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Research Article

Seismic Performance of Multi-Storey RCC Building with Floating Columns

Suchita Hirde[#] and Dhananjay Rahangdale[#*]

[#]Applied Mechanics Department, Govt. College of Engineering, Karad, 415124 (M.S.) India

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Abstract

This study highlights the importance of explicitly recognizing the presence of the floating column in the analysis of building. 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. The RCC building models having (G+7) storey without floating columns and with floating column at each storey level, alternate location are considered for the study. The response spectrum analysis and pushover analysis of building is carried out using structural engineering software SAP 2000 and the seismic performance of building with various floating columns location is compared with respect to various parameters.

Keywords: *Floating columns, response spectrum analysis and pushover analysis*

1. Introduction

Earthquake are natural hazards under which disaster are mainly caused by damage or collapse of buildings. Earthquake causes damage especially to the multi-storey RCC Building with floating columns that float or hang on beams at an intermediate storey and do not go to the foundation, have discontinuities in the load transfer path. Many buildings with floating columns adopted to get more space for parking or reception lobbies collapsed or were severely damaged during past earthquake. Hence it is required to study the effect of positioning of floating columns on seismic performance of the building.

Concept of floating columns

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground.

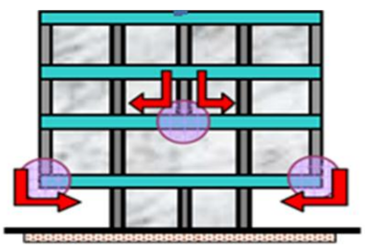

Fig.1 Floating columns building (source: Earthquake tips)

*Corresponding author: **Dhananjay Rahangdale** is a PG Student and **Suchita Hirde** is working as Professor

The term floating column is a vertical element which ends at its lower level rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. Such columns where the load is considered as point load. Theoretically such structures can be analyzed and designed. In practice, the true columns below the termination level are not constructed with care and more liable to failure.

2. Structural modelling and analysis

In this paper analytical study of G+7 storey public building with floating columns at various alternate position are safely designed by using STAAD-Pro for static loading. Then after getting safe dimension of beam and columns, the buildings are modeled using finite element software SAP2000. Then these loading are analyzed using response spectrum method and non-linear static pushover analysis. For the easy understanding and convenience each model is named depending on location of floating columns on particular floor. The first letter in the name of model 'F' indicate for floating columns and 'W' indicate for without floating columns. The second letter 'I' denotes location of floating column in inner side on that floor, where numeric value i.e. 1, 2, 3, 4, and 5, indicate floor location of floating columns. For analysis purpose following models have been considered

WF	Building without floating columns as shown in fig. 4.
FI-1	Building with floating columns at ground floor with increased dimension of beam and column at first storey as shown in fig. 5.
FI-2	Building with floating columns at first floor with increased dimension of column up to two storey as shown in fig. 6.
FI-3	Building with floating columns at second floor with increased dimension of column up to three storey as shown in fig. 7.
FI-4	Building with floating columns at third floor with increased dimension of column up to four storey as shown in fig. 8.
FI-5	Building with floating columns at fourth floor with increased dimension of column at up to five storey as shown in fig. 9.

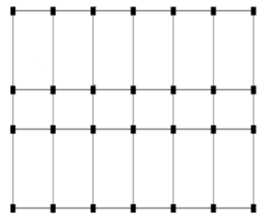

Fig.2 Plan without floating columns model

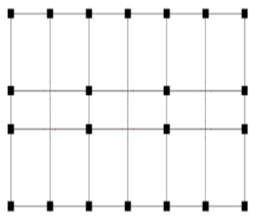

Fig.3 Plan with floating columns models

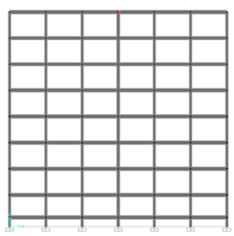

Fig.4 Elevation of 'WF' building

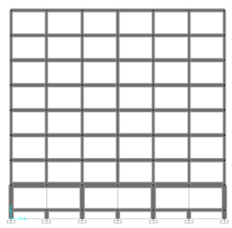

Fig.5 Elevation of 'FI-1' building

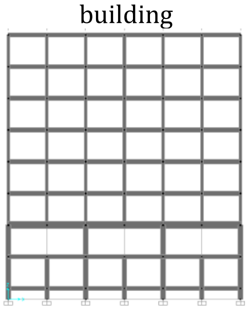

Fig.6 Elevation of FI-2 building

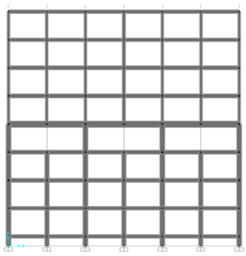

Fig.7 Elevation of 'FI-3' building

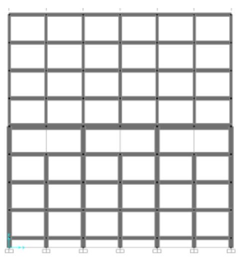

Fig.8 Elevation of FI-4 building

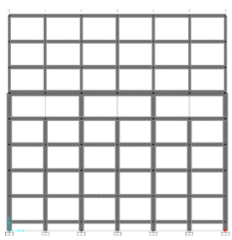

Fig.9 Elevation of FI-5 building

Table 1 Details of building models

1	Type of Structure	SMRF
2	Grade of concrete	M30
4	Size of building	12.5 X 24m
5	Grade of steel	Fe 415
n	Floor to floor ht.	3.5 m
7	Plinth ht. above GL	1.2 m
8	Parapet height	1.5 m
9	Slab thickness	0.20 m
10	External wall	0.23 m
11	Internal wall	0.15 m
12	Size of column	300x600 mm
13	Size of columns for bottom storey	500x800mm
14	Size of beams	300x500 mm
15	Size of beam below floating columns	500x 800 mm
14	Live load on floor	3kN/m^2
15	Live load on roof	1.5 kN/m^2
16	Floor finishes	2 kN/m^2
17	Roof treatment	1.5 kN/m^2
18	Density of concrete	25 N/m^3

The performance of the building with various location of floating columns is studied with respect to the parameters such as base shear, fundamental time period, top floor displacement and member forces are compared within the considered location of floating columns. The four columns A, B, C, and D as shown in Fig 10 are considered for the study of member forces.

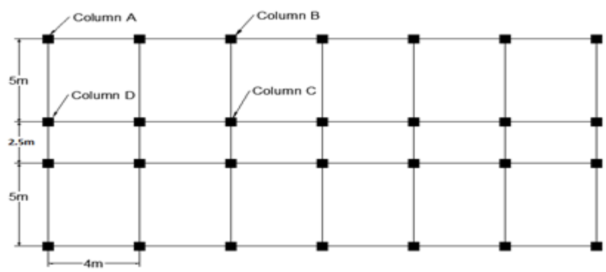

Fig 10 Plan of building showing columns A, B, C and D considered in study

3. Results and discussion

In this paper an attempt is made to study the seismic performance of building with floating column. The dynamic response of these buildings is presented in terms of base shear, fundamental time period, roof displacement, storey drift and member forces of selected columns as shown in figure 4 to figure 11. These results are compared within these 6 models with their considered configurations of floating columns. The main objective of this paper is to study the effect of positioning of floating columns for the building situated in seismic zone IV and V for medium soil. The result obtained from the analysis are analyzed and represented in graphical form as shown in fig.11 to fig.19.

3.1) Effect of positioning of floating columns by response spectrum method with different zone.

a) Effect on base shear

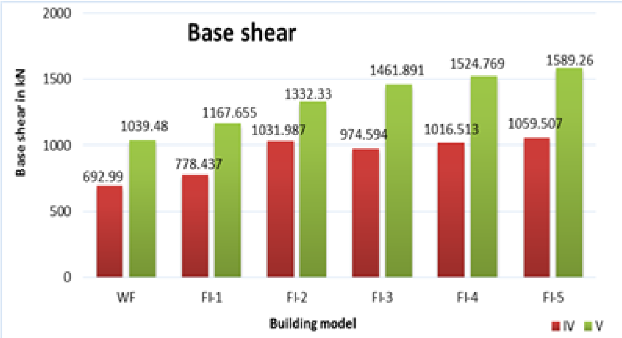

Fig.11 Base shear for in zone IV and V for different building models

From fig. 11, it is observed that base shear for zone IV is about 33-34% less than that of zone V, base shear increases from seismic zone IV to V, because seismic coefficient increases from lower to higher zone. It is found that about 10-12% base shear increases for each model from model WF to FI-5, because dimension of column is increased up to that storey where floating columns are located.

b) Effect on time period

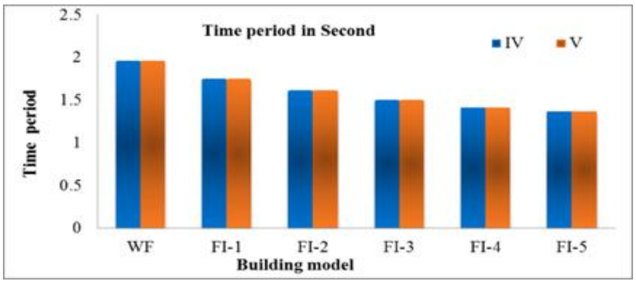

Fig.12 variation of time period for different building models

Fig.12 shows nearly 10-12% reduction in time period as per shifting of floating columns in upper storey.

c) Effect on roof displacement

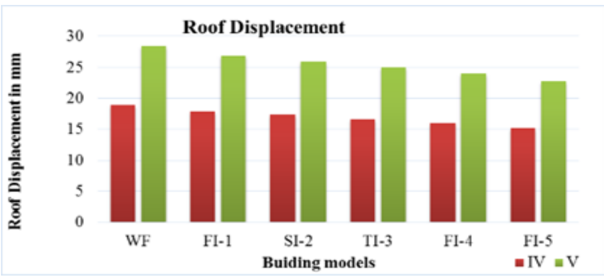

Fig.13 variation of roof displacement for different building models

Fig.13 shows nearly 33-34% increase in roof displacement from zone IV to V, because seismic coefficient increases from lower to higher zone, it shows nearly 5-6% reduction in roof displacement from WF to FI-5, because as the floating columns are shifted to upper storeys, increase in dimension of columns is increased up to that storey where floating column is provided, hence stiffness increases.

d) Effect on storey drift

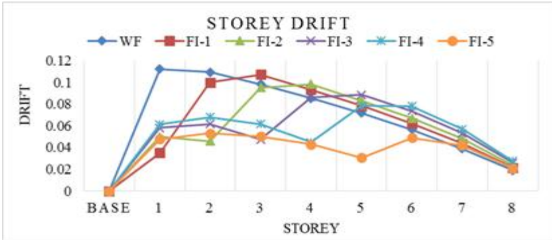

Fig.14 variation of storey drift for zone IV for different building models

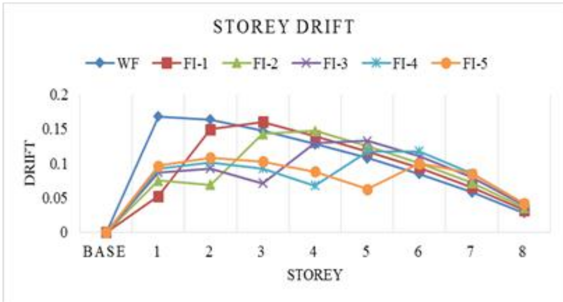

Fig.15 variation of storey drift for zone V for different building models

From fig.14 and fig.15, it is observed that there is abrupt change in storey drift in the storey where floating columns are provided because of decrease of lateral strength of storey due to provision of floating columns causes abrupt storey drift, again it is observed that storey drift for zone IV is about 30-31% less than zone V, because seismic coefficient increases from lower to higher zone.

e) Member forces in columns

- *Axial force in columns*

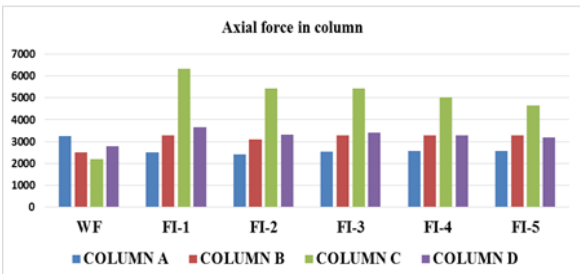

Fig. 16 Axial forces in columns for building in zone V for medium soil

Table 2 Performance point and performance level for models with floating columns at various positions

Models	Direction	Displacement (mm)	Base Shear (kN)	No of hinges					Seismic performance level
				A to B	B to IO	IO to LS	LS to CP	Total	
WF	X-Direction	132.46	1426.559	1038	276	0	0	1314	B to IO
	Y-Direction	126.67	1521.40	997	317	0	0	1314	
FI-1	X-Direction	173.668	1062.152	838	364	90	4	1296	LS to CP
	Y-Direction	141.269	1414.769	797	373	126	0	1296	
FI-2	X-Direction	162.1	1275.986	870	358	18	0	1302	IO-LS
	Y-Direction	121.241	1649.001	826	446	30	0	1302	
FI-3	X-Direction	127.366	1528.974	904	390	10	0	1302	IO-LS
	Y-Direction	91.267	1876.79	867	435	0	0	1302	
FI-4	X-Direction	112.876	1860.326	830	472	0	0	1302	B-IO
	Y-Direction	99.763	2231.53	848	454	0	0	1302	
FI-5	X-Direction	98.774	1972.969	922	368	0	0	1290	B-IO
	Y-Direction	74.669	1477.74	880	422	0	0	1290	

From fig.16, it is observed that axial force for column A, B and D is nearly constant for all building models, with change in positioning of floating columns, because these columns are located on outer side of building, therefore not affected due to change in position of floating columns. Again it is observed that for 'column C' the axial forces is about 65 to 70 % more in case of model FI-1 as compared to model WF. And it get reduced nearly 8 to 10% as the floating columns is shifted to upper storey.

- *Shear force in columns*

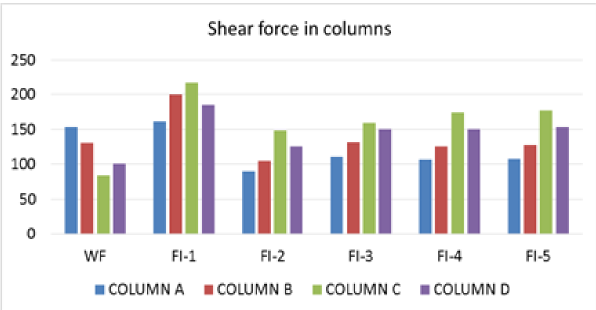

Fig.17 Shear forces in column for building in zone V for medium soil

From fig.17, it is observed that nearly 14-15% shear force is reduced in FI-2, FI-3, FI-4, FI-5 as compared to FI-1(floor at which floating columns are located), again it is observed that shear force is nearly constant in FI-2, FI-3, FI-4 and FI-5, it is observed that for 'column C' the shear force is about 50 to 60 % more in case of model FI-1 as compared to model WF.

- *Bending moment in columns*

From fig.18, it is observed that nearly 45-50% bending moment increases in column C of FI-1 as compared to WF. Again it can be clearly seen that the bending moment in all columns (A, B, C and D) get increased from FI-1 to FI-5, because as the floating columns is shifted to upper floor, size of column increases up to that floor where floating columns are shifted.

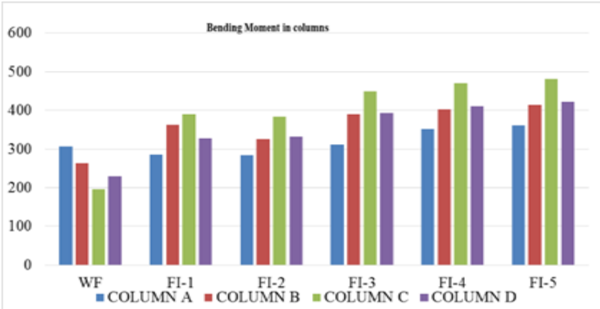

Fig. 18 bending moment in column for building in zone V for medium soil

3.2) Comparison of performance of various models

From Table 2 it is clear that the performance level of 'WF' model is very safe as compared to FI-1, FI-2 and FI-3 model, because in WF building the hinges are formed in between B-IO, as compared to FI-1 in which hinges are found in between LS-CP, as well as FI-2 and FI-3 in which hinges are found in between IO-LS. It shows decreasing performance of building with provision of floating columns.

From Table 2 it is found that in case of building with floating columns FI-4 and FI-5 is more safe as compared to FI-1, FI-2 and FI-3 model, Because in FI-4 and FI-5 models hinges are found in B-IO only. But in FI-1, FI-2 and FI-3 models hinges are found in a LS-CP.

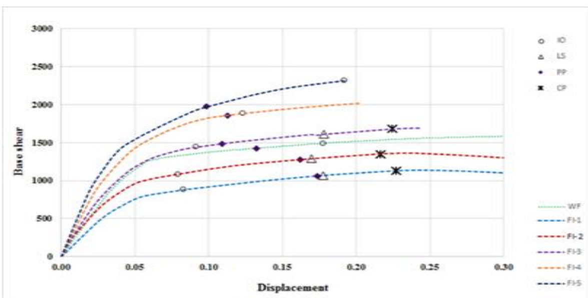

Fig. 19 Capacity curve for WF, FI-1, FI-2, FI-3, FI-4 and FI-5 building model

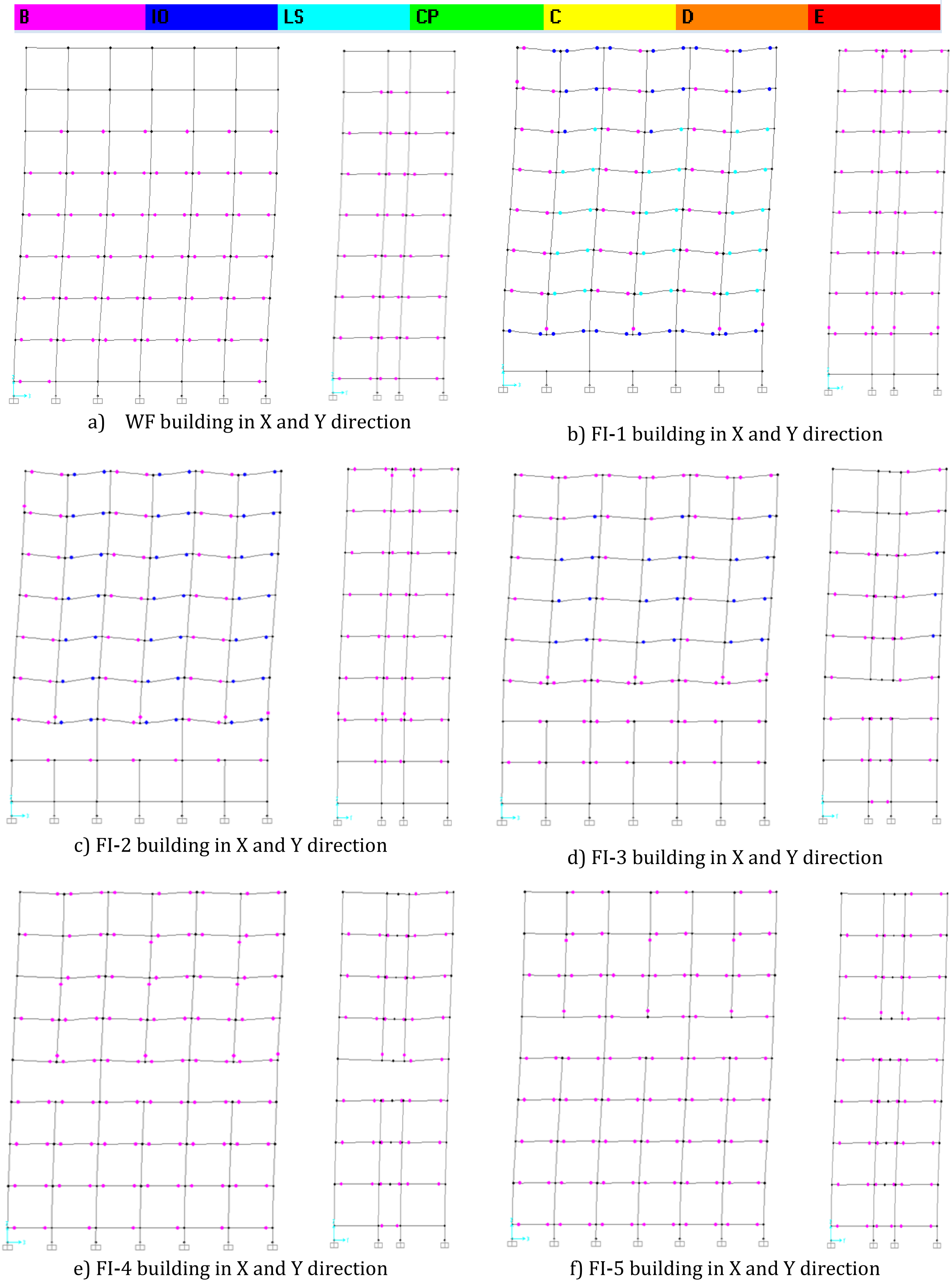

Fig.20 Pushover analysis: hinge pattern diagram

3.3) Effect on hinge pattern of various models

- From hinge formation pattern in Fig. 20(a) for WF building in X and Y direction, it is seen that hinges developed in beams are in acceptable level, whereas in column hinges are not formed.
- In case of Fig. 20(b) for FI-1 building in X and Y direction, it is seen that hinge developed in beam

are in LS-CP. whereas hinges are developed in columns are in IO level.

- From hinge formation pattern in fig. 20(b) to fig. 20(f), as the floating columns are shifted to upper storey (i.e. FI-1 to FI-5), it is seen that improvement in hinge formation pattern i.e. From CP to IO.

Conclusion

1) Performance parameters such as base shear, roof displacement and storey drift for zone IV is about 33-34% less than that of zone V, Base shear increases from seismic zone IV to V because seismic coefficient increases from lower to higher zone for different type of zones.
2) The reduction in lateral displacement is observed to be 5-6% for dynamic base shear in X and Y directions for models WF to FI-1, FI-1 to FI-2 like that up to FI-5, It shows removal of floating column at upper storey is more efficient than bottom storey.
3) It is found that there is abrupt change in storey drift in the storey where floating columns is provided because decrease in lateral strength of storey due to provision of floating column causes abrupt storey drift at that particular floor where floating column is provided.
4) It is concluded that in case of building with floating columns FI-4 and FI-5 is more safe as compared to FI-1, FI-2 and FI-3 model, because in FI-4 and FI-5 models hinges are found in B-IO range only. But in FI-1, FI-2 and FI-3 models hinges are found in a LS-CP.
5) From hinge formation pattern in building without floating columns (WF) in X and Y direction, it is seen that hinges developed in a beams are in acceptable level, whereas as in column hinges are not observed.
6) It shows that it is vulnerable to provide floating columns in bottom storey. The seismic performance improve with shifting of floating columns storey to higher level.

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