SEISMIC PERFORMANCE AND STRUCTURAL STABILITY ANALYSIS OF FLOATING COLUMN BUILDING

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Abstract - *In the present modern construction the floating column is a distinguishing character in high rise buildings. This study is done to obtain the seismic response of a building and to analyse and construct the structure wherein there will be less harms to the structure and its segment under the excitation of earthquake. A G+9 storied building with architectural complexity such as external Floating Columns is analysed dynamically for earthquake zone V. In overall study of seismic analysis, worst case scenario is found out. Dynamic response spectrum analysis is done for multi storey frame with floating column to achieve the above aim. The different studies are carried out and the comparative studies is carried out in terms of displacement, storey drift, storey stiffness and base shear and suitable strengthening is provided. This building is designed and analysed with the help of ETABS Software.*

Key Words: **ETABS Software, Floating column, Response spectrum analysis.**

1. INTRODUCTION

Earthquakes disasters had always been one of the natural hazards under which buildings are mainly caused by damage or collapse. In this world Indian subcontinent has been experienced with some of the most severe earthquake. Hence it is important to consider the seismic examination for the planning of multi-storeyed structures. The objective of seismic analysis started as the structure should be able to endure minor shaking intensity without sustaining any damage. Multi storied buildings are the symbol of modern society. Due to lack of space, increasing population and also for aesthetic view and functional requirements, Construction of high rise building in urban cities are required to have column free space. For this purpose, the concept of floating column is coming in picture. These sections are profoundly disadvantageous in building underlying seismically active regions. The code of earthquake engineering has been planned with the point that individuals get sufficient opportunity to escape from the structure, the structure is less harmed and the building comes in faster use. Code of practice for earthquake engineering has been planned with the point that human lives are ensured, harm is restricted and administration structures stay operational.

1.1 Floating Columns

Floating column is nothing but a vertical member or element that rests on a beam, but doesn't transfer load directly to the foundation. Generally, the columns transfer the loads coming from the slabs and beams to the foundation. The floating column acts as a point load on the beam and this beam transfers the load to the column below it. Floating columns arises in use to bid extra open space for assembly hall of parking purpose. The floating column building doesn't create any issue under vertical loading condition however it rises helplessness in lateral loading condition, because of vertical irregularity. During the earthquake the lateral forces established in higher storey have to be transmitted by the proposed cantilever beams due to this the overturning forces are established over the column of the ground floor. The column may start off on the first or second or any other intermediate floor while resting on a beam. Usually column rest on the foundation to transfer the load from slabs and beams. But the floating column rests on the beam.

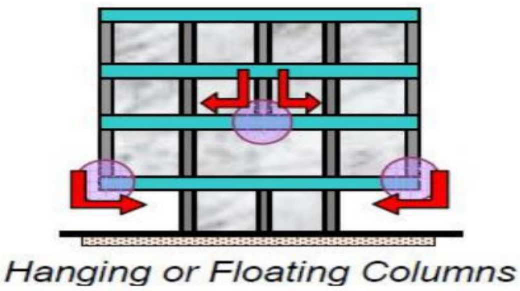

Fig -1: Floating column

1.2 Response Spectrum Method

The response spectrum analysis is a linear dynamic analysis method that measures every natural mode of vibration to the maximum seismic response of an elastic structure. The response spectrum is a graph of the maximum amplitude (velocity shift or acceleration) versus time for many linear oscillators with a single degree of freedom to generate the components of the earth's motion. This graph can be used to select the response of any free oscillator by natural frequency. Such use is in the evaluation of the building's peak to an earthquake. Response spectra are one of seismic engineering for analysing the performance of structures during earthquakes. The natural frequency of the structure and the building's peak response can be determined by reading the value from the fundamental response spectrum of the frequency. In seismic area, most building standards use this value to calculate the force that the structure must design.

2. STRENGTHENING TECHNIQUES OF RC BUILDING

Presence of floating columns in RC structures presents abrupt discontinuities in the horizontal strength and firmness along its stature. The seismic presentation of this sort of insufficient designs can be improved either by reinforcing the ground story sections (local modification) or by diminishing the seismic interest through the supplemental energy scattering components (global modification). A few neighbourhood adjustment strategies like steel jacketing, concrete jacketing, steel confining, FRP jacketing and supporting components have been utilized for inactive energy scattering in the worldwide (structure-level) alteration procedures. For present investigation, the structure with coasting sections is given sidelong bracings to lessen the parallel deformity.

3. BRACING

The bracing systems are used to resist horizontal forces like seismic action, wind load and to transmit to the foundation. The bracing members are arranged in many forms, which carry solely tension, or alternatively tension and compression. Such systems reduce bending moment and shear force in the columns. By the provision of braces in a structure, it becomes more stable as the result of transferring of loads sideways and it helps in reducing the sway of structure.

3.1 Concentric Braces

The braces provided in a structure can be called as concentric if the centre lines of bracing members are intersected with that of beams and columns as shown in figure 2.

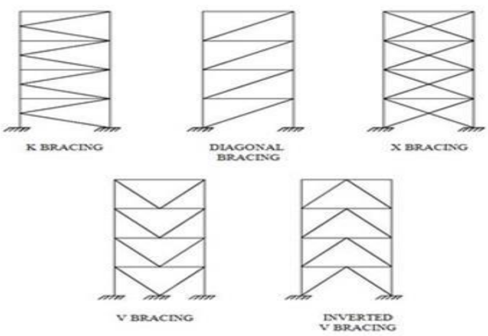

Fig -2: Concentric braces

4. ETABS

ETABS is sophisticated engineering software developed for a special application program designed specifically for the building system. ETABS can work with the most comprehensive and complex building models, including a wide range of nonlinear behaviours. In this day and age, the most important weapon for the designers is no other than ETABS. Using ETABS, the structures can be analysed in various analytical methods, which are response spectrum method, a time history analysis, an equivalent static method, and a pushover analysis.

5. MODELLING

In this project, building selected is G+9 multi-storeyed building in the zone V region. The building is divided into 15 cases depending on the position of removal of columns. The results that are obtained in all the cases are compared with the normal building. Seismic data of building and building parameters are shown in table 1 and table 2

Table -1: Seismic data of building

Parameters	Specifications
Seismic zone	IV & V
Importance factor (I)	1.0
Zone factor (Z)	0.24 & 0.36
Response reduction factor ®	5 (SMRF)
Damping ratio	5%
Soil Type	Medium (II)

Table -2: Building parameters

Parameters	Specifications
Number of storey	G+9
Height of Building	31.5m
Floor Height	3.15m
Density of concrete	25 KN/m3
Thickness of Slab	150mm
Beam Size	300×300mm
Column Size	450×450mm
Wall thickness	240mm
Floating Column	300×300mm
Live Load	3kN/m^2
Floor Finish	1kN/m^2
Support Condition	Fixed
Material properties	M30 grade of concrete and fe 415 grade of steel

6.1 Types of Models for Analysis

- Model 1: G+9 building without floating column i.e. normal building
- Model 2: G+9 building with floating column is provided at 4 outer corners of the building in the ground storey
- Model 3: G+9 building with floating column is provided at 4 outer corners of the building in the fourth storey
- Model 4: G+9 building with floating column is provided at 4 outer corners of the building in the seventh storey
- Model 5: G+9 building with floating column is provided at 4 inner corners of the outer side of the shorter span in the ground storey
- Model 6: G+9 building with floating column is provided at 4 inner corners of the outer side of the shorter span in the fourth storey
- Model 7: G+9 building with floating column is provided at 4 inner corners of the outer side of the shorter span in the seventh storey
- Model 8: G+9 building with floating column is provided at 4 inner corners of the outer side of the longer span in the ground storey
- Model 9: G+9 building with floating column is provided at 4 inner corners of the outer side of the longer span in the fourth storey
- Model 10: G+9 building with floating column is provided at 4 inner corners of the outer side of the longer span in the seventh storey
- Model 11: G+9 building with floating column is provided at 4 inner corners of the building in the ground storey
- Model 12: G+9 building with floating column is provided at 4 inner corners of the building in the fourth storey
- Model 13: G+9 building with floating column is provided at 4 inner corners of the building in the seventh storey
- Model 14: G+9 building with floating column is provided at centre and inner corners of the building in the fourth storey
- Model 15: G+9 building with floating column is provided at centre and inner corners of the building in the eighth storey

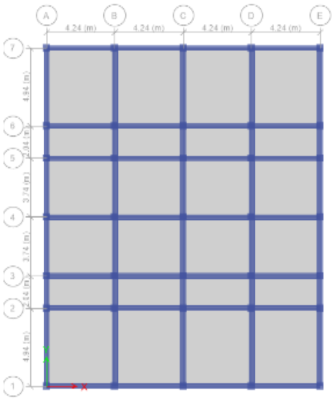

Fig -3: Model 1

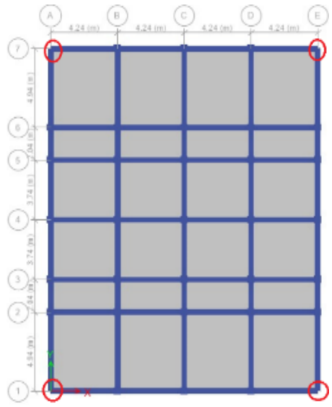

Fig -4: Model 2, 3 & 4

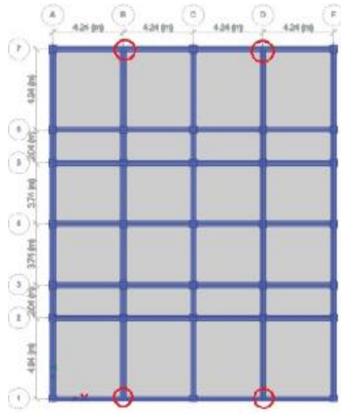

Fig -5: Model 5, 6 & 7

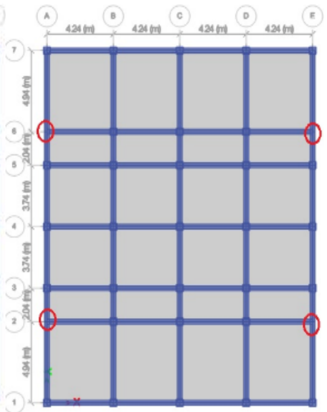

Fig -6: Model 8, 9 & 10

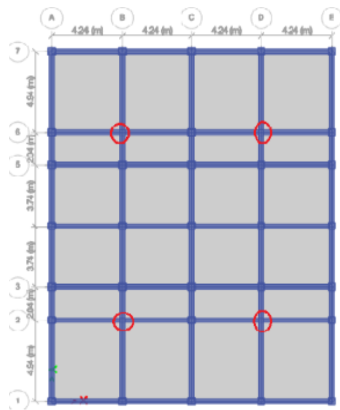

Fig -7: Model 11, 12 &13

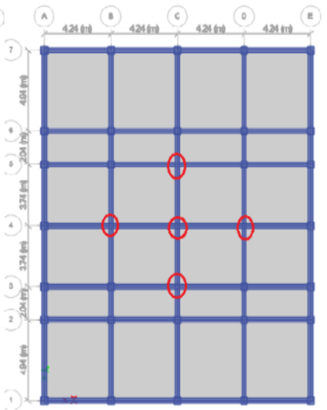

Fig -8: Model 14 &15

6. ANALYSIS AND RESULTS

The dynamic analysis of 15 models using ETABS software is completed and response spectrum method is used to determine the storey drift, storey displacement, storey stiffness and storey shear.

6.1 Storey Drift

The results variation of storey drift due to different location of floating column floor wise are tabulated in table 3, 4 and 5 The storey drift increases 5-

10% for floating column building as compared to building without floating column.

Table -3: Comparison of storey drift

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
0	0	0	0	0	0
1	0.00006	0.00006	0.00005	0.00005	0.00006
2	0.00010	0.00010	0.00009	0.00010	0.00010
3	0.00009	0.00011	0.00009	0.00010	0.00010
4	0.00009	0.00010	0.00009	0.00010	0.00010
5	0.00008	0.00009	0.00009	0.00009	0.00009
6	0.00007	0.00009	0.00008	0.00008	0.00008
7	0.00008	0.00008	0.00007	0.00008	0.00007
8	0.00005	0.00006	0.00006	0.00006	0.00006
9	0.00004	0.00005	0.00004	0.00005	0.00004
10	0.00003	0.00003	0.00003	0.00003	0.00003

Table -4: Comparison of storey drift

Storey	Model 6	Model 7	Model 8	Model 9	Model 10
0	0	0	0	0	0
1	0.00005	0.00005	0.00006	0.00005	0.00005
2	0.00010	0.00010	0.00010	0.00010	0.00010
3	0.00010	0.00010	0.00011	0.00010	0.00010
4	0.00011	0.00010	0.00010	0.00010	0.00010
5	0.00009	0.00009	0.00009	0.00009	0.00009
6	0.00008	0.00008	0.00008	0.00008	0.00008
7	0.00007	0.00008	0.00007	0.00007	0.00007
8	0.00006	0.00006	0.00006	0.00006	0.00006
9	0.00004	0.00004	0.00005	0.00005	0.00004
10	0.00003	0.00003	0.00003	0.00003	0.00003

Table -5: Comparison of storey drift

Storey	Model 11	Model 12	Model 13	Model 14	Model 15
0	0	0	0	0	0
1	0.00006	0.00005	0.00005	0.00005	0.00005
2	0.00010	0.00010	0.00010	0.00010	0.00010
3	0.00010	0.00010	0.00010	0.00010	0.00010
4	0.00010	0.00011	0.00010	0.00010	0.00010
5	0.00009	0.00009	0.00009	0.00010	0.00009
6	0.00008	0.00008	0.00008	0.00008	0.00008
7	0.00007	0.00007	0.00008	0.00007	0.00007
8	0.00006	0.00006	0.00006	0.00006	0.00006
9	0.00004	0.00004	0.00004	0.00004	0.00005
10	0.00003	0.00003	0.00003	0.00003	0.00003

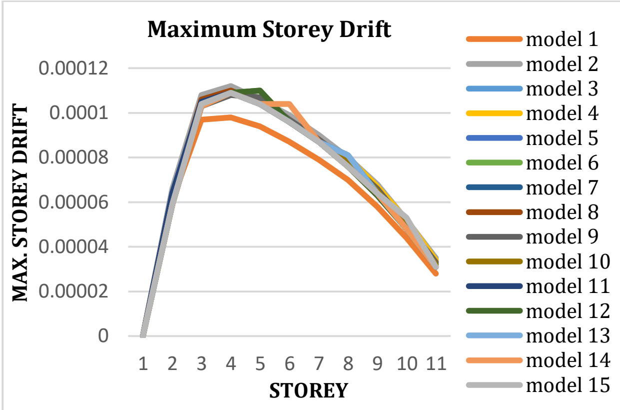

Fig -9: Comparison of storey drift

6.2 Storey Displacement

The results variation of storey displacement due to different location of floating column floor wise are tabulated in table 6, 7 and 8. The storey displacement increases 5-10% for floating column building as compared to building without floating column.

Table -6: Comparison of storey displacement

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
0	0	0	0	0	0
1	0.197	0.209	0.185	0.187	0.203
2	0.516	0.546	0.507	0.512	0.533
3	0.842	0.895	0.844	0.853	0.875
4	1.146	1.224	1.174	1.173	1.197
5	1.422	1.523	1.47	1.463	1.488
6	1.664	1.787	1.735	1.719	1.743
7	1.869	2.014	1.963	1.944	1.959
8	2.035	2.2	2.149	2.123	2.132
9	2.155	2.34	2.289	2.258	2.258
10	2.229	2.435	2.383	2.346	2.336

Table -7: Comparison of storey displacement

Storey	Model 6	Model 7	Model 8	Model 9	Model 10
0	0	0	0	0	0
1	0.187	0.187	0.2	0.186	0.187
2	0.512	0.513	0.533	0.51	0.513
3	0.854	0.855	0.879	0.85	0.855
4	1.193	1.176	1.204	1.181	1.176
5	1.482	1.467	1.498	1.474	1.467
6	1.737	1.722	1.758	1.733	1.722
7	1.953	1.951	1.979	1.955	1.946
8	2.126	2.123	2.157	2.133	2.121
9	2.251	2.249	2.289	2.265	2.25
10	2.329	2.328	2.374	2.35	2.331

Table -8: Comparison of storey displacement

Storey	Model 11	Model 12	Model 13	Model 14	Model 15
0	0	0	0	0	0
1	0.204	0.186	0.187	0.186	0.187
2	0.534	0.512	0.513	0.511	0.514
3	0.876	0.854	0.854	0.851	0.856
4	1.198	1.195	1.175	1.174	1.179
5	1.488	1.486	1.466	1.487	1.47
6	1.744	1.74	1.722	1.742	1.725
7	1.96	1.956	1.952	1.957	1.942
8	2.133	2.128	2.125	2.13	2.117
9	2.258	2.254	2.251	2.255	2.253
10	2.337	2.332	2.33	2.333	2.332

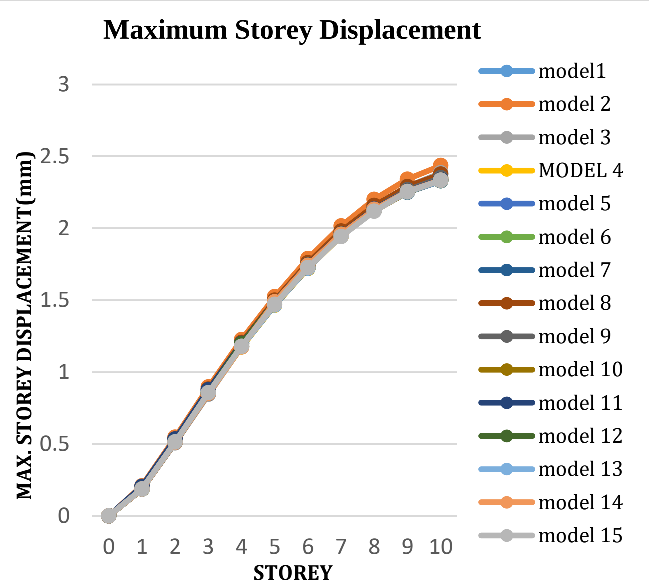

Fig -10: Comparison of storey displacement

6.3 Storey Shear

The variation in base shear due to different location of floating column floor wise are tabulated in table 9, 10 and 11. It is observed that due to the introduction of floating columns in the building the value of base shear decreases due to increase of natural period of vibration of structure. The base shear is decreases by 5-10% for floating column building as compared to without floating column building.

Table -9: Comparison of storey shear

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
0	0	0	0	0	0
1	92.81	76.06	76.46	77.13	76.15
2	89.91	73.55	74.07	74.76	73.69
3	84.69	69.1	69.67	70.38	69.27
4	78.33	63.79	64.42	65.03	63.95
5	71.51	58.26	58.878	59.35	58.41
6	64.31	52.593	53.11	53.45	52.71
7	56.27	46.312	46.75	47.04	46.41
8	46.59	38.63	38.99	39.21	38.7
9	34.33	28.66	28.94	29.07	28.71
10	18.62	15.54	15.78	15.84	15.63

Table -10: Comparison of storey shear

Storey	Model 6	Model 7	Model 8	Model 9	Model 10
0	0	0	0	0	0
1	76.49	77.07	76.21	76.59	77.24
2	74.1	74.69	73.73	74.21	74.87
3	69.71	70.31	69.32	69.85	70.51
4	64.47	64.95	64.01	64.65	65.17
5	58.91	59.28	58.46	59.07	59.48
6	53.14	53.41	52.72	53.23	53.55
7	46.75	47.05	46.36	46.76	47.11
8	38.98	39.2	38.6	38.95	39.2
9	28.93	29.05	28.6	28.87	29.01
10	15.77	15.82	15.55	15.72	15.79

Table -11: Comparison of storey shear

Storey	Model 11	Model 12	Model 13	Model 14	Model 15
0	0	0	0	0	0
1	76.39	76.58	77.2	76.78	77.28
2	73.91	74.2	74.83	74.4	74.92
3	69.49	69.85	70.46	70.02	70.56
4	64.18	64.68	65.12	64.71	65.21
5	58.61	59.08	59.44	59.26	59.5
6	52.84	53.21	53.53	53.39	53.52
7	46.44	46.73	47.12	46.87	46.88
8	38.65	38.9	39.19	38.98	38.93
9	28.62	28.84	28.99	28.85	29.08
10	15.55	15.7	15.77	15.68	15.86

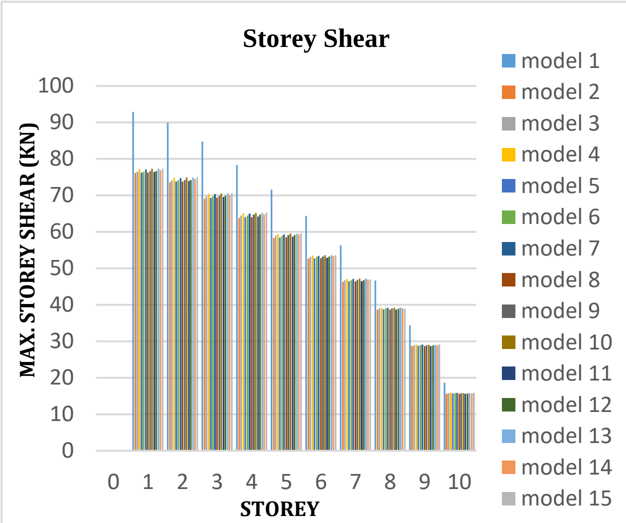

Fig -11: Comparison of storey shear

6.4 Storey Stiffness

It is observed that due to the introduction of floating columns in the building the value of base stiffness decreases due to increase of natural period of vibration of structure. The base stiffness is decreases by 5-10% for floating column building as compared to without floating column building.

Table -12: Comparison of storey stiffness

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
0	0	0	0	0	0
1	485297	389631	433469	433485	403401
2	296204	238941	247870	248252	239927
3	273065	217094	224264	224128	217752
4	265664	209317	208695	216284	209875
5	261538	204722	207457	211935	205346
6	258643	201486	202438	209354	202188
7	256271	198765	199506	200140	199557
8	253282	195083	195664	200575	196016
9	245750	186032	186612	189819	187166
10	209487	149403	150259	154027	151012

Table -13: Comparison of storey stiffness

Storey	Model 6	Model 7	Model 8	Model 9	Model 10
0	0	0	0	0	0
1	433461	433729	392956	434357	433580
2	248092	248225	237998	249156	248380
3	224255	224153	216472	224872	224384
4	207928	216251	209556	203450	216727
5	207693	211848	205976	208387	212721
6	203045	207664	203679	205072	209844
7	200152	198634	201827	202855	197148
8	196444	200539	199088	199973	203984
9	187577	190982	191269	192208	195806
10	151567	155306	156492	157696	161769

Table -14: Comparison of storey stiffness

Storey	Model 11	Model 12	Model 13	Model 14	Model 15
0	0	0	0	0	0
1	391624	434272	433572	433586	433620
2	238816	249051	248365	248303	248193
3	217611	224093	224349	224021	224180
4	210738	201591	216649	215574	216409
5	207230	208564	212621	194727	212306
6	204977	206126	209225	209043	209505
7	203171	204009	195433	207158	207159
8	200532	201309	203974	204744	203017
9	192935	193819	196888	197700	180466
10	158509	159698	163062	164076	167080

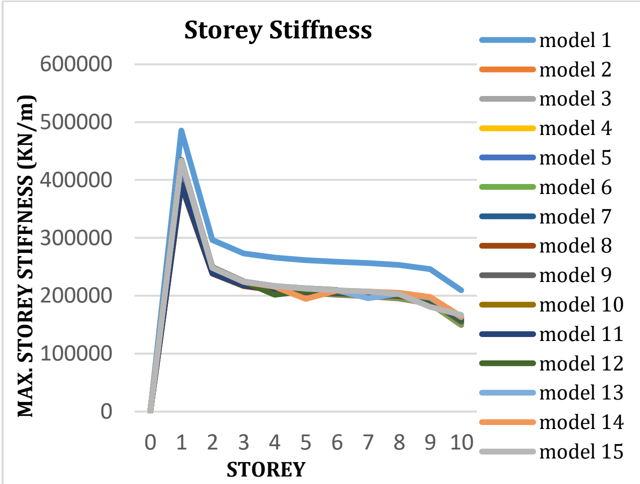

Fig -12: Comparison of storey stiffness

7. STRENGTHENING OF FLOATING COLUMN BUILDING

Various strengthening techniques adopted in floating column building in order to minimise the drift value to prevent the structural collapse.

7.1 Increasing depth of beam

The concept of floating column mainly comprises of disrupting flow of transfer of earthquake force. Floating columns are to be designed as a normal compression member. But while designing transfer beam, it is designed as beam carrying all that load of column as a single point load. But it is to be kept in mind that earthquake force developed must be brought down along the shortest path that is load is distributed among two intermediate columns supporting that beam. Floating column is supported by high shear capacity beams/ deep beams.

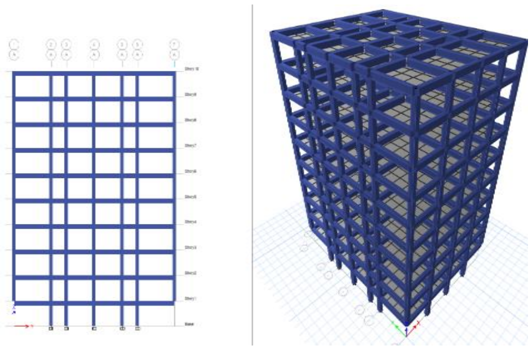

Fig -13: Extruded 3D view model of floating column building with increased beam depth

Here the displacement value increases with the storey height and is less than that of the displacement obtained where response spectrum analysis is done for floating column provided at the ground floor of the building. Also, the drift value is less than that of the drift obtained for bare frame structure and within the permissible limit.

7.2 X-Bracing at base

X-bracing is a structural engineering practice where the lateral load on a building is reduced by transferring the load into the exterior columns. In construction, cross bracing is a system utilized to reinforce building structures in which diagonal supports intersect. Cross bracing can increase a building's capability to withstand seismic activity.

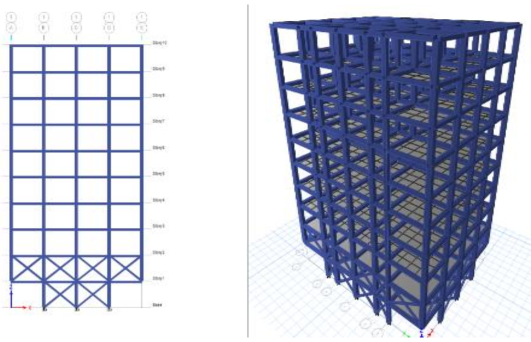

Fig -14: Extruded 3D view model of floating column building provided with bracing at the base

Here the displacement value increases with the storey height but it is greater than that of the displacement obtained in the above case. Also, the drift value is greater than that of the drift obtained for floating column structure where depth of beam is increased but it is within the permissible limit.

7.3 X-Bracing at corner

Here the displacement value increases with the storey height but it is greater than that of the displacement obtained where beam depth is increased is for floating column building and is less than that of the displacement obtained in the above case and response spectrum analysis. Also, the drift value is greater than that of the drift obtained for floating column structure where depth of beam is increased but it is within the permissible limit and is less than that of the drift obtained in the above case and response spectrum analysis.

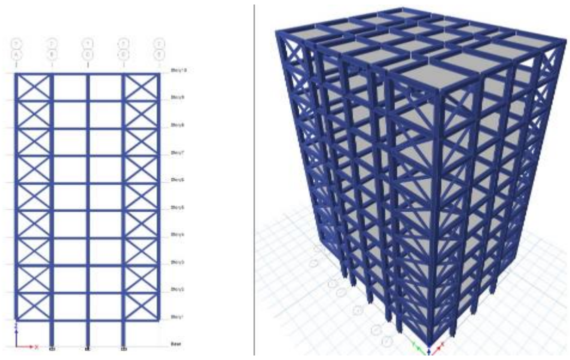

Fig -15: Extruded 3D view model of floating column building provided with x bracing at the corner

7.4 V-Bracing at corner

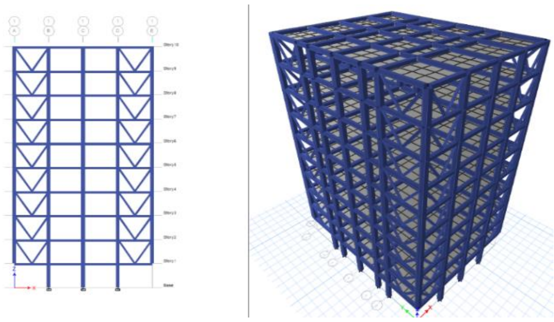

Fig -16: Extruded 3D view model of floating column building provided with v bracing at the corner

Here the displacement value increases with the storey height but it is greater than that of the displacement obtained where beam depth is increased and is less than that of the displacement obtained in the above 2 cases. Also, the drift value is greater than that of the drift obtained for floating column structure where depth of beam is increased but it is within the permissible limit and is less than that of the drift obtained in the above case

7.5 Comparison of Results

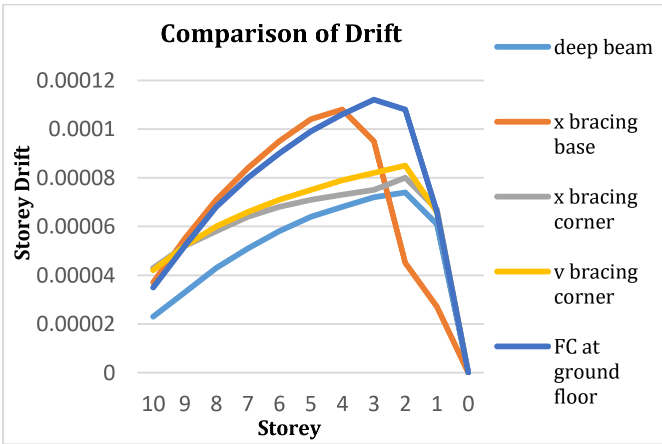

Fig -17: Comparison of drift

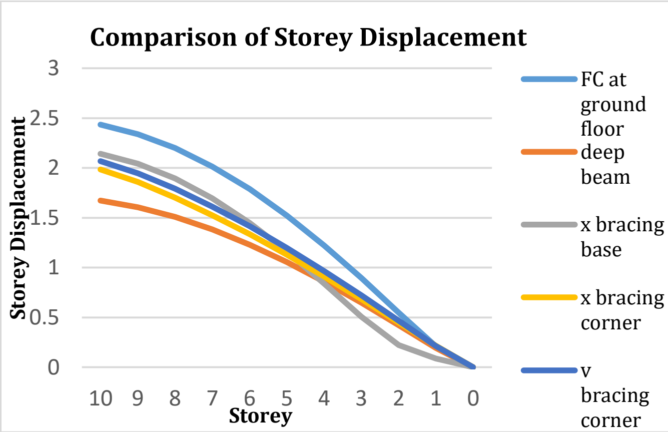

Fig -18: Comparison of displacement

Table -15: Comparison of displacement and drift

Model	Max. displacement (mm)	Max. drift
FC at ground floor - bare	2.435	0.000112
FC at ground floor - deep beam	1.672	0.000074
FC at ground floor – x bracing base	2.142	0.000108
FC at ground floor – x bracing corner	1.986	0.000080
FC at ground floor – v bracing corner	2.069	0.000085

The lateral displacement and drift is less than that of all the above obtained cases and it is within the permissible limit i.e., 0.004 times the height of each storey (3.15m). Here deep beam structure has minimum displacement and drift value compared to other cases. But it is not economical due to the heavy structure. Hence X-bracing provided in corner has lesser displacement and drift values than other cases and it is more suitable.

8. CONCLUSIONS

In this study, the behaviour of floating column building has been analysed by linear dynamic response spectrum analysis. From the study, it is concluded that:

- Maximum story displacement and story drift is more in floating column building compared to normal building.
- The value of displacement is greater for floating column provided at outer corners of ground storey (Model 2) and displacement increases from lower storey to higher storey for all cases
- Storey drift also increase in structure as column discontinuity increase and it is maximum in lower stories for all cases. Model 2 having higher values compared to other models
- As per analysis, the storey shear force was found to be maximum for the top storey and it decreased to a minimum in the first storey in all cases and it is minimum in floating column provided at outer corner of ground storey (model 2)
- Storey stiffness of a particular storey decreases due to the existence of floating column in the structure and it is maximum in lower stories for all cases. Model 2 having lower values compared to other models.
- From these results it can be concluded that Model 2 is more critical compared to all other models and compared to other floating column buildings
- The location of floating column is made significant impact on building, by analytically it cannot be said that which location is most appropriate for all types of building. Every time we need to be carried out careful analysis.
- The introduction of bracings provided at the corner on the floating column building and at the base as a strengthening
- It is suggested to avoid providing of floating columns in buildings without providing the bracings, shear wall or any other lateral load resisting elements

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