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Experimental Investigation Analysis with Floating Column in Multistorey Building

Ponnaganti Divya[1] | K. L. Lilith Kumar[2]

[1]PG Student, Dept of CIVIL, Nova College of Engineering & Technology, Jangareddygudem
[2]Assistant Professor, Dept of CIVIL, Nova College of Engineering & Technology, Jangareddygudem

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ABSTRACT

In present scenario buildings with floating column is a typical feature in the modern multistory construction in urban India. Such features are highly undesirable in building built in seismically active areas. 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. FEM codes are developed 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 floor displacement, inter storey drift, base shear, overturning moment are computed for both the frames with and without floating column.

INTRODUCTION

Many urban multistorey 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.

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.

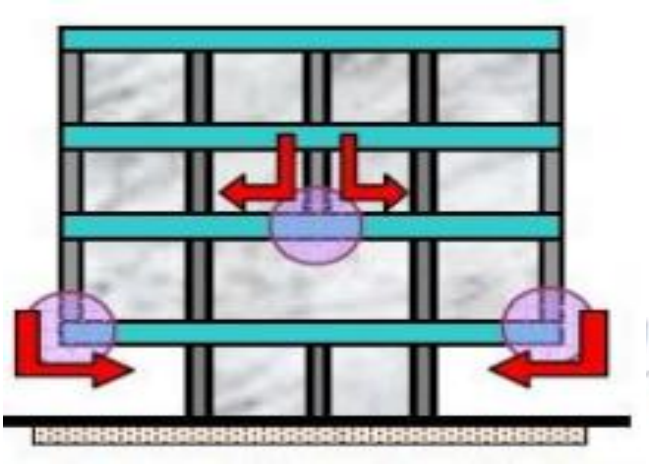

Figure 1: Hanging or Floating Columns

Arlekar, Jain & Murty [2], (1997) said that such features were highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. They highlighted the importance of explicitly recognizing the 9 presence of the open first storey in the analysis of the building, involving stiffness balance of the open first storey and the storey above, were proposed to reduce the irregularity introduced by the open first storey. Awkar and Lui [3], (1997) studied responses of multi-story flexibly connected frames subjected to earthquake excitations using a computer model. The model incorporates connection flexibility as well as geometrical and material nonlinearities in the analyses and concluded that the study indicates that connection flexibility tends to increase upper stories' inter-storey drifts but reduce base shears and base overturning moments for multi-story frames. Balsamoa, Colombo, Manfredi, Negro & Prota [4] (2005) performed pseudodynamic tests on an RC structure repaired with CFRP laminates. The opportunities provided by the use of Carbon Fiber Reinforced Polymer (CFRP) composites for the seismic repair of reinforced concrete (RC) structures were assessed on a full-scale dual system subjected to pseudodynamic tests in the ELSA laboratory. The aim of the CFRP repair was to recover the structural properties that the frame had before the seismic actions by providing both columns and joints with more deformation capacity. The repair was characterized by a selection of different fiber textures depending on the main mechanism controlling each component. The driving principles in the design of the CFRP repair and the outcomes of the experimental tests are presented in the paper. Comparisons between original and repaired structures are discussed in terms of global and local performance. In addition to the validation of the proposed technique, the experimental results will represent a reference database for the development of design criteria for the seismic repair of RC frames using composite materials.

FINITE ELEMENT FORMULATION:

The finite element method (FEM), which is sometimes also referred as finite element analysis (FEA), is a computational technique which is used to obtain the solutions of various boundary value problems in engineering, approximately. Boundary value problems are sometimes also referred to as field value problems. It can be said to be a mathematical problem wherein one or more dependent variables must satisfy a differential equation everywhere within the domain of independent variables and also satisfy certain specific conditions at the boundary of those domains. The field value problems in FEM generally has field as a domain of interest which often represent a physical structure. The field variables are thus governed by differential equations and the boundary values refer to the specified value of the field variables on the boundaries of the field. The field variables might include heat flux, temperature, physical displacement, and fluid velocity depending upon the type of physical problem which is being analyzed.

Plane frame element:

The plane frame element is a two-dimensional finite element with both local and global coordinates. The plane frame element has modulus of elasticity E, moment of inertia I, cross sectional area A, and length L. Each plane frame element has two nodes and is inclined with an 14 angle of θ measured counter-clockwise from the positive global X axis as shown in figure. Let C= cosθ and S= sinθ.

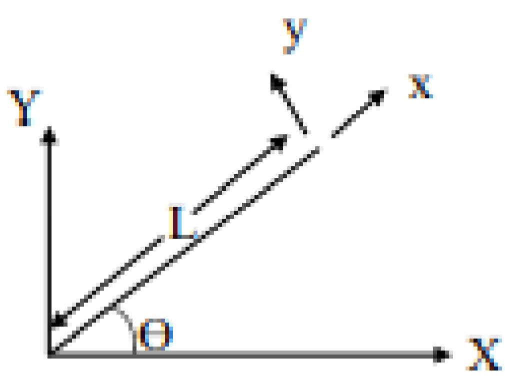

Figure 2: The plane frame element

It is clear that the plane frame element has six degree of freedom – three at each node (two displacements and a rotation). The sign convention used is that displacements are positive if they point upwards and rotations are positive if they are counter clockwise. Consequently for a structure with n nodes, the global stiffness matrix K will be 3n X 3n (since we have three degrees of freedom at each node). The global stiffness matrix K is assembled by making calls to the MATLAB function Plane Frame Assemble which is written specially for this purpose.

Steps followed for the analysis of frame

- Discretising the domain: Dividing the element into number of nodes and numbering them globally i;e breaking down the domain into smaller parts.
- Writing of the Element stiffness matrices: The element stiffness matrix or the local stiffness matrix is found for all elements and the global stiffness matrix of size 3n x 3n is assembled using these local stiffness matrices.
- Assembling the global stiffness matrices: The element stiffness matrices are combined globally based on their degrees of freedom values.
- Applying the boundary condition: The boundary element condition is applied by suitably deleting the rows and columns which are not of our interest.
- Solving the equation: The equation is solved in MATLAB to give the value of U.
- Post- processing: The reaction at the support and internal forces are calculated.

RESULT AND DISCUSSION:

a. Static analysis

A four storey two bay 2d frame with and without floating column are analyzed for static loading using the present FEM code and the commercial software STAAD Pro.

The following are the input data of the test specimen: Size of beam – 0.1 X 0.15 m Size of column – 0.1 X 0.125 m Span of each bay – 3.0 m Storey height – 3.0 m Modulus of Elasticity, E = 206.84 X 106 kN/m2 Support condition – Fixed Loading type – Live (3.0 kN at 3rd floor and 2 kN at 4th floor).

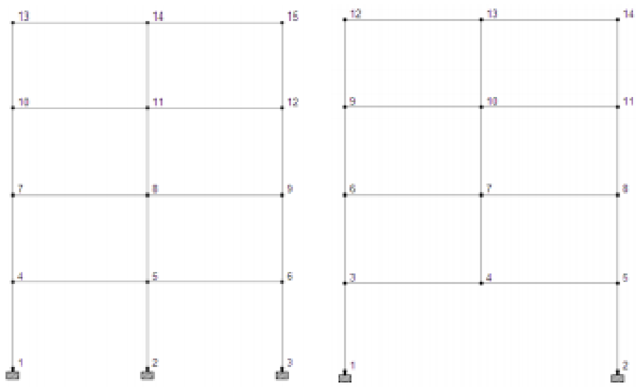

Figure 3: 2D Frame with usual columns and 2D Frame with Floating column

Node	Horizontal X mm	Vertical Y mm	Rotational rZ rad
1	0	0	0
2	0	0	0
3	0	0	0
4	1.6	0	0
5	1.6	0	0
6	1.6	0	0
7	3.8	0	0
8	3.8	0	0
9	3.8	0	0
10	5.8	0	0
11	5.8	0	0
12	5.8	0	0
13	6.7	0	0
14	6.7	0	0
15	6.7	0	0

Node	Horizontal X mm	Vertical Y mm	Rotational rZ rad
1	0	0	0
2	0	0	0
3	0	0	0
4	1.4	0	0
5	1.4	0	0
6	1.4	0	0
7	3.6	0	0
8	3.6	0	0
9	3.6	0	0
10	5.6	0	0
11	5.6	0	0
12	5.6	0	0
13	6.8	0	0
14	6.8	0	0
15	6.8	0	0

Table 1 Global deflection at each node and table 2 Global deflection at each node for general frame obtained for general frame obtained in present FEM in STAAD Pro.

Forced vibration analysis

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.

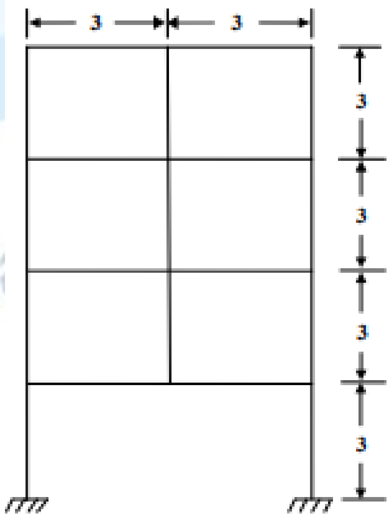

Figure 4: Geometry of the 2 dimensional frame with floating column

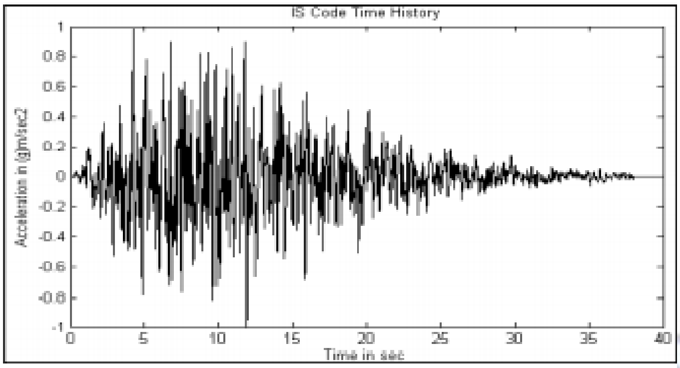

Figure 5: Compatible time history as per spectra of IS 1893 (part 1): 2002

Free vibration frequencies of the 2D steel frame with floating column are presented in Table 3. In this table the values obtained in present FEM and STAAD Pro are compared. Table 4 shows the comparison of maximum top floor displacement of the frame obtained in present FEM and STAAD Pro which are in very close agreement.

Mode	STAAD Pro	Present FEM	% Variation
1	2.16	2.17	0.28
2	6.78	7.00	3.13
3	11.57	12.62	8.32
4	12.37	13.04	5.14

Table 3 Comparison of predicted frequency (Hz) of the 2D steel frame with floating column obtained in present FEM and STAAD Pro.

Maximum top floor displacement (mm)		% Variation
STAAD Pro.	Present FEM	
123	124	0.81

Table 4 Comparison of predicted maximum top floor displacement (mm) of the 2D steel frame with floating column in present FEM and STAAD Pro.

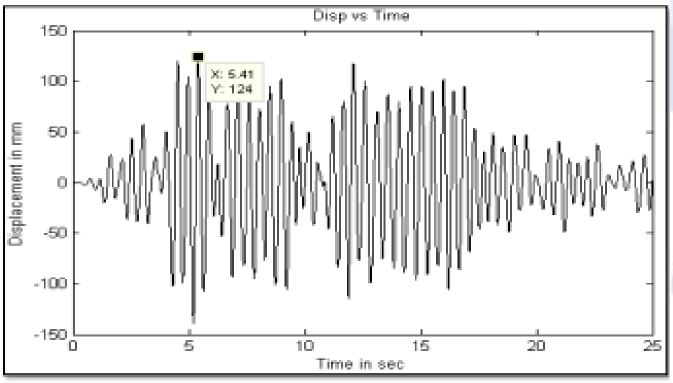

Figure 5: Displacement vs time response of the 2D steel frame with floating column obtained in present FEM

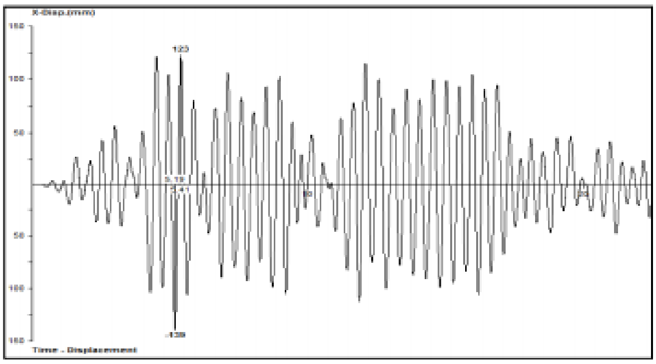

Figure 6: Displacement vs time response of the 2D steel frame with floating column obtained in STAAD Pro

CONCLUSION

The behavior of multistory building with and without floating column is studied under different earthquake excitation. The compatible time history and Elcentro earthquake data has been considered. The PGA of both the earthquake has been scaled to 0.2g and duration of excitation are kept same. A finite element model has been developed to study the dynamic behavior of multi-story frame. The static and free vibration results obtained using present finite element code are validated. The dynamic analysis of frame is studied by varying the column dimension. It is concluded that with increase in ground floor column the maximum displacement, inter storey drift values are reducing. The base shear and overturning moment vary with the change in column dimension.

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