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Aerodynamic Effect of Tall Building over a Small Building

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Abstract - *This paper aims to clarify the aerodynamic effect of tall building over an adjacent small building through CFD analysis using Ansys Fluent software. The flow through the tall building creates a low pressure region behind it causing the suction effect. The suction effect in between the buildings leads to ventilation problem for the short building. During the high velocity winds, there may be chances of structural damage to the small building. The gap (distance) between the tall and small building plays major key role in deciding the safety parameters of the small building. The results shows that peak suction pressure (C_P value of about -2.5) created on the top surface of tall building highly responsible for ventilation problem in small building.*

Key words: **suction effect, structural damage, steady state, low pressure region, flow physics**

1. INTRODUCTION

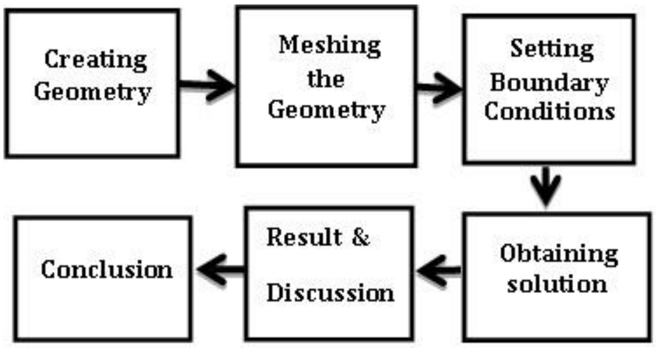
The urban fabric of a city is a reflection of events that took place, growth, transition and change where buildings conveys messages about way in which they were put together in the architectural sense. Tall buildings change the pattern of air movements around them, affecting their cleansing qualities. In the case two building are considered in urban are beside the road. The study of stationary aerodynamic conditions, with change in pressure, velocity around and between the buildings through simulation or experiments can give vast details about the circulation of wind inside the buildings.

For comfortable living, proper ventilation with sufficient humidity and temperature levels are necessary factors inside any room of the house. These factors majorly depend upon the circulation of wind around the house. The wind circulation around a house is highly influenced by its surrounding buildings, streets, open places etc. In densely populated cities buildings are located very close to each other such that the flow passing through one building can create a large aerodynamic influence on other building.

The fluid flow after passing over any body becomes a wake, which is highly unsteady and turbulent in nature. When another body is immersed in this flow, it can exhibit a different flow physics than the routine. Here an attempt is made to simulate such a kind of flow physics using Ansys Fluent software.

Mohammed Asim Ahmed et al. (2015) observed the displacement occurrence in multiple storey buildings due to winds of different terrain category. Three models are analyzed at wind speed of 47 m/s. They proved that as the height of the model increases, deflection on top storey also increases due to varying wind load. A K Mittal et al. (2014) in this paper concentrated on the advantages and disadvantages of the tall building. The importance of wind tunnel testing is explained in detail. The wind loads acting on tall buildings are proven to be at least twice than the values obtained through codes of practice. Tanaka et al. (2013) conducted aerodynamic force measurements, wind pressure measurements and LES (Large-Eddy Simulation) for tall building models with various building shapes of the same height and volume. Wind tunnel experiments were performed in a closed-circuit-type with more than 25 models and found that tapered models are better in along wind direction and cornered models are better for across wind directions. Mendis. P et al. (2007) in this paper focuses on various types of wind loads acting on tall buildings along and across the structure. Several wind tunnel tests were conducted and computation work carried out by them to study the flow behavior over the tall building and concluded that wind tunnel testing and computational analysis is necessary for successful and efficient design of a tall building. Ning Lin et al. (2005) worked on nine models of tall buildings with different rectangular cross-sections which were tested in a wind tunnel to study the characteristics of wind forces. This paper summarizes the findings of an extensive wind-tunnel study on local wind forces on isolated tall buildings.

1.1 Methodology



Problem statement

The wind flow analysis is made over buildings, where the tall building is placed ahead of the small building as shown in *fig 2*. The natural wind flows which can occur in the range of velocities from 1 m/s to 50 m/s in extreme cases, a velocity of 10 m/s is simulated here and corresponding pressure and velocity distributions are analyzed on the front and rear faces of both the buildings.

2. GEOMETRY MODELLING

The geometry is 2 dimensional and analyzed for side view. Geometry is modelled and meshed in Ansys 18.0. The tall building is considered to be a 10 floor building with each floor height as 12 feet or 3.612m and a total height as 36.12m. The small building is considered to be a 6 floor building with height of 72 feet or 21.67m. Both the buildings considered to be square cross section with 25 feet width. The distance between the buildings is considered as 40 feet. Taking a scaling ratio of 1 feet = 1mm, 2D drawings are made in Ansys Design Modeler as shown in figures 2 & 3 for front and top views respectively, and then exported to Ansys Mesh for making grid.

Table-1: Dimensions used for making front view

SL.No	Name	Value in mm
1	Domain	Horizontal 740 Vertical 400
2	Building 1	Horizontal 25 Vertical 120
3	Building 2	Horizontal 25 Vertical 72
4	Distance between buildings	40

A rectangular domain is made with a size of 740mm width and height of 400mm for the both front and top view simulations. The tall building is placed at a distance of 200mm from the inlet in front view and 150mm from the inlet in the top view as shown in figures 2 & 3.

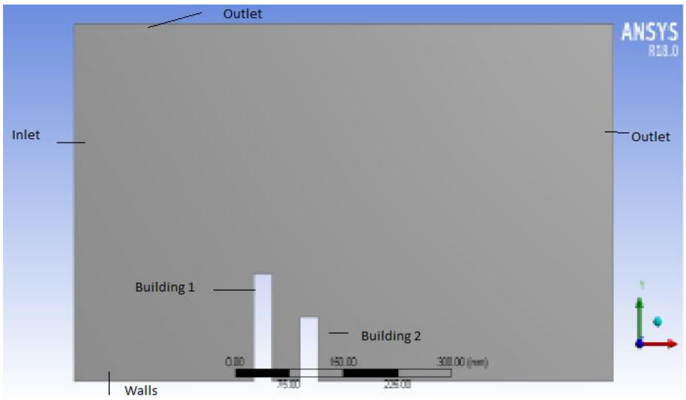


Fig-2: Domain with tall and small buildings in front view

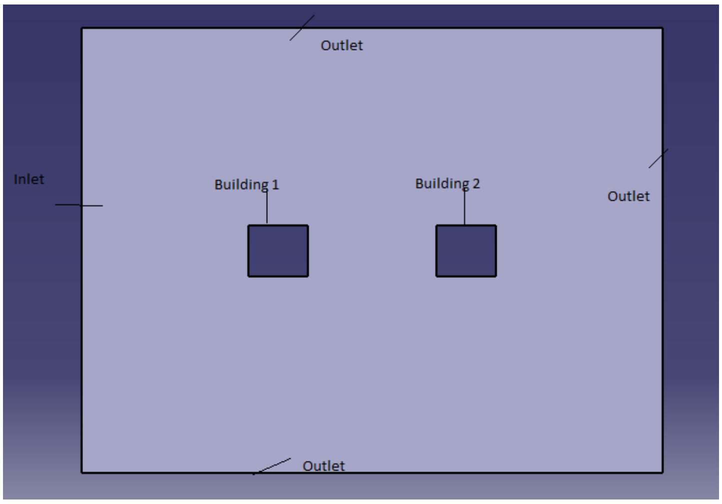


Fig-3: Top view (*Figure indicating the top view of building*)

3. MESHING

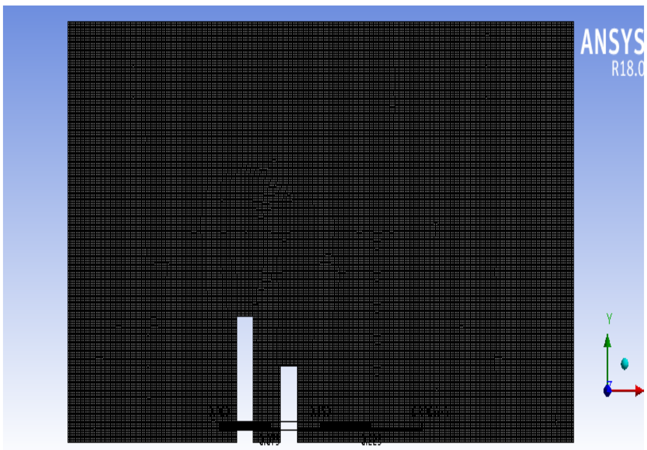


Fig-4: Grid made for front view

A uniform orthogonal mesh is created using the Ansys 18.0. This structured mesh is created with minimum orthogonal quality of 0.7 as shown in figure *4*. This mesh has 74, 543 number of nodes and 73, 871 elements for top view grid.

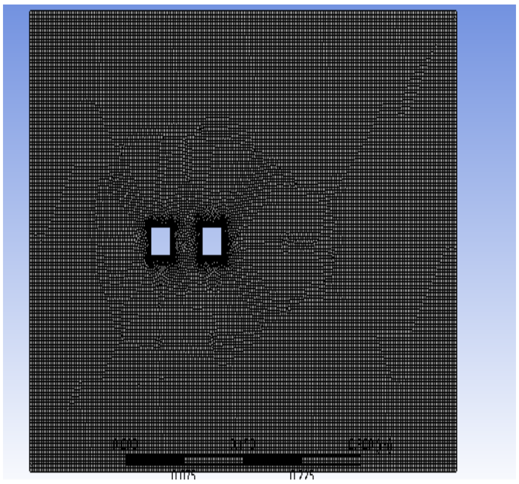


Fig-5: Grid made for top view

Same kind of approach is used for making grid in top view. As shown in fig. 5, top view grid consists of 26,710 nodes and 26,256 elements with minimum orthogonal quality 0.74. The boundary conditions are taken as mentioned in Table 2 and wind flow is simulated from left edge to the right edge of the domain. An incompressible, laminar, steady state solver is used with SIMPLE solver for pressure-velocity coupling. 5000 Iterations were carried out for a residual convergence criterion of 10^{-6} for continuity equation.

Table -2: Boundary Condition

Geometry	**Boundary Condition**
Left Edge	Velocity inlet with 10m/s fixed value
Top & Right Edges	Outlet
Bottom Edge	walls
Building 1 and 2	

4. RESULTS & DISCUSSION

Pressure & velocity contours are analyzed for finding out the pressure distribution and corresponding velocities around the buildings.

Pressure contours

Figures 6 & 7 representing the pressure contours for side view and Top view of the buildings. Front face of the tall building experiences high pressure and top surface of the tall building shows a low pressure formation. A low pressure area formed far away from the two buildings in the downstream represents a strong wake.

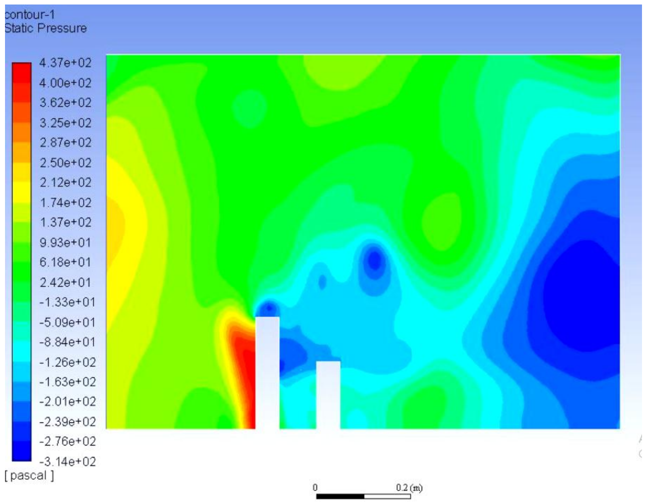


Fig-6: Static Pressure Contours showing low pressure area formation over the top surface of tall building

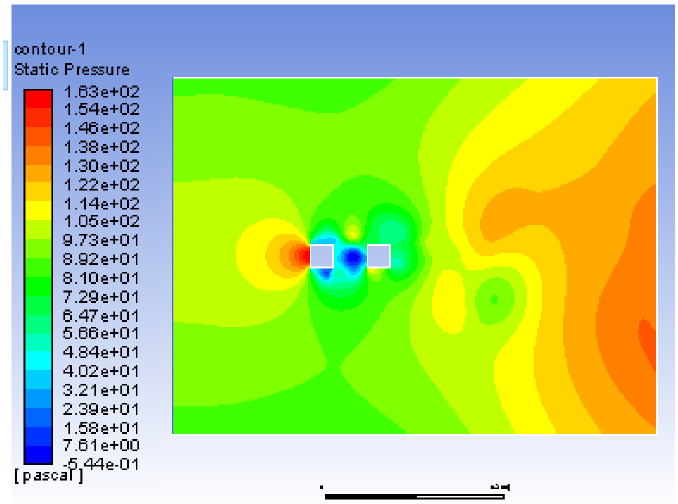


Fig-7: Contours (*The figure indicates top view contour of the Two building at 3000 iteration)*

Coefficient of Pressure C_P is given by the formula

$$C_P = (P-P_\infty)/q_\infty = (P-P_\infty) /(0.5\rho_\infty V^2)$$

Where P is the static pressure at a given location where CP is desired to be found, P_∞ is the undisturbed free stream static pressure which is taken just ahead of tall building, q_∞ is the dynamic pressure, ρ_∞ is the density of undisturbed free stream and V is the velocity of the undisturbed free stream.

C_P is found on the tall and small building faces in height wise order to analyze the pressure distribution. A highest positive value of C_P indicates headon pressure or windward pressure and a peak negative value indicates a suction pressure.

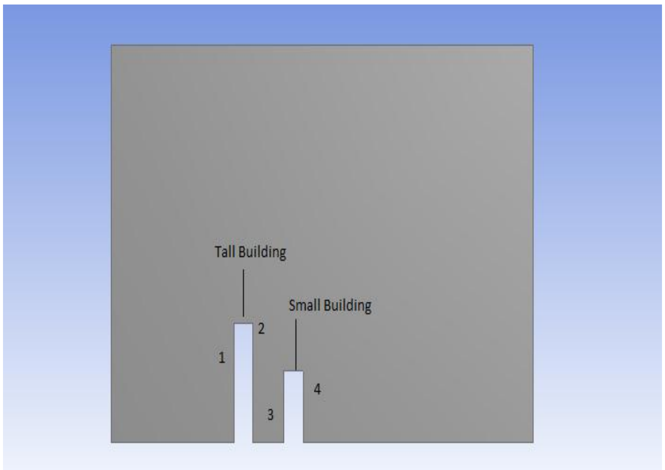


Fig-8: *Schematics diagram of domain defining all the location where the value of Cp is measured.*

1. Tall building front face
2. Tall building Rear face
3. Small building Front face
4. Small building Rear face

Graphs are plotted height wise direction for front and rear faces of both the buildings versus corresponding Coefficient of Pressure C_P.

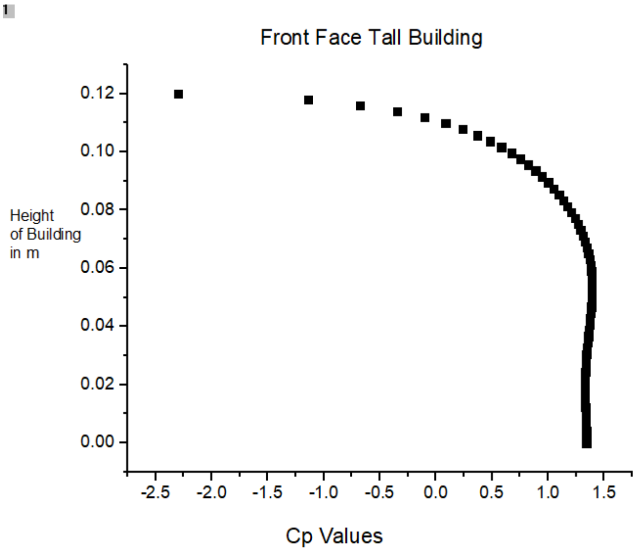


Fig-9: C_P distribution on front face of tall building

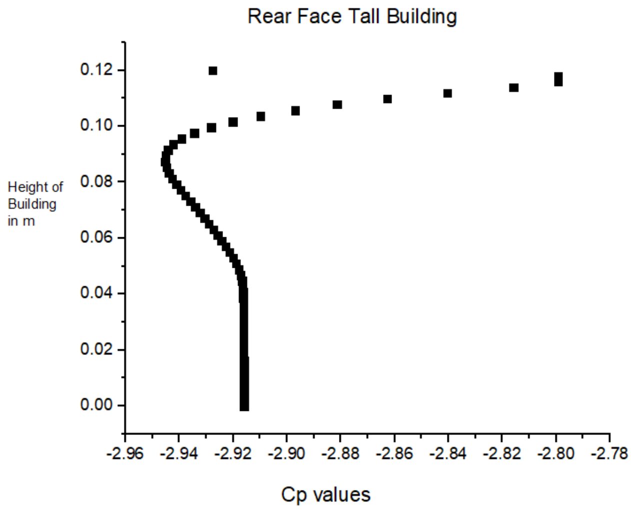


Fig-10: C_P distribution on rear face of tall building

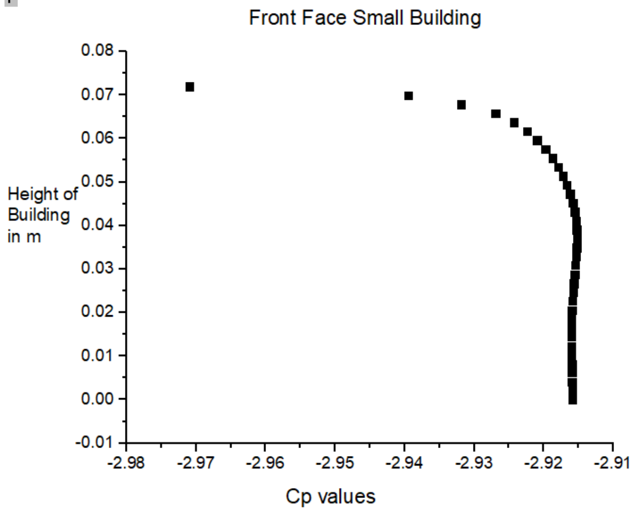


Fig-10: C_P distribution on front face of small building

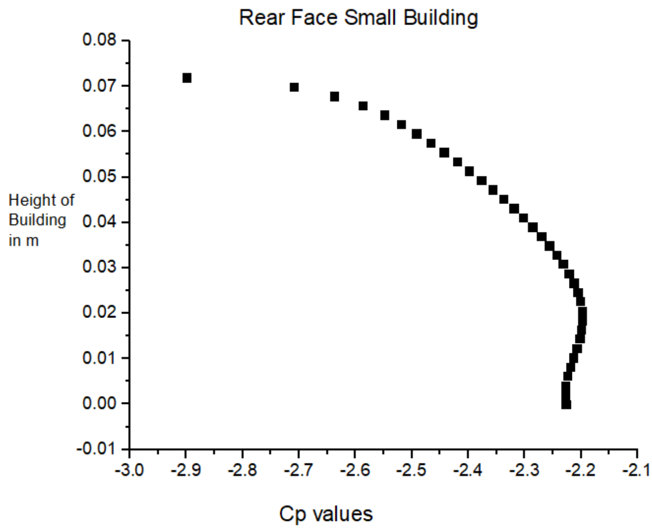


Fig-10: C_P distribution on rear face of small building

Figure 9 shows that up to a height of about 70 feet on tall building front face experiences the highest positive pressure and from 70 feet to 120 feet height the negative pressure is seen indicating a peak value of -2.5 on the top surface of tall building. The rear face experiences a uniform negative pressure up to a height of 50 feet and for the later part of the face, the value still incresses towards -2.95 indicating a strong suction. While both front and rear faces of the small building are fully submerged in the wake flow of the tall building showing a minimum Cp value of -2.25 to a maximum value of -2.95.

5. CONCLUSION

The study from the above graphs indicate that tall buildings can show a lot of aerodynamic impact over surrounding short buildings. Tall buildings obstruct the main flow over the short building. The obstruction of the flow causes the low pressure region in between the two buildings. This case is studied for 10m/s velocity, but if the velocity rises then it may damage building structure creating a resonance phenomenon. Also it can be well concluded that construction of tall building in front of small building give rises various issues and should be constructed with proper aerodynamic modifications. Here the effort is taken to prove it computationally that construction of tall building gives out negative effects. This data can further be used to design such types of buildings in near future and study the effect of such buildings in a city environment and on neighboring buildings.

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