

COMPARATIVE STUDY ON STATIC NON LINEAR ANALYSIS OF MULTI-STORIED RC BUILDING WITH AND WITHOUT FLOATING -COLUMN USING ETABS

¹Channappa Nagur,²Sameer Chitnis

¹M. Tech Student[CADS], Department of Civil Engineering, SDM College of Engineering and Technology, Dharward, India

²Assistant Professor, Department of Civil Engineering, SDM College of Engineering and Technology, Dharward, India

Abstract—In current Indian projects, RC structures and floating column structures are common. Such structures are extremely sensitive to earthquakes in earthquake-prone areas, as evidenced by multiple instances of significant shaking during previous earthquakes, such as Bhuj 2001. The purpose of this work is to determine the impacts of a floating column in an RC building when seismic forces are applied. The analysis is carried out and compared utilizing static nonlinear analysis. Push over analysis is used for this activity because it yields the building's performance level for testing design capacity up to breakdown, which aids in determining the structure's real performance. Three RC models are used to achieve this goal which are G+10 story namely model 1 (RC building without floating column), model 2 (RC building with floating column at floor 1), model 3 (RC building with floating column at floor 2) are analyzed and compared with the seismic parameters such as column force, story displacement, interaction ratio and pushover curve of RC structure for seismic forces by using ETABS 2016 software.

Keywords—interaction ratio, displacement, pushover analysis, column forces, ETAB2016

were seriously harmed. There are discontinuities in the load transmission path in RC buildings with floating columns.

India may be a growing where the development of cities is occurring at a faster rate within the country, such as adopting the methods and types of construction that have seen rapid development in recent decades. Multi-story buildings with field complications are counted as part of urbanisation. These difficulties include soft construction, floating columns, heavy loads, stiffness reduction, and so on. Nowadays, most urban multistory structures have an open first storey as an unavoidable characteristic. The principal usage of an open 1st floor within multistory structures is to accommodate parking or reception lobbies. Standard civil engineering structures, on the other hand, are built using strength and stiffness requirements. Except for the columns that convey the building's weight to the ground, the ground construction is usually left open. This research project uses a field difficulty to implement a multi-story skyscraper. The complexity of a multi-story structure with a floating column, and hence the building's performance in greater seismic locations, is determined and certain recommendations are assumed.

The structures are constructed for forces that are significantly less than the projected design earthquake forces, according to the earthquake-resistant design philosophy. As a result, inelastic deformations occur when a structure undergoes strong seismic action. Even if the structure does not collapse, the damages may be irreparable, therefore damage management has become a more explicit design consideration, which can only be accomplished by incorporating some form of non-linear procedure into the seismic analysis technique.

A. Static Non Linear / Pushover Analysis

Pushover analysis is another name for it. The static non linear analysis was already performed over many years ago and has now become the primary process in analysis for performance-based seismic evaluation. It is done for effectively investigating the ultimate strength and limit state after yielding that has been explored and utilised in practise for seismic analysis and seismic design.

I. INTRODUCTION

In today's India, an open storey is an inevitable element of many metropolitan multi-story buildings. The first floor is mostly being modified to accommodate parking or reception lobbies. The general shape, scale, and geometry of a building, as well as how earthquake forces are transported to the ground, have a significant impact on its behaviour during earthquakes. The general shape, scale, and geometry of a building, as well as how the powers of seismic events transported to the surface, have a significant impact on its behaviour during earthquakes. Any diversion in the load transmission path causes in weak building. The seismic action created at all floors in a structure must be transported down along the height to the ground using the shortest way. At the level of discontinuity, perpendicular setbacks on structures (such as structures with a few stories wider than all) create a sharp rise in seismic force. Buildings with fewer columns or walls in one floor or with exceptionally tall story are more prone to collapse or harm in that storey. During the 2001 Bhuj earthquake in Gujarat, a large number of structures with an open floor level designed for parking

Static Non linear analysis is a technique for calculating structure response in the case of a large earthquake. The study entails incrementally adding lateral or horizontal forces to the structure in a predetermined sequence, i.e. pushing the building and graphing the total applied shear force and corresponding lateral displacement at each increment, until the collapse state is reached. Earthquake-induced stresses are roughly represented by corresponding static lateral forces. Pushover analysis is a static nonlinear that gradually increases the magnitude of the structural loading. Weak links and failure modes in the structure are discovered as the intensity of the loading increases. The structural elements tend to yield and deform elastically as the load and displacement increase. The resulting graphic curve depicts the building's capacity in an easy-to-understand manner. Structures with predictable seismic performance can be built using this method. This method's fundamental components are as follows:

- **Capacity:** It denotes a structure's ability to withstand seismic forces. The strength at the yield point of an element's or structure's capacity curve is usually referred to as capacity.
- **Performance:** It is the point where the capacity and demand spectrums meet. The performance of a building is determined by the structural and nonstructural components' performance. After acquiring the performance point, the structures' performance is compared to these performance levels.
- **Immediate occupancy:** It is the earthquake damage state in which only minor structural damage has occurred. There is a very slim probability of a life-threatening injury as a result of structural failure.
- **Life safety:** It is a condition in which structural damage has occurred as a result of an earthquake, yet there is still some protection against entire or partial damage. Although injuries occur as a result of the earthquake, the probability of a life-threatening injury from structural damage is quite low.
- **Collapse prevention:** The building has been severely damaged in this state, with huge permanent drifts. With substantial damage to nonstructural parts, the structure may have little strength and stiffness.

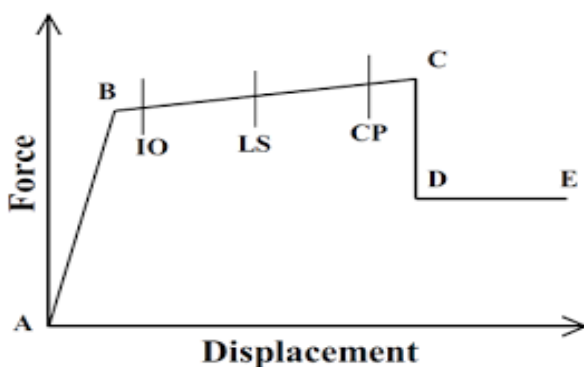


Fig 1. Performance levels .

B. Possible improvements in Pushover Analysis.

Lateral Load Patterns with effective load pattern selection is critical for an accurate performance evaluation. Load patterns should be approached the anticipated distribution of inertia forces in seismic design, necessitating higher mode effects to be incorporated into the chosen lateral load pattern in some circumstances.

An invariant load pattern assumes that:

a) Throughout the earthquake, the inertia forces will be nearly constant.

b) With this continuous load pattern, the highest deformations obtained will be comparable to those expected for the design earthquake.

When the structural response is mostly driven by the first mode and there is just one load yielding mechanism, these two assumptions are quite close to reality.

The adoption of at least two load patterns is advised since no single load distribution can detect the range of local demands envisaged in a design earthquake. In the non-linear static technique, for example, the FEMA-273 and EC8 offer two lateral load patterns. The constant load pattern causes lower-story demands to be conservative when compared to upper-story demands, emphasizing the importance of storey shear forces over overturning moments. For the second load pattern, a modal pattern that can account for elastic higher mode effects is a viable choice.

C. WHY PUSHOVER ANALYSIS ?

- Better understand building behavior .
- Identify weak element.
- Realistic prediction of failure mechanism.

D. FLOATING COLUMN

A column is a vertical component that emerges from the base of the structure to the ground and transfers the load. A vertical element is referred to as a floating column that rests on a beam, without the footing. The beams in turn transfer the load to other columns below it. Many structures use floating columns, particularly above the ground floor whereby transfer girders are used, to create more open space on the ground floor. These free spaces may be needed for a meeting room or parking. Transfer girders must be correctly planned and detailed, especially in earthquake-prone areas. On the beam that supports it, the column is a concentrated load. In terms of analysis, the column is frequently assumed to be pinned at the bottom and hence treated as a point load on the transfer beam. This type of structure can be analysed using STAAD Pro, ETABS, and SAP2000. I'm going with ETABS. Although floating columns can support gravity loads, the transfer girder must be of appropriate proportions and have little deflection. In the future, one will undoubtedly continue to create structures that are exciting rather than

dull. This does not, however, have to be done at the expense of poor behaviour or the structural stability of buildings during earthquakes. Buildings with earthquake-prone architectural components should be avoided at all costs. If not, they must be drastically lowered. When structures have irregular qualities, the structural design demands much more technical effort, and the structure may be bad as one with basic architectural features. As a result, in seismic zones, structures constructed with these types of discontinuous components are at risk. Those structures, on the other hand, cannot be demolished; instead, research to strengthen the structural elements can be recommended.

E. WHY USE FLOATING COLUMN ?

- In today's scenario there is more demand for the space to utilise for the commercial purpose, In multistory residential building in cities to accommodate for the more number of parking spaces, clear spaces for the conference hall or In shopping malls, instead of columns, there should be plenty of open space. These columns are designed as floating columns in these instances.
- Floating columns gives us the liberty to alter the plans in upper floors.
- Here An effort has been made to investigate seismic activity of the floating-column .

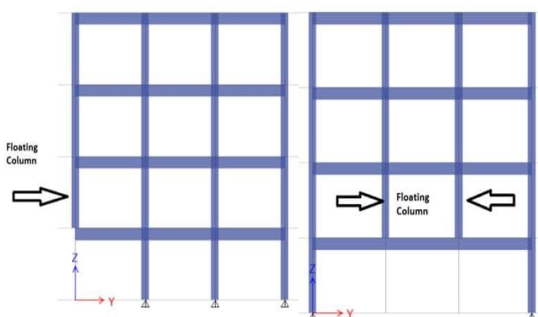


Fig 2. Building with floating columns.

II. OBJECTIVES

To study the behaviour of G+10 RC building with and without floating-column under seismic loads.

III. METHODOLOGY

- The G+10 RC building is being considered for the project .In Etabs software the RC building is modeled with assuming all building components, mentioned in the problem definition.
- And pushover analysis is carried out for the assumed models ,if components failed, assumed dimensions are varied accordingly until satisfied .
- Here all structural elements are not designed , just assumed or considered as per practice .

• Procedure for pushover analysis :

- In a pushover analysis, the lateral load is incrementally raised while preserving a preset pattern of distribution along the building's altitude.
- The structure is dislocated until the control node reaches the desired displacement or structural damage.
- Throughout the procedure, the plastic hinging, sequence of cracking, and building damages are monitored.
- And parameters such as column force, story displacement and interaction ratio of all the three models are compared along with the pushover curve as well.

A. Methodology

All three models 1,2and 3 are modelled in the ETABS programme

With the following specifications as mentioned in table 4.1 and 4.2.

1	Type of building	R C Building
2	Number of storey	G+10
3	Plan	16 x 16 m
4	Story height at base	3m
5	Live load on each floor and roof.	3kN/m ² , 1.5kN/m ²
6	Floor to floor height	3m
7	Grade of reinforcing Steel	Fe415
8	Floor finish *	1.5kN/m ²
9	Wall load	12KN/m
10	Parapet wall load	4.5KN/m
11	Density of Concrete*	25 kN/m ³
12	Density of brick masonry*	20 kN/m ³
13	Zone	IV
14	Soil type	III
15	Seismic zone factor**	0.24 for zone iv
16	Response Reduction Factor (R)	3
17	Importance Factor (I)	1

Table 1 Specification of RC building.

Members	Model 1 (without floating column)	Model 2 (with floating column at story 1)	Model 2 (with floating column at story 2)
Column	450x 600mm	450x 600mm	450x 600mm
Beam	300 x 450mm	300 x 450mm	300 x 450mm
Beam below floating columns	-	300 x 600mm	300 x 600mm
Slab thickness	125mm	125mm	125mm

Table 2 Specification of structural members .

B. MODELING IN ETABS

The following is an explanation of the modelling details. To perform static non linear analysis, ETABS creates a three-dimensional model of the building structure. Tables 4.1 and 4.2 show how to describe beam and column elements as rectangular framed elements with material qualities and section properties. I'm exploring three distinct models with the same material attributes for better outcomes.

Model 1 having all the columns reaching down to the ground/base. As shown in figure 4.1 and figure 4.2

Model 2 has a floating column at the c6 position of model 1 which is resting on the first floor and all other columns reaching the ground.fig 4.3 and fig 4.4 shows the plan and elevation.

Model3 in which floating column is at c11 position of model 1 but resting on the second floor and all other columns reaching the ground .fig4.5 and 4.6 shows the frame structures .

The structures are further analyzed for static non-linear analysis which is also called as pushover analysis.



Fig 3. Plan of model 1

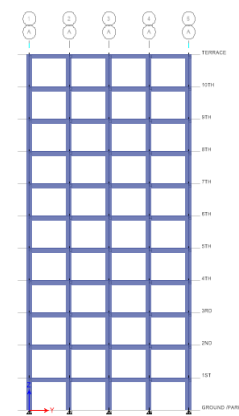


Fig 4. Elevation of model 1

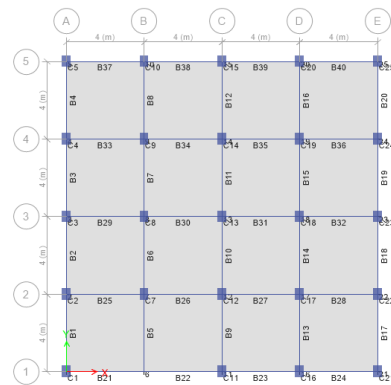


Fig 5. Plan of model 2

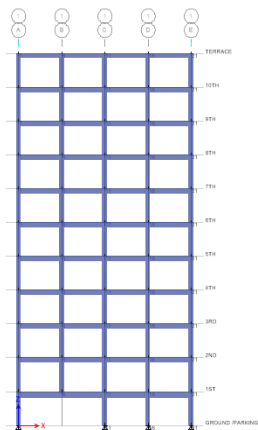


Fig 6. Elevation of model 2

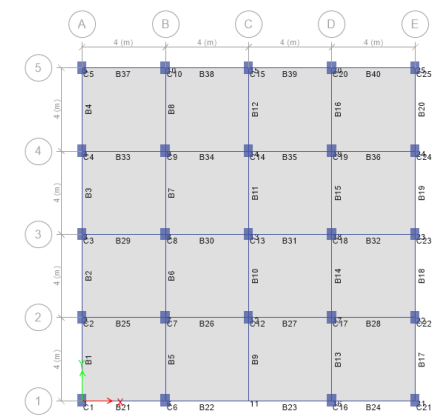


Fig7.Plan of model 3

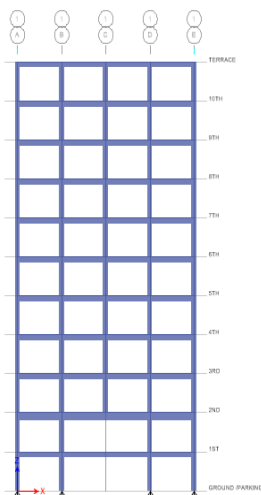


Fig 8. Elevation of model 3

carried out in compliance with IS 1893 (part-1): 2002, which includes the strength and stiffness effects as well as inelastic deformations in the members, and the members are designed. Using IS 1893 (part-1) response spectrum method in the ETABS to assess the stiffness of members, and all the members were found to be safe for further static non linear analysis.

Further for column and beam elements hinge points are assigned at 0.1 and 0.9. Now All three models are subjected to a pushover analysis. And all three models are safe with the columns and beams and are ok with the design check.

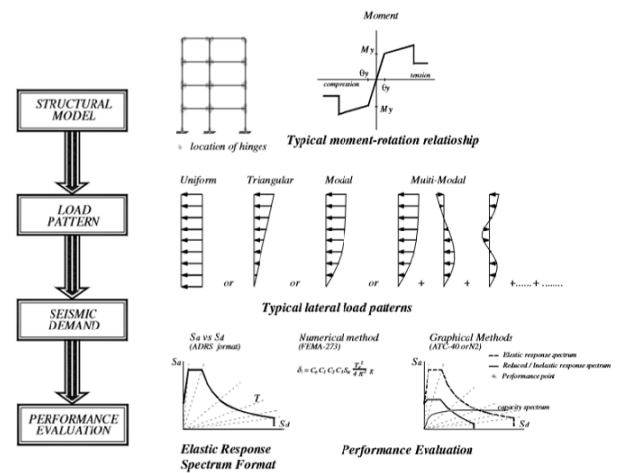


Fig 9.Flow chart of pushover analysis .

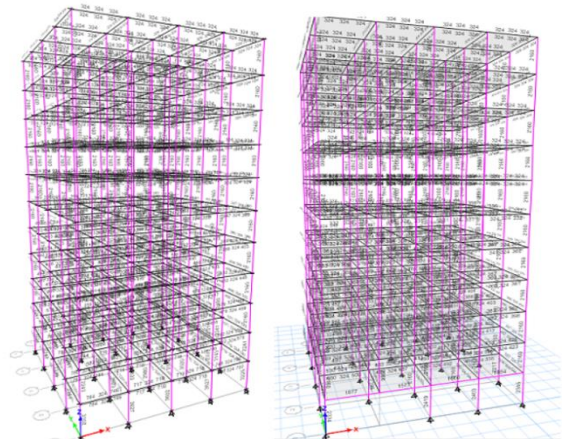


Fig 10.Model 1 and Model 2 design check.

C. Analysis

To avoid earth quake damage, additional arrangements must be made in all three structures to strengthen the lateral structural strength of the members. Dynamic analysis (linear or non-linear) of buildings is

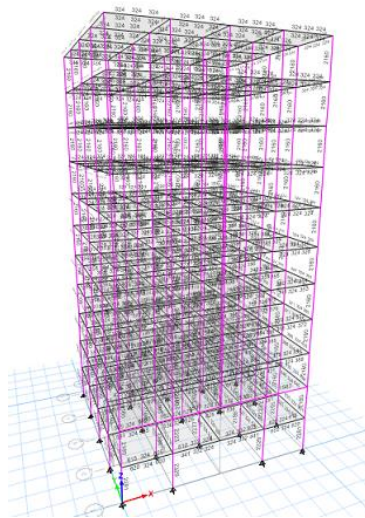


Fig 11. Model 3 design check.

Plastic hinges occur at the ends of columns and ends of beams in frame constructions when earthquakes strike. Plastic hinges are most commonly caused by uniaxial bending moments in beam elements, while axial loads and biaxial bending moments are the most common causes of plastic hinges in column components. As a result, various types of plastic hinge must be used for the column and beam elements individually in push-over analysis.

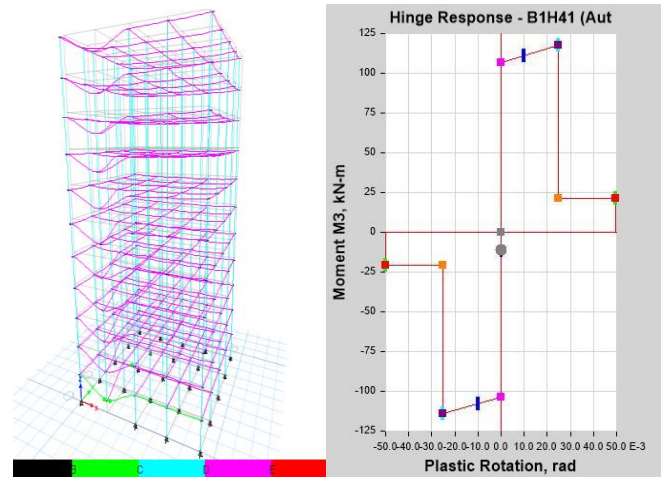


Fig 13. First hinge formation and hinge response of Model 2

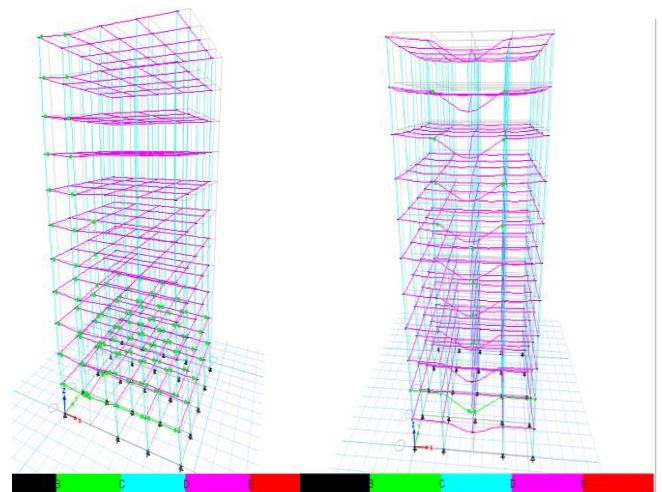


Fig 14. First hinge formation and hinge response of Model 3

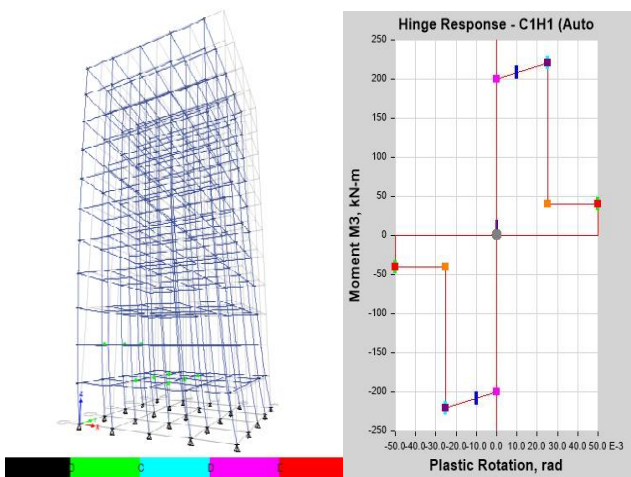


Fig 12. First hinge formation and hinge response of Model 1

Hinges formed in all the models are normal but more care to be taken in order to overcome the severe circumstances. Hinges formed at beams and columns showing light green nodes in all the models are to be well designed in order to overcome hinges.

In model 1 B6, B11, B12 have hinges. In model 2 floating column has more hinges and beams attached to it are to be taken care. Highly more number of hinges arise in model 3.

IV. RESULTS AND CONCLUSION

A. COLUMN FORCE (P)

Column force in columns beneath and around beam supporting floating columns is compared to column force in buildings without floating columns, with the following results.

STORY	COLUMN	LOAD CASE	P (KN)
1	C1	PAX	1419.775
1	C7	PAX	2046.266

1	C11	PAX	1480
1	C16	PAX	1459.719
1	C21	PAX	1021.638

Table 3 Column force of Model 1.

STORY	COLUMN	LOAD CASE	P (KN)
1	C1	PAX	1876.83
1	C7	PAX	2936.465
1	C11	PAX	2302.59
1	C16	PAX	1656.044
1	C21	PAX	1164.961

Table 4 Column force of Model 2.

STORY	COLUMN	LOAD CASE	P (KN)
1	C1	PAX	2097.15
1	C6	PAX	2778.33
1	C16	PAX	2511.33
1	C12	PAX	1967.93
1	C21	PAX	2535.53

Table 5 Column force of Model 3.

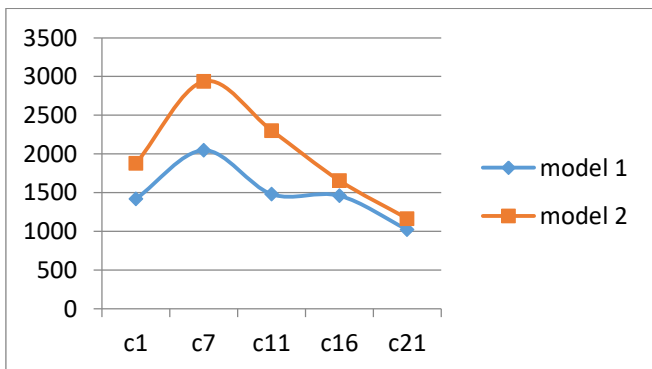


Fig 15. Comparison of column forces of Model 1 and Model 2

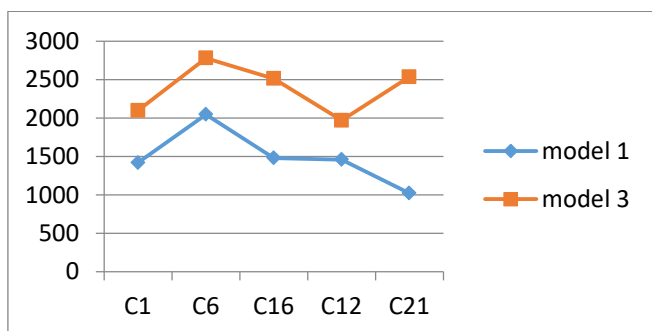


Fig 16. Comparison of column forces of Model 1 and Model 3

B. STORY DISPLACEMENT

Story	Elevation	Location	X-Dir(mm)	Y-Dir(mm)
TERRACE	33	Top	0.011	0.024
10TH	30	Top	0.003	0.017
9TH	27	Top	0.001	0.014
8TH	24	Top	0.001	0.015
7TH	21	Top	0.001	0.015
6TH	18	Top	0.001	0.015
5TH	15	Top	0.001	0.015
4TH	12	Top	0.001	0.015
3RD	9	Top	0.002	0.015
2ND	6	Top	0.002	0.014
1ST	3	Top	0.006	0.022
GROUND /PARKING	0	Top	0	0

Table 6 Story displacement of Model 1.

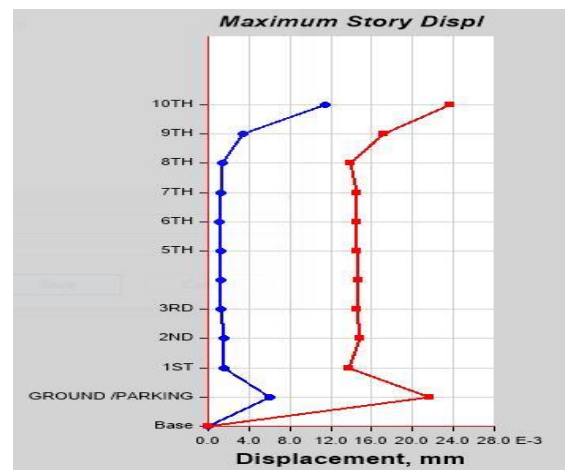


Fig 17. Maximum story displacement of Model 1 in X and Y direction.

Story	Elevation	Location	X-Dir(mm)	Y-Dir(mm)
TERRACE	33	Top	3.054	6.881
10TH	30	Top	2.77	6.253
9TH	27	Top	2.517	5.63
8TH	24	Top	2.304	5.008
7TH	21	Top	2.086	4.384
6TH	18	Top	1.852	3.76
5TH	15	Top	1.607	3.135
4TH	12	Top	1.349	2.568
3RD	9	Top	1.071	2.142
2ND	6	Top	0.783	1.732
1ST	3	Top	0.407	0.854
GROUND /PARKING	0	Top	0	0

Table 7 Story displacement of Model 2

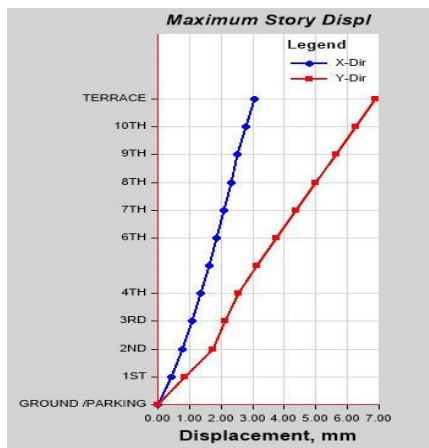


Fig 18. Maximum story displacement of Model 2 in X and Y direction.

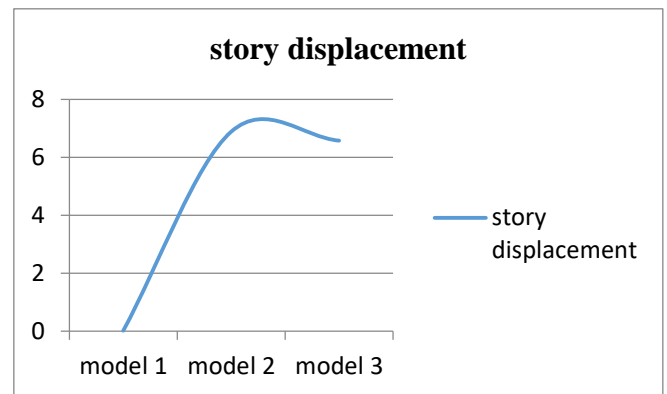


Fig20. Comparison of story displacement of Model 1, Model 2 and Model 3.

Story	Elevation	Location	X-Dir(mm)	Y-Dir(mm)
TERRACE	33	Top	2.997	6.574
10TH	30	Top	2.938	5.933
9TH	27	Top	2.855	5.294
8TH	24	Top	2.735	4.656
7TH	21	Top	2.577	4.018
6TH	18	Top	2.38	3.382
5TH	15	Top	2.148	2.75
4TH	12	Top	1.877	2.122
3RD	9	Top	1.57	1.504
2ND	6	Top	1.214	0.917
1ST	3	Top	0.754	0.439
GROUND/PARKING	0	Top	0	0

Table 8 Story displacement of Model 3

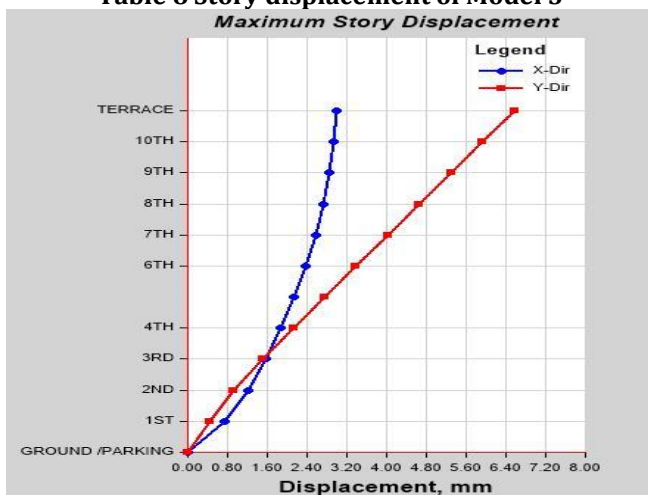


Fig19. Maximum story displacement of Model 3 in X and Y direction.

C. PUSHOVER CURVE

BASE SHEAR VS DISPLACEMENT

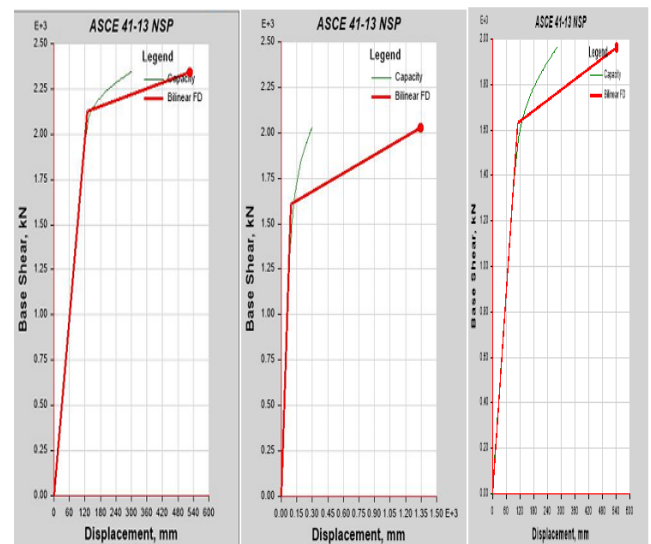


Fig 21. Pushover curve of model 1, model 2 and model 3.

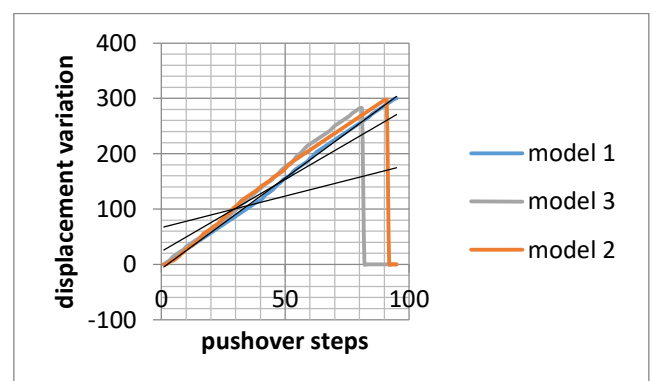


Fig 22. Stepwise displacement variation of model 1, model 2 and model 3

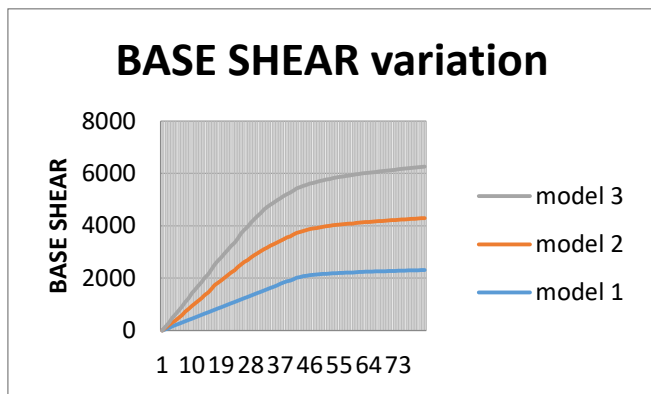


Fig 23. Stepwise base shear variation of model 1, model 2 and model 3

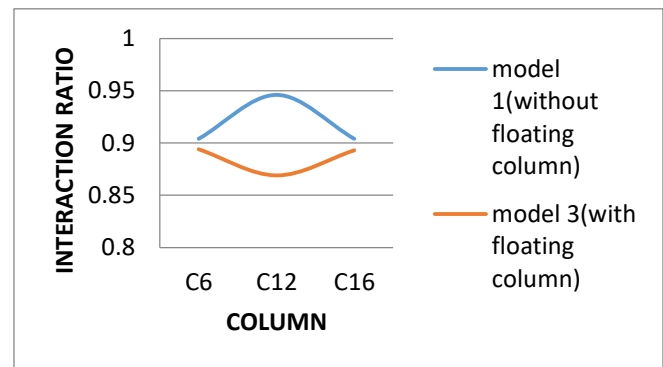


Fig 25. Comparison of interaction ratio of Model 1 and Model 3.

D. INTERACTION RATIO

Interaction ratio of chosen columns which are beside the floating column at base are compared with building without floating column and the values are as shown below

column	Interaction ratio	
	model 1 (without floating - column)	model 2 (with floating - column)
C1	0.922	0.894
C7	0.943	0.824
C11	0.904	0.987

Table 9 Interaction ratio of Model 1 and Model 2.

column	Interaction ratio	
	model 1 (without floating - column)	model 3 (with floating - column)
C6	0.904	0.894
C12	0.946	0.869
C16	0.904	0.893

Table 10 Interaction ratio of Model 1 and Model 3.

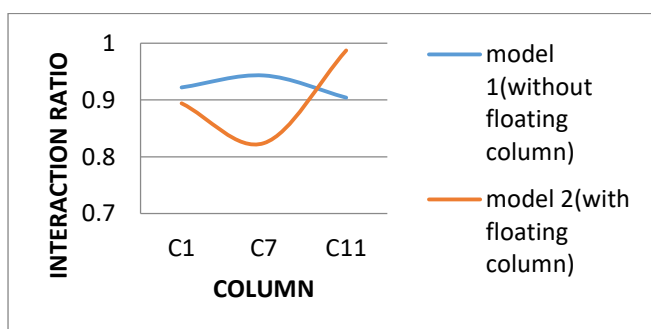


Fig 24. Comparison of interaction ratio of Model 1 and Model 2.

V. DISCUSSION

In this project work, RC building of G+10 story is considered and the behavior of the buildings with and without floating-columns are analyzed for seismic and gravity conditions. Analysis is done for RC building with and without floating column (considering columns which are beneath and around beam supporting floating column). The seismic parameters such as story displacement, column force and interaction ratio are studied and the comparison between these parameters are given in between regular structure and structure with floating-column.

RC building models considered in this work are

- Model-1 : RC building with no floating-column.
- Model-2 : RC building with floating-column at C6 column position in floor 1.
- Model-3 : RC building with floating-column at C11 column position in floor 2.

VI. CONCLUSION

1. Forces in columns C1, C6, C16, C12, C21, C7 and C11 are studied and compared between Model 1 with Model 2 and similarly compared between Model 1 and Model 3. It is seen that column forces in Model 2 and Model 3 are increased by minimum of 45%. The sections of these column should be appropriately increased to withstand safely.
2. When an RC building with a floating column is compared to an RC building without a floating column, the roof displacement increases dramatically. As a result, the addition of a floating column to an RC structure causes an increase in roof displacement. This has a direct impact on the RC structure's stiffness.
3. Interaction ratio of columns in all Model-1, Model-2 and Model-3 are less than 1 and are safe.
4. Due to seismic action model 2 and model 3 are more vulnerable to plastic hinges around the floating column and are to be addressed with safety by increasing the beam sections resting on it.

REFERENCES

- [1] NIE Jianguo, QIN Kai "Push-Over Analysis of the Seismic Behavior of a Concrete- Filled Rectangular Tubular Frame Structure" TSINGHUA SCIENCE AND TECHNOLOGY ISSN 1007-0214 20/21 pp124-130 Volume 11, Number 1, February 2006
- [2] A.P. Mundada , 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 ,Oct 2014.
- [3] Sk.Shama Banu, Shani Priyanka "Study of Behavior of Seismic Evaluation of Multistoried Building with Floating Column" International Journal of Civil Engineering In Research Trends Volume2, Issue12, December-2015, pp. 983-988 .
- [4] R. Bento, S. Falcao "Non-linear Static Procedures In Performance Based Seismic Design" 13th World Conference On Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 2522.
- [5] Ramesh Bantupalli , Srimukha "Pushover Analysis of Multi-Storey RCC Frame with and without Vertical Irregularities" International Journal of Engineering and Management Research Volume-6, Issue-4, July-August 2016 .
- [6] P.K. Umesh, Cinitha, Nagesh "Nonlinear Static Analysis to Assess Seismic Performance and Vulnerability of Code - Conforming RC Buildings" APPLIED and THEORETICAL MECHANICS .
- [7] ATC 55, 2005 improvements nonlinear static seismic analysis procedures FEMA 440, NEHRP.
- [8] IS 1893 2016 Part1. "Criteria for Earthquake Resistant Design of Structures". Bureau of Indian Standards
- [9] IS 456: 2000, "Plain Reinforced Concrete Code of Practice", Bureau of Indian Standards.
- [10] Craig Comartin, Mark Aschheim "A summary of FEMA 440: Improvement of Nonlinear Static Seismic Analysis Procedures". 13th World Conference of Earthquake Engineering