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Seismic Analysis of Multistorey Building with Floating Column

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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

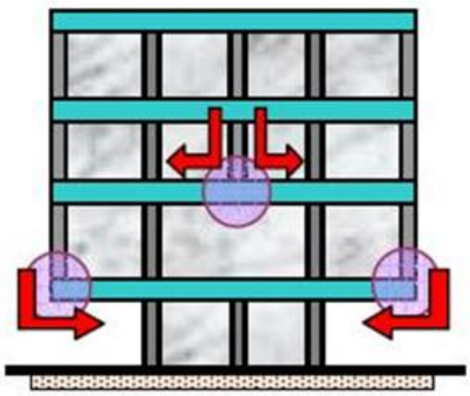
Introduction

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.

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

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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.

Objective and scope of present work

The objective of the present work is to study the behavior of multistory buildings with floating columns under earthquake excitations.

Finite element method is used to solve the dynamic governing equation. Linear time history analysis is carried out for the multistory buildings under different earthquake loading of varying frequency content. The base of the building frame is assumed to be fixed. Newmark's direct integration scheme is used to advance the solution in time.

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.

FINITE ELEMENT FORMULATION

The finite element method (FEM), which is sometimes also referred to 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.

Static analysis

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 angle of θ measured counterclockwise from the positive global X axis as shown in figure. Let C= cosθ and S= sinθ.

RESULT AND DISCUSSION

The behavior 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 MATLAB platform.

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*.

Example 4.1

The following are the input data of the test specimen:
Size of beam – 0.1 X 0.15 m

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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 10^6 kN/m^2
Support condition – Fixed
Loading type – Live (3.0 kN at 3rd floor and 2 kN at 4th floor)

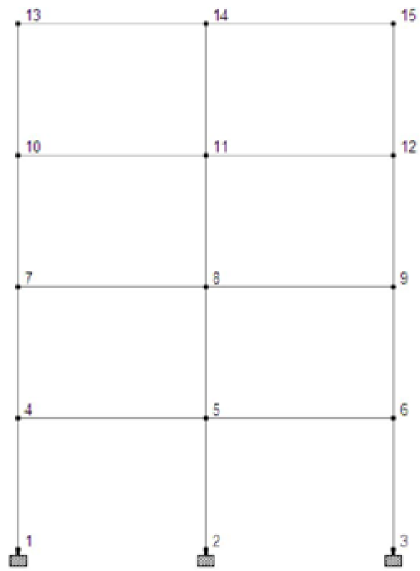

Fig. 4.1 2D Frame with usual columns

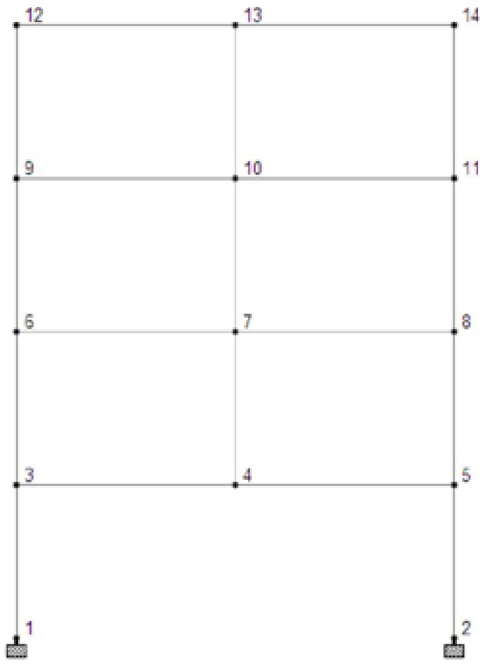

Fig.4.2 2D Frame with Floating column

Table 4.1 Global deflection at each node for general frame obtained in present FEM

Node	Horizontal	Vertical	Rotational
	X mm	Y mm	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

Table 4.2 Global deflection at each node for general frame obtained in STAAD Pro.

Node	Horizontal	Vertical	Rotational
	X mm	Y mm	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

Free vibration analysis

Example 4.2

In this example a two storey one bay 2D frame is taken. Fig.4.3 shows the sketchmatic view of the 2D frame. The results obtained are compared with Maurice Petyt[21]. The input data are as follows:
Span of bay = 0.4572 m
Storey height = 0.2286 m
Size of beam = (0.0127 x 0.003175) m
Size of column = (0.0127 x 0.003175) m
Modulus of elasticity, E = 206.84 x10^6 kN/m^2
Density, ρ = 7.83 x 10^3 Kg/m^3

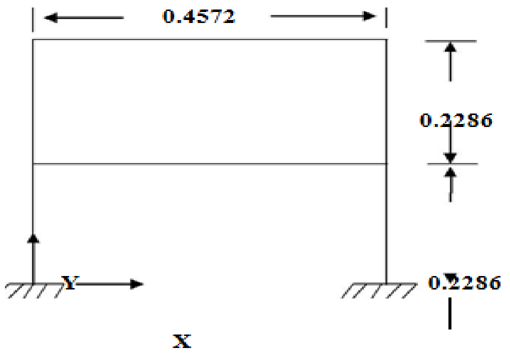

Fig. 4.3 Geometry of the 2 dimensional framework. Dimensions are in meter

Table 4.5 shows the value of free vibration frequency of the 2D frame calculated in present FEM. It is observed from Table 4.5 that the present results are in good agreement with the result given by Maurice Petyt [21].

Table 4.5 Free vibration frequency(Hz) of the 2D frame without floating column

Mode	Maurice Petyt [21]	Present FEM	% Variation
1	15.14	15.14	0.00
2	53.32	53.31	0.02
3	155.48	155.52	0.03
4	186.51	186.59	0.04
5	270.85	270.64	0.08

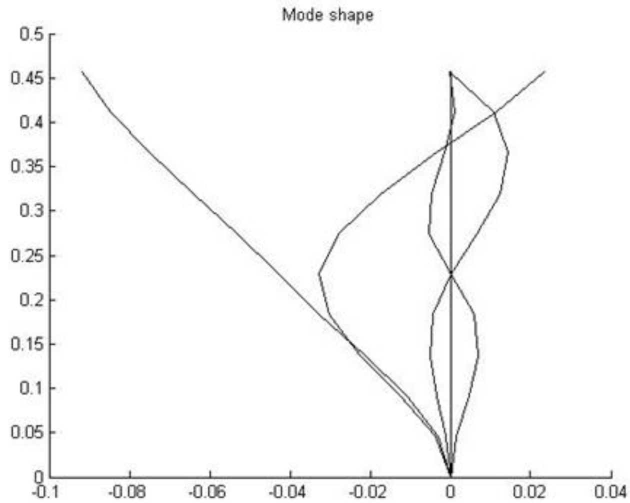

Fig. 4.4 Mode shape of the 2D framework

4. 3 Forced vibration analysis

Example 4.3

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. The dimension and material properties of the frame is as follows:
Young's modulus. E= 206.84 x 10^6 kN/m^2
Density, ρ = 7.83 x10^3 Kg/m^3
Size of beam = (0.1 x 0.15) m
Size of column = (0.1 x 0.125) m

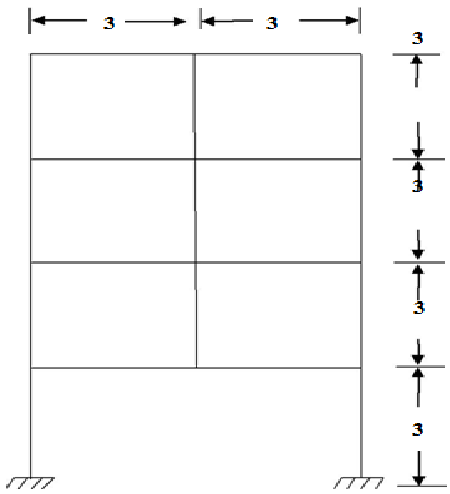

Fig. 4.5 Geometry of the 2 dimensional frame with floating column. Dimensions are in meter

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Fig.4.6 shows the compatible time history as per spectra of IS 1893 (part 1): 2002. Fig.4.7 and 4.8 show the maximum top floor displacement of the 2D frame obtained in present FEM and STAAD Pro respectively.

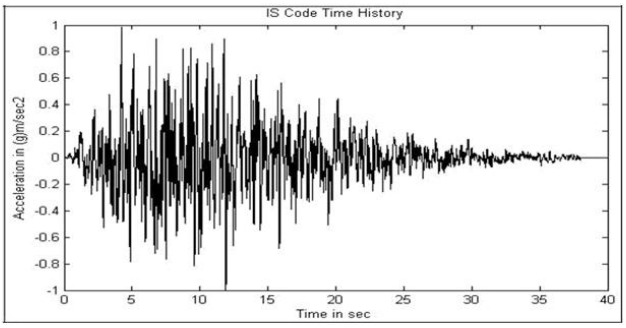

Fig. 4.6 Compatible time history as per spectra of IS 1893 (part 1): 2002

Free vibration frequencies of the 2D steel frame with floating column are presented in Table 4.6. In this table the values obtained in present FEM and STAAD Pro are compared. Table 4.7 shows the comparison of maximum top floor displacement of the frame obtained in present FEM and STAAD Pro which are in very close agreement.

Table 4.6 Comparison of predicted frequency (Hz) of the 2D steel frame with floating column obtained in present FEM and STAAD Pro.

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

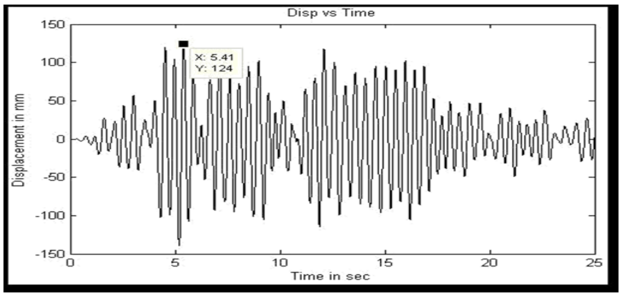

Fig. 4.7 Displacement vs time response of the 2D steel frame with floating column obtained in present FEM

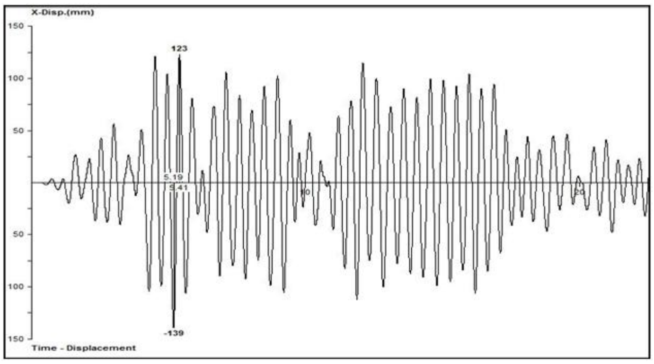

Fig. 4.8 Displacement vs time response of the 2D steel frame with floating column obtained in STAAD Pro

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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