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Comparative Study on Dynamic Response of Buildings with Floating Columns

Manjunatha B. B., Chaithra M.*, Avinash A. R.

Department of Civil Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, India

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Abstract High-rise buildings are essential for providing the necessary space for both residence and offices due to the lack of large areas in an urban setting. However, these multi-storey buildings are prone to lateral loads such as earthquake loads due to their large mass. Often, columns of such multi-storey buildings are truncated at some level either due to some obstructions or some architectural restrictions. Such columns that do not directly rest on the foundation are called floating columns. The floating columns are generally considered harmful, especially for buildings constructed in seismically active areas. Their existence creates a discontinuity in the path to transfer the load resulting in an inadequate structure performance. Hence, this study focuses on reducing the risk factor due to seismic effects by strengthening buildings with floating columns using the shear walls, bracings, and masonry infills. A typical building with floating columns located at two different seismic zones was considered for the study. This building was strengthened by considering various approaches such as diagonal bracings, shear walls and infill walls. The equivalent static method is used in the study to carry out the seismic analysis. The results indicate that using any strengthening methods mentioned above can significantly reduce storey displacements. However, providing a shear wall is found to be more effective in reducing the storey displacements in both the directions of earthquake forces when compared with other methods. Though infills and bracings can reduce storey drifts, it was also found that at lower storey levels, there is a considerable increase in the storey drifts when bracings and infill walls are considered. This is mainly attributed to the presence of the open first storey. However, the storey drift values reduce at the higher levels.

Keywords Floating Column, Masonry Infill, Bracings, Shear Wall, Equivalent Static Analysis

1. Introduction

The seismic forces must be carried to the ground from the main structure along the direct path without any discontinuity or deviation in an earthquake event. Any deviation in the load path may generate a sudden influx in earthquake forces and may lead to failure of the structure. The columns are intended to transfer the loads to the foundation. However, sometimes in buildings, the columns are truncated at some storey levels resulting in abrupt changes in the load transfer path. Such columns are referred to as floating columns. Many buildings are constructed with such truncated columns to allow large open space requirements, typically for parking space. However, these floating columns affect the behaviour of the structure when subjected to seismic forces.

Various investigations have been performed on the performance of building with floating columns resting on different earthquake zones. In one of the studies, the researchers have arrived at the critical load combinations to be considered for the dynamic analysis of structures with such floating columns [1]. Further, some researchers have studied the effect of floating columns by comparing the seismic response of the building without and with floating columns [2]. Since the size and shape of columns significantly affect the seismic response, few researchers have studied the impact of the size factor of columns and beams bearing the load of floating columns [3]. Since bracings are typically used to reduce the drift of structures in seismic-resistant design, some authors have studied the effect of bracings on the seismic response of buildings with floating columns [4]. The impact of floating columns present on various levels of composite structures was also studied by some of the researchers [5]. Few authors have extended their study on the effect of floating columns on seismic loads by considering both the response spectrum method and equivalent static analysis [6]. A parametric study was also conducted by some researchers for a multi-storey building by considering maximum deflection, bending moment and shear force [7]. Also, the impact of the floating column at different locations within the floor and along the height of the multi-storied RC structure was studied by researchers using response spectrum analysis [8]. Some researchers extended their study to evaluate the influence of the floating column on the number of storeys in a building on various parameters [9].

In the present research, initially, the effect of the floating column on the dynamic response of a typical multi-storey building has been studied. Further, the study is extended to consider different strengthening strategies and their effectiveness in alleviating the harmful effects of the floating columns. For the study, four different models of RC building with floating columns situated in Zone IV and Zone V as per Indian seismic code of practice IS 1893 (Part 1): 2016 are considered with X - bracings, shear wall, and masonry infill wall are considered. Seismic force is applied on each model in both x and y directions. The equivalent static load (ESL) method is employed for the analysis as prescribed in IS 1893 (Part 1): 2016. The responses are obtained in terms of storey displacements and storey drifts. Bending moment and deflection in transfer girder is also evaluated. These responses are compared with the response of a regular building without floating columns and any additional strengthening measures.

2. Methodology

For the study, a regular, sixteen-storey framed multi-storey building with an open basement storey is considered, as shown in Figure 1. In the building, the columns in the exterior middle bay of the building are truncated to obtain ample unhindered space. Various building models considered for the study are shown in Figure 2. Model 1 is a regular building without any floating columns, and model 2 to model 5 has six floating columns. Out of these, Model 2 does not have any additional strengthening measure. Model 3, model 4 and model 5 are buildings with masonry infill walls, bracings and shear walls, respectively. The details of the models considered in the analysis are as given in Table 1. The structure is discretized as two noded frame elements and four noded shell elements.

For Model 2, the effect of infill stiffness is considered by an equivalent diagonal strut (EDS). The cross-sectional details of EDS are calculated based on IS 1893 (Part 1): 2016. The width of the diagonal strut (w_{ds}) is given by the equation,

$$w_{ds} = 0.175\alpha_h^{-0.4}L_{ds} \tag{1}$$

where,

L_{ds} – Length of the diagonal strut

$$\alpha_h = h\ (E_m\ t\ \sin\ 2\theta /\ 4\ E_f\ I_c\ h)^{0.25} \tag{2}$$

where,

h – the clear height of the infill wall

θ – the angle made by the strut with the horizontal

t – thickness of the wall

I_c – Moment of inertia of the adjoining column

E_f – Modulus of elasticity for frame element (in MPa)

E_m – Modulus of elasticity of masonry infill, which can be obtained as,

$$E_m = 550\ f_m \tag{3}$$

where,

$$f_m = 0.433 f_b^{0.64} f_{mo}^{0.36} \tag{4}$$

where f_b and f_{mo} are the compressive strength of brick and mortar, respectively (in MPa).

For model 3, X – bracings are provided between the floating column positions to provide more stiffness to the structure.

For model 4, shear walls are provided at the corners of the building.

Based on the seismic intensities sustained during past earthquakes, four seismic zones are considered in India (Zone II, III, IV and V). The area falling under zone IV and V are prone to higher seismic forces.

The analysis is conducted using ETABS software. ETABS is an industry-leading software capable of carrying out Finite Element Analysis.

For the analysis, the ESL method is considered as specified in IS 1893 (Part 1): 2016. In this method, the dynamic analysis of the building is conducted by considering the dynamic loading to be equivalent to the horizontal static force. The base shear of the building is calculated based on time period of vibration, seismic weight, and mode shape. The calculated force at the base is then distributed at each storey of the building along its height in terms of horizontal forces. The total shear force at the base along any principal direction of the structure is obtained by the equation,

$$V_B = W.A_h \tag{5}$$

where,

W – Building seismic weight

A_h – Design horizontal seismic coefficient for the structure, which can be calculated as,

$$A_h = (Z/2)\ (S_a/g)\ (I/R) \tag{6}$$

where,

Z – seismic zone factor

I – Structure importance factor

R – Response reduction factor

S_a/g – design acceleration coefficient for various soil types, depending on the fundamental time period (T) of the building.

The Z, R, I, and S_a/g values are obtained from IS 1893 (Part 1): 2016.

The computed shear force at the base is then distributed at each floor of the building along its height. The horizontal force at any level, Q_i is determined using the equation,

$$Q_i = (V_B \; W_i h_i^2) \;/\; (\Sigma \; W_i h_i^2) \tag{7}$$

where,

h_i – Height of storey ‘i’ measured from the base.

W_i – Seismic weight of floor ‘i’

Table 1. Details of the buildings considered in the study

General Details		**Geometric properties**	
Type of the building	Residential	Beam size	230 mm × 350 mm
Number of storeys	G + 15	Column size	230 mm × 350 mm
Typical storey height	3 m	Slab thickness	150 mm
Spacing of bays in both directions	5 m	Size of hollow steel bracings	200 mm × 200 mm × 5 mm
Material Properties		Masonry infill wall thickness	230 mm
Poisson’s ratio (μ)	0.15	Equivalent strut width for masonry	753.4 mm
The density of brick masonry	20 kN/m²	Shear wall thickness	250 mm
Grade of concrete	M30	Seismic load parameters as per IS 1893 (Part 1): 2016	
Grade of steel	Fe415	Importance factor of building	1
Loads		Type of soil	Medium (II)
Roof load	1.5 kN/m²	Seismic zone	Zone IV and Zone V
Floor load	4 kN/m²	Response reduction factor	5
Wall load	12.19 kN/m²	Type of frame	SMRF

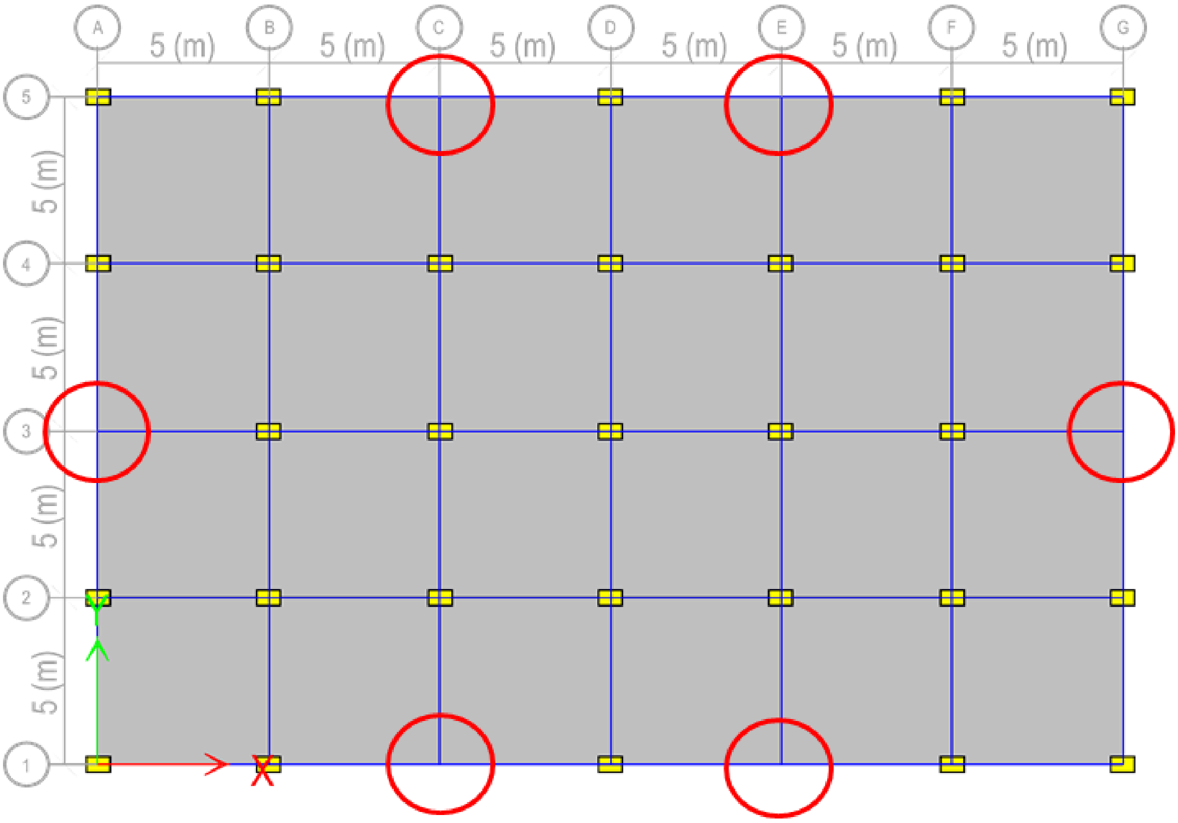

Figure 1. Plan of the considered building with the positions of floating columns

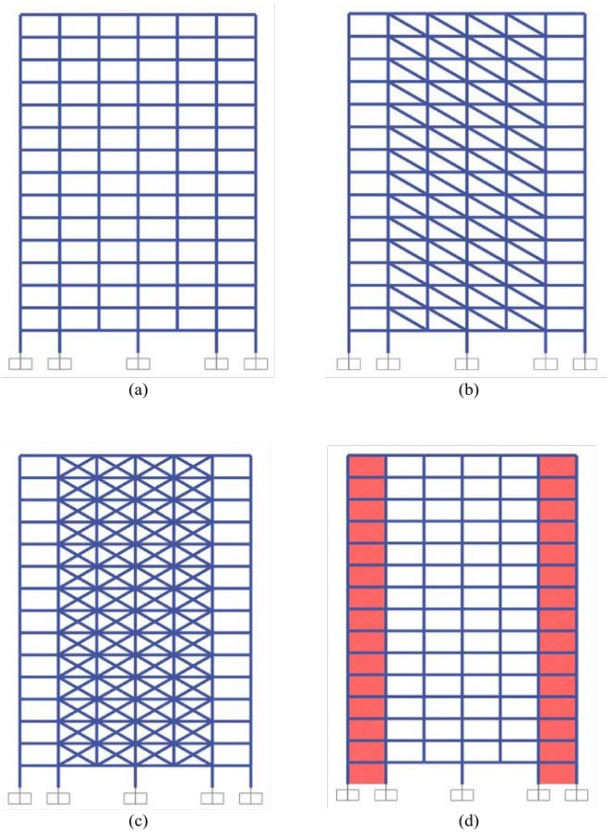

Figure 2. Elevation of various models of RC structure considered for the analysis (a) Regular building with floating column (Model 2) (b) Building with masonry infill modelled with equivalent struts (Model 3) (c) Building with bracings (Model 4) (d) Building with shear walls (Model 5)

3. Results and Discussions

3.1. Storey Displacement

The variation of storey displacement of various models located in zone IV and zone V, subjected to seismic force in the two principal directions (x and y), are shown in Figure 3 to Figure 6, respectively.

The figures show that the storey displacement of structures with floating columns located in seismic zone IV increases slightly compared to traditional buildings without floating columns. However, by considering the infill masonry wall to the same structure with the floating columns, the maximum displacement value is found to be reduced by 42%. Also, it can be seen that by providing X – bracing and shear wall, the peak displacement of the building is reduced by 53% and 47%, respectively. Hence, the building with a shear wall gives more resistance against deflection than the structure with the floating column with infill masonry and the structure with the X – bracings. A similar response is obtained for the structures in zone V. However, the response is more in this case as the magnitude of the seismic force is more in zone V compared to zone IV. It can also be observed that the maximum displacement of structures subjected to seismic force in y-direction for all the models, except the structure with shear wall at the corners, exceeds the IS code specified permissible value for storey displacement, which is calculated as 90 mm for the considered structure. Hence, the sizes of columns and beams of the structure assumed for the study are to be reconsidered for buildings in zone V in order to get the values within the permissible limits.

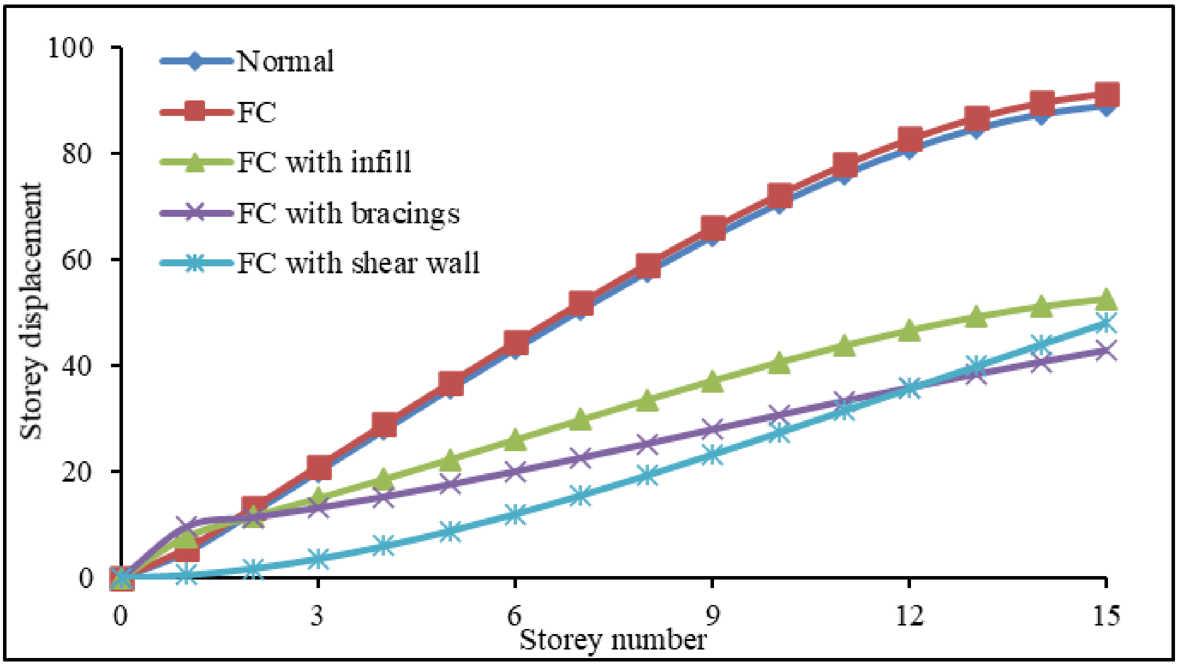

Figure 3. Storey displacement variation along X - direction for RC structure in Zone IV

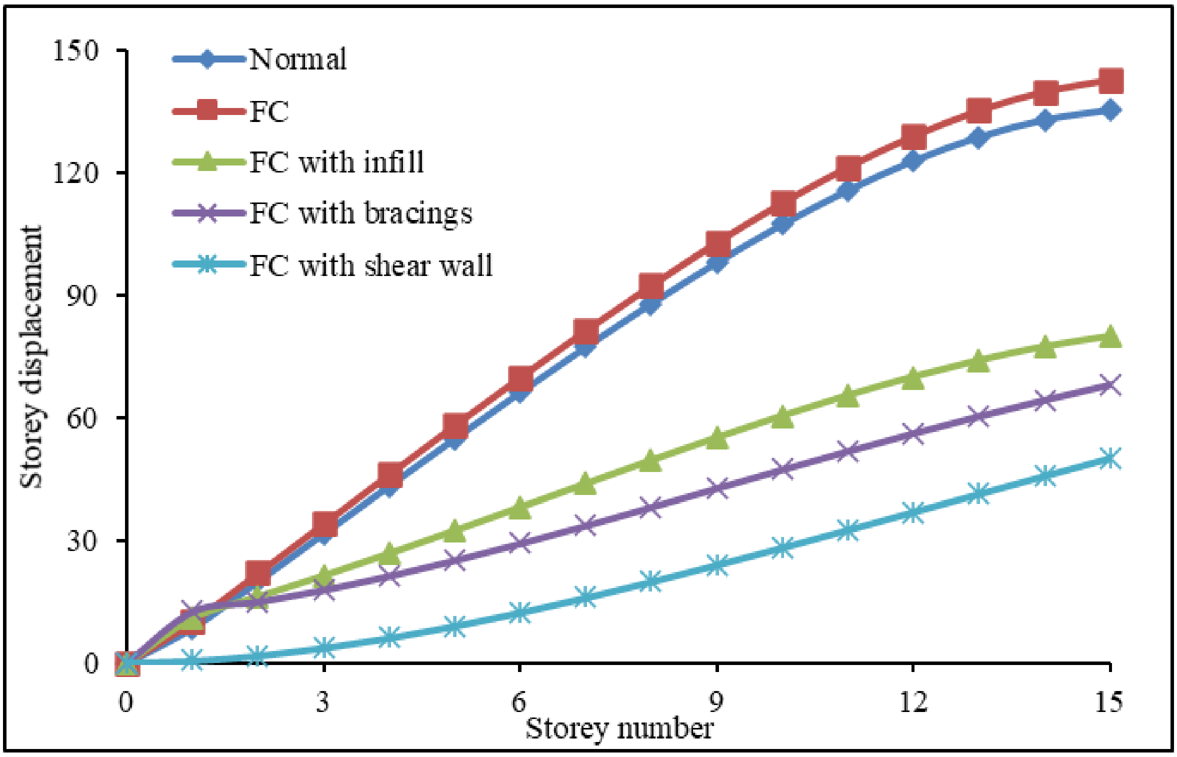

Figure 4. Storey displacement variation along Y - direction for RC structure in Zone IV

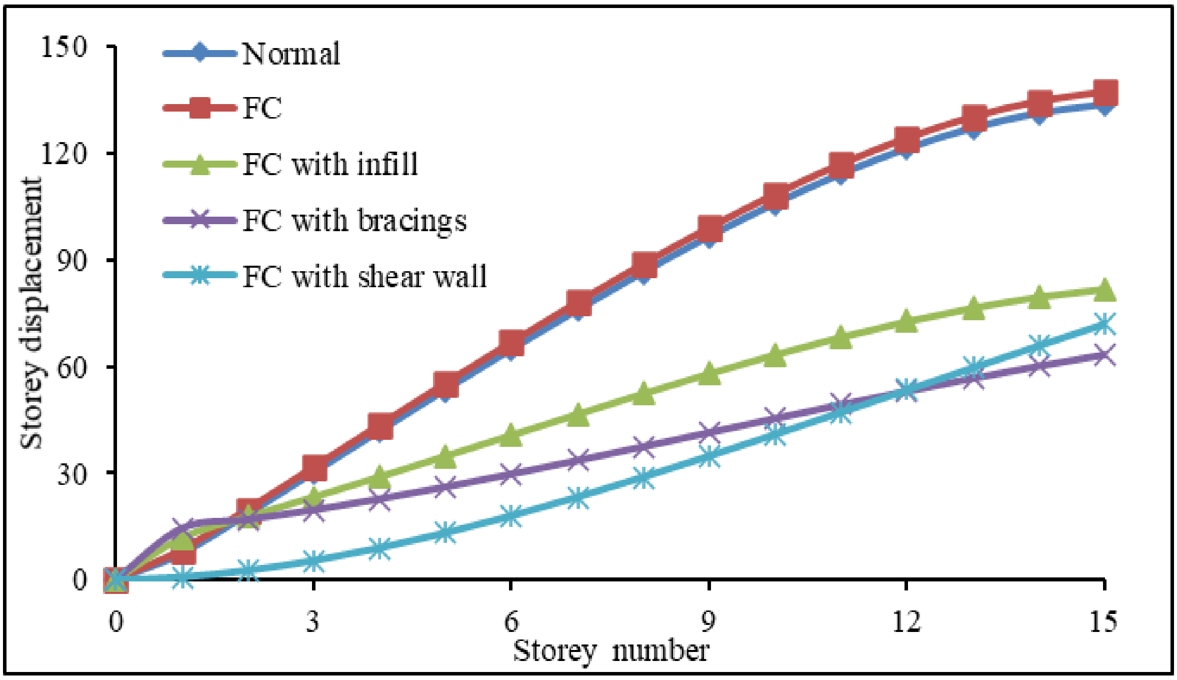

Figure 5. Storey displacement variation along X - direction for RC structure in Zone V

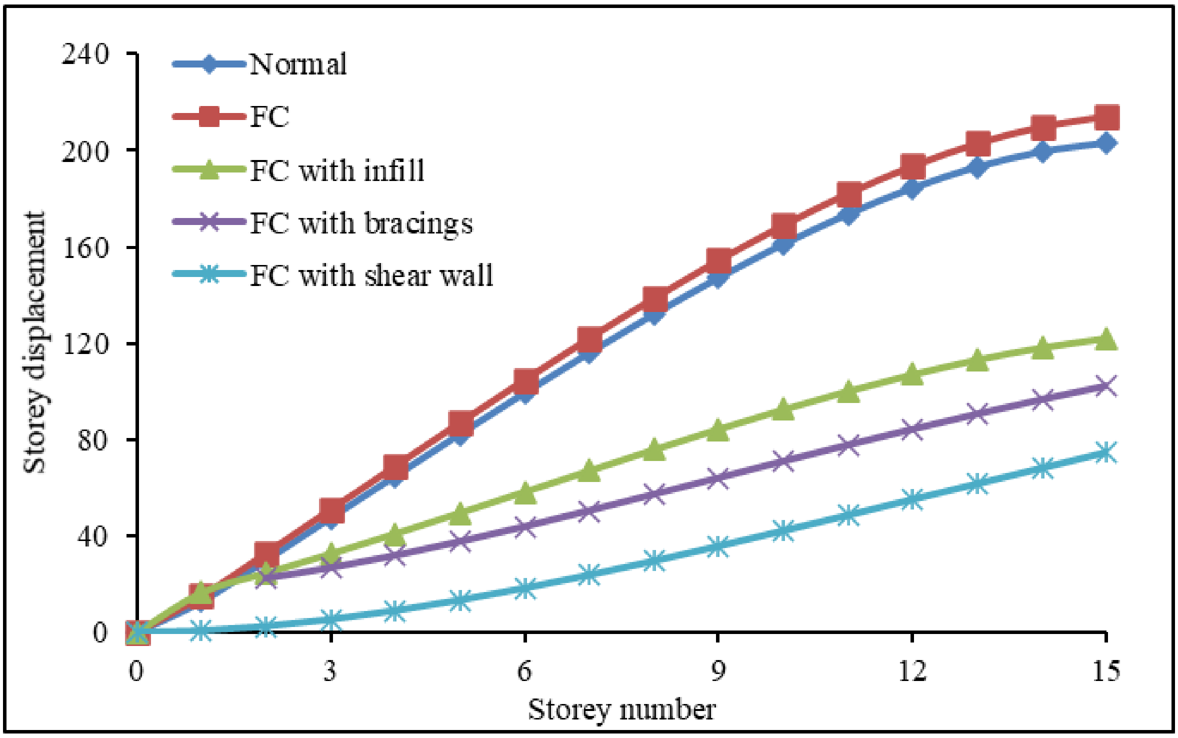

Figure 6. Storey displacement variation along Y - direction for RC structure in Zone V

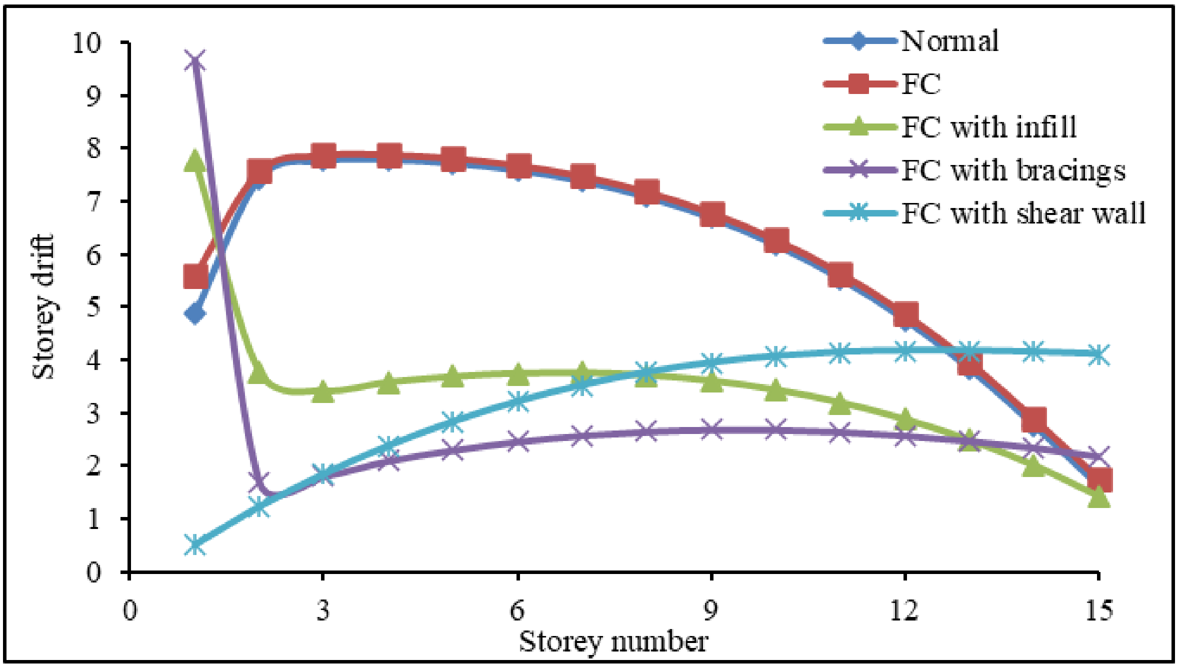

Figure 7. Storey drift variation along X - direction for RC structure in Zone IV

3.2. Storey Drift

The variation of storey drift for various models located in zone IV and zone V, subjected to seismic force in the two principal directions (x and y), are shown in Figure 7 - Figure 10, respectively. From the figures, it can be observed that the storey drift values increase abruptly at the base of the structure where floating columns are provided and then decreases gradually along the height of the structure. However, when masonry infill and bracings are provided, the storey drift value decreases at the location of the floating column. Also, the effect is found to be more for the structures with bracings. It can also be observed that, for the structures with shear walls, the storey drift increases gradually along the height of the structure without any abrupt change in the value.

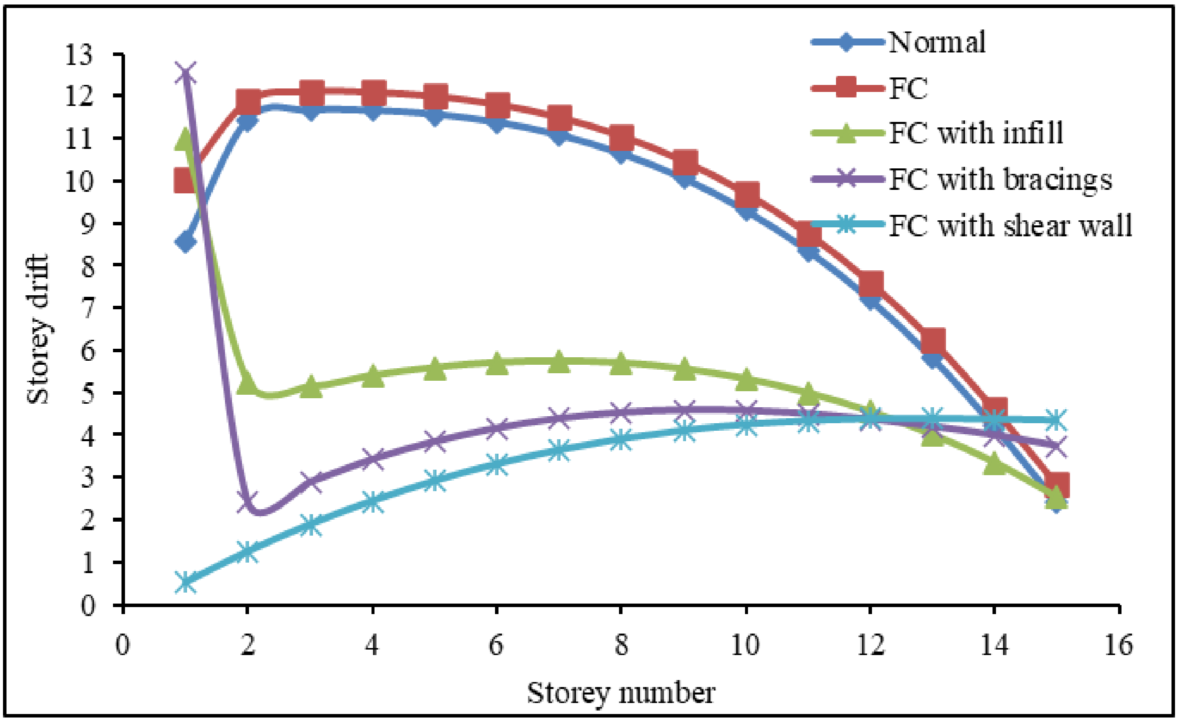

Figure 8. Storey drift variation along Y - direction for RC structure in Zone IV

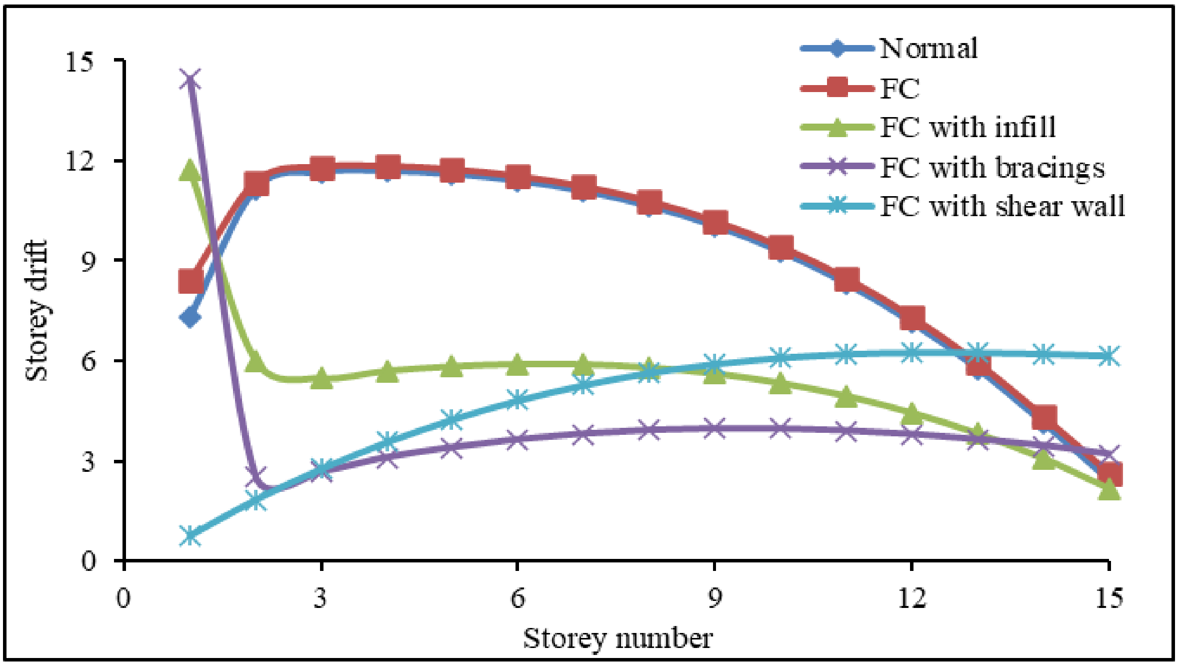

Figure 9. Storey drift variation along X - direction for RC structure in Zone V

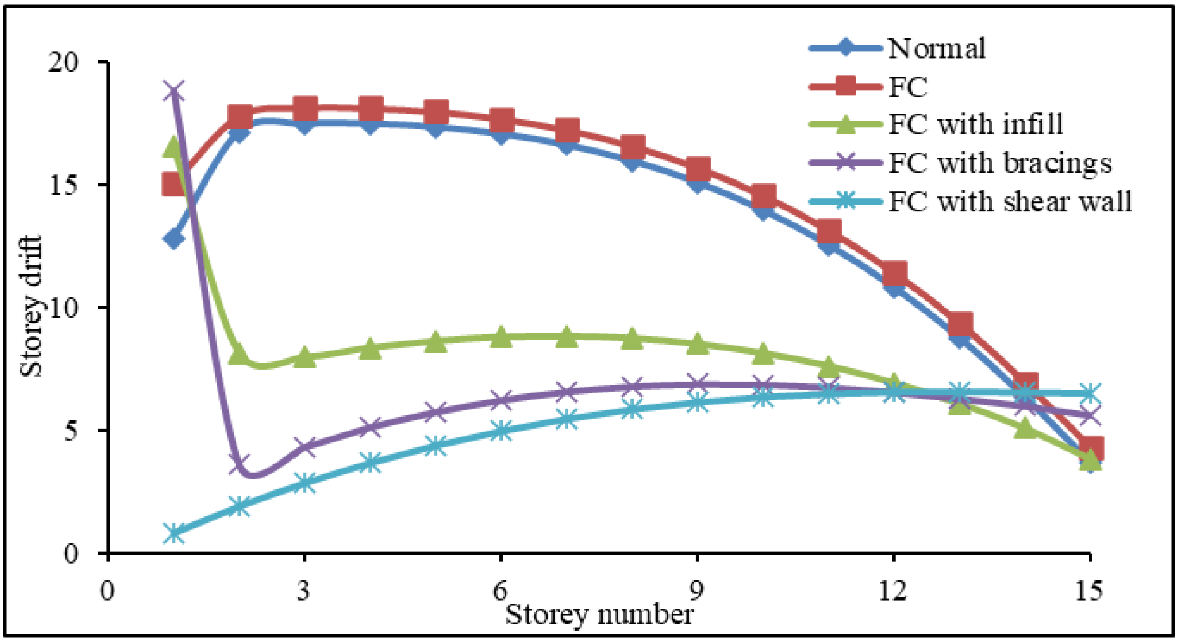

Figure 10. Storey drift variation along X - direction for RC structure in Zone V

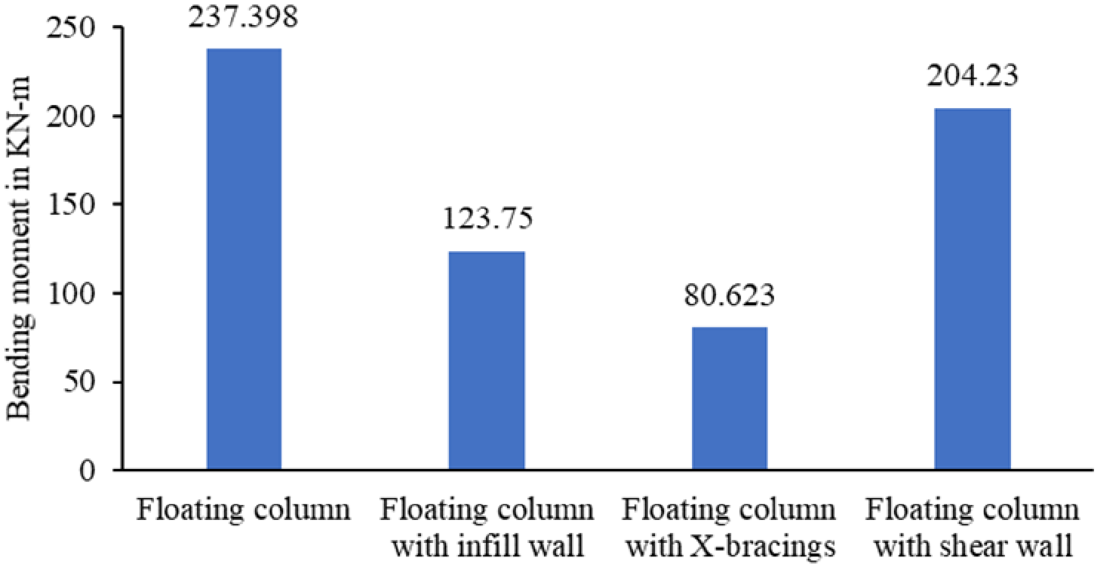

Figure 11. Bending moment in transfer girder for the structures with load in the x-direction

3.3. Bending Moment and Deflection in Transfer Girder

The bending moment in transfer beam obtained using the ESL method for four models subjected to seismic load in the two principal directions (x and y) are shown in figure 11 and figure 12, respectively. It can be observed from the figures that the bending moment values obtained due to load in both x and y directions in the regular structure with floating column are more compared to the structures with masonry infill, bracings and shear wall. However, the bending moment reduces when the structure is strengthened using masonry infill, X – bracings or shear walls. It can also be noted that the effect is more when X – bracings are provided in the structure compared to other models considered in the study.

Figure 13 and figure 14 indicates the deflection in transfer girder obtained for four models with floating column subjected to seismic load in x and y directions, respectively. It is found that the deflection of the beam is more in structure with the floating column. It can also be noticed that when the structure is strengthened using infill masonry, X – bracings or shear walls, the displacement of the girder reduces. However, the effect is found more in the structure with the bracings as these bracings provide more stiffness than the other models considered in the study.

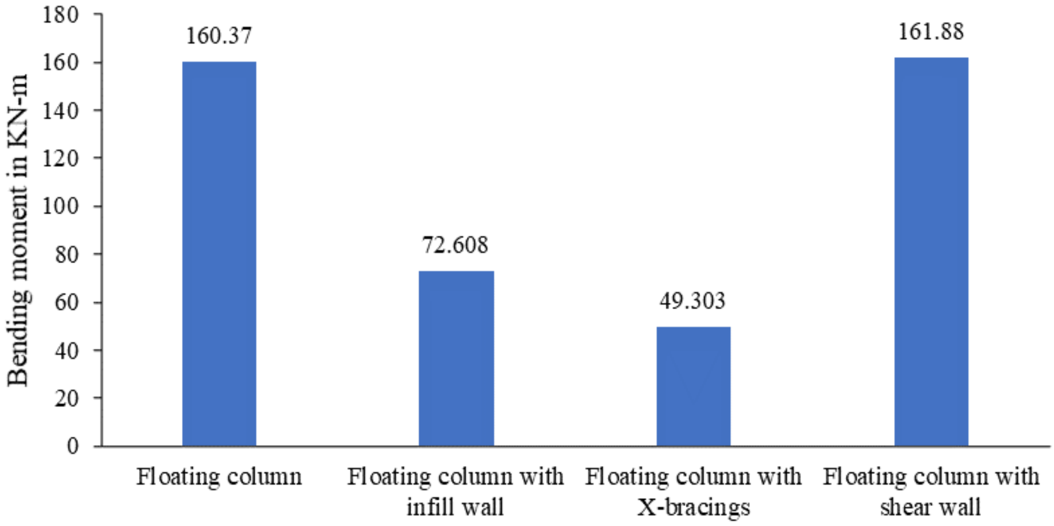

Figure 12. Bending moment in transfer girder for the structures with seismic load in the y-direction

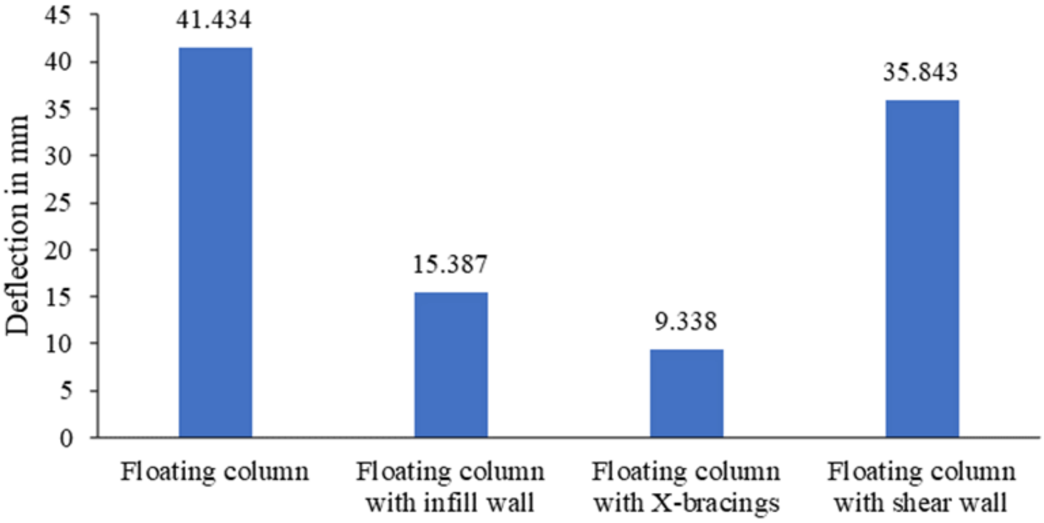

Figure 13. Deflection in transfer girder for the structures with load in the x-direction

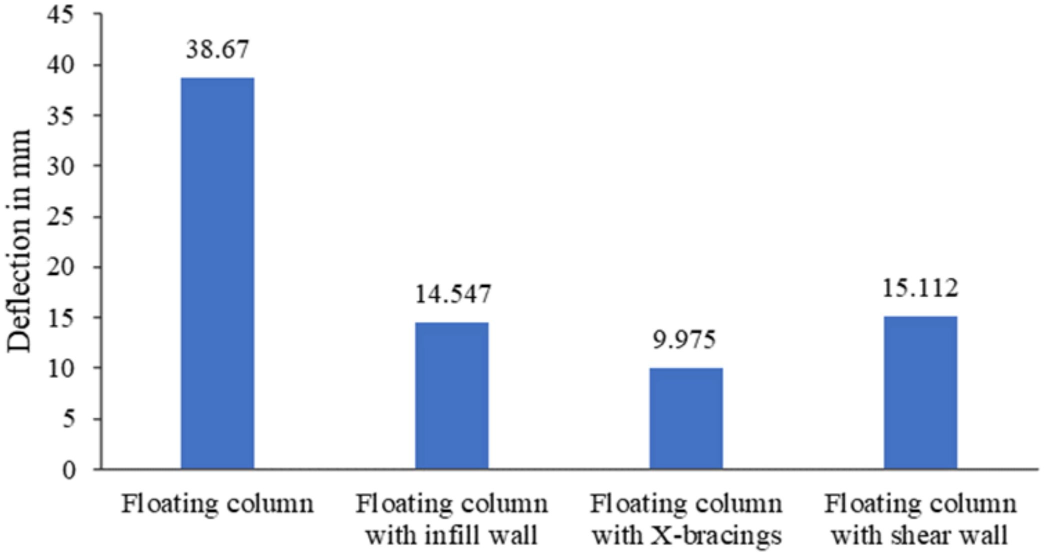

Figure 14. Deflection in transfer girder for the structures with load in the y-direction

4. Conclusions

A regular G + 15 RC framed multi-storey building located in seismic Zone IV and Zone V, respectively, is considered for the study. Five different models were considered, and each structure is subjected to seismic force in both x and y directions. The analysis is done by the ESL method. It is found that the storey displacement value of the structure increases from the lower zone to the higher zone as the magnitude of seismic force increases from lower to higher zones. Similar results are obtained for storey drift. Floating columns considered are found to be capable of carrying gravity loads. However, transfer girder should be provided with adequate stiffness to support these columns in order to reduce the stresses on other members. By including infill masonry, X – bracing, or shear wall to the structure with the floating column, the building can be made less vulnerable to earthquake. Providing a shear wall is found to be a much more effective solution to reduce the drift of the structure, which in turn reduces the forces on the members of the structure compared to other models considered in the study. However, when the response is considered in terms of bending moment and displacement of the transfer girder, the building with X – bracings is found to be more effective as these bracings are placed between the positions of the floating column and hence provide more stiffness to the structure compared to the regular building with the floating column.

REFERENCES

[1] Nikhil Bandwal, Anant Pande, Vaishali Mendhe, Amruta Yadav, “To study seismic behavior of RC building with floating columns,” International Research Journal of Engineering and Technology, vol. 3, no. 8, pp. 1592–1596, May 2014.

[2] P. Mundada and S. G. Sawdatkar, “Comparative Seismic Analysis of Multistorey Building with and without Floating Column”, International Journal of Current Engineering and Technology, vol. 4, no. 5, pp. 3395 – 3400.

[3] Rohilla, Isha, S. M. Gupta, and Babita Saini. "Seismic response of multi-storey irregular building with floating column." IEEE Trans. Power System, vol. 19, no. 1, pp. 356-365, March 2015.

[4] Mahesh M, K Lakshmi “Comparative Seismic Study on 3D RC Frame Structure with & without Floating Columns for Stiffness Irregularities Subjected to Seismic Loading”, International Research Journal of Engineering and Technology, vol. 2, no. 5, Aug 2015.

[5] Meghana, B. S., and T. H. Sadashiva Murthy. "Effect of floating column on the behavior of composite multi-storied building subjected to seismic load." International Research Journal of Engineering and Technology, vol. 3, no. 6, pp. 2613-2619, June 2016.

[6] Raghavendra, Allacheruvu, T. Appa Reddy, and G. N. Sreekanth. "Comparative Seismic Study on Strengthening of Floating Column Building Using Bracings." International Journal of Advances in Mechanical and Civil Engineering, ISSN 2394-2827, 2016.

[7] Vignesh Kini K, Rajeeva S. V, “Comparison of response spectrum analysis and construction sequence analysis of RC and steel-concrete composite multi-storey building with floating columns”, International Journal of Research in Engineering and Technology, vol. 6, no. 5, eISSN:2319-1163, pp. 64-68, May-2017.

[8] Priya Prasannan, Ancy Mathew, “Seismic Performance of RC Floating Column Considering Different Configurations”, International Journals of Engineering Research & Technology, vol. 6, no. 5, pp: 100-107, May-2017.

[9] Sreadha, A. R., & Pany, C., “Seismic Study of Multistorey Building using Floating Column”, International Journal of Emerging Science and Engineering (IJESE) ISSN, 2319-6378, April 2020.

[10] Sreekanth Gandla Nanabala, Pradeep Kumar Ramancharla, “Seismic Analysis of a Normal Building and Floating Column Building”, International Journal of Engineering Research & Technology, September 2014.

[11] Swapnil B. Cholekar and Basavlingappa. S. M, “Comparative analysis of multi-storied RC and composite building due to mass irregularity”, International research journal of engineering and technology, vol. 2, no. 4, pp. 603-608, July-2015.

[12] Tyagi S. & Tyagi B.S, “Seismic analysis of multi-storey building with a floating column”, International Research Journal of Engineering and Technology, vol. 5, no. 5, pp. 3479–3483, May 2018.

[13] IS:1893 (Part 1): 2016, Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi, India.