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Interference effects on tail characteristics of extreme pressure value distributions

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ABSTRACT

This study investigates the interference effects on the tail characteristics of extreme pressure coefficients. Systematic wind tunnel tests are conducted, from which a large amount of data is generated to describe the tail characteristics of extreme pressure coefficients under interference effects. Through the identification of shape parameter of Generalized Extreme Value distribution (GEVD) function and the estimation of fluctuation level of extreme pressures, optimal peak pressure coefficients are predicted to compare with the Cook and Mayne coefficients. Results show that the design fractiles based on estimated parameters are generally lower than 78%, and the identified concave tail characteristics imply a ceiling coefficient value. The largest negative peak pressure coefficients are found when the interfering building is in the upstream region of the principal building and most of them are along the vertical edges of side faces parallel to the wind direction. By calculating the error percentages due to the assumption of Gumbel tail, the estimation bias is indicated and the significances of both the shape parameter and the fluctuation level of extreme pressures are presented.

1. Introduction

Buildings that undergo interference effects caused by neighboring buildings require an improved wind load resistant design rather than that for isolated buildings. The issue with the interference effects is still one of the most common and difficult research topics in the field of wind engineering.

Over the past decades, researchers have adopted various methodologies to investigate the interference effects on overall wind loads of high-rise buildings. Disturbances that may affect the wind forces, such as the approaching flow characteristics, wind directions, relative location of neighboring buildings, cross sectional shapes and aspect ratios, Scruton numbers, Strouhal numbers, modal frequency, and mode shapes, have been widely discussed. (Saunders and Melbourne, 1979; Bailey and Kwok, 1985; Blessmann and Riera, 1985; Kareem, 1987; Taniike and Inaoka, 1988; Taniike, 1991, 1992; Zhang et al., 1994, 1995; Khanduri et al., 1998, 2000; Thepmongkorn et al., 2002; Tang and Kwok, 2004; Xie and Gu, 2004, 2007; Huang and Gu, 2005; Zhao and Lam, 2008; Lam et al., 2008, 2011; Fang et al., 2013; Yu et al., 2015; Lo et al., 2016). Among these research works, square or rectangular prisms, as well as cylindrical prisms, chimneys, storage tanks, or cladding structures were chosen for discussions (Kareem et al., 1998; Niemann and Kasperski, 1999; Wang et al., 2014; Uematsu et al., 2015).

Some recent works have just recently introduced in details the design of local wind loads for cladding. Kim et al. (2011) conducted systematic wind tunnel tests to investigate the effects of aspect ratios under various wind directions. The wind direction was proved to be one of the most crucial factors in local peak pressure design and the positions along the vertical edges need to be paid more attention to when considering interference effects. Hui et al. (2012) investigated the interfered local peak pressures over the surface of high-rise buildings with various configurations. Results showed that building shape is another important factor for severely amplified or suppressed wind forces by neighboring buildings. Kim et al. (2013) adopted dynamic particle image velocimetry system (DPIV) to help explain interference mechanisms. The DPIV results showed that the interfered wind force generated from an oblique-upwind located building can increase the momentum over the upper surface of the principal building and result in high pressure coefficient near the leading edge. Through the DPIV system, the interference mechanisms were intuitively demonstrated. Hui et al. (2013) used rectangular cross sectional models for the principal and the interfering building models in parallel and perpendicular arrangements. The largest maximum or minimum pressures over faces were found and plotted into contours in terms of interference factors. Unfavorable wind directions for different interference locations were found and flow visualization was conducted as supplemental tools. Kim et al. (2015) investigated the story aerodynamic

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Nomenclature

B	Width of the principal building model
x/B	Distance factor between the principal and the interfering building models in the transverse direction
y/B	Distance factor between the principal and the interfering building models in the lateral direction
t_{mov}	Moving averaging time lag
L	Characteristic length of cladding
$\overline{U}_H$	Mean wind speed at building height
μ	Location parameter of extremes based on Eq. (2)
s	Scale parameter of extremes based on Eq. (2)
k	Shape parameter of extremes based on Eq. (2)
m	Mean value of extremes based on Eq. (2a)
σ	Standard deviation of extremes based on Eq. (2a)
τ	Shape parameter of extremes based on Eq. (2a)
Γ	Gamma function
γ	Euler constant
c	Extreme pressure coefficient
v	Extreme wind speed
$c.o.v.$	Coefficient of variation
w_{des}	Design wind load
v_{des}	Design wind speed
c_{des}	Design wind pressure coefficient
ρ_{des}	Air density
$f_v(v)$	Probability density function of design wind speed v
$f_c(c)$	Probability density function of design wind pressure coefficient c
$F_c(c)$	Probability distribution of design wind pressure coefficient c
p_{target}	Target exceedance probability of design wind load
c^*	Estimated design pressure coefficient based on Eq. (9)
U_c	Mode of extreme pressure coefficients
a_c	Dispersion of extreme pressure coefficients
θ	Wind direction
IF	Interference factor defined by largest maximum or minimum pressure coefficients

forces by integrating the pressure data and discussed the variation of the interfered wind force distribution against height with the integrated force spectra. However, among the related works of local peak pressure, the distribution behavior of extreme values is seldom mentioned, particularly the tail characteristics which can produce non-Gumbel extremes rather than the commonly adopted Gumbel assumption. Furthermore, the design pressure coefficients depend on both the distribution shape and the fluctuation level of extremes (Kasperski, 2009). It is essential and important that these two factors are discussed before deciding the appropriate design wind pressures.

This study investigates the interference effects on the local peak pressures over a square prism building with only one specific wind direction. The effects induced by the building shape and wind direction are neglected in order to focus on the significance of the tail characteristics and the fluctuation level to the estimation of peak values. Based on the experimental results, the tail characteristics of the extreme value distribution type and the fluctuation level of extreme values are examined for estimating design fractiles as well as the optimal design pressure coefficients. Errors caused by the Gumbel-assumed distribution are also calculated. Interference effects are interpreted for different location series and those critical cases are discussed.

2. Experimental setup

The pressure measurement tests are conducted in the 13 × 1.8 × 2.2 m turbulent boundary layer wind tunnel of Wind Engineering Research Center at Tamkang University. A 1/400 scale turbulent flow over an urban terrain with a power law index exponent for a mean velocity profile of 0.25 is simulated with properly equipped spires, saw barriers, and roughness blocks. The vertical flow characteristics are shown in Fig. 1. The mean wind velocity and the turbulence intensity at the model height are 9.2 m/sec and 12% respectively. The velocity scale is set at 6.8.

The model configuration is shown in Fig. 2. The principal building model and the interfering building model share the same sizes, which are 60 cm in height and 10 cm in both of the depth and the width. A total of 420 pressure taps are installed over the surfaces of the principal building model, except for the top roof. Each face includes 15 levels and each level contains 28 taps. Table 1 lists the level heights of the principal building model. Simultaneous pressure data are recorded at a sampling rate of 200 Hz by a multi-channel scanning system and are repeated for 600 samples. Each sample has 2048 points and is equivalent to a 10-min reference period in full scale. Pressure signals from the tubes are processed with the inverse FFT method to eliminate the tubing effects. The transfer function and the phase difference are shown in Fig. 3. The tube length is 130 cm for all tubes.

The sampling rate produces a time interval t_{mov} of about 0.3 s for fluctuating pressures in full scale. Because of the equivalent design wind speed of 62.6 m/sec at building height in full scale, the characteristic length of the cladding diagonal is around 18 m by Eq. (1) according to Holmes (1997). To reduce the characteristic length, the sampling rate should be raised to a higher value; however, due to the performance limitation of the multi-channel scanning system, peak values are discussed without adopting any moving averaging technique.

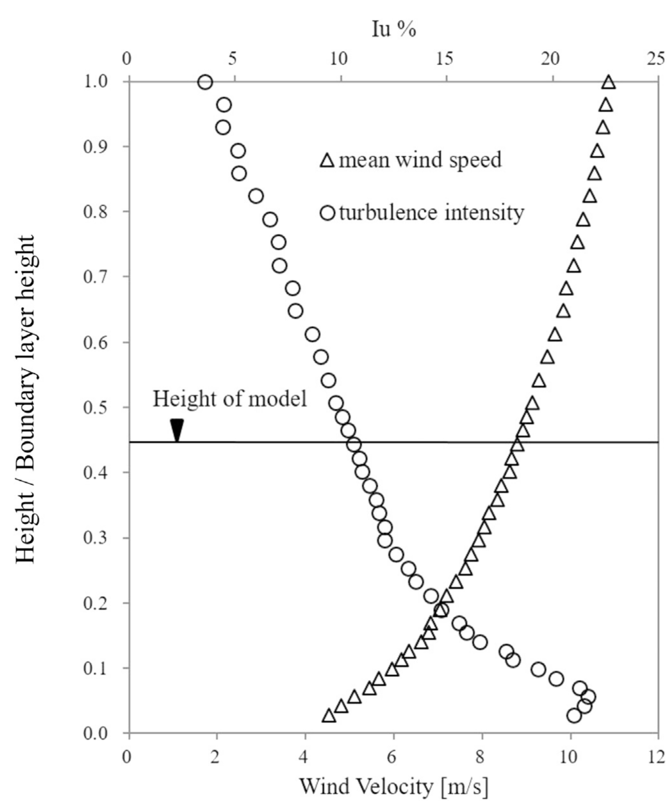

Fig. 1. Vertical turbulent characteristics of simulated flow.