Wind Engineering Joint Usage/Research Center
FY2015 Research Result Report

Research Field: Wind disaster and wind resistant design
Research Period: FY2015 Apr. ～ FY2016 Mar.
Research Number: 152004
Research Theme: Interference effect on a square prism based aeroelastic experiments
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Budget [FY2015]: 258,000Yen

1. Research Aim

This paper intends to address that the significant interference effect between two high-rise not only comes from the upstream buildings but also the building existing in the downstream area, especially when the two buildings are close to each other. Aeroelastic vibration test and high-frequency force balance tests were conducted for two identical square prism models with an aspect ratio of 8 under a turbulent boundary layer flow. Critical locations for interfering buildings were discussed and shown with altered force spectrum characteristics and different patterns of response trajectories. Finally, an idealized 2D numerical simulation of CFD was tried for the simulations of some critical cases. Although the absolute values from CFD results could not perfectly be compared with the experimental results, the simulated vorticity movement generated from both buildings could provide an intuitive way for the enhancement of the downstream interference mechanism.

2. Research Method

Both the high-frequency balance test and vibration test were conducted in the 18 × 1.8 × 2.2 m boundary layer wind tunnel of Wind Engineering Research Center at Tokyo Polytechnic University. A 1/400 scale turbulent flow over a sub-urban terrain with a power law index exponent for mean velocity profile of 0.19 was simulated by properly equipped spires, saw barriers, and roughness blocks. For the vibration test, a rigid aero-elastic square prism model was manufactured for the role of the principal building. The size of the model was 0.07 m in both width (B) and depth (D) and 0.56 m in height (H), which made it the aspect ratio (H/B) equals 8. The fundamental frequency f_0 was identified as 6.3 Hz in both along-wind (x) and across-wind (y) directions based on free vibration tests; the structural damping ratios, ξ_x and ξ_y, were estimated 0.77% in x and 0.73% in y by random decrement technique. The generalized mass M was 0.15 kg and the mass-damping parameter was determined by

$$\delta = M\xi / \rho B^2 H \tag{1}$$

where ρ is the air density. For the aero-elastic model in this study, the mass-damping parameter was 0.35, which was slightly lower than the range of typical full scale high-rise buildings (0.4 – 0.6) and could be converted to a Scruton number of 1.05 based on the linear mode shape assumption of its rigid elastic feature. The displacement signals were recorded by two laser sensors for x and y directions in the sampling rate of 550 Hz. The sampling length was 16,384 for one sample record and the ensemble size was 15 in order to obtain a statistical result. For the high-frequency force balance test, the square prism model was fixed and un-flexible to the balancer for both horizontal forces measuring in the same sampling conditions. Instantaneous wind velocity was recorded at the model height for further normalizations. The interfering building was made of acrylic and had the identical size of the principal building; unlike the principal model, this interfering model was made rigid and un-flexible providing only the disturbed flow comes from the upstream or the downstream. The interference locations of interest were focused on those considered significant in general (Fig. 1). Both models were orientated with one face normal to the wind.

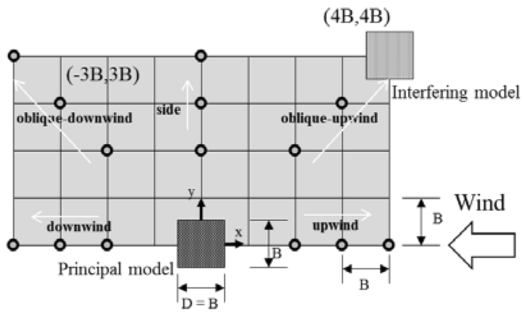

Fig. 1 Diagram of locations for principal model and interfering model

(Figure is extracted from published paper: https://doi.org/10.1016/j.jweia.2016.10.002)

3. Research Results

Downstream interference effect was seldom mentioned in the past. In this study, critical interference locations were selected for the understanding of the formation of interference mechanism either from the upstream or the downstream. Aeroelastic vibration tests, high-frequency force balance tests, and an idealized 2D CFD simulation were conducted for observation and demonstration of difference mechanisms these critical cases could be. From the results, several conclusions are made as below.

(1) The interference effects either from the upstream or from the downstream may not only reduce the wind forces on the principal model, but also amplify them at certain critical locations.

(2) For the principal model with a small Scruton number, the existence of an interfering model largely determines the vibration behavior at the vortex-induced status depending on locations.

(3) Critical cases at (x/B, y/B) = (2, 2) and (-2, 2) were found to be in two different response trajectory shape as indicated by Bailey and Kwok (1985); moreover, another critical case at (-2, 0) was also found in this study with another kind of response trajectory shape, an even larger across-wind vibration and a thinner along-wind vibration. The interfered wind forces were explained through the wind force spectrum shapes in regarded to different reduced velocities.

The mechanism of downstream interference effect of the case at (-2, 0) was enhanced by the vorticity patterns of an idealized 2D CFD simulation results. Although the 2D simulation may not be able to provide exact absolute values for parametric comparisons, the movement of the vortex shedding was demonstrated in a more intuitive way for mechanism formation.

4. Published Paper etc.

Lo, Y.L., Kim, Y.C., 2015. Investigation on Aerodynamic Behavior of High-rise Buildings under Interference Effects, 2015 Symposium of Progress on Wind Engineering and Structural Dynamics, Nov. 1-2, 2015, Tamsui, Taiwan (Presented)

Lo, Y.L., Kim, Y.C., Li, Y.C., Downstream Interference Effect of High-rise Buildings under Turbulent Boundary Layer Flow. (Prepared to submit to international journal)

5. Research Organization

1. Representative Researcher

Yuan-Lung Lo/ Assistant Professor, Dept. Civil Eng., Tamkang Univ., Taiwan (ROC)

2. Collaborate Researchers

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