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ADVANCED SEISMIC ANALYSIS AND PERFORMANCE EVALUATION OF MULTISTORY BUILDINGS WITH FLOATING COLUMNS

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Abstract: This study emphasises the importance of explicitly recognising the presence of the floating column in the analysis of buildings, as floating columns are a common feature in modern multistory construction in urban India, but they are highly undesirable in buildings built in seismically active areas. Alternative measures, involving stiffness balance of the first storey and the storey above, are proposed to reduce the irregularity introduced by 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.

Keywords: Seismic analysis, performance evaluation, multistory buildings, floating columns, finite element analysis, response spectrum analysis, seismic response, structural optimization, retrofitting strategies, seismic design.

1. INTRODUCTION

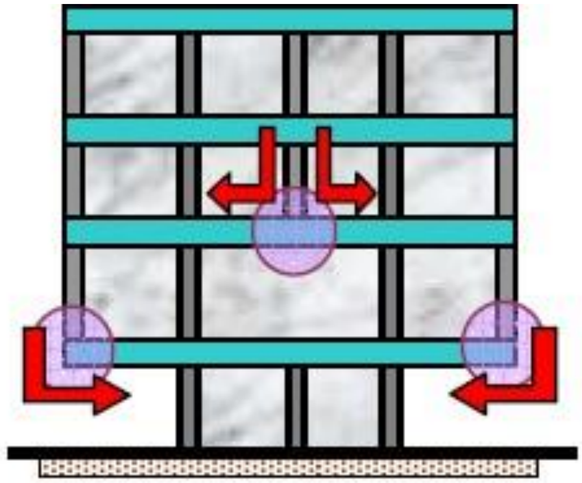
1.1 Introduction

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.

1.2 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.

1.3 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.

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.

3.1 Static Analysis

3.1.1 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.

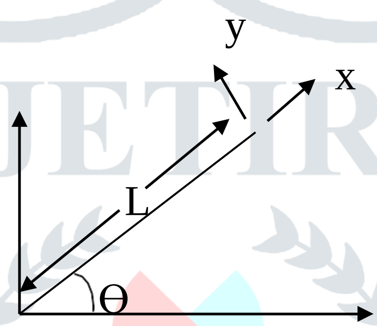


Fig. 3.1 The Plane Frame Element

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 counterclockwise. 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.Once the global stiffness matrix K is obtained we have the following structure equation:

$$[K]\{U\} = \{F\} \qquad (3.1)$$

Where [K] is stiffness matrix, {U} is the global nodal displacement vector and {F} is the global nodal force vector. At this step boundary conditions are applied manually to the vectors U and F. Then the matrix equation (3.1) is solved by partitioning and Gaussian elimination. Finally once the unknown displacements and reactions are found, the nodal force vector is obtained for each element as follows:

$$\{f\} = [k]\,[R]\,\{u\} \qquad (3.2)$$

Where {f} is the 6 X 1 nodal force vector in the element and {u} is the 6 X 1 element displacement vector. The matrices [k] and [R] are given by the following:

3.1.2 Steps Followed For the Analysis of Frame

1. **Discretising the domain:** Dividing the element into number of nodes and numbering them globally i;e breaking down the domain into smaller parts.

2. **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.

3. **Assembling the global stiffness matrices:** The element stiffness matrices are combined globally based on their degrees of freedom values.

4. **Applying the boundary condition:** The boundary element condition is applied by suitably deleting the rows and columns which are not of our interest.

5. **Solving the equation:** The equation is solved in MATLAB to give the value of U.

6. **Post- processing**: The reaction at the support and internal forces are calculated.

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.

4.1 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

Size of column – 0.1 X 0.125 mSpan 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 and Fig.4.2 show the sketchmatic view of the two frames without and with floating column respectively. From Table 4.1 and 4.2, we can observe that the nodal displacement values obtained from present FEM in case of frame with floating column are more than the corresponding nodal displacement values of the frame without floating column. Table 4.3 and

4.4 shows the nodal displacement value obtained from STAAD Pro of the frame without and with floating column respectively and the result are very comparable with the result obtained in present FEM.

. *Fig. 4.1 2D Frame with Usual Columns*

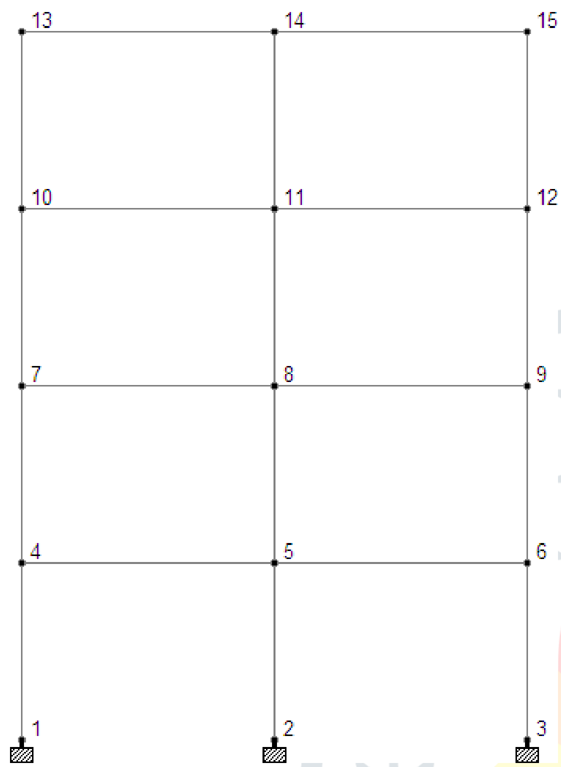


Fig.4.2 2D Frame with Floating Column

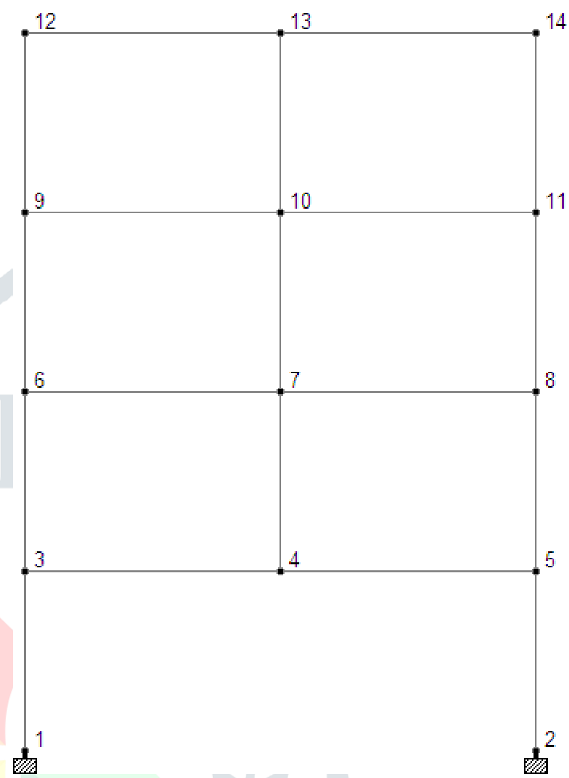


Table 4.3 Global Deflection At Each Node Frame With Floating Column Obtained In Present FEM

Node	Horizontal	Vertical	Rotational
	X mm	Y mm	rZ rad
1	0	0	0
2	0	0	0
3	2.6	0	0
4	2.6	0	0
5	2.6	0	0
6	4.8	0	0
7	4.8	0	0
8	4.8	0	0
9	6.8	0	0
10	6.8	0	0
11	6.8	0	0
12	7.8	0	0
13	7.8	0	0
14	7.8	0	0

Table 4.4 Global Deflection At Each NodeFor For Frame With Floating Column Obtained In STAAD Pro

Node	Horizontal	Vertical	Rotational
	X mm	Y mm	rZ rad
1	0	0	0
2	0	0	0
3	2.6	0	0
4	2.6	0	0
5	2.6	0	0
6	4.8	0	0
7	4.8	0	0
8	4.8	0	0
9	6.8	0	0
10	6.8	0	0
11	6.8	0	0
12	7.7	0	0
13	7.7	0	0
14	7.7	0	0

4. 2 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

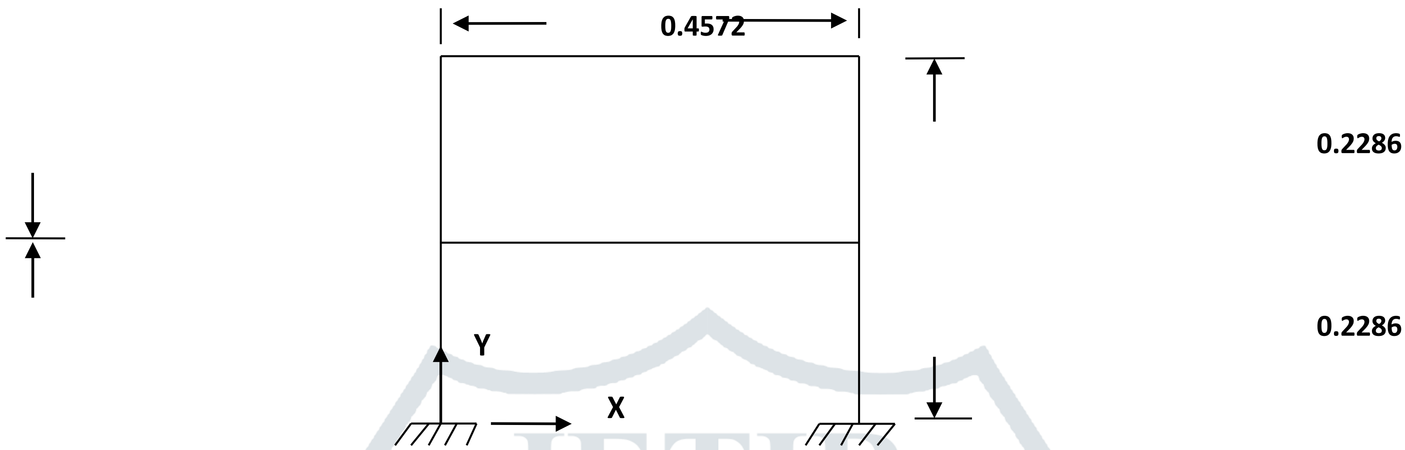


Fig. 4.3 Geometry of the 2 Dimensional Framework. Dimensions Are In Meter

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

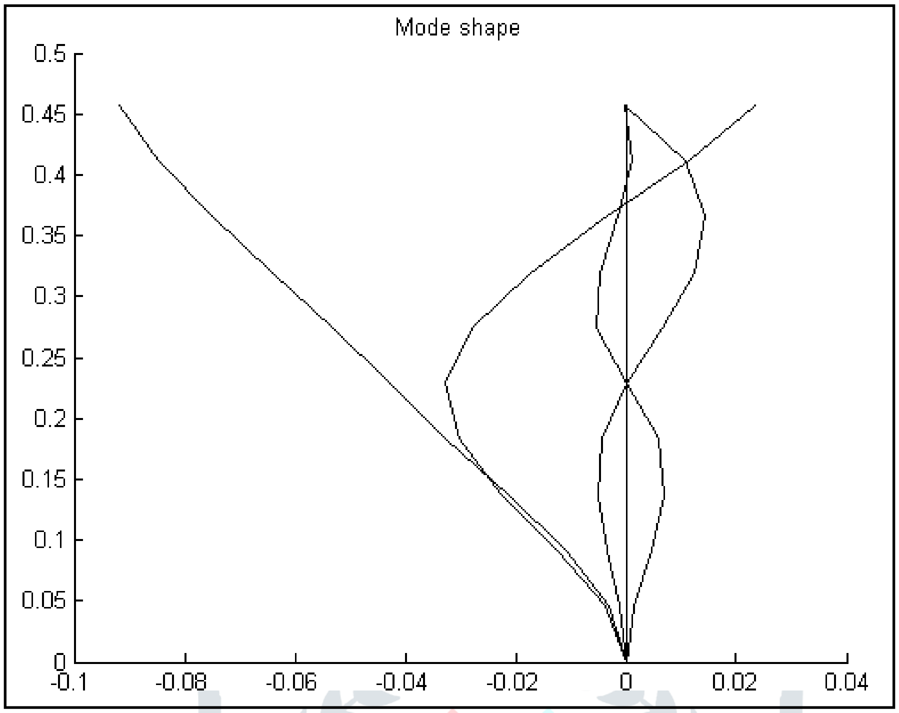


Fig. 4.4 Mode Shape Of the 2D Framework

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 are as follows:

Young's modulus. E= 206.84 x 10^6 kN/m^2

3 3

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

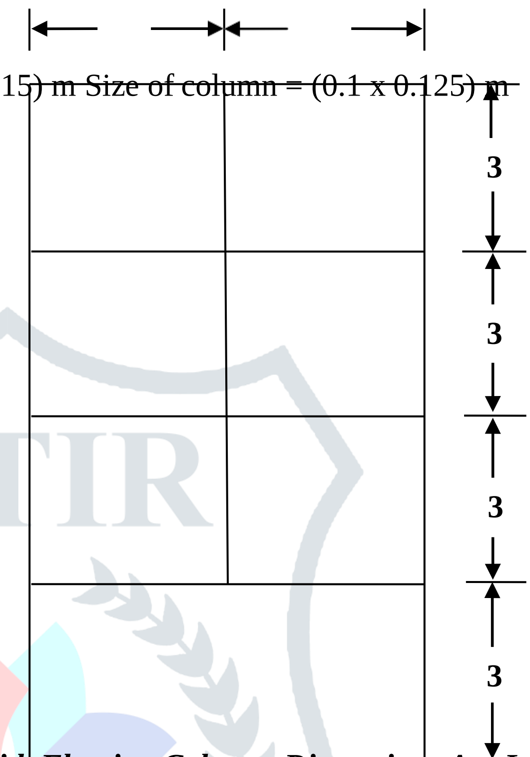


Fig. 4.5 Geometry of the 2 Dimensional Frame with Floating Column. Dimensions Are In Meter

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.

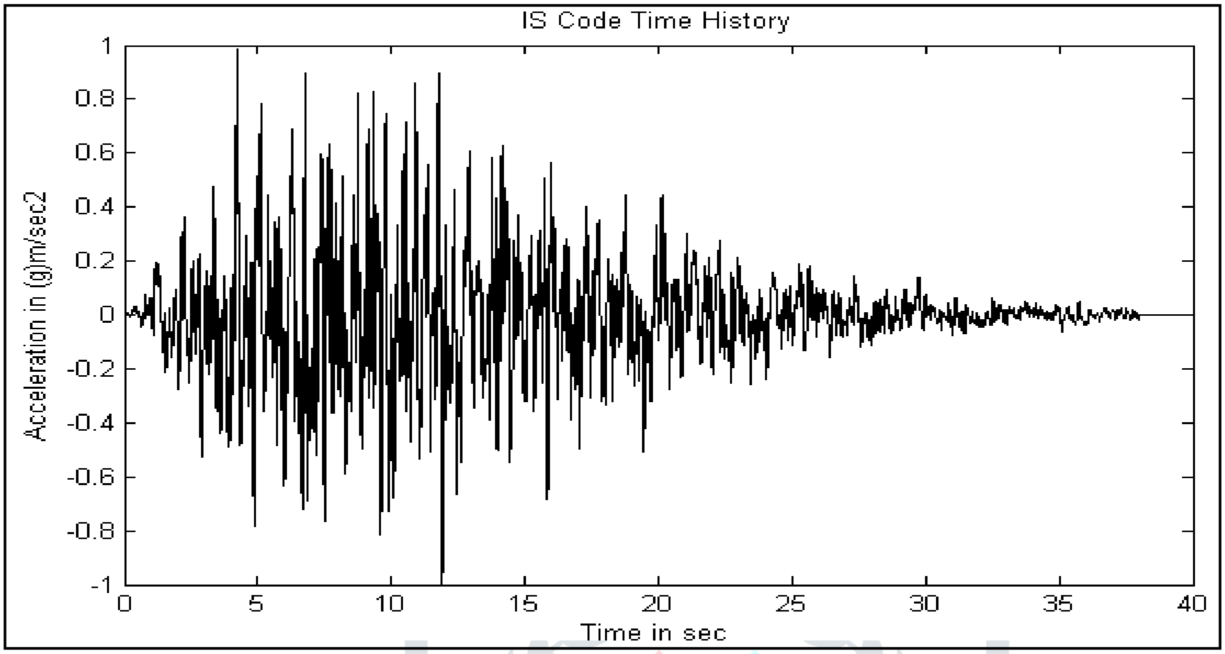


Fig. 4.6 Compatible Time History as Per Spectra of IS 1893 (Part 1): 2002

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

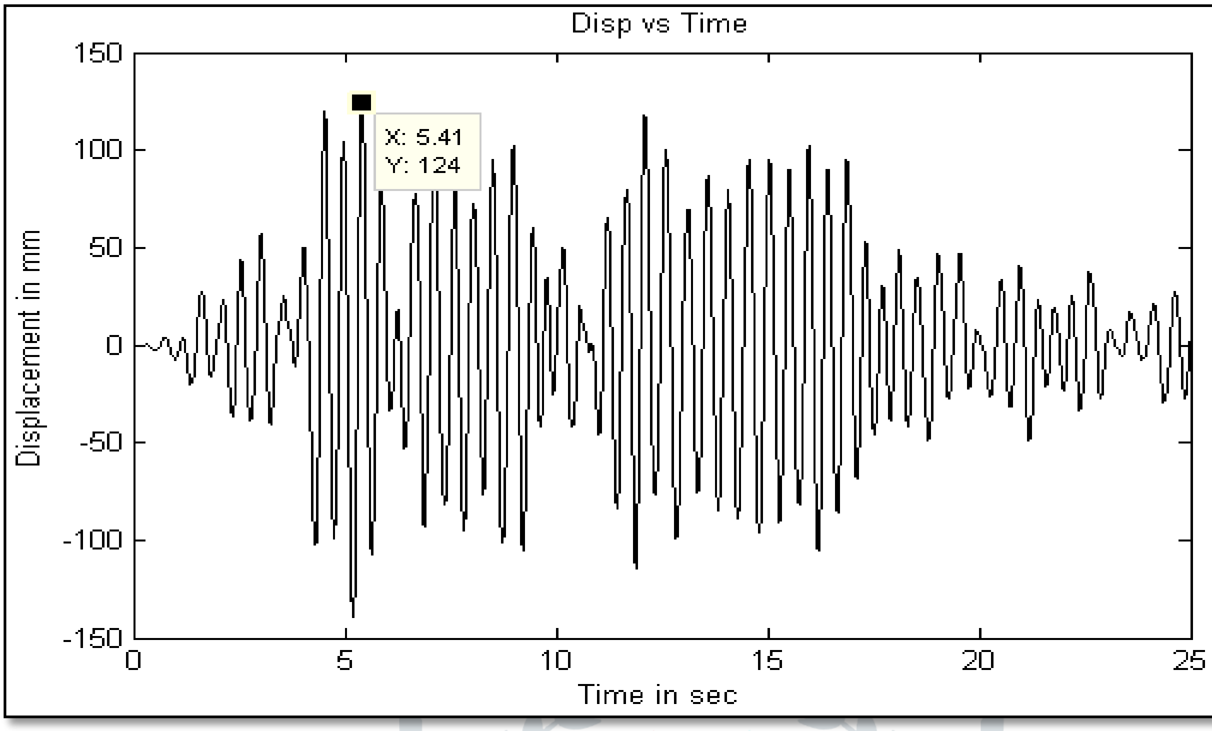


Fig. 4.7 Displacement Vs Time Response of the 2D Steel Frame with Floating Column Obtained In Present FEM

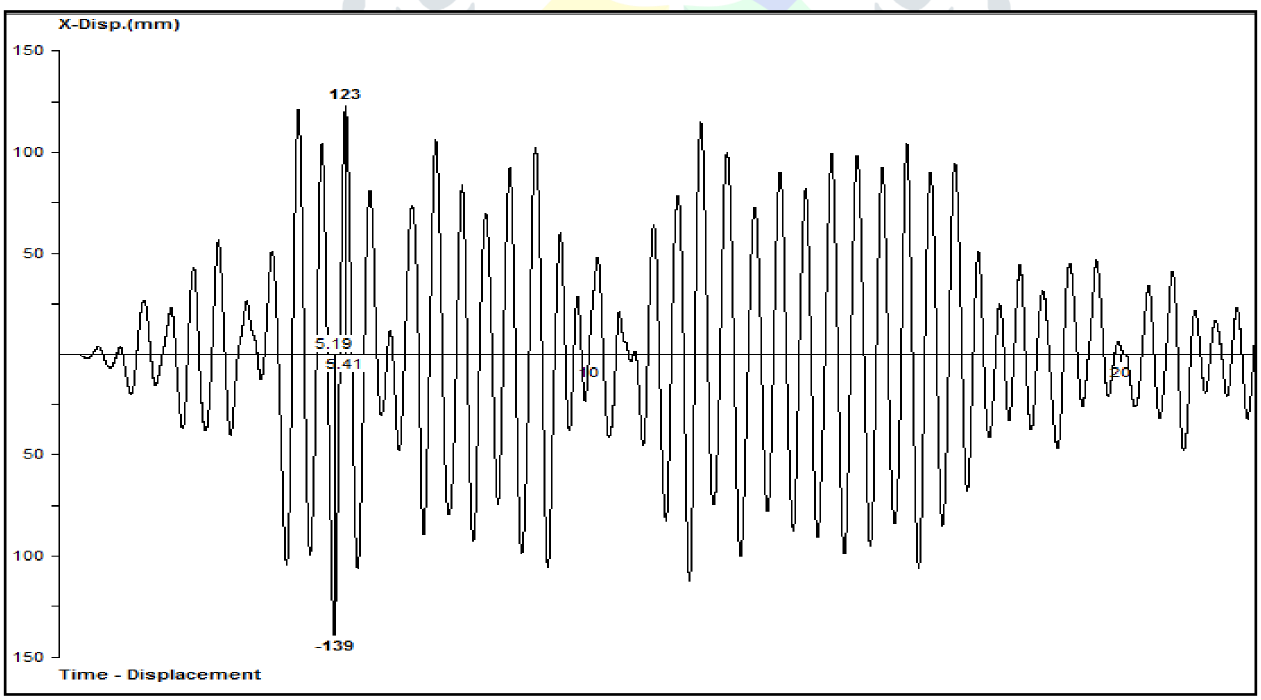


Fig. 4.8 Displacement Vs Time Response of the 2D Steel Frame with Floating Column Obtained In STAAD Pro

Table 4.7 Comparison Of Predicted Maximum Top Floor Displacement (Mm) Of The 2D SteelFrame With Floating Column In Present FEM And STAAD Pro.

Maximum Top Floor Displacement (mm)		**% Variation**
STAAD Pro.	**Present FEM**	
123	124	0.81

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 is 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 codes 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.

REFERENCES

1. **Agarwal Pankaj, Shrikhande Manish** (2009), “Earthquake resistant design of structures”, PHI learning private limited, New Delhi.
2. **Arlekar Jaswant N, Jain Sudhir K. and Murty C.V.R,** (1997), “Seismic Response of RC Frame Buildings with Soft First Storeys”. Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, 1997, New Delhi.
3. **Awkar J. C. and Lui E.M,** “Seismic analysis and response of multistory semirigid frames”, Journal of Engineering Structures, Volume 21, Issue 5, Page no: 425-442, 1997.
4. **Balsamoa A, Colombo A, Manfredi G, Negro P & Prota P** (2005), ”Seismic behavior of a full-scale RC frame repaired using CFRP laminates”. Engineering Structures 27 (2005) 769– 780.
5. **Bardakis V.G., Dritsos S.E.** (2007), “Evaluating assumptions for seismic assessment of existing buildings “.Soil Dynamics and Earthquake Engineering 27 (2007) 223–233.

6. **Brodericka B.M., Elghazouli A.Y. and Goggins J,** “Earthquake testing and response analysis of concentrically-braced sub-frames”, Journal of Constructional Steel Research
,Volume 64, Issue 9, Page no: 997-1007,2008.

7. **Chopra, Anil k.** (1995), “Dynamics of structures”, Prentice Hall.

8. **Daryl L. Logan** (2007), “A First Course in the Finite Element Method”, Thomson, USA

9. **Fall H.G** (2006)**,** “Direct Stiffness Method For 2D Frames-Theory of structure”.

10. **Garcia Reyes, Hajirasouliha Iman, Pilakoutas Kypros,** (2010),”Seismic behaviour of deficient RC frames strengthened with CFRP composites”. Engineering Structures 32 (2010) 3075-3085.

11. **Hartley Gilbert and Abdel-Akher Ahmed,** “Analysis of building frames” Journal of Structural Engineering, Vol. 119, No. 2, Page no:468-483, 1993.

12. **Kattan P I** (2003), “MATLAB guide to Finite Element”, Springer, Berlin & New York.

13. **K. N. V. Prasada Rao, K. Seetharamulu, and S. Krishnamoorthy,** “Frames with staggered panels: experimental study*”*, Journal of Structural Engineering, VOL 110, No. 5, Page no: 1134-1148, 1984.

14. **Krishnamoorthy CS,** Finite element analysis, TMH Publications, 1987

15. **Maison Bruce F. and Neuss Carl F.,** “Dynamic analysis of a forty four story building”, Journal of Structural Engineering, Vol. 111, No. 7, Page No:1559- 572,July, 1985.

16. **Maison Bruce F.** and **Ventura Carlos E.,** “DYNAMIC ANALYSIS OF THIRTEEN- STORY BUILDING”, Journal of Structural Engineering, Vol. 117, No. 12, Page no:3783- 3803,1991.

17. **Mortezaei A., Ronagh H.R., Kheyroddin A.,** (2009), “Seismic evaluation of FRP strengthened RC buildings subjected to near-fault ground motions having fling step”. Composite Structures 92 (2010) 1200–1211.

18. **Niroomandia A., Maherib A, Maheric Mahmoud R., Mahini S.S.** (2010) “Seismic performance of ordinary RC frames retrofitted at joints by FRP sheets”. Engineering Structures 32 (2010) 2326- 2336.

19. **Ozyigit H. Alper,** “Linear vibrations of frames carrying a concentrated mass”, Mathematical and Computational Applications, Vol. 14, No. 3, pp. 197-206, 2009.

20. **Paz Mario** (2010), “Structural dynamics”, CBS publishers.

21. **Petyt Maurice** (2010), “Introduction to Finite element vibration analysis” Cambridge University Press, New York.

22. **Sekulovic Miodrag, Salatic Ratko and Nefovska Marija,** “Dynamic analysis of steel frames with flexible connections”, Journal of computer and structures, Volume 80, Issue 11, Page no: 935-955, Volume 80, 2002.

23. **Vasilopoulosa A.A and Beskos D.E.,** “Seismic design of plane steel frames using advanced methods of analysis”, Soil Dynamics and Earthquake Engineering Volume 26, Issue 12, December 2006, Pages 1077-1100.

24. **Williams Ryan J., Gardoni Paolo, Bracci Joseph M.,** (2009), “Decision analysis for seismic retrofit of

structures". Structural Safety 31 (2009) 188–196.

25. **Wilson E.L** "Three dimensional Static and Dynamic analysis of structures-A physical approach with emphasis on earthquake engineering", Computers and Structures, Inc Publication, 3rd Edition 2002.