P04

Wind Tunnel Experiment by Particle Image Velocimetry on Turbulent Flow Field around 2D Street Canyon with Eaves

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Abstract
This study seeks the influence of the secondary roughness on turbulent flow fields in a 2D street canyon by a wind tunnel experiment (WTE) using Time-resolved particle image velocimetry (TR-PIV) system. The measurements revealed that the temporally averaged flow fields and the spatial distributions of turbulent statistics are drastically changed by the complexity of roughness. Moreover, the ventilation rate is reduced by the eaves attached to roofs because the eaves prevent turbulent coherent structure from penetration into the canyon.

1. Introduction

The turbulent flow nature around buildings has attracted much interest in both urban climatology and wind engineering, and a vast number of experiments and numerical simulations have been conducted for decades. However, most of the past studies assumed real urban geometry as idealized block arrays (e.g., Cheng and Castro, 2002)[1)], and did not take diverse and complicated topography of real buildings into account. A pioneering study by Mohamad et al. (2014)[2)] revealed the drastic effect of a porch on temporal-averaged flow field around 2D building models.

Under these circumstances, the authors have performed a wind tunnel experiment to investigate how turbulent flow field in 2D street canyon is changed by flat eaves overhang a street canyon. Time-Resolved Particle Image Velocimetry (TR-PIV) was employed to capture spatial distributions of turbulent statistics as well as unsteady flow motions around the canopy.

2. Experimental setting

The closed-circuit wind tunnel with the test section of height 1.0 m, width 1.5 m and length 8 m (Figure 1) was used for the measurement of two types of canopy topography. In Case A, 40 horizontally-long bars with a cross section of 25 mm × 25 mm (hereafter, H=25mm) were arranged face to face with a 75mm interval perpendicular to the mean wind direction in the test section. On the other hand, in Case B, the 29th to 36th bar from the windward was replaced with bars attached with eaves (Figure 2). Stream wise and vertical velocity components were measured by PIV at a frequency of 1000Hz for a period of 43.6 seconds. The spatial resolution of the camera was 512pixe×512pixel and image magnification was about 0.17mm/pixel.

3. Result

Figure 3 presents temporally-averaged velocity vector maps in the two cases. In Figure 3 (a), a large recirculation eddy and a small secondary eddy behind the upstream obstacle are observed inside the canyon. On the other hand, in Figure 3 (b), a complicated flow structure

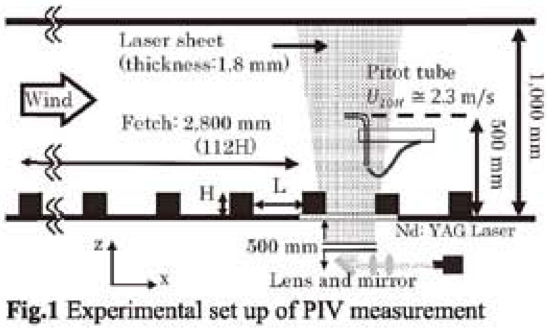

Fig.1 Experimental set up of PIV measurement

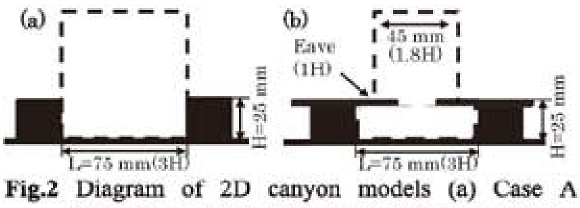

Fig.2 Diagram of 2D canyon models (a) Case A (L/H=3, no eaves) (b) Case B (L/H=3, having eaves) black dashed lines: the measurement area

consisting of multi-vortex arises inside the canyon. Although velocity is small in the large part of the canyon, the velocity at the crossover region of the center and right eddy around x/H=2.1 is slightly large. This is probably associated with the penetration of high-speed downward flow into the canyon, and moreover, the high-speed flow is thought to be a driving force of the center and right eddy.

Figure 4 and figure 5 presents the spatial distribution of the standard deviation of stream wise and vertical velocity component normalized by the reference velocity (σ_u/U_{20H}, σ_w/U_{20H}). It is obvious that the turbulent intensity becomes weak in the whole area in case B, and this fact indicates that the turbulence production by roughness is reduced by eaves. In the canyon layer, both σ_u and σ_w are almost zero at the upstream region, however, they are slightly large in a tongue-like region around x/H=2.0. This seems to be caused by the high speed flow penetrating into the canyon through the gap of eaves.

Figure 6 are contour maps of the Reynolds stress normalized by square of reference wind velocity ($-\overline{u'w'}/U_{20H}^2$). The stream wise elongated peak of Reynolds stress is observed at the height of 1.0H in Case A. This feature is observed in two-dimentional canyon flow regardless of the street aspect ratio (ratio of canyon width and roughness height)(e.g. Simoens et al. 2007[3]), however, such elongated-peak of the Reynolds stress at the top of canyon does not appear in Case B although a small peak arises near the edge of the downstream eave.

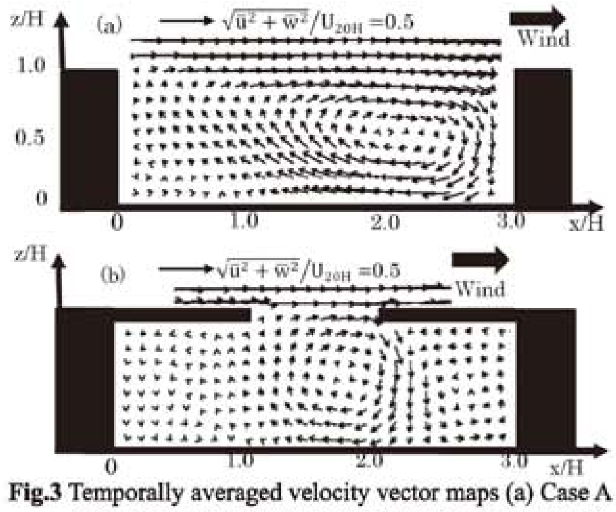

Fig.3 Temporally averaged velocity vector maps (a) Case A (L/H=3, no eaves) (b) Case B (L/H=3, having eaves)

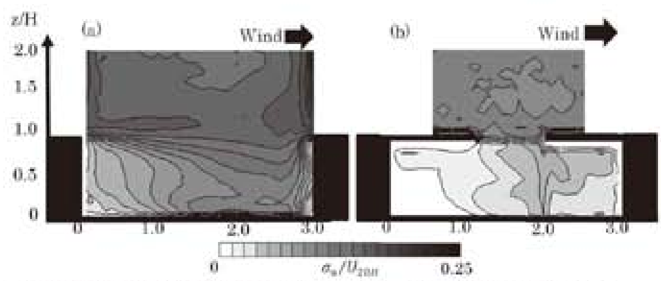

Fig.4 Spatial distributions of (σ_u/U_{20H}) (a) Case A (L/H=3, no eaves) (b) Case B (L/H=3, having eaves)

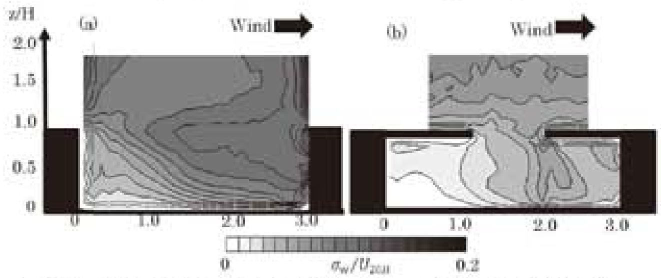

Fig.5 Spatial distributions of (σ_w/U_{20H}) (a) Case A (L/H=3, no eaves) (b) Case B (L/H=3, having eaves)

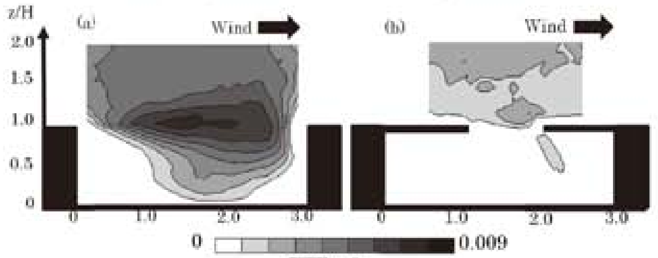

Fig.6 Spatial distributions of $-\overline{u'w'}/U_{20H}^2$ (a) Case A (L/H=3, no eaves) (b) Case B (L/H=3, having eaves)

4. Conclusion

A PIV experiment was performed to investigate how secondary roughness changes the turbulent flow nature around the roughness. The temporally-averaged flow field is drastically changed by the eaves, causing the complicated structure. Standard deviations and Reynolds stress are slightly large in the tongue-like regions under the downstream-side eave, however, the turbulent production is strongly limited by the eaves reducing turbulent intensity and Reynolds stress in the large part of the measurement area.

Acknowledgment

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Reference

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