8 building (a) X-direction (b) Y-direction and 3D model

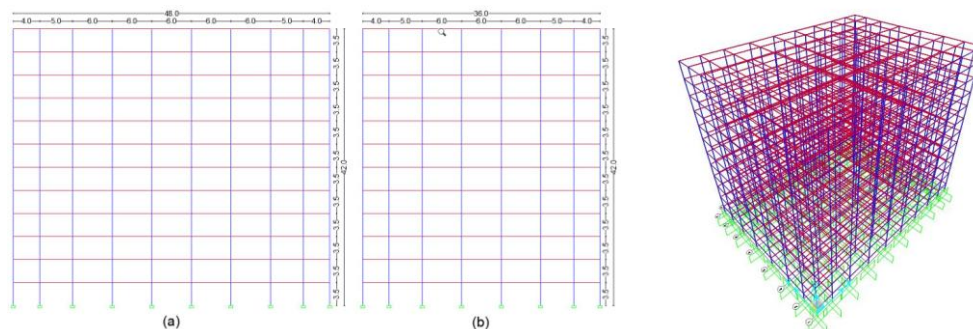


Fig. 5 Elevation of G+10 building (a) X-direction (b) Y-direction and 3D model

Results

Comparison of the study building models for various parameters like time period, base shear and storey displacement (in terms of interstorey drift ratio) having different support systems (fixed base, high damping rubber bearing, lead rubber bearing and natural rubber bearing) and varying seismic zone are done. The results are shown below.

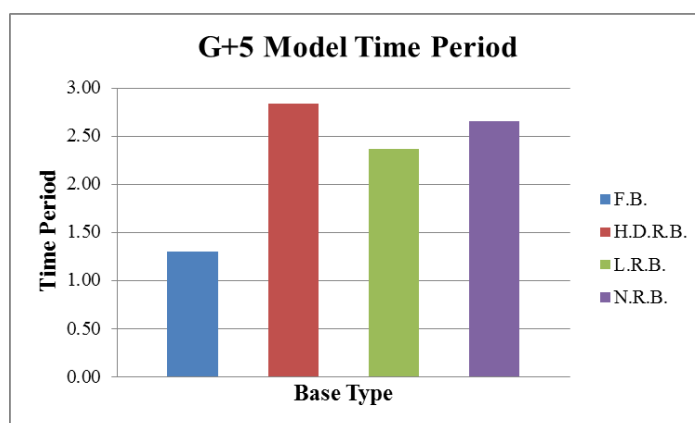


Fig. 6 Time period of G+ 5 model based on bearing types.

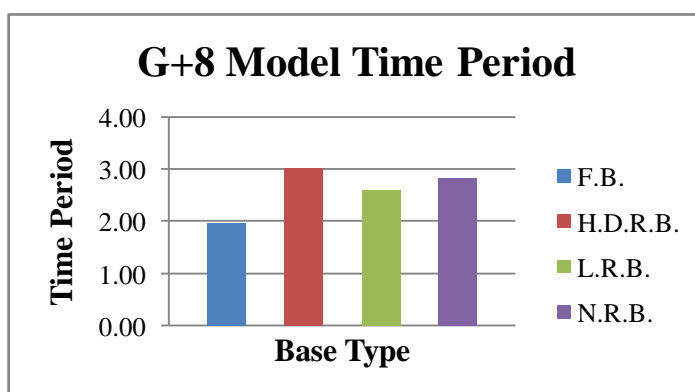


Fig. 7 Time period of G+ 8 model based on bearing types

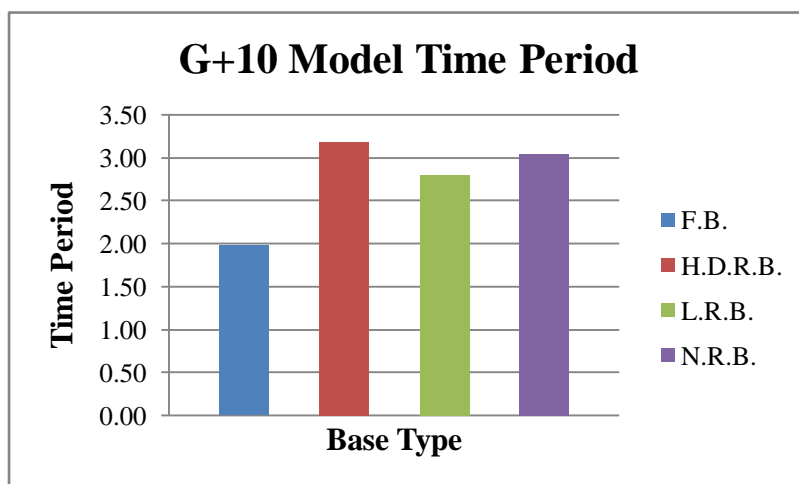


Fig. 8 Time period of G+ 10 model based on bearing types

Figure 6 to Figure8 show that fixed base building models have lower time period of as compare to other isolated base type building model. In a bearing wise comparison H.D.R bearing, N.R. bearing and L.R. bearing showing higher, moderate and lower time period respectively. In the height wise comparison all building models follow the same pattern as discussed above but with the increment in height decrement in the time period is observed.

G+5 Model

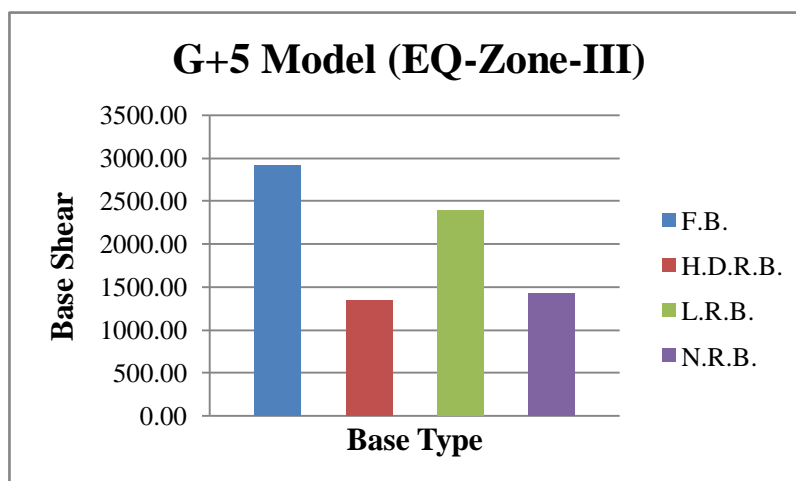


Fig. 9 Base shear of G+ 5 models for zone III

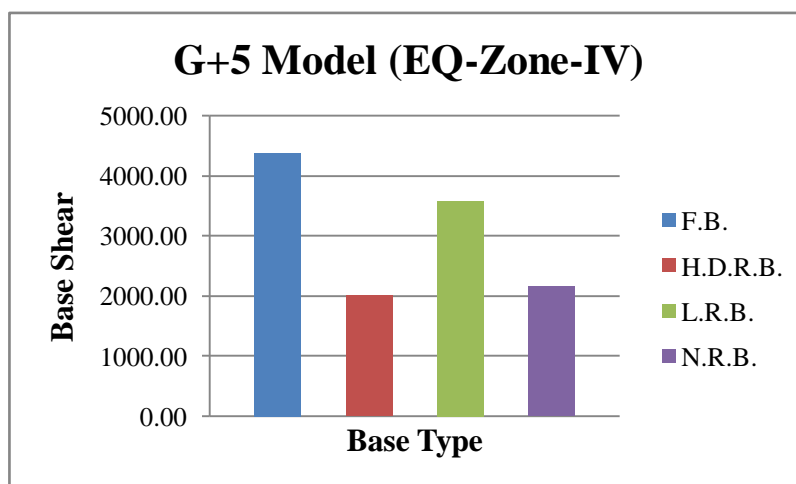


Fig. 10 Base shear of G+ 5 models for zone IV

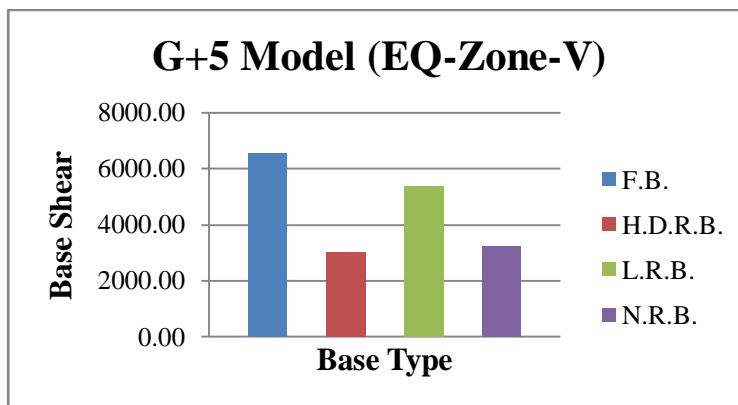


Fig. 11 Base shear of G+ 5 models for zone V

G+8 Model

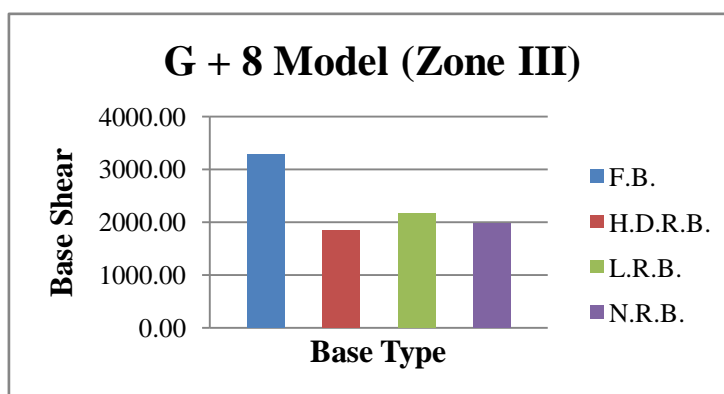


Fig. 12 Base shear of G+ 8 models for zone III

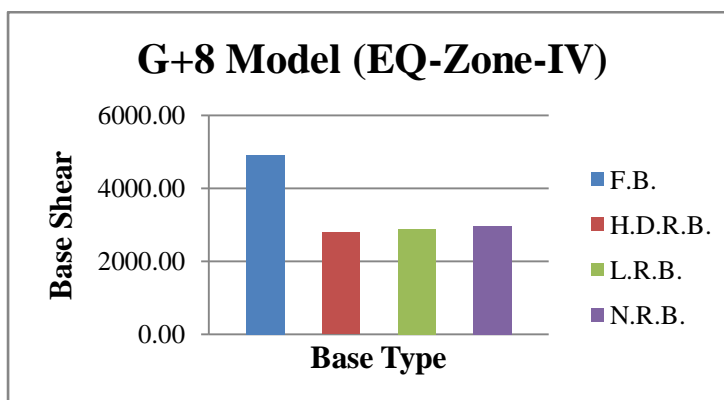


Fig. 13 Base shear of G+ 8 models for zone IV

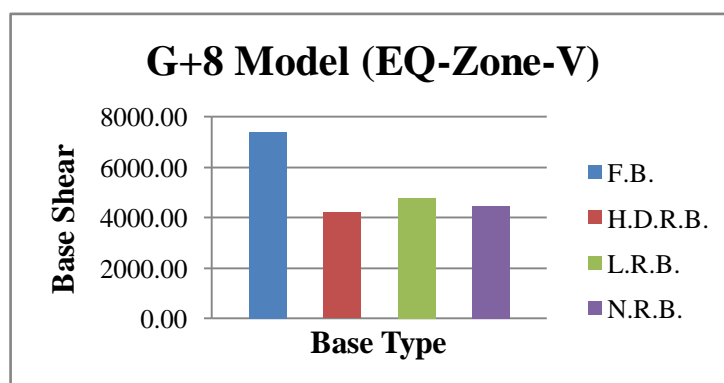


Fig. 14 Base shear of G+ 8 models for zone IV

G+10 Model

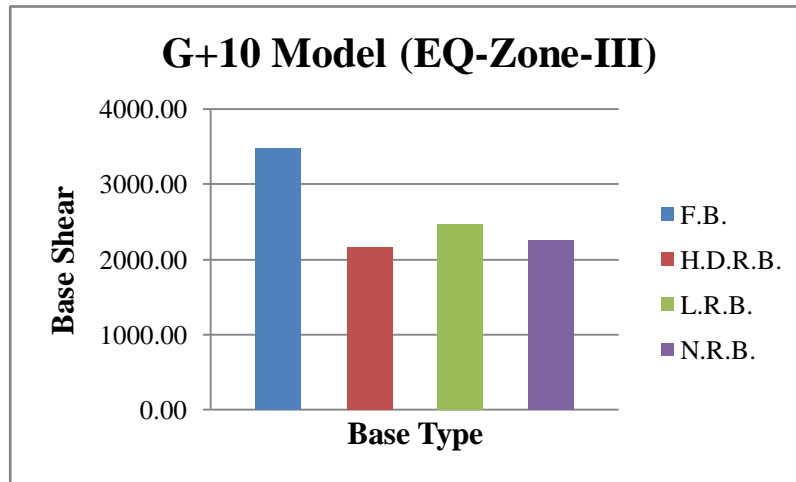


Fig. 15 Base shear of G+ 10 models for zone III

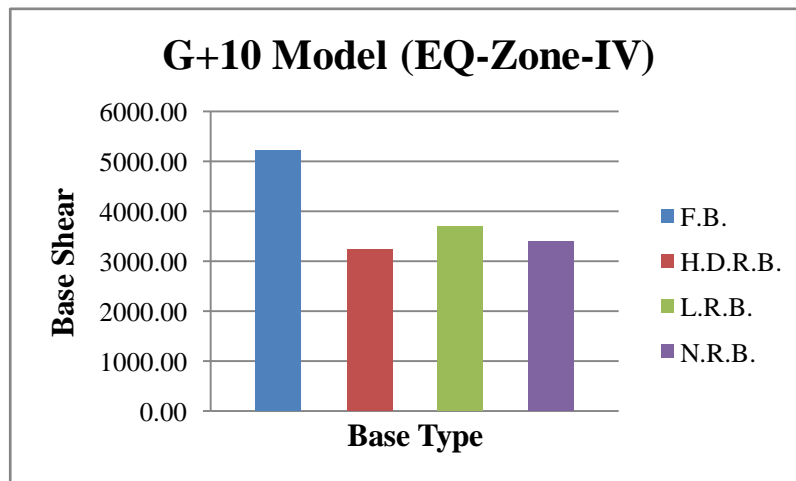


Fig. 16 Base shear of G+ 10 models for zone IV

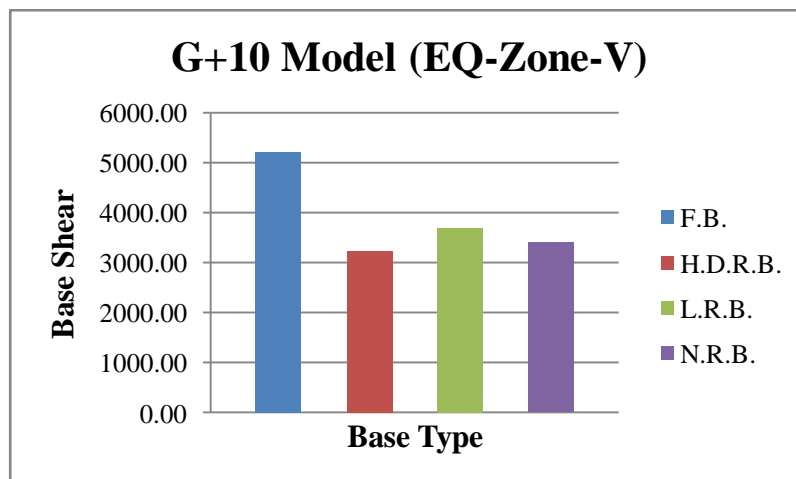


Fig. 17 Base shear of G+ 10 models for zone V

Figure 9 to Figure 17 showing the base shear of all study models. Fixed base shear building model is showing the maximum base shear with respect to other building models having base isolation systems. In a base isolation systems H.D.R bearing, N.R. bearing and L.R. bearing is showing low, moderate and high base shear values. The change in the base shear is due to change in the time period because time period is a function of base shear. In a height wise and zone wise comparison same pattern is followed by all the building models with increment in the height and seismic zone base shear is increasing.

Interstorey Drift Ratio

G+5 Building Model

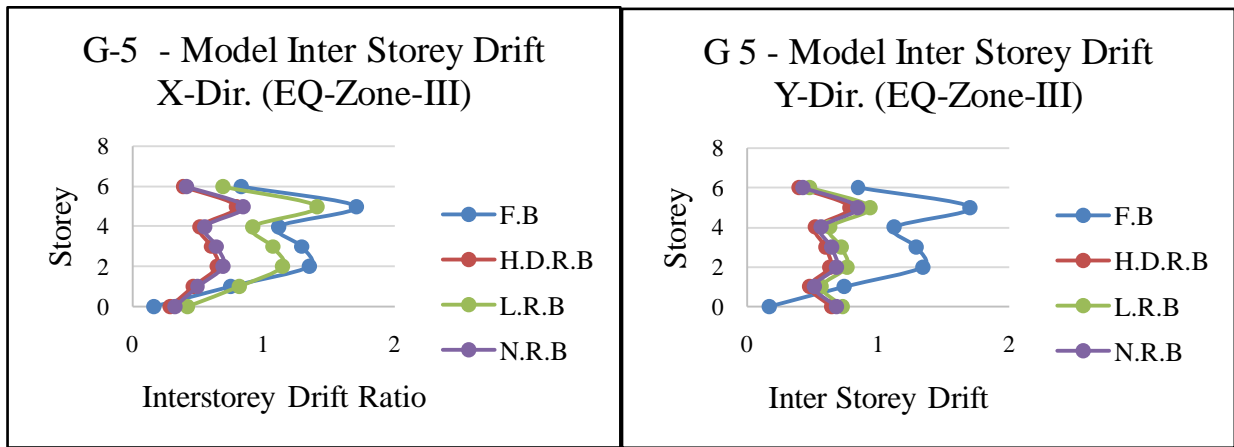


Fig. 18 Interstorey drift ratio of G+ 5 models for zone III in X and Y direction

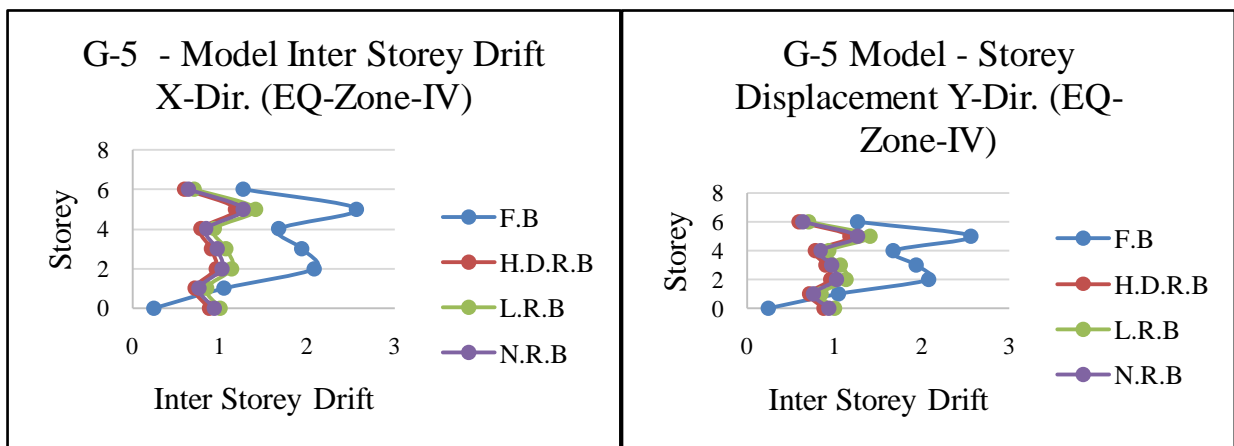


Fig. 19 Interstorey drift ratio of G+ 5 models for zone IV in X and Y direction

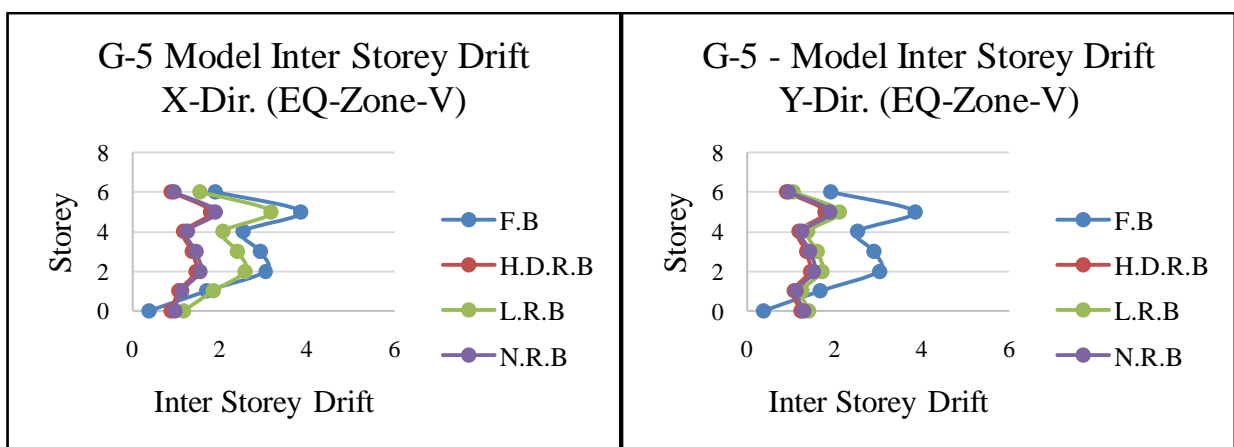


Fig. 20 Interstorey drift ratio of G+ 5 models for zone V in X and Y direction

G+8 Building Model

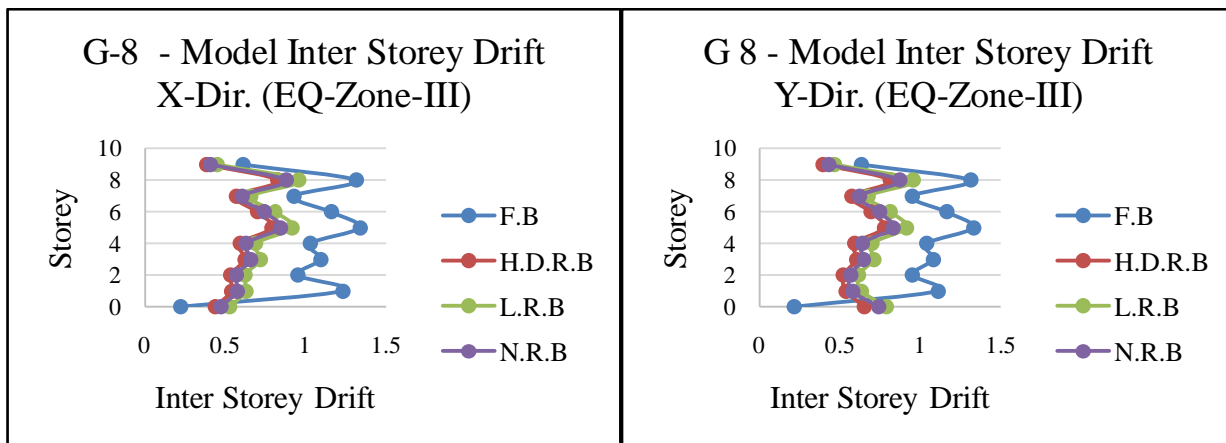


Fig. 21 Interstorey drift ratio of G+ 8 models for zone III in X and Y direction

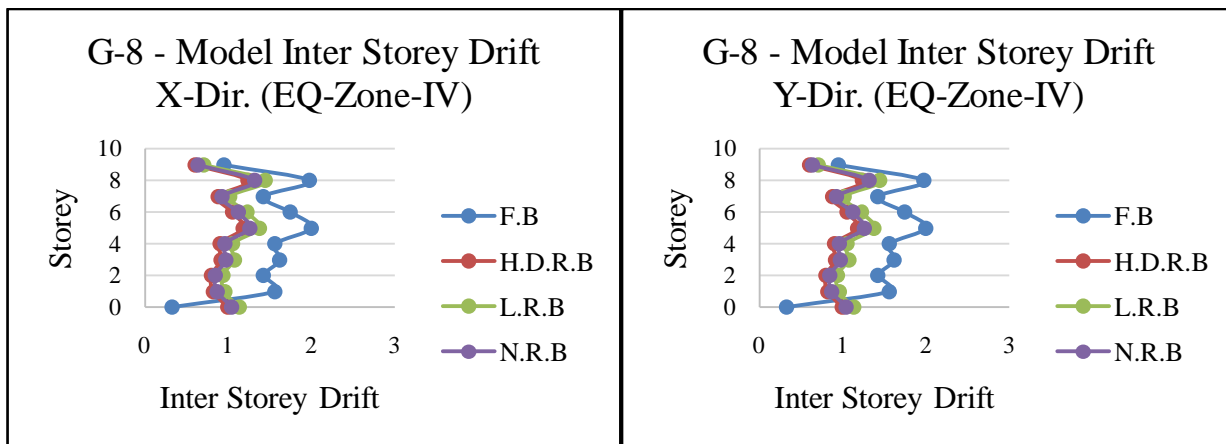


Fig. 22 Interstorey drift ratio of G+ 8 models for zone IV in X and Y direction

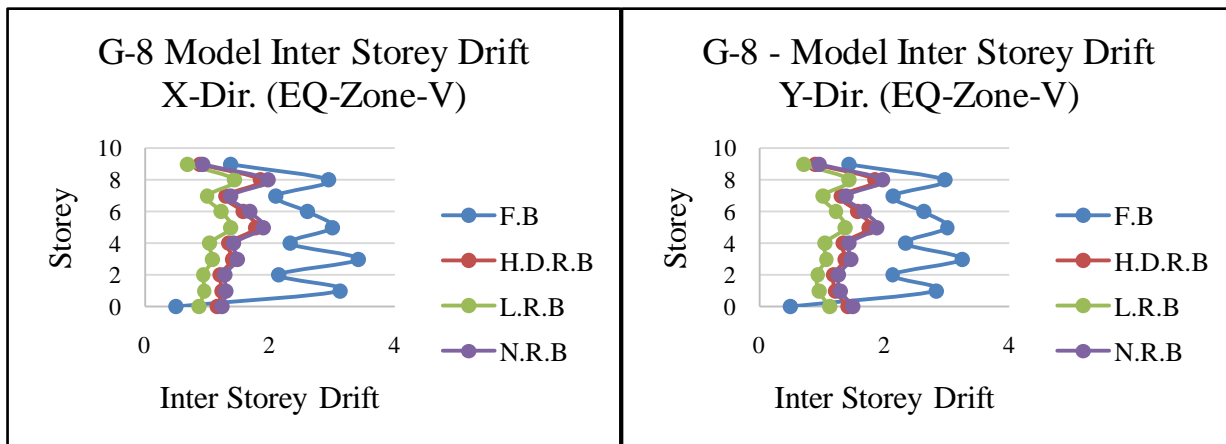


Fig. 23 Interstorey drift ratio of G+ 8 models for zone V in X and Y direction

G+10 Building Model

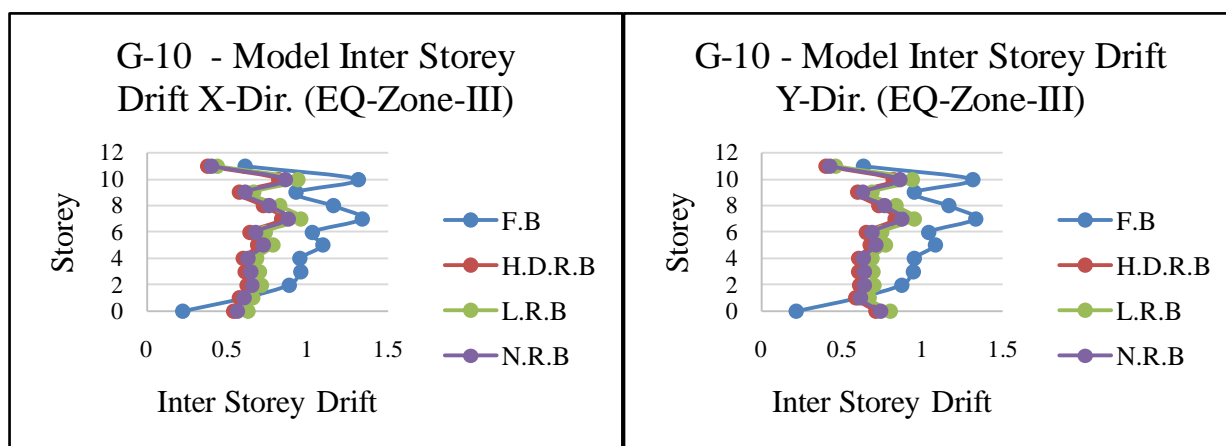


Fig. 24 Interstorey drift ratio of G+ 10 models for zone III in X and Y direction

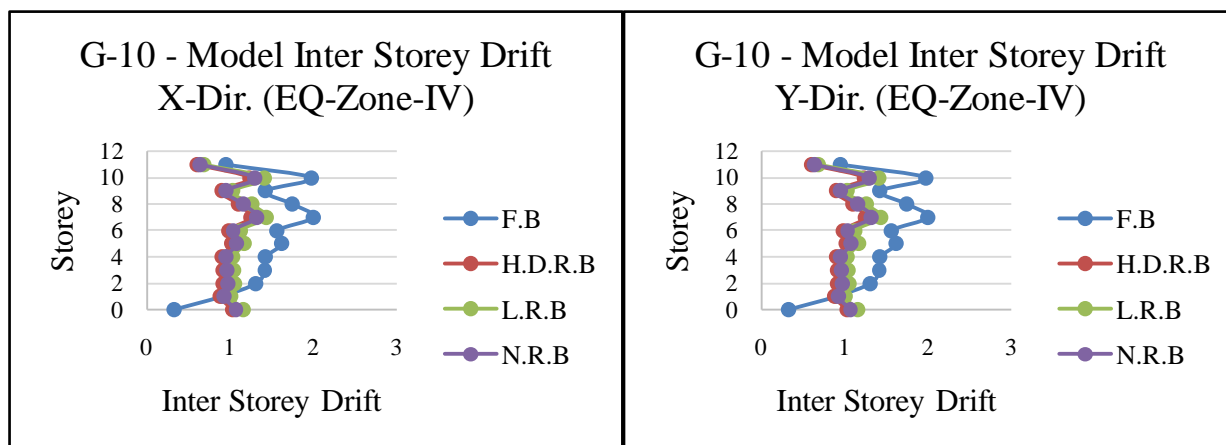


Fig. 25 Interstorey drift ratio of G+ 10 models for zone IV in X and Y direction

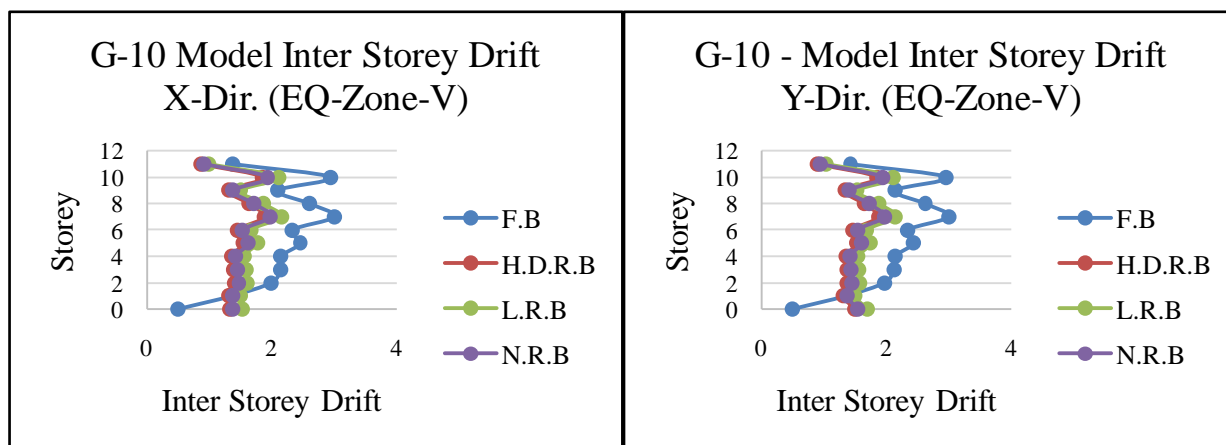


Fig. 26 Interstorey drift ratio of G+ 10 models for zone V in X and Y direction

Figure 18 to Figure 26 is showing the interstorey drift ratio for all building models in X and Y direction. It is observed that building models having base isolators (H.D.R bearing, N.R. bearing and L.R. bearing) is showing the minimum interstorey displacement as compare to fixed base building models. Isolators increases damping in the structure and damping decreases interstorey drift. It is observed that base isolated structures have certain displacement at the base and superstructure act as partially rigid body. In a base isolation systems H.D.R bearing, N.R. bearing and L.R. bearing is showing minimum, moderate and maximum interstorey drift ratio respectively. In a zone wise comparison same pattern is followed by all the building models with increment in the seismic zone interstorey drift ratio is increasing.

Conclusion

- The result of the research shows that the response of the structure can be reduced by the use of rubber isolator's.
- Time period of the base isolated structure increases as compared to the fixed base structure.
- The base shear is reduced by 50-60% by the use is rubber isolator.
- Story displacement of the base isolated structure increases as compared to the fixed base structure.
- Moment and shear forces are reduced as compared to fixed base structure.
- By using different type of rubber bearings, concrete and steel 15-20 % reduced.
- Base isolation system minimize displacement and interstorey drift in both direction as compared with fixed base system.

Base isolation technique has found to be reliable for seismic protection of multi-story structure.

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