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Seismic Analysis and Positioning of Floating Columns in a Multistorey Building using ETABS

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Abstract: **Many multi-storey and commercial buildings have been developed with architectural complications in recent years. In seismically active zones, buildings with floating columns offer a substantial danger. The presence of floating columns in the structure, disrupts the weight transfer path, resulting in a change in the behaviour and load transfer of the structure. This paper studies the lateral force analysis of a floating column building with a G+10 story height. The main goals of this project are to investigate how multi-story buildings with floating columns behave when subjected to earthquake excitations, to determine whether a structure built in seismic zone II is safe or unsafe when using a floating column, and to determine the most crucial and best position for a floating column within a G+10 structure. The response spectrum analysis is used to assess construction models, with the assumption that when the structure is finished, it will be subjected to all of the loads in a single stretch. The building models are analyzed with the aid of the CSI ETABS 2018 programme.**

Keywords: **Floating columns, G+10 building, analysis, response spectrum analysis.**

1. Introduction

Modern construction technology places great emphasis on architectural and other features, as most multi-storey buildings require an open ground floor to accommodate parking lots, lobbies and other architectural aesthetics. Multi-storey building development for residential, industrial or commercial purposes has been common place in recent years. These multi-storey buildings need additional parking or open areas below. This open ground-level design causes columns to be interrupted, resulting in floating columns, which makes the structure fascinating from the side. The floating column concept was born out of architectural requirements to enhance the visual appeal of a structure while also overcoming Floor Space Index problems. A meeting room or banquet hall on the lower levels may also be required in commercial buildings. We prefer free space to columns for these particular purposes. Floating columns come into play in this scenario. The freedom to change the floor plans above is provided by floating columns. A column is a vertical element that starts at the foundation level and securely transfers the load from the structure to the earth. The load from the previous levels is transferred to the support, like any other building. The full load is subsequently transmitted to the floating column's support beam. The floating column is constructed in the same way as a standard column. These columns will be positioned to hang from a base with no solid support, transferring the load to the foundation. The beam on which the floating column is supported is designed to carry the column's whole load as a single point load. This beam, also known as a girder or transfer beam, has a large cross-section. During earthquakes, a building's behaviour is influenced by its general design, scale, and geometry, as well as how the earthquake forces are transmitted to the ground. The shortest path must be used to get the earthquake forces created in a building down to the ground. Any divergence or discontinuity in this transferred load causes the building to function poorly.

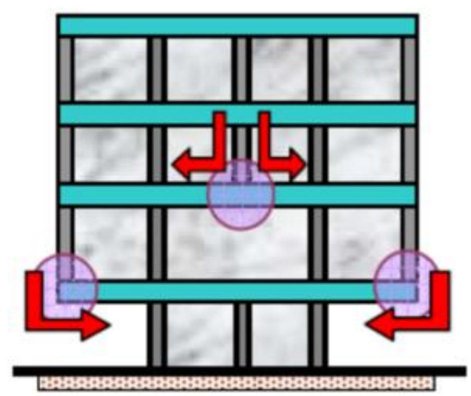

Fig. 1. Floating column building

The following are the objectives of this project:

1. To investigate how multi-storey structures with floating columns respond to earthquakes.
2. To compare Nodal displacement for all models.
3. To compare storey drift for all models.
4. To compare the maximum deflection in the transfer beams of the building in all specified models.
5. Determine the best position for a floating column within a building structure.

2. Literature Review

The floating columns topic has been covered in a variety of technical works. The review article addresses a number of topics, including seismic analysis of floating column buildings

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according to seismic zones, storey displacement, storey drift, and response spectrum methods according to various IS-codes. Following are some of those:

Ganesh Awchat (2021) in his paper titled "Seismic Analysis of a Multi-storeyed Building with Configuration of Floating Columns" studied that by imparting of a floating column in the structure has a significant influence on the period.

Sasidhar T., (2017) in his paper titled “Analysis of Multi Storied Building with and without Floating Column using Etabs" concluded that the provision of a floating column is advantageous in providing a good floor space index but the risk and vulnerability of the building increases.

Rajeeva S. V., (2017) in his paper titled "Seismic Behaviour of RC and Steel-concrete Composite Multi-storey Building with Floating Columns with and without Shear Walls" had said that the storey shear and base shear values obtained for both RC and steel-concrete composite structure with floating columns and shear walls is more compared to RC and steel-concrete composite structure with floating columns and without shear walls because of increase of seismic weight of the structure.

N. Lingeshwaran (2017) in his paper titled “Effect of Base Isolation in Multistoried Reinforced Concrete Building" concluded that the Base isolation method has proved to be a better method of earthquake-resistant design. The result of base shear is reduced by both isolators compared to the fixed base structure.

Yogendra R., (2014) in his paper titled "Seismic Response of Complex Buildings with Floating Column for Zone II and Zone V" has concluded that the multi-storey building with complexities will undergo large displacement than the model having only a floating column.

Sagar Jamle (2018) in his paper titled “Optimum Location of Floating Column in Multistorey Building with Seismic Loading” explores the analysis and comparison of Nodal displacement, storey drift, maximum shear force, maximum bending moment and maximum axial forces for various cases.

Waykule S. B., (2016) in his paper titled " Study of Behaviour of Floating Column for Seismic Analysis of Multistorey Building" had observed that building with floating column has more storey drift as compared to building without floating column.

Girish Joshi (2021) in his paper titled "Study of Behaviour of Multistorey Building with Floating Column: A Review" concluded that Storey displacement increases as the height of the building increases and storey drift increases as storey displacement increases. The base shear value decreases due to the introduction of a floating column.

3. Methodology

A. Modelling and Analysis

The experiment involved a G+10 storey structure with a floating column in India's zone II, as defined by IS 1893 (Part1):2016. The analysis also takes into account various positions of floating columns on the building's first floor. ETABS software is used to model and analyse the building. Seismic analysis is also performed to determine whether the structure is safe. To determine the values of storey drift and displacement, the response spectrum approach is employed.

This approach can be used to discover the crucial and optimum places for a floating column. The first storey of the structure has a floating column. This research looks at seven different models.

B. Model Specification of Project

Table 1
Building configuration

Parameter	Assumed Data
Number of storeys	G + 10
Utility of Building	Residential
Number of bays along X-direction	5
Number of bays along Y-direction	5
Storey height	3m
Height of building	33m
Bay width along X-direction	5m
Bay width along Y-direction	5m

Table 2
Material properties

Parameter	Values
Material	Concrete
Grade of concrete	M30
Grade of steel	HYSD500

Table 3
Section properties

Parameter	Values
Beam size	530mm x 530mm
Column size	700mm x 700mm
Slab thickness	150mm

Table 4
Seismic data for G+10 building

Parameter	Values
Seismic zone	Zone II
Seismic zone factor, Z	0.10
Importance Factor, I	1.2
Response reduction factor, R	3
Site type	Medium stiff (II)

C. Different cases considered based on positioning of floating columns in the building

A G+10 storied building model is investigated, with 5 bays in the x-direction and 5 bays in the y-direction for a total of 7 examples, each with a floating column at varied places inside the first-floor level storey.

- Model 1: Normal building
- Model 2: removing only 2 columns in the first-floor level storey
- Model 3: removing only 4 columns in the first-floor level storey
- Model 4: removing only 6 columns in the first-floor level storey
- Model 5: removing only 8 columns in the first-floor level storey
- Model 6: removing columns at the corners in the first-floor level storey
- Model 7: removing columns along the outer periphery in the first-floor level storey

The following models are generated in the form of ETABS modelling structures and are shown below. The absence of columns can be seen from the top view of the storey which shows that the floating columns are present at that particular point of the building.

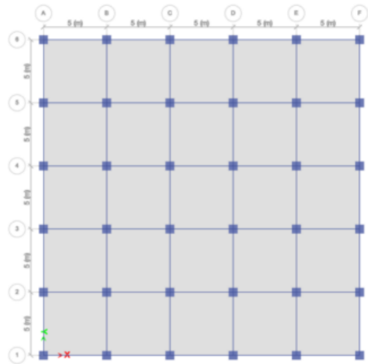

Fig. 2. Model 1

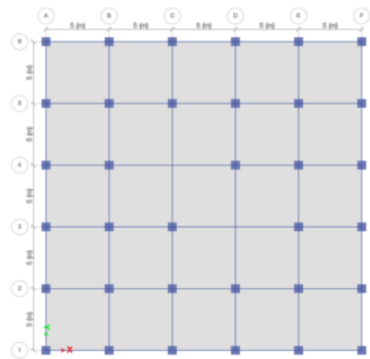

Fig. 3. Model 2

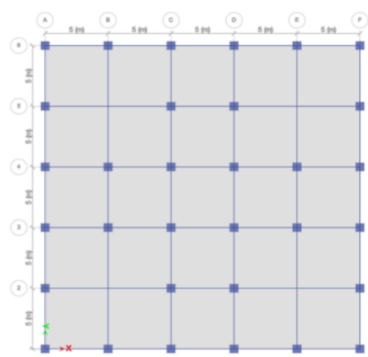

Fig. 4. Model 3

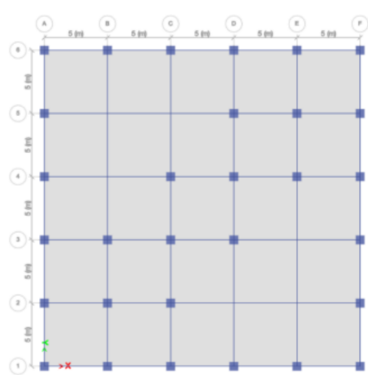

Fig. 5. Model 4

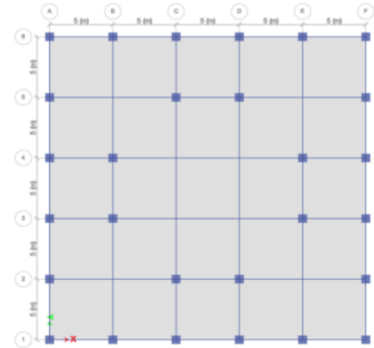

Fig. 6. Model 5

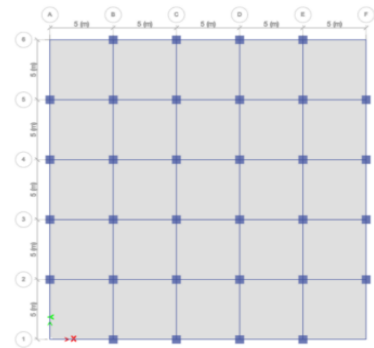

Fig. 7. Model 6

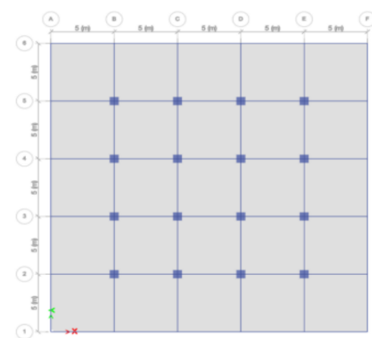

Fig. 8. Model 7

Table 5
Maximum storey drift

Storey Elevation (m)	**Model 1 (mm)**	**Model 2 (mm)**	**Model 3 (mm)**	Model 4 (mm)
0	0	0	0	0
3	0.00029	0.000289	0.000288	0.000287
6	0.000521	0.000533	0.00055	0.000565
9	0.000575	0.000574	0.000573	0.000573
12	0.000579	0.000578	0.000576	0.000574
15	0.000565	0.000563	0.000561	0.000559
18	0.000536	0.000534	0.000532	0.00053
21	0.000493	0.000492	0.00049	0.000488
24	0.000434	0.000433	0.000431	0.00043
27	0.000358	0.000357	0.000356	0.000354
30	0.000265	0.000264	0.000263	0.000262
33	0.000167	0.000167	0.000166	0.000165

The many features of the above-mentioned models' cases outcomes are to be determined. The following structural features, storey displacement, storey drift, transfer beam deflection, shear force and bending moment are used to generate the results. For the above scenarios that were examined for this project work, the following outcomes have been provided in a tabular Illustration.

Table 6
Maximum storey drift

Storey Elevation (m)	Model 5 (mm)	Model 6 (mm)	Model 7 (mm)
0	0	0	0
3	0.000286	0.000281	0.000226
6	0.000583	0.000535	0.000731
9	0.000572	0.000586	0.00073
12	0.000571	0.000592	0.000737
15	0.000556	0.000578	0.000725
18	0.000528	0.00055	0.000701
21	0.000485	0.000508	0.000665
24	0.000428	0.000451	0.000618
27	0.000352	0.000377	0.000557
30	0.000261	0.000286	0.000483
33	0.000164	0.000191	0.000408

Table 7
Storey displacement in X direction

Storey Elevation (m)	Model 1 (mm)	Model 2 (mm)	Model 3 (mm)	Model 4 (mm)
0	0	0	0	0
3	0.871	0.868	0.865	1.293
6	2.434	2.468	2.514	3.835
9	4.158	4.189	4.235	6.412
12	5.896	5.922	5.962	8.993
15	7.59	7.611	7.644	11.507
18	9.199	9.214	9.241	13.893
21	10.679	10.689	10.71	16.088
24	11.982	11.988	12.004	18.021
27	13.056	13.059	13.071	19.615
30	13.852	13.852	13.861	20.795
33	14.353	14.351	14.358	21.539

Table 8
Storey displacement in X direction

Storey Elevation (m)	Model 5 (mm)	Model 6 (mm)	Model 7 (mm)
0	0	0	0
3	0.859	0.842	1.017
6	2.608	2.447	4.305
9	4.323	4.205	7.588
12	6.037	5.982	10.906
15	7.705	7.715	14.168
18	9.288	9.365	17.322
21	10.744	10.89	20.316
24	12.027	12.243	23.097
27	13.085	13.373	25.603
30	13.868	14.232	27.778
33	14.361	14.806	29.613

Table 9
Storey displacement in Y direction

Storey Elevation (m)	Model 1 (mm)	Model 2 (mm)	Model 3 (mm)	Model 4 (mm)
0	0	0	0	0
3	0.871	0.868	0.865	1.293
6	2.434	2.468	2.514	3.835
9	4.158	4.189	4.235	6.412
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Table 10
Storey displacement in Y direction

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24	12.027	12.243	23.097
27	13.085	13.373	25.603
30	13.868	14.232	27.778
33	14.361	14.806	29.613

Table 11
Maximum deflections of transfer beam under floating columns

Model Case	Deflection Value (mm)
MODEL 1	0.655
MODEL 2	0.876
MODEL 3	0.848
MODEL 4	1.128
MODEL 5	1.081
MODEL 6	0.555
MODEL 7	1.605

Table 12
Maximum deflections of transfer beam under floating columns

Model Case	Shear Force (kN)
MODEL 1	84.492
MODEL 2	131.766
MODEL 3	122.344
MODEL 4	159.442
MODEL 5	186.142
MODEL 6	93.604
MODEL 7	247.830

Table 13
Maximum deflections of transfer beam under floating columns

Model Case	Bending Moment (kN-m)
MODEL 1	61.713
MODEL 2	191.002
MODEL 3	180.007
MODEL 4	240.728
MODEL 5	315.994
MODEL 6	150.125
MODEL 7	432.538

4. Results and Discussion

A. *Storey Drifts*

The greatest lateral displacement of one floor relative to another is known as storey drift. An inter-storey drift is another name for it. Criteria for earthquake hazard assessment of seismic loads on various structures, IS 1893 (Part-I): 2016, Cl.No.7.11.1.1 Pg. No. 26, is an Indian standard code book.

Storey Drift for the g+10 Storey building is calculated and represented in a tabular format and also graphically represented.

- From the graph, it seems that the storey drift is maximum for the structure with a floating column in the outer periphery of the building in the first-floor level storey.
- The maximum drift is found to be for storey-4 in the

model 7 out of all the model cases of the floating column structures.

- In any storey, the storey drift should not exceed 0.004 times the storey height. The storey's worst height is 3m. As a result, according to IS 1893 (Part-I): 2016, the drift limit is 0.004 X 3m = 12 mm.

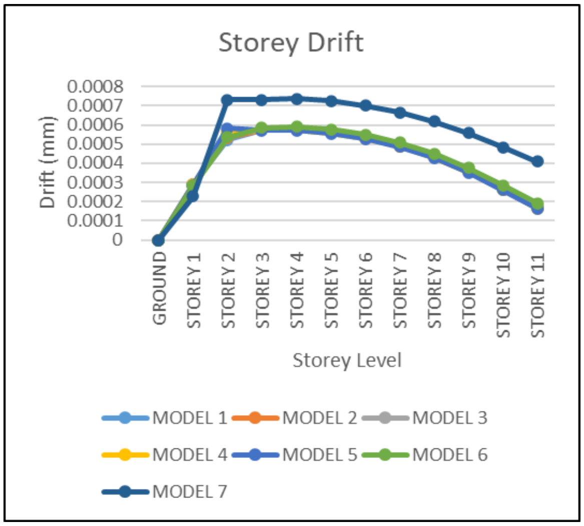

Fig. 9. Graphical representation of Maximum Storey Drift

B. *Storey Displacement*

The displacement of a single storey with respect to the foundation or ground level of the structure is referred to as storey displacement. As we travel up the structure, it makes sense to assume that the overall displacement values will increase. A graph of storey displacement in relation to building height so resembles the deflected form precisely. Horizontal displacement is important when buildings are exposed to lateral loads such as seismic and wind loads.

Storey displacement is tabulated and given a graphical representation for both X-Direction and Y-Direction.

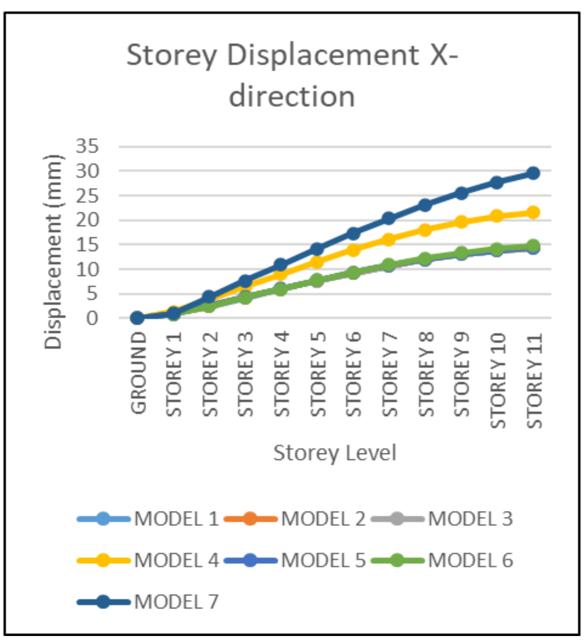

Fig. 10. Graphical representation of storey displacement in X direction

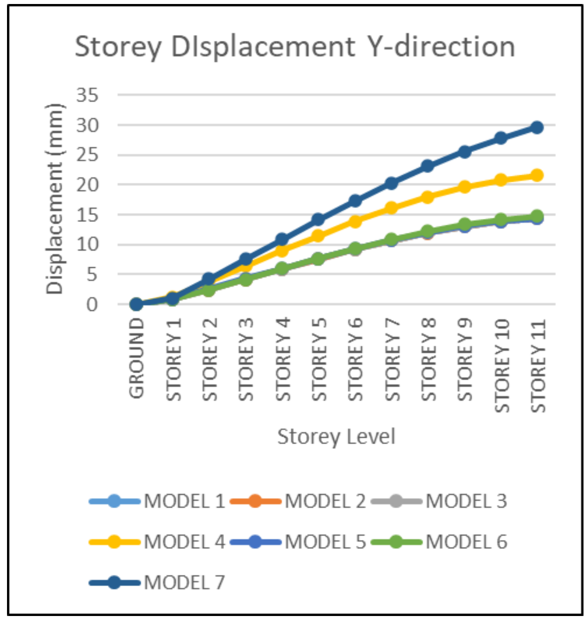

Fig. 11. Graphical representation of storey displacement in Y direction

- The behaviour of a graph is slightly similar for all the cases except in the cases of model 4 and model 7 as shown.
- From the above graph, we can also observe that maximum lateral displacements occur in case of structures with the model cases of removing 6 columns in the first-floor level storey and removing the columns along the outer periphery in the first-floor level storey.
- The maximum Storey displacements for the Structure with the floating column in model 7 is 29.613 mm along X-direction whereas in Y-direction is 29.613 mm which are the highest displacement values among all cases.
- The maximum allowable storey displacement shall be taken as the calculated value obtained of H/500. The value of H is 33m. Then the calculation shall be 33000/500= 66m. Therefore, the storey displacement shall not exceed 66m.

C. *Deflections*

The amount of displacement that a certain structural member may experience with the aid of a significant amount of load is known as deflection. It may also be known as the angle or the separation. The slope of the deflected form of the body under a load directly affects the distance that a member will deflect under that force. By integrating the function that is used to characterize the slope of the member under that load, it may be calculated.

A beam is a long segment of a body that can support a weight while defying bending. Beam deflection is the term for the movement of a beam when a force is applied to it in a certain direction. The beam has the ability to be bent or shifted from its initial position. The deflection is represented by this distance along each member point.

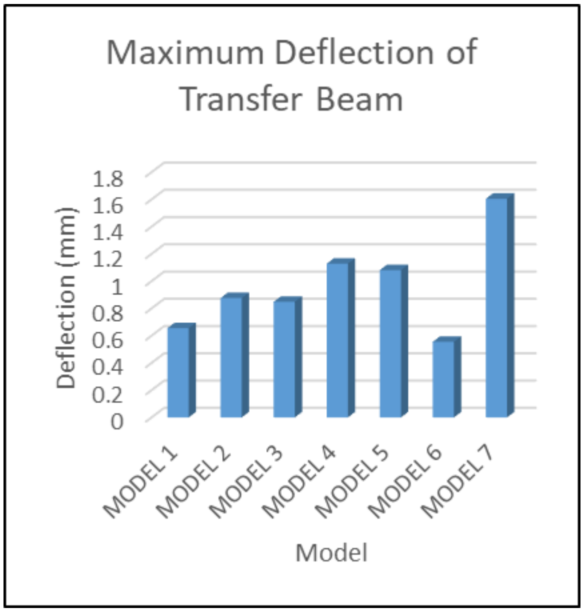

Fig. 12. Maximum deflections of transfer beam under floating columns

- The graph above indicates the deflection of the transfer beam below the floating column of the Structure for R.C. Building models possessing various positioning of floating columns.
- Model 7 of all the model cases shows highest value of deflection and Model 6 shows lowest value of deflection in the transfer beam below the floating column.
- The maximum deflection is limited to the beam's span length divided by 250. Here the beam span length is 5m. Then the calculation shall be 5000/250= 20mm. Therefore, the deflection value shall not exceed 20mm.

D. Shear Force and Bending Moment

The maximum values of shear force and bending moment have shown that the model 6 is nominally closer to the shear force and bending moment of a normal building which is model 1.

5. Conclusion

- To determine storey drift and displacement, the response spectrum approach is applied.
- Under Seismic Zone II, the behaviour of multi-storey buildings with floating columns is investigated.
- In all circumstances, displacement rises from lower to the higher storey.
- The structures with floating columns particularly located in model 4 and model 7 have higher displacement comparatively than a normal building.
- As the column discontinuity increases, the storey drift of the structure also increases. Compared to the previous models, Model 7 has higher values.
- The deflection values of transfer beams show that model 6 which is, removing columns at the corners in the first-floor level storey has a lower deflection value than the rest of the other building models.
- Shear force and Bending moment values of Model 6 are justifiably closer to that of a normal building.
- Model 6 which is, removing columns at the corners in the first-floor level storey can be designated as the optimum floating column building by observing its displacement and storey drift values along with having less deflection value of transfer beam among all the models.

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