ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Analysis of Wind Load Effects like Deflection, Bending Moment and Axial Forces on Different Shapes of High-Rise Buildings

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ABSTRACT:

Modern tall buildings go higher with the advances in structural design and high strength materials. However, every advance in height comes with a new difficulty. Efficient structural systems, high strength materials, and increased heights results with decrease in building weight and damping, and increase in slenderness. On the other hand, as the height and slenderness increase, buildings suffer from increased flexibility, which has negative effects on wind loading. Flexible structures are affected by vibration under the action of wind which cause building motion, and plays an important role in the structural and architectural designs. Understandably, contemporary tall buildings are much more vulnerable to wind excitation than their predecessors. Hence, different design methods and modifications are possible in order to ensure the functional performance of flexible structures and control the wind induced motion of tall buildings.

An extremely important and effective design approach among these methods is aerodynamic modifications in architecture.In the present thesis, multistory buildings of 40 storey, 60 storey and 80 storey were modeled for different shapes of structures i.e. Rectangular structure, Rectangular structure with rounded corners, Square structure, Square structure with rounded corners, Circular structure and Elliptical structure. The influence of height and shapes on wind loads and their effects on the response of the structure is studied in the present case. The analysis of the building has been carried out using standard commercial software (STAAD PRO) and the estimation of wind loads is done by Indian standard code IS-875(Part-3). The effect of rounding of the corners of tall structures is studied through computational fluid dynamics (CFD) on pressure distribution on the surface of the structure. Standard software fluent is used for CFD analysis.

Keywords:

STAAD.Pro, IS:456-2000, IS: 875(Part-3), Computational Fluid Dynamics, Fluent, High Rise Buildings.

1INTRODUCTION:

Wind loads are of important, particularly in the design of large structures. The wind velocity that should be considered in the design of structure depends upon the geological location and the exposure of the structure. Wind is a phenomenon of great complexity because of the many flow situations arising from the interaction of wind with structures. Wind is composed of a multitude of eddies of varying sizes and rotational characteristics carried along in a general stream of air moving relative to the earth's surface. These eddies give wind its gusty or turbulent character. The gustiness of strong winds in the lower levels of the atmosphere largely arises from interaction with surface features.The average wind speed over a time period of the order of ten minutes or more tends to increase with height, while the gustiness tends to decrease with height. Some structures, particularly those that are tall or slender, respond dynamically to the effects of wind.

There are several different phenomena giving rise to dynamic response of structures in wind. These include buffeting, vortex shedding, galloping and flutter. Slender structures are likely to be sensitive to dynamic response in line with the wind direction as a consequence of turbulence buffeting. Transverse or cross-wind response is more likely to arise from vortex shedding or galloping but may also result from excitation by turbulence buffeting. Flutter is a coupled motion, often being a combination of bending and torsion, and can result in instability. For building structures flutter and galloping are generally not an issue.

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An important problem associated with wind induced motion of buildings is concerned with human response to vibration and perception of motion. At this point it is enough to note that humans are surprisingly sensitive to vibration to the extent that motions may feel uncomfortable even if they correspond to relatively low levels of stress and strain. Therefore, for most tall buildings serviceability considerations govern the design but not strength issues.

2. NATURE OF WIND:

Windy weather poses a variety of problems in new skyscrapers, causing concern for building owners and engineers alike. The forces exerted by winds on buildings increase dramatically with the increase in building heights. The velocity of wind increases with height, and the pressure increase as the square of the velocity of wind. Wind is the term used for air in motion and is usually applied to the natural horizontal motion of the atmosphere. Motion in a vertical or near vertical direction is called a current. Winds are produced by difference in atmospheric pressure, which are primarily attributable to differences in temperature.

These temperature differences are caused largely by unequal distribution of heat from the sun, together with the difference in thermal properties of land and ocean surfaces. When temperatures of adjacent regions become unequal, the warmer and lighter air tends to rise and flow over the colder, heavier air. Winds initiated in this way are usually greatly modified by the rotation of earth. Movement of air near the surface of the earth is three-dimensional nature, with a horizontal motion which is much greater than the vertical motion. Thunderstorms are one of the most familiar features of temperature summer weather, characterized by long hot spells punctuated by release of torrential rain.

3. TYPES OF WIND:

Of the several types of wind that encompass the earth's surface, winds which are of interest in the design of tall buildings can be classified into three major types: the prevailing wind's, seasonal wind's, and local wind's.

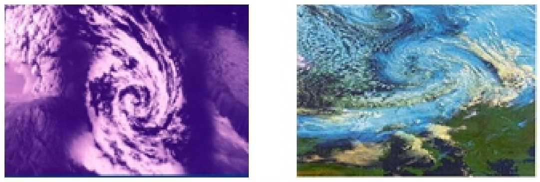
1.The prevailing winds: Surface air moving from the horse latitudes toward the low pressure equatorial belt constitutes the prevailing winds on trade winds.

2. The seasonal winds: The air over the land is warmer in summer and cooler in winter than the air adjacent to oceans during the same seasons.

3. The local winds: Corresponding with the seasonal variation in temperature and pressure over land and water, daily changes occur which have a similar but local effect. Similar daily changes in temperature occur over irregular terrain and cause mountain and valley breezes.

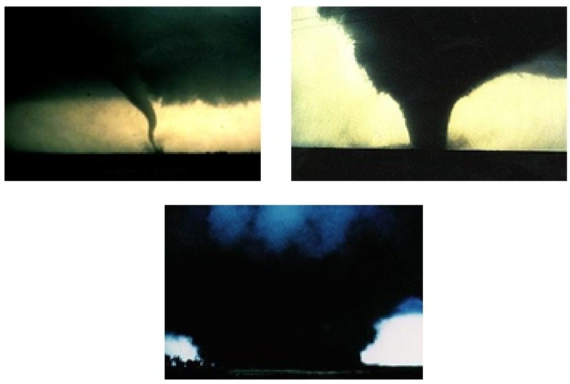
4. EXTREME WIND CONDITION:

Extreme winds such as thunderstorms, hurricanes, tornadoes, and typhoons, impose loads on structures that are many times more than those normally assumed in their design.



Cyclonic Storms

Thunderstorms



Tornados

4.DYNAMIC NATURE OF WIND ON STRUCTURES:

When wind hits a blunt body in its path, it transfers some of its energy to the body. The measure of the amount of energy transferred is called the gust response factor.

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Wind turbulence is affected by terrain roughness and height above the ground. A tall, slender, and flexible structure could have a significant dynamic response to wind because of buffeting. This damping amplification of response would depend on how the gust frequency correlates with the natural frequency of the structure and also on the size of the gust in relation to the building size.

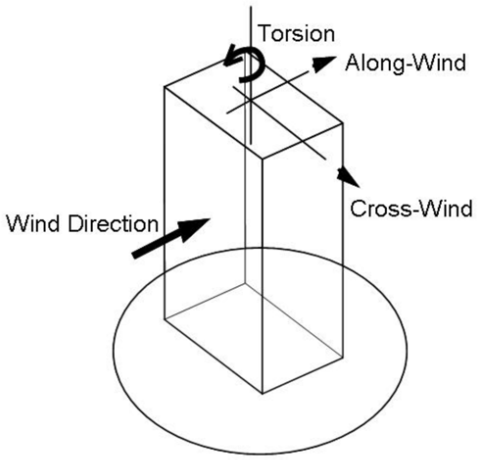

Fig: 1 Wind Response Directions.

5. OBJECTIVES:

The wind pressures not only depend on the height of the building frame but also on the shape of the building, To study the dynamic interaction between the wind and structure, the dynamic properties like the size and shape of the building, frequency, damping etc become relevant and they also influence gust pressure.The main objective of the present work is to study the effect and variation of wind pressure with the shape, rounding of the corners and height of the structure. In the present study the variations of the gust pressure with shape of the structure on typical multi-storied frames as per dynamic response factor method given by the draft code IS-875 part 3 – is studied.

In the present thesis, multistory buildings of 40 storey, 60 storey and 80 storey were modeled for different shapes of structures i.e. rectangular structure, rectangular structure with rounded corners, square structure, square structure with rounded corners, circular structure and elliptical structure. The analysis of the building has been carried out using STAAD PRO and the dynamic response factor method, pressures are calculated using Indian standard code IS-875(Part-3.

The effect of rounding of the corners of tall structures is studied through computational fluid dynamics (CFD) on pressure distribution on the surface of the structure. Standard software fluent is used for CFD analysis.The present thesis would bring out the influence of factors like height, shape of the structure, rounding of the corners, along wind response, bending Moment and axial force etc.

6. METHODOLOGY:

Tall and slender structures are flexible and exhibit a dynamic response to wind. Tall structures vibrate in wind due to turbulence inherent in wind as well as that generated by the structure itself due to separation of flow. Thus there is a mean and fluctuating response to the wind. Besides, the dynamic forces act not only in the direction of wind flow but also in the direction nearly perpendicular to the flow (lift forces), so that tall structures also exhibit in across- wind response.

Rectangle 25mx50m
Square 35mx35m
Circle radius 40m
Ellipse 60mx30m (major axis by minor axis)

In case of wind loads it is assumed that buildings are in terrain category 3 and the basic wind speed (Vb) is taken as 44m/sec. The dynamic pressures are calculated according to IS 875 (part-3). These pressures are applied on all the four sides of the buildings i.e. windward side positive X-direction, leeward side negative X-direction, windward side positive Z-direction, leeward side negative Z-direction.

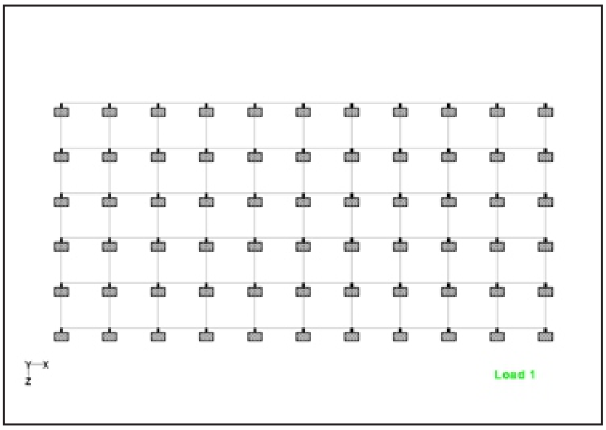

Fig: 2 Top view of Rectangular structure

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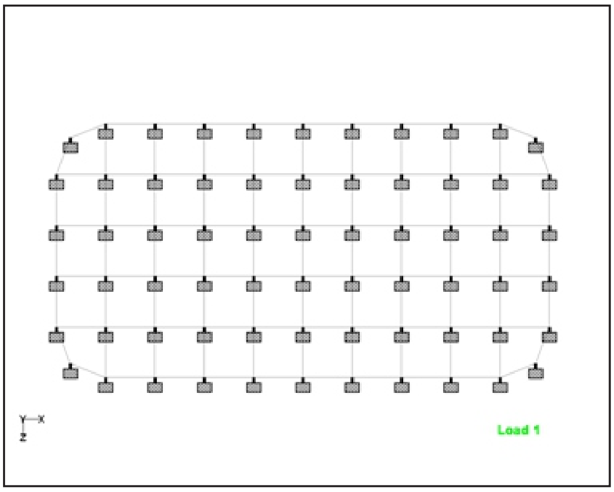

Fig: 3 Top view of Rectangular structure rounded at the corners.

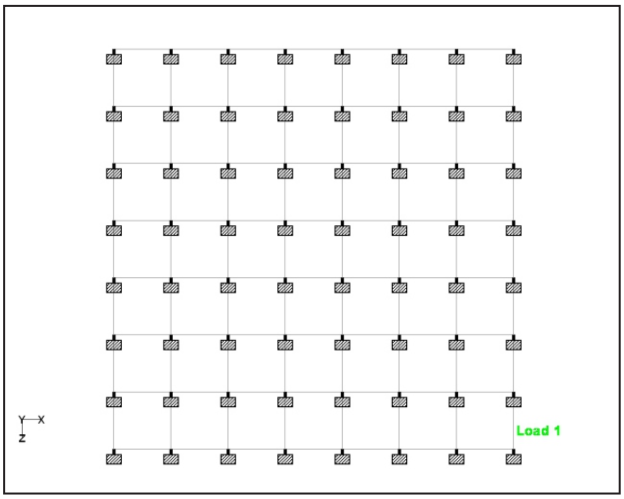

Fig: 4 Top view of Square structure.

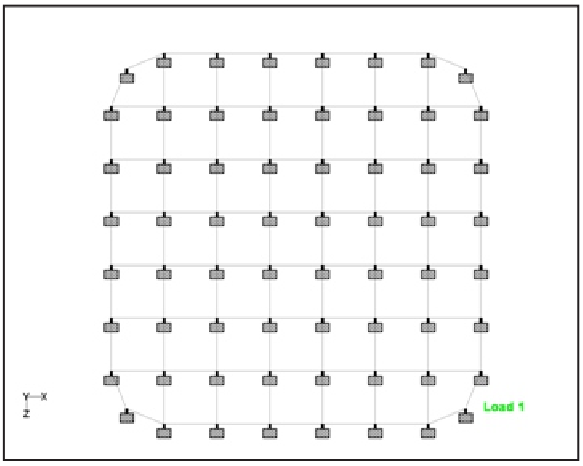

Fig: 5 Top view of Square structures with rounded corners without shear walls.

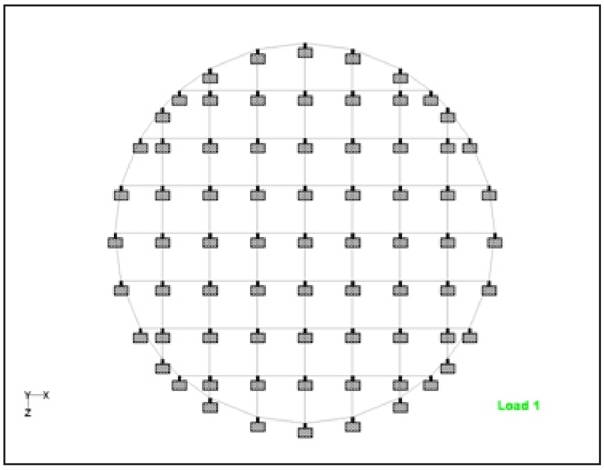

Fig: 6 Top view of Circular structure.

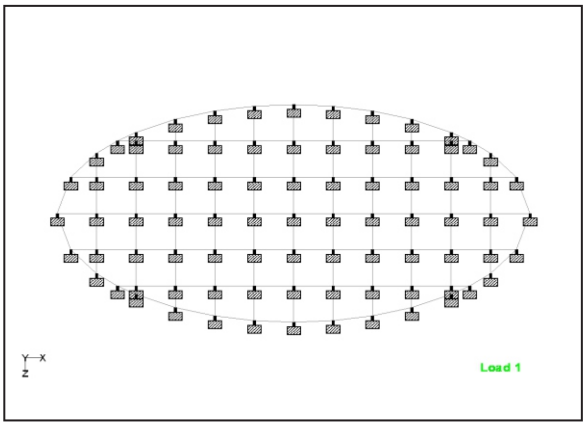

Fig: 7 Top view of Elliptical structure.

CONCLUSIONS:

1.The bending moments were reduced by an average 70% by rounding of the corners compared to regular sharp cornered structures. However, as the height of the structure was increasing the reduction of the bending moment due to rounding of the corners was decreasing gradually.

2.b. The axial forces of rectangular and square structures were decreasing by rounding of the corners for low heights of the building. But for very tall buildings the rounding of the corners increased the axial forces in the corner columns.

3.c. The roof displacement of square structures were decreased by about 50 % by rounding of the corners of the structure but for rectangular structure the roof displacement were reduced by an average of 10% by the rounding of the corners. Rounding of the corners was effective for very tall buildings.

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4.d. Circular structure is also much effective in reducing the lateral drift of the structure. Elliptical structures are also effective in reducing the lateral drifts compared to rectangular structures but not as effective as square and circular structure.

5.e. It was observed from the limited study of computational fluid dynamics that the wind loads acting on a structure not only depend on the wind velocity and turbulence but also on the shape of the building. Rounding of corners of buildings reduces the wind forces acting on the building. Negative forces on the side walls are much greater compared to the windward face of the structure due to the cross wind effects of the building.

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