Assessing the Seismic Response of Multi-Story Asymmetric Structural system in Zone-IV using Extended N2 Method

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Abstract – *The nonlinear structural analysis using N2 method that takes into consideration two discrete mathematical models recently needs special attention, namely the response spectrum and the nonlinear static (pushover) analysis for seismic evaluation and corresponding design consideration for R/C structure. Here an attempt is made to enhance the criteria i.e. the extended N2 method to evaluate performance of multi-story asymmetric structural system with higher modal effects and elastic range by combining both pushover and elastic modal analysis with ground motions using different load condition with the help of SAP2000. In this paper, we have made an attempt to compare the analysis of MDOF structural system like G+12 and G+15 asymmetric structure in seismic zone IV with previous research work for G+5 and G+9 story structures, results of which is believed to be particularly new, gives us all design parameter useful to the engineers. It is noticed that when the results are compared with the response spectrum and displacement coefficient method in FEMA356, the displacement and drift demand obtained are fairly accurate for the respective frame type considered.*

***Key Words*: Nonlinear analysis, Extended N2 method, Pushover analysis, Response spectrum, Seismic response.**

1. INTRODUCTION

Earthquake is one of the most serious and unpredictable natural disasters known to human beings, although analysis of ruins due to seismic effect have showed that the new structural analysis methods used for estimating of structural performance of buildings to minimize economic losses due to property damage and disruption on businesses, loss of human life might be very large. Hence, the seismic performance of structures subjected to ground motions are always become a critical issue. The behavior of a structure in earthquake has shown that many buildings cannot occurrence the earthquake forces, even some of the buildings that were designed based on proposed linear static analysis as per relevant IS code provision, since need for dynamic analysis is considered complicated and time-consuming; thus, nonlinear static method has made unique progressive value among other methods. Simplified nonlinear analysis and performance evaluation methods, which combined the static pushover analysis of a multi-degree-of-freedom (MDOFs) system model and the response spectrum analysis of an equivalent single-degree-of-freedom (SDOFs) model, are intended to achieve a satisfactory balance between required reliability and applicability for everyday design use [2]. Global displacement and internal story drift are the valuable part for damage parameters which can be controlled in performance based seismic design [1]. The nonlinear time history analysis is the fundamental approach for the time being, even though it is not practical for regular design methodology. The extended N2 method proposed by Prof. Peter Fajfar is based on the assumption that the structure remains in the elastic range when vibrating in higher modal effect. The basic assumption used in pushover static based method is that the structural vibration is being established in a single mode [4].

But throughout the globe researchers have been done to take into account the influence of higher modal effects in elevation (e.g. Antoniou and Pinho 2004; Chopra and Goel 2002; Moghadm 2002; Poursha et al. 2009; Elnashai 2001; Kalkan and Kunnath 2006, 2007). The extension of the N2 method to R/C plan-asymmetric buildings, where torsional effect is being established, was made by assuming that the torsional influences in the inelastic range are the same as in the elastic range determined by standard elastic modal analysis [5-8]. The structure remains in elastic range when vibration is higher modes and that the seismic demand can be estimated as an envelope of demands determined by a pushover analysis, which does not take into account the higher mode effects.

2. MODELING

These are the geometric and a structural detail of the G+12 model show in Fig. 1. is as follows:

- Plan area – 20m×25m
- Story height – 3m
- Beam – 300mm×450mm
- Column – 600mm×600mm
- Live load - 3 KN/m^2
- Concrete – M30
- Reinforcement – HYSD 415
- Location – Seismic Zone IV
- Soil type – Hard rock soil

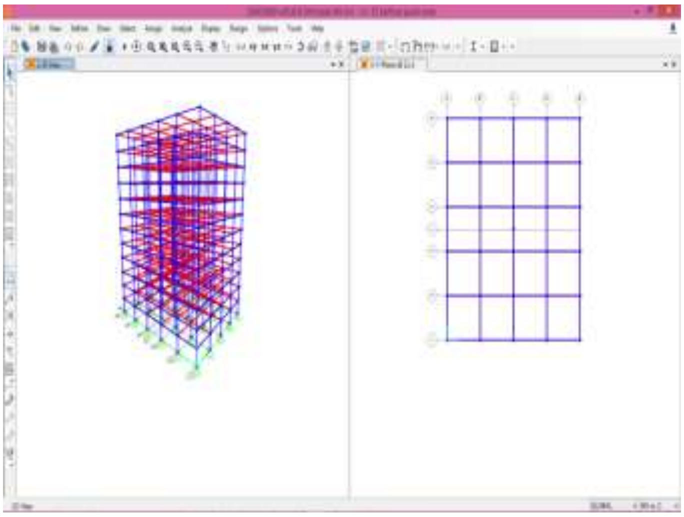

Fig-1: Plan elevation of G+12 asymmetric structure

These are the geometric and a structural detail of the G+15 model show in Fig. 2. is as follows:

- Plan area – 25m×15m
- Story height – 3m
- Beam – 350mm×450mm
- Column – 600mm×600mm
- Live load - 3 KN/m^2
- Concrete – M30
- Reinforcement – HYSD 415
- Location – Seismic Zone IV
- Soil type – Hard rock soil

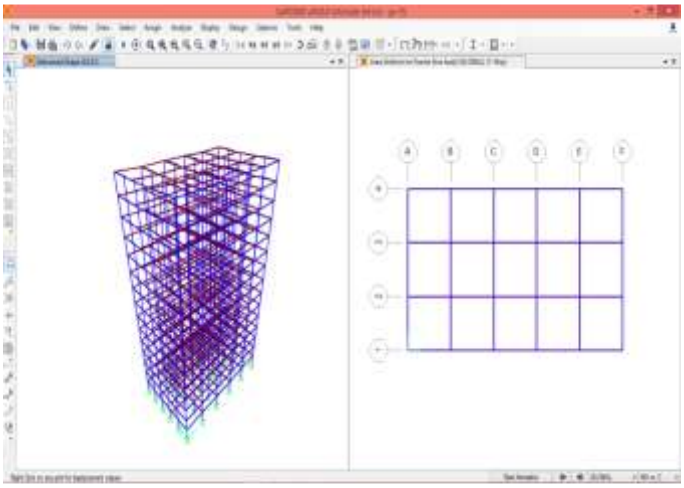

Fig-2: Plan elevation of G+15 asymmetric structure

3. METHODOLOGY

In this present study design analysis estimated by SAP2000 for asymmetric G+12 and G+15 structure in seismic Zone IV. The response spectrum analysis is done by ground motion event ELCENTRO with high PGA value 6.27 m/s^2 for five percent damping and average acceleration coefficient is taken as 2.50 where time period (T) is 0.1 sec for both structures. For design of RC frames structures, Bureau of Indian Standards (IS) codes, IS 456-2000, “Plain and Reinforced Concrete code of practice”, IS 1893-2016 (Part 1), “Criteria for Earthquake resistance design of structures” are used.

4. RESULT ANALYSIS

The result analysis of G+12 and G+15 R/C asymmetric structure is as below with differentiating the response spectrum and pushover curve with respected to previous research work [1]. The nonlinear static and dynamic both cases are simplified by the higher modal effect where the ground motion is acting on the bi-directional approach. In this case structural response is changeable due to ground motion effectiveness that causes variation of base reaction obtained with modal participation values. In this paper, the extended N2 method, which can be used for analysis of plan-asymmetric building structures, has been summarized and applied to the given example. The results are analyzed through X direction for both structures in where for pushover analysis the results are shown in X and Y direction.

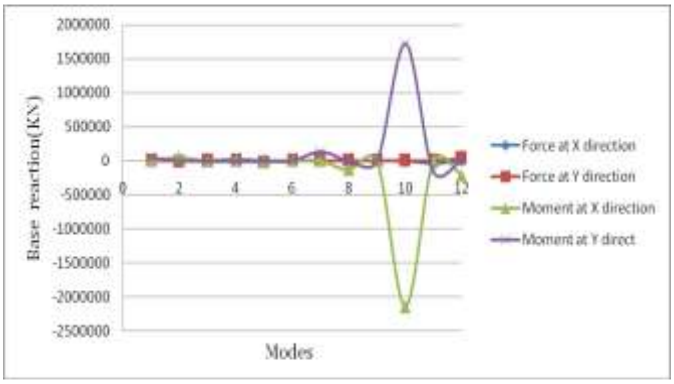

Fig- 3: Base reaction for G+12 in X direction

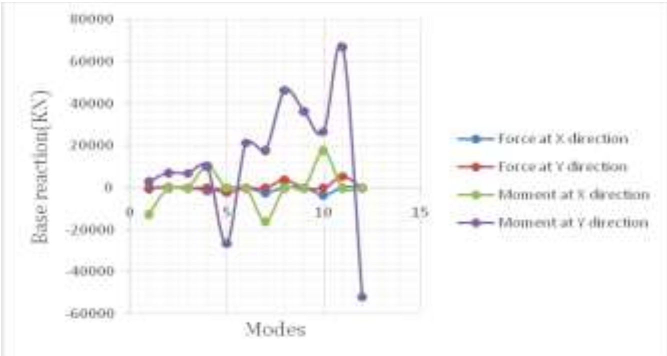

Fig- 4: Base reaction for G+15 in X direction

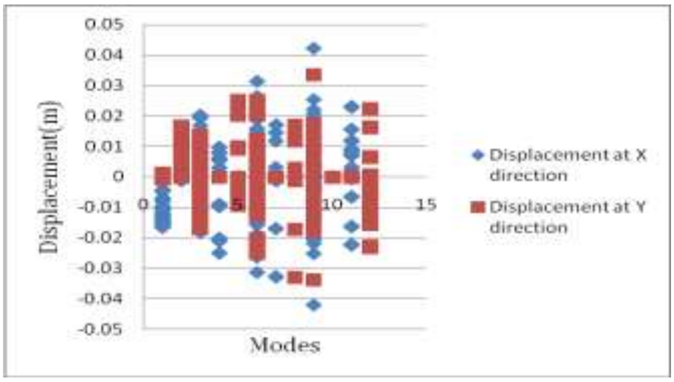

Fig-5: Joint displacement for G+12 in X direction

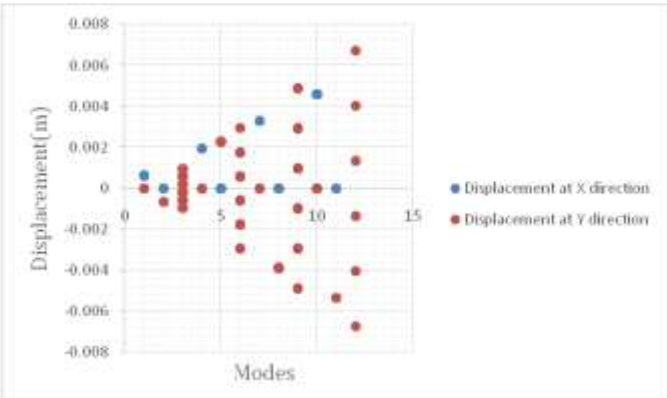

Fig- 6: Joint displacement for G+15 in X direction

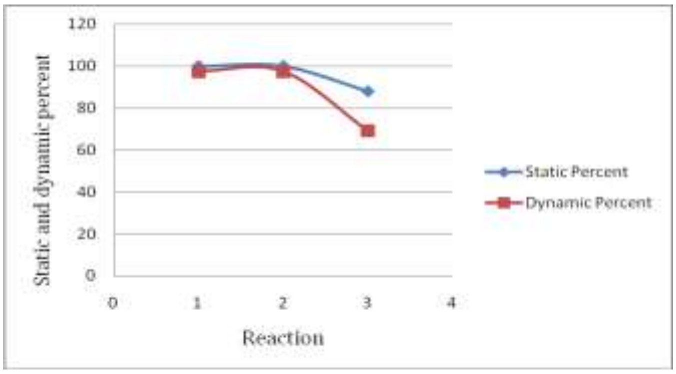

Fig- 7: Modal load participation ratio for G+12 in X direction

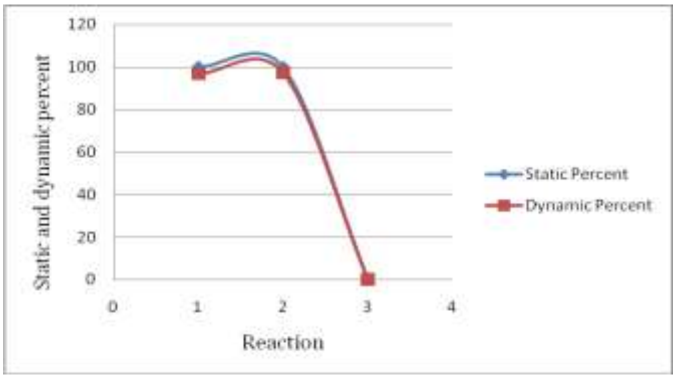

Fig- 8: Modal load participation ratio for G+15 in X direction

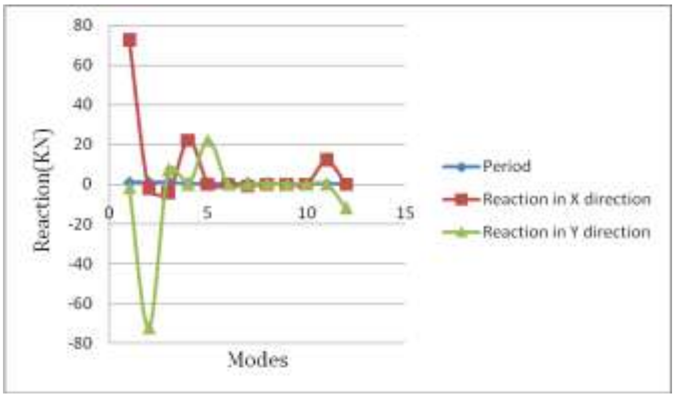

Fig- 9: Modal p-delta participating factor for G+12 in X direction

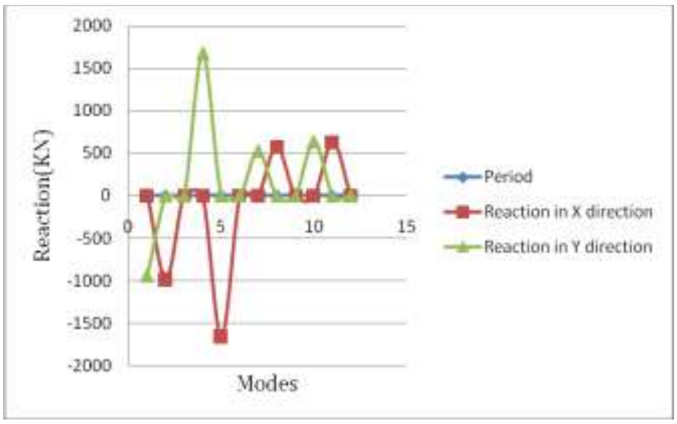

Fig-10: Modal p-delta participating factor for G+15 in X direction

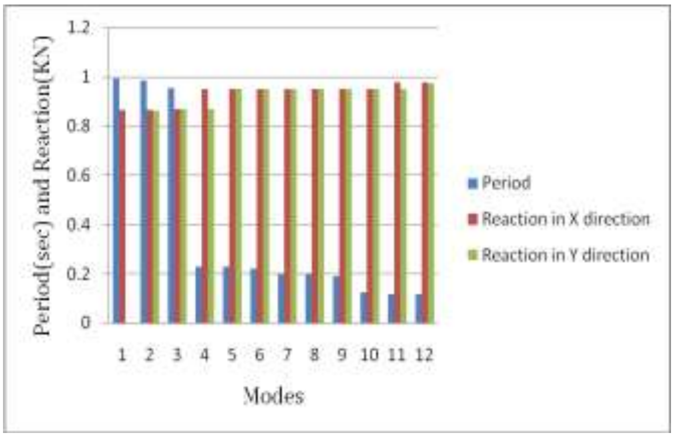

Fig- 11: Modal p-delta participating mass ratio for G+12 in X direction

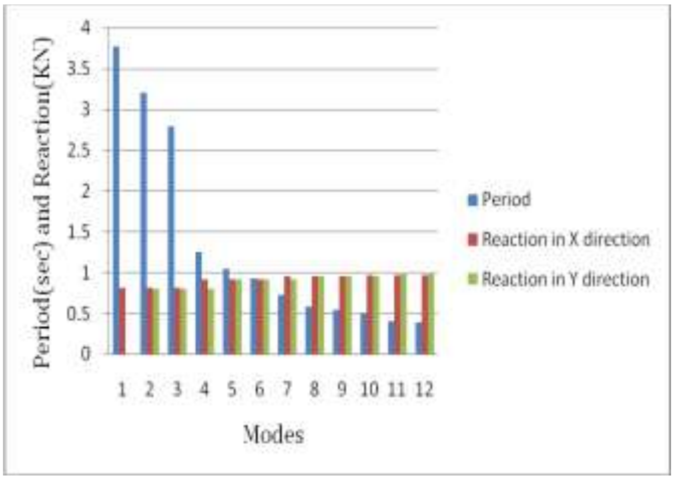

Fig- 12: Modal p-delta participating mass ratio for G+15 in X direction

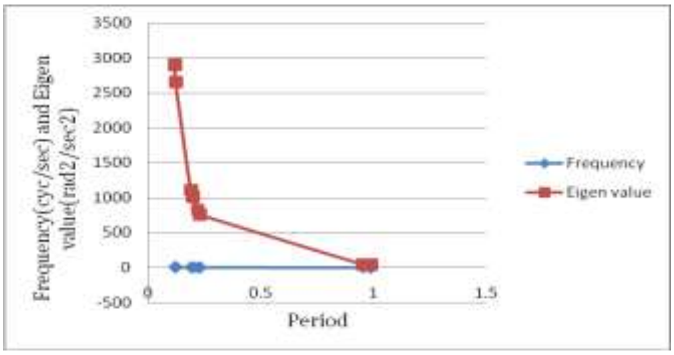

Fig-13: Modal p-delta periods and frequenciesfor G+12 in X direction

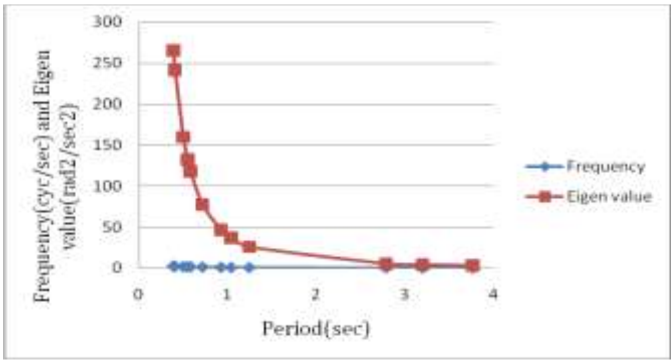

Fig- 14: Modal p-delta periods and frequenciesfor G+15 in X direction

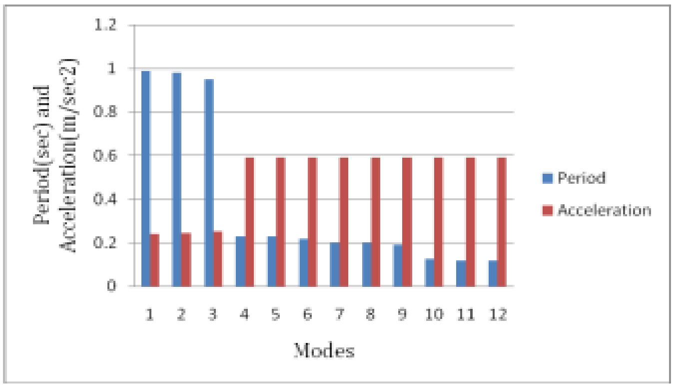

Fig- 15: Response modal information spectrum for G+12 in X direction

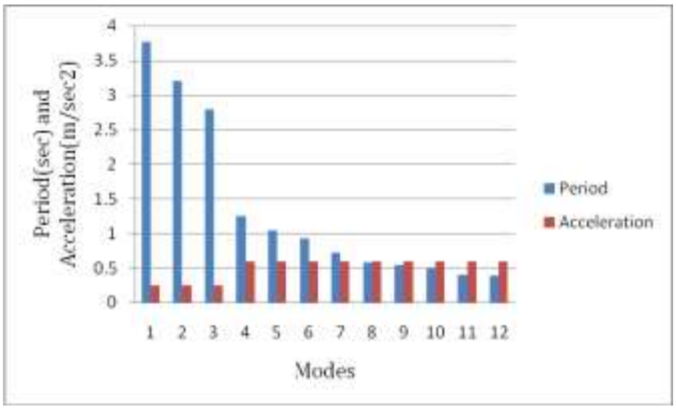

Fig- 16: Response modal information spectrum for G+15 in X direction

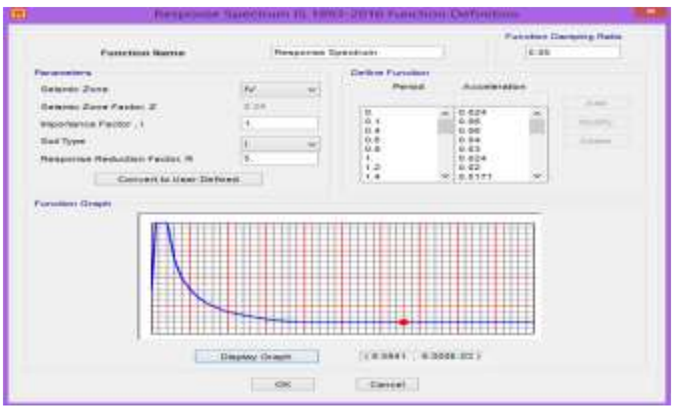

Fig- 17: Response spectrum for G+12 structure

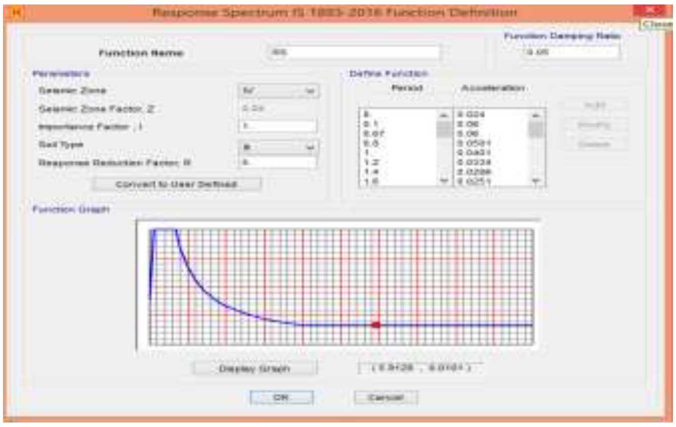

Fig- 18: Response spectrum for G+15 structure

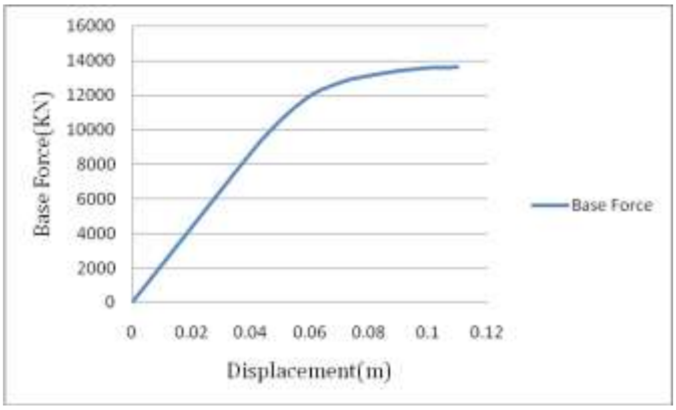

Fig- 19: Pushover capacity curve for G+12 in X direction

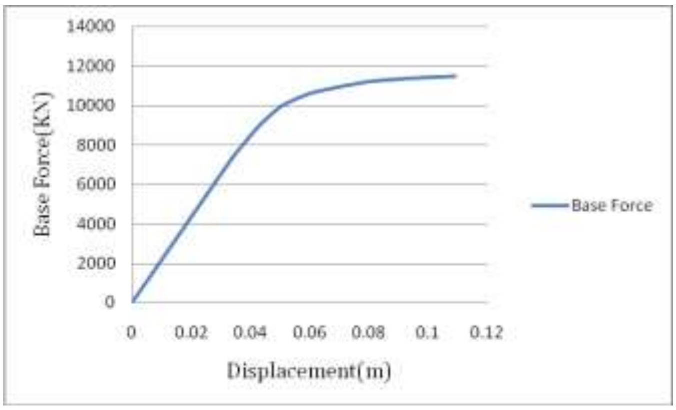

Fig- 20: Pushover capacity curve for G+12 in Y direction

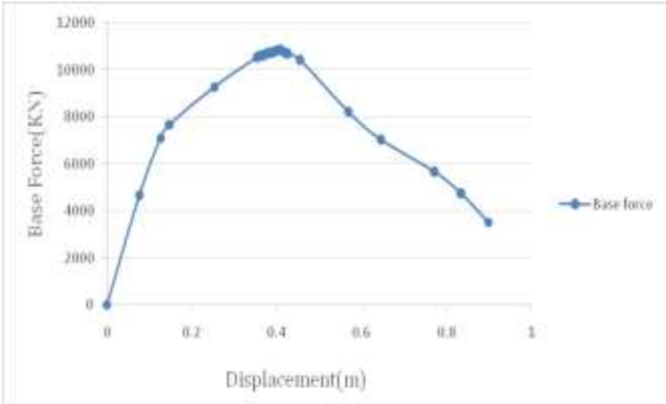

Fig- 21: Pushover capacity curve for G+15 in X direction

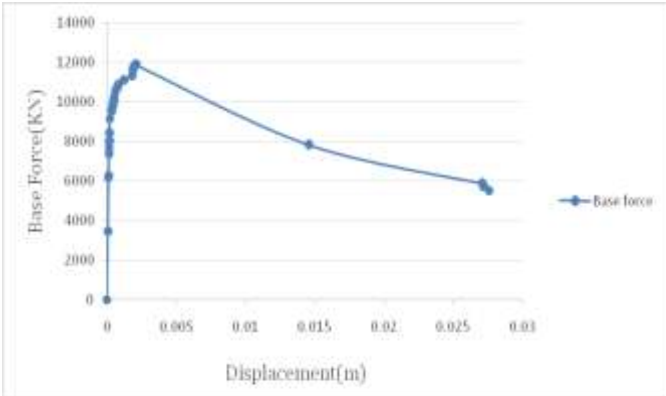

Fig- 22: Pushover capacity curve for G+15 in Y direction

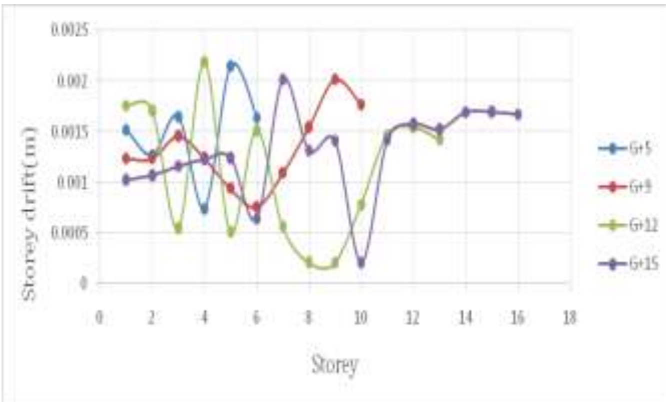

Fig- 23: Story drift for different models

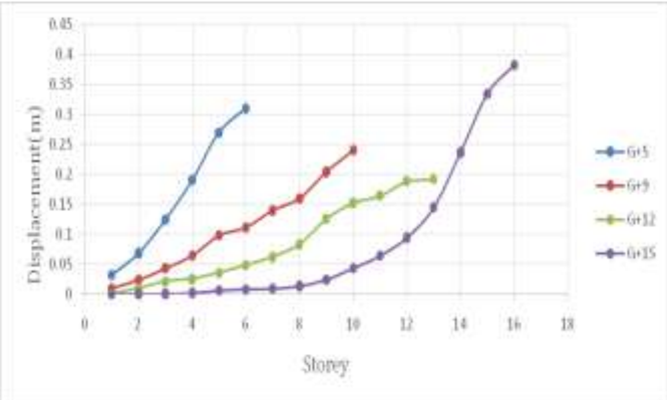

Fig- 24: Displacement for different story

5. CONCLUSIONS

- The base reaction for different structures is analyzed where the moment and force in both directions' changes with the mode of vibration in Fig. 3-4.
- The joint displacement in X direction is higher than in Y direction. The displacement value is more effective than G+5 and G+9 asymmetric structures in [1] of Fig. 5-6.
- The ratio of modal load participation in dynamic approach is lower than the modal load participation values in static approach with respect to base reaction Fig. 7-8.
- Modal p-delta participation factor, mass ratio, periods and frequencies are obtained as shown in Fig. 9-14.
- For higher modal effects the periods are decreased randomly, when acceleration is increased for response modal information spectrum as shown in Fig. 15-16.
- The response spectrum at Zone IV for G+12 and G+15 structures are shown in Fig. 17-18 and it is compared with G+5 and G+9 structures in [1] that satisfy FEMA356 guidelines.
- The pushover capacity curve along X and Y direction is obtained. The base force value for G+ 15 structures is higher than those obtained in G+12, G+5 and G+9 structures with respect to displacement [1] in Fig. 19-22.
- From this case study, we can conclude that with the increase in base reaction values in different MDOF systems, the displacement value decreases.
- The maximum story drift demand obtained for different stores i.e. G+5, G+9, G+12 and G+15, and as per IS 1893-2016 the criteria for story drift which is 0.004 times the height of the story is satisfied as depicted in Fig. 23.
- The variation of displacement coefficient for different structural system is shown in Fig. 24, which satisfies FEMA356 guidelines.

Furthermore, we can also conclude that extended N2 method can also be employed for seismic performance evaluation of reinforced asymmetric structures. From Fig.23 it is observed that the mid-height of story drift values obtained using extended N2 method is less compared to the response spectrum values for G+12 being 0.001496m and for G+15 being 0.001328m; this is because the elastic modal analysis doesn't take into consideration non-linear effects due to higher modes. Therefore, for medium to high-rise buildings extended N2 method fails to accurately predict base shear demands due to higher mode effects involved.

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