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Analysis of interference effects on torsional moment between two high-rise buildings based on pressure and flow field measurement

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ABSTRACT

Wind induced interference effects between high-rise buildings have become quite important in structural engineering in modern cities recently due to the close proximity of high-rise buildings. In this study, the wind induced interference effects on the torsional load on two adjacent high-rise buildings are studied through wind tunnel experiment. Two different sectional shapes of high-rise buildings are studied and four kinds of arrangements are investigated. Existing interference factors are adopted to quantitatively evaluate the interference effects. Results show that the mean torsion on a building when under interfered conditions can be tripled that for the isolated case. Although the interference effect on the fluctuating torsion is not as strong as on the mean torsion, the interference factor can be as large as 1.6. The extreme torsion under interference effects is also higher at 1.8 times that of the isolated case. With the help of pressure measurement on the principal building and the flow field information around the buildings, the underlying mechanisms of some typical cases which exhibit strong interference effects are discussed. Results show that the intricate flow field around the principal building with the presence of an interfering building is the main case of the large torsion it experiences.

1. Introduction

A lot of high-rise buildings have been constructed in close proximity in modern cities. The wind induced interference effects on the dynamics of the buildings have become more and more prominent. Since the flow pattern surrounding the buildings might be significantly different from that for the isolated building, the wind loadings acting on the buildings may be greatly changed or enhanced with possibly no reference to the overall or local wind load (Xie and Gu, 2007; Lam et al., 2008; Zhao and Lam, 2008; Kim et al., 2011; Hui et al., 2012, 2013a). Some researchers also investigated the interference effects on the dynamic response of high-rise building (Bailey and Kwok, 1985; Huang et al., 2017)

Wind induced interference effects on torsion of a building in a group need carefully attention, and many studies have shown that the torsion of high-rise buildings cannot be neglected as in an isolated building. Blessmann and Riera (1985) reported the strong interference effects on torsional moment. Based on the research made by Blessmann (1992), the Brazilian wind load code(1988) (NBR-6123) suggested that the torsional moment on a building should account for the unfavorable influence of the surroundings in urban area. Studies have also been made on the torsional response of high-rise building under interference effects. Zhang et al., (1994, 1995) found that the mean and standard deviation of torsional responses of a asymmetric principal building could be significantly enhanced due to the presence of the interfering building. They claimed that the enhancement is due to the vortex shedding from the interfering building resonating at the natural frequency of the building submerged in the wake. Recently, Yu et al. (2016) studied the interference effects between two square-section buildings with different breadth ratios and height ratios. They found that the torsional response under interference effects can reach up to 2.98 times of the isolated condition.

It has been shown that the torsion of a building with the presence of an adjacent building is quite critical. Studies on the interference effects on wind induced torsion are necessary for both the design of high-rise buildings in group and for understanding the mechanism of this torsion enhancement due to wind load. In this study, wind tunnel experiment was carried out for this purpose with pressure measure-

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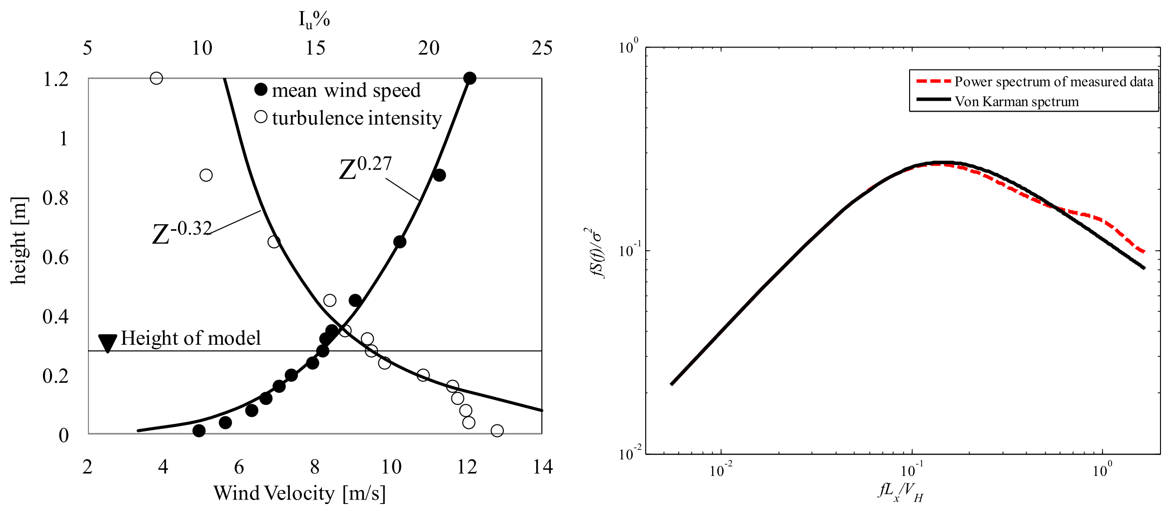
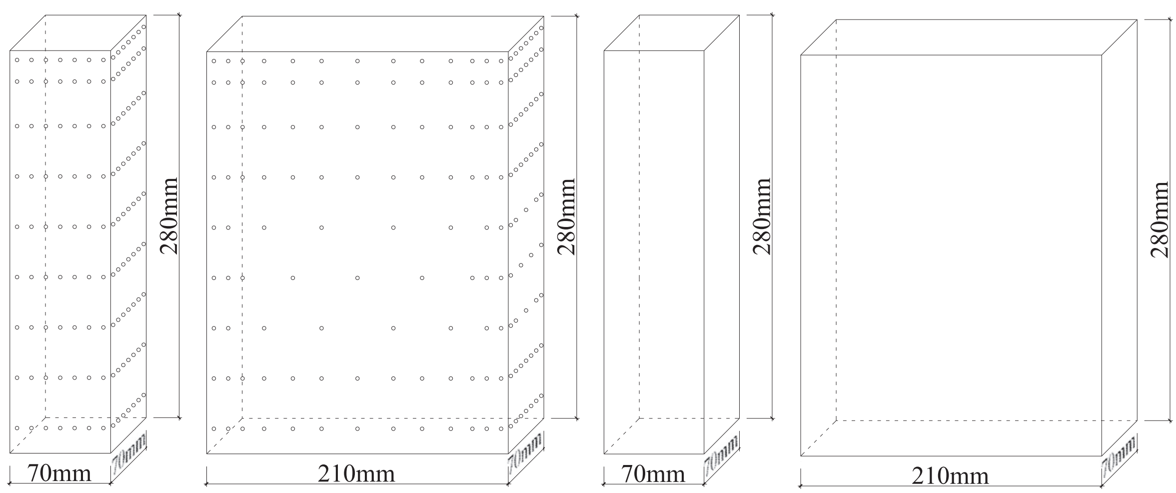


(a) wind profiles of experiment (b) wind power spectrum

Fig. 1. Characteristics of longitudinal wind in experiment.



(a) Principal building models (b) Interfering building models

Fig. 2. Building models for pressure measurement.

ment on the building models. Two types of building shapes in four different arrangements are studied in the experiment.

Since the mechanisms interference effects can be better described with the help of flow field pattern (Taniike, 1992; Hui et al., 2013b), the flow field surrounding the buildings is also examined quantitatively in this study by means of Particle Image Velocimetry (PIV) experiment. The mechanisms and underlying physics of the interference effects on torsion are discussed in detail with the above results.

2. Experimental setup

2.1. Pressure measurement

The boundary layer wind tunnel for the laboratory studies is located in Tokyo Polytechnic University. The test section is 2.2 m wide and 1.8 m high. A power law exponent of 0.27 is fitted for the approaching mean wind speed to represent an urban wind exposure. The mean wind speed and the turbulence intensity at the roof height of the model (0.28 m) were 8 m/s and 17%, respectively. The longitudinal mean wind velocity profile, turbulence intensity profile, and power spectrum of wind speed at roof height are shown in Fig. 1. The length scale and velocity scale were set at 1:400 and 1/5, respectively. The integral length scale of this experiment is about 0.56 m at the model eight, which means it corresponds to a 224 m integral length scale in full scale at 112 m high above the ground. This value is a reasonable simulation based on the full scale measurement in large city (Hui et al., 2017). Therefore, the length scale in this experiment is reasonable. This means the target mean wind speed was 40 m/s at roof height in full scale. Pressures on the building models were recorded with a sampling frequency of 781 Hz.

Two kinds of building shapes with the same height of 280 mm were studied. The first one was a 70 mm×70 mm square-section model and the second one was a 210 mm×70 mm rectangular-section model. They are shown in Fig. 2. Four different experimental arrangements were designed for the wind tunnel test, and they are named as A-1 to A-4 hereafter for convenience. Fig. 3 shows the arrangements. A-1 and A-2 were used to test the interference effects between two buildings with different shapes. A-3 and A-4 were used to investigate the interference effects between the rectangular-section buildings but with different relative orientations. The