# SIGNIFICANCE OF SHEAR WALL IN HIGHRISE IRREGULAR BUILDINGS

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# Significance of Shear Wall in Highrise Irregular Buildings

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**Abstract**
The usefulness of shear walls in the structural planning of multi-story buildings has long been recognized. When walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. Reinforced concrete framed buildings are adequate for resisting both vertical and horizontal loads acting on them. Extensive research has been done in the design and analysis of shear wall highrise buildings. However, significance of shear wall in highrise irregular structures is not much discussed in literature. A study on an irregular highrise building with shear wall and without shear wall was studied to understand the lateral loads, story drifts and torsion effects. From the results it is inferred that shear walls are more resistant to lateral loads in an irregular structure.

**Keywords**
Shear Wall, Lateral Loads, Irregular, Torsion

## I. Introduction

Shear walls are specially designed structural walls included in the buildings to resist horizontal forces that are induced in the plane of the wall due to wind, earthquake and other forces. They are mainly flexural members and usually provided in highrise buildings to avoid the total collapse of the highrise buildings under seismic forces. Shear wall has high in-plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads. However, when the buildings are tall, say more than twelve story or so, beam and column sizes workout large and reinforcement at the beam and column junction works out quite heavy, so that, there is a lot of congestion at these joints and it is difficult to place and vibrate concrete at these places, which does not contribute to the safety of buildings. These practical difficulties call for introduction of shear walls in highrise buildings. Deep straight walls or angular, U shaped and box shaped shear walls were used based on functional and architectural requirement of the highrise building.

A study was conducted on symmetric rectangular highrise structure to find the appropriate location for the shear wall based on its elastic and elasto-plastic behaviour and found that the top deflection was reduced and reached within the permissible deflection after providing the shear wall (Anshuman et.al; 2011). Lateral displacement and inter-story drift was studied on a square symmetric structure with walls at the centre and at the edges, and found that the presence of shear wall can affect the seismic behaviour of frame structure to large extent, and the shear wall increases the strength and stiffness of the structure (Shahjad Jamil sardar et.al; 2013). A study was conducted on G+ 5 stories symmetric building in Zone IV was presented with some preliminary investigation which was analyzed by changing various positions of shear wall with different shapes and found that a box type shear wall at centre is more safer than to other type of walls placed at different locations (Himalee Rahangdale et al; 2013). A comparative study on wind behaviour of buildings with and without shear wall was carried out and found that the displacements of with shear wall was 20 % less than without shear wall (Alfa Rasikan et al; 2013). The effectiveness of shear wall was studied on bare frame structural system and dual frame structural system and found that shear wall is more economical for structure greater than 10 story (P.P. Chandurkar et.al; 2013). A study was conducted to investigate the effectiveness of shear wall in a residential medium rise building considering frame system and duel system and found that frame type structural system becomes economical as compared to the dual type structural system and it can be used for medium rise residential buildings situated in high seismic zone. (P.S. Kumbhare et.al; 2012). The optimum configuration of a multi-story building by changing shear wall location was studied and found that column, beam forces are found to increase on grids opposite to the changing position of shear wall away from the centroid of the building. (M. Ashraf, 2008). A study by J.L. Humar et.al; (2002) examines the relationship between strength and stiffness for concrete shear walls and concluded that square shaped shear wall is the most effective and L shaped is the least effective. (Romy Mohan, et. al; 2011). In general, Equivalent Static Method can be used effectively for symmetric buildings up to 25 m height. For higher and unsymmetrical buildings Response Spectrum Method should be used. For important structures Time History Analysis should be performed. This paper also deals with the dynamic linear analysis using Response Spectrum Method with Finite element based software - ETABS to study lateral load distribution, story drifts and torsional effects.

## II. Building Description & Model Implementation

A residential building of G+15 irregular structure having the base dimension of plan 24.38m x 25.98m with a stilt floor of height 4m and typical floor of height 3m is considered for the analysis. The structure is planned to be reinforced concrete with cement/ fly ash brick infill wall. The superstructure is modelled using standard software ETABS as a space frame with a grid of columns in the vertical direction, interconnected with beam members in the orthogonal directions at each floor level. The nodes (the meeting points of beams with beams and beams with columns) will be treated as rigid joints due to monolithic construction. The end nodes at the bottom of the model will be modelled as fixed supports due to rigid connection of the columns with footings at the foundation level. The columns will also be inter-connected at the plinth beams to increase the stability of the structure, wherever necessary. All slabs are modelled as membrane/shell elements wherever necessary. Geometry of the building for the column as least lateral dimension of 300mm and minimum width of main beams as 400mm is considered. Column pedestal is provided as per the design requirement. Design service loads are expected to act on the structure during its intended life and they are considered with reference to relevant codes of IS 875 part1- 1987 for dead loads and imposed loads, IS 875 part3-1987 for wind loads, IS 1893 part1-2002 for earthquake loads. The dead and imposed loads of all the reinforced concrete members will be given as self weights of the members; all the floor loads expressed as load per square area is applied as distributed floor loads onto the supporting beams as per clause 24.5 of IS 456: 2000. All wall loads are applied as uniformly distributed load per unit length onto the supporting beams; the wind and earthquake loads are applied as lateral loads at each floor level. Material grades of M30 & Fe

415 were used for the design. Fig. 1 shows the plan view of the structure without shear wall. The circles marked in Figure 1 at grid E and G is the shear wall locations for this parametric study. Elevation view of the structure without shear wall and with shear wall is shown in Figure 2.

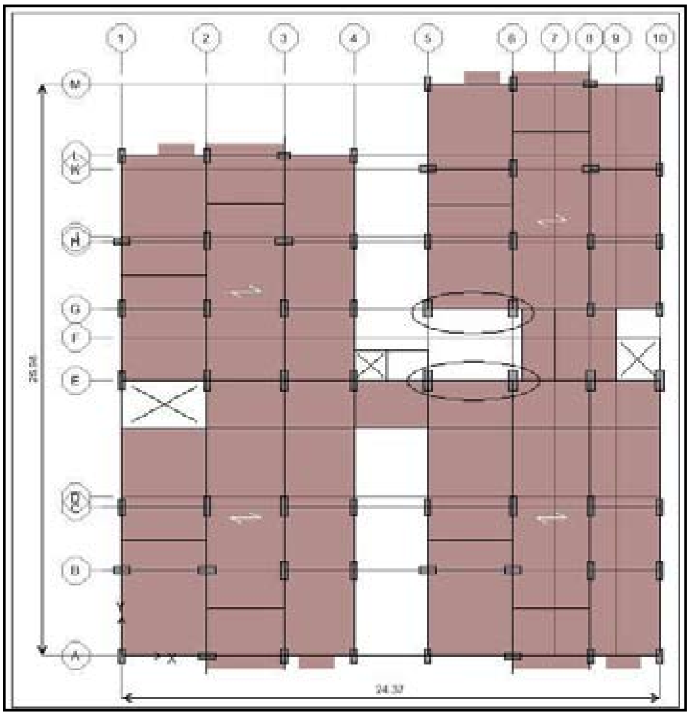

Fig. 1: Plan at Floor Level

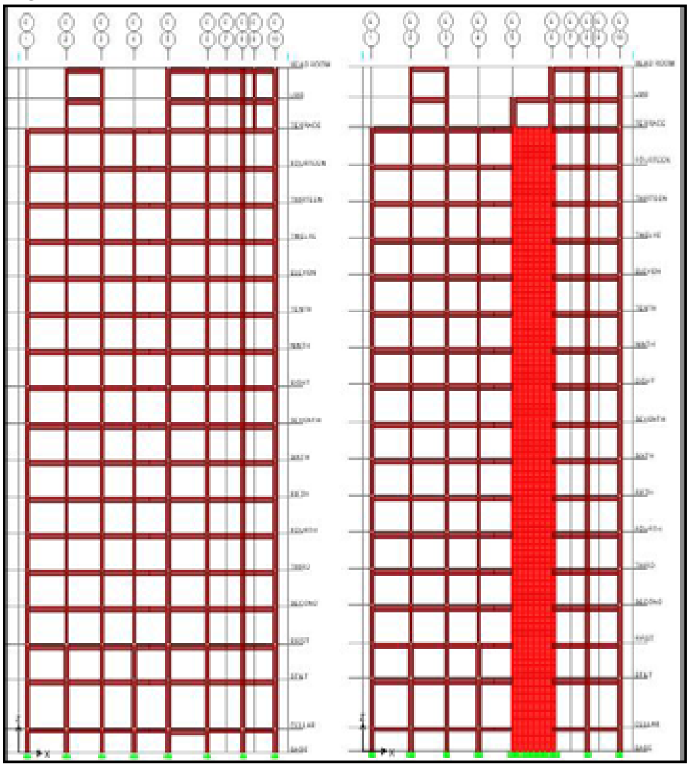

Fig. 2: Elevation view at grid E

### III. Lateral Load Analysis

Dynamic linear analysis using response spectrum method is performed by taking zone factor Z=0.1, importance factor I=1 and response reduction factor R=3. From the analysis results, obtained base shear in X direction and in Y direction were shown in Table 1. Vertical distribution of base shear to different floor levels is computed from story shear results extracted from analysis. Table 2 shows the result of lateral forces at floor level for structure without shear wall and with shear wall. Lateral forces are distributed to frames along X direction for structure without shear wall and with shear wall. In case of structure without shear wall, distribution of force is less for frame E shown in fig. 3. In case of structure with shear wall, at frame E and frame G distribution of lateral forces to the frame are higher than the structure without wall. In fig. 4 except frame E and frame G all other frame forces are reduced causes the reduction in torsional forces.

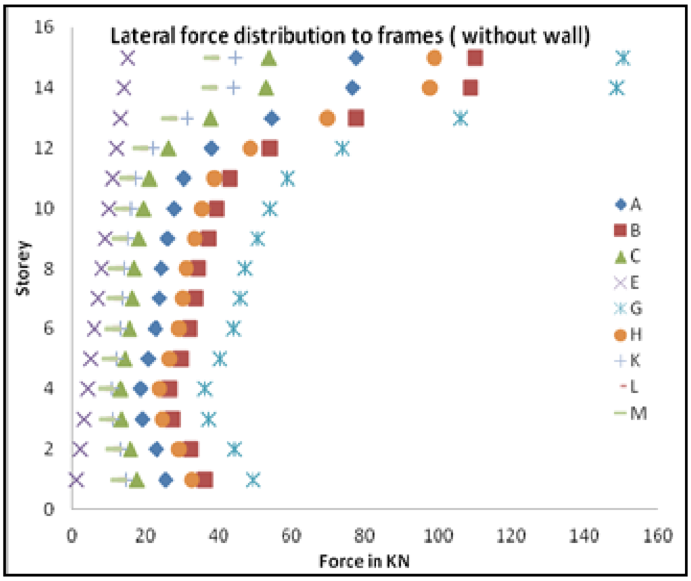


Fig. 3: Lateral Force Distribution to Frames (Without Wall)

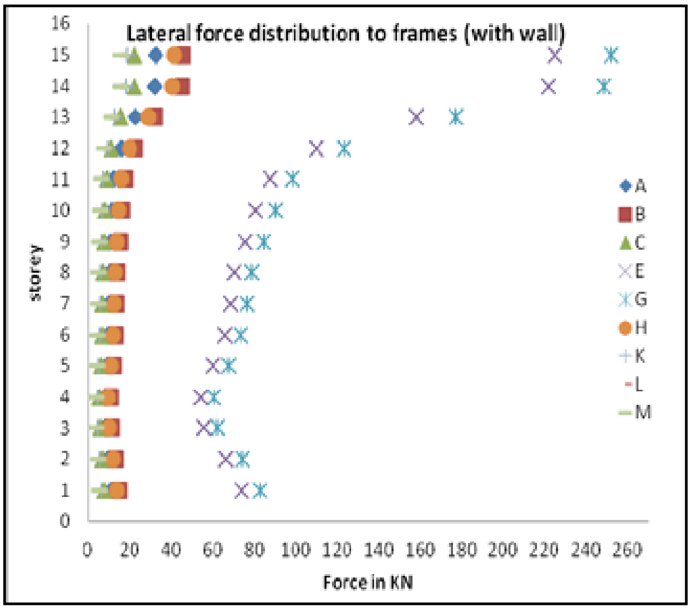


Fig. 4: Lateral Force Distribution to Frames (With Shear Wall)

### IV. Calculation of Center of Mass, Center of Stiffness and Eccentricity

Centre of mass (CM) of structure without shear wall and with shear wall is extracted from analysis results. Stiffness is computed for each column of each frame and added all column stiffness of the corresponding frame will give the total frame stiffness. Sum of all frame stiffness in the X direction will give the total stiffness of the each floor in the respective direction. Lateral stiffness of shear wall for the deflection due to unit load is computed by considering bending deflection, shear deflection and rocking deflection. Table 1 shows the CM and centre of stiffness (CS) for structure without shear wall and structure with shear wall. Figure 5 shows the graphical representation of CM and CS. CS1 represents the centre of stiffness for structure without shear wall and CS2 represents the centre of stiffness for structure with shear wall. The difference between the CM and CS gives the static eccentricity of the structure. The design eccentricity is computed using clause 7.9.2 of IS 1893:2002. In case of structure with shear wall static eccentricity in Y direction is 2.403m which creates torsion irregularity of the building. Where as in case of structure with shear wall, centre of stiffness shifts near to centre of mass which reduces the torsional effect in the structure.

Table 1: Base Shear, CM, CS and Eccentricity

| | Without shear wall | | With shear wall | |
|---|---|---|---|---|
| | X | Y | X | Y |
| Length | 24.37 | 25.98 | 24.37 | 25.98 |
| CM | 12.59 | 12.17 | 12.59 | 12.18 |
| CS | 12.20 | 9.77 | 13.10 | 11.55 |
| $e_{si}$ | 0.393 | 2.403 | -0.509 | 0.626 |
| $V_b$ | 4891.57 | 5050.57 | 4895.13 | 5054.24 |
| $e_{di}$ | 1.81 | 4.90 | 0.46 | 2.24 |

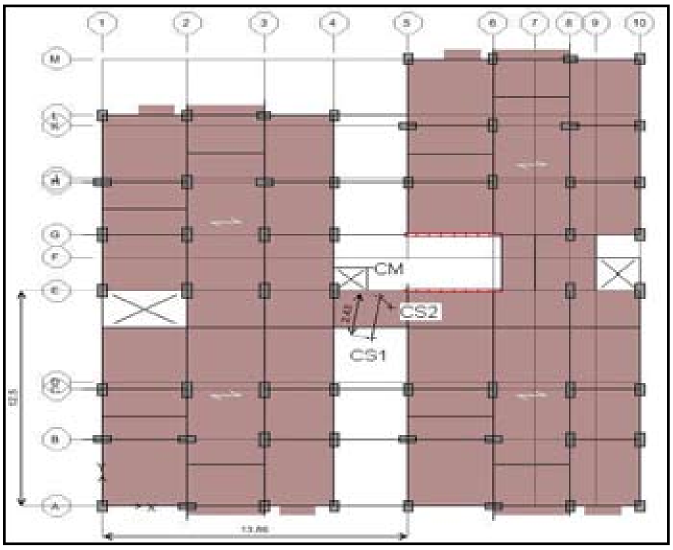


Fig. 5: Location of Center of Mass and Center of Stiffness

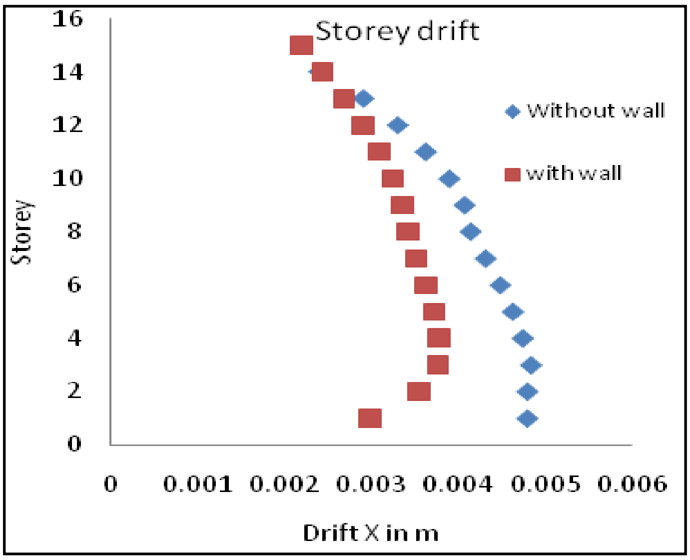


Fig. 6:

Story drift: Maximum story drift is extracted from analysis results and compared for structure without shear wall and with shear wall. Fig. 6 shows the maximum story drifts for both cases. Story drift is reduced in case of structure with shear wall.

## V. Conclusion

Dynamic linear analysis using response spectrum method is performed and lateral load analysis is done for structure without shear wall and structure with shear wall. Results are compared for the frame lateral forces and story drifts of both the cases. It is also observed that lateral forces are reducing when the shear walls are added at the appropriate locations of frames having minimum lateral forces. Therefore, it is inferred that shear walls are more resistant to lateral loads in an irregular structure. Also they can be used to reduce the effects of torsion.

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