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Effect of Eccentricity on Structural Characteristics of a Building

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Abstract—*Eccentricity has been a key issue in the structural functioning and behavior of any building. In the recent past we have seen a large growth in the formation of asymmetric buildings as not only they are functionally sound but also visually challenging and attractive. But the effect of this asymmetric shape of the structure plays a greater role in the analysis and designing part. In the current work an attempt has been made to clearly understand and visualize the effect of eccentricity and asymmetric shape in the performance of the structure. Evaluation is carried out using SAP2000 V14 software of three types of building namely Square-shaped, L-shaped and T-shaped. Area of each floor, storey-height, and total plinth area of all the models are kept same (same seismic mass for all the buildings) for the convenience of comparison. Non-linear Pushover analysis and Linear Time-History analysis have been carried out for all the models and then their performance characteristics such as frequency, mode shape, base shear and inter-storey drift are compared.*

Keywords*: Inter-storey drift ratio (IDR), RC frame, Base shear, Pushover Curve, Stiffness, Frequency.*

1. INTRODUCTION

The problem of structural irregularity has been analyzed in a large number of papers, which pointed out the negative effects of the lack of regularity on the elastic and inelastic seismic response of structures and suggested design approaches able to limit the risks connected to it. Every structure to be erected in a seismic region has to be designed and constructed in such a way to meet with an adequate degree of reliability and specific requirements connected to the return period of seismic action, Ghersi[1].

When a building is subjected to seismic excitation, horizontal inertia forces are generated in the building. The resultant of these forces is assumed to act through the center of mass (C.M) of the structure. The vertical members in the structure resist these forces and the total resultant of these systems of forces act through a point called as center of stiffness (C.S). When the center of mass and center of stiffness does not coincide, eccentricities are developed in the buildings which further generate torsion. When the buildings are subjected to lateral loads, the phenomenon of torsional coupling occurs due to interaction between lateral loads and resistant forces. Torsional coupling generates greater damage in the buildings. Eccentricity may occur due to presence of structural irregularities, S Varadharajan *et. al.*[2]. By reducing the distance between the center of mass and the center of stiffness, torsional effects should be minimized. The stiffness characteristics control the dynamic response of the building structure. The choice of the stiffness characteristics of structures is an important step in the conceptual design phase. The good behavior of the structure can be provided with a well distributed lateral load resisting system. The inelastic seismic behavior of asymmetric-plan buildings is considered by using the histories of base shear and torque (BST), Ladjinovic and Folic[3].

A lack of symmetry produces torsional effects that are sometimes difficult to assess, and can be very adverse. The preferred method of minimizing torsional effects is to select floor plans that are regular and reasonably compact. Complex plan buildings should be divided by seismic separation joints introduced between rectangular blocks. The behavior of buildings during earthquakes will be satisfactory only if all measures are taken to provide a favorable failure mechanism. A special account must be taken so that torsional effects do not endanger or preclude the global ductile behavior of the structure. Buildings with an asymmetric distribution of stiffness and strength in plan undergo coupled lateral and torsional motions during earthquakes. Because of torsion, the seismic demands of asymmetric buildings increase above those required by just translational deformation.

Structural asymmetry can be a major reason for the poor performance of buildings under severe seismic loading. Asymmetry contributes significantly for translational-torsional coupling in the seismic response, which can lead to increased lateral deflections, increased member forces and ultimately collapse. In this paper the inelastic seismic behavior of symmetric and asymmetric multi-storied buildings are studied and the effects of torsion on buildings are investigated, B K Raghuprasad *et. al.*[4].

2. METHODOLOGY

In this research work, SAP 2000 V14 software is used. Various models of RCC frames have been prepared for analysis and design. The building models are named as Square-shaped, L-shaped and T-shaped. Each model consists of four bays of equal areas, 5m X 5m, and are five-storied. The storey-height for all the models are kept same, 3.25m. The size of beams and columns are also kept identical for ease in the purpose of comparison. The reinforcement detailing are also kept similar.

Beams: 250mm X 400mm

Columns: 400mm X 400mm

(with 8 nos. of 25mm dia HYSD bars)

The thickness of slab is kept as 150mm for all the models. M20 grade concrete and Fe415 HYSD rebar is used.

Seismic zone V is considered for the analysis purpose of the structures conforming to IS 1893: 2002. Different load patterns used in the research work are Dead Load, Dead Slab, Dead Wall, Roof Treatment, Floor Finish, Live Load and Roof Live. 13 load combinations are used which are as per the provisions of IS code.

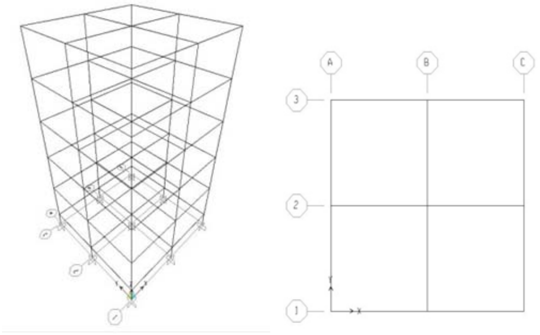

Fig. 1: 3D elevation and plan of square-shaped building.

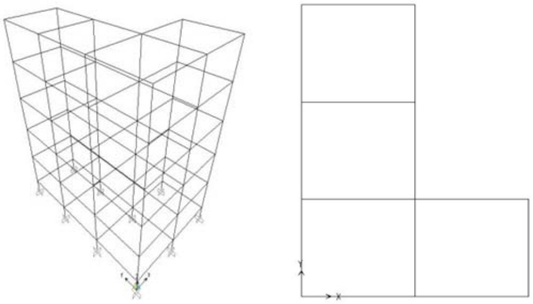

Fig. 2: 3D elevation and plan of L-shaped building.

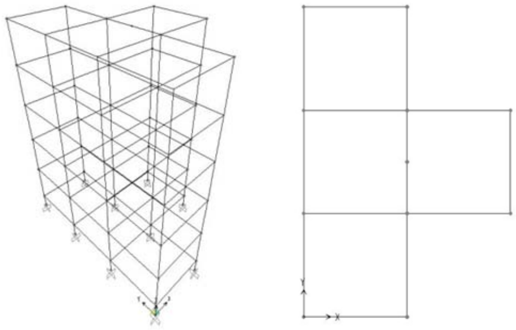

Fig. 3: 3D elevation and plan of T-shaped building.

Table 1: Load Combinations.

Sl. No.	Load Combinations
1	1.2(DL+LL+EQLx)
2	1.2(DL+LL-EQLx)
3	1.2(DL+LL+EQLy)
4	1.2(DL+LL-EQLy)
5	1.5(DL+EQLx)
6	1.5(DL-EQLx)
7	1.5(DL+EQLy)
8	1.5(DL-EQLy)
9	0.9DL+1.5EQLx
10	0.9DL-1.5EQLx
11	0.9DL+1.5EQLy
12	0.9DL-1.5EQLy
13	1.5(DL+LL)

All the models are then analyzed by SAP2000. Static linear analysis is performed to get the results. Then the models are designed by the software conforming to IS 456: 2000. From the modal analysis results, natural time period of vibration of the structures and their natural frequencies are collected and plotted for comparison. Then pushover analysis is done and the performance points of all the models are determined.

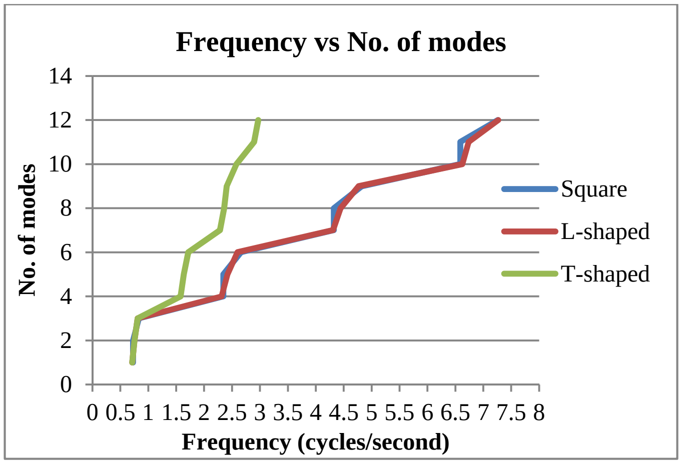

Fig. 4: Frequency vs No. of modes.

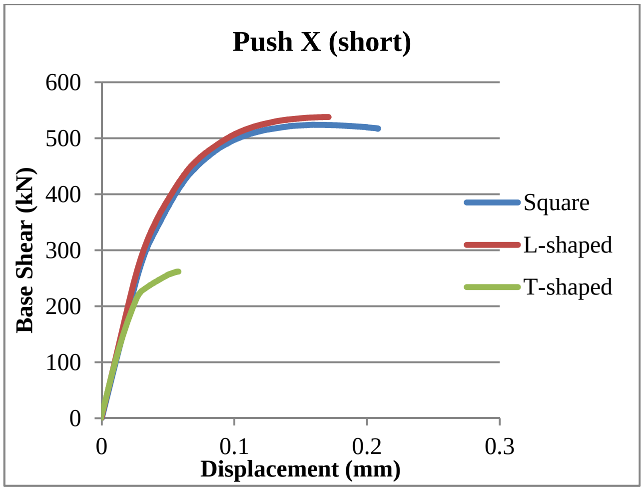

Fig. 5: Pushover Curve in X-axis.

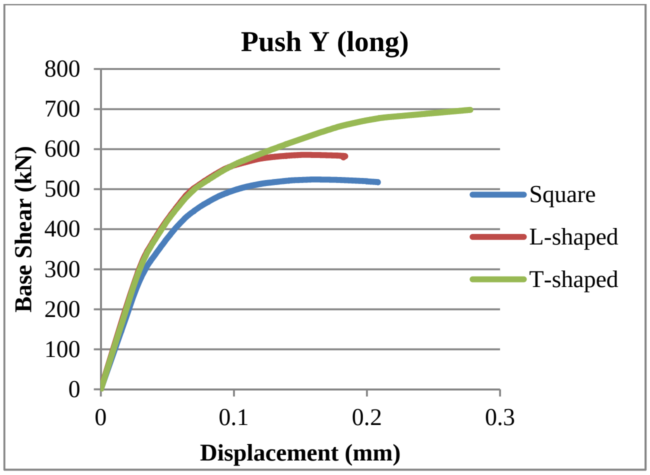

Fig. 6: Pushover Curve in Y-axis.

Then Linear Time-History analysis is carried out using five spectrum compatible ground motions namely Bonds Corner 1979, Cholame 1966, El Centro 1979, Managua 1972 and Mexico 1980 to find the IDR for all the buildings and are compared in the following figures.

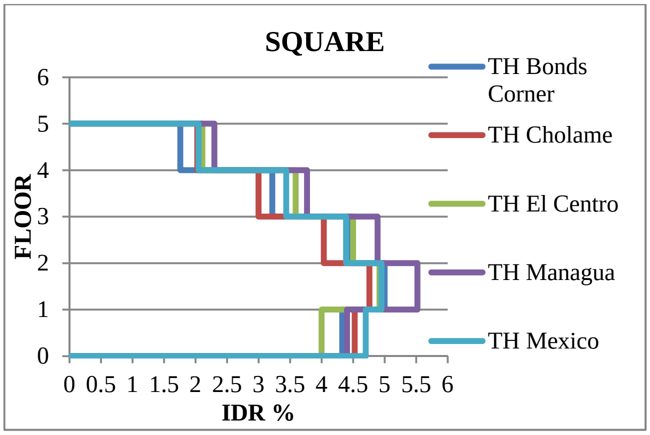

Fig7: Inter-storey drift ratio for square building.

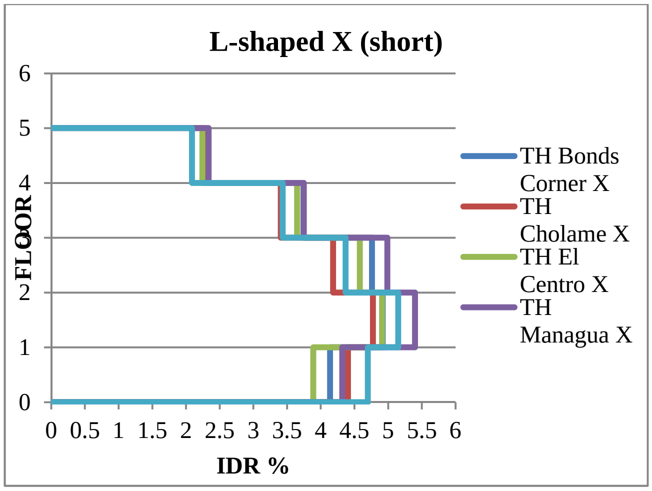

Fig8: Inter-storey drift ratio for L-shaped building in shorter direction.

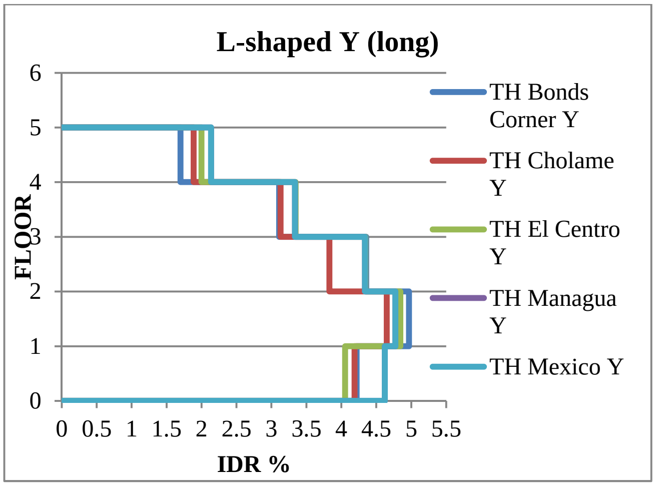

Fig. 9: Inter-storey drift ratio for L-shaped building in longer direction.

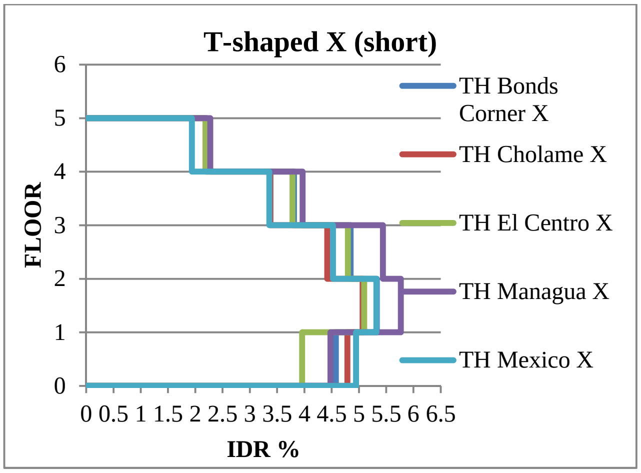

Fig. 10: Inter-storey drift ratio for T-shaped building in shorter direction.

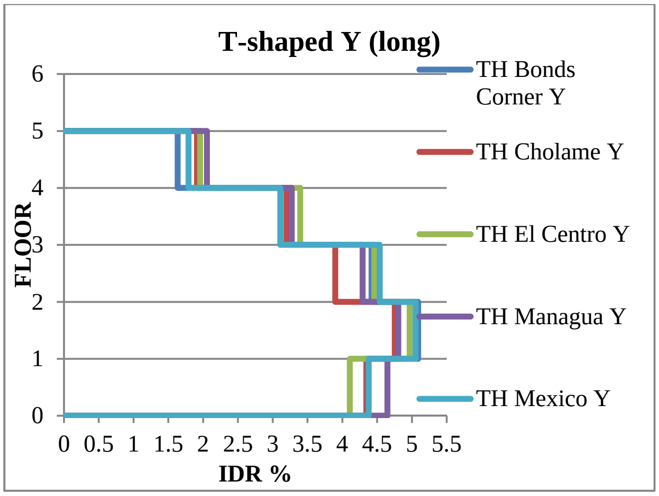

Fig. 11: Inter-storey drift ratio for T-shaped building in longer direction.

3. RESULT AND DISCUSSION

From Fig 5, it can be said that the Square and L-shaped buildings show similar pushover curves in the X direction i.e. the shorter direction but the T-shaped building displays a rather less displacement. While in case of the Y direction i.e. the longer direction the curves are almost similar with L and T shaped buildings having slightly larger base shear than the Square shaped building for same displacement values.

Fig 7-11 shows that the maximum IDR for the Square shaped L-shaped and T-shaped buildings are almost similar, around 5.5% for X-axis i.e. the shorter direction but in case of the longer direction i.e. Y-axis, it is slightly less, around 5%.

4. CONCLUSION

Thus, it can be concluded that for irregular buildings, the shorter direction displays more IDR than the longer direction and is more susceptible to earthquake motions. Further studies can be made using different structural and non-structural elements in the buildings. Non-linear Time-History analysis may be carried out to check the inelastic behavior of the buildings during earthquake.

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