International Journal Of Advance Research, Ideas And Innovations In Technology

IJARIIT

ISSN: 2454-132X
Impact Factor: 6.078

*(Volume 8, Issue 4 - V8I4-1157)*
Available online at: https://www.ijariit.com

# Seismic analysis of a multistory building using push over and nonlinear time history methods.

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## ABSTRACT

***Non-linear analysis of G+5 storied RCC structure by using push over and Non-linear Time History Methods considering different ground motions. Bhatwari, Gopeshwar, Myanmar, and Srinagar are the ground motion data considered for Non-linear Time History Method. For modelling and analysis SAP 2000 software has been used for G+5 storied RCC structure. In this paper, Base Shear, Displacement, Plastic Hinge formation, Performance point, Push Over Curve are generated after analysis.***

***Keywords*** — *Push Over Analysis, Non-linear Time History Analysis, Push over curve, Performance Point.*

## 1. INTRODUCTION

Mostly the buildings are constructed based on usual standard codes which considers gravity loads consisting of live and dead loads. Many of these structures, experiences low magnitude of loads in their design life which leads only up to elastic range response, however sudden earthquake causes strong loads which leads the structure beyond its elastic limit range. The performance of the structure is non linear during seismic loading. Therefore, it is essential to perform a nonlinear analysis of the structure. In practical terms the non-linear behavior of the residential building is defined by the formation of plastic hinges and loss of considered stiffness. In such a case we need to find the performance level of the structure in plastic range. Hence to find performance of the structure during lateral loads causing non linearity we used Push over analysis and Non-linear Time History analysis. Many buildings were affected during Nepal earthquake 25th April 2015 which were designed based on conventional design codes. So, to ensure life safety, deformation-based design should be adopted to avoid or at least to develop the ductile behavior of structure.In the present study, push over analysis is carried out on G+5 residential building situated in zone v based on classification of IS 1893:2016 seismic zones in India.The analysis is performed in SAP 2000. After designing the structure for gravity loads based on IS 456:2000 Push over analysis was carried out.

## 2. LITERATURE REVIEW

**Kushal Rathod, Sumit Gupta (2020)** In this research paper a nonlinear time history analysis of 10 storey RCC building is performed. After analysis results such as storey drift, pseudo spectral acceleration, maximum displacement is found out.

**Sara Honarparast, Omar Chaallan (2019)** In this study non linear analysis of RC coupled walls is carried out. Comparison of old design, modern design and retrofitted with externally bonded CFRP Composites are done.

**Zair Khan, Hina Gupta (2017)** In this study both capacity and demand curves are intersected in between immediate occupancy and life safety zone. Such that building is subjected to moderate damage when subjected to pushover loads in seismic zone V.

**M. Hosseini, B. Hashemi (2017)** In this study seismic evaluation of RC buildings for near-source earthquake by using non linear time history analysis is carried out. To ensure life safety performance level of building code provisions still needs to be improved with inclusion of extensive vertical ground motion of near source earthquake.

**S. Karimzadeh, A. Asken (2017)** In this study assessment of alternative simulation technique in nonlinear time history analysis of multistorey building is carried out. It is been observed that for specific period band in terms of ground motion and linear elastic SDOF responses correlate with nonlinear MDOF.

**Gaurav Kapgate, D.L. Budhlani (2015)** Non linear time history analysis of a structure with and without shear wall is performed. Results found that by addition of shear wall base shear is increased than in bare frame. Also inner shear wall reduces large displacement in both direction than outer shear wall.

 

**P. Subash, S. Elavenil (2011)** A Three dimensional RC frames analysis was considered for Lateral and gravity loads, and seismic performance of frames by using response spectrum and time history analysis were carried out.

## 3. OBJECTIVES

a) To determine performance of a G+5 multistorey building at 4 different locations in India having severe earthquake magnitudes.
b) To obtain push over curve, performance point, cyclic push over curve to determine the capacity of structure.
c) To find out base shear, displacement, plastic hinge, and mode shape results by non-linear time history analysis method to determine demand of a structure.
d) To compare the capacity curve of Response spectrum for zone v with actual capacity curve extracted from the ground motion assigned.

## 4. METHODS

In present study, RC building of G+5 storey has been modelled and analysed by using SAP2000 software.

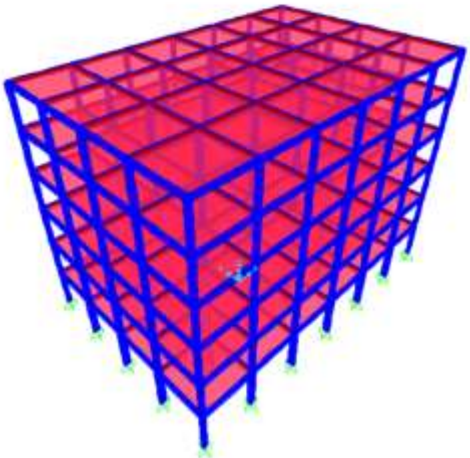

**Fig. 1 – 3D View**

Non-linear Time History Analysis:
In this method, seismic loading considered is dynamic loading i.e. actual ground acceleration is applied to the structure and our structural model is non-linear. In this method, we can start with Zero initial conditions in which the structure has zero displacement and velocity, all elements are unstressed and there is no history of non-linear deformation or else continue from previous non-linear analysis, in which the displacements, velocities, stresses, loads, and non-linear state histories from the end of previous analysis is carried forward. We have adopted the later one in which non-linear gravity load case is predecessor of Non-linear Time History Analysis.

Following are the Indian Ground Accelerations:

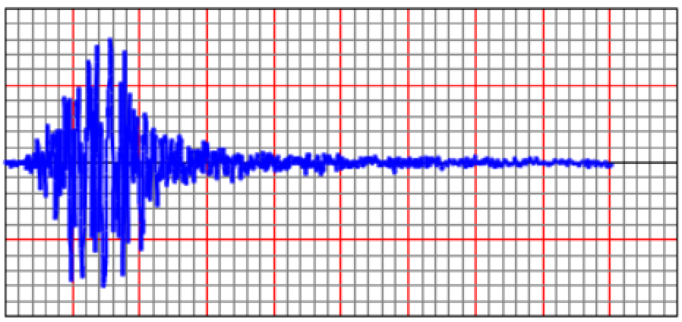

**Fig. 2 – Bhatwari**

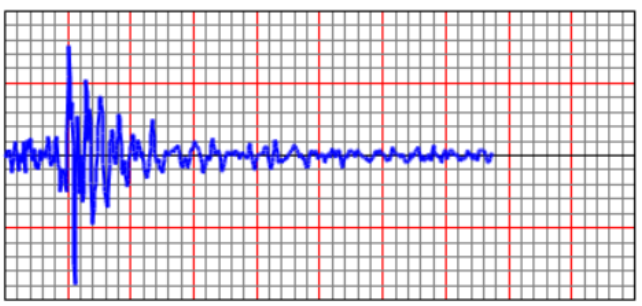

**Fig. 3 – Gopeshwar**

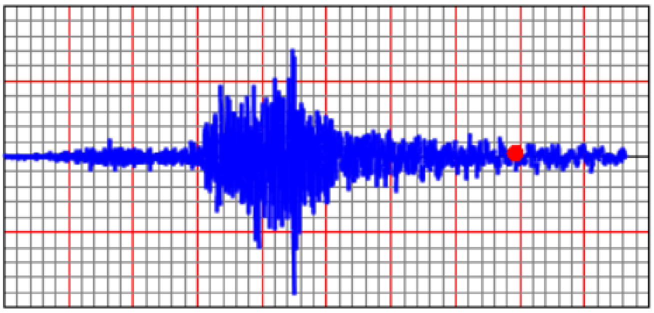

**Fig. 4 – Myanmar**

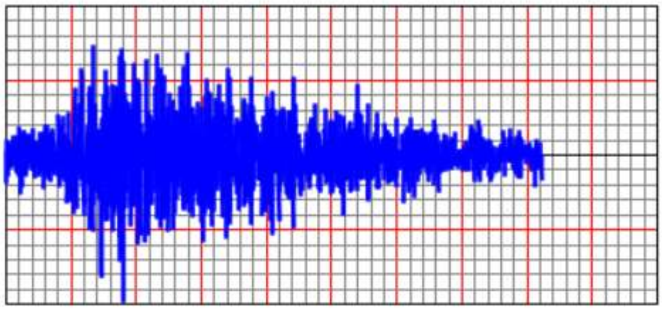

**Fig. 5 – Srinagar**

**Push Over Analysis**
Displacement method is adopted for POA in which building model is displaced to find out capacity of the building. In this method, performance point is find out by intersecting demand curve and capacity curve in terms of base shear and displacement.

**Plastic Hinge**
In SAP2000, plastic hinge is provided so that particular member will follow non-linear pattern after yield point. It is provided at ends since, maximum stresses are developed at ends of beam and column due to bending and lateral loading. Which means if beam reaches yield point it will follow nonlinear stiffness pattern.

**Plastic Hinge assigned in SAP2000:**

**Fig. 6 – Hinge Location63**

 

**Problem Statement**
The five storey RCC building has been considered for analysis. Following are the details of the structure.

The (G+5) RC multi storied structure considered for the analysis. The general form of plan shown in fig.1 & fig.1A. Building is modelled for Indian seismic zone V as per IS:1893(Part 1)-2016.

**Table 1 Dimensions of the structure:**

| | |
|---|---|
| Plan Area ($m^2$) | 16m X 24m |
| Floor height | 3m |
| Material | M30 & FE500 |
| Size of column (mm) | 230X500 |
| Size of beam (mm) | 230X450 |
| Thickness of slab (mm) | 150 |

Loading considered

At typical floor,

Floor finish = 1.5 kN/$m^2$

Live load = 2.0 kN/$m^2$

Wall load (outer, 230 thk) = 13.6 kN/m

Wall load (inner, 150 thk) = 9.5 kN/m

At terrace floor,

Floor finsh = 1.5kN/$m^2$

Live load = 3.0 kN/$m^2$

Water roofing (200 thk) = 4 kN/$m^2$

Wall load (parapet 230 thk) = 6.25 kN/m

Seismic parameters

(As per IS1893:2016)

Soil type = II (medium)

Importanc factor = 1.0

Response reduction factor = 5

Zone factor (for zone V) = 0.36

Time period (in X & Y dir) = 0.702 sec.

## 5.RESULTS

**Base Shear from NTHA:**
Bhatwari

VBx = 4303.29 KN, VBy = 6378.61 KN

Gopeshwar,

VBx = 629.85 KN, VBy = 452.59 KN

Myanmar,

VBx = 773.73 KN, VBy = 930.69 KN

Srinagar,

VBx = 318.35 KN, VBy = 328.16 KN

**Hinge Formation**
The effective strength of hinges are used deformation controlled actions. Push over analysis is carried out for either used defined non-linear hinge properties or default hinge properties available in SAP 2000 based on FEMA 356 [9] and ATC-40 guidelines. These codes provides the hinge properties for several ranges of detailing. SAP2000 includes default hinge properties and recommend PMM hinges for columns and M3 hinges for beams.

**Push Over Curve**
The Push over curve resulting for G+5 building is shown in figure below.

Initially the curve is linear but start to deviate from due to inelastic action of columns and beams. As the building is pushed well enough into the inelastic range the curve again becomes linear but with little slope.

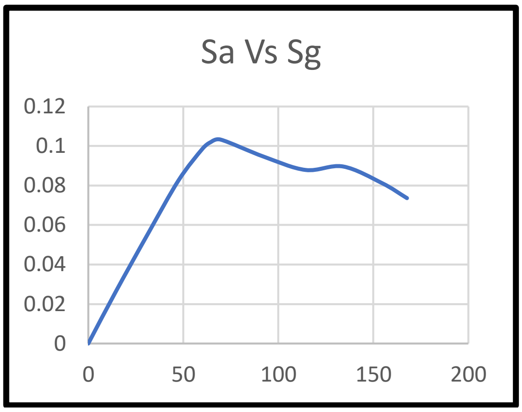


**Fig. 7 – Push Over Curve**

Push over curve is used to determine the actual capacity of the structure during an earthquake. It also indicates that by how much the structure will regain its capacity after deformation after earthquake. We got to know the actual ductility of the structure.

**Cyclic Push Over Curve:**

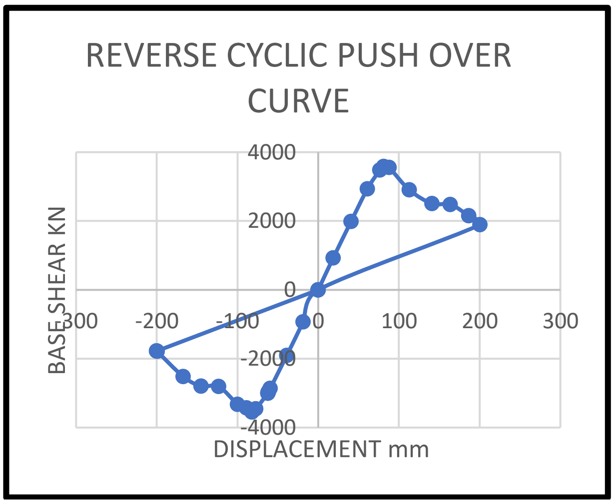


**Fig. 8 – Reverse Cyclic Push Over Curve**

A reversal load is applied on the structure to produce a cyclic push over curve. The reversal loading is considered as an earthquake event and the hysteretic behaviour indicates the seismic performance to resist the earthquake load.

**Performance of structure with different ground motion:**
Hinge mechanism of G+5 structure for different ground motion acceleration is shown in following graphs. It represents the development of the hinges at beam and column junction indicating different level of performance as Immediate occupancy, Life safety, Collapse prevention and collapse represented by different colour codes. In Bhatwari region, Yellow colour code represents collapse of the structure at ground to second floor levels. Whereas, at Myanmar the building is under Life safety.

**Bhatwari:**

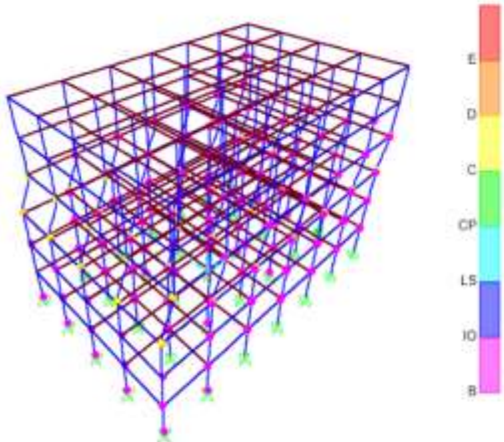


**Fig. 9 – Bhatwari Performance level**

**Gopeshwar:**

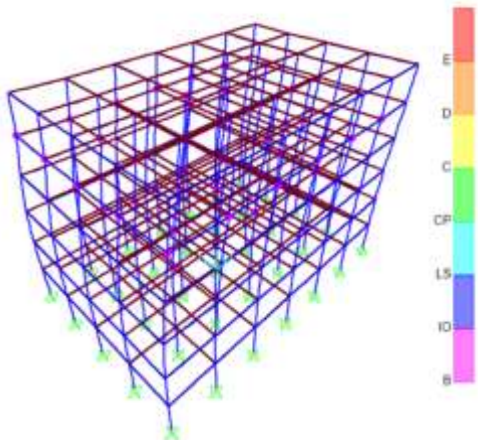


**Fig. 10 – Gopeshwar Performance level**

**Myanmar:**

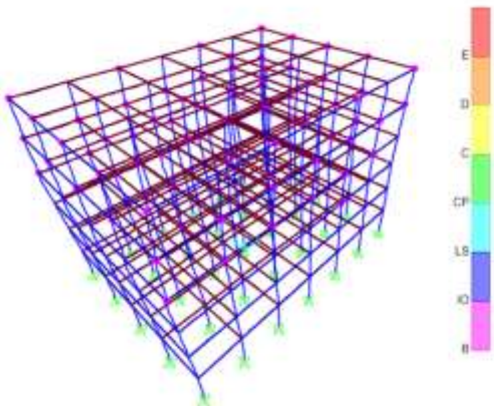


**Fig. 11 – Myanmar Performance level**

**Srinagar:**

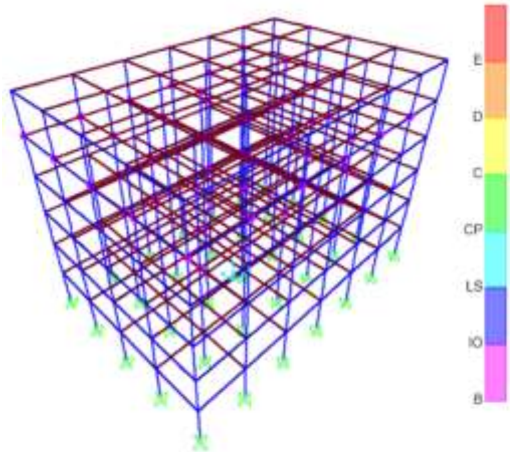


**Fig. 12 – Srinagar Performance level**

**Capacity Spectrum of structure with different ground motion:**

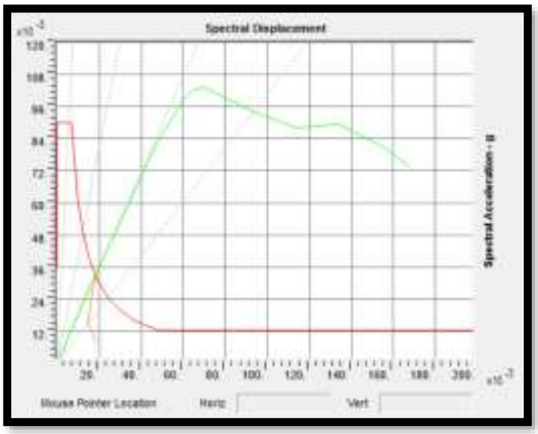


**Fig. 13 – Capacity Spectrum for Zone V Response Spectrum**

**Performance Point–**

**(V,D) = (1115.649 KN, 0.023 m)**

**Bhatwari:**


**Fig. 14 – Capacity Spectrum for Bhatwari**

**Performance Point–**

**(V,D) = (994.266 KN, 0.02 m)**

 

**Gopeshwar:**

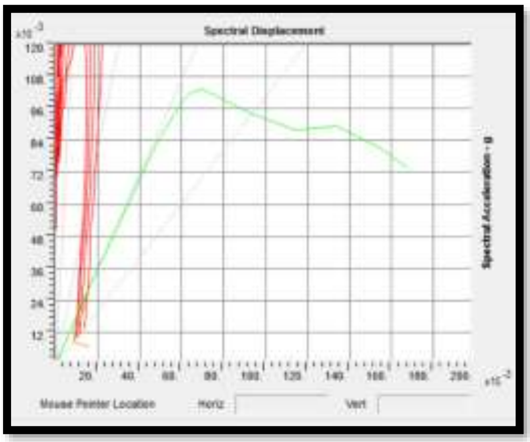


**Fig. 15 – Capacity Spectrum for Gopeshwar**

**Performance Point–**

**(V,D) = (968.104 KN, 0.019 m)**

**Myanmar:**


**Fig. 16 – Capacity Spectrum for Myanmar**

**PerformancePoint–**

**(V,D) = (1020.33.104 KN,0.021 m)**

**Srinagar**

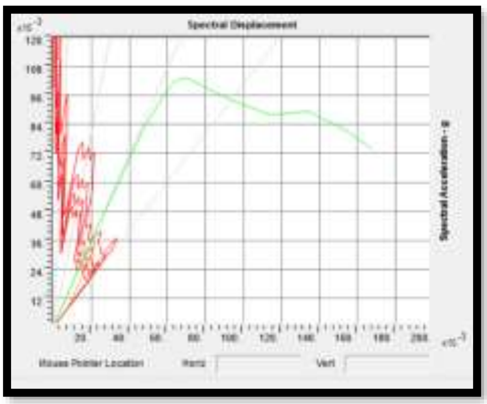


**Fig. 17 – Capacity Spectrum for Srinagar**

**Performance Point–**

**(V,D) = (1278.889 KN, 0.026 m)**

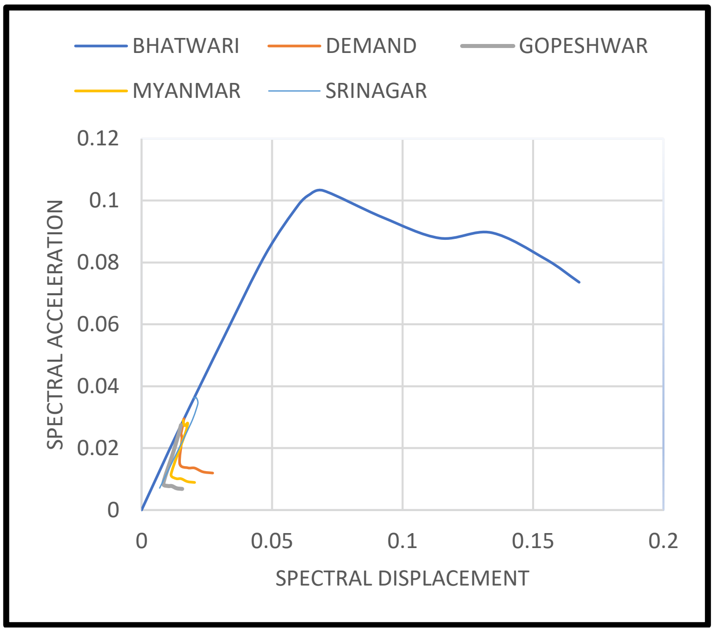


**Fig. 18 – Capacity Spectrum with for different ground motion**

The vital output of the push over depends on the response of demand and capacity. If the capacity envelope intersects with the demand curve near elastic range then the structure is said tom have a good resistance. It can be concluded that the structure behaves poorly if the structure intersects the demand and capacity curve with little reserve of strength and deformation capacity. The above graph represents the capacity spectrum of the structure for different ground motions. As we know that every region has different ground motion acceleration therefore, this graph helps us to identify the actual capacity of the structure if constructed in that particular region.

**Mander's Confined Curve:**
Mander's confined curve is generated for different sizes of columns and beams as per ductile detailing governed by IS 13920. Following are the graphs of confined concrete structural members which are used in our push over analysis.

**Columns:**

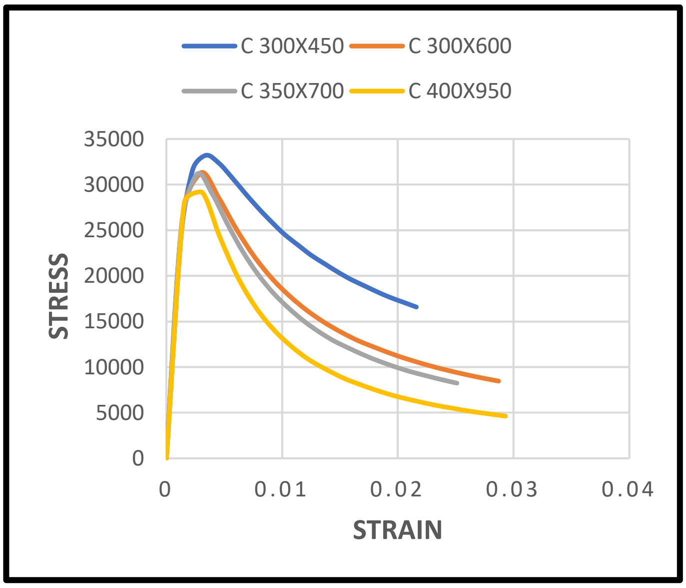


**Fig. 19 – Manders confined curve for Columns**

**Beams:**

 

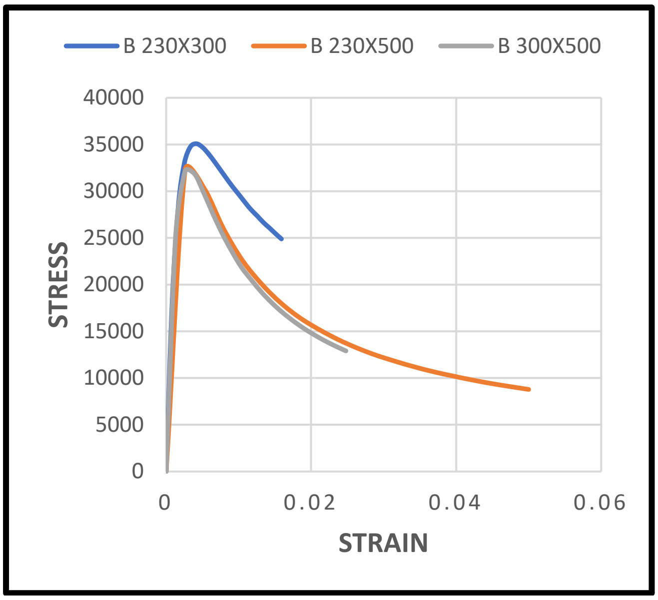


**Fig. 20 – Manders confined curve for Beams**

**Mode Shape:**

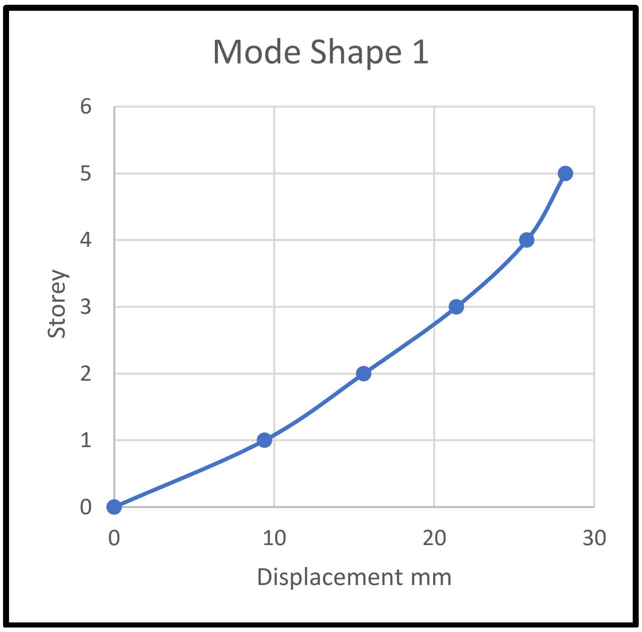


**Fig. 21 – Mode Shape 1**

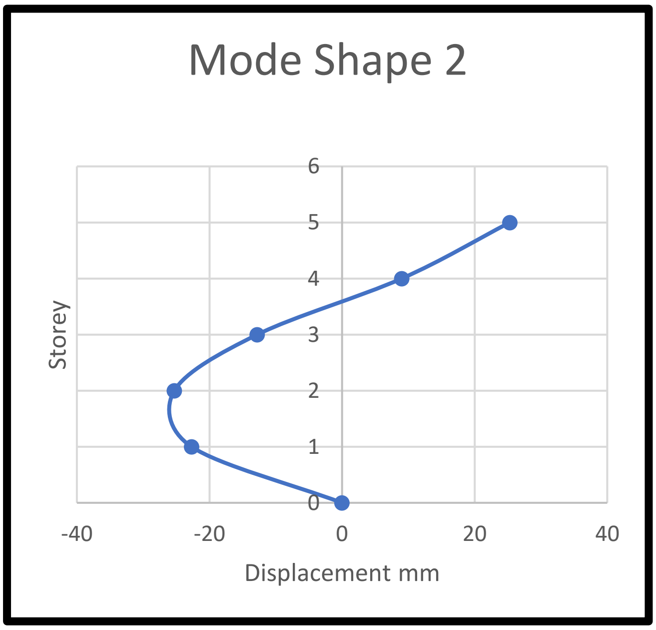


**Fig. 22 – Mode Shape 2**

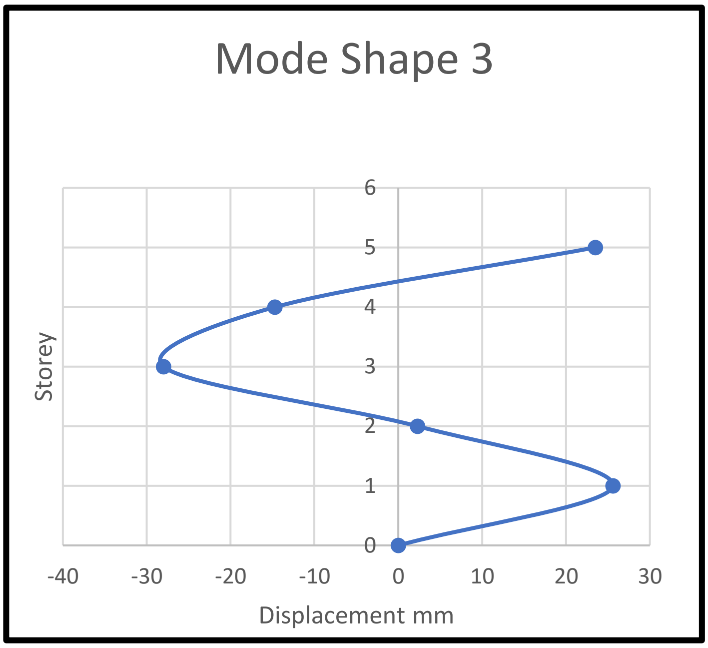


**Fig. 23 – Mode Shape 3**

## 6. DISCUSSION

The first plastic hinge predicted by push over analysis was at the second floor level. This identification of a plastic hinge formation is an important feature of push over analysis as it provides a designer an insight that which part of the structural member need special consideration during the design process.
Modal Analysis:

Mass participation factor of 95% is achieved after 12 mode shapes. The model properties of different mode shapes are shown in fig. for clearer illustration only three modes are selected eliminating closely spaced staggered modes.

## 7. CONCLUSION

Performance point of response spectrum for zone v when compared with actual performance extracted by assigning ground motion of Bhatwari, Gopeshwar, Myanmar and Srinagar varies significantly. So, it may be concluded that nonlinear push over analysis is very important to know the actual behaviour of the structure.

After studying all the graphs and curves we conclude that the result from push over analysis was able to achieve the performance point within its elastic range.

Push over analysis is the simplest way to find the response of new as well as existing structure.

If the building is designed with proper Standards will perform better under seismic forces.

According to Moment Curvature analysis results concluded that the increase of longitudinal reinforcements affects the yielding and ultimate capacities of the structural members. By this increment the capacities of the cross sectional members become more brittle.

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