Seismic Vulnerability Assessment of Open Ground Storey Building using Pushover analysis and Response Spectrum Analysis

Vishnu R. Bhakad[1], D.H.Tupe[2], G.R.Gandhe[3]

[1]PG Student Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad 431005, India
[2]Assistant Professor, Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra, India.
[3]Professor, Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra, India.

---***---

Abstract - *In World increasing population hence developing problem so provision require shelter and vehicle parking. There is arising lots of problem for the vehicle parking, reception lobbies, communication halls or any purpose in the multi-storey building, and these type of building is also known as open ground storey(soft storey) building or open first storey building. There are more of advantages of this type of building but from the earthquake point of view these types of buildings are much vulnerable. In the open ground storey building walls are present at the all the storey rather than ground storey and during the time of earthquake or dynamic loading the upper storey except ground storey columns are heavily stressed. These phenomenon is occurring due to stiffness discontinuity present in the open ground storey building here all the upper storey are have higher stiffness than the ground storey of the building. These situation works like a vibration of inverted pendulum. This project is proposed to critically study Seismic Vulnerability Assessment of Open Ground Storey Building using Pushover analysis and Response Spectrum Analysis. Modeling will be made of a frame structure in the software SAAP2000 20. Analysis and design of the G+7,G+14 and G+21 storey RCC structure with different alternative in open ground storey will be done with the help of SAAP2000 20 i.e. five models for each G+7,G+14 and G+21 storey will be prepared, one would be bare frame, second frame with infill's panels, third open ground storey structure, fourth open first storey structure, fifth open ground storey with part peripheral RCC wall, sixth open ground storey with central core wall and seventh would be open ground storey with complete peripheral RCC wall. The data obtained from analysis report of SAAP2000 20 will be studied and the performance of the structures will be compared.*

***Key Words*: Open Ground Storey Structure, Static Nonlinear Analysis, Pushover analysis, Capacity, Base Shear, Response Spectrum method, Nonlinear Hinges and IS1893:2016.**

1. INTRODUCTION

For fast growing country like India there is arising lots of problem for the men and vehicle parking is used as a parking space for the multi-storey building and this type of building is also known as open ground storey building or open first storey building. There are lots of advantages of this type of building but from the earthquake point of view these types of buildings are much vulnerable. The walls are present in open ground storey at the all the storey level other than ground storey and during the time of earthquake the ground storey columns are heavily stressed except upper storey. This situation occurring due to discontinuity of stiffness, present in the open ground storey building here all the upper storey are have higher stiffness than the ground storey of the building. These phenomenon works like a vibration of inverted pendulum. In the conventional design practice code the strength and stiffness of in filled walls are ignored and the frames strength only designed. In the design practice code, there is no provision for the design of the frame is bare frame design. With the infill the strength and stiffness of bare frame is increases but at the open ground storey is not, then the fundamental time period component to bare frame and consequently increases the base shear demands in the ground storey beams and column. In the past earthquake, the failure patterns are observed in bhuj earthquake and Jabalpur earthquake there is in the open ground storey building. The infill part is at other side and open ground storey is other side affected by earthquake. After the bhuj earthquake Indian code IS 1893:2002 are revised and give some recommendation. In clause7.10.3.(a) state that, "the column and beams of the soft storey are to be designed for 2.5 times the storey shear and moment calculated under seismic loads of bare frames ". The value 2.5 is used as multiplication factor for the open ground storey beam and column.

1.1 General

Now days we can use any software to analyse linear/non-linear, static/dynamic analysis. It's necessary to develop a computational model using software like STAAD, ETAB and SAAP. Hence in this chapter we will discuss the parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study. In this chapter is discussed, a detailed description on the nonlinear modeling of RC building frames in SAAP2000 20.

1.2 Example Frames

The type of building frames considered for the case study is 5X5 bay frame. The buildings were of 7, 14 & 21 storied with the number of bays remaining constant i.e. 5. Types of building frames considered are shown in the table below:

Table -1: Seismic Design Data

Sr.No	Frame Name	Frame Type	Storeys	Bays	Type of Infill Wall
1	M1-A	Bare	7	5	No Infill Wall
2	M1-B	Fully infilled	7	5	Strong
3	M1-C	OGS	7	5	Strong
4	M1-D	OFS	7	5	Strong
5	M1-E	Shear wall at partial periphery OGS	7	5	Strong
6	M1-F	Shear wall at core OGS	7	5	Strong
7	M1-G	Shear wall at full periphery	7	5	Strong
8	M2-A	Bare	14	5	No Infill Wall
9	M2-B	Fully infilled	14	5	Strong
10	M2-C	OGS	14	5	Strong
11	M2-D	OFS	14	5	Strong
12	M2-E	Shear wall at patial periphery OGS	14	5	Strong
13	M2-F	Shear wall at core OGS	14	5	Strong
14	M2-G	Shear wall at full periphery	14	5	Strong
15	M3-A	Bare	21	5	No Infill Wall
16	M3-B	Fully infilled	21	5	Strong
17	M3-C	OGS	21	5	Strong
18	M3-D	OFS	21	5	Strong
19	M3-E	Shear wall at patial periphery OGS	21	5	Strong
20	M3-F	Shear wall at core OGS	21	5	Strong
21	M3-G	Shear wall at full periphery	21	5	Strong

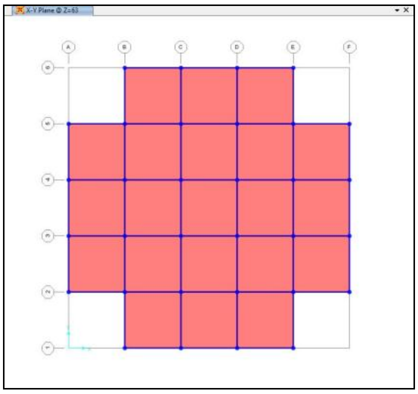


Fig-1: Plan for model all models.

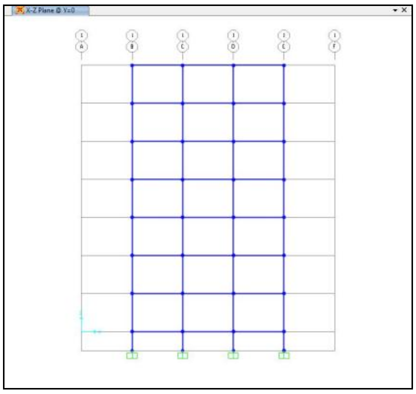


Fig-2: Elevation for model M1-A

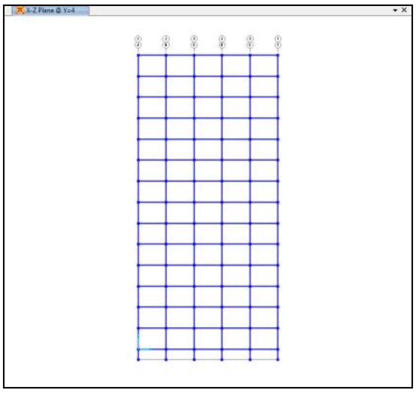


Fig-3: Elevation for model M2-A

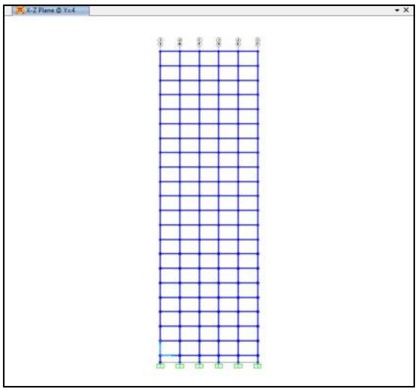


Fig-4: Elevation for model M3-A

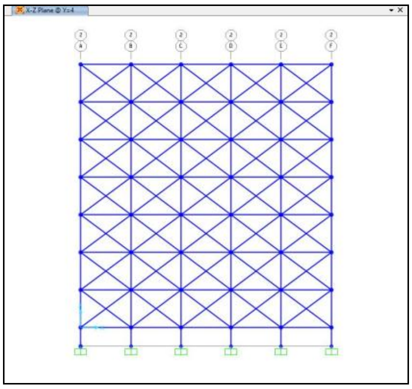


Fig-5: Elevation for model M1-B

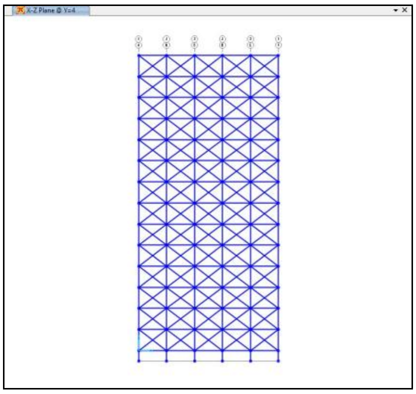


Fig-6: Elevation for model M2-B

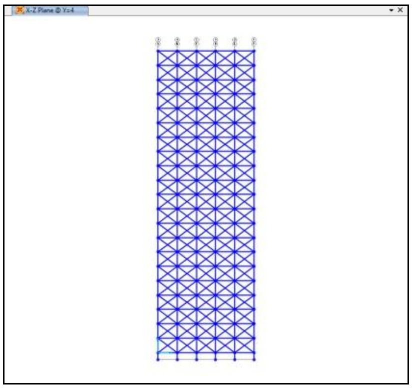


Fig-7: Elevation for model M3-B

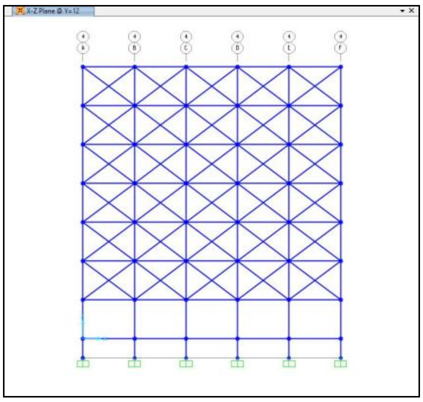


Fig-8: Elevation for model M1-C

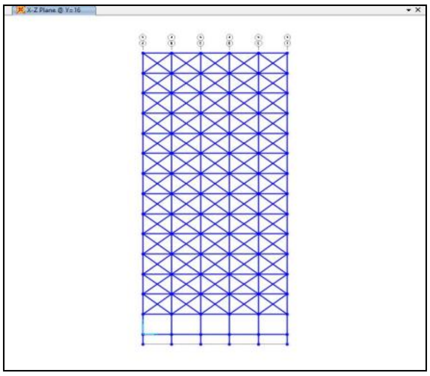


Fig-9: Elevation for model M2-C

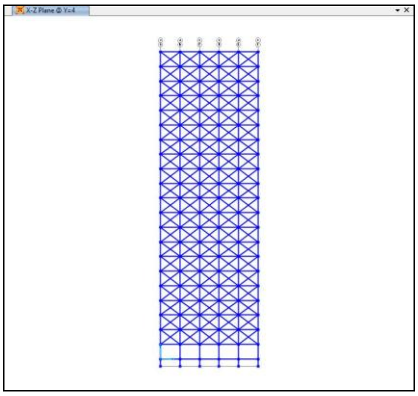


Fig-10: Elevation for model M3-C

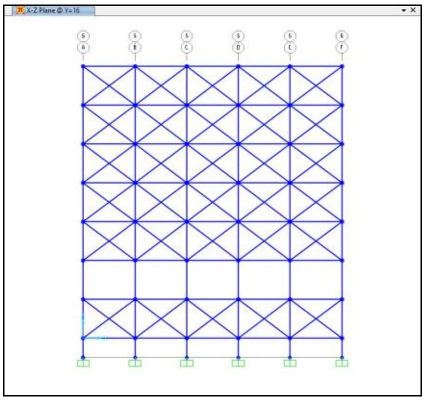


Fig-11: Elevation for model M1-D

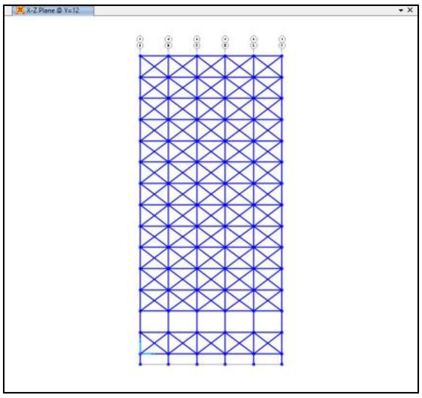


Fig-12: Elevation for model M2-D

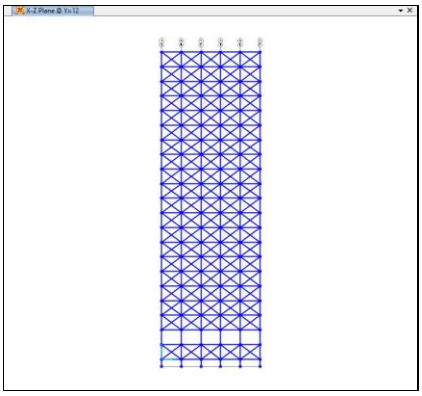


Fig-13: Elevation for model M3-D

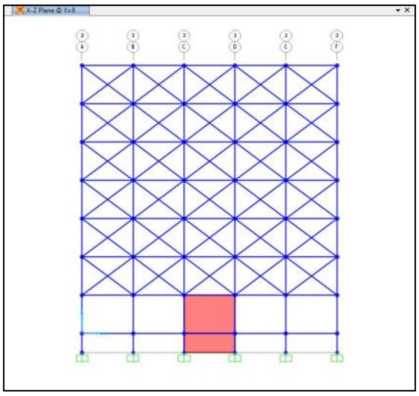


Fig-14: Elevation for model M1-E

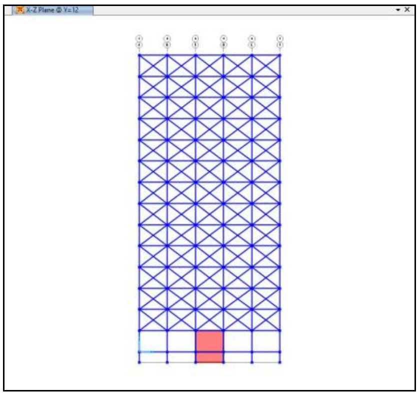


Fig-15: Elevation for model M2-E

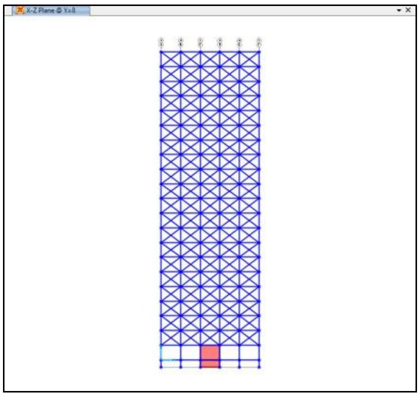


Fig-16: Elevation for model M3-E

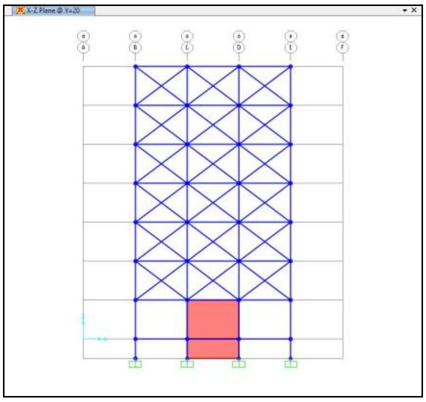


Fig-17: Elevation for model M1-F

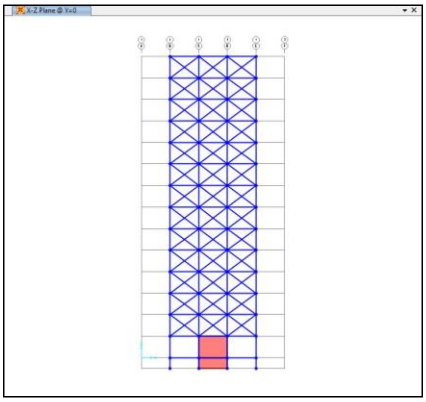


Fig-18: Elevation for model M2-F

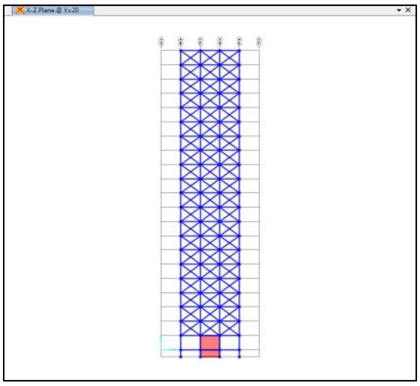


Fig-19: Elevation for model M3-F

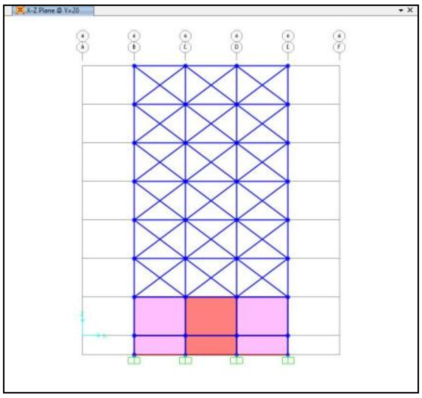


Fig-20: Elevation for model M1-G

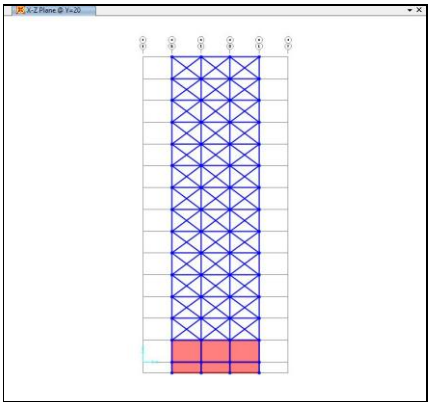


Fig-21: Elevation for model M2-G

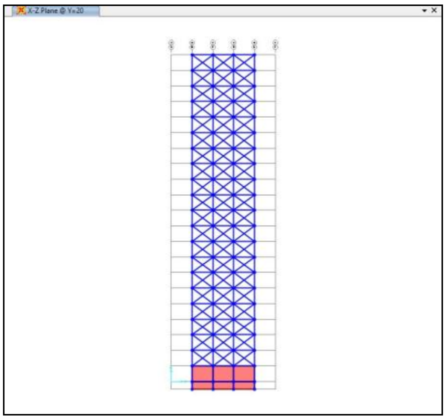


Fig-22: Elevation for model M2-G

Apart from variations in height we have considered other variations in the type of building frames for this project. The same frames were redesigned for other different cases like variation in OGS (wall in periphery of frame and in central core), sometimes we need to have parking in first storey instead of Ground storey so this one case is also considered in this study.

2. Methodology

The present analysis deals with the Static Nonlinear Analysis and Dynamic linear analysis i.e. pushover analysis and Response Spectrum Method respectively of a multi-storied building with G+7, G+14 and G+21 floors. For the three-dimensional modeling and analysis of the structure standard software SAAP2000 20 is used. Seismic force is applied with X and Z directions and also nonlinear hinged is assigned to all beams and column respectively to check the performance of the building. Frames are then analyzed by Response spectrum method and pushover method after analyses following results are studied.

1. Maximum storey displacements 2.Storey drifts 3.Static base share. 4. Dynamic Base share. 5. Storey stiffness. 6. Fundamental time period. 7. Model shape 8.Model periods and frequency 9.Model participation mass ratio. 10. Plastic Hinge Formation.

Table -2: Seismic Design Data:

Sr. No.	Content	Description
1	Type of structure	Special moment resistant frame
2	Response Reduction Factor	5
3	Seismic zone	III
4	Zone factor	0.16
5	Importance factor	1.2
6	damping ratio	5%
7	Soil type	Hard soil

3. Material Properties

Table3. Material Properties and geometric parameters Assumed

Sr. No	Design Parameter	Value
1	Unit weight of concrete	25 kN/m3
2	Unit weight of Infill walls	18kN/m3
3	Characteristic Strength of concrete	25 MPa
4	Characteristic Strength of concrete	415 MPa
5	Compressive strength of strong masonry (Em)	5000MPa
6	Compressive strength of weak masonry (Em)	350MPa
7	Modulus of elasticity of Masonry Infill walls (Em)	750f'm
8	Damping ratio	5%
9	Modulus of elasticity of steel	2E5 MPa
10	Frame Type	Special Moment Resisting Frame
12	Slab thickness	150 mm
13	Wall thickness	230 mm

4. Structural Elements

The dimensions of the elements of the structure were:
For model M-1
1. Beam: 230 mm x 600 mm
2. Column: 300 mm x 830 mm
3. Slab thickness: 150 mm
4. Wall thickness: 150 mm
5. Parapet height: 1200 mm
6. Founding depth: 1500 mm

Table4. Structural Elements

Sr. No.	Description	Models		
		M1	M2	M3
1	Beam	230 X 600	230 X 600	230 X 600
2	Column	300 X 830	450 X 800	600 X 900
3	Slab thickness	150	150	150
4	Wall thickness	150	150	150
5	Parapet height	1200	1200	1200
6	Founding depth	1500	1500	1500
7	Shear wall thickness	200	200	200

5 Loads Considered

The types of load considered during the design were:
1. Self-weight of beams and columns.
2. Weight of slab.
3. Infill weight.
4. Parapet weight.
5. Floor finish of 2 KN/m2.
6. Live load of 5 KN/m2.

6 Structural Modelling

All the above structures were now ready for modelling and were about to be modelled in the software SAP. As per our objective we were focused on the behavior analysis of the building frame here in this step we introduced the type of non-linear analysis to study the behavior said to be as pushover analysis.

6 Results for Response Spectrum

The following results are deals with the Dynamic linear analysis i.e. Response Spectrum Method respectively of a multi-storied building with G+7, G+14 and G+21 floors.

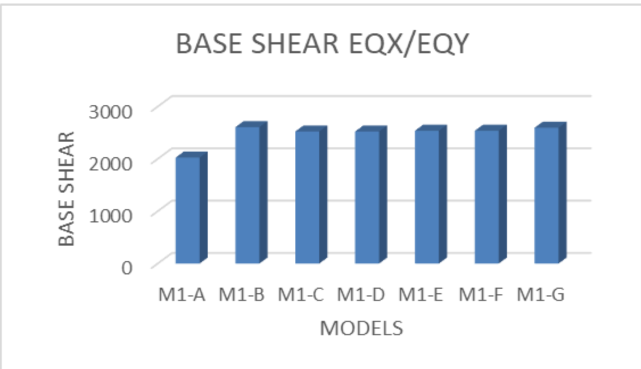


Fig -23: Base shear for 7 storey frames along EQX/EQY

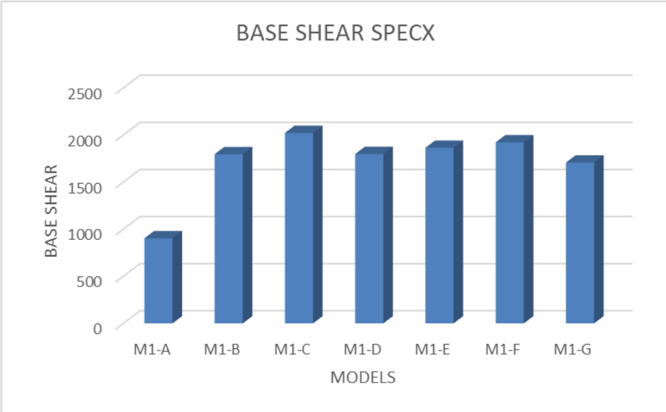


Fig -24: Base shear for 7 storey frames along SPECX

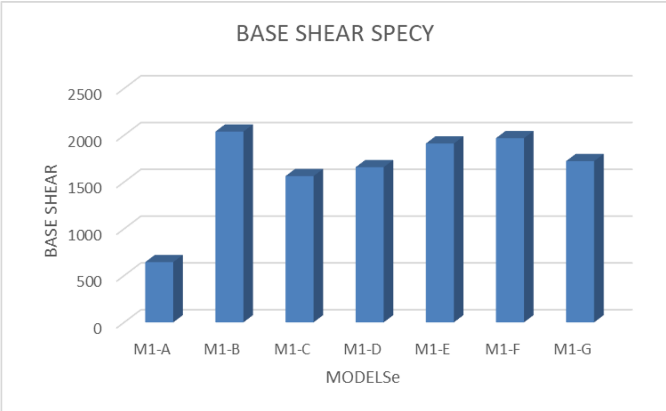


Fig -25: Base shear for 7 storey frames along SPECY

Fig. 23, 24 and 25 shows the base shear along EQX/EQY, SPECX and SPECY respectively for different types of 7 storey frame.

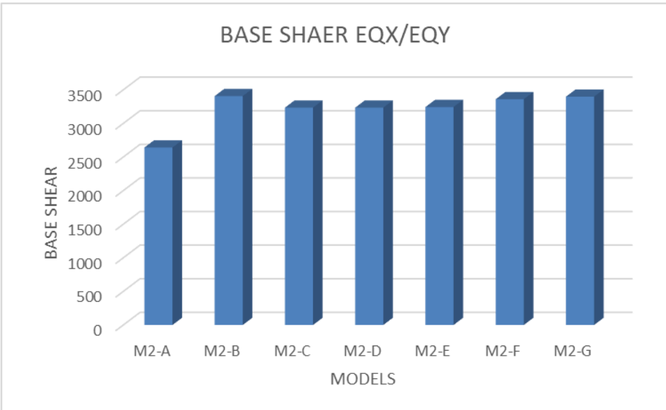


Fig -26: Base shear for 14 storey frames along EQX/EQY

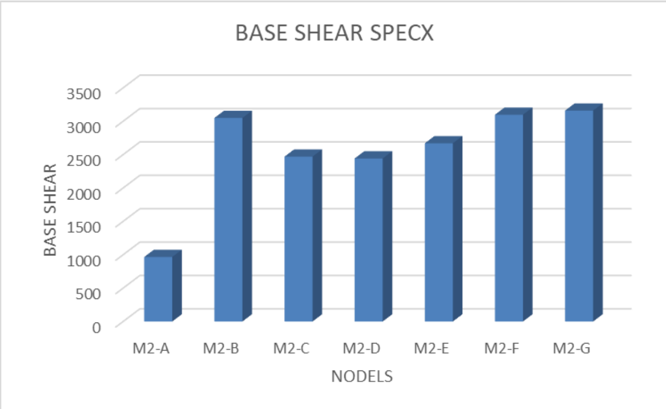


Fig-27: Base shear for 14 storey frames along SPECX

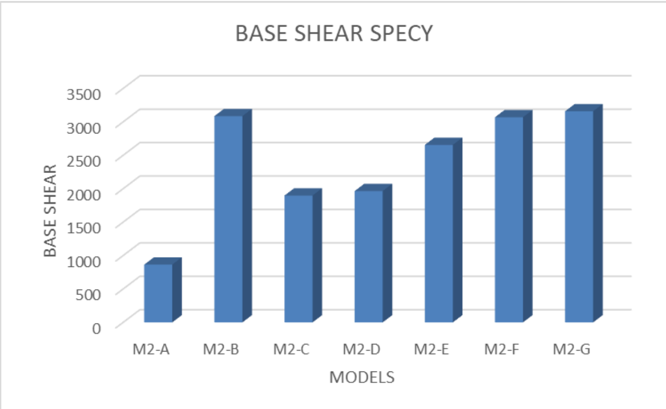


Fig-28: Base shear for 14 storey frames along SPECY

Fig. 26, 27 and 28 shows the base shear along EQX/EQY, SPECX and SPECY respectively for different types of 14 storey frame.

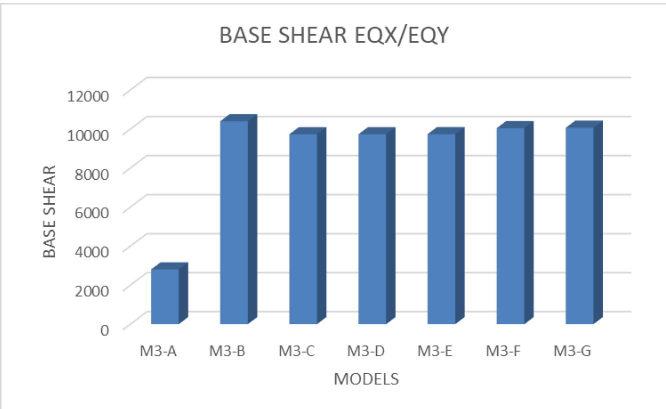
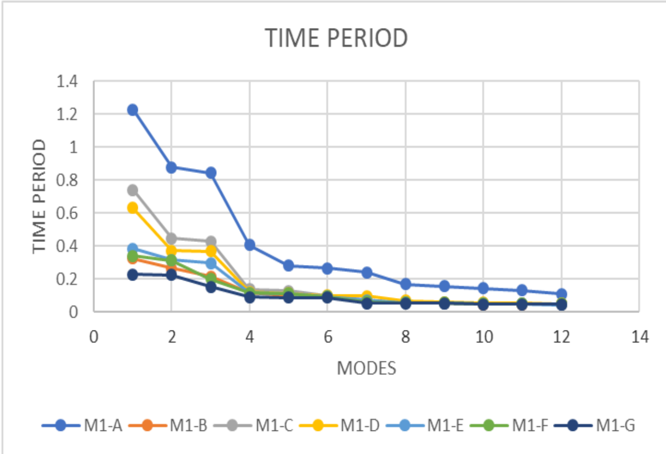
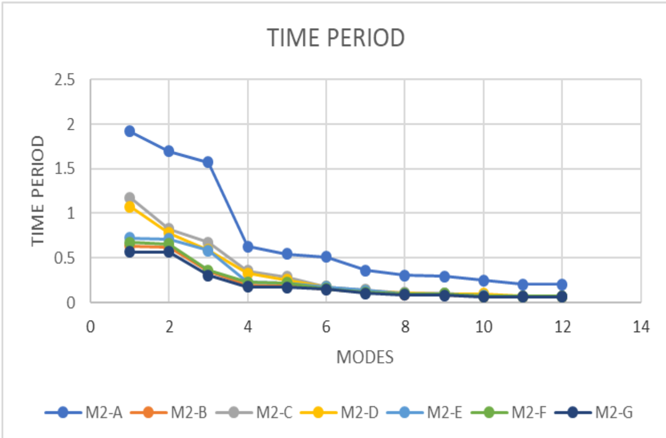


Fig -29: Base shear for 21 storey frames along EQX/EQY

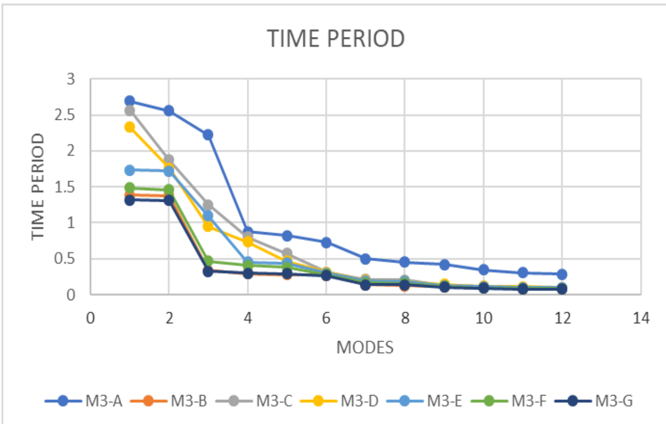
Fig. 29 shows the base shear along EQX/EQY for different types of 21 storey frame.



Graph-1: Time period for 7 storey frames.



Graph-2: Time period for 14 storey frames.



Graph-2: Time period for 14 storey frames.

Graph 1, 2 and 3 shows the time period for different modes for 7, 14 and 21 storey frame respectively.

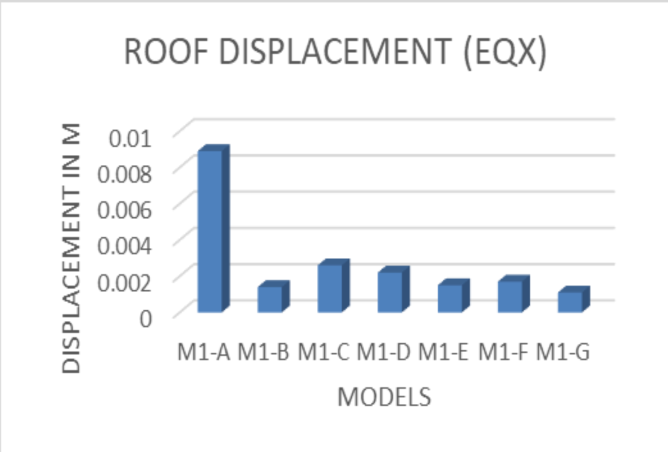


Fig-30: Roof displacement for 7 storey frames.

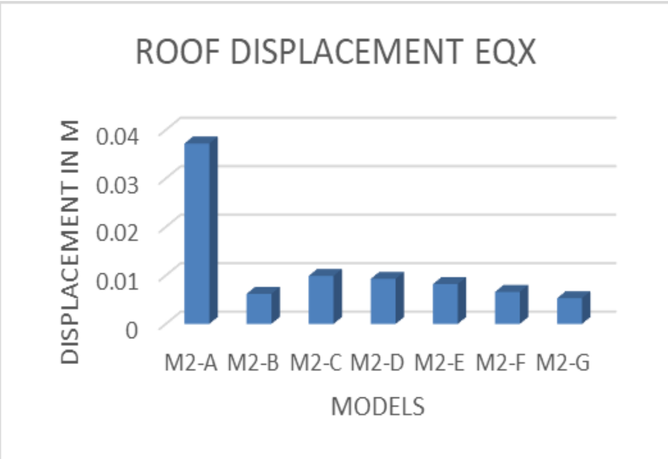


Fig-31: Roof displacement for 14 storey frames.

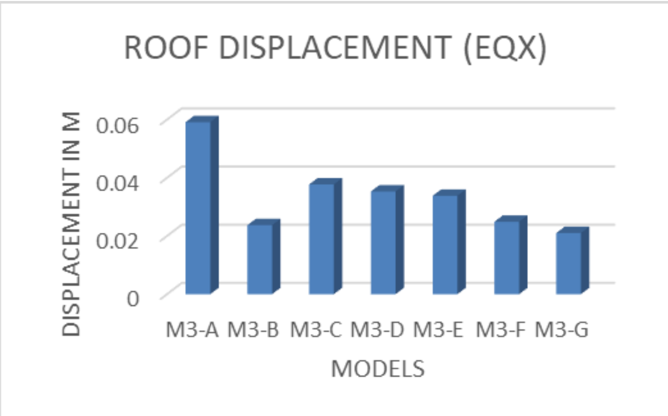


Fig-32: Roof displacement for 21 storey frames.

Fig. 30,31and 32 shows the roof displacement for different models for 7, 14 and 21 storey frame respectively.

6 Results for Static Nonlinear Analysis

The following results are deals with the Static Nonlinear Analysis i.e. pushover analysis respectively of a multi-storied building with G+7, G+14 and G+21 floors.

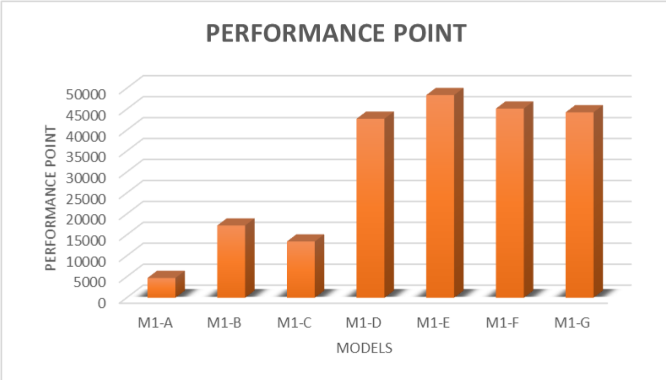


Fig-33: Performance point for 7 storey frames.

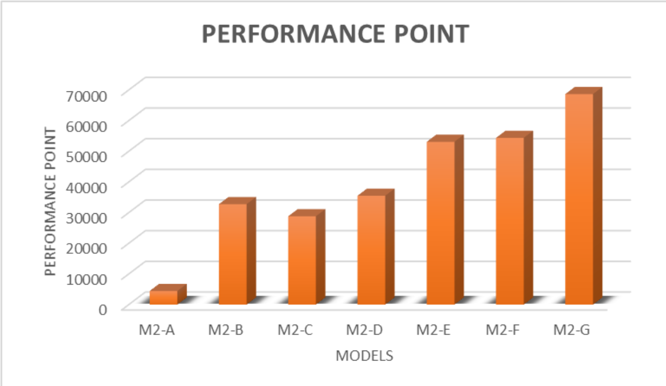


Fig-34: Performance point for 14 storey frames.

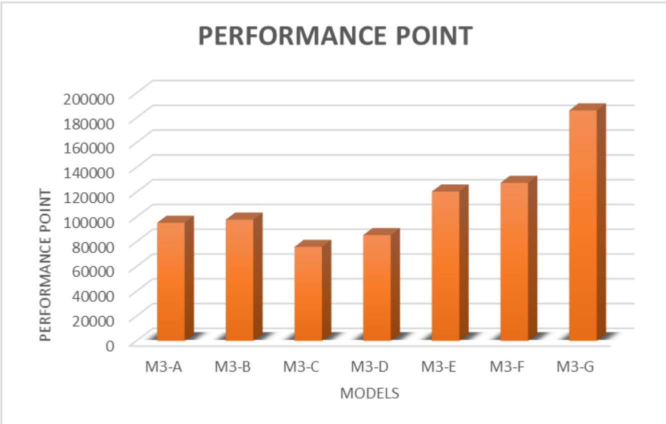


Fig-35: Performance point for 14 storey frames.

Fig. 33,34and 35 shows the performance point for different models for 7, 14 and 21 storey frame respectively.

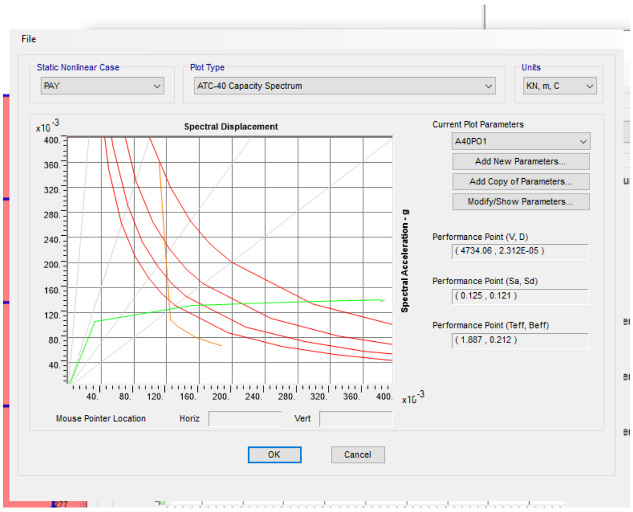


Fig-36: Performance point for 14 storey frames.

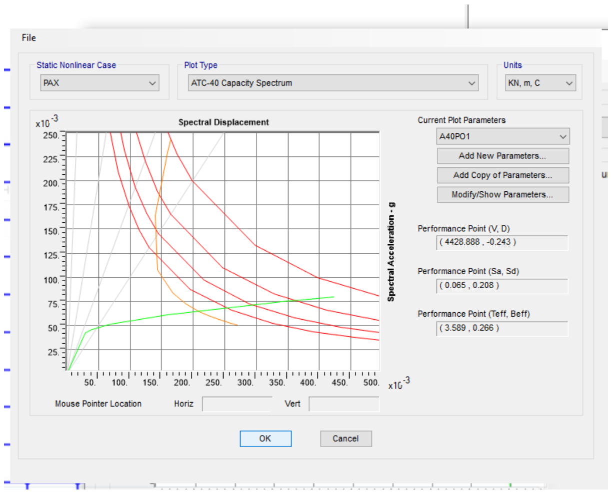


Fig-37: Performance point for 14 storey frames.

Fig. 36 and 37 shows capacity spectrum curve for M1-A and M2-A and also performance point.

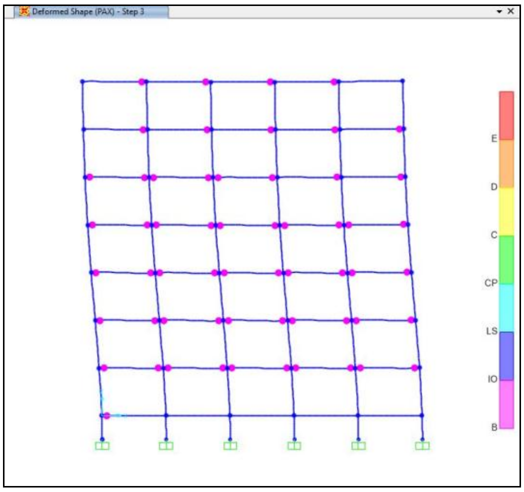


Fig-38: Distribution of Plastic Hinges for model M1-A

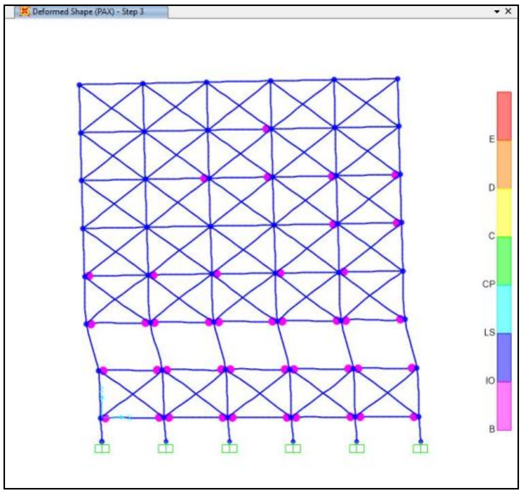


Fig-39: Distribution of Plastic Hinges for model M1-D

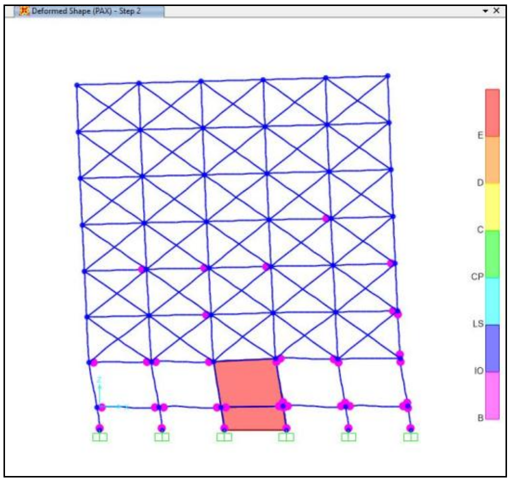


Fig-40: Distribution of Plastic Hinges for model M1-E

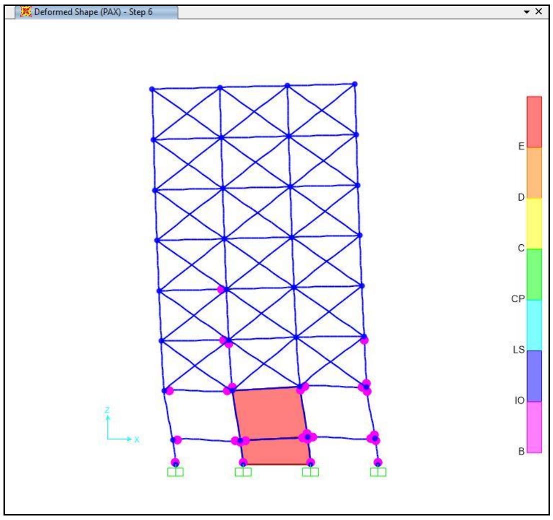


Fig-41: Distribution of Plastic Hinges for model M1-F

Fig. 38, 39, 40 and 41 shows the distribution of nonlinear hinges for some models.

7 Acknowledgements

I express my deepest gratitude to my project guide Prof. D. H. Tupe and Prof. G. R. Gandhe, whose encouragement, guidance and support from the initial level to the final level enabled me to develop an understanding of the subject.

8. CONCLUSIONS

From the above study of Static Nonlinear Analysis and Dynamic linear analysis i.e. pushover analysis and Response Spectrum Method following points are concluded.

1. As the height of building increases its mass increases but its overall stiffness decreases. Hence the natural time period of the building increases with building height.
2. From the above results one has to accept that as we increase the no. of stories base shear and storey shear get increased.
3. Deflection of bare frame i.e. without infill panels is more as compared to with infill frames.
4. Performance of building with shear wall at open ground storey is more as compared with bare frame and OGS frame.
5. From the overall analysis it shows that the with infill model performance better than the without infill model

REFERENCES

[1] Ms. Nivedita N. Raut & Ms. Swati D. Ambadkar, "Pushover Analysis of Multistoried Building," Volume 13 Issue 4 Version 1.0 Year 2013D. Online ISSN: 2249-4596 & Print ISSN: 0975-5861.

[2] K. Peethambaran, and V. Philip, "Seismic performance assessment of multi- storied RC moment resisting frames based on plan aspect ratio by pushover analysis", International Journal for Innovative Research in Science & Technology, vol 2, issue 05, Oct 2015.

[3] Vijay Vadgama,2 Girish Joshi "Analysis of G+12 Structures with different material of Shear wall using SAP2000,"(2016).

[4] Rahul Ghosh, Dr. Rama Debbarma, "Seismic Vulnerability Assessment of Soft Storeyed,"

[5] "Structures with Plan Irregularity and Collapse Prevention," Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[6] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[7] Syed ahamed, and Dr.Jagadish.G.kori, (2013) "Performance based seismic analysis of an unsymmetrical building using pushover analysis" international journal of engineering research online Vol.1.Issue.2, pages (100-110).

[8] IS 1893(Part1): 2016."Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi, 2016.

[9] Mouzzoun, O.Moustachi, A.Taleb (2014) Seismic performance assessment of infill reinforced Concrete frame buildings with soft storey, Journal of Environmental Science, Computer Sciences and Engineering & Technology, Sec. C, Vol.3.No.2, 1035-1047.

[10] A. Kadid, and A. Boumrkik, "Pushover analysis of reinforced concrete frame structures," Department of Civil Engineering, University of Batna, Algeria, Asian journal of civil engineering (building and housing) vol. 9, no. 1, pp.75-83, 2008.

[11] H. R. Tamboli, and U. N. Karadi, "Seismic analysis of RC Frame structure with and without masonry infill walls," Indian Journal of Natural Sciences, vol.3, issue 14, pp. 1137-1148, Oct 2012.

[12] IS: 456 (Fourth Revision), "Indian standard code for practice for plain reinforced concrete for general building construction," Bureau of Indian Standards, New Delhi, 2000.

[13] Duan, and Hueste, "Seismic performance of a reinforced concrete frame building in China," Engineering Structures, vol 41, pp. 77–89, 2012.

[14] B. Patel, and D. Shah, "Formulation of response reduction factor for RCC framed staging of elevated water tank using static pushover analysis," Proceedings of the World Congress on Engineering, vol 3, World Congress on Engineering, London, U.K, Jul 2010.

[15] A. M. Chandler, and P. A. Mendis, "Performance of reinforced concrete frames using force and displacement based seismic assessment methods," Engineering Structures, 22, pp. 352–363, Mar 2000.