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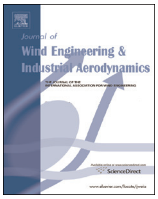

Interference effects on wind pressure distribution between two high-rise buildings

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ABSTRACT

Interference effects on wind pressure distributions between two buildings with various configurations in tandem, oblique, and parallel arrangements were studied in detail by applying the synchronous pressure measurement technique. Configurations included six kinds of breadth ratios ($B_r = B_{\text{interfering}}/B_{\text{principal}}$) and four kinds of height ratios ($H_r = H_{\text{interfering}}/H_{\text{principal}}$). The characteristics of wind pressure distribution were further investigated in the most unfavorable parallel arrangements. Results showed that the mean pressure was often beneficial because of shielding, whereas the peak pressure of the lateral facade adjacent to the interfering building was mainly amplified. With increased B_r and H_r, the corresponding shielding and amplification effects became more remarkable. When $H_r < 1$ in tandem arrangement, the local mean and peak pressures on the lateral facade increased by 56% and 53%, respectively, because of the three-dimensional flow effects. The channeling effect in parallel arrangement should be given sufficient attention for the observed maximum interference factors (IF_{max}) of the mean and peak pressures reach up to 2.6 and 1.91, respectively. Finally, high precision regression equations were proposed to present the relationship between the maximum block interference factor (BIF_{max}) and building spacing in parallel arrangement.

1. Introduction

With the increasing height and intensity of modern high-rise buildings, the mutual interference effects among them become increasingly complicated. Many researchers had investigated this topic (Sykes, 1983; Bailey and Kwok, 1985; Taniike, 1992; Xie and Gu, 2004, 2007; Lam et al., 2008, 2011; Mara et al., 2014). However, these researchers mainly focused on the overall wind loads and static/dynamic interference effects. Few reports discussed that high-rise buildings collapse because of interference effect in reality, whereas building enclosures, especially the curtain walls, are often destroyed by strong windstorm. Sparks et al. (1994) investigated the economic losses of buildings damaged by hurricanes in cities nearby coasts and found that more than half of the losses are attributed to the damage of building enclosures.

Few systematic studies have examined the interference effects of wind pressure on high-rise buildings because of the complexity of such effects. Through a wind tunnel test, Gowda and Sitheeq (1993) studied the interference effect of building spacing on surface wind pressure of downstream building in tandem arrangement and found that a downstream building is fully submerged in the shear boundary layer of an upwind building when building spacing is less. Thus, the whole surface of downstream building suffers from higher negative pressures.

Wind tunnel investigations on an 11-storey building, Jóźwiak et al. (1995) discovered that local negative pressures on the leeward side, in the region of the gap between buildings, are greater by as much as 1.8 times than that measured for an isolated building. However, the interference effect remarkably decreases if a reasonable position is selected for the building.

Local wind pressure coefficients between two buildings were studied by Kim et al. (2011) by using wind tunnel experiments. Five types of interfering buildings with different heights were considered. Results showed that the minimum negative peak pressure on a principal building increased with increasing height ratios of an interfering building. The oblique configuration generates more severe negative peak pressures than the tandem configuration.

Hui et al. (2012, 2013a, 2013b) investigated the interference effects of local pressure coefficients between two buildings with different shapes by conducting wind tunnel experiments. Partical image velocimetry tests were used to describe and explain the

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interference effects from the perspective of flow field. Results showed that interference effects significantly depend on building shapes and wind direction. Unfavorable positions are generally concentrated at the edges and corners of the building. The largest minimum peak pressure on a building can be 50% larger than that on an isolated one.

Present studies on interference effects of wind pressure generally focus on two buildings with no sufficient variation range for the location of the interfering building. The interference effects of breadth ratio ($B_r = B_{\text{interfering}}/B_{\text{principal}}$) and height ratio ($H_r = H_{\text{interfering}}/H_{\text{principal}}$) on wind pressures are seldom systematically considered in investigations. Further studies on the relationship between the maximum interference effect and building spacing in remarkable parallel arrangements have not yet conducted.

This paper systematically studies wind pressure distribution on a principal building by using the synchronous pressure measurement technique. The interference effect on wind pressure is a multi-objective problem that is difficult to analyze quantitatively. Thus, the method of dividing each building facade into blocks is adopted to study the mean and peak pressure coefficient distribution characteristics for two buildings arranged in tandem, oblique, and parallel. The interference effects of B_r and H_r are considered. Moreover, interference effects on remarkable parallel arrangements are further analyzed in detail. High-precision regression equations are proposed to present the relationship between the maximum interference factor ($\text{BIF}_{\max}$) and building spacing.

2. Experimental setup

Wind tunnel tests were performed in a Boundary Layer Wind Tunnel Laboratory. The tunnel had a testing section of 3.0 m width and 2.0 m height. The square section model was 100 mm × 100 mm in plane and 600 mm in height (Depth:Width:Height = 1:1:6). The length scale was set as 1:400, such that the model represented full-scale high-rise building that was 40 m × 40 m in plane and 240 m in height. Exposure category B with a power law exponent of 0.16, which represented a suburban flat terrain, was simulated according to the Chinese Load Code (GB50009-2001). The simulated mean wind profile, turbulence intensity distribution, and power spectrum at the height of the roof are shown in Fig. 1, in which the turbulence intensity distribution was simulated according to the Japanese Recommendations for Loads on Buildings (AIJ, 1996).

To examine interference effect on the local peak pressures of the principal building and also taking the amount of 1590 kinds of work cases into account, a total of 196 pressure taps were installed on the walls of this building. Seven tap floors (A, B, C, D, E, F, and G) were arranged along the height, in which each tap floor had 28 pressure taps, as shown in Fig. 2. The corresponding heights of the tap floor were 36, 68, 100, 132, 164, 196, and 228 m.

The shape of the principal building remained unchanged in the experiment. The interference effects of six kinds of B_r (0.4, 0.6, 0.8, 1.0, 1.2 and 1.4) and four kinds of H_r (0.8, 1.0, 1.2 and 1.4) were considered. The position grid of the interfering building is shown in Fig. 3, in which "A" stands for the stationary principal building; "B" denotes the moving interfering building; "+" is the position of interfering building; and x and y are the longitudinal and lateral distances, respectively, between the two models. Wind direction, as shown in Fig. 3, remained unchanged, which indicates that the interference effect of wind direction was not considered.

The industrial linear guide was adopted as the sliding guide for the interfering building. This guide has the advantages of high rigidity, high accuracy, and high reliability. In wind tunnel tests, the sliding guide was laid in the region of the coordinate grid, and the interfering building was fixed on the matched slipping block of the sliding guide, which could effectively reduce the experiment error induced by model swaying. Images of wind tunnel tests are shown in Fig. 4. Although the work cases reached 1590, the industrial linear guide could significantly improve the experiment efficiency. DSM3200 made by Scanivalve LTD was used to measure wind pressure synchronously on the principal building. The reference wind velocity was 11.4 m/s at the height of 0.6 m. The test sampling frequency was 312.5 Hz and sampling time was 65.536 s. The wind speed scale was set as 4.7, thus, the sampling time in reality was 93 min according to the similarity law.

The non-dimension form of time history of the pressure coefficient for each tap was calculated by selecting dynamic pressure at the height of roof as the reference pressure. $\bar{C}_p$ was the mean pressure coefficient. To obtain the peak pressure coefficient, the history

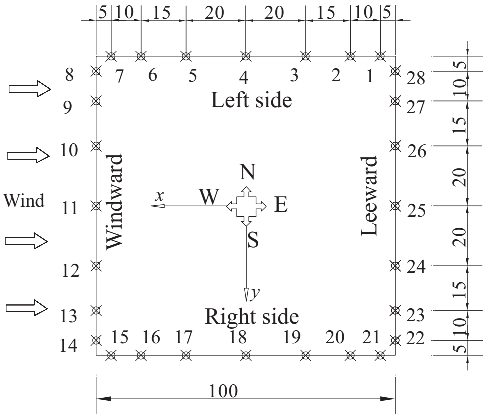

Fig. 2. Tapping locations on each tap floor (unit: mm).

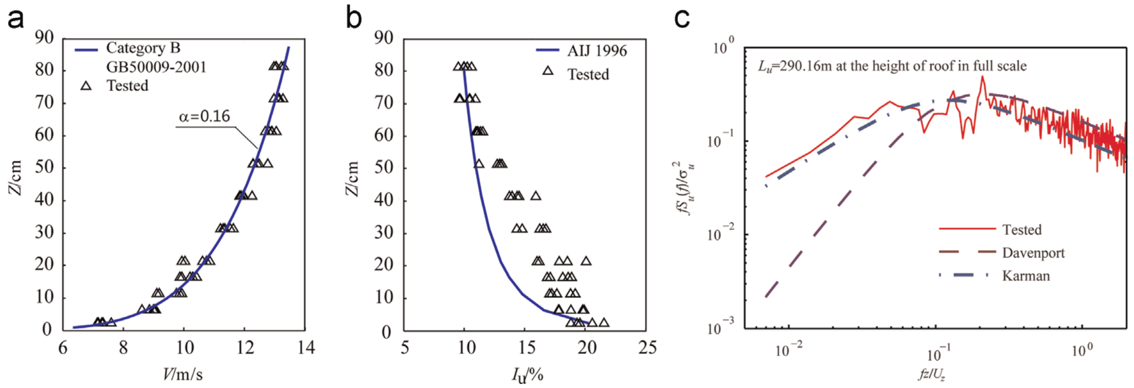

Fig. 1. Simulated wind parameters in terrain B, (a) mean speed profile, (b) turbulence intensity profile, and (c) spectrum at the height of roof.