Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 199 (2017) 28–37

Procedia Engineering

www.elsevier.com/locate/procedia

10th International Conference on Structural Dynamics, EURODYN 2017

Aerodynamic and Pedestrian-Level Wind Characteristics of Super-Tall Buildings with Various Configurations

Yukio Tamura[a b,*], Xiaoda Xu[a], Hideyuki Tanaka[c], Yon Chul Kim[a], Akihito Yoshida[a], Qingshan Yang[d]

[a]*Beijing's Key Laboratory of Structural Wind Engineering and Urban Wind Environment, School of Civil Engineering, Beijing Jiaotong University, Beijing 100044, China*

[b]*Wind Engineering Joint Usage/Research Center, Tokyo Polytechnic University, Atsugi, Kanagawa, 243-0297 Japan*

[c]*Takenaka Corporation Research & Development Institute 1-5-1, Ohtsuka Inzai, Chiba 270-1395, Japan*

[d]*School of Civil Engineering, Chongqing University, Chongqing 400044, China*

Abstract

Recent super-tall building design has been released from the spell of compulsory symmetric shape design, and free-style design is increasing. This is mainly due to architects' and structural designers' challenging demands for novel and unconventional expressions. Another important aspect is that rather complicated sectional shapes are basically good with regard to aerodynamic properties for cross-wind responses. A series of wind tunnel tests have been carried out to determine aerodynamic performance and pedestrian-level wind characteristics of many super-tall buildings with various configurations: square plan, rectangular plan, elliptic plan, with corner cut, with corner chamfered, tilted, tapered, inverse tapered, with setbacks, helical, openings and so on. Dynamic wind-induced response analyses of these models have also been conducted. The results of these tests have led to comprehensive discussions on the aerodynamic and pedestrian level wind characteristics of various tall building configurations.

Peer-review under responsibility of the organizing committee of EURODYN 2017.

Keywords: super-tall building; wind-induced response; pedestrian level wind, polygon plane; helical shape; tapered shape; and opening.

* Corresponding author. Tel.: +818055068434; fax: +818055068434
E-mail address: yukio@arch.t-kougei.ac.jp

1877-7058 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the organizing committee of EURODYN 2017.
10.1016/j.proeng.2017.09.146

1. Introduction

The trend of manhattanization requires the attention of wind engineering researchers, particularly the increasing preference for free-style building shapes, as seen in Burj Kalifa and Shanghai Tower. To avoid excessive seismic-induced torsional vibrations due to eccentricity, super-tall buildings have been traditionally designed to be symmetric rectangular, triangular or circular in plan. However, freewheeling building shapes have advantages not only in architectural design reflecting architects' challenging spirits for new forms but also in structural design reducing wind loads. Development of analytical and vibration control techniques has greatly contributed to this trend. In particular, cross-wind response, which is a major factor in safety and habitability of tall buildings, is greatly suppressed.

The authors' group has conducted wind tunnel experiments for super-tall buildings with unconventional configurations to investigate the aerodynamic response and pedestrian level wind characteristics. The findings provide the structural designer with comprehensive wind tunnel test data that can be used in preliminary design, and can be helpful in evaluating the most effective structural shape in wind-resistant design for tall buildings with various aerodynamic modifications. The characteristics of pedestrian-level wind are significantly affected by some important parameters such as corner modifications, twist angle of helical models, number of sides of building plan, etc.

2. Wind Tunnel Experiments

2.1. Approaching flow conditions

Wind tunnel experiments were performed in a closed-circuit-type boundary-layer wind tunnel whose working section is 1.8m high by 2.0m wide. **Figure. 1** shows the condition of the approaching turbulent boundary layer flow with a power-law index of 0.27, representing an urban area.

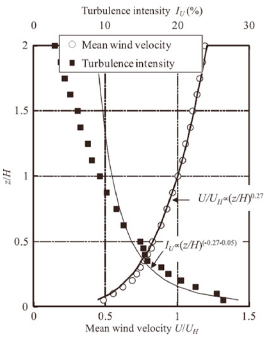

Fig.1. Flow conditions of wind tunnel experiment [1].

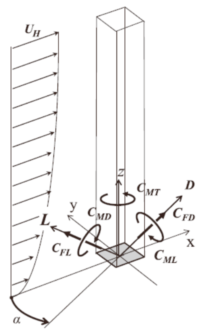

Fig. 2. Coordinate system [1].

Dynamic wind forces were measured by a 6-component high-frequency force balance supporting light-weight and stiff models. The measured wind forces and aerodynamic moments are normalized by $q_H BH$ and $q_H BH^2$ to get wind force coefficients and moment coefficients, respectively. Here, q_H is the velocity pressure at model height H, and B is commonly set at the width of the Square Model. Thus, the force and moment coefficients of the models can be directly compared. **Figure. 2** shows the definitions of wind forces and moments, and the coordinate system employed in this study. Wind pressure measurements were conducted on 28 models. They were determined from the results of aerodynamic force measurements and for relatively realistic building shapes in the current era. The details of wind tunnel tests for aerodynamic characteristics of super-tall building models should be referred to Tamura et al. (2010)[1].

Pedestrian-level wind measurements were conducted on 40 models. To make the measurements more accurate, thermistor anemometers were set 5mm above the wind tunnel floor (2.5m above the ground in full scale), a little bit higher than an average human being's height. Anemometers were distributed over an area of 792mm×792mm, which is almost 8 times the square model's side, and the pitch between two sensors was a minimum of 2cm in the inner area.