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PEDESTRIAN LEVEL WIND FIELD UNDER INFLUENCE OF THE TWISTING EFFECT, A CASE STUDY OF ISOLATE BUILDING

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Abstract

In the field of environmental engineering, the pedestrian-level wind field is of great importance since it influences not only pedestrian comforts but also air pollutant dispersion processes in urban areas. Previously, studies concerning the pedestrian-level wind field, based on the physical modeling approach, use the conventional straight wind flow to provide boundary conditions for the investigation. Due to the presence of hilly topographies, the wind flow penetrating the urban areas of Hong Kong is frequently found under the influence of the twisting effect, i.e. the vertical variation of wind-attack angles. An investigation on the influence of the twisting effect on the pedestrian-level wind field is therefore necessary from the perspective of environmental safety and pedestrian comforts for Hong Kong residents. In the present study, a series of wind-tunnel tests are conducted in which the approaching wind flow is adjusted to show vertical variations of wind-attack angles in a controllable manner. The measurements of wind speeds at the pedestrian level are then taken around isolated building models with different dimensions. From the wind-tunnel test results, the influence of the twisting effect is investigated. In detail, the low-wind-speed zones, which may lead to the undesired air ventilations and dispersions of air pollutants, around isolated buildings are identified, and the impacts of the twisting effect on the characteristics of the low-wind-speed zone are discussed. Furthermore, the role of building dimensions in the influence process is investigated through comparing across wind-tunnel test results. It is concluded that the twisting effect has obvious impacts on the pedestrian-level wind field. In fact, the low-wind-speed zone is found deviate from the centerline of the building. The differences in the pedestrian-level wind fields around buildings with different dimensions in the twisted wind flow are found, on the other hand, similar to the differences found in the conventional straight wind flow.

Keywords: **air pollutant dispersions; pedestrian-level wind; twisting effect**

INTRODUCTION

From the environmental engineering point-of-view, the pedestrian-level wind field is of crucial importance because it provides the precondition for tackling various environmental problems. For example, the pedestrian-level wind field (a) directly impacts the outdoor thermal comfort of pedestrians (Stathopoulos 2006), (b) shapes the local environment within which human exposures to traffic exhausts are calculated (Kubota, et al. 2008) and (c) plays an important role in the air pollutant dispersion process in a street canyon (Vardoulakis, et al. 2003). Given the importance of the pedestrian-level wind, numerous studies have been conducted to investigate the characteristics of the pedestrian-level wind field in the urban area, especially in the highly built-up city centers (Mochida and Lun 2008; To and Lam 1995). Predictably, in the trend of global urbanization, the pedestrian-level wind field would continue to be a focus for researchers in the field of environmental engineering as the increase in concerns with the impacts of constructions on the urban environment.

While most of previous studies investigated the extreme pedestrian-level wind speeds around building corners, which may lead to unpleasant or even dangerous environment for pedestrians (Stathopoulos and Wu 1995; Stathopoulos 2006), bad air ventilations in urban areas resulted from low pedestrian-level wind speeds have attracted attentions from scholars since the dawn of the global urbanization (Penwarden 1973). It has been found that traffic exhausts concentrate in low-wind-speed zones around building clusters, which could harm pedestrian health (van Wijnen, et al. 1995). Furthermore, the air pollutant dispersion has been found worsened due to low wind speeds resulted from the sheltering effect of urban morphology (Tsai and Chen 2004). Given the negative impacts, the studies focusing on the low-wind-speed zones have been accumulated along with the acceleration of urban constructions worldwide. For example, Santamouris, et al (1999) investigated low wind speeds induced by circulatory vortex or double vortex flow insides deep street canyons. The general features of the low-wind-speed were discussed, in terms of statistics, based on the results from a series of field-measurements. Similarly, Kubota, et al (2008) studied, by physical modeling approach, the relationship between the mean wind speed in the residential area and the building coverage ratio. Since the outbreak of SARS in 2003, air ventilations have been an active research topic for the scholars in Hong Kong and Greater China Area (Ng 2009; Yim, et al. 2009). In fact, a feasibility study has been conducted to show it is necessary to stipulate a set of air ventilation regulations, which ensure sufficient air ventilations penetrating the "concrete forest", for the land development and redevelopment in Hong Kong (Ng 2009). Therefore, it can be readily asserted that the pedestrian-level wind field in a tropical metropolitan such as Hong Kong impacts the overall well-being of residents from different perspectives, and both the high-speed and low-speed conditions can be hazardous.

Meanwhile, it is well established that the wind field above complex terrain is perturbed by the terrain topography in a complex manner (Bitsuamlak, Stathopoulos and Bedard 2004). For one thing, the wind flow near the ground is accelerated when crosses a hill top or a ridge. For another thing, the wind flow is detoured by a 3-D hill to present a vertical variation of wind directions. While the wind flow acceleration, which is termed speed-up effect, has been thoroughly investigated from both the theoretical (Jackson and Hunt 1975) and experimental (Miller and Davenport 1998) perspectives, the 3-D hill induced wind direction variations in the vertical direction, which is termed twisting effect hereafter, has yet been systematically investigated. To the best of our knowledge, the only work involves the detour of the wind flow passing a 3-D hill is the experimental study of Gong and Ibbetson (1989). The twisting effect observed in the wind-tunnel test was, however, only used to explain the horizontal distribution of the speed-up factor, an indicator of the speed-up effect. Besides the work of Gong and Ibbetson (1989), Engineering Science Data Unit (ESDU, 1993) provides a model to calculate the vertical variation of wind directions above a 3-D hill, i.e. a descriptive model of the twisting effect. When investigating the pedestrian-level wind field in the area with complex terrains, it is necessary to take into consideration the impacts of terrains on both wind speeds and wind directions. Taking Hong Kong as an example, highly built-up areas, such as the waterfront part of Central, are frequently surrounded by significant topographic features. When the wind flow approaches the site of interest from the direction covering with topographic features, both the speed-up effect and twisting effect have to be considered. Given the efforts devoted into the investigation of the speed-up effect, an investigation on the impact of the twisting effect is valuable.

In addition, most previous studies concerning the pedestrian-level wind field focused on the characteristics of the high-wind-speed zones. The only study that the authors are aware of focusing on the low-wind-speed zone at the pedestrian-level is conducted by Tsang, et al (2012). In fact, Tsang, et al (2012) showed the characteristics of the low-wind-speed zone in the pedestrian-level wind field perturbed by building models with different dimensions. Comparing with the work revealing the influence of building dimensions on the high-wind-speed zones, such a study is inadequate to comprehensively show the characteristics of the low-wind-speed zone. For example, the study of Tsang, et al (2012) only preliminary discussed different low-wind-speed zone in a qualitative manner. In other words, the quantitative relationship between the characteristics of the low-wind-speed zone and building dimensions has yet been derived in their work. Considering the necessity of including the twisting effect, a further investigation, which involves the quantitative influence of building dimensions on the pedestrian-level low-wind-speed zone, is suggested to reveal, based on the physical simulation approach, the influence of the twisting effect on the pedestrian-level wind field.

Before any further discussion, it is necessary to present a more specific definition of the twisting effect. Understandably, when the wind flow passes a 3-D hill, the near-ground flow is detoured by the geometry of the hill. The wind flow aloft, on the other hand, maintains the straight streamlines as the influence of the underlying terrain is limited. Consequently, the wind flow above a 3-D hill is twisted to connect the detoured flow near the ground and the straight flow aloft. If the wind-attack angel is defined according to the longitudinal and lateral wind components as,

$$\theta = \tan^{-1}\left(\frac{v}{u}\right) \qquad (1)$$

the twisting effect can be described as the wind-attack angle (θ) varies from a certain value near the ground to zero at an infinite height. In equation (1), u and v are the longitudinal and lateral wind components, which are defined according to the orientation of the hill. According to a previous study (Gong and Ibbetson 1989), the influence of the twisting effect maintains for a considerable distance downstream the topographic features (3-D hills). Considering the urban area downstream high mountains, such as Victoria Peak, it is projected that its pedestrian-level wind field is under the influence of the twisting effect.

Using the wind-tunnel simulation techniques, the present study systemically investigates the influence of the twisting effect on the pedestrian-level wind field around an isolated building. In detail, the approaching wind flow is modulated to have the wind-attack angle (θ) varies from 13° and 22° near the ground to 0° aloft. In the test section, a series of cubes are erected to model the isolated building with different dimensions. The pedestrian-level wind field is measured by the Irwin sensors installed at a horizontal grid. In addition to the flows with the vertical variation of θ, the straight flow ($\theta = 0°$ at all the heights) is employed to repeat the test as a control case. Measurements taken under the influence of the twisting effect are then compared to the measurements taken in the straight flow. In order to investigate the role of building dimensions in the interaction between the twisted wind flow and the isolated building, the building models with different heights and widths are employed. When analyzing the wind-tunnel measurements, focuses are placed on the low-wind-speed zone.

After introduction, section 2 presents the results from a series of AVA wind-tunnel studies, in which the real Hong Kong topographies are modeled, to demonstrate the prevalence of the twisting effect in the urban areas of Hong Kong. Afterwards, the details of the wind-tunnel tests are presented. Section 4 contains discussions on the characteristics of the pedestrian-level wind field observed, and section 5 presents the conclusion remarks.

AVA WIND-TUNNEL TESTS

In order to provide the general guidance for the detailed and local wind-tunnel tests in the framework of the AVA, a sereis of wind-tunnel tests have been conducted in the Wind/Wave Tunnel Facility in the Hong Kong University of Science and Technology. In the tests, the real Hong Kong topograhies at selected sites are modelled by foams and woods. Given the approximate test primeter of 10km (in the full-scale) for most sites under invesitgation, both the surrounding terrains and urban morphologies are realibly modelled. The appraoching wind flow was modulated according to the specifictions provided by Hong Kong wind code. In other words, the mean wind profile was adjusted accoridng to the power-law model with an exponent of 0.11. The entire model was placed in the turntable having the wind-attack angle, defined according to the earth-relative coordinate system, varies from $0°$ to $360°$ at a step of $22.5°$.

It has been found from the wind-tunnel test results that the influence of the twising effect at the sites downsteam hilly terrains is not neligible when asessing the wind field at the pedestrian-level. In detail, the measurements of both the longitudinal and lateral wind components were taken by a miniature pressure probe at a series of discrete heights (25, 50, 75, 100, 200, 300, 400 and 500m in the full-scale). From the measured longitudinal and lateral wind components, the wind-attack angle was calcualted using the definition presented in equation (1). For a single site, the wind-attack angle profile illustratively showed the vertical variation of wind directions. For a summary of the wind-attack angle profiles, it helps assess the prevalnace of the twisitng effect. More specifically, if the maixmum wind-attack angle, most likely found near the ground, is defined as the maixum twisitng angle (θ_{max}), the excedence probabilyt of θ_{max} calculated based on the entire database accumulated from the AVA wind-tunnel test reuls reveal the prevalance of the twising effect in the urban area of Hong Kong.

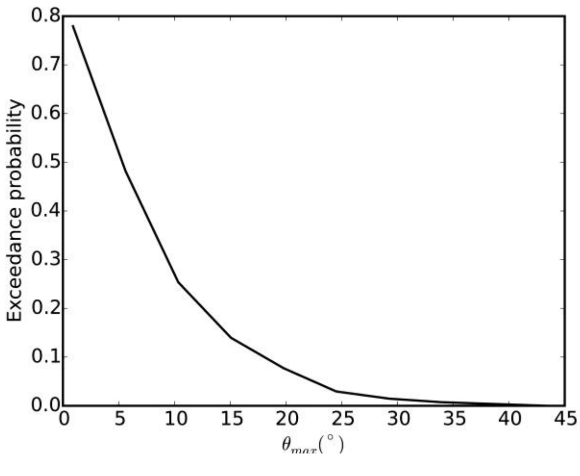

Fig. 1 The excedence probablity of θ_{max} from the AVA wind-tunnel tests

Fig. 1 presents the variation of the exceedence probablity with θ_{max}. It is clear that the measured profiles with $\theta_{max} > 10°$ takes more than 20% of all the profiles under investigation. Even for the profiles with $\theta_{max} > 20°$, the ratio is only slight lower than 10%. Considering that the sites been selected in the AVA wind-tunnel study are from mature communities and new land developments in Hong Kong are highly likely in the moutaineous area, the influence of the twisting effect in the areas planned for new developments should be even more significant than the inference made accoridng to Fig. 1.

WIND-TUNNEL TEST SET-UPS

All the wind-tunnel tests contained in the present study are conducted in the low wind speed section of the Wind/Wave Tunnel Facility in Hong Kong University of Science and Technology. The test section is 5m in width and 4m in height with the maximum wind speed of 10 m/s. Only three selected aspects of the wind-tunnel test set-ups, namely the simulation of the wind flow with desired vertical variation of θ, the selection of building dimensions and measurement techniques, are reported with details because the rest follows the procedures to conduct conventional wind-tunnel tests. In order to be concise, the profile showing the vertical variation of θ is labeled as the twisted profile and the profile showing $\theta = 0°$ at all heights is labeled as the straight profile. In detail, two twisted profiles with the maximum twisting angle (θ_{max}) of 13° and 22°, labeled as TWP1 and TWP2 respectively, are simulated using a series of vane system (1.5m high) installed 4m upstream the test section center. Due to the complex interaction between the approaching wind flow and the vane system, it is impossible to generate a wind field with the desired twisting effect covering the entire test section. In fact, it has been found that a rectangular, whose center locates 0.5m downstream the turntable center, with dimensions of 3m × 2m showing vertical variations of θ close to the targets. Besides the twisted profiles, regularly-arranged roughness elements, which modulate the approaching wind flow to show a power-law-described profile (labeled as CWP), are installed instead of the wooden vane system to repeat the wind-tunnel test. The normalized wind speed and turbulence intensity profiles corresponding to the straight and the twisted profiles are shown in Fig. 2 (a). The vertical variations of the wind-attack angle (θ) in the two twisted profile, on the other hand, are shown in Fig. 2(b). It should be noted that the vertical variation of θ is modulated to follow a negative power-law curve. More specifically, the modulation makes the maximum twisting angle appear at the bottom-level. Gradually decreasing with the height, the wind-attack angle is modulated to reduce to zero at the height of 1m (in the wind-tunnel scale).

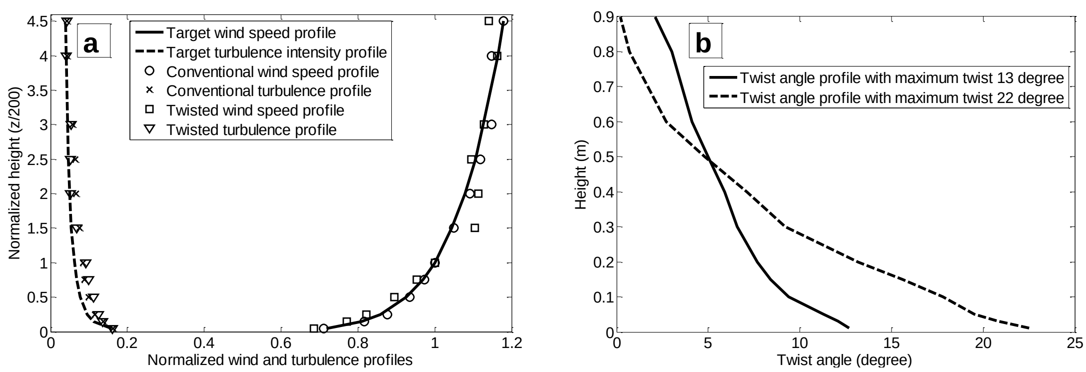

Fig. 2 The normalized wind speed and turbulence intensity profiles (a) and the wind-attack angle profiles (b) measured in the calibration phase of wind-tunnel tests.

Pedestrian-level wind speeds are measured by Irwin sensors, which are essentially Omni directional pressure sensors capable of measuring only the wind speed magnitude. Irwin sensors have been used by researchers in previous studies with similar settings (Irwin 1981; Wu and

Stathopoulos 1994), who substantiated the validity of the Irwin sensor measurements in calculating the pedestrian-level wind speeds. The Irwin sensors used in the present study are similar to those used by Tsang (2012). In detail, the sensors are installed with 10mm high protrude tube as shown in Fig. 3(a). Due to the geometric scale of 1: 200, the 10 mm high protrude tube measures the wind speed at the height of 2m in the full-scale. Around 200 Irwin sensors are arranged in a rectangular grid covering an area of 100mm × 75mm (wind-tunnel scale) as shown in Fig. 3(b). It is worth to note that the grid spacing becomes larger far downstream the building due to the number of connections available and the stability of the pressure scanner. The measurements are taken for 120 second period at a frequency of 500 Hz. A photography showing the experimental set-ups is provided in Fig. 4.

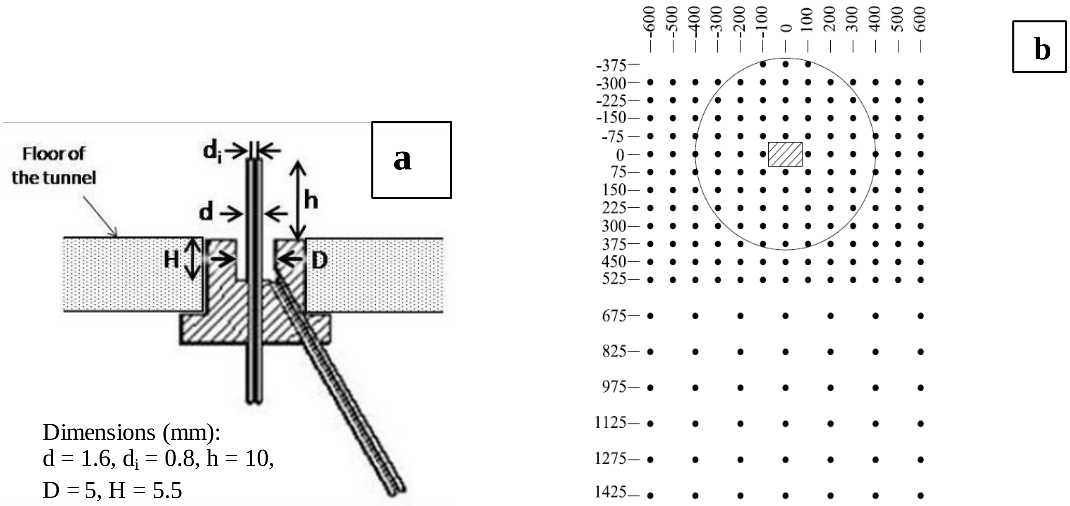

Fig. 3 A illustration of a re-fabricated Irwin sensor (a) and the measurement grid (b, numbers are shown in the unit of mm).

Fig. 4 The building model and the vane system set-ups

At the turntable center, there are 5 isolated building models constructed and tested. Table 1 summarizes the building model dimensions. In Table 1, H is the building height, W is the building width and D is the building depth defined as the length of the building in the along-wind direction. In the first three (M1-M3) building models, the building height decreases while the building width kept constant. In the last three models, the building height is fixed and the building width increases.

Model	Dimensions(H×W×D) (mm)	Aspect ratio (H/W)
M1	600×150×100	4:1
M2	300×150×100	2:1
M3	225×150×100	1.5:1
M4	225×225×100	1:1
M5	225×300×100	0.75:1
M6	225×450×100	0.50:1

Table 1. Building dimensions and aspect ratios of five isolated building models

Discussion

Since the wind flow in the wind-tunnel test does not accurately simulate wind-speed magnitudes, only the normalized wind speeds, or the relative magnitudes, are physically meaningful in terms of interpreting the wind-tunnel results. Consequently, an indicator of the relative wind strength, i.e. the velocity ratio (VR) defined as,

$$\mathrm{VR} = \frac{\overline{V_{10}}}{\overline{V_{a,10}}} \qquad (2)$$

is employed. In equation (2), $\overline{V_{10}}$ is the mean wind speed measured in the wind-tunnel test at the height of 10mm (wind-tunnel scale), $\overline{V_{a,10}}$ is the mean wind speed measured at the exact location as $\overline{V_{10}}$ without the building model erected. In other words, for each wind-tunnel test conducted, a corresponding test is carried out in which the experimental set-ups are exactly the same except for the absence of the building model. The measurements taken in the corresponding test are then used to normalize the measurements taken in the main test to show the horizontal variation of the relative wind strength.

Fig. 4 presents the contours of VRs calculated based on the wind-tunnel tests in which model M3 is installed. The contours corresponding to the twisted profile shown in Figs. 4(b) and 4(c) are compared to the contour corresponding to the straight profile shown in Fig. 4(a). It is obvious from the comparison that the twisting effect has significant impacts on the pedestrian-level wind field around isolated buildings. In fact, since the maximum twisting angles (θ_{max}), which appear near the ground, of the profiles TWP1 and TWP2 are 13° and 22°, the pedestrian-level wind field corresponding to the twisted profiles TWP1 and TWP2 is more similar to the fields in the wind flow approaching the building at the angles of 13° and 22°. More specifically, the wake behind the building, where low wind speeds are commonly observed, deviates from the centerline of the building when the pedestrian-level wind field is under the influence of the twisting effect. The center of the low-wind-speed zone, defined as where VR$<$ 0.8 in the wake, is consequently found shift from right behind the building model to form an angle, which is defined as the deviation angle, with the centerline of the building. In fact, the deviation angle increases with the maximum twisting angle. Its value, however, is found less than the maximum twisting angle. Such an observation reveals the differences in the pedestrian-level wind fields between under the influence of the twisted profiles (TWP1 and TWP2) and the straight profile attacking the building at certain angle (13° and 22°in the case of Fig. 1). Besides, the increase of the deviation angle is not synchronized with the increase in the maximum twisting angle, which implies the complex interaction between the twisted approaching flow and the isolated building.

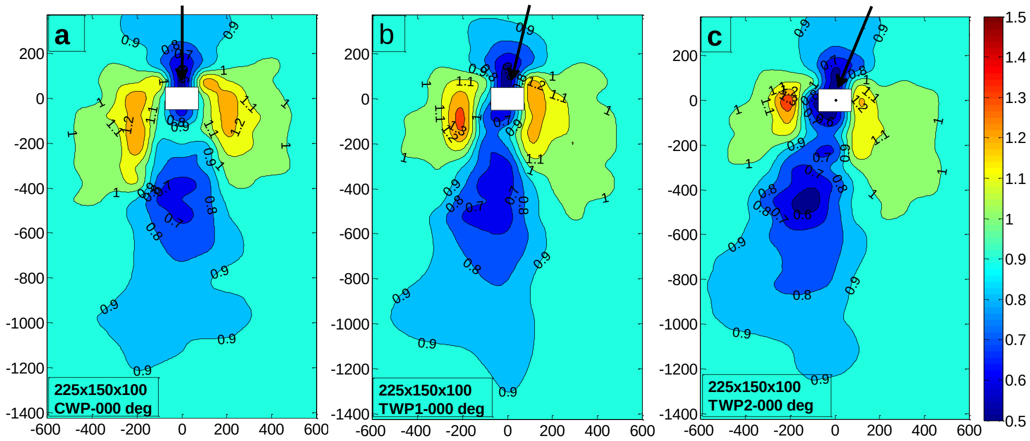

Fig. 4 the contours of VRs measured in the wind-tunnel tests of the model M3

As in Fig.4 Figs. 5 and 6 present the pedestrian-level wind field measured in the tests in which the model M1 and M6 are installed. Similar patterns as in Fig. 4 are observed in Figs. 5 and 6. In detail, the low-wind-speed zone in the wake is repeatedly observed shift from the centerline of the building with the increase of the maximum twisting angle, and the deviation angle is found similar under the influence of the same twisted profile but different building dimensions. In other words, within the range of the building dimensions tested (M1~M6), the influence of building heights and widths on the deviation angle is negligible. As a result, the relationship between the deviation angle and the maximum twisting angle derived from the present study can be considered as widely applicable regardless of the building dimension. The distance between the low-wind-speed zone and the building center is, on the other hand, found determined by the interaction between the building dimensions and the twisting effect. In fact, while the low-wind-speed zone corresponding to the straight profile is closest to the building (among CWP, TWP1 and TWP2) when the building height is 45m, it moves to the furthest when the building height increases to 125m.

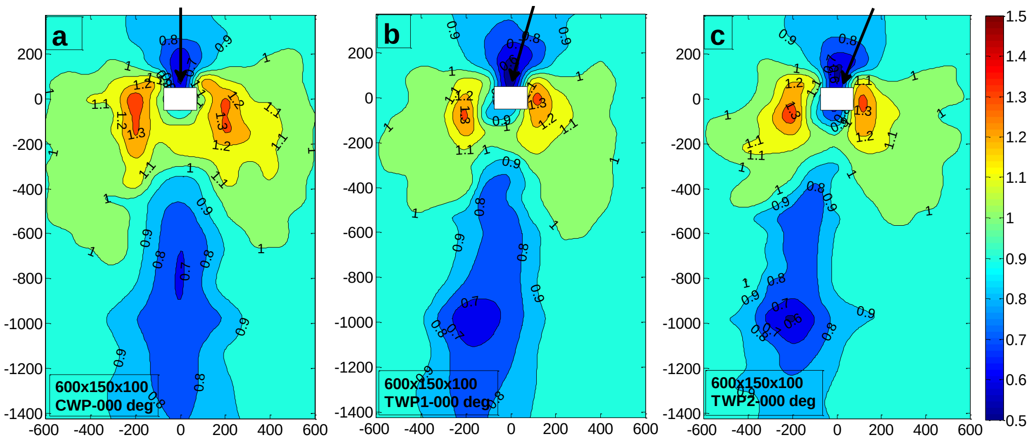

Fig. 5 the contours of VRs measured in the wind-tunnel tests of the model M1

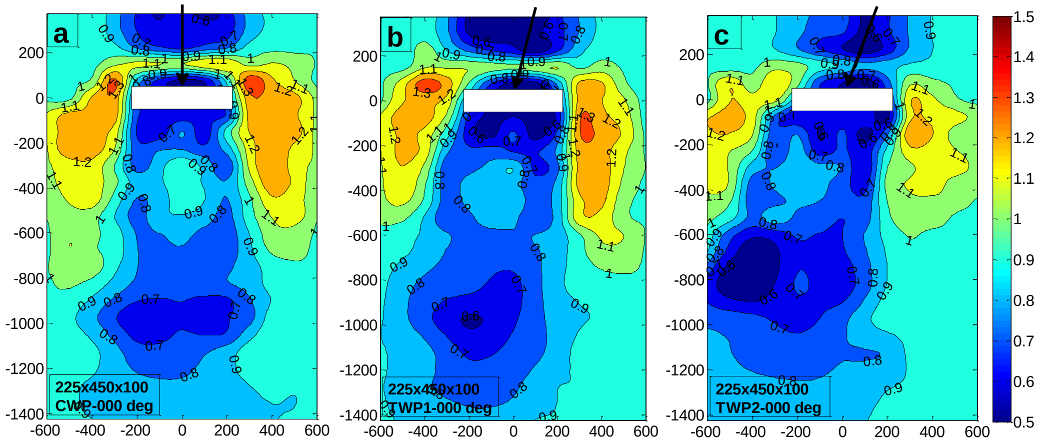

Fig. 6 the contours of VRs measured in the wind-tunnel tests of the model M6

From comparing contours presented in Figs. 4(a), (b) and (c), it is apparent the low-wind-speed zones near the building is disconnected from the low-wind-speed zones far downstream under the influence of the straight wind profile. For the pedestrian-level wind field under the influence of TWP1 and TWP2, the low-wind-speed zones are merged. While Fig. 5 is found similar to Fig. 4(a), Fig. 6 is found similar to Figs. 4(b) and (c). It is hypothesized that the sheltering effect of the building in the twisted flow is more significant as the equivalent front area increases with the maximum twisting angle. In other words, the sheltering effect of a slender building in the twisted flow should be predicted according to the sheltering effect of a wider building. The increases in the sheltering effect also explain the decrease of wind speed-ups behind buildings shown in Fig. 5. In fact, the maximum wind speed behind buildings, shown in Fig. 5, decreases with the increasing maximum twisting angle. The minimum wind speed in the low-wind-speed zone just behind the building, on the other hand, decreases with the increasing maximum twisting angle. Such an observation implies the complex interaction between the twisting effect and the slender building. In detail, when the maximum twisting angle increases, the increase of the sheltering effect reduces the wind speed-up behind the building, which is resulted from he re-conflux of the wind flows detoured by the obstacle. Furthermore, secondary block effect, induced by the building corner opposite to the approaching flow, further stalls the wind flow behind the building. Different from Fig. 5, the minimum wind speed in the low-wind-speed zone far downstream the wider building shown in Fig. 6 decreases with the increasing maximum twisting angle. Besides the increase in the sheltering effect, such an observation implies that more vortices appear in the wake of a wider building in the twisted flow. More specifically, it is postulated that the vertical variation of wind directions makes the wind-flow-detour around wider building more complicated, and more vortices therefore appear in the wake. Consequently, more kinetic energy contained in the wind flow is dissipated into heat by the vortex mechanism to further slowdown the air motions.

In order to show the impact of building dimensions in a more illustrative way, the deviation angle (α_L) and distance between the center of the low-wind-speed zone and building center (d_L) are precisely defined and plotted against the variations in building dimensions (building height and building width). While the deviation angle quantitatively shows the influence of the twisting effect on the wake, the combination of deviation angle (α_L) and distance d_L determines the location of the low-wind-speed zone in the wake of a building immersed into a twisted wind flow. With the help of α_L and d_L, it is possible for the architect and city planner to estimate the low-wind-speed location resulted from new land developments. For the deviation angle, it is calculated according to the coordinates (x and y) of the low-wind-speed zone center, which is essentially a centroid of the area showing VR$<$ 0.8. For the distance d_L, it is simply the distance between the centroid found in the previous step and the building section center. Fig. 7 presents the variations of α_L and d_L with the building height. It is clear from the figure that the building height merely influences the deviation angle which confirms the finding made previously. The distance d_L is found, on other hand, increase with the increase of the building height, which substantiates our established understanding concerning the influence of building dimensions (shown in Fig. 7(b)). In other words, the twisting effect has not changed the trend in which d_L increase with the building height. The increase of d_L under the influence of the twisted profiles, however, is found slower than the increase under the influence of the straight profile. Similar to Fig. 7, Fig. 8 presents the variation of α_L and d_L with the building width. Clearly, similar trends, as shown in Fig. 7. are observed in Fig. 8. In fact, the figures reveal that the building width, as well as the building height, has negligible impacts on the deviation angle. With regards the distance d_L, it is discovered that the variation shown in Fig. 8(b) lacks a clear pattern of variations. In other words, the data points shown in Fig. 8(b) are too few to make any convincible conclusions.

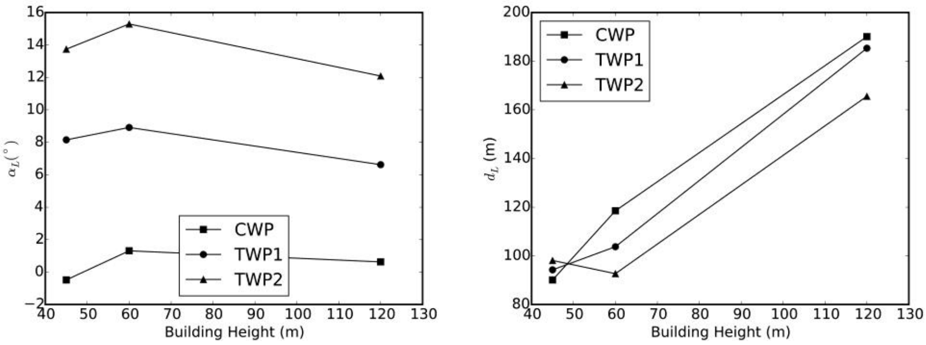

Fig. 7 the variations of α_L and d_L with the building height

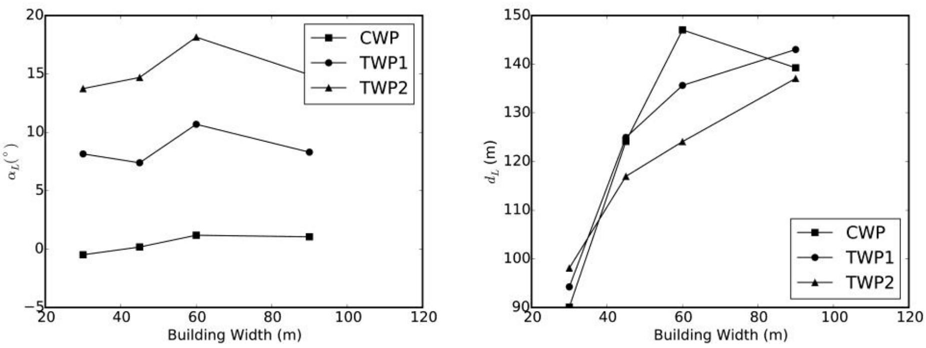

Fig. 8 the variations of α_L and d_L with the building width

In addition to the deviation angle α_L and the distance d_L, the size of the low-wind-speed zone is also of interest because it implies the risk of bad air ventilations around a particular building, which in turn contributes to undesired air pollutant dispersions in urban area. To quantitatively show the size of the low-wind-speed zone, the ratio between the area where VR$<$ 0.8 and the entire area covering with the Irwin sensors, which is labeled as r_L, is calculated. Fig. 9(a) plots the variation of r_L with the building height. It shows that a clear pattern for variations is not presented. In addition, the ratios corresponding to the twisted profiles (TWP1 and TWP2) are found similar to the one corresponding to the straight profile. Therefore, it is concluded that the building height has negligible impacts on the size of the low-wind-speed zone regardless of the presence of the twisting effect. Similar to Fig. 9(a), Fig. 9(b) presents the variations of r_L with the building width. Following our expectations, the ratio increases with the building width. More specifically, because the sheltering effect induced by a wider building is more significant when comparing to a slender building, r_L increase with the building width. The merit of Fig., 9(b) is, however, revealing that the variations of r_L corresponding to the straight profile and two twisted profiles are similar, which directly substantiates that the influence of the building width in the twisted flow is not significantly different from in the conventional straight flow. In other words, the variations of r_L shown in Fig. 9 implies that the pedestrian-level wind field around a wider building under the influence of the twisting effect is predictable based on (a) our established understanding concerning the influence of the building width and (b) a thorough investigation on the influence of the twisting effect on a regularly-dimensioned building.

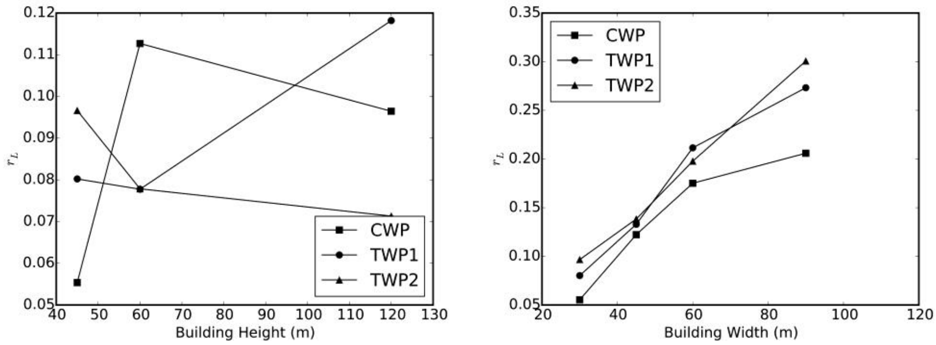

Fig. 9 the variations of r_L with the building height and width

Conclusion

The pedestrian-level wind field is of crucial importance in the field of environmental engineering because it impacts both the pedestrian comforts and air pollutants dispersions. Due to its importance, studies have been conducted to show the characteristics of the pedestrian-level wind field around buildings with different dimensions. The vertical variation of wind-attack angles in the wind flow approaching the building of interest has, however, yet been systematically investigated in the previous studies.

In a metropolitan surrounded by complex terrains (such as Hong Kong), the wind flow approaching a building of interest is certainly modulated by the terrains. If the wind flow passes a 3-D hill, it is found that the wind direction varies vertically to reduce the near-ground detoured wind flow to the straight flow aloft. In other words, the wind flow penetrating the urban area of Hong Kong certainly exhibits the vertical variation of wind-attack angles, i.e. the twisting effect. Consequently, it is necessary to take into consideration the twisting effect in an investigation on the pedestrian-level wind field.

When the approaching wind flow in wind-tunnel tests is adjusted to show the twisting effect in a controllable manner, the wind-tunnel measurements taken at the modeled pedestrian-level reveal the influence of the twisting effect on the pedestrian-level wind field. In the present study, Irwin sensors installed at a horizontal grid inside the wind-tunnel are employed to take measurements of wind speeds around an isolated building with different dimensions. While the mean and turbulent wind profiles of the wind-tunnel approaching flow are adjusted according to the code specification, the profile of wind-attack angles is modulated to reflect the twisting effect. From comparing the pedestrian-level wind field measured under the influence of either the straight or the twisted profiles, the characteristics of the pedestrian-level wind field in the twisted wind flow are investigated. In addition, the wind-tunnel tests are repeated to have buildings with different dimensions tested. The role of building dimensions in the interaction between the building and the twisted approaching wind flow is then studied.

The wind-tunnel test results show that, (a) the twisting effect has obvious impacts on the pedestrian-level wind field and the low-wind-speed zone in the wake has been found shift from the building centerline according to the maximum twisting angle exhibited in the twisted profile, (b) the impacts of building dimensions on the pedestrian-level wind filed in the twisted wind flow are similar as in the conventional straight flow and (c) the twisting effect, however, could lead to a slower growth of the distance between the low-wind-speed zone center to the building when the building height increases.

The series of wind-tunnel tests reported in the present paper forms the base for a further investigation, which is our planned work, on the air pollutant dispersion process inside street canyons under the influence of the twisting effect. More specially, the compactly arranged buildings are planned to be modeled in the next phase of the wind-tunnel investigation. With the help of the present and planned wind-tunnel investigations, the pedestrian-level wind field information gathered is ingested into an air quality model as driving force to simulate the air pollutant dispersion process inside an idealized street canyon. The numerical simulation results are then planned to be analyzed along with the field measurements taken at some discrete points in Hong Kong streets. Such a project aims advancing our understanding on the air pollutant dispersions in urban area through more realistically modeling the wind flow approaching urban morphologies.

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