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Wind Load Analysis of High Rise Triangular Building using CFD

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Abstract : The building structure are subjected to high wind loads which tends to deform laterally and induced high stresses. The objective of current research is to investigate the effect of wind load on high rise triangular building structure using techniques of Computational Fluid Dynamics. The triangular shaped building is investigated under wind load conditions. The design of triangular shaped building structure is modified by rounding of triangular edges. The CFD is a viable tool in evaluating the effect of wind load on triangular shaped building structure. From the CFD analysis the drag force and induced pressure on the building structure is evaluated. The FSI studies are conducted for sharp edged building and rounded edged building. The rounded edged building structure has shown lower shear stress as compared to triangular sharp edged shaped building.

***IndexTerms* - Building structure, wind load, CFD**

I. INTRODUCTION

High wind gusts tends to induce lateral deformation on high rise building structures along with high magnitude of base shear. To mitigate the effects of wind load the design of building structure can be modified to reduce the induced drag force and pressure. Out of different shapes the rectangular cross section structure is found to have higher drag force and resistance to external air flow. Other building profiles like elliptical, cylindrical and triangular profile have shown lower deformation and base reaction as compared to square profile building structure.

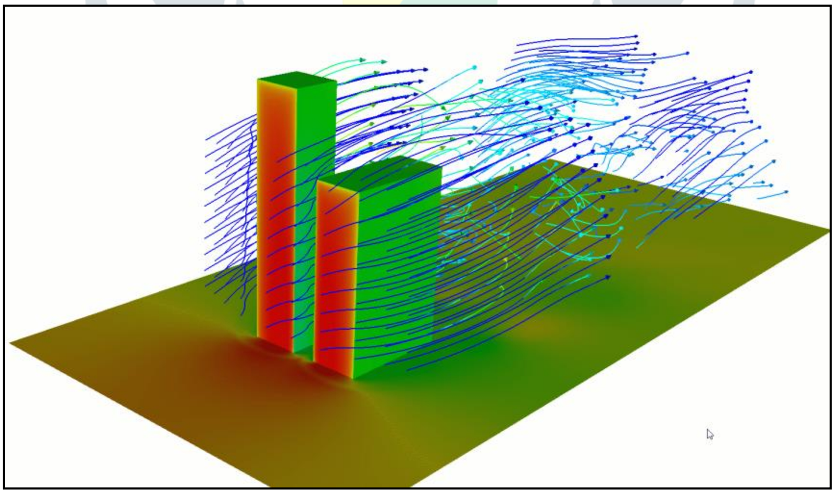

Figure 1: Wind load on rectangular structure

Although wind loads depend on the external geometry of the building, wind loads for tall buildings cannot be generalized due to the wide variability of building shapes and surroundings, which may be unique to each case. So, at an early stage of the design, screening of building modifications to mitigate wind loads and to address recommended usability issues.

II. LITERATURE REVIEW

Kijewski and Kareem et. al. [1] have conducted research on 200m tall building subjected to aerodynamic loads. The applied wind loads are based on Equivalent Static Wind Loads (ESWL) approach. The analysis enabled to determine the load distribution on building of irregular shapes and sizes. The analysis is conducted on the basis of data recorded in the wind tunnel (WT) facility.

Whalen et al. (2000) [2] have conducted research on wind load analysis of low rise building using “Database Assisted

Design (DAD) concept". The concept is later applied to tall buildings as well and at National Institute of Standard and Technology (NIST). The time history analysis is conducted based on wind tunnel tests parameters. The wind directionality effect is also addressed in the research as well.

Iancovici (2019) [3] have conducted investigation on tall building structure to determine linear elastic behavior under wind loads. To investigate the effect of wind load a nonlinear FEA program is developed to identify damage induced on the structures. The time domain studies can be conducted for damage assessment at each section.

Jancauskas and Holmes et. al. [5] have conducted research on different building structure using wind tunnel testing. The standards for testing of building structures are prescribed. The provisions are as per Australian/New Zealand Standard (AS/NZS 1170.2:2011) based on wind tunnel study.

III OBJECTIVES

The objective of current research is to investigate the effect of wind load on high rise building structure using techniques of Computational Fluid Dynamics. The triangular shaped building is investigated under wind load conditions. The design of triangular shaped building structure is modified by rounding of triangular edges.

IV METHODOLOGY

The methodology steps of triangular building structure involves briefly 3 different stages i.e. pre-processing stage, solution stage and post-processing stage. The design of building structure is developed and imported in ANSYS design modeler. The design is converted in .iges file format.

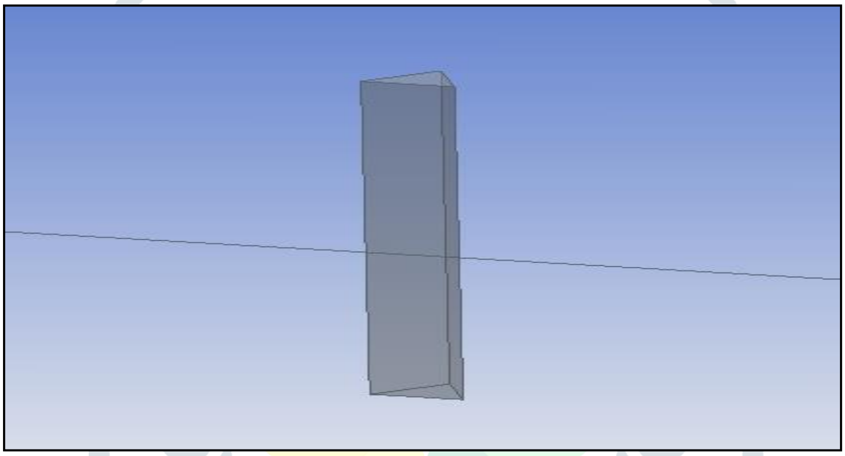

Figure 2: CAD design of triangular shaped building structure

The imported design of triangular building structure is checked for geometric errors and surface imperfections.

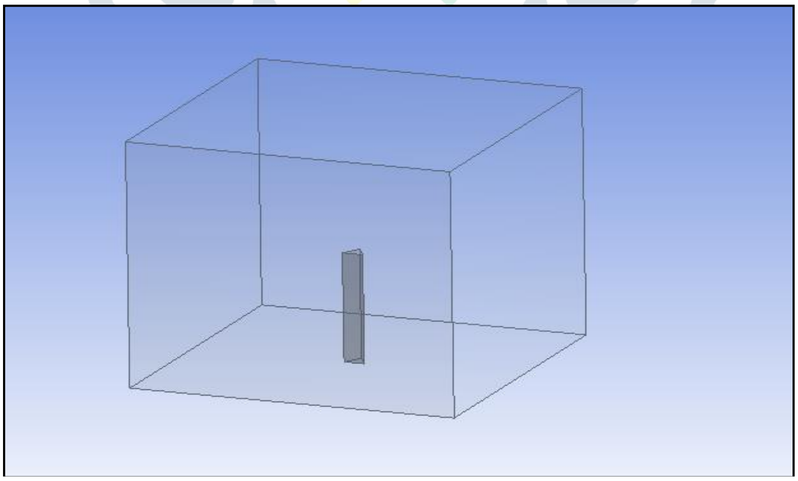

Figure 3: Enclosure model surrounding chimney

The enclosure is modeled with 150m*150m*150m volume. The enclosure developed is shown in figure 3 above. The model of enclosure is discretized with tetrahedral element

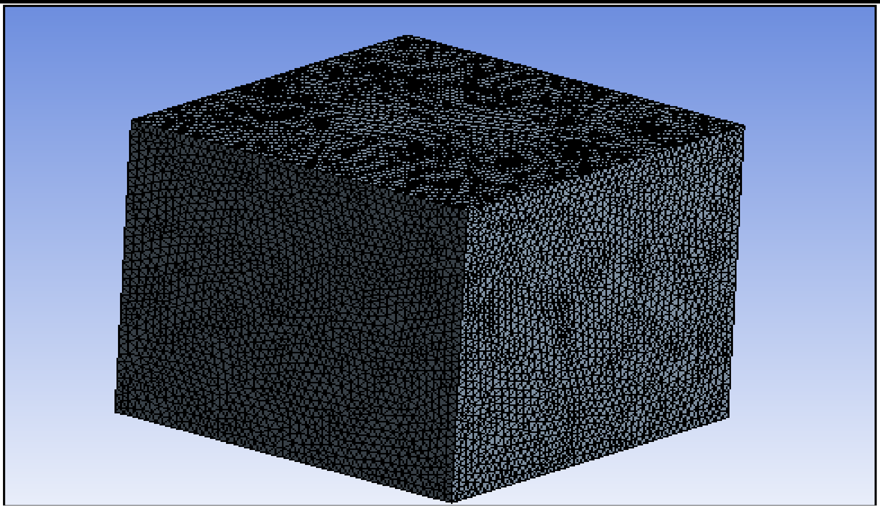

Figure 4: Meshed model of computational domain

The meshing is done with curvature effect and relevance center set to fine. The transition ratio is set to 0.77 and growth rate for building structure is set to 1.2. The domain type is defined for the model and applied with boundary conditions as shown in figure 5 below.

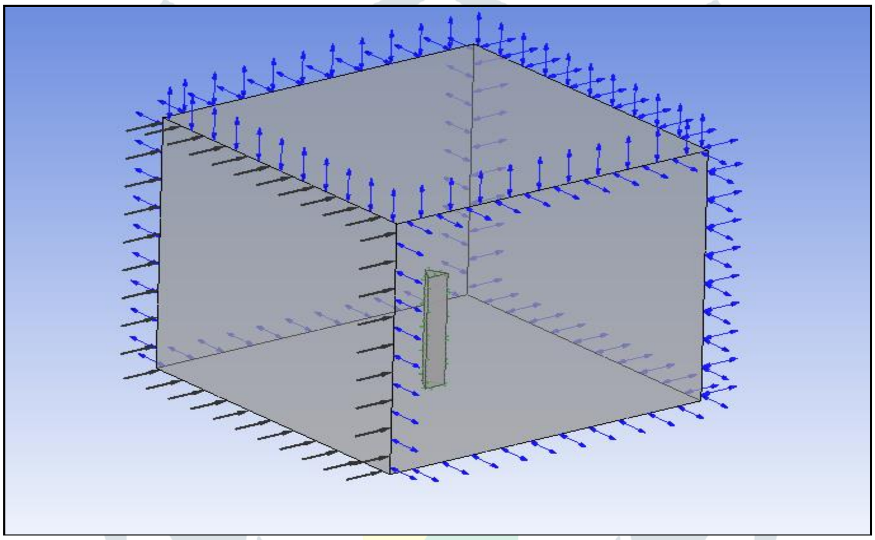

Figure 5: Domain definition and boundary condition

The domain is defined for computational space. The "fluid" type domain is defined. The reference pressure is set to 1 atm for all the boundaries. The inlet boundary condition and outlet boundary conditions are defined.

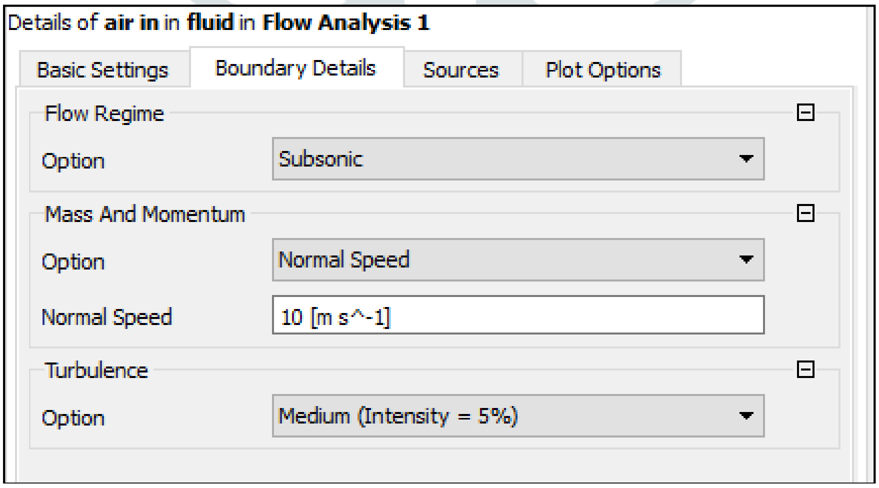

Figure 6: Domain definition and boundary condition

Air inlet boundary conditions are defined which is set to 10m/s at normal speed and turbulence model intensity set to medium.

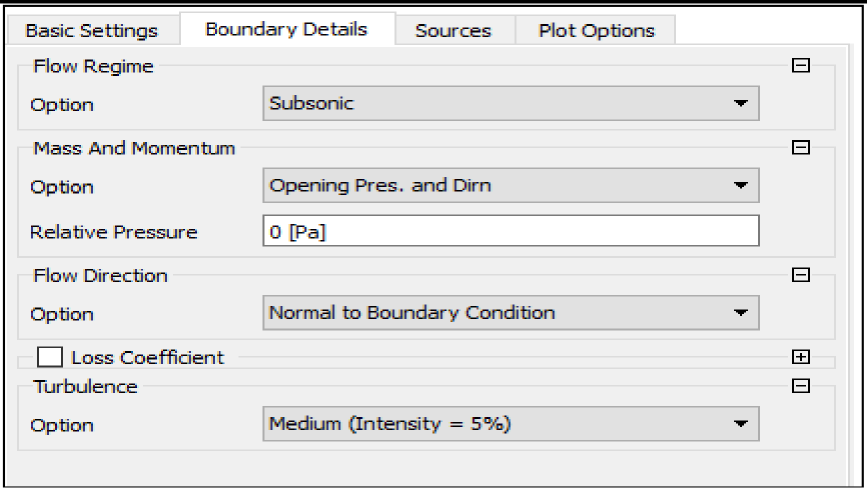

Figure 7: Air outlet boundary condition

V RESULTS AND DISCUSSION

The drag force plot is generated for triangular shape building structure as shown in figure 8. The high drag force value is obtained at the mid-section region of triangular building where maximum drag force obtained is 4712N. The drag force at other regions is 2760N.

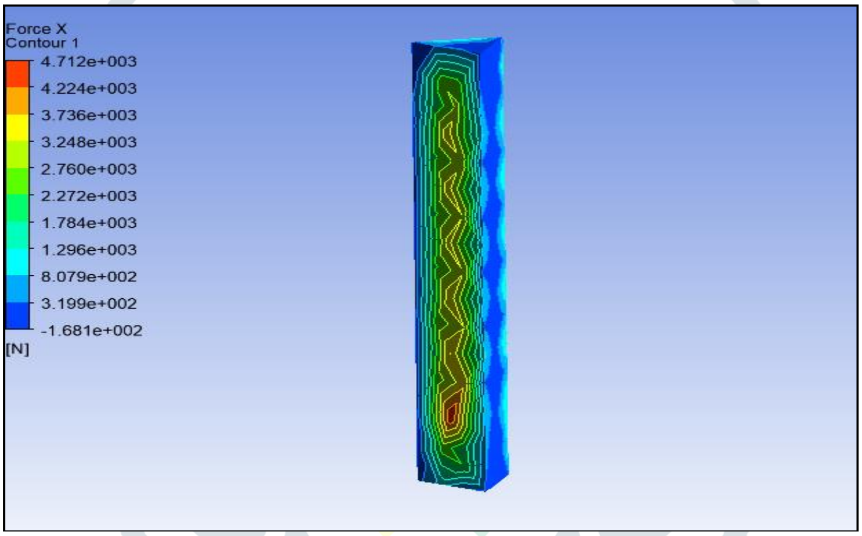

Figure 8: Drag force plot on triangular building structure

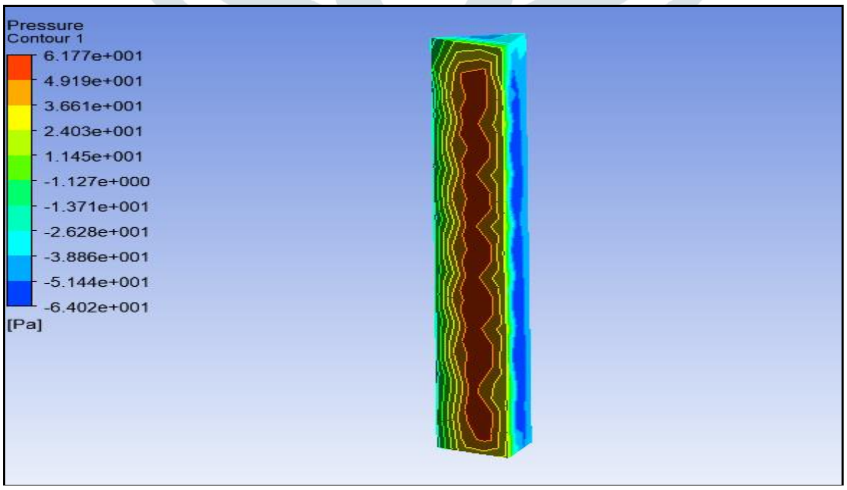

Figure 9: Pressure distribution plot on triangular building structure

The pressure distribution plot is obtained for triangular building structure as shown in figure 9 above. The pressure value is maximum at the mid center region and is almost evenly distributed along the height of building. The maximum pressure value obtained from the CFD analysis is 61.77Pa. The pressure at the windward side is high and pressure at the leeward side is low. This pressure distribution tends to bend the building and induce shear stress.

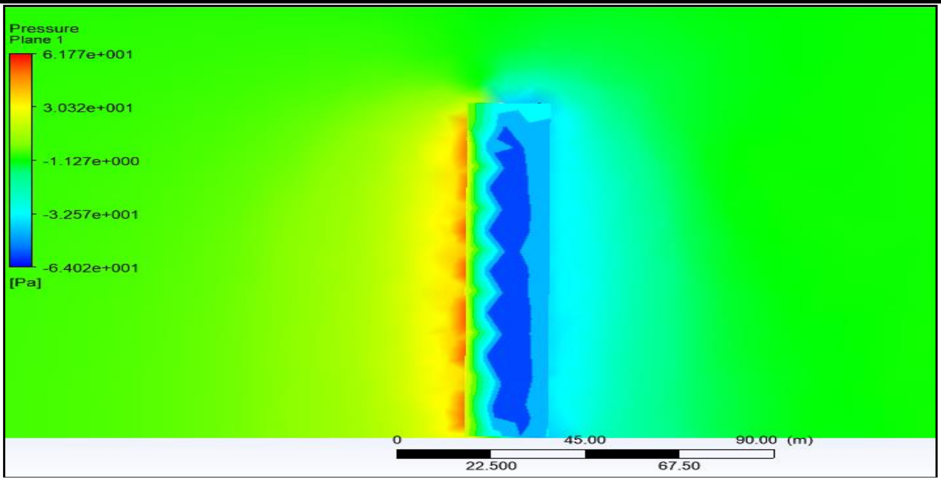

Figure 10: Pressure distribution plot across plane

The pressure distribution plot is obtained across plane as shown in figure 10 above. The plot shows higher pressure at the windward side with magnitude of 61.77Pa and is lower on leeward side with magnitude of -32.5Pa. The pressure is almost uniform across other regions of the plane.

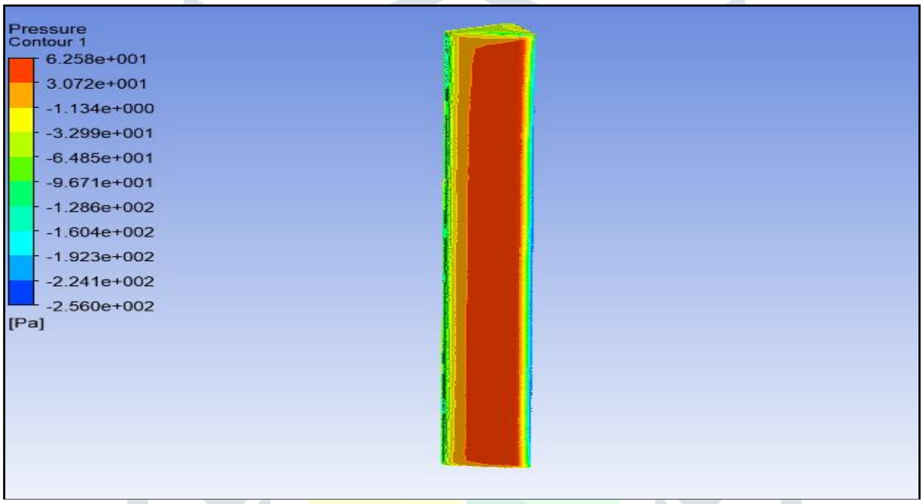

Figure 11: Pressure acting on windward side of the rounded edged building

The pressure distribution plot is obtained for the building as shown in figure 11 above. The plot shows higher magnitude of pressure at the windward side wherein the value of pressure is 62.58Pa.

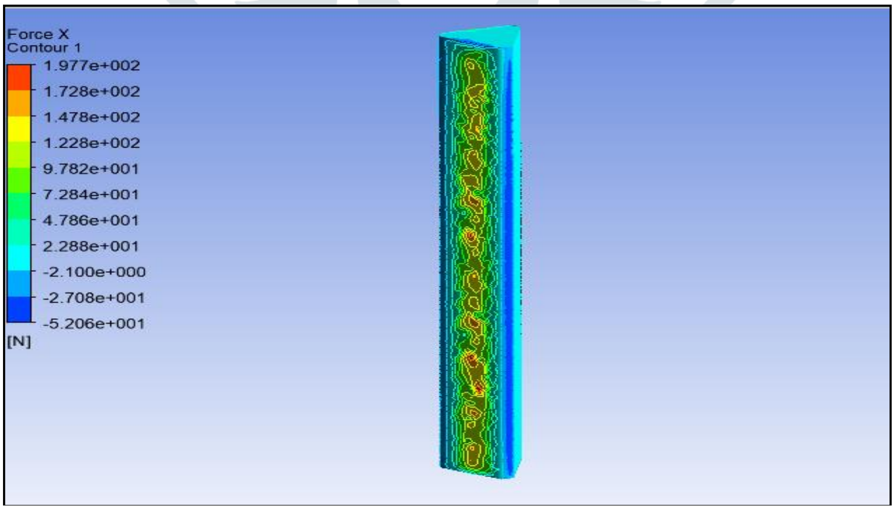

Figure 12: Drag force acting on windward side of the rounded edged building

The drag force contour plot is obtained for rounded edge building as shown in figure 12 above. The maximum drag force is obtained which is 197.7N.

Table 1: Comparative chart for both designs

Design Type	Shear stress (Mpa)
Triangular sharp edged shape	0.00966
Rounded Triangular Edge without opening	0.00959

VI CONCLUSION

The CFD is a viable tool in evaluating the effect of wind load on triangular shaped building structure. From the CFD analysis the drag force and induced pressure on the building structure is evaluated. The FSI studies are conducted for sharp edged building and rounded edged building. The rounded edged building structure has shown lower shear stress as compared to triangular sharp edged shaped building.

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