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Seismic Analysis of A Normal Building and Floating Column Building

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***Abstract* — In present scenario buildings with floating columns are of typical feature in the modern multistorey construction practices in urban India. Such types of constructions are highly undesirable in building built in seismically active areas. This paper studies the analysis of a G+5 storey normal building and a G+5 storey floating column building for external lateral forces. The analysis is done by the use of SAP 2000.**

This paper also studies the variation of the both structures by applying the intensities of the past earthquakes i.e., applying the ground motions to the both structures, from that displacement time history values are compared.

This study is to find whether the structure is safe or unsafe with floating column when built in seismically active areas and also to find floating column building is economical or uneconomical.

Index Terms – Floating column building, Normal building,

I. INTRODUCTION

Now a days multistorey buildings constructed for the purpose of residential, commercial, industrial etc., with an open ground storey is becoming a common feature. For the purpose of parking all, usually the ground storey is kept free without any constructions, except the columns which transfer the building weight to the ground.

For a hotel or commercial building, where the lower floors contain banquet halls, conference rooms, lobbies, show rooms or parking areas, large interrupted space required for the movement of people or vehicles. Closely spaced columns based on the layout of upper floors are not desirable in the lower floors. So to avoid that problem floating column concept has come into existence.

Research Significance:

In urban areas, multi storey buildings are constructed by providing floating columns at the ground floor for the various purposes which are stated above. These floating column buildings are designed for gravity loads and safe under gravity loads but these buildings are not designed for earthquake loads. So these buildings are unsafe in seismic prone areas. The paper aims to create awareness about these issues in earthquake resistant design of multi-storeyed buildings.

Overview of floating column building:

This paper deals with the comparison of a G+5 storey building with all columns and a G+5 storey building without edge columns. Here a G+5 building without edge columns is nothing but a floating column building that is the building in which the columns at the edge of ground floor are removed. From the first story to the top storey all columns are present. Then the load transferred by the edge columns is transferred to the interior columns present in the ground storey.

By applying the static loads both the structures are safe. After applying the dynamic loads that is earthquake loads in lateral direction the structure without edge columns is unsafe, that is displacement of this structure is more than the structure with edge columns and stiffness of structure is also less than the structure with edge columns. To make the structure safe beams and columns are to be increased.

By increasing the dimensions of beams and columns research is carried out to find whether the structure without edge columns will be safe or not. Also study is carried out to find which structure is economical and the variation of economy between the both buildings can be identified.

Table 1: Geometrical dimensions of the building

Member dimensions			
Slab	Thickness		150 mm
Beams	Normal building		230mm x 500mm
	Floating column building	Interior beams	230mm x 500mm
		Cantilever projection at edges	650mm x 850mm
Columns	Normal building		350mm x 500mm
	Floating column building	Top 2 floors	350mm x 500mm
		All floors except top 2 floors	700mm x 900mm
Brick infill	Exterior wall thickness		250 mm
	Interior wall thickness		150 mm
Loads			
Unit weight of concrete			25 kN/m^2
Unit weight of brick infill			20 kN/m^2
Floors	Live load		4 kN/m^2
	Dead load		2 kN/m^2
Roof	Live load		4 kN/m^2
	Dead load		2 kN/m^2
Grade of rebar steel			
Beams			Fe415
Columns			Fe415

Model Studies:

A ground plus five storeyed (G+5) normal and a floating column building, with specially moment resisting frames in two orthogonal directions were selected for the study. Both the buildings are considered to be located in Zone III as per IS 1893:2002. The dimensions of beams, columns and slab and also applied loads are summarized in the above table 1.

Model 1:

Here a G+5 building with all edge columns which is nothing but a normal building is considered as mode 1 with dimensions of beams as 230 mm X 500 mm and column as 350 mm X 500 mm. For the overall building the dimensions of beams and columns are same in both X and Y directions.

Model 2:

Model 2 building is obtained by removing all the edge columns at ground floor of the model 1 building without changing in the dimensions of beams and columns. Model 2 building members are failed to withstand for the applied gravity loads and lateral loads.

Model 3:

As the Model 2 building is failed, so another building is created by changing the dimensions of the members to make the building to withstand for the applied gravity loads and lateral loads. The building with changes in columns and beams is considered as model 3 building. For a Model 3 building, up to G+3floor all column dimensions are taken as 700 mm X 900 mm. remaining all floors may have column size as 350 mm X 500 mm. Also all the beams will have 230 mm X 500 mm except the projected cantilever beam which are 650 mm X 850 mm.

Equivalent static method:

Equivalent Lateral force method is one in which all the lateral loads at each floor are calculated manually. Then the structure behaviour is identified by applying the lateral loads acting at each story in X and Y directions manually. These lateral loads are calculated by considering the various parameters like the Response reduction factor(R), Zone factor (Z), Importance factor (I), Horizontal acceleration coefficient (A_h), Structural response factor (S_a/g) and Total seismic weight of building (W) as per the IS code 1893-2002.

For a Normal (Model 1) building:

Calculated seismic weight of normal building is 53853 kN.

Fundamental natural time period = $0.075 * h^{0.75}$

$= 0.075 * 21^{0.75}$

$= 0.735$ sec

From time period value by interpolating in IS 1893 of clause 6.4.5 we get S_a/g as 1.85

$A_h = (Z/2)*(I//R)*(S_a/g)$

$A_h = (0.16/2)*(1/5)*(1.85)$

$= 0.0296$

Base Shear of Building = $A_h * W$

$= 0.0296 * 53853.125$

$= 1594.0525$ kN

Calculated base shear is distributed at each floor of the building.

Table 2: Lateral forces at each floor for Model 1 building

	Distributed base shear as Lateral force to each floor (kN)	Lateral force at each joint (kN)
Terrace	510	85
5th Floor	492	82
4th Floor	315	52
3rd Floor	178	30
2nd Floor	79	13
1st Floor	20	3

As model 2 building also has dimensions as model 1 building the same lateral forces are applied for model 2 building.

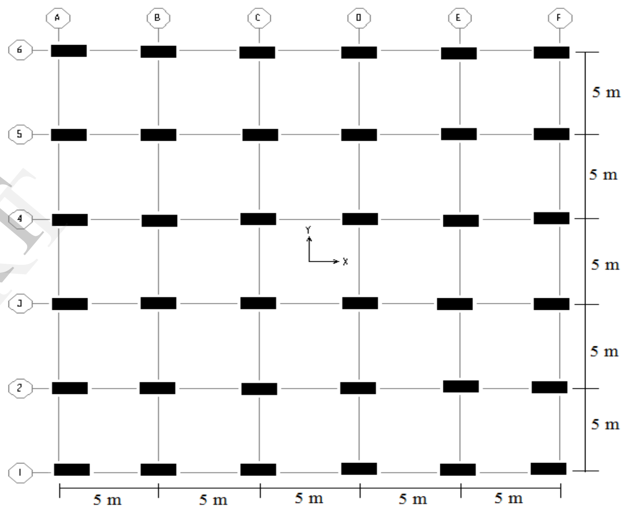

Figure 1: Shows the plan of a normal building (model 1)

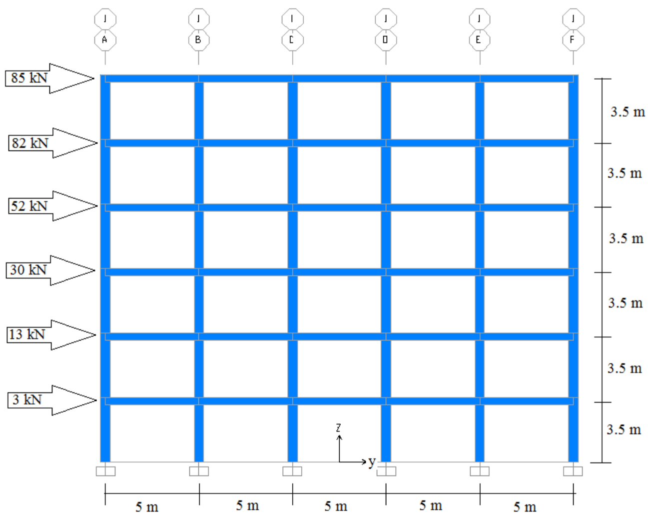

Figure 2: Shows the application of lateral load in X-direction for a edge frame in YZ view

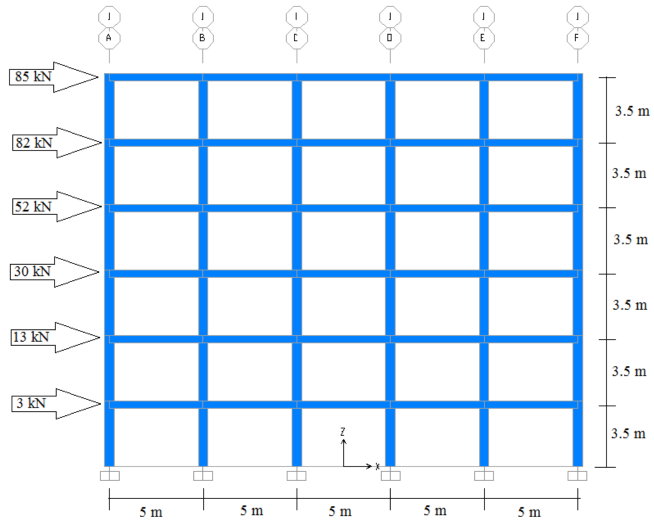

Figure 3: Shows the application of lateral load in Y-direction for a edge frame in XZ view

For a Floating column (Model 3) building:

Calculated seismic weight of a floating column building is 61078 kN.

Fundamental natural time period = $0.075 * h^{0.75}$

$= 0.075 * 21^{0.75}$

$= 0.735$ sec

From time period value by interpolating in IS 1893 we get S_a/g as 1.85

$A_h = (Z/2)*(I//R)*(S_a/g)$

$= (0.16/2)*(1/5)*(1.85)$

$= 0.0296$

Base Shear of Building = $A_h * W$

$= 0.0296 * 61078$

$= 1808$ kN

Table 3: Lateral forces at each floor for Model 3 building

	Distributed base shear as Lateral force to each floor (kN)	Lateral force at each joint (kN)
Terrace	610	102
5th Floor	497	83
4th Floor	318	53
3rd Floor	246	41
2nd Floor	109	18
1st Floor	27	5

The obtained base shear at each floor is applied at each joint of the floor by dividing the base shear with the total number of joints in each floor that is 6.

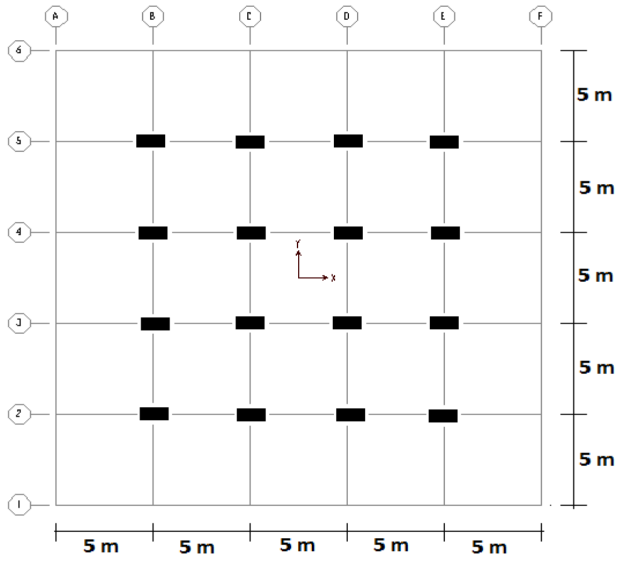

Figure 4: Shows the plan of a floating column (model 2 & model 3) building at base

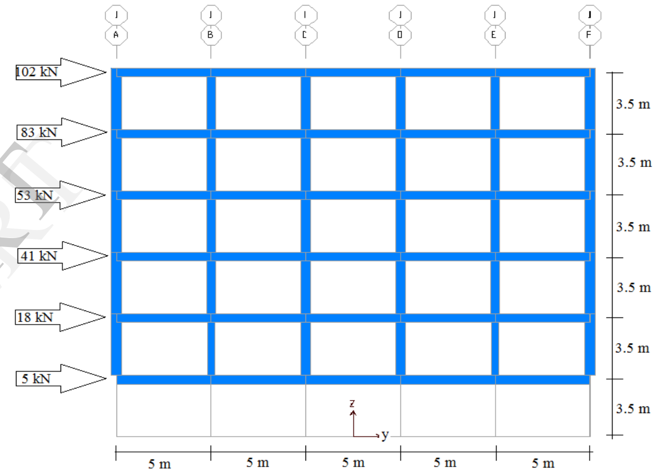

Figure 5: Shows the application of lateral load in X-direction for a edge frame in YZ view

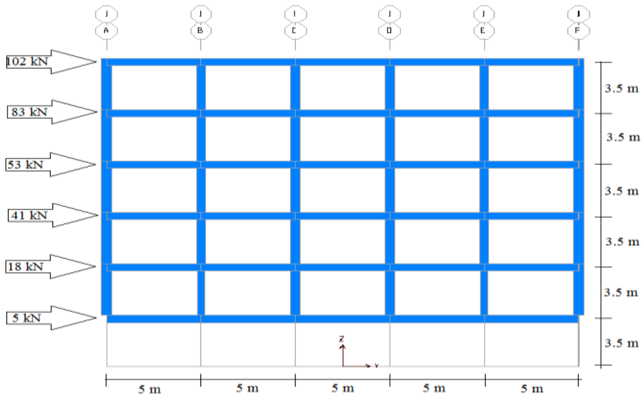

Figure 6: Shows the application of lateral load in Y-direction for a edge frame in XZ view

COMPARISIONS

Comparison based on displacement due to lateral load:

By the application of lateral loads in X and Y directions the structure can be analysed for various load combinations given by clause 6.3.1.2 of IS 1893:2002.

For the given load combinations maximum displacement at each floor is noted in X, Y and Z direction and are shown below in the form of a graph.

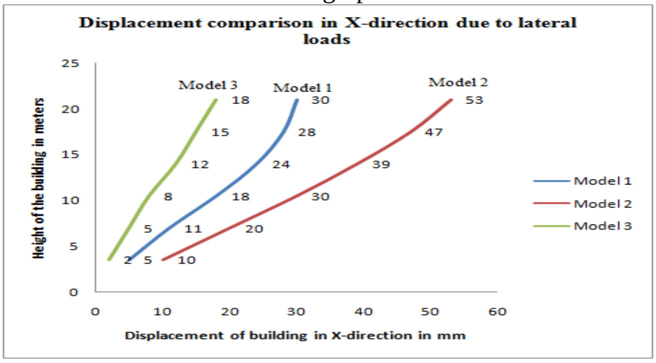

Figure 7: Displacement of 3 models in X-direction due to lateral loads

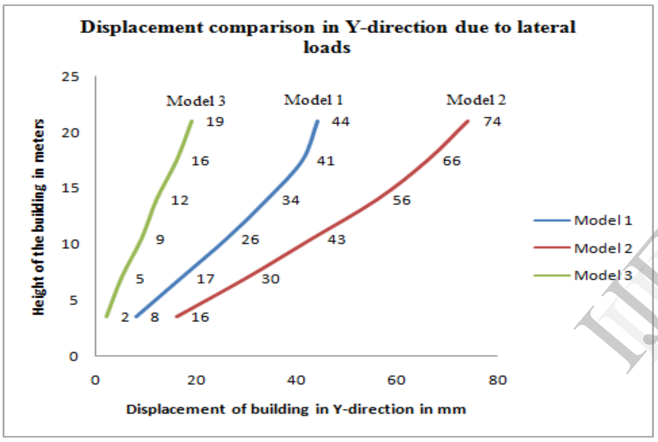

Figure 8: Displacement of 3 models in Y-direction due to lateral loads

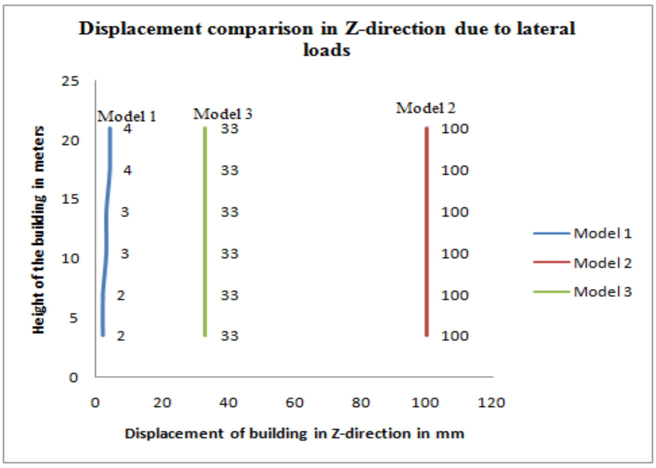

Figure 9: Displacement of 3 models in Z-direction due to lateral loads

From the above graphs it is observed that the model 1 building has less displacement when compared to a model 2 building in X, Y and Z directions. So model 2 is unsafe when compared to a model 1 building.

Also model 3 building has lesser displacements than model 1 building in X and Y directions. So model 3 is safe in X and Y directions. But in Z direction the displacement of model 3 is higher (i.e., 87%) than model 1. So model 3 is unsafe in Z direction.

From this we conclude that model 3 is unsafe for construction.

Comparison based on Stiffness:

The stiffness of all the three models can be calculated and compared as per the table 5 of IS 1893:2002 (part 1) to find whether the above three models are safe from soft storey effect or not.

Table 3: shows the lateral stiffness at each floor

Lateral stiffness for a building			
	Model 1	Model 2	Model 3
Overall building	62500	25641	71429
6th Floor	500000	333333	1000000
5th Floor	500000	333333	1000000
4th Floor	500000	333333	2527806
3rd Floor	500000	333333	2660282
2nd Floor	500000	333333	2470966
1st Floor	500000	166667	1552795

From the above values as per the table 5 of IS 1893: 2002 it states that the stiffness of each floor is compared to the stiffness of the storey above and also stiffness is compared to the average stiffness of the three stories above.

Table 4: Variation of lateral stiffness at each floor

Floor level	Percentage of variation of lateral stiffness to the three storeys above			Percentage of variation of lateral stiffness floor to floor		
	model 1	model 2	model 3	model 1	model 2	mod el 3
6th Floor	-	-	-	0	0	0
5th Floor	100	100	100	0	0	0
4th Floor	100	100	252	0	0	60
3rd Floor	100	100	176	0	0	05
2nd floor	100	100	119	0	0	08
1st Floor	100	50	61	0	100	60

As per Clause 7.1 from table 5 of IS 1893-2002,

It states that if the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average of the lateral stiffness of the three storeys above, then it will be said to have soft storey effect

It also states that if the lateral stiffness is less than 60 percent of that of the storey above or less than 70 percent of the average stiffness of the three storeys above, then it is said to have extreme soft storey effect. From results we concluded that the lateral stiffness of model 3 building is less than 60 percent between the 1st floor and 4th floor.

Then the model 3 building will suffer extreme soft storey effect. So the structure is unsafe.

Comparison of quantity of steel and concrete:

For the three model buildings, a comparison of quantity of steel and concrete are made based on the results obtained by the analysis of the both buildings. Here the quantity of steel and concrete are compared only in the model 1 and model 3 building because the model 2 building is unsafe and also the quantity of steel and concrete is little bit less than the model 1 building.

For the model 1 and model 3 only the quantity of steel and concrete in beams and columns are calculated because as the thickness of slab, brick walls and all other are same and the loading is also same then the comparison makes no difference between the two buildings. The sizes of beams and columns are varied in the both buildings so the comparison is based only for beams and columns.

Table 5: Variation of quantity of rebar steel and concrete

		Model 1 building	**Model 3 building**	**%age of variation**
Quantity of rebar in Tonnes	beams	30	43	40
	columns	16	30	
Quantity of concrete in m^3	beams	206	356	42
	columns	131	230	

From the above table it is noticed that the quantity of rebar steel of model 3 building is 40 % (i.e., 27 Tonnes) more than a model 1 building.
Also the quantity of concrete of model 3 building is 42 % (i.e., 249 cubic meters) more than a model 1 building.
By the above comparison as both the quantity of steel and concrete are more, then the model 3 building is uneconomical than model 1 building.

Comparison based on Time history Analysis:

Time history analysis provides the linear or nonlinear evaluation of dynamic structural response under loading which may vary according to the specified time function. In this paper, linear time history analysis is done by applying the past earthquake intensities with motion in X direction. So the displacement of buildings in Y direction is very less and negligible. So the comparison of displacement due to ground motion is done in X and Z directions only.

Earthquakes such as Petrolia (PGA=0.662g), Northridge (PGA=0.583g), Nocembra umbra (PGA=0.470g) and parkfield (PGA=0.434g) are applied. Here PGA denotes peak ground acceleration of that earthquake.

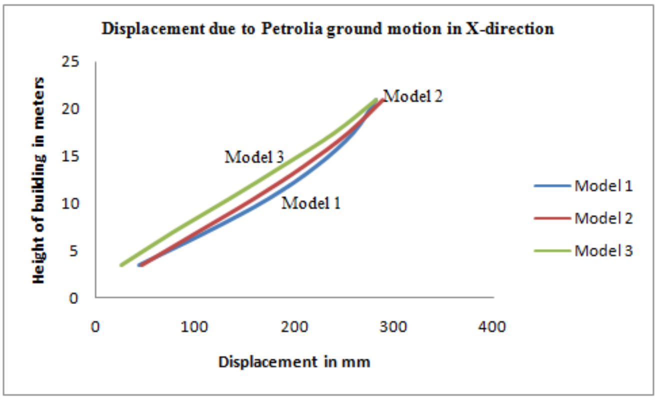

Figure 10: Displacement due to Petrolia in X-direction

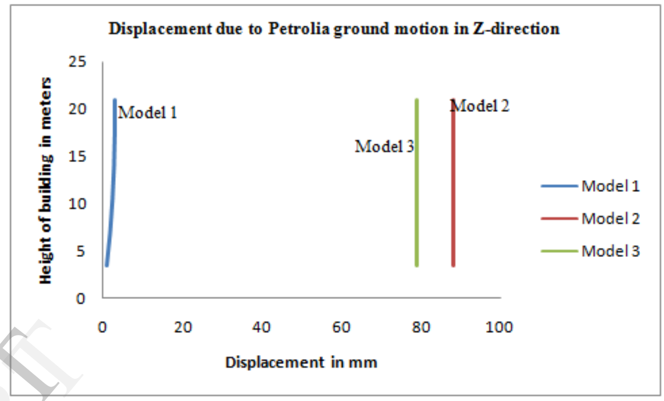

Figure 11: Displacement due to Petrolia in Z-direction

From the above graphs by the application of Petrolia ground motion it is noticed that three models will have equal displacements in X-direction, but in Z-direction model 2 has more displacement than model 1 and model 3. As model 2 is ignored due to failing of beams and columns. As model 3 is having more displacement than model 1 then it model 3 is unsafe than model 1.

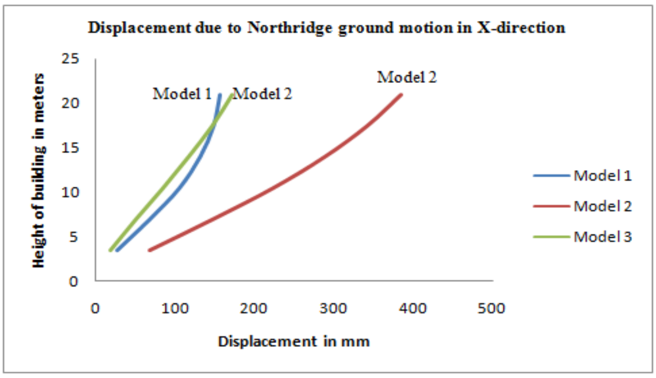

Figure 12: Displacement due to Northridge in X-direction

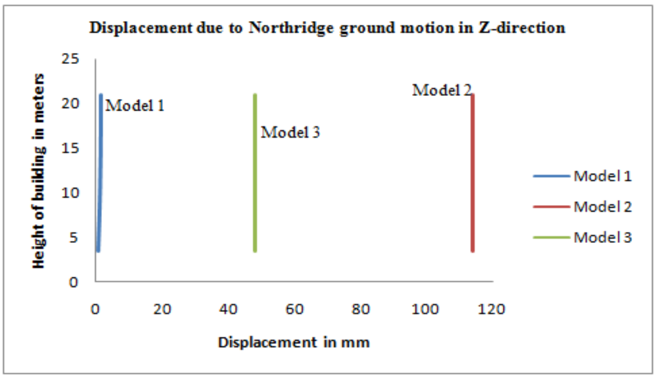

Figure 13: Displacement due to Northridge in Z-direction

From the above graphs by the application of Northridge ground motion it is noticed that model 2 has more displacement than model 1 and model 3.As model 2 is ignored due to failing of beams and columns. As model 3 is having more displacement than model 1 then it model 3 is unsafe than model 1.

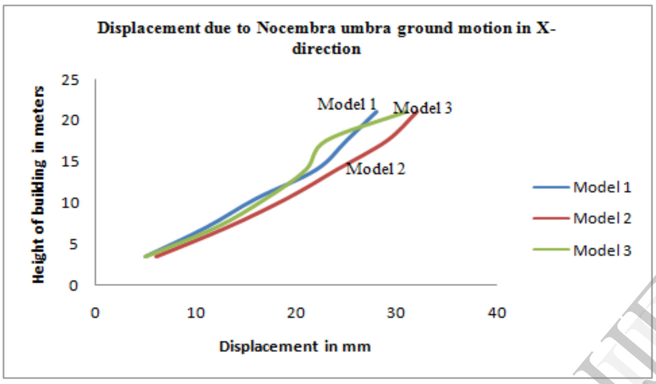

Figure 14: Displacement due to Nocembra umbra in X-direction

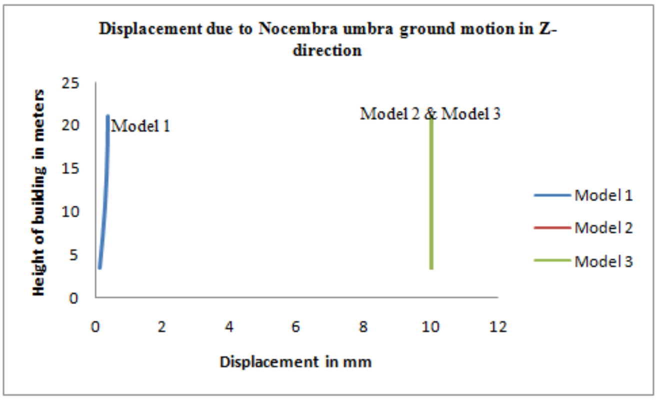

Figure 15: Displacement due to Nocembra umbra in Z-direction

From the above graphs by the application of Nocembra umbra ground motion it is noticed that model 2 has more displacement than model 1 and model 3.As model 2 is ignored due to failing of beams and columns. As model 3 is having more displacement than model 1 then it model 3 is unsafe than model 1.

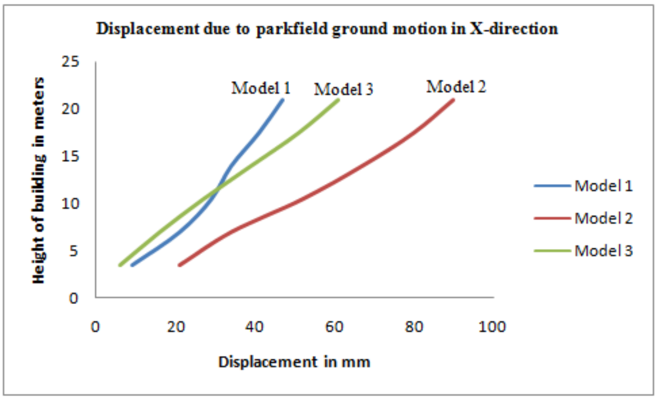

Figure 16: Displacement due to Parkfield in X-direction

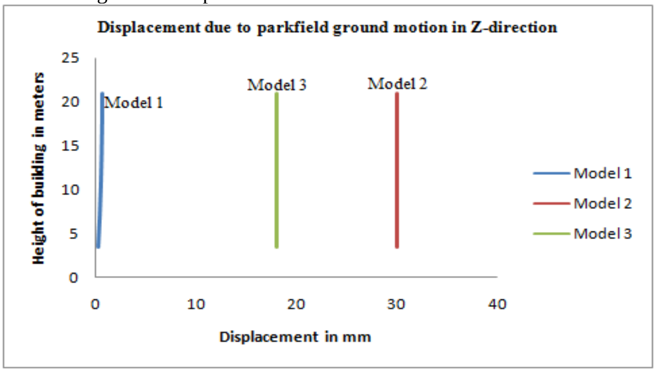

Figure 17: Displacement due to Parkfield in Z-direction

From the above graphs by the application of Parkfield ground motion it is noticed that model 2 has more displacement than model 1 and model 3.As model 2 is ignored due to failing of beams and columns. As model 3 is having more displacement than model 1 then it model 3 is unsafe than model 1.

CONCLUSIONS:

The study presented in the paper compares the difference between normal building and a building on floating column. The following conclusions were drawn based on the investigation.

- By the application of lateral loads in X and Y direction at each floor, the displacements of floating column building in X and Y directions are less than the normal building but displacement of floating column building in Z direction is large compared to that of a normal building. So the floating column building is unsafe for construction when compared to a normal building.

- By the calculation of lateral stiffness at each floor for the buildings it is observed that floating column building will suffer extreme soft storey effect where normal building is free from soft storey effect. So the floating column building is unsafe.

- After the analysis of buildings, comparison of quantity of steel and concrete are calculated from which floating column building has 40% more rebar steel and 42% more concrete quantity than a normal building. So the floating column building is uneconomical to that of a normal building.

- From the time history analysis it is noticed that the floating column building is having more displacements than a normal building. So floating column building is unsafe than a normal building.

The final conclusion is that do not prefer to construct floating column buildings. With increase in dimensions of all members also it is getting more displacements than a normal buildings and also the cost for construction also increased. So avoid constructing floating column buildings.

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