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Influence of Vertical rib on Wind Pressures and Aerodynamic Forces of High-rise Buildings

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SUMMARY:
Façade appurtenances such as vertical ribs are increasingly used on high-rise buildings to enhance the architectural appearance. These attached vertical ribs may modify the wind pressure acting on a building by changing the local flow pattern around the building. Thus, to study the influence of vertical ribs on wind loads of tall buildings is an important task in wind resistant design. In the present paper, multiple point synchronous pressure (MPSP) measurement and high-frequency force balance (HFFB) technique are employed to study the influence of different vertical ribs on the local wind pressures and the aerodynamic forces of high-rise building. The results show that the vertical ribs have a significant influence on the local wind pressure and aerodynamic force. The HFFB results are slightly greater than MPSP results.

Keywords: high-rise building; wind tunnel test; vertical rib; wind pressure; high-frequency force balance ;extensional depth ;Aerodynamic force

1. GENERAL INSTRUCTIONS

Recently, vertical ribs have been widely used in high-rise buildings, which has led to an increasing number of studies regarding their effects on the wind pressures of high-rise buildings. Hui et al. (2022) simulated various rib arrangements on a building using large eddy simulation to show their influence on the surface pressure. This study showed that under the optimal rib arrangement, the mean drag force and fluctuating lift force can be reduced by 38% and 70%, respectively. Using particle image velocimetry (PIV) technology, Liu et al. (2021) studied the air flow field around a building with horizontal or vertical ribs. They showed that the vertical ribs could reduce the turbulence intensity in the separated shear layer and near wake region. However, most previous studies focused on the effect of rib arrangement on the wind pressure while that of a rib extension depth was insufficiently looked into. Huang et al. (2017) found that an increase in the extension length of the vertical rib could notably reduce the vortex intensity and the vibration amplitude of a tall building, but the rib extension length used in their study was quite small, within the range of 0%–0.4% times the building width. Yang et al. (2020) showed that the installation of vertical ribs could significantly reduce the crosswind base bending moment by a maximum of 51.3%. However, only two large extensional depths of the vertical ribs equal to 7.5% and 12.5% of the building width were employed in their study, which may be uncommon in real projects. Therefore, it is necessary to investigate the effects of vertical ribs with various moderate (i.e., reasonable) extensional depths on the wind pressure distribution when aiming to provide useful guidance for aerodynamic optimizations of high-rise buildings.

2.WIND TUNNEL EXPERIMENTS

All experiments in this study were conducted in atmospheric boundary layer wind tunnel ZD-1 at Zhejiang University, which had a test section of 4 m (width) by 3 m (height). The prototype building is square with a height (H) × width (B) × depth (D) of 100 m × 30 m × 30 m. And the geometric scale was set as 1:100. Fig. 1 shows the mean wind speed (U_z) and turbulence intensity (I_z) measured at different heights, where Z_H is the height of the building model, and U_H is the mean wind speed corresponding to Z_H. In addition, the power spectrum of wind speed measured from the experiment is in good agreement with the Von Karman spectrum, as shown in Fig. 3 and Fig. 4.

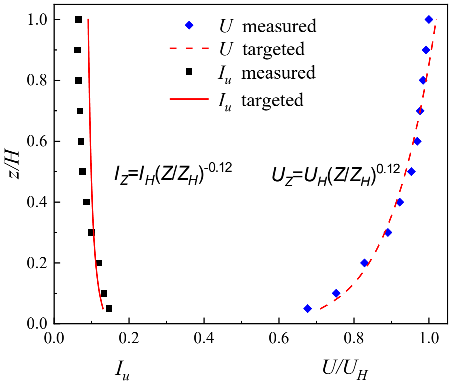


Figure 1. mean wind speed and turbulence intensity profile

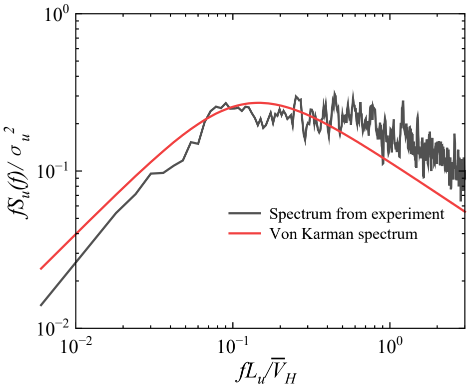


Figure 2. power spectrum

Table 1 shows the different distributions of vertical ribs used in the experiments, where the extensional depth of the facade is b and the spacing is d. The thickness of architectural facades in the pressure measurement is set as 1 mm. Model S is a reference model without architectural facades. And the test models with different distributions of vertical ribs are shown in Figure 2.

Table 1. Investigated facade models

Model Cases	b/mm	b/B(%)	d/mm	d/B
S	0	0	0	0
1	3	1	25	1/12
2	6	2	25	1/12
3	9	3	25	1/12
4	12	4	25	1/12
5	3	1	50	1/6
6	6	2	50	1/6
7	9	3	50	1/6
8	12	4	50	1/6

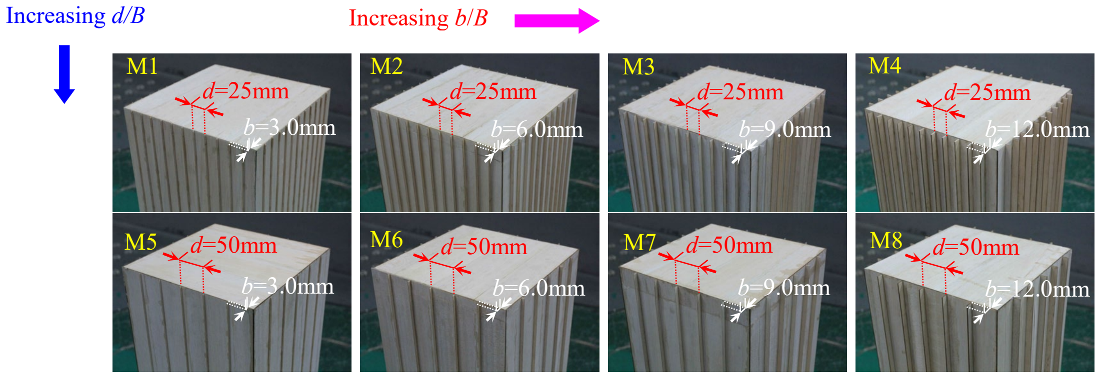


Figure 3 Test model with vertical rib of HFFB tests

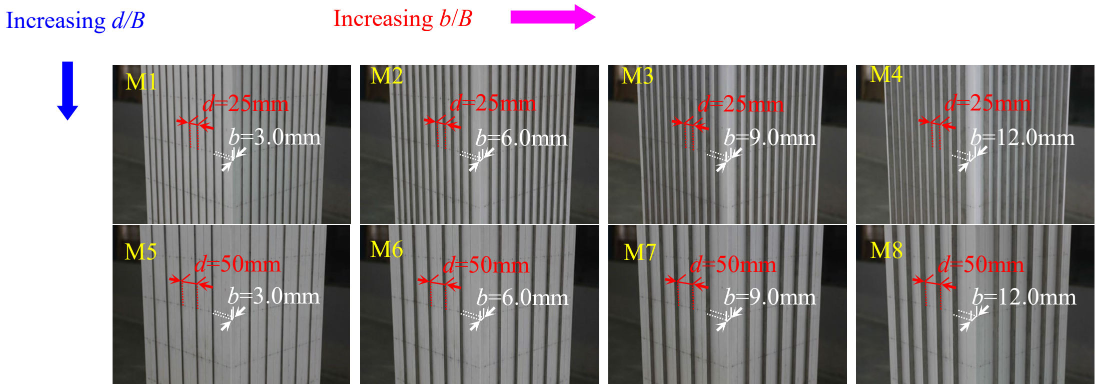


Figure 4 Test model with vertical rib of MPSP tests

3. RESULTS AND DISCUSSION

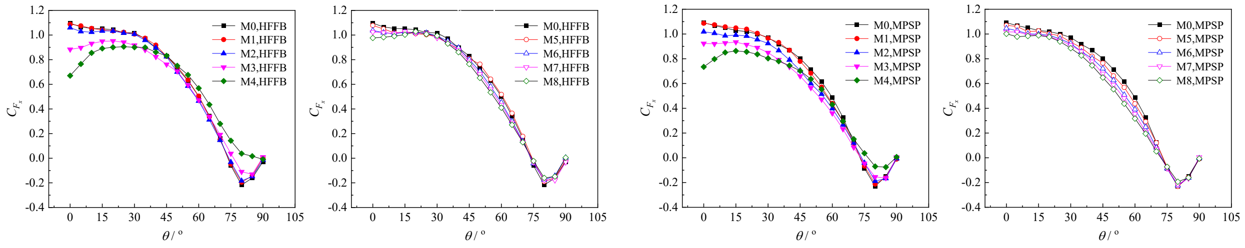
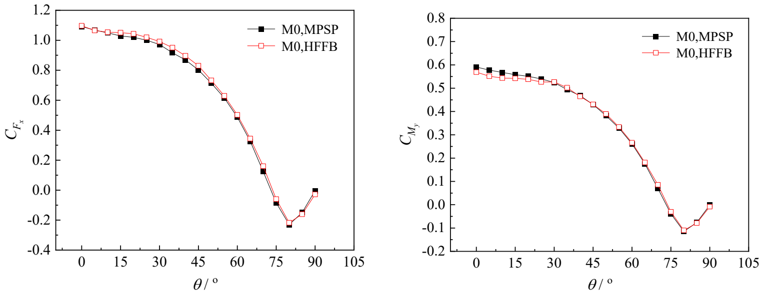


Figure 5 Force coefficients in HFFB tests and MPSP tests (Average value)

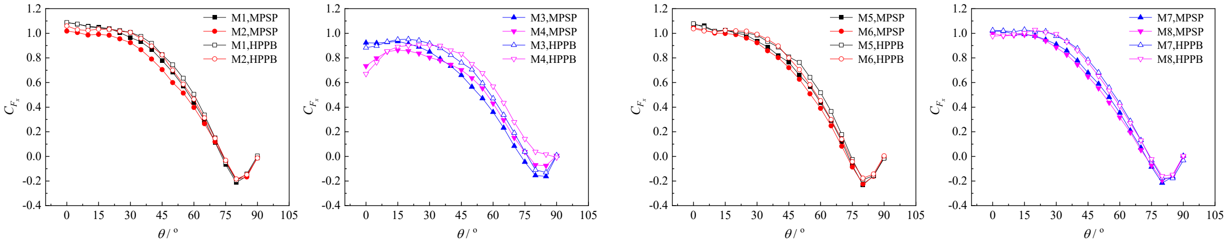
The variation curve of mean base shear force for each model under different directions is shown in Fig. 5. The results of HFFB and MPSP show a similar trend. The mean base shear force curves of the models with vertical ribs differ greatly from that of model S. This is due to the vertical ribs, which will affect the cross flow of the tall building model. The mean base shear forces of models with *d*/B=1/12 decrease significantly compared with that of model S, and the largest relative difference can reach 38.9% at the wind incidence angle of 0°. The mean base shear forces of models with *d*/B=1/6 decrease slightly compared with that of model S, and the largest relative difference can reach 11.1% at the wind incidence angle of 0°.The reduction of base shear force shows an increasing trend with the increase in the rib extensional depth.



(a) *Fx* (b) *My*

Figure 6 Comparison of model M0 in HFFB and MPSP tests (Average value)

Fig. 6 shows that in model S the result of MPSP is in good agreement with that of the HFFB. Therefore, it is meaningful to compare the results of HFFB and MPSP under other working conditions.



(a) *d*/B=1/12 (b) *d*/B=1/6

Figure 7 Comparison of models in HFFB and MPSP tests (Average value)

Fig. 7 shows that the mean base shear force obtained by HFFB is larger than that obtained by pressure measurement with the largest relative difference of about 7.2%**.**

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REFERENCES

Hui, Y.; Liu, J.; Wang, J.; Yang, Q., 2022. Effects of facade rib arrangement on aerodynamic characteristics and flow structure of a square cylinder. Journal of Wind Engineering and Industrial Aerodynamics 214, 108924.

Liu, J.; Hui, Y.; Yang, Q.; Tamura, Y., 2021. Flow field investigation for aerodynamic effects of surface mounted ribs on square-sectioned high-rise buildings. J. Wind Eng. Ind. Aerod. 211, 104551

Huang, D.; He, S.; Zhu, X.; He, X., 2017. Influence of surface roughness on wind load and wind-induced response of super-tall building. Journal of Hunan University(Natural Sciences.) 44, 41–51.

Yang, Q.; Liu, Z.; Hui, Y.; Li, Z., 2020. Modification of aerodynamic force characteristics on high-rise buildings with arrangement of vertical plates. Journal of Wind Engineering and Industrial Aerodynamics 200, 104551.