CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 2

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 2*. Department of Civil Engineering, Aalborg University.

Wind-Tunnel Studies of Pedestrian-level Wind Environment in Street Canyons

Chien-Yuan Kuo[#1], Chun-Ta Tzeng[#2], Ming-Chin Ho[##3], Rong-Horng Chen[*4]
Chi-Ming Lai[**5]

[#] *Department of Architecture, National Cheng-Kung University*
1, University Road, Tainan City, Taiwan

[1]kcy@abri.gov.tw

[2]ctmt@mail.ncku.edu.tw

[##] *Architecture and Building Research Institute, Ministry of the Interior*

13F., No.200, Sec. 3, Beisin Rd., Sindian District, New Taipei City, Taiwan
[3]Ho@abri.gov.tw

[*] *Department of Mechanical and Energy Engineering, National Chiayi University*
300 Syuefu Road, Chiayi City, 600, Taiwan

[4]chenrh@mail.ncyu.edu.tw

[**] *Department of Civil Engineering, National Cheng-Kung University*
1, University Road, Tainan City, Taiwan

[5]cmlai@mail.ncku.edu.tw

Abstract
The pedestrian-level wind environment quality in the street canyon formed by high-rise buildings and other low-level buildings will be affected by multiple factors such as, the height and geometry of surrounding buildings, the width of street, wind direction, and wind speed. This study adopted wind tunnel experiments to observe the characteristics of the pedestrian-level wind environment in street canyons under different conditions including different street widths, heights of high-rise building (also the height of the podium), and incoming wind directions. The experimental results revealed that a podium with higher height would have stronger wind speeds of the flow field within the street canyon and different incoming wind directions would change the high wind speed zone within the street canyon accordingly.

Keywords - Pedestrian-level wind environment; street canyon; high-rise building; podium; wind-tunnel

1. Introduction

Different street canyon widths will form different wind environmental characteristics. Not only does the architectural design have considerations on the safety and aesthetics, the effect of the building on the microclimate is also currently an important issue. The ground level strong winds produced following high-rise building could pose problems for pedestrian-level safety and comfort. This issue has gained widespread attention and there are many studies in the literature that explore related problems. [1-4]

This study conducted wind-tunnel experiments to explore the pedestrian-level wind characteristics in the street canyon formed by a high-rise building with a podium and the adjacent attached low-rise houses under different podium heights, street canyon widths, and incoming wind directions. Regarding street canyon ventilation research, many studies in the literature took building patterns with symmetrical sections on two sides as the research object and only explored the wind speed of the center position of street canyons; whereas this study focused on taking the wind field guided by asymmetrical building sections that are formed by high-rise buildings containing a podium and their adjacent attached blocks.

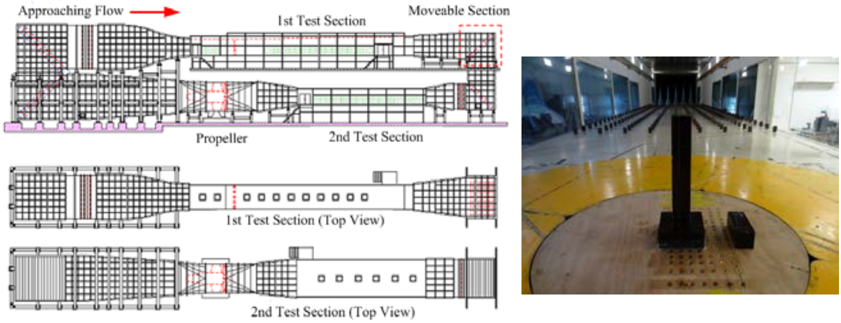
2. Research method

The following experiments were conducted in the Wind Tunnel Laboratory, Architecture and Building Research Institute, Ministry of the Interior, Taiwan. As shown in Fig. 1(a), the wind tunnel used was a closed type that possessed two test sections. The pedestrian-level wind field testing of this study was conducted using the second rotating disc of the wind-tunnel's first test section. With a maximum wind speed of 30m/s, this test section had a length of 36.5 m, width of 4 m, and height of 2.6 m.

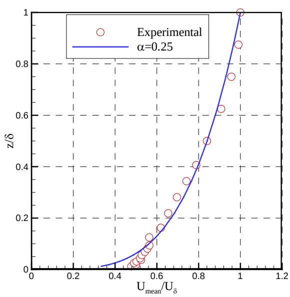
According to the related regulation in Taiwan, the suburban ground condition index is $\alpha = 0.25$; the atmospheric boundary layer height is 400m. By scaling down with 1/250, this study used a 1.6m spoiler and roughness elements to produce the ground conditions in order to comply with the requirements of the Act. As shown in Fig. 1(b), U_{mean} is the average wind speed at the height of z; U_{δ} is the average wind speed of atmospheric boundary layer height (δ = 400m). Fig. 1(c) is the wind turbulence intensity inside the wind tunnel. Schematic diagrams of the used wind tunnel.

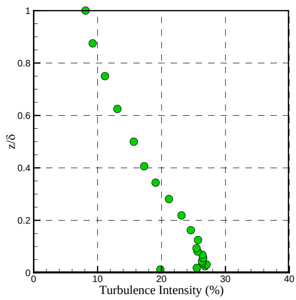
By taking the ground surface wind speed in/around the street canyon as the main focus for exploration, a rigid experimental model was adopted. The length and width of the podium as well as the length, width, and height of adjacent attached houses were fixed. The variables include: the podium height, the street canyon width, and the wind direction. Layouts of the experimental model and ground surface anemometers are shown in Fig. 2. The model dimension, D, was 8cm; the width of podium was set to be 2.5D; P_h was the podium height; the podium height ratios, P_h/D, were set to be 0.5, 1, and 2; S is the width of street canyon; while testing, the street canyon spacing ratios, S/D, were set to be 0.375, 0.75, 1.25, 1.75, and 2.25; the incoming wind angles were $\theta = 45^{\circ}$, 22.5°, 0°, -22.5°, and -45°.

The layout of the ground surface anemometers (Irwin probe) included the front area of the podium model, upstream of the street canyon, inside the street canyon, and downstream of the street canyon, a total of 60 points were placed. The outer diameter of the Irwin probe was 2cm, therefore it was not possible to lay out points for more than two lines when S = 0.375D and S = 0.75D. Hence, single-line layouts were created only on the center line for these 2 street canyon widths. As shown in Fig. 2, S = 1.25D, S = 1.75D, and S = 2.25D are all laid out with 3 lines, which are each separated by 5cm to the left and the right. Please check the details in our previous work [5].



(a) Schematic diagrams (left) and photo (right) of the used wind tunnel





(b) Average speed (c) Turbulence intensity

Fig.1 Wind characteristics of the wind tunnel used in this study

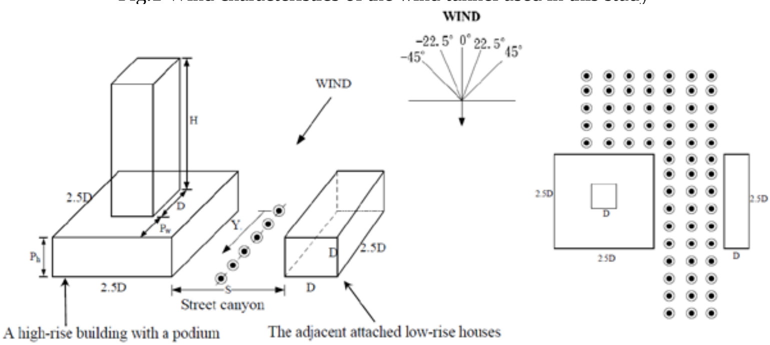


Fig. 2 Experimental model (left) and ground surface anemometers deployment (right)

3. Results and discussion

Fig. 3(a) shows the results for Ph = 0.5D, in which the podium height is lower than the height of attached houses, D. The dimensionless average wind speed for the entrance of the street canyon reduced with increasing street canyon width, whereas the wind speed downstream inside the street canyon was not affected by the street canyon width. At this point of time, the incoming upwind air-flow mostly crossed over the podium, the corner vortexes collectively entering the street canyon were relatively weaker, so the channeling effect was significantly reduced. When the street canyon width was small, two adjacent buildings in parallel formed a resistance flow field.

Fig. 3(b) shows the results for Ph = 1D, in which the podium height is equal to the height of the attached low-rise houses. Compared to Fig. 3(a) (Ph = 0.5D), Fig. 3(b) shows that there had been slight changes in the wind field characteristic of the street canyon with different widths. Not only did the wind speed in the whole street canyon increase, the downstream wind speed inside the street canyon began to change. When the street canyon width was S = 0.375D, the average wind speed was the highest at the entrance and was gradually declining as it approached the downstream of the street canyon. When the widths of street canyon were S = 0.75D and 1.25D, the average wind speeds at the street canyon entrance were lower; the wind speeds were the highest at the distance of Y = 0.5D away from the entrance and then were gradually declining along the street canyon downstream.

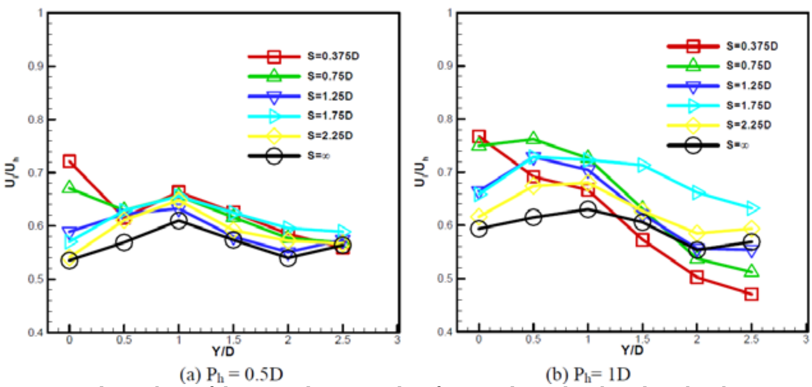
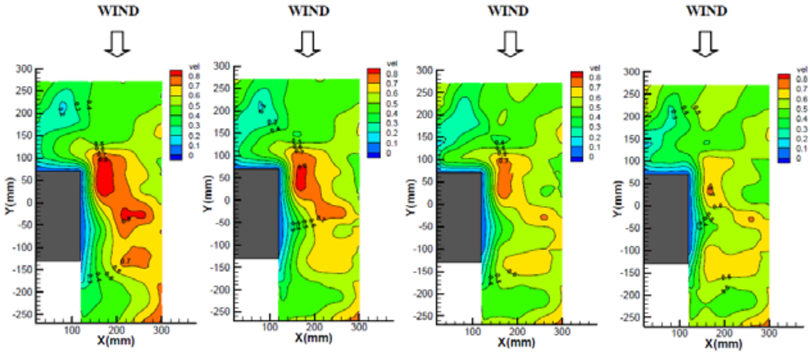


Fig. 3 Relationships of dimensionless ground surface wind speed with podium height, street canyon width, and measurement position when the wind direction is θ = 0 °

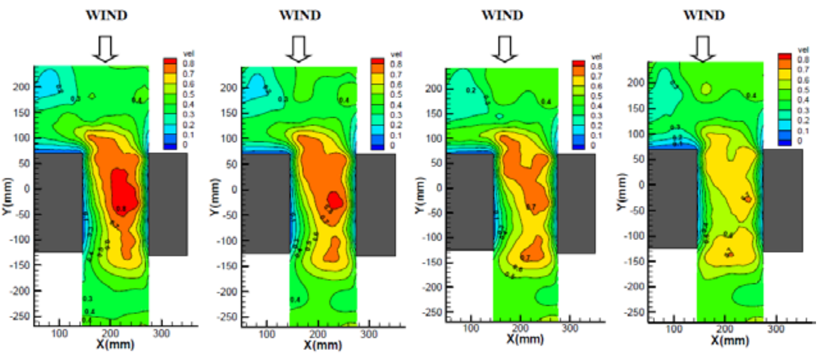
To understand the pedestrian-level wind field characteristics in the street canyon, this study took the contour plots to represent the wind speed distributions at the upstream, midstream, and downstream areas. As shown from Fig. 4 and Fig. 5, the numbers in the plots represent dimensionless average wind speed; colors closer to blue indicate lower wind speeds; colors closer to red indicate stronger wind speeds.

Fig. 4 shows the wind velocity contours for standalone high-rise buildings with a podium when the wind direction angle is 0^o. Fig. 5 shows the pedestrian-level wind field characteristics in the street canyon when S = 1.75D. The podium height in Fig. 5(a) was the highest, so the zone of emerging high wind speed in the street canyon was the largest; with lower podium height, the wind speeds were also decreasing (Fig. 5(b) - 5(d)). The high wind speed positions in Fig. 4 and Fig. 5 were slightly different. In Figure 5, the main high wind speed area was at the corner, whereas in Fig. 5, it appeared inside the street canyon. The main reason for this difference is that the airflow area inside the street canyon was suddenly narrowed down. Due to the Ventrui-effect, the wind speed inside the street with a smaller flow area was suddenly accelerated, causing the so-called channeling effect.



(a) P_h=2D (b) P_h=1.5D (c) P_h=1D (d) P_h=0.5D

Fig. 4 Dimensionless ground surface wind speed distributions when there is no street canyon on the side and $\theta = 0^o$



(a) P_h=2D (b) P_h=1.5D (c) P_h=1D (d) P_h=0.5D

Fig. 5 Dimensionless ground surface wind speed distributions when S = 1.75D and $\theta = 0^o$

4. Conclusions

Taking the street canyon formed by a high-rise building with podium and the adjacent attached low-rise houses as the main object, this study explored the pedestrian-level wind field characteristics inside the street canyon. The variables include the street canyon width, incoming wind direction, and podium height. Podium height dominated the wind field characteristics of the street canyon. Regardless of how large the street canyon width is, its inside all had dimensionless average wind velocity higher than the wind velocity before entering the street canyon, and there were significant channeling effects; while the wind fields inside the street canyon were greatly affected by the podium height. For higher podiums, the wind field velocity inside the street canyon was greater.

Acknowledgment

Support from the Architecture and Building Research Institute, Ministry of the Interior, Taiwan through grant No. PG10205-0122 in this study is gratefully acknowledged.

References

[1] T. Stathopoulos, H. Wu and C Bédard C. Wind environment around buildings: a knowledge-based approach. J. Wind. Eng. Ind. Aerod. 44 (1992) 2377-2388.

[2] B. Blocken, J. Carmeliet and T. Stathopoulos. CFD evaluation of wind speed conditions in passages between parallel buildings-effect of wall function roughness modifications for the atmospheric boundary layer flow. J. Wind. Eng. Ind. Aerod. 95 (2007) 941-962.

[3] B. Blocken, T. Stathopoulos and J. Carmeliet. Wind Environmental Conditions in Passages between Two Long Narrow Perpendicular Buildings. J. Aerosp. Eng. 21 (2008) 280-287.

[4] C.W. Tsang, K.C.S. Kwok and P.A. Hitchcock. Wind tunnel study of pedestrian level wind environment around tall buildings: Effects of building dimensions, separation and podium. Build. Environ. 49 (2012) 167-181.

[5] C.Y. Kuo, C.T. Tzeng, M.C. Ho and C.M. Lai. Wind Tunnel Studies of a Pedestrian-Level Wind Environment in a Street Canyon between a High-Rise Building with a Podium and Low-Level Attached Houses. Energies 8(10) (2015) 10942-10957.