Toward elegant building shapes and their aerodynamic performance

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Summary

A series of wind tunnel tests have been carried out to determine aerodynamic performance of many super-tall buildings with various configurations: square plan, rectangular plan, elliptic plan, with corner cut, with corner chamfered, tilted, tapered, inverse tapered, with setbacks, helical, openings and so on. Dynamic wind-induced response analyses of these models have also been conducted. The results of these tests have led to comprehensive discussions on the aerodynamic characteristics of various tall building configurations.

Keywords: tall buildings; wind-induced responses; polygon cross-section; helical shape.

1. Introduction

The authors' group has conducted wind tunnel experiments for the super-tall buildings with unconventional configurations to investigate the aerodynamic and response characteristics. The findings can provide the structural designer with comprehensive wind tunnel test data that can be used in the preliminary design stage, and can be helpful in evaluating the most effective structural shape in wind-resistant design for tall buildings with various aerodynamic modifications.

2. Experimental results

The full-scale height and the total volume of experimental models are commonly set at H = 400m (80 stories) and about 10^6m^3. The width B of the prototype model (Square model) is 50m and the aspect ratio H/B is 8. As an approaching flow, a turbulent boundary layer flow with a power-law index of 0.27 representing an urban area was simulated. Dynamic wind forces were measured by a 6-component high-frequency force balance supporting light-weight and stiff models. Wind direction α was changed from 0°, which is normal to a wall surface, to 45° or 180° every 5° depending upon the building configuration. Wind pressure measurements were conducted on 28 models. The fluctuating wind pressures of each pressure tap were measured and recorded simultaneously using a vinyl tube 80cm long through a synchronous multi-pressure sensing system. The sampling frequency was 1kHz with a low-pass filter of 500Hz. The fluctuating wind pressures were revised considering the transfer function of the vinyl tube, and there are more than 200 measurement points. Fig. 1 shows the some results of response analysis; including the vertical profiles of the accelerations, story shear forces, displacements, and torsional moments of 8 models. The values are the largest values for all wind directions within the design wind speed ranges. The accelerations of the Corner modification models and Helical models are greatly reduced compared with that of the Square model. The story shear forces of the Corner modification, Setback, and Helical models are also reduced, but do not show higher mode effects. For displacements, there are no higher model effects, and the displacements of all models show smaller values than that of the Square model. For the torsional moments, the effect of helical angle is clearly seen, i.e. the larger torsional moment at upper height becomes smaller when changing the helical angle from 90° to 180°.

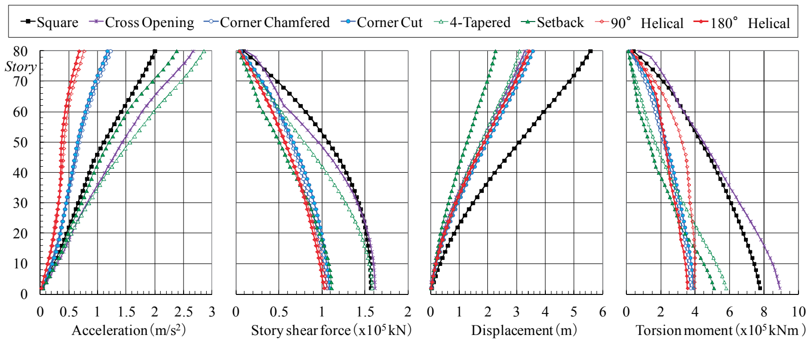
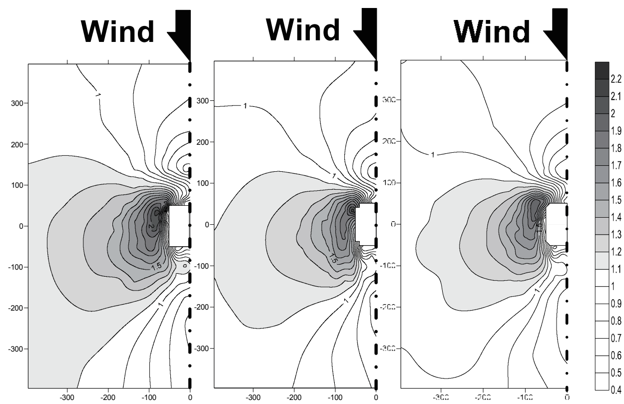


Fig. 1: Vertical profile of wind-induced responses for 500-year return period wind speed ([1])

3. Study on pedestrian level flows

The features of the mean wind speed distributions around the Square and Corner modification models are shown in Fig.2. It can see that compared with the Square model the wind speed ratio of the Corner modification models are significantly reduced. The maximum wind speed ratio of the Square model is 2.2. The wind speed ratio of the Corner Cut model and the Corner Chamfered model are 2.0 and 1.9, respectively.



(a) Square (b) Corner Cut (c) Corner Chamfered

Fig.2: Pedestrian-level wind environment

4. Concluding remarks

Evaluations of aerodynamic and response characteristics depending on building shapes are indispensable in super-tall building projects, prior to planning the vibration control systems for super-tall buildings.

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6. Reference

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