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WIND INTERFERENCE ON A HEXAGONAL SHAPED HIGH-RISE BUILDINGS WITH DIFFERENT OPENINGS

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ABSTRACT:

The wind load and pressure on a tall hexagonal structure altered as the apertures changed in this study. In various conditions, wind angles ranging from 0 to 90 degrees with a 30-degree gap are being used. The distance between the interference building and the model building was gradually raised from 50mm to 200mm at 50mm intervals. At a scale of 1:500, the main building model was studied. The ANSYS CFX package's validity was also tested using a rigid model with dimensions of 100mm x 100mm and a height of 700mm. The k-ε-turbulence model was utilised in the investigation, which was conducted using Computational Fluid Dynamics (CFD) and the ANSYS CFX software package. According to the analysis, changing the percentage of opening area has an influence on building stability because it affects the pressure on the leeward and windward faces. Contours and vortex formation were used to highlight the relationship between different scenarios. As the distance between the interference and model buildings expands, so does the pressure coefficient of the faces. The effects of apertures on the model building were also investigated, with 5-40% openings provided.

Keywords: Hexagonal-Shape Building; ANSYS (CFX); Wind Pressure Coefficient; Contours; Vortex Formation

1. INTRODUCTION:

The introduction of new technology and the rapid rate of scientific research have resulted in an increase in the height, width, and scale of structures, making them even more sensitive to wind damage. As a result, the impact of wind loads on these types of constructions is becoming increasingly important [1,2]. Wind loads on the model structure were initially explored in this work, and then the change in wind loads was investigated when openings were added to our model. Various studies are now being undertaken using computational fluid dynamics (CFD) to examine the effects of wind on tall structures.

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ANSYS (CFX) is a well-known tool for analysing wind load on many types of structures. Buildings with complicated shapes may also be simulated for numerical analysis, and the shape can be partitioned into smaller sections with correct meshing [3,4]. The study [5] looked at the mean pressure coefficient of a tall structure with a 'E' layout both experimentally and computationally. For experimental objectives, wind tunnel testing was employed, while CFD simulation was used for numerical analysis.

The current Indian Standard Code for wind loads over structures contains information on pressure variation and force coefficients. When apertures are provided to irregular structures, however, they fail to manage the complexities of wind loads across them [6]. The primary purpose of this study is to investigate wind loads over isolated structures as well as the effect of interference when a second building with 5-40% openings is introduced during wind testing.

The major goal of this research is to examine wind loads on the buildings with different percentage of openings by comparing the contours and C_P values on different faces. Fig. 1 represents model X i.e., the validation building having a square cross section and dimensions same as that of the hexagonal shaped buildings, the one used for analysis. Height of all the models is 350 metres which is scaled down to 700 millimetres for the ease of simulation. Below Fig.1 shows the buildings of validation model X.

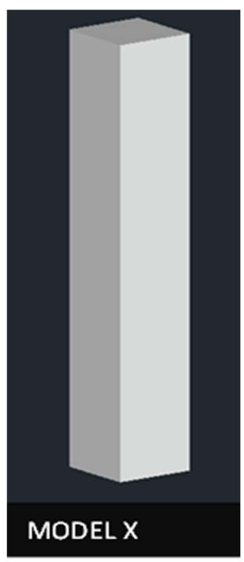

Figure 1: Validation Model

2 ANALYSIS MODEL DEVELOPMENT

2.1 GEOMETRIC DESIGN:

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In the current study, there are three hexagonal shaped buildings named A, B and C with different percentage of openings. These buildings are designed using AutoCAD 3D software and can be seen in Fig.2 Design of the Buildings.

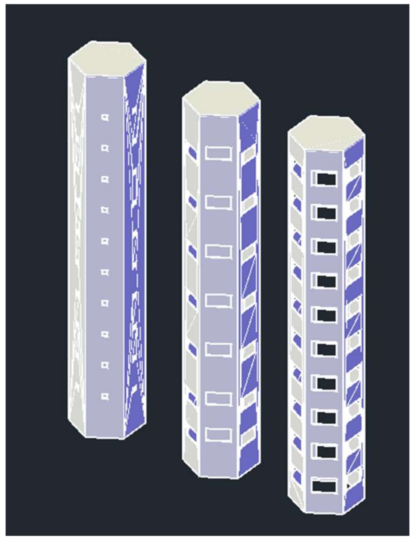

Figure 2: Design of Building A, B and C

The windward face of the building, the one facing the wind is named A while the leeward face, the one on the opposite side is named B. Rest of the faces are named C, D, E and F. The buildings are simulated in a specified domain which is designed as per the guidelines of IS:875 Part -3 [6]. Contours of the Face A and Face B is being compared for different openings along with different wind angles. The wind angles opted for these simulations include 0º, 30º, 60º and 90º.

Description along with the openings percentage of the three buildings are mentioned below –:

1. Model A is the first building with minimum opening percentage of less than five percent of the total area of the building. Total opening area holds up to 12500 mm^2 i.e., 4.97% of the total building area. Figure 3 represents the design of Model A.
2. Model B is the second building with opening percentage between five percent and twenty percent of the total area of the building. Total opening area holds up to 42000 mm^2 i.e., 16.7% of the total building area. Figure 4 represents the design of Model B.
3. Model C is the third building with maximum opening percentage between twenty percent and forty percent of the total area of the building. Total opening area holds up to 72000 mm^2 i.e., 28.66% of the total building area. Figure 5 represents the design of Model C.

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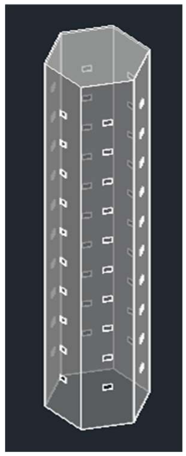

Figure 3
Model A

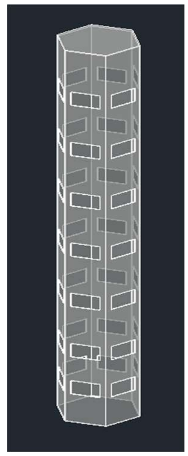

Figure 4
Model B

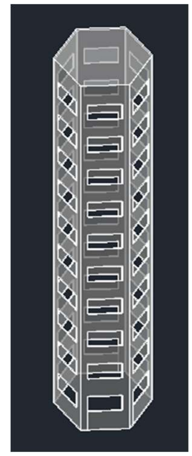

Figure 5
Model C

2.2 ANSYS SIMULATION:

The ANSYS CFX software package is used for simulation, which allows us to apply a variety of boundary conditions. This software's approach consists of five steps: Geometry, Mesh, Setup, Solution, and Result. In the initial stage, we export the analysis building from AutoCAD and specify a domain for the analysis. To avoid flow re-circulation, the domain dimensions are defined in accordance with Indian Standards [6], with the domain boundaries 5h from the model's windward face, lateral faces, and roof and 15h from the model's leeward face (where let h be the height of the model).

Meshing is the following stage, which separates the whole model, including the domain, into tiny tetrahedral nodes of size 0.2m for better results [7]. Inflation is also available to improve the non-slip properties of the building walls. In the current investigation, the model receives 20 inflation layers, as shown in Fig.6 Meshing of Structure.

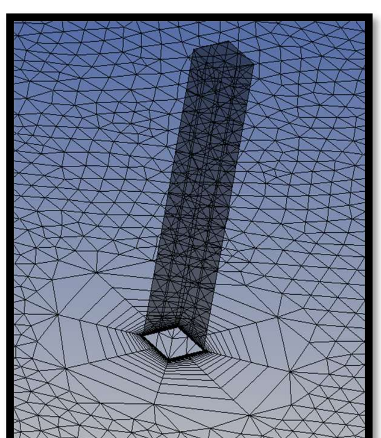

Figure 6: Meshing of Structure

Next step is setting up the boundary conditions for the whole simulation. The ground and walls of buildings are given a no slip wall condition while the ground and external walls of domain are given a free slip wall condition. For determining the speed of the wind power law is used (Equation 1) . The inputs for the setup are $\alpha = 0.133$, $Z_{ref} = 0.7$ m, and $U_{ref} = 10$ m/s.

$$Power\ law = U_{ref}\left(\frac{Z}{Z_{ref}}\right)^{\alpha} \qquad (1)$$

Then the solution is run which takes approximately two to three hours as hundred iterations are performed on each element. In the final step of result the pressure coefficient is calculated using the Equation 2.

$$C_P = \frac{Pressure}{(0.5 * \rho * U_{ref}^2)} \qquad (2)$$

Where the value of U_{ref} = 10m/s and the value of density $\rho = 1.225$ kg/m^3.

The contours for these Cp (Pressure coefficient) values are then plotted and the results are drawn from it. Results along with the conclusions are mentioned in the section 4 and 5 respectively.

3. VALIDATIONS:

Table 1: Comparing Cp values of Validation Model with acceptable Cp values in accordance to IS: 875 Part 3-2015

Pressure Coefficients (C_P)	FACES OF VALIDATION BUILDING			
	A	B	C	D
According to IS:875 (Part III) 2015	0.95	-1.25	-0.7	-0.7
Validation Model	0.78	-0.77	-0.73	-0.71

For validation process an isolated building with square cross section with dimensions same as that of our main observational building is simulated in exactly identical boundary conditions as that of our main simulation. The height of the building is 700mm and the cross-section of the building is 100mm by 100mm throughout the height. Pressure coefficient (C_P) values for all the faces - A, B, C and D (Face A being windward side, Face B being leeward side and Face C and D being lateral faces) are compared with the acceptable values as given in IS: 875 (Part III) – 2015 [6].

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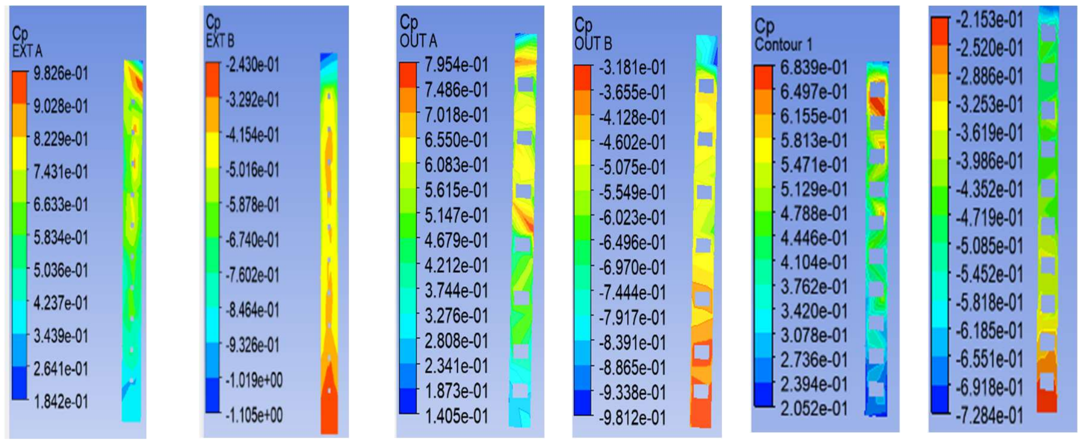
The average error of all four faces was found to be about 12.64 percent which is significantly less and thus, identical boundary conditions was used in the main model.

The conclusions drawn from pressure contours are then discussed below-:

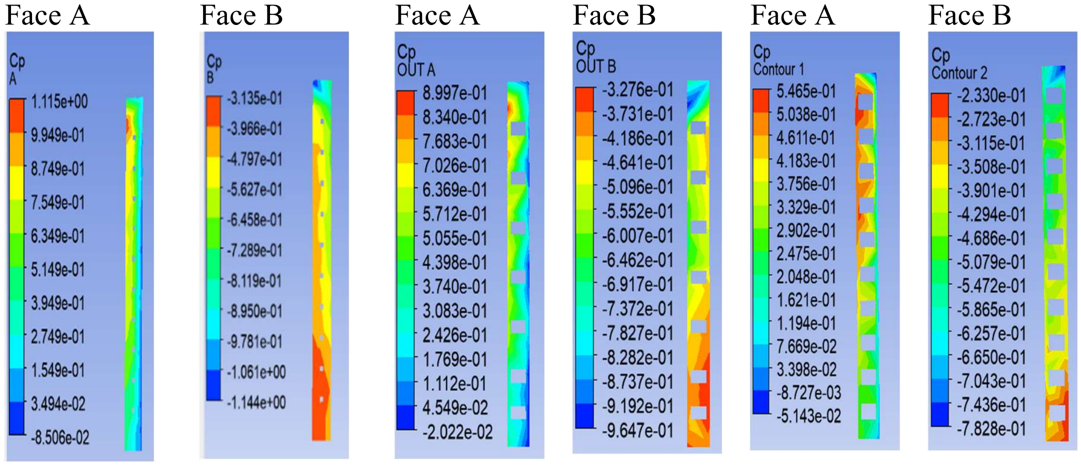
<u>Case 1</u> <u>Incident wind angle is 0º</u>

Model A		**Model B**		**Model C**	
Face A	Face B	Face A	Face B	Face A	Face B



<u>Case 2</u> <u>Incident wind angle is 30º</u>

Model A		**Model B**		**Model C**	
Face A	Face B	Face A	Face B	Face A	Face B



<u>4.RESULTS AND DISCUSSION:</u>

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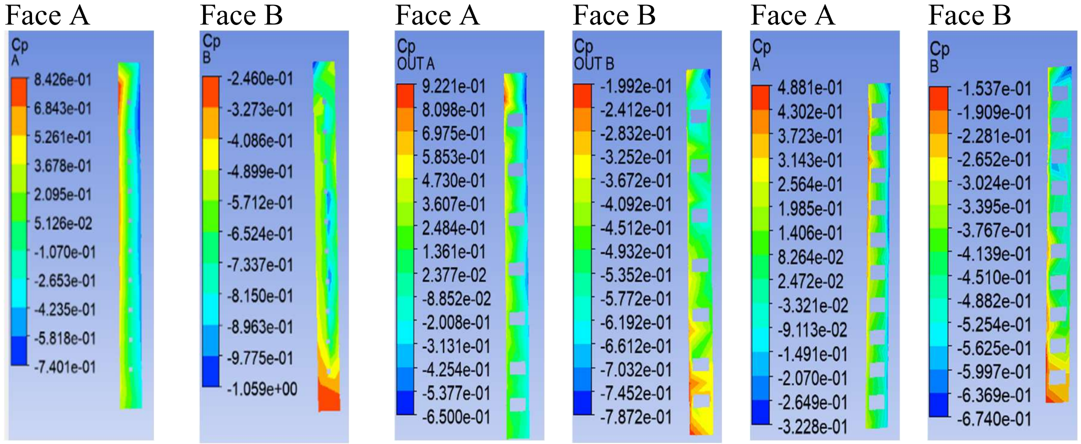
Contours are described as shading on a simulated body in which different colours of shade signify different values. As the shade darkens, so does the associated value. The outlines in this example represent the C_p values. Each contour comes with a caption that shows the related value to the specific colour. The situations are categorised based on the distance between the two structures, which is further subdivided based on wind angles.

The value of C_p increases as the colour darkens. The positive value of the pressure coefficient reflects wind pressure, whereas the negative value represents suction force. A legend is always provided on the side to give us with the values that correspond to different colours so that we can determine which colour corresponds to which value [8,9].

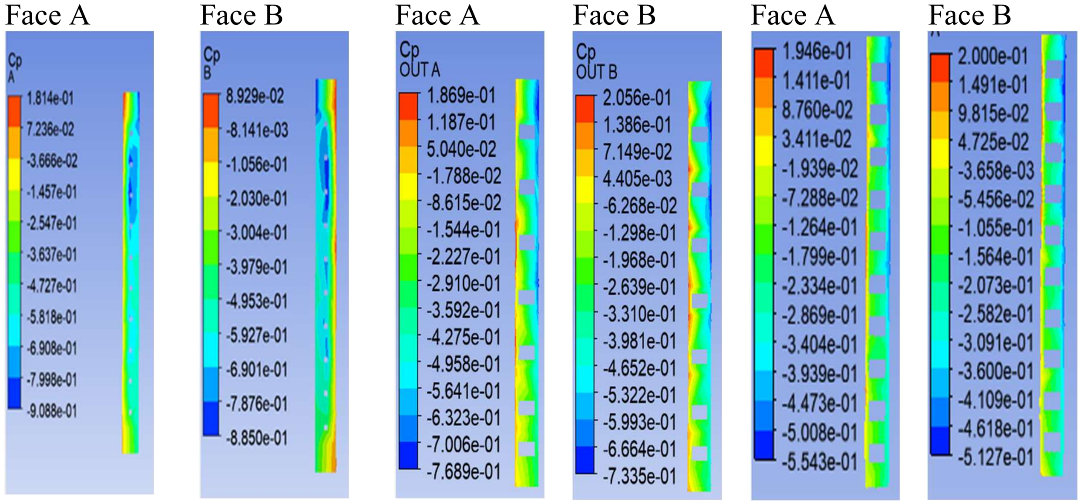
Case 3 Incident wind angle is 60°

Model A		**Model B**		**Model C**	
Face A	Face B	Face A	Face B	Face A	Face B



Case 4 Incident wind angle is 90°

Model A		**Model B**		**Model C**	
Face A	Face B	Face A	Face B	Face A	Face B



The contours given lead to the following conclusions:

- It can be seen that range of C_P for face A is decreasing as the opening percentage increases but as the angle of incidence increases the same trend is not observed. For 0 and 30 degrees the same trend is observed while as the angle changes to 60 degrees the C_P range of the model B becomes greater than the other two cases. While for the case of 90 degrees the range of model C in greatest among all.

- 1.115 is the maximum C_p value observed for face A which was found for model A when the wind angle incidence is 30 degrees while the most negative value observed for the same is -0.908 for model A when the incidence angle is 90 degrees.
- For face B it is observed that as the opening percentage of windows increases, the range of the C_p values become less negative as it is observed for the wind incidence angle 0 degrees, the value of C_p for model A, B and C is -1.1, -0.98 and -0.72 respectively. It is observed that in the fourth case where the incidence angle is 90 degrees the range of C_p values become positive in all the three models.
- The reason for the changes in C_p value is because of the formation of vortex i.e., the swirling of wind particles about a particular axis because of which the C_p value decreases for the face A [10,11].

5. CONCLUSIONS:

Wind being a fluid has very complex nature and thus gives rise to many unpredictable flow conditions which needed to be studied in order to build more high-rise structures. The followings conclusions are drawn from this study.

- This study account for the effect of different percentages of openings on high rise hexagonal shaped buildings.
- The validation section discusses about the C_P values obtained for the model X and they were in agreement with those given by IS: 875 (Part III) – 2015. Therefore, Model A is also validated by consequence.
- The study concludes that changing in the percentage of opening area has an effect of building stability as it changes the pressure on leeward and wind ward faces.
- Vortex formation also takes place as there is change in the opening percentage for the high rise building which is a very important and crucial element for the stability of high rise buildings.

REFERENCES:

1. Gu M, Quan Y. Across-wind loads and effects of super-tall buildings and structures. Science China Technological Sciences. 2011 Oct;54(10):2531-41.
2. Raj R, Ahuja AK. Wind loads on cross shape tall buildings. J. Acad. Ind. Res. 2013 Jul;2(2):111-3.
3. Kumar A, Raj R. Study of Pressure Distribution on an Irregular Octagonal Plan Oval-Shape Building Using CFD. Civil Engineering Journal. 2021 Oct 1;7(10):1787-805.

4. Nagar1a SK, Raj R, Dev2b N. Experimental study of wind-induced pressures on tall buildings of different shapes. Wind and Structures. 2020;31(5):441-53.
5. Bhattacharyya B, Dalui SK. Investigation of mean wind pressures on 'E'plan shaped tall building. Wind and structures. 2018 Feb 1;26(2):99-114.
6. "IS (Indian Standard). 2015. Indian standard code of practice for design wind load on building and structures. IS 875 (Part 3). New Delhi, India: IS."
7. Raj R, Rukhaiyar A, Jayant B, Dahiya K. CFD Analysis for wind flow characteristics of varying cross section tall building using ANSYS.
8. Goyal PK, Kumari S, Singh S, Saroj RK, Meena RK, Raj R. Numerical Study of Wind Loads on Y Plan-Shaped Tall Building Using CFD. Civil Engineering Journal. 2022 Feb 1;8(2):263-77.
9. Meena RK, Raj R, Anbukumar S. Numerical Investigation of Wind Load on Side Ratio of High-Rise Buildings. InAdvances in Construction Materials and Sustainable Environment 2022 (pp. 937-951). Springer, Singapore.
10. Pal S, Raj R, Anbukumar S. Bilateral interference of wind loads induced on duplicate building models of various shapes. Latin American Journal of Solids and Structures. 2021 Jul 26;18.
11. Gaur N, Raj R, Goyal PK. Interference effect on corner-configured structures with variable geometry and blockage configurations under wind loads using CFD. Asian Journal of Civil Engineering. 2021 Dec;22(8):1607-23.

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