STUDY ON CONFIGURATIONS OF FLOATING COLUMNS IN AN ASYMMETRICAL IRREGULAR RC FRAMED BUILDING UNDER EARTHQUAKE LOADING

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Abstract

In the present scenario, due to less availability of space and more population, in multi storey buildings (both residential and commercial) an open space is reserved for parking, assembly hall or for auditorium purposes generally at the ground floor. To comply with the need of large open spaces without or with minimal use of columns, Floating Columns were introduced. Floating Columns are the columns which rest on beams and do not have foundation. These columns have a discontinuous path for load transfer hence they are considered unsafe from earthquake point of view. Various configurations of floating columns are studied throughout the study done by various authors. Their effect on the structure is compared with buildings without floating columns, for different seismic zonal areas and safest configuration of floating column is found out.

Keywords: Floating Column, Storey Drift, Drift reduction factor, Storey Displacement, lateral displacement.

1. INTRODUCTION

Column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The floating column is also the vertical member but it starts from the lower story level and cannot transfer the load up to foundation. It rests on the transfer beam and this beam transfers the forces to the column below it. Conventional Civil Engineering structures are designed on the basis of strength and stiffness criteria. In case of earthquake forces the demand is for ductility. 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 .The behavior of a building during earthquakes depends mainly on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. 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. It sometimes becomes necessary to avoid columns at one or more storeys even in zones with high earthquake risk. To minimize the risk in such cases, shear walls, infill walls and diagonal struts are introduced. They are helpful in providing better stiffness and stability to such structures.

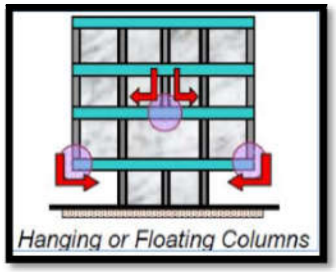

Fig 1: Floating Columns

1.1 Floating Columns

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.

1.2 Transfer Beam

In Frame as load carrying system when column is not allowed to continue downward due to some restriction, problem is resolved by using transfer beam. A transfer beam carries the load of an especially heavy load, typically a column. It is used to transfer the load of a column above to two separate columns below. This is often needed in cases where you need different or larger column spacing. One example where we often see transfer beams is in high rise buildings. These buildings often have retail spaces and parking garages at the lower levels and residential or office units on the upper levels. At the transfer beam , the column applies point load which is then transferred to the columns below (generally having larger cross section).

2. IRREGULARITIES

2.1 Plan Irregularity

2.1.1Torsion Irregularity: Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure.

2.1.2 Re-entrant Corners: Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction.

2.1.3 Diaphragm Discontinuity: Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.

2.1.4 Out-of-Plane Offsets: Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements.

2.1.5 Non-parallel Systems: The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

2.2 Vertical irregularities:

2.2.1 Stiffness Irregularity: Soft storey: A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storeys above. Extreme Soft Storey: An extreme soft storey is one in which the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three storeys above. For example, buildings on stilts will fall under this category.

2.2.2 Mass Irregularity: Mass irregularities are considered to exist where the effective mass of any storey is more than 150% of effective mass of an adjacent storey.

2.2.3 Vertical Geometric Irregularity: Geometric irregularity exists, when the horizontal dimension of the lateral force resisting system in any storey is more than 150% of that in an adjacent storey.

2.2.4 Discontinuity in capacity: Weak Storey: A weak storey is one in which the storey lateral strength is less than 80% of that in the storey above, the storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction.

2.2.5 In-Plane Discontinuity: An in Vertical Elements Resisting Lateral Force An in-plane offset of the lateral force resisting elements greater than the length of those elements.

Illustrative diagrams for the above irregularities are shown in the following pictures.

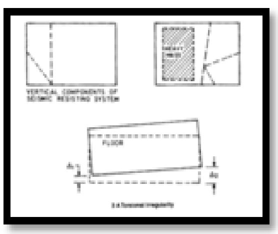

Fig 2: Torsional Irregularity

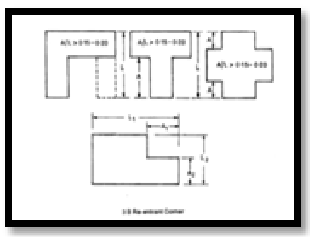

Fig 3: Re-entrant Corner irregularity

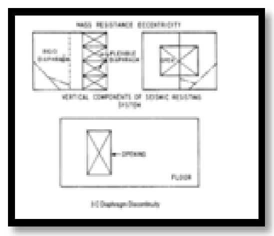

Fig 4: Diaphragm Discontinuity

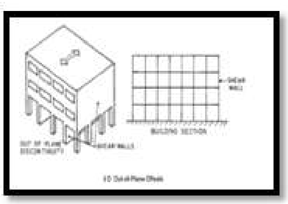

Fig 5: Out-of-plane offsets

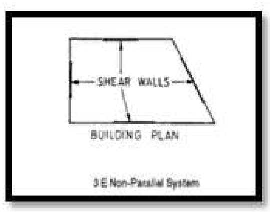

Fig 6: Non Parallel System

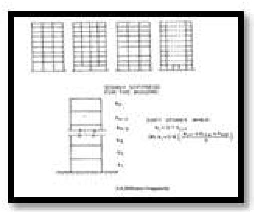

Fig 7: Stiffness irregularity

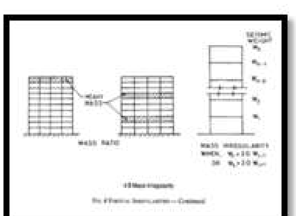

Fig 8: Mass Irregularity

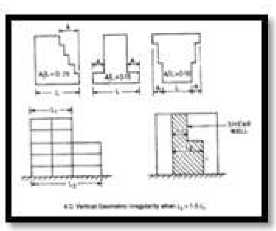

Fig 9: Vertical Geometric Irregularity

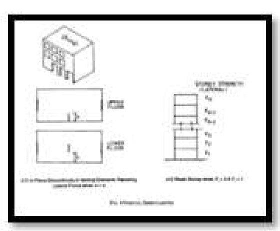

Fig 10: In-Plane Discontinuity

3. OBJECTIVE

In the review paper, a deep study is done about the floating columns in various aspects. Majorly this study is about various configurations of floating columns in a building which is most effective with strength of structure point of view. The objectives of is paper are as follows:

[1] Study of various configurations of floating columns in a building.
[2] To study analysis on irregular and asymmetrical structures.
[3] To study the effect of Floating Column on Building Performance subjected to Lateral Load.
[4] To study the response of floating columns in a multi-storey building.

4. Literature Review

1) Shehal Ashok Bhoyar et al. in 2017 carried an analysis on "Effect of Floating Column on Building Performance subjected to Lateral Load" on a framed structure of G+5 regular and irregular plan with and without floating columns .This project is only focused on the corner floating columns. This was done for external lateral forces .Using ETABS , shear base , story drift and lateral displacement of both the buildings were compared . The method adopted for above analysis is equivalent static method. It was found the buildings with floating column (both regular and irregular) are more prone to failure. Performance of the building varies to according to position and orientation of floating column.

9) Prerna Nautiyal et al. **in February 2014**, performed "Seismic Response Evaluation of RC frame building with Floating Column considering different Soil Conditions". .This paper aims to study the effect of a floating column under earthquake excitation for various soil conditions. Also 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 aims. For the analysis purpose two models have been considered 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)

For these 2 models, various positions of floating columns on each floor are taken. These cases are analyzed for seismic zone V for medium and hard soil type. Result of RSA for varying soil conditions has shown that the base shear demands for medium soil is found higher than that of the hard soil in both cases. The magnification factor evaluated for base shear and moments for object two in case of G+3 building model has been found in the range of 0.73 – 0.96 for base shear, 0.69 to 2.4 for moments in interior and exterior columns and 0.89 – 2.74 for moments in beams. The magnification factor in the case of G+6 has been found in the range of 0.8-0.98 for base shear, 0.71 to 2.95 for moments in interior and exterior columns and 0.9 – 3.6 for moments in beams.

3) Bhavya BS et al. in 2016, performed an analysis of "Reinforced Concrete unsymmetrical building with Floating Columns and Soft Storey considering different configuration" on a G+7 structure situated in seismic zone III and V on a medium soil (type II). The plan was remodeled into 12 different models . Equivalent seismic analysis and Response Spectrum Method were used for analysis by ETABS 15.2.0 software. The effect of shear wall , infill walls with diagonal structure and bracings were introduced in the building to improve the seismic performance of building along with floating column in seismic areas. The results found that the displacement and storey shear of building increases from lower zones to higher zones. Storey shear reduces in the building with floating column. The building with shear wall configuration exhibits more stiffness compared to other models. On comparison with other configurations, building with shear wall is much preferred.

4) KV. Sudheer et al. in 2015, carried the "Design and Analysis a high rise building with and without Floating Column". A 16 storey building is analyzed for storey shear , lateral displacement and storey drift using ETABS . Floating columns were introduced from 11th storey . By applying various loads and combinations study is done to find out whether the structure is safe or not . Extreme storey drift was calculated at 5th and 6th stories of the building also floating column building was found uneconomical .

5) Ms. Waykule S.B. et al. in January 2017, performed an analysis of "Comparative Study of Floating Column of multi storey building by using software". In this paper , analysis of G+5 building is done with and without floating column in highly seismic zone for hard soil . Linear static method and time history methods were carried out to compare the result between both models . From linear static method , time period , base shear , storey displacement , storey drift were calculated . With the help of time history , response of all the models were plotted using SAP 2000 V17 software .4 models are created such that floating column were created at 1st ,2nd ,3rd floor building and without floating column building .It was observed that as the floating column shifts from 1st storey towards the top , time period , base shear , storey drift and storey displacement is increased.

6) SK. Abdul Rehman et al. in March 2017 performed a "Seismic Analysis of Framed Structures with and without Floating Columns" . A G+5 modeled framed structure was assumed in earthquake zone III . In the first model , no floating columns were kept while in the second model, floating column was introduced at the ground floor. On ETABS software, equivalent static method , response spectrum method and time history method observations for base shear , storey drift and displacement were found out . The results were compared using Bar Graphs. Analysis found that buildings with floating column are not safe under earthquake loading.

7) Shiwli Roy et al. in August 2015 performed analysis on "Comparative studies of Floating Column of different multistoried building" studied about the floating columns in different multistoried buildings. Floating columns in G+3 , G+5 and G+10 structures were analyzed. Comparison was done on bending moment and shear force between these structures. Analysis of the frame structures was done on STAAD PRO V8i.

Conclusion from the analysis was found that shear force and bending moments are same for all the columns on same floor but it increases with increase in height of the structure. The variation in bending moment and structure shows that bending moment is max for column on ground floor. For comparison of floating column in a G+3 structure , the variation in shear force shows that shear force is max in floating column located at ground floor . The shear force of normal columns is less than floating column. Bending moment is max in floating column on 1st floor.

8) Trupanshu Patel et al. in May 2017 performed "Effect of floating column on RCC building with and without infill wall subjected to seismic force". Author the behavior of G+3 building with floating column. The entire work consisted of 29 models, modeled and analyzed using SAP 2000. Analysis was done for the location of Surat city which belongs to zone III, medium soil condition. The 29 models were divided into 4 categories : a) Model 1: without floating column and infill walls. b) Floating columns at corner, internal and center locations of GF, FF, SF. c) Increment in live load on ¼ portion of typical floor above the discontinued columns on the corner, internal and centre floating columns at GF, FF, SF. d)Similar as model 1-10 with infill walls.

It was found that floating columns at corners on any floor shows poor performance compared to others. The incremental load considered in model on one side gives 5% increase in eccentricity which does not make major changes in displacement. Infill walls provide seismic strengthening and reduce seismic response of building. Infills also reduce horizontal displacement by 182.26% and vertical displacement by 140.03% in the floors. Provision of infill walls reduces the use of cement concrete as the size of structural members decreases thus makes the structure economical.

9) Umesh Patil et al. in July 2015, did a "Seismic Analysis of G+5 Framed Structures with and Without Floating Columns Using ETABS-2013 Software". In the paper G+5 storey RCC structure was considered for earthquake analysis. For comparison three models were used, one with normal structure, second with shear walls and third with masonry infill walls. Three methods Equivalent static method, response spectrum and time history method were used for analysis using ETABS2013 Software. The structure was assumed to be situated in earthquake Zone III on a medium soil(type II). The parameters evaluated were Base shear, Storey drift and Displacement. Out of all the three methods used to evaluate base shear and storey drift ,Multi-storey building with shear walls has performed exceedingly well when compared with normal multi-storey and shear walls. While in case of displacement, building with masonry infill walls has performed better.

10) Isha Rohilla et al. carried out a "Seismic Response of Multi-storey Irregular Building with Floating Column". In this paper, the critical position of floating column in vertically irregular buildings was discussed for G+5 and G+7 RC buildings for zone II and zone V. medium soil conditions were used for analysis. Also the effect of size of beams and columns carrying the load of floating column had been assessed. The response of building such as storey drift, storey displacement and storey shear had been found. To evaluate the results ETABS software was used. From the analysis the author concluded that: Floating columns should be avoided in high rise building in zone 5 because of its poor performance while they are safe in zone2. Storey displacement and storey drift increases due to presence of floating column. Storey shear decreases in presence of floating column because of reduction mass of column in structure. 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 decrease storey displacement and storey drift in upper floors so dimensions should be increased in two consecutive floors for better performance of building.

11) Y.Abhinay et al. 2017 made a "Comparison of Seismic Analysis of a Floating Column Building and a Normal Building". In the analysis, residential buildings with 6 Storeys and 12 Storeys are analyzed with column, Beams & Slabs. The buildings are analyzed & designed with and without edge columns at base storey. The Buildings are analyzed in two earthquake zones III and V according to IS 1893-2002 with soil type I and III. Static Load combinations and Response Spectrum Analysis is done to compare the results. Results are compared in the form of Storey displacements, Storey Shear, Storey Over turning Moments with & without columns at base storey in both Static and Dynamic Analysis. ETABS 2013 has been utilized for analyzing the above Building Structure. Zone wise results are presented using tables and graphs. Three cases were made , Case 1: Normal building without floating column, Case 2:Building with floating column, Case 3: Building with floating column and with changed dimensions of beams and columns. It was found that the displacement, shear and moment is more when the floating column is provided to reduce the displacement the section properties of the building are changed for better performance. Floating column building will suffer extreme soft storey effect. So the Floating column building is unsafe. After the analysis of buildings, comparison of quantity of steel and concrete are calculated from which it is to be identified that floating column building with change in dimensions has 40 % more quantity of rebar steel and 42 % more concrete quantity than Normal building. So the Floating column building is uneconomical to that of a Normal building.

5. CRITIQUE

Vast research has been done related to Floating Columns by various authors within last four years. Various configurations and positions of floating columns have already been adopted and several conclusions have been found out in various parameters like storey drift, displacement, shear force etc. in both regular and irregular buildings, former being more. Floating columns buildings were the majorly damaged structures in Bhuj earthquake, 2001. So it is very important to find a solution to the bad response of floating column buildings under earthquake loading. For this various researches have been done.

Researchers have concluded that floating columns are not good where earthquake loading is considered. Also they have been found cost ineffective as they use more quantity of material than normal columns. The study of various research papers have proved that the behavior of floating columns depend mainly on the position and orientation of floating column in a building. Due to its ineffectiveness in all fields, its introduction along with shear walls, infill walls and struts and bracings have been introduced.

6. CONCLUSION

The study proves that failure of storeys having floating columns can have a serious effect and collapse of the building. Hence, floating columns should be avoided as far as possible in seismic regions and if they are unavoidable, then the structure should be strengthened by adopting some remedial features such as infill, bracings and shear wall etc. As far as possible irregularities in a building must be avoided. But, if irregularities have to be introduced for any reason, they must be designed properly following the conditions of IS 1893-part-1: 2002 and IS-456: 2000, and joints should be made ductile as per IS 13920:1993. Now a days, complex shaped buildings are getting popular, but they carry a risk of sustaining damages during earthquakes. Therefore, such buildings should be designed properly taking care of their dynamic behavior.

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