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Wind effect and aerodynamic wind resistance measures of a 257m apartment building

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SUMMARY:
With high-frequency force balance technique, detailed wind tunnel tests were carried out on two super high-rise buildings (300m Office and 257m Apartment) of a building complex located on the coast of South China. The effects of different local modifications (including concave corner, chamfer and balcony unclosed) in different position corner areas on the elevation of the Apartment, adjacent Office and a 215m upstream Hotel on the crosswind effect of the Apartment were investigated. The results show that the 50-year return period cross wind load and 10-year return period maximum peak acceleration of the isolated Apartment are 10080MN•m and 0.50m/s^2. The architectural layout of the complex can reduce the wind load and acceleration of the Apartment by 64% and 54%, but the upstream Hotel will increase the peak acceleration of the Apartment by 16%. When only considering the complex, the recommended scheme of upper concave corner and the lower balcony unclosed can reduce the crosswind load and peak acceleration of the Apartment by 20% and 15%. When considering the interference effect of all the surrounding buildings, the recommended scheme can reduce the 10-year return period peak acceleration by 12%.

Keywords: high-rise building, cross wind effect, aerodynamic wind resistance measure

1. INTRODUCTION

Super-high-rise buildings are sensitive to wind load. At present, the research of aerodynamic measures mainly focuses on single building. Typical aerodynamic measures include corner, chamfered corner, and rounded corner (Gu et al., 2013). Many researchers (Kawai et al., 2013; Miyashita et al., 2013; Gu et al., 2013; Tamura et al., 2013; Zhang et al.) studied the influence of corner, chamfered corner, and rounded corner on aerodynamic characteristics of rectangular high-rise buildings. A study (Xie et al.) about Shenzhen Jingji Financial Centre found that the effect of aerodynamic measures will be influenced by surroundings. So, it is necessary to study and evaluate the applicability of aerodynamic measures with complex surrounding environment.

1.1. Project information

Take a super high-rise building complex near the coast of South China as an example. The complex consists of a 300m high Office, a 257m high Apartment. Fig. 1 shows the general layout and the elevation of Apartment.

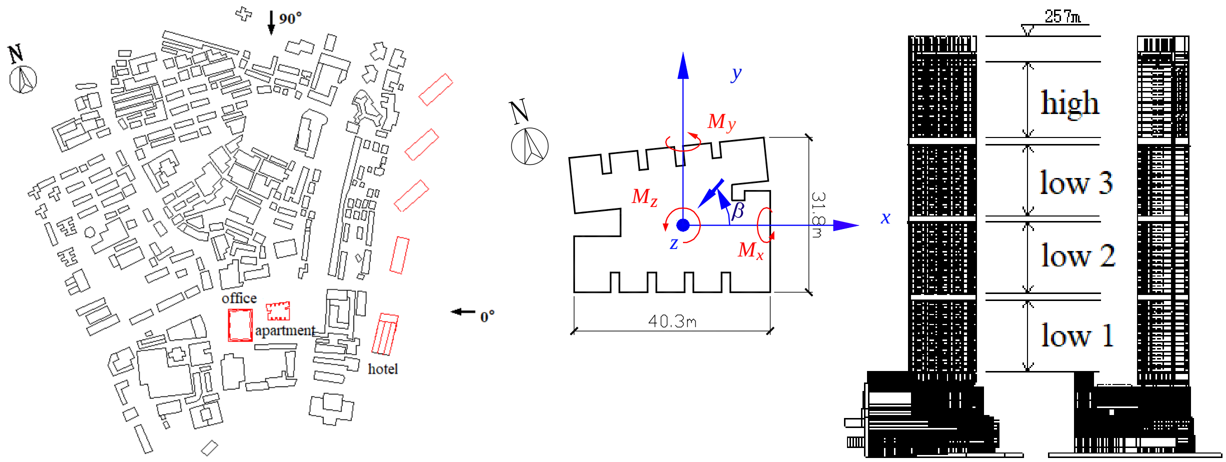


Figure 1. Main layout and elevation.

This paper mainly introduces the detailed wind tunnel test results of the Apartment. Firstly, it analyzes and compares the interference effects of the Office and Apartment Hotel buildings on the Apartment, and then studies the effects of aerodynamic measures such as corner and chamfered corner at different positions and discusses the applicability of aerodynamic measures in different surroundings.

2. WIND TUNNEL TEST INFORMATION

All the experiments in this study were conducted in the boundary layer wind tunnel at South China University of Technology. The wind tunnel is 3 m high and 5.4 m wide.

2.1. Test cases

To improve the test efficiency, the test model was printed by 3D printing technology, which can accurately simulate the detailed structure of the building.

In addition to considering the influence of the Office and the surroundings on the Apartment, the test is mainly to investigate the vibration reduction effect of the Apartment by corner or chamfered corner on the southeast and northeast corners of the building. There are 8 cases, surrounding: Apartment only, with Hotel, with Office, all surroundings; aerodynamic measure: no measures (case A), high corner and low opening (case B), high corner and low closing (case C) and high chamfered corner and low closing (case D).

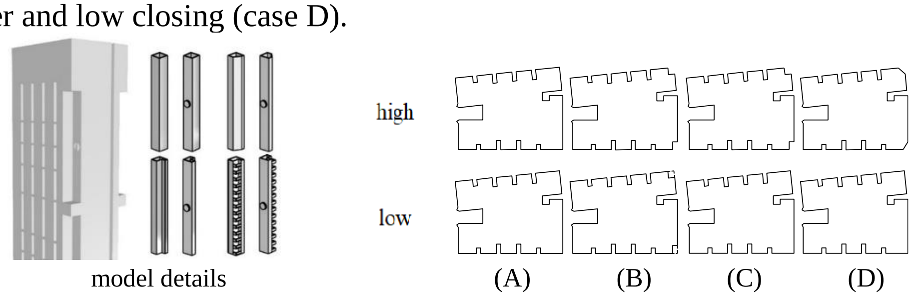


Figure 2. Schematic of aerodynamic measures.

2.2. Data process

In this study, the Correlation method of coupling aerodynamic loading for high frequency force balance test (Zhang et al., 2018) was adopted to eliminate the dynamic amplification effect of the balance-model system on the base moment spectrum. Moreover, the additional vibration modes caused by the nonperfect rigid connection between the model components and environmental noise interference were suppressed after the correction.

3. RESULTS AND DISCUSSION

The wind-sensitive angle of wind-induced vibration acceleration is 0 ~ 10 (near the east wind). Therefore, considering wind direction of -50 ~ 50 facing the sea only.

3.1. Influence of surrounding buildings on wind-induced load and response of Apartment

As Shown in Fig. 3, the maximum peak acceleration of Apartment is 0.50m/s^2 at 10° without any surroundings and highly exceed the limits. The Hotel can significantly reduce the wind-induced vibration acceleration of the Apartment to 0.29 m/s^2 as a shelter. The Office has the most advantageous on the wind-induced vibration acceleration of the Apartment, and the acceleration is 0.23m/s^2, which is only 46% of that of the single Apartment. However, the acceleration of all surrounding buildings including Hotel increases to 0.27 m/s^2, which is close to the interference result of Hotel alone. Considering the integration of the Office and the Apartment, it can be considered that the Hotel can increase the acceleration of the Apartment by 16%.

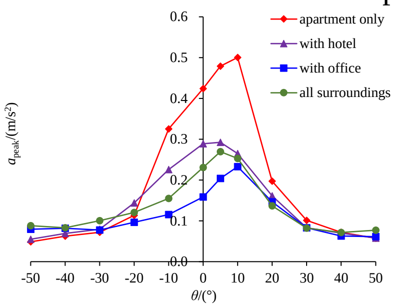
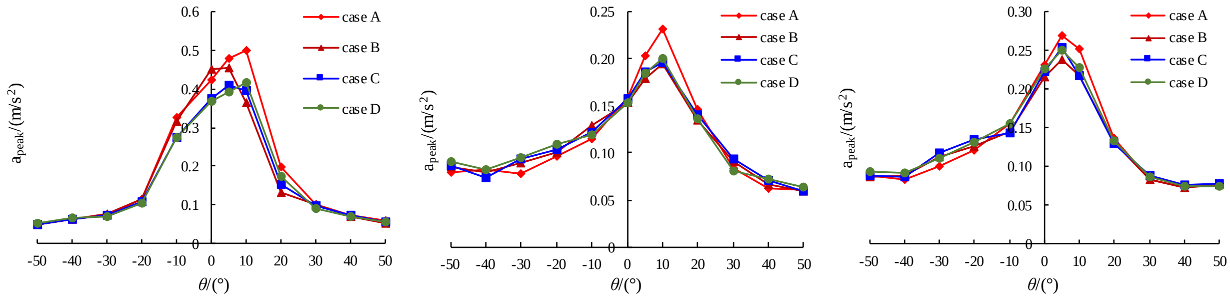


Figure 3. Variation of peak accelerations of Apartment with different surroundings.

3.2 Effects of aerodynamic measures

The shape of the building is an important factor of the wind-induced load and response. The above results show that the Office and the existing surroundings can fully restrain the crosswind of the Apartment, but the peak acceleration is 0.27m/s^2, which still exceed the limits. To reduce the peak acceleration, the available aerodynamic measures shown in Fig.2 are considered.

It can be seen from the Fig. 5 that all three measures can reduce the wind-induced vibration acceleration in different directions. As shown in Fig. 5(a), the maximum peak acceleration occurs at 10°, and the peak acceleration can be reduced by 18% from 0.5m/s^2 to 0.41m/s^2. The effects of case C and case D are similar. As shown in Fig. 5(b), considering Office as surrounding, three cases have nearly same effects, and can reduce the peak acceleration by 15%. As shown in Fig. 5(c), considering all the surroundings, comparing with the result of case A in Fig. 5(b), the result of case A increase to 0.27m/s^2, and case B has the minimum peak acceleration 0.24 m/s^2, which meets the limits 0.25 m/s^2. Finally, recommend case B as design scheme.



(a)Apartment only (b)with Office (c)all surroundings

Figure 5. Influence of aerodynamic measures on peak accelerations.

4. CONCLUSIONS

According to the research in this paper, the following conclusions can be drawn:

(1) For the 257m-high Apartment, thanks to the better architectural layout, the adjacent Office interferes with the flow separation and vortex shedding of the Apartment, which makes the crosswind wind load and wind vibration acceleration of the Apartment only 36% and 46% of the single case, respectively. For the Office and the Apartment, Hotel can increase the peak acceleration of the Apartment by 16%.

(2) The crosswind wind load can be reduced in different degrees by corners of the windward side of the Apartment. The recommended scheme is high corner and low opening, which can reduce the load of the single tower and the Office by 27.2% and 20% respectively.

(3) When the Office and the Apartment are integrated, the recommended scheme can reduce the peak acceleration of the Apartment by 15%, but the Hotel will reduce the efficiency of aerodynamic measures.

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