Large Eddy Simulation and Wind Tunnel Study of Flow Interference Between Buildings in Tandem Configuration

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1. INTRODUCTION & OBJECTIVE

Rapid urbanization and limited land availability in metropolitan cities such as Bangalore have led to dense clusters of buildings, significantly influencing local wind flow and pedestrian comfort. Wind-induced flow separation, turbulence, and pressure fluctuations in such built environments may compromise structural safety, ventilation, and air quality. The built environment refers to human-made surroundings such as buildings, parks, and transportation systems that shape daily life [Wikipedia.com]. Figure 1.1 provides an illustration of a typical built environment.

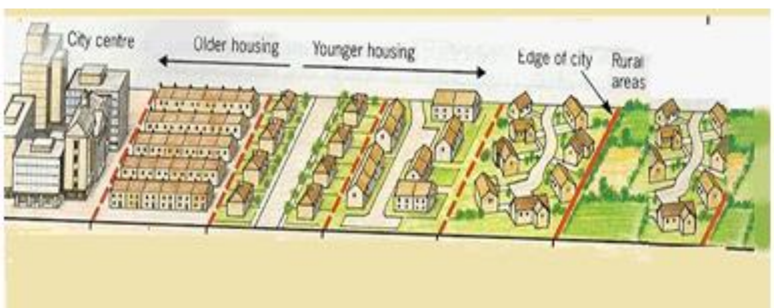

Fig.1.1 Part of built environment [Courtesy: www.mae.engr.ucdavis.edu]

The objective of this study is

- To investigate wind effects on two buildings arranged in tandem configuration, including rectangular and hut-type models.
- Using Computational Fluid Dynamics (CFD) with Large Eddy Simulation (LES), validated against wind tunnel tests.

This work quantifies flow separation, wake turbulence, and pressure coefficient (Cp) distributions.

2. METHODS OF ANALYSIS

Numerical simulations were conducted using LES with dynamic subgrid-scale modeling to capture unsteady turbulent flow features around prismatic and hut-type building models. Both isolated and tandem arrangements were studied, and boundary conditions corresponded to atmospheric boundary layer profiles. Experimental validation was carried out in a low-speed wind tunnel with rectangular and hut-shaped models arranged in tandem. Pressure coefficients were obtained using wall tappings connected to a pressure Data Acquisition System. The Velocity and vorticity fields were analyzed to identify wake characteristics and turbulence growth.

3. RESULTS AND/OR HIGHLIGHTS OF IMPORTANT POINTS

- For two rectangular buildings in tandem, flow separation occurred at the windward sharp edges. The separated flow reached 1.28 times, inlet velocity, while the wake velocity dropped to nearly 1/20th of inlet velocity.
- Vorticity contours revealed turbulence intensities nearly 10 times higher in the wake zone compared to outer regions.
- For a hut-shaped building followed by a rectangular building, wake velocity reduced to 0.0371 m/s (≈1/25th of inlet velocity), with vorticity magnitudes almost 30 times higher than outer regions.
- Both configurations demonstrated severe pressure gradients across windward and leeward faces, leading to high drag and turbulence amplification.
- Experimental Cp distributions showed good agreement with CFD results, validating numerical predictions.

4. CONCLUSIONS

The study demonstrates that tandem building arrangements significantly intensify wake turbulence and pressure gradients compared to isolated structures. Flow separation and velocity reduction of over 95% in wake zones indicate potential hazards for structural safety, and pedestrian comfort. The findings highlight the importance of considering building orientation and spacing during urban planning to mitigate adverse wind effects.

5. REFERENCES

[1] Y. M. Su, “Investigation of building layout and urban ventilation design in Taiwan,” Build. Environ., vol. 45, no. 5, pp. 1204–1215, 2010.
[2] T. Murakami, S. Mochida, and Y. Hayashi, “CFD analysis of turbulent flow past square cylinders using LES,” J. Wind Eng. Ind. Aerodyn., vol. 41, pp. 257–268, 1992.
[3] W. K. Chow and J. Li, “Wind-induced flow around two adjacent high-rise buildings,” Build. Environ., vol. 40, no. 5, pp. 549–560, 2005.
[4] B. Blocken and T. Stathopoulos, “CFD simulations of pollutant dispersion in building environments,” Atmos. Environ., vol. 42, no. 20, pp. 4873–4882, 2008.

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