Seismic assessment of irregular reinforced concrete frame structures using triple friction pendulum bearing

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Abstract. In the present scenario due to the fluctuating demand and need for the recent generation has made the designers and engineers plan the building have irregularity. The current study copes with the irregular building having the asymmetric plan as per code IS 1893:2002(Part1). If these buildings are constructed in the earthquake-vulnerable area then they should be designed to resist earthquake forces. Base isolation is the one of the most prominent and widely accepted passive control technique developed to prevent or minimize these forces by isolating the superstructure from the substructure. The Triple Friction Pendulum Bearing (TFPB) is picked as an isolator for the current study.TFPB has offered better seismic performance, lower bearing costs and lower construction cost and has adaptive behaviour. The response of a G+10 and G+20 base isolated and fixed base building are evaluated. For the analysis, symmetrical and different asymmetrical plan shapes like L, T,+, C are considered. Response Spectrum Analysis is carried out for the study by using the software SAP 2000 version 19 for two cases. The results show that in the base isolated building there is a grow in storey displacement, time period and greatly reduced the base shear, storey acceleration compared to base fixed structures.

Keywords: Triple Friction Pendulum Bearing, Base Isolation, Plan irregular building, Time period, Base Shear

1. Introduction

During the last decades, modern architectural designs have made plenty of challenges for civil engineers. Studies of previously earthquakes demonstrate that the irregular buildings in plan and /or height are usually vulnerable than the regular ones. The prime explanation for the collapse in asymmetric is attributed to the non-monotonous lateral deformation of the resisting plane.[9]Now a day the base isolation techniques represent an interesting design strategy for decoupling the structure from the damaging effects of the earthquake by increasing the structure flexibility and providing a convenient damping ratio together with energy dissipation.[1,2] Mainly two types of seismic isolators

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namely elastomeric and frictional one, used for isolation. Single, Double Concave Friction Pendulum is two different types of frictional isolators which are recently used in numerous buildings and bridges. From this type of isolators, the Triple Concave Friction Pendulum (TCFP) isolator is the newest generation and the earthquake behaviour of it is being examined by researchers.[9]For the present study Triple Friction Pendulum Bearing is used as the base isolator. It was proposed by Victor Zayas.

The TFPB associates with three pendulums in one bearing and each having the properties to select and accumulate the structure's response to different seismic strengths and frequencies. This approach is based on the assertions that lower the coefficient of friction, less the shear transmitted. The TFPB differs from the single, that there is 3 friction pendulum mechanism are achieved by using 4 concave surfaces with sliding occurring on two of the surfaces at a given time, existing in each bearing instead of one pendulum mechanism. These mechanisms are actuated at different phases based on the strong seismic demand. An image of the TFP's disassembled parts and a cross-section of a TFP bearing are shown in figures 1, 2 below, respectively. [4]

Figure 1. Triple friction pendulum bearing

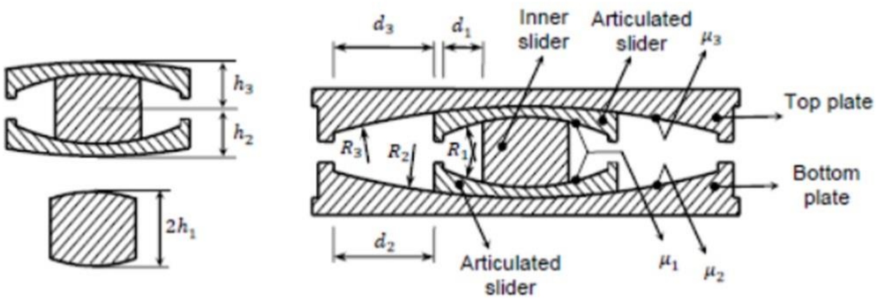


Figure 2. Sectional view and basic parameters

2. Objective

The objectives of the current study are,

- The work is focussed on the study of the effects of seismic forces on multistoried buildings with base fixed and isolated in SAP 2000.
- To assess the effect of the asymmetric plan on the seismic response of different multistoried building and to find more acceptable building among them.
- To design and study the effectiveness of Triple Friction Pendulum Bearing used as a base isolator, and analyze its performance when increasing the height of the buildings.

3. Methodology

In the existent study, G+10 and G+20 reinforced concrete building having the symmetric and asymmetric plan are considered. Four geometric plan irregular models are considered. The building is situated in zone V, having the medium soil of India is considered.

Table 1. Loadings and properties on the building

Loadings	
Live load on floor	3kN/m²
Live load on roof	1.5kN/m²
Floor finish	1.5kN/m²
Geometric Properties	
Plan dimension in X direction	36m
Plan dimension in Y direction	20m
Building Type	SMRF
Storey height	3.1
Beam size	230X400mm
Column Size(Bottom 5 Storey)	250X750mm
Remaining 6 Storey	230X500mm
Material Properties	
Grade of Concrete	M25
Grade of Steel	Fe415
Soil Type	Medium(Type-II)
Zone Factor: Z	0.36
Importance factor: I	1
Special Moment Resisting Frame: R	5

The work started with the modelling and analysis of G+10 and G+20 building for two cases. The initial one is fixed and the second is base isolated. Triple Friction Pendulum isolator is used as the base isolator in this study. After analysis of fixed base regular model using the software SAP 2000, the maximum vertical reaction is obtained. By using ASCE-Code 7 the Triple Friction Pendulum Bearing is designed manually and the same is used as a base isolator for all models considered. After the modelling, the analysis is done by the method of Response Spectrum for the fixed and isolated base and the observations are compared.

Table 2. Link properties of Isolator

Property	Inner slider	Outer Slider
Element height(mm)	121	161
Elastic Stiffness(kN/m)	50175.029	42717.503
Effective Stiffness(kN/m)	36085384	36085384
friction Coefficient-fast	0.159	0.187
friction Coefficient-slow	0.08	0.093
Radius(mm)	526	3395
Rate parameter(sec/mm)	0.0006	0.0007

4. Modelling and Analysis

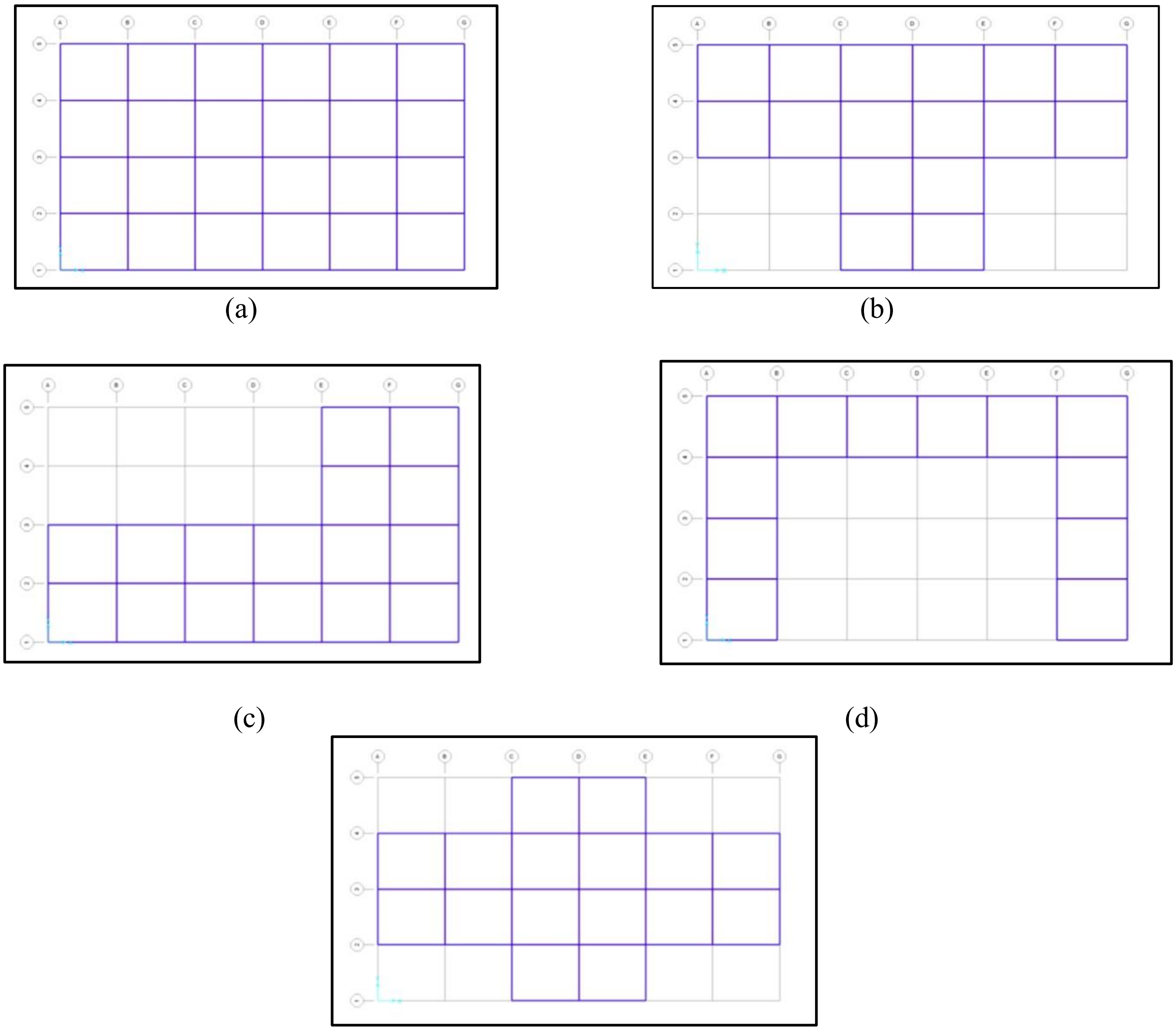
The Design Software SAP 2000 has been used for the modelling and analysis of the buildings. For the present study, Linear Dynamic Analysis is performed.

4.1. Models considered

The following models are considered for the analysis and it is build up using the Sap 2000 software.

Table 3. Models Considered For the Study

Notation	Shape	Base Condition
1A	Regular	Fixed Base
1B	Regular	TFPB
2A	T-shaped	Fixed Base
2B	T-shaped	TFPB
3A	L-shaped	Fixed Base
3B	L-shaped	TFPB
4A	C-shaped	Fixed Base
4B	C-shaped	TFPB
5A	+ shaped	Fixed Base
5B	+ shaped	TFPB



(a) (b) (c) (d) (e)

Figure 3. Plan view of (a) Regular,(b)T,(c) L,(d) C and (e) + shaped G+10 and G+20 storied RC Building

5. Results and Discussions

5.1. Time period

Table 4. Comparison of mode period for G+10 and G+20 of different models

	Mode Period(sec)					
	G+10			G+20		
Models	Mode-1	Mode-2	Mode-3	Mode-1	Mode-2	Mode-3
1A	2.014	1.598	1.391	4.151	3.249	2.864
1B	2.457	1.993	1.759	4.557	3.622	3.215
2A	2.487	2.058	1.876	5.053	4.178	3.821
2B	2.972	2.505	2.332	5.487	4.59	4.253
3A	1.954	1.619	1.349	4.065	3.338	2.795
3B	2.376	2.003	1.7032	4.446	3.695	3.129
4A	1.801	1.589	1.328	3.749	3.378	2.779
4B	2.184	1.949	1.658	4.102	3.668	3.098
5A	1.952	1.587	1.349	4.049	3.245	2.793
5B	2.374	1.964	1.703	4.433	3.599	3.127

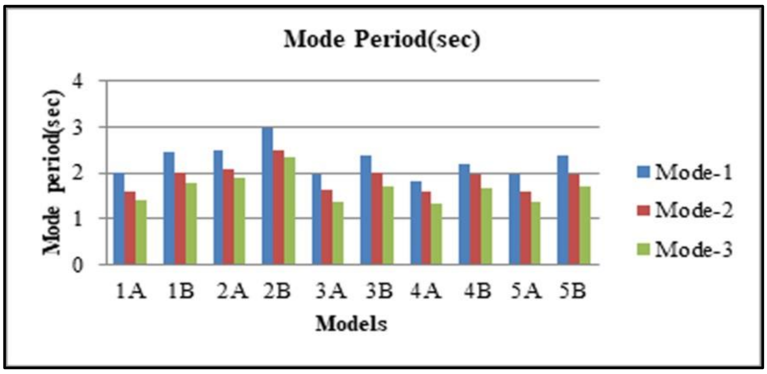


Figure 4. Mode period for G+10 storied building

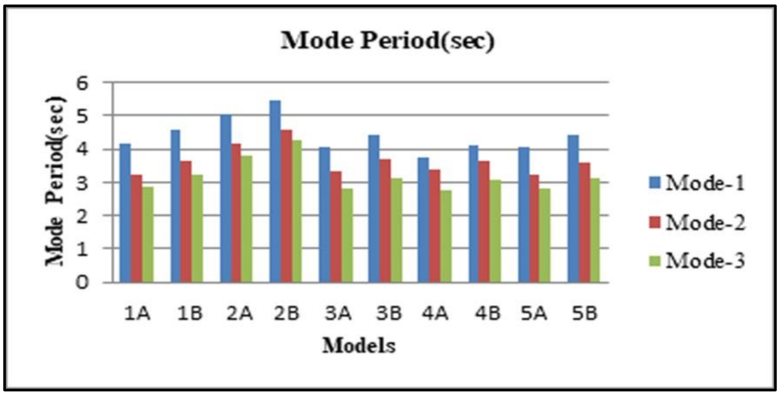


Figure 5. Mode period for G+20 storied building

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The table 4 and figure 4 & 5 shows the mode period corresponding to Mode-1, Mode-2 and Mode-3 for different models. The values clearly show that the mode period of TFPB is increased by around 22% for regular, L, C, + shaped G+10 compared to fixed and it is around by 10% for G+20.This is due to the reason of flexibility of the isolator. From that T-shape shows a low increase in mode period compared to other models.

5.2. Base Shear

Table 5. Comparability of base shear for G+10 and G+20 of different models

	Base Shear (kN)			
	G+10		G+20	
Models	RSX	RSY	RSX	RSY
1A	810.808	748.032	974.149	720.792
1B	727.246	652.199	810.808	728.608
2A	666.951	527.1	620.835	619.579
2B	591.769	464.863	612.306	594.278
3A	579.028	536.491	690.675	506.989
3B	522.419	471.404	656.387	503.988
4A	466.835	473.832	534.814	444.185
4B	427.851	420.233	528.470	420.233
5A	580.521	537.87	696.548	556.724
5B	523.401	472.333	661.075	508.982

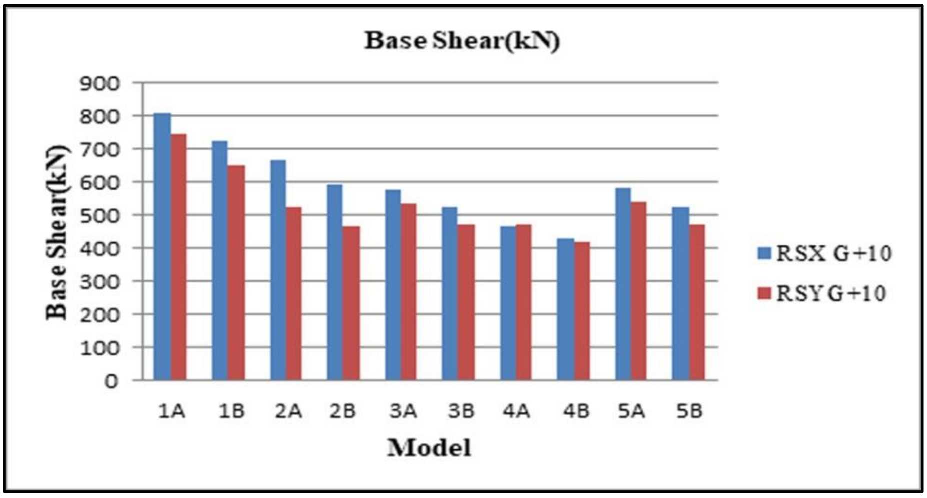

Figure 6. Base shear for G+10 storied building

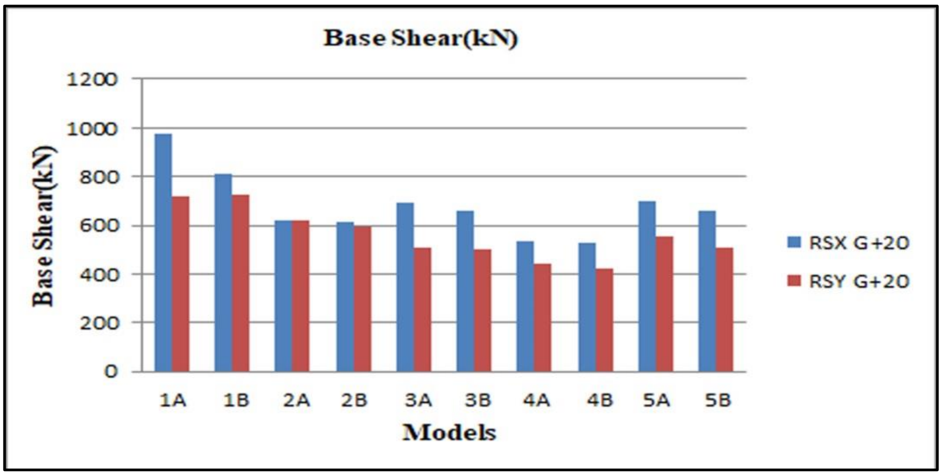

Figure 7. Mode period for G+20 storied building

The table 5 and figure 6,7 shows the base shear in X and Y- direction for different models of G+10 and G+20.For G+10 RC frame building, the outcome reveals that the ratio of base shear for TFPB decreases by around 10% than the fixed base. The model 4B shows the vast reduction in base shear compared to others. For G+20 RC frame building shows that base shear decreases by around 20%. TFPB is more suitable for G+20 multi-storey building.

6. Conclusion

It is observed that the base isolation increases the flexibility at the base level of the buildings. The natural period of a building increases with the height. When considering the fixed base and isolated building, the base shear is reduced considerably for TFPB.C-Shaped building gives a maximum performance and T-shape building is major exposure to the earthquake than the other models.TFPB is more suitable for G+20 multi-storey building and it is found that the time period increases for isolated building due to the presence of flexible isolator. The TFPB reduces the base shear, acceleration and increases the displacement and mode period. From the study, it has been concluded that by using the isolators for plan irregular building gives an outstanding performance at higher seismic zone area.

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