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Interference effects on local peak pressures between two buildings

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ABSTRACT

Local peak pressure coefficients between two buildings were studied by using wind tunnel experiments for various locations, different height ratios of interfering building and wind directions. The measured local peak pressure coefficients were compared to those obtained previously from a study on an isolated building. This study also investigated interference effects for local peak pressures on a principal building with various configurations and different height ratios of an interfering building. The experimental results have been examined and presented from the viewpoint of cladding design. The results show that highest peak suctions on a principal building increased with increase in height ratios of the interfering building. The oblique configuration generated more severe peak suction than the tandem configuration. To examine the interference effects for local peak pressures in detail, interference factors for maximum positive and minimum negative peak pressures at each measurement point (i, j) of the principal building for all wind directions are presented and discussed.

1. Introduction

Most wind load standards have been derived for an isolated building. However, wind loads on tall buildings surrounded by other tall buildings in real environments may be quite different from those on isolated tall buildings. Surrounding tall buildings can either greatly increase or greatly decrease not only overall wind load on a building but also local peak pressure acting on the cladding of a building. Unfortunately, few standards have referred to wind-induced interference effects on wind loads on buildings (Australian/New Zealand Standard, 2002; Architectural Institute of Japan, 2004), and these standards only briefly discuss wind loads with effects of neighboring tall buildings and mainly deal with shielding effects, which is only one of the interference effects. It is difficult to predict wind loads because there are a large number of variables involved, such as building size and shape, relative locations of interfering building(s), wind directions, upstream terrain conditions and so on. Interference effects have been studied by many researchers over the past several decades (Bailey and Kwok, 1985; Taniike, 1992; Khanduri et al., 1998, 2000; Thepmongkorn et al., 2002; Tang and Kwok, 2004; Cheng and Lin, 2005; Xie and Gu, 2007; Zhao and Lam, 2008). These studies have focused on overall wind loads and wind-induced responses caused by interference effects. In several limiting conditions, for example, terrain conditions, wind directions, and different heights and sizes of interfering buildings, they produced not only experimental data for the database from a huge number of wind tunnel experiments, but also empirical formulas for evaluating overall wind loads on interfering buildings. Such databases and formulations can be used for approximate estimation of overall wind loads on buildings under interference for preliminary design purposes.

Khanduri et al. (2000) reported behaviors of drag and lift coefficients on a building through a huge amount of experimental works on buildings of varying square sizes, heights of an interfering building, several wind directions and various upstream terrain conditions. Then, they used interference influence grids to simplify and generalize their results obtained from wind pressure experiments to provide guidance for real structure design.

Xie and Gu, (2007) reported on interference effects on base bending moment responses in along-wind and across-wind directions for various spacings between groups of two and three buildings. They also proposed regression equations that reflect the inherent complex relationship to simplify the expressions of interference effects on base bending moment responses, and showed how to use their results in the design of real tall buildings.

However, most past studies have focused mainly on overall wind loads and wind-induced responses on the target building for structural design. Although these studies utilized pressure experiments, they focused on overall wind load behavior.

In order to determine cladding pressures, Surry and Mallais (1982) reported on high suction near the ground and the top of a sharp-cornered tower building with and without an interfering building for a fixed spacing between two buildings. They pointed out that for buildings of unusual geometry, special care should

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Notations

B	width of principal building
B_i	width of interfering building
$\hat{C}_p(i,j,\theta)$	maximum peak pressure coefficient at measurement point (i, j) at wind direction θ, where $\hat{C}_p(i,j,\theta) = \hat{q}(i,j,\theta)/1/2\rho U_H^2$
$\check{C}_p(i,j,\theta)$	minimum peak pressure coefficient at measurement point (i, j) at wind direction θ, where $\check{C}_p(i,j,\theta) = \check{q}(i,j,\theta)/1/2\rho U_H^2$
$\hat{C}_p$	largest maximum peak pressure coefficient for all measurement points and all wind directions
$\check{C}_p$	smallest minimum peak pressure coefficient for all measurement points and all wind directions
$\hat{C}_p(\theta)$	largest maximum peak pressure coefficient among all measurement points at wind direction θ
$\check{C}_p(\theta)$	smallest minimum peak pressure coefficient among all measurement points at wind direction θ
$\hat{C}_p(i,j)$	maximum positive peak pressure coefficient at measurement point (i, j) for all wind directions
$\check{C}_p(i,j)$	minimum negative peak pressure coefficient at measurement point (i, j) for all wind directions
D	depth of principal building
D_i	depth of interfering building
H	height of principal building
H_i	height of interfering building
H_r	height ratio of interfering building ($=H_i/H$)
$I_{F,max}$	interference factor for maximum positive peak pressure coefficient for all measurement points and all wind directions
$I_{F,min}$	interference factor for minimum negative peak pressure coefficient for all measurement points and all wind directions
$I_{F,max}(i,j)$	interference factor for maximum positive peak pressure coefficient at measurement point (i, j) for all wind directions
$I_{F,min}(i,j)$	interference factor for minimum negative peak pressure coefficient at measurement point (i, j) for all wind directions
I_z	turbulent intensity at height z
L_u	longitudinal integral scale
n	frequency
q_H	velocity pressure at height of principal building
$S_u(n)$	spectral density function for wind velocity
S_x	center-to-center longitudinal spacing between principal and interfering building
S_y	center-to-center lateral spacing between principal and interfering building
$\overline{U}_H$	mean wind velocity at height (H) of principal building
z	height above ground
z_1	Reference height
σ_u	Standard deviation of wind velocity

be taken to examine the likely effects of current and future environments. However, their research also had immense limitations such as a fixed location and size of the interfering building. Interference effects regarding local peak pressure on grouped tall buildings have rarely been studied from the viewpoint of cladding design.

This paper focuses on local peak pressures on a high-rise building under interference from this viewpoint. It also investigates interference effects affecting maximum positive and minimum negative peak pressure coefficients for72 wind directions for various configurations and height ratios of an interfering building. In detail, interference factors for maximum positive and minimum negative peak pressures at each measurement point (i, j) of a principal building for 72 wind directions are presented and discussed.

2. Experimental setup

Wind tunnel experiments on a high-rise building model with various configurations and height ratios of an interfering building were carried out in a Boundary Layer Wind Tunnel located at Tokyo Polytechnic University, Japan. The test section of the wind tunnel was 2.2 m wide and 1.8 m high. For this study, the flow of the atmospheric boundary layer in the wind tunnel was interpreted as a geometrical scale of approximately 1:400. The approach flow represented an urban wind exposure using the spire-roughness technique with a power law exponent of 0.27. The wind speed and the turbulence intensity at the height of the model were 8.2 m/s and 20%, respectively. The velocity scale was set to approximately 1/4. Measured longitudinal mean wind velocity, turbulence intensity profiles and longitudinal spectrum are shown in Fig. 1.

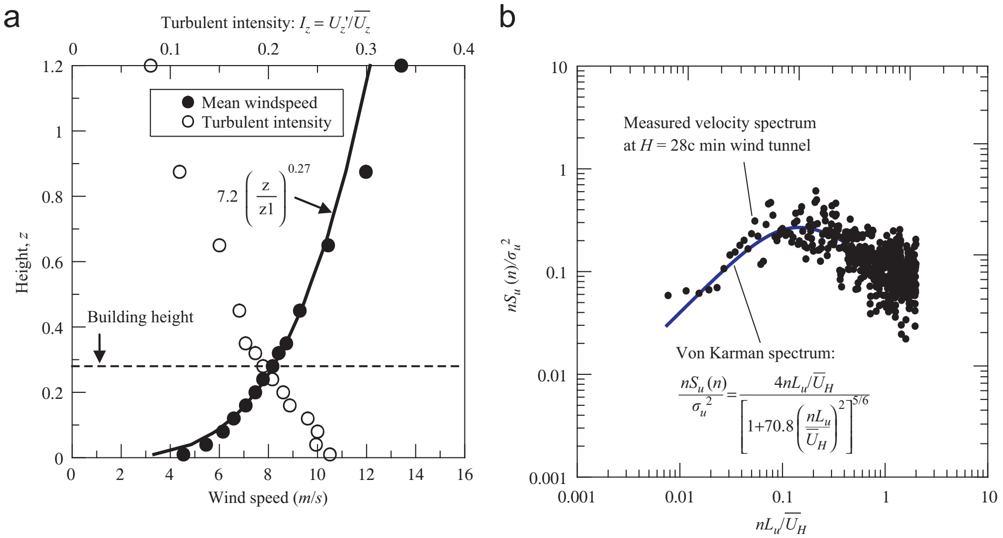

Fig. 1. Simulated wind parameters in wind tunnel: (a) mean wind speed and turbulent intensity profiles; (b) longitudinal turbulence spectrum.