Seismic Analysis of Multi-Storey Building with and without Floating Column

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***Abstract*--In present scenario buildings with floating column is a typical feature in the modern multi storey construction in urban India. Such features are highly undesirable in building built in seismically active areas. Earthquakes occurred in recent past have indicated that if the structures are not properly designed and constructed with required quality may cause great destruction of structures. This fact has resulted in to ensure safety against earthquake forces of tall structures hence, there is need to determine seismic responses of such building for designing earthquake resistant structures by carrying seismic analysis of the structure. This study highlights the importance of explicitly recognizing the presence of the floating column in the analysis of building. Alternate measures, involving stiffness balance of the first storey and the storey above, are proposed to reduce the irregularity introduced by the floating columns.**

Time history analysis is one of the important techniques for structural seismic analysis especially when the evaluated structural response is nonlinear. In the present work dynamic analysis of G+14 multistoried RCC building considering for Sumatra earthquake is carried out by time history analysis and response spectrum analysis and seismic responses of such building are comparatively studied and modeled with the help of ETABS software. The floor displacement, inter storey drift, base shear are computed for both the building with and without floating column.

Keywords—floating column, time history, response spectrum, floor displacement, inter storey drift, base shear, ETABS

I. INTRODUCTION

Many urban multi-storey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period. The seismic force distribution is dependent on the distribution of stiffness and mass along the height. The process of urbanization has been a common feature throughout the past decades. Urbanization and Growth of high rise buildings is the need of current population and earthquakes have the potential for causing the greatest damages to those tall structures. Hence, it is necessary to take in to account the seismic load for the design of high-rise structure.

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which at its lower level rests on a beam which is a horizontal member. Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation, have discontinuities in the load transfer path. The beams in turn transfer the load to other columns below it. In such columns the loads were considered as a point load.

There are many projects in which floating columns are already adopted, especially above the ground floor, so that more open space is available on the ground floor. These open spaces may be required for assembly hall or parking purpose. The column is a concentrated load on the beam which supports it. The structures already made with these kinds of discontinuous members are endangered in seismic regions. But those structures cannot be demolished; rather study can be done to strengthen the structure. The stiffness of these columns can be increased by retrofitting or these may be provided by bracing to decrease the lateral deformation. Many high rise buildings are planned and constructed with architectural complexities. The complexities are nothing but soft storey, floating column, heavy load, the reduction in stiffness, etc.

Conventional Civil Engineering structures are designed on the basis of strength and stiffness criteria. The strength is related to ultimate limit state, which assures that the forces developed in the structure remain in elastic range. The stiffness is related to serviceability limit states which assure that the structural displacement remains with the permissible limits. In case of earthquake forces the demand is for ductility. Ductility is an essential attribute of a structure that must respond to strong ground motions. Ductility is the ability of the structure to undergo distortion or deformation without damage or failure which results in dissipation of energy. Larger is the capacity of the structure to deform plastically without collapse, more is the resulting ductility and the energy dissipation. This causes reduction in effective earthquake forces.

Fig 1 Hanoi Museum in Vietnam

II. OBJECTIVE

- To study the behavior of multi storey buildings with and without floating columns under earthquake excitations.
- To compare the behavior of buildings with floating columns provided inside and at the corners of the building.
- To determine the storey drift, lateral displacement and storey shears of the building using ETABS.

III. METHODS OF ANALYSIS

The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as:

A. *Equivalent static analysis:*

All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings. This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one as it requires less computational efforts and is based on formulates given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individual's lateral load resisting elements.The main objective of structural analysis is to determine internal forces, stresses and deformation of structures under various load effect.

B. *Dynamic Analysis:*

Dynamic analysis of structure is a part of structural analysis in which behavior of flexible structure subjected to dynamic loading is studied. Dynamic load always changes with time. Dynamic load comprises of wind, live load, earthquake load etc. Thus in general we can say almost all the real life problems can be studied dynamically. If dynamic loads changes gradually the structure's response may be approximately calculated by a static analysis in which inertia forces can be neglected. But if the dynamic load changes quickly, the response must be determined with the help of dynamic analysis in which we cannot neglect inertial force which is equal to mass time of acceleration (Newton's 2nd law).

1) *Response Spectrum Analysis:*

Response spectrum method is the linear dynamic analysis method. This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the peak responses of a structure during an earthquake is obtained directly from the earthquake responses (or design) spectrum. The response of Multi-Degree- of–Freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of Single - Degree- of – Freedom (SDOF) system, which are then combined to compute the total response. Modal analysis leads to the response history of the structure to a specified ground motion; however, the method is usually used in conjunction with a response spectrum. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum relative velocity or maximum relative displacement.

2) *Time History Method:*

Time History analysis is a step by step analysis of the dynamic response of the structure at each increment of time when its base is subjected to specific ground motion time history. To perform such an analysis a representative earthquake time history is required for a structure being evaluated. It is used to determine the seismic response of a structure under dynamic loading of representative earthquake.

A linear time history analysis overcomes all the disadvantagesof modalresponse spectrum analysis, provided non-linear behavior is not involved. This method requires greater computational efforts for calculating the response at discrete time. One interesting advantage of such procedure is that the relative signs of response qualities are preserved in the response histories. This is important when interaction effects are considered in design among stress resultants.

Here dynamic response of the plane frame is modeled to specified time history compatible to IS code spectrum and Sumatra earthquake.

IV. STRUCTURAL MODELING AND ANALYSIS

The behaviors of the multi storey building with and without floating column have been carried out under earthquake excitation. The building is modelled for Sumatra earthquake and response spectrum analysis.

The building considered here consists of fifteen storeys, i.e.G+14. The building is modeled using the software ETABS 9. 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 nonstructural elements that do not significantly influence the building behavior are not modeled. Beams and columns are modeled as two nodded 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. In the modeling, material is considered as an isotropic material. The 3D building model generated in ETABS 9 is shown in figure 2

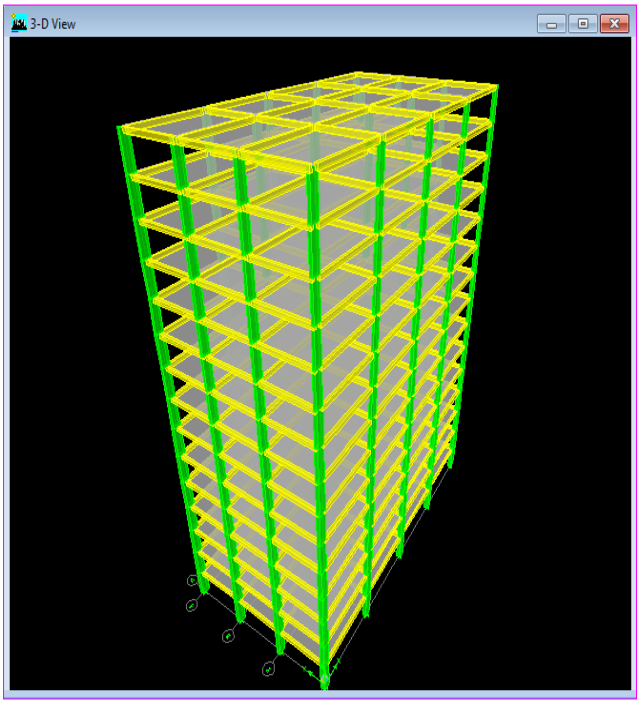

Fig.2 3D model of building generated in ETABS 9

A. *Building Description*

In this study, three cases have been discussed. In Case 1, the building without floating column is considered. In Case 2, the building with floating column inside the structure is considered. In Case 3, the building with floating column provided at the four corners is considered. In Case 2 and Case 3, fifteen models are considered each at inside and outside of the building.

Case 1:- Building without floating column

The plan dimensions in X and Y directions are 40m and 50 m respectively. The base of the building frame is assumed to be fixed. The details of the building without floating column are given in Table 1.

TABLE.1 DETAILS OF BUILDING WITHOUT FLOATING COLUMN

Number of storeys	Fifteen(G+14)
Floor height	3.5m
Seismic zone	III
Zone factor	0.16
Type of soil	Medium
Response reduction factor	5
Importance factor	1
Damping in structure	5%
Infill wall	230mm thick brick masonry
Materials	M30 Grade concrete &Fe500 Reinforcement
Unit weights	a)concrete =25KN/m^3 b)masonry =23KN/m^3 c)concrete plaster =20.4KN/m^3 d)ceiling =0.25KN/m^3
Live load	a)on roof =1.5KN/m^2 b)on floor =1.75KN/m^2
Floor finish	15mm thick
Ceiling	13mm thick
Depth of slab	125mm
Wall thickness	230mm
Size of beam	300x500mm
Size of column	550x1000mm(from 1-5 storey) 400x1000mm(from 5-10 storey) 300x1000mm(from 10 -15 storey)

Case 2:- Buildings with floating column inside the structure

The details of the building are similar to that of Case 1 except the detailing's in beams and columns. Here the size of column is kept fixed and size of beam is changed while providing floating column. The details of beams and columns are shown in Table 2 and Table 3.

TABLE.2 DETAILS OF BEAMS IN BUILDING WITH FLOATING COLUMN INSIDE THE STRUCTURE

Storey on which floating column provided	Size of beams
1	500x700mm(from 1-5storey) 400x900mm(from 5-15 storey)
2	500x700mm(from 1-5storey) 400x900mm(from 5-15 storey)
3	500x700mm(from 1-5storey) 400x900mm(from 5-15 storey)
4	500x700mm(from 1-5storey) 400x900mm(from 5-15 storey)
5	400x900mm(from 1-15storey)
6	400x900mm(from 1-15storey)
7	400x900mm(from 1-15storey)
8	400x1000mm(from 1-15storey)
9	400x700mm(from 1-15storey)
10	400x700mm(from 1-15storey)
11	400x700mm(from 1-15storey)
12	400x700mm(from 1-15storey)
13	400x700mm(from 1-15storey)
14	400x600mm(from 1-15storey)
15	400x600mm(from 1-15storey)

TABLE.3 DETAILS OF COLUMN IN BUILDING WITH FLOATING COLUMN INSIDE THE STRUCTURE

Size of column
400x1000mm(from 1-5 storey) 600x1000mm(from 5-10 storey) 800x1000mm(from 10-15 storey)

Case 3:- Buildings with floating column at the corners of the building

The details of the building are similar to that of Case 1 except the detailing's in beams. Here also the size of column is kept fixed and size of beam is changed while providing floating column on the corners. The details of beams are shown in Table 4. The size of column is similar to that of buildings without floating column.

TABLE.4 DETAILS OF BEAMS IN BUILDING WITH FLOATING COLUMN AT THE CORNERS OF THE STRUCTURE

Storey on which floating column provided	Size of beams
1	400x700mm
2	400x700mm
3	400x700mm
4	400x700mm
5	400x700mm
6	400x700mm
7	400x700mm
8	400x700mm
9	400x700mm
10	400x700mm
11	400x700mm
12	400x700mm
13	400x700mm
14	400x600mm
15	400x600mm

B. Model Analysis

The parametric study of storey shear, storey displacement and inter storey drift of building in different stories is performed here. In Case 2 and Case 3, the buildings are again divided by providing floating columns on inner and outer edge of the building at same position but at different floor. The results obtained from analysis are listed below and compared by graphical representation.

1) Comparison based on storey displacement between the normal building and the building with floating column provided on inner side.

By the application of earthquake loads in X and Y directions the structure can be analyzed for various load combinations given by clause 6.3.1.2 of IS 1893:2002.For the given load combinations maximum displacement at each floor is noted in X and Y direction and are shown below in the form of a graph

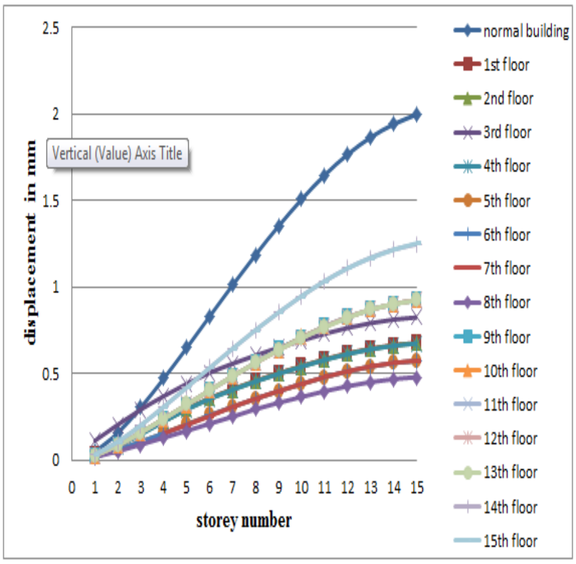

Fig.3 Storey displacements between the normal building and the building with floating column provided on inner side in X-direction

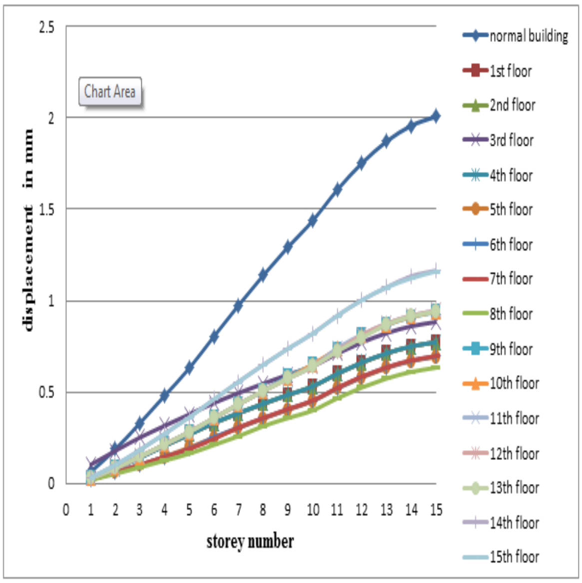

Fig.4 Storey displacements between the normal building and the building with floating column provided on inner side in Y-direction.

From the graph 3 and 4 we can see that the displacement is more for normal building without any floating column. And the least storey displacement is noticed for building with floating column provided on inner side of 8th storey. The building with floating column provided on the inner side of 14th and 15th storey has more displacement than 8th storey. This can be seen in both X and Y directions.

2) Comparison based on storey displacement between the normal building and the building with floating column provided on outer edge.

From the graph 5 and 6 we can see that the displacement is more for normal building without floating column. Here the least displacement occur for the building with floating column provided on the corner of the first storey and the maximum displacement occur for building with floating column provided on corner of the14th and 15th storey when compared with the building with floating column on the corner of the first storey.

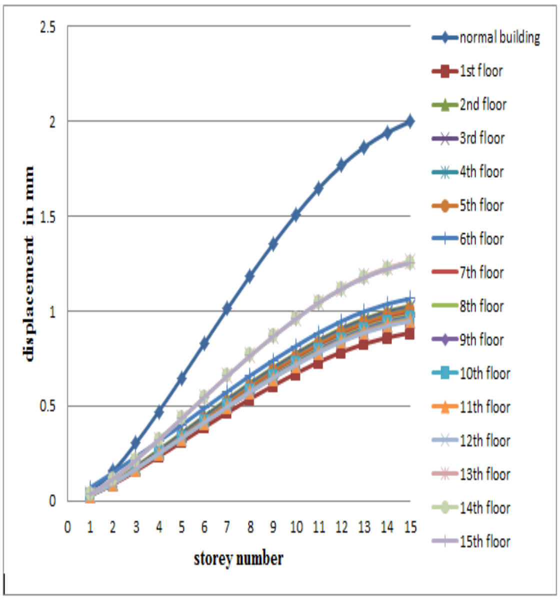

Fig.5 Storey displacements between the normal building and the building with floating column provided on outer edge in X-direction

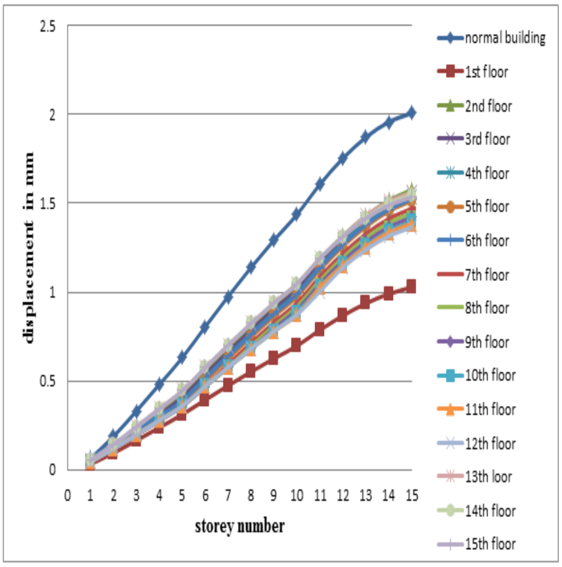

Fig.6 Storey displacements between the normal building and the building with floating column provided on outer side in Y-direction

3) Comparison based on inter storey drift between the normal building and the building with floating column provided on inner side.

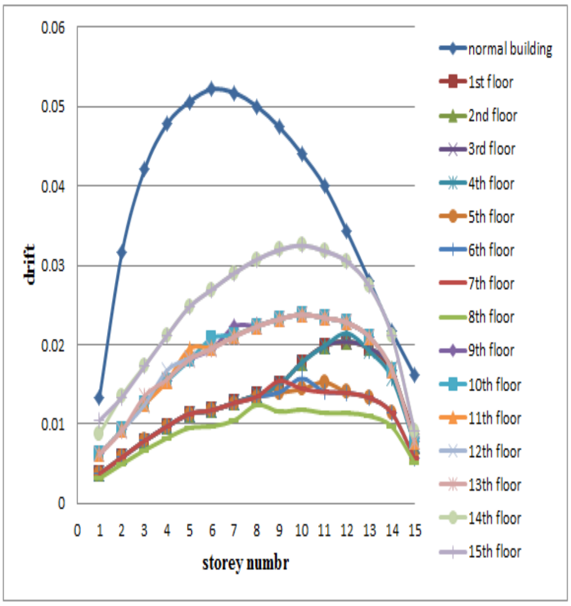

Fig.7 Inter storey drift between the normal building and the building with floating column provided on inner side in X-direction.

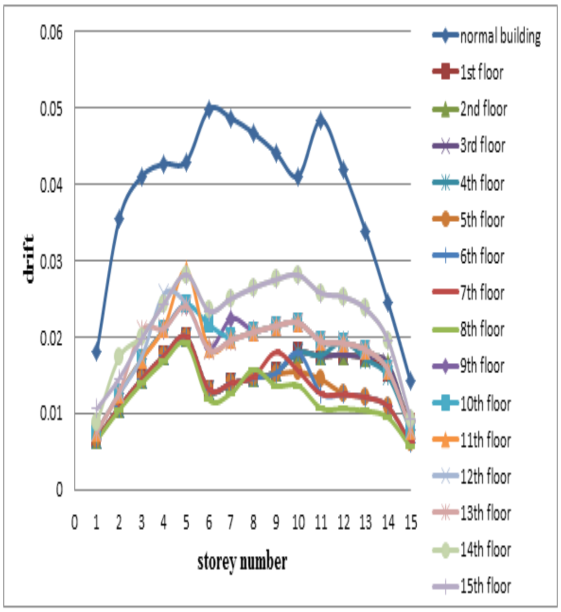

Fig.8 Inter storey drift between the normal building and the building with floating column provided on inner side in Y-direction

From the graph 7 and 8 we can see that the storey drift is maximum for normal building without any floating column. And the least storey drift is noticed for building with floating column provided on inner side of 8th storey. The building with floating column provided on the inner side of14th and 15thstorey has more storey drift than 8th storey. This can be seen in both X and Y directions.

4) Comparison based on inter storey drift between the normal building and the building with floating column provided on outer edge.

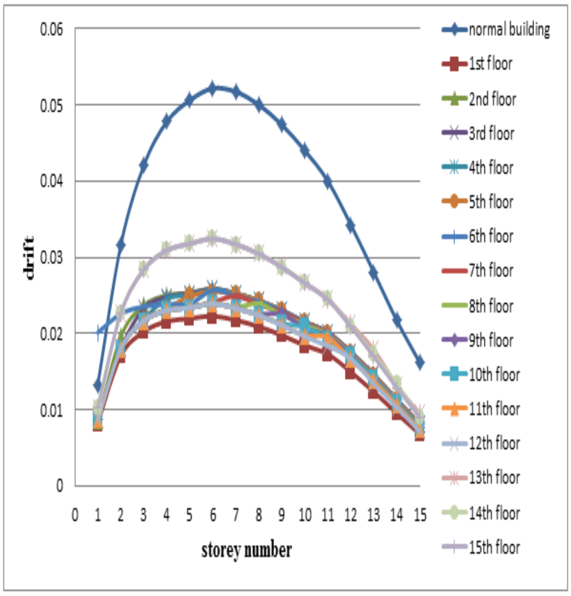

Fig.9 Inter storey drift between the normal building and the building with floating column provided on corner in X-direction

From the graph we can see that the storey drift is maximum for normal building without floating column. Here the least storey drift occur for the building with floating column provided on the corner of the first storey and the storey drift that occur for the building with floating column provided on corner of the 14th and 15th storey is more than that of the building with floating column provided on the corner of first storey.

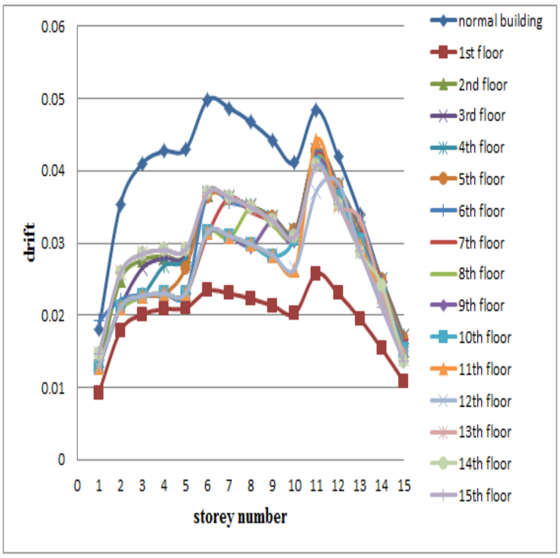

Fig.10 Inter storey drift between the normal building and the building with floating column provided on corner in Y-direction.

5) *Comparison based on storey shear between the normal building and the building with floating column provided on inner side.*

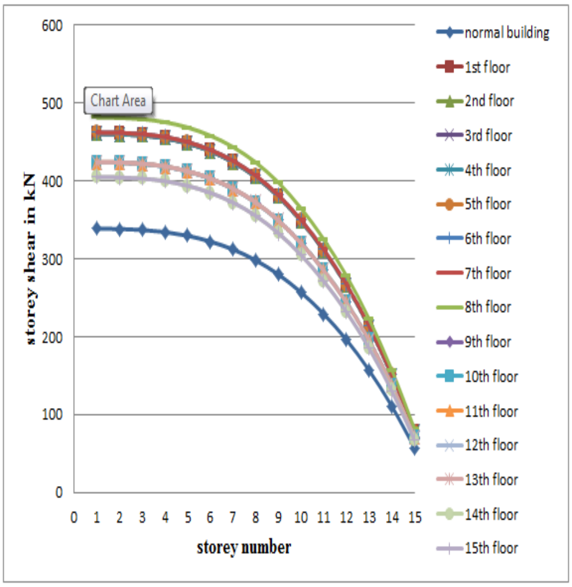

Fig.11 Storey shear between the normal building and the building with floating column provided on inner side

6) Comparison based on storey shear between the normal building and the building with floating column provided on outer edge.

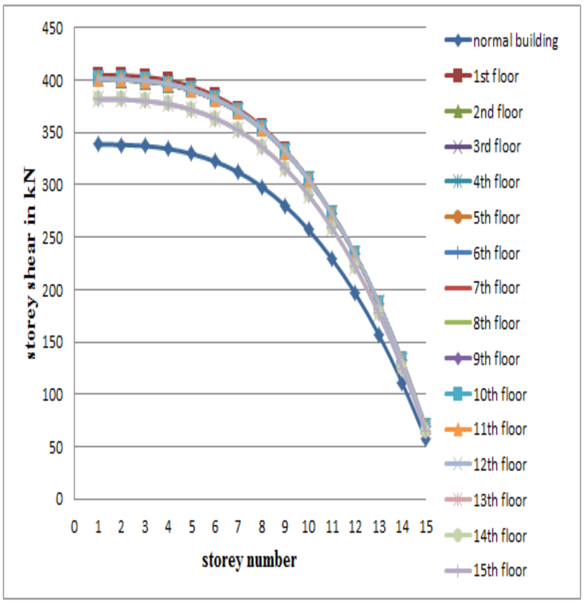

Fig.12 Storey shear between the normal building and the building with floating column provided on outer edge

From the graph we can see that the storey shear is minimum for the normal building without floating column. For the building with floating column provided on the inner and corner of the 14^{th} and 15^{th}storey shows less storey shear when compared with other buildings with floating column. The storey shear of building with floating column provided on the inner side of 8^{th} storey is greater when compared with other buildings

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V. CONCLUSION

In this paper entitled seismic analysis of multistoried building with and without floating column, an analytical study is carried out on normal building without any floating column and buildings with floating columns on each floor where the floating column is provided on inner and corner of each floor. Here the buildings are designed in such a way that the building is made safe while providing floating columns on each floor of the building. Therefore the size of the beams and columns are different for each building. In this study mainly three cases have been taken. First, a normal building without any floating column. Second, building with floating column provided on the inner side and this case is again divided into fifteen subcases by providing floating column on inner side of the building on each floor. Third, building with floating column provide on the corner of the building and again this case is divided into fifteen subcases b providing floating column on the outer of each floor.

The size of beams and columns has been changed accordingly to make the building safe while providing floating columns on each floor. Preliminary study is carried out on a building model comparing three cases. Following are some conclusions based on work done in the present study. The main objective of my study was to study the seismic performance of the buildings with and without floating column by using ETABS. Based on the analysis results following conclusions are drawn,

- The storey displacement of Case 1 is more when compared with Case 2 and Case 3. This is because the size of beams and columns in Case 1 is less when compared with Case 2 and Case 3. With increase in size of beams and columns, storey displacement decreases.
- The storey displacement for the building with floating column provided on the inner side of the 8^{th} storey is less when compared to the building with floating column provided on the 14^{th} and 15^{th} storey. The storey displacement for the building with floating column on the corner of the first storey is less when compared with the building with floating column provided on the 14^{th} and15^{th} storey.
- The inter storey drift for the building with floating column provided on the inner side of the 8^{th} storey is less when compared to the building with floating column provided on the 14^{th} and 15^{th} storey. The inter storey drift for the building with floating column on the corner of the first storey is less when compared with the building with floating column provided on the 14^{th} and 15^{th} storey.
- Generally, storey shear reduces due to presence of floating column in building as the mass is less for building with floating column. But here the normal building without floating column has the minimum shear value. This is because the size of beams and columns in normal building is less when compared with buildings with floating column. So the mass of building decreases. Due to increase in size of beams and

columns the mass increases and therefore storey shear increases.

- The value of storey shear is more for the building with floating column provided on the inner side of the building than the building with floating column provided on the 14th and 15thstorey. In case of building with floating column provided on the outer edge, the shear values are nearly equal but for the building with floating column provided on the 14th and 15th storey the value is less compared to others.

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