A Study on Optimizing the Positioning of Shear Walls for a Plus Shaped Irregular Building

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Abstract - *Due to the presence of irregularities in plan, re-entrant corner and torsional irregularity analyzed by engineers, which have maximum influence on the seismic response. U, H, V, E, and plus-shaped buildings build as per architecture requirement, the re-entrant corners have suffered severe damage. These types of buildings separated into parts to reduce the ill-effect of re-entrant corners. Especially in plus-shaped tall, multistoried buildings, re-entrant corners are more critical as they go beyond the code specified limits. Shear walls in high seismic regions require special detailing and the positioning of shear walls influences the performance of the structure under dynamic loading. Without altering the specifications of a shear wall, only changing the positions of shear walls for this plus shaped building can do wonders. A ten storied plus-shaped structure with longer wings has more chance to tear away from the corner and is prone to dog-tail wagging movement. Shear walls provided at the central core, edges of the flange, and at re-entrant corners to examine which condition performs best. Introducing shear walls at re-entrant corners can resist the harmful effect that arises from these irregularities.*

Key Words: re-entrant corner, shear wall, horizontal irregularity, displacement, storey drift

1.INTRODUCTION

An irregular structure is formed to enhance the utility also as aesthetics of the structure because of architectural requirements or land shapes that are too costly to waste, despite its structural vulnerabilities due to ground movement. Irregular structures, especially those located in high seismic zones, particular care is to be taken for their seismic responses. The presence of re-entrant corners produces the variation of rigidity which results in different relative movements between building parts separated by re-entrant corners [1]. An irregular building will never perform satisfactorily in an earthquake as against a building with regular configuration, despite strictly following codes for analyzing such structures [2].

A complex architectural plan of a multistoried building structure [3], undergoes severe damages and loss of life due to the impact of lateral forces during earthquakes. The magnitudes of variation in seismic responses depend on the type, degree, and the location of irregularities present. A building with asymmetry, shows maximum storey drift, and displacement [4]. The huge devastating effect on people and structures during the past few earthquakes has exposed deficiencies and loopholes in the study and construction processes of Earthquake Engineering. Design Codes have changed considering those analysis, last modified Indian Standard code used is IS 1893:2016, Criteria for Earthquake Resistance Design of Structures with a new amendment 2, 2020 [5].

Three plus-shaped ten storied building structure models at zone V with different positioning of shear walls are analyzed using the response spectrum method of dynamic analysis to understand various seismic responses. The purpose of this study is to investigate these irregular structures with different positioning of shear walls [6] using the response spectrum method and to compare parameters from the result obtained using graphs and tables. This study aims to find the optimum locations for placement of shear walls for a plus shaped building with extreme re-entrant corner irregularity [7], each structure studied individually. The effect of the different locational placement of shear walls on the torsional properties for this irregular building has studied. The Bureau of Indian Standards has recently published a new amendment [5], with major revisions on the irregularity of building, which is taken into consideration and not many researchers have worked with the criteria recommended on this code.

2. METHODOLOGY

The shear walls are continued up to the roof from the foundation following the same load path and well connected to the moment-resisting frame with beam and column members. As this building is plus shaped and requires extensive application of shear walls in several locations to resist irregularity in the plan, the positions of shear walls are altered and analyzed for responses on the wing frames. Shear walls are provided symmetrically along the periphery or as a core [8, 9, 10]. No door or window openings in the shear wall are considered for simulation but openings of small size can provide symmetrically. As the building is irregular, linear dynamic analysis by the Response spectrum method [1, 11] has adopted.

For this study, a 10-storey building is taken and modelled with three types of arrangements of shear walls. Major assumptions considered [12, 13, 14] for the analysis of these structures are given in Table 1.

Table -1: Building General Specification

Number of storeys	10
Column Size (External)	0.4mx0.8m
Column Size (Internal)	0.4mx1.0m
Size of beam	0.3mx0.5m
Base Support	Fixed
Thickness of Slabs	150 mm
Thickness of Shear wall	200 mm
Height of each floor	3.0 m
Floor finish	1kN/m2
Partition Walls	1kN/m2
Live Load	3 kN/m2
Seismic Zone	V
Soil Condition	Medium
Software Used	STAAD. Pro Connect Edition

Design acceleration coefficient for zone V and medium soil [15] corresponding to natural period of the structure, considering 5 percent damping, is shown in Fig. 1 used by the program. For this un-normalized spectrum, the scale factor is initially provided as 1 and corrected afterward comparing calculated base shear from response spectrum method with the base shear calculated by empirical formula.

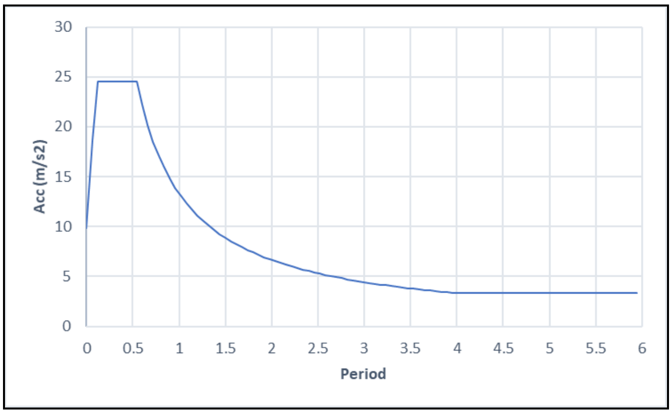

Fig. 1: Response spectrum for zone V medium soil corresponding to 5 percent damping

Three models, shown in Fig. 1, Fig.2, Fig. 3 with different arrangement of shear walls is considered, one is with shear wall at edges and another one is with shear walls at core and edges and the third one is with shear walls at edges and at re-entrant corners.

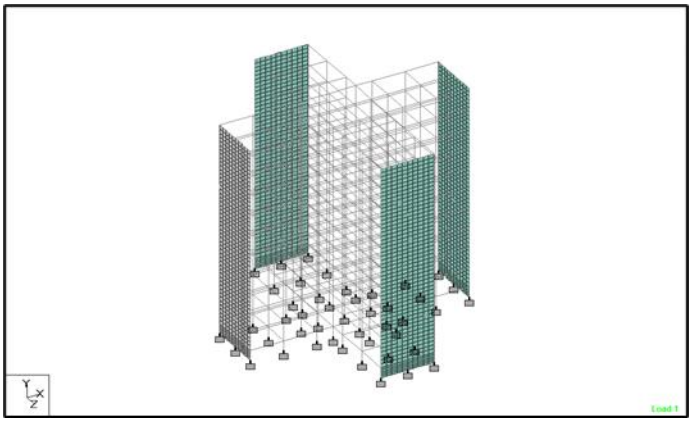

Fig.2: 3D model of the structure with shear wall at edges (Model 1)

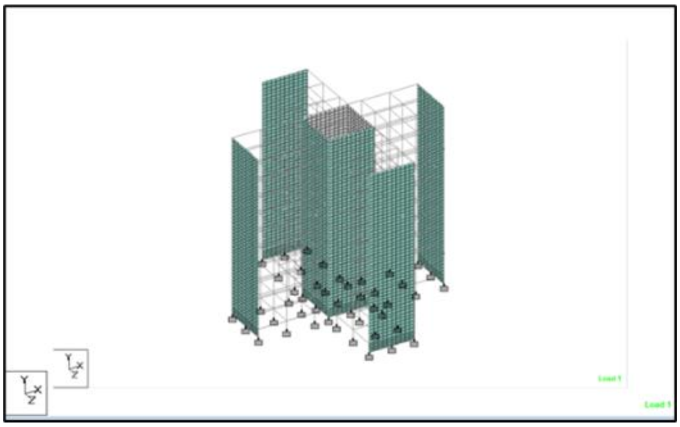

Fig. 3: 3D model of the structure with shear wall at core and edges (Model 2)

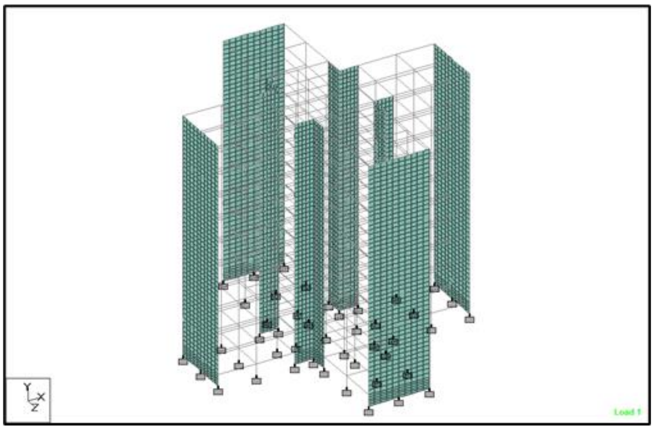

Fig. 4: 3D model of the structure with shear wall at edges and re-entrant corners (Model 3)

Using STAAD. Pro software, above mentioned structures using the plan dimensions shown in Fig. 5, are analyzed by dynamic analysis using response spectrum method considering all recommendations for seismic zone V by IS 1893 to get seismic performances [16].

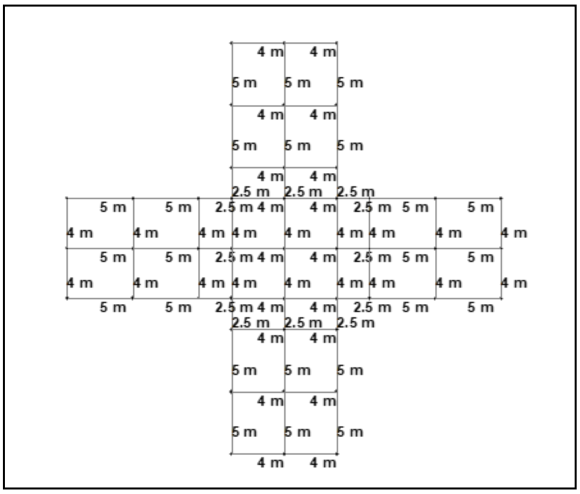

Fig. 5: Plan dimensions of structures

3. RESULTS AND DISCUSSION

3.1 Storey Drift

L/250, i.e., 0.002 in Fig. 6 is that the maximum permissible drift ratio and all models have passed this. Values gradually increase from lower to higher stories.

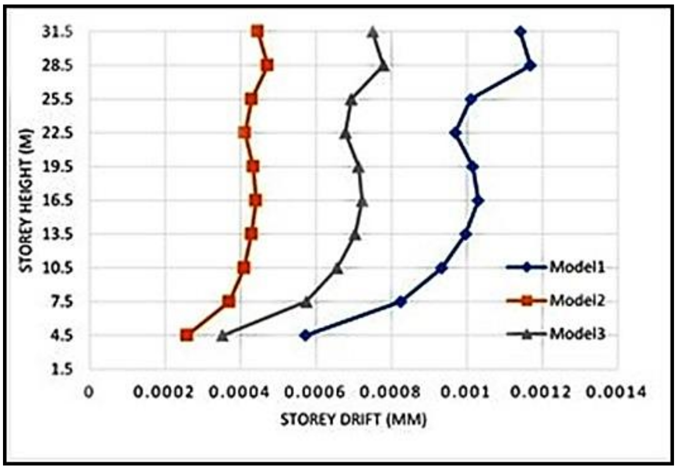

Fig. 6: Inter storey drift

3.2 Maximum Displacement

The maximum displacement of joints values for three orthogonal axes (X, Y, and Z directions) are shown in Fig. 7. It is clear from the chart that the system used in model 1 exhibit higher maximum displacement values as others are designed with a core wall and another with shear wall at re-entrant corners, restricts them to deflect more.

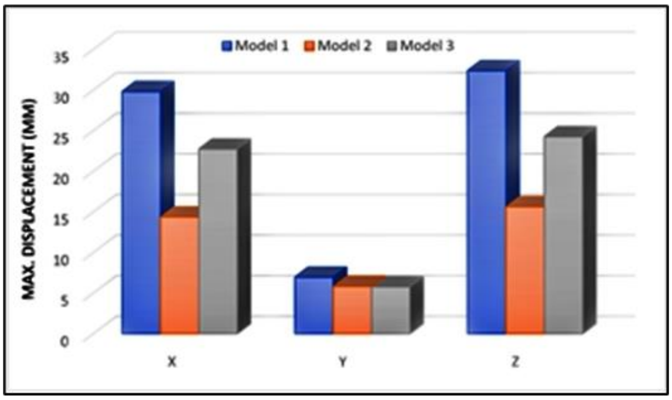

Fig. 7: Maximum displacement for three orthogonal axes

3.3 Maximum absolute displacement

From the roof wise displacement values, it is clear from the Fig. 8 shown below, that the displacement value of model 2 is almost 44% and 64% in comparison to the highest displacement values of model 1 and model 3 respectively for 10th storey.

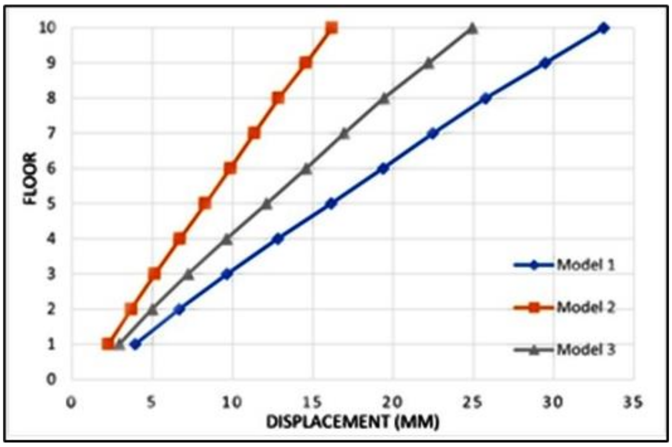

Fig. 8: Maximum displacement floor wise

3.4 Torsional Moment

The structure is symmetrical in the plan but irregular in shape. Accidental torsion results from uncertainty in the distribution of mass and stiffness and arises from the rotational component of seismic excitation represented in Fig. 9. As the structure is symmetrical about axes and shear walls are placed symmetrically, the center of rigidity and center of mass almost coincide. The structure found safe in respect of torsional irregularity conforms to the latest amendment 2, revised November, 2020 of the IS code 1893(Part-I) 2016.

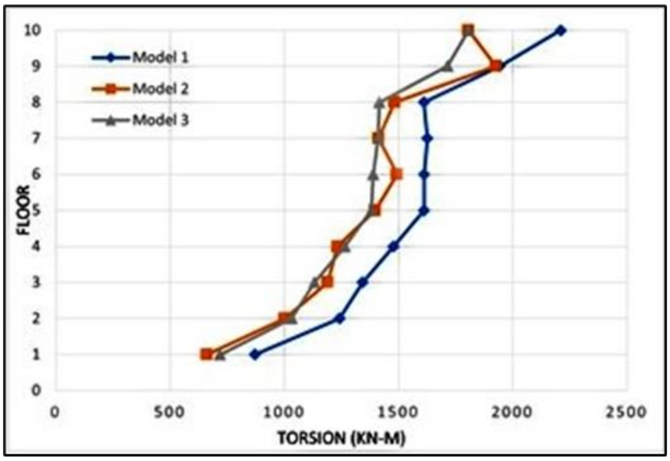

Fig. 1: Torsional moment floor wise

3.5 Lateral stiffness

Lateral stiffness for the whole structure is analysed and plotted to check stiffness of the structure [17] for X and Z direction It is clear from Fig. 10, that the model 2 is stiffer than others.

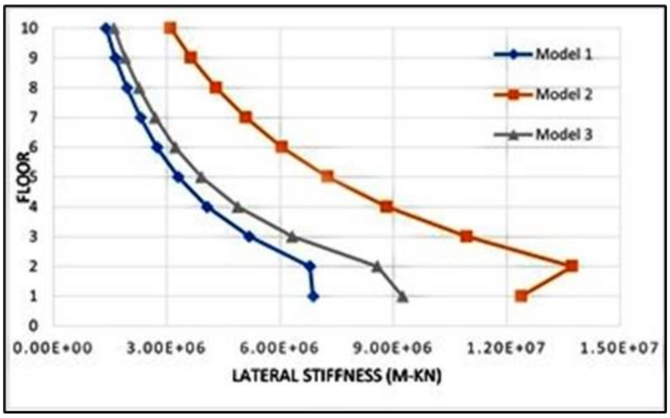

Fig. 2: Floor wise stiffness values

3.6 Period for first translational and torsional mode

The periodic oscillation can be judged by the periods corresponding to natural frequencies for each mode [18]. The periods for each mode are furnished in Table 2.

Table 2: Period for first three modes

Model No.	Shear wall position	Mo-de	Frequen-cy in Hz	Peri-od in s	Direction
1	At edges of four wings	1	1.382	0.724	X(Translation)
		2	1.512	0.661	Y(Translation)
		3	2.251	0.444	(Rotational)
2	At core and edges of four wings	1	2.069	0.483	X(Translation)
		2	2.163	0.462	Y(Translation)
		3	2.872	0.348	(Rotational)
3	At reentrant corners and four	1	1.960	0.668	X(Translation)
		2	1.603	0.624	Y(Translation)
		3	2.282	0.638	(Rotational)

4. CONCLUSIONS

Though all models are considered with extreme irregularity, comparing with the criterion based on the latest amendment of the code in terms of re-entrant corners or torsion, all three models are performed well. All structures are modeled with shear walls at various locations, following mandatory criterion of the code for zone V. Skillfully choosing the positions of shear walls can make a difference in the performance of structures. Storey displacements are found low for model 2, with shear walls at the core and edges, as well as this structure exhibits extremely high values of stiffness and low flexibility. It is performed better in storey drift showing almost equal drifts for all floors. Model 1 exhibits high flexibility in comparison with the other two models, shows higher values of periods. Model 2, where shear walls are placed at the core and along edges, performs better.

The model with shear walls at edges and at re-entrant corners showing lower values for torsional moments. Torsional moments reduce considerably by providing shear walls at re-entrant corners.

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BIOGRAPHIES

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