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PERFORMANCE ANALYSIS OF HIGH RISE R.C.C STRUCTURE WITH CONSIDERATION OF SLIDING ISOLATION SYSTEM

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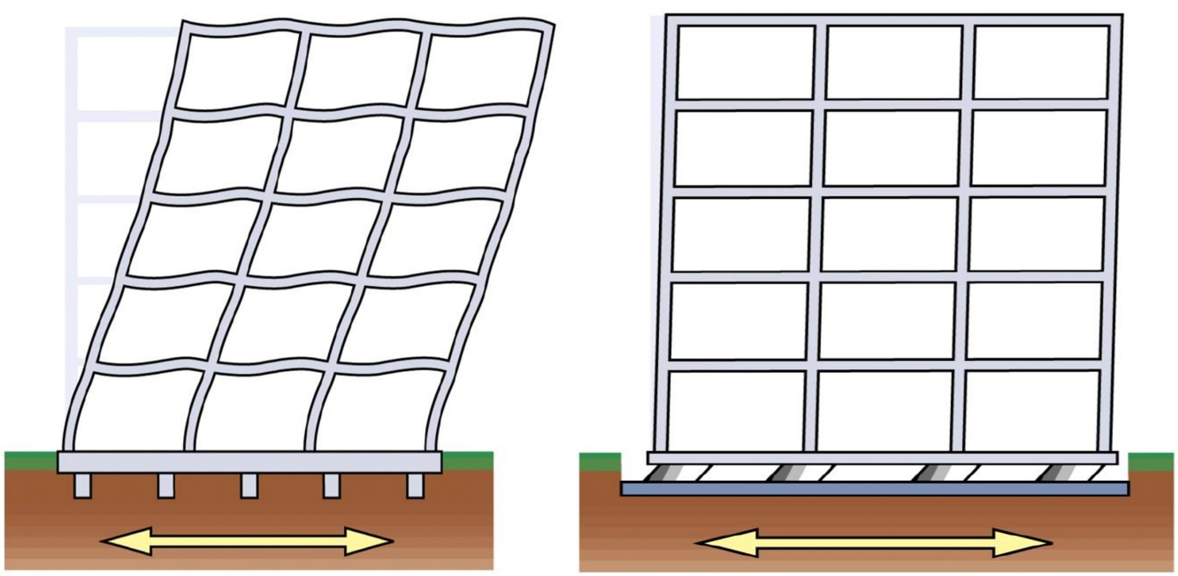
Abstract : Sliding isolation systems work by placing a low friction material beneath the superstructure thus allowing the entire structure to move at the base level as a rigid body under seismic loading. In the past, this had been achieved simply by placing materials such as sand or talc beneath the structure the frictional bearings increase the structures natural period by causing the building to slide along the concave inner surface of the bearing. The bearings filter out the imparting earthquake forces through the frictional interface. This frictional interface also generates a dynamic friction force that acts as a damping system in the event of an earthquake. This lateral displacement greatly reduces the forces transmitted to the structure even during strong magnitude eight earthquakes. This type of system also possesses a re-cantering capability, which allows the structure to canter itself, if any displacement is occurred during a seismic event due to the concave surface of the bearings and gravity.

Keywords: Sliding Isolation, Frictional Interferance, Damping System.

Introduction

To protect structures from earthquake damages, the use of base isolation systems have been suggested in contrast to the conventional technique of strengthening the structural members. The main concept in base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the predominant energy containing frequencies of earthquake ground motions.



Conventional structure Isolated structure

Figure 1.1.1: Behavior of Building Structure with Base

Isolation System

The other purpose of an isolation system is to provide means of energy dissipation and thereby, reducing the transmitted acceleration into the superstructure. Accordingly, by using base isolation devices in the foundations, the structure is essentially uncoupled from the ground motion during earthquakes.

Excellent reviews of earlier and recent works on base isolation system have been provided. A significant amount of the recent research in base isolation has focussed on the use of frictional element to concentrate flexibility of structural system and to add damping to the isolated structure.

The advantages of a frictional type system over conventional rubber bearings are: (1) the friction forces developed at the base are proportional to the mass supported by that bearing implying that there is no eccentricity between the centre of mass of the superstructure and the centre of stiffness. Therefore, if the mass distribution is different from that which is assumed in the original design, the effect of torsion at the base are diminished, (2) the frictional isolator have no unique natural frequency and therefore, dissipate the seismic energy over a wide range of frequency input without the risk of resonance with the ground motion and (3) frictional type system ensures a maximum acceleration transmissibility equal to maximum limiting frictional force. Simplest frictional base isolation device is pure-friction without any restoring force. More advanced devices involve pure friction elements in combination with a restoring force. The restoring force in the system reduces the base displacements and brings back the system to its original position after an earthquake. Some of the commonly proposed sliding isolation system with restoring force include the resilient-friction base isolator (R-FBI) system, Alexisismon isolation system , the friction pendulum system (FPS) and elliptical rolling rods. The sliding systems performs very well under a variety of severe earthquake loading and are very effective in reducing the large levels of the superstructure's acceleration without inducing large base displacements. Chen and Ahmadi examined the sensitivity of the base-isolated structure to fluctuating component of the wind and found that the sliding systems are less sensitive to wind excitation as compared to conventional isolation systems. Jangid investigated that the sliding systems are less sensitive to the effects of torsional coupling in asymmetric base-isolated structures. Comparative studies of base isolation systems show that the response of the sliding system does not vary with the frequency content of earthquake ground motions. Inspite of several advantages, the sliding base isolation systems generate high frequency components in the acceleration response of the structure which could be detrimental to the structural contents. However, this obstacle can be overcome by providing an optimum frictional element in the sliding system designed for a particular structural system.

Literature Review

R.S.Jangid studied the optimum friction coefficient of a sliding system with a restoring force for the minimum acceleration response of a base-isolated structure under earthquake ground motion is investigated. The stochastic model of El-Centro 1940 earthquake which preserves the non-stationary evolution of amplitude and frequency content of the original record is used for the model of earthquake. The base-isolated structure consists of a linear flexible multi-storey structure supported on the sliding system. The sliding system is modelled to provide a friction force and a linear restoring force. The non-stationary stochastic response of the isolated structure is obtained using the time dependent equivalent linearisation technique as the force-deformation behaviour of the sliding system is highly non-linear. The response of the system is analysed for the optimum friction coefficient of the sliding base isolation system. The criterion selected for optimality is the minimisation of the root mean square top floor absolute acceleration. The optimum friction coefficient of sliding isolation system is obtained under important parametric variations such as: period and damping of the superstructure, ratio of the base mass to the superstructure floor mass, the damping ratio of the isolation system, the period of base isolation system and the intensity of earthquake excitation. It has been shown that the above parameters have significant effects on optimum friction coefficient of the of the sliding base isolation system.

Maria Qing Feng, Masanobu Shinozuka, ShunjiFujii studied the friction-controllable sliding base isolation system. To overcome the problems associated with conventional passive sliding isolation systems that have hindered their practical effectiveness, a hybrid sliding base isolation system is developed using friction-controllable bearings. This innovative hybrid system uses a variable friction force that is computer controlled by changing the pressure in the fluid chamber of the bearing. The variable friction force makes the sliding isolation system more effective in controlling the structural response under earthquakes with a broad range of intensity. A prototype hybrid sliding isolation system is physically developed and tested on a shaking table using a structural model equipped with this system. Control algorithms specially developed for controlling the frictional force that has an inherent nonlinear feature are used in this study, and their effectiveness is verified. Simulation of structural response under passive or hybrid control technique shows good agreement with the experimental results.

The base isolation systems currently under implementation can be mainly classified as elastomeric bearing systems and sliding systems. The elastomeric bearings provide the most straightforward method of seismic isolation. With its horizontal flexibility, the elastomeric bearings provide protection against earthquakes by shifting the fundamental frequency of structural vibration to a much lower value and away from the frequency range where the most energy of the earthquake ground motion exists. The sliding isolation, in contrast to elastomeric isolation, has the following dynamic characteristics: A structure supported entirely by sliding bearings experiences forces at the sliding interface that are always bounded by the frictional force, regardless of the intensity and frequency content of the ground excitation. However, a freely sliding structure might produce large sliding displace-ment, and induce some residual displacement after each earthquake. In some cases, the sliding displacement might become unacceptably large. A number of studies have been performed to reduce the displacement, especially the residual displacement, through the use of recentering devices. In fact, several sliding isolation systems with such devices have been developed. The most notable of these systems are the Friction Pendulum System (FPS) (Zayas et al. 1987), the TAISEI's Shake Suppression (TASS) system (Kawamura et al. 1988) and the Resilient-Friction Base Isolator (R-FBI) system (Mostaghel and Khodaverdian 1987). Each of these systems provides a unique recentering capability.

Satish Nagarajaiah, Micheal Riley, Andrei Reinhorn studied the hybrid control of bridges using sliding bearings, with recentering springs, in parallel with servohydraulic actuators. A new control algorithm with absolute acceleration feedback, based on instantaneous optimal control laws, is developed. The developed control algorithm is implemented in a shake-table study of an actively controlled sliding-isolated bridge. The objective of implementing the hybrid system is to evaluate its advantages in addition to those due to the passive sliding system. The experimental system used in the shake-table test is described and the results of the experiments are presented. It is shown that substantial reduction of response acceleration is possible, using hybrid control, while confining the sliding displacement within an acceptable range, and eliminating almost completely post earthquake permanent offsets.

Sliding-isolation systems in bridges reduce the deck response acceleration and limit the damage to piers supporting the bridge deck. However, in the event of large earthquakes larger forces can be transferred, due to excessive sliding displacements, engagement of displacement restraints, and due to permanent offsets. One of the ways to effectively tackle these issues is to use combined active and passive control systems, referred to as hybrid control systems.

Glenn J. Madden, Michael D. Symans, & Nat Wongprasert Studied the ability of an adaptive seismic isolation system to protect structures subjected to disparate earthquake ground motions. The isolation system consists of sliding isolation bearings in combination with an adaptive hydraulic damper. The damping capacity of the hydraulic damper can be modified in real time to respond to the effects that the earthquake ground motion has on the structure. An experimental laboratory implementation of the adaptive isolation system within a scale-model building structure is described. Analytical models of the isolation system components and the test structure are developed and calibrated through experimental system identification tests. Results from experimental shaking table tests are then used to validate the results from numerical simulations which utilized the analytical models. Although the adaptive base-isolation system results in a complex nonlinear dynamic system, the analytical predictions agreed reasonably well with the experimental test data. The experimental and analytical results demonstrate that, for both near-field and far-field earthquake ground motions, an adaptive sliding base isolation system is capable of reducing the interstory drift response of structures while simultaneously limiting the displacement response of the isolation system.

M.K.Shrimali, R.S.Jangid Studied the response of liquid storage tanks isolated by the sliding systems is investigated under two horizontal components of real earthquake ground motion. The continuous liquid mass is lumped as convective mass, impulsive mass and rigid mass. The corresponding stiffness associated with these lumped masses is calculated depending upon the properties of the tank wall and liquid mass. The governing equations of motion of the tank with a sliding system are derived and solved by Newmark's step-by-step method with iterations. The frictional forces mobilized at the interface of the sliding system are assumed to be velocity dependent and their interaction in two horizontal directions is duly considered. A parametric study is also conducted to study the effects of important system parameters on the effectiveness of seismic isolation of the liquid storage tanks. The various parameters considered are (i) the period of isolation (ii) the damping of isolation bearings and (iii) the coefficient of friction of sliding bearings. It has been found that the bi-directional interaction of frictional forces has noticeable effects and if these effects are ignored then the sliding base displacements will be underestimated which can be crucial from the design point of view. Further, the dependence of the friction coefficient on relative velocity of the sliding bearings has no significant effects on the peak response of the isolated liquid storage tanks.

Touraj Taghikhany Studied the Seismic isolation is one of the effective methods to protect equipments. It helps to control seismic response accelerations in equipment below its allowable level. Among different types of isolation systems, the combination of restoring spring and slider, also called as resilient sliding isolation (RSI) system, is the one which has been effectively used for protection of equipment. Principal design parameters for this type of isolation system are stiffness of spring and friction coefficient of slider. There may be number of combinations of these design parameters which can enable the isolated equipment to remain functional during and after the predicted seismic event. The optimum design of RSI can be considered as the one which maintains the response acceleration in the equipment below its allowable limit and at the same time keeps the relative displacement between floor and the equipment to the minimum. This study deals with optimum design of resilient sliders. First the RSI system is modeled analytically and accuracy of the model is then validated by shaking table tests. The validated model is used to determine optimum design parameters for different levels of allowable accelerations. Results show that the optimum period decreases and the optimum friction coefficient increases with higher allowable acceleration.

Methodology

1. Introductory information on Base Isolation system and their various property as introduced to the structures. It covers Need, objective of this study.

2. Detailed literature review of various methods for the convectional base isolation and sliding isolation system

3. Seismic evaluation methods and computational modeling of RCC buildings using ETABS. It describes in detail the modeling of fixed based, using base isolation such as rubber isolator and friction isolators is applied at base of the building. Detailed procedure of nonlinear time history analysis explained.

4. Results and discussion the results obtained from nonlinear dynamic time

History analysis based on the natural ground motions.

5. Conclusions and future scope of work.

Results and Discussion

All the analysis was done by nonlinear time history analysis. Type of analysis for all the structure is model nonlinear time history analysis considering Indian Bhuj earthquake ground motion data. The earthquake ground vibration data named Bhuj earthquake occurred at January 26, 2001. This vibration data is recorded at Ahmadabad. It has total 26706 acceleration data point at interval 0.005 sec. The PGA value for Bhuj earthquake is 0.09g.

4.2 Comparative Study of different isolation system

In this section total 12 analyses was done for four different buildings i.e. (G+20) storey without strut, (G+20) storey with strut, (G+30) storey without strut, and (G+30) storey with strut by using HDRB & FPS isolators by using earthquake ground motion data.

4.2.1 Results for (G+20) Storey Building without Strut

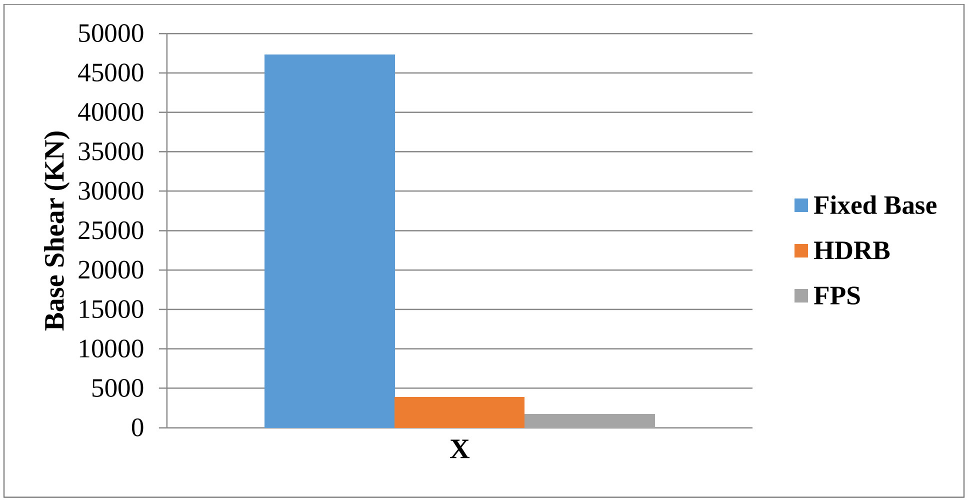


Figure 4.2.1.1: Base Shear in X-Direction

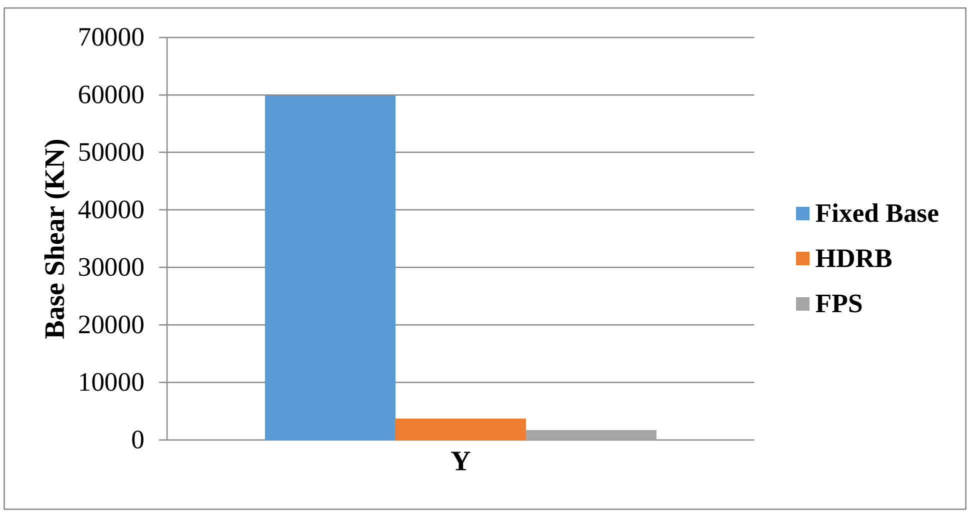


Figure 4.2.1.2: Base Shear in Y-Direction

From Figure 4.2.1.1 it is seen that base shear in X-direction is reduced by 96% and From Figure 4.2.1.2 in Y direction it is reduced by 97% for the case of Friction Pendulum System when compared with fixed base. The base shear in X-direction is reduced by 91% and in Y-direction it is reduced by 93% for the case of High Density Rubber Bearing When compared with fixed base.

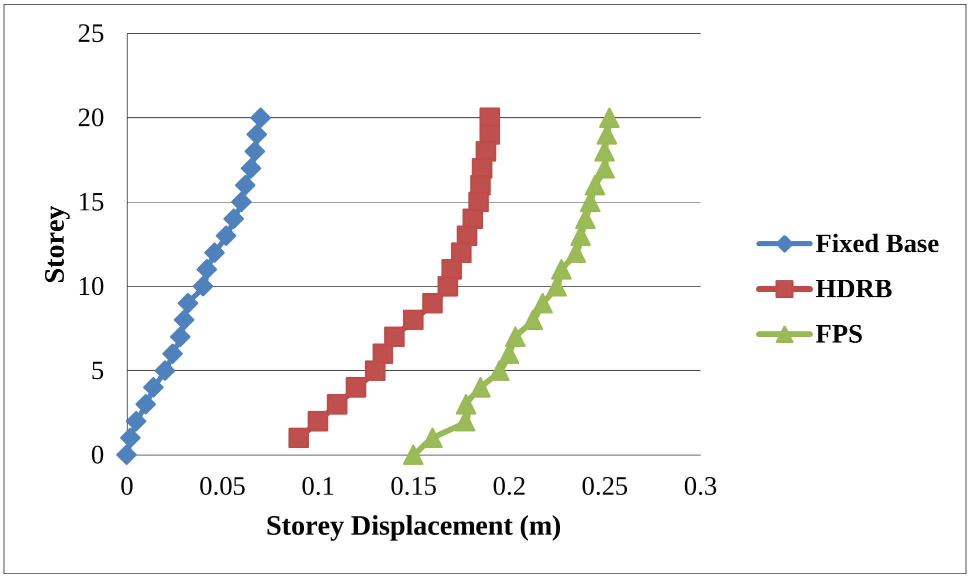


Figure 4.2.1.3: Storey Displacement in X-Direction

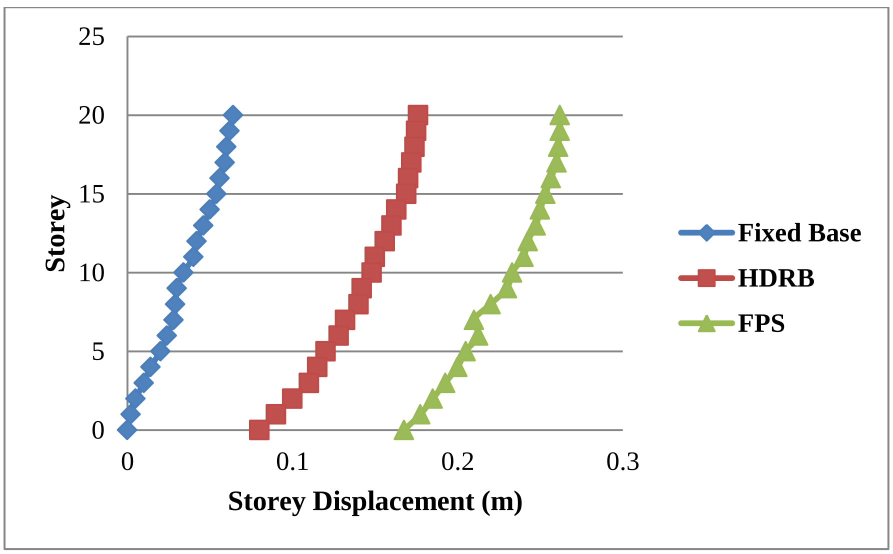


Figure 4.2.1.4 Storey Displacement in Y-Direction

From Figure 4.2.1.3 and 4.2.1.4 it is seen that base displacement given by friction pendulum system isolator compared to the high density rubber type isolator. But maximum top displacement is given by high density rubber bearing type isolators.

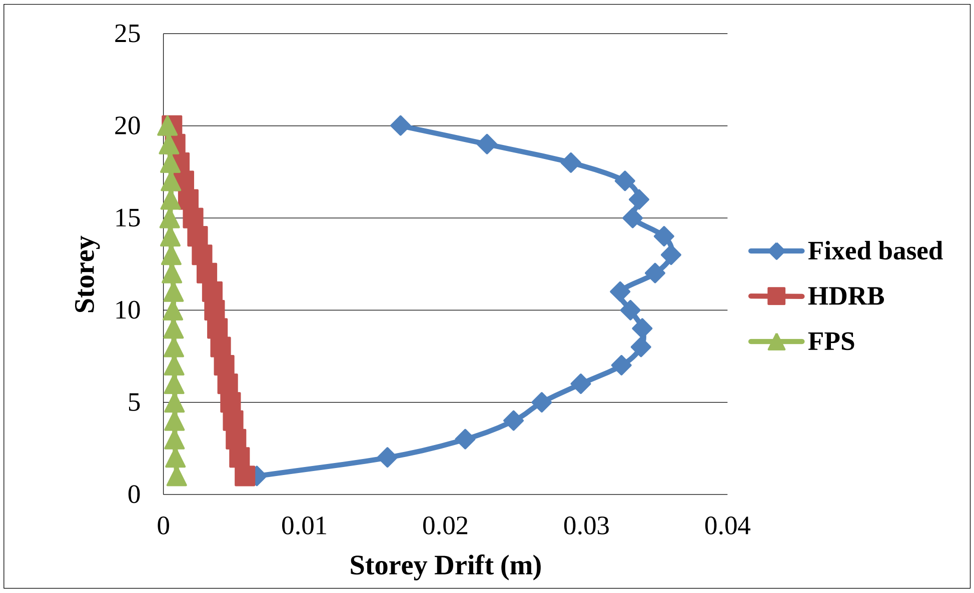


Figure 4.2.1.5: Storey Drift in X-Direction

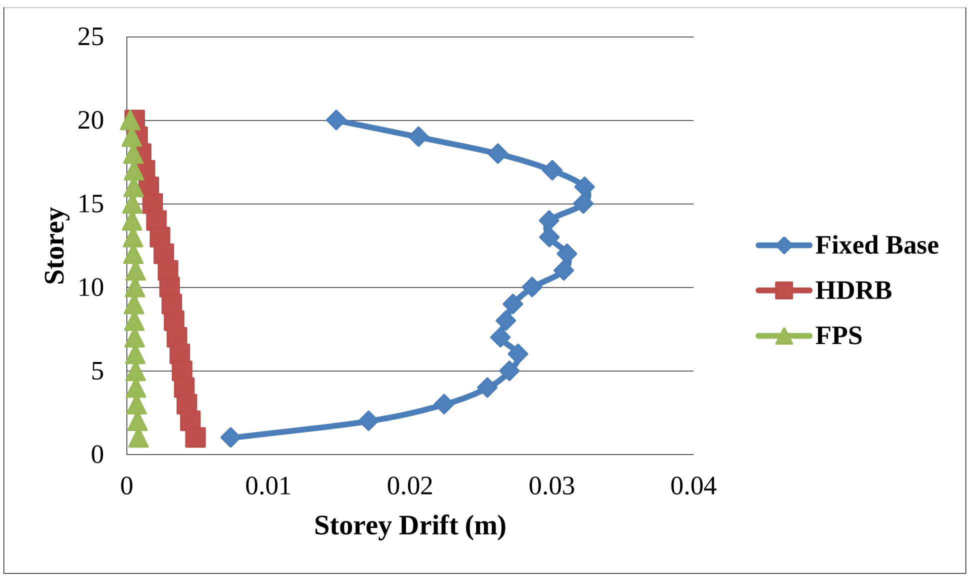


Figure 4.2.1.6: Storey Drift in Y-Direction

From Figure 4.2.1.5 and 4.2.1.6 it is seen that storey drift was greatly reduces by friction pendulum type isolator compared with high density rubber bearing. Both type of isolator reduce drift at greater extent compared with fixed base structure.

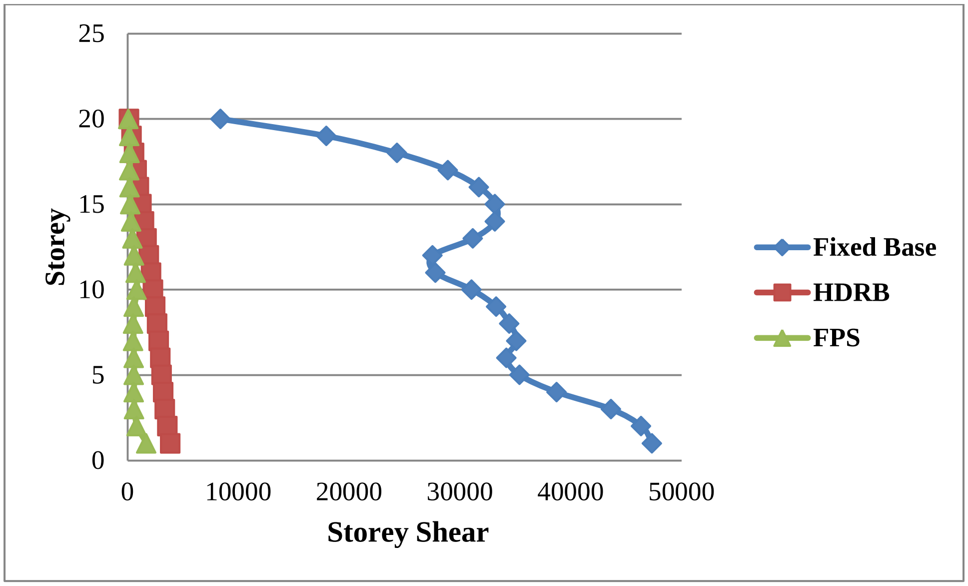


Figure 4.2.1.7: Storey Shear in X-Direction

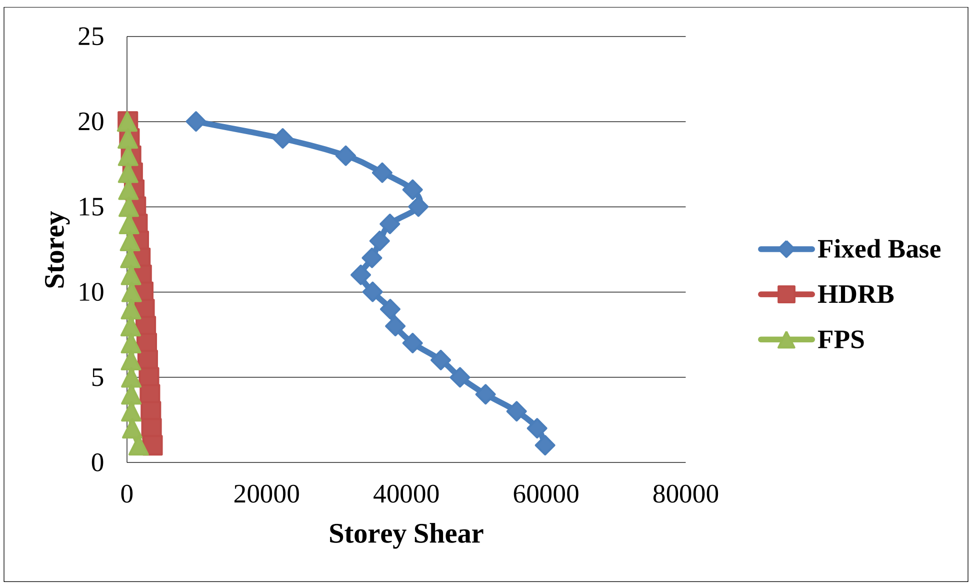


Figure 4.2.1.8: Storey Shear in Y-Direction

From Figure 4.1.2.7 and 4.3.1.8 storey shear was greatly reduces by the use of friction pendulum type isolator compared with high density rubber bearing isolator. It was 50% reduce storey shear in friction pendulum type isolator than density rubber bearing isolator as friction pendulum type isolator compared with density rubber isolator. Both types of isolators reduce storey shear at greater extent compared with fixed base structure.

4.2.2 Results for (G+20) Storey Building with Strut

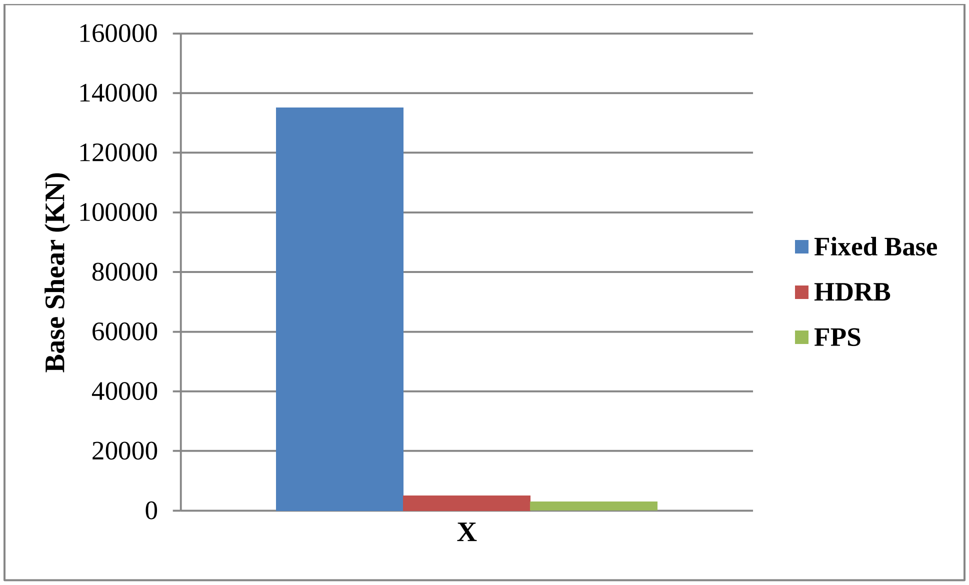


Figure 4.2.2.1: Base Shear in X Direction

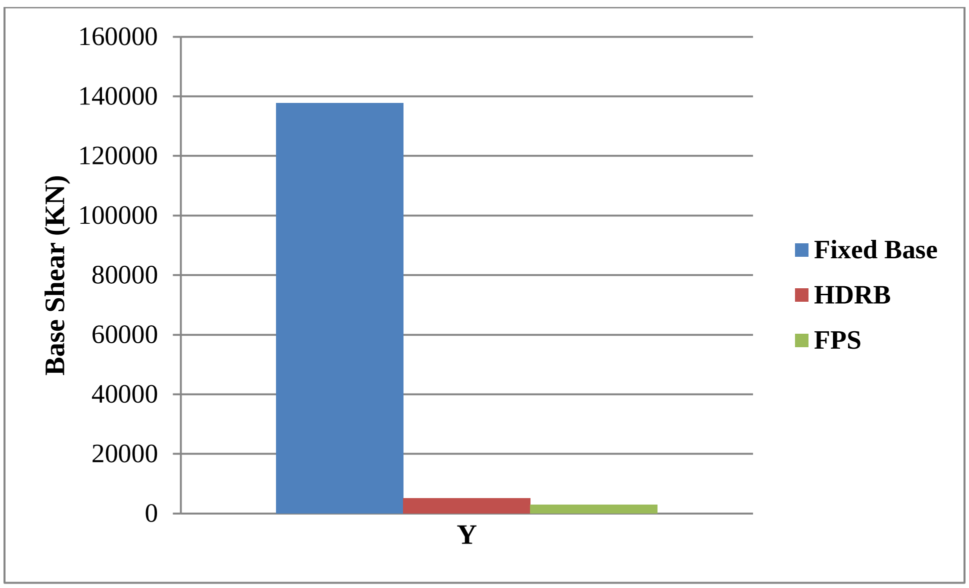


Figure 4.2.2.2: Base Shear in Y Direction

From Figure 4.2.2.1 and 4.2.2.2 it is seen that the base shear in X and Y direction is reduced by 98% for the case of Friction Pendulum System when compared with fixed base. The base shear in X and Y direction it is reduced by 95% for the case of High Density Rubber Bearing when compared with fixed base.

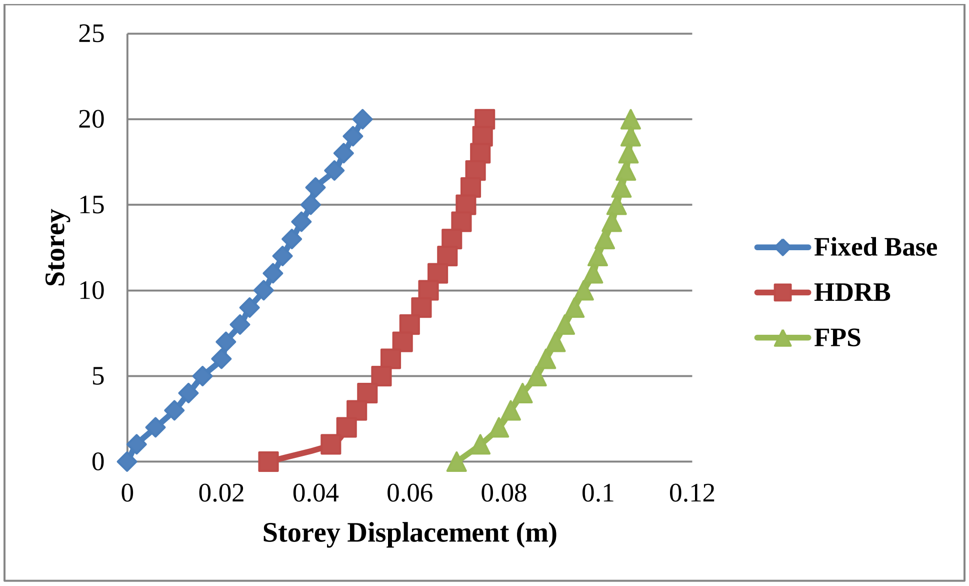


Figure 4.2.2.3: Storey Displacement in X-Direction

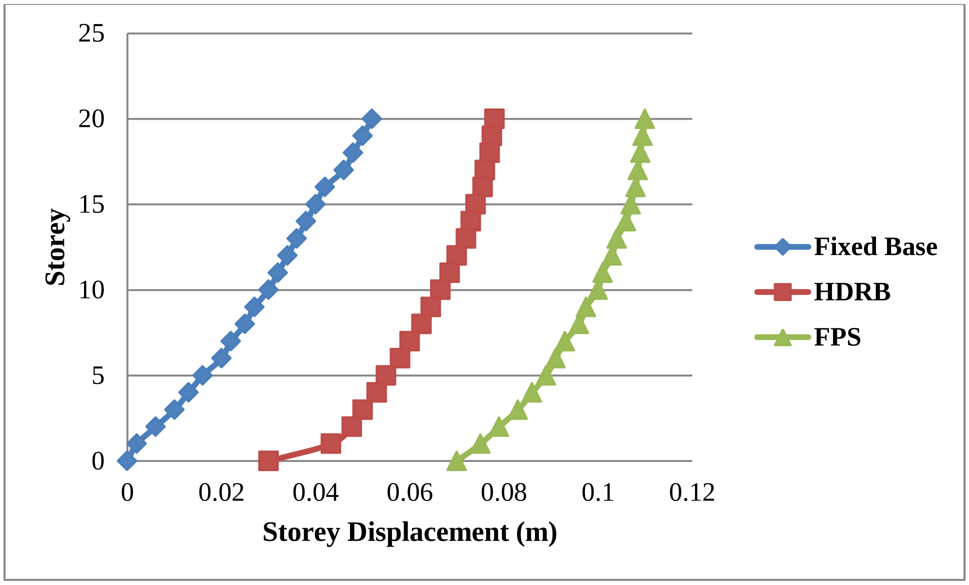


Figure 4.2.2.4: Storey Displacement in Y-Direction

From Figure 4.2.2.3 and 4.2.2.4 it is seen that maximum base displacement is given by friction pendulum system type isolator than high density rubber bearing type isolator when it compared with fixed base structure. Maximum top displacement is given by high density rubber bearing type isolator. Maximum top and base displacement given by friction pendulum system isolator compared to the high density rubber bearing type isolator compared with fixed base structure.

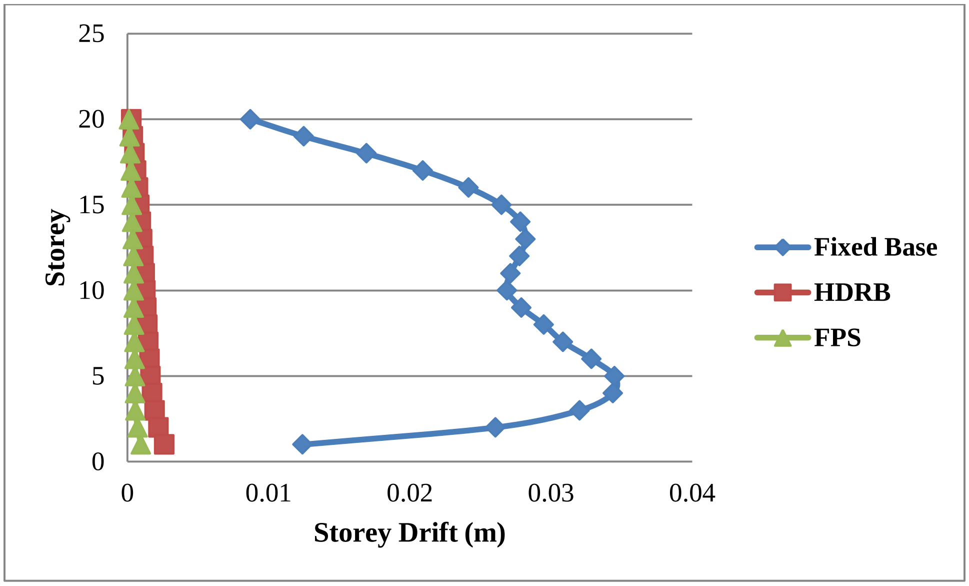


Figure: 4.2.2.5 Storey Drift in X-Direction

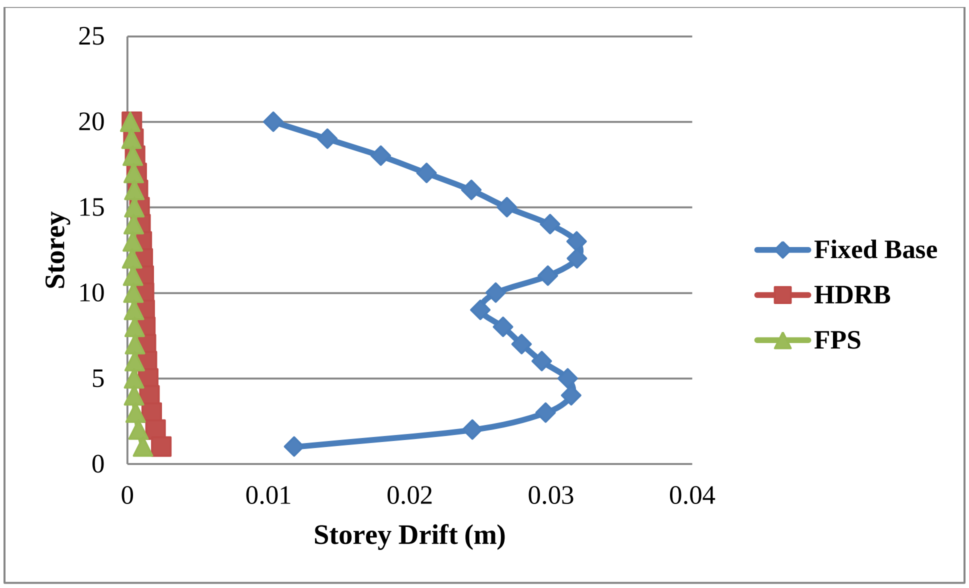


Figure 4.2.2.6: Storey Drift in Y-Direction

From Figure 4.2.2.5 it is observed that storey drift is greatly reduce when friction pendulum system type isolator used as base isolator compared to high density rubber bearing type isolator. Both types of isolators reduce the storey drift compared to fixed base structure. Same Conclusion was made for Figure 4.2.2.6.

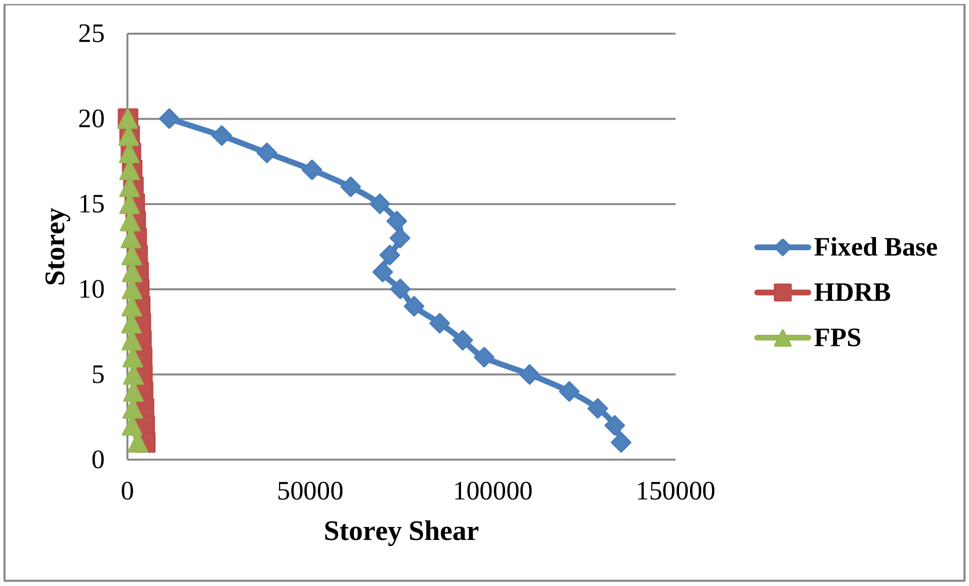


Figure 4.2.2.7: Storey Shear in X-Direction

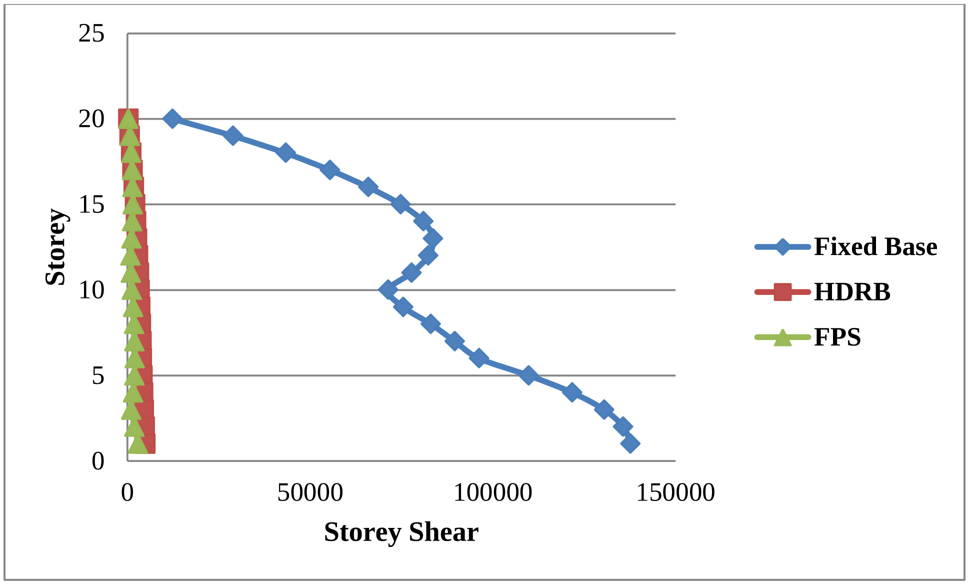


Figure 4.2.2.8: Storey Shear in Y-Direction

From Figure 4.2.2.7 and 4.2.2.8 storey shear was greatly reduces by the use of friction pendulum type isolator compared with high density rubber bearing isolator. It was 50% reduce storey shear in friction pendulum type isolator than density rubber bearing isolator as friction pendulum type isolator compared with density rubber isolator. Both types of isolators reduce storey shear at greater extent compared with fixed base structure.

4.2.3 Results for (G+30) Storey Building without Strut

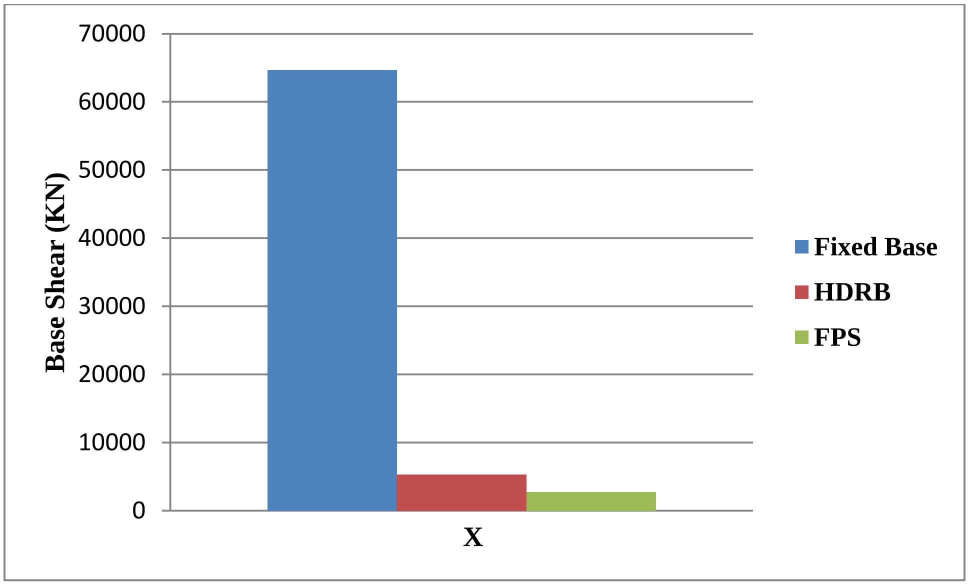


Figure 4.2.3.1 Base Shear in X-Direction

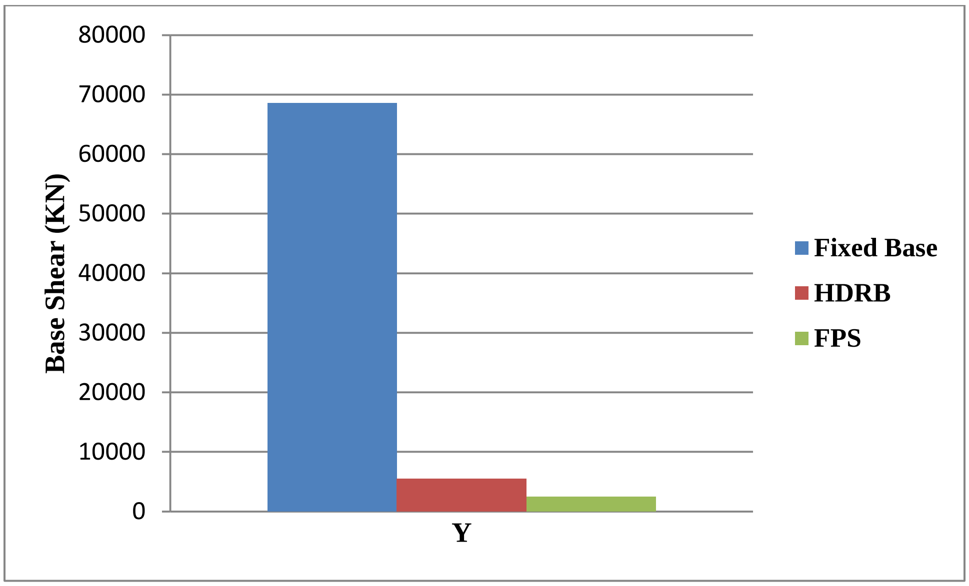


Figure 4.2.3.2 Base Shear in Y-Direction

From Figure 4.2.3.1 it is seen that base shear in X-direction is reduced by 95% and From Figure 4.2.3.2 in Y direction it is reduced by 97% for the case of Friction Pendulum System when compared with fixed base. The base shear in X-direction is reduced by 91% and in Y-direction it is reduced by 90% for the case of High Density Rubber Bearing When compared with fixed base.

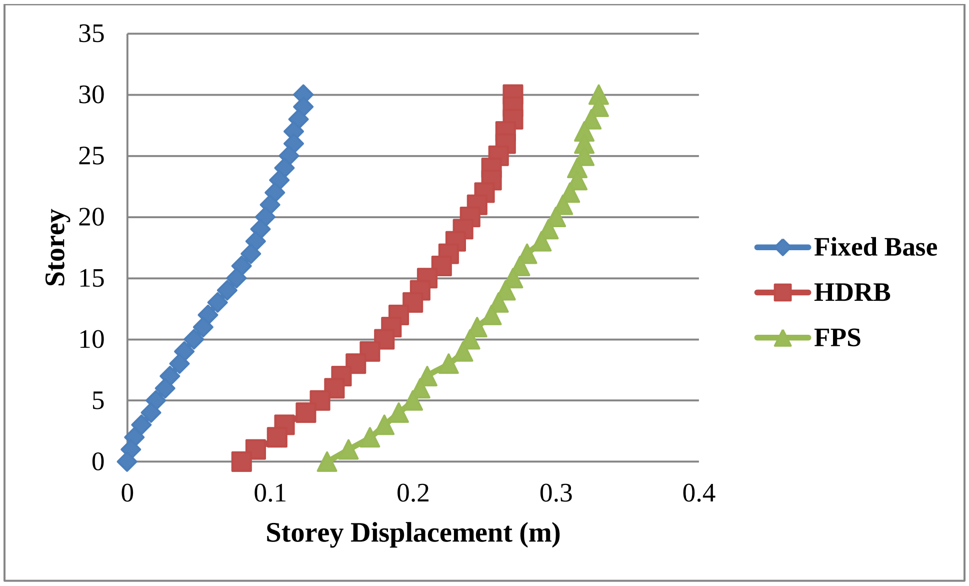


Figure 4.2.3.3: Storey Displacement in X-Direction

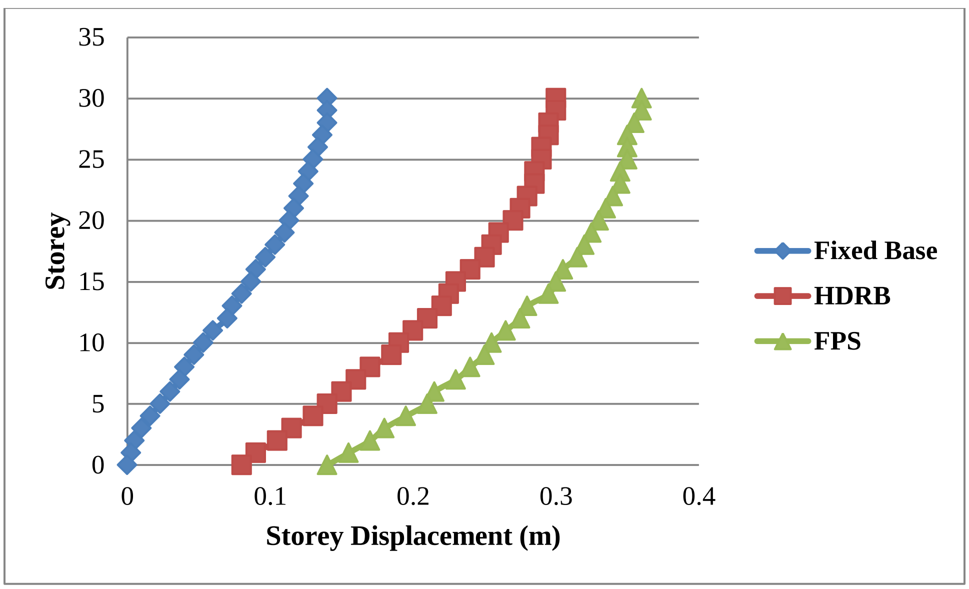


Figure 4.2.3.4: Storey Displacement in Y-Direction

Maximum top displacement is given by high density rubber bearing type isolator. Maximum top and base displacement given by friction pendulum system isolator compared to the high density rubber bearing type isolator compared with fixed base structure. From Figure 4.2.3.3 and 4.2.3.4 it is seen that maximum base displacement is given by friction pendulum system type isolator than high density rubber bearing type isolator when it compared with fixed base structure

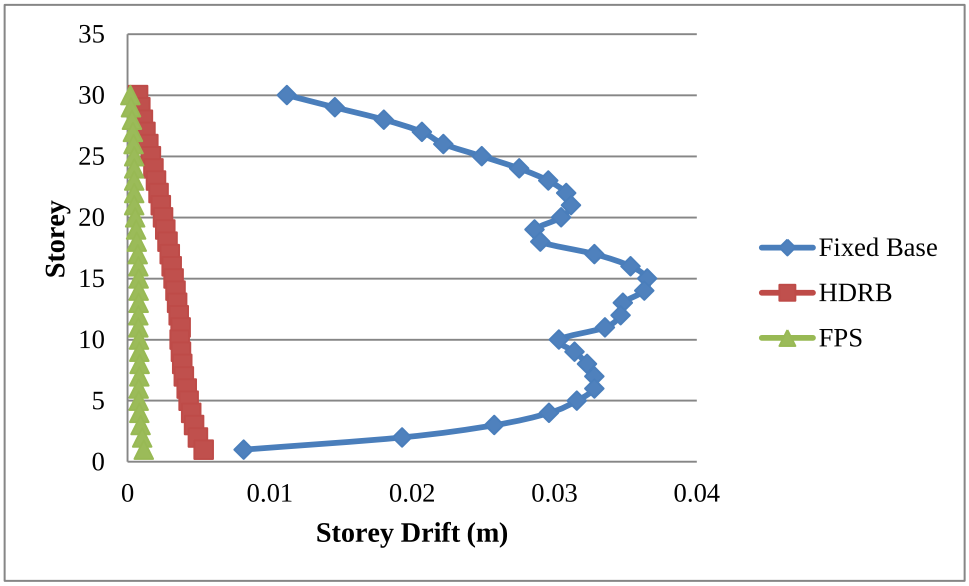


Figure 4.2.3.5: Storey Drift in X-Direction

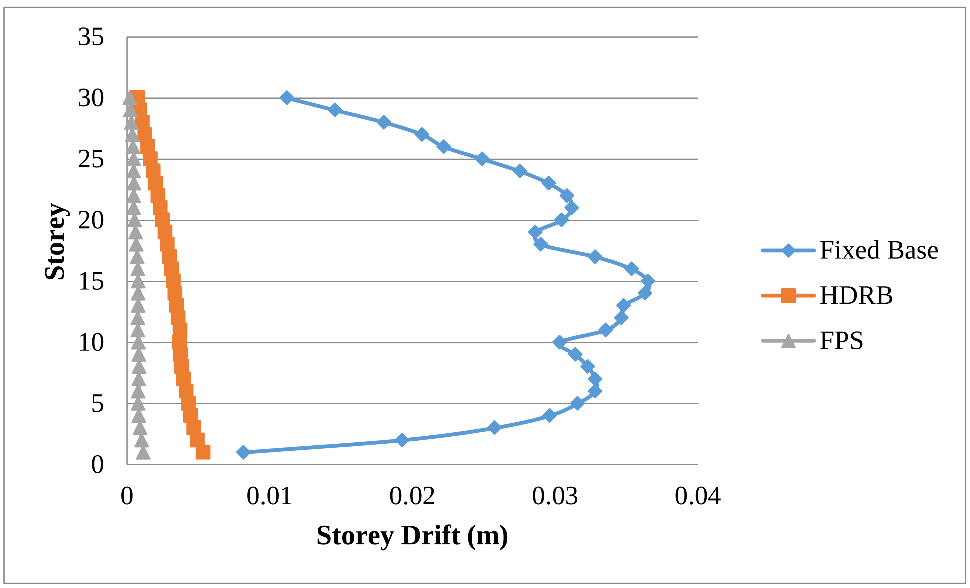


Figure 4.2.3.6: Storey Drift in Y-Direction

From Figure 4.2.3.5 it is observed that storey drift is greatly reduce when friction pendulum system type isolator used as base isolator compared to high density rubber bearing type isolator. Both types of isolators reduce the storey drift compared to fixed base structure. Same Conclusion was made for Figure 4.2.3.6.

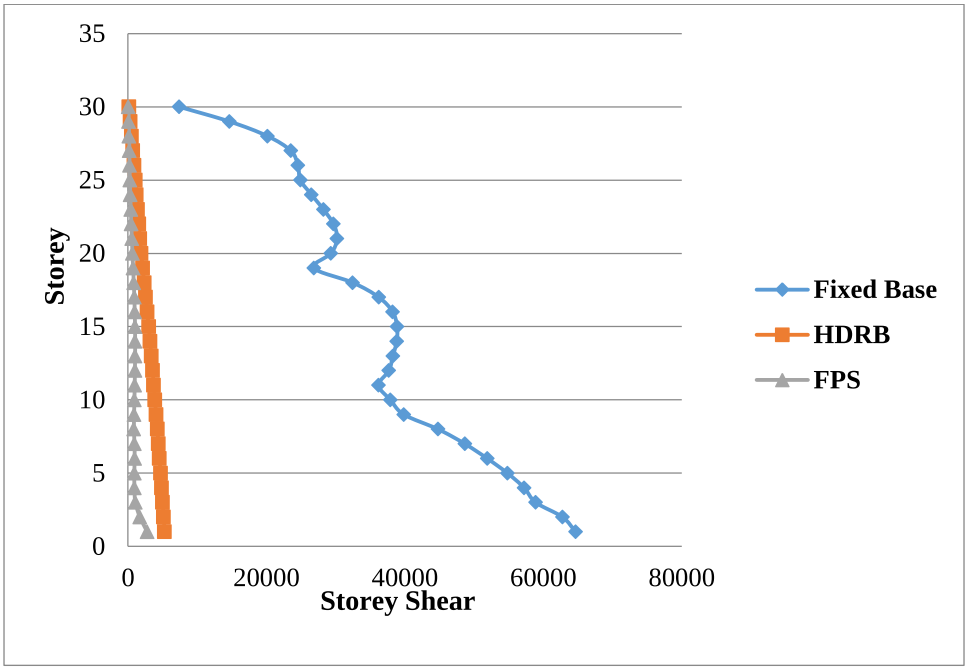


Figure 4.2.3.7: Storey Shear in X-Direction

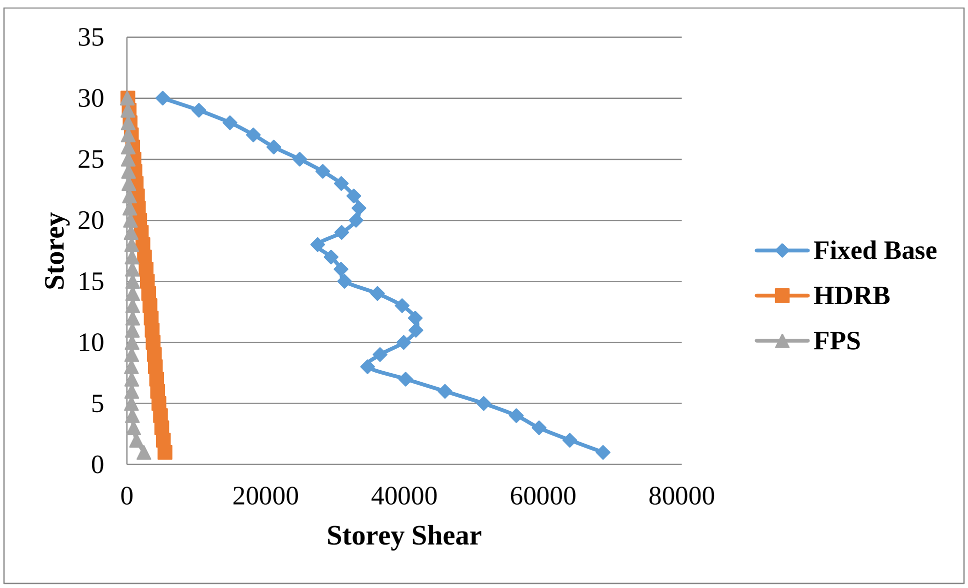


Figure 4.2.3.8: Storey Shear in Y-Direction

From Figure 4.2.3.7 and 4.2.3.8 storey shear was greatly reduces by the use of friction pendulum type isolator compared with high density rubber bearing isolator. It was 50% reduce storey shear in friction pendulum type isolator than density rubber bearing isolator as friction pendulum type isolator compared with density rubber isolator. Both types of isolators reduce storey shear at greater extent compared with fixed base structure.

4.2.4 Results for (G+30) Storey Building with Strut

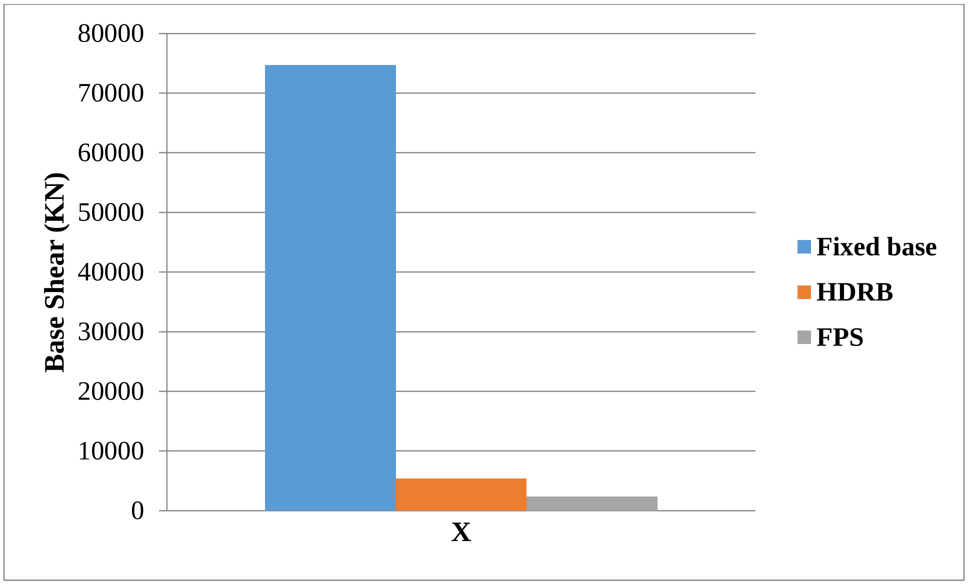


Figure 4.2.4.1: Base Shear in X Direction

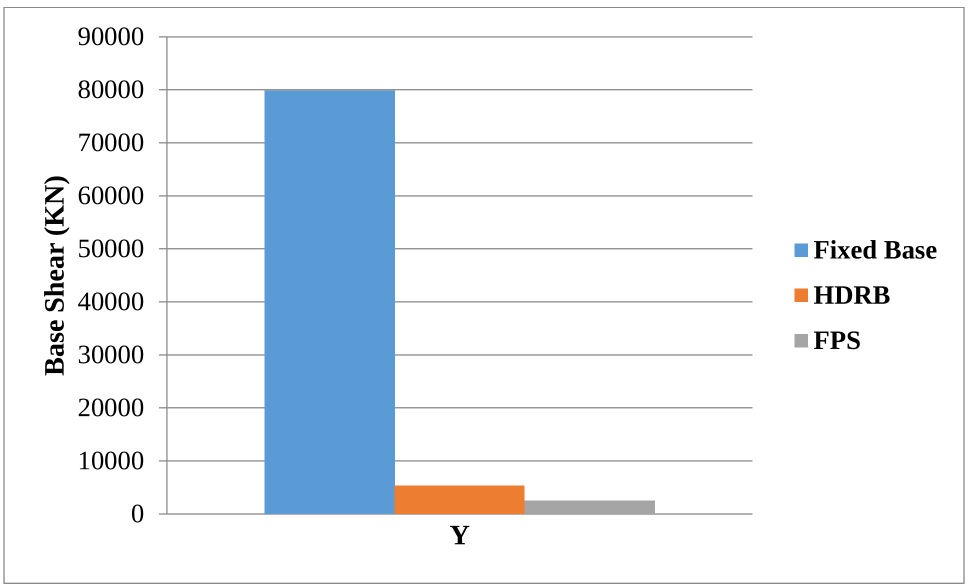


Figure 4.2.4.2: Base Shear in Y Direction

From Figure 4.2.4.1 it is seen that base shear in X-direction is reduced by 96% and From Figure 4.2.4.2 in Y direction it is reduced by 97% for the case of Friction Pendulum System when compared with fixed base. The base shear in X-direction is reduced by 93% and in Y-direction it is reduced by 94% for the case of High Density Rubber Bearing When compared with fixed base.

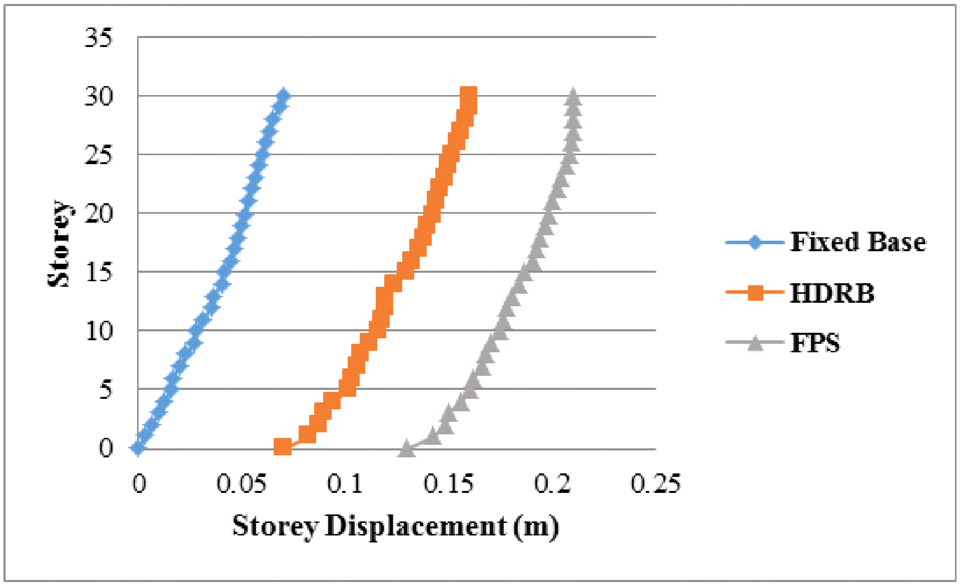


Figure 4.2.4.3: Storey Displacement in X- Direction

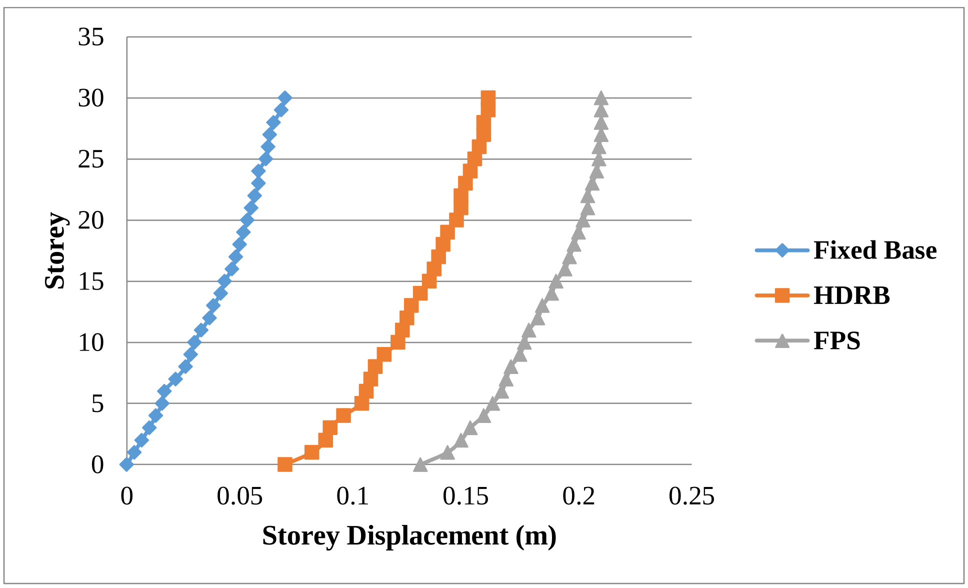


Figure 4.2.4.4: Storey Displacement in Y- Direction

Maximum top displacement is given by high density rubber bearing type isolator. Maximum top and base displacement given by friction pendulum system isolator compared to the high density rubber bearing type isolator compared with fixed base structure. From Figure 4.2.4.3 and 4.2.4.4 it is seen that maximum base displacement is given by friction pendulum system type isolator than high density rubber bearing type isolator when it compared with fixed base structure.

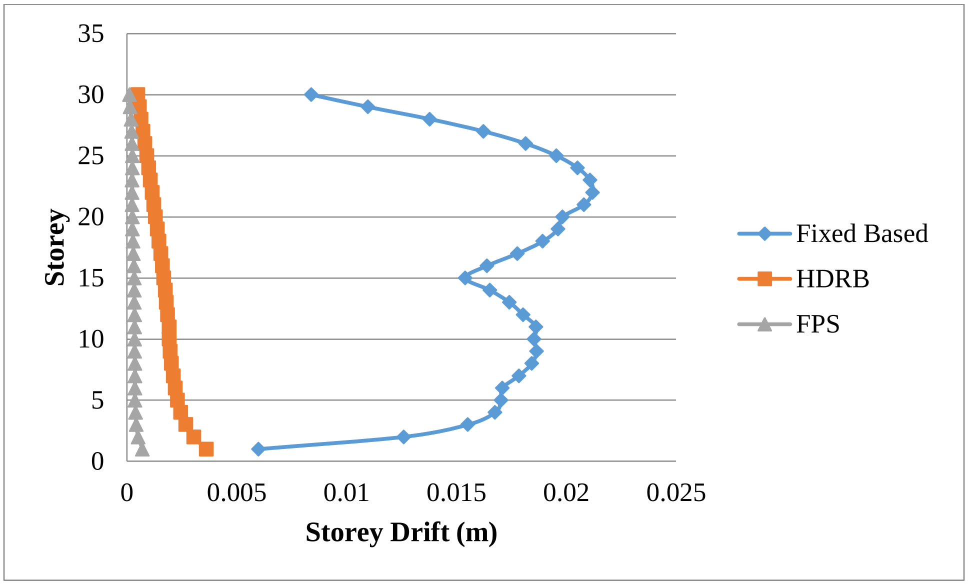


Figure 4.2.4.5: Storey Drift in X- Direction

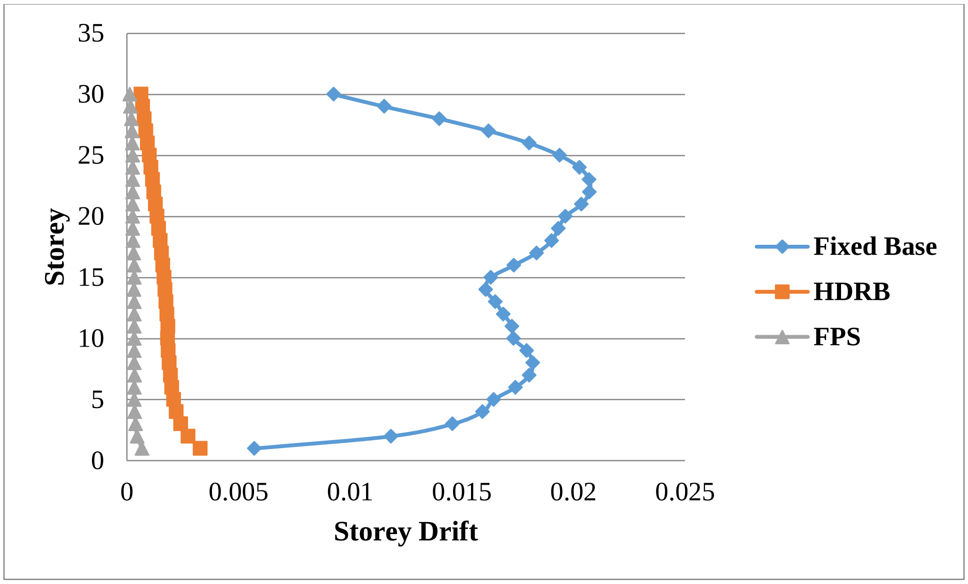


Figure 4.2.4.6: Storey Drift in Y- Direction

From Figure 4.2.4.5 it is observed that storey drift is greatly reduce when friction pendulum system type isolator used as base isolator compared to high density rubber bearing type isolator. Both types of isolators reduce the storey drift compared to fixed base structure. Same Conclusion was made for Figure 4.2.4.6.

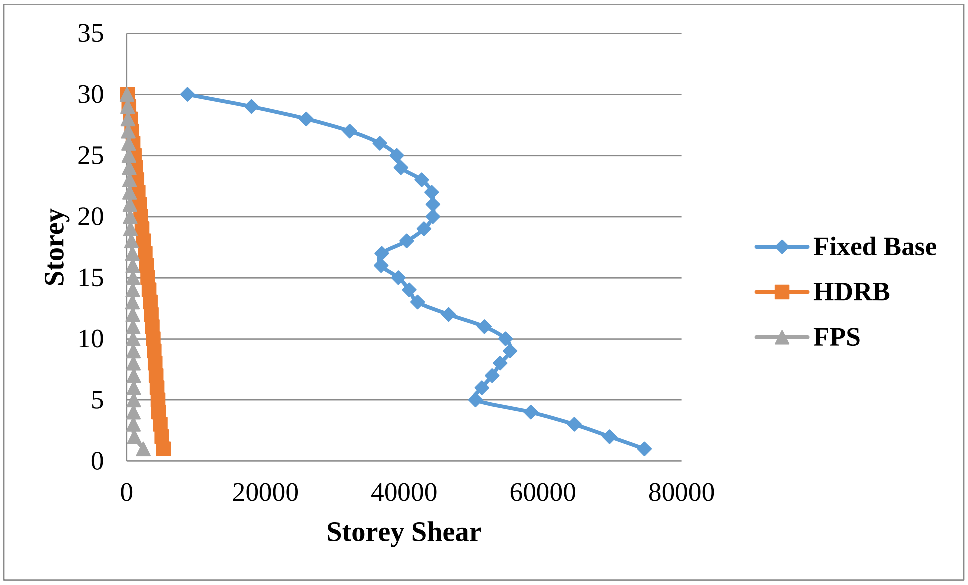


Figure 4.2.4.7: Storey Shear in X- Direction

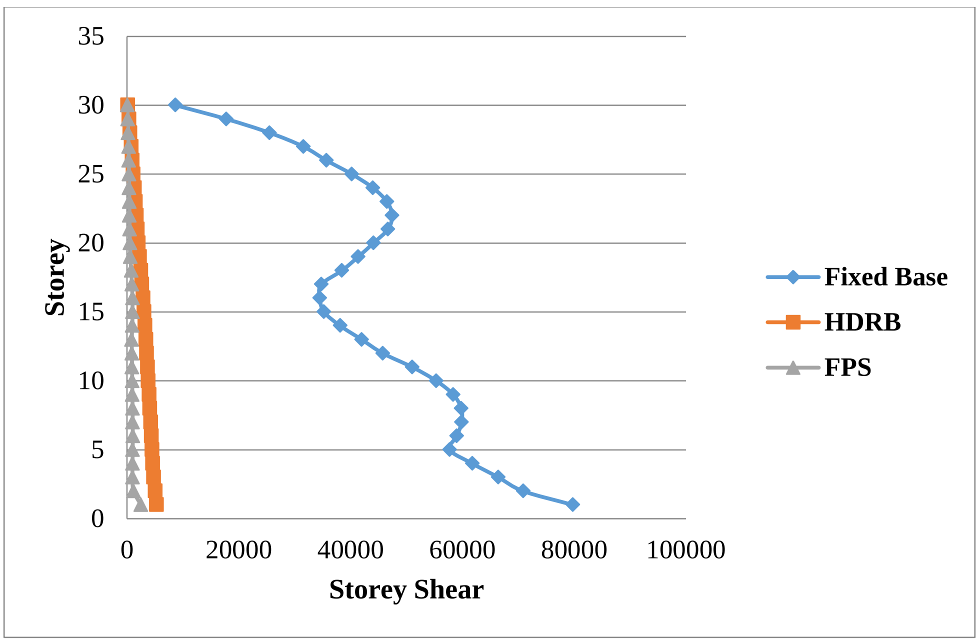


Figure 4.2.4.8: Storey Shear in Y- Direction

From Figure 4.2.4.7 and 4.2.4.8 storey shear was greatly reduces by the use of friction pendulum type isolator compared with high density rubber bearing isolator. It was 50% reduce storey shear in friction pendulum type isolator than density rubber bearing isolator as friction pendulum type isolator compared with density rubber isolator. Both types of isolators reduce storey shear at greater extent compared with fixed base structure.

4.3 Time Period Comparisons

In this section comparison of time periods of fixed base base isolated structure are presented for all the three structures.

4.3.1 (G+20) Storey Structure without strut

Table 4.3.1.1 shows the comparison of time period for all three cases i.e. fixed base, for HDRB and for FPS isolation System

Table 4.3.1.1: Time Period for (G+20) Structure without Strut

FIXED BASE	HDRB	FPS
3.83 sec	6.47 sec	7.41 sec

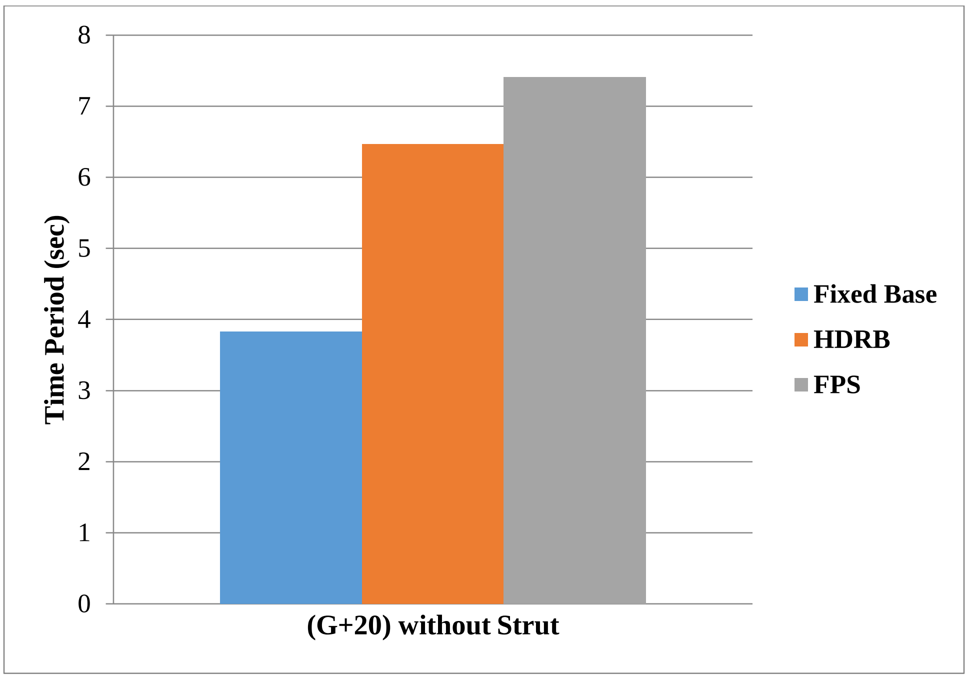


Figure 4.3.1.1: Time Period for (G+20) Storey Structure without Strut

From Table 4.3.1.1 and Figure 4.3.1.1 it is seen that time period increased by the use of base isolator over the conventional fixed base structure. But, Friction Pendulum System lengthen the time period at greater extent compared to High Density Rubber Bearing

4.3.2 (G+20) Storey Structure with Strut

Table 4.3.2.1: Time Period for (G+20) Structure with Strut

FIXED BASE	HDRB	FPS
2.42 sec	5.15 sec	4.06 sec

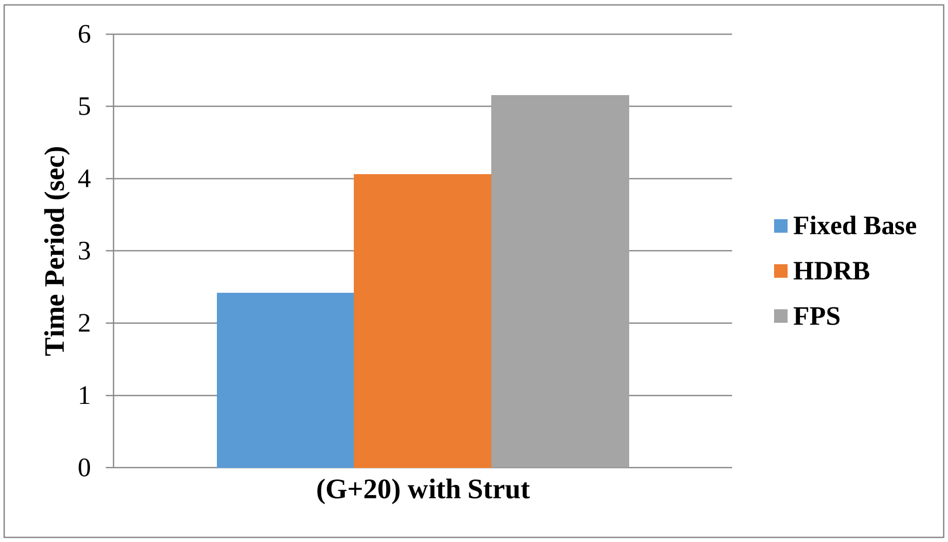


Figure 4.2.3.6: Storey Drift in Y-Direction

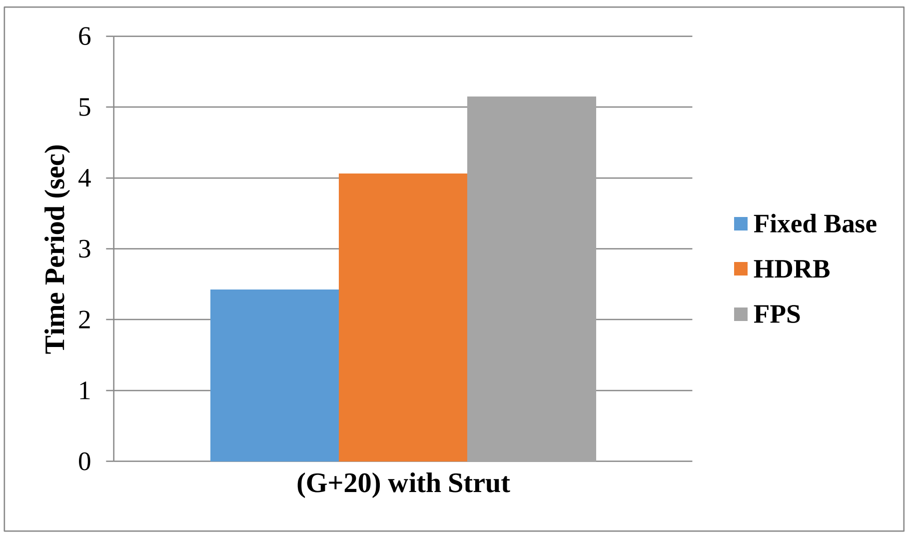


Figure 4.3.2.1: Time Period for (G+20) Storey Structure with Strut

From Table 4.3.2.1 and Figure 4.3.2.1 it is seen that time period increased by the use of base isolator over the conventional fixed base structure. But, Friction Pendulum System lengthen the time period at greater extent compared to High Density Rubber Bearing

4.3.3 (G+30) Storey Structure without Strut

Table 4.3.3.1: Time Period for (G+30) Structure without Strut

FIXED BASE	HDRB	FPS
5.65 sec	8.79 sec	7.83 sec

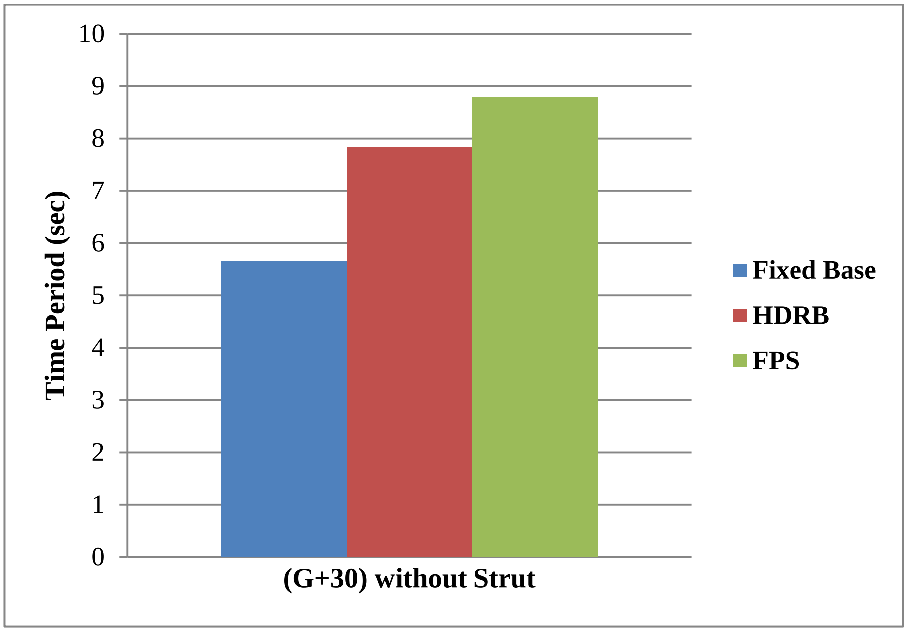


Figure 4.3.3.1: Time Period for (G+30) Storey Structure without Strut

From Table 4.3.3.1 and Figure 4.3.3.1 it is seen that time period increased by the use of base isolator over the conventional fixed base structure. But, Friction Pendulum System lengthen the time period at greater extent compared to High Density Rubber Bearing

4.3.4 (G+30) Storey Structure with Strut

Table 4.3.4.1: Time Period for (G+30) Structure with Strut

FIXED BASE	HDRB	FPS
5.65 sec	8.79 sec	7.83 sec

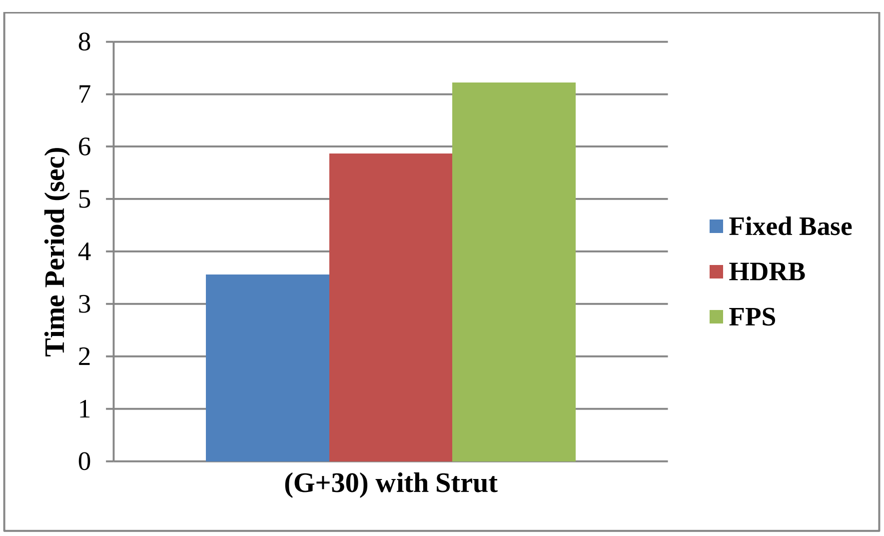


Figure 4.3.4.1: Time Period for (G+30) Storey Structure with Strut

From Table 4.3.4.1 and Figure 4.3.4.1 it is seen that time period increased by the use of base isolator over the conventional fixed base structure. But, Friction Pendulum System lengthen the time period at greater extent compared to High Density Rubber Bearing

Conclusions

1. It is concluded that time period of the structure in case of FPS and HDRB it is increased over conventional fixed base structure.
2. It is concluded that base shear of structure reduces by the use of base isolator. But it is greatly reduces by use of FPS over HDRB.
3. It is also concluded that FPS gives maximum base displacement compared to HDRB.
4. Storey drift is reduce by both HDRB and FPS. But it is greatly reduces by the use of FPS.
5. It is seen that base isolation technique lengthens the time period of structure at greater extent for mid rise structure. But, as the number of stories goes on increasing the proportion of increment in time period of base isolated structure goes on decreasing.
6. It is concluded that as the number of storey's increase, the friction pendulum system give minimum value for top displacement. Hence, it is concluded that this type of system helps to minimize top displacement for multi storey structure.
7. It is concluded that Friction Pendulum system helps in reducing storey drift &storey acceleration at greater extent than High Density Rubber Bearing for both mid-Storey and multi-storey structure.
8. Friction pendulum system is beneficial than lead rubber bearing isolator & slightly higher than high density rubber isolator in terms of cost.

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