A Study of Building Geometry to Improve Pedestrian Level Wind around High-rise Buildings

Chien-Yuan Kuo[1], Chun-Ta Tzeng[2] Yi-Chao Li[3]

Abstract

There are lots of ways to improve pedestrian level wind of high-rise buildings, and adding building podium is a common way (the so-called "podium design" is fundamental underlying expansion. Hereinafter refer to as podium design). Podium design is common in Taiwan. Therefore, this research focuses on the experiments and verification of improving effectiveness of pedestrian level wind for high-rise buildings with podium design. Improper size of podium could not improve the effectiveness of pedestrian level wind but cause other environmental problems; for example, if the podium is too large, it would become a block of wind field. By blocking the city's aeration, prevailing winds cannot blow into the centre of cities, and there would be less natural aeration. Besides, while podium design is too high or too narrow, both of them cannot ease up the influence of conventional airflow to pedestrian level wind. Therefore, a proper podium design is necessary. This research is mainly discussing how podium design eases up the effectiveness of pedestrian level wind of high-rise buildings by conducting wind tunnel experiments. So, there is a series of wind tunnel experiments designed for measuring ground surface wind speed of different models. While conducting wind tunnel experiments, surface roughness elements of terrain B will be constructed on the basis of proper wind speed profile in Taiwan urban. For the measurement of the variation of wind field characteristics with different profile models and at different angles, the Irwin probes were positioned at the upstream, downstream and single side of the building models. This research discusses wind field characteristics of the building without podium design, and how the size of podium influences the characteristics of pedestrian level wind as well.

Keywords: Podium Design, Pedestrian level wind, Wind Tunnel Experiment.

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1. Foreword

Once high-rise buildings were built, huge structures will become obstacles of wind flow. Due to downburst effect, an opposed airflow emerges near ground surface at windward side under the blockage of buildings. At leeward side, convolution air filed emerges due to the interaction between wind flow and wake flows on both sides; moreover, while wind flow passes both sides of the building, due to the separation of vortex, the wind speed at both corners will be very high. This sudden vortex and strong wind will definitely impact on the surroundings, especially for pedestrians' safety and comfort. To resolve this problem, Environment Protection Administration announced article 22 and 42 of the laws and regulations of "Assessment of Environmental Impacts of Develop Activity" on December 31st, 1997, regulating that there must be assessments of wind flow around the surroundings which might be caused by high-rise buildings, and proper improvement strategies must be proposed. Similar regulations can also be found in article 7 of "Points of Management and Maintenance of Comprehensive Design in Public Area of Taipei City".

There are several ways to improve pedestrian wind flow for high-rise buildings. Adding building podium is a common way. The so-called "podium design" is fundamental underlying expansion. Hereinafter refer to as podium design. Podium design is common in Taiwan. Therefore, this research focuses on the experiments and verification of improving effectiveness of pedestrian wind flow for buildings with podium design. Improper podium design cannot improve pedestrian wind flow but cause other environmental problems; for example, if the podium design is too large, it would become a block of wind flow. By blocking the city's aeration, prevailing winds cannot blow into the centre of city, and there would be less natural aeration. Besides, while the height of podium is too high or the width is too narrow, both of the podiums cannot ease up the serious influence of pedestrian wind flow. Therefore, a proper podium design is essential. This research conducted wind tunnel experiments with models from the perspective of wind engineering. This research discusses wind field characteristics of the building without podium design, and how the size of podium influences the characteristics of pedestrian level wind as well.

2. Research Content

This research is mainly discussing how the dimensions of podiums ease up the effectiveness of pedestrian wind flow of high-rise buildings by conducting wind tunnel experiments. A series of wind tunnel experiments designed for measuring ground surface wind speed of different models were conducted. While conducting wind tunnel experiments, surface roughness elements of suburban terrain were constructed based on the proper wind speed profile in Taiwan urban. For the measurements of the variation of wind flow characteristics for different profile models and at different angles, surface wind speed meters were poisoned at the upstream, downstream and single side of buildings.

To measure the wind flow characteristics nearby, the first step of wind tunnel experiment is to design square tower models without podium for buildings with different heights. The reasonable positions for wind speed measurement were arranged according to the literatures. In order to get a better understanding of how sizes of podium influence the wind flow characteristics, this research measured wind speed at upstream, downstream, and single side of the models with different height-width ratios.

3. Methodology

3.1 Wind Tunnel Experimental Setup

The key point of this research is mainly about the discussion of wind flow characteristics of high-rise buildings with podiums. The essential point of the discussion is the distribution of ground surface wind speed around buildings. Parameters set for the experiments include the following: with or without podium, the height-width ratio of the podium, and with or without a lower building at windward side.

First, this research discusses differences of wind flow characteristics around the buildings between tower models with and without podium. Then, the proper height-width rations of podiums were analyzed based on the experiments results. There are two parts for the experiments. One is for the experiment for tower model without podium, and the other is for tower with podium. The ratio of experimental model is 1 to 250. The experiment of single tower model without podium is presented in Figure 1. The width of square tower, D is 8 cm. H refers to the height of square tower. The height-width ratios set for the experiments are 1, 3, 5, and 7. The surrounding conditions of the tower models without and with a lower building were assessed. The height of the lower building is 1D and the distance between the lower building and the tower model is 1.5D.

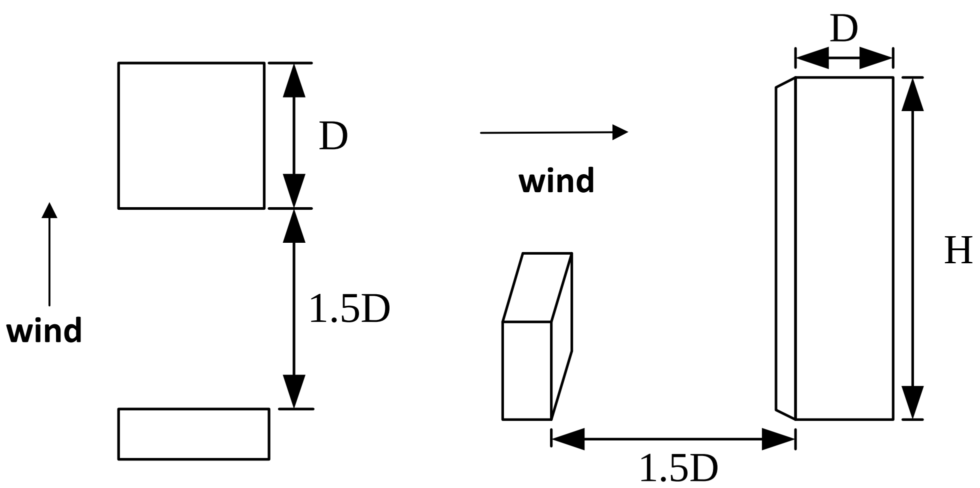

Figure 1 Layout of Single Tower Experiment

The layout of square tower model with podium is presented in Figure 2. Pw refers to the length of projection of the podium, and Ph refers to the height of the podium. For the experiments, projection ratio were set as Pw/D=0.25 and 0.5, and height ratio were Ph/D=0.5, 1, 1.5, and 2.

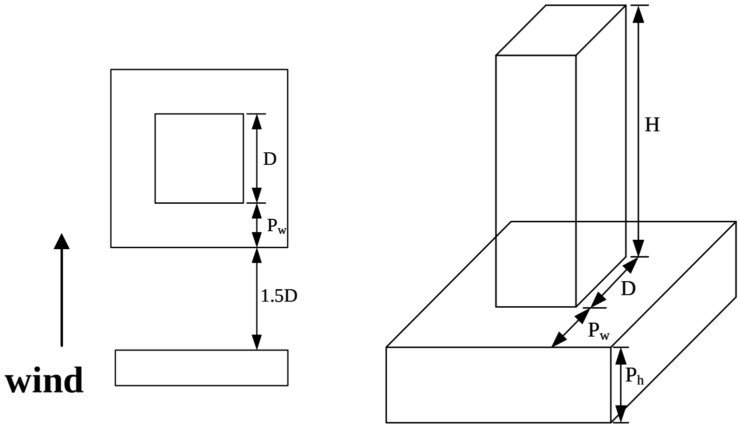

Figure 2 Layout of Square Tower Experiment

The experiments for this research were carried out at the wind tunnel lab. in Architecture and Building Research Institute, Ministry of the Interior. The length of the test section is 36.5 meters, 4 meters wide and 2.6 meters high. The highest wind speed is 30 m/s. Roughness elements of suburban terrain in the test section is arranged, stimulating ground conditions in most cities in Taiwan. For the measurements of the wind flow characteristics for ground surface at upstream, corner sides, and downstream, 60 Irwin probes around the models were arranged. Figure 3 shows the mean Velocity profile and the turbulence intensity characteristics measured at the model location. A power law of exponent α=0.25 gives the fit of the mean speed profile which corresponds to the suburban terrain. The layout of Irwin probes and the model is presented in Figure 4.

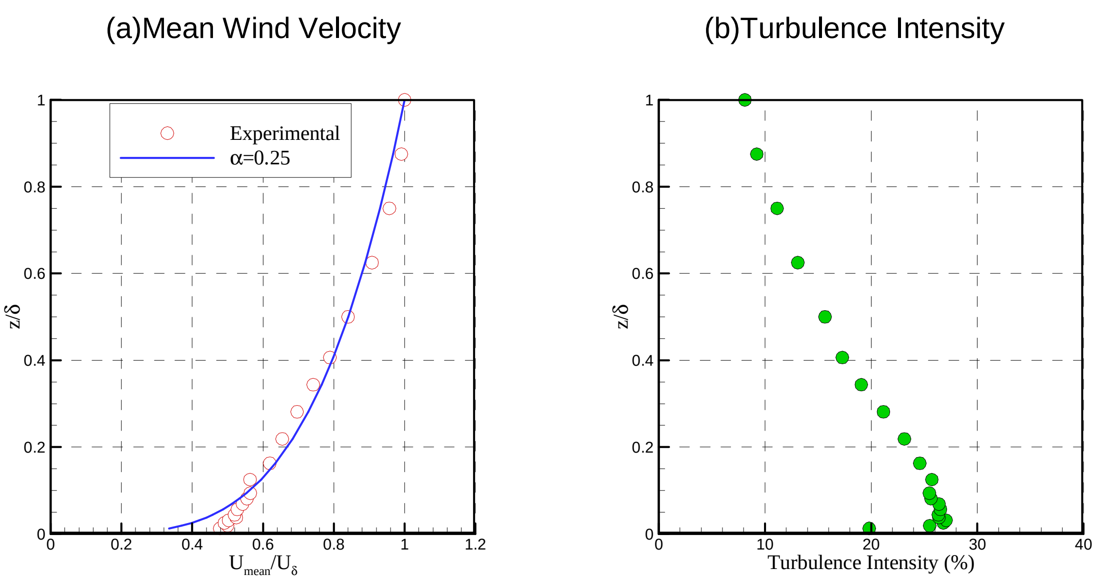

Figure 3 Wind Velocity Profile In the Wind Tunnel Lab.

Figure 4 Layout of the Model and Irwin Probes

3.2 Results and Discussion

3.2.1 With a low building at windward side

For the discuss of wind flow characteristics of single tower at ground surface, the aspect ratio of the single tower model in this research is designed as 1, 3, 5, and 7. Also, a low building was allocated in front of the model. The height of this low building was designed as 1D, and it is 1.5D (1.5D=12cm) far away from the single tower model. The result presented in Figure 5. (a), (b), (c), and (d) are distribution maps of dimensionless average wind speed of ground surface at the model height of 1D, 3D, 5D, and 7D respectively. Based on Figure 5, it is observed that with the increase of the heights of models, the wind speed at the upstream increases accordingly. While the height of building model is 5D, strong wind appears at the upstream corner of building distinctly.

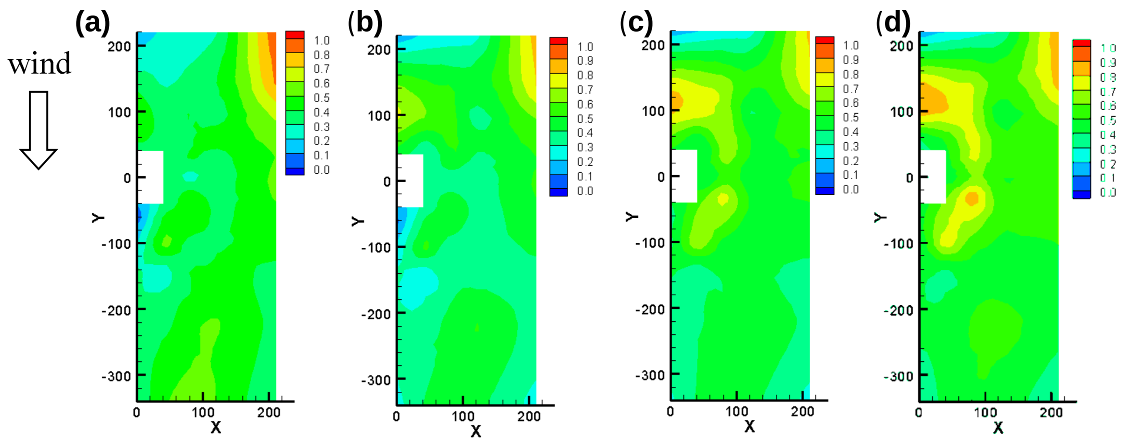

Figure 5 The Distribution of Ground Surface Wind Speed at Different Height Ratio of Single Tower Model with a Low Building at Windward Side (a)H=1D (b) H =3D (c) H =5D (d) H =7D

3.2.2 Without low buildings at windward side

Figure 6 presents the situation of the single tower model without low buildings at windward side. With the increase of the heights of models, the wind speed at the upstream increases accordingly.

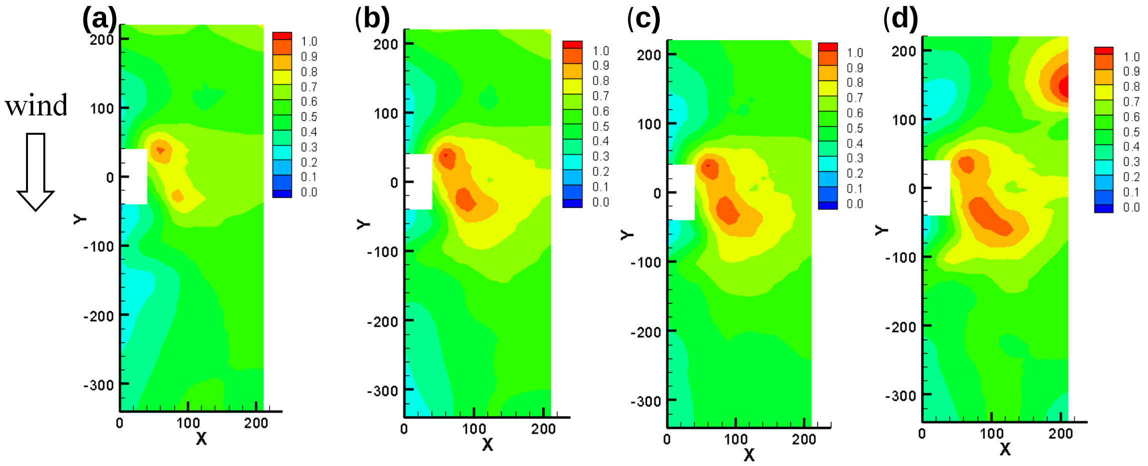

Figure 6 The Distribution of Ground Surface Wind Speed at Different Height Ratio of Single Tower Model without a Low Building at Windward Side (a)H=1D (b) H =3D (c) H =5D (d) H =7D

3.2.3 With low building at windward side, Projection Ratio of Podium: Pw=0.25D

With a low building at windward side, and the projection ratio of podiums set as Pw=0.25D, the results for different podium heights are presented in Figure 7. The low building for the experiment is designed as 8cm high; the distance between the low building and the model with podium is about 12cm. In Figure 7, (a), (b), (c), and (d) are distribution maps of dimensionless average wind speed of the podium height of at 4cm, 8cm, 12cm, and 16cm respectively. At the upstream of the model, when the height of podium is 4cm, no distinct high speed wind is found. However, while the height of podium increasing, the approaching airflow turns into backflow due to the podiums. Therefore, the strength and area of high wind speed expands along with the increase of height of buildings. There is similar situation at both sides of the buildings and corner at downstream. However, low wind speed was found at downstream of the building because of the blockage of the building.

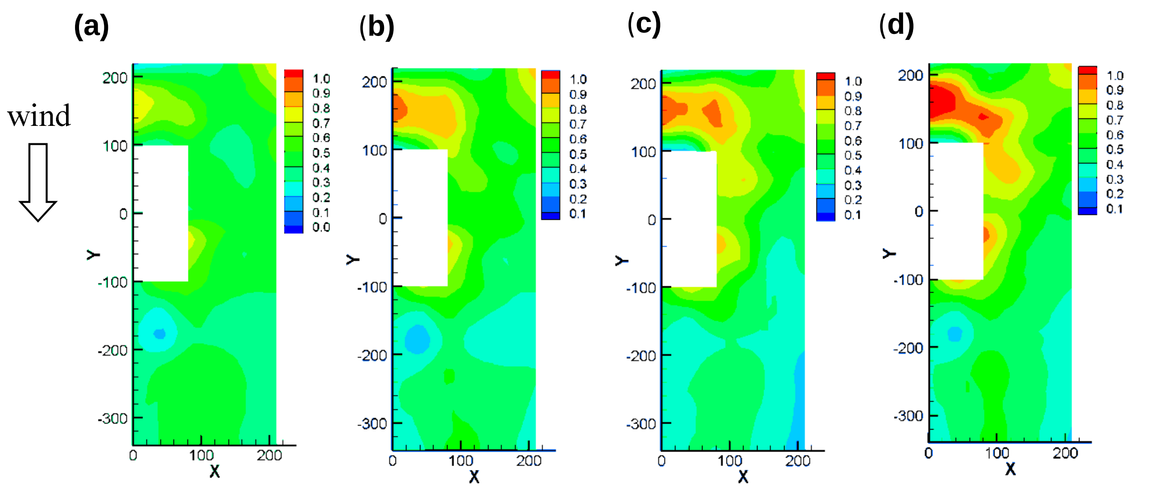

Figure 7 The Distribution of Ground Surface Wind Speed at Pw=0.25D of the Model with a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2D

3.2.4 Without low buildings at windward side, projection ratio of podiums: Pw=0.25D

Without a low building at windward side, and the projection ratio set as Pw=0.25D, the results for different heights of podiums are presented in Figure 8. While there is no low building at windward side, lower ground surface wind speed is found. However, high wind speed area shows up at the corner of the buildings. Strong wind at this corner eases up along with the increase of height of podiums. Besides, in comparison with the previous scenario of which with a low building, situation is unclear at downstream area in this case.

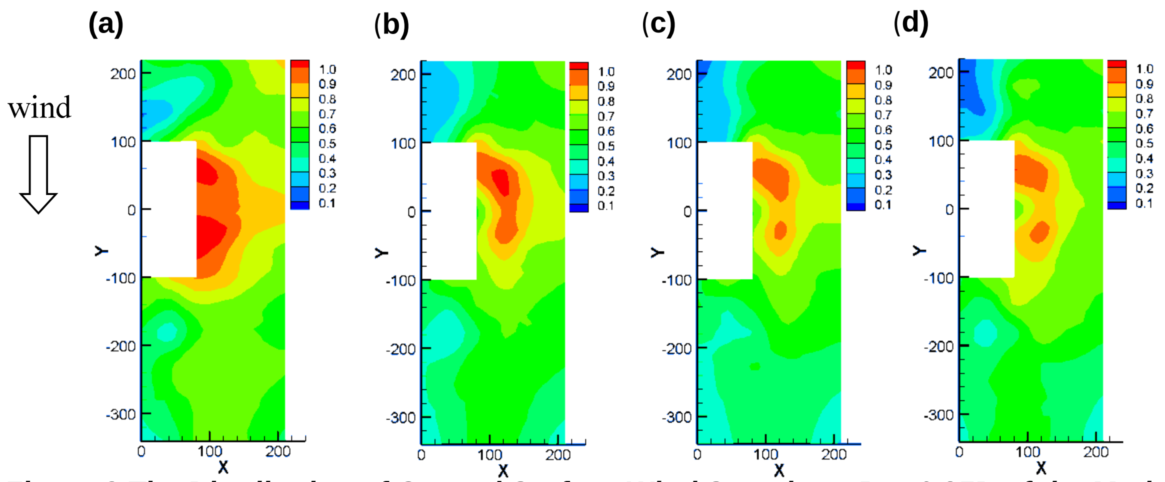

Figure 8 The Distribution of Ground Surface Wind Speed at Pw=0.25D of the Model without a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2

3.2.5 Without low buildings at windward side, projection ratio of Podiums: Pw=0. 5D

Without a low building at windward side, and the projection ratio set as Pw=0.5D, the results for different heights of podiums are presented in Figure 9. The experimental results are similar to Figure 7. With the increase of the height of the podiums, the ground surface wind speed getting stronger, and the area expanding as well. However, when the width of podium is wider at the corner of downstream, the strong wind area is smaller. Further researches are needed to prove whether the result is related to the podium width.

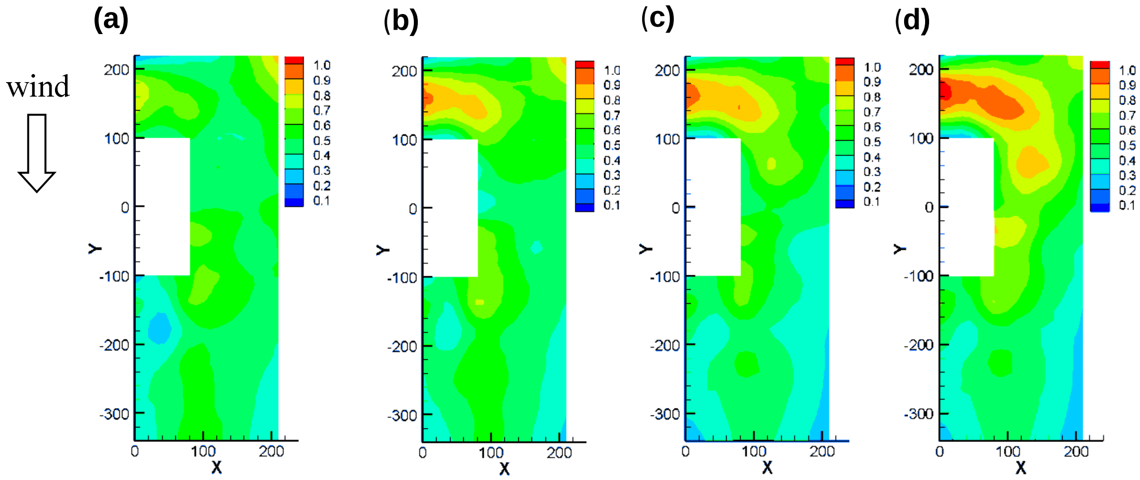

Figure 9 The Distribution of Ground Surface Wind Speed at Pw=0.5D of the Model with a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2D

3.2.6 Without low buildings at windward side, projection ratio of podiums: Pw=0. 5D

Without a low building at windward side, and the projection ratio set as Pw=0.5D, the results for different heights of podiums are presented in Figure 10. Situation of wind speed at upstream of the building is similar to Figure 8. Without any blockage, the downward backflow formed by the approaching airflow conflicts with the wind flow in different directions at the back while bumping into the high-rise building of which results in wind speeds eased up. However, the tendency of corner flow is slightly different from Figure 8. The corner flow in Figure 8 is nearer to the building and the strong wind area shrinks along with the increase of podium heights. On the contrary, corner flow in Figure 9 is not close to the building and it gets farer along with the increasing of podium heights. Also, the strong wind area expands along with the increase of podium height. The differences between these two maps could be analyzed and concluded based on further experimental results.

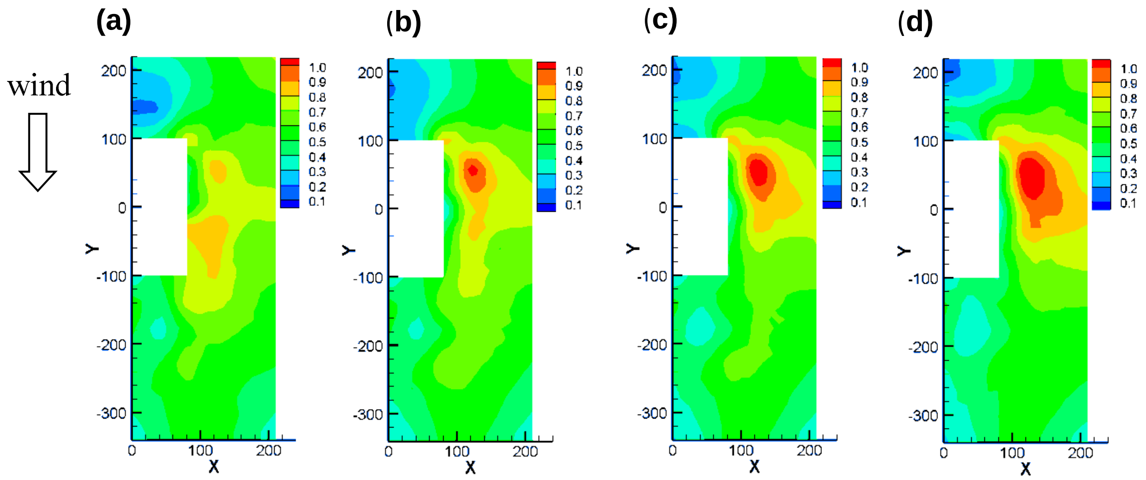

Figure 10 The Distribution of Ground Surface Wind Speed at Pw=0.5D of the Model without a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2D

4. Conclusion

Pedestrian level wind environment around a high-rise building with a podium has been experimentally investigated in the wind tunnel using Irwin-probes. Distributions of normalized mean wind speeds around a high-rise building with a podium were found effected by the height of podium. When the height of podium is higher and higher, normalized mean wind speed in the upwind corner is getting larger. Meanwhile, if there is a lower building in front of high-rise building, the normalized mean wind speeds in the upward area were affected by the downwash wind flow to induce a strong wind area. This research is presented that proper height of podium is essential in case high speed of pedestrian level wind was found in the upwind area or corner.

Acknowledgement

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