International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 3, Issue 7, July-2017

# COMPARATVE STUDY ON RC FRAME WITH FIXED BASE, BASE ISOLATED RC FRAME USING FRICTION PENDULUM BEARING AND RC FRAME WITH FRICTION DAMPER USING TIME HISTORY ANALYSIS

Ruchita S. Jadhav[1], Dr.M.M.Murudi[2]

[1]*Structural Engineering department, Sardar Patel College of Engineering,*
[2] *Structural Engineering department, Sardar Patel College of Engineering,*

***Abstract*— Most of the existing buildings which do not fulfil the current seismic requirements, may suffer extensive damage or even collapse due to earthquake. So to mitigate the effects of vulnerable earthquakes on the strucutre, the base isolation technique and energy dissipation technique is the best alternative as a seismic protection system. The present study is an effort to understand seismic performance of structure with fixed base, structure with friction damper and base isolated structure. In this thesis , a G+5 strucutre is considered and analysed.Total three models of the building frame with fixed base, with friction damper and with friction pendulum bearing are considered. The analysis of strucutre is done by time history method and response spectrum method. The structure is modelled using finite element software ETABS 15.2.2. The building is assumed to be situated in Zone V (as per IS 1893: Part 1) and on medium soil condition. The time history analysis is used to find the seismic performance of strucuture for all three models.Friction Pendulum Bearing (FPB) and Friction Damper(FD) are used for improvement of RC frame building. The procedure of analysis adopted for fixed base strucutre is repeated for Friction Damper(FD) and base isolated structure(FPB) structures,so it will help in comparative parametric study. The results of analysis are compared in terms of storey shear, storey displacement, modal gtime period, storey accelerartion, storey drift etc. and obtained results are presented in graphically and in tabuluar form.***

***Key Words:*** ***Base isolated strucuture, time history analysis, response spectrum method, friction damper, friction pendulum bearing, ETABS 15.2.2.***

## I. INTRODUCTION

Earthquakes can create serious damage to structures. The structures already built are vulnerable to future earthquakes. The damage to structures causes deaths, injuries, economic loss, and loss of functions. Earthquake risk is associated with seismic hazard, vulnerability of buildings. Vulnerability of building is important in causing risk to life. Earthquakes cause inertia forces proportional to the product of the building mass and the ground accelerations. As the ground accelerations increases, the strength of the building must be increased to avoid structural damage. It is not practical to continue to increase the strength of the building indefinitely. In high seismic zones the accelerations causing forces in the building may exceed one or even two times the acceleration due to gravity, g. It is easy to visualize the strength needed for this level of load, which means that the building could be tipped on its side and held horizontal without damage. Earthquakes will happen and are yet uncontrollable. So it should be tried to increase the capacity.

Safety of life in any seismic event is a prime consideration of earthquake resistant design philosophies. Experience from the past earthquakes has revealed that much loss of life and property results due to inadequacies and faulty practices in design of structures. To improve the behavior of inadequate building and to minimize the damage, it is essential to retrofit the inadequate buildings.

During earthquake the conventional structure without seismic isolation is subjected to substantial storey drifts, which may lead to damage or even collapse of the building. Whereas isolated structure vibrates almost like a rigid body with large displacement due to the presence of isolators at the base of structures.

The objective of the study is to compare a G+5 RC Structure with fixed base, with base isolation (Friction pendulum Bearing) and with Friction Damper (FD).

## II. Concept of Base isolation and Dampers

### 1. Base isolation

Base isolation is one of the most widely accepted techniques to protect structures and to mitigate the risk to life and property from strong earthquakes. A seismically isolated structure has a fundamental frequency that is much lower than the Fundamental frequency of the corresponding fixed supported structure and the predominant frequencies of a typical earthquake are achieved by mounting the structures on a set of isolators that provides low horizontal stiffness and consequently, shifts the fundamental frequencies of the structures to much lower values. A seismically isolated structure experiences reduced seismic forces and accelerations and moves essentially as a rigid body, preventing damage due to deformations. In the base isolation strategy, it is possible to obtain a considerable reduction of large displacements attained at the base level as a consequence of the energy dissipation due to damping and hysteretic properties of isolation device. Many buildings have been constructed on various types of seismic bearings, and such structures have shown superior performance during earthquakes.

**Friction Pendulum Bearing:**

Sliding systems with a predefined coefficient of friction can provide isolation by limiting acceleration and forces that are transferred. Sliders are capable of providing resistance under service conditions, flexibility and force-displacements by sliding movement. Shaped or spherical sliders are often preferred over flat sliding systems because of their restoring effect. Flat sliders provide no restoring force and there are possibilities of displacement with aftershocks.

*Fig. 1 Friction Pendulum Bearing*

### 2. Dampers

Structural passive control systems have been developed with a design philosophy different than that of traditional seismic design method. These control systems primarily include seismic isolation systems & energy dissipation systems. A variety of energy dissipation systems have been developed in the two decades such as friction damper, metallic damper, viscous damper. A structure installed with these dampers does not rely on plastic hinges to dissipate the seismic energy. On contrary, the dissipation of energy is concentrated on some added damper so that the damage of the main structure is reduced and functions of the structure can be possibly preserved.

**Friction Dampers:**

These dampers operate on the principle of frictional sliding. And the friction been sliding faces is used to dissipate energy. These devices can also be fitted between two storeys to damp their relative motion.

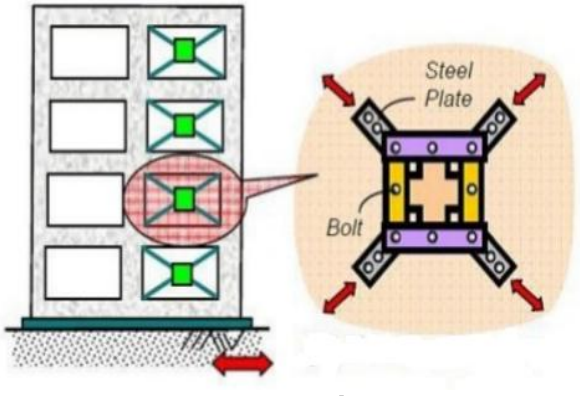

*Fig. 2 Friction dampers*

Generally these devices have good performance characteristics and their behavior is relatively less affected by the load frequency, number of load cycles or variation in temperature. These devices differ in their mechanical complexity and in the materials used for the sliding surfaces. It is a device that can he located at the intersection of cross bracings. When loaded. The tension brace induces slippage at the friction joint, and the 4 links force the compression brace to slip. In this manner, energy is dissipated in both braces. Also they reduce the inter-storey drift and thereby provide structural stability. These dampers have an advantage that they are less affected by temperature changes and number of load cycles.

## III. MODELING AND ANALYSIS

*A.STRUCTURE DETAILS*

- Type of structure: SMRF(Concrete Structure)

- Depth of slab:125mm
- Unit weight of RCC:25kN/m$^3$
- Unit weight of Masonry :20kN/m$^3$
- Height of each story: 3m
- Zone:5
- Member used: Beam:230 x 450
- Column: 300 x 600
- Soil type: Medium
- Grade of concrete: M30
- Grade of steel: Fe415
- Width of bay:4.5m

Floor loads

- Live load=2kN/m$^2$
- Floor finish=1.5kN/ m$^2$
- Terrace live load=1.5kN/m$^2$
- Terrace floor load=2.5kN/m$^2$

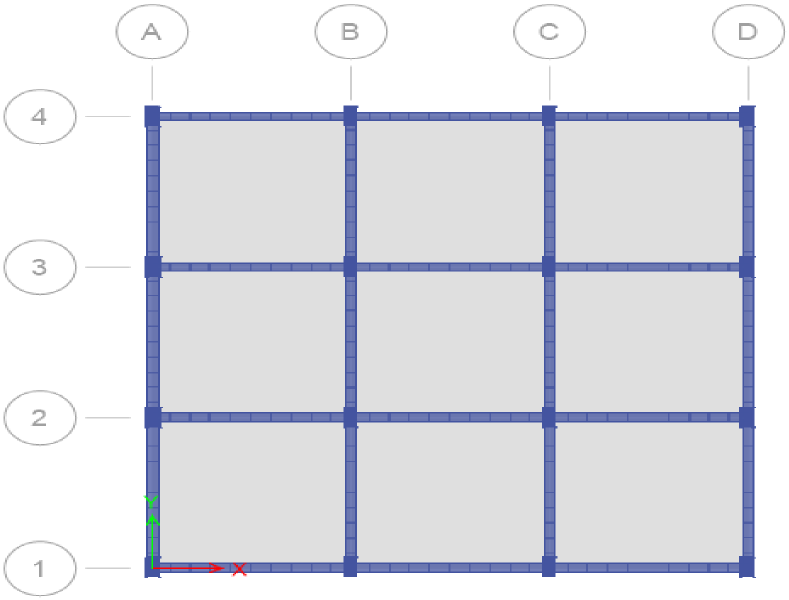

*Fig. 3 Plan view of G+5*

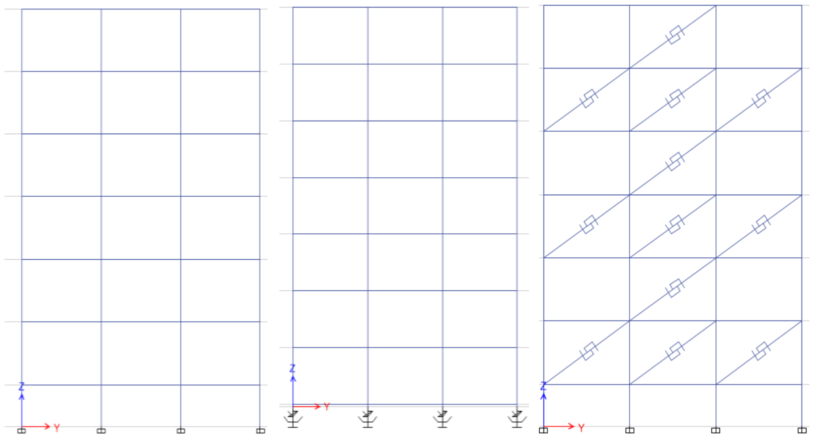

*Fig. 4 Elevation of G+5 with fixed base, with Friction Pendulum Bearing and Friction Dampers.*

In this a G+5 structure of height 20m was considered. The structure has a symmetrical plan of 13.5 x 13.5m. The structure is situated in Zone V on medium soil. For the analysis, Non-Linear Time History method has been used in ETABS 15.2.2. To conduct time history analysis, the ground motion records used are El-Centro having peak ground acceleration of 0.313g. The structure is analyzed with fixed base, with friction damper and with friction pendulum bearing for various parameters.

The properties of friction pendulum bearing and friction damper are as follows:

TABLE 1
PROPERTIES OF FRICTION PENDULUM BEARING FOR G+5

| **Linear** | | | **Non-Linear** | | | | |
|---|---|---|---|---|---|---|---|
| **Direction** | **Stiffness (KN-m)** | **Effective Damping** | **Direction** | **Stiffness (KN-m)** | **Rate Parameter** | **µ** | **R(m)** |
| U1 | 29000000 | 0.1 | U1 | 29000000 | - | - | - |
| U2 | 1450 | 0.1 | U2 | 29000 | 40 | 0.08 | 1.0 |
| U3 | 1450 | 0.1 | U3 | 29000 | 40 | 0.08 | 1.0 |

TABLE 2
PROPERTIES OF FRICTION DAMPER FOR G+5

| | | |
|---|---|---|
| **Mass ( for all storey )** | | 2250 kg |
| **Weight ( for all storey )** | | 2.25 kN |
| **Rotational Inertia (for 1,2 & 3)** | | 0 |
| **Effective stiffness, Ke** | | |
| **For G+05 storey** | **along X direction** | 109198.28 kN/m |
| | **along Y direction** | 102476.73 kN/m |
| **Effective damping, Ke** | | |
| **For G+05 storey** | **along X direction** | 3570.50 kN-s/m |
| | **along Y direction** | 3458.87 kN-s/m |

## IV. RESULTS

### *A. Storey Shear (kN) in X and Y Direction*

TABLE NO. 3
STOREY SHEAR IN X-DIRECTION FOR G+5 STRUCTURE

| **Storey** | **Fixed Base** | **With Friction Damper** | **With FPB** |
|---|---|---|---|
| Roof | 40.7659 | 25.7016 | 25.5986 |
| Fifth | 86.8832 | 54.4645 | 51.2309 |
| Fourth | 120.1954 | 81.4413 | 71.7653 |
| Third | 139.9169 | 104.541 | 86.5101 |
| Second | 145.2917 | 126.6974 | 95.3083 |
| First | 132.1051 | 130.4419 | 98.0884 |
| Plinth | 127.4577 | 111.3833 | 95.4125 |
| Base | 0 | 0 | 0 |

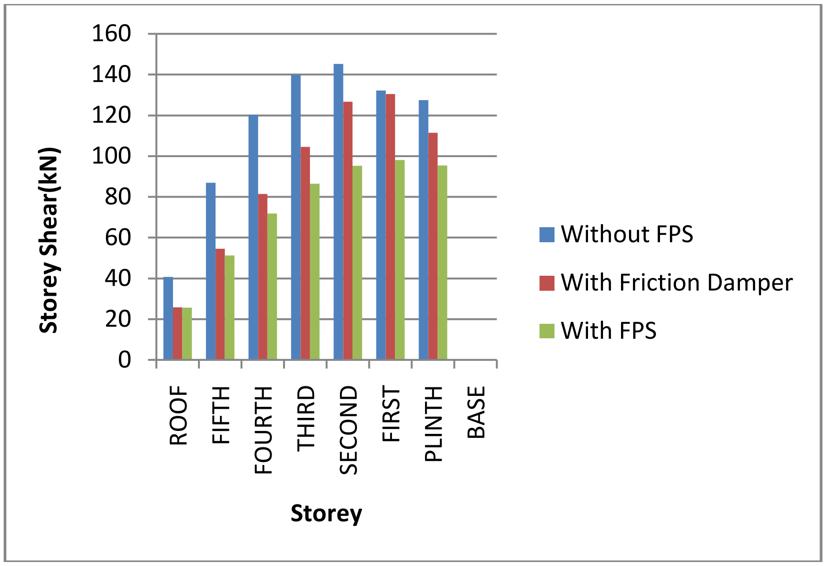

*Fig .5 Storey Shear in X-Direction for G+ 5 Structure*

TABLE 5
STOREY SHEAR IN Y-DIRECTION FOR G+5 STRUCTURE

| Storey | Fixed Base | With Friction Damper | With FPB |
|---|---|---|---|
| ROOF | 35.8936 | 30.4107 | 21.9839 |
| FIFTH | 68.9367 | 67.9167 | 46.1543 |
| FOURTH | 90.7957 | 89.4056 | 68.8407 |
| THIRD | 101.626 | 100.3147 | 88.6373 |
| SECOND | 109.6617 | 104.0117 | 104.0024 |
| FIRST | 118.218 | 119.1099 | 113.9357 |
| PLINTH | 121.8993 | 120.2475 | 118.5608 |
| BASE | 0 | 0 | 0 |

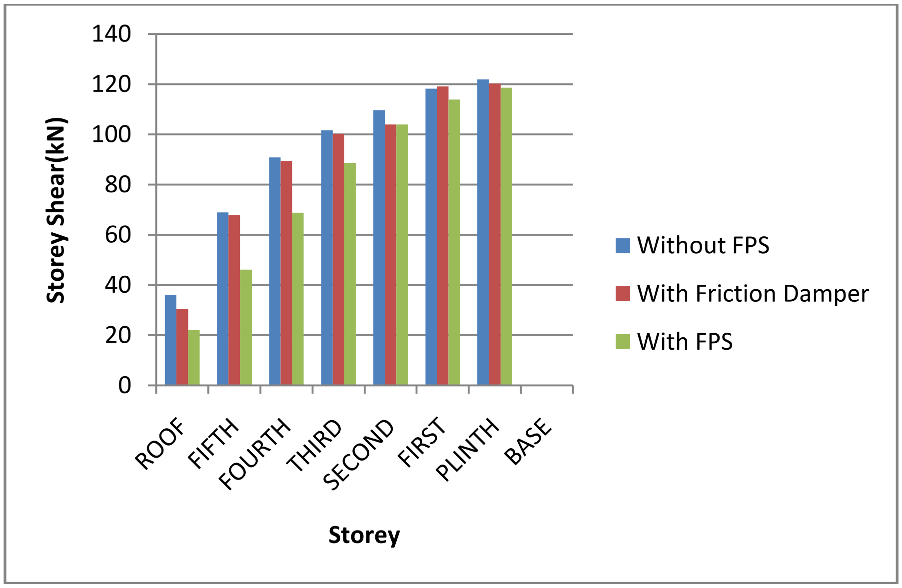

*Fig .6. Storey Shear in Y-Direction for G+ 5 Structure*

### *B. Maximum Displacement (mm) in X and Y Direction*

TABLE 6
MAXIMUM DISPLACEMENT OF G+5 IN X-DIRECTION

| **Storey** | **Fixed Base** | **With Friction Damper** | **With FPB** |
|---|---|---|---|
| ROOF | 2.332 | 1.813 | 6.341 |
| FIFTH | 2.197 | 1.681 | 6.207 |
| FOURTH | 1.967 | 1.548 | 5.962 |
| THIRD | 1.644 | 1.24 | 5.63 |
| SECOND | 1.215 | 1.014 | 5.231 |
| FIRST | 0.697 | 0.565 | 4.764 |
| PLINTH | 0.163 | 0.269 | 4.215 |
| BASE | 0 | 0 | 3.652 |

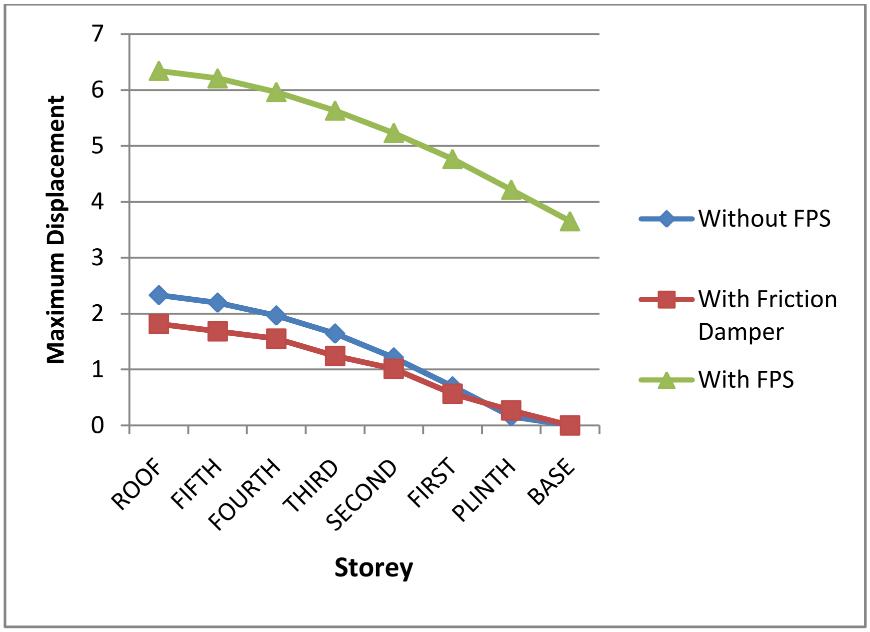

*Fig.7 Maximum Displacement of G+5 in X-Direction*

TABLE 7

MAXIMUM DISPLACEMENT OF G+5 IN Y-DIRECTION

| **Storey** | **Fixed Base** | **With Friction Damper** | **With FPB** |
|---|---|---|---|
| Roof | 3.123 | 1.723 | 5.333 |
| Fifth | 2.897 | 1.588 | 5.229 |
| Fourth | 2.542 | 1.429 | 5.057 |
| Third | 2.022 | 1.163 | 4.812 |
| Second | 1.425 | 0.896 | 4.496 |
| First | 0.757 | 0.499 | 4.134 |
| Plinth | 0.167 | 0.158 | 3.751 |
| Base | 0 | 0 | 3.389 |

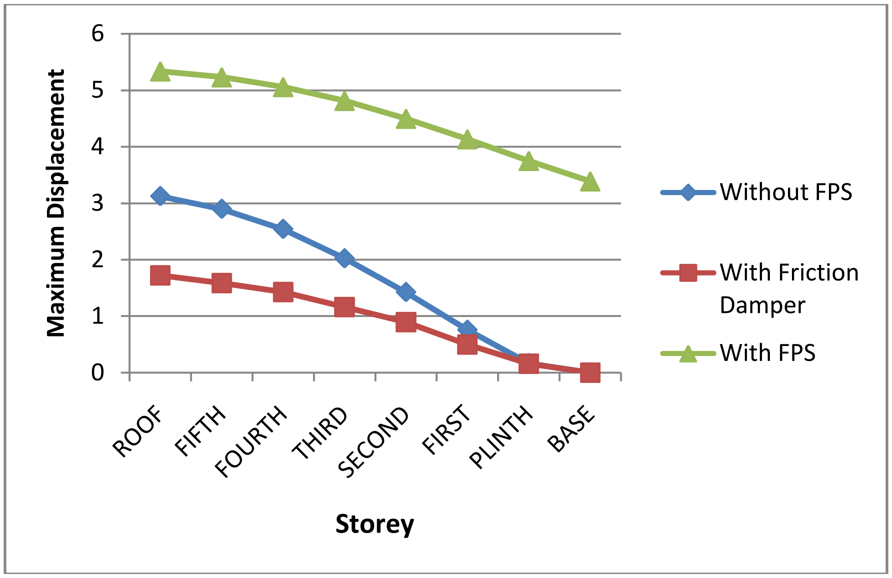

*Fig.8 Maximum Displacement of G+5 in Y-Direction*

C. *Modal Time Period (sec)*

TABLE 8
MODAL TIME PERIOD FOR G+5 STRUCTURE

| Mode | Fixed Base | With FPB | With Damper |
|---|---|---|---|
| 1 | 1.309 | 1.547 | 0.598 |
| 2 | 1.035 | 1.454 | 0.51 |
| 3 | 1.015 | 1.334 | 0.379 |
| 4 | 0.427 | 0.476 | 0.202 |
| 5 | 0.322 | 0.406 | 0.166 |
| 6 | 0.32 | 0.385 | 0.13 |
| 7 | 0.247 | 0.258 | 0.122 |
| 8 | 0.178 | 0.202 | 0.1 |
| 9 | 0.171 | 0.199 | 0.097 |
| 10 | 0.171 | 0.169 | 0.081 |
| 11 | 0.132 | 0.124 | 0.076 |

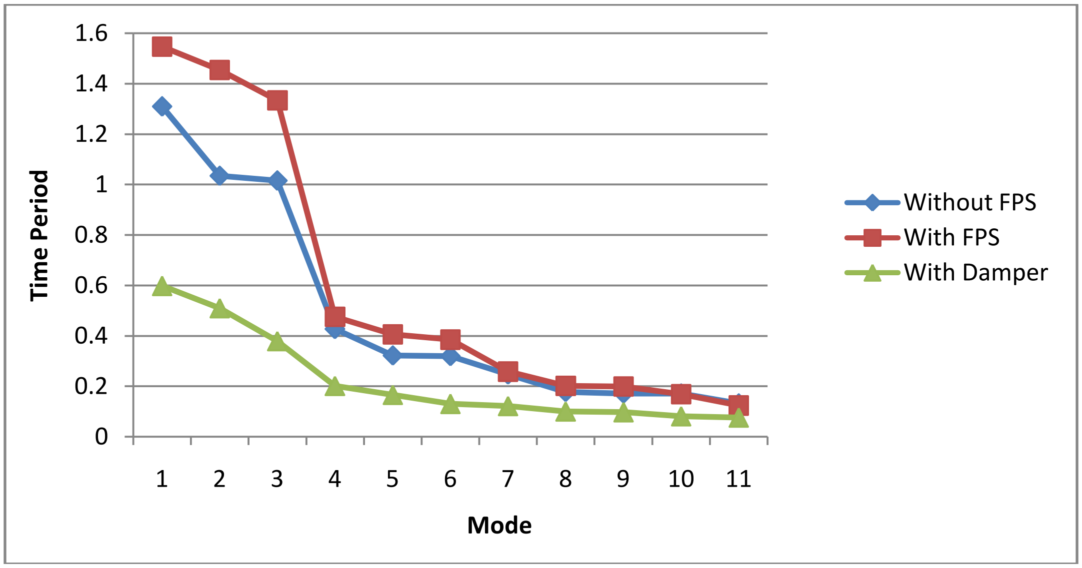

*Fig. 9 Modal Time Period (sec)*

*D. Storey Acceleration (mm/sec²) in X and Y Direction*

TABLE 9
STOREY ACCELERATION IN X DIRECTION FOR G+ 5 STRUCTURES

| **Storey** | **Fixed Base** | **With FPB** | **With Friction Damper** |
|---|---|---|---|
| | **mm/sec²** | **mm/sec²** | **mm/sec²** |
| Roof | 724.92 | 320.14 | 778.2 |
| Fifth | 678.98 | 294.23 | 680.1 |
| Fourth | 621.45 | 260.68 | 620.85 |
| Third | 500.23 | 237.19 | 524.25 |
| Second | 459.9 | 228.63 | 463.52 |
| First | 323.96 | 231.05 | 337.09 |
| Plinth | 174.88 | 236.09 | 187.88 |
| Base | 0 | 235.56 | 0 |

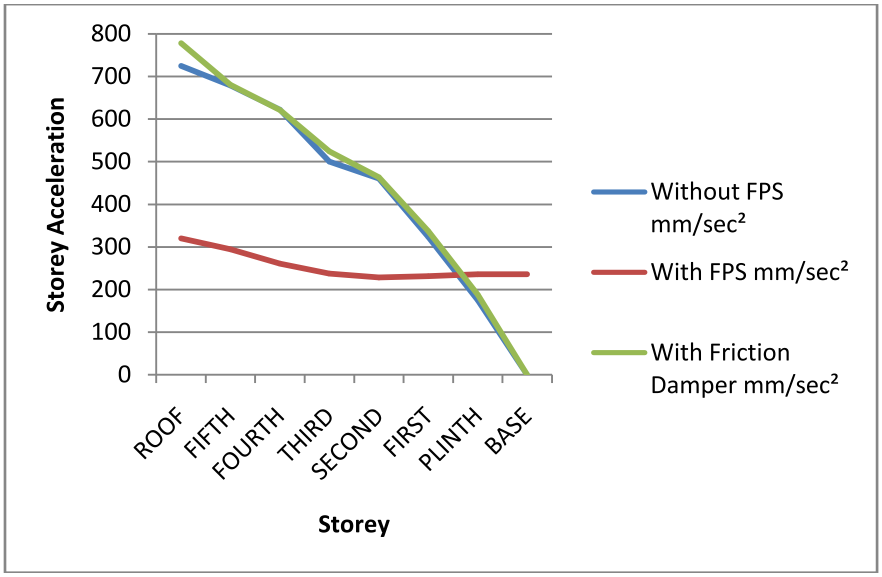

*Fig .10 Storey Acceleration in X Direction for G+ 5 Structures*

TABLE 10
STOREY ACCELERATION IN Y DIRECTION FOR G+ 5 STRUCTURES

| **Story** | Fixed Base | With Friction Damper | With FPB |
|---|---|---|---|
| | **mm/sec²** | **mm/sec²** | **mm/sec²** |
| ROOF | 1061.64 | 902.26 | 430.22 |
| FIFTH | 897.8 | 794.67 | 408.89 |
| FOURTH | 811.8 | 708.37 | 382.41 |
| THIRD | 707.56 | 584.42 | 358.01 |
| SECOND | 608.94 | 469.77 | 339.92 |
| FIRST | 449.28 | 306.5 | 328.04 |
| PLINTH | 125.25 | 119.37 | 319.43 |
| BASE | 0 | 0 | 310.92 |

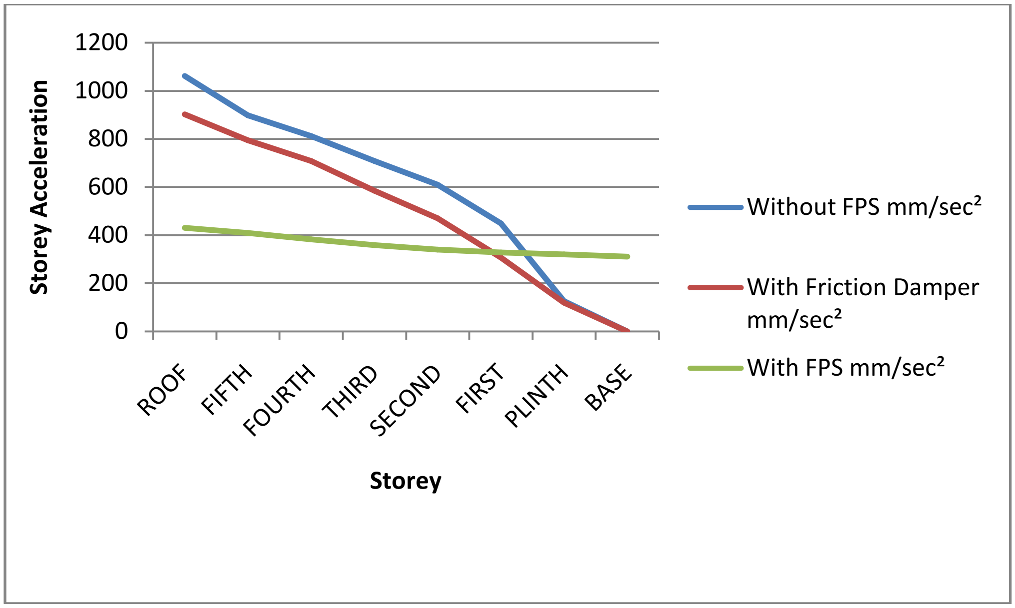

*Fig.11 Storey Acceleration in Y Direction for G+ 5 Structures*

## V. CONCLUSION

- In structure with friction damper, storey shear in X & Y directions are reduced at greater extent. The friction isolator separates the superstructure from substructure. This decreases the force in base isolated structure. In structure with friction damper, storey shear in X & Y directions is reduced to a certain extend.
- In base isolated structure with friction pendulum bearing, storey drift and storey displacement are reduced to a greater extend. The variation in maximum displacement in base isolated structure is very low. This is due to the rigid movement of superstructure.
- In base isolated structure with friction pendulum bearing, storey acceleration is reduced to a greater extent. This is due to decrease in lateral loads. This results in reduction of inertia forces and consequently reduction in internal forces of structural members. In structure with friction damper, storey acceleration is reduced to a certain extend.
- The friction pendulum bearing lengthens the time period of base isolated structure at greater extend. Friction damper reduces the time period of the structure to a certain extend.
- Overall significant reduction in values of storey displacement, storey drift, storey acceleration and base shear by lengthening the natural time period of vibration for base isolated structures for storey height of 20 meter.
- Base isolation is found to be most effective for low-story RC structure. From the above, it is concluded that seismic performance of base isolated structure is better as compared to structure with friction damper.

## REFERENCES

**1.** H.P. Santhosh, K.S. Manjunath, K. Sathish Kumar, “Seismic analysis of low to medium rise building for base isolation”, International Journal of Research in Engineering and Technology, eISSN : 2319-1163, pISSN : 2321-7308, Nov-2013.
**2.** S. M. Dhawade, “Comparative Study for Seismic Performance of Base Isolated & Fixed Based RC Frame Structure”, International Journal of Civil Engineering Research, ISSN 2278-3652 Volume 5, Number 2 (2014), pp.183-190
**3.** Ashish R. Akhare, Tejas R.Wankhade , “Seismic Performance of RC Structure Using Different Base Isolator”, International Journal of Engineering Science & Research Technology, ISSN : 2277-9655, 3(5) : May 2014.
**4.** Sonali Anilduke , Amay Khedikar, “Comparision Of Building For Seismic Response By Using Base Isolation**”,** IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163,pISSN: 2321-7308, June-2015.
**5.** Babak Esmailzadeh Hakimi , Alireza Rahnavard , Teymour Honarbakhsh,” Seismic Design of Structures using Friction Damper Bracings”, 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada,2004.
**6.** Ri-Hui Zhang And T. T. Soong, “Seismic Design Of Viscoelastic Dampers For Structural Applications”, ASCE.
**7.** R.S. Jangid , “Optimum friction pendulum system for near-fault motions”, Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai.

**8.** Nicholas Reidar Marrs, “Seismic Performance Comparison of a Fixed-Base versus a Base-Isolated Office Building”, International Journal of Advance research, Ideas and Innovationsin technology, 2014.
**9.** S.Keerthana1 , K. Sathish Kumar2 , K. Balamonica2, “Seismic Response Reduction of Structures using Base Isolation”, IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 2, February 2015.
**10.** Pall, A. S., and Marsh C. (1982), ‘Response of Friction Damped Braced Frames’, Journal of the Structural Division, American Society of Civil Engineers, 108(ST6).