

## **INTERFERENCE EXCITATION MECHANISMS ON CAARC BUILDING MODEL**

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**Abstract:** A pair of Commonwealth Advisory Aeronautical Research Council (CAARC) standard tall building model was tested in 1:400 scale for an reduced wind velocity of 6 under an open terrain. Under the interference effects of a building having similar dimensions, the standard deviation displacement and twist angle responses were increased significantly. Information gathered by simultaneous pressure measurements technique was used to explore the characteristics of and correlation between forces acting on different parts of the affected building. It was found that the additional information is particular useful for explaining the excitation mechanism on tall buildings which can not be properly explained by the measurement techniques which only measure the integrated effects of the surrounding flow on buildings.

## 1 INTRODUCTION

Wind effects on tall buildings have been investigated in many studies since the 1960s. Most of those studies have applied appropriate measurement techniques, with many of the earlier studies using aeroelastic models and more recently the high frequency force balance (HFFB) technique, which measures the overall wind loads acting on a tall building model, to explore the wind-induced excitation mechanisms. Similar approaches were also adopted to explore the excitation mechanisms due to interference effects on tall buildings since 1970s. However, the HFFB technique may not provide adequate information to fully explore the relevant excitation mechanisms. This research aims to investigate interference excitation mechanisms by analyzing the forces acting on a particular part of the affected building. In this research program, the HFFB technique was adopted for a series of wind tunnel tests to investigate the integrated interference effects on a principal building. Simultaneous pressure measurement tests were also conducted to gather pressure data to explore the characteristics of and correlation between forces acting on different parts of the affected building.

## 2 EXPERIMENTAL SETUP

The experiments were conducted in the 3 m x 2 m high-speed test section of the boundary layer wind tunnel of the CLP Power Wind Wave Tunnel Facility at The Hong Kong University of Science and Technology. A pair of CAARC standard tall building models were tested in 1:400 scale and used for both the principal and interfering buildings. The approaching wind was modelled as a terrain category 2 defined in AS/NZS1170.2:2002 in 1:400 scale. Wind-induced responses were determined for a reduced wind velocity,  $U_r = \bar{U}(H)/n_1 b$ , of 6, in which  $\bar{U}(H)$  is the mean wind velocity at the top of the building,  $n_1$  is the natural frequency of the fundamental translational mode of the prototype, and  $b$  is the breadth of the prototype. The incident wind was normal to the breadth of the principal and interfering building as shown in Fig. (1).

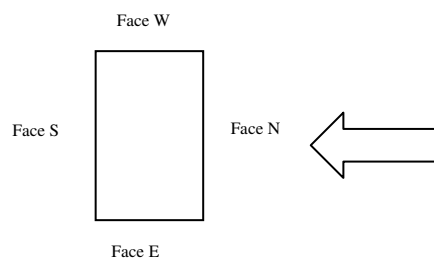


Figure 1: Approaching wind direction with respect to building faces.

By using HFFB technique, the aerodynamic modal forces were estimated from the overturning and torsional moment measured at the base of the building model. Those modal forces were then used to predict the wind-induced responses of the principal building.

Electronic differential pressure transducers were used to measure surface pressure fluctuations on the pressure-tapped building model. 216 pressure taps in total were installed in the pressure-tapped model to achieve a high pressure tap density. The measured fluctuating local pressure time histories were integrated to determine the aerodynamic modal forces acting on the principal building. The modal force characteristics were explored by investigating the force spectra and phase spectra of modal force acting on each building faces.

### 3 EXPERIMENTAL RESULTS AND DISCUSSION

While the force spectra obtained from the HFFB tests, which were used to predict the responses of building, demonstrate the integrated effects of the surrounding flow on the building,

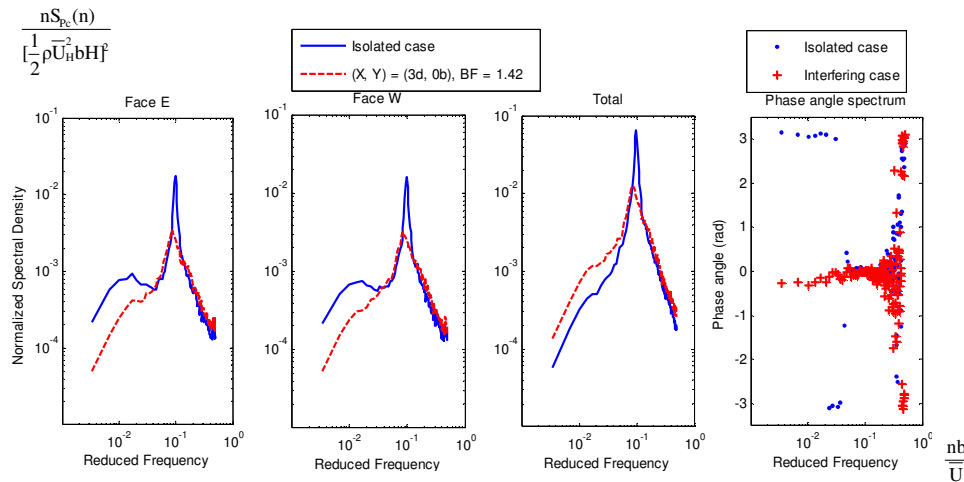


Figure 2: Normalized crosswind force spectra of individual faces and phase angle spectrum of the principal building with and without interfering building at (3d, 0b) obtained from pressure measurement

the force spectra obtained from the pressure test provide information on the frequency composition of forces acting on particular faces of building. Wong [1] showed that the force spectra obtained by both techniques are consistent with each other.

The phase angle spectra, which are particularly useful in determining the influence of the interfering building on the correlation between forces acting on each of the faces of the principal building, were also determined. When the phase angle between forces is close to 0, the forces are in-phase. These forces are combined effectively. When the phase angle between the forces is close to  $\pm\pi$ , the forces are out-of-phase. These forces are counteracting forces. The information from phase angle spectra helps to explain the different energy distributions between the total force spectra and the spectra of force acting on individual faces.

The measured buffeting factors (BF) contours [2] were presented in Wong [1]. Critical locations were identified for standard deviation crosswind displacement response and twist angle response when the interfering building was placed at (X, Y) = (3d, 0b) and (2d, 0b), respectively.

#### 3.1 Standard deviation crosswind displacement responses, (X, Y) = (3d, 0b), BF = 1.42

The excitation energies at a reduced frequency of about 0.1 were reduced significantly and the excitation energies in the high reduced frequency range were enhanced, as shown in the total crosswind force spectra presented in Fig. (2). The excitation energies in the low reduced frequency range were also enhanced. These enhancements were unexpected as the principal building was submerged in the highly turbulent wake region behind the interfering building.

The crosswind forces spectra of side faces show that the excitation energies in the low reduced frequency range were reduced, which is different from the total crosswind force spectrum, as expected. This is attributed to the redistribution of the crosswind excitation energies from the low to high frequency range. The enhancements of the low frequency excitation energies in the total crosswind wind force spectrum are attributed to the combining effect in this frequency range as shown in the phase angle spectrum presented in Fig. (2).

### 3.2 Standard deviation twist angle responses, $(X, Y) = (2d, 0b)$ , $BF = 1.84$

A critical location for standard deviation twist angle response was identified when the interfering building was placed at  $(X, Y) = (2d, 0b)$ . Fig (3) shows the normalized torque spectra acting on the side faces of the principal. The figure shows that the additional energy peak centered at a reduced frequency of about 0.1 was registered in the torque spectra of side faces, which are Face E and W. The energy distributions of torque spectra of the windward and leeward faces, which are Face N and S, were also altered significantly. The excitation energy peak centered at a reduced frequency of about 0.1 was reduced in both spectra. Furthermore, the high reduced frequency excitation energies in the torque spectra of Face N were enhanced significantly. This appears to be the result of the direct influence of the highly turbulent wake region behind the interfering building.

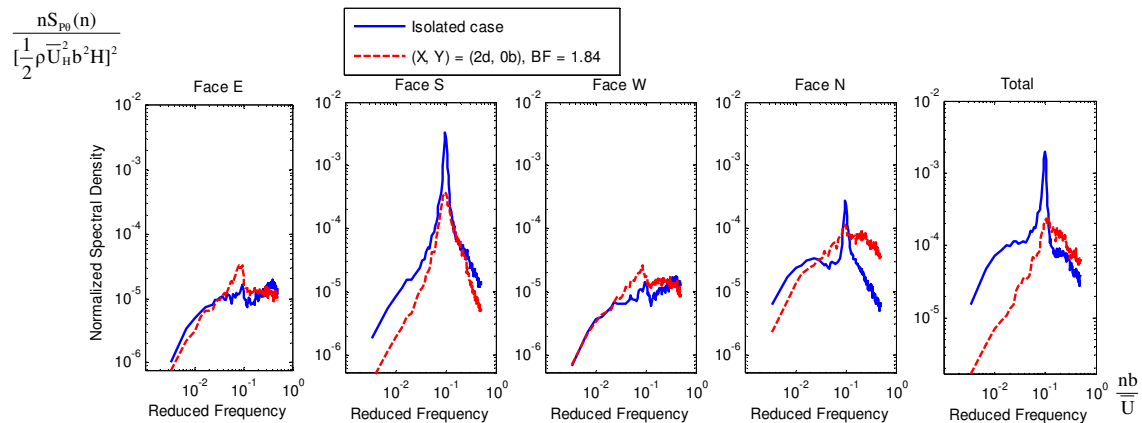


Figure 3: Normalized torque spectra of the principal building with and without interfering building at  $(2d, 0b)$  obtained from pressure measurement

## 4 CONCLUSION

Results obtained using high frequency force balance technique showed that the standard deviation displacement and twist angle responses of the CAARC standard tall building were changed significantly by the presence of an interfering building having similar dimensions, at a reduced wind velocity of 6. For critical building arrangements, the interference effects on the principal building caused an increase in response as high as 80% compared with the isolated building condition.

Simultaneous pressure measurements were also used to explore the excitation mechanisms due to interference effects. Results of correlation analyses based on the measured pressure data sheds new light on the interference excitation mechanisms and complement the results obtained from the high frequency force balance tests.

## 5 REFERENCES

- [1] K.S. Wong, *Wind-induced interference effects on eccentric tall buildings*. MPhil Thesis, Dept. Civil Eng., The Hong Kong University of Science and Technology, 2007
- [2] J.W. Saunders and W.H. Melbourne, Buffeting effects of upstream buildings. Proceedings of 5th International Conference On Wind Engineering, Fort Collins, Colorado, Pergamon Press, Oxford, 1979, pp. 593 – 608.