ANALYSIS OF BEHAVIOUR OF A HIGH RISE BUILDING WITH VARIOUS PLAN CONFIGURATIONS UNDER THE INFLUENCE OF SEISMIC FORCES

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ABSTRACT

Due to large population and small per capita area, need of tall buildings becomes more essential in the society. The limitations of the available land frequently restricts the freedom of an engineer to create a perfect structure. In such situations the buildings will have to be designed in various shapes even with oblique corners so as to utilize the maximum benefits of available land. As earthquakes are one of the greatest damaging natural hazards to the building, the design and construction of tall structures which is capable of resisting the adverse effects of earth quake forces is the most important.. Three RCC building frames having plan configurations viz. (1) Square, (2) Hexagonal and (3) Octagonal are considered and analysis of the parameters like Base reactions, axial forces, storey drift, storey stiffness, Mode-Period etc. and Non linear static pushover analysis are carried out using ETABS2015. The results are tabulated ,compared and final conclusions are framed.

Key Words - ETABS, Modeling, Pushover analysis, seismic force, Storey Drift

1. INTRODUCTION

Tall buildings are a special class of structures with their own peculiar characteristics and requirements. They are often occupied by a large number of people. Therefore, their damage, loss of functionality, or collapse can have very severe and adverse consequences on the life and on the economy of the affected regions. Each tall building represents a significant investment and as such tall building analysis is generally performed using more sophisticated techniques and methodologies. Therefore, understanding modern approaches to seismic analysis of tall buildings may be very valuable to structural engineers and researchers. In many situations the shape of the plot available for the construction of a building project may not be a regular one. Hence the shape of the building may be influenced by the plot configurations. Further it will be interesting to study the stability of buildings with different geometry of shape and their behaviour against seismic and other forces. In this project the behaviour of a multi-storeyed RCC building frame having three geometrical shapes *viz*. (1) Square, (2) Hexagon and (3) Octagon are analyzed using the software ETABS 2015.

The structural parameters of all the buildings such as story forces, story drift, base reactions, mode-periods etc. are discussed. Seismic evaluation of the buildings are carried out by Nonlinear static Push over Analysis. The primary objective of the study is to ascertain in which aspects each of the building is strong and weak and what are the effects of various shapes of the structures against seismic and other forces which adversely affect the stability and life of the structures.

2. LITERATURE REVIEW

[1] Fabio Mazza, Engineering Structures 80 (2014) 98–108 –Elsevier presented a paper on "Modeling and nonlinear static analysis of reinforced concrete framed buildings irregular in plan." The aim of this study was to assess the seismic vulnerability directions of reinforced concrete framed building with asymmetric plan, in terms of displacement and strength. The case study selected for this work is the existing town hall of Spilinga , a small town near Vibo Valentia (Italy), which was a two-storey R.C framed structure, with an L-shaped irregular plan. A lumped plasticity model (LPM) with a flat surface modeling (FSM) of the axial load–biaxial bending moment elastic domain of R.C cross-sections is implemented in a computer code for the nonlinear static analysis of R.C spatial framed structures. These finally highlight that, in case of in-plan irregularity, the use of capacity domains revealed essential to estimate the directions of least seismic capacity.

[2] Kai Hu, Yimeng Yang , Suifeng Mu , Ge Qu, Procedia Engineering 31 (2012) 474 – 480 –Elsevier presented a paper on "study on high-rise structure with oblique columns by ETABS, SAP2000, MIDAS/GEN and SATWE." The main objective of this paper was to execute Response spectrum, Time history and Linking slab in-plan stresses analysis combined with a practical project, by using the software programs SAP 2000, MIDAS/GEN and SATWE, which were also compared following the analysis results. The project was located in the Shanghai. The main structure was a 29-storey building, including 3 floors underground and 26 floors above ground. The results given by all softwares were compared and proposes that Slab, as the important lateral force resistant component, should not be ignored in design works, especially to those complex structures, the slabs stress analysis at weaken positions is really essential.

[3] Hendramawat A Safarizki, S.A. Kristiawan, and A. Basuki, Procedia Engineering 54 (2013) 447 – 456 –Elsevier presented a paper on "evaluation of the use of steel bracing to improve seismic performance of reinforced concrete building." The aim of this paper was to evaluate the possible improvement of seismic performance of existing reinforced concrete building (the 5th Building of UNS Engineering Faculty) by the use of steel bracing. Three methods of seismic evaluation were employed for the purpose of the study i.e. Nonlinear Static Pushover Displacement Coefficient Method as described in FEMA 356, Improvement of Nonlinear Static Pushover Displacement Coefficient Method as described in FEMA 440 and Dynamic time history analysis following the Indonesian Code of Seismic Resistance Building (SNI 03-1726-2002) criteria. This paper concluded that Steel bracing could be utilized for seismic retrofitting of the 5th Building of UNS Engineering Faculty. Both nonlinear static pushover analysis based on FEMA 356 and FEMA 440 and dynamic time history analysis confirmed this.

[4] T. Mahdia and V. Bahreini, Procedia Engineering 54 (2013) 341 – 352 – Elsevier presented a paper on "Seismic response of asymmetrical infilled concrete frames." The aim of this paper was to evaluate the nonlinear seismic behavior of intermediate moment-resisting reinforced concrete (RC) space frames with unsymmetrical plan in three, four and five storeyes. Analyses of these buildings were made with and without considering the masonry infill (MI). The major points observed from this study are (1) On comparing uniform and triangular distributions of lateral loads, triangular distributions yield higher values and different vertical load combinations make no significant differences in the results (2) Columns forces in in filled frames are smaller than the corresponding ones in the bare frames (3) Bare frames are more vulnerable than in filled frames etc.

3. METHODOLOGY

Structural design of buildings for seismic loads is primarily concerned with structural safety during major ground motions, but serviceability and the potential for economic loss are also of concern. Seismic loading requires an understanding of the structural performance under large inelastic deformations. Behavior under this loading is fundamentally different from wind or gravity loading, requiring much more detailed analysis to assure acceptable seismic performance beyond the elastic range. Some structural damage can be expected when the building experiences design ground motions because almost all building codes allow inelastic energy dissipation in structural systems. In general, for a multi storey building it is necessary to take into account contributions from more than one mode. Apart from gravity loads, the structure will experience dominant lateral forces of considerable magnitude during earthquake shaking. It is essential to estimate and specify these lateral forces on the structure in order to design the structure to resist an earthquake. It is impossible to exactly determine the earthquake induced lateral forces that are expected to act on the structure during its lifetime. However, considering the consequential effects of earthquake due to eventual failure of the structure, it is important to estimate these forces in a rational and realistic manner.

3.1 Non-linear static Pushover Analysis

In this project the seismic analysis of the structures are carried out by non-linear static pushover analysis. The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. A plot of total base shear versus top displacement in a structure is obtained by this analysis that would indicate a premature failure or weakness. All the beams and columns which reach yield or have experienced crushing and even fracture are identified. A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads that shows the inertial forces which would be experienced by the structure when subjected to ground motion. Under incrementally increasing loads many structural elements may yield sequentially. Therefore, at each event, the structure experiences a decrease in stiffness. Using a nonlinear static pushover analysis, a representative non-linear force displacement relationship can be obtained.

4. DEFINING THE PROBLEM

4. 1 Modeling of Building Frames

Modeling means the formation of structural body in the structure software and assigning the loads to the members as per loading consideration. Here the three R.C.C building frames having G+ 15 storey each are selected to model in ETABS as given below.

Type. A : Square in plan 24m x 24m size at 4m span and 3m storey height.

Type. B : Hexagonal in plan 28m x 32m size (Axes) at 4m span and 3m storey height

Type. C : Octagonal in plan 28m x 28m size (Axes.) at 4m span and 3m storey height.

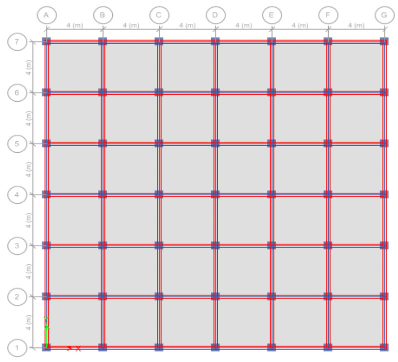

Fig. 4.1 Square plan for Type. A

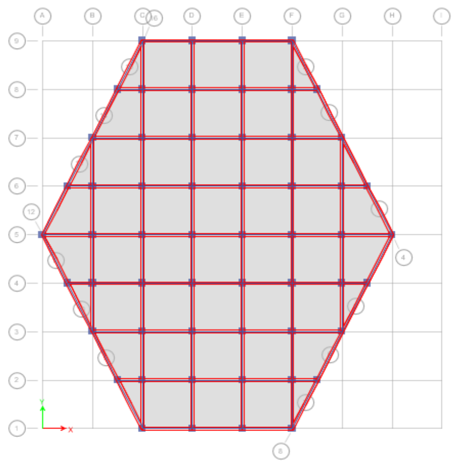

Fig. 4.2 Hexagonal plan for Type. B

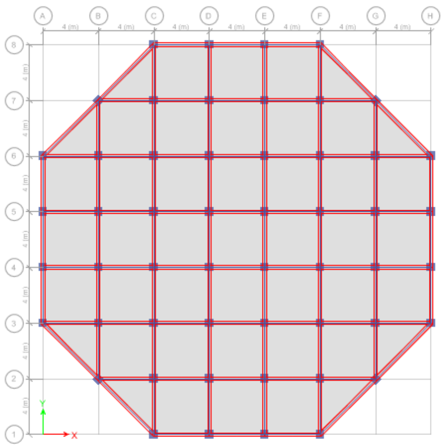

Fig.4.3 Octagonal plan for Type. C

4.1.1 Material and Geometrical properties

Following material properties have been considered in modeling the structures.

Density of RCC	:	25 kN/m^3
Density of Masonry	:	20 kN/m^3
Young's modulus of concrete	:	2x10^4 N/mm^2
Poisson ratio	:	0.17
Depth of foundation	:	2.0 m below ground level
Storey height	:	3.0 m
Height of base	:	2.0 m
Number of storeyes	:	G + 15
Column size	:	600 mm x 600 mm
Beam size	:	250 mm x 450 mm.

Plinth Beam	:	250mm x300 mm
Thickness of slab	:	150 mm
Wall thickness	:	230 mm

The earthquake loads are derived for following seismic parameters as per IS : 1893 (2002)

a. Earth Quake Zone	:	III
b. Response reduction Factor	:	5
c. Importance Factor	:	1.5
d. Damping	:	5%
e. Soil Type	:	Medium soil

5. RESULTS AND DISCUSION

The three types of RCC building frames *viz.*(1) Square, (2) Hexagonal and (3) octagonal with brick wall are analyzed using the software ETABS 2015. The results obtained by the analysis regarding the structural behavior of each building are tabulated and explained as follows.

5.1 Base Reactions

The base reactions in terms of shear force and bending moment of each building frame are given in both tabular and graphical form. From the chart and table it can be seen that the shear force in horizontal X and Y direction is very less in case of square shape and it is maximum in Hexagonal shape. But the shear force in vertical Z direction is very less in case of octagonal building as compared to others. Also Hexagonal model is subjected to maximum shear force.

Table 5.1 Comparison of Base Reactions

ITEM	SQUARE	HEXAGON	OCTAGON
Shear Force (X) in KN	22.4157	25.9443	25.7168
Shear Force (Y) in KN	22.4157	26.1604	25.7168
Shear Force (Z) in KN	1362827.0000	1510571.0000	425816.6039
Bending Moment(X) in KN-m	16394985.0000	24169134.0000	21904784.0000
Bending Moment(Y) in KN-m	415.5969	485.3575	476.3775
Bending Moment(Z) in KN-m	26312.5852	415.1084	23710.3692

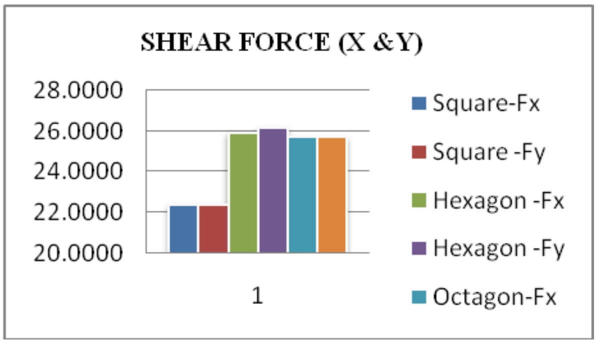

Fig. 5.1 Shear Force in X&Y

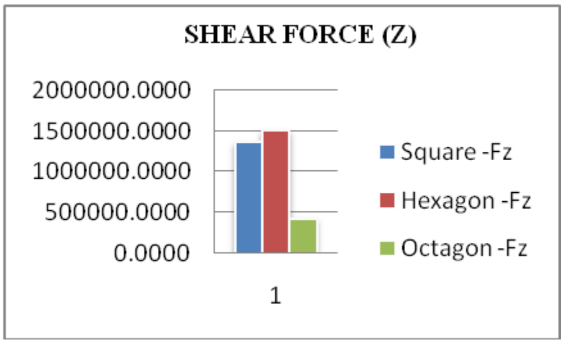

Fig. 5.2 Shear Force in Z

In general the bending moment experienced in both x and Y direction is minimum in case of square building while the maximum occur in hexagon. But in Z direction the bending moment experienced by hexagon is very less as compared to others.

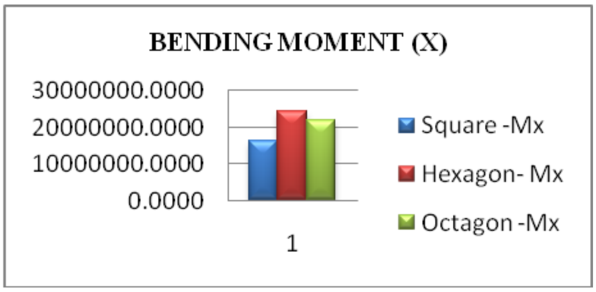

Fig.5.3 Bending Moment in X

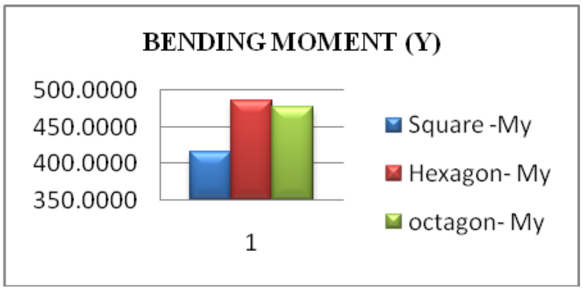

Fig.5.4 Bending Moment in Y

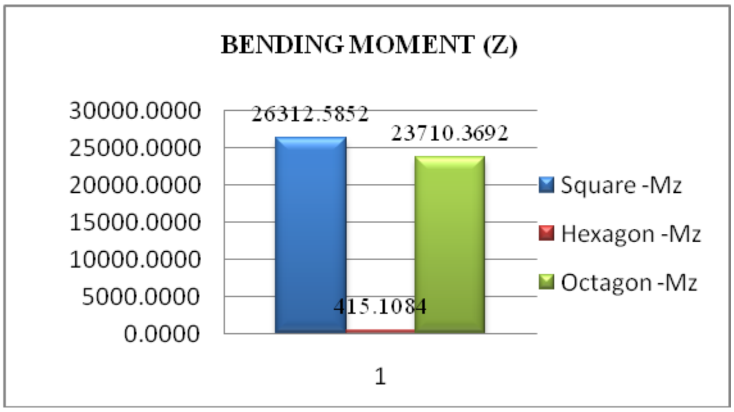

Fig.5.5 Bending Moment in Z

5.2 Column Axial Forces

Considering the maximum forces in all the structures the axial forces exerted in octagonal model is less than the other two. It is 6% excess in square and 0.3% excess in hexagon as compared to Octagon.

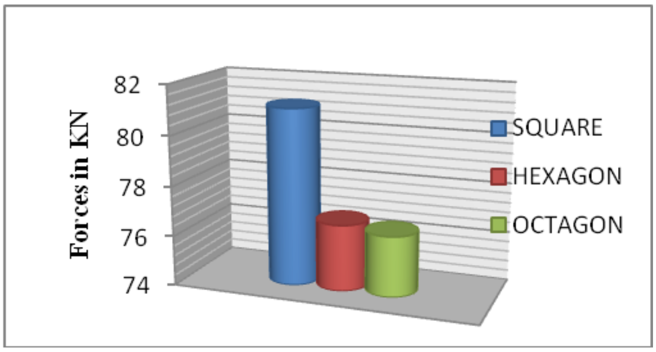

Fig.5.6 Column Axial Forces

5.3 Storey Drift

Storey drift is the comparative displacement of one level of storey relative to the level of the other above or below. From the result it is observed that storey drift is maximum for square model which occur at GF. In each model maximum storey drift occur at GF and 1F. In all directions minimum storey drift is exerted on hexagonal model.

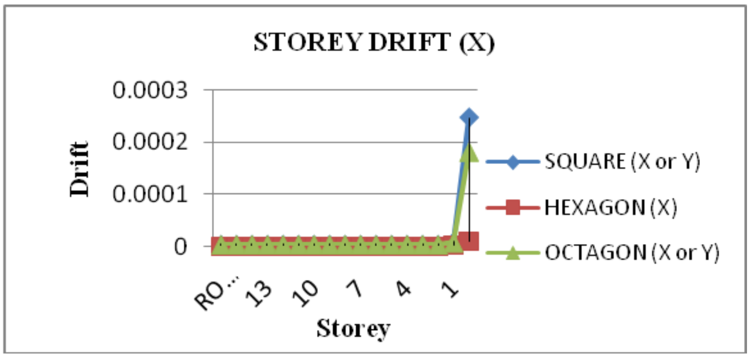

Fig.5.7 Storey Drift (X)

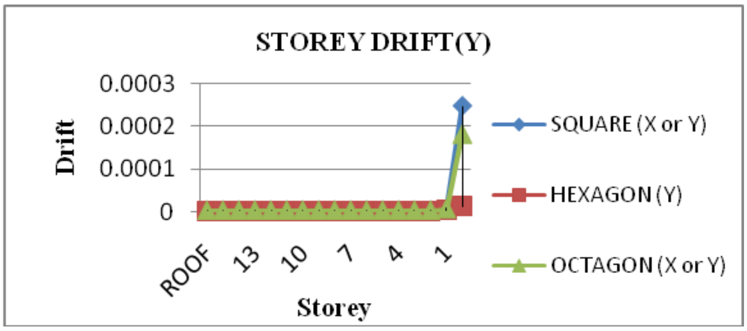

Fig.5.8 Storey Drift (Y)

5.4 Story Stiffness

The maximum value of storey stiffness is observed for hexagonal shape in Y direction. Storey stiffness of octagonal shape is greater than square shape in both the directions. But in X direction octagonal shape posses maximum storey stiffness value as compared to others.

Fig.5.9 Storey Stiffness (X)

Fig.5.10 Storey Stiffness (Y)

5.5 Mode –Period

The minimum time period for all the models is 0.002sec at mode 12, whereas the maximum time period occur at mode 1 which is same for hexagon and octagon, little higher than that of square.

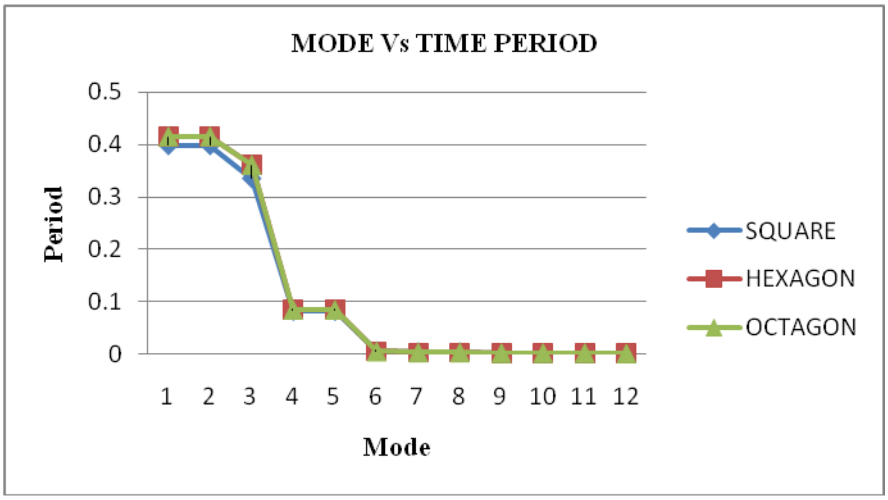

Fig.5.11 Mode Vs Time Period

5.6 Storey Forces

The storey forces exerted on octagonal model is higher than that in the other models. It is about 10.8 to 17.75 percentage more for hexagonal model and 14.45 to 17.78 percent more for octagonal model as compared to square model. But in 9th and 12th floors of hexagonal model it is 1.8percentage less than that in square model.

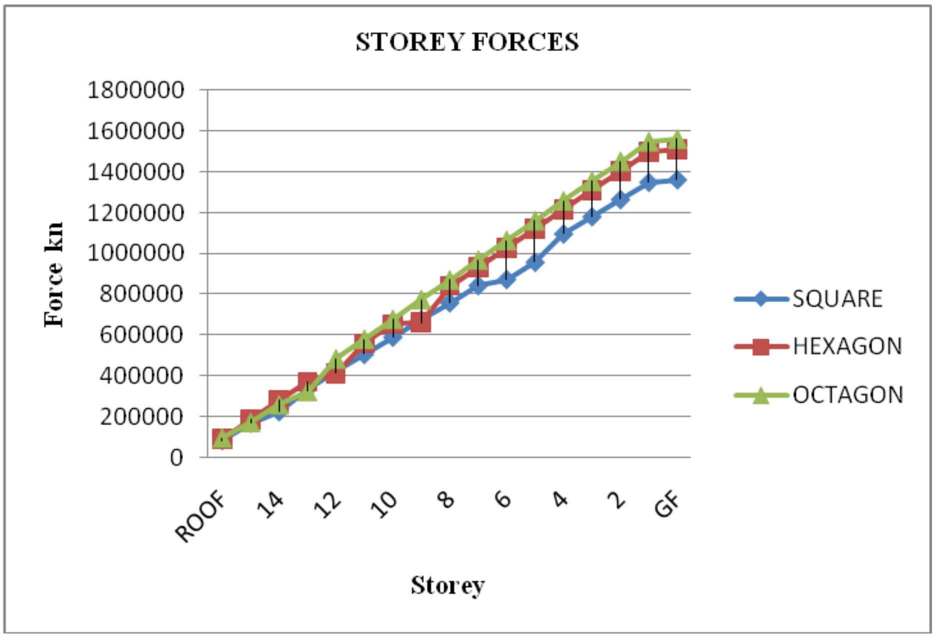

Fig.5.12 Storey Forces

5.7 Pushover Curve

From the push over curve it is observed that minimum displacement occur in hexagonal model for a maximum base force. ie. The Hexagonal model is able to resist more base shear with minimum displacement than that on the other two, under earthquake loading. Square and octagonal model shows almost same behaviour.

Table 5.2 Displacement Vs Base shear

Type	Displacement (mm)	Base Force (KN)
SQR	0.459	148649.3058
HEX	0.00004636	172636.6691
OCT	0.504	170335.0612

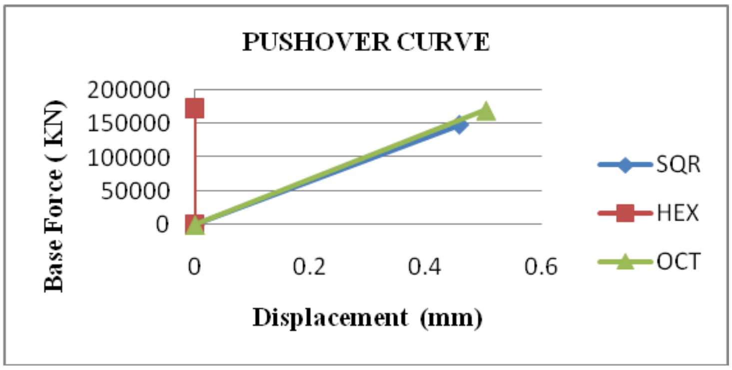

Fig.5.13 Pushover curve

6. CONCLUSIONS

By comparing the analysis results of all the three models so far discussed, the following conclusions are drawn.

- Considering the base reactions Square model performs well. But in Z direction, shear force is minimum in Octagonal model and Bending Moment is minimum in Hexagonal model.
- Column axial forces are very less in Octagonal model as compared to others whereas they are maximum in square models.
- On the basis of storey drift Hexagonal model is the best and square model is poor.
- Regarding the storey stiffness Hexagon is the best in Y direction and Octagon is best X direction.
- On the basis of mode-period Square model is the best. Other models are equal in performance.
- Regarding the storey forces, Square model performs well and Octagon is poor.
- Analysis of Pushover curve reveals that Hexagonal model is able to resist more Base Shear with minimum displacements whereas square is inferior one in performance among the three.

On the basis of the present study it is unable to state that any one of the three models analyzed here is superior to others. Each model posses its own merits and demerits. This study reveals the effect of shape of the structures in resisting the various disturbing forces against their stability. There is further scope for research regarding the most suitable shape of the structure which can resist seismic and other forces effectively. It cannot be predicted that it may be of any conventional shape , but may be a combination of all these three or of any other shapes.

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