Performance of RC frame structure with floating column and soft storey in different earthquake zones using pushover analysis

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Abstract - *Open first storey and Floating column are typical features in the modern multi-storey constructions in urban India. The increase in urban population for the past few years has made the vehicle parking a major concern and hence the first storey of the apartment is used for parking. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes like Bhuj 2001. In this study an attempt is made to reveal the effects of floating column & soft storey in different earthquake zones by seismic analysis. For this purpose Push over analysis is adopted because this analysis will yield performance level of building for design capacity (displacement) carried out up to failure, it helps determination of collapse load and ductility capacity of the structure. In this present study four number of G+10 storey RCC building frame models are considered, out of which two models are regular bare frame building and two models are irregular buildings are considered. The pushover analysis is performed for the considered four models as per IS 1893:2002 & ATC 40, using ETABS version 9.7.4. From the pushover analysis the properties of the buildings such as displacement, storey shear, and storey drift and performance point have been studied for different models in different earthquake zones.*

Key Words: Pushover analysis, irregular building, Floating column, drift.

1. INTRODUCTION

1.1 General:

Many urban multistory 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 stories. The upper stories have brick unfilled wall panels. The draft Indian seismic code classifies a soft storey as one whose lateral stiffness is less than 70% of the storey above or below [Draft IS: 1893, 1997]. For the upper storey's, however, the forces in the columns are effectively reduced due to the presence of the Buildings with abrupt changes in storey stiffness have uneven lateral force distribution along the height, which is likely to locally induce stress concentration. This has adverse effect on the performance of buildings during ground shaking. Such buildings are required to be analyzed by the dynamic analysis and designed carefully.

1.2 Performance level:

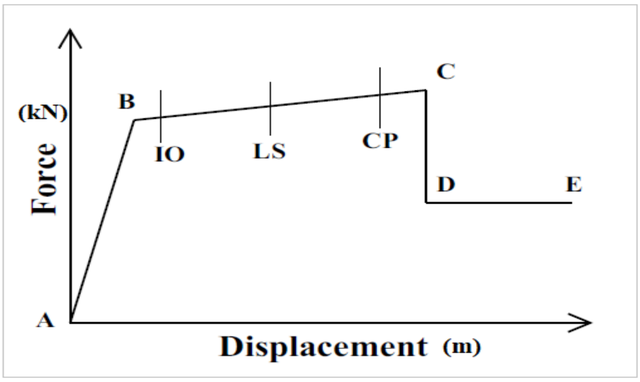

Fig-1 showing details of pushover curve

Immediate occupancy: It is the damage state due to earthquake in which limited structural damages has occurred. There are negligible chances of life threatening injury due to structural failure.

Life safety: It is a state in which damage to the structure due to earthquake may have occurred but in which some margin against either total or partial collapse remains. Injuries during the earthquake may occur, but the risk of life threatening injury from structural damage is very low.

Collapse prevention: In this state the building has experienced extreme damage with large permanent drifts. The structure may have little residual strength and stiffness with extensive damages occurred to non-structural elements.

2. MODELLING

2.1 Building Studied:

A G+10 storey building is taken for the analysis. The storey height is taken as 3.0m for all floors. Building frame is modelled in ETABS 9.3.7 by defining beam, column and slab. Slab is modelled as thin membrane. Frame elements are assumed to be rigid. Hinges are assigned to the frame elements. These hinges are default hinges which are available in ETABS 9.9.7. The following are the models created in ETAB 9.3.7 software which are used to study the performance of the structure in earthquake zone II and zone

V in soil type II (medium soil). The descriptions of the models which are created in ETABS 9.3.7 are as follows.

2.1.1 Description of models:

Model-1	Regular building(without floating column)
Model-2	Regular building(with floating column)
Model-3	Irregular building(without floating column)
Model-4	Irregular building(with floating column)

2.1.2 Design Data:

Type of structure	Multi-storied RC Moment resisting frame
Seismic zone	II and V
Zone factor	0.10 (Zone II),0.36(Zone V)
Soil type	II (Medium soil)
Wall thickness	230 mm
Live load	4.0 kN/m^2
Floor finish	1.5 kN/m^2
Earthquake load	As per IS-1893:2002
Damping	5%
Importance factor (I)	1

2.1.3 Description of Building Frame:

Number of stories	11 (G+10)
Each floor height	3.0 m
Base floor height	3.0m
Slab thickness	125 mm
Column size	230x300mm, 230x450mm
Beam size	230x300mm, 230x375mm,230x450mm
Materials	Concrete M25 for beams and slabs, Concrete M30 for columns Fe500 steel

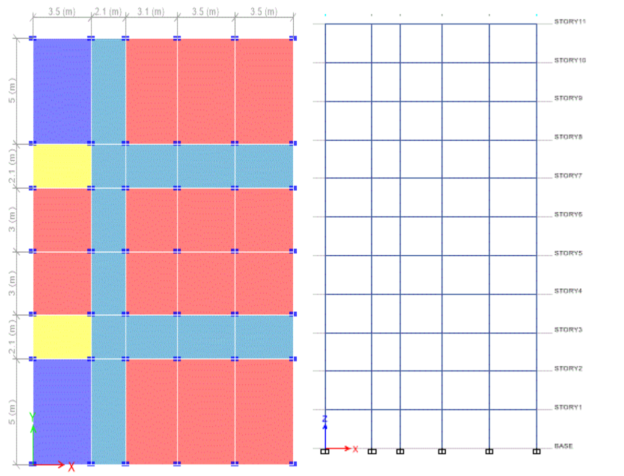

Fig-2 showing details of regular building without floating column (plan and elevation) of model-1

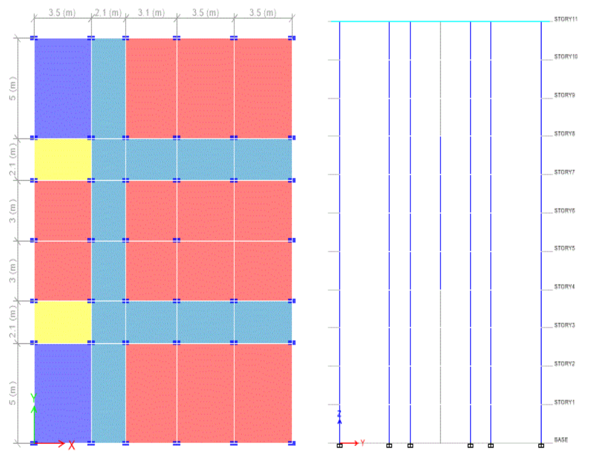

Fig-3 showing details of regular building with floating column (plan and elevation) of model-2

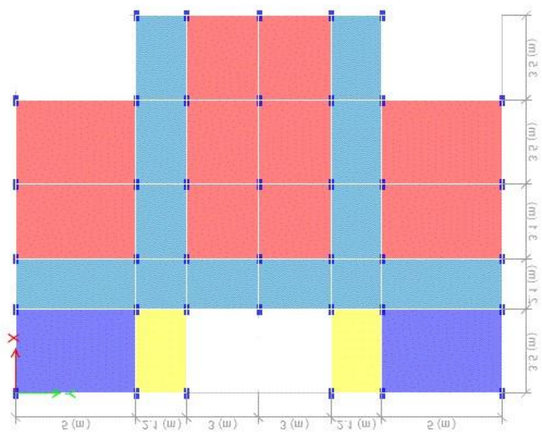

Fig-4 showing details of irregular building without floating column (plan) of model-3

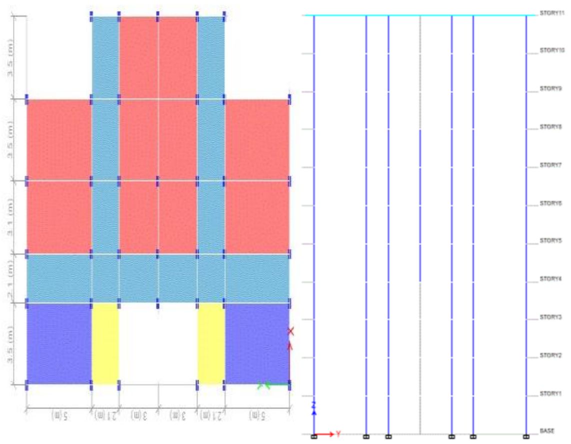

Fig-5 showing details of irregular building with floating column (plan and elevation) of model-4

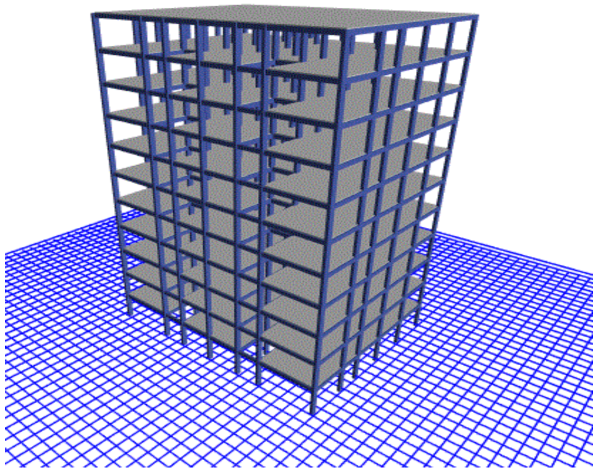

Fig-6 showing 3-D view of model-1& model-2

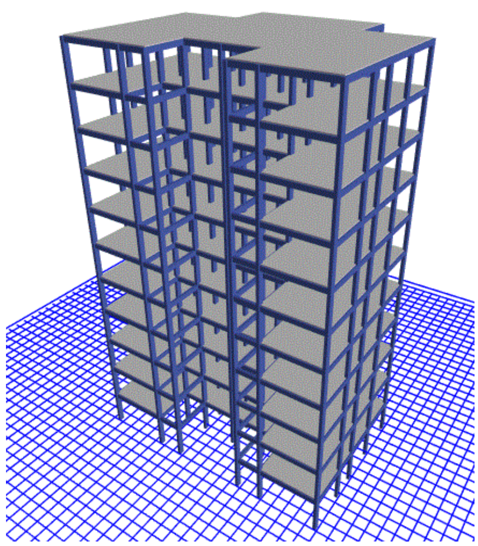

Fig-7 showing 3-D view of model-3& model-4

3. RESULTS AND DISCUSSIONS

In this, results of high rise RCC building frame with and without floating column are presented and discussed in detail. The results of different frame building models are compared using pushover analysis. The analysis of the different building models is performed by using ETABS 9.3.7.

3.1 Lateral Displacement:

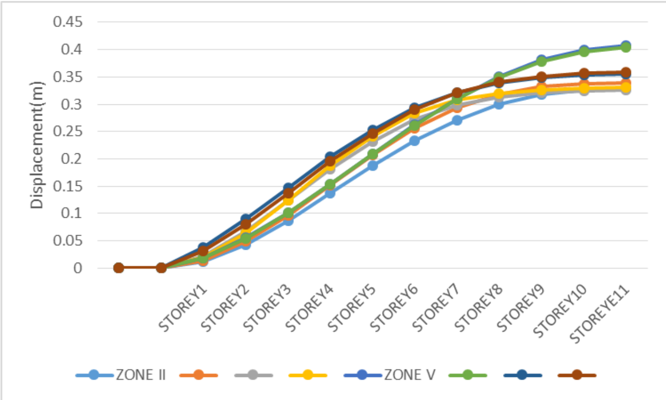

Fig-8 Showing displacement in x-direction and y-direction (model-1 and model-2) by pushover analysis (in meters) in Zone II and Zone V.

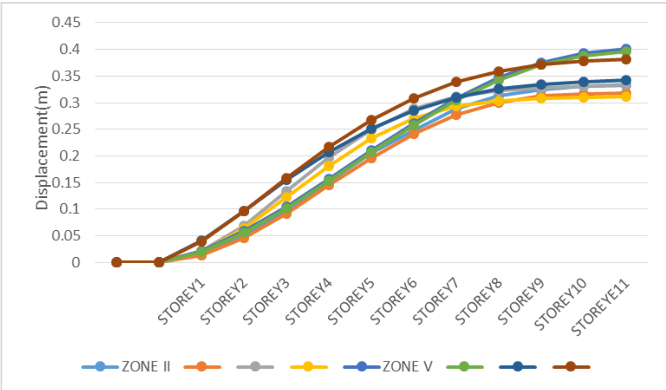

Fig-9 Showing displacement in x-direction and y-direction (model-3 and model-4) by pushover analysis (in meters) in Zone II and Zone V.

Discussions on Displacement results:

1) The displacement in X-direction is found to be maximum in Model-1 in Zone V which is equal to 0.4074 m.
2) The displacement in Y-direction is found to be maximum in Model-4 in Zone V which is equal to 0.3815 m.
3) There is about 21.84% increase in displacement when compared with lowest displacement in Model-4 in Zone II with highest displacement in Model-1 in Zone V in X-direction.
4) There is about 18.32% increase in displacement when compared with lowest displacement in Model-

4 in Zone II with highest displacement in Model-4 in Zone V in Y-direction.

3.2 Storey Drift:

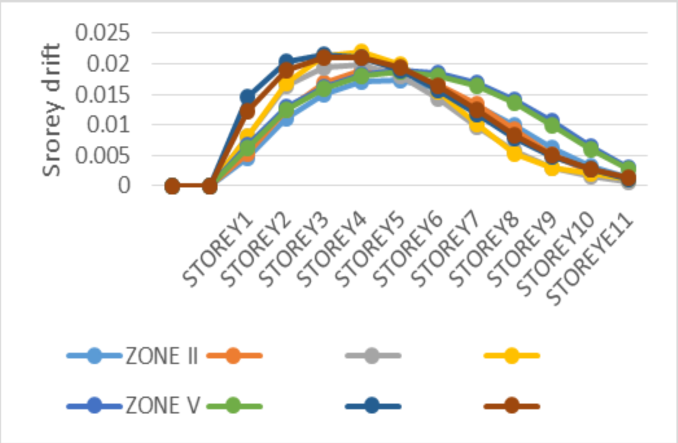

Fig-10 Showing storey drift in x-direction and y-direction (model-1 and model-2) by pushover analysis in Zone II and Zone V.

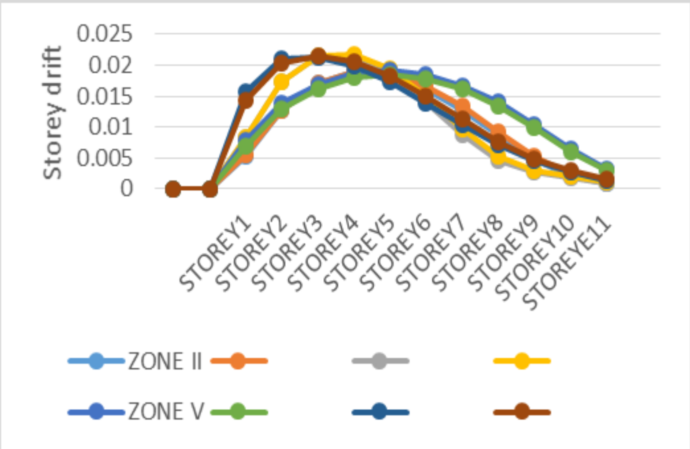

Fig-11 Showing storey drift in x-direction and y-direction (model-3 and model-4) by pushover analysis in Zone II and Zone V.

Discussions on Storey drift results:

1) The storey drift in X direction is found to be maximum in Model-3 in Zone V which is equal to 0.019144 at storey 5.

2) The storey drift in Y direction is found to be maximum in Model-4 in Zone II which is equal to 0.021722 at storey 4.

3) There is about 45-50% increase in storey drift when compared to other storeys due to the existence of soft storey at the bottom.

3.3 Storey Shear:

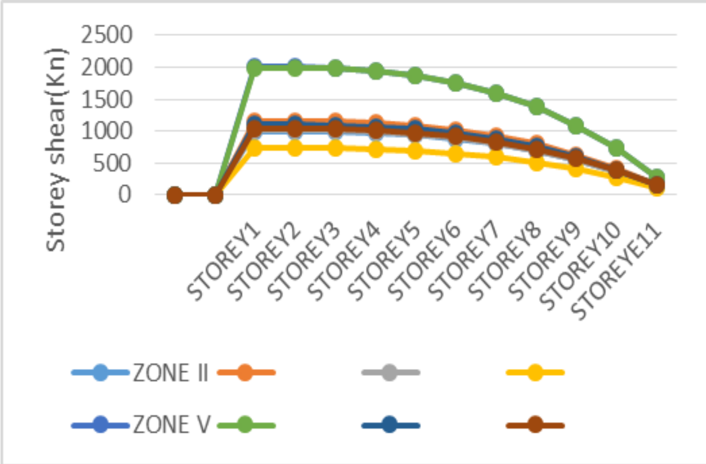

Fig-12 Showing storey shear(kn) in x-direction and y-direction (model-1 and model-2) by pushover analysis in Zone II and Zone V.

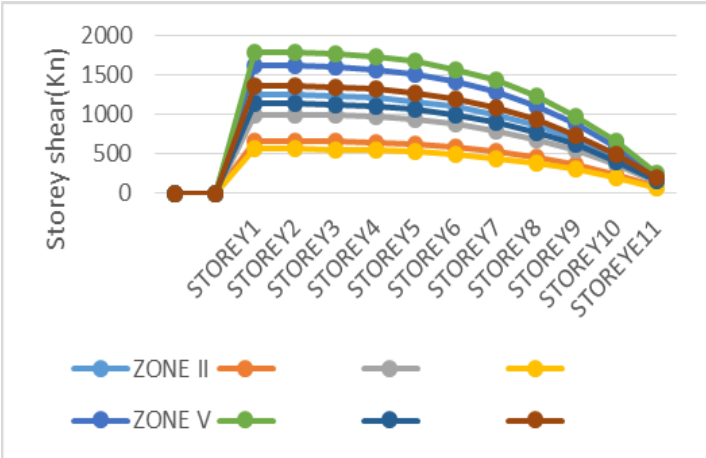

Fig-13 Showing storey shear(kn) in x-direction and y-direction (model-3 and model-4) by pushover analysis in Zone II and Zone V.

Discussions on Storey Shear result:

1) The maximum storey shear in X direction is found to be in Model-1 in Zone V which is equal to 2013.5 KN.
2) The maximum storey shear in Y direction is found to be in Model-4 in Zone V which is equal to 1799.01 KN.
3) Storey shear is more in Zone V than Zone II.

Zone II		Zone V	
x		x	
x		x	
y		y	
y		y	

.

For Model-1&2 refer fig-8, 10 and 12
For Model-3&4 refer fig-9, 11 and 13

3.4 Performance Point:

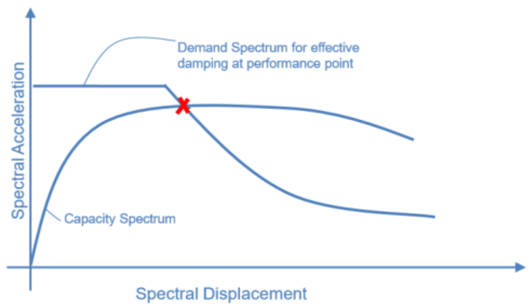

Fig-14 showing details of performance point

Performance Point: It is an intersection point of capacity spectrum and demand spectrum. The performance of a building is depended upon the performance of the structural and the non-structural components. After obtaining the performance point, the performance of the structures against this performance level.

Table: 1 Performance parameter in longitudinal direction (x) for Zone II.

MODEL NO	BASE SHEAR (kN)	DISPLACEMENT (M)	SPECTRAL ACCELARATION (m/s^2)	SPECTRAL DISPLACEMENT (m)
Model 1	1828.94	0.319	0.052	0.256
Model 2	1812.77	0.324	0.052	0.26
Model 3	1620.29	0.299	0.056	0.239
Model 4	2108.17	0.248	0.074	0.191

Table: 2 Performance parameter in transverse direction (y) for Zone II.

MODEL NO	BASE SHEAR (kN)	DISPLACEMENT (M)	SPECTRAL ACCELARATION (m/s^2)	SPECTRAL DISPLACEMENT (m)
Model 1	1513.61	0.348	0.041	0.29
Model 2	1484.73	0.339	0.04	0.284
Model 3	1336.21	0.352	0.044	0.289
Model 4	1764.96	0.317	0.058	0.252

1) It's found that displacement of buildings Model-1, Model-2 and Model-3 has more displacement about 22.25%, 23.45% and 17.05% respectively than Model-4 in X-direction.
2) Displacement of buildings Model-1, Model-2 and Model-3 has more displacement about 8.90%, 6.48% and 9.94% respectively than Model-4 in Y-direction.
3) Base shear of the buildings Model-1, Model-2 and Model-3 has less shear about 13.24%, 14.05% and 23.14% respectively when compared with Model-4 in X-direction.
4) Base shear of the buildings Model-1, Model-2 and Model-3 has less shear about 14.24%, 15.87% and 24.29% respectively when compared with Model-4 in Y-direction.

Table: 3 Performance parameter in longitudinal direction (x) for Zone V.

MODEL NO	BASE SHEAR (kN)	DISPLACEMENT (M)	SPECTRAL ACCELARATION (m/s^2)	SPECTRAL DISPLACEMENT (m)
Model 1	2385.62	0.259	0.07	0.199
Model 2	1802.98	0.323	0.051	0.26
Model 3	1648.933	0.295	0.057	0.237
Model 4	1620.29	0.299	0.056	0.239

Table: 4 Performance parameter in transverse direction (y) for Zone V.

MODEL NO	BASE SHEAR (kN)	DISPLACEMENT (M)	SPECTRAL ACCELARATION (m/s²)	SPECTRAL DISPLACEMENT (m)
Model 1	2009.02	0.324	0.054	0.262
Model 2	1485.59	0.339	0.04	0.283
Model 3	1345.36	0.348	0.044	0.285
Model 4	1336.21	0.352	0.044	0.289

1) It's found that displacement of buildings Model-2, Model-3 and Model-4 has more displacement about 19.8%, 12.2% and 13.37% respectively than Model-1 in X-direction.
2) Displacement of buildings Model-2, Model-3 and Model-4 has more displacement about 4.42%, 6.89% and 7.95% respectively than Model-1 in Y-direction.
3) Base shear of the buildings Model-2, Model-3 and Model-4 has less shear about 24.42%, 30.88% and 32.08% respectively when compared with Model-1 in X-direction.
4) Base shear of the buildings Model-2, Model-3 and Model-4 has less shear about 26.05%, 33.03% and 33.48% respectively when compared with Model-1 in Y-direction.

4. Conclusions

1) The displacement of the building increases from lower zones to higher zones about 18-23%, because the magnitude of intensity will be more for higher zones, similarly for drift, because it is correlated with the displacement.
2) The base shear at performance point of building without floating column is about 25% more when compared with buildings with floating column.
3) The bending moment and shear force in column where the floating column is provided at storey 5 is found to be more about 45% and 40% respectively when compared with buildings without floating column at storey 5.
4) More vulnerable zone for earthquake is zone V. It requires more capable structure to resist lateral forces compare to other zone structures, in the above study we found that Zone V has higher capacity from capacity spectrum curves.

5. REFERENCES

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