INTERFERENCE EFFECTS ON ACROSS-WIND RESPONSE OF A SQUARE PRISM BASED ON AERO-ELASTIC TESTS

Yuan-Lung Lo[1] and Yong Chul Kim[2]

[1] *Assistant Professor, Department of Civil Engineering, Tamkang University, Tamsui, New Taipei City, Taiwan, yllo@mail.tku.edu.tw*

[2] *Associate Professor, Department of Architecture, Tokyo Polytechnic University, Atsugi, Kanagawa, Japan, kimyc@arch.t-kougei.ac.jp*

ABSTRACT

In this research, investigation on the vibration of a square prism aero-elastic model interfered by another identical rigid model was conducted by means of wind tunnel tests. Comparisons between isolated model tests and interfered model tests were made in several interference locations. It was found that certain interference locations enlarge significantly across-wind responses as commonly expected from the high-frequency force balance tests. Further, from the experimental results, the leeward interference location can also make distinct across-wind vibrating responses, which sometimes even larger than the cases in the windward locations. It is strongly suggested to include more variety in experimental settings in order to examine the detail information of interference effect.

KEYWORDS: INTERFERENCE, AEROELASTIC, ACROSS-WIND RESPONSE, DAMPING RATIO

Introduction

In recent years, interference effects between buildings gains more and more wind engineering researchers' attention. Amplifying or shielding effects introduced by neighboring buildings have been examined through a large number of wind tunnel tests for the past few decades. Generally speaking, three types of tests were conducted: (1) high frequency force balance tests, (2) surface pressure measurement tests, and (3) aeroelastic model tests. Most observations were made based on the former two. Aeroelastic model tests were, in most of the cases, concerned as a validation role to enhance the concluded mechanism of interfered aerodynamic behavior based on the former two tests. However, Peng and Gu (2003) indicated that differences could be found between the high-frequency force balance (HFFB) test and the aeroelastic model test owing to the occurrence of negative aerodynamic damping of the principal model, which cannot be reflected in the HFFB test. With the consideration of aerodynamic damping, the results from the two types of test could be matched.

In this research, investigation on vibration of interfered a high-rise building is attempted based on aero-elastic tests. An isolated model is preliminarily utilized for the control test. Interfered root-mean-square response is calculated for the across-wind direction. A unit-free interference index of vibration is used to indicate the amplifying or shielding effects. Then, the comparisons between isolated model and interfered model are made for further understanding of this aero-elastic phenomenon.

Experimental Settings

To simplify the possible factors that can disturb the interfered behavior, the same squared cross sectional models with the height-width ratio equals eight are made for the target and the interfering models. One atmospheric boundary layer flow is simulated and the number of interference locations is reduced according to Kim et al. (2013). As in Figure 1, mean wind velocity profile and turbulence intensity profile of the simulated flow are shown. The power law index is 0.19 for a sub-urban terrain. Figure 2 shows the interference locations relative to the target model and the aero-elastic model mechanism. Only the bold circles are discussed in this research. Table 1 lists the assumed parameters in the experiments. The wind velocity at model height is 4.97 m/sec. The attack wind angle is fixed to 0º.

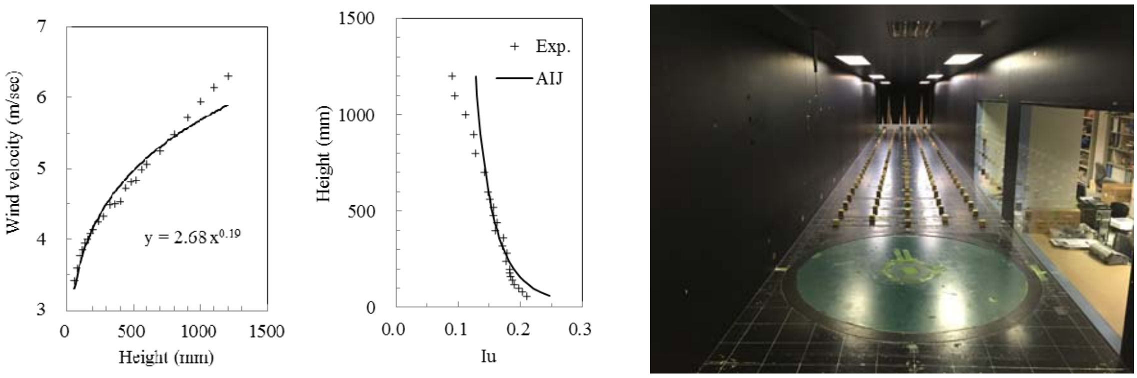


Figure 1: Mean wind velocity profile (left) and turbulence intensity profile (right)

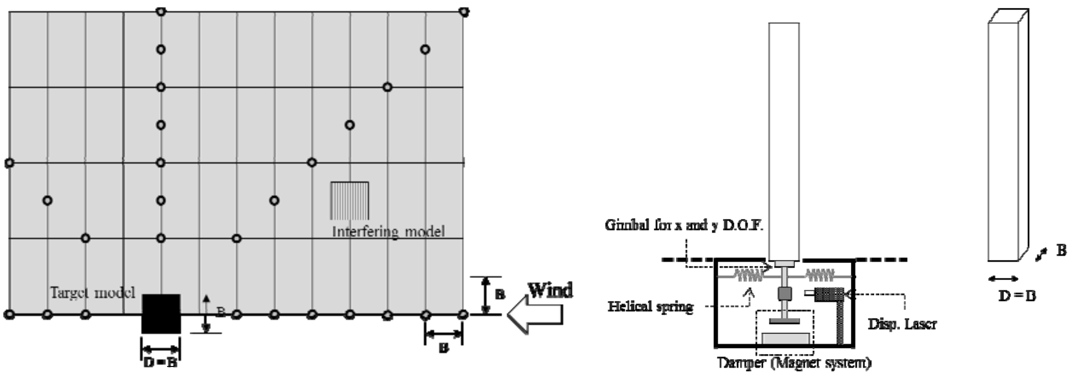


Figure 2: Diagram for interference locations and schematic diagram for aero-elastic model

Table 1: Data processing settings

Scale factor		Structural information		Data processing	
λ_L	1/400	$f_{n,x}$	6.374 Hz	f_s	550 Hz
λ_U	1/20	ξ_x	0.77%	T	30 seconds
λ_T	1/20	$f_{n,y}$	6.374 Hz	Ensemble size	15
		ξ_y	0.73%	Sample length	16500 (≈16384)

Note: x-dir. represents the along-wind direction and y-dir. represents the across-wind direction

Results and Discussions

Isolated Model Test

Figure 3 and 4 show the responses and identified structural frequencies in the along-wind and across-wind direction of an isolated model. It is indicated that the root-mean-square (RMS) value of response increases as reduced velocity. However, in this experiment, the interval of reduced velocity may be too large to see the model's detailed vibrating behavior, especially the range of U/f_nB = 6 ~ 10 in the across-wind direction.

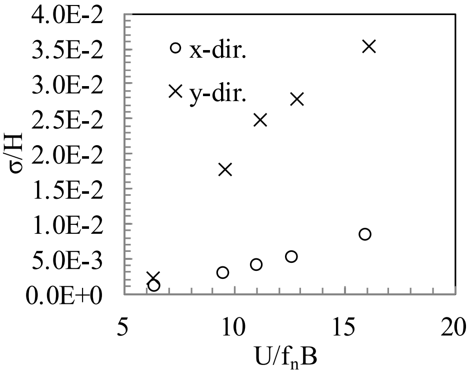


Figure 3: Normalized RMS responses against reduced velocity

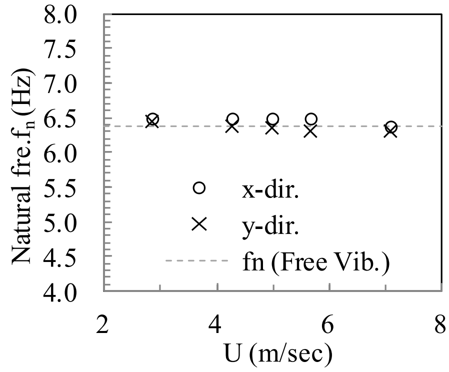


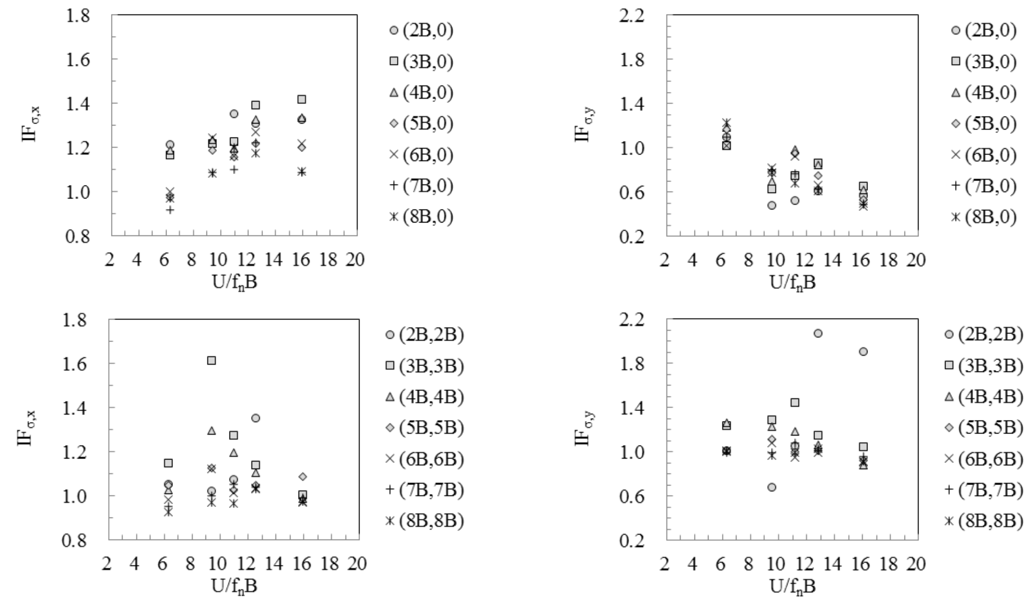
Figure 4: Identified structural frequencies against velocity

Interfered Model Test

To simply discuss the interference effect on along-wind and across-wind directional vibrations, the root-mean-square value of roof displacement from interfered model is normalized by that from isolated model and is indexed $IF_{\sigma,i}$ as shown in Equation 1.

$$IF_{\sigma,i} = \sigma_{i,\mathrm{int}erfered} \big/ \sigma_{i,isolated} \qquad i = x \text{ or } y \tag{1}$$

Figure 5 shows the distributions of interference indices of along-wind and across-wind directions defined as Equation 1. The distribution is plotted into five groups for clearance, which are the windward, the windward-diagonal, the by-side, the leeward-diagonal and the leeward locations.



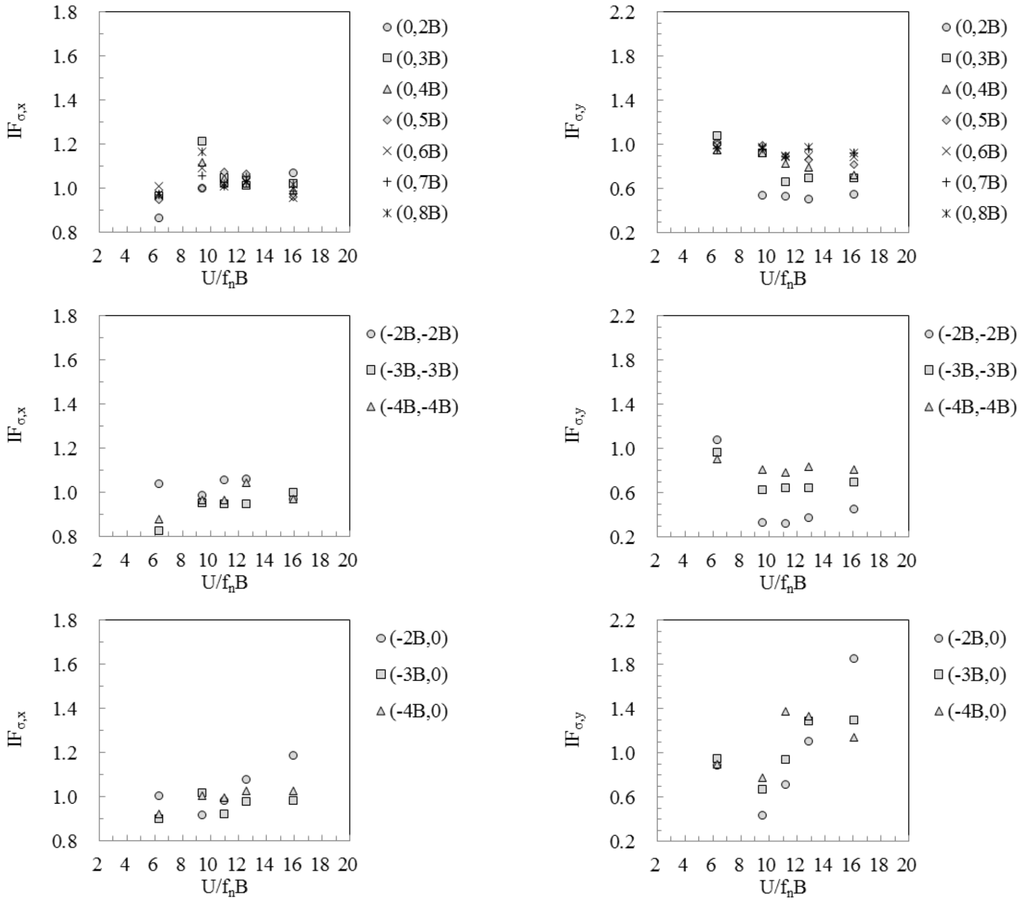


Figure 5: Interference indices of responses against reduced velocity at different locations

Most of the cases show consistent observation as expected. For the along-wind responses, a large along-wind response can be found in the case at (x, y) = (3B, 3B). For the across-wind responses, the case at (x, y) = (2B, 2B) doubles the across-wind response from the isolated model test when the reduced velocity is getting higher. Interestingly, another significant amplifying case can also be found at (x, y) = (-2B, 0) when the reduced velocity is large. Except for the cases in the W locations, amplifying or shielding phenomena have different tendencies before and after the value about 10 for reduced velocity.

Conclusions

In this research, investigation on interference effect on a square prism has been conducted based on aero-elastic tests. The experimental results show not only the windward-diagonal location can significantly enlarge the across-wind response, but also the leeward location which is closer to the target model can result in strong amplification on responses.

Acknowledgement

This work is greatly supported based on the research project approved by Joint Usage/Research Center in Tokyo Polytechnic University.

References

Huang, P. and Gu, M. (2003), "Experimental Study on Aerodynamic Damping of Tall Buildings after Being Interfered", Journal of Tongji University, 31(6), 652-656.

Kim, W., Tamura, Y., and Yoshida, A. (2011), "Interference Effects on Local Peak Pressures between Two Buildings", Journal of Wind Engineering and Industrial Aerodynamics, 99(5), 584-600.