Structural Behavior of RC Buildings with Floating Columns on Sloped Terrain Under Seismic Forces

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Abstract: *In some parts of world, hilly area is more prone to seismic activity; e.g. northeast region of India. In this hilly regions, traditionally material like, the adobe, brunt brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multistorey buildings on hill slope in and around the cities. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic codal provisions have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground motions. Little information is available in the literature about the analysis of buildings on sloping ground. The investigation presented in this paper aimed at predicting the seismic response of RC buildings with different configuration on sloping and plain ground.*

Keywords: *Equivalent static method, Floating Column, Lateral loads, Maximum story drift, Response spectrum method, Seismic force.*

I. INTRODUCTION

If irregular features like floating columns are added in buildings, a considerably higher level of engineering efforts are needed in the structural design and yet the building may not be as good as one with simple architectural features. Many multi-storey buildings also have open first storey as an irregular future. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. The behaviour of a building during seismic action depends critically on its overall size, shape and geometry, also how the earthquake forces are carried to the foundation of building. The seismic forces developed at different floors in a building need to be carried down along the height to the ground by the shortest way; any deviation or discontinuity in this load transfer path results in poor performance of the normal building. Buildings with vertical irregularities (like the hotel buildings with a few storeys wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity and deviation. Buildings that have less columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. There are lots of building structures with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. There are buildings having columns that hang or float on beams or girder at an intermediate storey and do not go all the way to the foundation, have discontinuities in the load transfer path.

Floating Column

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground, and the term "Floating Column" is also a vertical element which at its lower level rests on a beam which is a horizontal member.

A common form of discontinuity in load path in moment frames arises with a floating columns, i.e., when a column coming from top of the building is discontinued at a lower level, usually at the ground storey. In such cases, loads from the overhanging portions take a roundabout way and travel to the nearest column that is continuous till the foundation. This leads to increased demand on the columns in the ground storey and can cause failure of these columns. Usually these high-rise and architectural complex buildings showed a least serviceable behaviour during past earthquakes.

There are many projects in India in which floating column are already adopted, especially above the ground floor, where the transfer girders are employed, so that more open space is available on the ground floor, and these open spaces may be required for assembly hall or parking purpose.

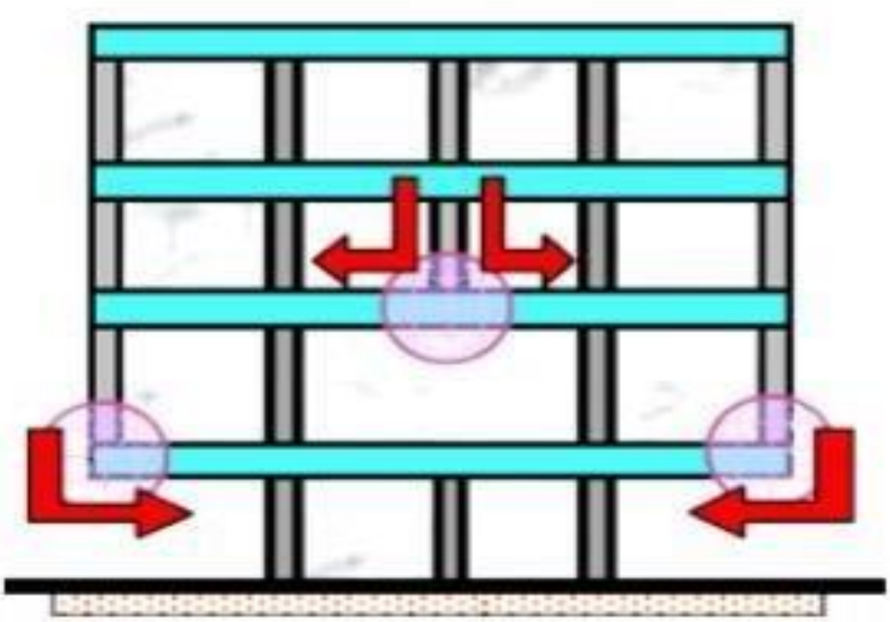


Figure 1. Building with Floating Column

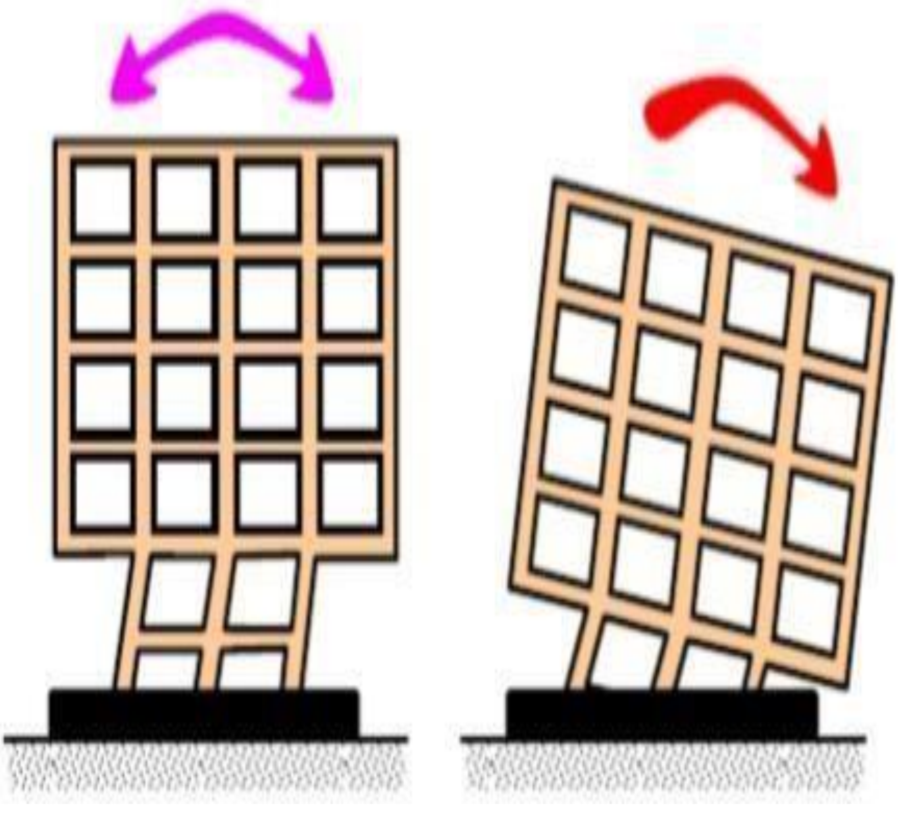


Figure 2- Buildings with floating columns: Overloading of columns in ground storey cause failure of buildings with floating columns during strong earthquake shaking

The column is a concentrated load on the beam which supports it in this condition. Hence the structures already made with these kinds of discontinuous members are endangered in seismic regions. If we will do so much calculation for a multi-storey tall building manually then it will take more time as well as human errors can be occurred which affect results. So, the use of STAAD-PRO will make it easy. STAAD-PRO can solve typical problem like Static analysis, Seismic analysis and Natural frequency. These types of problem can be solved by STAAD- PRO along with IS-CODE.

In this study, the behavior of the multi-storey buildings with floating columns at higher seismic zones using STAAD Pro are modelled and analyzed.

II. LITERATURE REVIEW

Now a day's lots of multi-story buildings are constructed with floating column for purpose of getting more space at parking areas for movement. But same case highly damaged during highly seismic zone as compared to normal building in earthquake. And this work also studies the related literature associated with seismic behaviour of multi-story building with and without floating column considered.

Abbawi, Z.W.S. 2024 In this study seismic performance of multistoried building with and without floating column and buckling analysis of columns are carried out and five and ten stories structure models are used which are located at zone IV. Static and dynamic analysis of all models carried out STAAD,PRO software. This study is abstract to spot the structural response for parameters like floor displacement, base shear, shear force, bending moment for the columns. It is also carried out to determining the elastic critical load for elastic buckling. This critical load used to determination of the corresponding member strength. The seismic analysis the different type of RCC Framed structure which are with or without floating column which are located in a seismic zone IV at a medium soil. In this observed that if floating column are used in framed structure it will reduce the dead load of structures. Storey Drift is decrease with increase the height of structure in each model. This study also represent the end forces decrease if floating column are started from5th floor level than the 2nd floor level

G.B. Bhaskar 2023 defined the Estimation of storey of a building with mass and stiffness variation due to seismic excitation. This paper investigate the proportional distribution 10 of lateral forces evolved through seismic action in each storey level due to changes in mass and stiffness of building. The result concludes as a building structure with high mass and stiffness ratio provides instability of huge storey shear. A proportionate amount of mass and stiffness distribution is advantages to control over the storey and base shear.

C.M. Deshmukh 2023 In this paper present study about analysis of G+5 Building with and without floating column in highly seismic zone v. Two models are created such as floatingcolumn at 1stand without floating column building. Linear static and time history analysis are carried out of all the two models .from linear static analysis compare all the of models result obtained in the form of seismic parameter such as time period, base shear, storey displacement, storey drift .and from time history analysis plot the response of all the models .modeling and analysis done by using sap 2000v17 software.

Kim, J.M., Lee, H.J. and Ryu, J.H., 2023 investigated the elastic buckling of steel column with three different cross section i.e. square, rectangle and circle cross section and two different boundary condition i.e. fixed-free (FF) and pinned-pinned(PP) under the axial compression. The solution and effect of boundary condition , cross section, slenderness ratio on the buckling load of the steel column not only numerical computation have been performed but also finite element modeling are used for this. They conclude that The square section has a most efficient shape of column against buckling but the rectangular section has least efficient shape in both FF and PP boundary conditions. The square cross section has the lowest slenderness ratio than the rectangular cross section in both FF and PP.

Amit Jay Daksh, Dr. Sharad Kumar Soni (2022) carried out study to analyse the building with floating columns and to find out its comparison with the building without floating column with different soil in terms of storey drift, base shear and time period frequency using Staad Pro V8i (SS4) software. They concluded that After locating building on slopping ground (In study slope of 10 degree to be provided), for that much amount of slope the structure will not give too much variation on basis of each parameters except natural frequency and time period which tends to more stability on red soil as compared to normal building.

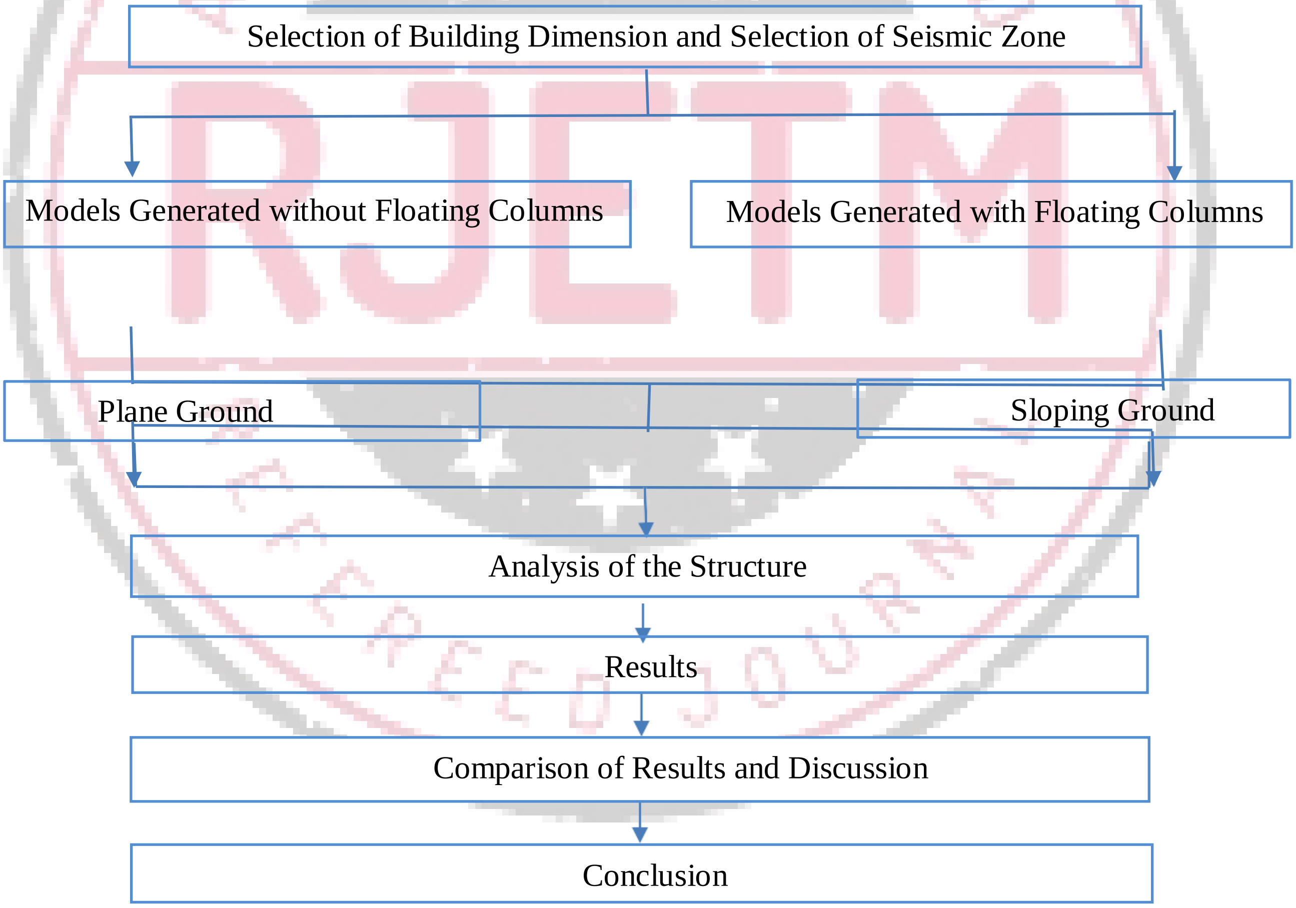
Deepak Jain, Dr. Savita Maru (2021) concluded that the building with floating column has more time period as compared to building without floating columns. The building with floating column has less base shear as compared to building without floating column. Floating column building has more displacement as compared to without floating column building. Building with floating column has more storey drift as compared to building without floating column. Floating column at different location results into variation in dynamic response. Building with floating column are more vulnerable in high seismic zone than buildings without floating column. Building without floating column are more economical than building with floating column. Hard soil type is more feasible to construct buildings with floating column. Soft and loamy soil is not at all safe for the floating column buildings.

Akshay Gajbhiye, Aswin C.P (2021) In the present analysis, 8 models are studied. The first model considers a multi-storeyed building without any shear wall and floating column. Other models analysed are with shear wall and by varying the location of floating columns. The analysis and design are done by STAAD.pro V8i SS6 version software and the method used is response spectrum analysis in earthquake zone 4. The effect of floating column location on parameters such as Base shear, Displacement, Maximum moment, storey shear and percentage of steel reinforcement are discussed. The comparison of results of different models is also carried out in detail using graphs and bar charts in this study. The suitable location for providing a floating column with the shear wall is also discussed. Use of floating column results in the increase of base shear, maximum moment, peak storey shear and percentage of steel reinforcement. It is clearly shown that the use of a shear wall in the structure gives the best behaviour of the structure as compared with the normal building.

Vishwanth T. Kambale, V. S. Kshirsaga (2021) Concluded that Drift of a specific story increments because of the presence of floating column in the structure. It has been seen that chances of failure of buildings of structures with floating column are a lot higher when contrasted with the structures.

III. RESEARCH METHODOLOGY.

In our study comparison of various building having orderly decrease in length of floating column on plane and slopping ground (slope of 100 in this study) condition under presence of seismic force. Here G+4 building (15.8 m height) is considered and dead load, live load, infill wall load, floor load etc are applied for its behaviour and comparison. The response of all the structure is studied for useful interpretation of results.



Flow Chart

The study is carried out to analyse the building with floating columns and to find out its comparison with the building without floating column in terms of storey drift, base shear, time period and frequency using Staad Pro V8i (SS4) software.

Building Description

Model consists of G+4 storey RCC building having four bays in each direction with width of bay as 4m. The story height for 1st storey to 4th storey is 3.2m and ground storey height is kept as 3m respectively. The RCC frame consists of beam of sizes 0.23m x 0.4m and column sizes 0.4m x 0.23m for columns of 1st,2nd,3rd,4th storey and 0.4m × 0.4m for ground storey respectively. Slab thickness is taken as 150mm. The models are analysed on plane as well as sloping ground (slope of 100 in this study). The frame on sloping ground under consideration for present study is as shown in Figure 3.2. The concrete of grade M20 and steel of grade Fe 415 are used.

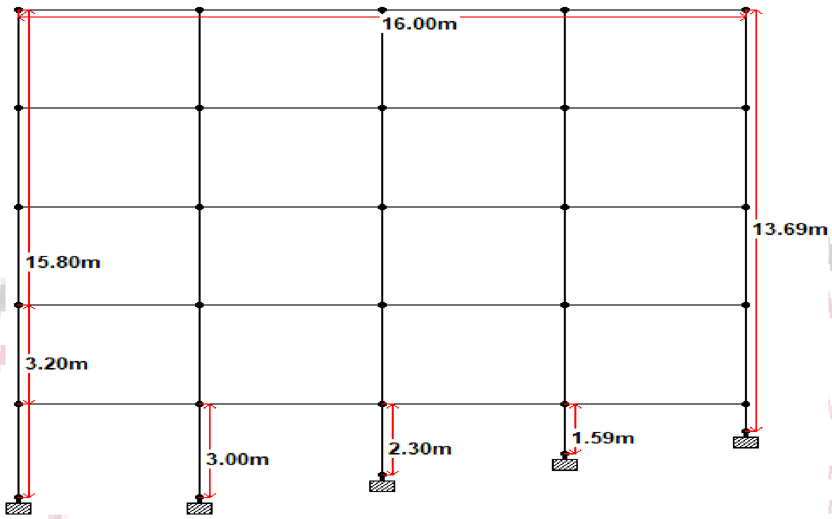


Figure 3 Building frame on sloping ground

Loads

1) Dead Load

Dead load of each floor = 11.9 KN/m2 (include floor load, floor finish load and brick infill load as per relevant IS code).

2) Live Load

Live load on floors = 4 KN/m2 (as per IS 875 part 2 for residential and commercial building.

Table1 Building description

S.no	Specification	Plane Ground	Sloping Ground (10^0)
1	Plan dimension	16 x 16 m	16 x 16 m
2	Length in x- direction	16 m	16 m
3	Length in z- direction	16 m	16 m
4	Storey height	1st to 4th -3.2 m Ground -3.0m	1st to 4th -3.2 m Ground -3.0m
5	No. of storeys	G+4	G+4
6	No. of bays	4*4	4*4
6	Soil type	Medium Soil	Medium Soil
7	Seismic zone	5	5

IV. MODELLING AND ANALYSIS

Modeling

The G+4 building is modelled using software Staad Pro V8i (SS4). Total 10 models have to be made with different location of Floating Columns. Five models are considered on plane ground condition and five other models are considered on sloping ground. Floating Columns located on first storey, second storey and further up to top storey in different models.

Beams and columns are modelled with six degrees of freedom at each node. The area loads are applied on the slabs. The dead weight of infill is assigned as uniformly distributed load over beams. Fixed supports are considered for all columns with foundation.

The following models of building are considered

Model 1**-** Structure without floating column on plane ground

Model 2- Structure without floating column on sloping ground

Model 3- Structure with floating column on 1st floor on sloping ground

Model 4- Structure with floating column on 2nd floor on sloping ground

Model 5- Structure with floating column on 3rd floor on sloping ground

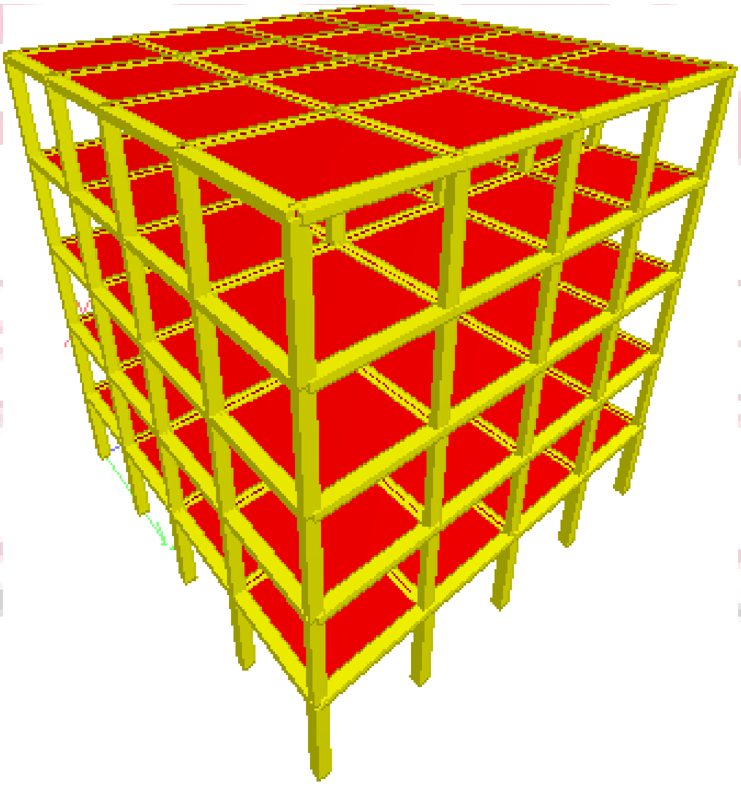
Model 6**-** Structure with floating column on 4th floor on sloping ground

Model 7- Structure with floating column on 1st floor on plane ground

Model 8**-** Structure with floating column on 2nd floor on plane ground

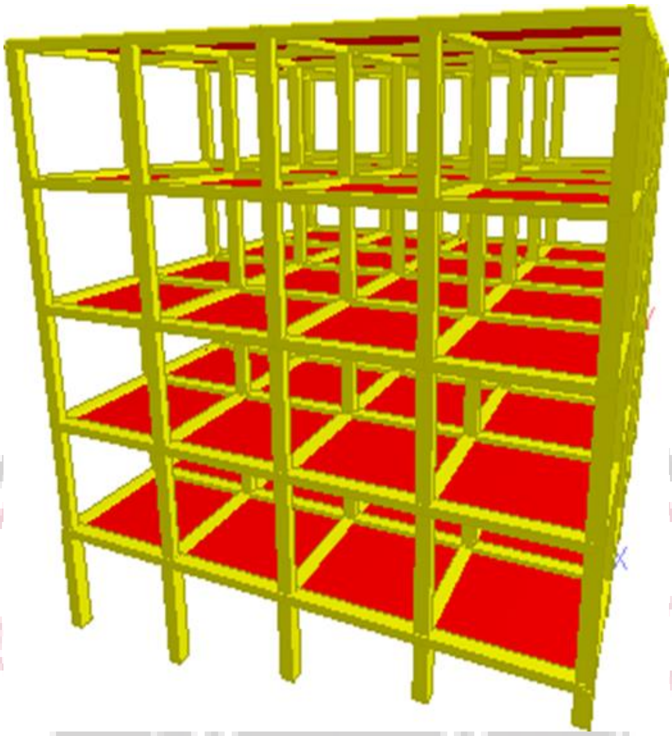
Model 9**-** Structure with floating column on 3rd floor on plane ground

Model 10- Structure with floating column on 4th floor on plane ground



Model 1- Structure without floating column on plane ground

Model 2- *Structure without floating column on sloping ground*



Model 2- Structure without floating column on sloping ground

In present study, comparison of seismic response parameters such as time period, base shear, storey displacement, storey drift and dynamic response are done by varying the location of floating columns storey wise by using linear static analysis. Results are compared in tabular form and graphically for the analysis of building on plane and sloping ground.

Natural frequencies of oscillation of a building depend on its mass and its stiffness (or flexibility).

$F = 2\pi(k/m)1/2$

Where, F= natural frequency in Hz k = stiffness of building

m = mass of building

"Building tend to have lower natural frequency when they are either heavier (more mass) or less stiff (that is more flexible)"

In this study after decreasing length of FC on ground conditions, stiffness decreases (or flexibility increases) and mass also decreases but due to dominant effect of stiffness, natural frequency decreases. At low natural frequencies, the structure can resonate (chances of matching the external frequency (By EQ or other loads) with natural frequency of building) easily which is susceptible condition for collapse of building.

V. CONCLUSION

After analysis of models based on presence of floating columns on the basis of various parameters, following conclusions are drawn: -

1. It is observed that building with Floating column has less natural frequency as compared to building without Floating column. It is also observed that when the location of floating column is changed from first floor to second floor and further upper floors the value of natural frequency goes on decreasing. Although there is slight increase in value of natural frequency when the floating column lies in the top storey. This shows poor performance of a building with floating columns during earthquake.
2. It is observed that building with Floating column has more time period as compared to building without Floating column. It is also observed that when the location of floating column is changed from first floor to second floor and further upper floors the value of time period goes on increasing. Although there is slight decrease in value of time period when the floating column lies in the top storey. This shows less stability and resistance against earthquake of a building with floating columns.

3. It is observed that building with Floating column has less peak storey shear as compared to building without Floating column. It is also observed that when the location of floating column is changed from first floor to second floor and further upper floors the value of peak storey shear of each storey goes on decreasing. Although there is slight increase in value of peak storey shear when the floating column lies in the top storey. Thus, it shows less resistance against earthquake force at base and other storey levels for a building with floating columns.

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