# Performance evaluation of G+5, G+10 and G+15 story symmetric and asymmetric buildings using Pushover analysis.

**Madhukaran[1], Dr.H.Eramma[2], Sandeepkumar.D.S[3], Raghavendra.M.R[4]**

*[1,2] Faculty Civil Engineering Department, UBDTCE, Davanagere*
*[3,4] Students UBDTCE, Davanagere*

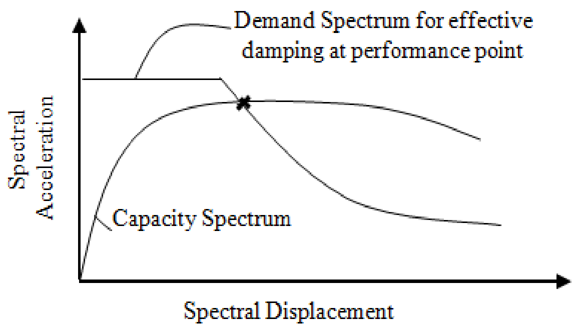
---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract** - *In the current study we have modeled symmetric and asymmetric buildings such as H-shape, L-shape, Long slender shape, Rectangular shape and T-shape buildings for G+5, G+10 and G+15 stories using ETABS 9.7 non-linear version software. We have plotted Pushover graphs compared earthquake demand V/S capacity of the building using non-linear static Pushover analysis. We have observed that capacity of the symmetric buildings is much higher than asymmetric buildings.*

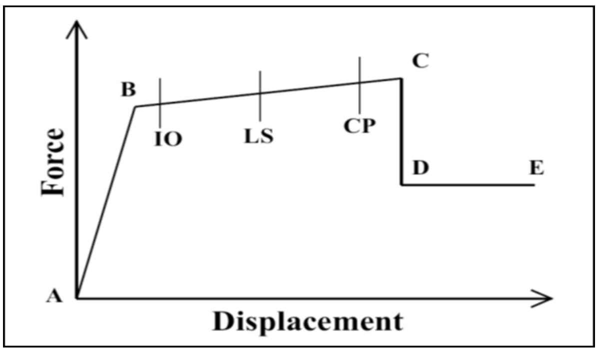
***Key Words***: Pushover, Capacity spectrum, hinges and performance.

## I. INTRODUCTION

The Pushover Analysis or Non–Linear Static analysis Procedure is defined in the Federal Emergency Management Agency document 356 (FEMA 356) as a non–linear static approximation of the response a structure will undergo when subjected to dynamic earthquake loading. The static approximation consists of applying a vertical distribution of lateral loads to a model which captures the material non–linearity of an existing or previously designed structure, and monotonically increasing those loads until the peak response of the structure is obtained on a base shear vs. roof displacement plot. At the University of Ljubljana this method for simplified push-over analysis has been developed, which is intended to achieve a satisfactory balance between required reliability and applicability for everyday design use, and which might contribute to the practical implementation of new trends in seismic design (Kilar, 1995). It is based on an extension of the pseudo three-dimensional mathematical model of a building structure into the inelastic range. The method was implemented into a prototype of the interactive and user friendly computer program NEAVEK. In the paper the method is briefly described and applied. The graphical presentation makes possible a visual evaluation of how the structure will perform when subjected to earthquake ground motion (Freeman, 1998). The capacity of the structure represented by a force displacement curve is obtained by non-linear static pushover analysis. The base shear forces and roof displacements are converted to the spectral accelerations and spectral displacements of an equivalent Single-Degree-Of-Freedom (SDOF) system, respectively. These spectral values define the capacity spectrum. The demands of the earthquake ground motion are defined by highly damped elastic spectra. The Acceleration Displacement Response Spectrum (ADRS) format is used, in which spectral accelerations are plotted against spectral displacements, with the periods represented by radial lines (Fajfar, 1999). The intersection of the capacity spectrum and the demand curve provides an estimate of the inelastic acceleration and displacement demand. In this paper, the result of the pushover analysis was compared with the existing BNBC 1993 response spectrum.




**Plastic Hinge:**




Plastic hinges are defined at the end of the Beam and Column element as per FEMA 356 standard. The nonlinear load deformation relationship is shown in the Figure 4 where generalized force versus deformation curves used to specify component modelling and acceptance criteria for deformation-controlled actions (FEMA 356, 2000). The unloaded condition is expressed as point A whereas B corresponds to effective yield point. The slope of BC is generally taken from 0 to 10 percentage of the initial slope. This line BC represents strain hardening phenomena of the material. Point C represents the nominal strength and an abscissa value at which significant strength degradation begins (line CD). Beyond point D, the component responds with substantially reduced strength to point E. At deformations greater than point E, the component strength is effectively zero. These five points are used to define the hinge rotation behavior of RC members according to FEMA. Three more points corresponding to the target Building Performance Levels such as Collapse Prevention (CP), Life Safety (LS), and Immediate Occupancy (IO) are used to define the acceptance criteria for the hinge of primary members (P) and secondary members (S) as shown in Figure 4 ((FEMA 356, 2000).

Following procedure is generally used for the analysis according to IS 1893 – 2002.

i) Calculation of lumped weight.

ii) Calculation of fundamental natural period.

The fundamental natural period of vibration (Ta) in seconds of a moment resisting frame building,

Ta = 0.075 $h^{0.75}$ (without brick infill panels)

Ta = 0.09 h/ √d (with brick infill panels)

Where

h = Height of the building

d = Base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

iii) Determination of base shear (VB) of the building.

VB = Ah x W

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

Where,

$A_h$ is the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficient (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

iv) Lateral distribution of design base shear;

The design base shear VB thus obtained is then distributed along the height of the building using a parabolic distribution expression:

$$Q = V_B \frac{W_1 h_1}{\sum_{j=1}^{n} W_j h_k^{\,2}}$$

Where $Q_1$ is the design lateral force, $W_1$ is the seismic weight, $h_1$ is the height of the $i^{th}$ floor measured from base and n is the number of stories in the building.

## II. MODELLING AND ANALYSIS

The following load combinations are considered in the current study.

| Types of analysis | Load factors | |
|---|---|---|
| EQUIVALENT STATIC ANALYSIS | X- Direction | 0.9 DL+1.5 EQX |
| | | 1.5 (DL+EQX) |
| | | 1.2 (DL+LL+EQX) |
| | Y-Direction | 0.9 DL+1.5 EQY |
| | | 1.5 (DL+EQY) |
| | | 1.2 (DL+LL+EQY) |
| RESPONSE SPECTRUM ANALYSIS | X- Direction | 0.9 DL+1.5 RESX |
| | | 1.5 (DL+RESX) |
| | | 1.2 (DL+LL+RESX) |
| | Y-Direction | 0.9 DL+1.5 RESY |
| | | 1.5 (DL+RESY) |
| | | 1.2 (DL+LL+RESY) |

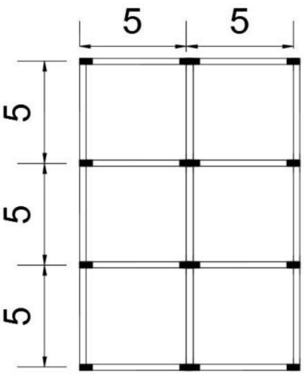
Among all the load combinations considered, the maximum response is observed in 1.5 (DL + EQL) combination. Therefore those values are tabulated and compared.

The entire analysis has done for all the 3D models using ETABS 9.7 non-linear version software. The results are tabulated in order to focus the parameters such as time period, story shear, story drift and lateral displacement.

**Input parameters**

Type of building G+5, G+10 and G+15 story reinforced structure.

| | |
|---|---|
| Height b/w the floor | 3.0 m |
| Ground floor height | 3.0 m |
| Wall thickness | 300 mm |
| Unit weight of R.C.C **(IS 875-1987, P-1)** | 25 kN/$m^3$ |
| Unit weight of bricks **(IS 875-1987, P-1)** | 18 kN/$m^3$ |
| Grade of concrete (M20) | 20 N/$mm^2$ |
| Grade of steel (Fe415) | 415 N/$mm^2$ |
| Size of beam | 230x450 mm |
| Size of column | 900x900 mm |
| Thickness of slab | 150 mm |
| Live load | 3 kN/$m^2$ |
| Floor finishes | 1.25 kN/$m^2$ |



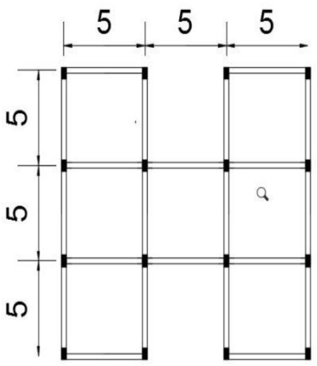


Fig. : L-shape plan. Fig. : H-shape plan.

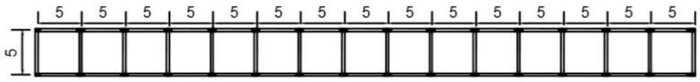
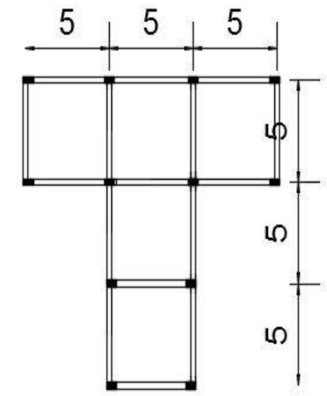


Fig.:Long slender shape plan.



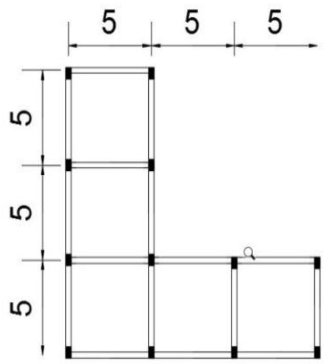


Fig. : T-shape plan Fig. : Rectangular shape
plan

## III. RESULTS AND DISCUSSIONS

### PUSHOVER CURVES

The static pushover curve is a force-displacement curve obtained from a static nonlinear analysis. Non-linear static pushover analysis is done to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design. The graphs below provides the pushover curve, that is Base shear Vs Roof displacement curve for symmetric and asymmetric buildings that is H-shape, L-shape, Rectangular shape, Long slender shape and T-shape buildings. Hinges forming Table for H-shape, L-shape, Long slender shape, Rectangular shape and T-shape building is also given below.

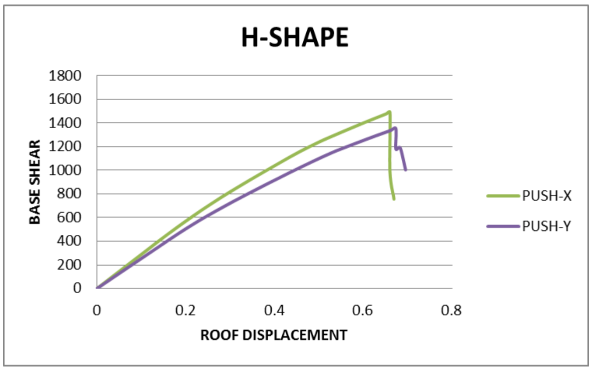



Fig.: Pushover curve for H-shaped building.

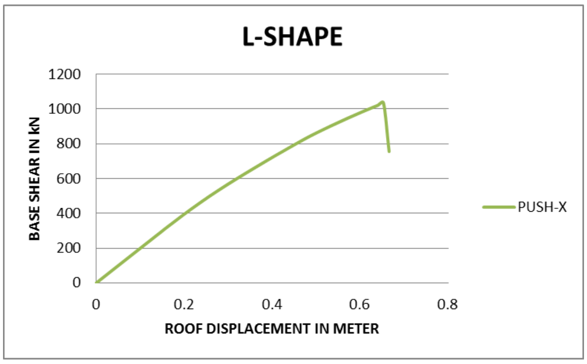



Fig.: Pushover curve for L-shaped building.

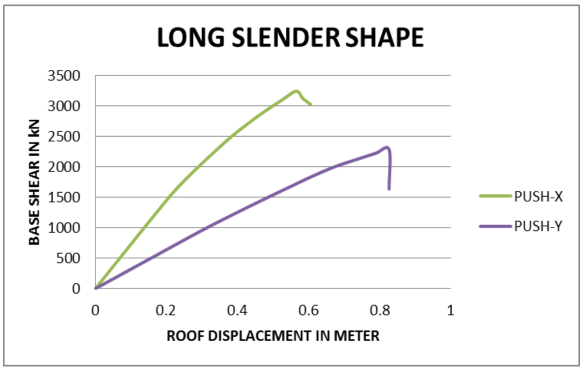



Fig.: Pushover curve for Long Slender-shaped building.

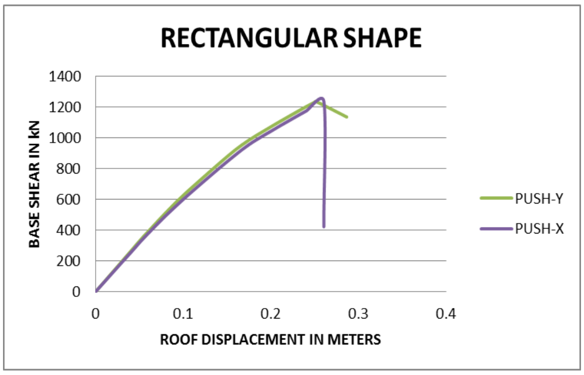



Fig.: Pushover curve forRectangular-shaped building.

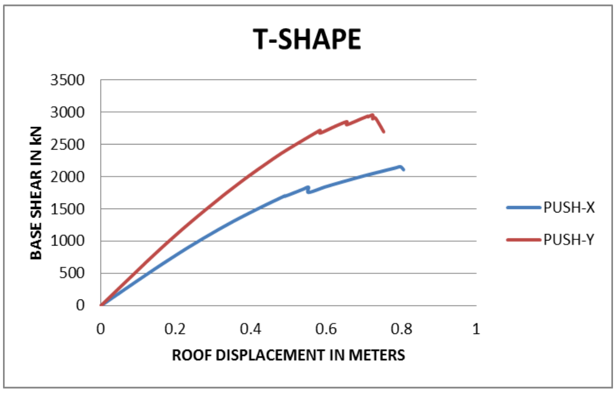



**Fig.: Pushover curve for T-shaped building.**

The above figures provides the pushover curves for symmetric and asymmetric building that is H-shape, L-shape, Rectangular shape, Long slender shape and T-shape buildings in both X and Y directions. For L-shape building Pushover graph is same in both directions because the plan is identical in both directions.

## CAPACITY SPECTRUM

The capacity spectrum method by means of a graphical procedure compares the capacity of a structure with the demands of earthquake ground motion. A graphical construction that includes both capacity and demand spectra results in an intersection of the two curves that estimates the performance of the structure to the earthquake.

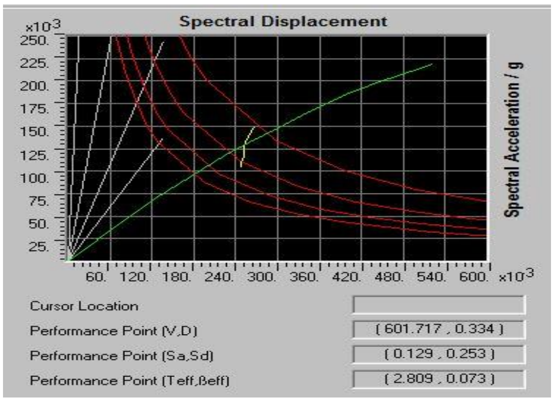



**Fig. : Capacity spectrum of T- shape plan.**

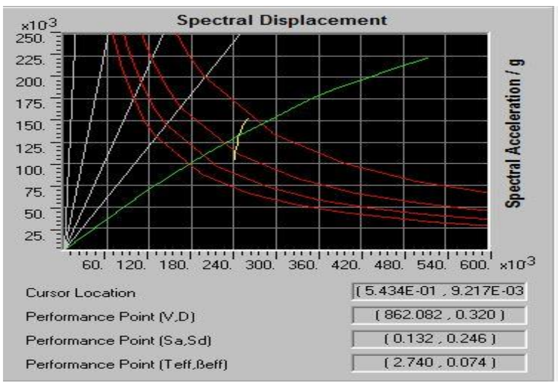



**Fig. : Capacity spectrum of Rectangular shape plan.**

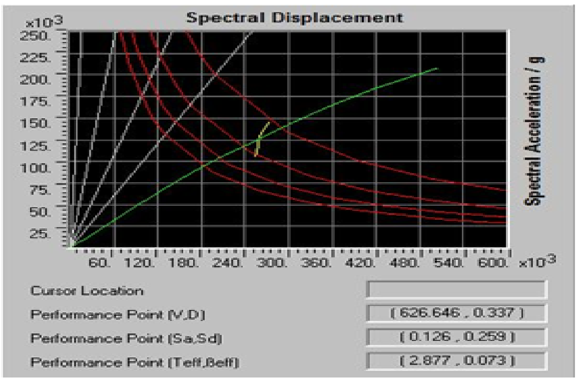



**Fig. : Capacity spectrum of L- shape plan.**

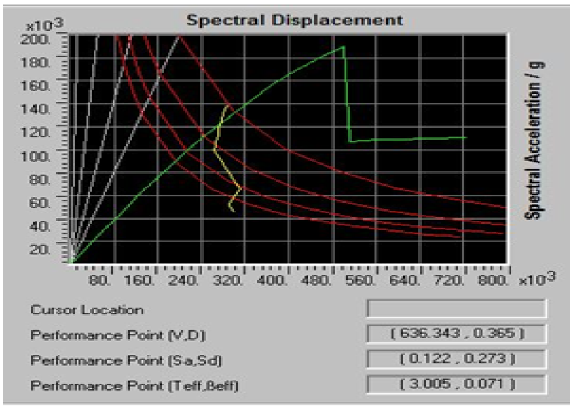



**Fig. : Capacity spectrum of H- shape plan.**

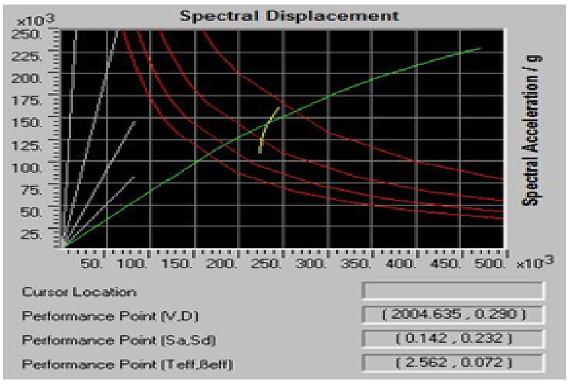



**Fig. : Capacity spectrum of Longslender shape plan.**

The above figures provides the capacity of symmetric and asymmetric building that is H-shape, L-shape, Rectangular shape, Long slender shape and T-shape buildings. It can be noted that long slender shape building has higher capacity than other buildings.

## HINGES FORMATION

The formation of hinges depends on demand to capacity ratio (DCR). The members in which the seismic demand exceeds its capacity, hinge formation takes place. The Location of plastic hinge can vary according to the geometrical properties of structural components. The order of sequence of hinge formation controls the deformation characteristics of the structures. The Performance of the structure under ground motion can be understood in much better way if the hinge formation and corresponding displacement characteristics is observed.

| Performance levels | RECTANGULAR | | T-SHAPE | |
|---|---|---|---|---|
| | Base Shear (kN) | Number of Hinges | Base Shear (kN) | Number of Hinges |
| Operational | 1177 | 314 | 2339 | 328 |
| Damage control | 1190 | 14 | 2419 | 16 |
| Limited Safety | 1242 | - | 2460 | 6 |
| Hazard | 1254 | - | 2510 | - |
| | | 328 | | 344 |

**Table: Hinges formation for Rectangular and T-shape buildings.**

| Performance levels | H-SHAPE | | L-SHAPE | | LONG SLENDER | |
|---|---|---|---|---|---|---|
| | Base Shear (kN) | Number of Hinges | Base Shear (kN) | Number of Hinges | Base Shear (kN) | Number of Hinges |
| Operational | 1155 | 280 | 1040 | 292 | 3026 | 802 |
| Damage control | 1185 | 40 | 1063 | 46 | 3031 | 52 |
| Limited Safety | 1214 | - | 1086 | 32 | 3033 | 36 |
| Hazard | 1242 | - | 1109 | - | 3061 | - |
| | | 320 | | 370 | | 890 |

**Table: Hinges formation for H, L and Long slender shape buildings.**

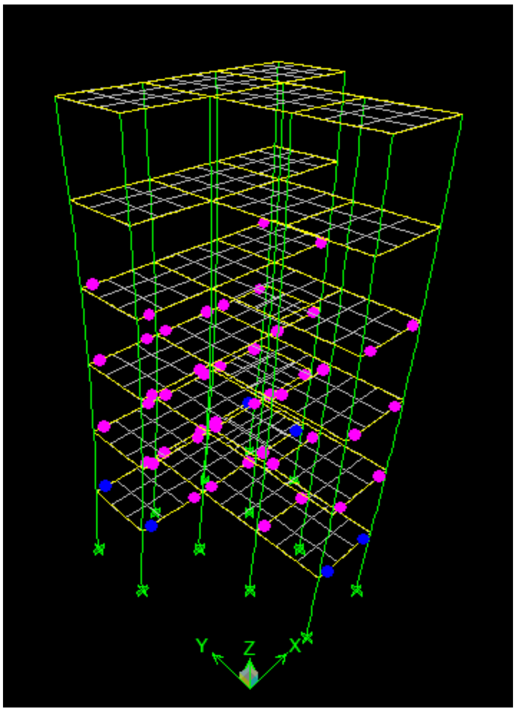


**Fig: Hinges formation for T-shape buildings.**

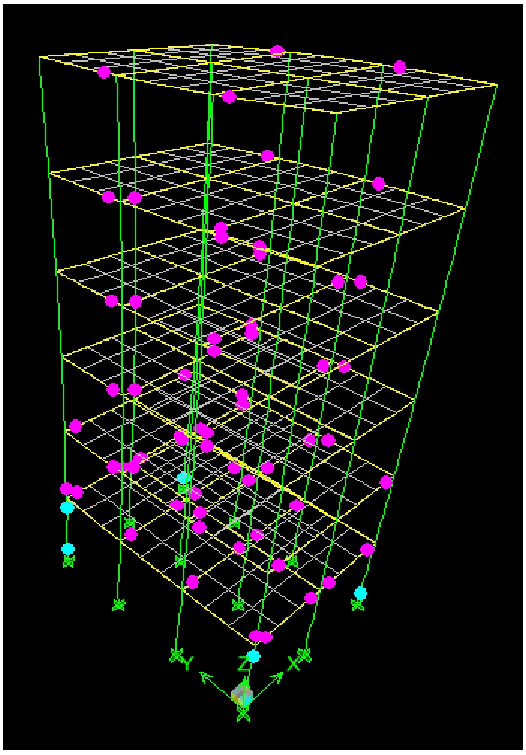


**Fig: Hinges formation for Rectangle shape buildings.**

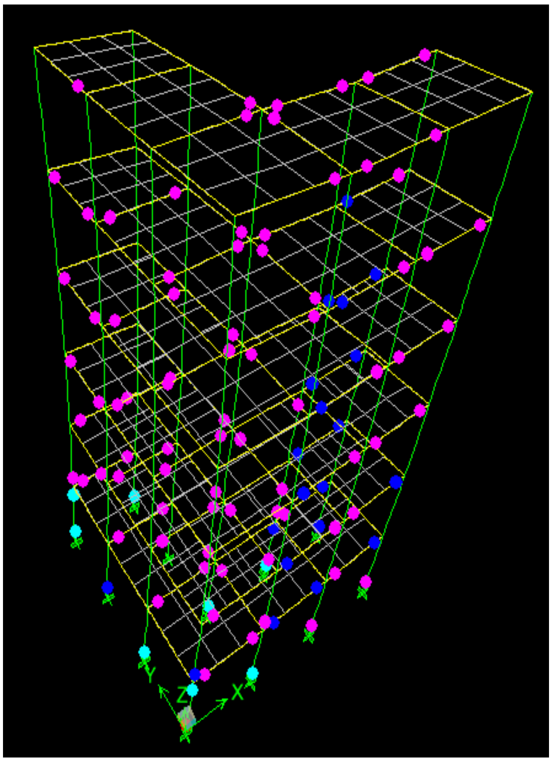


**Fig: Hinges formation for L-shape buildings.**

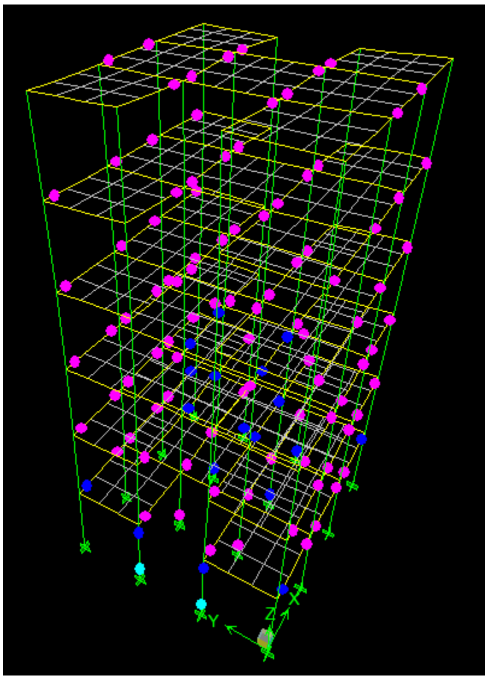


**Fig: Hinges formation for H-shape buildings.**

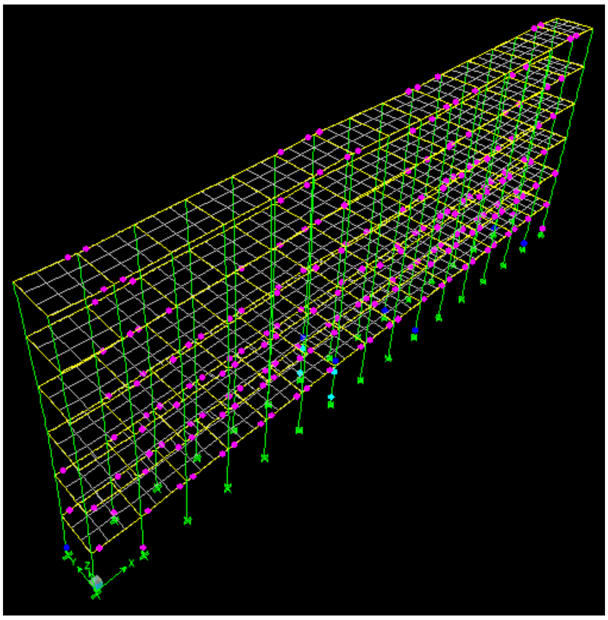


**Fig: Hinges formation for Long slender shape buildings.**

The above tables and figures provides 3-D pictures of hinges formation of symmetric and asymmetric building that is H-shape, L-shape, Rectangular shape, Long slender shape and T-shape buildings . Like other factors which affect the target displacement, the plastic hinges that forms in the structure have their own importance. Therefore it is necessary to understand the sequence of hinge formation during ground motions.

## VI. CONCLUSION

1. The proposed simple procedure for the push-over analysis of building structures is capable to estimate several important characteristics of nonlinear structural behavior, especially the real strength and the global plastic mechanism. The efforts needed for data preparation, computation and interpretation of results are much smaller as in the case of other nonlinear analysis methods. So, the proposed procedure may be appropriate for practical analysis and design of earthquake resistant building structures and for evaluation of existing structures

2. Totally 890 hinges are formed in Long slender shape building. This is comparatively more among all shape building.

3. Totally 320 hinges are formed in H-shape building. This is comparatively less among all shape building.

4. Performance point of Rectangular shape building is 862.082kN and 0.320m. From this we can conclude that symmetric buildings take higher base force at lesser displacement .

5. Whereas Performance point of L-shape building is 626.646kN and 0.337m, Performance point of H-shape building is 636.343kN and 0.365m and Performance point of T-shape building is 601.343kN and 0.334m. From this we can conclude that asymmetric buildings takes lower base force even at higher displacements.

## REFERENCES

1. Dr. H Eramma, pulakeshi H L (2015), "Seismic Performance Evaluation of RC Building Connected With and Without X-Braced Friction Dampers", International Journal of Research in Engineering and Technology.

2. Avtar S Pall, Rashmi Pall (1996), "Friction Dampers For Seismic Control of Buildings, A Canadian Experience", Eleventh World Conference on Earthquake Engineering, Paper No. 497.

3. Shilpa G, Nikam, S. K. Wagholikar, G. R. Patil (2014), "Seismic Energy Dissipation of a Building Using Friction Damper", International Journal Of Innovative and Exploring Engineering (IJITEE).

4. Naveet Kaur, V. A. Matsagar, A. K. Nagpal (2012), "Earthquake Response of Mid-Rise to High-Rise Buildings With Friction Dampers", Council of Tall Buildings and Urban Habitat (CTBUH).

5. Chiara PASSONI, Andrea BELLERI, Alesandra MARINI, Paolo RIVA (2014), "Existing Structure

Connected With Dampers: State of The Art and Future Developments", Second European Conference on Earthquake Engineering and Seismology, Istanbul.

6. F. Bharatia, A. Esfandiari (2012), "Exploring the Efficiency of Dampers for Repair and Strengthing of Existing Buildings ", Journal of Structural Engineering and Geotechnics.

7. Zbigniew Skup (2010), "Analysis of Damping of Vibrations Through A Frictional Damper", Journal of Theoretical and Applied Mechanics.

8. Ramesh Chandra, Moti Masand, S. K. Nandi, C. P. Tripathi, Rashmi Pall, Avtar Pall (2008), "Friction-Dampers for Seismic Control of La Gardenia Towers South City, Gurgaon, India",WCEE.

9. P. Dupont, P. Kasturi, S. Stokes (1997),"Semi-Active Control of Friction Dampers", Journal of Sound and Vibration.

10. Kishor Bajad, Rahul Watile (2014),"Application of Dampers for RCC Building to Reduce Seismic Risk", International Journal of Research in Advent Technology.

11. A.V. Bhaskararao, R. S. Jangid(2003), "Seismic Analysis of Structures connected With Friction Dampers",Departement of Civil Engineerinfg, IIT Bombay, Powai, Mumbai.