Performance of High Rise Building Under Seismic and Wind Excitation for the Different Plan Configurations of Same Area

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Abstract - *Tall buildings are built out of necessity to achieve high density development. They provide the opportunity to control urban sprawl with their relatively small foot print. They save space and accommodate more residents as compared to shorter buildings. The higher floors are relatively more airy and receive more sunlight. However it is more complicated and more expensive to build high rise. Foundations and structure have to cope with heavy loads, wind and potential earth quakes.*

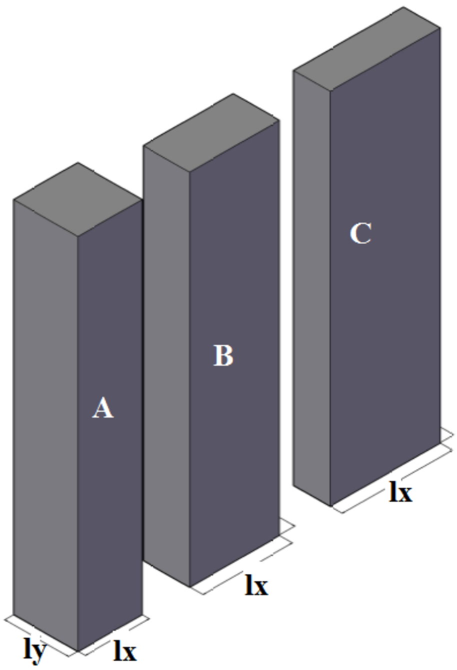
This paper is aimed at studying how high rise building structures of different Plan configurations will behave during seismic and wind excitation. Tall RCC buildings will respond differently based upon their overall geometry, size and shape. Twenty-one models starting with Ly:Lx ratio of 1:1 to 1:3 for G+60 storey structure are modeled. These are assumed to be located in seismic zone, zone -IV. All the models are modeled and analyzed using Finite Element Analysis and evaluated using the software ETABS 2017. The authors present the result of their analysis in this paper.

Key Words: **Plan configurations, Seismic Load, wind Load, displacement, CSI ETABS 2017**

1. INTRODUCTION

Today in metro cities there is no alternative to high-rise building construction. There is scarcity of land on the other hand urban population is growing every year. The demand of housing requirement is ever increasing. It is necessary to be vigilant about the safety and stability of high risers. This passion for high rise buildings continues to challenge the architects and engineers. Countries and city are competing with each other to construct the most iconic high rise structures. Today we have come to a stage from tall to super tall to mega tall structures. The ideal aspects of a building form are simplicity, regularity and symmetry in both plan and elevation. In high rise RCC structures' construction, earthquake and high speed wind forces are known to be causing vibrations and oscillations in the structures. The increase in intensity of vibration can cause damage to structures.

One of the most important factors is the ratio of the length to the width Ly:Lx of the plan of the building. Another factor is 'Slenderness ratio', the ratio of the height to the least lateral dimension of the building. More slender the building more is the overturning moments created. Higher Plan shapes on the other hand can create comparatively more stiffness in one direction and further make the other direction more vulnerable to excitations.



Building A has plan aspect ratio Ly:Lx of 1:1,

B 1:2 and C 1:3

Figure 1: plan configurations of models

2. Literature Review

Sanjay Kumar Sadh (2016) concluded in his research paper that, all the seismic parameters, viz. Base Shear, Storey Overturning Moment, Storey Drift, Storey Displacement and Modal Period of Vibration increase with the number of bays (Horizontal Aspect ratio/ Plan Aspect Ratio) and number of storeys (Vertical Aspect ratio/Slenderness Ratio). According to his studies, the higher the number of bays or storeys, higher is the values of all these parameters.

According to **M. Mezzi et al (2004),** new tools to be applied at conceptual design level for building including new protection systems have been pointed out deriving them by the special behavior of these constructions that have to be characterized by the capacity to move. They have been defined as discontinuity, motion and flexibility. Some optimization evaluations regarding the global distribution of mass and stiffness in isolated building are presented together with a significant application to a special building.

M. Mezzi (2008) in his paper pointed that, the conceptual design of building is dominated by the reference to the vertical loads and to the traditional rules of fixity and rigidity correlated to them. This is also true for building in seismic areas. Recent earthquake protection techniques, like isolation, energy dissipation, active and hybrid control, demonstrated to significantly enhance the seismic performances of buildings.

Recently, Zhi-Yi Chen (2017), carried out time history analyses and ultimate bearing capacity analysis of central columns on the seismic behavior of a typical two-story three-span subway station structure. Emphasis was placed on the static axial compression ratio and aspect ratio, H/B, of the central columns. He concluded in his paper that, the increase in aspect ratio of the central column reduces the structural seismic capacity. He also observed that the influence of H/B on the seismic performance of structures is more complicated.

Chandradhara G. P. (2014) reiterated in their study that, as the aspect ratio increases moments in the column decreases considerably for wind load cases, whereas, the moments remain same for all aspect ratio for gravity loads. Author also pointed out that, as the height of the building increases moments in the column increases for low rise building. It remains constant for medium height buildings and the axial forces in the column are almost same for all load cases when the height of building is less than 15mts.

R.Kazi et al (2014) investigated that, the response of structure can be dramatically reduced by using viscoelastic damper without increasing the stiffness of the structure. They also found that, the performance of visco-elastic damper devices is much better for the tall buildings with slender design.

Nikhil S (2017) Summarized in his study that, that the square configuration which has an aspect ratio of 1 performs best seismically. They also found that, damping ratio has improved significantly with change in aspect ratio and along with the location study of Visco-Elastic dampers, even the aspect ratio is effective in reducing the structural responses of the structure.

3. METHODOLOGY

A G+60 story R.C.C. multistory building has been considered for analysis. Twenty-one models starting with Ly:Lx ratio of 1:1 to 1:3 for G+60 storey structure are modeled with different shape configurations, located in a highly wind and seismic zone, Zone IV. The plan area of the building is kept same however the shapes of building changes according to different shape configurations. Analytical modeling of structural components has been done. The columns are considered fixed at the base. Beams and Columns are modeled as frame element and joined node to nodes. Analytical modeling of structural components has been done on Finite Element Analysis using the software ETABS 2017

4. MODELLING DETAILS

4.1 Structural Details

As mentioned earlier, the model considered for analysis is G+60 multistory residential building. Total height of the building is 180 m and floor to floor height is 3m.

Table 1: Model details

Particulars	Plan shape	Plan Size	Plan Area
Model 1	1:1	32m x 32m	1024m^2
Model 2	1:1.1	33m x 31m	1023m^2
Model 3	1:1.2	35m x 29m	1015m^2
Model 4	1:1.3	37m x 28m	1036m^2
Model 5	1:1.4	38m x 27m	1026m^2
Model 6	1:1.5	39m x 26m	1014m^2
Model 7	1:1.6	40m x 25m	1000m^2
Model 8	1:1.7	41m x 25m	1025m^2
Model 9	1:1.8	43m x 24m	1032m^2
Model 10	1:1.9	44m x 23m	1012m^2
Model 11	1:2	45m x 23m	1035m^2
Model 12	1:2.1	46m x 22m	1012m^2
Model 13	1:2.2	47m x 22m	1034m^2
Model 14	1:2.3	48m x 21m	1008m^2
Model 15	1:2.4	49m x 20m	980m^2
Model 16	1:2.5	50m x 20m	1000m^2
Model 17	1:2.6	51m x 20m	1020m^2
Model 18	1:2.7	52m x 19m	988m^2
Model 19	1:2.8	53m x 19m	1007m^2
Model 20	1:2.9	54m x 18m	972m^2
Model 21	1:3	55m x 18m	990m^2

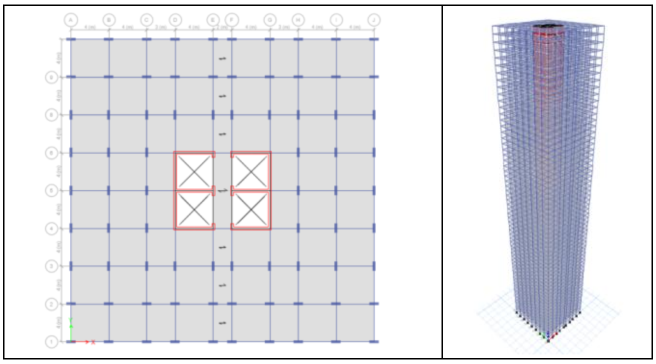


Figure 2: Plan and 3D illustration of Model 1 with Plan aspect ratio 1:1

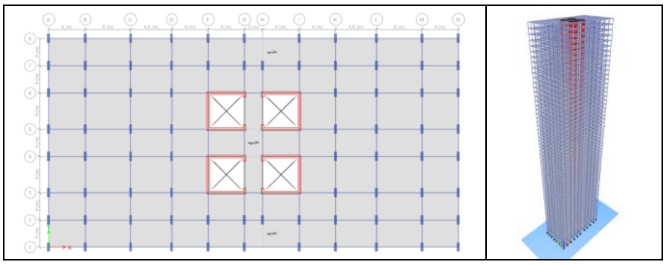


Figure 3: Plan and 3D illustration of Model 11 with Plan aspect ratio 1:2

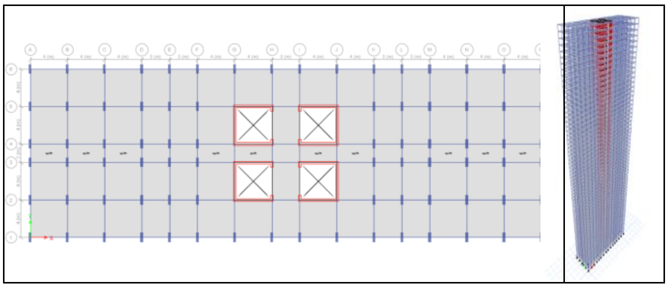


Figure 4: Plan and 3D illustration of Model 21 with Plan aspect ratio 1:3

Table 2: Frame and Shell Sections

Name	Dimensions	Concrete Grade
Floor Slab	150 mm	M30
Staircase Slab	150 mm	M30
Interior Wall	200 mm	Not Applicable
Exterior Wall	200 mm	Not Applicable
R.C.C Wall	200 mm	M45
Beam	350 x 600 mm	M40
Column	600 x 1600 mm	M45

Table 3: Material properties

Name	Type	E Mpa
AAC Block	Concrete	2059.39
HYSD500	Rebar	200000
M30	Concrete	27386.13
M40	Concrete	31622.78
M45	Concrete	33541.02

Table 4: Load conditions

1. Gravity Loads: Dead load according to IS 875 part I
   Live Load according to IS 875 part II
2. Wind loads: In accordance with IS 875: 2015 part III
   Basic wind speed : 55 m/s
   Risk coefficient and topography factor are taken as unity.
3. Seismic Load: Criteria as per IS 1893: 2016
   Zone IV, Site type II

5. RESULT AND DISCUSSION

Results are shown as comparison of all twenty-one models starting from plan aspect ratio of 1:1 to 1:3 for G+60 storey structure, analysis with different aspect ratios located in a high wind and seismic zone. Results show a relative displacement on each storey due to Earthquake in X direction of the building.

Fig. 5 shows analysis of all twenty-one models in ETABS, for displacement at each level due to earthquake in X direction.

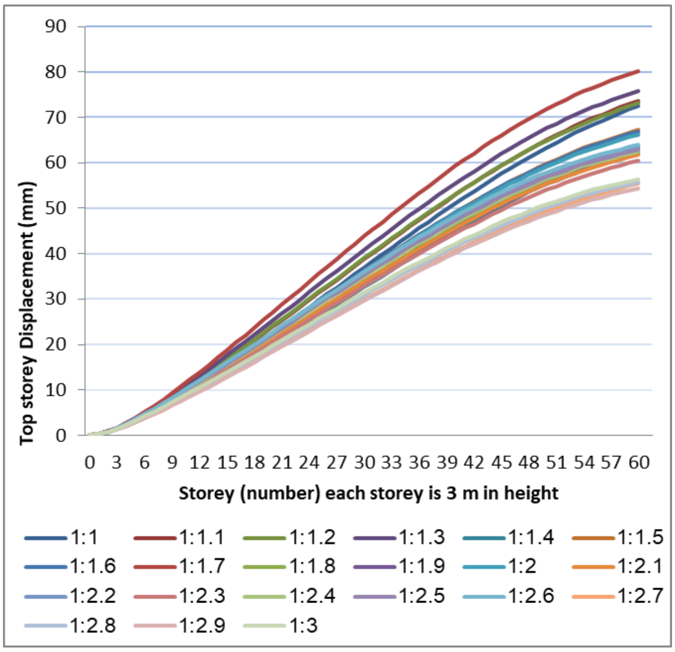


Figure 5: Storey vs. Top storey displacement due to earthquake in X direction.

It is within permissible limit according to IS Code 1893:2016.

Results are shown as comparison of all twenty-one models starting from plan aspect ratio of 1:1 to 1:3 for G+60 storey structure, analysis with different aspect ratios located in a high wind and seismic zone. Results show a relative displacement on each storey due to Earthquake in Y direction of the building.

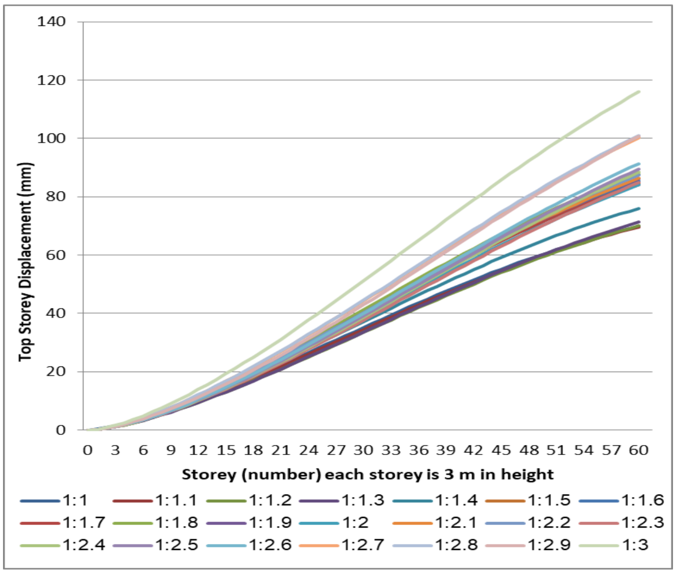


Figure 6: Storey vs. top storey displacement due to earthquake in Y direction.

Fig. 6 shows analysis of all twenty-one models in ETABS, for displacement at each level due to earthquake in Y direction. It is within permissible limit according to IS 1893:2016.

Results are shown as comparison of all twenty-one models starting from plan aspect ratio of 1:1 to 1:3 for G+60 storey structure, analysis with different aspect ratios located in a high wind and seismic zone. Results show a relative displacement on each storey due to wind in X direction of the building.

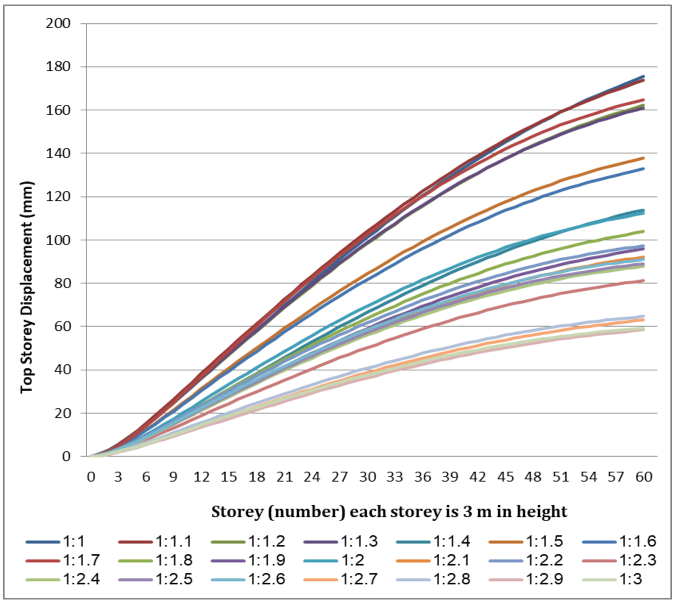


Figure 7: Storey vs. top storey displacement due to wind in X direction.

Fig. 7 shows analysis of all twenty-one models in ETABS, for displacement at each level due to wind in X direction. It is within permissible limit according to IS 1893:2016.

Results are shown as comparison of all twenty-one models starting from plan aspect ratio of 1:1 to 1:3 for G+60 storey structure, analysis with different aspect ratios located in a high wind and seismic zone. Results show a relative displacement on each storey due to wind in Y direction of the building.

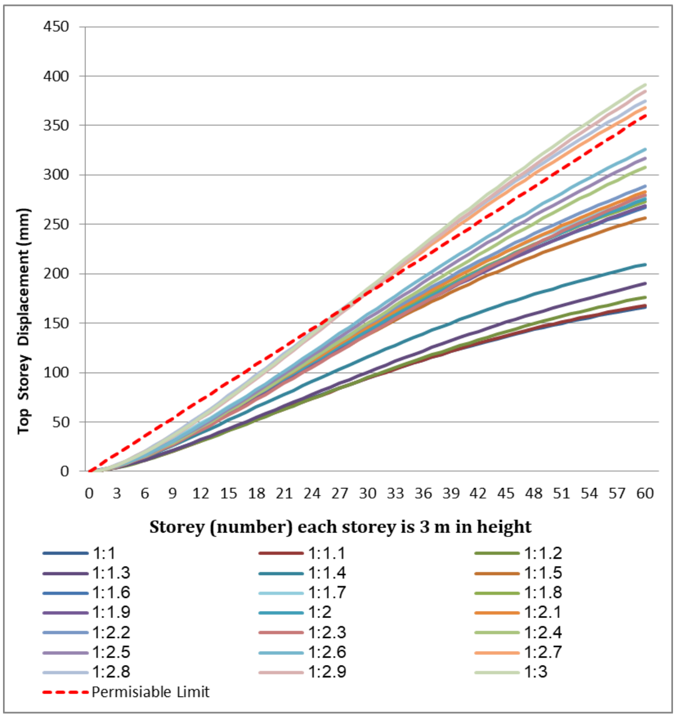


Figure 8: Storey vs. top storey displacement due to wind in Y direction.

Fig. 8 shows analysis of all twenty-one models in ETABS, for displacement at each level due to wind in Y direction. Up to the plan aspect ratio of 1:2.6 the displacement is within the permissible limit. Beyond this ratio the displacement exceeded the permissible value. All floors above 30 indicate higher displacement.

3. CONCLUSIONS

1. From the present study it can be concluded that, Plan aspect ratio Ly:Lx of the building above 1:2.6 is not feasible for 180m height of the building (G+60).

2. The displacement of the top storey increases as the Plan aspect ratio increases in Y direction. On the contrary, this stability of the building is observed to be increasing with the increase in Ly:Lx ratio.

3. The Plan aspect ratio Ly: Lx is an important factor for high rise building. Parameter of storey drift in Y-direction for top

storey displacement is maximized with increase in aspect ratios.

4. The present study reveals that the square configuration which has Plan aspect ratio of 1 performs best seismically.

5. Time period of the building increases as the Plan aspect ratio increases.

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