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Analysis of Multi-Storey Building Considering Wind Effects

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ABSTRACT

In this modern era of building construction, the demand for tall structures has been increasing immensely. The horizontal land space is almost exhausted in many places. This has forced people to occupy vertical spacing. The increasing demand for the construction of tall buildings has led to the development of new construction technologies. As the height of the building rises high above the ground, the wind forces become predominant. This results in the abnormal behavior of the structure. For the structure's safety, proper analysis and a clear understanding of the wind forces are required. The main factor to be considered is the maximum storey displacement. The top storey displacement of the structure is studied for a multistory building. This structure is provided with a shear wall at various positions to reduce the lateral displacement. A shear wall is offered to counteract the effects of lateral load acting on it. Seismic load and wind load are the two common loads shear wall is designed to carry. A shear wall of 200 mm thickness is provided in this study. Five different shear wall positioning have been provided, and the top storey displacement of the structure is studied. The research aims at understanding the behavior of the structure every time the shear wall position is changed. Software analysis of the structure has been carried out with the help of E-Tabs. The detailed studies have clearly shown a significant change in the maximum storey displacement at the given shear wall positioning. The shear wall positions can be improvised to provide better stiffness and moment of resistance to the structure. The values of each analysis have been noted, and the detailed performance of the structure is studied.

1. INTRODUCTION

In general, the consequence of lateral load (i.e., earthquake and wind) increases as the height of the building increases. There are three methods which can be used to defy lateral load effects on multistoried buildings. They are dual system, frame action and/or Shear walls. Peak inter-storey drift and lateral sway are the two methods used to assess the stiffness and lateral stability of building. In seismic design, both structural elements and lateral force resisting systems can be affected by drift and lateral displacement. The structure sways due to the lateral force acting on it (in terms of lateral force resisting system). Consequently, a relationship exists between movement due to lateral loads and the lateral force resisting system; this relationship can be arrived at, manually or analytically [1].

Estimates of different design criteria, like rotations of joints in moment resisting frames and in eccentric braced frames can be obtained with the help of the results obtained. The lateral analysis can also be used to approximate the effect of lateral sway on structural elements which are not a part of the lateral force resisting system like beams and columns. These are explicitly not considered as a part of the lateral force resisting system. To ensure the ability of the structure to sustain inelastic rotations resulting from drift and deformation, design provisions for moment frame and eccentric braced frame structures have a few requirements. In addition to this the connections and structural elements which are not a part of the lateral force resisting system, if their lateral deflections become too large, need to be detailed expecting maximum displacement and drifts during an earthquake, i.e., they experience rotations and deflections similar to those of the lateral force resisting system. The displacement is to be limited to certain values to limit nonstructural damage. It is seen that without any standard serviceability design of limit state different engineers tend to design buildings with different levels of performance and inconsistent economy. Thus, a standard can be created based on the criteria obtained by Finley A Charney on Wind drift Serviceability Limit State Design on Multistory building (1990). When studies were conducted on various cross-sectional shapes of the building, it was found that the overturning moment on rectangular shaped buildings were insignificant by S.T.Thoroddsen, J.A.Peterka and J.E.Cermak on Correlation of the Components of Wind loading on Tall Building (1988).

2. THEORY

A multistory or a high rise building usually has two significant loading concerns: seismic load and wind load. The wind load effect increases as the height of the structure increases. The assessment of wind load on a particular structure is done based on the wind pressure maps given in Bureau of Indian standards 875 (part III) – 2015. The wind speeds given in the codes has been worked out for return period of 50 years given by Indian Meteorological Department (IMD). Various factors like topography, terrain effects, size of the structure are considered for the assessment of the behavior of the building [2].

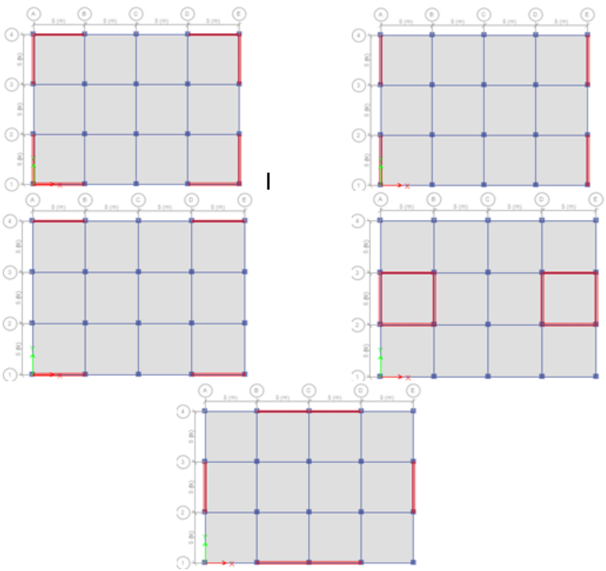


Figure 1. Various Shear wall positioning considered

2.1 Objectives of the Study

The objective of this study is to analyze a high-rise/ a multistorey building taking into account wind effects. Shear wall is provided to the considered structure and the results are compared in order to find out the best suitable shear wall position to obtain least deflection/ displacement [3].

2.2 Scope of study

The scope of this study has been limited to change in the positioning of the shear wall. Five different shear wall positioning has been considered as shown in the Figure1.

3. METHODOLOGY

ETABS software is used to carry out the required analysis. The high-rise building is analyzed by providing loading as per IS 875 (Part III). The shear of 200mm thickness is provided to this building and then analyzed again similarly.

3.1 Parameters of the building

The parameters considered for this study are:

- Beam Dimension: 300mm*500mm
- Column Dimension: 500mm*500mm
- Slab thickness: 200mm
- Storey Height: 4m+21 storey@ 3.3m=73.3m
- Bay Length: 5m*5m
- Length: 20m
- Width: 15m
- Grade of Concrete: M30
- Grade of Steel: Fe415
- Wall thickness(Inner): 150mm
- Wall thickness(Outer): 230mm

3.2 Model Assumptions

- Dead loads are invariant for various sizes of members.
- All the structural members are linear and prismatic.
- The concrete assumed is linearly elastic. P-□ effect is neglected.
- The connections between the members of the building are rigid while the building is fixed at the base.
- The building considered is a residential complex.

3.3 Load Considerations

3.3.1 Dead Load

The load of the beams and columns has been taken into account by ETABS itself. The dead load of the slab is taken as 1.86 kN/m^2. The load of the brick wall of 230mm outer wall thickness is taken as 12.68 kN/m^2 and the load of inner wall of 150mm thickness is taken as 8.4 kN/m^2.

3.3.2 Live Load

Live load has been considered as per IS 875 (part II) i.e., 2 kN/m^2 at floors.

3.3.3 Wind Load

The wind loads are considered as per IS 875 (part-III) – 2015. Basic wind speed has been selected from Appendix A of the code. The location considered in this study is Chennai (Madras), whose basic wind speed is 50 m/s. Design wind speed (Vz) is the modification of the basic wind speed by including the following effects to obtain design wind velocity at the required height (Vz) for the structure under consideration.

It can be mathematically expressed by:

$$V_z=V_bk_1k_2k_3$$

Where,

k_1 = 1.0 (clause 5.3.1 of the code) which is for the case of All general buildings and structures, whose mean probable design life is 50 years, for a basic wind speed of 50m/s. [probability factor]

k_2 = 1.06 (clause 5.3.2 of the code) which is considered for terrain category 3 and class C as the height of the building exceeds 50m [terrain, height and structure size factor]

k_3 = 1.0 (clause 5.3.3 of the code) which is for flat terrain. [Topography factor]

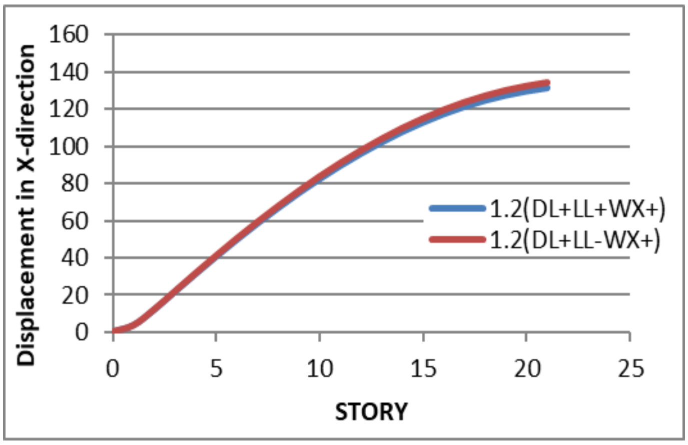
3.3.4 Load Combinations

Load combinations are considered as per IS456:2000

a. 1.2(DL+LL+WX+)
b. 1.2(DL+LL-WX+)
c. 1.2(DL+LL+WY-)
d. 1.2(DL+LL-WY-)

4. RESULTS AND DISCUSSION

The analysis of the structure has been done initially without providing shear wall. Table 1 shows the storey displacement for various load combinations considered above. Figure 2 shows the displacement of the structure according to the considered load combination. As seen in the given graphs the displacement of the structure for 1.2(DL+LL+WX+) and 1.2(DL+LL-WX+) are almost the same. Similarly, for wind in negative Y-direction the displacement is almost same for both 1.2(DL+LL+WY-) and 1.2(DL+LL–WY-) [4].



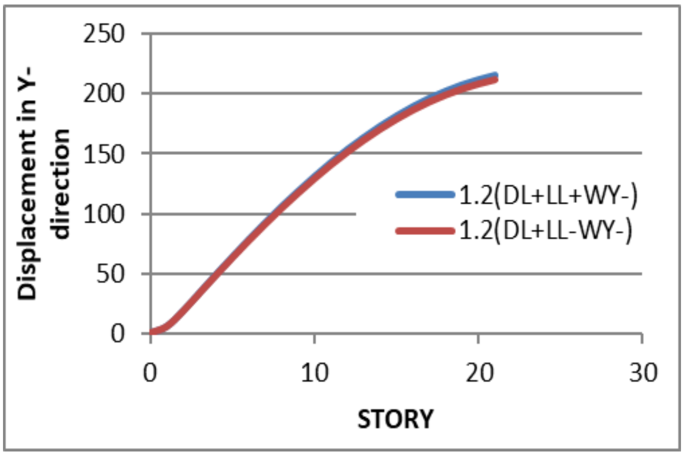


Figure 2. Displacement of the structure without Shear Wall

Various cases are considered based on different shear wall positioning. A shear wall of 200mm thickness is considered. The top story displacement of the structure for load combination case (a) is shown on Table 2 Load combination case (a) corresponds to the load combination as per IS 456:2000 of 1.2(DL+LL+WX+) and the corresponding graph is shown in Figure 3.

Table 1. Story Displacement of the structure without Shear Wall

	Top story displacement (mm)
Without Shear Wall	131.493
Shear Wall Position 1	21.211
Shear Wall Position 2	115.092
Shear Wall Position 3	58.265
Shear Wall Position 4	26.723
Shear Wall Position 5	32.555

From Table 2, storey displacement for the structure without shear wall is found to be 131.5mm. Lesser value of storey displacement was observed at Shear wall Position 1.

Table 2. Top story displacement for load combination (a)

	Displacement (mm)			
Story	1.2(DL+LL+WX+)	1.2(DL+LL-WX+)	1.2(DL+LL+WY-)	1.2(DL+LL-WY-)
21	131.493	133.992	216.018	212.447
20	129.769	132.144	212.394	209.003
19	127.57	129.807	208.037	204.809
18	124.792	126.904	202.814	199.762
17	121.432	123.413	196.721	193.84
16	117.491	119.343	189.765	187.056
15	112.982	114.703	181.964	179.428
14	107.918	109.508	173.34	170.978
13	102.316	103.774	163.918	161.73
12	96.192	97.518	153.726	151.712
11	89.565	90.757	142.792	140.955
10	82.454	83.512	131.15	129.49
9	74.882	75.805	118.836	117.354
8	66.875	67.661	105.896	104.593
7	58.461	59.109	92.378	91.257
6	49.673	50.212	78.334	77.396
5	40.55	40.983	63.817	63.064
4	31.14	31.465	48.897	48.33
3	21.511	21.728	33.683	33.304
2	11.854	11.97	18.5	18.299
1	3.473	3.523	5.452	5.372
0	0	0	0	0

The following tables show the top story displacement for load combination cases (b), (c) and (d). Load combination (b) corresponds to 1.2(DL+LL-WX+), load combination (c) corresponds to 1.2(DL+LL+WY-) and load combination (d) corresponds to 1.2(DL+LL-WY-).

Table 3 shows the storey displacement for load combination case (b) without shear wall is 133.992mm. Lesser value of displacement is observed in Shear wall Position 1.

From Table 4, the storey displacement for load combination case (c) was 216.018mm for structure without shear wall. The lesser value of the displacement is obtained from shear wall position 1 i.e., 35.552mm [5].

Table 3. Top story displacement for load combination (b)

	Top story displacement (mm)
Without Shear Wall	133.992
Shear Wall Position 1	22.312
Shear Wall Position 2	116.21
Shear Wall Position 3	61.374
Shear Wall Position 4	27.463
Shear Wall Position 5	33.386

Table 4. Top Story displacement for load combination (c)

	Top story displacement (mm)
Without Shear Wall	216.018
Shear Wall Position 1	35.552
Shear Wall Position 2	81.852
Shear Wall Position 3	166.037
Shear Wall Position 4	61.553
Shear Wall Position 5	90.858

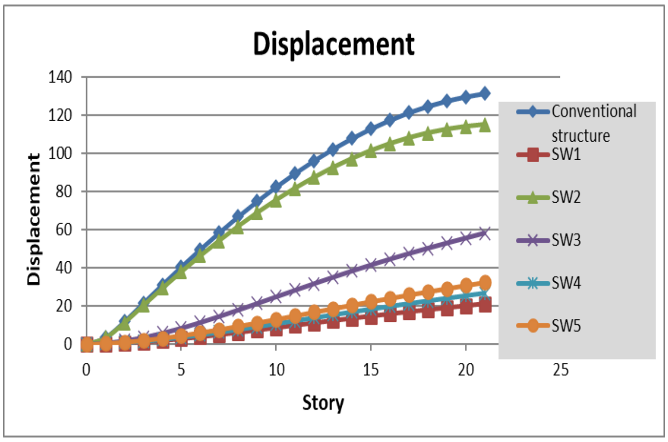


Figure 3. Displacement of the structure for load combination case (a)

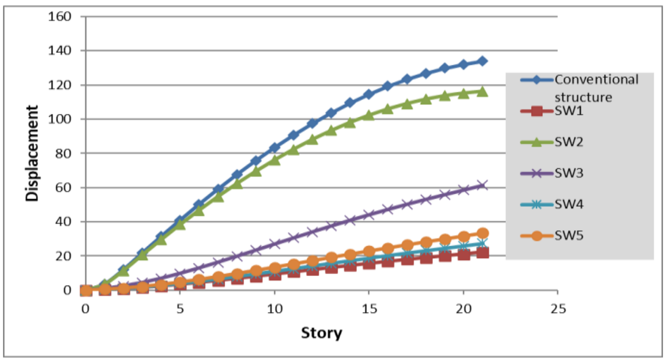


Figure 4. Displacement of the structure for load combination case (b)

Similarly, Table 5 shows the displacement for load combination case (d) without shear wall is 212.447mm and the lesser displacement is obtained for the shear wall position 1 i.e., 34.345mm.

The graphs of all the load combinations are shown in the following figures. All the values of story displacement are extracted from ETABS [6,7].

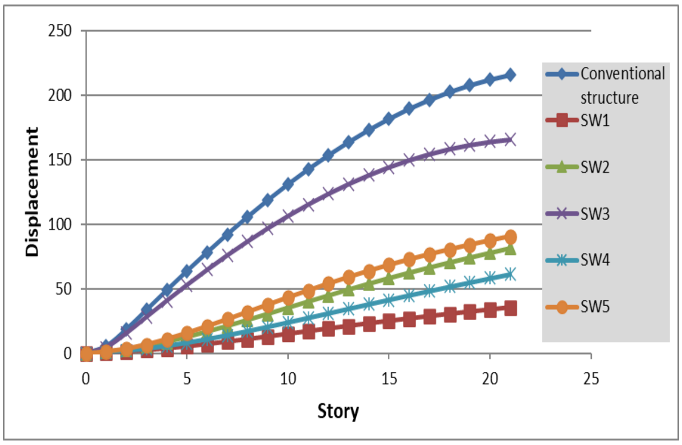


Figure 5. Displacement of the structure for load combination case (c)

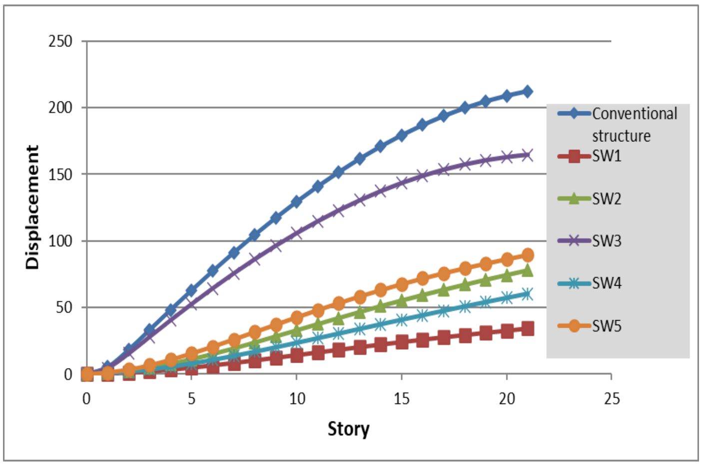


Figure 6. Displacement of the structure for load combination case (d)

5. CONCLUSION

Based on the test results, the following conclusions can be drawn.

- The effect of shear wall has been analyzed for the multi-storeyed structure.
- Different positions of shear wall were considered in this study and position 1(at corners) was found to give lesser displacement.

REFERENCES

[1] Charney, F. A. (1990). Wind drift serviceability limit state design of multistory buildings. *Journal of Wind Engineering and Industrial Aerodynamics*, *36*, 203-212.

[2] Thoroddsen, S. T., Peterka, J. A., & Cermak, J. E. (1988). Correlation of the components of wind-loading on tall buildings. In *Advances in Wind Engineering* (pp. 351-360). Elsevier.

[3] Chan, C. M., Huang, M. F., & Kwok, K. C. (2010). Integrated wind load analysis and stiffness optimization of tall buildings with 3D modes. *Engineering structures*, *32*(5), 1252-1261.

[4] Bureau of Indian Standards 875:2015.

[5] Bureau of Indian Standards 456:2000.

[6] Tilak, U. V., & Reddy, A. N. (2015). Effect of different percentage replacement of weathered aggregate in place of Normal Aggregate on young's Modulus of concrete to produce high strength and flexible/Ductile concrete for use in Railway concrete sleepers. *SSRG Int. J. Civ. Eng*, *2*(11), 24-29.

[7] Reddy, A. N., & Tilak, U. V. (2015). Drying Shrinkage and Durability Studies on Alkali Activated Slag Concrete Using Different Activators. *International Journal of Innovative Research in Science, Engineering and Technology*, *4*(11).