Study of Various Configurations in High-Rise Structures

Shivam Mishra & Sameer Dhuri
Students, Veermata Jijabai Technological Institute,India

Mahua. A. Chakrabarti & Keshav K. Sangle.
Professor, Veermata Jijabai Technological Institute, India

SUMMARY:

Earthquake is one of the most devastating natural calamities known to man. Most earthquake related deaths are caused by the collapse of structures. The structural configuration plays a role of paramount importance in reducing the death toll in an earthquake. Numerous researchers have suggested the use of seismic isolation as a method to reduce vibrational damage and to increase seismic sustainability. Seismic isolators have proved to be efficient for low to medium rise structures but for high-rise structures, this method has not been feasible because of high over turning moments. Scarcity of land has insinuated a growing trend of high-rise structures. The protection of engineering structures, including material content and human occupants has been a worldwide priority. Recent devastating earthquakes around the world have confirmed the need to understand the dynamic response of structural conformations. A comprehensive study has been carried out on various possible structural configurations and their corresponding seismic performance. The advantages and disadvantages of various possible configurations have been discussed. The behaviour of structures of different shapes has been analysed. This research provides an insight in understanding the contribution of structural layout to overall seismic resistance of the structural system.

Keywords: *Earthquake, High-Rise Structure, Structural Configuration, Pushover Analysis*

1. INTRODUCTION

The basic approach of earthquake resistant design should be based on lateral strength as well as deformability and ductility capacity of structure with limited damage but no collapse. Ductility in the structure will arise from inelastic material behaviour and detailing of reinforcement in such a manner that brittle failure is avoided and ductility is induced by allowing steel to yield in a controlled manner. Therefore, one of the primary tasks of an engineer designing earthquake resistant building is to ensure that the building will possess enough ductility to withstand the size and types of earthquakes, which it is likely to experience during its lifetime.

2. STRUCTURAL DUCTILITY

Structural ductility in a global sense depends on the displacement ductility of its members because response displacement of each member can be evaluated even with static analysis. Its quantification requires a relationship between the lateral load and displacement of the whole building. This may be obtained by pushover analysis by plotting total base shear versus the top displacement or preferably, versus the displacement at the level where the resultant forces are applied.

$$Qb = \sum Fi \tag{1}$$

$$u_b = \frac{\sum_{i=1}^{n} F_i U_i}{Q_b} \tag{2}$$

Where F_i is the lateral force at floor i and U_i its lateral displacement. The ductility of a structure may be quantified by the factor:

$$\mu_b = \frac{u_{max}}{u_y} \tag{3}$$

3. NUMERICAL STUDY

Three different conformations in plan were modeled using Etabs 9.7.3. (C.S.I) Each was modeled as 20 storey reinforced concrete structure. The total floor plan area was kept constant for all three configurations. The members were designed for specific dead, live, and lateral loads (IBC 2006). The live loads were specified as 3kN/m^2. After obtaining the safe sections with calculated amount of steel, the structure was subjected to Displacement Controlled Pushover at the roof level critical points (centre of mass in plan view) of top storey.

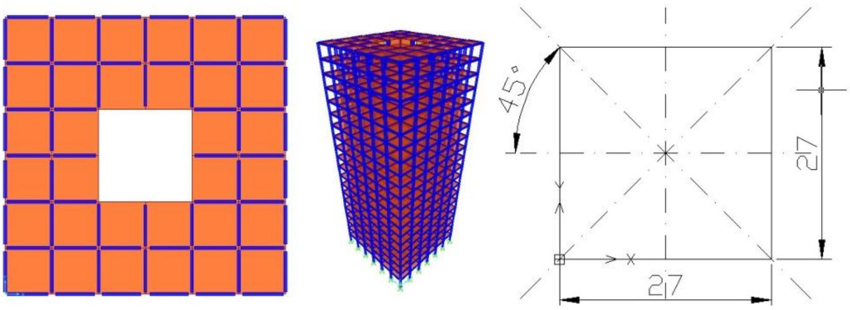

Figure 1. Square Configuration (Plan, Perspective View)

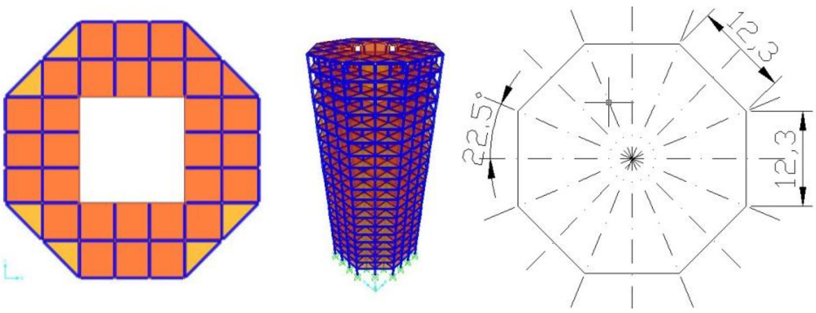

Figure 2. Octagon Configuration (Plan, Perspective View)

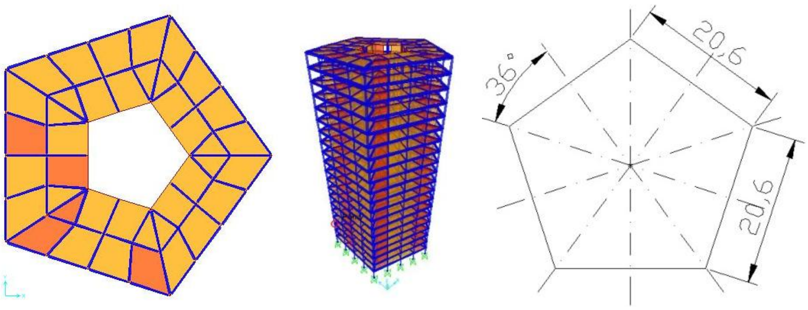

Figure 3.Pentagon Configuration (Plan, Perspective View)

4. PUSHOVER METHODOLOGY

A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads, representing the inertial forces which would be experienced by the structure when subjected to ground shaking. Under incrementally increasing loads various structural elements may yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic non-linear force displacement relationship can be determined.

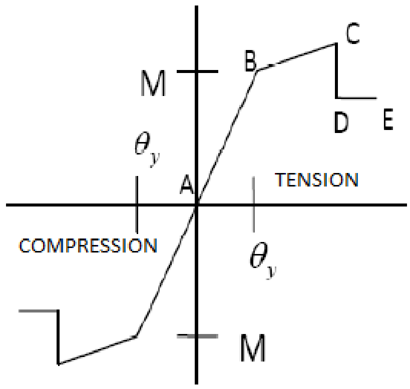

Figure 4. Concrete Hinge Properties for Reinforced Concrete

5. ELEMENT DESCRIPTION OF ANALYSIS PROGRAM

In Etabs 9.7.3, a frame element is modeled as a line element having linearly elastic properties and nonlinear force displacement characteristics of individual frame elements are modeled as hinges represented by a series of straight line segments. A generalized force-displacement characteristic of a non-degrading frame element (or hinge properties) in Etabs is shown in figure. Point A corresponds to unloaded condition and point B represents yielding of the element. The ordinate at C corresponds to nominal strength and abscissa at C corresponds to the deformation at which significant strength degradation begins. The drop from C to D represents the initial failure of the element and resistance to lateral loads beyond point C is usually unreliable. The residual resistance from D to E allows the frame elements to sustain gravity loads. Beyond point E, the maximum deformation capacity, gravity load can no longer be sustained. Uncoupled moment (M2and M3), torsion (T), axial force (P) and shear (V2 andV3) force-displacement relations can be defined. As the column axial load changes under lateral loading, there is also a coupled P-M2-M3 (PMM) hinge which yields based on the interaction of axial force and bending moments at the hinge location. Also, more than one type of hinge can be assigned at the same location of a frame element. The built-in default hinge properties for steel and concrete members are based on ATC-40 and FEMA-273 criteria.

6. DESCRIPTION OF FRAMED STRUCTURE

The G+20 building is considered in this study. This structure is designed as a reinforced cement concrete structure according to American Code ACI 318-05/IBC 2003 and is located in Seismic Category D. The material Properties are M30 Grade concrete, Fe 415 steel for the longitudinal and transverse reinforcement. The plan layout is shown in fig 3. The typical floor height is 3.5m and the details of beams and columns are shown in table.

7. RESULTS

7.1. Results monitored along X axis:

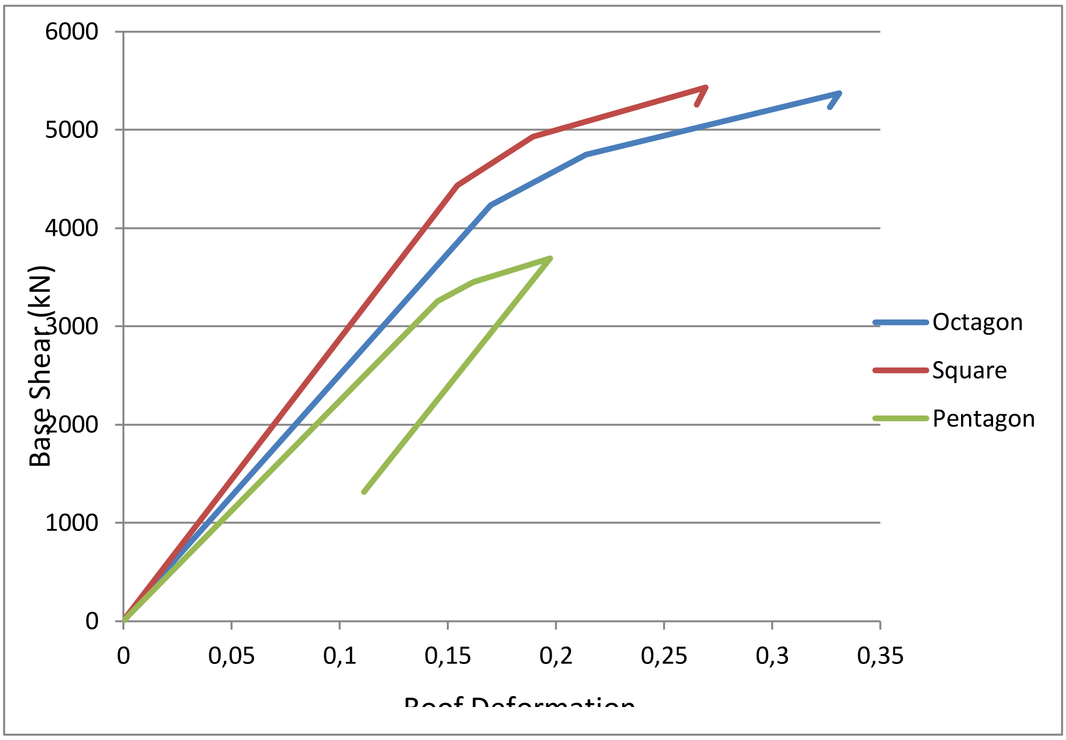

Figure 5. Pushover curve for 0 degree angle push monitored along X-axis

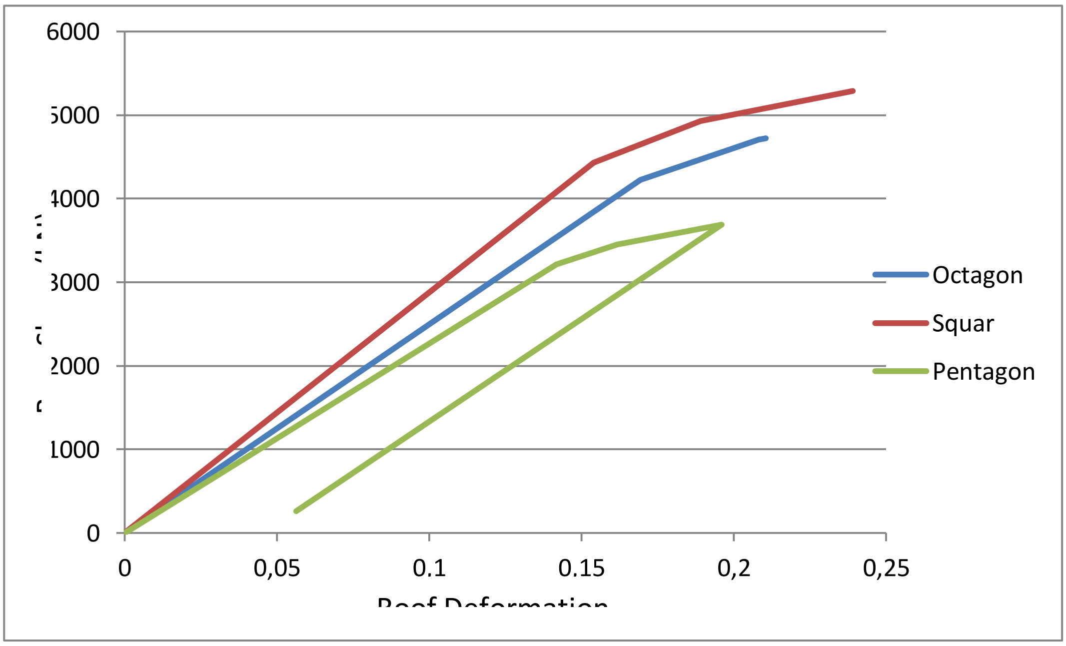

Figure 6. Pushover curve for 4.5 degree angle push monitored along X-axis

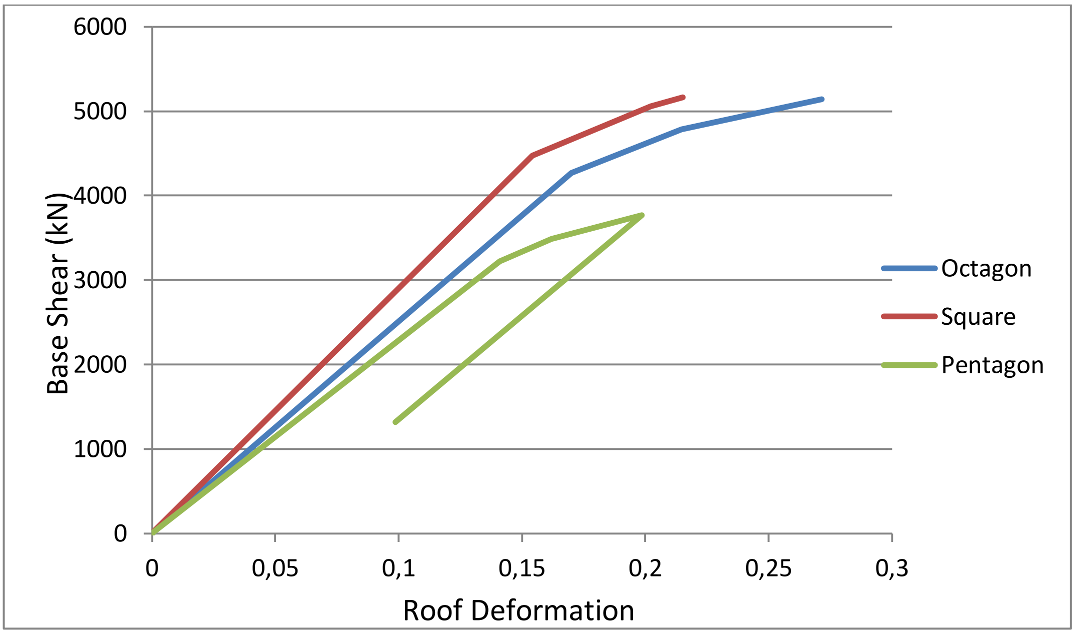

Figure 7. Pushover curve for 9 degree angle push monitored along X-axis

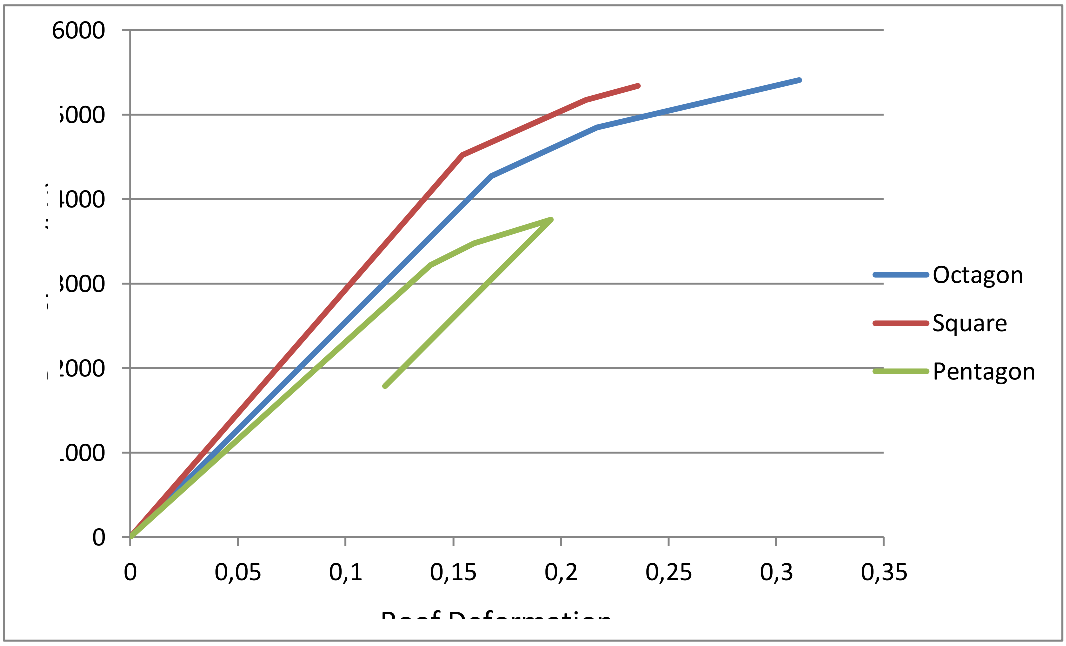

Figure 8. Pushover curve for 13.5 degree angle push monitored along X-axis

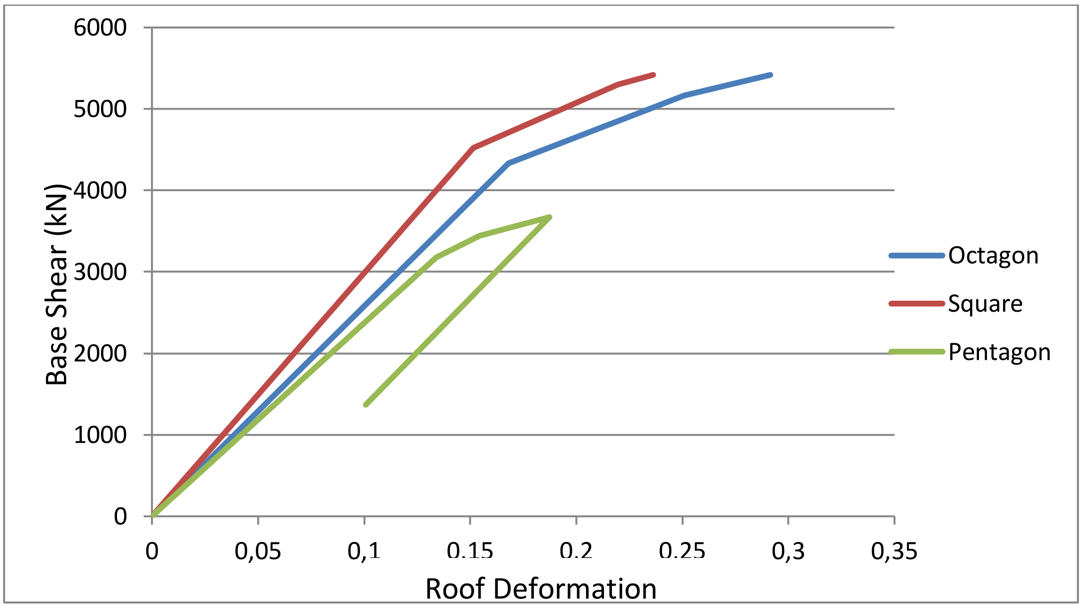

Figure 9. Pushover curve for 18 degree angle push monitored along X-axis

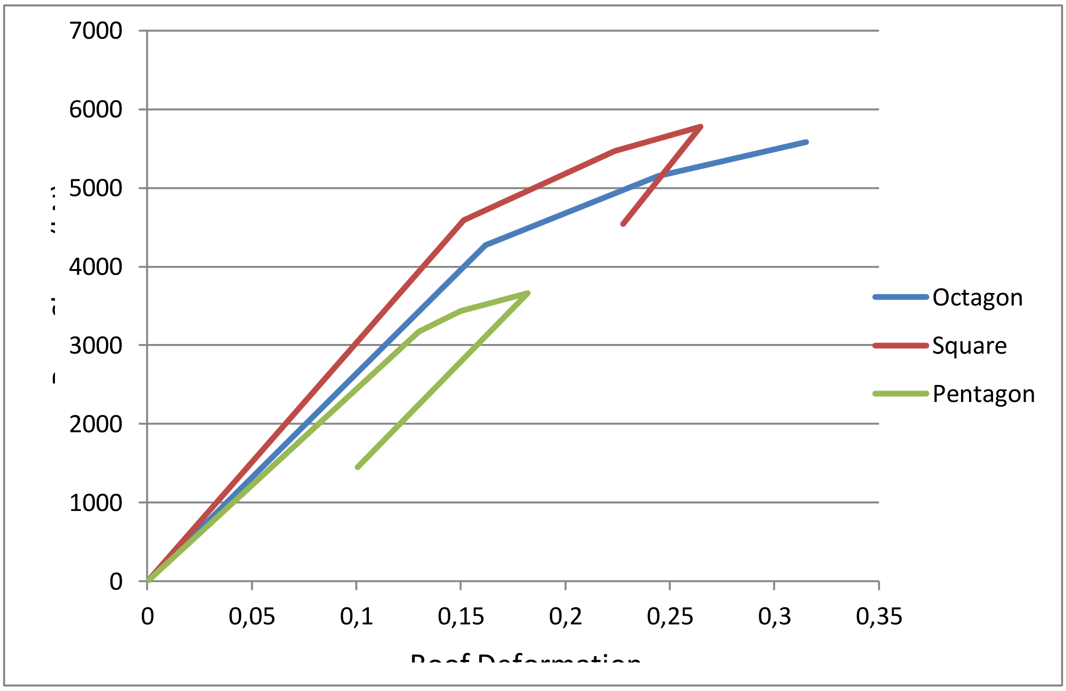

Figure 10. Pushover curve for 22.5 degree angle push monitored along X-axis

7.2. Results monitored along Y axis

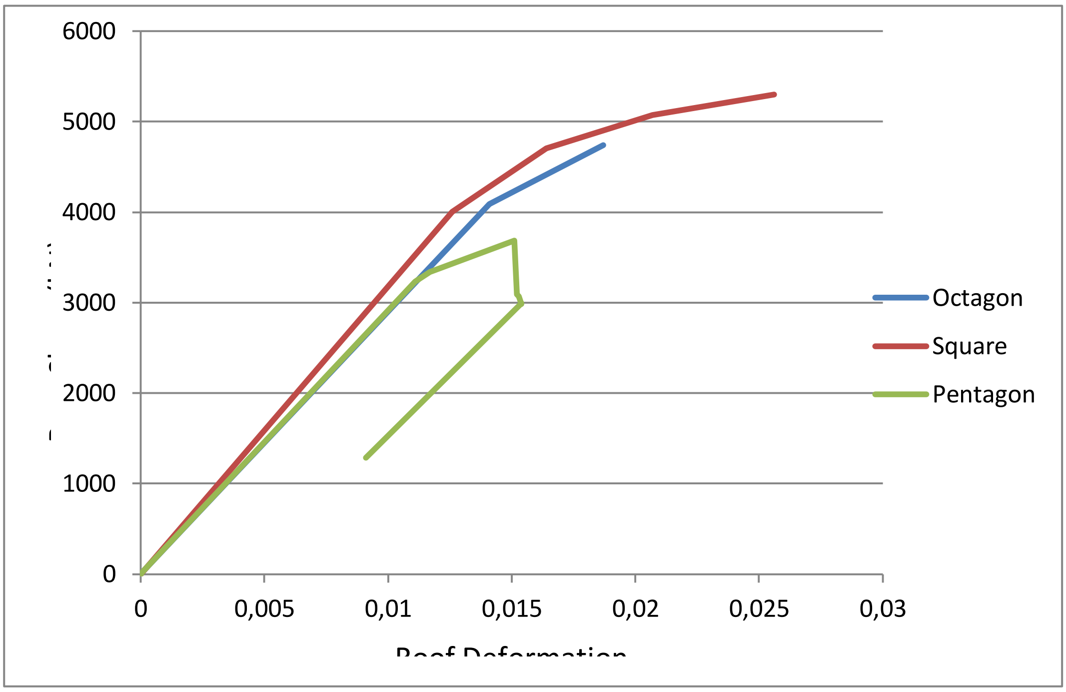

Figure 11. Pushover curve for 4.5 degree angle push monitored along Y-axis

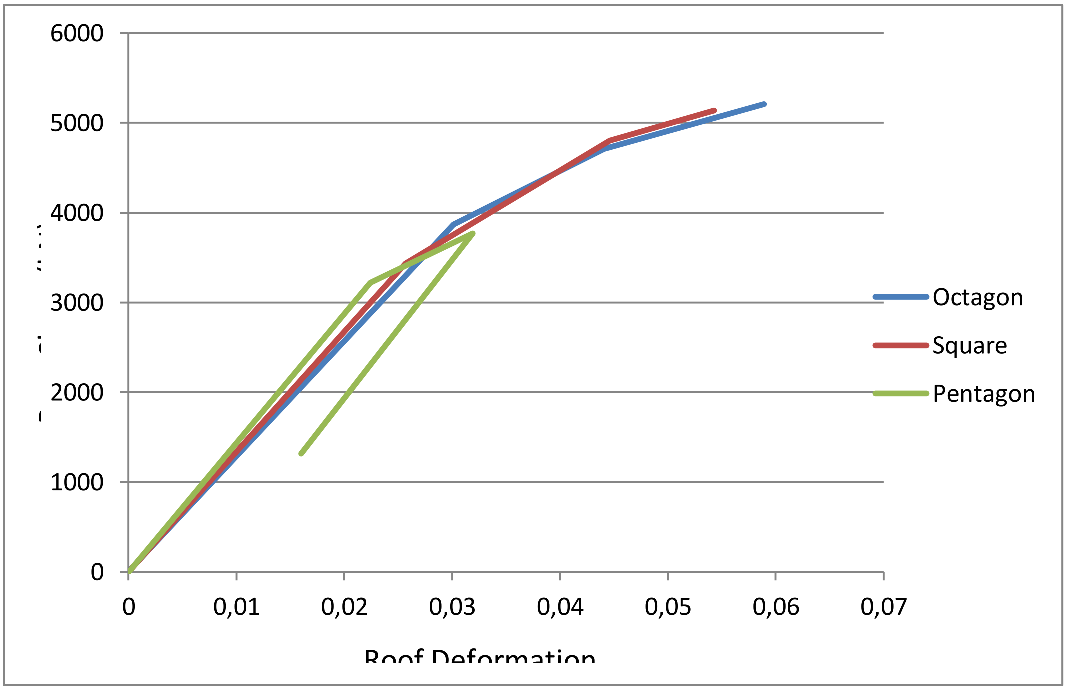

Figure 12. Pushover curve for 9 degree angle push monitored along Y-axis

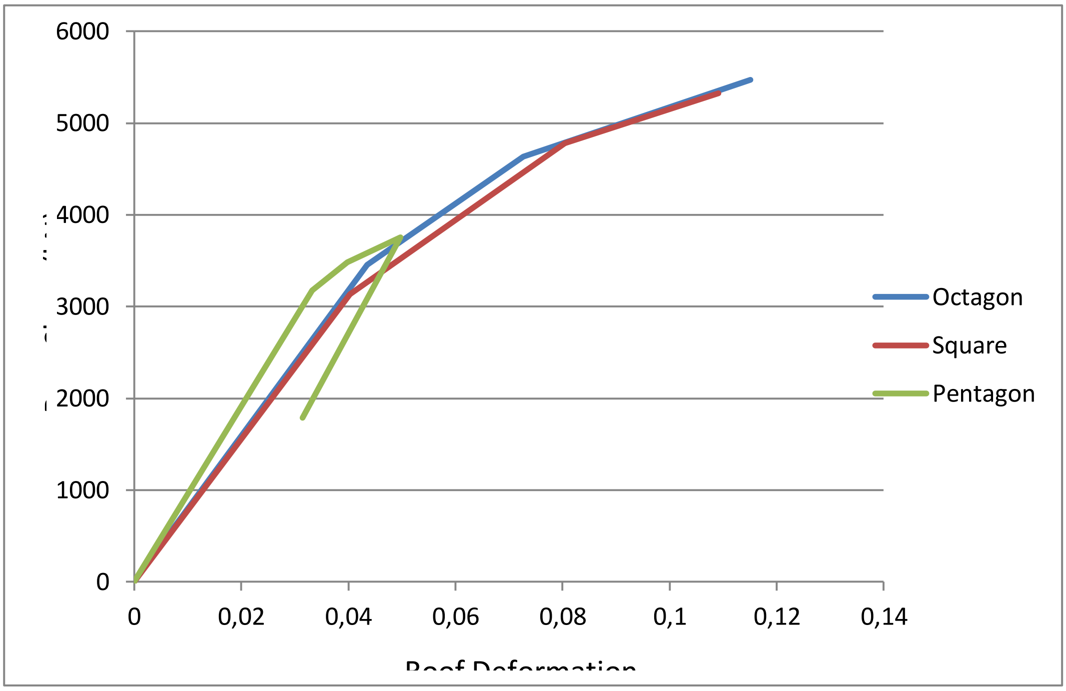

Figure 13. Pushover curve for 13.5 degree angle push monitored along Y-axis

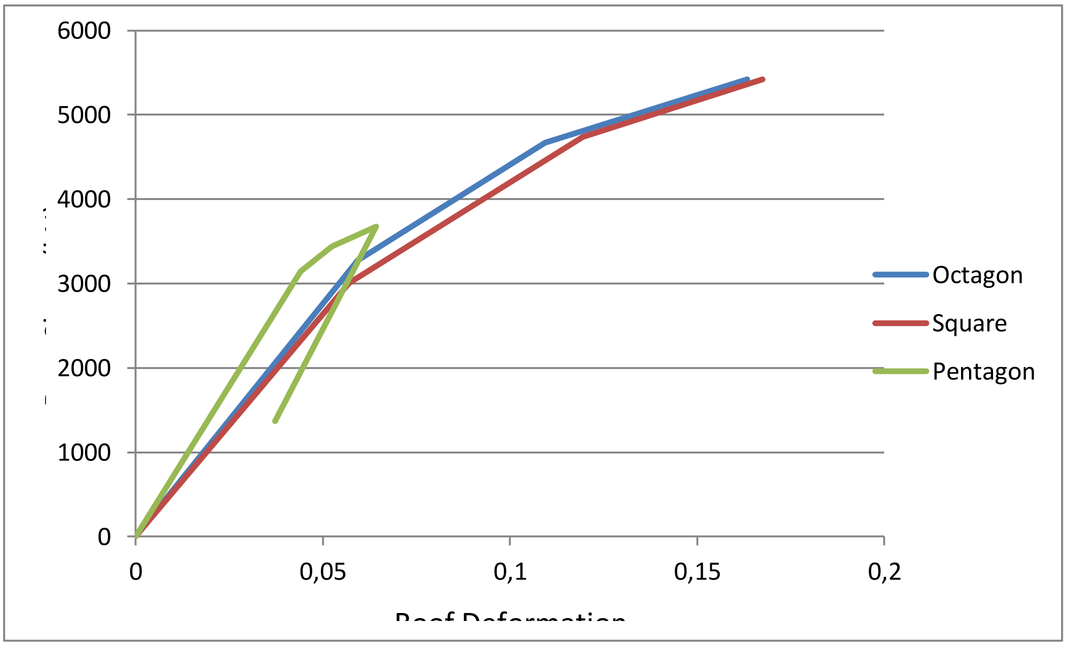

Figure 14. Pushover curve for 18 degree angle push monitored along Y-axis

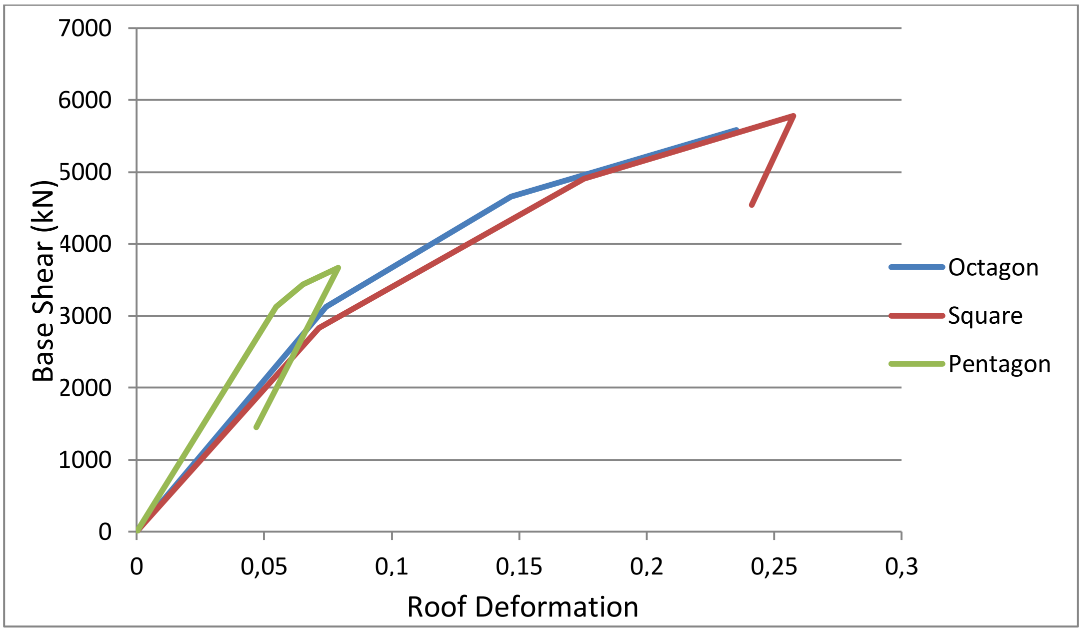

Figure 15. Pushover curve for 22.5 degree angle push monitored along Y-axis

Table 1. Ductility ratios monitored along X-axis

Ductility Ratios Monitored along X-axis			
Angle of Push	**Square**	**Octagon**	**Pentagon**
0	1.74	1.95	1.36
4.5	1.55	1.24	1.38
9	1.40	1.60	1.41
13.5	1.53	1.85	1.40
18	1.56	1.73	1.40
22.5	1.75	1.95	1.40

Ductility Ratios Monitored along Y-axis			
Angle of Push	**Square**	**Octagon**	**Pentagon**
4.5	2.03	1.33	1.39
9	2.11	1.96	1.42
13.5	2.71	2.65	1.49
18	2.93	2.76	1.46
22.5	3.61	3.16	1.45

8. CONCLUSIONS

As per the pushover curves obtained by the nonlinear static analysis of all three conformations at various angles, monitored along X and Y axis, the octagonal shape configuration has performed consistently better than any other shapes when deformations were monitored along X axis of the structure while Square had a higher ductility ratio when deformations were monitored along Y axis.

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