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Effects of facade appurtenances on the local pressure of high-rise building

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ABSTRACT

The effects of façade appurtenances of high-rise building on local peak wind pressures were investigated through a series of wind tunnel experiments. Totally 21 appurtenances configurations simulated by thin horizontal splitter plates were studied. The unfavorable wind directions causing the largest peak pressure and the locations of the largest peak pressure were checked. It is noted that the locations of largest positive peak pressures can be strongly affected by the changes of vertical distance of plates. The area of large positive peak pressures of the models with appurtenances can be greatly smaller than the model without appurtenances. It is also found that the largest negative peak pressure on the higher leading corner can be mostly reduced by 42% from the smooth surface condition. By further checking the first four orders of moment of the probability density distribution of the pressure at upper leading corner, it is found that the splitter plates can strongly affect the characteristics of the probability distribution. The results also show that the appurtenances can not only reduce the negative local peak pressure of the higher leading corner on side face, but also dramatically reduce the variation range of negative peak pressure on the whole side face.

1. Introduction

With the high-rise buildings becoming slender and more flexible with the increase of height, they are more sensitive to wind load. Not only the overall effect including wind-induced dynamic vibration and base restraint force, but also the local effect such as local peak wind pressure, which should be carefully concerned by structural wind engineering researchers.

The mechanism of vortex formation and development for square-section high-rise buildings which might lead to serious dynamic responses has been explained in detail by many studies, including computational fluid dynamics (CFD) simulation and wind tunnel experiments (Peterka et al., 1985; Okuda and Taniike, 1993; Tominaga et al., 2008). Based on these results, many investigators started to focus on the measures to improve the aerodynamic performance by altering or suppressing the generation of vortex by modifying the shape of building, such as corner cut, chamfer, taper, set-back, openings and helical (Kwok et al., 1988; Tanaka et al., 2012; Kim et al., 2014). Tamura et al. (2017) investigated the aerodynamic characteristics of super-tall building models with various unconventional configurations based on a series of comprehensive experimental studies. They reported that most configurations can reduce aerodynamic force, but helical models and polygon models do better. It has been proved that those approaches could reduce the wind-induced response and aerodynamic force effectively.

Some studies investigated the effect of local small scale changes of the building on local wind pressures. The earlier studies about local aerodynamic measure were made by Stathopoulos and Zhu (1988, 1990). They investigated the effect of uniform roughness, such as balconies and mullions, on the wind pressure. They reported that balconies with a width up to 4 m without walls reduce the pressure coefficient values on the building surface slightly. Conversely, mullions induce adverse wind effects at wall edges. They also made suggestions on the design of balcony based on their study. Maruta et al. (1998) reported effects of different balcony width on the local wind pressure and the balconies were fixed on each facade to measure the characteristics of the wind pressure variation in the same time. Reduction rate of peak pressure reached 0.67 when surface roughness magnitude equals to 1/10. The role of turbulence and the mechanism of local peak pressure reduction effect were also discussed in that study. More experiment investigations about surface roughness effect were made by many other researchers (Chand et al., 1998; Letchford et al., 2016).

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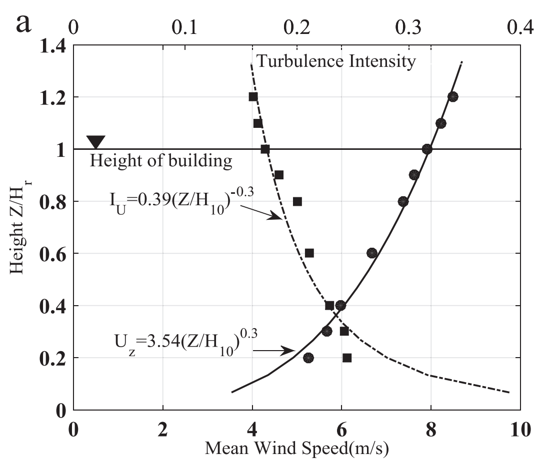
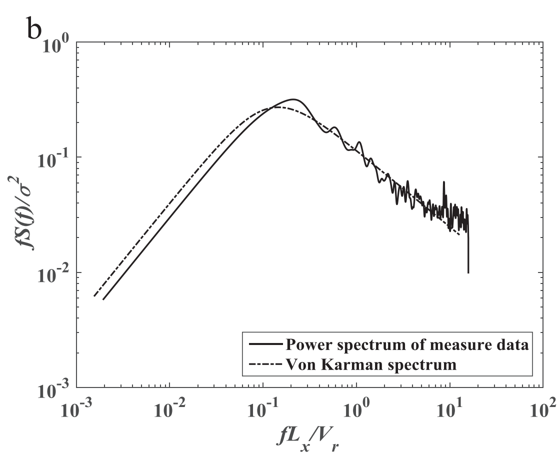
Fig. 1. Wind tunnel setup and models.

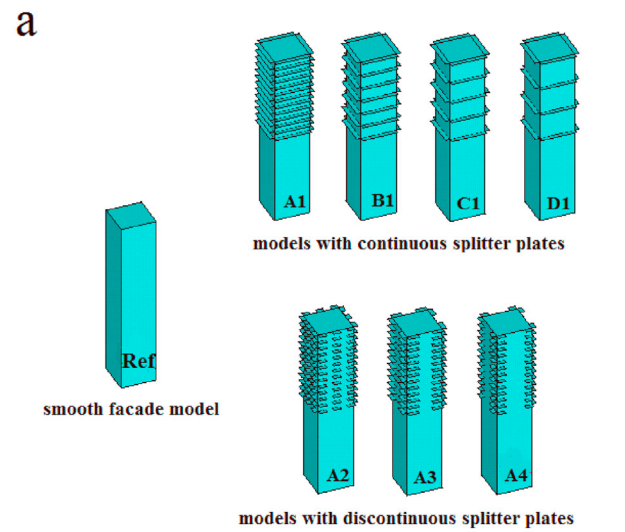


(a) Profile of mean wind speed and turbulence intensity

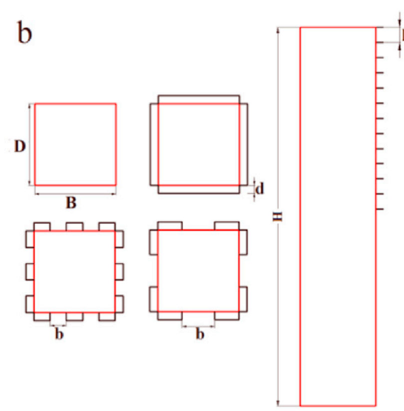


(b) Power spectrum of fluctuating wind speed

Fig. 2. Wind field information and characteristic in this study.



(a) Three-dimensional sketch of models



(b) Model configurations and appurtenances parameters

Fig. 3. Model information in this study.

From the literature, surface roughness of building may reduce the local peak pressure on the side face by restraining the transmission of disturbances with approaching flow. However, only limited types of surface roughness were considered in previous study, and it can be expected that various arrangements of façade appurtenances may have quite different effects on wind pressure. In present study, more configurations of appurtenances are applied to investigate the effect of appurtenances on wind pressure systematically. Wind tunnel experiments were carried out based on a model of square section high-rise building and different appurtenances configurations are simulated by thin splitter plates horizontally attached to the facades. They are classified by horizontal gap distance ratios, vertical separation distance ratios and extensional depth ratios. Only the horizontal thin plates were adopted in this study, so that only the effects of appurtenances on the local wind load are studied, and the effects of change of cross-section shape are excluded. The relation between local extreme pressure coefficients and appurtenances configurations are investigated and discussed in details.

2. Wind tunnel experiments and model configurations

Wind tunnel experiments in this study were carried out in the boundary layer wind tunnel at Hunan University, China. The test section of the wind tunnel is 3 m wide, 2.5 m high and 11.5 m long. The urban terrain with power law index (α) of the mean wind speed profile approximately equaling to 0.3 (GB 50009-2012) is simulated through spires-and-roughness-blocks technique in the wind tunnel. The wind tunnel setup is shown in Fig. 1. The velocity scale is set to 1:8, and the geometric scale of 1:300 is adopted. As shown in Fig. 2(a), the mean wind