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Interference effects on wind loading of a row of closely spaced tall buildings

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Abstract

Interference effects on a row of square-plan tall buildings arranged in close proximity are investigated with wind tunnel experiments. Wind forces and moments on each building in the row are measured with the base balance under different wind incidence angles and different separation distances between buildings. As a result of sheltering, inner buildings inside the row are found to experience much reduced wind load components acting along direction of the row (x) at most wind angles, as compared to the isolated building situation. However, these load components may exhibit phenomena of upwind-acting force and even negative drag force. Increase in x-direction wind loads is observed on the upwind edge building when wind blows at an oblique angle to the row. Other interference effects on y-direction wind loads and torsion are described. Pressure measurements on building walls and numerical computation of wind flow are carried out at some flow cases to explore the interference mechanisms. At wind angle around 30° to the row, wind is visualized to flow through the narrow building gaps at high speeds, resulting in highly negative pressure on associated building walls. This negative pressure and the single-wake behavior of flow over the row of buildings provide explanations for the observed interference effects. Interference on fluctuating wind loads is also investigated. Across-wind load fluctuations are much smaller than the isolated building case with the disappearance of vortex shedding peak in the load spectra. Buildings in a row thus do not exhibit resonant across-wind response at reduced velocities around 10 as an isolated square-plan tall building.

Keywords: Interference effect; Wind loads; Wind pressure; Sheltering; Channeling; Wind tunnel testing

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1. Introduction

When two or more buildings are placed in close proximity, flow interference occurs and wind loads on each building are modified from its isolated single building situation. Interference effects on wind loading of buildings have been reported in the literature for decades, see Khanduri et al. (1998) for a review. Most investigations were based on wind tunnel experiments and the building configuration being most extensively studied is two square-plan building models placed in different relative positions. Earlier studies used rigid models where mean wind pressures and wind forces were measured (e.g., Blessman and Riera, 1979; Saunders and Melbourne, 1979; Hussain and Lee, 1980; English, 1985). Dynamic behaviors are important for tall buildings so that in later studies, wind-induced dynamic response and loading of buildings were investigated (e.g., Bailey and Kwok, 1985; Taniike, 1992; Zhang et al., 1994). Measurements were made with lumped-mass aeroelastic models (Bailey and Kwok, 1985; Zhang et al., 1994) or through the base-balance technique (Taniike, 1992).

A number of important findings on interference have been obtained from the wealth of past studies even though they involved two buildings only. The most common interference mechanisms include sheltering effect, flow channeling, flow asymmetry and wake buffeting. An upstream building generally provides shielding on the downstream building. This normally leads to reduction of mean along-wind force on the downstream building. However, fluctuating wind force may become larger due to turbulence buffeting (Bailey and Kwok, 1985). Presence of a neighbouring building introduces asymmetry in wind flow pattern around the test building, leading to possible highly magnification of wind-induced torsion (Zhang et al., 1994). An upstream building is generally little affected by a downstream building but when two buildings are in very close proximity, wind flow is channelled to sweep through the building gap. Highly negative wind pressure is produced on corresponding building walls and this may modify the wind forces on the upwind building. Interference effect is found to depend on upstream terrain type, with more pronounced effects on a more open exposure (Kareem, 1987).

While it is accepted that interference effects depend on the arrangement pattern of buildings and the wind incidence direction, most investigations only reported results for wind incidence normal to the buildings. The building separations being studied were mostly larger than one building width. A notable exception is the experiments of Sakamoto and Haniu (1988) in which forces were measured on two square prisms in a turbulence boundary layer. While tests were limited to flow at normal incidence to the prisms, the two prisms were placed in a large number of relative positions in the tandem, side-by-side and staggered arrangement with a prism separation varying from almost zero to over 10 prism breadths. In the tandem arrangement, the upstream prism was found to experience reduced drag force with the presence of the downstream prism at a clear separation (S) larger than one prism breadth (B). However, when $S/B<1$, the drag force on the upstream prism was found to be much larger than the single prism value. Suppression of vortex shedding from the upstream prism was also observed at this close separation. In the side-by-side arrangement, the drag forces on the prisms were found to have the smallest value when S/B is near to 1. At this value of $S/B\approx 1$, the prisms also experienced the largest lift. The findings in that study suggest that the interference behavior between two buildings at $S/B<1$ is different than that at a wider separation.