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Interference effects between two high-rise buildings on wind-induced torsion

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ABSTRACT

The distribution variation and correlation of envelope interference factor (*EIF*) of the base torsion responses for principal building were studied by applying the rigid model wind tunnel test. The influence factor including different breadth ratio (B_r=0.4, 0.6, 0.8, 1.0, 1.2 and 1.4), height ratio (H_r=0.8, 1.0, 1.2 and 1.4), reduced velocity and approaching turbulence intensity were considered. Furthermore, the mechanism and occurrence condition of wake vortex-excited resonance were also studied. Results showed that the maximum value of *EIF* was 1.9 when vortex-excited resonance failed to happen. The correlation coefficient of *EIF* between B_r=0.8 and B_r=1.0 was 90.2%. Vortex-excited torsion resonance which induced from wake of interfering building occurred when B_r=0.4, and the maximum value of *EIF* reached up to 2.98. With increased H_r, the value of *EIF* increased. Good correlation was shown among different height ratios. For breadth ratios range from 0.3 to 0.5, it was suggested the reduced velocity should be out of the range of 3.33–5.56 to avoid occurring vortex-excited torsion resonance.

1. Introduction

Wind-induced interference effect was always a hot spot in wind engineering research since the collapse of England bridge thermal power plant in 1965 (Armitt, 1980). However, most of current researches on interference effect were focus on base pneumatic bending moment, base response of bending moment and local pressure distribution (Xie and Gu, 2004, 2007; Lam et al., 2008; Kim et al., 2011; Hui et al., 2012, 2013; Yu et al., 2015), some of the research results had been adopted by Chinese load code for the design of building structures (GB50009-2012, Architectural Industry Press of China, 2012).

Interference effects on torsional responses for high-rise buildings were seldom considered because of cognitive and experimental limitation, and previous researches in this respect only consider some simple influence factors. However, it was shown that the interference effects on torsional responses could not be ignored. Blessmann and Riera (1985) had examined interference effect of torsion for two square cross section tall buildings, it was discovered that the maximum torsional moment coefficient was 3 times of isolated case. Zhang et al. (1994) had studied interference effects on torsional responses for different breadths and shapes of tall buildings by wind tunnel test on aeroelastic model, it was found that torsional responses were significantly enhanced by a factor of up to 2.2 times that of the isolated building when vortex shedding from the interfering building was in resonance with the natural frequency of the principal building. Zhang et al. (1995) further experimentally investigated interference effects on torsional response of a tall square cross-section building with structural asymmetry. Results showed that the mean and standard deviation torsional responses of the asymmetric principal building could be significantly enhanced due to the presence of the interfering building.

Besides, few studies had examined the interference effect by correlation method. Xie and Gu (2005) quantitatively analyzed the correlation of base bending moment interference factors in different breadths and heights of interfering building by the high frequency force balance (HFFB) method. Measured results showed significant correlations exist in the distributions of the interference factors estimated in different configurations, and the correlation coefficient of mean interference factors was found in the range of 92~99%. Xie and Gu (2007) further studied the correlation of mean and dynamics interference effects of base-bending moment among 3 buildings with different height ratios. Results showed the correlation coefficients of mean

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interference factor reached up to 94%, while that of across-wind dynamics interference factor also reached up to 83%.

In this paper, the time-varying external pressures on the surface of principal building were obtained by applying the synchronous pressure measurement technique in various interference cases, and the base torsion responses were calculated. Distributions and correlation of the enveloped interference factor (*EIF*) of the peak base torsion responses in different breadth ratios, height ratios, reduced velocities and approaching turbulence intensities were detailed analyzed. Finally, the interference mechanism and occurrence condition of vortex-induced resonance were further studied.

2. Wind tunnel experiment

2.1. Experimental method

Theoretically, three kinds of experimental methods including high frequency force balance (HFFB), aeroelastic model (AEM) and high frequency pressure integration (HFPI) can be used to conduct research on interference effect of torsional response. However, the measure range of a common high frequency force balance is always too large to meet the precision of torsional component for its low signal-to-noise ratio. Although AEM method can theoretically obtain the torsional response, accelerometer can only get the resonance component but cannot get the dominant average and background components. Thus it is usually to measurement displacement when adopted AEM method, but the torsional displacement is angular rotation which is difficult to measure. Actually, AEM method can simulate the interaction between wind and building, but it is necessary to conduct wind tunnel experiments in different velocities to obtain structural response in different velocities, which is a disadvantage for carrying massive wind tunnel tests on interference effect. Thus, AEM cannot be as a main method to study interference effects. High frequency pressure integration (HFPI) method which based on synchronous pressure measurement technique can be used to obtained wind-induced responses for high-rise building. Actually, the precision of aerodynamic torsional moment and base torsion responses obtained from HFPI method is higher than that from HFFB method (Aly, 2013). Thus, HFPI method is selected to investigate the interference effects between two high-rise buildings on wind-induced torsion.

2.2. Experimental setup

The experimental models were consist of two rigid model: the pressure model, called the principal building, and the other model, called the interfering building. Both the principal and interfering buildings are square in section. The principal building model was 100 mm×100 mm in plan and 600 mm in height. The length scale was set as 1:400, such that the model represented a full-scale tall building with height of 240 m. Seven tap floors were arranged along the height, in which each tap floor had 28 pressure taps. The principal building model and tapping location on each tap floor was shown in Fig. 1. In wind tunnel test, the wind direction was kept constant, and DSM3200 made by Scanivalve LTD was used to synchronously measure wind pressure on the principal building. The shape of the principal building remained unchanged, and the interference effect of six kinds of breadth ratios ($B_r=B_i/B_p$=0.4, 0.6, 0.8, 1.0, 1.2 and 1.4) and four height ratios ($H_r=H_i/H_p$=0.8, 1.0, 1.2 and 1.4) were considered, where B_i and H_i were the breadth and height of the interfering building, B_p and H_p were the breadth and height of the principal building, respectively. Table 1 showed the cases of the experimental model used in this study. The position grid of the interfering building and image of wind tunnel test was shown in Fig. 2, in which "A" stood for the stationary principal building; "B" stood for the moving interfering building, x and y were the distances between the two models in the longitudinal and transverse directions respectively, and b was the width of the principal building.

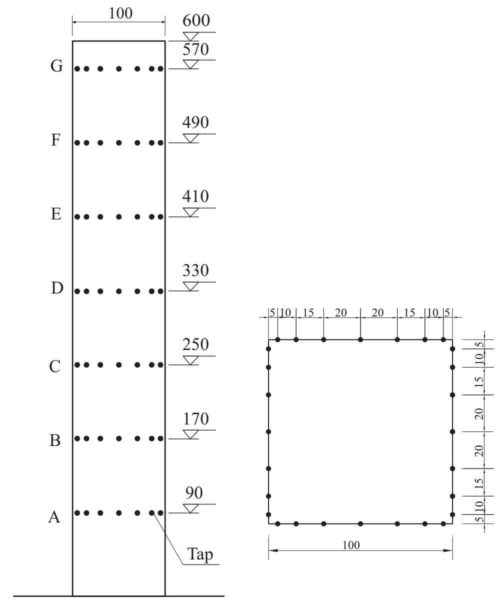

Fig. 1. Principal building model and tapping locations on each tap floor (unit: mm).

Table 1
Experimental models.

Experimental models	Dimensions (mm) (B_p×D_p×H_p)[a] (B_i×D_i×H_i)[b]	Breadth ratios ($B_r=B_i/B_p$)	Height ratios ($H_r=H_i/H_p$)	Locations
Principal building	100×100×600	–	–	1
Interfering building	40×40×600	0.4	1.0	64
	60×60×600	0.6	1.0	64
	80×80×600	0.8	1.0	64
	100×100×600	1.0	1.0	64
	120×120×600	1.2	1.0	64
	140×140×600	1.4	1.0	64
	100×100×480	1.0	0.8	64
	100×100×600	1.0	1.0	64
	100×100×720	1.0	1.2	64
	100×100×840	1.0	1.4	64

[a] B_p×D_p×H_p: dimension of principal building.
[b] B_i×D_i×H_i: dimension of interfering building.

Wind tunnel experiments were conducted in a Boundary Layer Wind Tunnel Laboratory. The test section of the wind tunnel was 3.0 m wide and 2.0 m high. The maximum block ratio is 2.4%. Exposure category B with a power law exponent of 0.15 which represented a suburban flat terrain, was simulated according to the Chinese Load code (GB50009-2012, Architectural Industry Press of China, 2012). The simulated mean wind profile, turbulence intensity distribution, and power spectrum at the height of the rooftop were shown in Fig. 3, in which standard velocity and turbulence profiles were simulated according to Chinese Load code (GB50009-2012, Architectural Industry Press of China, 2012), U_H was the mean wind speed at the height of rooftop. To further investigate the influence of turbulence intensity on the torsional interference effect, the normalized mean speed profile was kept unchanged, while the high and low turbulence profiles were simulated, as also shown in Fig. 3. The reference wind velocity (standard velocity) was 11.4 m/s at the height of 0.6 m. The test sampling time period was 65.536 s, and sampling frequency was 312.5 Hz.