Comparison Study of Responses Generated In Rectangular and Octagonal Shaped High Rise Buildings under Wind Loads

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Abstract - *Comparison study of Responses generated in RCC Framed structure Rectangular and Octagonal Shaped High rise buildings under wind loads is presented in this paper. The effect of shape plays a vital role in the effect generated by wind load as the height of building increases. As sufficient information is not available in the standard codes of practice regarding irregular plans and cross-sectional shapes of high rise buildings, hence, more exploration and research needs to be done in the subjected area. With this objective, this study focuses on presenting comparison of reactions including base shear (FX), moment about X axis (MX), moment about Y axis (MY) and Deflection in X direction of rectangular and Octagonal shaped High Rise building with composite columns exposed to 0° and 90° attack angles of wind. Bentley STAAD Pro software v8i module is used to design and analyze Structure prototype (G+26 with 3.5 m floor height) to compare responses and analysis of structural system against wind load.*

Key Words: High Rise Building, Shape factor, Wind load analysis, Composite columns, Base Shear, Building Deflection

1. INTRODUCTION

Increasing population and migration of people towards cities for livelihood demands vertical expansion of cities to provide residential, industrial, recreational and educational infrastructures. The wind is large- scale movements of air currents blowing perpendicular to Building elevations, In design stage of high Rise buildings, the consideration of wind loads is very crucial as it is a complicated load with nonlinear occurrence and wide variation against different shapes and elevations, its analysis is very complex in nature. Standard codes of practices are available for assisting engineers to design structures to resist wind loads but the shapes of structures considered in them are generally square and rectangular shaped and give very minimal information of pressure distribution on High Rise buildings under wind loads. Review of research work done in this field shows that majority of the work has been done on pressure distributions of regular shaped High rise building models only.

1.1 Building Specifications

To perform the study and analyze wind loads on structure with different plan shape, a G+26 story building is designed in STAAD Pro. The total height of the building is 94m. The basic wind speed is for Delhi, India region i.e. 47 m/s.

Table – 1: Building Specifications

Particulars	Rectangular Building	Octagonal Building
Type of building	High Rise	High Rise
Type of structure	RCC framed structure	RCC framed structure
Location	Delhi	Delhi
Plan of building	26 m x 18 m	26 m x 18 m
No of floor	G + 26	G + 26
Height of each floor	3.5 m	3.5 m
Seismic Zone	IV	IV
Density of Concrete	25 KN/m3	25 KN/m3
Live load	3.5 KN/m2	3.5 KN/m2
Beam size	250 x 500 mm	250 x 500 mm
Slab thickness	150 mm	150 mm
Grade of concrete	M40	M40
Steel grade	Fe 500	Fe 500
Column Dimensions		
Up to 9th Floor	800 x 800 mm	800 x 800 mm
10th to 18th Floor	600 x 600 mm	600 x 600 mm
19th to 27th Floor	400 x 400 mm	400 x 400 mm

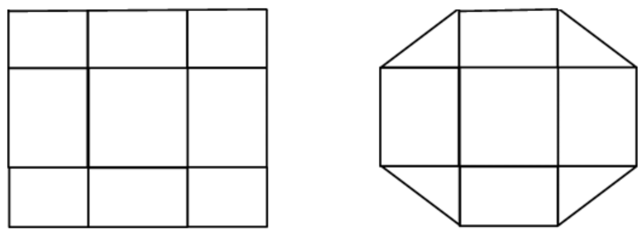

Fig. 1: Plan of buildings

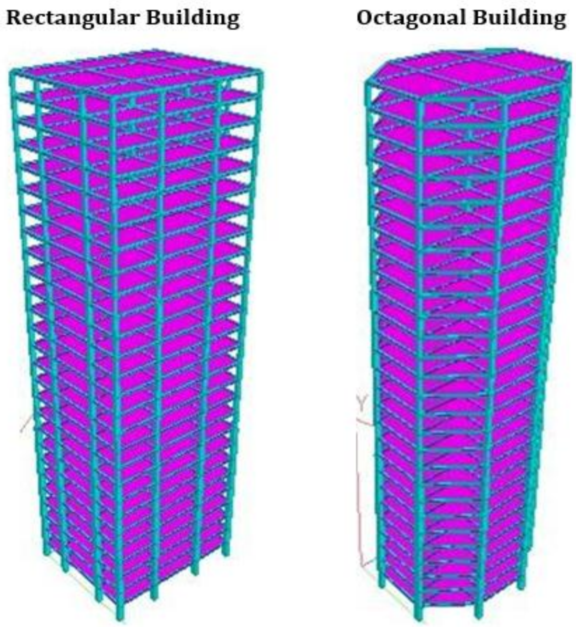

Fig. 2: 3D view of Building Elevations

2. METHODOLOGY

The steps used for designing the Structure in STAAD Pro are as follows:

1. Provide the nodes with co-ordinates and connect them by using the command "ADD BEAM" to make the plan.
2. Assign properties to the structure i.e. giving dimension to the beam (250 x 500 mm) and columns (800 x 800 mm).
3. By selecting all the nodes, use of translation repeat with step spacing= 3.5m, and global direction as Y, No. of steps = 10.
4. Edit the size of all columns at 10th Floor of plan as 600 x 600 mm, then use translation repeat with step spacing = 3.5m, global direction = Y, No. steps = 9.
5. Edit the size of all columns at 19th Floor of plan as 400 x 400 mm, then use translation repeat with step spacing = 3.5m, global direction = Y, No. steps = 9.
6. Assign supports to the structure.
7. Define Wind Loads - In Wind Load Definitions we input Wind intensities with respect to height.
8. Insert Load case details:

- **Dead Load (DL)**

  The Self weight of the structure is taken as Dead load comprising the weight of the various structural components such as slab, beam and column.

- **Live Load (LL)**

  The Live load is taken as the weight of movable members, concentrated load, load due to impact load and vibrations. As per IS 875[i] the value of live load is taken as 3.5 KN/m2.

- **Seismic load**

  Earthquake load is taken as per zone category specified in the IS code 1893 (Part 1): 2002[ii] for the location where building is located.

- **Wind Load (WL-X and WL-Z)**

  In this study, the location of building is Delhi which falls under the Zone IV, where wind speed is 47 m/s. Wind loads are taken as per IS 875 (Part 3): 2015[iii].

9. Assign loads to the structure.
10. Run Analysis and check for errors.
11. Make necessary changes in Design
12. Run Analysis and check for errors.

Designing is done as per IS 456:2000[iv]

The steps mentioned above are followed for Designing Rectangular Building first, then the same are repeated for Designing of Octagonal Building and then the analysis data is studied for response analysis and comparison.

3. RESULTS AND OBSERVATIONS

The results obtained from the design analysis of both the structures were studied, tabulated and compared in terms of base shear (FX), moment about X axis (MX), moment about Y axis (MY) and Deflection in X direction exposed to 0° and 90° attack angles of wind.

The analysis was carried out for both the structures and Graphs were plotted showing comparison for the corner column (Column A, Fig. 3) of both the structures. Displacement is the movement due to lateral forces of wind in either X or Y direction. The maximum impact of the displacement is found in the X direction hence for displacement only X direction is considered.

3.1 Comparisons of Buildings exposed to 0° angle of attack:

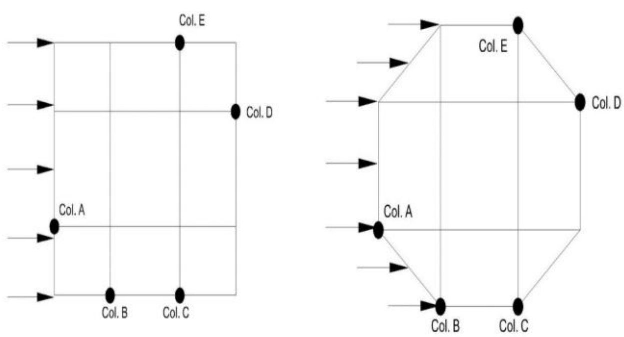

Fig. 3: Plans of Buildings with Wind angle of attack 0°

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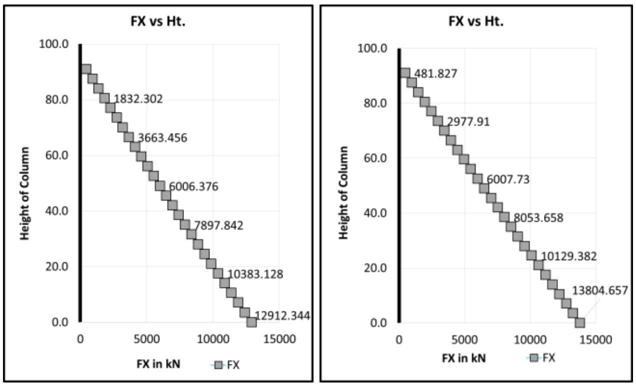
3.1.1 Base shear (Fx) :

Column A Base shear (Fx) - Rec. Build. Vs Oct. Build.

Base shear is the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. More the base shear more stable the structure is under seismic load. The Base shear of Octagonal plan shaped building increased by 7 % as compared to Rectangular plan shaped Building i.e. from 12,911 kN to 13,804 kN



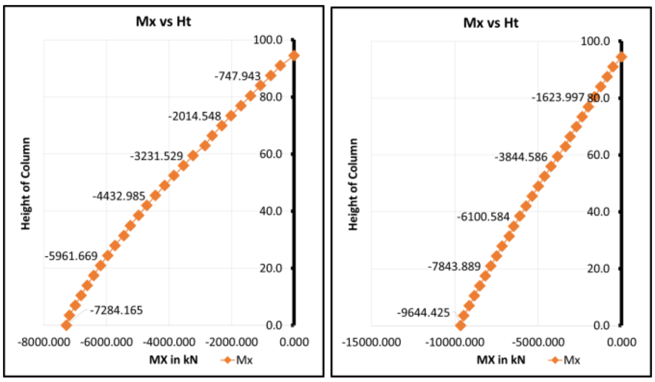
Rectangular plan Building Wind angle of attack 0˚ Octagonal plan Building Wind angle of attack 0˚

Chart 1: Comparison of Column A Base shear at 0˚

3.1.2 Moment about X axis (Mx):

Column A moment about X axis: Rec. Build. Vs Oct. Build

Moment about given axis means the component of force causing rotation in that direction. Value of moment in X direction is the force trying to rotate the structure sideways left or right side. The moment about X axis of Octagonal plan shaped building increased by 32.5 % as compared to Rectangular plan shaped Building i.e. from 7,284 kN to 9,644 kN.



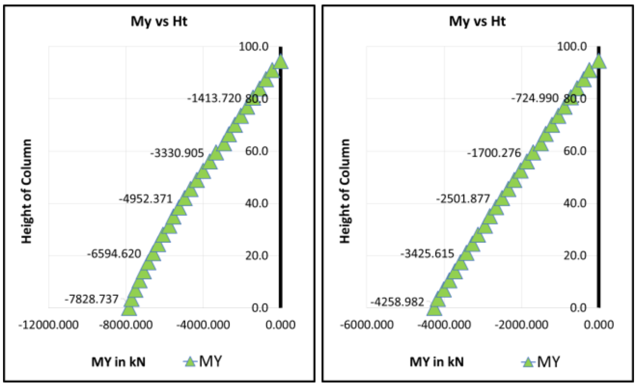
Rectangular plan Building Wind angle of attack 0˚ Octagonal plan Building Wind angle of attack 0˚

Chart 2: Comparison of Column A Moment about X axis

3.1.3 Moment about Y axis (My):

Column A moment about Y axis: Rec. Build. Vs Oct. Build

Value of moment in Y direction is the force trying to twist the structure as the height increases. The moment about Y axis of Octagonal plan shaped building decreased by 45.59 % as compared to Rectangular plan shaped Building i.e. from 7,828 kN to 4,259 kN. This shows that octagonal building is less prone to twisting in Y direction as the height of structure increases.



Rectangular plan Building Wind angle of attack 0˚ Octagonal plan Building Wind angle of attack 0˚

Chart 3: Comparison of Column A Moment about Y axis

3.1.4 Displacement in x direction:

Column A displacement in x direction: Rec. Vs Oct. Build

Displacement of Oct. Building column reduced by 29 % as compared to rectangular building's column i.e. displacement of topmost element from base was 45 mm in rectangular building whereas the same in Octagonal building was 32 mm. hence the structure is less impacted by Wind load as compared to rectangular building.

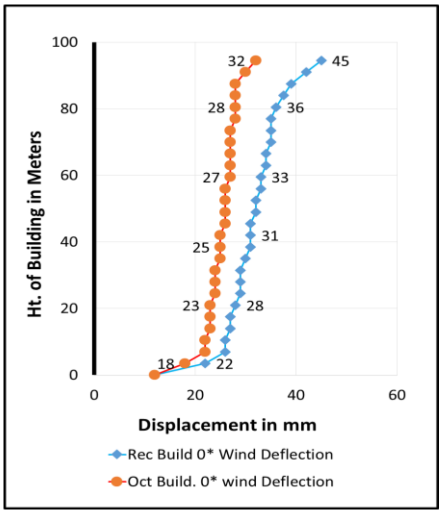


Chart 4: Column A deflection in x direction w.r.t Height under wind angle of attack 0˚

3.2 Comparisons of Buildings exposed to 90˚ Angle of attack:

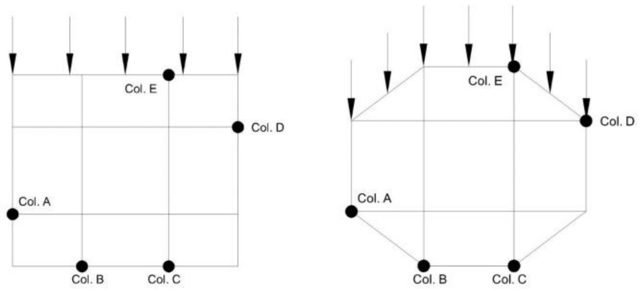
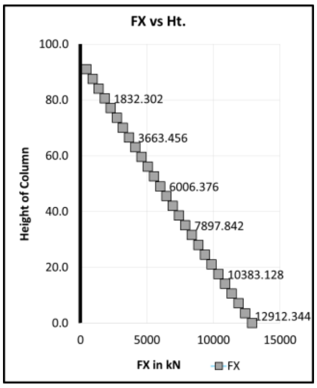


Fig. 4: Plans of Buildings with Wind angle of attack 90˚

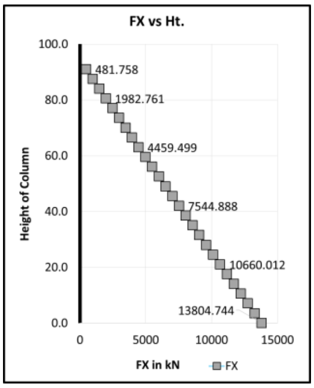
3.2.1 Base shear (Fx) :

Column A Base shear (Fx) - Rec. Build. Vs Oct. Build.

The Base shear of Octagonal plan shaped building increased by 6.9 % as compared to Rectangular plan shaped Building i.e. from 12,912 kN to 13,805 kN



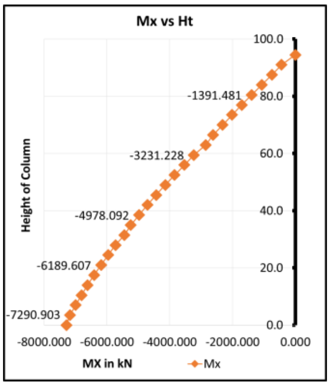
Rectangular plan Building
Wind angle of attack 90˚



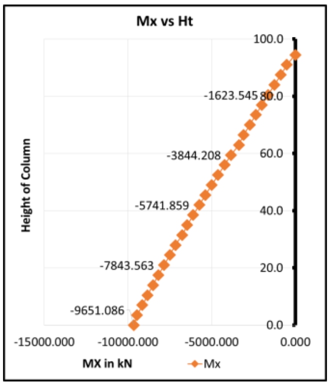
Octagonal plan Building
Wind angle of attack 90˚

Chart 5: Comparison of Column A Base shear

3.2.2 Moment about X axis (Mx):



Rectangular plan Building
Wind angle of attack 0˚



Octagonal plan Building
Wind angle of attack 0˚

Chart 6: Comparison of Column A Moment about X axis

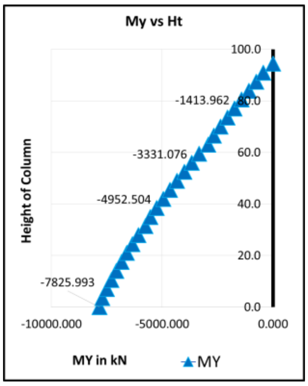
Column A moment about X axis: Rec. Build. Vs Oct. Build

The moment about X axis of Octagonal plan shaped building increased by 32.39 % as compared to Rectangular plan shaped Building i.e. from 7,290 kN to 9,651 kN.

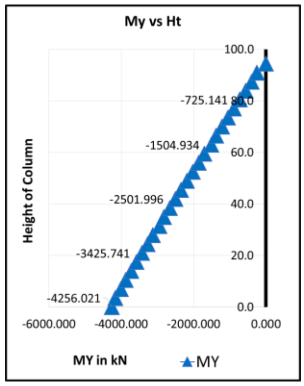
3.2.3 Moment about Y axis (My):

Column A moment about Y axis: Rec. Build. Vs Oct. Build

The moment about Y axis of Octagonal plan shaped building decreased by 45.62 % as compared to Rectangular plan shaped Building i.e. from 7,826 kN to 4,256 kN. This also shows that octagonal building is less prone to twisting in Y direction.



Rectangular plan Building
Wind angle of attack 90˚



Octagonal plan Building
Wind angle of attack 90˚

Chart 7: Comparison of Column A Moment about Y axis

3.1.4 Displacement in x direction:

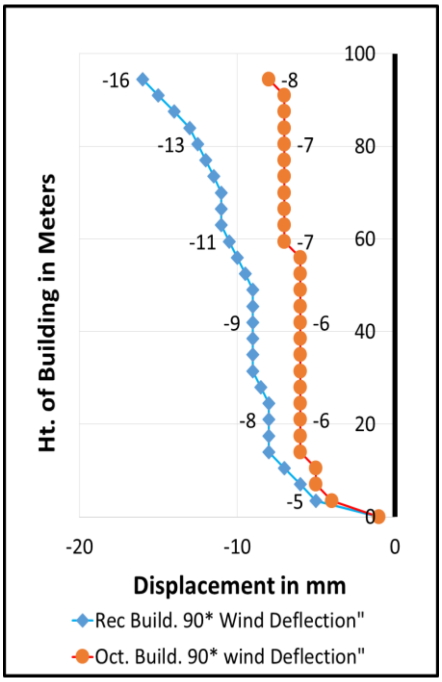


Chart 8: Column A deflection in x direction w.r.t Height under wind angle of attack 90˚

Column A displacement in x direction: Rec. Vs Oct. Build Displacement of Oct. Building column reduced by 50 % as compared to rectangular building's column i.e. displacement of topmost element from base was 16 mm in rectangular building whereas the same in Octagonal building was only 8 mm. hence the structure is less impacted by Wind load as compared to rectangular building in 90˚ angle of attack as well.

4. CONCLUSIONS

Based on the findings presented above, after performing the analysis of the building frames using STAAD PRO software, and comparing the results, it is concluded that:

Table - 2: Results and Conclusions

Column "A" Reactions	Result in Rectangular Building	Result in Octagonal Building	Remarks
Under 0˚ Wind Angle of Attack			
Base Shear (Fx)	12,911 kN	13,804 kN	Increased by 7 %
Moment about X axis (Mx)	7,284 kN	9,644 kN	Increased by 32.5 %
Moment about Y axis (My)	7,828 kN	4,259 kN	Decreased by 45.59 %
Displacement	45 mm	32 mm	Decreased by 29 %
Under 90˚ Wind Angle of Attack			
Base Shear (Fx)	12,912 kN	13,805 kN	Increased by 6.9 %
Moment about X axis (Mx)	7,290 kN	9,651 kN	Increased by 32.39 %
Moment about Y axis (My)	7,826 kN	4,256 kN	Decreased by 45.62 %
Displacement	16 mm	8 mm	Decreased by 50 %

1. The displacement of topmost elements in Octagonal Building were 40 % closer to their original position as compared to displacement of topmost elements in Rectangular plan shaped Building. Analysis shows that as the height increases, the Avg. Displacement increases, but the Rectangular shaped building shows more displacement as compare to Octagonal plan shaped structure.
2. As per the findings listed above (in Table -2), the average Base shear values of Octagonal plan shaped building have increased by 7 % w.r.t Rectangular shaped structure. And thus, Octagonal Building is safer than rectangular building under seismic conditions.
3. The average Moment about X axis of Octagonal Building increased by 32.45 %, as compared to rectangular Building of same specifications and properties.
4. On average, Octagonal Building is 45.6 % less impacted by Moment about Y axis (in Vertical direction) i.e. twisting effect, hence is far more safer and efficient in resisting twisting effect of wind loads as compared to Rectangular plan shaped High rise Building.
5. It is also observed that in both cases bending moment and shear force is maximum at bottom and minimum at top.

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