

## Research Article

## Comparative Seismic Analysis of Multistorey Building with and without Floating Column

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Accepted 20 Sept 2014, Available online 01 Oct 2014, Vol.4, No.5 (Oct 2014)

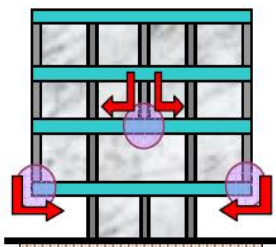
### Abstract

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings. Structural engineering is a part of civil engineering dealing with the analysis and design of structures that support or resist loads. This paper deals with the study of architectural drawing and the framing drawing of the building having floating columns. Existing residential building comprising of G+ 7 structures has been selected for carrying out the project work. The load distribution on the floating columns and the various effects due to it is also been studied in the paper. The importance and effects due to line of action of force is also studied. In this paper we are dealing with the comparative study of seismic analysis of multi-storied building with and without floating columns. The equivalent static analysis is carried out on the entire project mathematical 3D model using the software STAAD Pro V8i and the comparison of these models are been presented. This will help us to find the various analytical properties of the structure and we may also have a very systematic and economical design for the structure.

**Keywords:** Floating Column, STAAD-PRO, RCC frame, Column Shear

### 1. Introduction

The floating column is a vertical member which rest on a beam and doesn't have a foundation. 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 [Sukumar Behera *et al*, 2012].



Hanging or Floating Columns

Fig.1: Floating column

The floating column is used for the purpose of architectural view and site situations. It can be analyzed by using STAAD Pro, ETABS and SAP2000.

The Provision of floating columns can be stated as most of the buildings in India are covering the maximum

possible area on a plot within the available 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 storey, overhangs up to 1.2 m to 1.5 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 [Maison Bruce F *et al*, 1995].

But Provision of floating columns resting at the tip of taper 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

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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

Thus this paper explains the concept of analysis of floating column in residential area. In section second, some theory and formulations used for analysis of the buildings are discussed. In section third, the comparison between floating and without floating structure and values of various parameters like axial loads and bending moments, etc are discussed, whereas the result, observation and conclusion for the present work is discussed in further section.

## 2. Building Description

The study is carried out on a building with and without floating columns. The plan layout of the building is shown in the figure. The building considered is a residential building having G+7. The plan dimension is height of each storey is kept same as other prevalent data is tabulated in table

### 2.1 Modeling of Building

The building is modeled using the software STAD Pro. V8i. The analytical models of the building include all the component that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beam, column, slab, wall, foundation retaining wall, elevator, and staircase. The non structural elements that do not significantly influence the building behavior are not modeled. Beams and columns are modeled as two noded beams. The floor slabs are assumed to act as diaphragms, which ensure integral action of all vertical load resisting elements. The wall load is uniformly distributed over beams. Walls are considered to be rigidly connected to beams and columns. The modeling of the wall is discussed in the section 3.4. In the modeling, material is considered as an isotropic material. The 3d building model generated in is shown in STAD Pro [Maison Bruce F *et al*, 1985].

### 2.2 Building without Floating Column

Total building consists of 2 phases. 1<sup>st</sup> phase consists of lower two storey provided for parking purpose. 2<sup>nd</sup> phase is of residential flats from 1<sup>st</sup> floor to 7<sup>th</sup> floor. The typical plan for all the floors is as below:

#### Phase1: Upper and lower ground floor

Upper and lower ground is provided car parking for Nearly 15 cars can be parked on each parking floor. Structure consists of 52 columns arranged in systematic manner. Lower parking is at basement and upper parking is at ground level. Built up area is 3733.205 sq.m. and height of basement is 3.04m and that of upper floor is 3.65m.

#### Phase 2: 1<sup>st</sup> floor to 7<sup>th</sup> floor

Each floor includes residential area consisting of a flat system. The flat system consist of 2 BHK and 3 BHK at alternate floors. The built up area is 3733.2 sq. m and the terrace area is 1863.47 sq. m .the floor consist of all the columns coming from the ground level. Certain overhang is provided on either side of the floor. Staircase of dog legged type is provided and elevator of 1.4 X 1.72 m. Terrace of 3 X 7.35 m at each floor is provided.

### 2.3 Building with Floating Column

Total building consists of 3 phases. 1<sup>st</sup> phase consists of lower two storey provided for parking purpose. 2<sup>nd</sup> phase is of residential flats from 1<sup>st</sup> floor to 5th floor. 3<sup>rd</sup> phase is of duplex.

#### Phase1: upper and lower ground floor

This phase is also for parking as in building without floating column but placements of columns are changed.

#### Phase 2: 1<sup>st</sup> floor to 5<sup>th</sup> floor

Each floor includes residential area consisting of a flat system. The flat system consist of 2 BHK and 3 BHK at alternate floors. The built up area is 3733.2 sq. m and the terrace area is 1863.47 sq. m .the floor consist of all the columns coming from the ground level. Certain overhang is provided on either side of the floor. Staircase of dog legged type is provided and elevator of 1.4 X 1.72 m. Terrace of 3 X 7.35 m at each floor is provided. In this building 6 numbers of columns are floated from 2<sup>nd</sup> slab

#### Phase3: 6<sup>th</sup> floor plan

On 6<sup>th</sup> floor duplex is provided. Some more columns are floated here

### 2.4 Building with Floating Column with struts

It is similar to Phase 3.4 building with floating column only difference that in this case struts are provided supporting the columns which reduces the bending moment.

### 2.5 Analysis of Building

Seismic codes are different for a particular region or a country. In India, Indian standard criterion for earthquake resistant design of structures IS 1893(part 1): 2002 is the main code that provides outline for calculating seismic design forces. This force depends on the mass and seismic coefficient of the structures and the latter in turn depends on properties like seismic zone in which the structures lies, importance of the structure the soil strata, its stiffness and its ductility [Agarwal Pankaj *et al*, 2009]]. The code recommends the following method of analysis-

1. Equivalent static analysis method
2. Dynamic method
  - a. Response spectrum analysis

b. Time history analysis

Here the analysis of 3D building model is explained using equivalent static analysis method only. This method is briefly described in this section. The lateral loads are calculated and then distributed along the height of the building as per empirical equations given in the code. The building model is then analyzed by using the software STAAD Pro V8i. Different parameters such as axial load, moment distribution, importance of line of action of force and seismic factors are studied for the models.

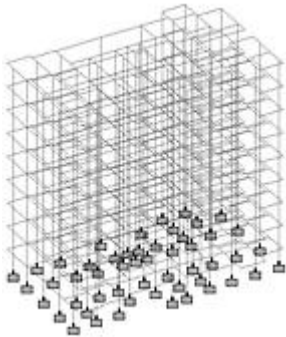


Fig.2 RCC frame

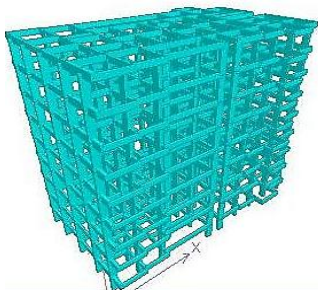


Fig.3 Model of building generated in STAAD.Pro.V8i

3. Performance Analysis

Behavior of the structure with and without floating column subjected to earthquake loading is a complicated phenomenon [Krishnamoorthy et al, 1987]. There are several numbers of factors affecting the behavior of building out of which the axial loading, moment and line of action of force are considered for study in this work. For this, building with and without floating columns are considered. The 3D analysis is carried out in both the buildings. The equivalent static analytic method is carried out on both the 3D models using the software STAAD. Pro V8i. The results obtained from the analysis are discussed in next section.

3.1 Method of analysis

Equivalent static analysis is carried out on all the three models. The results are presented in the form of graphs. The results in tabular form are given in appendix.

3.2 Equivalent static analysis

Equivalent static analysis is performed on all the three models. The loads are calculated and the results obtained

are compared with respect to following parameters like bending moment in X and Y direction, deflection and column shear.

3.3 Model cases

Case 1

It is the model in which all the columns are rested on the ground. All the columns rise up to the top floor of the building and no column is floated or terminated at any level .it refers to normal frame building.

Case 2a

In this all the column are not rested on the ground level. Certain columns are floated from the first floor to upper floors. Also some columns are terminated at 1<sup>st</sup> floor from which the columns are floated. In this case, the plan covers more area than as compared to case1. Cantilever projections are also provided at certain points.

Case 2b

It is same as case 2.a except that struts are provided below the floating columns in order to balance the moments and provides stability.

Certain columns i.e. similar columns in all three models are considered and checked for its moments in X and Z directions, deflection and column shear at each floor. A column in all the models are analyzed and compared with all the cases.

3.4 Columns in consideration

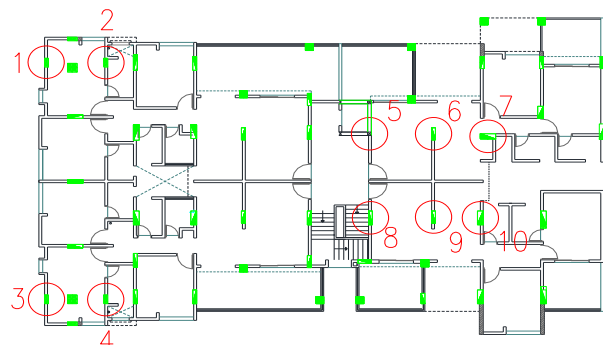


Fig.4: Column in consideration

3.5 Column 1

Column 1 rises from bottom to top in all the storey's in case 1 and is terminated in case 2a at the 1<sup>st</sup> floor and in case 2b strut is provided below the column.

Table 1: Moment in X- direction

Flr. no.	Mx					
	Case1		Case2a		Case2b	
	Top	Bottom	Top	Bottom	Top	Bottom
1	4.792	4.79	62.84	64.22	16.64	3.43
2	4.938	4.99	134.2	59.21	38.15	45.68

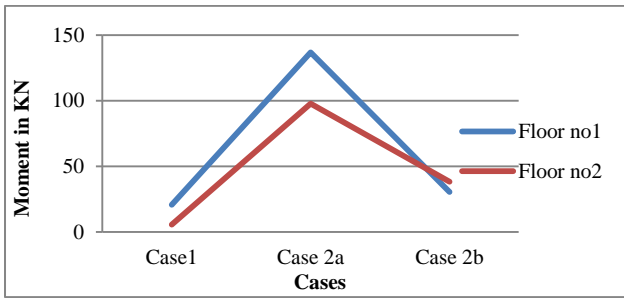


Fig.5: Cases Vs Moment at Top in X Direction

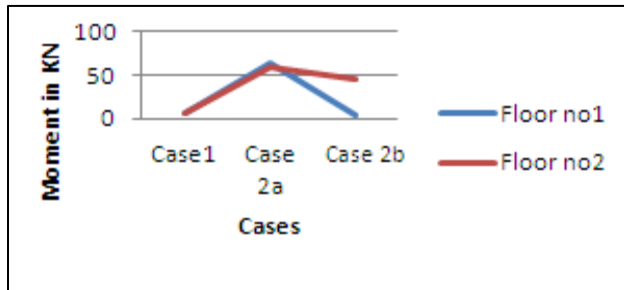


Fig.6: Cases Vs Moment at Bottom in X Direction

Table 2: Moments in Z- Direction

Flr. No.	Mz					
	Case1		Case 2a		Case 2b	
	Top	Bottom	Top	Bottom	Top	Bottom
1	3.71	20.91	117.04	136.87	22.31	30.65
2	1.08	5.71	250.83	97.89	25.04	38.39

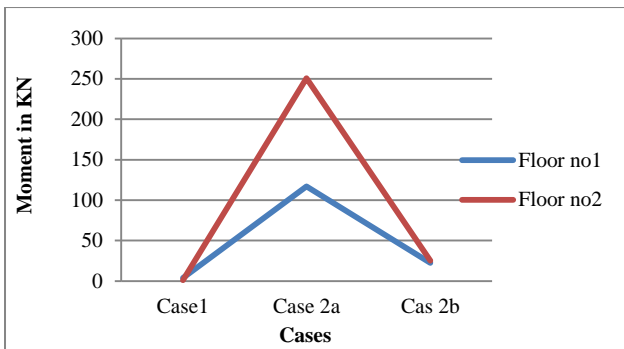


Fig.7: Cases Vs Moment at Top in Z Direction

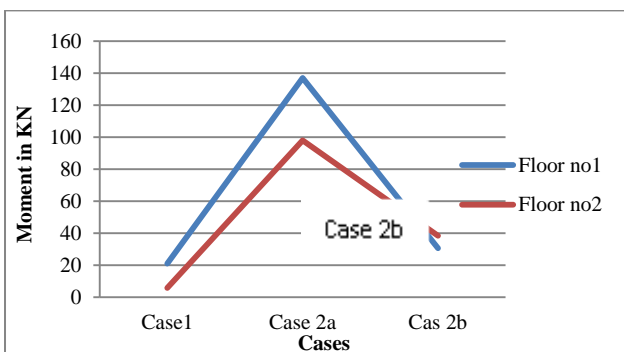


Fig.8: Cases Vs Moment at Bottom in Z Direction

Table 3: Deflection at Each Floor

Floor No.	Deflection	
	Case2a	Case 2b
1	2.024	0.687
2	2.648	0.741

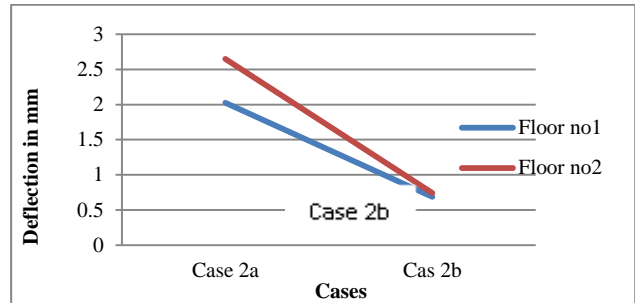


Fig.9: Cases Vs Deflection

Table 4: Column Shear at Each Floor

Floor No.	Column Shear		
	Case 1	Case 2a	Case 2b
1	5.66	78.51	93.19
2	5.66	83.57	17.42
3	2.98	114.71	20.87

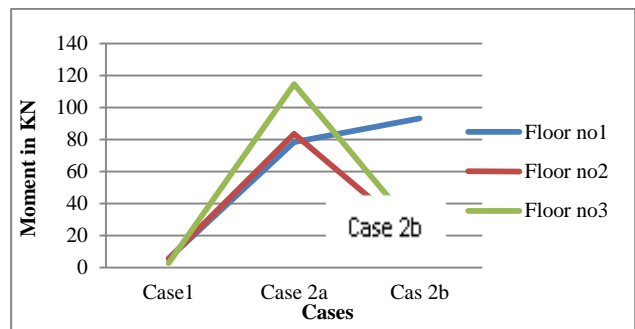


Fig.10: Cases Vs Column Shear

Column 2

Column 2 rises from bottom to top at each floor in case 1 and case 2 and struts are provided below column 1. The effects on column 2 are observed due to the termination and floating of column 1.

Table 5: Moments in X- Direction

Flr. no.	Mx					
	Case1		Case2a		Case2b	
	Top	Bottom	Top	Bottom	Top	Bottom
1	26.57	28.21	13.41	1.45	23.75	6.38
2	25.56	26.00	14.81	18.64	28.07	36.18
3	24.75	25.07	20.40	40.83	10.11	36.17
4	24.08	24.19	25.35	33.45	14.28	23.99
5	23.49	23.44	20.87	24.53	12.87	16.78
6	23.21	22.92	15.51	16.26	11.27	8.33
7	23.37	22.40	7.93	5.22	4.23	6.07
8	19.40	20.77	3.28	0.84	18.12	13.64

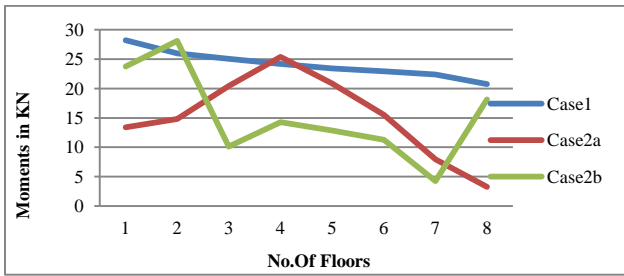


Fig.11: No. Of Floor Vs Moment at Top in X Direction

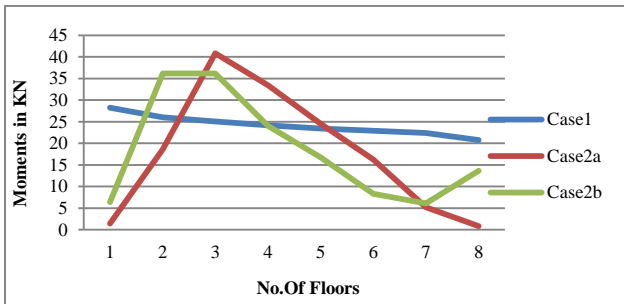


Fig.12: No. Of Floor Vs Moment at Bottom in X Direction

Table 6: Moments in Z- Direction

Flr. No.	Mz					
	Case1		Case2a		Case2b	
	Top	Bottom	Top	Bottom	Top	Bottom
1	3.12	7.86	6.84	7.25	53.62	32.93
2	4.32	4.64	1.85	0.37	46.27	29.03
3	4.43	3.24	2.70	1.85	5.17	57.93
4	4.28	2.05	4.37	4.40	8.37	2.76
5	3.88	0.50	3.18	4.25	9.00	13.99
6	2.44	1.45	2.04	0.90	7.55	10.55
7	0.03	2.68	0.09	1.14	1.16	9.77
8	2.02	1.99	1.43	1.66	4.05	5.85

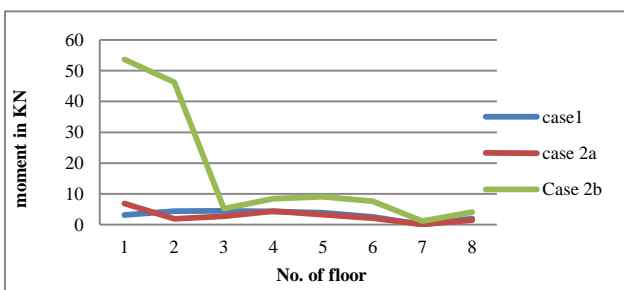


Fig.13: No. Of Floor Vs Moment at Top in Z Direction

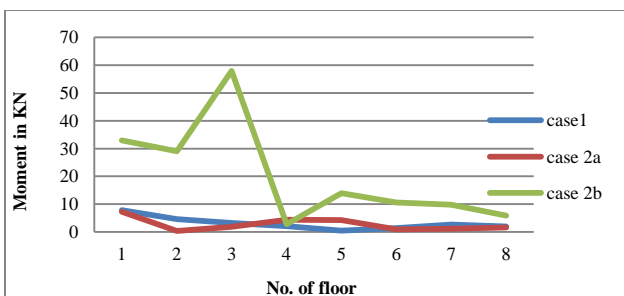


Fig.14: No. Of Floor Vs Moment at Bottom in Z Direction

Table 7: Deflection at Each Floor

Floor No.	Deflection	
	Case2a	Case 2b
1	2.023	0.676
2	2.65	0.73
3	3.897	0.641
4	5.138	2.601
5	5.951	3.738
6	5.945	4.016
7	4.979	3.594
8	3.508	2.863

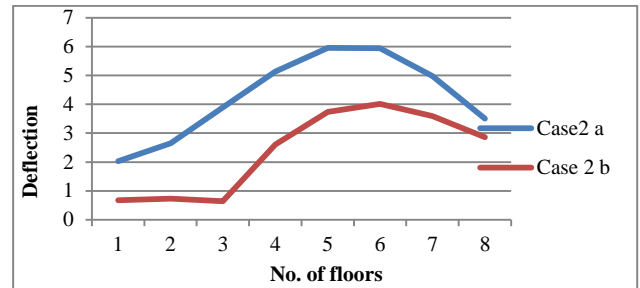


Fig.15: No. of Floor Vs Deflection

Table 8: Column Shear at Each Floor

Floor No.	Column Shear		
	Case1	Case2a	Case2b
1	4.11	4.60	96.06
2	3.61	4.64	28.47
3	2.95	0.73	24.77
4	2.53	1.34	20.76
5	2.08	2.89	5.49
6	1.44	1.79	0.72
7	0.34	0.97	0.48
8	0.87	0.41	2.83
9	1.32	1.02	3.26

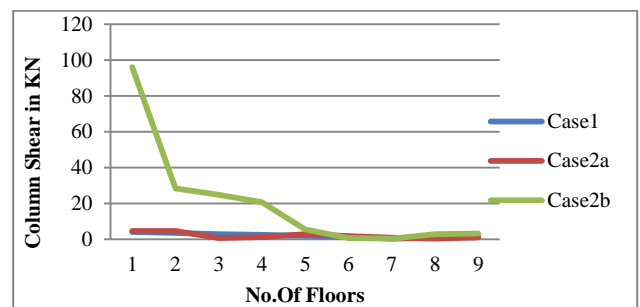


Fig.16: No. of Floor Vs Column Shear

4. Comparison of analysis result

From the above readings, the analysis results of the building model are compared for all three cases, the observations are as follows,

- 1) There is remarkable increase in Mx in case 2a than case 1 and the value of Mx reduces considerably in case 2b.
- 2) The deflection in case 2a is more than deflection in case 2b
- 3) The column shear varies according to the situation and the orientation of columns.

- 4) There is no much variation in moments on column number 5, 7, 8 and 10 in case 2 a and case 2b as struts are not provided in this region.

### Conclusions

In this paper entitled comparative seismic analysis of multistoried building with and without floating column analytical study is carried out on floating column and other columns affected due to floating column. Preliminary study is carried out on a building model comparing three cases. Following are some conclusions based on work done in the present study. In the model floating columns and struts are provided on the specified locations in different cases. The 3- D analysis of building is carried out for all three cases i.e. normal framed building without floating columns, with floating columns and with struts supporting floating columns and comparative study is done. The main objective of the study is to improve the seismic performance of building with floating columns and proper design of building with floating columns.

A simplified probabilistic risk analysis (PRA) procedure is presented for the seismic reliability of G+7 storey RCC building by considering effect of with and without floating column in the modeling. The moment about X and moment about Z are compared by equivalent static analysis method. The above building models are generated using the software STAAD Pro 8Vi and are analyzed using equivalent static method. Based on the analysis results following conclusions are drawn,

1. The probability of failure of Case 2a is higher by comparing values of  $M_x$  and  $M_z$  with other cases. In case 1 the columns are provided from ground level and rise up to the top floor in continuity. Thus it has more stability and resistance to seismic forces. Due to the floating columns moments are greatly increase on the adjacent column and these adjacent columns are to be checked and design for these increase moments
2. The probabilities of failure of without floating column are less as compared to with floating column. In this case, the moment values are significantly less than with floating column (Case 2a)
3. The difference in the probabilities of failure with floating column is more than floating column with inclined compressive member i.e. struts. (Case2b).
4. From the study, It is found that, the deflection in Case 2a (with floating column) is more than the deflection in Case 2b (floating column with struts). Thus due the provisions of struts in the building with floating columns ,the deflection is greatly reduced. This is because struts provide stability to the columns balancing the moments.
5. In Case 2a and Case2b, column shear values are increasing or decreasing significantly depending upon position and orientation of column.
6. Moments at every node or every slab level varies significantly. Thus at every node the moments has to be checked and design for every level separately for the safety and economy purpose
7. Provision of floating column is advantageous in increasing FSI of the building but is a risky factor and increases the vulnerability of the building.

### Future Scope

The present study is limited to maximum G+7 storied building with floating column in the present study three cases (Case 1, Case2a, Case2b) are compared in which failure checked by moments, deflection and column shear. So there is large scope for the further study in future:

1. The applicability of the procedure of taller structure and structure with large time periods needs to be investigated.
2. The building with floating column can be checked for base shear.
3. The frequency, time period and twisting moment in column can be calculated for given models in all three cases.
4. The reactions at footing level is to be investigated and modified for the present study.
5. To perform a static non linear (Push-over) analysis and checked whether that plastic hinges will form at floating columns.
6. An experimental investigation and verification can be done with small scale model on a shake table under simulated motions.
7. Design and estimation of building is necessary for checking the cost effectiveness of these measures used for improving the seismic performance of structure.

### References

- Agarwal Pankaj, Shrikhande Manish (2009). Earthquake resistant design of structures, PHI learning private limited, New Delhi.
- Maison Bruce F. and Ventura Carlos E. (1991) Dynamic analysis of thirteen-story building, Journal of Structural Engineering, Vol. 117, No. 12, Page no: 3783-3803.
- Maison Bruce F. and Neuss Carl F. (July 1985) Dynamic analysis of a forty four story building, Journal of Structural Engineering, Vol. 111, No. 7, Page No:1559- 572.
- Krishnamoorthy CS (1987). Finite element analysis, TMH Publications.
- Sukumar Behera (May 2012), Seismic Analysis of Multistorey Building with Floating Column NIT, Rourkela- 769008.
- Paz Mario (2010). Structural dynamics, CBS publishers