CLARIFYING THE EFFECT OF HIGH-RISE BUILDINGS ON STRONG WIND OCCURRENCE WITHIN URBAN CANOPY

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ABSTRACT

Pedestrian-level winds (PLW) are crucial for ensuring comfort and safety in urban areas, influenced by meteorological conditions and building morphology. However, in high-rise urban environments, turbulence complicates PLW assessments. This study aims to capture multi-point instantaneous wind speed data through wind-tunnel experiments, advancing understanding of unsteady wind flows in urban areas.

KEY WORDS

Pedestrian-level wind (PLW)
Particle Image Velocimetry (PIV)

1. INTRODUCTION

Pedestrian-level wind (PLW) is an important factor for maintaining comfortable and safe pedestrian spaces. PLW speeds are determined by both meteorological variations and the aerodynamic effects of urban building morphology. The complexity of urban building morphology can generate considerable turbulence due to the strong shear stress between the canopy layer and above. Consequently, the aerodynamic effects of buildings on turbulent flow fields within the canopy layer have been research targets. Studies have often assumed idealized approaching flows using wind-tunnel experiments (WTE).[1] In recent decades, the relationships between mean wind speeds and building geometries have been studied to provide both idealized building arrays and realistic districts for PLW assessments and urban ventilation. [2].However, the turbulent nature of PLWs, which significantly contributes to rare wind events such as stagnation and gusts, has not been fully accounted for. Nowadays, with the increasing number of high-rise buildings in urban areas worldwide and one major issue is the occurrence of strong winds at pedestrian levels. WTE experiments usually exceed with building models, using thermistor anemometers and hot-wire anemometers. These anemometers can obtain average speed data, but airflow around buildings is unsteady and non-uniform. Therefore, we need to measure instantaneous values across a wide plane. CFD assessments use turbulence models and require comparison of predicted results with experimental data. Wind environment evaluations typically use average wind speed, but this method has limitations. Therefore, Our research aims to measure unsteady, non-contact, and multi-point wind speed data in urban canopies, including high-rise buildings, through WTE experiments.

2. EXPERIMENT

Particle Image Velocimetry (PIV) systems visualizes invisible airflow by tracking particle movement, comparing continuous images, and calculating wind speed. PIV systems can obtain multipoint data in unsteady and non-contact measurements, making it easy and accurate to understand the flow. Our research attempts to use PIV for horizontal planes in urban canopies and evaluate the instantaneous wind speed. Figure 1 shows the plan view of the model, and side view.
We irradiate the area with a laser from this point and use two lenses. The laser proceeds horizontally along the floor and spread the laser using a laser line generator. By irradiating the target area, we can capture images from a floor camera. The urban canopy is a staggered array with a building coverage of 25%. Reference wind speed is 4.00m/s. Figure 3 shows Experiment models. High-rise buildings were included on one side with 0.1m model assemblies. Setting 0.1m = H, we use three types of buildings: H, 1.5H, and 3.0H, to compare the wind environment in the urban canopy.

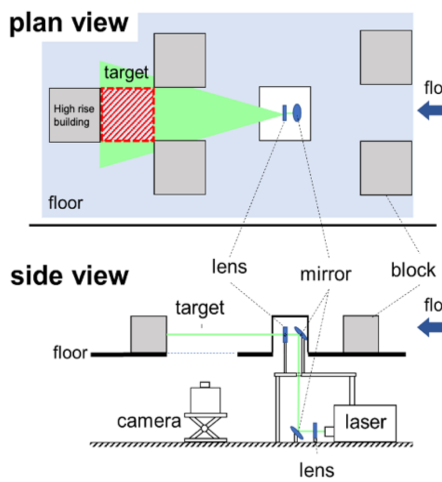

Fig.1 Experimental system

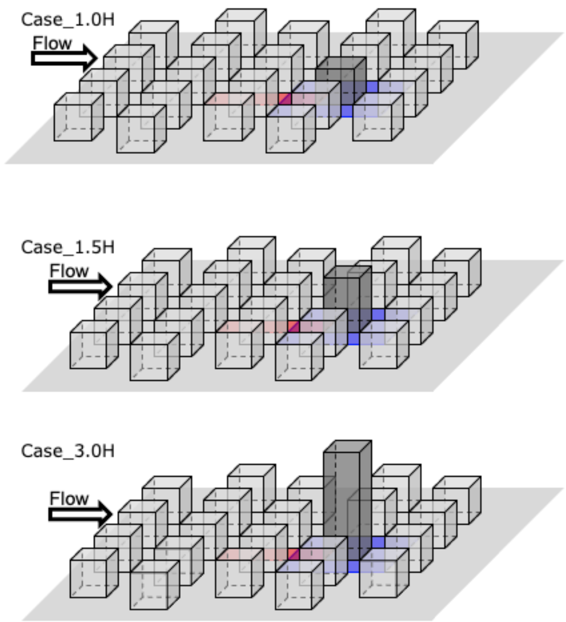

Fig.2: Experiment models

3. RESEARCH PLAN

In this study, we utilize the Particle Image Velocimetry (PIV) system to capture data. in. three areas around high-rise buildings: the front, the surroundings, and the rear. Figure 3 illustrates the high-rise building models and the planned measurement areas. The high-rise buildings are set at three different heights: 1.0H, 1.5H, and 3.0H. The objective of this research is to obtain unsteady, non-contact, and multi-point wind speed data within the urban canopy, particularly around high-rise buildings. For this purpose, we installed a series of building models in a wind tunnel and measured the wind speeds using PIV. The research plan involves measuring wind speeds in the areas in front of, around, and behind the high-rise buildings at heights of 1.0H, 1.5H, and 3.0H. By evaluating instantaneous wind speeds, we aim to understand the complex wind flow characteristics in urban environments. This study addresses the limitations of previous

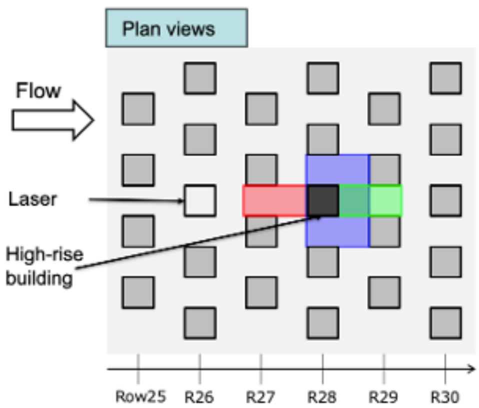

Fig.3: Measurement Areas

4. RESULTS

In this experiment, we investigated the wind speed distribution within the urban canopy at different high-rise building heights (1.0H, 1.5H, and 3.0H).Measurements were taken in two street blocks located in front of the high-rise buildings. The horizontal wind speed profile at a height of z = 0.1m was measured, and the wind speed ratios were normalized using the reference wind speed($\bar{u}/Uref$) Figures 4, 5, and 6 present contour mapfor each case. The results showed that as building height increases, the reverse flow region expands, and in the case of 3.0H, the reverse flow region becomes larger than the forward flow. These findings indicate that reverse flow regions have a significant impact on the pedestrian-level wind environment, especially as building height increases.

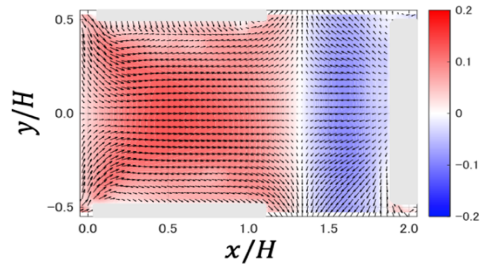

Fig.4: Case1.0H Contour map

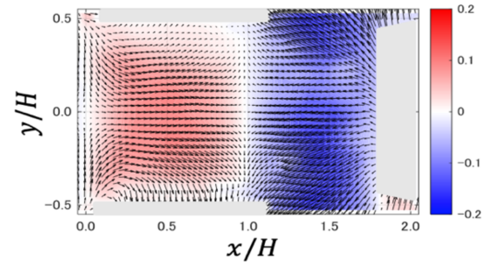

Fig.5: Case1.5H Contour map

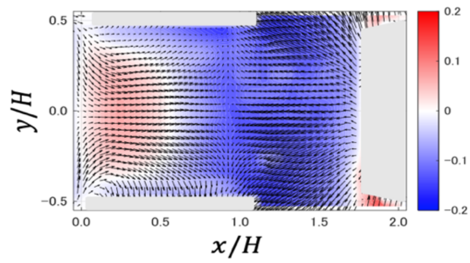

Fig.6: Case3.0H Contour map

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