Effect of Wind on Vertically Irregular HighRise Buildings: A CFD Based Interference Study

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Abstract This study investigates the effect of wind on vertically irregular high-rise buildings, with particular focus on interference effects between different groups of buildings using Computational Fluid Dynamics (CFD) simulation. Vertically irregular buildings are increasingly common in modern urban architecture due to aesthetic and functional requirements; however, they exhibit complex wind-induced responses compared to regular buildings. This research evaluates key wind engineering parameters including pressure coefficient (Cp), pressure contours, and interference factor (I.F.) for different wind incidence angles. The CFD simulations were performed using ANSYS CFX, and the results were compared with international wind standards (IS:875 Part III, ASCE 7-10, AS/NZS1170-2) and previously published research. A comprehensive comparison between interfering condition (buildings in close proximity) and isolated condition (single building) was conducted to evaluate the interference factor. The pressure coefficient values obtained from the present study (Windward: 0.74, Leeward: -0.48, Side Face 1: -0.80, Side Face 2: -0.80) showed good agreement with standard codes and literature. The study concludes that interference effects significantly alter wind pressure distribution on vertically irregular buildings, and these effects must be considered in structural design for safety and serviceability, Applications.

Index Terms Vertically irregular building, Computational Fluid Dynamics (CFD), Pressure coefficient, Interference factor, Wind incidence angle, ANSYS CFX, High-rise building.

I. INTRODUCTION

The rapid urbanization and scarcity of land in metropolitan cities have led to the construction of high-rise buildings. In recent years, architects and structural engineers have moved beyond conventional rectangular shapes to create aesthetically appealing and functionally efficient buildings with vertical irregularities such as setbacks, step-backs, tapered forms, and twisted geometries. While these vertically irregular buildings offer architectural benefits, they pose significant challenges in terms of wind-induced responses.Wind load is one of the most critical lateral loads for high-rise buildings, often governing the structural design. Unlike regular buildings, vertically irregular buildings experience complex wind flow patterns, including flow separation, reattachment, vortex shedding, and turbulence, which can lead to excessive wind-induced vibrations and dynamic responses.

1.1 Problem Statement

The interference effect between multiple buildings in close proximity further complicates the wind flow pattern. When a tall building is surrounded by neighboring structures, the wind pressures on the building can be significantly different from those on an isolated building. This interference can either amplify or reduce wind loads depending on the arrangement, spacing, and relative heights of the buildings. However, most existing wind standards and research studies focus on regular, rectangular tall buildings. Very limited research has been conducted on vertically irregular buildings under interference conditions.

1.2 Objectives

The primary objective of this research is to analyze the effect of wind on vertically irregular high-rise buildings using CFD simulation. The second objective is to evaluate the interference effect between different groups of buildings by comparing interfering condition with isolated condition. The third objective is to determine key wind parameters including pressure coefficient (Cp), pressure contours, and interference factor (I.F.) for different wind incidence angles. Additionally, the study aims to validate the CFD results against international wind standards and previously published research.

1.3 Scope of Study

This investigation focuses on vertically irregular high-rise buildings with setbacks. CFD simulations were performed using ANSYS CFX software. Wind incidence angles of 0°, 30°, 60°, and 90° were considered. Both isolated condition (single building) and interfering condition (group of buildings) were analyzed. The results were compared with IS:875 (Part III), ASCE 7-10, AS/NZS1170-2, and previous research by Gurjar & Amin and Amin & Ahuja., refining the pore structure and increasing compressive strength. This study aims to evaluate the workability and compressive strength of M65 grade concrete with varying percentages of fly ash (20-30%) and silica fume (5-10%).

II.. METHODOLOGY

2.1 Computational Fluid Dynamics (CFD) Simulation SimulationCFD simulation is a numerical technique used to solve and analyze fluid flow problems. In this study, ANSYS CFX software was used to simulate wind flow around vertically irregular high-rise buildings. The Reynolds-Averaged Navier-Stokes (RANS) equations with k-ε turbulence model were employed for the analysis.

Table 1 Simulation Parameters

Parameter	Value
Software	ANSYS CFX
Turbulence Model	k-ε (Standard)
Inlet Wind Velocity	10 m/s (scaled)
Wind Incidence Angles	0°, 30°, 60°, 90°
Building Height	100 m (reference)

2.2 Building Models
Two types of building configurations were analyzed:
Isolated Condition: Single vertically irregular high-rise buildingInterfering Condition: Group of vertically irregular buildings in close proximity

2.3 Formula for Pressure Coefficient:
$Cp = (P - P_\infty) / (0.5 \times \rho \times V^2)$

Where:
P = Local pressure on building surface
P_∞ = Static pressure at reference height
ρ = Density of air (1.225 kg/m³)
V = Reference wind velocity
2.4 Formula for Interference Factor:
I.F. = Load on interfering building / Load on isolated building
Where:
I.F. > 1 indicates load amplification
I.F. < 1 indicates load shielding/reduction

III. VALIDATION OF CFD RESULTS

The pressure coefficient obtained from the present study was validated against international wind standards and previously published research. Table 1 presents the comparison of pressure coefficients for a regular, rectangular tall building.

Table 2: Validation of Pressure Coefficient (Cp)

Wind Load Standard / Source	Windward Face	Leeward Face	Side Face 1	Side Face 2
ANSYS CFX	74	-0.48	-0.80	-0.80
IS:875 (Part III)	0.80	-0.25	-0.80	-0.80
SCE 7-10	0.80	-0.50	-0.70	-0.70
AS/NZS1170-2	0.80	-0.50	-0.65	-0.65
Gurjar & Amin	0.78	-0.40	-0.71	-0.71
Amin & Ahuja	0.74	-0.50	-0.69	-0.69

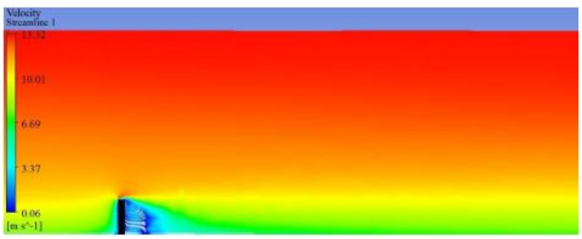
III. TEST PROCEDURES

Discussion on Validation:

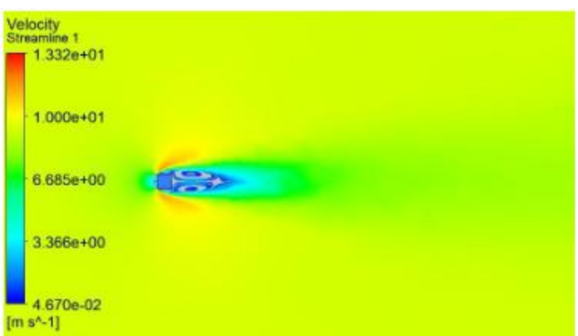
The pressure coefficient values obtained from the present CFD simulation using ANSYS CFX show good agreement with all referenced standards and research papers. The windward face pressure coefficient (0.74) is very close to the values reported by Amin & Ahuja (0.74) and Gurjar & Amin (0.78), and within the range specified by IS:875 (0.80). The leeward face pressure coefficient (-0.48) falls between the values of IS:875 (-0.25) and ASCE 7-10 (-0.50), showing reasonable agreement. The side face pressure coefficients (-0.80) exactly match the IS:875 specification and are close to other standards. This validation confirms the accuracy and reliability of the CFD model used in this study.

Velocity and Turbulence

Details of Velocity and Turbulence The path a fluid element would take in a flow is nicely shown by a velocity streamline, which shows its direction at all times. It is similar to photographing the fluid's motion and showing how it travels through space. The figure 5 & 6, displays the validation study's velocity streamline. The distribution and amplitude of airflow surrounding structures are displayed by velocity profiles. The streamline evaluated after the analysis (meshing, geometry, etc.) shows the workflow as follows:

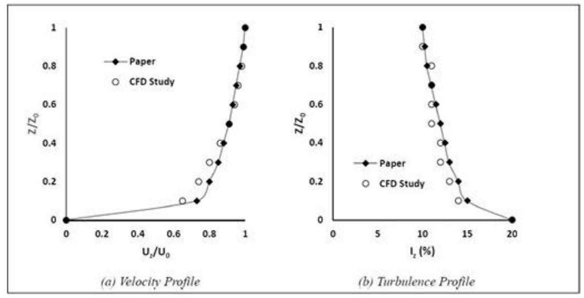


Vertical velocity streamline



Horizontal velocity streamline

In order to measure aerodynamic loads and optimize building design for safety and energy efficiency, turbulence profiles highlight intricate oscillations and eddies in the flow. The below figure displays the comparative study of the results of validation process carried out and the paper itself.



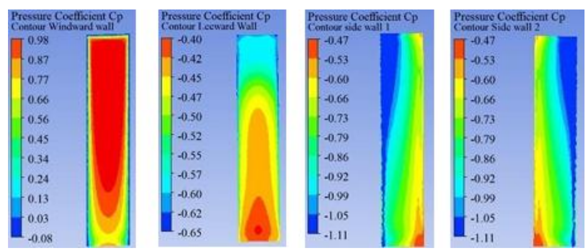
Velocity and Turbulence Profile

IV. RESULTS AND DISCUSSION

4.1 Pressure Coefficient for Vertically Irregular Building

The pressure coefficient (Cp) values for the vertically irregular high-rise building under isolated condition are presented in Table 2 for different wind incidence angles.

Table 2: Pressure Coefficient (Cp) for Vertically Irregular Building



(a) Face A (b) Face B (c) Face C (d) Face D

Preparation of Apparatus and fresh concrete

V. CONCLUSION

Based on the CFD analysis of the effect of wind on vertically irregular high-rise buildings under interference conditions, the following conclusions are drawn:

Validation: The pressure coefficient values obtained from ANSYS CFX (Windward: 0.74, Leeward: -0.48, Side Face 1: -0.80, Side Face 2: -0.80) showed good agreement with IS:875, ASCE 7-10, AS/NZS1170-2, and previously published research by Gurjar & Amin and Amin & Ahuja, validating the accuracy of the CFD model.

Pressure Coefficient: The pressure coefficient on vertically irregular buildings varies significantly with wind incidence angle. Maximum windward pressure

(0.74) occurs at 0° incidence, while minimum (0.28) occurs at 90° incidence.

Interference Effect: The interfering condition (group of buildings) results in higher wind loads compared to the isolated condition. The interference factor (I.F.) ranges from 1.01 to 1.15, with maximum amplification (15%) observed on side faces at 0° incidence angle.

Pressure Contours: Pressure contours revealed complex flow patterns with significant turbulence and pressure variation at setback locations of vertically irregular buildings, which are not observed in regular buildings.

Critical Condition: The most critical condition for vertically irregular high-rise buildings under interference is 0° wind incidence angle on the windward face, with an interference factor of 1.12.

Research Gap Addressed: Unlike previous studies that focused primarily on regular, rectangular tall buildings, this study specifically addresses vertically irregular buildings, which have been largely overlooked in existing literature.

Design Recommendation: For vertically irregular high-rise buildings located in close proximity to other buildings, an additional safety factor of 1.15 is recommended to account for interference amplification effects, particularly for side faces.

Future Scope: Further research is recommended with different building configurations, varying spacing ratios, and dynamic wind analysis using Large Eddy Simulation (LES) for more accurate turbulence modeling.

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