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Seismic Performance of Multi-Storey RCC Building with Floating Columns

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Abstract- Now *a day's floating columns are used in multi-story buildings in urban India. There are various uses of floating columns such as space for assembly hall, reception lobbies and parking purpose etc. Such features are highly undesirable in building built in seismically active areas. Due to discontinuity in load transfer path result in poor performance of building. In this paper an attempt is made to study the comparison of seismic performance of building with normal building and floating columns building for various seismic zones in case of medium soil. For this purpose Pushover analysis is adopted to get performance point and hinge pattern in a multi-storey buildings. To achieve this objective, model of G+7 storey normal building and building with different locations of floating columns are analyzed and the base shear and displacement of multi-storey RCC buildings have been compared. The analysis is being carried out using SAP2000 software package.*

Keywords*: *floating columns, push over analysis, performance point, hinge pattern.

1. Introduction

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 storeys 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. Earthquake are natural hazards under which disaster are mainly caused by damage or collapse of buildings. Many buildings with floating column adopted to get more space for parking or reception lobbies collapsed and were severely damaged in earthquake. Hence analysis and positioning of floating columns needs special attention

Concept of 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.

There are many projects in which floating columns are adopted, especially above the ground floor or in 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.

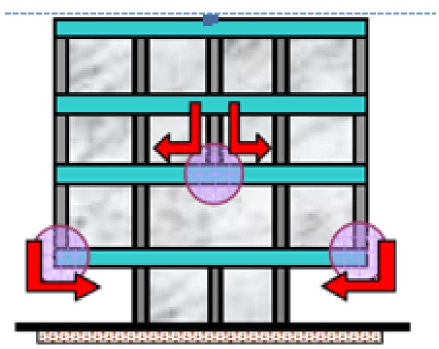

Figure 1 Fig.1 Floating columns building
(Source: Earthquake tips IITK)

The column act as 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. Looking ahead, of course, one will continue to make buildings interesting rather than monotonous. However, this need not be done at the cost of poor behavior and earthquake safety of buildings. Architectural features that are detrimental to earthquake response of buildings should be avoided. If not, they must be minimized. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design and yet the building may not be as good as one with simple architectural features.

2. Pushover analysis of floating column building

In this paper an attempt is made to analyze the building with floating columns for various location of floating columns using pushover analysis so as to study the effect of location of floating columns on seismic performance of building. Pushover analysis is a static nonlinear procedure in which the magnitude of lateral load is increased monotonically maintaining a predefined distribution pattern along the height of building. Building is displaced till 'control node' reaches target displacement, or building collapse. The sequence of cracking, plastic hinging and failure of structural components throughout the procedure is observed. The relation between base shear and control node displacement is plotted for all the pushover analysis. This curve is called pushover curve or capacity curve. The structural performance level based on roof drift is as follows:

1) Immediate Occupancy Level: Immediate Occupancy means the post-earthquake damages state in which only very limited structural damages have been occurred.

2) Life Safety Performance Level: Life Safety means the post-earthquake damages state in which significant damages to the structure have been occurred, but some margin against either partial or total structural collapse remains.

3) Collapse Prevention Performance Level: Collapse Prevention, means the buildings are on the verge of experiencing partial or total collapse. (ATC, 1997a)

The performance levels (IO, LS and CP) of a structural element are represented in force verses deformation curve.

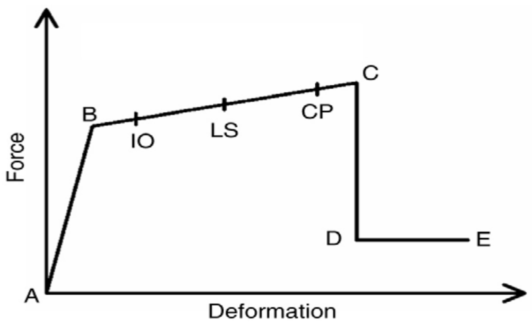

Fig 2. Force-Deformation for Pushover Hinge

i) Point A corresponds to unloaded condition.
ii) Point B corresponds to the onset of yielding.
iii) Point C corresponds to ultimate strength.
iv) Point D corresponds to the residual strength.
v) Point E corresponds to the maximum deformation capacity with residual strength.

3. Modeling and Analysis of Building

In this paper analytical study of "G+7 storied public building with floating columns and without floating columns which are safely designed by using STAAD-Pro for static loading have been presented. The buildings are modeled using finite element software SAP2000 version 14.4.2 and non-linear static pushover analysis is performed on both building models.

Table 1: Building description

1	Type of Structure	SMRF
2	Grade of concrete	M30
4	Size of building	12.5 X 24m
5	Grade of steel	Fe 415
6	Floor to floor height	3.5 m
7	Plinth height 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	C1: 300 x 800mm C2: 300 x 600 mm C3: 500 x 800 mm
13	Size of beams	B1: 300 x 500 mm B2: 500 x 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 kN/m^3

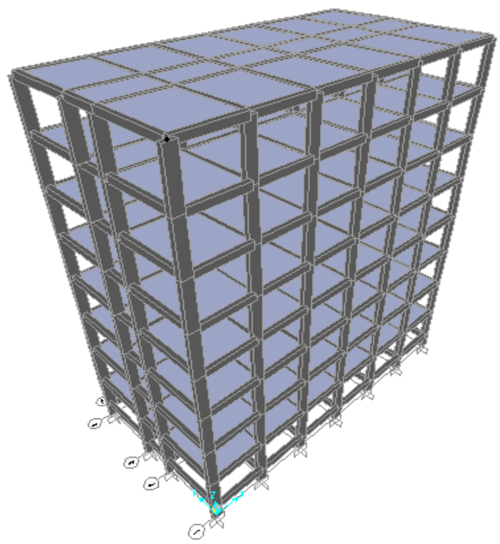

Fig3: Isometric view of model

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Model I: Normal Building without floating columns

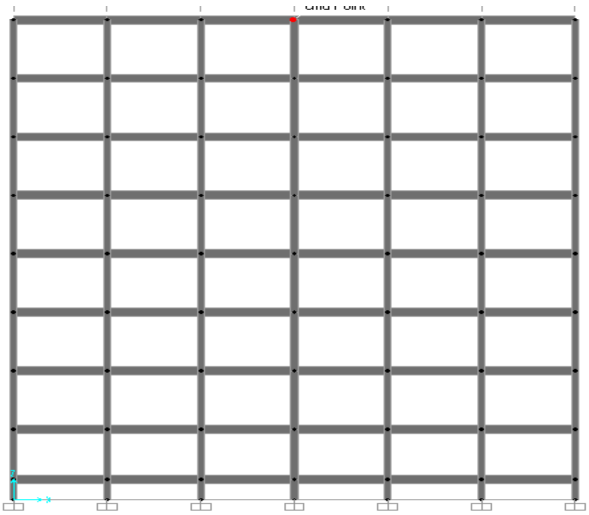

Fig 4: Elevation of normal building

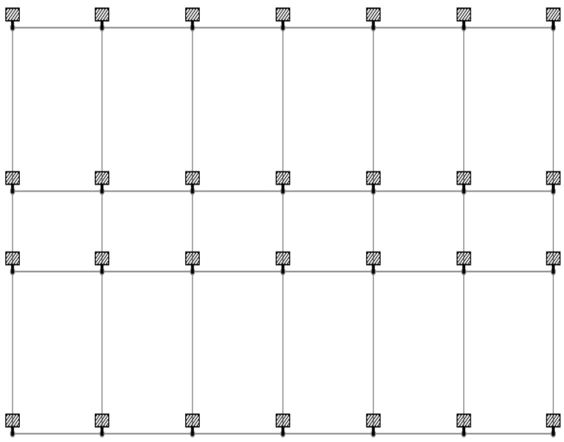

Fig. 5 Plan of normal building

Model II: Building in which floating columns are located at ground floor i.e. alternate columns in exterior frame along the two long edges except the corner ones are floating columns. In this case column and Beam size at ground floor level are large as compared to normal building.

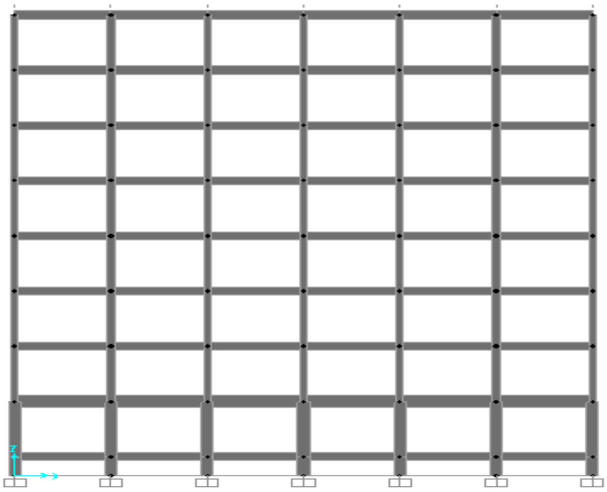

Fig 6: Elevation of floating columns building

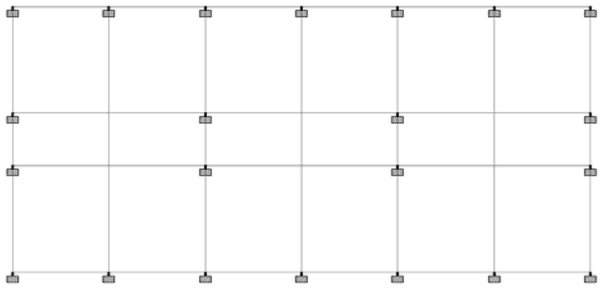

Fig 7: plan of floating columns building

Model III: Building with floating columns in which dimension increases at two consecutive floors.

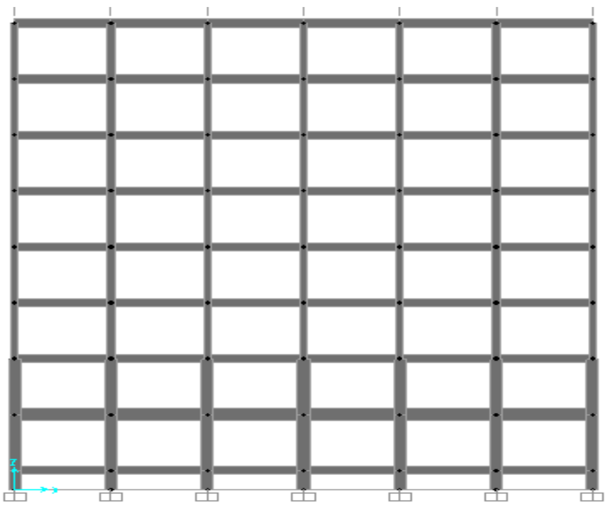

Fig 8: Elevation of building with increase in dimension at two consecutive floors

Table 2 Performance point and performance level for model without floating columns and model with floating columns

Building	Earthquake Zone	Performance Point				Seismic Performances level
		X direction		Y direction		
		V (kN)	D (mm)	V (kN)	D (mm)	
Building Without floating columns	III	1420.891	103	1521.638	95	Behind IO
	IV	1523.782	161	1654.791	149	IO-LS
	V	1719.914	467	1932.853	409	Beyond LS
Building with floating columns in which dimension increases at one floor	III	1455.247	90	1571.008	82	Behind IO
	IV	1565.796	133	1765.756	124	Beyond IO
	V	1732.114	376	2020.903	356	LS-CP
Building with floating columns dimension increases at two consecutive floors.	III	1550.752	84	1699.963	79	Behind IO
	IV	1667.635	123	1930.499	116	Behind IO
	V	1807.654	327	2184.424	308	Up to LS

3. Result and Discussion

The results obtained from non-linear static pushover analysis on all the building models as per different zone are presented in table 2 in the form of base shear, story displacement, performance point and performance level for model without floating columns and with floating columns are shown in table 2.

3.1 Base shear

Shear induced at the base of building during earthquake is called base shear which depend on seismic mass and stiffness of buildings. The results of variation in Base shear due to the effect of floating columns for different earthquake zone on medium stiff soil are tabulated in table 2. It is found that due to increase in size of beam and columns in Model II and Model III it is found that increase in base shear as compared to Model I. As the mass increases and base shear increases for floating columns building.

3.2 Storey displacement: Storey displacement is the lateral movement of the structure caused by lateral force. The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. The comparisons of story displacements for X-direction and Y-direction are shown in table 2.usually Story displacement increase when floating columns are introduced in the building. But after increase in dimension of beam and column at floor where floating column is provide it is found that decrease in (improvement) in displacements.

3.3 Hinge formation pattern:

Fig.9 to fig.11 shows hinge formation pattern in G+7 storied normal building for different seismic zone i.e. III, IV, V resp.From this hinge formation pattern it is clear that hinges are formed in beams only for zone III and IV which are behind IO (immediate occupancy) only in zone V hinges are formed in column beyond LS.(life safety).and in column beyond IO.

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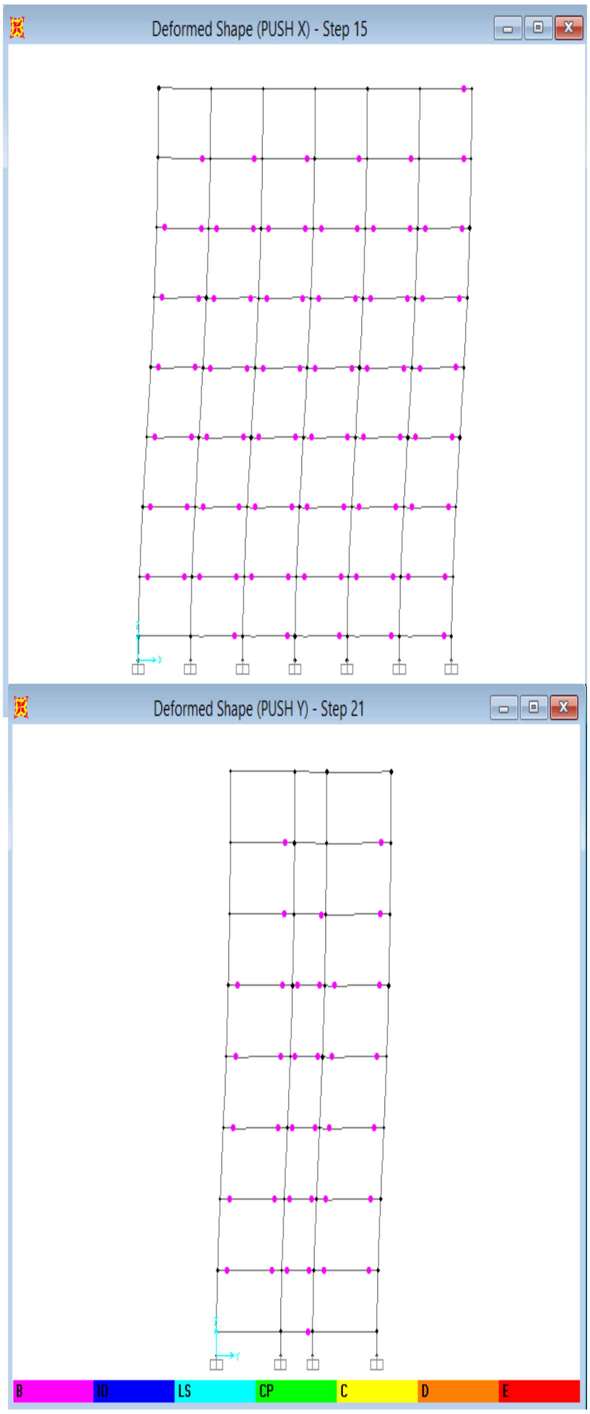

Fig no 9: Hinge formation at performance point for zone III building without floating columns in X and Y direction

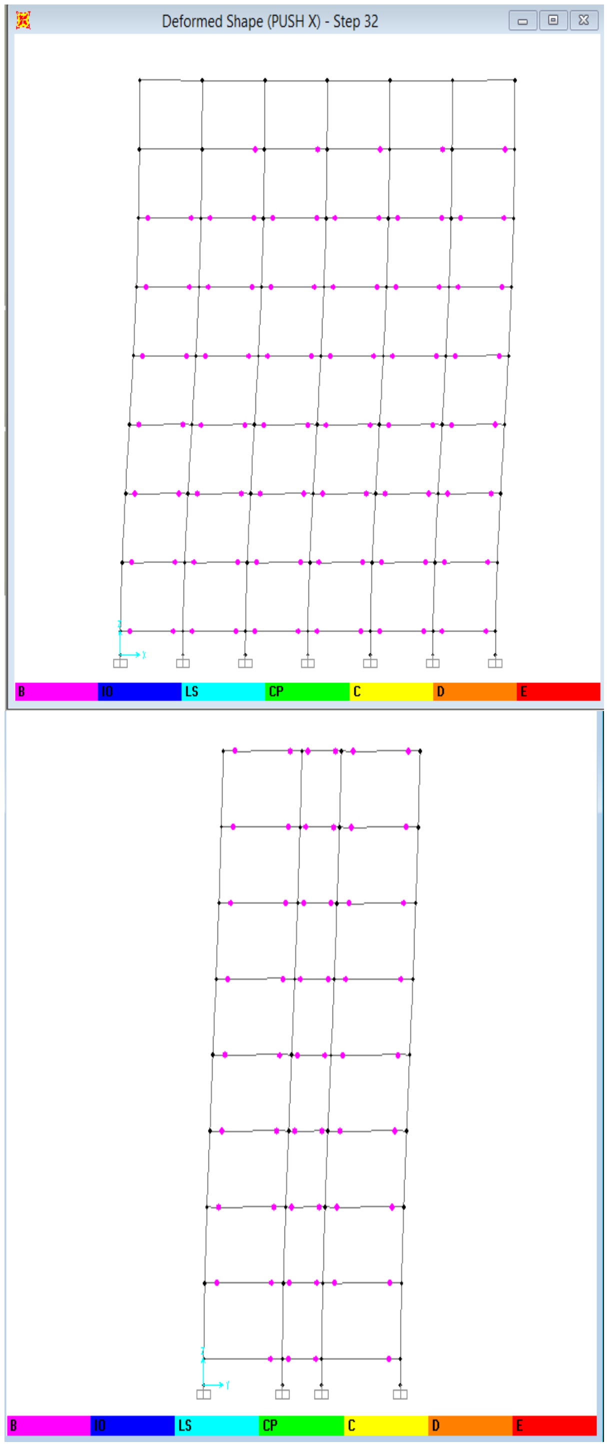

Fig.10 Hinge formation at performance point for zone IV building without floating columns in X and Y direction

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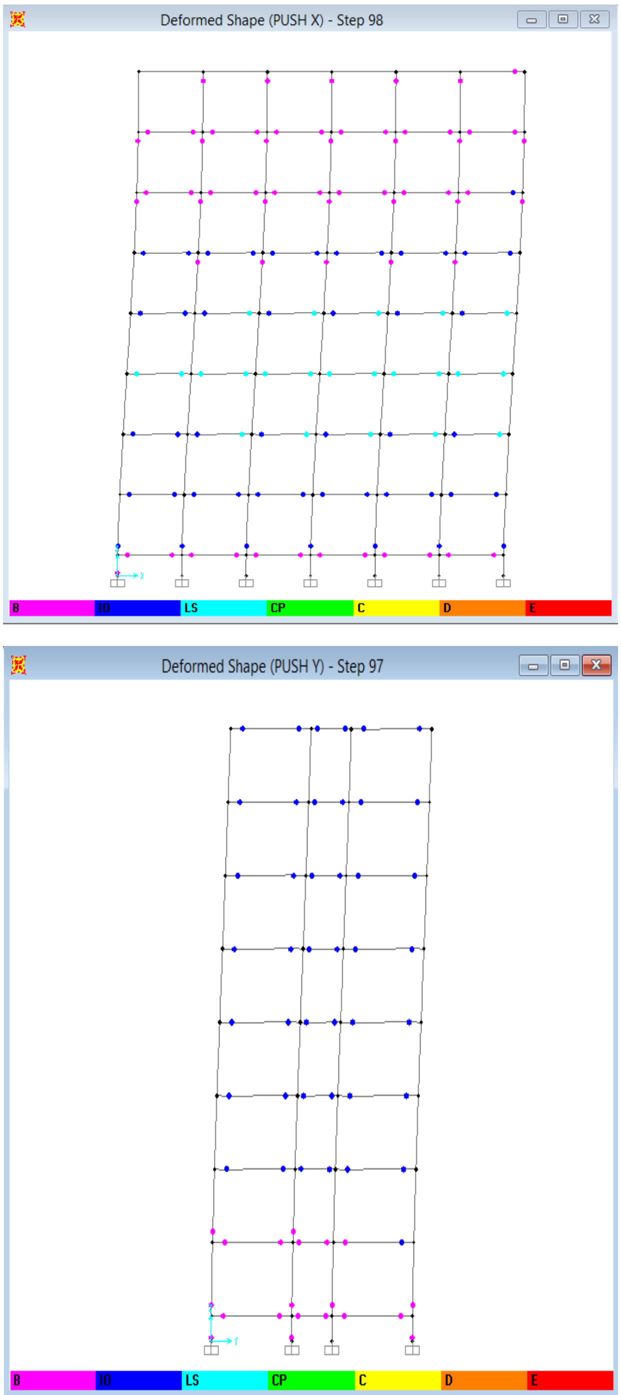

Fig 11: Hinge formation at performance point for zone V building without floating columns in X and Y direction

MODEL II

Fig.12 to fig.14 shows hinge formation pattern in G+7 storied floating columns building with increase in dimension of beam columns at two consecutive floor for different seismic zone i.e. III, IV, V resp. From this hinge formation pattern it is clear that hinges are not formed at that floor where increase the dimension in any zone. For zone III and IV which are behind IO (immediate occupancy) only in zone V hinges are formed in column beyond LS. (Life safety)

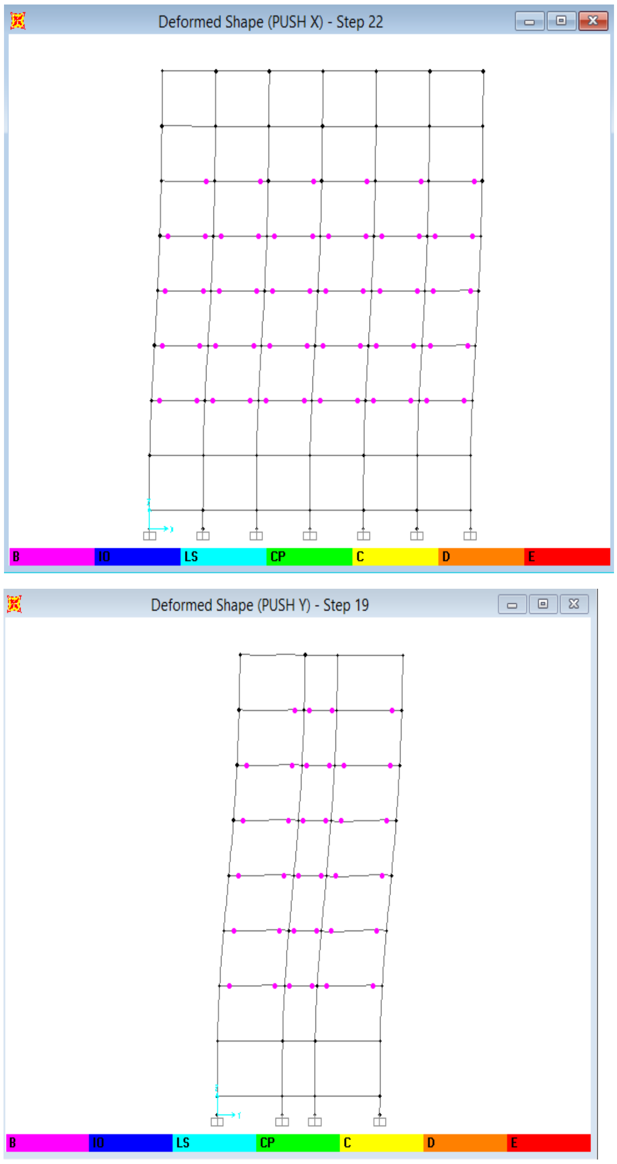

Fig12: Hinge formation at performance point for zone III building with floating columns in model II in X and Y direction

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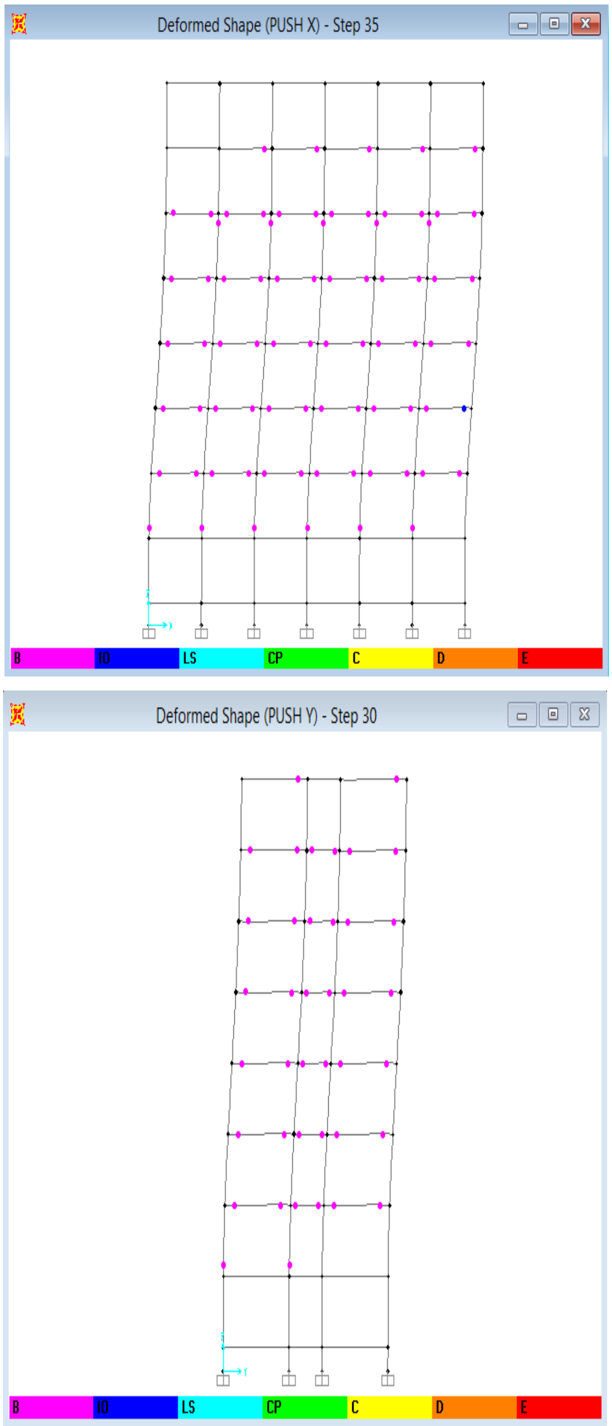

Fig 13: Hinge formation at performance point for zone IV building with floating columns in model II in X and Y direction

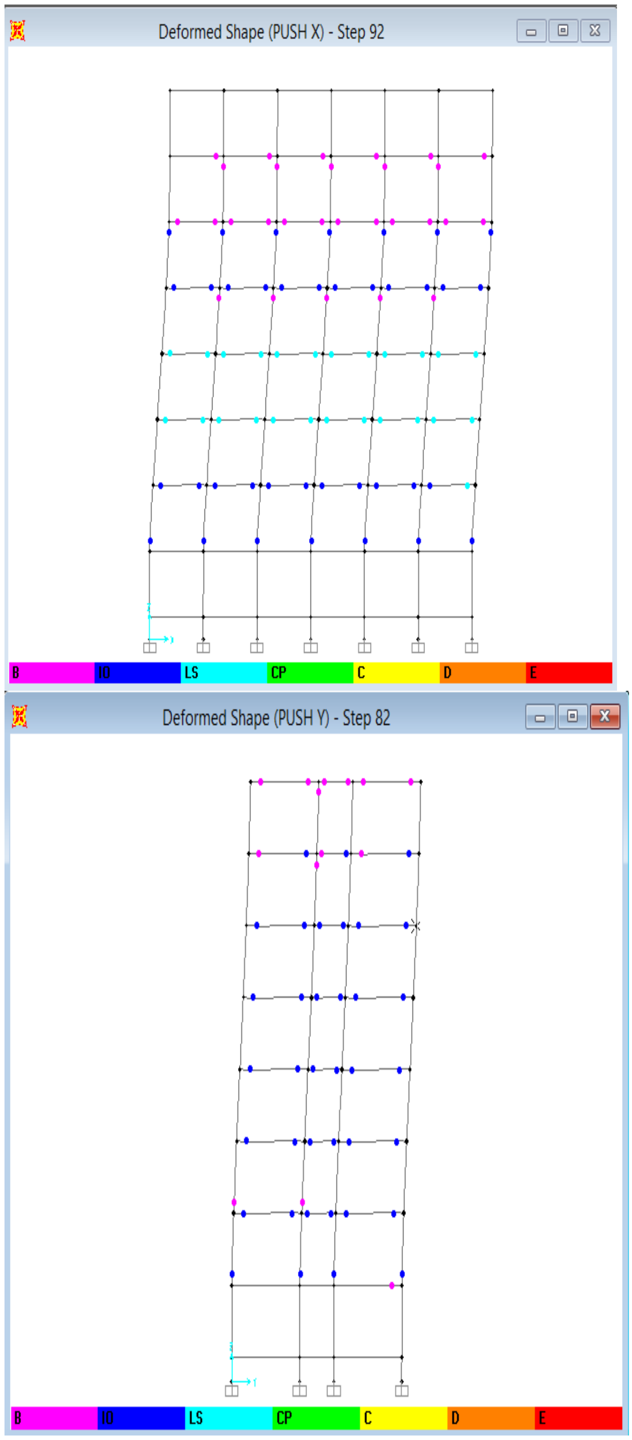

Fig 14: Hinge formation at performance point for zone V building with floating columns in model II in X and Y direction

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MODEL III

Fig.15 to fig.17 shows hinge formation pattern in G+7 storied floating columns building with increase in dimension of beam columns at two consecutive floor for different seismic zone i.e. III, IV, V resp. From this hinge formation pattern it is clear that hinges are not formed at both the consecutive floor in any zone.it is observed that much more improvement in formation of hinges after increase in dimension of beam and column of two consecutive floor.as shown in fig 15,16 and 17

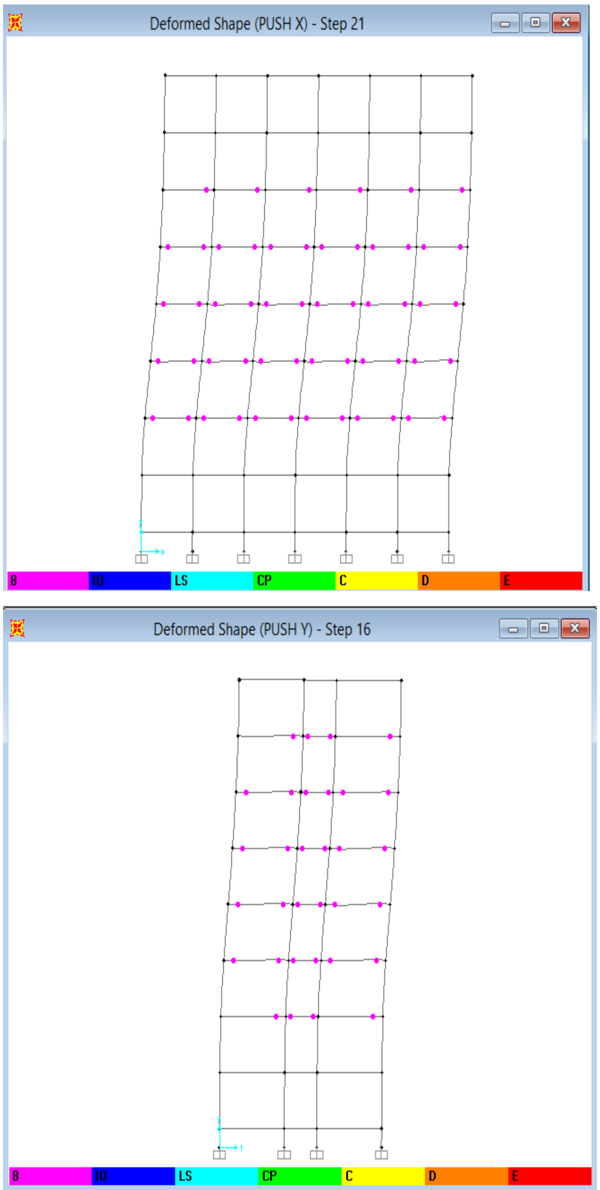

Fig 15: Hinge formation at performance point for zone III building with floating columns in model III in X and Y direction

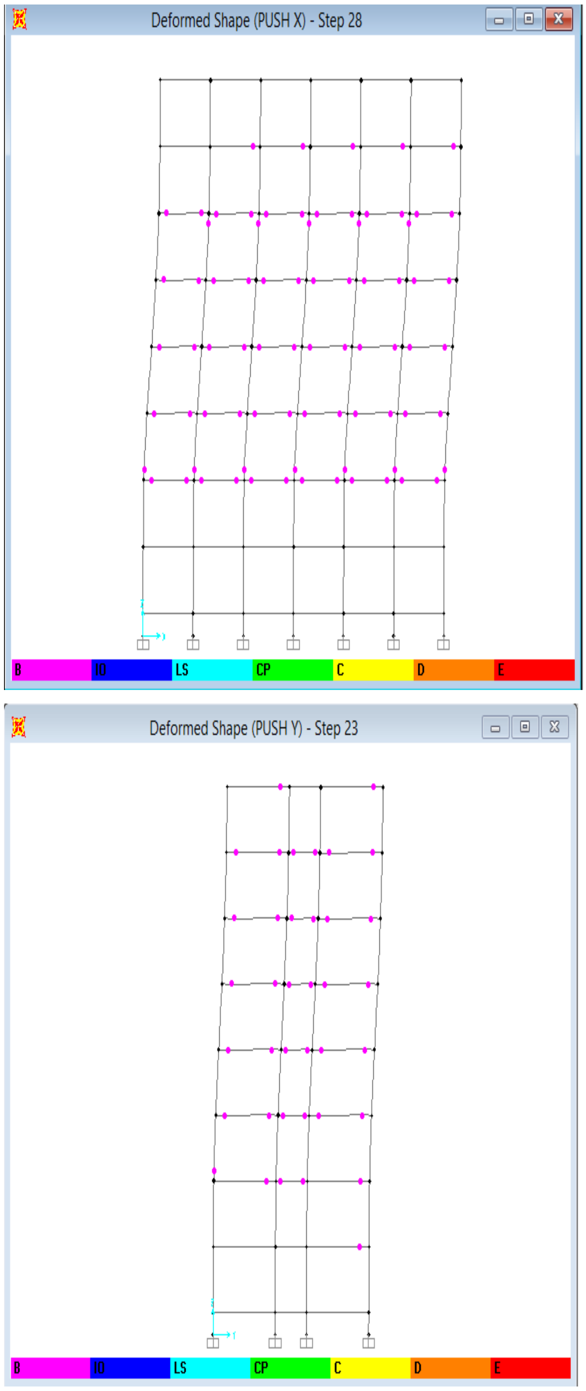

Fig 16: Hinge formation at performance point for zone IV building with floating columns in model III in X and Y direction.

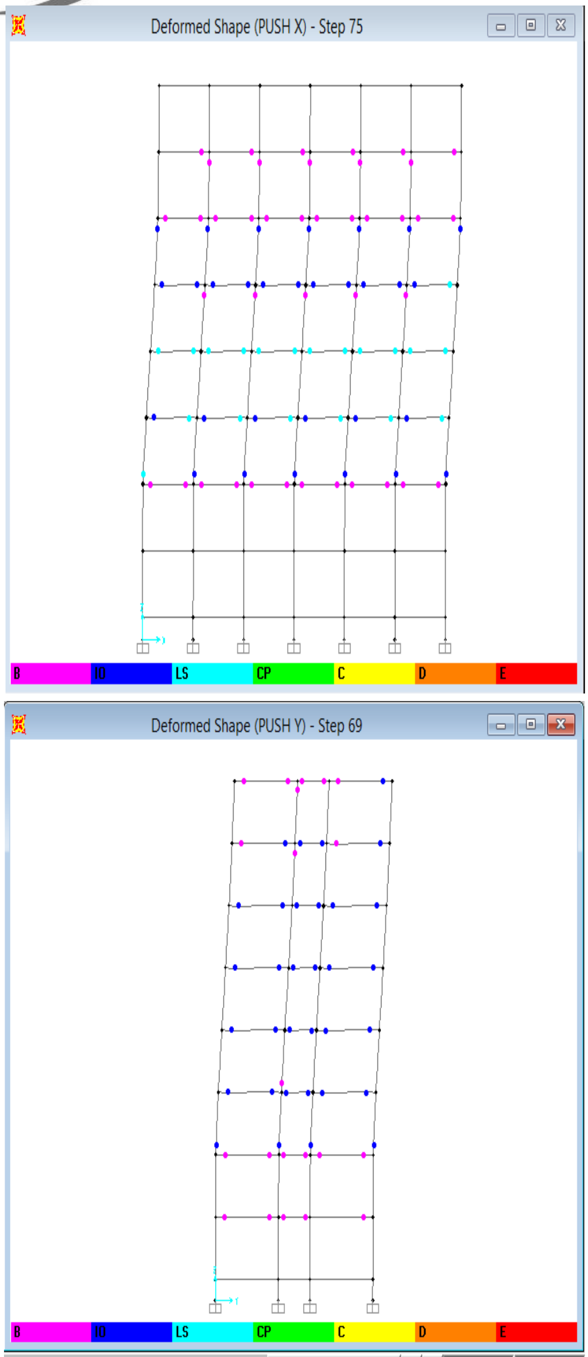

Fig 17: Hinge formation at performance point for zone 5 building with floating columns in model III X and Y direction

Conclusions

From the analytical study following conclusions are drawn

1. In case of normal building (mode I) in zone III and IV hinges are developed only in beams which are in between B to IO. Where in case of zone V hinged are developed in column which is behind IO(immediate occupancy). But in case of building with floating column for zone III and IV hinges are developed at beam are beyond CP (collapse prevention) near location of floating column. Where in zone V hinges are developed in column beyond LS (life safety).

2. Due to increase in dimension at two consecutive floor for same building under same loading condition in case of model III as compared to model II building with floating columns it is observed that the story displacement carried at performance point is decrease (improved) by 8 to 12% in all zone for X and Y direction respectively.

3. There is very much increment in base shear for Building with floating column this is due to increase in seismic weight of building. Because larger beam and column sizes are provided to resist load of floating columns.

4. Story displacement decreases (improvement) in model II and III as compared to model I for all respective zones with increase in dimension of beam and columns in case of floating columns building.

5. Floating columns should be avoided in high rise building in zone V because of its very poor performance i.e. hing formation obtained beyond LS as shown in table no 2.

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