STUDY OF TORSIONAL IRREGULAR MULTISTOREY STRUCTURE UNDER SEISMIC FORCES

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Abstract - *Buildings with irregular configurations are more sensitive to earthquake damage, as evidenced by past and recent earthquakes. To limit the risk of seismic damage, it's critical to research the seismic response of these structures in active seismic zones. Torsion–induced failures are disastrous for multi–story buildings because the torsional reaction of the structure not only alters the uniform translational seismic floor displacement but also causes stress concentration, necessitating higher structural strength and ductility. A structure's susceptibility is caused by plan and vertical imperfections, which make it a prime source of failure during an earthquake. The goal of this research is to gain a thorough understanding of the torsional behavior of building structural systems in asymmetric buildings with torsional irregularity. Because the Centre of mass and rigidity in symmetric structures usually coincide, the torsion effect for such structures is due to accidental eccentricity; however, asymmetric structures have an irregular distribution of mass and stiffness, which causes torsion and is the most important factor influencing the seismic damage of the structure.*

Key Words: Torsional irregularity, Plan asymmetry, Eccentricity, Shear wall core

1.INTRODUCTION

Earthquakes are one of nature's most unpredictable and deadly disasters. Although earthquakes cannot be anticipated or averted, structures should be built to withstand the forces of earthquakes. Main attributes the structure should possess to perform well in earthquake are,

1. SIMPLE AND REGULAR CONFIGURATION
2. ADEQUATE LATERAL STRENGTH
3. STIFFNESS
4. DUCTILITY

So, selection of the structure's basic plan configuration plays a critical role in the structural design. The decision on the conceptual design will influence the ability of the structure to withstand earthquake ground shaking.
The irregularities of the asymmetric distribution of mass, stiffness and strength are main source of severe damages because of excessive floor rotations and translations.
These irregularities are broadly classified into two categories as per IS 1893 (2016) which are as below,

1. PLAN IRREGULARITIES
- Torsional irregularity
- Re-entrant corners
- Floor slabs with excessive openings or cut-outs
- Out-of-plane offset in vertical elements
- Non-parallel lateral force resisting system
2. Vertical irregularities
- Stiffness irregularity (soft storey)
- Mass irregularity
- Vertical geometric irregularity
- In plane discontinuity in vertical elements resisting lateral force
- Strength irregularity (weak storey)
- Floating or stub column
- Irregular modes of oscillations in two principal plan directions

Even under solely translational ground shaking, the lateral-torsional coupling caused by eccentricity between the centre of mass (CM) and the centre of rigidity (CR) in asymmetric building systems creates torsional vibration. The inertia force acts through the centre of mass during seismic shaking of structural systems, while the resistive force acts through the centre of stiffness, as shown in Fig.

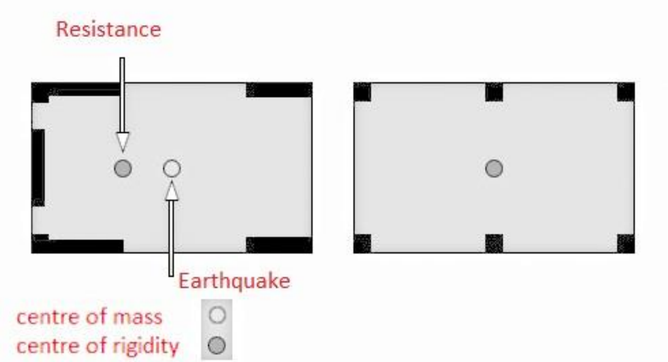

Fig -1: Centre of mass and rigidity

1.1 AS PER IS CODE 1893 (PART 1) – 2016

a) Any floor's greatest horizontal displacement in the direction of lateral force at one end is more than 1.5 times the floor's minimum horizontal displacement in that direction at the other end.

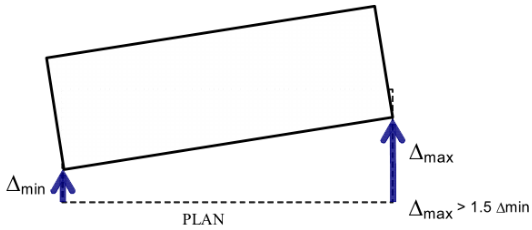

Fig -2: Torsional irregularity

b) The fundamental torsional mode of oscillation has a longer natural period than the first two translational modes of oscillation in each primary direction.

1.2 AS PER ASCE 7-05

When the maximum storey drift at one end of the structure transverse to an axis is more than 1.2 times the average of the storey drift (or inter-story drifts) at the two ends of the structure, torsion should be addressed. The storey drift (or inter-story drifts) at the two extremities of the structure are Δ 1 and Δ 2, respectively, and then θ is the torsion parameter criterion.

$$\theta = \Delta_2 / \frac{\Delta 1 + \Delta 2}{2}$$

2. OBJECTIVES

The principal objective of the present work is to study the seismic response of irregular R.C. multi-story buildings which are located in earthquake zone (IV) and having medium soil type (II) in India using response spectrum analysis.

1) To study the seismic response of R.C. multi-story building with torsional irregularity using response spectrum analysis.
2) To evaluate the effect of shear wall location in plan on seismic response of the structure.
3) To compare the seismic response of the building in terms of natural time period, base shear, ratio of maximum to minimum displacement of a floor, inter story drift and story lateral displacement.
4) To identify the most efficient configuration of the building among the considered models.

3. RELATED WORK

The torsional effect of multi-story structures has been the subject of numerous scientific studies. Vipin Gupta and Dr. P.S. Pajgade gave an overview of the research done on the torsional behavior of multistory buildings with plan and vertical irregularities. It also focuses on torsion-related codal provisions. They found from their review that torsion is the most essential element leading to major damage or complete collapse of a building; consequently, symmetric buildings should be assessed for torsion as well. As a result, buildings should be constructed with both intentional and unintentional quirkiness in mind. It was discovered that irregular profile structures experienced greater stresses and displacement than regular profile buildings. Because structures are never totally regular, designers must regularly assess the likely degree of irregularity and the impact of this irregularity on the structure during an earthquake.

The conditions that cause the torsional irregularity coefficient to reach the upper bound value of 2 are examined by Gunay Ozmen. The behavior of a series of eight walled and framed sample structures with various structural shear wall arrangements was studied under earthquake loading. The torsional irregularity coefficient was found to be highest when the number of axes and stories were both low. The coefficient was also found to be highest when structural barriers were placed as close to the gravity centers as possible without coinciding with them.

Amin Alavi et al. attempted to model the seismic response of RC buildings with re-entrant corners in high seismic zones for various locations of shear walls. They looked at a five-story structure with six shear wall positions. They took into account the torsion of both negative and positive X and Y directions by mistake. The findings showed that irregular structures are more fragile, and that eccentricities between the center of mass and the center of resistance had a greater impact on the torsional behavior of structures during an earthquake.

4. SEISMIC ANALYSIS OF STRUCTURE

Seismic analysis is a branch of structural analysis that involves calculating a structure's response to earthquakes. In earthquake-prone areas, it is a part of the structural design, earthquake engineering, or structural assessment process.

1)Equivalent Static analysis

Only regular structures with limited height can be subjected to linear static analysis or comparable static analysis. The dynamic character of seismic loads must be considered in every seismic design. Analyzing simple regular structures with analogous linear static methods, on the other hand, is frequently sufficient. Most codes of practice for normal, low- to medium-rise buildings allow this. It starts with a calculation of the base shear load and its distribution on each level using the code's calculations. The total horizontal force on the structure is computed using the mass of the structure, the basic period of vibration, and the related mode shape.

2) Response spectrum analysis

During earthquake ground motions, it is a representation of the maximum reaction of an idealized single degree of freedom system with a given period and damping. For various damping values, the maximum response can be described in terms of maximum absolute acceleration, maximum relative velocity, or maximum relative displacement plotted against undamped natural time. The response spectrum case of analysis was performed in accordance with IS 1893 for this purpose. The structure should be represented by an analytical or computer model in the calculation of structural response (whether modal analysis or otherwise), so that reasonable and sensible findings may be obtained by its behavior.

3) Non-linear static analysis

Push-over analysis is another name for this procedure. In the sense that it allows for inelastic behavior of the structure, this method is superior than linear static and dynamic analysis. The technique continues to assume a set of static incremental lateral loads across the structure's height. It gives data on the structure's strength, deformation, and ductility, as well as the distribution of demands. This allows for the identification of important members that are likely to approach limit states during an earthquake and should be addressed during the design and detailing process. A static nonlinear study of a structure under permanent vertical loads and gradually increasing lateral stresses is known as a pushover analysis.

4) Non-linear dynamic analysis

The real behavior of the structure during an earthquake is described by a non-linear dynamic analysis or inelastic time history analysis. The method is based on direct numerical integration of the motion differential equations while taking into account the structure element's elastoplastic deformation. As the level climbs from bottom to top, this method captures the influence of amplification owing to resonance, the variety of displacements at various levels of a frame, an increase in motion duration, and a desire of regularization of movements.

5. DETAILS OF THE STRUCTURES

Storey height- 4.0 meters
Column1- 9X30 inches
Column2- 12X30 inches
Column3- 35X35 inches
Column4- 12X32 inches
Beam- 9X15 inches
Shear wall- 9 inches
Lift pardi- 6 inches

The Figures below shows the plan of the trials of structures that are taken into consideration for the torsional analysis. Wall load is considered as 6KN/m. Earthquake load is defined as per IS 1893 (2016). The seismic details of the structures are tabulated as below.

Type of structures	Multi-storey RC building	
Number of Stories	G+10	
Materials	Concrete	M30
	Reinforcing bar	Fe500
Slab section	Slab	150mm
Zonal considerations	Zone	IV
	Zone factor	0.24
	Soil type	II
	Importance factor	1
	Reduction factor	5
Live load	3 KN/m2	

Table -1: Seismic details of the structures

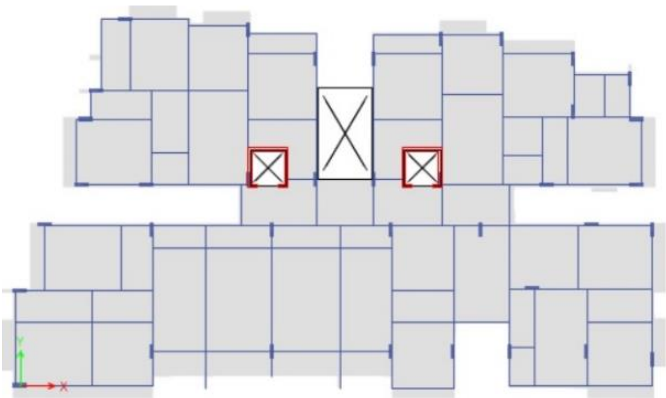

Fig -3: Model 1

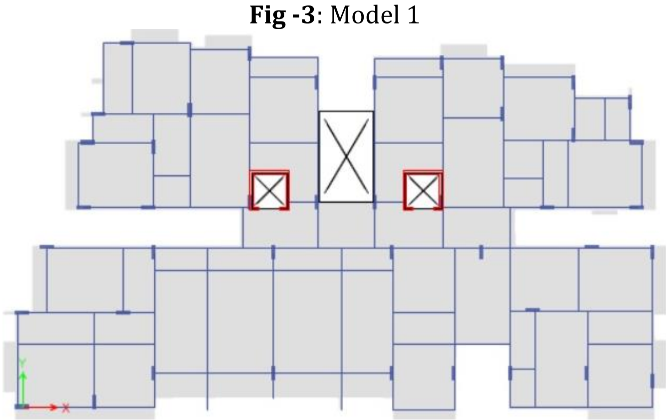

Fig -4: Model 2

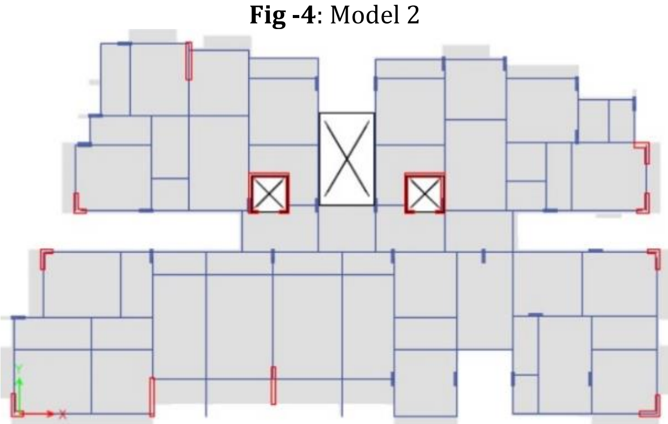

Fig -5: Model 3

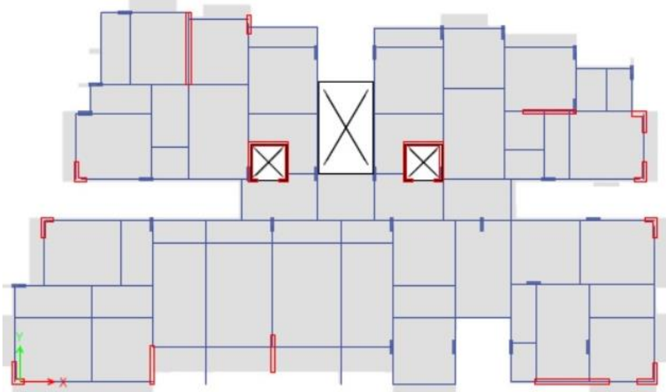

Fig -6: Model 4

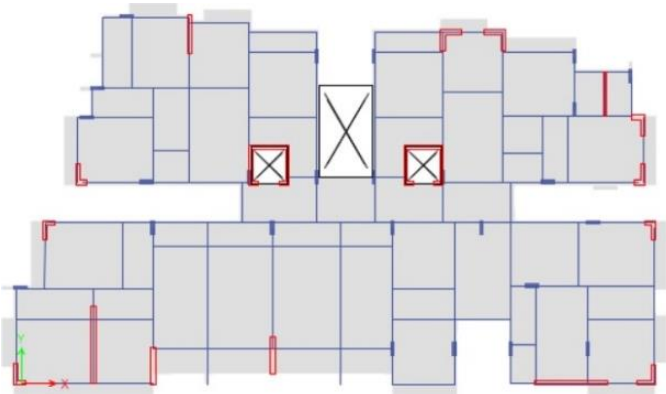

Fig -7: Model 5

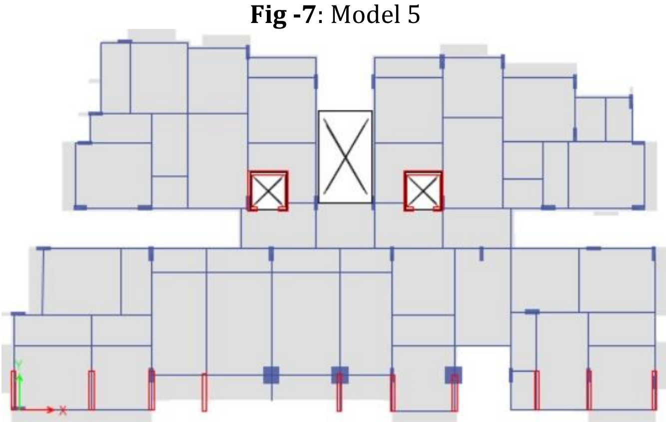

Fig -8: Model 6

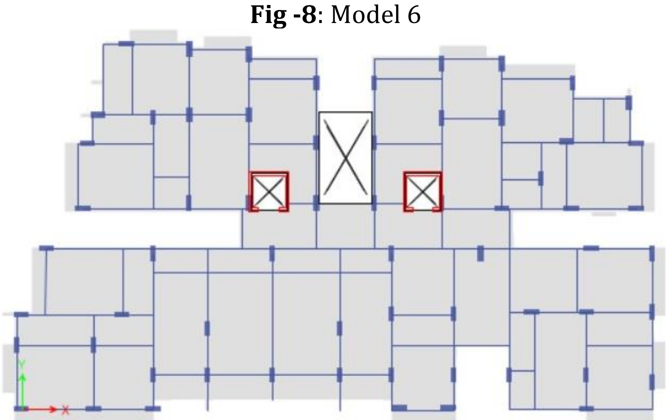

Fig -9: Model 7

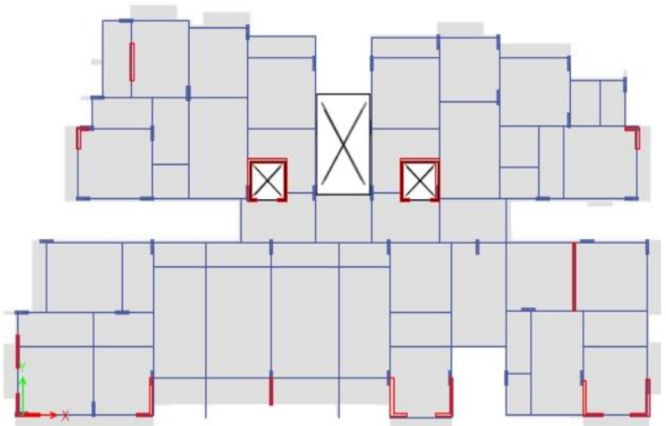

Fig -10: Model 8

6. RESULTS AND DISCUSSION

The response spectrum analysis for the models have been carried out using ETABS 2018 software. The seismic details were incorporated in accordance to the IS code 1893:2016. The torsional irregularity has been found in reference to IS CODE 1893:2016. On the basis of several torsion characteristics, the analysis was carried out in order to determine the most torsional irregular structure.

6.1 MODES

The twenty mode numbers versus the natural period of vibration are presented in Figure 4.10. The model 1 has shown the maximum natural period of 1.734 seconds and the lowest is found for the strengthened structure (model 8) with 1.045 seconds, implying that the Structures with a longer period of vibration are less resistant to earthquakes. The model 1 has longer period of vibration because it is flexible (smaller stiffness k), no stiff elements are introduced for the model 1 i.e., staircase load, shear wall etc, which in turn increases its flexibility whereas in case of Model 8 stiff elements like shear walls have been introduced near the edges of the structure and thus it is less flexible and will show high resistance to seismic actions. It is noted that more flexible longer period design may be expected to experience proportionately lesser accelerations than a stiffer building.

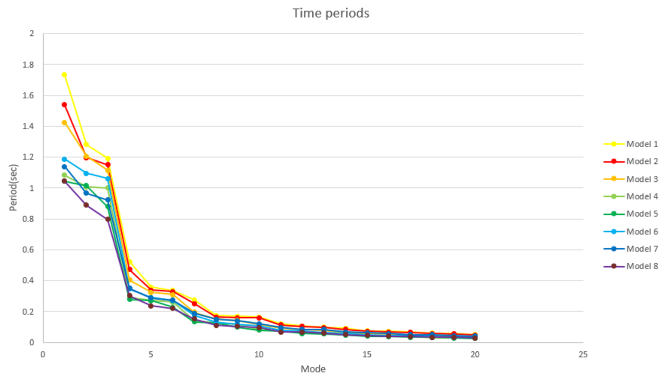

Fig -11: Natural periods of vibration

6.2 ECCENTRICITY

Larger the eccentricity between the centre of rigidity and centre of mass, larger will be the torsional effect. While comparing X and Y direction Model 1 have got more torsional tendency. It is because of the eccentricity between the load and the resistance, the floor experiences rotation along with translation, which in turn requires more strength and ductility at certain part of the structure.

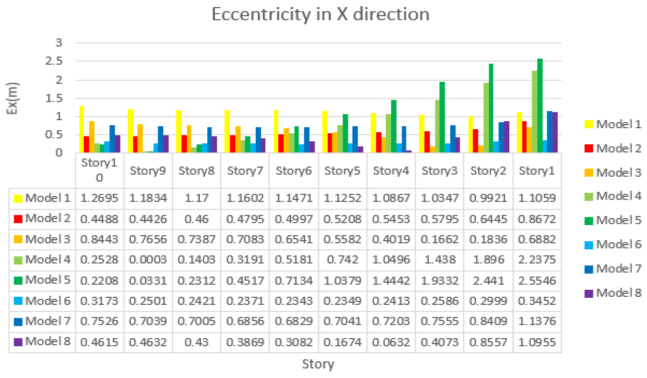

Chart -1: Eccentricity in X direction

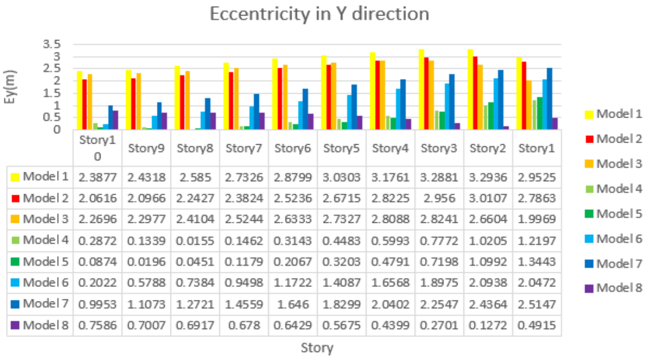

Chart -2: Eccentricity in Y direction

6.3 TORSIONAL IRREGULARITY

The torsional irregularity or ratio of maximum to minimum displacement for different stories of models 1 to 8 are shown in Figure below. From the graph it is evident that structures which have shear wall located on edges and having minimum eccentricities has got least percentage of variation of maximum to minimum displacement ratio. Asymmetric structure with shear wall core near centre of mass but not coinciding with centre of mass exhibited maximum drift ratios and indicates it has got higher degree of irregularity. Therefore, strengthening has been carried out for the same. Models 4, 5 and 8 exhibited almost same range of irregularity. In case of model 1, 2 and 7 no shear walls (except lift core) were introduced which in turn made the structure to have unequal mass and stiffness distribution. By introducing shear walls for the Model 4, 5 and 8 it is seen that the torsional irregularity ratio has decreased tremendously due to the introduction of stiff elements which are capable of holding the structure against twisting or torsion and also it came within the code suggested ratio of 1.5.

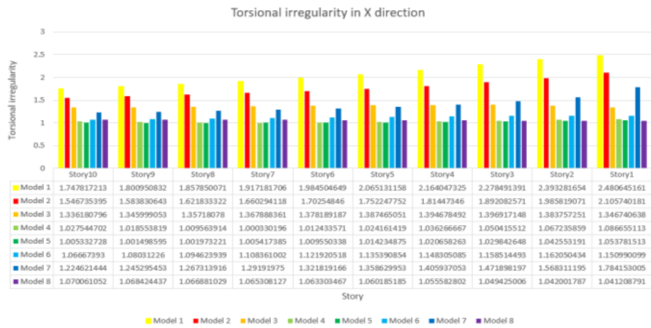

Chart -3: Torsional irregularity in X direction

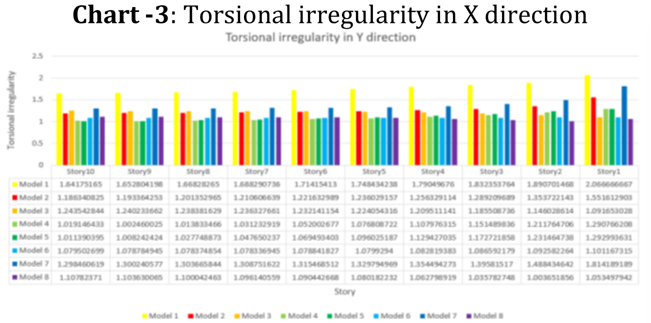

Chart -4: Torsional irregularity in Y direction

6.4 DRIFT

IS 1893:2016 Cl 7.11.1 suggests that the drift values should not exceed the permissible drift range. Along X and Y directions model 1 has got higher drift value in all stories when compared with other structures. It has got the value of 0.00169 in the fourth storey in X direction and 0.00165 in fourth storey in Y direction and hence the structure has a got a drift value which is within the limits prescribed by the code. The highest acceptable drift value is 0.004H, where H is the storey height (H=4m) and the permissible drift value is 0.016, according to the code.

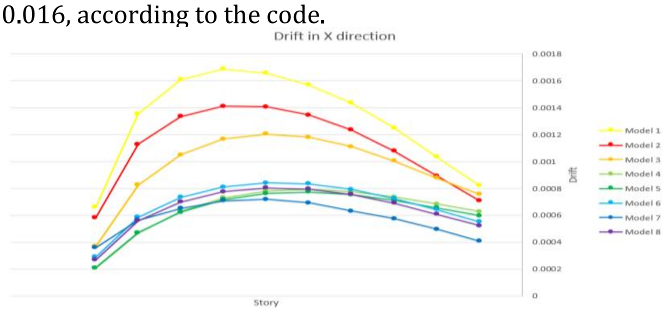

Chart -5: Drift in X direction

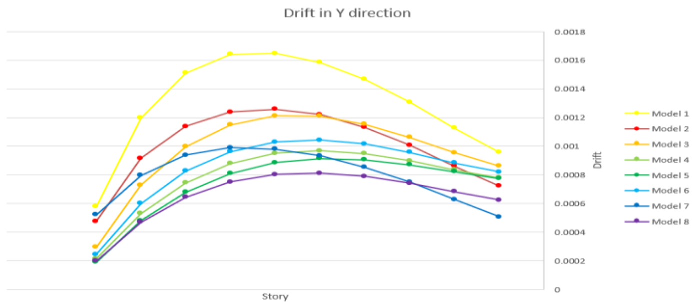

Chart -6: Drift in Y direction

6.5 STOREY DISPLACEMENT

The storey displacements of all the five models are represented below. It shows an increase in storey displacement along the height of the structure. Model 1 shows the maximum displacement along X direction followed by model 2, 3, 6, 7, 8 and model 5, 4. The strengthened model 5 shows minimum displacement indicating the stiffness has increased.

Storey displacement is the predicted movement of a structure under lateral loads, in medium and high-rise structures, the higher the axial forces and deformations in the column and the accumulation of their effects over a greater height, all these causes the flexural component to become dominant. There is also floor rotation for displacement in addition to translational motion.

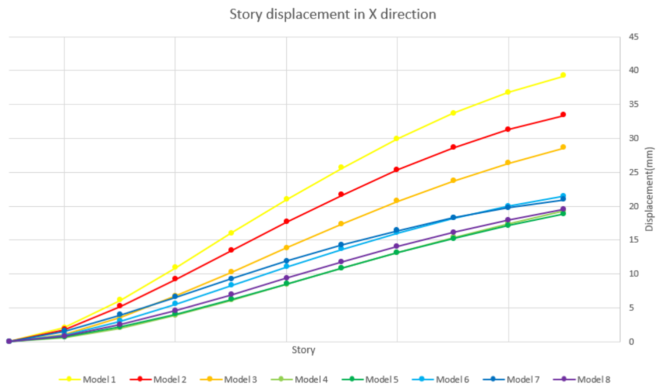

Chart -7: Displacements in X direction

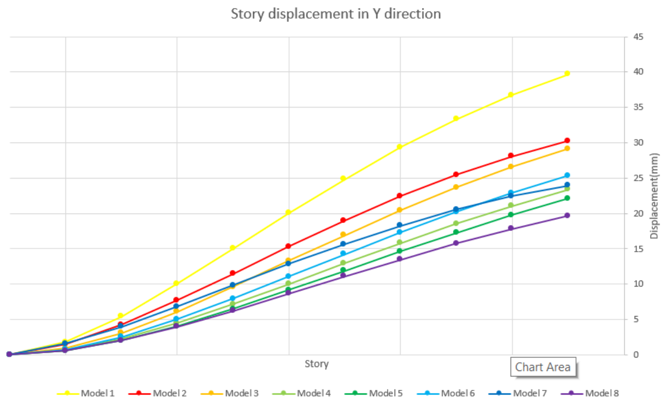

Chart -8: Displacements in Y direction

7. CONCLUSIONS

1. Because there is no stiffness change in symmetrical type buildings, the local zone has no effect on torsional irregularity in symmetrical structures. Furthermore, local zones have an identical impact on each floor.
2. In the event of a non-symmetric construction, local zones have an impact on torsional irregularity.
3. The eccentricities are lower on the top floors, but rise as we descend.
4. Torsional irregularity is maximized when shear walls are placed as close to the center of mass as feasible without colliding with it.
5. Torsional irregularity can also be decreased by lowering the stiffness of structural walls in the middle.

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