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Seismic Behaviour of Multistorey Buildings Having Floating Columns

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Abstract: **In recent times, multi-storey buildings in urban cities are required to have column free space due to shortage of space, population and also for aesthetic and functional requirements. For this buildings are provided with floating columns at one or more storey. These floating columns are highly disadvantageous in a building built in seismically active areas. The earthquake forces that are developed at different floor levels in a building need to be carried down along the height to the ground by the shortest path. Deviation or discontinuity in this load transfer path results in poor performance of the building. The object of the present work is to study the behaviour of multistorey buildings having floating columns under seismic forces and observe the effect of shear wall in the same building. For this purpose three cases of multi-storey buildings are considered having 8 storey, 12 storey and 16 storey. All the three cases are considered having floating columns provided with and without shear wall, and also analyzed for zone III, zone IV and zone V by using software Staad Pro. Observation shows that the provision of floating columns is advantageous in increasing FSI of the building but is a risky factor and increases the vulnerability of the building. From the analysis result parameters lateral displacement and storey drift of the building increases from lower to higher zones because the magnitude of intensity will be more for higher zones. By the use of shear wall these parametric values reduces in all the models. Present work provides a good source of information on the parameters lateral displacement and storey drift in the multistory buildings having floating columns with and without shear wall.**

Keywords: **Floating Columns, Seismic Behaviour, Lateral Displacement, Storey Drift, Shear wall.**

1. INTRODUCTION

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 ends (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. Such columns where the load was considered as point load. Theoretically such structures can be analyzed and designed. In practice, the true columns below the termination level [usually the stilt level] are not constructed with care and more liable to failure.

Hypothetically, there is no need for such floating columns – the spans of all beams need not be nearly the same and some spans can be larger than others. This way, the columns supporting beams with larger spans would be designed and constructed with greater care.

For Floating columns, the Transfer Girder and columns supporting Transfer Girder needs special attention. If load factor needs to be augmented (for Transfer Girder and its columns) to have additional safety of structure, shall be adopted. In the given system, floating columns need not be treated to carry any Earth Quake forces. Therefore entire Earth Quake of the system is shared by the columns/shear walls without considering any contribution from Float columns. However in design and details of Float columns, minimum 25% Earth Quake must be catered in addition to full gravity forces.

This way the overall system as some breathing safety during Earth Quake However, Floating columns are competent enough to carry gravity loading but Transfer Girder must be of adequate dimensions (Stiffness) with very minimal deflection.

2. LITERATURE REVIEW

Research on the behaviour of the floating column with different models is described below:

ISHA ROHILLA et. al. [2015], discussed the critical position of floating column in vertically irregular buildings for G+5 and G+7 RC buildings for zone II and zone V. Also the effect of size of beams and columns carrying the load of floating column has been assessed. The response of building such as storey drift, storey displacement and storey shear has been used to evaluate the results obtained using ETABS software. On the basis of analysis and results following conclusions have been made:

1. Floating columns should be avoided in high rise building in zone 5 because of its poor performance.
2. Storey displacement and storey drift increases due to presence of floating column.
3. Storey displacement increases with increase in load on floating column.
4. Storey shear decreases in presence of floating column because of reduction mass of column in structure.
5. Increase in size of beams and columns improve the performance of building with floating column by reducing the values of storey displacement and storey drift.

Increasing dimensions of beams and columns of only one floor does not decreases storey displacement and storey drift in upper floors so dimensions should be increased in two consecutive floors for better performance of building.

KAVYA N et. al. [2015], studied the seismic behavior of the RC multistory buildings with and without floating column are considered. The analysis is carried out for the multi-storey buildings of G+3 situated at zone IV, using ETABS software. To determine seismic behavior of the Buildings with and without floating columns for zone IV the basic components like inter storey drift, lateral displacement, and fundamental time period this analysis has been carried using the software ETABS V 9.7.1. for the analysis purpose Equivalent static method, and Response spectrum methods are adopted. In this building model RC multi storied structures of 4 stories are considered with and without floating columns for the analysis. The typical height of the floors is considered as 3.6m and the height of the ground storey is taken as 4.8m. to avoid the tensional response under the pure lateral forces the buildings are kept symmetric in both the orthogonal directions in plan. On the basis of analysis following conclusions are drawn:

1. The natural time periods obtained from the empirical expressions do not agree with the analytical natural periods. Hence, the dynamic analysis is to be carried out before analyzing these type of structures. And also it can be concluded from the analysis that the natural time period depends on the building configuration.
2. Lateral displacement increases along the height of the building. There is more increase in the displacement for the floating column buildings compared with the regular building.
3. The inter storey drift also increases as the increase in the number of storeys. The storey drift is more for the floating column buildings because as the columns are removed the mass gets increased hence the drift.
4. As the mass and stiffness increases the base shear also increases. Therefore, the base shear is more for the floating column buildings compared to the conventional buildings.

Hence, from the study it can be concluded that as far as possible, the floating columns are to be avoided especially, in the seismic prone areas.

SARITA SINGLA et. al. [2015], investigates the effects of the structural irregularity which is produced by the discontinuity of a column in a building subjected to seismic loads. In this paper static analysis and dynamic analysis using response spectrum method is done for a multi-storied building with and without floating columns. Different cases of the building are studied by varying the location of floating columns floor wise and within the floor. The structural response of the building models with respect to Fundamental time period, Spectral acceleration, Base shear, Storey drift and Storey displacements is investigated. The analysis is carried out using software STAAD Pro V8i software. A 12.5m x 24m multi-storied building (G+6), with special moment resisting frame was selected for study. The building has a one brick thick exterior wall along the periphery and all the interior walls are half brick thick. It was considered to be located in Zone IV on Type II soil. In this study first a normal building (NB) without any floating columns is modeled. Then, two types of models, namely 1 and 2 are modeled. In model 1, the floating columns are located at ground floor and in model 2 they are located at first floor. For each model three different cases are studied by varying the location of floating columns. In all six cases have been studied namely-NB, 1A, 1B, 1C, 2A, 2B and 2C.

For the analysis purpose two models have been considered namely as:

MODEL 1 – Building in which floating columns are located at ground floor.

MODEL 2 – Building in which floating columns are located at first floor.

MODEL 1 – Following cases have been considered under this model based on the location of floating columns –

CASE 1A – Corner columns and alternate columns in exterior frame along the two long edges are floating columns.

CASE 1B – Corner columns and all the columns in the centre most frame along the short edge are floating columns.

CASE 1C – Alternate columns in exterior frame along the two long edges except the corner ones and those in the centre most frame along the short edge are floating columns.

MODEL 2 – Following cases have been considered under this model based on the location of floating columns –

CASE 2A – Corner columns and alternate columns in exterior frame along the two long edges are floating columns.

CASE 2B – Corner columns and all the columns in the centre most frame along the short edge are floating columns.

CASE 2C – Alternate columns in exterior frame along the two long edges except the corner ones and those in the centre most frame along the short edge are floating columns.

Following are some of the conclusions which are drawn on the basis of this study.

1. It was observed that in building with floating columns there is an increase in fundamental time period in both X-direction as well as Z-direction as compared to building without floating columns (NB).
2. By introduction of floating columns in a building base shear and spectral acceleration decreases. Thus, it has this technical and functional advantage over conventional construction.
3. The storey displacements increase when floating columns are introduced in the building. The deflections were more in Model 1 as compared to Model 2, which proves that buildings with floating columns in ground floor are more vulnerable during earthquake. It was also observed that deflections increase marginally in that storey where floating columns are located.

A.P. MUNDADA et. al. [2014], studied the 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. Also they concluded that provision of floating column is advantageous in increasing FSI of the building but is a risky factor and increases the vulnerability of the building.

KEERTHIGOWDA B. S et. al. [2014], examined the adverse effect of the floating columns in building. Models of the frame are developed for multi-storey RC buildings with and without floating columns to carry out comparative study of structural parameters such as natural period, base shear, and horizontal displacement under seismic excitation. Results obtained depicts that the alternative measure of providing lateral bracing to decrease the lateral deformation, should be taken. The RC building with floating column after providing lateral bracing is analyzed. A comparative study of the results obtained is carried out for three models. The building with floating columns after providing bracings showed improved seismic performance. The main purpose of present study was to assess seismic performance of the RC building with floating columns and seismic performance of RC building with floating columns after providing lateral bracings. For this purpose response spectrum analysis (RSA) is performed considering three models (without floating columns, with floating columns and floating columns with bracings). Through the parametric study of storey drift, storey shear, time period and displacement, it was found that the multi-storey buildings with floating columns performed poorly under seismic excitation. Thus to improve seismic performance of the multi-storey RC building, lateral bracings were provided. The bracings improved seismic performance of multi-storey building considerably as different parameters such as storey drift, storey shear, time period and displacement improved upto 10% to 30%.

PRATYUSH MALAVIYA et. al. [2014], studied the effect of floating columns on the cost analysis of a structure designed on STAAD Pro V8i. For this purpose a 2 storied15mt x 20mt regular structure is considered for the study. Modeling, analysis, estimation and design of the structure is done separately on the software. Analysis is performed on the zone II, zone III, zone IV and zone V. It is concluded that in the framed structure with no floating columns the nodal displacements is minimum with uniform distribution of stresses at all beams and columns. As a result it is most economical.

PRERNA NAUTIYAL et. al. [2014], investigated the effect of a floating column under earthquake excitation for various soil conditions and as there is no provision or magnification factor specified in I.S. Code, hence the determination of such factors for safe and economical design of a building having floating column. Linear Dynamic Analysis is done for 2D multi storey frame with and without floating column to achieve the above aim i.e. the responses (effect) and factors for safe and economical design of the structure under different earthquake excitation. For the analysis purpose two models have been considered namely as:

Model A: Four storied (G+3) special Moment Resisting Frame (Case 1).

Model B: Six storied (G+5) special Moment Resisting Frame (Case 2).

From the study it is concluded that the base shear demands for medium soil are found higher than that of the hard soil in both cases (i.e. G+3 and G+ 6 models). As the height of the building increases, variation in base shear from medium to hard soil condition decreases. For different soil conditions (medium to hard) the max moments vary from 22- 26% for four storied building model and 16-26% for six storied building model. It has been found that max. variation in values of max. moments comes at the ground floor (26%) for both the cases whereas the min. variation comes at the top floor (22% for case 1 and 16% for case 2). It can further been concluded that as the height of the building increases the variation of max. moments gets reduced for different soil conditions.

SABARI S et. al. [2014], highlighted 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. FEM analysis carried for 2D multi storey frames with and without floating column to study the responses of the structure under different earthquake excitation having different frequency content keeping the PGA and time duration factor constant. The time history of roof displacement, inter storey drift, base shear, column axial force are computed for both the frames with and without Floating Column. It is concluded that by increasing the column size the maximum displacement and inter storey drift values are reducing.

SREEKANTH GANDLA NANABALA et. al. [2014], studied the analysis of a G+5 storey normal building and a G+5 storey floating column building for external lateral forces. The analysis is done by the use of SAP 2000. They also studied the variation of the both structures by applying the intensities of the past earthquakes i.e., applying the ground motions to the both structures, from that displacement time history values are compared. This study is to find whether the structure is safe or unsafe with floating column when built in seismically active areas and also to find floating column building is economical or uneconomical. Based on the investigation following conclusions were drawn.

1. By the application of lateral loads in X and Y direction at each floor, the displacements of floating column building in X and Y directions are less than the normal building but displacement of floating column building in Z direction is large compared to that of a normal building. So the floating column building is unsafe for construction when compared to a normal building.

2. By the calculation of lateral stiffness at each floor for the buildings it is observed that floating column building will suffer extreme soft storey effect where normal building is free from soft storey effect. So the floating column building is unsafe.

3. After the analysis of buildings, comparison of quantity of steel and concrete are calculated from which floating column building has 40% more rebar steel and 42% more concrete quantity than a normal building. So the floating column building is uneconomical to that of a normal building.

4. From the time history analysis it is noticed that the floating column building is having more displacements than a normal building. So floating column building is unsafe than a normal building.

The final conclusion is that do not prefer to construct floating column buildings. With increase in dimensions of all members also it is getting more displacements than a normal buildings and also the cost for construction also increased. So avoid constructing floating column buildings.

SRIKANTH.M.K et. al. [2014], studied the importance of explicitly recognizing the presence of the floating column in the analysis of building and also, along with floating column some complexities were considered for ten storey building at different alternative location and for lower and higher zones. Alternate measures, involving stiffness balance of that storey where floating column is provided and the storey above, are proposed to reduce the irregularity introduced by the floating columns. The high rise building is analyzed for earthquake force by considering two type of structural system. Frame with only floating column and floating column with complexities for reinforced concrete building. Analysis was carried out by using Extended Three Dimensional Analysis of Building Systems (ETABS) version 9.7.4 software. The entire work consists of four models (Model FC, Model FC+4, Model FC+HL, Model FC+4+HL). And these models were analysed for lower (II) and higher (V) seismic zones for medium soil condition. The results are tabulated for base shear, story drift and lateral displacements. The model having only floating column, the model having a floating column by increasing the height of the storey, the model having a floating column by heavy load on the slab where floating column is provided, and a last model in which floating column is provided by rising the storey height a heavy load on slab, these four models were analysed by changing the location of floating column firstly in the middle, outer and in edge of the frame of building. The models considered the present study are:

Model FC: Where **only Floating Column** is provided in a particular location, particular floor and in a particular zone.

Model FC+4: **Where Floating Column** is provided by **rising the Story Height by 4 m** in a particular location, particular floor and in a particular zone.

Model FC+HL: Where **Floating Column** is provided by applying **Heavy Load** on the slab, particular floor and in a particular zone. (Heavy load may be swimming pool, water tank or machinery room etc...)

Model FC+4+HL: Where **Floating Column** is provided by **rising the Story Height by 4 m** along with provision of **Heavy Load** in a particular location, particular floor and in a particular zone.

Based on the study the conclusions are as follows:

1. The models FC+4, FC+HL, FC+4+HL are not preferred in higher zones because the more displacement value according to code. In lower zones all models were preferred but while designing special care should be taken.
2. The displacement of the building increases from lower zones to higher zones, because the magnitude of intensity will be more for higher zones, similarly for drift, because it is correlated with the displacement.
3. Storey shear will be more for lower floors, then the higher floors due to the reduction in weight when we go from bottom to top floors. And with this if we reduce the stiffness of upper floors automatically there will be a reduction in weight on those floors so in the top floors the storey shear will be less compared to bottom stories.
4. The response of the building which is having only floating column will be less when compared to other (FC+4, FC+HL, FC+4+HL) models of the study.
5. The maximum value of Displacement and Drift are more for the models FC+HL and FC+4+HL than the models FC and FC+4, due to increment in weight.
6. Whether the floating columns on ground floor or in eight floors the displacement values increases when a floating column is provided in edge and middle than the outer face of the frame.
7. The multi-storey building with complexities will undergo large displacement then the model having only floating column.
8. In all models the displacement values are less for lower zones and it goes on increases for higher zone.
9. There is a sudden change in storey shear in models FC+HL and FC+4+HL it is due to the heavy load on the slab, so there should not be any a sudden change in load in upper floors.
10. The drifts are deviated more in model FC+4+HL compared to other models, particularly in above and below where floating column, which is provided in zone II and V so this model either be redesigned by replacing the properties of the model.

T.RAJA SEKHAR et. al. [2014], developed FEM codes for 2D multi storey frames with and without floating column to study the responses of the structure at different earthquake conditions having different frequency by keeping the PGA and time duration factor constant. The behavior of building frame with and without floating column is studied under static load, free vibration and forced vibration condition. The results are plotted for both the frames with and without floating column by comparing each other time history of floor displacement, base shear. 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. It is concluded that with increase in ground floor column the maximum displacement is reducing and base shear varies with the column dimensions.

3. PROBLEM FORMULATION AND ANALYSIS

The object of the present work is to compare the behaviour of multi-storey buildings having floating columns with and without shear walls under seismic forces. For this purpose three cases of multi-storey buildings are considered. To reduce lateral displacement and storey drift shear walls have been provided.

In case-I, total 8 storeys are provided. Building area provided is 28 m x 28 m upto lower 4 stores and 32 m x 32 m upto upper 4 storeys. The building is of (G + 7) configuration, having storey height of 3.6m. The columns are provided in 4m x 4m grid form. Shear walls are placed at the centre of plan.

The sizes of beams are taken as 300mm x 500mm throughout the height of building.

The sizes of columns are taken as 400mm x 400mm at interior columns and 600mm x 600mm at periphery columns.

The thickness of shear wall is taken as 150mm.

In case-II, total 12 storeys are provided. Building area provided is 28 m x 28 m upto lower 4 stores and 32 m x 32 m upto upper 8 storeys. The building is of (G + 11) configuration, having storey height of 3.6m. The columns are provided in 4m x 4m grid form. Shear walls are placed at the centre of plan.

The sizes of beams are taken as 300mm x 500mm throughout the height of building.

The sizes of columns are taken as 400mm x 400mm at interior columns and 600mm x 600mm at periphery columns.

The thickness of shear wall is taken as 150mm.

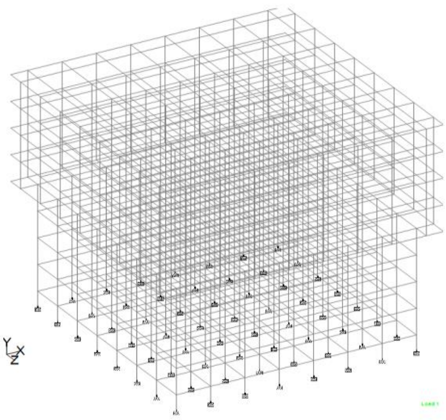
In case-III, total 16 storeys are provided. Building area provided is 28 m x 28 m upto lower 4 storeys and 32 m x 32 m upto upper 12 storeys. The building is of (G + 15) configuration, having storey height of 3.6m. The columns are provided in 4m x 4m grid form. Shear walls are placed at the centre of plan.

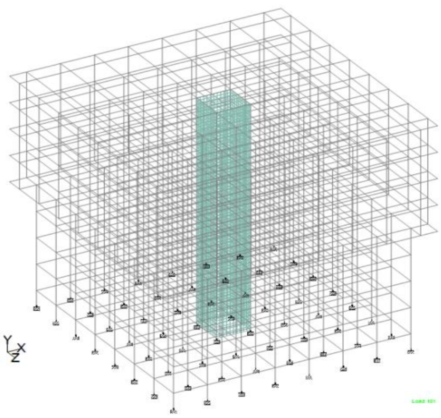
The sizes of beams are taken as 300mm x 500mm throughout the height of building.

The sizes of columns are taken as 400mm x 400mm at interior columns and 600mm x 600mm at periphery columns.

The thickness of shear wall is taken as 150mm.

To study the behaviour the response parameters selected are lateral displacement and storey drift. All the cases are assumed to be located in zone III, zone IV and zone V. All the three cases are analysed with and without shear wall.





8 STOREY MODEL WITHOUT SHEARWALL **8 STOREY MODEL WITH SHEARWALL**

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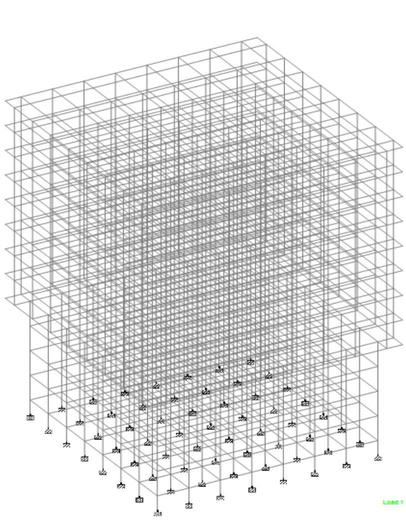
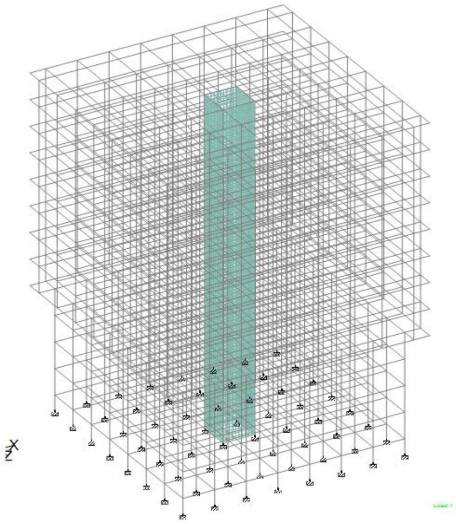
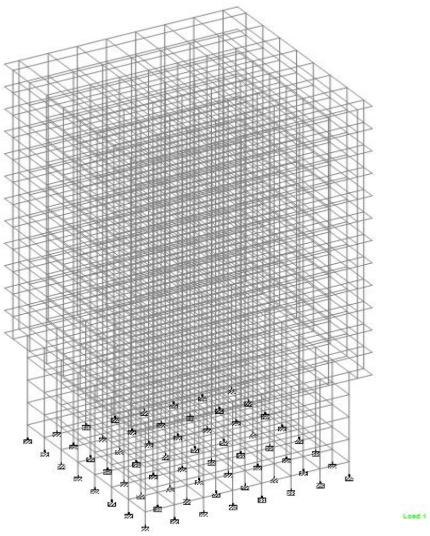


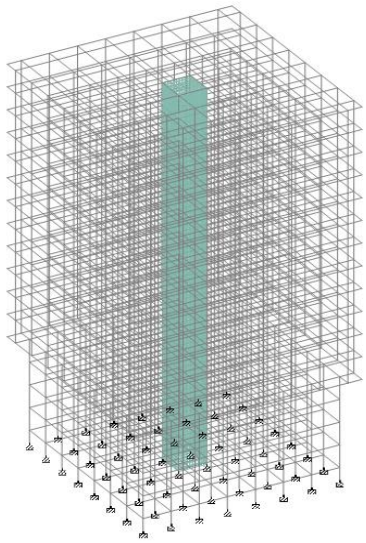
12 STOREY MODEL WITHOUT SHEARWALL



12 STOREY MODEL WITH SHEARWALL



16 STOREY MODEL WITHOUT SHEARWALL



16 STOREY MODEL WITH SHEARWALL

4. CONCLUSION

Within the scope of present work following conclusions are drawn:

1. For all the cases considered drift values follow around similar path along storey height with maximum value lying somewhere near about the middle storey.
2. For all the models considered displacement values follow around similar gradually increasing straight path along storey height.
3. In all the models storey drift and displacement values are less for lower zones and it goes on increases for higher zones because the magnitude of intensity will be the more for higher zones.
4. The storey drift and displacement is more for floating column buildings because as the columns are removed the mass gets increased and hence drift and displacement also increases.
5. By providing shear wall drift and displacement values reduces as compared to without shear wall models for all the zones.
6. As drift values are safe within maximum permissible limits in without shear wall models so there is no necessity of providing shear walls from drift view point.

7. In zone IV 16 storey building model, zone V 8 storey and 12 storey building models displacement values crosses the maximum permissible limits in case of without shear wall but it becomes safe in case of building models with shear wall.
8. In zone V 16 storey model is not safe for both without and with shear wall. Hence it is advised to increase size of column to reduce the displacement values.

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