Pedestrian level wind around super-tall building: Effects of podium

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Pedestrian level wind around super-tall building: Effects of podium

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Abstract. Super-tall building may cause the severe pedestrian level wind problems. In past studies, the characteristics of pedestrian level wind around isolated super-tall building had been investigated. The maximum wind speed and high wind speed zones usually appeared near the corner of buildings. However, in practice, the super-tall building always has the podium for commercial and public services, such as shopping malls, parking lots and entertainment places. The podium may change the flow field near the ground around the super tall building. Thus, a series of wind-tunnel tests were carried out in this study to investigate the podium effects on pedestrian level wind around the super-tall buildings. It was found that the super-tall building with a low rise podium shown the better behaviour on pedestrian level wind than the isolated super-tall building.

1. Introduction
Due to the scarcity of urban land, high-rise buildings development and utilization become an important way to try and ease congestion in the city. With the construction of more and more tall and super tall buildings, the pedestrian level wind environment problem has attracted significant attention [1-3]. Tall and super tall building may generate the uncomfortable or even dangerous wind condition to the pedestrians [4-5]. In past studies of author’s research group, the characteristics of pedestrian level wind around the isolated super-tall building with various configuration have been investigated [6]. It was found that the maximum wind speed and high wind speed zones usually appeared near the corner of super tall buildings. However, the pedestrian level wind is very sensitive to the near-ground environment. In practice, the super-tall building is always around by the podium which may cause significant change of pedestrian level wind around super-tall buildings. Therefore, with reference to pedestrian level wind characteristic of isolated square building, a series of wind-tunnel tests were carried out to investigate the podium effects.

2. Wind tunnel experiment
The experiments were carried out in an open-circuit-type boundary-layer wind tunnel at Tokyo polytechnic university. The working section of the wind tunnel was 1.8m high by 2.2m wide.
Blockage ratios of all test models were less than 5%. The power-law exponent of the approaching flow profile was 0.27, as shown in figure 1. The mean wind speed and the turbulence intensity at the top of reference square model were $U/H = 11.5 \text{m/s}$ and $I_{UL} = 11.2\%$, respectively.

The geometrical scale of all test buildings was set at 1/500. The dimensions of the referenced square building were $H_0 = 400 \text{m}$, and $B_0 = 50 \text{m}$, $(H/B)_0 = 8$. The podium was located at the right side of the reference building, as shown in figure 2. The podium height was changed from 20m to 60m at increments 20m, and podium width was changed from 50m ($B_0$) to 200m ($4B_0$) at increments 50m ($B_0$), to investigated effect of $H$ and $B$ of the podium on pedestrian level wind. Here, the depth $(D)$ of reference square building and podium was fixed to 50m.

Thermistor anemometers were set 5mm above the wind tunnel floor (2.5m above the ground in full-scale), although a little higher than the average human being height. Anemometers were distributed over an area of 476mm×952mm, and the pitch between two sensors was a minimum of 2cm in the inner area (figure 3). The measurement area was focused on the area near the right corner of the podium, which easily created the maximum wind speed and high wind speed zones at the pedestrian level height [6].

![Figure 1. Approaching wind conditions](image1)

![Figure 2. Model configurations](image2)

![Figure 3. Distribution of thermistor anemometer](image3)

### 3. Parameters for describing pedestrian-level wind characteristics

#### 3.1 Speed up ratio $R$

The speed up ratio $R$ is defined as:

$$ R = \frac{U_i}{U_{i0}} \quad (1) $$

where $U_i$ is the mean pedestrian-level wind speed at point $i$ around a building model, and $U_{i0}$ is the mean wind speed at the same point without the building [6].

#### 3.2 Normalized speed up area $A'_{r}$

The normalize speed up area $A'_{r}$ is defined as follows, based on the plan area $B^2$ of reference square model.
Figure 4. Speed up area $A_R$

where $A_R$ is the total area inside a contour line corresponding to speed-up ratio $R$ as figure 4 [6] shows.

4. Results and Discussions

4.1 Distributions of Speed up ratio

Figure 5 shows the speed up ratio around isolated referenced square model (a) and podiums with a constant height $H$ and varying width $B$ ((b)-(e)). From the figure 5 (a), it is seen that the maximum speed up ratio and high wind speed zone appear near the upstream corner of referenced square model. It should be noted that the maximum speed up ratio $R_{\text{max}}$ is around 2.1, which means the wind speed of incoming flow increased almost two times around the referenced square model. It can cause the uncomfortable or even dangerous wind condition for pedestrian [6].

Figure 5 (b)-(e) shows the speed up ratio distributions for the podiums with the fixed depth ($D=50m$) and height ($H=20m$), while the width $B$ was varied from 50m ($1B_0$) to 200m ($4B_0$). It can be seen that high wind speed zone of isolated referenced square models was covered by the podium. The new high wind speed zone was generated near the upstream corner of podium. Compared with the referenced square model, the maximum speed up ratio and high wind speed zone of the model with podium appeared significant decrease. Besides, with the increase of width $B$ of podium, the effects of referenced square model became less and less, and the maximum speed up ratio and high wind speed zone became smaller and smaller. On the whole, the pedestrian level wind environment around the super-tall buildings with podium shows much better behaviour than that around the isolated super-tall building.

Figure 5. Effects of podium width $B$ on the speed up ratio distribution (a) Referenced square model (b) Podium: $H=20m$; $B=50m$ (c) Podium: $H=20m$; $B=100m$ (d) Podium: $H=20m$; $B=150m$ (e) Podium: $H=20m$; $B=200m$. 

$$A_R^* = \frac{A_R}{B^2}$$ (2)
The general features of speed up ratio distribution around the podiums with a constant width $B$ and varying height $H$ are shown in figure 6. The width and depth of podium was fixed at 50m ($D_0$), while the height $H$ was varied from 20m to 60m, at the increments at 20m. The maximum speed up $R_{\text{max}}$ and high wind speed zones near the upstream corner of the podium increased with the podium height $H$ because the extent of sheltering effects of the reference square model and podium was larger.

4.2 Maximum speed up ratio $R_{\text{max}}$

The effects of width $B$ and height $H$ of podium on maximum speed up area $R_{\text{max}}$ are shown in figure 7. The red dotted line represents the $R_{\text{max}}$ of the isolated referenced square model. Figure 7 (a) shows the variation of $R_{\text{max}}$ for the podium with width $B$. As the width $B$ of podium increased, the $R_{\text{max}}$ presents the clearly decreasing tendency. The podium ($B=200m; H=20m$) shows the best behaviour on $R_{\text{max}}$. Compared with the isolated reference square models, the $R_{\text{max}}$ of podium ($B=200m; H=20m$) reduces almost 33%. The podium ($B=50m; H=60m$) shows the same $R_{\text{max}}$ with the isolated models, which is worst in all test cases. Figure 7(b) shows the variation of $R_{\text{max}}$ for the podium with height $H$. It can be seen that with the increase of the height $H$, the $R_{\text{max}}$ increases because the blockage effects of the referenced models and podium becomes larger.

4.3 Normalized speed up area $A'_{\text{Ref}}$

The effects of width $B$ and height $H$ of podium on normalized speed up area $A'_{\text{Ref}}$ are shown in figure 8. The red dotted line represents the $A'_{\text{Ref}}$ of the isolated referenced square model. The effects of width $B$ of podium on $A'_{\text{Ref}}$ are shown in figure 8 (a), showing the clearly decreasing tendency of $A'_{\text{Ref}}$ with the width $B$. The increasing height $H$ of podium will cause the increase of $A'_{\text{Ref}}$, as shown in figure 8 (b). Compared with isolated referenced square model, the significant reduction on $A'_{\text{Ref}}$ due to the podium effects when the height $H=20m$ can be found, which is almost 90% reduction for the podium width.
$B=200\text{m}$. However, when the height $H$ is $60\text{m}$, the blockage effects becomes very significant which causes the $A^*_R$ is almost larger than the isolated referenced square model.

![Figure 8. Variation of normalized speed up area $A^*_R$ of the referenced model and podium (a) Variation with the podium width $B$ (b) Variation with the podium height $H$](image)

5. Concluding Remarks

In order to investigate podium effects on pedestrian level wind, a series of wind tunnel tests were carried out on square models with varying dimensional of podiums. The following conclusions are derived from the present study.

- The super-tall building with a low rise podium shows better behaviour on pedestrian level wind environment than the isolated super-tall building.
- As the podium width increases, the effects of super-tall building become less and less, and the maximum speed up ratio $R_{max}$ and the normalized speed up area $A^*_R$ decreases.
- As the podium height increases, the extent of blockage effects becomes larger, the maximum speed up ratio $R_{max}$ and the normalized speed up area $A^*_R$ increases.

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