International Journal for Modern Trends in Science and Technology, 8(06): 319-326, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0806055
Available online at: http://www.ijmtst.com/vol8issue06.html

Time History Analysis of A Multi Storey Building using floating columns

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To Cite this Article
Palivela Teja and B.Ramesh. Time History Analysis of A Multi Storey Building using floating columns. International Journal for Modern Trends in Science and Technology 2022, 8(06), pp. 319-326. https://doi.org/10.46501/IJMTST0806055

Article Info
Received: 16 May 2022; Accepted: 11 June 2022; Published: 16 June 2022.

ABSTRACT

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which ends (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. Such columns where the load was considered as point load. Theoretically such structures can be analyzed and designed. In recent times, multi-storey buildings in urban cities are required to have column free space due to shortage of space, population and also for aesthetic and functional requirements. For these buildings are provided with floating columns at one or more storey. These floating columns are highly disadvantageous in a building built in seismically active areas. In the present study multistoried building with floating column is analyzed by ETABS. Here G+12 structure is analyzed with and without floating columns by using response spectrum method and time history method under earthquake load in zone II and compared with parameters like lateral loads, storey displacements, storey drifts, storey shears, storey stiffness and base shears. From the results it is observed that the storey displacements, storey drifts and storey shears are more for a building without floating columns when compared with a building with floating columns.

1. INTRODUCTION

Many urban multi-storey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height. The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building.

1.0 FLOATING COLUMN:

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it.

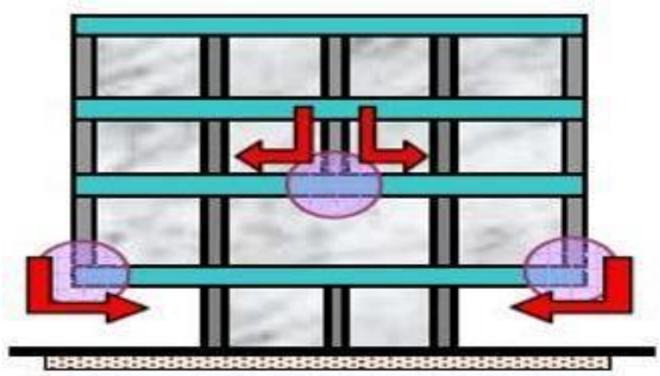

FIG 1.1 HANGING OR FLOATING COLUMNS

There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. The transfer girders have to be designed and detailed properly, especially in earth quake zones.

1.2 OBJECTIVE AND SCOPE OF PRESENT WORK

The objective of the present work is to study the behaviour of g+12 buildings with and without floating columns under earthquake excitations. Finite element method is used to solve the dynamic governing equation. Response spectrum analysis and time history analysis is carried out for the multi-story buildings under different earthquake loading of varying frequency content. The base of the building frame is assumed to be fixed.

2. REVIEW OF LITERATURES

Current literature survey includes earthquake response of multi storey building frames with usual columns. Some of the literatures emphasized on strengthening of the existing buildings in seismic prone regions.

Syed tajodeen [1] in this paper they analyzed the seismic analysis of RC building with floating column before and after providing lateral bracing. He analyzed the structure in zone 5 using Etabssoftware. The method he used for finding seismic analysis is response spectrum method. He concluded that through the parametric study of storey drift, storey shear, time period and displacement, it was found that the multi-storey buildings with floating columns performed poorly under seismic excitation.

Waykule.S. B1, Kadam.[2] In this paper they studied about analysis of G+5 Building with and without floating column in highly seismic zone v. four models are created such as floating column at 1st, 2ndand 3rd floor buildings and without floating column building. Linear static and time history analysis are carried out of all the four models. From linear static analysis compare all the of models result obtained in the form of seismic parameter such as time period, base shear, storey displacement, storey drift.

Mohamed Aqeeb Ulla, Krishna [3] had done research on Seismic analysis of r c buildings with floating columns using non-linear static analysis and linear static analysis. The term floating-column is additionally an upright member that ends (due to subject field design/ web site situation) at its lower level (termination Level) rests on a beam that may be a horizontal member. The beams successively transfer the load to alternative columns below it.

Trupanshu Patel [4] in the present work is done to study the behaviour of G+3 buildings having floating columns. However recent studies based on floating columns, which mostly concentrated on higher seismic zones and very few works is available for lower seismic zones Also to obtain the effects of mass variations and infill walls on behaviour of normal and floating column building, one forth portion of typical floor has been provided with higher mass compare to other portions and different building models were analysed with and without provisions of infill walls.

Maison and Neuss [5] Members of ASCE have performed the computer analysis of an existing forty-four story steel frame high-rise Building to study the influence of various modelling aspects on the predicted dynamic properties and computed seismic response behaviours.

Maison and Ventura [6] Members of ASCE computed dynamic properties and response behaviours OF THIRTEEN-STORY BUILDING and this result are compared to the true values as determined from the recorded motions in the building during two actual earthquakes and shown that state-of- practice design type analytical models can predict the actual dynamic properties.

3. METHODOLAGY

All the structures are designed for the combined effects of gravity loads and seismic loads to verify that adequate vertical and lateral strength and stiffness are achieved to satisfy the structural performance and acceptance deformation levels prescribed in the governing building code. Because of the inherent factor of safety used in the design specification, most structures tend to adequately protected against vertical shaking. Vertical acceleration should also be considered in structures with large spans, those in which stability for design, or for overall stability analysis of structuresIn general, most earthquake code provisions implicitly require the structures be able to resist: -

- Minor earthquake without any damage.
- Moderate earthquake with negligible structural damage and some non-structural damage.
- Major earthquake with some structural damage and non-structural damage without collapse.
- The structure is expected to undergo fairly large deformation by yielding in some structural members.

Seismic codes are unique to a particular region or country. In India, IS 1893:2002 (part-1) is the main code that provided outline for calculation of seismic design force.

3.1 TIME HISTORY ANALYSIS

It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a specific ground motion in order to examine the exact non-linear behavior of building structures, non-linear time history analysis has to be carried out. In this method, the structure is subjected to real ground motion records.

3.2 LINEAR TIME HISTORY ANALYSIS

The linear time history method involves a time-step-by-step evaluation of the building response, using discretized record or synthetic earthquake records as base motion input. Pair of ground motion records for simultaneous analysis along each horizontal axis of the building should be consistent. Consistent pairs are the orthogonal motions expected at a given site based on the same earthquake. The damping matrix associated with the mathematical model shall reflect the damping in the building a deformation levels near the yield. The seismic input is modelled using either modal spectral analysis or time history analysis but, in both cases, the corresponding internal forces and displacement are determined using linear elastic analysis.

4. MODELLING AND ANALYSIS

In this chapter building details of the modelled structure are presented. The building structures with and without floating columns is analysed using response spectrum method and time history method in ETABS 2016. The models of the structures are presented below in this chapter.

4.1 BUILDING DATA

Table 4.1 Description of the Building data

1	**Details of the building**			
i)	Structure			OMRF
ii)	Number of stories			G+12
iii)	Type of building			Regular and Symmetrical in plan
iv)	Plan area			8.5 m x 8.5 m
v)	Height of the building			36 m
vi)	Storey height- Bottom story Typical story			3.0 m 3.0 m
vi)	Support			Fixed
viii)	Seismic zones			II
2	**Material properties**			
i)	Grade of concrete			M30
ii)	Grade of steel			Fe415
iii)	Density of reinforced concrete			25 kN/m³
iv)	Young's modulus of M30 concrete, Ec			27386127.87 kN/m²
v)	Young's modulus steel, Es			2 x 10⁸kN/m²
3	**Type of Loads & their intensities**			
i)	Floor finish			1.5 kN/m²
ii)	Live load on floors			3 kN/m²
iii)	wall load on beams			3.9 kN/m²
iv)	Parapet wall load			1 kN/ m²
4	**Seismic Properties**			
i)	Zones	II	0.10	
ii)	Importance factor (I)		1	
iii)	Response reduction factor (R)		5%	
iv)	Soil type		II	
v)	Damping ratio		0.05	

vi)	Time history function		Elcentro	

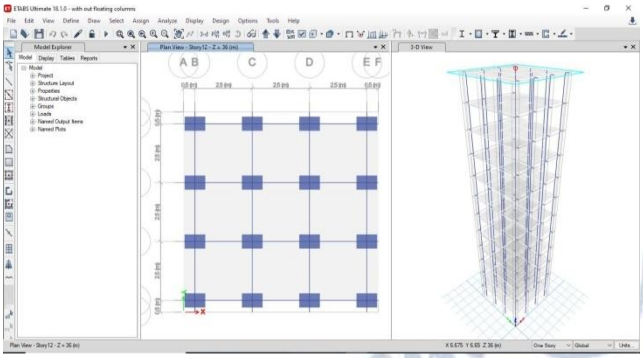

FIG 4.1 MODEL OF G+12 BUILDING WITHOUT FLOATING COLUMNS

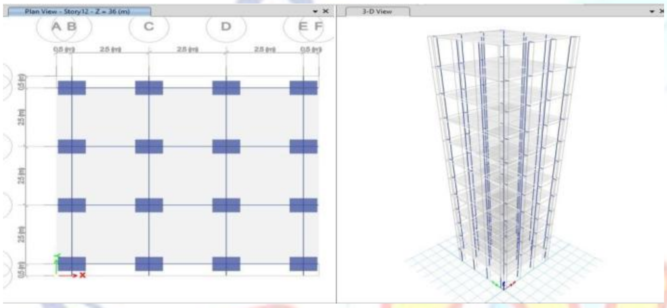

Fig 4.2 Model of G+12 building with floating columns

From the figures 4.2 and 4.3it is clear that the floating columns are provided in story 1 and the remaining storeys column placement is same as the normal building.

5. RESULTS OF BUILDING WITHOUT FLOATING COLUMNS

5.1.1 Lateral Loads

TABLE 5.1 LATERAL LOADS ON A BUILDING WITHOUT FLOATING COLUMNS

Story	ation M	Location	-Dir kN	-Dir kN
Story12	36	Top	449.7438	379.5391
Story11	33	Top	455.1609	383.2568
Story10	30	Top	376.3396	316.9147
Story9	27	Top	305.025	256.8909
Story8	24	Top	241.2173	203.1854
Story7	21	Top	184.9164	155.7982
Story6	18	Top	136.1222	114.7293
Story5	15	Top	94.8349	79.9787
Story4	12	Top	61.0543	51.5464
Story3	9	Top	34.7806	29.4323
Story2	6	Top	16.0136	13.6366
Story1	3	Top	4.8702	4.2574
Base	0	Top	0	0

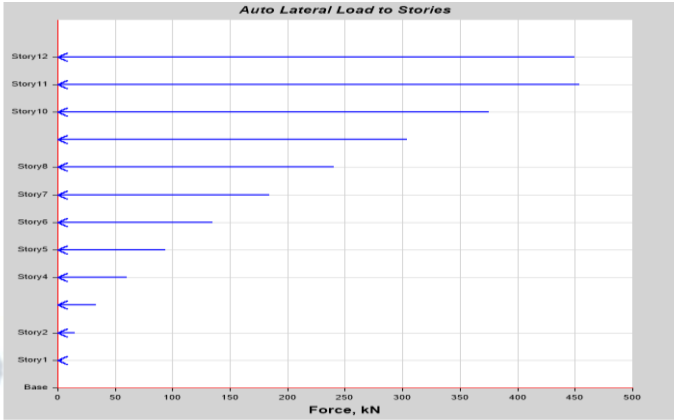

Fig 5.1 Lateral loads on stories in X-direction for a building without floating columns

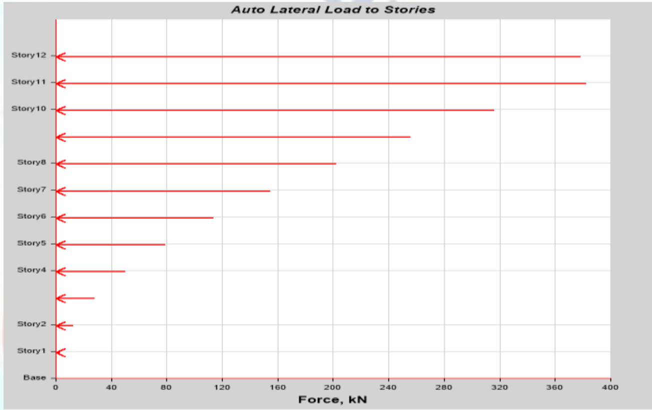

Fig 5.2 Lateral loads on stories in Y- direction for a building without floating columns From the table 5.1 and table 5.7it is clear thatthe lateral loads on a building with floating columns are 45% less than the building without floating columns

5.1.2 STORY DISPLACEMENTS

Table 5.2 Story displacements of a building without floating columns

Story	ation m	Location	For EQ X		For EQ Y	
			-Dir mm	-Dir mm	-Dir mm	-Dir mm
Story12	36	Top	29.6	1.702E-03	9.603E-04	31.5
Story11	33	Top	27.7	1.733E-03	9.958E-04	30.6
Story10	30	Top	25.5	1.345E-03	7.718E-04	28.5
Story9	27	Top	23.9	1.091E-03	6.036E-04	26.8
Story8	24	Top	20.7	8.722E-04	4.526E-04	23.4
Story7	21	Top	17.9	6.818E-04	3.1E-04	21.6
Story6	18	Top	15.3	5.196E-04	1.687E-04	18.2
Story5	15	Top	12.8	3.845E-04	5.524E-05	16.6
Story4	12	Top	10.5	2.767E-04	1.951E-04	13.8
Story3	9	Top	7.9	1.584E-04	2.544E-03	11.5
Story2	6	Top	5.6	3.618E-04	2.029E-02	8.6
Story1	3	Top	3.4	1.024E-03	5.634E-03	5.7
Base	0	Top	0	0	0	0

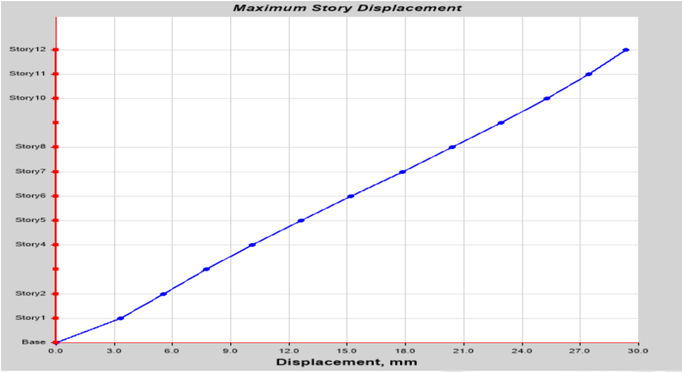

FIG 5.3 STOREY DISPLACEMENTS OF A BUILDING WITHOUT FLOATING COLUMNS FOR EQ X

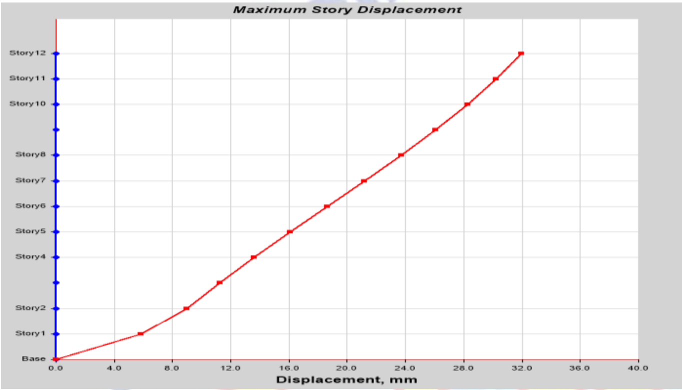

Fig 5.4 Storey displacements of a building without floating columns for EQ Y

The storey displacements of a building without floating columns are 50% more than the building with floating columns. Time history response values of base shear for a building without floating columns

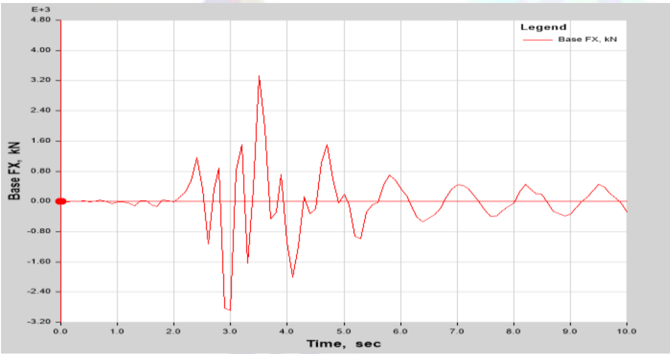

Fig 5.5 Base shear values of a building without floating columns at different time periods

The maximum base shear occurred in building without floating columns is 3333.67 KN at 3.5 sec.

5.2 RESULTS OF BUILDING WITH FLOATING COLUMNS

5.2.1 Lateral Loads

TABLE 5.3 LATERAL LOADS ON A BUILDING WITH FLOATING COLUMNS

Story	vation M	Location	-Dir kN	-Dir kN
Story12	36	Top	203.6074	175.4348
Story11	33	Top	235.3813	202.7905
Story10	30	Top	194.7035	167.769
Story9	27	Top	157.8998	136.0829
Story8	24	Top	124.9702	107.7321
Story7	21	Top	95.9147	82.7168
Story6	18	Top	68.7333	61.0368
Story5	15	Top	49.4259	42.6922
Story4	12	Top	31.9926	27.683
Story3	9	Top	18.4333	16.0092
Story2	6	Top	7.9481	7.6708
Story1	3	Top	3.0029	2.7244
Base	0	Top	0	0

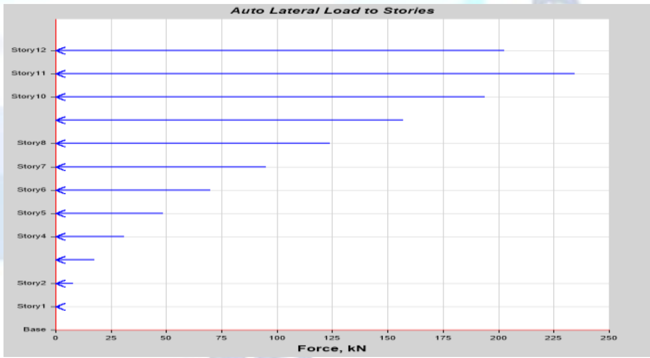

Fig 5.6 Lateral loads on stories in X-direction for a building with floating columns

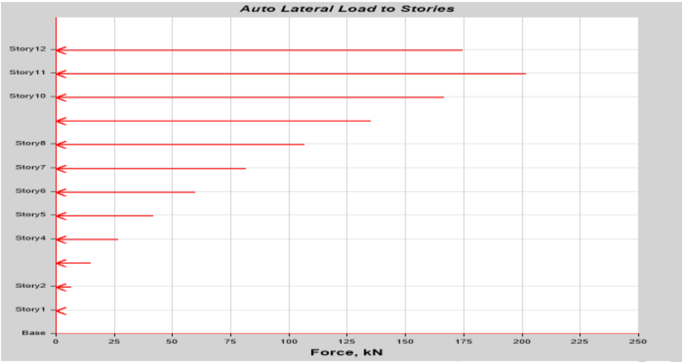

FIG 5.7 LATERAL LOADS ON STORIES IN Y- DIRECTION FOR A BUILDING WITH FLOATING COLUMNS

5.2.2 Story Displacements

TABLE 5.4 STORY DISPLACEMENTS OF A BUILDING WITH FLOATING COLUMNS

Story	ation m	Location	For EQ X		For EQ Y	
			-Dir mm	-Dir mm	-Dir mm	-Dir mm
Story12	36	Top	14.9	5.002E-04	5.539E-04	15.8
Story11	33	Top	13.5	5.523E-04	2.786E-04	16
Story10	30	Top	12.7	4.081E-04	2.89E-04	15
Story9	27	Top	11.5	3.267E-04	2.704E-04	12.9
Story8	24	Top	10	2.582E-04	2.663E-04	11.6
Story7	21	Top	8.5	1.991E-04	2.803E-04	10.2
Story6	18	Top	7.9	1.49E-04	3.152E-04	8.9
Story5	15	Top	5.7	1.099E-04	3.793E-04	7.5
Story4	12	Top	4.8	7.225E-05	6.459E-04	6.2
Story3	9	Top	3.6	3.599E-05	9.352E-04	4.7
Story2	6	Top	2.5	1.292E-03	1.747E-02	3.4
Story1	3	Top	1.5	1.045E-03	1.563E-02	2.3
Base	0	Top	0	0	0	0

Fig 5.8 Storey displacements of a building with floating columns for EQ X

FIG 5.9 STOREY DISPLACEMENTS OF A BUILDING WITH FLOATING COLUMNS FOR EQ Y

The storey displacements of a building with floating columns in X-direction are increasing with respect to Y-direction. The storey displacements of a building with floating columns are 50% less than the building without floating columns.

TABLE 5.5 STORY SHEARS OF A BUILDING WITH FLOATING COLUMNS

Story	ation m	Location	For EQ X		For EQ Y	
			-Dir kN	-Dir kN	-Dir kN	-Dir kN
Story12	36	Top	-203.6074	0	0	-174.4348
		Bottom	-201.6074	0	0	-174.6348
Story11	33	Top	-437.9887	0	0	-376.2253
		Bottom	-435.9887	0	0	-376.5253
Story10	30	Top	-631.6922	0	0	-542.9942
		Bottom	-632.6922	0	0	-543.9942
Story9	27	Top	-786.592	0	0	-678.0771
		Bottom	-786.592	0	0	-679.0771
Story8	24	Top	-912.5623	0	0	-784.8092
		Bottom	-912.5623	0	0	-785.8092
Story7	21	Top	-1007.477	0	0	-866.526
		Bottom	-1006.477	0	0	-866.726
Story6	18	Top	-1076.3103	0	0	-926.5629
		Bottom	-1076.2103	0	0	-926.6629
Story5	15	Top	-1124.6362	0	0	-968.2551
		Bottom	-1124.5362	0	0	-968.3551
Story4	12	Top	-1155.4287	0	0	-994.7381
		Bottom	-1155.8287	0	0	-994.9381
Story3	9	Top	-1173.062	0	0	-1009.8473
		Bottom	-1174.062	0	0	-1009.9473
Story2	6	Top	-1181.8102	0	0	-1016.6181
		Bottom	-1182.8102	0	0	-1016.7181
Story1	3	Top	-1182.913	0	0	-1018.3425
		Bottom	-1183.813	0	0	-1018.5425
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

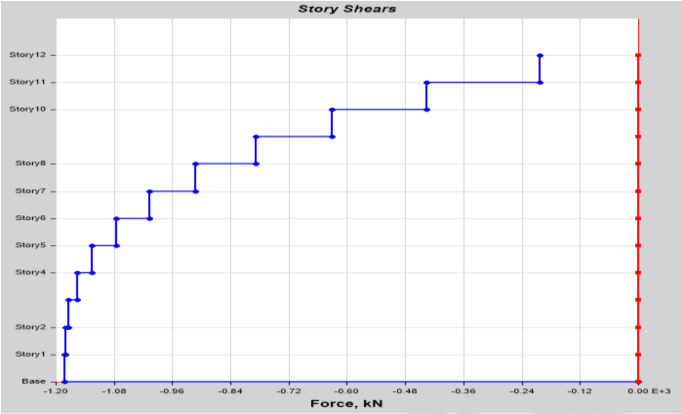

Fig 5.10 Storey shears of a building with floating columns for EQ X

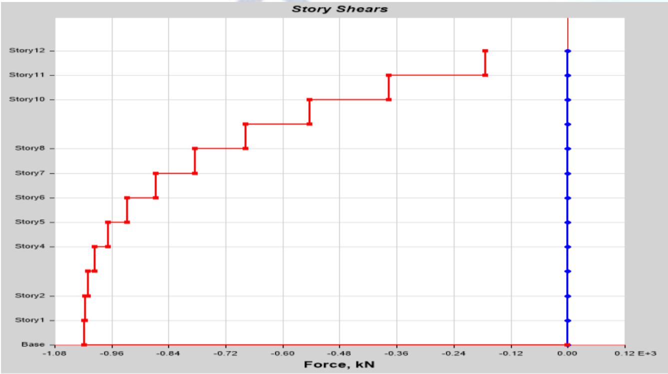

FIG 5.11 STOREY SHEARS OF A BUILDING WITH FLOATING COLUMNS FOR EQ Y

TABLE 5.6 STORY STIFFNESS VALUES OF A BUILDING WITH FLOATING COLUMNS

Story	ation m	Location	For EQ X		For EQ Y	
			X-Dir kN/m	Y-Dir kN/m	X-Dir kN/m	Y-Dir kN/m
Story12	36	Top	201517.269	0	0	191522.919
Story11	33	Top	388103.185	0	0	355677.985
Story10	30	Top	511121.202	0	0	458205.589
Story9	27	Top	599704.073	0	0	529733.722
Story8	24	Top	669518.101	0	0	584674.33
Story7	21	Top	730087.932	0	0	631272.778
Story6	18	Top	788319.751	0	0	675089.732
Story5	15	Top	850506.63	0	0	720598.169
Story4	12	Top	925133.919	0	0	771436.242
Story3	9	Top	1030949.07	0	0	819866.526
Story2	6	Top	1312026.578	0	0	737230.956
Story1	3	Top	908223.032	0	0	472583.164
Base	0	Top	0	0	0	0

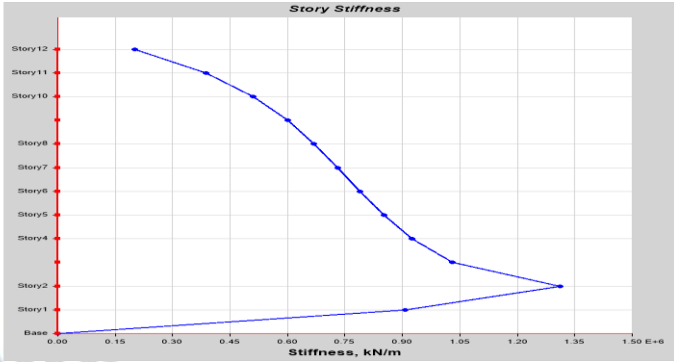

Fig 5.12 Storey stiffness values of a building with floating columns for EQ X

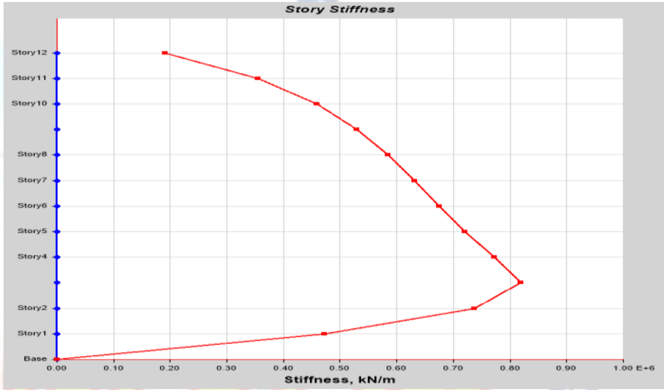

FIG 5.13 STOREY STIFFNESS VALUES OF A BUILDING WITH FLOATING COLUMNS FOR EQ Y

It was observed that building with floating column is stiffer than the building without floating columns.

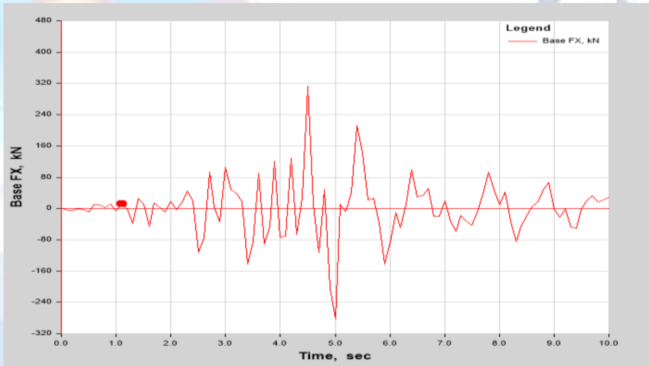

FIG 5.14 BASE SHEAR VALUES OF A BUILDING WITH FLOATING COLUMNS AT DIFFERENT TIME PERIODS

The maximum base shear occurred in building with floating columns is -283.4257 KN at 5 sec.

6 CONCLUSION

The behaviour of multi-storey building with and without floating column is studied under different earthquake excitation. The compatible response spectrum, time history and Elcentro earthquake data has been considered. A finite element model has been developed to study the dynamic behaviour of multi -story frame. The static and free vibration results obtained using present finite element code is validated. The dynamic analysis of frame is studied with and without floating columns. It is concluded that

- The storey displacements of a building with floating columns in X-direction are increasing with respect to Y-direction. The storey displacements of a building with floating columns are 50% less than the building without floating columns.
- The storey drifts of a building with floating columns in Y-direction are increasing with respect to X-direction. The storey drifts of a building with floating columns are 60% less than the building without floating columns.
- The storey shears of a building with floating columns in X-direction are increasing with respect to Y-direction. The storey shears of a building with floating columns are 48% less than the building without floating columns.
- It was observed that building with floating column has less base shear as compared to building without floating column. The maximum base shear occurred in building with floating columns is - 283.4257 KN at 5 sec and the maximum base shear occurred in building without floating columns is 3333.67 KN at 3.5 sec.
- It was observed that in building with floating column has more time period as compared to building without floating columns.
- With increase in ground floor column the maximum displacement, inter storey drift values are reducing. The base shear and overturning moment vary with the change in column dimension.
- The lateral loads on a building with floating columns are 45% less than the building without floating columns.
- It was observed that building with floating column is stiffer than the building without floating columns.

6.2 Future Scope

This study can be extended by providing the floating columns in different storeys and at different locations. We can study in severe earthquake zones by providing the earthquake resistant structural elements to the building with floating columns.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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