Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 04, April -2018

SEISMIC PERFORMANCE OF IRREGULAR BUILDING IN PLAN USING TRIPLE FRICTION PENDULUM

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Abstract — *In recent Era, Vertical development of city with good aesthetic and elegant structures is more preferable so the irregularity of buildings comes in picture. The damage to the well-designed structures caused by earthquake, has attracted the attention of engineers to use adaptive seismic isolation system such as Triple friction pendulum bearings (TFPBs). An adaptive seismic isolator can revelation different stiffness and damping during its performance in different earthquake hazards level. The base isolation has been adopted as one of the most important passive control technique to resist the earthquake forces. Triple Friction Pendulum (TFP) bearing consists of two facing concave steel surfaces separated by an internal nested assembly of two facing concave surfaces separated by an articulated slider. In this study, the effect of the horizontal irregularities of base-isolated structures will be demonstrated using TFPS. A reasonable variety of superstructures with different irregularity of plan considered. Three-dimensional models of superstructures with linear behavior mounted on nonlinear TFP isolators with various effective periods and damping are studied elaborately. Base shear, storey drifts, base displacement, acceleration are selected as prominent responses of base-isolated structures. The analytical study is carried out with nonlinear time history analysis by SAP2000 V.17 software with different time history. Seismic comparison of regular to irregular base-isolated building is being aim of this study.*

Keywords- *Triple Friction Pendulum bearings, base-isolated structures, time history, non-linear analysis, SAP2000, Earthquake, Irregularity*

I. INTRODUCTION

An earthquake is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities. Earthquake is one of the major natural disaster to life on the earth. In the past earthquake has affected number of country and zone and damaged the mostly man-made structure. The recent area of work is earthquake resistant design of structure currently adopted all over the world. In order to reduce the earthquake response of buildings during earthquake ground motion, energy absorbing passive control devices are generally used. If the earthquake has natural frequencies with high energy that match the natural frequencies of the building, it will cause the building to oscillate violently in harmony with the earthquake frequency. However, if the natural frequency of the building can be changed to a frequency that does not coincide with that of earthquakes, the building is less likely to fail. This is exactly what a base isolator does. The base isolator reduces the stiffness of the structure and thereby lowers its natural frequency.

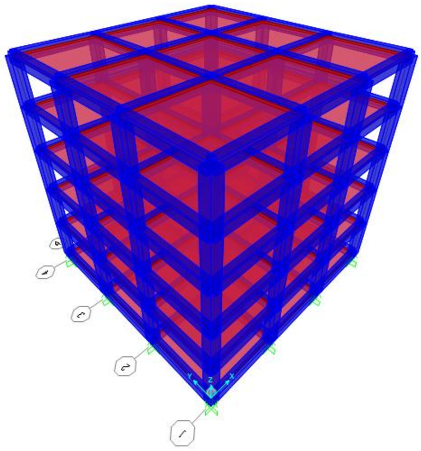
Base isolation is one of the most important concepts for earthquake engineering which can be defined as separating or decoupling the structure from its foundation. In other words, base isolation is a technique developed to prevent or minimize damage to buildings during an earthquake. This gives the structure a fundamental frequency that is much lower than both of its fixed base frequency and the predominant frequency of the ground motion. This lengthening of the fundamental time period results in the avoidance of resonance and the significant decrease of the floor acceleration. When the base isolation is provided the superstructure being relatively very stiff compared to fixed base and behaves as a rigid body. The rigid body motions of the super structure results in the reduction of base shear, floor acceleration and storey drifts of the structure and reduce the damage to the structural and non-structural member.

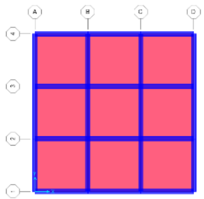
The triple friction pendulum isolator exhibits multiple changes in stiffness and strength with increasing amplitude of displacement. The name ‘triple’ describes a behavior in which sliding occurs in no more than three sliding surfaces regardless of geometry and frictional values. These are 3 friction pendulum mechanisms existing in each bearing instead of just one mechanism.

As it is well known, structural regularity is an important issue for a good seismic response. When a building is subjected to seismic excitation, horizontal inertia forces are generated in the building. The resultant of these forces is assumed to act through the center of mass (C.M) of the structure. The vertical members in the structure resist these forces and the total resultant of these systems of forces act through a point called as center of stiffness (C.S). When the center of mass and center of stiffness does not coincide, eccentricities are developed in the buildings which further generate torsion. When the buildings are subjected to lateral loads, then phenomenon of torsional coupling occurs due to interaction between lateral loads and resistant forces. Torsional coupling generates greater damage in the buildings. Eccentricity may occur due to presence of structural irregularities.

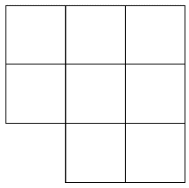
II. STRUCUTRAL CONFIGURATION & GROUND MOTION CONSIDERATION

For this study, G+5 storey RC building having plan dimension of 18 × 18 m and storey height of 3m is considered as regular building which is shown in Figure 1. Also four different irregular building in plan is considered with Re-entrance corner with different projection in x direction. Four different irregular building's plan is as shown in Figure 2.

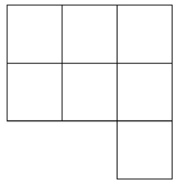




Plan view of Regular building (REB1)

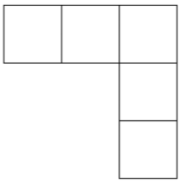


IRB1

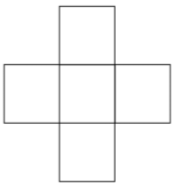


IRB2

Figure 1 3D & Plan View of Regular building (REB1)



IRB3



IRB3

Figure 2 Plan view of considered Irregular building

Table 1 Building Properties

Sr.	Description	Dimension (m)
1	**Beam size**	0.6 x 0.45
2	**Column size**	0.6 x 0.6
3	**Slab thickness**	0.150
4	**Storey height**	3.0
5	**Live load**	3 kN/m^2
6	**Bay size**	6m x 6m
7	**Grade of concrete**	M30
8	**Grade of steel**	Fe-415

There are two different ground motion considered for the non-linear time history analysis of 5 storey building using SAP2000 in which the Imperial Valley at El Centro can be considered as DBE (Design Basis Earthquake) and Loma Prieta at Capitola can be considered as MCE (Maximum Considerable Earthquake). All the records was generally normalized by g.

Table 2 Detail of Earthquake Ground motion

No.	Earthquakes	Magnitude	Location	PGA	Points	Time Steps	
1	1940 Imperial Valley	6.95	El Centro	0.313	2000	0.02	DBE
2	1989 Loma Prieta	6.9	Capitola	0.420	1997	0.02	MCE

III. MODELING ASPECTS OF TFP

Table 3 Geometric Properties of TFPS

Properties	$R_1 = R_4$	$R_2 = R_3$	$h_1 = h_4$	$h_2 = h_3$	$d_1 = d_2$	$d_2 = d_3$
Value	0.2032 m	0.0508 m	0.0304 m	0.0228 m	0.0424 m	0.0076 m

Table 4 Linear properties of TFPS used in SAP2000

Effective stiffness U1 (kN/m)	249363.9169
Effective stiffness U2 & U3 (kN/m)	4921.25
Height of outer surface (m)	0.0305
Height of inner surface (m)	0.0229

Table 5 Non Linear properties of TFPS used in SAP2000

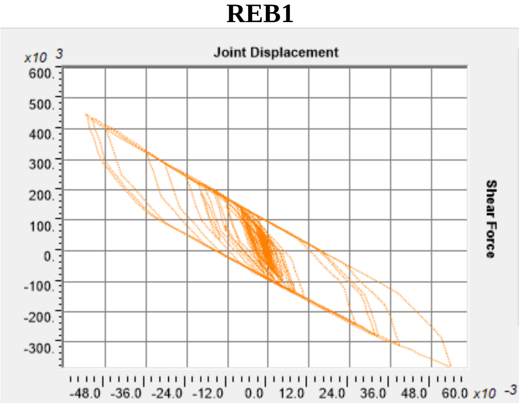
Parameter	Outer Top	Outer Bottom	Inner Top	Inner Bottom
Elastic stiffness (kN/m)	183375.04	75507.61	32360	32360
Friction coefficient slow	0.085	0.035	0.015	0.015
Friction coefficient fast	0.085	0.035	0.015	0.015
Rate parameter	1	1	1	1
Radius of sliding surface (m)	0.1727	0.1182	0.0279	0.0279
Stop distance (m)	0.0425	0.0425	0.0076	0.0076

IV. ANALYSIS RESULTS AND DISCUSSION

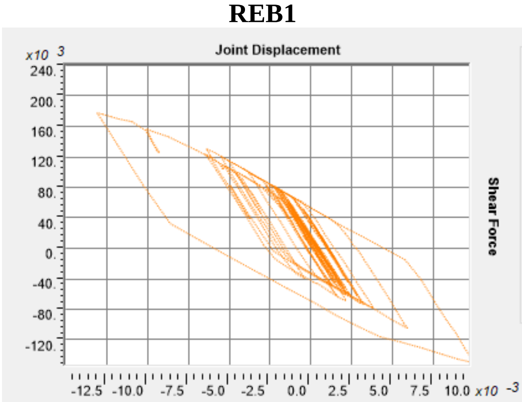
A. Hysteresis behavior

The force-displacement behavior of building represents the energy dissipation of isolator during the earthquake. The area of hysteresis loop provides the value of energy dissipated during the different ground motion.

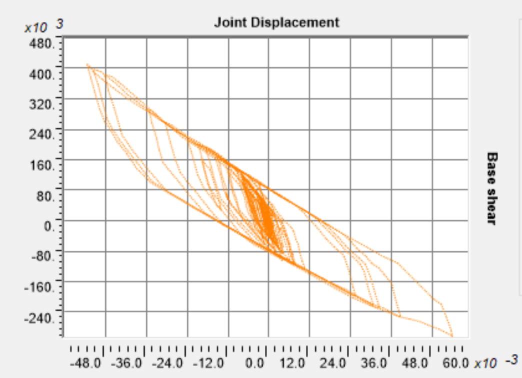
REB1



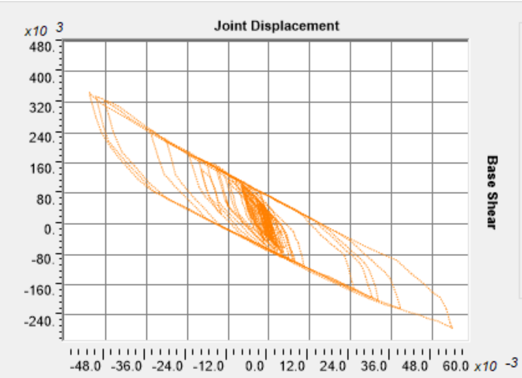
REB1



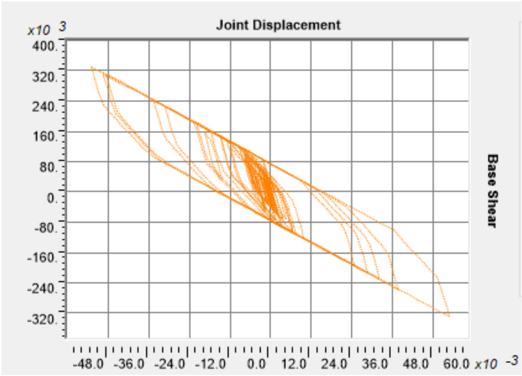
IRB1



IRB2



IRB3



IRB4

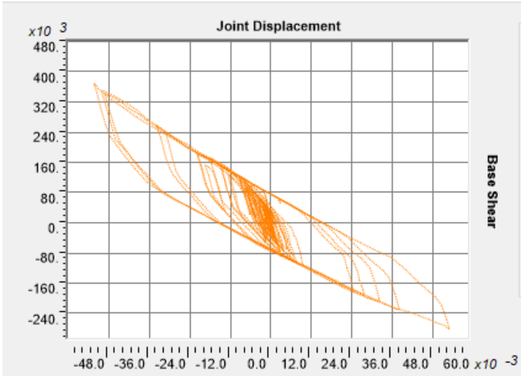
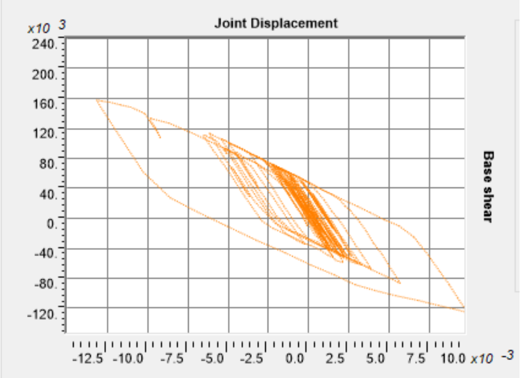
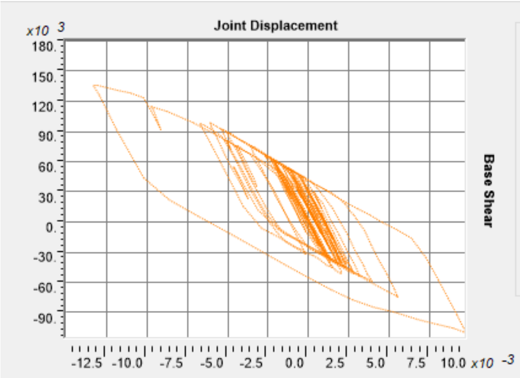


Figure 3 Hysteresis behavior for Loma Prieta

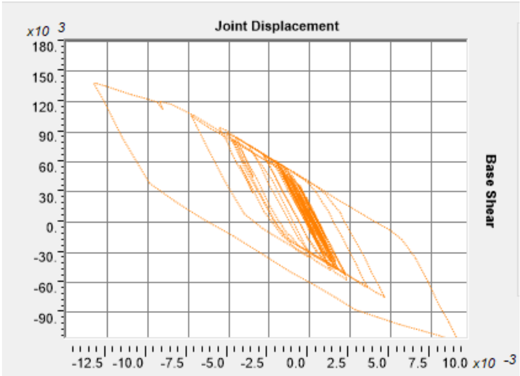
IRB1



IRB2



IRB3



IRB4

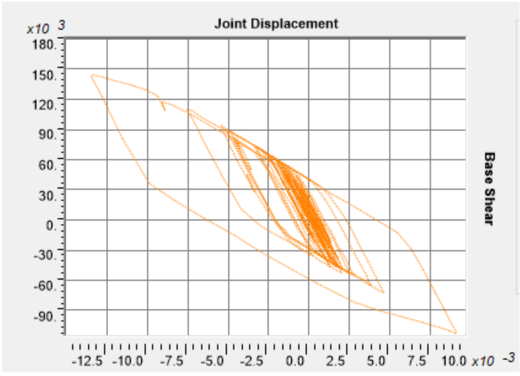


Figure 4 Hysteresis behavior for imperial valley

Fig.3 & 4 shows the hysteresis behavior comparison for regular and irregular building considering different ground motion characteristics. It is found that the hysteresis behavior for Loma Prieta is more perfect than the behavior of Imperial Valley ground motion.

B. Storey Displacement

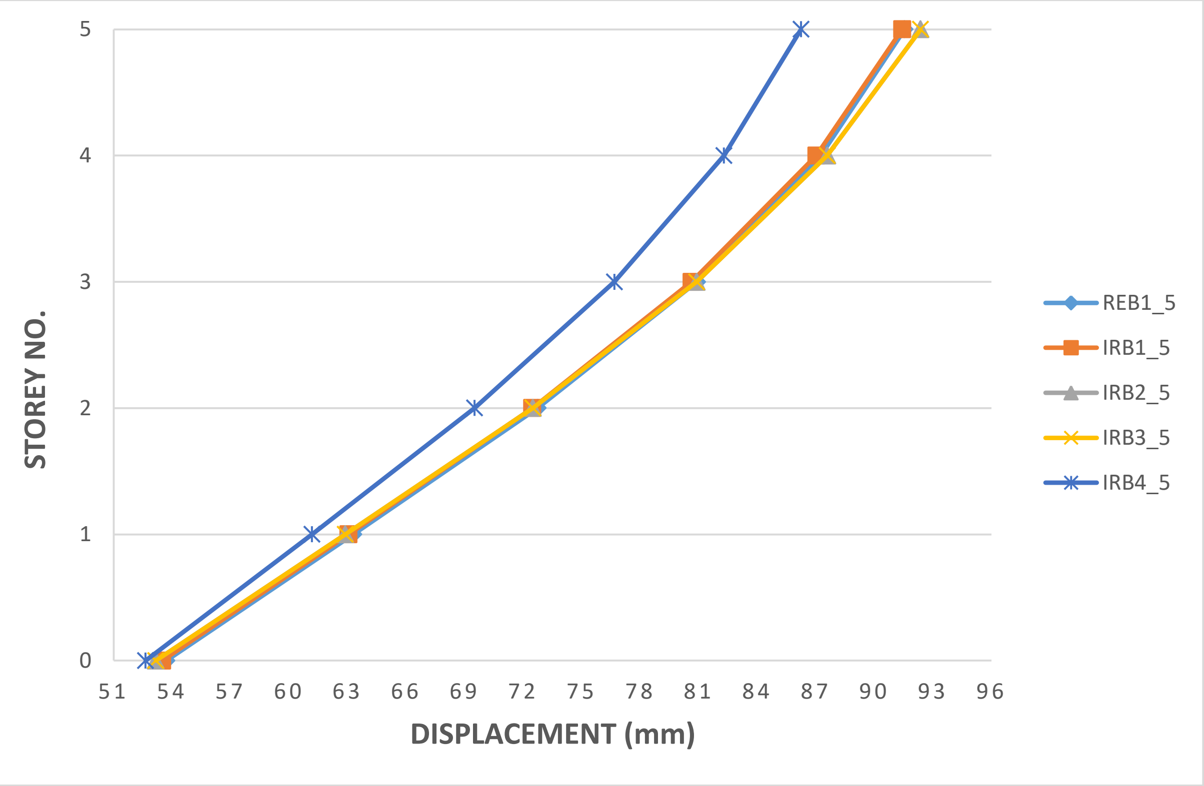


Figure 5 Storey wise Displacement for Loma Prieta ground motion

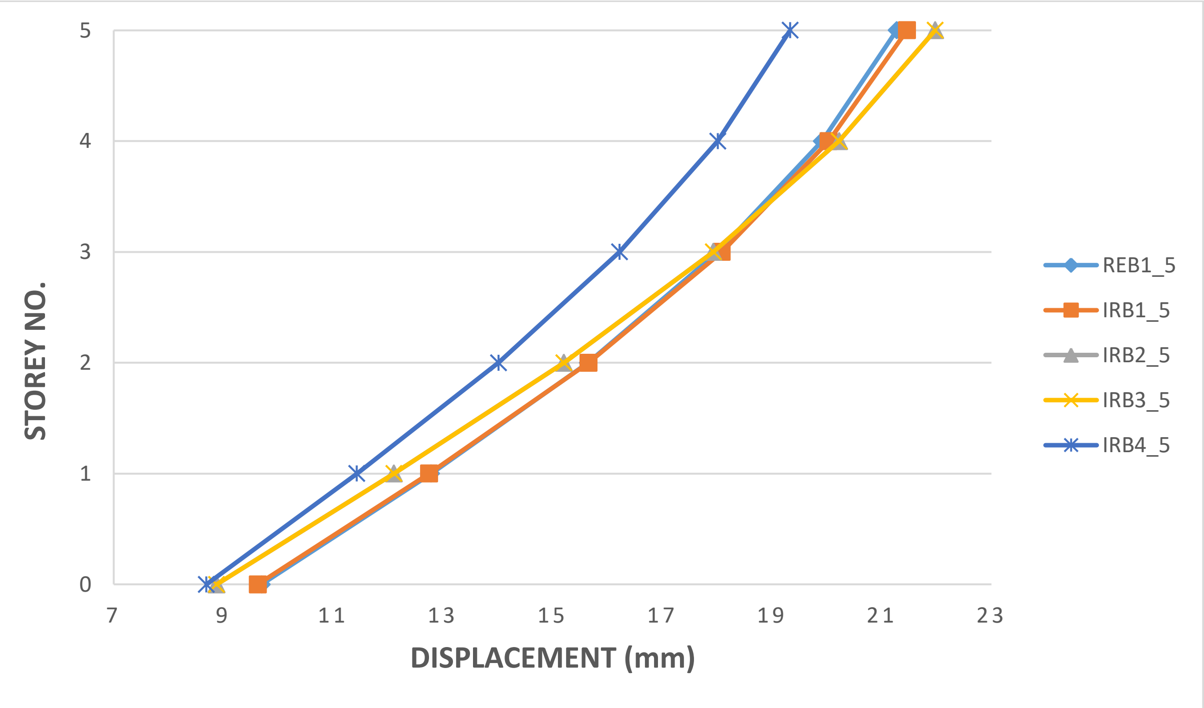


Figure 6 Storey wise displacement of Imperial Valley ground motion

Fig. 5 & 6 Shows the story displacement for different ground motion characteristics.
For Loma Prieta, It is observed that the reduction in average story displacement with comparison of REB1 is 0.32%, 0.12%, -1.05% & 4.42% for IRB1, IRB2, IRB3 and IRB4 respectively. The maximum reduction was observed in IRB4.
For Imperial Valley, It is observed that the reduction in average story displacement with comparison of REB1 is -0.20%, 2.43%, -3.39% & 11.99% for IRB1, IRB2, IRB3, IRB4 respectively. Again the maximum reduction was observed in IRB4.

C. Storey Acceleration

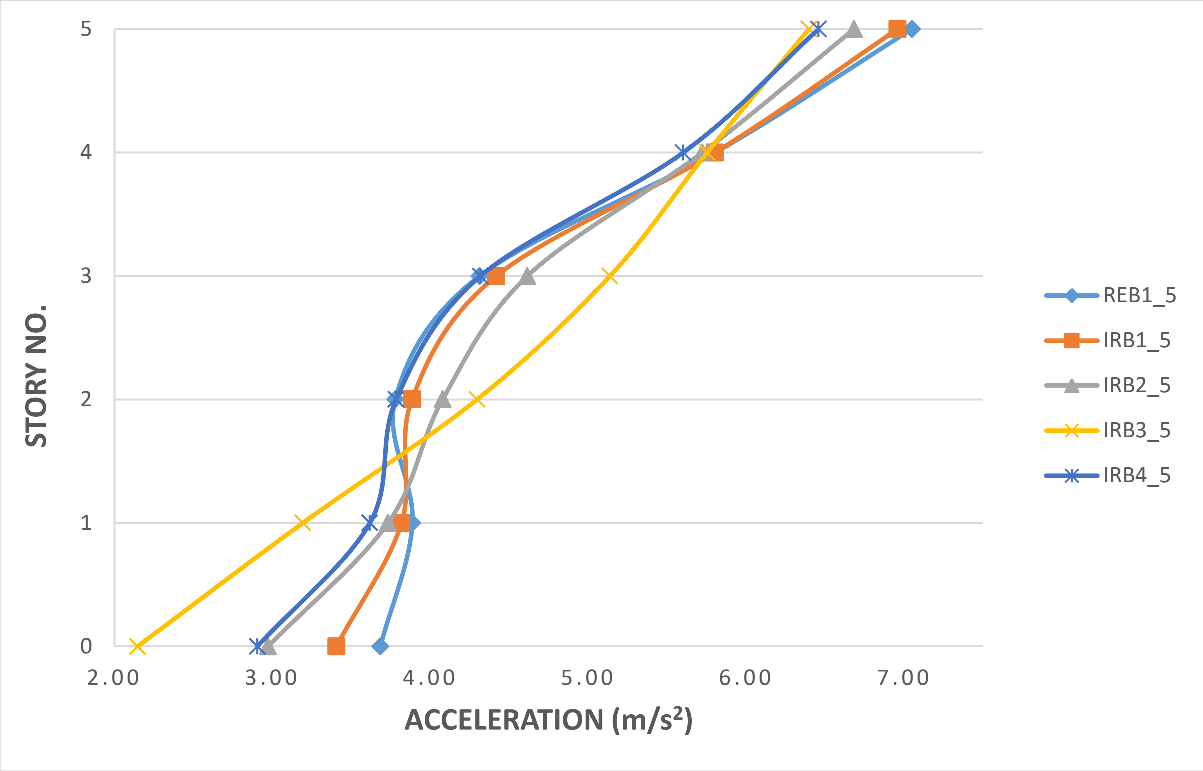


Figure 7 Storey acceleration for Loma Prieta ground motion

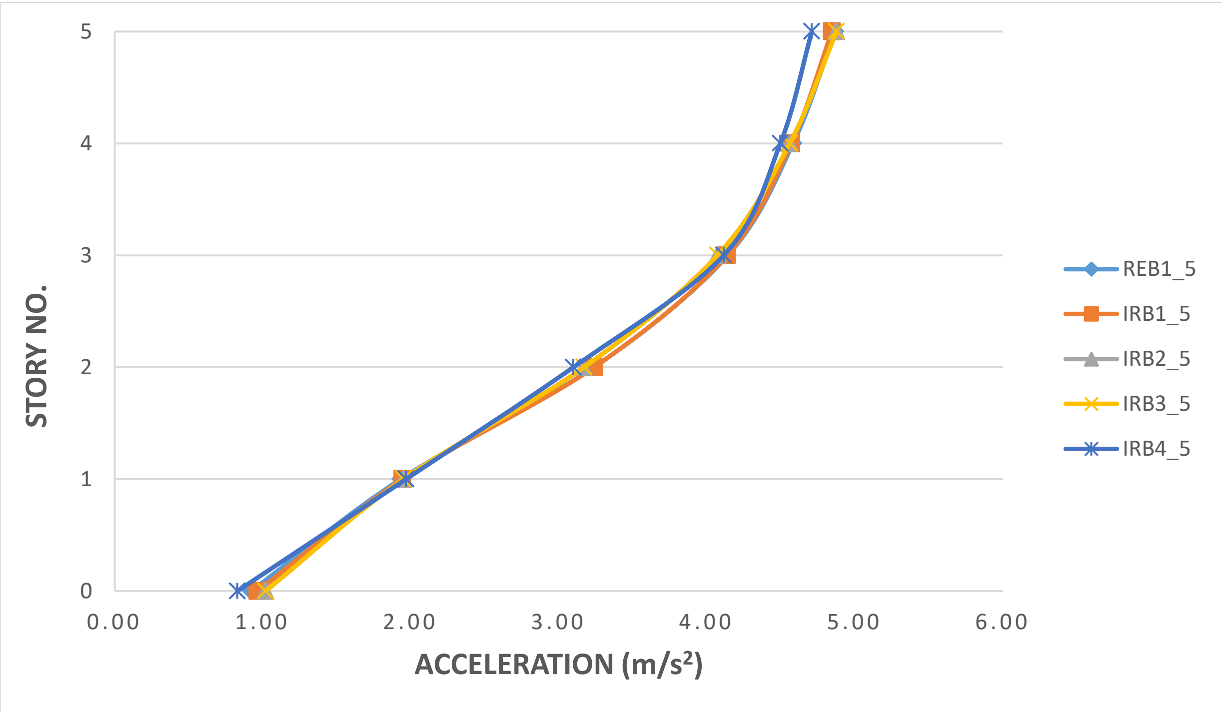


Figure 8 Storey acceleration for Imperial Valley ground motion

Fig. 7 & 8 Shows the story Acceleration for different ground motion characteristics.
For Loma Prieta, It is observed that the reduction in average story Acceleration with comparison of REB1 is -0.78%, -1.25%, -2.13% & 3.04% for IRB1, IRB2, IRB3, and IRB4 respectively. The maximum reduction was observed in IRB4 and maximum acceleration increases in IRB3.

For Imperial Valley, It is observed that the reduction in average story acceleration with comparison of REB1 is -0.78%, -1.25%, -2.13% & 3.04% for IRB1, IRB2, IRB3, and IRB4 respectively. Again the maximum reduction was observed in IRB4 and maximum acceleration increases in IRB3.

D. Storey Drift

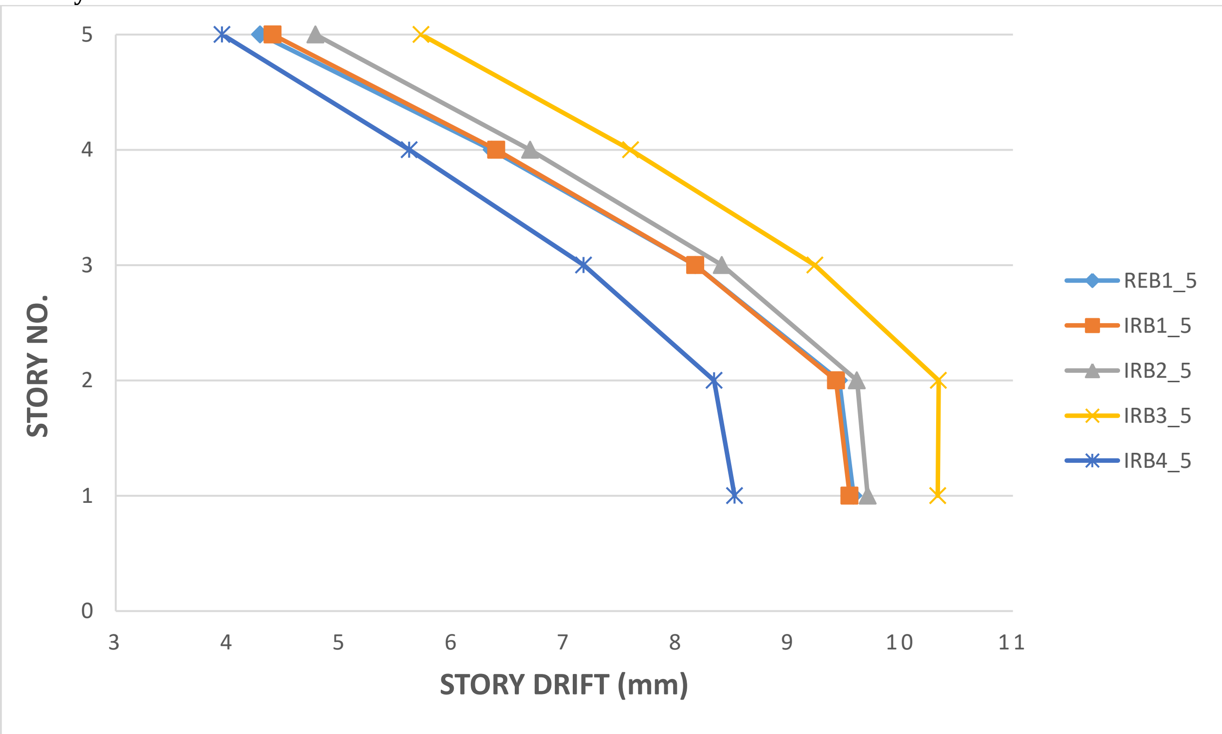


Figure 9 Storey Drift for Loma Prieta ground motion

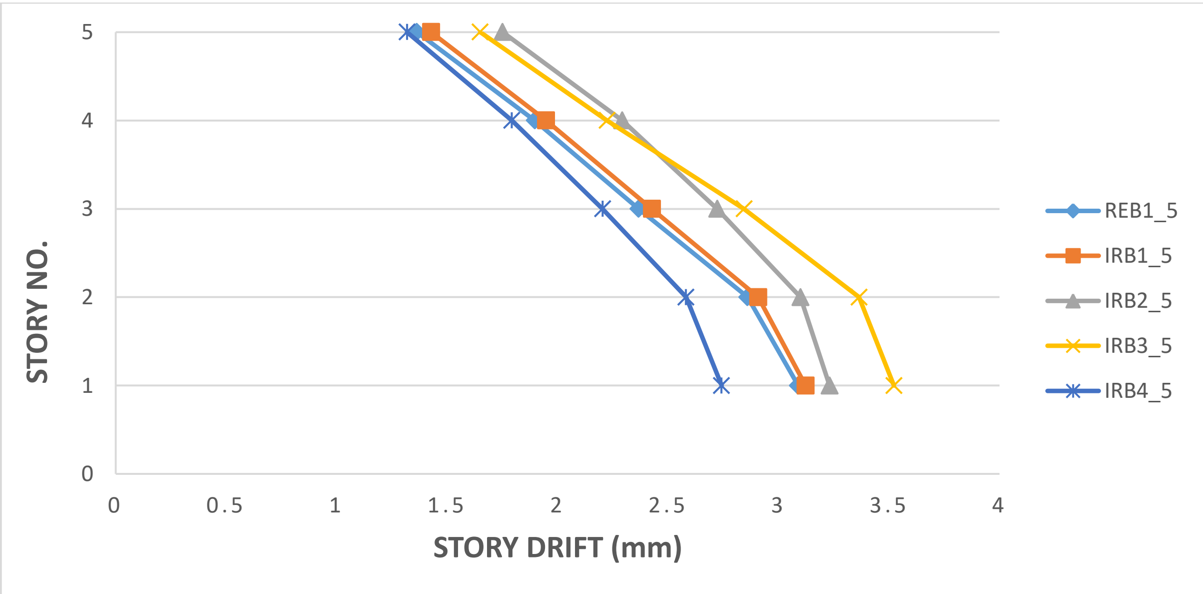


Figure 10 Storey Drift for Imperial Valley Ground motion

Fig. 9 & 10 Shows the story Acceleration for different ground motion characteristics.
For Loma Prieta, It is observed that the reduction in average story Acceleration with comparison of REB1 is -0.51%, -4.56%, -16.65%, 10.90% for IRB1, IRB2, IRB3, and IRB4 respectively. The maximum reduction was observed in IRB4 and maximum drift increases in IRB3.

For Imperial Valley, It is observed that the reduction in average story acceleration with comparison of REB1 is --2.55%, -15.47%, -18.03% , 7.31% for IRB1, IRB2, IRB3, and IRB4 respectively. Again the maximum reduction was observed in IRB4 and maximum acceleration increases in IRB3.

V. CONCLUSION

In this Study, Seismic Response of Regular and irregular building under the different ground motion characteristics using TFPS isolator has been investigated in SAP2000. After the above non-linear time history analysis following observations are noted.

a) Triple FP isolator were found to be an excellent seismic control device for these plan irregularity of building in controlling forced response such as Base shear , Storey drift, Storey acceleration, storey displacement, and Time period of structure.
b) For the storey drift, average Percentage variation of IRB1, IRB2, IRB3, IRB4 is 0.06%, 1.28%, -2.22%, 8.21% respectively to the regular building REB1 for both time history. So the IRB4 has maximum reduction in comparison of other model and IRB3 shows the maximum increment in Storey drift.
c) For storey acceleration and storey displacement, IRB4 is performing well in comparison of IRB1, IRB2, and IRB3. Respectively percentage reduction is 4.82%, 8.21% for IRB4 to the Regular building REB1.
d) Same as IRB3 is not performing appropriately in comparison of all other building. Average Percentage increase comparison for Storey drift, storey displacement is 17.34%, 2.22% respectively to the regular building REB1.

As per the above observation, IRB4 which is Shaped as a '+' Sign is performing better in comparison of all other re-entranced corner building which was taken into the consideration. IRB4 is Symmetrical irregular building with equal projection on both direction X and Y. It's also observed that IRB3 ('L' Shaped with max projection in X & y Direction) has higher seismic response which cause max damage during earthquake in comparison of other considered building

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