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Pushover Analysis of a Multi-Storied Building in Two Different Zones

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ABSTRACT: Pushover analysis which is also stated as Non-linear static analysis is widely used procedures for the seismic assessment or evaluation of the structures. The advantage of using pushover analysis is its simplicity, efficiency in modeling and low computational time. Since the linear analysis is inadequate in assessing the seismic demand of the structure under the severe earthquakes, the pushover analysis is used to evaluate the seismic demand of the proposed structure or for the existing structures. In this study pushover analysis is carried to understand the behavior of G+8 multistoried building in two different zones using ETABS software. From the analysis results it was found that maximum lateral load, story displacement and monitored displacement is increased in zone III compared to that of zone II. But the maximum base force is increased in zone II that of zone III. Here the hinges are formed between IO (Immediate Occupancy) to LS (Life Safety) which indicates the building is safe. Hence the structural model analyzed in this state is safe.

KEYWORDS: Pushover analysis, seismic coefficient, response spectrum, target displacement, hinge, monotonic loading.

I. INTRODUCTION

Earthquakes are due to sudden shaking of the ground, which is caused by the passage of seismic waves through earth's rocks. Earthquake is also known as a quake, tremor or a temblor. The abrupt release of the energy in the earth's crust which causes seismic waves results is known as earthquake. The energy in the earth's crust may be released by gravity, elastic strain, chemical reactions and motion of the massive bodies. Among all of these, the energy released due to the elastic strain is most important cause, since this is the only form of energy which can be stored in sufficient quantity in the earth that produces major disturbances.. Most of the structures in India are low rise structures (up to four stories). A close look at response spectrum from IS 1893 will indicate that short period structures (structures with less height) are subjected to large amount of earthquake force. In spite of this fact most of the design engineers ignore severity of the problem subjecting the occupants to a higher level of risk during the earthquakes.

Buildings that are designed with earlier (older) codes are exposed to earthquake, which results in widespread loss of life and property. It is important to study the weakness of the structures in contrast with seismic activity. In the city majority of the buildings are designed based on the older design codes and hence owner of those buildings are at risk in the event of moderate to strong shaking of earth. In order to overcome these problems pushover analysis has been generally used on earthquake response prediction of building structures under severe earthquakes.

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Vol. 8, Issue 6, June 2019

II. OBJECTIVES

- To carry out the response spectrum analysis as per IS 1893-Part 1 (2002) codal provision for developed structure models.
- To study the behavior of the building in the form of top deflection by pushing the building in one horizontal direction.
- To perform the pushover analysis by applying lateral loads obtained from response spectrum analysis as per IS-1893 (Part-1): 2002.
- To obtain the seismic parameters like lateral loads to stories, story displacement, story drift, story shear, static pushover curve and hinge results.
- To compare the performance point in two different zones for the considered building.

III. LITERATURE SURVEY

Pushover Analysis of RC Building: Comparative Study on Seismic Zones of India (April 2017). P. PoluRaju, V. Mani Deep: In this study to understand the behaviour of G+9 multi-storeyed residential building located in different seismic zones (II, III, IV, V) of India having similar geometrical properties the non-linear static analysis (pushover analysis) has been done using SAP 2000 software. The behaviour of a multi-storeyed building has been examined in terms of force-displacement relationships, sequential hinge formations and inelastic behaviour of structure etc.

Effect of Lateral Load Patterns in Pushover Analysis (November 2009). Abhilash R, Biju V, Thiruvananthapuram: A regular single bay four storied RCC structure is selected for the pushover analysis by applying different lateral load patterns using ETABS and SAP2000 software's. Four lateral load patterns selected in this study are uniform load distribution and equivalent lateral force distribution as per FEMA-257, lateral load patterns as per Upper bond pushover analysis (UBPA) method and lateral loads obtained from response spectrum analysis as per IS-1893(2002). Here the structure is modelled first in ETABS and dynamic properties of the structure is calculated, based on that the lateral loads are calculated and the structure is again modelled and analysed in SAP2000 software by applying different lateral loads.

Pushover Analysis of RCC Building (2013). Neethu K. N, Saji K. Kannur University, Kerala: In this paper the pushover analysis is conducted to determine the seismic capacities of an existing building which is asymmetric in plan. Here as per IS 456:2000 and IS 1893:2002 the building frame is designed. The main objective is that to verify the type of performance that a building can give which is designed as per Indian codes. In this study, an educational building is considered which is situated in Kerala and the seismic performance is checked. The pushover analysis was carried out in SAP2000 software. In this analysis the maximum roof displacement of 640 mm was chosen. From the results it was found that the educational building is seismically safe.

IV. PROPOSED METHODOLOGY AND MODELLING

Pushover analysis: Pushover analysis which is also stated as Non-linear static analysis is widely used procedures for the seismic assessment or evaluation of the structures. The advantage of using pushover analysis is its simplicity, efficiency in modeling and low computational time. During recent years Non-linear static procedure (NSP) has been gaining significance for building assessment and design verification. Pushover analysis is considered as step forward from the use of linear analysis, since they are based on a more accurate estimate of yielding within the structure, instead of assumed and uniform ductility. Also the generation of the pushover curve under the lateral load provides the non-linear behavior of the structure.

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Vol. 8, Issue 6, June 2019

Target displacement: The target displacement serves as an estimate of the global displacement of the structure is anticipated to experience in a design earthquake. Target displacement is the roof displacement at the center of mass of the structure. A model directly incorporating the inelastic material response under the non-linear static procedure is displaced to a target displacement, and internal deformations are determined. The target displacement is intended to represent the maximum displacement which is likely to be experienced during the design earthquake. The lateral loads and roof displacement is given in fig. 1.

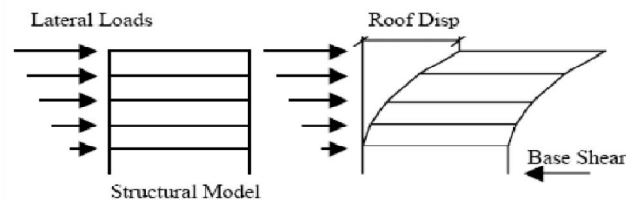


Fig. 1 – Lateral loads and roof displacement.

A G+8 building with OMRF (Ordinary Moment Resisting Frame) building is selected for the study. Two zones Zone II and Zone III are considered located on medium soil, as per IS 1893: 2002. The buildings are modeled using ETABS software. The pushover analysis of a RC structure is carried out. Here the developed RC structure models are subjected to response spectrum analysis and pushover analysis is performed as per IS 1893- 2002 (Part 1). The table 1.shows the different parameters considered for the development of structure model. Dead loads and live loads are taken as per the codal provision IS 875-1987 (Part 1) and IS 875-1987 (Part 2) respectively. For earthquake IS 1893-2002 (Part 1) is considered for the analysis. Cross sectional dimensions of the slab, beams, columns are chosen by trial and error method in such a way that the RC Structures developed are safe.

Table 1 - Parameters considered for the development of the structure.

SL. NO.	PARAMETERS	REMARKS
1	Type of structure	Commercial
2	Total stories	G+8
3	Total height	25.2 m
4	Bay width in X-direction	9 m (6 bays)
5	Bay width in Y-direction	9 m (4 bays)
6	Size of beam	250*500 mm
7	Size of column	400*800 mm
8	Slab thickness	150 mm
9	Story height	3 m
10	Concrete grade for beams	M40
11	Concrete grade for columns	M40
12	Concrete grade for slabs	M30
13	Steel grade (main bars)	Fe 500
14	Steel grade (lateral ties)	Fe 415
15	Density of concrete	25 KN/m ³
16	Density of brick	20 KN/m ³
17	Live load on floor Live load on terrace	3 KN/m ³ 1.5 KN/m ³
18	Super dead load on floor Super dead load on terrace	1.5 KN/m ³ 1.5 KN/m ³

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Vol. 8, Issue 6, June 2019

19	Wall load on other floors (exterior only)	12.28 KN/m
20	Wall load on terrace (exterior only)	4.22 KN/m
21	Damping ratio	5%
22	Soil type	Medium (II)
23	Zone factor	0.1 and 0.16
24	Importance factor	1
25	Response reduction factor	3
26	Wind speed	33 m/s (Bangalore)
27	Terrain category	3

Figure 2 shows the building model in different views where (a) plan, (b) elevation, (c) isometric view.

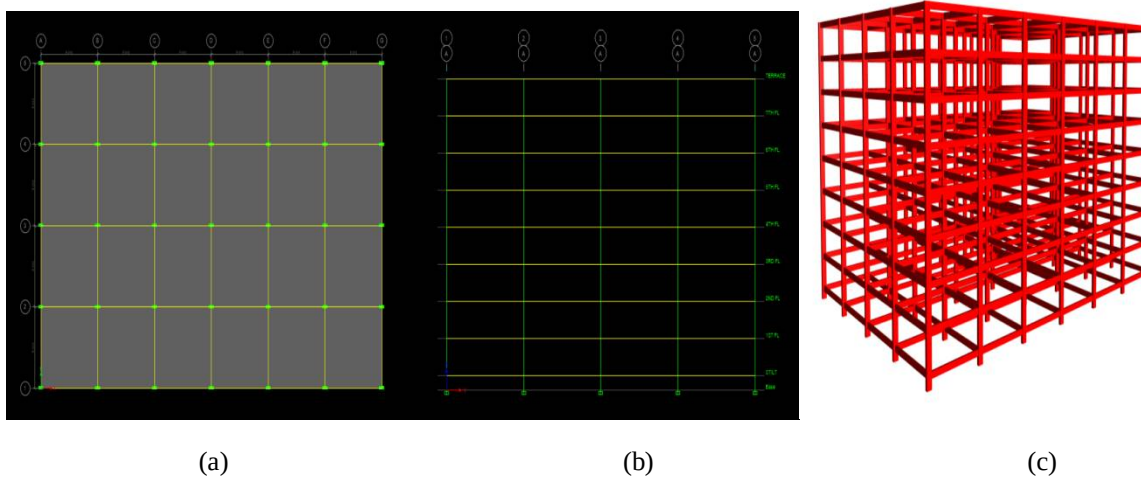


Fig. 2 - Building Model

V. RESULTS AND DISCUSSIONS

The results that are obtained from response spectrum analysis and pushover analysis for the developed structure model as per IS 1893-Part 1 (2002) using ETABS (Version 2016) software. The displacements and hinge formations in PX (push X) and PY (push Y) for two different zones are observed.

Hinge formation in the model for zone III is shown in figure 3 and figure 4.

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Vol. 8, Issue 6, June 2019

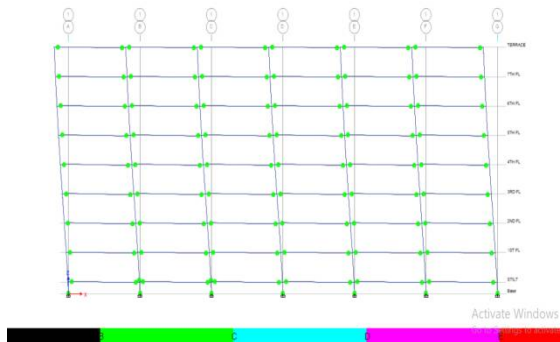


Fig. 3 - Displacements in PX (zone III)

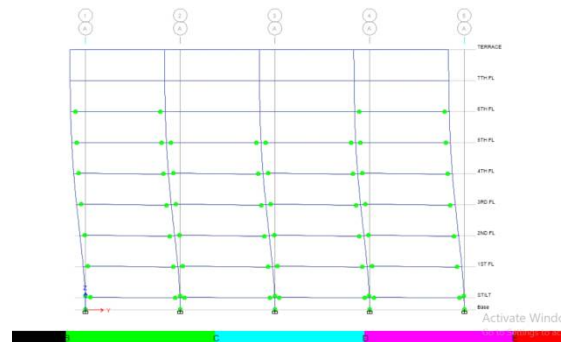


Fig. 4 - Displacement in PY (zone III)

The maximum lateral load to stories obtained by response spectrum analysis for two different zones are shown in table 2.

Table 2 – Maximum lateral load obtained by RSA.

Sl. No.	Zone	Maximum lateral load KN
1	Zone II	1026.98
2	Zone III	1715.43

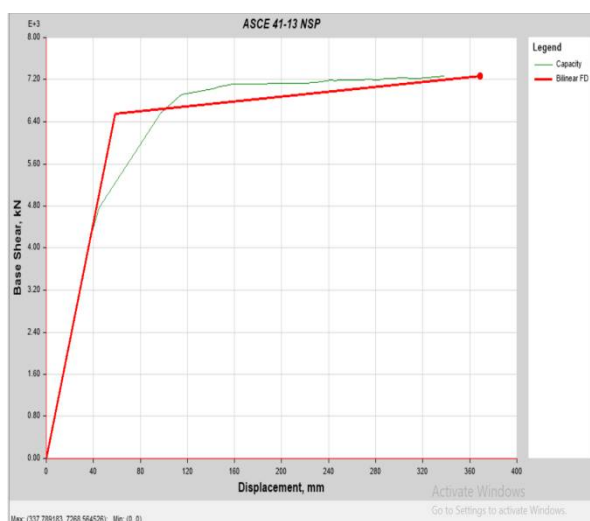


Fig. 5 - Base shear v/s monitored displacement (II)

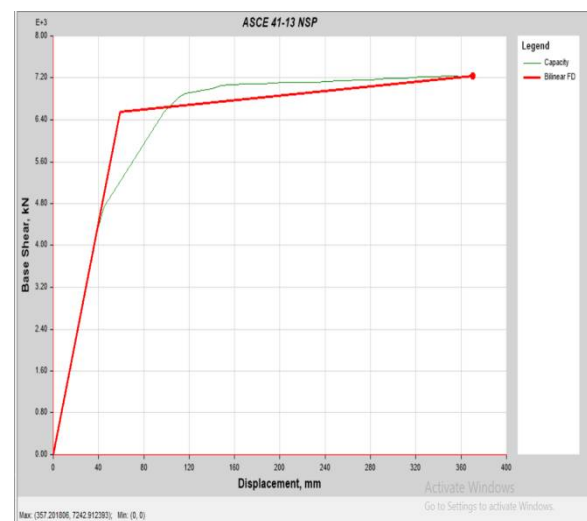


Fig. 6 - Base shear v/s monitored displacement (II)

The base shear v/s monitored displacement plot as per ASCE 41-13 NSP for zone II and zone III is shown in the figure 5 and 6.

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Vol. 8, Issue 6, June 2019

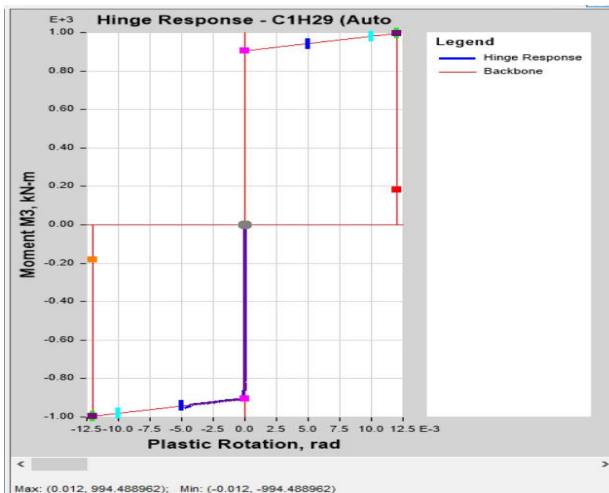


Fig. 7 – Hinge response in column for PX (III)

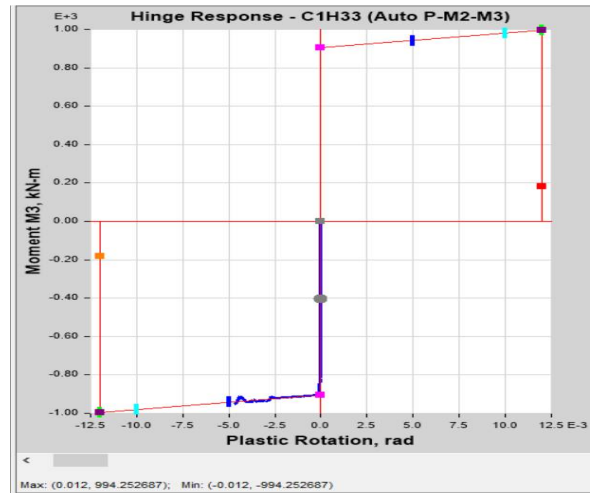


Fig. 8 - Hinge response in column for PX (II)

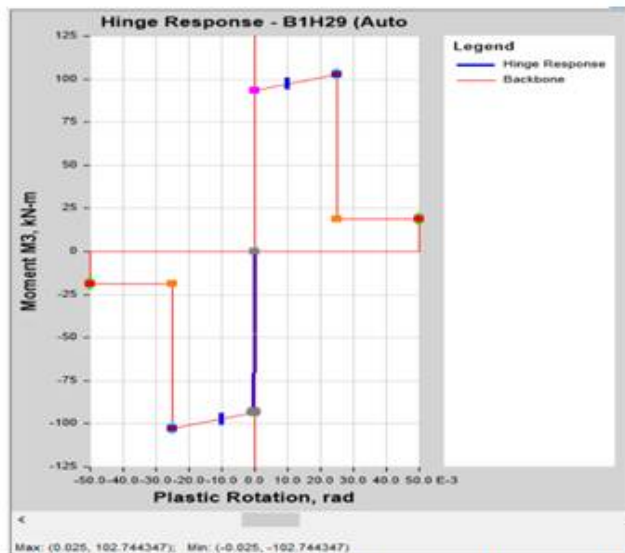


Fig. 9 – Hinge response in beam for PY (zone III)

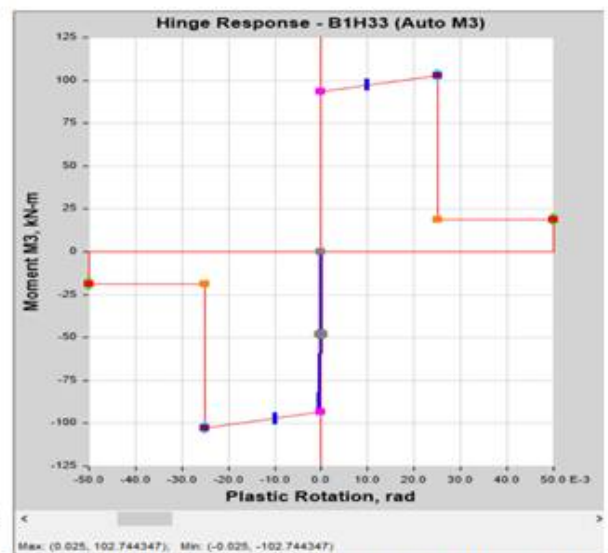


Fig. 10 - Hinge response in beam for PY (zone II)

Hinge results obtained from nonlinear static analysis for beams and columns for zone II and III are shown in figure 7, 8, 9 and 10.

The maximum story displacement values obtained in PX direction and PY direction for different zones are shown in fig 11 and 12.

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Vol. 8, Issue 6, June 2019

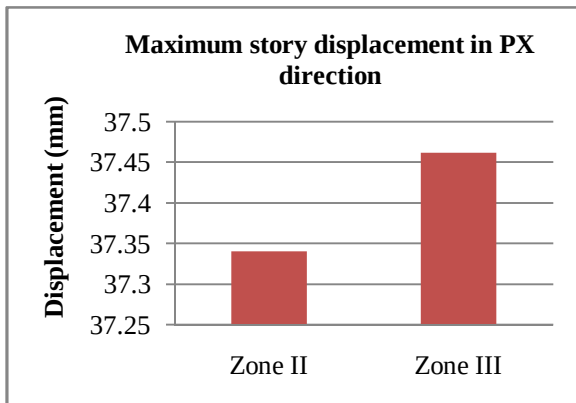


Fig.11- Maximum story displacement along PX

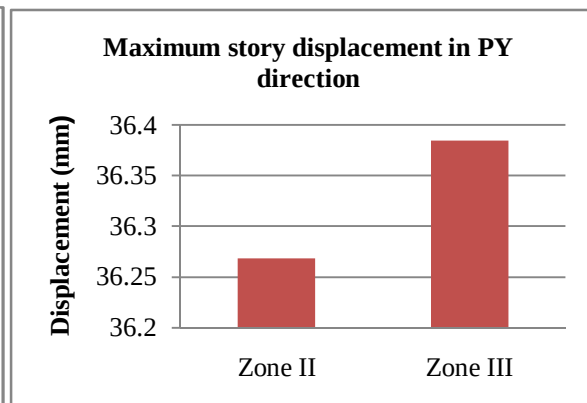


Fig.12- Maximum story displacement along PY

The maximum monitored displacement values obtained using pushover analysis in X and Y directions for different zones are shown in figure 13 and 14.

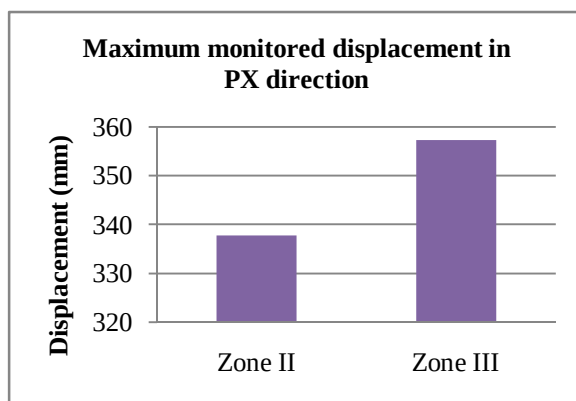


Fig.13-Max.monitored displacement along PX.

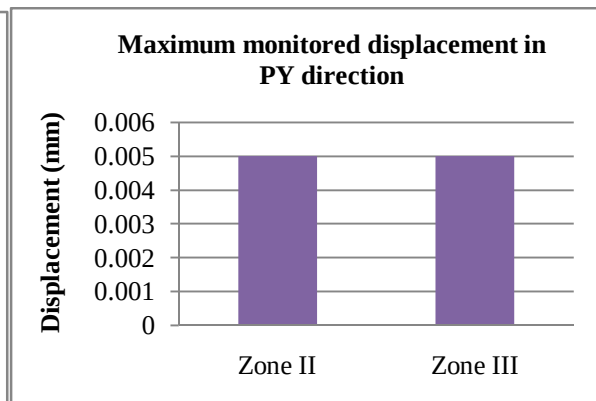


Fig.14- Max.monitored displacement along PY.

The maximum base force values obtained using pushover analysis in X and Y directions for different zones are shown in figure 15 and 16.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 8, Issue 6, June 2019

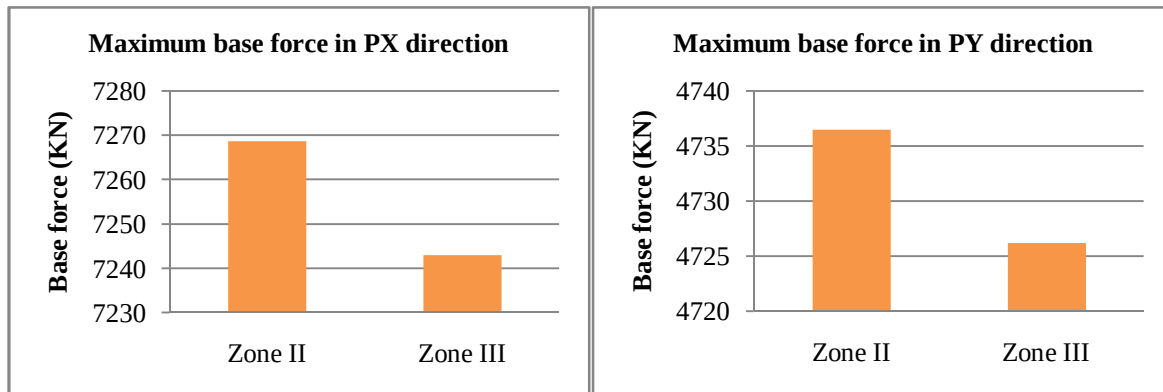


Fig.15- Maximum base force in PX direction.

Fig.16- Maximum base force in PY direction.

VI.CONCLUSION AND SCOPE FOR FUTURE WORK

In the present study, seismic parameters such as story displacement, story drifts, lateral load to stories and static pushover curves for base force v/s monitored displacement plots are obtained.

- The target displacement limit has shown no failure when the structure is subjected to analysis.
- Hinge formations are seen in the beams when pushover analysis is performed. In this study more hinges are formed in X direction when compared to Y direction.
- Also it has been seen that the hinges are formed between IO (intermediate occupancy) to LS (life safety) which indicates the building is safe. Hence the structure model analyzed in this state is safe.
- The lateral load to stories is more in zone III compared to zone II. But maximum story displacement and story drift results are almost same.
- The maximum monitored displacement is within the value of target displacement that is assumed. The behavior of the structure is significant to resist the lateral loads.

Future Scope: In this study pushover analysis is performed without infill walls, but this work can be extended with considering infill walls and shear walls. In the present study the frame has been analyzed under the monotonic loading, this can be also analyzed under the cyclic loading so that the load-deflection curves can be monitored. The nonlinear static procedure is extended for seismic damage assessment of asymmetrical buildings.

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