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Simplified formulas for evaluation of wind-induced interference effects among three tall buildings

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Abstract

The base-bending moment (BBM) response and the mean BBM of grouped high-rise buildings are studied by a series of wind tunnel tests on typical tall building models using the high-frequency force balance technique. Interference excitations of two upwind buildings with various heights in different upwind terrains are considered. An effective method is proposed to represent the distribution of the envelope interference factor (EIF) among three tall buildings. The results show that two upstream buildings cause more adverse dynamic effects on the downstream building than a single upstream building does. Significant correlations are found in the distributions of the interference factors of different configurations and upwind terrains. Relevant regression equations are proposed to simplify the complexity of the multi-parameter wind-induced mean and dynamic interference effects among three tall buildings. Finally, an example of how to use the data provided in this paper and the proposed methodology is presented.

Keywords: Tall building; Wind tunnel test; Wind load; Base-bending moment; Interference factor

1. Introduction

Wind loads on buildings in real environments can be quite different from those measured on isolated buildings in wind tunnels. Surroundings can significantly increase or decrease the wind forces on the interfered buildings. The parameters affecting the wind

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forces may include the geometries and orientations of these buildings, the reduced wind velocity ($V_r = V_H/f_0D$, where V_H is the mean velocity at the top of the building, f_0 is the natural frequency of the building, D is the characteristic breadth of the building), number of the adjacent buildings and the upstream terrain condition, etc.

Bailey and Kwok [1] investigated the enhanced dynamic response of a tall square building under the interference action from the neighbouring square and circular buildings. Taniike and Inaoka [2] and Taniike [3] investigated the increased response and the possible aeroelastic mechanism of a tall square building under the interference excitation of several types of upstream buildings with different breadths under different upstream flow conditions. The effects of different parameters on the interference effects of tall buildings have also been investigated by many researchers in the past 20 years or so. Some of these studies can be found in [4–9]. However, due to the huge amount of experimental workload, most previous investigations focused mainly on the interference effects between two buildings, that is, one interfering building and one principal building. Only a few studies on the interference effects among three buildings have been reported. Saunders and Melbourne [10] investigated the interference effects on a $150 \times 37 \times 37$ m building of upstream single and twin buildings in reduced velocities of 2, 4 and 6. They found that side-by-side arranged two upstream buildings could induce more adverse wind loads on the downstream building than a single upstream building. The interference effects among three or more buildings are still open to research.

Xie and Gu [11] made detailed discussions on the mean interference factor (MIF) among three tall buildings. In this paper, the mean interference effects among three tall buildings are further studied to be quantitatively expressed as a simplified diagram. Furthermore, quantitative analyses are also made to determine the effects of variables on the mean and dynamic interference effects among three square tall buildings. In fact, the interference effects among three buildings are very complex and difficult to be expressed in a simple style. In order to reach some critical conclusions that could be used to improve design codes, the envelope interference factor (EIF) is proposed to describe the dynamic interference effects. Some suggestions are finally provided for the assessment of wind-induced interference effects on design loads for tall buildings.

2. Description of experiment and analysis

2.1. Experimental equipment

Wind tunnel tests were conducted in the STDX-1 Boundary Wind Tunnel of the Department of Civil Engineering at Shantou University. According to the Chinese Load Code (GB50009-2001 [12]), the exposure categories B and D (corresponding to exponents of the power law of mean speed profile of 0.16 and 0.30) are simulated at a length scale of 1/400 by setting spires, barriers and rough elements in the test area. The simulated mean wind profiles (V/V_g), turbulence intensity distributions I_u (%) and the power spectra for the two exposure categories are shown in Fig. 1, where V_g is the mean wind speed at the gradient wind height.

The measurements in this paper are carried out by means of the Nitta's universal force-moment sensor model No. UFS-4515A100 and the attached signal conditioner and amplifier. The technical specifications for the sensor are shown in Table 1.