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INFLUENCE OF FLOATING COLUMNS ON SEISMIC RESPONSE OF MULTI-STOREYED RC FRAMED BUILDING

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ABSTRACT

In this work, the influence of Floating columns on seismic response of multi-storey building is studied. The present investigation is basically deals with the seismic behavior of buildings, i.e. the effect on Lateral displacement, Storey drift and Time period when Floating Columns are introduced in the structure. In this work, the Floating columns are varied in location along elevation of building. It is observed in all phases that introducing Floating Columns into the framed structure, the criticality of the structure increases in terms of seismic parameters, i.e. displacement, drift and time period. Apart from the seismic forces, the transfer girders have to be analyzed for deflections and forces under gravity loading by Construction Sequence analysis rather than conventional analysis to get realistic results.

Keywords— *Floating columns*, *Time period, Storey drift, Lateral displacement, Construction Sequence analysis, ETABS 2016.*

I. INTRODUCTION

Earthquake is a natural phenomenon associated with violent shaking of ground. Large strain energy released during an earthquake travels as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. During past earthquakes, reinforced concrete (RC) buildings have been damaged on a very large scale. A wide range of structural damages observed during past earthquakes across the world has been very educative in identifying the cause of failure. The principal causes of damage to RC buildings are soft storey, floating columns, mass irregularities, inconsistent seismic performance, soil and foundation effect, pounding of adjacent structures and inadequate ductile detailing of members. A vertical irregularity in buildings is a very common feature in urban areas. Irregularities in building structures refer to the non-uniform response of a structure due to nonuniform distribution of structural properties. In most of the situations, buildings become vertically irregular at the planning stage itself due to some architectural and functional reasons. This type of buildings demonstrated larger vulnerability in the past earthquakes. This type of irregularities arises due to the sudden reduction of stiffness or strength in a particular storey. For high seismic zone area, irregularity in building is perhaps a great challenge to a good structural engineer.

Column is basically a vertical member in a framed structure which transfers the loads from beams and slabs to the foundation. Columns usually run throughout the building from the foundation level to the top most storey of a building to function in transferring the loads to the foundation effectively. At any circumstance, a column is stopped or stubbed at any storey without any continuity to the adjacent lower storey which may be due to architectural requirements or site constraints, such a column hanging on the floors above, resting on

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transfer girders is referred to as Floating Column. Although the feature of Floating columns can be marvelously beautiful with regards to architectural perception and may bring out the aesthetics of the structure to a new level, such configurations of Floating columns resting on transfer girders can be hazardous in a high seismicity region. Floating Columns not only creates huge moments and forces on to the transfer girders but they tend to generate a discontinuity in the distribution of the forces making the structure vulnerable to damage and prone to collapse.

II. OBJECTIVES

A. Behaviour of 3D R.C framed structure with Floating Column.
B. Critical positioning of Floating Columns introduced at different storey levels and without altering the cross-sectional sizes of any framed members.

III. MODEL STUDIES

The models considered for the present study are G+7 storey structure with a typical storey height of 3.5 m. The model consisting of 4 x 6 bays, each bay spaced at 5m in X and Y directions. A comparison is made between models with 10 numbers of Floating columns at different storey level.

Table 1: Parameters Considered for the Study and Analysis of Model

Building Description	
Plan Dimension	20mx30m
Each bay dimension	5m
Grade of Concrete	M 25
Grade of Steel	Fe 500
Earth quake Zone	ZONE- III
Response Reduction Factor	3
Seismic Zone Factor	0.16
Damping Ratio	0.05
Structure Type	OMRF
Importance factor	1
Soil type	Type II, Medium soil
Number of storeys	G+ 7 storey
Height of typical floor	3.5m
Height of Building	28m
Slab thickness	150 mm
Beam size	0.230 x 0.500 m
Column size	0.500 x 0.500 m
Masonry wall thickness	0.230 m
Characteristic strength of concrete, fck	25MPa
Modulus of elasticity of concrete, Ec	25000MPa
Modulus elasticity of steel	2×10^5MPa
Density of Concrete	25 kN/m^3

A. Types of loads:

For the purpose of computing the maximum stresses in any structure or member of the structure, the following loads and load effects shall be taken into account.

a). Dead Loads b). Imposed Loads

Dead loads and imposed loads to be assumed in design shall be as specified in IS 875-1987(Part 1 & 2).

Table 2: Uniformly distributed load on slab in kN/m2

Component	Typical Storey 1 to 7		Terrace	
	Dead Load kN/m2	Live Load kN/m2	Dead Load kN/m2	Live Load kN/m2
Floor Finish	1.0	-	-	-
Live Load	-	2.5*	-	0.75**
Water proofing	-	-	0.22***	-

* - Table 1 of IS 875 (part2)-1987 For Business and office buildings.

** - Table 2 of IS 875 (part2)-1987 For Imposed loads on various types of roofs, Access not provided except for maintenance.

***- Table 2 of IS 875 (part1)-1987 For Roof Finishes Bitumen mecadam.

Table 3: Nomenclature of Building Data

Model	Building with
NFC	No Floating Column
FC-1	Floating Column in Storey-1
FC-2	Floating Column in Storey-2
FC-3	Floating Column in Storey-3
FC-4	Floating Column in Storey-4
FC-5	Floating Column in Storey-5
FC-6	Floating Column in Storey-6
FC-7	Floating Column in Storey-7

IV. ETABS MODELS

A. NFC- Model having No Floating Column at any storey

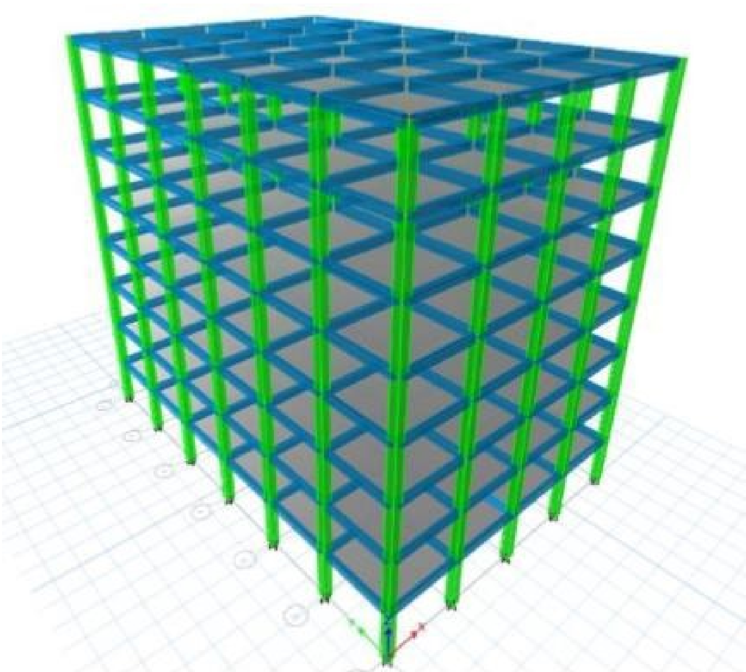


Fig 1:3D elevation of NFC Model

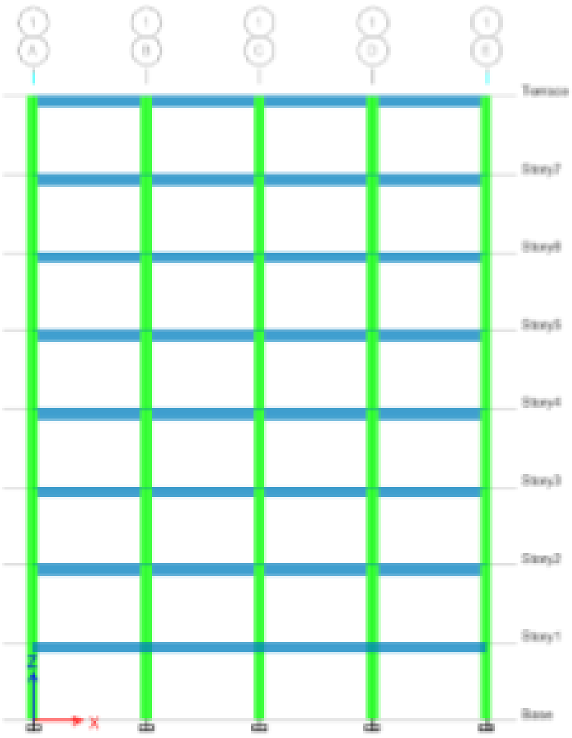


Fig 2: Front elevation of NFC Model

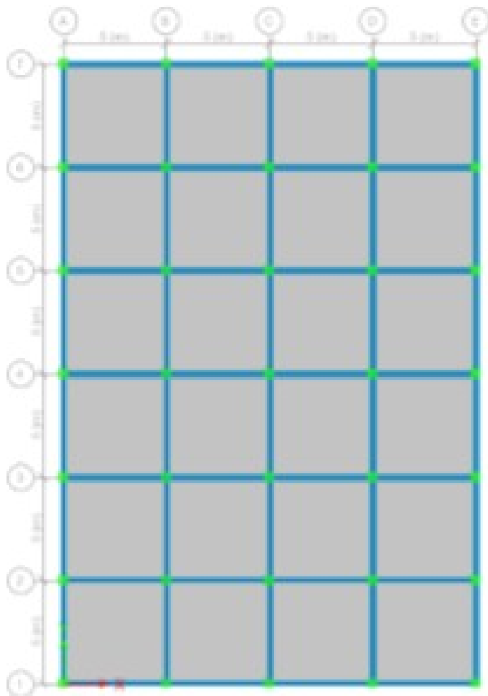


Fig 3: Plan of NFC Model

B. **FC-1- Model having Floating columns at 1st storey**

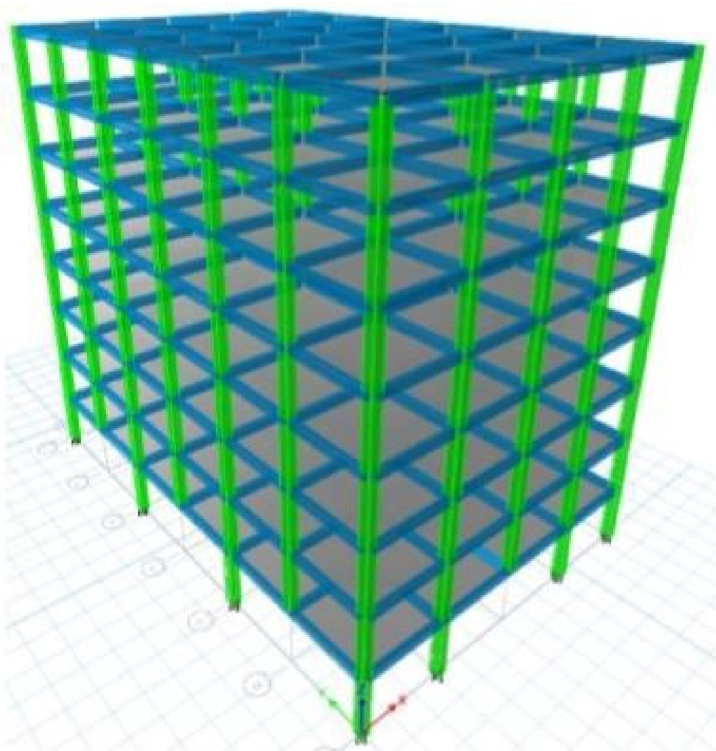
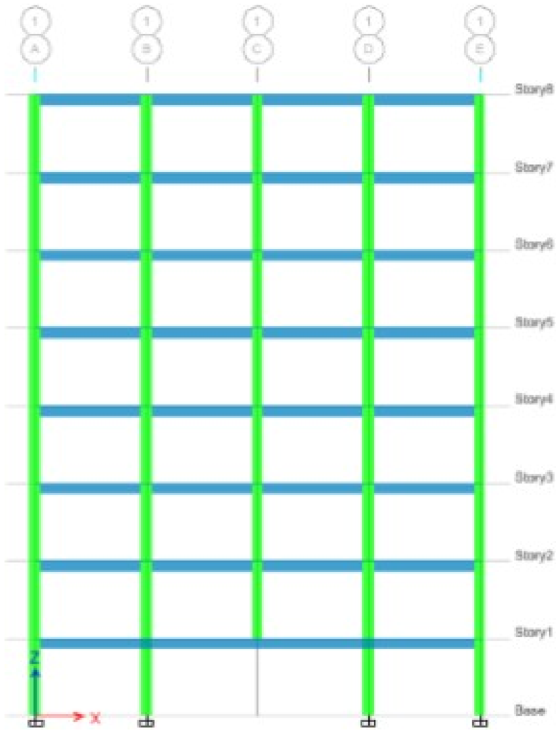


Fig 4: 3D elevation of FC-1 Model



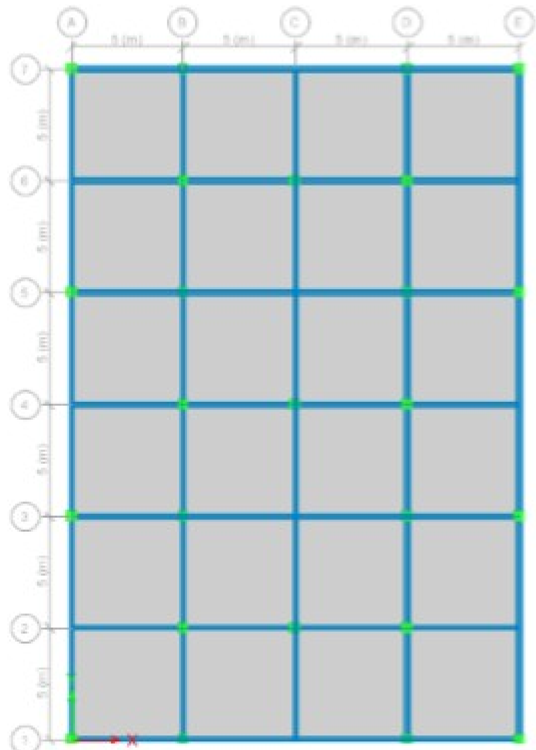


Fig 5:Front elevation of FC-1 Model

Fig 6:Plan of FC-1 Model

V. RESULTS AND DISCUSSIONS

A. Maximum Storey Displacement

The Maximum Storey displacements for different models at Earthquake zone III are presented below. Here the displacements obtained from both the methods namely equivalent Static Load cases (EQX,EQY) and Response Spectrum Load cases (RSPECX),(RSPECY) are tabulated in Table 3 and 4 shows a Storey Displacement values. Similarly Fig.7 and 8 indicates the plot of Storey Displacement versus number of storey subjected to earth quake loads along X and Y direction respectively.

Table 4: Maximum Storey Displacement of models in Zone- III along X direction subjected to EQX and RSPECX

Maximum Storey Displacement in X-direction (mm)		
MODEL	EQX ZONE 3	RSPECX ZONE 3
NFC	48.621	38.273
FC-1	53.661	41.534
FC-2	53.145	41.108
FC-3	52.401	40.894
FC-4	51.587	40.194
FC-5	50.779	39.582
FC-6	50.012	39.188
FC-7	49.338	38.775

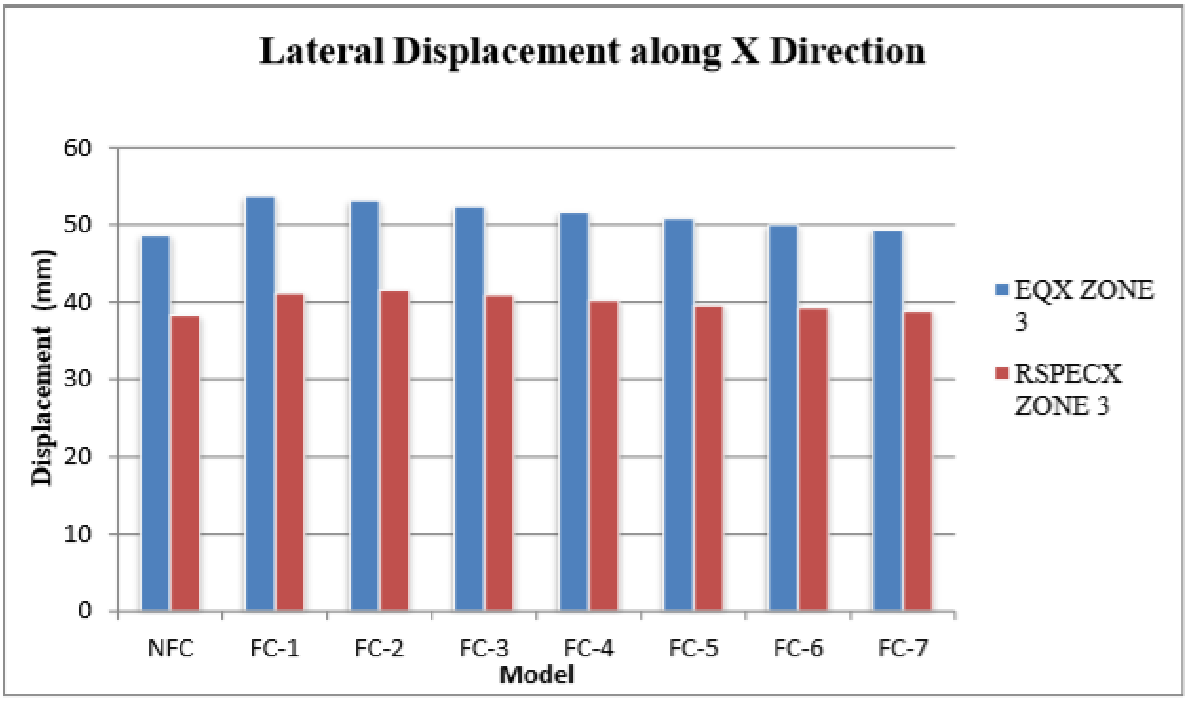


Fig 7: Maximum Storey Displacement Graph of models in Zone- III along X direction subjected to EQX and RSPECX

The model with Floating column at the 1st storey (FC-1) gives the maximum displacement. Therefore, for model FC-1 the location of Floating column at 1st storey is the most critical. FC-1 displays **8.76% & 7.11%** larger displacement than FC-7 under EQX & RSPECX respectively.

FC-1 produces **10.36% & 8.52%** larger displacement than NFC under EQX & RSPECX respectively.

It is noticeable that model with Floating column at the 7th storey (FC-7) displays the least lateral displacement in Floating Column models.

FC-7 produces **1.47% & 1.31%** larger displacement than No Floating Column model under EQX & RSPECX respectively. Hence the safest location for floating columns to exist in model is the FC-7.

The displacements obtained from Equivalent Static method are larger than that obtained from Response Spectrum method.

Table.5: Maximum Storey Displacement Graph of models in Zone- III along Y direction subjected to EQY and RSPECY

Maximum Storey Displacement in Y-direction (mm)		
MODEL	EQY ZONE 3	RSPECY ZONE 3
NFC	46.282	37.254
FC-1	48.885	39.671
FC-2	48.724	39.207
FC-3	48.662	39.010
FC-4	48.365	38.711
FC-5	48.001	38.299
FC-6	47.561	38.074
FC-7	47.042	37.774

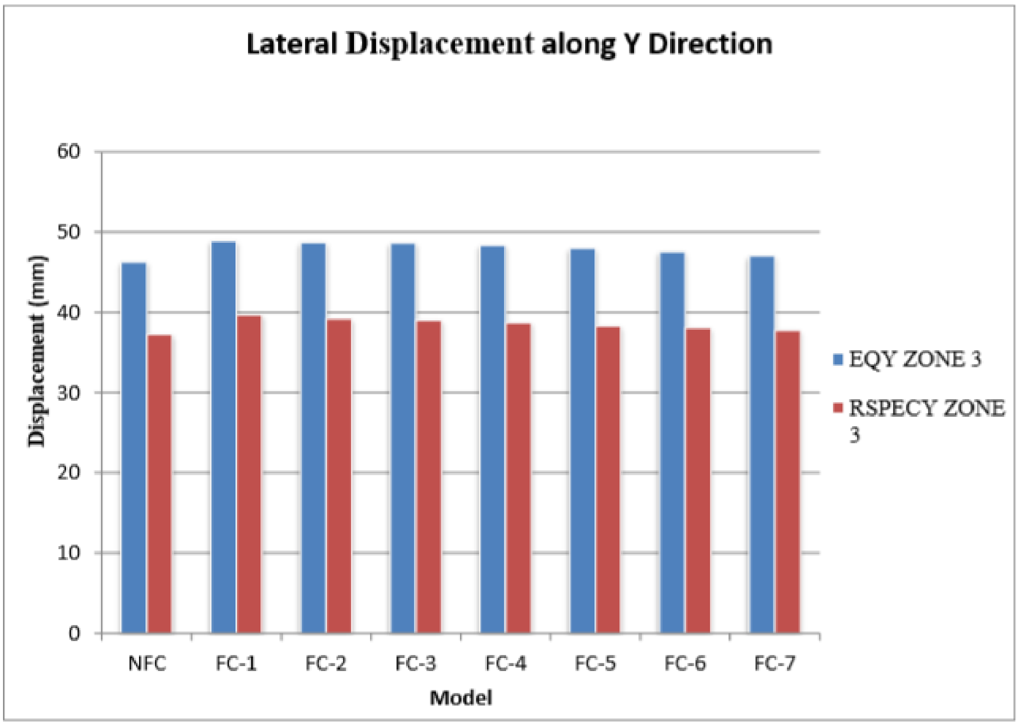


Fig 8: Maximum Storey Displacement Graph of models in Zone- III along Y direction subjected to EQY and RSPECY

The model with Floating column at the 1st storey (FC-1) gives the maximum displacement. Therefore for model FC-1 the location of Floating column at 1st storey is the most critical. FC-1 displays **3.91% & 5.02%** Larger displacement than FC-7 under EQY & RSPECY respectively.

FC-1 produces **5.62% & 6.48%** larger displacement than NFC under EQY & RSPECY respectively.

It is noticeable that model with Floating column at the 7th storey (FC-7) displays the least lateral displacement in Floating Column models.

FC-7 produces **1.64% & 1.39%** larger displacement than No Floating Column model under EQY & RSPECY respectively. Hence the safest location for floating columns to exist in model is the FC-7.

The displacements obtained from Equivalent Static method are larger than that obtained from Response Spectrum method.

B. Storey Drift

The Storey Drift for different models at Earthquake zone III are presented below. Here the Drift obtained from both the methods namely equivalent Static Load cases (EQX),(EQY) and Response Spectrum Load cases (RSPECX),(RSPECY) are shown in Fig.9 and 10 which indicates the plot of Storey Drift versus number of storey subjected to earth quake loads along X and Y direction respectively.

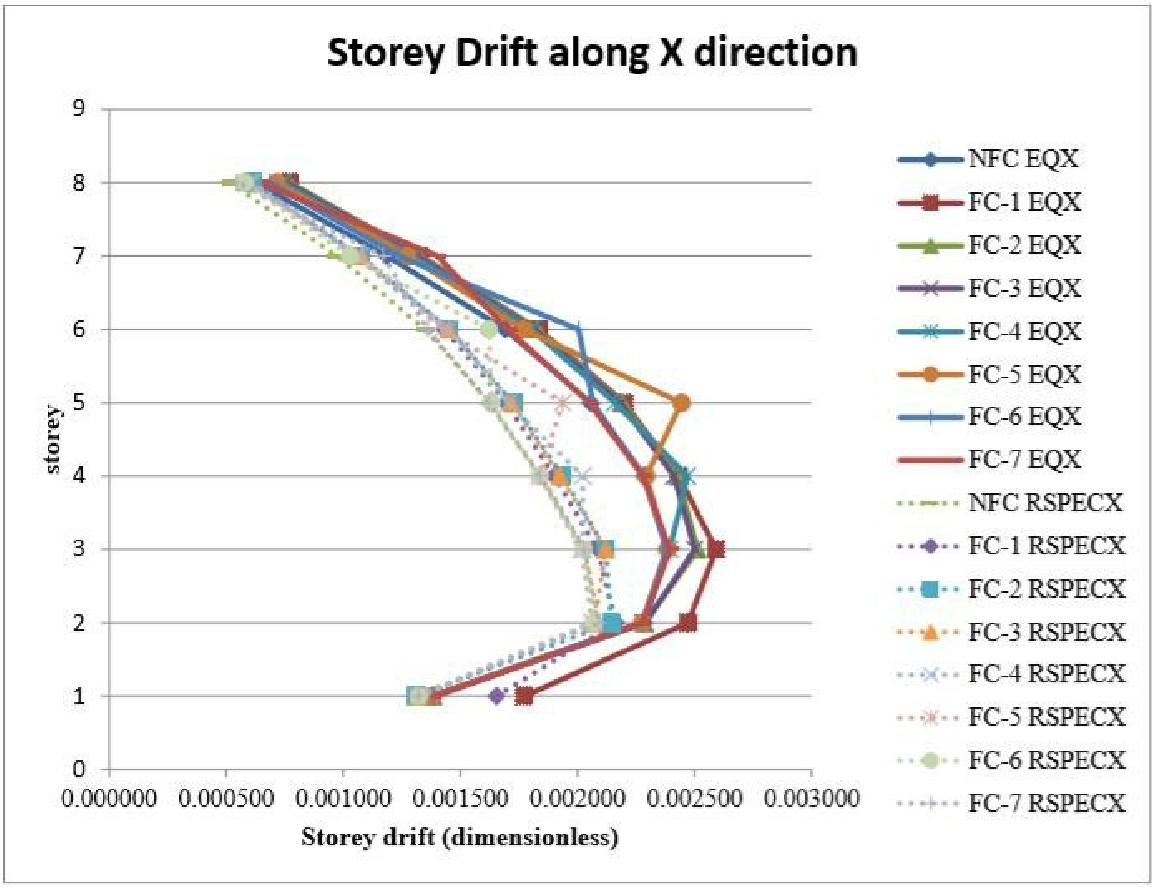


Fig.9: Storey Drift Graph of models along X direction in Zone- III at each floor level subjected to EQX and RSPECX

The model with Floating Column at the 1st storey (FC-1) shows the largest storey drift for both the load cases that is EQX and RSPECX. For FC-1 model, the maximum storey drift considering EQX and RSPECX is seen at 3rd storey level and at 2nd storey level respectively. FC-1 gives **8.95% & 4.34%** greater than FC-7 under RSPECX and EQX respectively.

The storey drift for FC-1 is **8.58% & 4.14%** greater in comparison to NFC model's storey drift considering EQX and RSPECX, respectively.

From the graph and tabulated values, it is seen that model with Floating Column at the 7th storey FC-7 displays the least storey drift. The storey drift for FC-7 is **0.29% & 0.77%** grater in comparison to NFC storey drift considering EQX and RSPECX, respectively. The Storey Drift values obtained from Equivalent Static method are larger than the values obtained from Response Spectrum method.

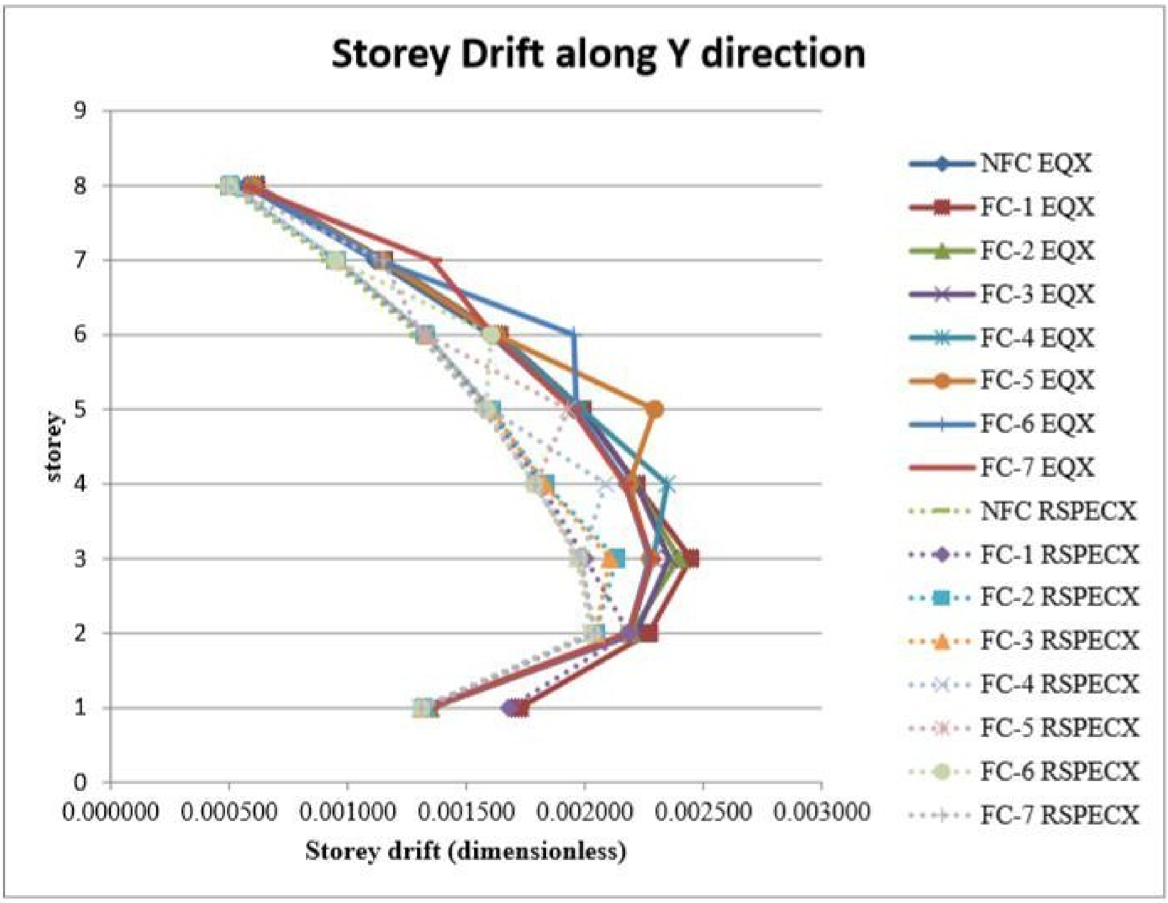


Fig.10: Storey Drift Graph of models along Y direction in Zone- III at each floor level subjected to EQY and RSPECY

The model with Floating Column at the 1st storey (FC-1) shows the largest storey drift for both the load cases that is EQX and RSPECX. For FC-1 model, the maximum storey drift considering EQX and RSPECX is seen at 3rd storey level and at 2nd storey level respectively. FC-1 gives 7.18% and 7.04% greater than FC-7 under RSPECX and EQX respectively.

The storey drift for FC-1 is 7.32% and 7.31% greater in comparison to NFC model's storey drift considering EQX and RSPECX, respectively.

From the graph and tabulated values, it is seen that model with Floating Column at the 7th storey FC-7 displays the least storey drift. The storey drift for FC-7 is 0.13% and 0.24% grater in comparison to NFC storey drift considering EQX and RSPECX, respectively. The Storey Drift values obtained from Equivalent Static method are larger than the values obtained from Response Spectrum method.

C. Fundamental Natural Period:

The Fundamental Natural Time Period obtained from Modal analysis for different models considered are presented here. The table 5 shown for earthquake zone III along with graph Fig 11.

Table 6: Fundamental Natural Period of Model

Fundamental Natural Period	
Model	Period in seconds
NFC	1.632
FC-1	1.715
FC-2	1.704
FC-3	1.687
FC-4	1.669
FC-5	1.653
FC-6	1.640
FC-7	1.632

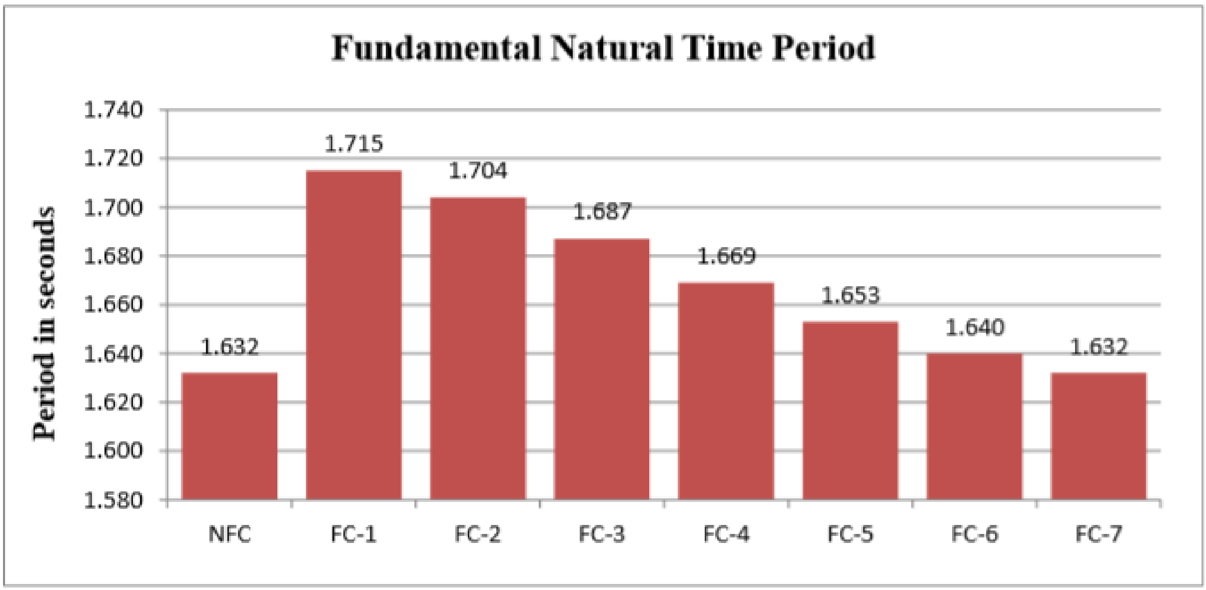


Fig.11: Fundamental Natural Period Graph of models

The model with Floating column at 1st storey shows longest natural period.

VI. CONCLUSIONS

A. It is evident from both static and dynamic analyses that introduction of Floating Column in a building increases the Lateral displacement and inter-storey drift with respect to its regular counterpart and thereby increasing the criticality of structure when seismic forces are considered.
B. It can be observed that Lateral displacement and storey drifts obtained from Equivalent Static method (EQX) are greater than the values obtained from Response spectrum method.
C. The Fundamental Natural Period of models increases as the floating column descends from top storey to the bottom storey. Hence, when Floating Column are at the bottom storey, the building will display the longest Natural Time Period and therefore sways more with respect to buildings with Floating Column at top storey.
D. Considering the importance of transfer beams in the buildings with unavoidable floating columns could be one solution to the problem.

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