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Experimental investigation on aerodynamic characteristics of various triangular-section high-rise buildings

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ABSTRACT

Six pressure models of high rise buildings were tested in a boundary layer wind tunnel. Five had triangular cross sections with configurations of Straight Triangle, Corner cut, 60° Helical, 180° Helical and 360° Helical, and the other had a configuration of Clover. This study investigates variations in along-wind and crosswind overturning moment coefficients, power spectral densities, and trajectories of various wind force coefficients, as well as the effects of helical angle and aerodynamic modifications on wind forces and peak spectral values. The results show that the helical models had more effect on aerodynamic characteristics.

1. Introduction

Tall buildings are particularly prone to dynamic excitations such as those from natural disasters like strong winds and earthquakes, and this has become an especially important design issue with manhattanization. One way to minimize wind-induced vibrations of tall buildings is to focus more on their shapes in the design stage. Tanaka et al. (2012) investigated aerodynamic forces and wind pressures acting on tall buildings with various unconventional configurations. Hayashida and Iwasa (1990) studied the effects of building plan shape on aerodynamic forces, and displacement responses have been studied for super-high-rise buildings with square and triangular cross-sections with corner modifications. Kim and You (2002) discussed aerodynamic modifications of building shape, such as by changing the cross-section with height through tapering, which alters the flow pattern around tall buildings, and can reduce wind-induced excitations. Many researchers have tested wind pressures on buildings with irregular plans (Amin and Ahuja, 2008), with plan shapes that change with height (Harikrishna et al., 2009), with different rectangular cross-sections (Lin et al., 2005), and with tapers with taper ratios of 5% and 10%, and with set-back at mid-height (Kim and Kanda, 2010a, 2010b; Kim et al., 2011). However, there have been very few studies on the aerodynamic characteristics of triangular-cross-section tall buildings with various configurations.

2. Experimental setup

Wind tunnel tests were conducted in a boundary layer wind tunnel at the Wind Engineering Research Center, Tokyo Polytechnic University, Japan. The wind tunnel test section was 19 m long with a cross-section 2.2 m wide by 1.8 m high. Equilateral triangle models with a side dimension of 0.076 m and a height of 0.4 m were used. All the models had the same volume, and Straight Triangle, Corner cut, Clover, 60° Helical, 180° Helical and 360° Helical models were tested to identify their aerodynamic characteristics. These models are shown in Fig. 1. There were about 21 measurement points (for the Straight Triangle, 60° Helical, 180° Helical and 360° Helical models) and 24 measurement points (for the Corner cut and Clover models) on each level on three surfaces as shown in Fig. 2(a), and the measurement points were instrumented at 10 levels giving about 210 measurement points for the Straight Triangle & helical models and about 240 measurement points for the Corner cut and Clover models. The coordinate system adopted for the calculations is shown in Fig. 2(b).

The profiles of mean wind speed and turbulence intensity are plotted in Fig. 3. The experiments were conducted for an urban (power-law exponent, $\alpha = 0.27$) flow, by changing the wind directions. The wind velocity and turbulence intensity at the top of the model are about 12 m/s and 11%, respectively. The turbulence integral scale near the model top is about 0.42 m.

A length scale of 1/1000 and a time scale of 1/167 were assumed. All the pressures were measured simultaneously with a sampling frequency of 781 Hz, and a low pass-filter with a cut-off frequency of 300 Hz was cascaded in each data acquisition channel to eliminate aliasing effects. The measuring time was adjusted such that 33 samples were obtained. The Reynolds number was about 9.6×10^4. Blockage corrections were not applied to the experimental results.

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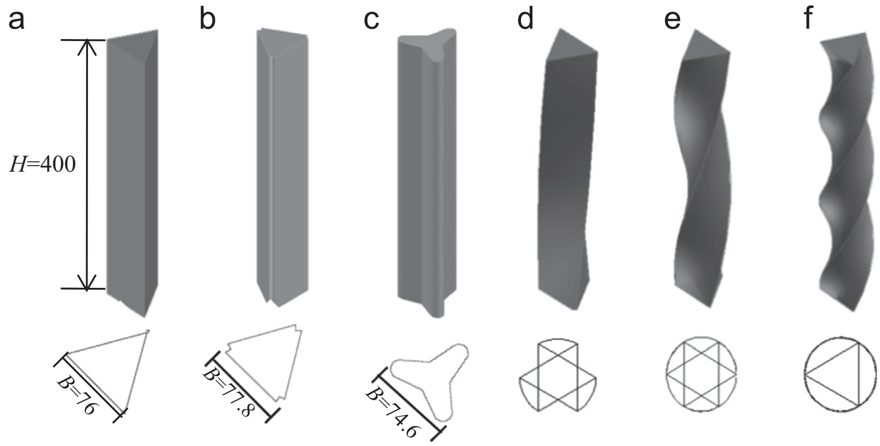

Fig. 1. Schematic diagram of models (unit: mm). *Note*: volume is same (1×10^6 mm^3).

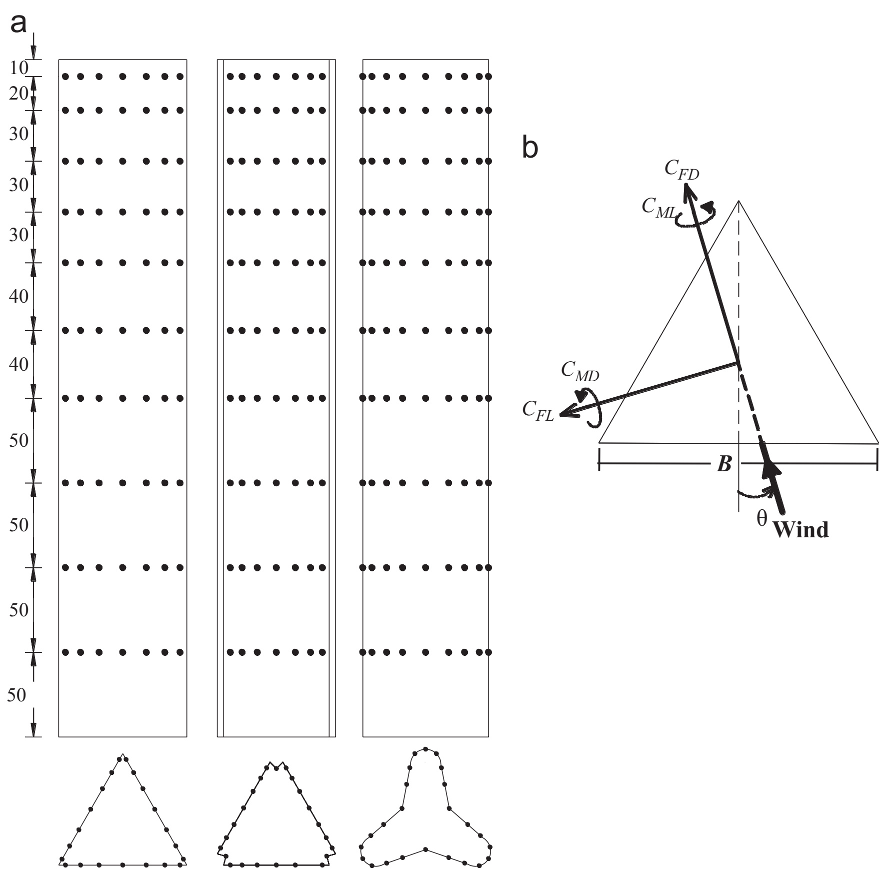

Fig. 2. Arrangement of (a) pressure taps and (b) coordinate system (unit: mm).

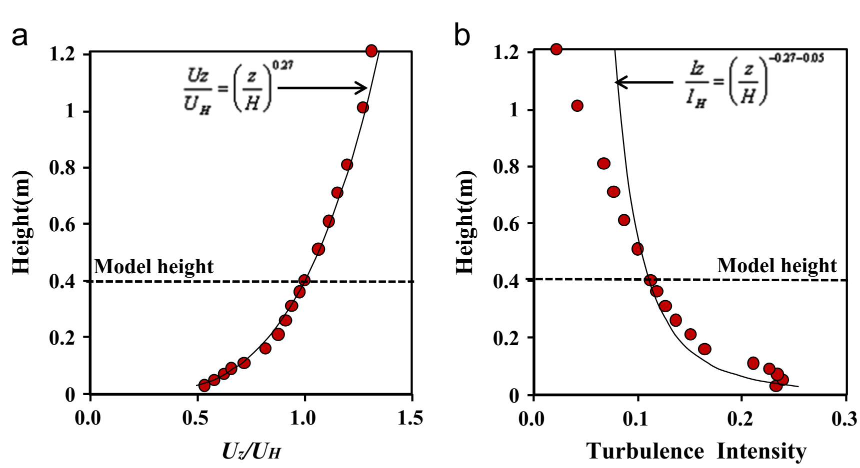

Fig. 3. Profile of (a) mean wind speed and (b) turbulence intensity.