EARTHQUAKE RESISTANCE OF MULTISTORIED BUILDING WITH FLOATING COLUMNS USING E TABS

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ABSTRACT

The columns which are supported on a beam instead of rigid foundation are called as floating columns. Many of the buildings in India are constructed with floating columns. This is primarily beam adopted to accommodate parking or reception lobbies in the first story. The earthquake force generated at different floor level of the building need to be carried out to the foundation by the shortest possible way which may not be the case when floating columns are provided. Providing floating columns may satisfy some of the functional requirements but structural behavior changes abruptly due provisions of floating columns. The flexural and shear demand of the beams which supports floating columns are much higher than surrounding beams, this leads to stiffness irregularities at a particular joint. Columns are main lateral load resisting elements in moment resisting frame and play a vital role in seismic performance of building. The stiffness of the storey below the floating column is usually lower than the storey above and below it. In this thesis the seismic performance of building with floating columns are presented in terms of various parameters such as displacement, storey drift, maximum column forces, time period of vibration etc. The building having various locations of floating columns ie floating columns starting from different stories are considered for the study. The building is modeled by using finite element software ETABS. Equivalent static analysis and response spectra dynamic analysis are performed on the various buildings and their seismic performance is evaluated.

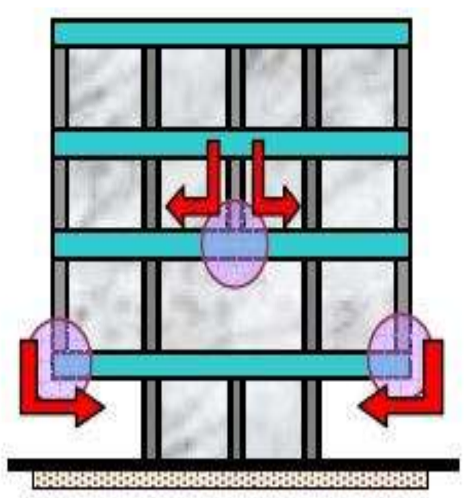
INTRODUCTION

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 behavior of a building during earthquakes depends critically 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. Buildings with vertical setbacks (like the hotel buildings with a few storey wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. 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.

What is floating column

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 (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.



Hanging or Floating Columns

There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. The transfer girders have to be designed and detailed properly, especially in earth quake zones. The column is a concentrated load on the beam which supports it. As far as analysis is concerned, the column is often assumed pinned at the base and is therefore taken as a point load on the transfer beam. STAAD Pro, ETABS and SAP2000 can be used to do the analysis of this type of structure. Floating columns are competent enough to carry gravity loading but transfer girder must be of adequate dimensions (Stiffness) with very minimal deflection.

Looking ahead, of course, one will continue to make buildings interesting rather than monotonous. However, this need not be done at the cost of poor behavior and earthquake safety of buildings. Architectural features that are detrimental to earthquake response of buildings should be avoided. If not, they must be minimized. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design and yet the building may not be as good as one with simple architectural features.

Hence, 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 or some remedial features can be suggested. The columns of the first storey can be made stronger, the stiffness of these columns can be increased by retrofitting or these may be provided with bracing to decrease the lateral deformation.

Some pictures showing the buildings built with floating columns:

40 Park Avenue South in New York, United States

Objective and scope of present work

1. To study the seismic response of the building with floating columns
2. To study and identify critical structural members in the building with floating columns
3. To study the flow of forces and increase or decrease in the column forces in the building

Scope of Study

1. To study the effect of floating column on the building
2. To evaluate the seismic forces in floating column

REVIEW OF LITERATURES

Current literature survey includes earthquake response of multi storey building frames with usual columns. Some of the literatures emphasized on strengthening of the existing buildings in seismic prone regions.

Maison and Neuss [15], (1984), Members of ASCE have preformed the computer analysis of an existing forty four story steel frame high-rise Building to study the influence of various modeling aspects on the predicted dynamic properties and computed seismic response behaviours. The predicted dynamic properties are compared to the building's true properties as previously determined from experimental testing. The seismic response behaviours are computed using the response spectrum (Newmark and ATC spectra) and equivalent static load methods.

Also**, Maison and Ventura** [16], (1991), Members of ASCE computed dynamic properties and response behaviours OF THIRTEEN-STORY BUILDING and this result are compared to the true values as determined from the recorded motions in the building during two actual earthquakes and shown that state-of-practice design type analytical models can predict the actual dynamic properties.

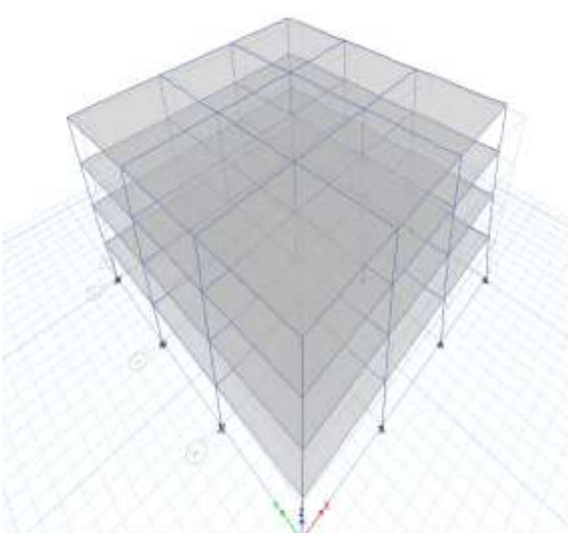
METHODOLOGY

Perform 3D model analysis by using ETABS software:

ETABS:

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS features an intuitive and powerful graphical interface coupled with unmatched modelling, analytical, and design procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of geometrical nonlinear behaviours, making it the tool of choice for structural engineers in the building industry (Computers and structures Inc. 2003).

The accuracy of analytical modeling of complex Wall Systems has always been of concern to the Structural Engineer. The computer models of these systems are usually idealized as line elements instead of continuum elements. Single walls are modelled as cantilevers and walls with openings are modeled as pier and spandrel systems. For simple systems, where lines of stiffness can be defined, these models can give a reasonable result. However, it has always been recognized that a continuum model based upon the finite element method is more appropriate and desirable. Nevertheless this option has been impractical for the Structural Engineer to use in practice primarily because such models have traditionally been costly to create, but more importantly, they do not produce information that is directly useable by the Structural Engineer.



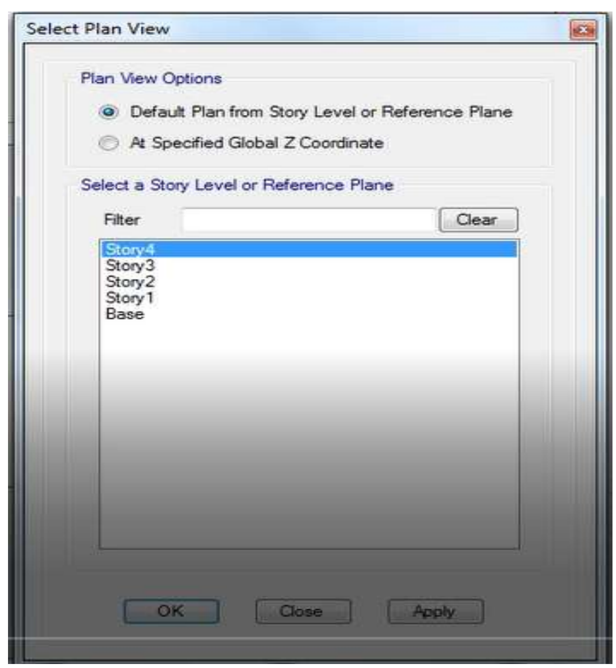
Perform-3D Model

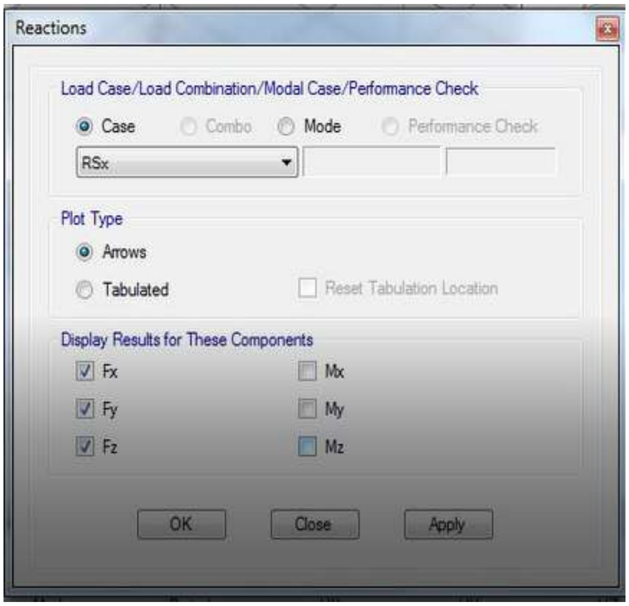
RUNNING ANALYSIS

Number of	=	98
With restraints	=	34
With mass	=	18
Number of frame/cable/tendon elements	=	158
Number of shell elements	=	36
Number of constraints/welds	=	4
Number of load patterns	=	13
Number of acceleration loads	=	6
Number of load cases	=	4

ANALYSIS IN ETABS

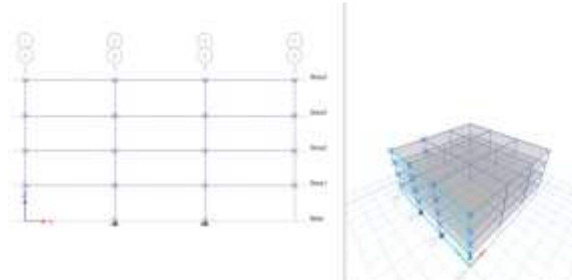
The first step in ETABS is to set the grid dimensions. This includes setting number of lines in X direction, Y direction and the spacing between grid lines. Then the storey data is defined which includes setting the number of stories, height of typical and bottom storey. The type of slab is also mentioned in the grid data.





There was good agreement between the response from the two analysis models. The Perform-3D model, which utilized fiber cross-section elements, had many events of nonlinearity while the ETABS lumped hinge model was bilinear. This behaviour was expected since the fiber cross-section element has a different stiffness with each iteration in displacement, while the frame element is linear until yielding occurs. Since the concrete walls in this project all had the same properties, hinging occurred simultaneously in all four in-plane loaded walls in a given direction, and there was correspondingly only one change of structural stiffness. It appears as though there is an approximately equal amount of area under each of the force-displacement relationships, satisfying the desired equal-energy principle discussed previously.

The first mode mass participation for the Perform-3D model was 82%, slightly greater than the 79% in the linear ETABS model and the 76% in the nonlinear ETABS model. There is an apparent trend in that the models exhibiting greater wall stiffness correspond to greater first mode mass participation, for which there is likely a lower tendency for the whiplashing effect that occurs in higher modes. Since the Perform-3D model uses uncracked section properties for wall stiffness in the modal calculation, it has the highest stiffness and the highest resulting first mode mass participation.



LINEAR EQUATION SOLUTION

Forming stiffness at zero (unstressed) initial conditions

Total number of equilibrium equations = 240

Number of non-zero stiffness terms = 4107

Number of Eigen values below shift = 0

<u>LINEAR STATIC CASES</u>

Using stiffness at zero (unstressed) initial conditions

TOTAL NUMBER OF CASES TO SOLVE = 1

NUMBER OF CASES TO SOLVE PER BLOCK = 1

RESULT AND DISCUSSION

The behaviour of building frame with and without floating column is studied under static load, free vibration and forced vibration condition. The finite element code has been developed in ETABS software.

Static analysis

A four storey two bay 2d frame with floating column are analyzed for static loading using the present FEM code and the commercial software *ETABS* .

. **Fig.** D Frame with usual columns

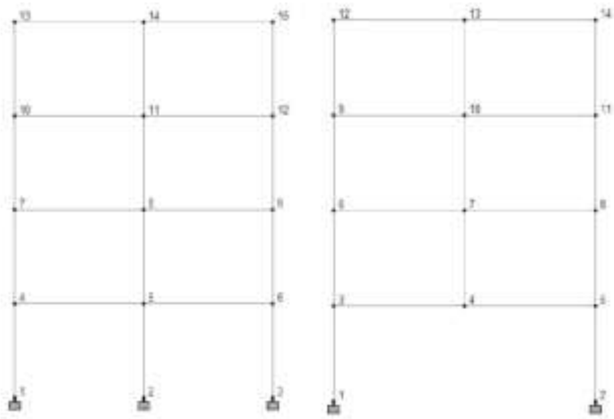


Fig: 2D Frame with Floating column

Table: shows the value of free vibration frequency of the 2D frame calculated in present FEM.

For the forced vibration analysis, a two bay four storey 2D steel frame is considered. The frame is subjected to ground motion, the compatible time history of acceleration as per spectra of IS 1893 (part 1): 2002.

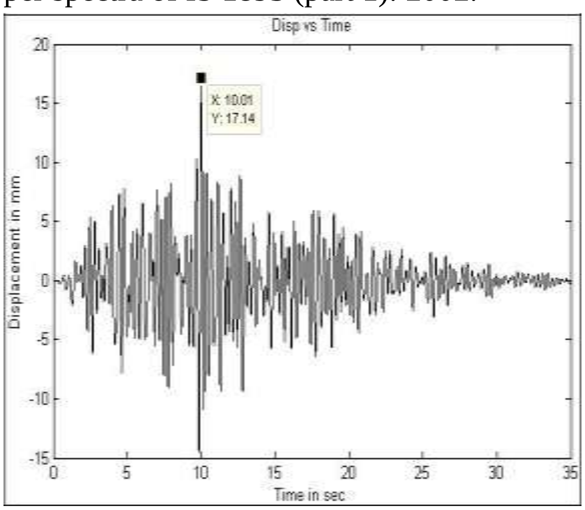


Fig. Displacement vs time response of the 2D concrete frame with floating column under IS code time history excitation

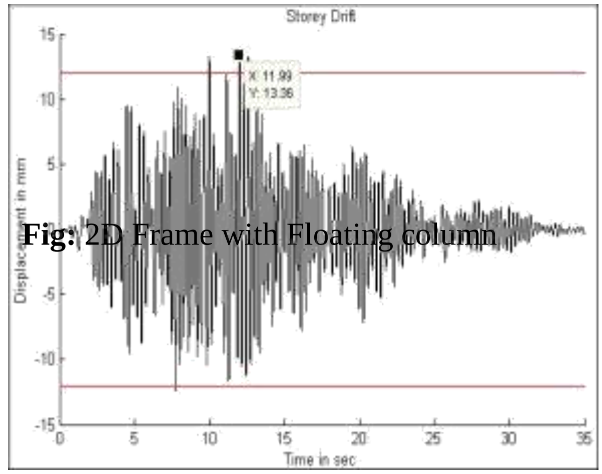


Fig. Storey drift vs time response of the 2D concrete frame without floating column under IS code time history excitation

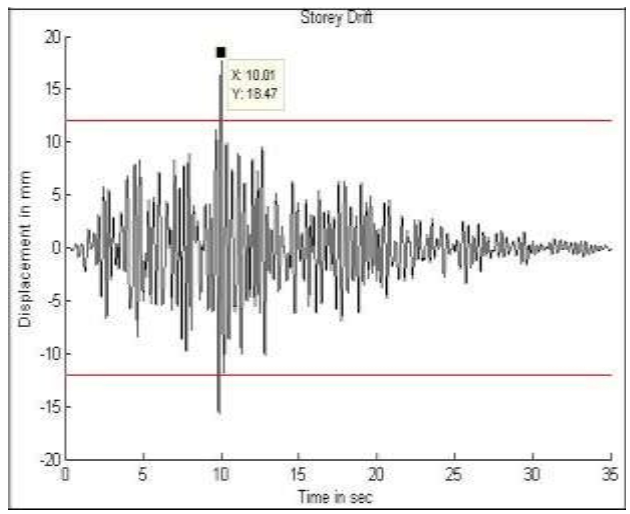


Table: Comparison of predicted storey drift (mm) of the 2D concrete frame with and without floating column under IS code time history excitation

Storey drift (mm)			
Max storey drift as per IS Code (0.004h)	**Frame with general columns**	**Frame with floating column**	
12	13.36	18.47	38.25

Table show that with the application of floating column in a frame the displacement and storey drift values are increasing abruptly. Hence the stiffness of the columns which are eventually transferring the load of the structure to the foundation are increased in further examples and responses are studied.

Tabular-result

Modal Participating Mass Ratios

Node Displacement Summary

TABLE: Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	UZ	Sum UX	Sum UY	Sum UZ	RX	RY	RZ	Sum RX	Sum RY	Sum RZ
Modal	1	1.088	0.0004	0.726	0	0.0004	0.726	0	0.0839	0.00004106	0.1853	0.0839	0.00004106	0.1853
Modal	2	1.02	0.8919	0.0005	0	0.8923	0.7265	0	0.0001	0.12	0	0.0839	0.12	0.1853
Modal	3	0.851	0.0001	0.1655	0	0.8924	0.892	0	0.0375	0.00001657	0.7158	0.1214	0.1201	0.9011
Modal	4	0.274	0.0078	0.064	0	0.9002	0.956	0	0.647	0.0721	0.0027	0.7685	0.1921	0.9039
Modal	5	0.272	0.0779	0.0075	0	0.978	0.9635	0	0.0718	0.7184	0.000008377	0.8403	0.9105	0.9039
Modal	6	0.237	0.0002	0.0141	0	0.9782	0.9777	0	0.0705	0.0019	0.0762	0.9108	0.9124	0.9801
Modal	7	0.124	0.0181	0.0001	0	0.9963	0.9778	0	0.0005	0.0664	0.0002	0.9113	0.9788	0.9803
Modal	8	0.123	0.0002	0.0184	0	0.9965	0.9962	0	0.0682	0.0008	0.0001	0.9796	0.9796	0.9804
Modal	9	0.112	0.0003	0.0006	0	0.9969	0.9969	0	0.0013	0.0012	0.0171	0.9808	0.9808	0.9976
Modal	10	0.073	0.0031	0	0	0.9999	0.9969	0	0	0.0188	0.00004338	0.9808	0.9996	0.9976
Modal	11	0.072	0	0.0031	0	0.9999	1	0	0.0192	5.274E-07	0.000006578	1	0.9996	0.9976
Modal	12	0.066	0.0001	0.000002398	0	1	1	0	0.000001016	0.0004	0.0024	1	1	1

Beam displacement detail summary

TABLE: Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	UZ	Sum UX	Sum UY	Sum UZ	RX	RY	RZ	Sum RX	Sum RY	Sum RZ
Modal	1	1.007	0.0001	0.7192	0	0.0001	0.7192	0	0.0904	0.00000753	0.1864	0.0904	0.00000753	0.1864
Modal	2	0.919	0.8733	0.0001	0	0.8734	0.7193	0	0.00001875	0.142	0.000009727	0.0904	0.142	0.1864
Modal	3	0.762	0.0001	0.1599	0	0.8735	0.8792	0	0.047	0.000006148	0.6779	0.1374	0.142	0.8643
Modal	4	0.264	0.0006	0.0689	0	0.874	0.948	0	0.6579	0.0043	0.0059	0.7953	0.1462	0.8702
Modal	5	0.255	0.0947	0.0006	0	0.9687	0.9487	0	0.0049	0.7374	0.000015	0.8003	0.8836	0.8702
Modal	6	0.216	0.0001	0.02	0	0.9688	0.9686	0	0.085	0.0008	0.0924	0.8852	0.8844	0.9626
Modal	7	0.12	0.0041	0.0164	0	0.9729	0.985	0	0.0582	0.0137	0.0004	0.9434	0.8981	0.963
Modal	8	0.119	0.0216	0.0039	0	0.9945	0.9888	0	0.0133	0.0728	0.00003439	0.9567	0.9709	0.963
Modal	9	0.103	0.0001	0.0055	0	0.9946	0.9943	0	0.014	0.0005	0.0299	0.9707	0.9714	0.9929
Modal	10	0.072	0.0048	0.0003	0	0.9994	0.9946	0	0.002	0.0254	0.0001	0.9727	0.9969	0.993
Modal	11	0.071	0.0005	0.0046	0	0.9999	0.9992	0	0.0246	0.0028	0.0001	0.9973	0.9996	0.9931
Modal	12	0.063	0.0001	0.0008	0	1	1	0	0.0027	0.0004	0.0069	1	1	1

Displacement

Displacement

CONCLUSION

The study presented in the paper compares the difference between normal building and a building on floating column. The following conclusions were drawn based on the investigation

1) By the application of lateral loads in X and Y direction at each floor, the lateral displacements of floating column building in X and Y directions are more 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 storey drift at each floor for the buildings it is observed that floating column building will suffer extreme storey drift than normal building. The storey Drift is maximum at 3rd and 4th storey levels in both the cases.

3) The building with floating columns experienced more storey shear than that of the normal building. This is due to the use of more quantity of materials than a normal building. So the floating column building is uneconomical to that of a normal building

4) The final conclusion is that do not prefer to construct floating column in buildings unless there is a proper purpose and functional requirement for those. If they are to be provided then proper care should be taken while designing the structure

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