GCOE Program TPU
New Frontier of Education and Research in Wind Engineering

Wind Effects

New Frontier of Education and Research in Wind Engineering

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INDEX

Report on "The 9th International Advanced School on Wind Engineering" (IAS9) in Metro Manila, Philippines

Date: August 13-15, 2012 (Structural Wind Engineering)
August 15-16, 2012 (Environmental Wind Engineering)
Venue: University of the Philippines, Diliman, Quezon City, Philippines

The International Advanced School (IAS) on Wind Engineering is one of the educational activities of the Global Center of Excellence (GCOE) Program of Tokyo Polytechnic University entitled "New Frontier of Education and Research in Wind Engineering." Its aim is to provide advanced professional training in the field of wind engineering.

The 9th IAS was held in Metro Manila, Philippines, from the 13th to the 16th of August, 2012. It was co-hosted by the GCOE Program of TPU led by Prof. Yukio Tamura (TPU), the University of the Philippines (UP), the Institute of Civil Engineering (ICE) and the UP National Engineering Center (NEC). The UP-side coordination was led by Prof. Jaime Hernandez Jr. and Prof. Maria Antonia Tanchuling (UP-ICE), in cooperation with the UP Office of the Vice Chancellor for Research & Development's (OVCRD) Prof. Benito Pacheco, Prof. Alexis Acacio (UP-ICE Director), Mrs. Arlene de Ocampo (NEC), and the rest of the NEC and UP-ICE staff.

The 4 days of the IAS9 was divided into two courses with different themes: Structural Wind Engineering (SWE) and Environmental Wind Engineering (EWE). Nine (9) globally renowned wind engineering experts from Canada, China, Germany, Japan, and New Zealand were invited to deliver advanced lectures on many different topics. Three (3) lecturers from UP also gave presentations that provided added information on local practices. The details of the lectures were as follows:

Structural Wind Engineering

Prof. Richard Flay (The University of Auckland)

- The planetary boundary layer
- Bluff body aerodynamics
- The Gust factor approach for analysing the along-wind response of tall structures

Prof. Theodore Stathopoulos (Concordia University)

- Understanding wind codes and standards: Fundamentals behind their provisions, Part I
- Understanding wind codes and standards: Fundamentals behind their provisions, Part II
- Understanding wind codes and standards: Fundamentals behind their provisions, Part III

Prof. Lingmi Zhang (Nanjing University of Aeronautics & Astronautics)

- Advances of operational modal analysis for building structures
- Advances of structural system identification and its potential for wind engineering application
- Structural condition assessment based on flexibility from ambient structural response

Prof. Michael Kasperski (Ruhr University, Bochum)

- Estimation of the design wind speed
- Specification of the design value of the aerodynamic coefficient
- Identification of the effective pressure distribution

Prof. Shuyang Cao (Tongji University)

- Actively-controlled wind tunnels
- CFD applications to some structural wind engineering problems
- Strong winds and their characteristics

Prof. Yukio Tamura (Tokyo Polytechnic University)

- Most efficient observations of random fields I
- Most efficient observations of random fields II
- Monitoring techniques in wind engineering

Prof. Jaime Hernandez, Jr. (University of the Philippines)

- Development of fragility curves of key building types due to severe wind loading using CFD I
- Development of fragility curves of key building types due to severe wind loading using CFD II

- Development of fragility curves of key building types due to severe wind loading using CFD III

Environmental Wind Engineering

Prof. Theodore Stathopoulos (Concordia University)

- Wind-induced dispersion of pollutants in the urban environment

Prof. Michael Schatzmann (University of Hamburg)

- Properties of Urban and Industrial Canopy Layer Flows
- Issues with validation of RANS CFD flow and dispersion models
- Issues with validation of LES CFD flow and dispersion models

Prof. Akashi Mochida (Tohoku University)

- Prediction of urban environment based on engineering CFD models
- Analysis of urban environment to guide urban design and site planning I
- Analysis of urban environment to guide urban design and site planning II

Mr. Michael Roberto Reyes (Philippine Green Building Council)

- Green Building Rating Systems in the Philippines

Prof. Rheo Lamorena-Lim

- Indoor Air Quality

Prof. Ryuichiro Yoshie

- Energy conservation effects of hybrid ventilation in high-rise office buildings
- Influence of form of building groups on urban ventilation
- Simultaneous measurement of fluctuating velocity, temperature and concentration in non-isothermal flow

The 9th IAS received excellent responses from students, engineers, designers, researchers, scientists, and consultants working in the fields of structural and environmental wind engineering. It attracted around 48 attendees in the SWE course and 20 in the EWE course, representing the academe, government institutions, consulting firms, and other private sector institutions. They all benefited from the two courses via rigorous discussions between participants and lecturers. The 9th IAS was evidently appreciated by the participants, who expressed the view that more international activities of this kind should be organized to facilitate collaborations and acknowledge exchanges.

A closing ceremony was held on August 15, 2012 for the SWE course attendees and on August 16, 2012 for the EWE course attendees, in which the participants received their certificates of participation in a "graduation ceremony"-like atmosphere, complete with heart-warming closing speeches from Prof. Benito Pacheco of the UP-OVCRD and Prof. Yukio Tamura of TPU. The success of the 9th IAS was a collaborative effort between TPU thru its GCOE program, and UP.

Report on the 7th China-Japan-Korea International Workshop on Wind Engineering

Date:June 1, 2012
Venue: POSCO International Center,Pohang Korea

The Japan-China-Korea International Workshop on Wind Engineering was held at the University of Science and Technology (POSTECH) in Pohang, Korea on 1st June 2012. This workshop has been held in either Japan or Korea since 2005, except for one adjournment because of swine flu. The original name of the workshop was JaWEiK (Japan Association of Wind Engineering and Wind Engineering Institute of Korea) and it has been co-sponsored by the 21st COE program of Tokyo Polytechnic University. At the last workshop, held at the Disaster Prevention Research Institute at Kyoto University, there was a formal consultation regarding participation by Chinese researchers. As a result, this year's workshop included researchers from three countries as a forum for information exchange in the field of wind engineering. Furthermore, the name of workshop was changed to CJK

(China-Japan-Korea) International Workshop on Wind Engineering.

The workshop began with greetings by the president of the Wind Engineering Institute of Korea (WEIK) Prof. Sang-Jun Lee (POSTECH). Next, 21 presentations were made by participants (7 by China, 8 by Korea, and 6 by Japan).

At the end of the workshop, Prof. Lee introduced POSTECH, announcing that it had achieved the 1st rank among universities established less than 50 years ago. POSTECH is a very new university (founded at 1986), and as of 2012 accommodated 266 professors, 1414 undergraduate students, and 1870 graduate students. POSTECH is a relatively small university, but its facilities, i.e. dormitories, restaurant, etc, are well maintained and of high-quality. Furthermore, it provides many opportunities for undergraduate students to obtain scholarships.

After the workshop, technical tours were made at Korea's only synchrotron radiation facility and wind tunnel.

Figure 1 Assembly picture of attendees

Figure 2 Technical tour of synchrotron radiation facility

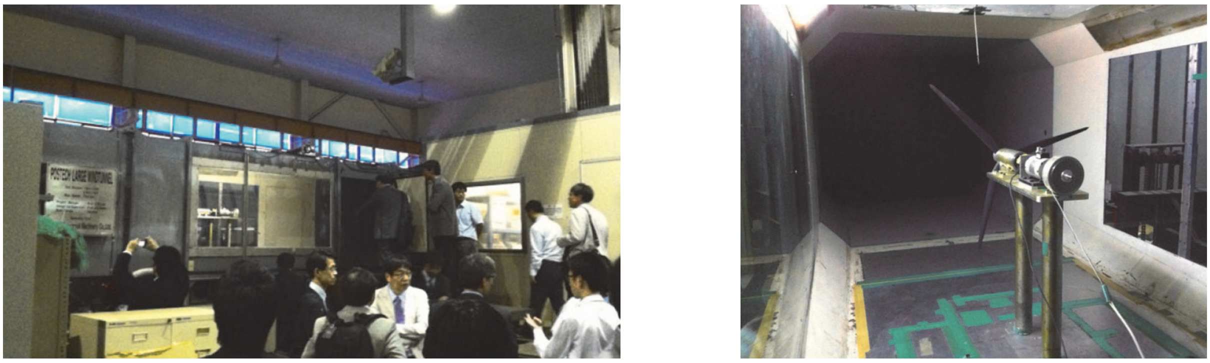

Figure 3 Technical tour of wind tunnel facility

Report on the 5th International Workshop on Equivalent Static Wind Loading

Date: June 2, 2012
Venue: POSCO International Center,Pohang Korea

The 5th International Workshop on Equivalent Static Wind Loading was held at POSCO International Center, POSTECH in Pohang, Korea on 2nd June 2012. The workshop is a part of strategic international cooperative program entitled "Evaluation and mitigation of environment impacts of earthquake and typhoon disaster on urban area and infrastructures." It is run by Tokyo Polytechnic University, Tongji University and Beijing Jiaotong University, and is funded by the Japan Science and Technology Agency and the National Natural Science Foundation of China. The workshop is held twice a year; the 1st was held at Tongji University, the 2nd at Tokyo Polytechnic University, the 3rd at Beijing Jiaotong University, and the 4th at the Disaster Prevention Research Institute at Kyoto University. After interim reports by Chinese and Japanese groups, research presentations of each sub-project were made: 4 by Japanese groups and 9 by Chinese groups. Prof. Ishihara of The University of Tokyo, who joined as an observer, gave one presentation concerning design wind speed. The next and last workshop of the cooperative program will be held at Miyako island in November 2012.

Figure 1 POSCO International Center

Report on the 7th International Colloquium on Bluff Body Aerodynamics and Applications (BBAA7)

Date: September 2-6, 2012
Venue: Jin Jiang Tower Hotel, Shanghai

The 7th International Colloquium on Bluff Body Aerodynamics and Applications (BBAA7) was held from September 2 to 6 at the Jin Jiang Tower Hotel in Shanghai. There were 206 presentations, including 5 keynote presentations, 2 invited lectures, 24 special presentations in three organized sessions and 175 normal presentations in 25 general sessions. The following papers were presented by members of the Tokyo Polytechnic University Global COE Program.

Masahiro Matsui, Takeshi Ohkuma, Yukio Tamura, "Evaluation of time history of design wind speeds and directions using typhoon model and empirical wind speed ratio"

Yukio Tamura a, Akira Katsumura, "Universal equivalent static wind load for structures"

Yi Hui, Akihito Yoshida, Yukio Tamura, "Interference effect on local peak pressure between two high-rise buildings with rectangular shape"

Thai-Hoa Le, Yukio Tamura, "Unsteady buffeting prediction of bridges using proper orthogonal decomposition"

Akihito Yoshida, Bandi Eswara Kumar, Yukio Tamura, Yong Chul Kim, Q. Yang, "Experimental investigation on aerodynamic characteristics of various triangular-section high-rise buildings"

Feng Wang, Yukio Tamura, Akihito Yoshida, Rei Okada, "Wind force characteristics of scaffoldings with sheets"

Geetha Rajasekharan Sabareesh, Masahiro Matsui, Yukio Tamura, "Ground roughness effects on internal pressures and local roof wind forces of building exposed to tornado-like flow"

Yong Chul Kim, Akihito Yoshida, Yukio Tamura, Hirotoshi Kikuchi, Kazuki Hibi, "Numerical simulation of pressure and flow field in large group of low-rise buildings"

Jinxin Cao, Yukio Tamura, Akihito Yoshida, "Aerodynamic characteristics of trees for green roofing systems"

Tingting Hu, Ryuichiro Yoshie, "Ventilation efficiency indices for evaluating ventilation performance of newly-built urban area"

Zhibin Ding, Yukio Tamura, Akihito Yoshida, "Internal stresses in cladding support members of long-span arched roof under wind load"

Jianying Jiao, Ryuichiro Yoshie, "Large-eddy simulation of flow around obstacle arrays using drag force method of gas-solid two-phase flow"

Ryuichiro Yoshie, Masanori Mochizuki, "Regeneration of occurrence frequencies and vertical profiles of wind velocity by WRF calculation"

Report of damage due to tornadoes in North Kanto area on May 6, 2012

Rei Okada, Masahiro Matsui, Akihito Yoshida, and Yukio Tamura
Tokyo Polytechnic University

1 . Outline of tornadoes that occurred on May 6th.

The 4 tornadoes shown in Table 1 occurred on May 6th in the north part of the Kanto area. The information in Table 1 can be seen on the Japan Meteorological Agency (JMA) homepage. Fig. 1 shows the F scale and size of the damaged areas.

Table 1 Tornado that occurred on May 6th

Tornado	City or Town [Prefecture]	F-scale by JMA	Damaged Area L×W
1	Joso, Tsukuba [Ibaraki]	F3 *	17km × 0.5km
2	Chikusei, Sakuragawa [Ibaraki]	F1	21km × 0.6km
3	Mooka, Mashiko, Motegi [Tochigi] Hitachi-omiya [Ibaraki]	F1 − F2	32km × 0.65km
4	Ohnuma [Fukushima]	F1	2km × 0.3km
* NOTE: F4 according to TPU investigation.			

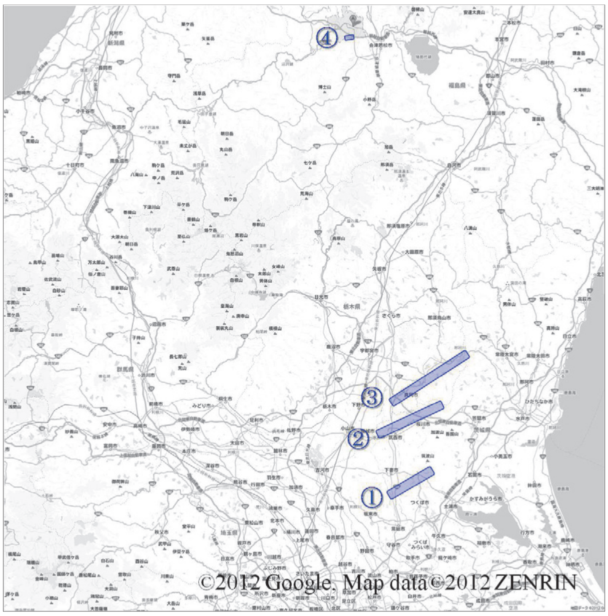

Fig. 1 Location of tornadoes

The damage statistics are shown in Table 2. This information has also been released on the JMA homepage.

The Wind Engineering Research Center, Tokyo Polytechnic University did a field investigation of the damaged area on May 7th, 8th, 9th and 13th [Tsukuba, Joso, Chikusei, and Sakuragawa]. This report summarizes the damage status in Joso city and Tsukuba city. This tornado is called the Tsukuba tornado in this report.

2. Outline of damages due to Tsukuba tornado

Fig. 2 shows the tornado path estimated from damage to structures.

Table 2 Statistics of damages due to tornado

Prefecture	City	Human		Damage to Residences			Damage to Non-residential buildings		
		Dead	Injured	Totally	Half	Partially	Totally	Half	Partially
Ibaraki	Tsukuba	1	37	76	158	388	105	60	243
	Joso	0	0	0	0	12	0	0	16
	Chikusei	0	1	0	0	115	7	1	104
	Sakuragawa	0	2	0	1	29	9	1	42
	Hitachiomiya	0	1	0	1	18	5	1	30
Tochigi	Mooka, Mashiko, Motegi	0	11	13	34	420	453		
Fukushima	Aizumisato	0	0	3			16		

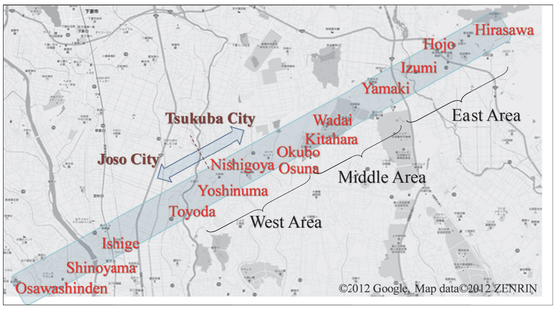

Fig. 2 Damage area of Tsukuba Tornado

The damage started from Ohsawa-shinden, in Joso city. The damage in Joso was are not severe. When the damage investigations were conducted, most damage had already been fixed, so this report summarizes the damage that occurred in Tsukuba city, which was concentrated in the Nishigoya, Yamaki, and Hojo areas.

The following sections show the damage in chronological order.

The damage is classified into 3 categories. The red, blue, and orange circles indicate totally collapsed structures, slightly damaged structures, and moderately damaged structures, respectively, in the following damage footprint figures.

The damage is divided into 3 areas and is described in sections 2.1 ~ 2.3.

2.1 Damage in Yoshimura , Nishigoya, Ohsago areas

After the tornado passed from Joso City to Tsukuba city, it passed over a rural area.

The damage foot prints in Yoshinuma, Nishigoya, Ohsago area [West area] are shown in Fig. 3. In the Yoshinuma area, some dwellings sustained damage to roof tiles, openings etc. However, no structural members sustained any damage. In the Nishigoya and Osuna areas, some structures sustained structural damage. Fig. 4 shows dwellings whose structural members sustained severe damage. Fig. 5 shows damage to claddings of a storage structure and a collapsed stone wall.

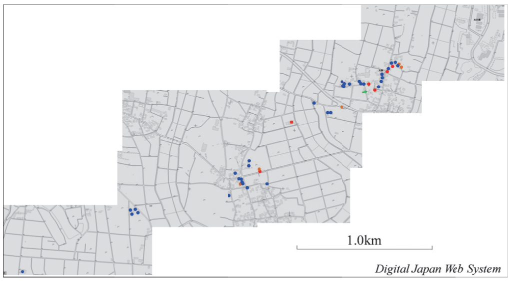

Fig. 3 Damage foot prints (West area)

Fig. 4 Severely damaged structures

Fig. 5 Damaged storage structure and cololapsed wall

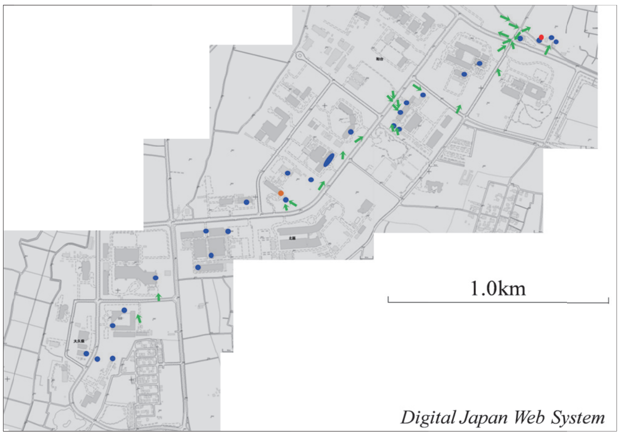

Fig. 6 Damage foot prints (Middle area)

2.2 Damage in Okubo, Kitahara, and Wadai areas

Fig. 6 shows the damage footprints in the Okubo, Kitahara, and Wadai areas [Middle area], which are an industrial zone. The tornado passed through the center part of this zone. Most buildings (Factories, Technical Institute of some companies) in this zone were RC or SRC structures. No structural members sustained damage in this area. However, there was major damage to windows and exterior-facing ceiling boards. Also many fallen trees were observed in this area. Fig. 7(a) shows a structure that sustained damage to its roof panels and cladding. Fig. 7(b) shows a structure that sustained damage to its stairwell glass. Fig. 7(c) shows the damaged structure. Its ceiling panel and entrance hall glass was broken. Fig. 7(d) shows an uprooted tree. In this area, 25 uprooted trees were observed. The locations and inclined direction are shown by green arrows in Fig. 6.

(a) Damage to wall and roof (b) Damaged stairwell glass

(c) Damaged ceiling and windows (d) Uprooted tree

Fig. 7 Damaged structures and tree

2.3 Damage in Yamaki, Izumi, Hojo, and Hirasawa areas

Fig. 8 shows the damage footprints in the Yamaki, Izumi, Hojo, and Hirasawa areas [East area].

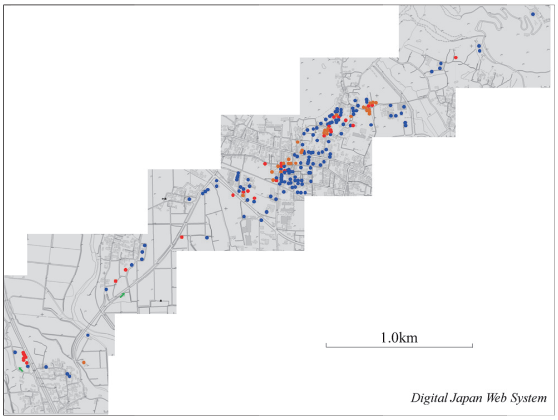

Fig. 8 Damage foot prints (East area)

In the Yamaki area, 7 wooden houses in one block collapsed totally, except the basement, as shown in Fig. 9. Fallen trees are shown in Fig. 10. The fallen directions are mostly westward. Near this damaged area, a storage structure collapsed completely, as shown in Fig. 10. The columns of this structure were damaged and layer collapse was occurred.

Fig. 9 7 houses totally collapsed

Fig.10 Fallen trees and totally collapsed storage

Fig. 11 shows the damage footprints in the Hojo area. One dwelling was overturned, including the basement. Based on our field investigation, in this area, more than 50 structures sustained severe damage. Including slight damage, a total of 150 structures sustained damage.

In Fig. 12, major damage to 17 structures are shown in 10 pictures.

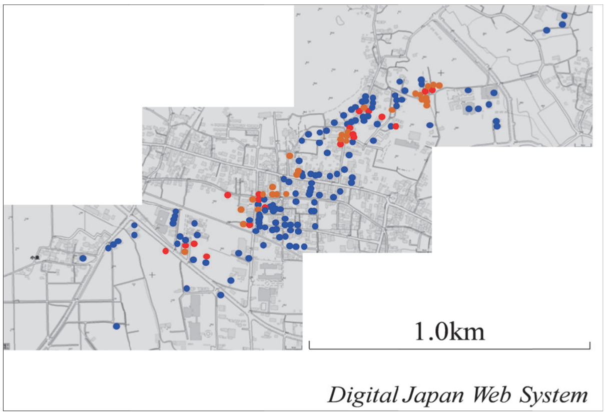

Fig. 11 Damage foot prints in Hojo area

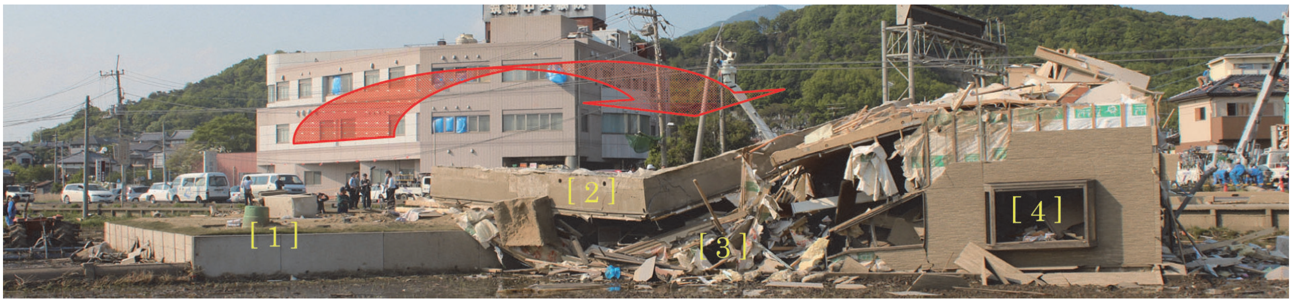

Fig. 12(a) Overturned house

Fig. 12(b) Apartment damaged by debris.

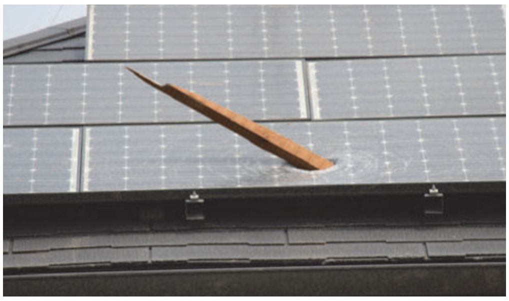

Fig. 12 (c) Debris

Fig. 12(d) and (e) Totally collapsed wooden houses in downtown area

Fig. 12(f) Shed roof panel blown off

Fig. 12 (g) Damage to cladding

Fig. 12(h), (i), and (j) Tornado caused immense damages to houses

In Fig. 12(a), the house was located at [1] before the tornado. During the tornado, the structure was overturned, and as a result, the basement turned upside down and moved to position [2]. The frame etc of the 1st and 2nd floors is located at positions [3] and [4], respectively, in this picture. The Fujita Scale of this tornado was first assessed as 2. However, based on the damage to the basement of this structure, the scale was upgraded to 3. In the past, 3 F3-class tornadoes (Mobara [1990], Toyohashi [1999], Saroma [2006]) have occurred in Japan.

The damage described in this report represents only a fraction of the damage due to this F3 class tornado. Most of the damage was caused by Vortex-Winds

[https://www.vortex-winds.org/damagedb/]

Report of damage by tornado in Aomori Prefecture on July 5, 2012

Rei Okada
Tokyo Polytechnic University

1 . Outline of tornado

The tornado occurred on July 5 [around 5PM] in Hirosaki city, Aomori prefecture. The damage statistics based on the report from Hirosaki city hall are shown in Table 1. The Wind Engineering Research Center, Tokyo Polytechnic University, sent an inspection team. The team arrived at Hirosaki on the evening of July 6 and conducted hearing surveys of Hirosaki City Hall and Fire Station. From the morning to the afternoon of July 7, field investigation at Onisawa area and Naranoki Area were conducted.

Table 1 Statistics of tornado damages

Human Suffering	Slight injury: 1
Dwelling Suffering	Half collapse: 5, Partial collapse: 28
non-Dwelling Suffering	Total collapse: 9, Half collapse: 3
Apple Tree Suffering	Adult tree: 109, Dwarfed tree: 59

2. Overview of damage to structures

Fig. 1 shows the damage foot prints.

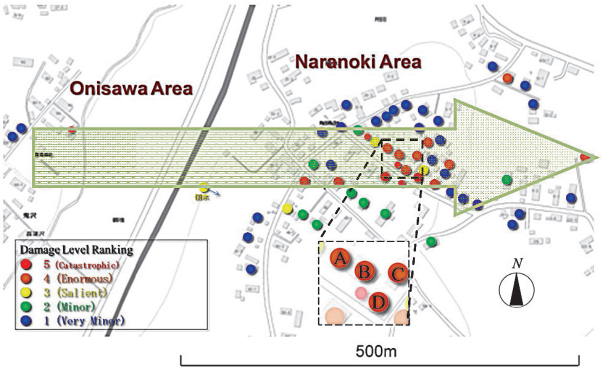

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Fig. 1 Damage footprints of tornado

The tornado passed from west to east over the damaged area. In the Onisawa area, there were many reports of tornado sightings. Fortunately, very minor damage to structures was found in the field investigation. For example, a small doghouse was overturned. In the Naranoki area, structures in the center zone suffered damage. Also in this area, structures were surrounded by an apple orchard. As shown in Table 1, around 170 apple trees and a few other kinds of trees sustained minor and major damage, as shown in Fig. 2

Fig. 2 Uprooted Trees

Major damage to structures located at the center of the damaged area (inside the black dotted square in the Fig. 1) is shown.

Fig. 3 shows damage to Structure A. This structure is a storage building, which consists of an original part (right side in Fig. 3(b)) and an extension part (left side in Fig. 3(a)). Only the walls, windows and roofs of the extension part were damaged. Fig. 4 shows a picture of damage to structure B. This structure sustained the most severe damage in this area.

(a) from NNE (b) from WSW

Fig. 3 Damaged Structure A

Damage to the ceiling, cladding, and windows can be observed. As shown in Fig. 5(a), a roofing steel panel was broken off especially in 2F. The other side of the roof, including the roof frame, was scattered. As shown in Fig. 5(b), scattering of the roof including the frame

(a) from SE (b) from SE

(c) from NW (d) from ESE

Fig. 4 Damaged Structure B

(a) Structure C (NNE) (b) Structure D (WNW)

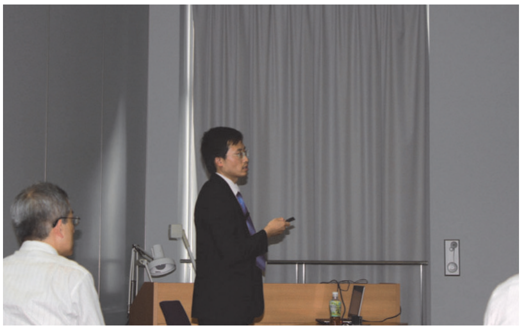
Fig. 5 Damaged Structures C and D

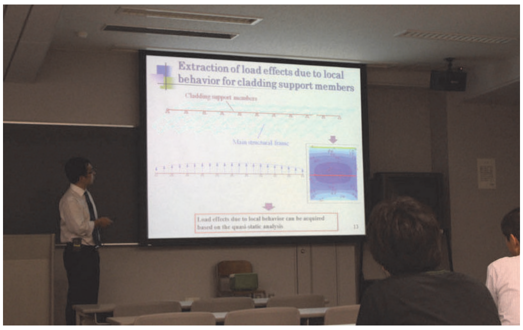
occurred. As shown in this figure, the cladding at the 1st floor was also damaged. For this kind damage, debris can be a trigger. Between Structures B and D, a small storage building was collapsed totally. A lot of debris could be found around these structures.

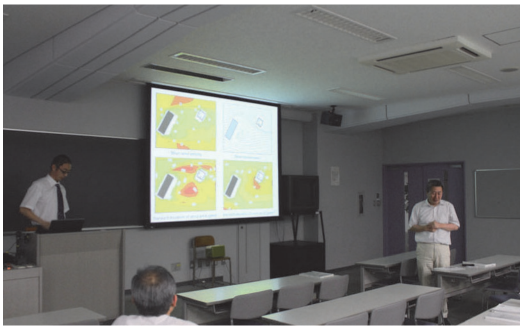
Public defense on doctoral dissertation

Public hearings on doctoral dissertations were held at the Atsugi campus of TPU on July 13, 2012 and on August 4, 2012. On July 13, PhD candidates Mr. Guoyi Jiang presented their doctoral dissertation drafts, and on August 4, Mr. Cao Jinxin, Mr. Zhibin Ding and Mr. Yi Hui presented theirs.

PhD students, researchers and engineering designers in the wind engineering field participated in the public hearings. There was active and fruitful discussion between audience and presenter. After the public hearings, the final assessments on the doctoral dissertation were carried out by five examiners including one external examiner to ensure the quality of the dissertation. TPU awarded a PhD degree to them in September, 2012.







Wind Tunnel Experiment and Large Eddy Simulation of Gas Dispersion in Non-isothermal Boundary Layer

Guoyi Jiang

Urban heat island phenomena and air pollution are serious problems in weak wind regions such as behind buildings and within street canyons, where buoyancy effect can not be neglected. In order to apply CFD techniques to estimation of ventilation and thermal/pollutant dispersion in urban areas, it is important to assess the performance of turbulence models adopted to simulate these phenomena. Low prediction accuracy of RANS models has been reported in weak regions, so the application of Large Eddy Simulation (LES) is studied. The performance of LES has been proved in neutral boundary layer cases, but hasn't been validated for thermal/gas dispersion in weak wind regions in non-isothermal boundary layers. Turbulent inflow data is very important for LES, and several techniques have been proposed for generating inflow fluctuations for LES in a neutral boundary layer, but few studies have considered non-isothermal cases. When applying LES to a non-isothermal field, not only inflow velocity fluctuation but also temperature fluctuation is necessary. However, it is not easy to generate both velocity and temperature fluctuations simultaneously, and no method of generating temperature fluctuations has yet been developed.

This research focused on the experimental scale. The objective was to develop and validate methods for generating velocity and temperature fluctuations simultaneously in non-isothermal boundary layers (both unstable and stable conditions), to clarify the influence of thermal stability on flow and gas dispersion behavior in non-isothermal boundary layers using wind tunnel experiments and LES, and to evaluate the performance of LES for thermal and gas dispersion in weak regions in both unstable and stable conditions. Two methods (a precursor method and a recycling method) of generating inflow turbulence (both velocity and temperature fluctuations) for LES boundary condition were proposed and examined. The characteristics of the generated flow (mean profiles and fluctuation profiles) by the two methods agreed well with those of wind tunnel experiments. It has thus been clarified that both methods can be applied to generation of inflow turbulence for LES in non-isothermal boundary layers.

Generated turbulent inflow data was used for LES for thermal/pollutant dispersion behind a single building and within urban street canyons, and the influence of thermal stability on a turbulent flow field and gas dispersion behavior was investigated. Both experiments and LES results showed that, due to the effect of buoyancy, turbulence was enhanced under unstable conditions and was suppressed under stable conditions. For the single building case, the gas dispersion area was narrow in the lateral direction under stable conditions (in the experiment), mainly due to the lower turbulence in the lateral direction. However, this was not observed in stable LES. The prediction accuracy of LES under unstable conditions was better than that under stable conditions. For the street canyon case, the mean stream-wise velocity, mean temperature and mean concentration predicted by LES showed good agreement with the experimental data (the prediction accuracy of LES under unstable conditions was slightly better than that under stable conditions). Higher concentration was observed inside the street canyon in both experiment and LES under stable conditions than under unstable conditions. The transport mechanism of the gas and air was investigated by flux analysis. Air flow rate was lower under stable conditions, and this is the reason for the high concentration inside the street canyon under stable conditions.

Experimental study on wind loading characteristics of green roofing systems

Cao Jinxin

With the popularization of green roofing systems, their wind resistant performance is becoming more and more important especially in typhoon areas. This study focused on two failure problems: uplift failure of extensive green roofing systems and windthrow failure of rooftop trees or shrubs of intensive systems. Thus, wind loads on modular systems and tree-type systems were investigated through boundary layer wind tunnel experiments.

Since it is difficult and unrealistic to measure wind loads on rooftop green roof modules or rooftop trees in the field, the alternative is to investigate wind force characteristics of rooftop model modules or model trees installed on a building model in a wind tunnel based on aerodynamic modeling of green roof modules and trees. Therefore, a hybrid-scale approach was adopted. For modular systems, aerodynamic characteristics of real green roof modules were investigated in uniform turbulent flows, and then wind forces on rooftop model modules were investigated through wind pressure measurements. For tree-type systems, aerodynamic characteristics of real trees were investigated in uniform turbulent flows, and then wind force measurements were made on rooftop model trees.

As the study basis, wind pressures on a multi-level flat roof were firstly measured through a wind tunnel experiment carried out on 1:67 scaled models of a series of medium-rise buildings. The minimum negative pressure on the windward high corner of a multi-level flat roof is similar to that for a simple flat roof, while negative pressures on the low roofs and positive values were highly dependent on step parameters such as step height and shape. Comparison of area-averaged pressure coefficients with ASCE/SEI7-10 indicates that absolute negative values in the high corner with small tributary areas in the present study were larger than those specified in the code, while negative values in other zones and positive values closely agree with the code.

For modular systems, aerodynamic characteristics including drag and uplift forces and force coefficients of four specimens of real green roof modules with three different vegetation species were firstly investigated through force measurements in uniform turbulent flows. The results show that the module with the maximum drag coefficient had the smallest uplift force coefficient. More importantly, the effect of reconfiguration of vegetation on the force coefficients of green roof modules was limited, which indicates that it is appropriate to assume the module to be a rigid model for wind force investigations on a rooftop model module. Based on this assumption, a series of wind pressure experiments were carried out on a scaled rooftop model module installed at different positions on a flat roof to identify wind loads on rooftop green roof modules. It was found that the most unfavourable values for both peak lateral and uplift force coefficients occurred at the corners of the roof, and they exceeded those suggested in the code. The overturning moments for the module were mainly determined by the uplift forces. The wind loads decreased as the parapet height increased. For practical design, considerations on relating roof pressures to uplift forces of rooftop modules, generalization of aerodynamic centers and estimation of failure wind speeds were proposed.

For tree-type systems, shrubby specimens of three tree species, one deciduous, one coniferous and one evergreen, were tested through force measurements to determine tree forces and tree forms including drag and overturning moments, wind-speed-specific fontal areas and tip displacements, and force coefficients in uniform turbulent flows. Over the range of wind speeds investigated, even considering frontal area reduction due to increasing wind speeds, drag coefficients decreased with increase in wind speed for deciduous and coniferous trees. In order to investigate wind load characteristics of rooftop model trees, aerodynamic modeling of trees was performed based on trial designs and verification of model trees with different crown materials and a self-constructed strain-gauged force sensor for measuring small forces. 80 tree locations with wind directions of 0 and 45 degrees were varied. The most unfavorable locations for 0 degrees were at the windward edge, while along-wind force coefficients remained constant along the central diagonal line across the entire roof for 45 degrees. The peak force coefficients for along-wind force did not show large variation when the parapet height was low compared to that without a parapet, but significantly decreased with higher parapet height.

Based on the generalization of the experimental results, wind resistant design considerations for both systems were finally proposed. For modular systems, design force coefficients as well as zone designations were provided, and a Parapet Factor was suggested. For tree-type systems, rather than presenting the design force coefficients, a Rooftop Factor and a Gust Effect Factor were given, with which the designer can estimate the lateral wind loads on trees by assuming their own tree drag coefficients. Also, a Parapet Factor was suggested considering its effect in reducing wind loads on rooftop trees.

Contributions of overall and local behaviors for largest wind load effects on structural members

Zhibin Ding

1. Introduction

The current wind-resistant design of structures is based on estimates of (1) overall wind effects, which must be taken into account in the design of structural frame, and (2) local wind effects, which govern the design of components and cladding. Overall wind effects are estimated based on overall wind-induced behavior of structural frames, considering the characteristics of fluctuating wind load as well as the dynamic characteristics of the whole structure, such as natural frequencies, corresponding vibration modes and damping ratios. Local wind effects are estimated based on imposed local wind pressures and tributary areas. However, it is not necessarily enough to determine the equivalent static wind load aimed at largest loading effects for structural members such as exterior walls of thin-walled cylindrical shell structures, cladding support members of large-span roof structures and so on. Wind load effects on such members depend not only on wind-induced overall behavior of structural frames, but also on local wind effects due to local wind pressures. By ignoring the contribution of overall behaviors or local behaviors, current wind load codes may underestimate internal forces.

It is very important to investigate the contributions of overall and local behaviors to largest wind load effects to improve understanding of wind load effects and design wind loads for such members. This study focused on exterior walls of thin-walled cylindrical shell structures and cladding support components of large-span roof structures.

2. Method to separate largest wind load effects due to overall and local behaviors

In order to investigate the contributions of overall and local behaviors to largest wind load effects, firstly, a method is proposed to separate wind load effects due to overall and local behaviors.

For cylindrical shell structures, wind load effects due to overall structural behaviors can be extracted by using an equivalent lumped-mass-model system. Wind-induced behavior of an equivalent lumped-mass model can be used to represent the overall behavior of a thin-walled cylindrical shell, applying wind forces integrated by the wind pressures for each height. Displacements from the lumped mass model can be transferred to displacements on nodes related to the cross section of the FE model assuming that there is no distortion in cross section when considering only overall wind-induced behaviors. Under these displacements, the load effects due to only overall behaviors can be calculated.

For cladding support components of a large-span roof structure, quasi-static analyses were adopted to calculate the largest load effects on cladding support components under local wind load. Instantaneous wind forces were applied to the local models (individual continuous beam for cladding support beams and local part for cladding support frame) and the load effects were calculated step by step.

The corresponding contribution was defined as ratios of the extracted results to the results from time-domain analyses of detailed finite element (FE) models of entire structures under actual total wind load. Following the equilibrium law, the contribution of the other aspect can be obtained as well.

3. Estimation of contributions of overall and local behaviors for largest wind load effects

Wind load used for the load effects analyses were measured from rigid scale models in wind tunnel experiments. Wind pressures on exterior walls of thin-walled cylindrical shell structures were measured by using two models with different aspect ratios (H/D=8, 0.25), corresponding to chimney and tank structures, respectively. On the other hand, wind pressures were measured on the upper surface of a closed arched roof model. The proper orthogonal decomposition (POD) method was adopted to obtain the principal coordinate system for fluctuating wind pressure fields, which is necessary for interpolating fluctuating wind pressures based on pressure data measured from a limited number of taps.

Contributions of overall and local behaviors for target wind load effects from the engineering viewpoint are estimated based on the proposed method and measured wind loads, e.g. axial, circumferential and membrane shear stresses of shell members located near the bottom and top of the cylindrical shell structure; and bending moment, shear force and axial force in cladding support components of large-span roof structure.

4. Proposals for estimation of wind load effects on structural members

Based on the results of this study, it is clear that considering only overall behaviors will result in underestimation of membrane stresses in the exterior walls of thin-walled cylindrical shell structure, especially for members near the windward meridian. Correspondingly, considering only local behaviors will result in underestimation of internal forces in cladding support components, with largest error up to 50%.

Classification and zone designation are necessary for estimating wind load effects on exterior shell walls of thin-walled cylindrical shell structure. Also, modification coefficients are proposed for the estimated largest wind load effects on structural members discussed in this study following current wind load codes.

Interference effects on local peak pressures between two high-rise buildings—considering square and rectangular shapes

Yi Hui

Modern tall buildings are often built in groups in urban areas. This results in flow interference, and wind loads on buildings are modified from the isolated building situation. Catastrophic incidents may result if the interference effects on load have not been considered in design. Investigation of interference effects is complicated by the large number of variables needed to describe the broad set of possible situations—sizes and shapes of buildings, relative locations of adjacent building(s), wind directions, upstream terrain conditions and so on.

The main objective of this dissertation was to tackle the problem of interference as it affects local peak pressures on a tall building in order to establish a generalized set of guidelines. Extensive wind tunnel experiments have been conducted to measure local peak pressures on a tall building with an interfering building for various wind directions and urban exposure conditions. Four arrangements between two high-rise buildings were studied. Two building shapes—square and rectangular—were involved. Interference effects are presented in the form of non-dimensional interference factors that represent local peak pressure coefficients on a building with interference from an adjacent building, relative to local peak pressure coefficients on an isolated building.

Results show that, on the one hand, the interfering building usually doesn't have a significant effect on maximum positive peak pressure. For most configurations, the interference factors for the largest maximum positive peak pressure were mainly in the range of 0.9-1.1. In a few cases, the positive peak pressures on the principal building were significantly reduced due to the shielding effects offered by the interfering building. On the other hand, the interfering building can have strong effects on the smallest minimum negative peak pressure. The interfering building can cause large interference factors (IF>1.1) over quite big areas on the faces of the principal building facing the interfering building in the experiment. The largest interference factor was greater than 1.5, which means the absolute value of the smallest minimum negative peak pressure coefficient is 50% higher than the design value of the isolated building situation. For some configurations, the interfering building could also greatly reduce the smallest minimum negative peak pressure.

The shapes of both the interfering building and the principal building can severely affect the resulting interference factors. This makes it difficult to generalize the interference effects and suggests that more studies and experiments on this topic are still necessary.

Wind direction is one of the most crucial parameters. For most cases, the interference effect was stronger when the interfering building was located upstream of the principal building, and the wind directions that cause high pressures on the principal building greatly depend on the configurations of the two buildings.

The regions along the vertical edges, especially the corners of building, are the critical positions on the principal building for negative pressure under interference effect. Special care is needed at these positions if the interference effects are considered in design.

The flow fields surrounding the two buildings were measured by a Particle Image Velocimetry (PIV) system. The flow fields revealed some of the reasons why the wind induced interference effects can increase and decrease the smallest minimum peak pressure on the principal building. The extreme instantaneous flow field shows that the high negative peak pressure at the leading edge of the principal building occurs for two main reasons.

Suggestions for codification were also given. For both positive and negative external pressure coefficient design values, interference factors were recommended for the modifications when considering interference effects from a neighboring building.

This study also focused on estimation of extreme pressure coefficients. The newly proposed method in the current study was modified based on the classic Cook-Mayne method for estimating extreme wind loading on structures. The major improvement from the Cook-Mayne method was that, while estimating the top-order annual extreme wind speeds, the wind speed was treated as a colored process and not a white process as Cook-Mayne did. This correction resulted in much more reasonable and accurate estimated extreme wind loads. Not This method can also be applied to estimation of the top-order extreme values of other colored random processes.

Announcement

The 7th Workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (APEC-WW2012)

Date: November 12-13, 2012
Venue: POSTECH International Convention Center, Pohang, Gyungbuk, Korea

Workshop on Tornado Disaster Risk Reduction in Bangladesh

Date: January 15, 2013
Venue: Bangladesh Meteorological Department (BMD), Dhaka, Bangladesh

The 6th International Symposium on Wind Effects on Buildings and Urban Environment (ISWE6) “Current-State-of-the-Art in Wind Engineering and Outlook for the Future”

Date: March 6, 2013
Venue: Hotel Sunroute Plaza Shinjuku, Tokyo, Japan

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