ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.7

Study of Seismic Behavior of Building with Different Positions and Types of Floating Column

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Abstract:
The columns which are supported on a beam instead of rigid foundation are called as floating columns. In many cases floating column adopted to fulfill room sizes criteria of architects. Many buildings in India are constructed with floating column. The lateral forces such as earthquake and wind forces are majorly effect on this kind of structure. Structure with floating column must be sound enough to resist such lateral forces. Structure shall sustain earthquake and wind load and shall pass in all load combination of IS456 and IS 1893-2002. There are numerous observations of damages caused by irregularity in buildings, such as vertical irregularity, is predominant to structure while earthquake excitation, the earthquake forces developed at different floor levels in building need to be brought down along the height to the ground by the shortest path, any deviation or discontinuity such as floating columns results in poor performance of building. The aim of thesis work is to compare the response of RC frame buildings with different types of floating columns under earthquake loading. The effect of earthquake forces on various building models for various parameters is proposed to be carried out with the help of RSA (Response Spectrum Analysis). This work includes analysis of structure by using ETABS software (Extended Three Dimensional Analysis of Building Systems).

Keywords: Floating column, Earthquake loading, R.C. frame, Response spectrum analysis, ETABS etc.

1. INTRODUCTION

The Columns Float or move in above stories such that to provide more open space is known as Floating columns. Floating columns are implemented, specially above the base floor, so that added open space is accessible for assembly hall or parking purpose. Floating columns are usually adopted above the ground story level. So that maximum space is made available in the ground floor which is essentially required in apartments, mall or other commercial buildings where parking is a major problem. The floating column act as a point load on the beam and this beam transfers the load to the columns below it. But such column cannot be implemented easily to construct practically since the true columns below the termination level are not constructed with care and hence finally cause to failure. The floating column is used for the purpose of architectural view and site situations and max possible area on a plot within the permissible bylaws. Since balconies are not counted in floor space index (FSI), buildings have balconies overhanging in the upper stories beyond the column foot print areas at the ground story, overhangs up to 1.2 m to 2.0 m in plan are usually provided on each side of the building. In such cases, floating columns are provided along the overhanging perimeter of the building. Most of the time, architect demands for the aesthetic view of the building, in such cases also many of the columns are terminated at certain floors and floating columns are introduced. But Provision of floating columns resting at the tip of overhanging beams increases the vulnerability of the lateral load resisting system due to vertical discontinuity. This type of construction does not create any problem under vertical loading conditions. But during an earthquake a clear load path is not available for transferring the lateral forces to the foundation. Lateral forces accumulated at the upper floor during the earthquake have to be transmitted by the projected cantilever beams. Overturning forces thus developed overwhelm the columns of the ground floor. Under this situation the columns begin to deform and buckle, resulting in total collapse. This is because of primary deficiency in the strength of ground floor columns, projecting cantilever beams and ductile detailing of beam column joint. In case of floating column, shear is induced to overturning forces to another resting element of the low level. This imposition of overturning forces overwhelms the columns of lower level through connecting elements. Therefore the most critical region of damage is the connecting element (link between discontinuous columns to lower level column) and lower level columns. Therefore, the primary concern in load path irregularity is the strength of lower level columns and strength of the connecting beams that support the load of discontinuous frame. Floating column provided in a structural system is highly undesirable especially in higher zones like III, IV & V.

2. LITERATURE REVIEW

The various literatures have been referred from journals, preceding, books etc to understand present status of project undertaken. From this literature data is summarized for work. These are explained below. Pardhi A., Shah P., [1] (2016), studied on Seismic Analysis of RCC building with & without floating columns. They study the response of floating column to the seismic forces and also study the weak critical members of the structure having floating column. T. Chandra Shekhar, Prasad J., [2] (2016), Compared Seismic analysis of a floating column building and a normal building using ETABS-2013. In this a residential building with 6 Storeys and 12 Storey are analyzed with columns, Beams and Slabs. The buildings are analyzed and designed with and without edge columns at base storey. The buildings are analyzed in two Earthquake zones with medium soil. Mahesha M, Lakshmi K.,[3] (2015), studied the significance of expressly perceiving the vicinity of the floating columns and significance of explicitly recognizing the presence of with and without floating column in the investigation of building furthermore alongside floating column with a few complexities were considered for G+16 storey building at different alternative location. Sabari S, [4] (2015) proposed to reduce the irregularities introduced by the floating column. They create the 2D multistorey frame with and without floating column to study the responses of structure under different earthquake excitation having different frequency content keeping the PGA and time duration factor constant. Badgire U. S, Shaikh A. N.[5], (2015) have analyzed RCC frame (G+10) with floating columns in different locations and investigate the base shear & Drift between floating columns located in outer periphery (4 sides & 2 Sides). It is concluded that probability of failure of floating column is more in case of floating columns located at periphery on longer side than the floating column at periphery on shorter side.

3. PROBLEM FORMULATION AND METHODOLOGY

3.1 Research gap

It is observed from the literature survey, that various studies have been done on floating columns, but in most studies the researchers have considered the comparative study of building with & without floating column. However very little literature was available on provision of floating column with strut support and on comparison on Single floating column or double floating columns in X and Y directions. Also there is very few literature available on effect of distance of floating column from original column, on building.

3.2 Problem Formulation

Several analysis methods, both elastic and inelastic, are available to predict the seismic behavior of the structures. A Response Spectrum Analysis (RSA) as per IS 1893:2002, will be carried out using ETABS software. ETABS is a fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface. ETABS is a standalone finite element based structural program for the analysis and design. It offers powerful user interface with many tools to aid in quick and accurate construction of the models, along with sophisticated technique needed to do more complex projects. Total twelve number of problems will be taken to comparative study of seismic analysis for buildings with different positions of floating column & building without floating column. The output results will be expressed in terms of roof displacements, storey drift, base shear, deflection of cantilever beam, lateral & axial forces acting on column.

3.3 Problem statement

With help of literature review mentioned above, the problem statement for present work is stated as "**Study of seismic behavior of building with different positions and types of floating column**".

3.4 Objectives of work

The aim of this work is to compare the responses of RC frame buildings with different types and possible locations of floating columns & also without floating column under earthquake loading. The major objectives of the work are as follows.

1. The primary aim of this work is the comparative study of different types of floating columns and non-floating columns with seismic behavior.
2. To compare the effect of floating column in RC building with reference to support of strut & without strut.
3. To study flow of forces and increase or decrease in the column forces in building by varying locations and length of cantilever.
4. Determination of seismic response of all the models by using response spectrum analysis in ETABS software.

3.5 Modelling of building

The (G+12) with a floating column building, with SMRF specially moment resisting frames in two orthogonal directions is selected for the study. The building is considered to be located in Zone III as per IS 1893:2002. The building is modelled using the software ETABS. The plan of building is shown in figure 1.

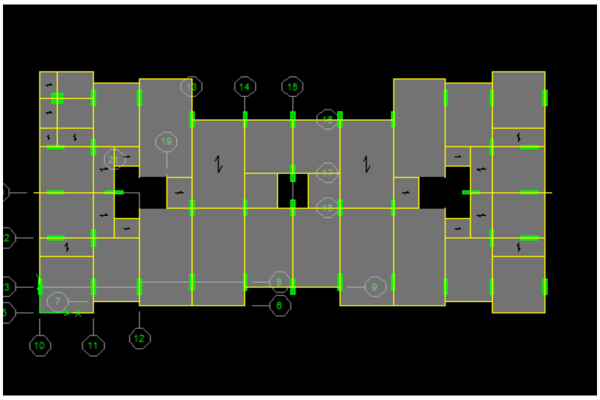

Figure.1. Plan of Building

In present work following cases are considered

Type A) Structure without floating column – Fig 2
Type B) Structure With one side floating Column – Fig 3
Type C) Structure with both side floating column – Fig 4
Type D) Structure with one side floating column with strut support. – Fig 5

Each type of structure considers for analysis for 3 more cases on the basis of distance of cantilever i.e. floating column from original column. Cases are as following.

a) Distance considered is equal to 1.2 m
b) Distance considered is equal to 1.5 m
c) Distance considered is equal to 2.0 m

Results from this analysis will give idea about behavior of structure in seismic and wind force.

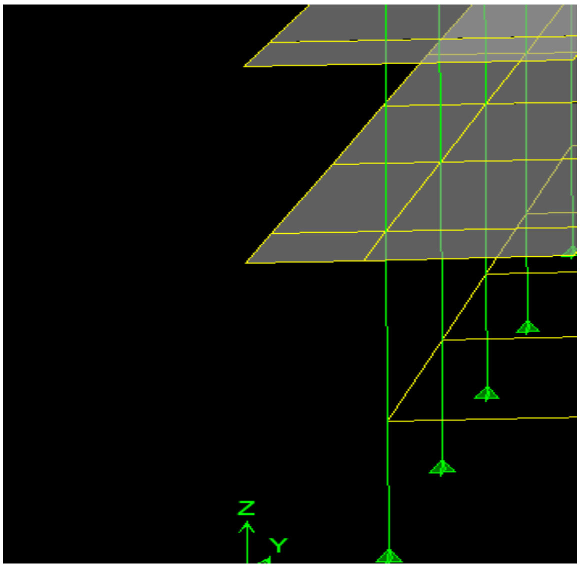

Figure.2. Type A Structure without floating column

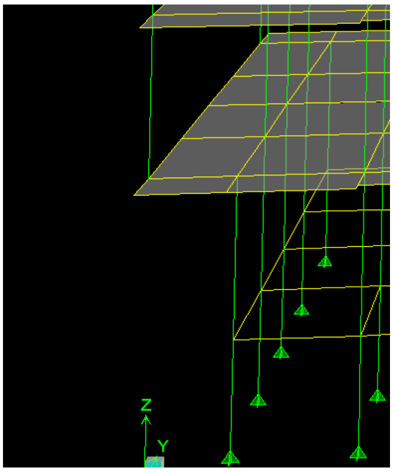

Figure. 3. Type B Structure with one side floating column

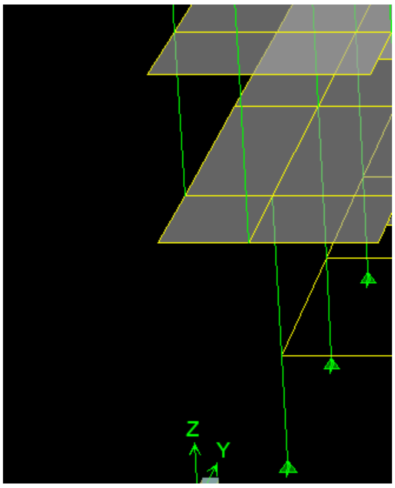

Figure.4. Type C Structure with both sides floating column

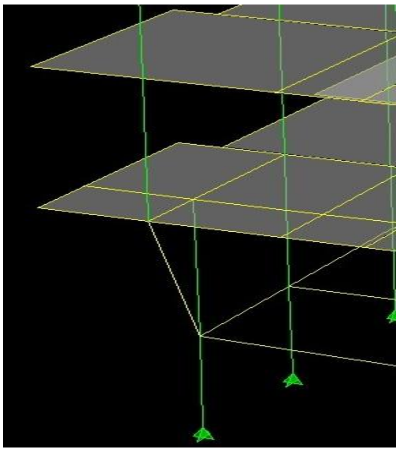

Figure.5. Type D floating column at one side with strut support

3.6 Design basic data

Location of building: Nashik
Zone: III (IS 1893 (part1):2002)
Type of soil: Medium Soil
Wind speed: 39 m/sec
Concrete grade: M25
Steel grade: Fe 500
No of floors: 12
Floor height 3.0 m.
Size of beam: 230 x 600
Size of column: 230 x 1000
Wall height = (3.000 m – 0.600 m) = 2.400 m
Wall load for 150 thick = 2.4 x 20 x 0.15 = 7.2 kN /m
Wall load for 100 thick = 2.4 x 20 x 0.10 = 4.8 kN/m
Parapet wall load = 1.5 x 20 x 0.15 = 4.5 kN/m
Response reduction factor: 5
Importance factor: 1.
Damping: 5%.
Time period: (calculated as per IS 1893:2002).
Slab load:

- Live load : 2 kN/m2
- Floor finish load : 1.5 kN/m2
- Sunk load : 20 x 0.3 = 6 kN/m2
- Bricks bat : 0.3 kN/m2
- Stair steps : 2.25 kN/m2
- Stair live load : 3 kN/m2

4. RESULTS AND DISCUSSIONS

Analysis is carried out of G+12 building by considering all earthquake and wind load combination and is checked for same load combination for all categories of structure and the following results are summarized.

4.1 Displacement

Table.1. Displacement of structure

	UX(mm)	UY(mm)	UZ(mm)
A1.2	56.1255	52.8463	18.3482
A1.5	56.7195	53.5234	18.3864
A2.0	57.9753	54.6133	30.2265
B1.2	56.3393	52.7831	18.307
B1.5	56.7935	53.3053	18.329
B2.0	57.5415	54.0695	21.8629
C1.2	55.2472	52.648	18.2587
C1.5	56.5035	52.9867	18.2587
C2.0	57.9083	54.2132	20.6209
D1.2	27.474	19.8787	15.1419
D1.5	56.6381	52.7669	18.3138
D2.0	57.3492	53.3706	18.3321

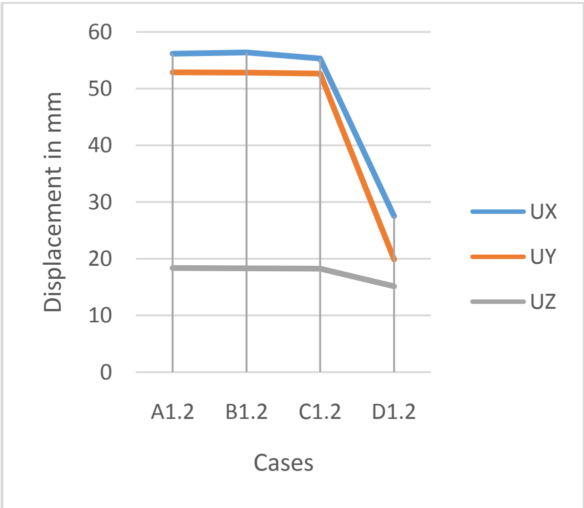

Figure.6.Displacement of structure for 1.2m cantilever length

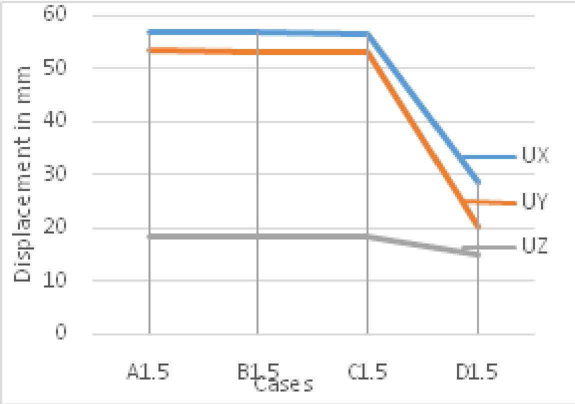

Figure.7. Displacement of structure for 1.5m cantilever length

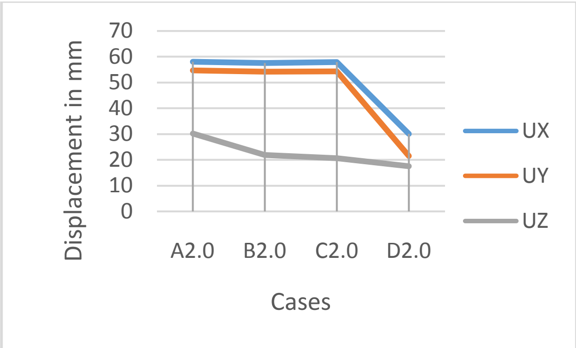

Figure.8. Displacement of structure for 2.0m cantilever length

It can be seen from the displacement analysis of structure Type A, b, C, & D. The displacement for Type A, Type B and Type C building is higher than Type D building. Type D building has displacement less as compare to other building due to strut support. Displacement can be control by almost 47%, 60% and 3 % in X, Y and Z direction respectively. The permissible deflection of building for regular design (Design without temperature and creeping effect) shall be span /250 as per IS 456-2000, Clause 23.2,a. Building Height is 43.1 m. i.e. 43100 mm. Permissible deflection for this building is 43100/250, i.e. 172.4 mm which is much more than all above results. Hence all building is safe for deflection.

4.2 Storey Drift

Analysis for Story drift is carried out summarized its result as below.

Table .2. Storey drift of structure for 1.2m cantilever length

	DriftX (mm)	DriftY (mm)
A1.2	0.00166	0.00153
B1.2	0.00168	0.00151
C1.2	0.00164	0.00155
D1.2	0.00226	0.00057

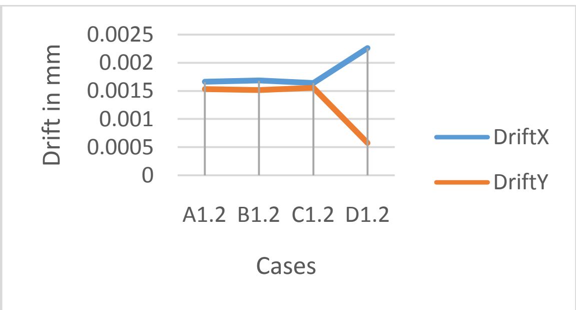

Figure. 9. Story drift of structure for 1.2m cantilever length

Table.3. Storey drift of structure for 1.5m cantilever length

	DriftX (mm)	DriftY (mm)
A1.5	0.001659	0.001551
B1.5	0.001687	0.001529
C1.5	0.001649	0.001567
D1.5	0.00409	0.001513

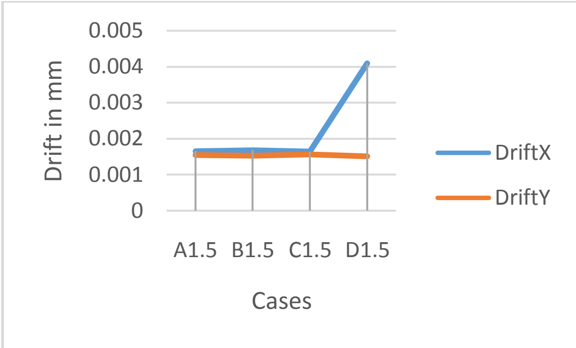

Figure.10. Story drift of structure for 1.5m cantilever length

Table. 4. Storey drift of structure for 2.0 m cantilever length

	DriftX (mm)	DriftY (mm)
A2.0	0.001698	0.001588
B2.0	0.001694	0.001554
C2.0	0.001682	0.001616
D2.0	0.005108	0.001535

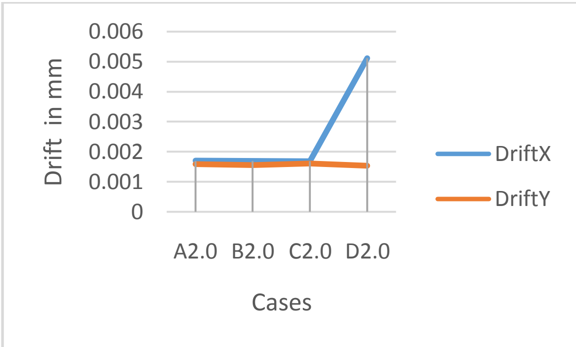

Figure.11. Story drift of structure for 1.5m cantilever length

In above Comparison there is major change in drift in column with strut support type building. Reason behind that is additional inclined for at ground floor due to strut column.

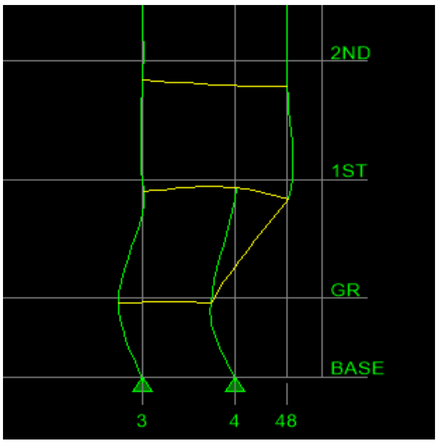

Figure.12. Displacement of point no.4

However drift is higher at ground floor. Permissible drift for structure is 0.004 time floor height. i.e. 0.004 x 3000 where

3000 mm is floor height. So permissible limit for this structure is 12 mm. Where occurred max. drift is 0.005108 mm at node number 4 at ground floor shown in figure 12. It is less than permissible limit hence structure is safe for story drift.

4.3 Storey Shear

Storey shear is lateral forces acting on structure due to wind and earthquake forces. Following graph showing the storey shear comparison for highest cantilever of 2.0 m.

Table .5. Storey shear (Tonn) with canitilever 1.2 m

	A1.2	B1.2	C1.2	D1.2
HR	114.02	114.02	114.02	114.02
TERRACE	854.51	858.85	866.26	850.85
12TH	1745.01	1748.11	1763.28	1738.11
11TH	2635.51	2637.37	2660.31	2624.37
10TH	3526.01	3530.63	3557.33	3511.63
9TH	4416.51	4420.90	4454.36	4399.10
8TH	5307.00	5309.16	5351.38	5286.26
7TH	6197.50	6201.42	6248.40	6173.92
6TH	7088.00	7091.68	7145.43	7060.68
5TH	7978.50	7982.94	8042.45	7948.34
4TH	8869.00	8872.20	8939.48	8835.00
3RD	9759.50	9761.47	9836.50	9721.17
2ND	10650.00	10656.73	10733.52	10607.53
1ST	11555.97	11557.85	11657.11	11521.55
GR	11935.01	11936.89	12036.15	11896.69

Table .6.Storey shear (Tonn) with canitilever 1.5 m

	A1.5	B1.5	C1.5	D1.5
HR	114.02	114.02	114.02	114.02
TERRACE	872.01	873.43	884.23	865.43
12TH	1780.78	1783.16	1799.52	1773.16
11TH	2689.54	2692.89	2714.81	2679.89
10TH	3598.30	3605.63	3630.10	3586.63
9TH	4507.07	4511.36	4545.38	4489.56
8TH	5415.83	5418.10	5460.67	5395.20
7TH	6324.59	6335.83	6375.96	6308.33
6TH	7233.36	7236.56	7291.25	7205.56
5TH	8142.12	8145.30	8206.54	8110.70
4TH	9050.89	9055.03	9121.83	9017.83
3RD	9959.65	9965.77	10037.12	9925.47
2ND	10868.41	10871.50	10952.41	10822.30
1ST	11793.27	11808.10	11903.91	11771.80
GR	12172.31	12187.14	12282.95	12146.94

Table.7. Storey shear (Tonn) with canitilever 2.0 m

	A2.0	B2.0	C2.0	D2.0
HR	114.02	114.02	114.02	114.02
TERRACE	902.62	904.04	916.06	896.04
12TH	1842.91	1845.29	1862.87	1835.29
11TH	2783.19	2786.54	2809.68	2773.54
10TH	3723.48	3730.81	3756.49	3711.81
9TH	4663.77	4668.06	4703.30	4646.26
8TH	5604.05	5606.32	5650.11	5583.42
7TH	6544.34	6555.58	6596.92	6528.08
6TH	7484.62	7487.82	7543.73	7456.82
5TH	8424.91	8428.09	8490.55	8393.49
4TH	9365.20	9369.34	9437.36	9332.14
3RD	10305.48	10311.60	10384.17	10271.30
2ND	11245.77	11248.86	11330.98	11199.66
1ST	12203.18	12218.01	12320.17	12181.71
GR	12582.22	12597.05	12699.21	12556.85

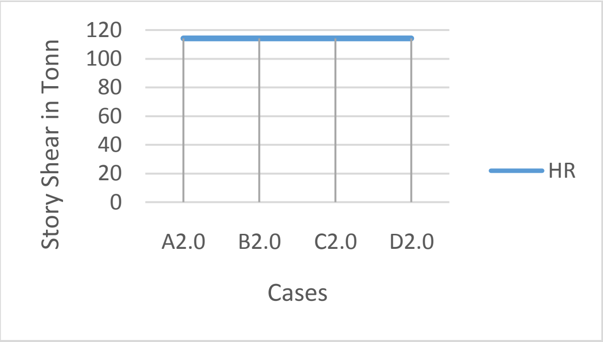

Figure.13. Story shear for headroom slab

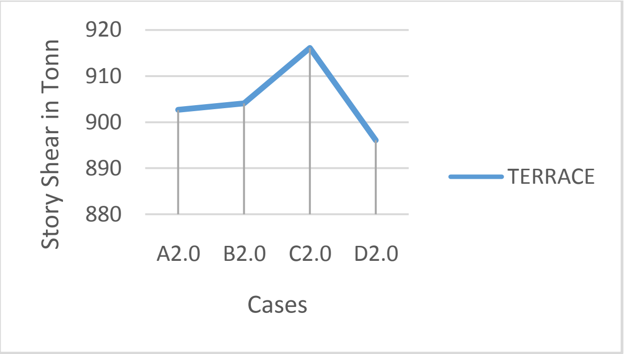

Figure.14. Story shear for Terrace slab

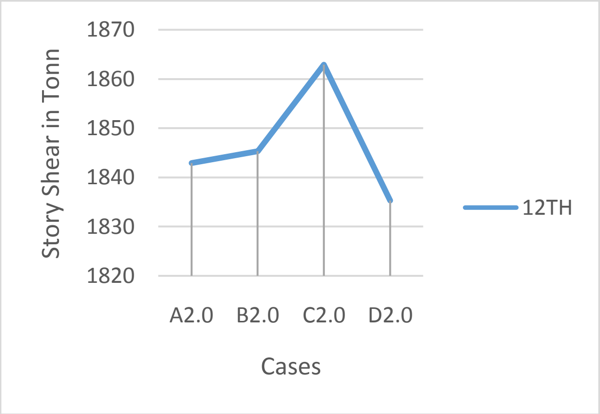

Figure.15. Story shear for 12th slab

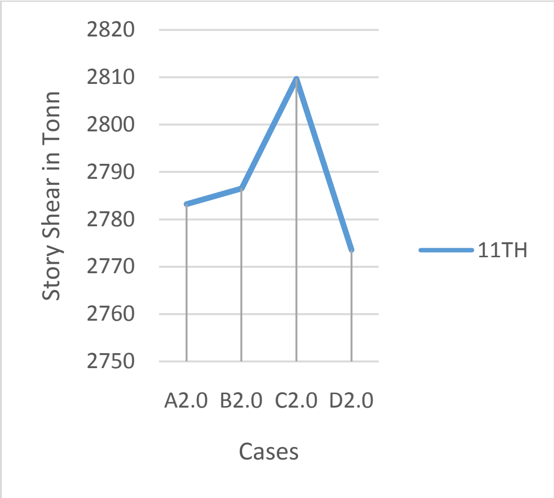

Figure.16. Story shear for 11th slab

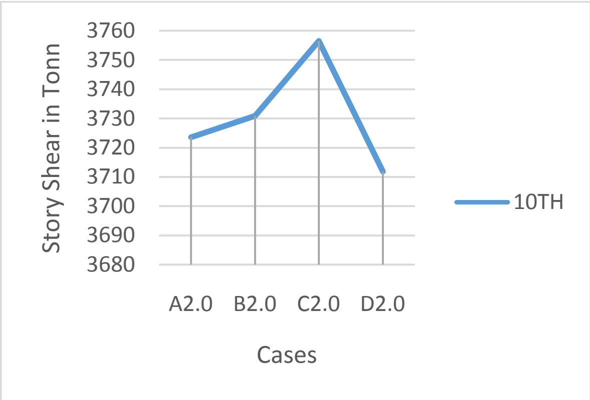

Figure.17. Story shear for 10th slab

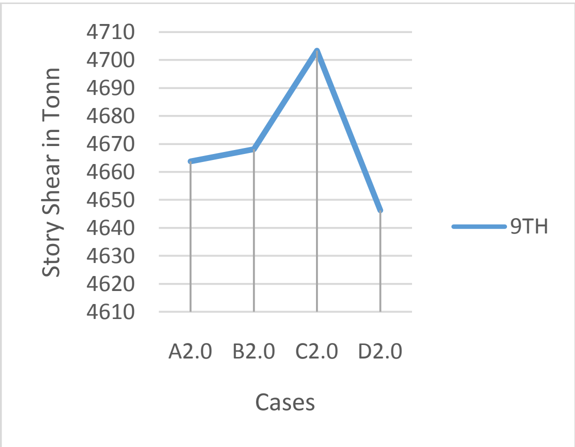

Figure.18. Story shear for 9th slab

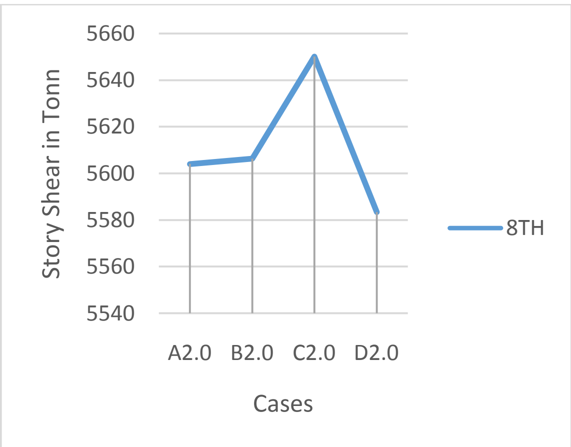

Figure.19. Story shear for 8th slab

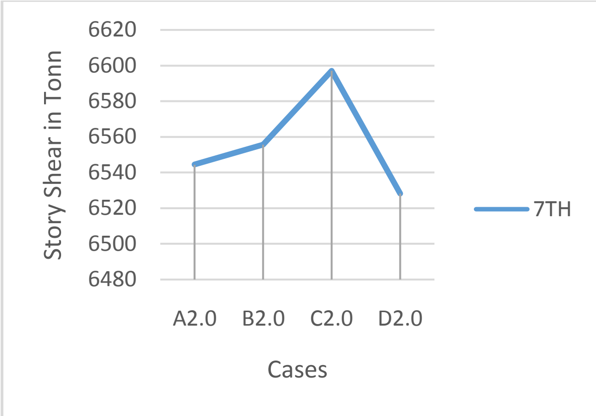

Figure.20. Story shear for 7th slab

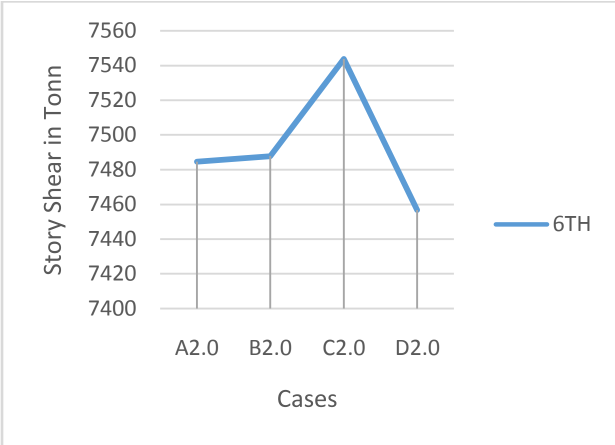

Figure.21. Story shear for 6th slab

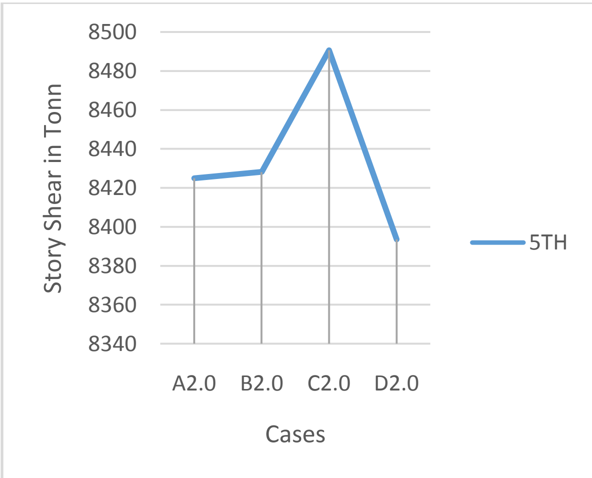

Figure.22. Story shear for 5th slab

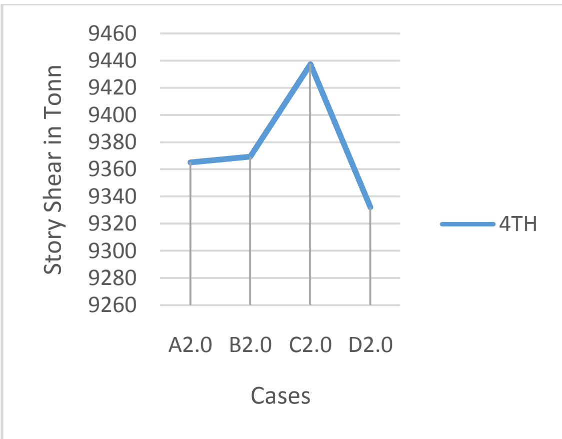

Figure.23. Story shear for 4th slab

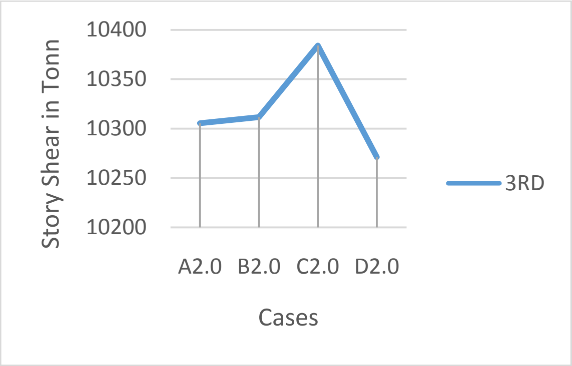

Figure.24. Story shear for 3rd slab

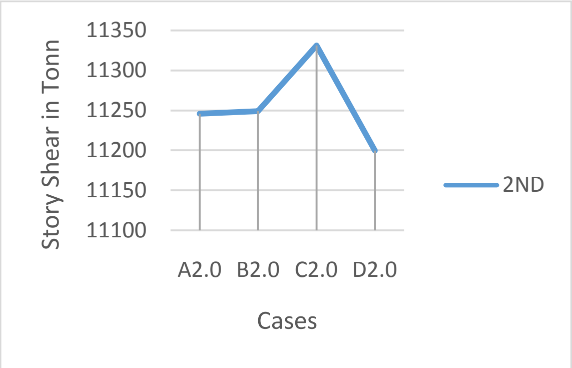

Figure.25. Story shear for 2nd slab

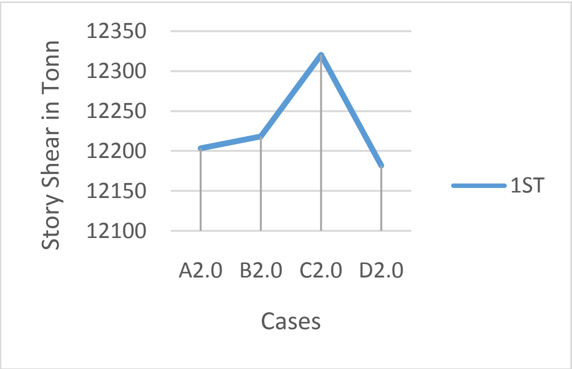

Figure.26. Story shear for 1st slab

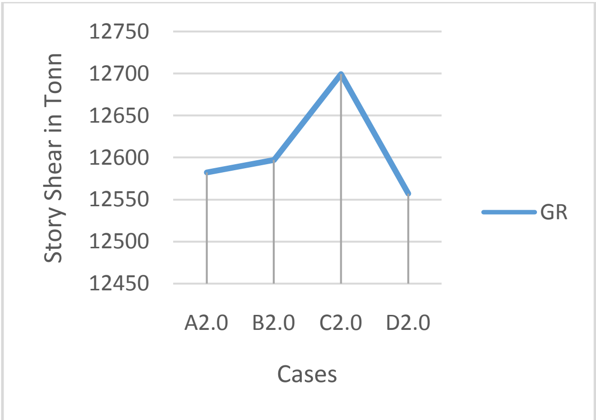

Figure.27. Story shear for ground floor

From the analysis it is found that value of storey shear is higher at both side floating column and it is less at floating column with strut support. As it is less at strut support it give more stability to structure and consume less reinforcement as compare to other type of structure.

4.5 Deflection of Cantilever

Deflection of the cantilevers are governing in case of floating column structure. Cantilever should be safe to sustain required udl and axial load. Following results are noted after analysis of all structures.

Table.7.Deflection (mm) of cantilever

	X Direction (mm)	Y Direction (mm)
A1.2	0.134	0.131
B1.2	2.259	1.137
C1.2	2.220	2.115
D1.2	1.240	0.714
A1.5	1.250	1.149
B1.5	2.951	1.200
C1.5	2.940	2.797
D1.5	1.230	0.757
A2.0	2.119	1.789
B2.0	4.312	1.268
C2.0	4.300	1.125
D2.0	1.800	0.826

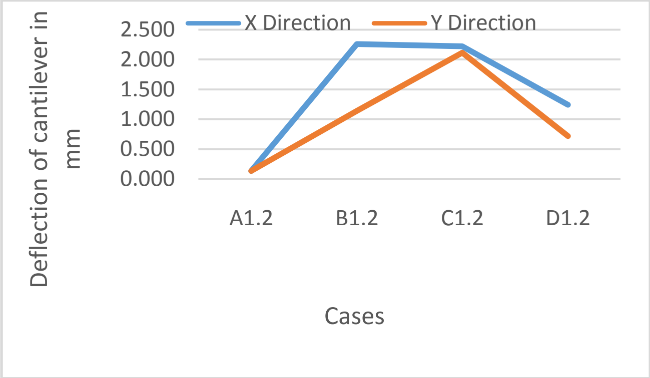

Figure.28. Deflection of cantilever for 1.2 m

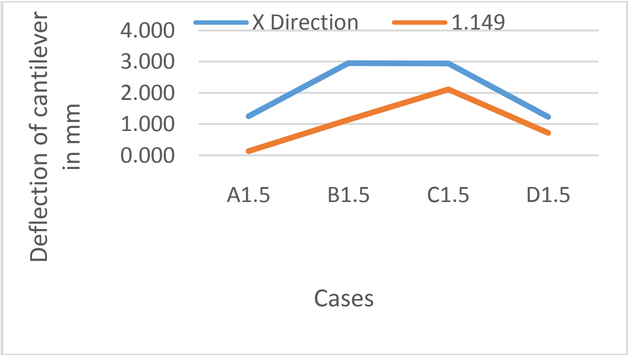

Figure.29. Deflection of cantilever for 1.5 m

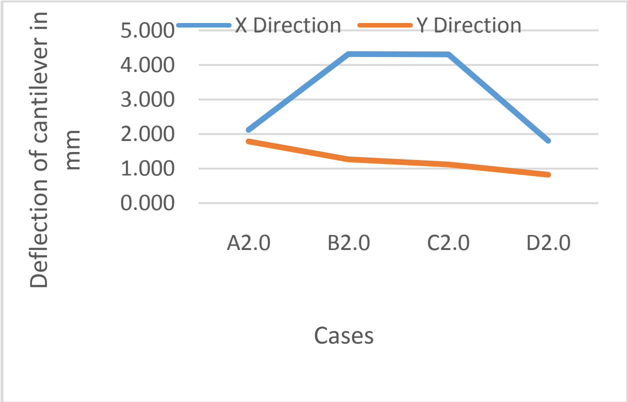

Figure.30. Deflection of cantilever for 2.0 m

In above result, deflection in more in Type C structure (double floating column), but it is less in Type D (floating column with strut support). So, we can say that strut support can reduce the deflection of the cantilever and make structure safer. A strut support is suitable to control deflection in large cantilevers. More over deflection in C case deflection in Y direction is more as compare to all cases of Y direction. It is more due to floating column.

5. CONCLUSION

Based on analysis following conclusions can be drawn.

1) Displacement of the structure is getting reduce in type D structure (Structure with floating column with strut support). Displacement can be controlled in type D by almost 50%, 62% and 17 % in X, Y and Z direction respectively.

2) Storey drift is high in type D building due to inclined load of strut support increasing drift of ground floor level. Inspite of higher drift at base of structure it is within permissible limit. Hence, we cannot consider it as a drawback of floating column with strut support.

3) Storey shear comparison carried out to know effect of lateral force on building structure. Storey shear highly affect Type C building because double floating column increasing mass of the building structure, as it is less for Type D (at strut support) which gives more stability to structure and will consume less reinforcement as compare to other type of structure.

4) Strut support is safer for large cantilever of 1.5 m and 2.0 m to reduce deflection of the building. So we can conclude that to control deflection we shall provide strut support to cantilever like 1.5 m or more.

6. REFERENCES

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