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Wind Load Analysis on A Multistoreyed Building Curved in Plan

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ABSTRACT: In this study a tall G+8 storied curved in plan (comprising an external and internal curved facade) has been analysed for wind acting in specified directions using STAAD pro v8i.For the curved profile, the wind load component has been calculated for each radial beam line. The combination of static load and wind load are taken into consideration. In the first case, the wind has been assumed to act towards the centre of the arc of the circle and in the second, away from the centre. The post processing reverberation in terms of bending moments, shear forces and support reactions has been studied in relation to the wind directions. Due to the effect of wind load on the structure, the storey-sage variation of the result with respect to different parameters are to be compared. The stiffness of the structure as a whole is expected to vary with the changed direction of the wind. The result would result in a parametric study of the effect of wind direction on curved profile. The orientation of the curved structure with respect to the direction of wind load has been studied.

I. INTRODUCTION

The importance of wind engineering is materializing in India ever since the need for taller buildings is coming forth. Considering the ever-increasing population as well as limited space, horizontal expansion is no more a viable solution especially in metropolitan cities. There is enough technology to build super-tall buildings today, but in India we are yet to catch up with the technology which is already established in other parts of the world. Nowadays, Construction of high-rise building is a basic need because of scarcity of land. Conventional method of manual design of high-rise building is time consuming as well as possibility of human errors. So, it is necessary to use some computer-based software which gives more accurate results and reduce the time. STAAD Pro is the structural software is nowadays accepted by structural engineers. STAAD.Pro is the structural engineering professional's choice for steel, concrete, timber, aluminium, and cold-formed steel design of virtually any structure including culverts, petrochemical plants, tunnels, bridges, piles, and much more through its flexible modelling environment, advanced features, and fluent data collaboration. STAAD.Pro allows structural engineers to analyze and design virtually any type of structure through its flexible modelling environment, advanced features and fluent data collaboration. Wind is air in motion relative to the surface of the earth. It varies with space and time.

Due to the unpredictable nature of wind, it is necessary to design tall structures by considering the critical effect of wind on the structure. Wind force depends upon exposed area of the structure. The wind force depends upon terrain and topography of location, nature of wind, size and shape of structure and dynamic properties of building. It is important for the estimation of wind loads on the flexible structures. The conventional approach to tall building design in the past was to limit the forms of the building to regular shapes like rectangular and square mostly, but today, much more complicated building geometries are being utilized. One such geometrical shape of curved multi-storey building (comprising an external and internal curved facade) is being analyzed for wind load using STAAD Pro**.** In this cramming we have contemplate only dead load and wind load because to clearly know the effect of wind load and avoid the confusion of which load is altering the parameter. We can know the shear force and bending moment using approximate analysis techniques but here we are considering the variation of axial forces in the radial beams. Nobody knows the axial effect in radial beams due to lateral force so we want to find out what is the variation in the axial force before we neglect and discard it. Modelling of the structure is done considering the practical possibilities and wind load is calculated as per IS 875 (part III).

II. MATERIAL AND METHODS

The virtual structure is modelled with concrete beams and columns along with concrete slabs and shear wall.
Assumed dimensions of the members
Concrete beam – 0.35m x 0.6m
Concrete column – 0.6m x 0.35m
Concrete slab – 0.15m
Concrete shear wall – 0.25m

Assumptions:

For calculation of wind load
- Basic wind speed - 50 m/s
- Mean predictable design life of structure - 50 years
- Terrain category – 2
- Upwind slope – 8^o

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Wind Load Calculations:

Calculation of wind load as per IS 875 part III

Wind force $F = C_f A_e p_d$

Where, C_f = force Coefficient

A_e= effective Area normal to Wind

p_d= design wind pressure

Design wind pressure $p_d = K_d K_a K_c p_z$

Where, K_d = wind directionality factor

K_a = area averaging factor

K_c = combination factor

P_z = wind pressure at height z = $0.6V_z^2$

Design wind speed $V_z = V_b k_1 k_2 k_3 k_4$

Where, V_b = basic wind speed

k_1 = probability factor

k_2 = terrain roughness and height factor

k_3 = topography factor = $1+ C S_o$

k_4 = importance factor for cyclonic region

MODELLING:

STAAD model details:

Considerations for modelling the structure

- Curved building comprising an external and internal facade
- Type of building – residential
- G+8 storey building

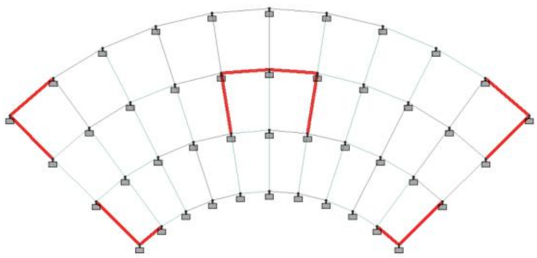

Figure1: plan of the structure showing shear wallposition

- No. of bays -10
- Height of each storey - 3.2m
- Length of each radial beam – 5 m.
- Shear walls at all four corners and central portion of the building
- Location of the structure – Vijayawada, AP.

Plan of the structure (top view) is shown in **Figure 1.** along with the position of shear walls placed within the structure. For better understanding 3-D view of the fully modelled structure is shown in **Figure 2.** showing the shear walls and slabs along with beams and columns.

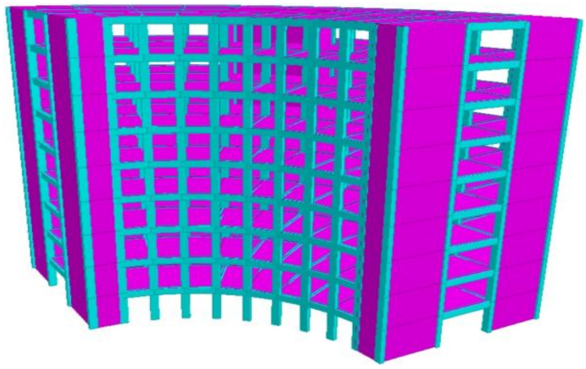

Figure 2. 3-D view of the structure

Columns are oriented such that the longer dimension of the rectangle is facing towards the open side of the facades with the help of beta angle. Beams that are located at the location of shear wall are removed to provide continuity for the shear wall. Provision of lift and stair case can be provided at the central bay where the shear wall is provided around.

Total no. of individual elements present in the model

Total no. of nodes – 440

Total no. of beams – 936

Total no. of plates – 378

III. RESULTS AND DISCUSSION

Analysis on wind load on a multi-storey building curved in plan with both external and internal facades is done taking the axial force in the radial beams as a parameter. Wind load is applied along all radial beams both inward and outward directions and the results are obtained.

Analysis of results:

Max axial force in each radial beam lines is noted for wind acting outward i.e., away from Centre in different directions and are represented in Fig 3

Max axial force in radial beams follow same pattern for most of the directions of wind i.e., increases from 4 to 5, 6 to 7 and 9 to 10; and decreases from 2 to 3, 5 to 6 and 7 to 8. This variation is because of the shear walls that are placed at corners and central portion of the structure.

Max axial force in each radial beam lines is noted for wind acting inward i.e., towards the centre in different directions and are represented in **Figure 3.**

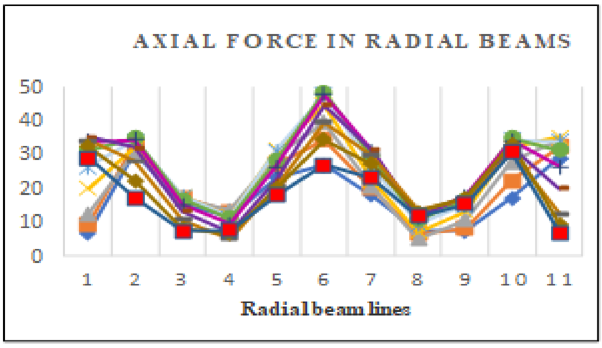

Figure 3. Variation of axial force w.r.t wind load acting inward at different angles

Max axial force in radial beams follow same pattern for most of the directions of wind i.e., increases from 4 to 5, 5 to 6, 8 to 9 and 9 to 10; and decreases from 2 to 3, 3 to 4, 6 to 7, and 7 to 8. This variation is because of the shear walls that are placed at corners and central portion of the structure. When compared both the above, inward and outward direction wind forces, shear wall showed much effect on the outward direction wind force. Shear wall at central portion of the structure reduces the axial force in the central beam line in the outward wind direction.

One similar thing between inward and outward direction of wind force is that axial force in symmetrical radial beams i.e., 315 and 45, 324 and 36, 333 and 27, 324 and 18, 351 and 9 are reciprocal to each other.

For wind directions 315, 324, 333, 342 and 351 axial force increases from 1 to 2 and 10 to 11 and decreases for other wind directions i.e., 9, 18, 27, 36 and 45 in both outward and inward wind directions.

Effect of shear wall:

Shear wall helps in reducing the effect of lateral loads on the structures. In this study the outcome of shear wall on the curved structure is studied. Axial force in radial beams with and without shear wall, when the wind force is acting along the central radial beam line both inward and outward directions is given in **Figure 4.**

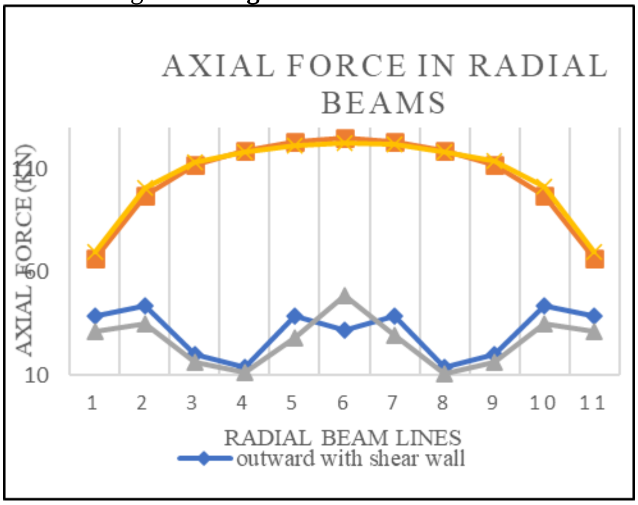

Figure 4. Variation of axial force in the central radial beam line when the wind is acting inward and outward and with and without shear walls.

Max axial force in the radial beams is reduced by 60% for both inward and outward directions of wind. Not only axial force other parameters like bending moment and shear forces also reduced by 75% and 82% respectively when the wind force is acting inward along the central beam line.

The max axial force in the radial beams when the wind force is acting outward and inward directions is shown in **Figure 5.**

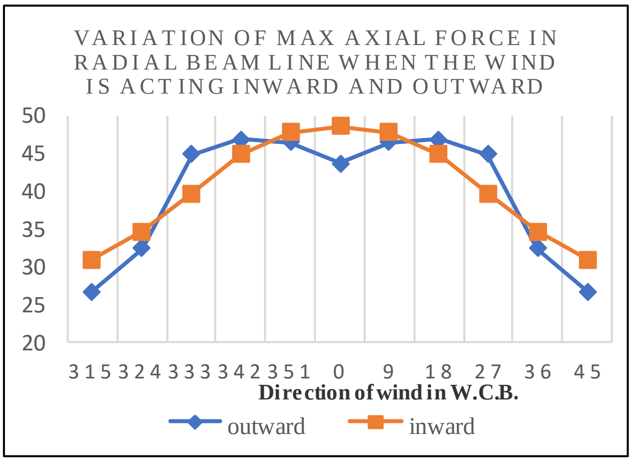

Figure 5. Variation of max axial force in radial beam line when the wind is acting inward and outward.

Wind force acting in outward direction has much effect due to shear wall. From **Fig 5.4.** we can observe a sharp increase and decrease in the axial force in between corner and central portion shear walls present in the structure. The axial force in the central beam line is reduced in outward wind direction whereas inward wind direction has not affected the axial force in central beam line.

5.4. Orientation of the structure:

Orientation of the structure is essential to minimize the effect of wind load. In case of conventional shapes elliptical and circular has less effect of wind load. As, already mentioned outward wind direction is much affected by shear wall in reduction of parameters like shear force and bending moment.

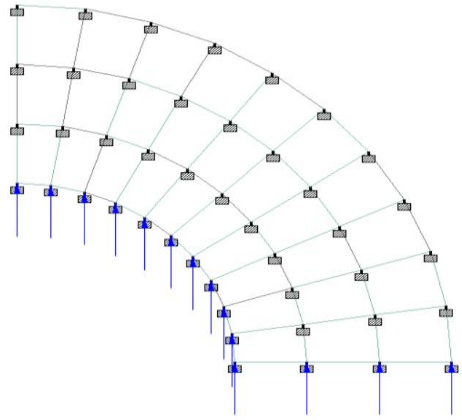

Figure 6. Best orientation of curved structure

Best orientation of the curved buildings when the wind is acting from south to north is shown in **Figure 7.** Out of 11 outward wind directions, wind acting along the 1st radial beam line has lesser bending moment and shear force which are key parameters in calculating the quantity of steel and concrete. A point to be noted here is that the critical wind direction is also when the wind acting outward direction along the 4th radial beam line. Reduction of max bending moment and max shear force for wind acting along 1st radial beam line i.e., 315^0 is 52% and 49% lesser respectively than that of max bending moment and shear force for wind acting 4th radial beam line i.e., 342^0.

IV. CONCLUSIONS

The major findings of the present theoretical study are listed below

1. Shear wall at the central portion of structure is much effective when the wind force direction is outward i.e., wind acting away from the centre of the structure.
2. Axial force in the radial beams are almost the same, except for the central radial beam, for both inward and outward directions of wind.
3. Axial force in radial beams are reciprocal to each other for the wind acting on symmetrical radial beam directions.
4. Shear wall reduces the quantities like axial force, shear force and bending moment to a greater extent in the radial beams.
5. Orientation of the curved structure w.r.t wind direction is determined.

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