The wind features of Taipei 101 Financial Building

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ABSTRACT: Wind features of the 508 m height Taipei 101 Financial Building are explored in an atmospheric turbulent boundary layer wind tunnel using a 1/500 model scale. The inverted-trapezoidal sections of the building tend to localize the wind effects on the building by retarding the pressure increasing rate and cause surface pressures to oscillate and exhibit jump behaviors. The effects of surrounding buildings can be large depending on their relative positions with respect to the 101 Building.

KEYWORDS: building aerodynamics, wind tunnel test, surface pressure, unsteady flows

1. INTRODUCTION

As one of the highly populated countries in the world, Taiwan has quite a few tall buildings. Among them, the Taipei 101 Financial Building is the most recent and tallest one. With its height of 508 m, it is also currently the highest building in the world. On the other hand, due to the unique geographical location, the buildings and structures of Taiwan need to withstand typhoons and earthquakes. For tall buildings, such as Taipei 101 Financial Building, current building codes require wind tunnel tests in the design stage to ensure building's safety and people's comfort. On November 1, 2005, typhoon Longwang swept through Taiwan and caused considerable damage to the eastern counties of Taiwan. The tuned-mass-damper of the 101 building also swung noticeably. But there was neither damage nor discomfort reported from the building administrator. It is undoubtedly that the building's wind-resist design is sufficient. This kind of tall building wind-resist capability is quite common(1) as wind tunnel tests are always required to access the design(2,3).

In this study, the wind features of a 1/500 scale model of the Taipei 101 Financial Building are explored by wind tunnel tests. Thus its wind field can be understood and the data can be used for the purpose of CFD validation.

2. Experimental approach

Experiments were conducted in the Atmospheric Wind Tunnel Facility of Architectural Building Research Institute, Department of Interior, located at Guei-Zen Campus, National Cheng Kung University. The tunnel is a continuous flow type and can be either closed-return or open-return, depending on the test objective. For building and bride tests, it is always running as a close-return tunnel, while for air pollution tests, it is open-return. The tunnel has two test sections, the first for building and the second for bridge tests. The former has a cross test sectional area of 4 m x 2.6 m, whereas the latter 6 m x 2.6 m. The maximum speed is about 30 m/s.

In this study, experiments were carried out in the first test section using a 1/500 scale model with a total height of 96.7 cm. The building has eight inverted trapezoidal sections, symbolizing countless influx of money, with the maximum width of 10.5 cm. The aspect ratio, excluding the top telecommunication post section, is about 8, typical for a tall building. The wind environment adopted wae a city type with a power law exponent of 0.36 and a boundary layer thickness of 120 cm.

Two model configurations were examined. One was the Taipei 101 Financial Building itself and the other was the building with other surrounding buildings as shown in figures 1(a) and 1(b), respectively. The mean turbulent velocity was measured by Pitot-static pressure probes. Turbulent quantities were measured by a constant temperature hot wire anemometry. Surface pressures were measured by pressure tabs on the model surfaces and connected to the RAD 3200 pressure transducers by plastic tubes. Tunnel temperatures were monitored by thermometers and RTD sensors.

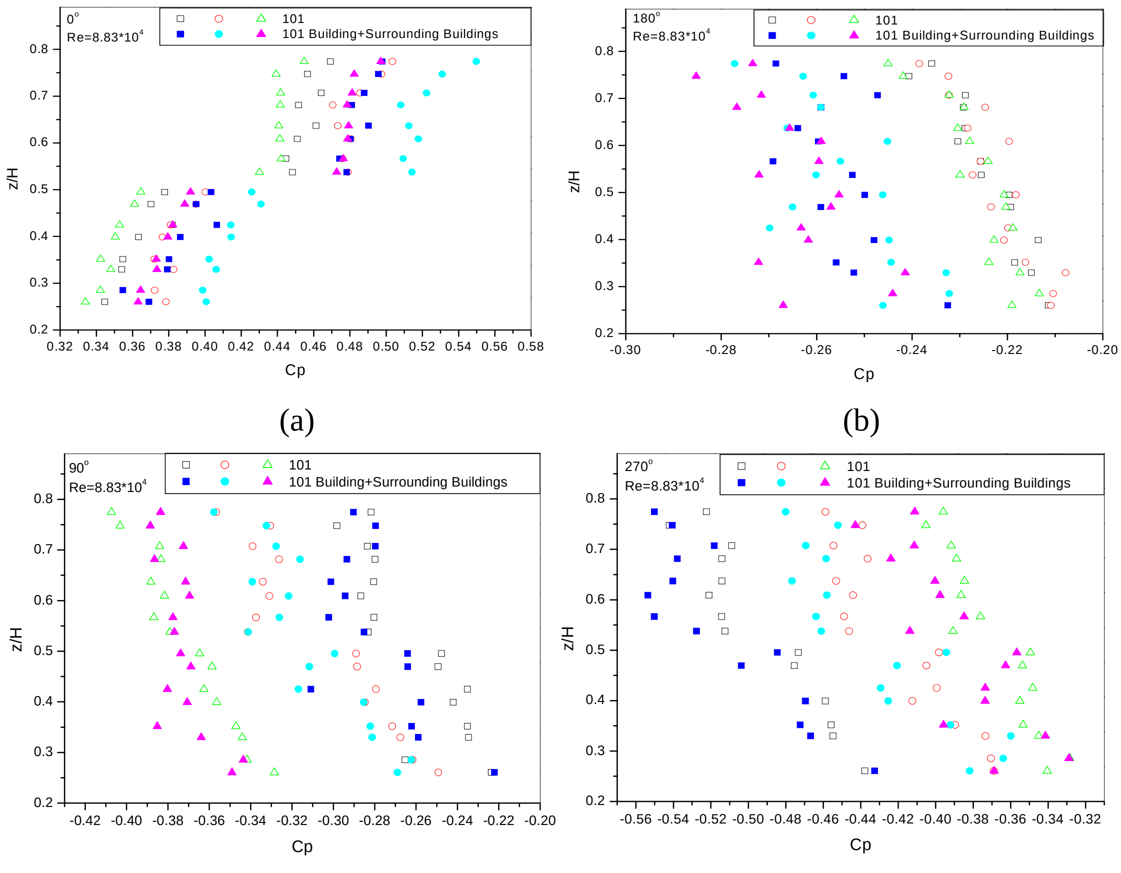
(a) 101 Building

(b) 101 Building + Surrounding Buildings

Fig. 1 Wind tunnel model test configurations

3. Results and discussion

Surface pressure distributions are shown in Fig. 2. At 0-degree wind direction, Fig. 2(a), (b), (c) and (d) depict the surface pressures on the windward face (0-degree face), leeward face (180-degree face), 90-degree side face and 270-degree side face, respectively. In each figure, two sets of results corresponding to the two model configurations mentioned above are presented; namely, one set for the 101 Building alone, the other set for the 101 Building with surrounding buildings. From Fig. 1(a), it can be seen that on the windward face, surface pressures increase with building height as expected. With the surrounding buildings, the surface pressures are larger than those at the corresponding locations without surrounding buildings. Comparing to a typical rectangular surface, the trapezoidal geometry shows two distinct features. First, surface pressures tend to oscillate as the height increases and their rate of increase is hindered by the discontinuous trap. Second, there is a relatively large jump in pressures at the mid-height of the building. This relatively large jump is likely caused by a combination of the retarding effect of geometric discontinuity and increasing dynamic pressures as the height increases. These two features are quite different from the fairly smooth increase in surface pressures of a rectangular building.



(a) (b)

(c) (d)

Fig. 2 0-degree wind-direction surface pressures coefficient distributions (0, 90, 180 and 270 degrees surfaces)

The pressure oscillations can also be observed at the other three faces shown in Fig. 2(b) through 2(d), indicating a persistent influence of the geometric discontinuity on the flow fields. As for the pressure distributions between the 101 Building with and without surrounding buildings, a large difference exists at the leeward face (Fig. 2(b)). Thus, the wind load in the along-wind direction is larger for the configuration of the 101 Building with surrounding buildings.

As a further comparison, the fluctuation pressure coefficients for the above four faces are shown in Fig. 3 as a function of the normalized building height. It can be seen that on the 0-degree surface, pressure fluctuation levels are higher for the configuration with surrounding buildings, primary due to some low-rise buildings upstream of the 101 Building. In contrast, the difference between the model test configurations is smaller on the 90- and 180-degree faces. A large difference also occurs for the 270-degree face, especially in the lower portion of the 101 Building, due to groups of surrounding buildings on this side of the 101 Building. Furthermore, all of the faces, except the 180-degree face, exhibit a relatively large jump in fluctuation surface pressure coefficients near the mid-height of the 101 Building, a trend consistent with that shown in Fig. 2. In other words, the geometrical discontinuity of the trapezoidal shape has special effect not observed in other types of buildings.

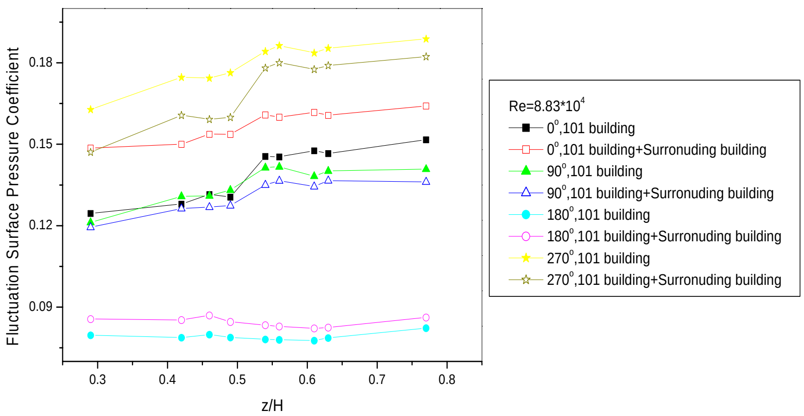


Fig 3. Fluctuation surface pressure coefficients (0-degree wind-direction, Re=8.83x10^4, 0-, 90-, 180-, 270-degree surfaces, H=building height)

4. Conclusions

Experiments were conducted for the Taipei 101 Financial Building by wind tunnel model tests. Key results show that the discontinuities of the trapezoidal sections of the 101 Building cause oscillation and jump in surface pressures. The effects of surrounding buildings depend strongly on their relative positions to the 101 Building.

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