"ASSESSMENT OF TORSIONAL COEFFICIENT FACTOR FOR THE STRUCTURE HAVING VARYING POSITION OF SHEAR WALLS"

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ABSTRACT

The effective design & construction of earthquake resistant structures have much importance factor all over the world. Raipur is emerging as one of the most populated cities in several recent years in Chhattisgarh and demand of high-rise structures with vertical and horizontal irregularity is increasing due to high cost of land which requires earthquake stability check. There is total no. of 9 model analyzed in this study. Linear Dynamic response spectrum method is used. The works comprises in two phases – first phase involves study of RCC (G+10) multi-storey building having three different types of shear walls i.e., Rectangular, L-shaped, and C-Shaped or Lift core. The study is to investigate the behavior of structure responses such as displacement, shear force due to change in location of shear walls. Second phase involves study of displacement response from which existence of torsional irregularity is evaluated. It shows that L-shape shear wall is performing better at the center location which will help structural engineer to avoid such circumstances with vulnerable location of shear wall.

Keywords: ***Seismic, RCC, Shear walls, Displacement, Storey shear force***

1.1 Introduction

The member such as shear wall are provided to resist seismic forces which are perpendicular to the height of the building. The thin walls are likely to bend more, are replaced with shear wall which resist overall forces. The cantilever action is also resisted by shear wall. A rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes in building construction. A reinforced concrete wall is one example. Wind, earthquake, and uneven settlement loads, combined with the weight of the structure and occupants, produce powerful twisting (torsional) forces. This causes shear failure of the structures. Shear walls are particularly important in high-rise buildings that are subjected to lateral wind and seismic forces. Shear walls are typically plane or flanged in section, whereas core walls are channel sections. They also have enough strength and stiffness to keep lateral displacements under control.Miss. Pratiksha Thombre, Dr.S.G. Makarande (2016) has studied that the hilly areas in northeast India contained seismic activity. Due to hilly areas building are required to be constructed on sloping ground due to lack of plain ground. The buildings are irregularly situated on hilly slopes in earthquake areas therefore many damages occurred when earthquake are affected, this may be causes lot human disaster and also affect the economic growth of these areas...In this paper we analyzed using Staad Pro comparison between sloping ground, with different slope and plain ground building using Response Spectrum Method as per IS 1893-2000. The dynamic response, Maximum displacement in columns is analyzed with different configurations of sloping ground.Sristi Gupta, Shivam Kumari (2018) in their paper has studied that the behavior of step back building will be analyzed. Position of shear walls and infill walls will varies in a building. These structural models will be analyzed for dynamic analysis on flat ground. Different parameters like lateral displacement, story drift, base shear, time period, bending moment, shear force will be analyzed and compared using ETABS software. Reference of IS 456 and IS 1893:2002will be considered. Etabs helps in 3D structural analysis and designing steel as well as concrete structures. It can increase work productivity, reduces the project cost and save time and helps in designing and analyzing with a greater accuracy.Rahul Manojsingh Pawar, S.B. Sohani (2017) has studied that the buildings situated on hill slopes in earthquake prone areas are generally irregular, torsional coupled & hence, susceptible to serve damage when affected by earthquake ground motion. The various floors of such building steps back towards the hill slope and at the same time buildings may have setbacks also. Buildings situated in hilly areas are much more vulnerable to seismic environment. In this study, 3D analytical model of 10,15 & 20 storied buildings has been generated for symmetric and asymmetric building Models and analyzed using structural analysis tool 'STADD-PRO" to study the effect of varying height of columns in ground stored due to sloping ground and the effect of shear wall at different positions during earthquake.Anil Baral (2013) uses the Equivalent Static Method (Seismic Coefficient Method) and Response Spectrum Analysis to examine the response of a building with different shear wall positioning. Five different RCC building models, one with no shear wall and the other four with different shear wall positions, that are subjected to earthquake load in zone V according to IS 1893 (2002), have been studied. This research also looks at how the bending moment, shear force for the beam, and axial force for the column change as the position of the RC shear wall changes. It is suggested to place the shear closer to the center.Naresh kumar verma (2020) investigates the effect of those on storey drift, stiffness, shear and moments, and stress within shear walls. The shear wall in the building is analyzed using 3-D software. This research looks at the effects of opening size and location. Because of this study, detailed results have been obtained, and useful conclusions have been drawn for practicing engineers.Rahul Manojsingh Pawar, S.B. Sohani (2017) has studied that the buildings on hill differ from other buildings. The various floors of such building steps back towards the hill slope and at the same time buildings may have setbacks also. In this study,3D analytical model of 10 storied buildings have been generated for symmetric and asymmetric building Models and analyzed using structural analysis tool 'STAAD-PRO" to study the effect of varying height of columns in ground stored due to sloping ground and the effect of shear wall at different positions during earthquake. From the studies it has been observed that the performance of the buildings on sloping ground suggests an increased vulnerability of the structure with formation of column hinges at base level and beam hinges at each story level at performance point.

Dr. S. A. Halkude, Mr. M. G. Kalyanshetti, Mr. V. D. Ingle (2013) in their paper has studied that in hilly regions, engineered construction is constrained by local topography resulting in the adoption of either a step back or step back & set back configuration as a structural form for buildings. The adopted form invariably results in a structure which is irregular by virtue of varying column heights leading to torsion and increased shear during seismic ground motion. The Response spectrum analysis (RSA) is carried out namely step back frame sand step back & set back building frames on sloping ground with varying number of bays and hill slope ratio. The dynamic response i.e. Fundamental time period, top storey displacement and, the base shear action induced in columns have been studied with different building configurations on sloping ground.Sujit Kumar, Dr. Vivek Garg, Dr. Abhay Sharma (2014) has studied that in normal design practice the designers generally ignore the effect of sloping ground on the structural behavior of the building. The seismic analysis of a G+4 storey RCC building on varying slope angles i.e., 7.5º and 15º is studied and compared with the same on the flat ground. The seismic forces are considered as per IS: 1893-2002. The structural analysis software STAAD Pro v8i is used to study the effect of sloping ground on building performance during earthquake. The analysis is carried out to evaluate the effect of sloping ground on structural forces. The horizontal reaction, bending moment in footings and axial force, bending moment in columns are critically analyzed to quantify the effects of various sloping ground. It has been observed that the footing columns of shorter height attract more forces, because of a considerable increase in their stiffness, which in turn increases the horizontal force (i.e. shear) and bending moment significantly. Thus, the section of these columns should be designed for modified forces due to the effect of sloping ground. The present study emphasizes the need for proper designing of structure resting on sloping ground.Chaitrali Arvind Deshpande, Prof. P. M. Mohite (2014) had studied on analysis of actual practiced building with step back and step back-setback configurations and ground conditions sloping and leveled ground, by using response spectrum method as per IS1893-2000.Effect of bottom ties on response of building when resting on sloping ground is also studied here. This studied shows that for sloping and leveled ground, step back-setback building gives effective response when earthquake occur.

2. Research Objectives

a) To model the RCC frame building having different types of shear walls using ETABS software.
b) To investigate the considered building having three different type of shear walls such as rectangular, L-shape and C-shape placed at different location of the building.
c) To interpret the building response such as displacement, storey shear force which were evaluated during dynamic analysis.
d) To get a suitable location and type of shear wall for the considered study.
e) To validate the existence of torsional irregularity based on different location of shear wall.

3. Working Methodology

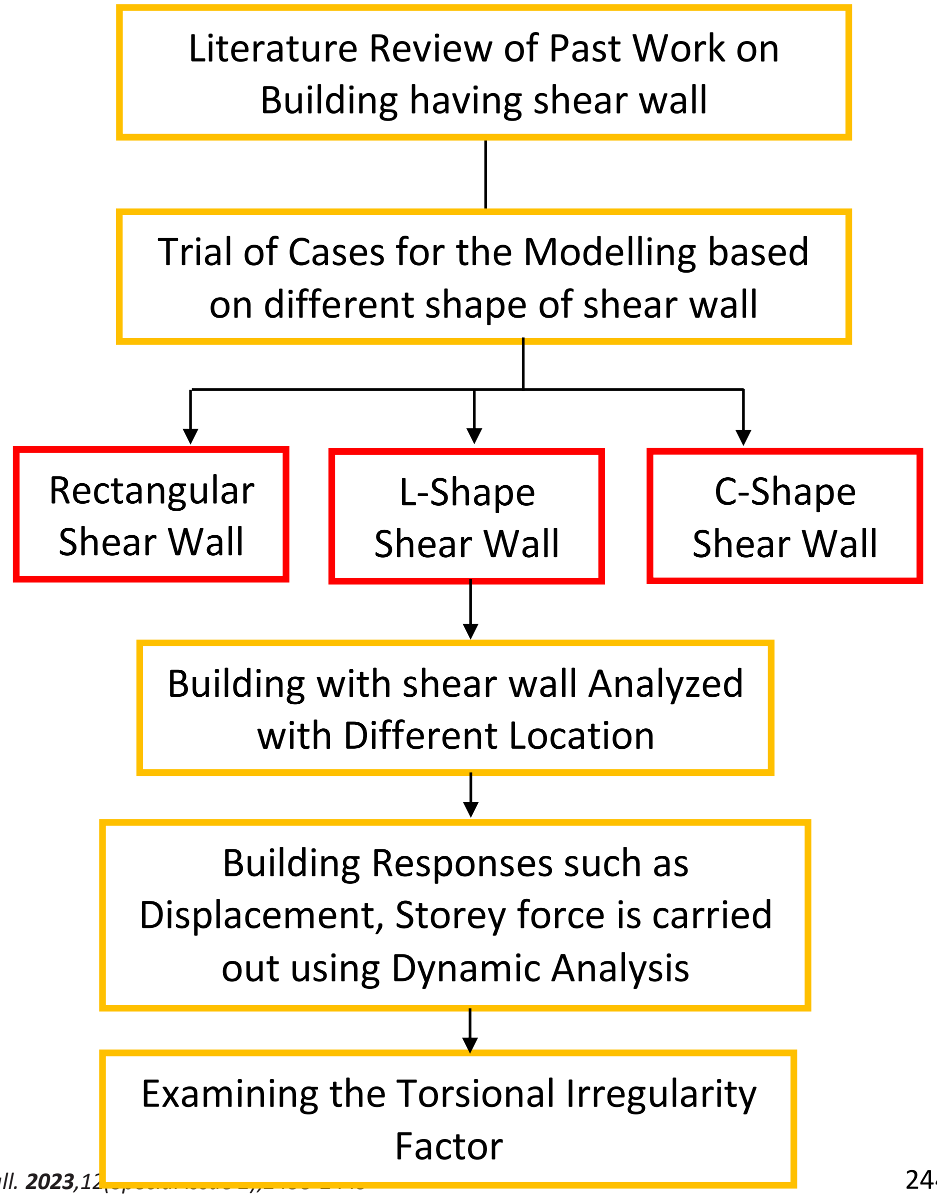
The literature survey done in the previous chapter were based on different categorization such as based on different shapes of shear wall, based on different location of shear wall, based on eccentricity of placement of shear wall and so on. An effort is made to study the effect of three basic shapes of shear walls in RCC building when placed at different location of building. The shape of shear wall is rectangular, L and C-shape commonly used in most of the building. The cases which are to be investigate is given below with description are as follows-

Table 1 Description of Proposed Model Cases

Description	Abbreviation

Reference Building having two Aspect Ratio	**BM**
Building with four rectangular Shear Wall along X-direction	**RSW1**
Building with 3-Rectangular Shear Wall along X-direction & 2- Rectangular Shear Wall along Y-direction	**RSW2**
Building with two rectangular shear walls at edge along Y-direction & two rectangular shear walls along X-direction	**RSW3**
Building with five rectangular Shear Wall along Y-direction	**RSW4**
Building with two L-shape Shear Wall at the center core	**LSW1**
Building with two L-shape Shear Wall placed at the corner diagonally	**LSW2**
Building with lift core/ C-shape shear wall 3.7 m away from the corner	**CSW1**
Building with two lift core/ C-shape shear wall 3.7 m away from the corner	**CSW2**

NOTE: B = Building, M= Model, R= Rectangular, L = L-Shape, C= C-Shape, SW = Shear Wall, Number = Model Number



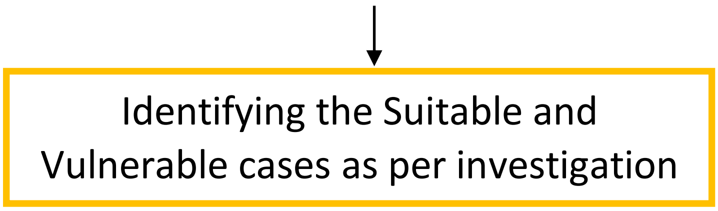


Fig. 1 Flow Chart of Summary of Methodology

3.1 Structural Configurations

The building configuration used in the research work is based on review study done in previous chapter. The structure used for modelling has plan aspect ratio of 2 in all considered cases. The plan size is 37 m X 16.8 m. The maximum height of the building as per IS 16700:2017 is based on zone intensity of that region. Here, the building height is 44m which is under the permissible limit. The number of storeys is 11. Each story height has height of 4 m. The beam size taken is 0.3 X 0.45 m as shown in figure below. The vertical member heigh is 0.48 X 0.48 m. The thickness of RCC slab adopted is 0.15 m. The shear wall considered for the work is 230 mm. The load detail is discussed below after modelling of the cases.

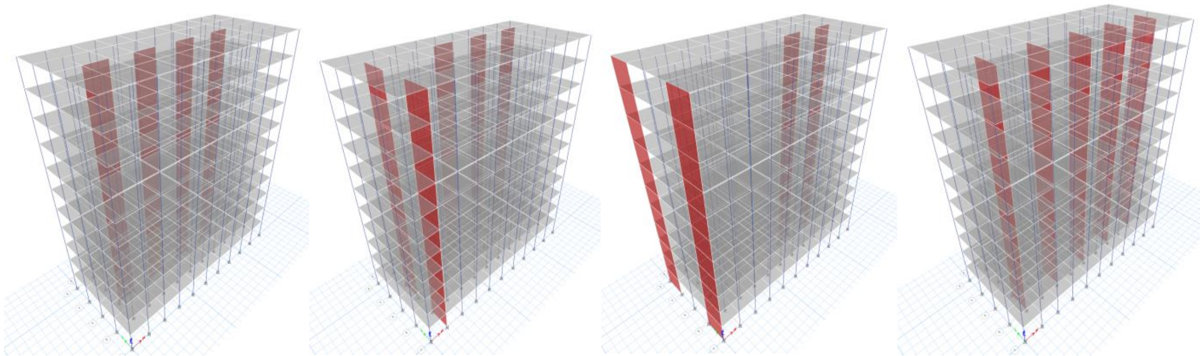
3.2 Modelling of Structure

The reference model having no retrofitting which is denoted here as "BM." The building dimension is such that the overall length of building is twice as much as the overall width of the building. The gross length of the building is 37 m. The gross width of the building is 16.8 m. The reference model diagrammatic view is shown in figure below. The second case as per sequence the building models RSW1 have rectangular shear wall type. The shear wall placed parallel to the x-direction or along the x-direction. The four rectangular shear walls are placed at the distance of 3.7 m away from each other starting from coordinates (3.7 ,8.4) ending to (29.6, 8.4).

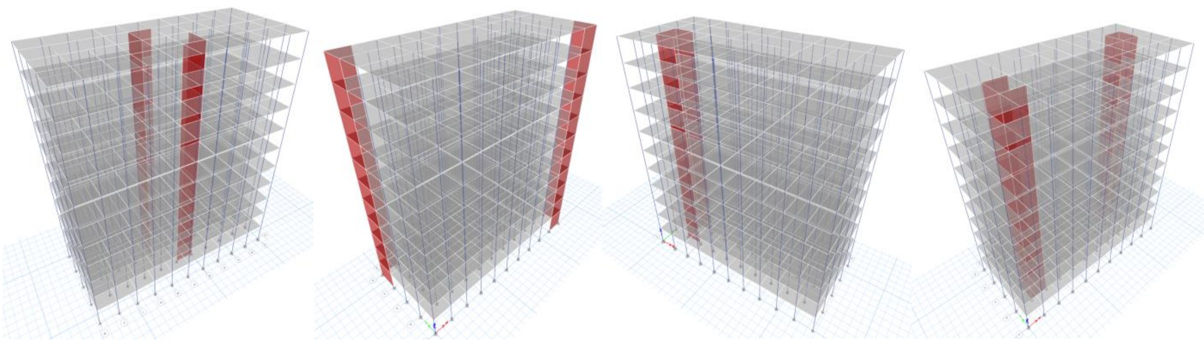
The third case i.e., the building models RSW2 have rectangular shear wall type. There are shear walls placed at both the direction parallel to the x-direction and y-direction. There are three rectangular shear walls placed at the distance of 3.7 m away from each other starting from coordinates (14.8 ,12.6) ending to (33.3, 12.6) along x-direction. The fourth case i.e., the building models RSW3 have rectangular shear wall type. There are shear walls placed at both the direction parallel to the x-direction and y-direction. There are 2 rectangular shear walls placed at the distance of 3.7 m away from each other starting from coordinates (22.2 ,8.4) ending to (33.3, 8.4) along x-direction and 2 walls along y-direction are at the end edge.

The fifth case i.e., the building models RSW4 have rectangular shear wall type. There are shear walls placed at parallel to the y-direction. There are 2 rectangular shear walls placed at the distance of 7.4 m away from each other starting from coordinates (3.7 ,4.2) ending to (33.3, 4.2) along y-direction.The sixth case i.e., the building models LSW1 have L-type shear wall. Here, the 2-shear walls are placed at center core of the building such that they are making a closed loop or facing each other as shown in figure below.

The seventh case i.e., the building models LSW2 have L-type shear wall. Here, the 2-shear walls are placed at corner of the building diagonally. The corner position is to make structure stiffer at the ends due to aspect ratio.The eight case i.e., the building model CSW1 have C-type shear wall. The c-shaped shear wall is also termed as lift-core. Here, the lift core is placed at the distance of 3.7 m away from the origin along x-direction. The opening of lift core is towards the y-direction.



(a) (b) (c) (d)



(e) (f) (g) (h)

Fig. 2 Three-Dimension view of Model Case (a) RSW1 (b)RSW2 (c)RSW3(d)RSW4 (e)LSW1 (f)LSW2 (g)CSW1 (h)CSW2

3.3 Material Configurations

The modelling has been done using design software i.e., CSI ETABS. The software is well known for its accuracy and developed by the American company. After modelling the structural property is defined as per our need. The materials configuration is based on the type of standards which is been used as here Indian standard material is utilized for the research study. The RCC members such as beam, column and conventional RCC slab are the basic elements modelled in the work. The material used are reinforced bar or Rebar, cement concrete. The following are the details regarding the material configurations-

Table 2 Material Properties

Particular	Value
Grade of Concrete	Mix-Grade 30
Grade of Primary and Secondary Steel	Fe500
Cover for RCC Beam and Column	0.025 mm & 0.040 mm
Density of Reinforced Concrete	25000 N/m^3
Density of Brick Masonry	20000 N/m^3
Young's modulus of steel	200000N/mm^2

3.4 Seismic Consideration

Table below shows the seismic parameters assigned for all the RCC frame buildings cases. The parameter values are given in Indian seismic code i.e., IS 1893:2016.

Table 3 Seismic Parameters used in RCC frame buildings

Particular	Value
Seismic Zone	ZONE -V
Intensity of Zone, Z	0.36
Reduction Factor, R	OMRF (VALUE=3)
Occupancy Factor, I	ALL GENERAL BUILDINGS (VALUE =1)
Rock/Soil Type	MEDIUM SOIL (VALUE = 2)
Structure Type	RCC FRAME BUILDING (VALUE = 1)
Damping Ratio	5 % (VALUE = 0.05)

3.5 Criteria for Torsional Irregularity

The torsional irregularity exists when the ratio of displacement at the one end of the building to the displacement of other end of the building is 1.5. This criterion is applicable for the building structures system. The mathematical expression is given by –

Torsional Coefficient Factor, $\eta_{bi} = \frac{\Delta_{one\ end}}{\Delta_{other\ end}} > 1.5$, then torsional irregularity exists

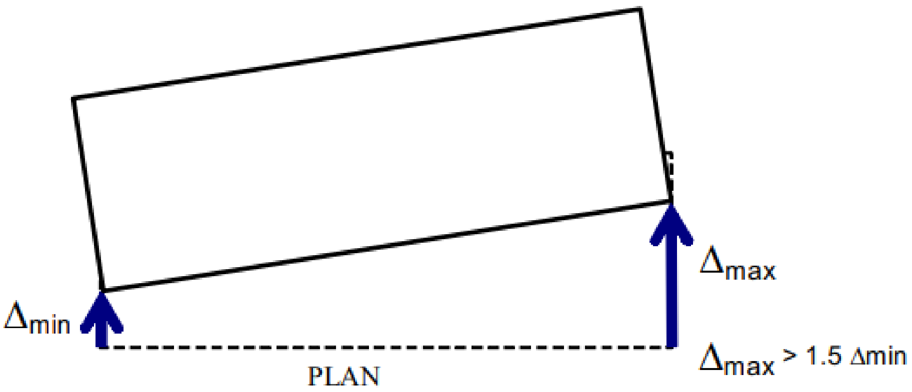


Fig. 3 Diagrammatic Expression for the Torsional Irregularity

4.1 Comparison of Displacement Result

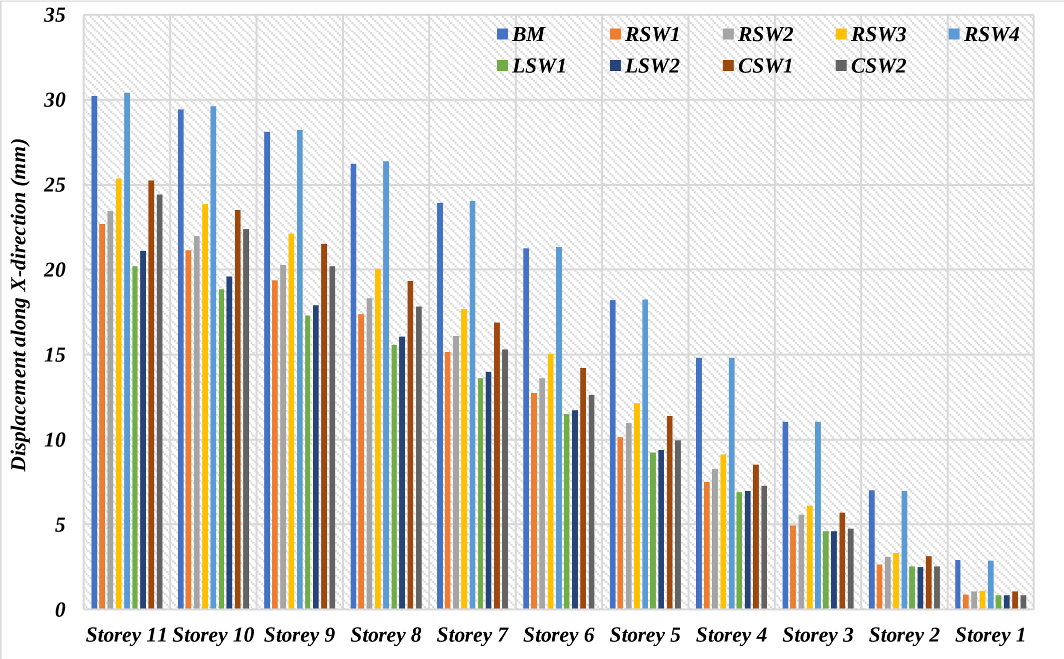


Fig. 4 Comparison of Displacement Value along X-direction

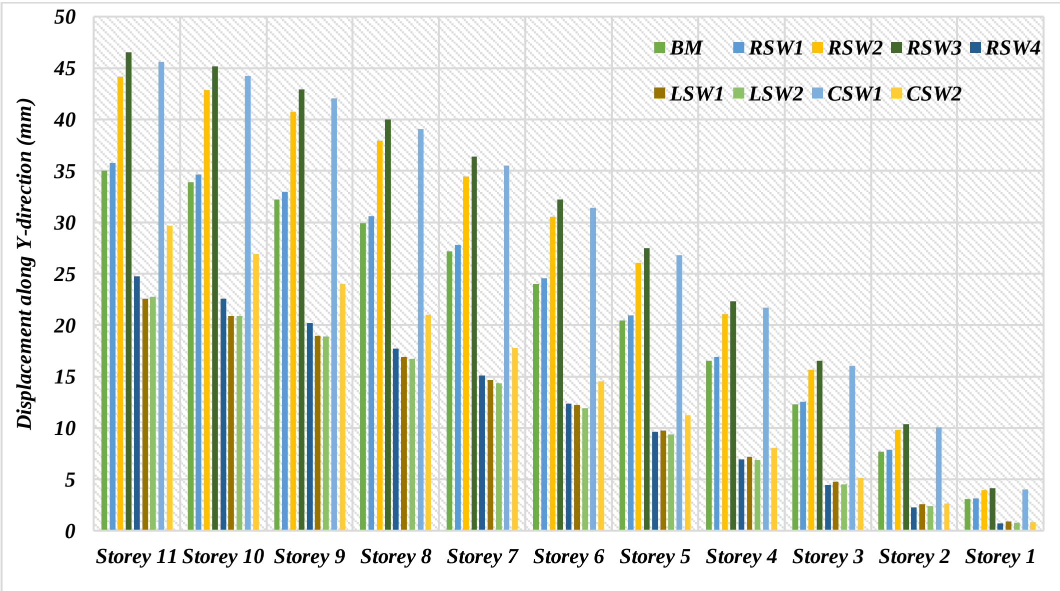


Fig. 5 Comparison of Displacement Value along Y-direction

The LSW1 case along x-axis shows very much less displacement value than of BM case because the L-shear wall are at the center which stabilize the overall structure. The displacement value for LSW1 case along Y-direction shows very less value as compared to BM case (i.e., 35 mm) along y-direction. This is due to application of stiffness applied at the center core.

The displacement value of CSW1 case along Y-direction is not as much good when compared with BM case (i.e., 35 m). This is due to presence of lift-core nearer to the edge and corner resulting large deformation along y-axis. This would be better if there is another lift core in the placed diagonally opposite to it.

4.2 Comparison of Storey Shear force Result

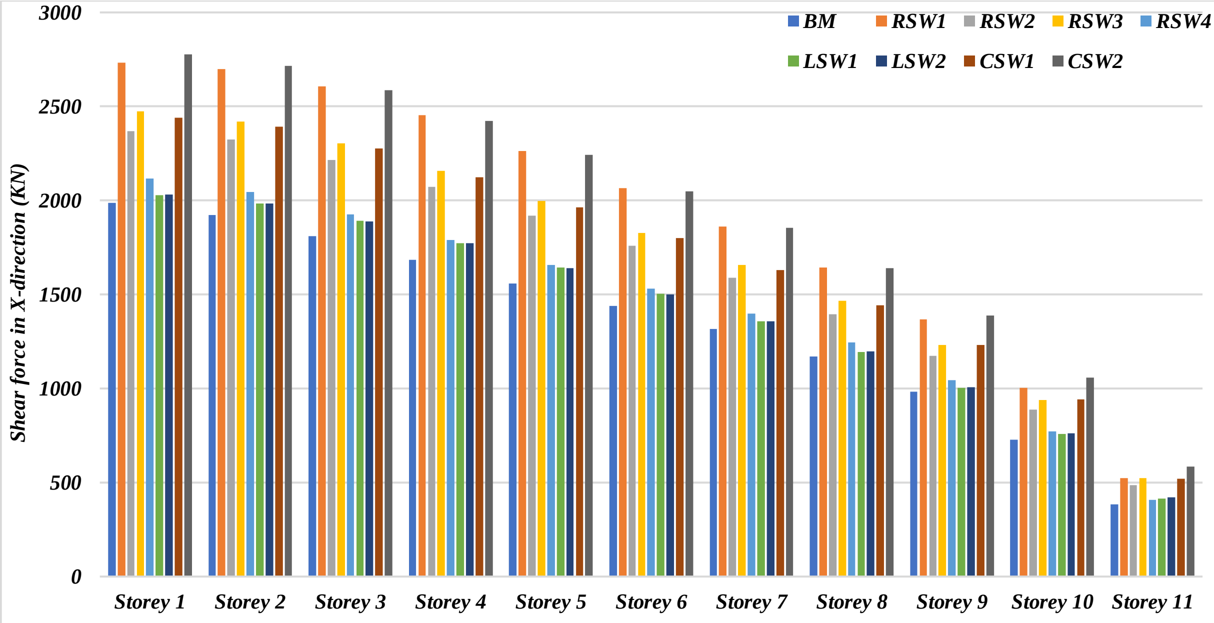


Fig. 5 Comparison of Shear Force Value along X-direction

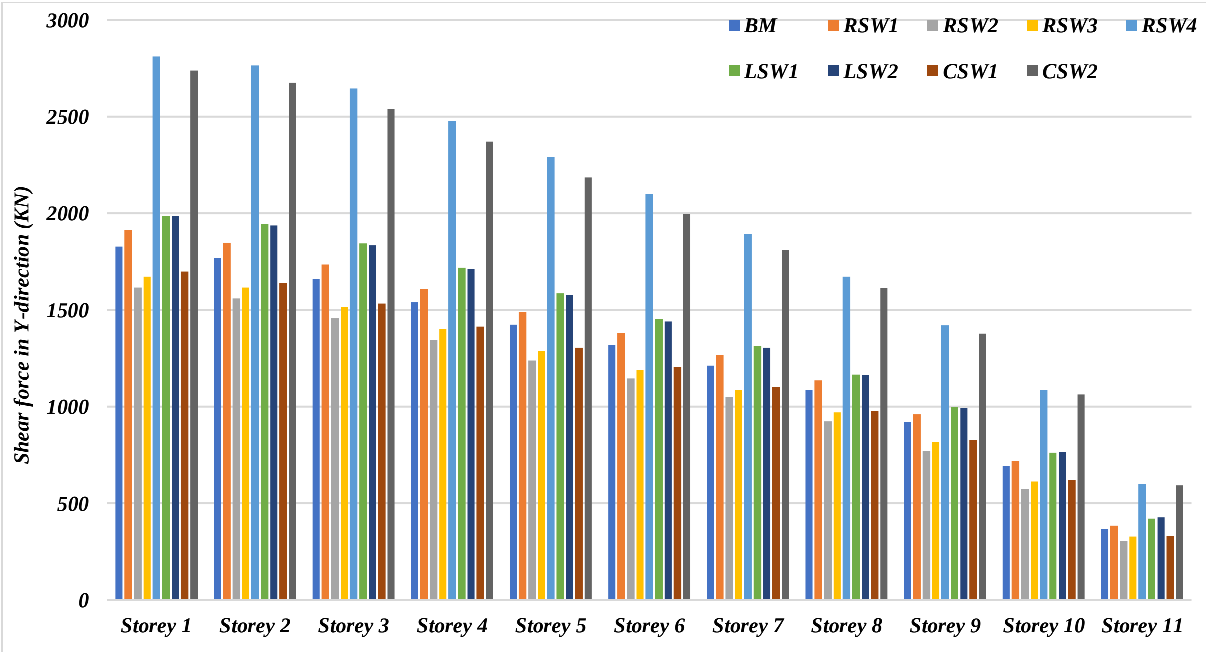


Fig. 6 Comparison of Shear Force Value along Y-direction

4.3 Evaluation of Existence of Torsional Irregularity

The mathematical expression for the torsional irregularity is given by –

Torsional Coefficient Factor, $\eta_{bi} = \frac{\Delta_{one\ end}}{\Delta_{other\ end}} > 1.5$, then torsional irregularity exists

Table 4 Check for Torsional Irregularity factor

Model case	Δ (Displacement at One End)	Δ (Displacement at Other End)	Ratio	Check
BM	35.023	35.023	1	Regular
RSW1	35.779	35.779	1	Regular

RSW2	44.151	20.475	2.16	Irregular
RSW3	46.507	21.029	2.21	Irregular
RSW4	24.742	24.742	1	Regular
LSW1	22.561	22.561	1	Regular
LSW2	22.764	22.764	1	Regular
CSW1	45.628	20.272	2.25	Irregular
CSW2	29.642	19.496	1.52	Irregular

BM, RSW1, RSW4, LSW1 and LSW2 model frames are only cases which are not having torsional irregularity whereas rest all cases are under torsional irregularity as the ratio is above 1.5 as per IS 1893:2002/2016. All the red marking in the table shows the torsional irregularity.

5. Conclusions

The following conclusions were made after careful interpretation

1) The reference model BM shows maximum displacement i.e., 35.02 mm and the model LSW1 case shows minimum displacement i.e., 22.56 mm. The reference model has displacement 55.23 % more than LSW1 case. This concludes that L-shape shear wall provided at the center and corner i.e., LSW1 and LSW2 are the best suitable location for the building in this study.
2) It is suggested that to provide shear walls at the corner or at the center for rectangular, L & C-shape walls. The C-shape shear walls were suitable to provide it in center location only in this study.
3) The L-shape shear walls are the only cases where there is no existence of torsional irregularity. The other cases are beyond the torsional factor i.e., 1.5 due to their wrong placement of shear wall. Therefore, it is recommended to provide the building a suitable type and location of the shear walls.

5.1 Scope of Future Work

There are different techniques that can be used for resisting the lateral forces. Some of them are- Reinforced *Concrete Jacketing* of column represents additional bars all around and pouring high performance concrete. Thus, increasing the load carrying capacity or strength of columns. Jacketing of column cost is less as compare to other retrofitting methods. Reinforced concrete jacketing can be employed as a repair or strengthening scheme.The main purposes of jacketing of columns in the irregular frames is to increase the shear capacity of columns in order to accomplish a strong column-weak beam design.*Steel Jacketing*technique is used when the loads applied to the column will be increased, as the irregular frames has space constraints and this technique does not increase the cross-sectional area of the column as done in concrete jacketing. *Carbon Fiber Polymers (CFRP) Jacket* is modern retrofitting technique in which fabric or strip is applied with the surface rolled and squeegeed to remove air. These are the high-strength fiber jacket system and are applicable both in a post-earthquake and pre-earthquake retrofitting.

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