Wind Effects

New Frontier of Education and Research in Wind Engineering

Bulletin

Vol.15 April 2011

Wind Engineering Research Center
Graduate School of Engineering
Tokyo Polytechnic University

INDEX

Reports of APEC-WW2010, APEC-WW & IG-WRDRR Joint Workshop and Pre-conference event of 4AMCDRR

The TPU Global COE Program has successfully organized a series of workshops on regional harmonization of wind loading and wind environmental specifications in Asia-Pacific economies (APEC-WW) from 2004 to 2009, and this year the 6th APEC-WW was held at Kwandong University, Gangneung, Korea from October 22-23, 2010 under the auspices of Prof. Young-Duk Kim. This series of workshop aims to 1) reach a common understanding of wind loading; 2) exchange information on the current status of wind loading standards/codes and to improve individual standards; 3) discuss bylaws/specifications for wind environmental assessment related to pedestrian level winds in an urban environment; and 4) discuss bylaws/specifications for air quality outside and inside buildings. 34 delegates attended the workshop and reported the results of Benchmark tests and their recent activities in wind engineering in both structural and environmental fields on behalf of 17 countries and economies. Resolutions for both groups are made individually after thorough face-to-face discussions on problems related to current wind standards/codes/ bylaws/specifications. At the end of the workshop, it was decided to hold the next APEC-WW workshop in Vietnam in 2011.

A joint workshop on“Wind-Related Disaster Risk Reduction (WRDRR) Activities in Asia-Pacific Region and Cooperative Actions” was co-organized by the TPU Global COE program and IG-WRDRR in Incheon, Korea on October 24, 2010. The International Group for Wind-Related Disaster Risk Reduction (IG-WRDRR) was formally launched under the framework of UN/ISDR, and it is responsible for establishing linkages and coordinating various communities to serve as inter-agency coordinators with a charter to work with international organizations involving agencies of the UN and involved NGOs, and to embolden their activities that help to serve as a bridge between policy makers and agencies responsible for actually carrying out the DRR at the local community level. Because extreme wind storms such as tropical cyclones are generally accompanied by high waves, storm surge, heavy rains, floods and landslides, the TPU

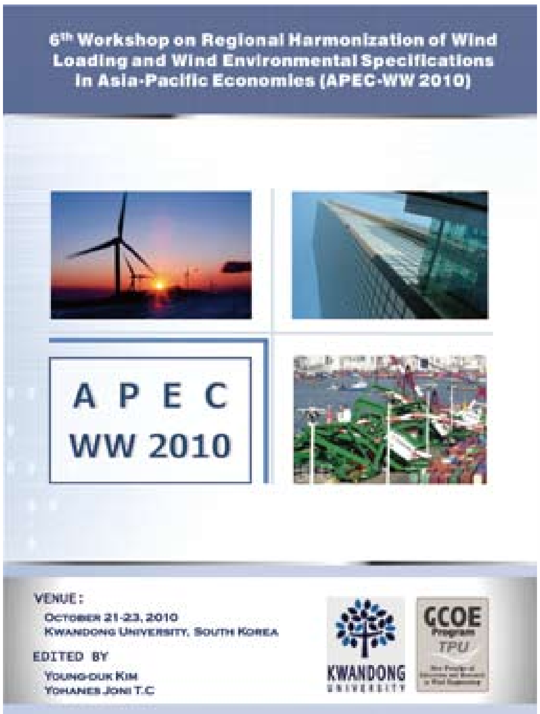


Figure 1. Proceedings of APEC-WW Workshop

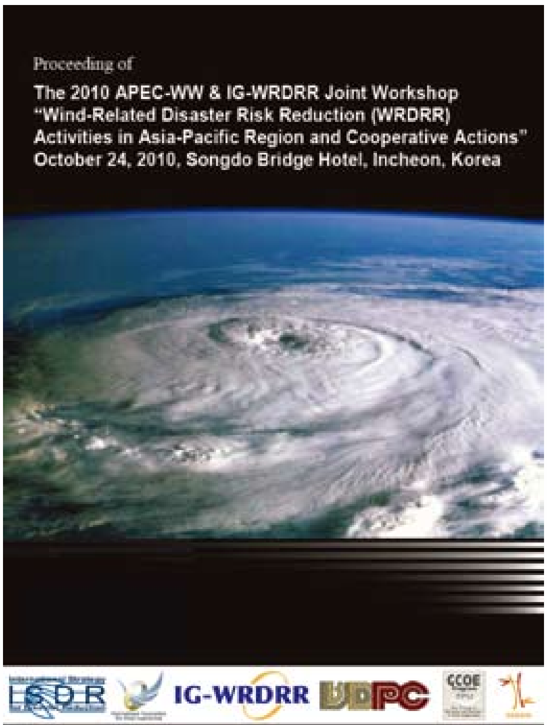


Figure 2. Proceedings of APEC-WW & IG-WRDRR Joint Workshop

Global COE Program has made great efforts to promote cooperative actions in WRDRR activities among various professional organizations. One of the actions that TPU Global Program has taken was to include WRDRR as one theme of APEC-WW. At the joint workshop, about 50 people from more than 20 countries in the Asia-Pacific region participated and shared the current status and activities for WRDRR.

The TPU Global COE Program co-organized the Pre-conference event 4AMCDRR (The 4th Asian Ministerial Conference on Disaster Risk Reduction) on "Climate Change and Wind-Related Disaster Risk Reduction Activities in Asia-Pacific Region" on 25 October 2010. The risk of future disasters continues to escalate with population shifts towards urban centers located in the paths of typhoons/cyclones and the impending threat of their increased intensity and frequency as hypothesized by potential climate change. Urbanization has also led to deterioration of regional and global environmental situations, which will have far reaching effects on social safety and public health. These tendencies are particularly significant in the Asian region. The Pre-conference event provided a platform for mutual exchange of information and knowledge between wind engineering experts, people working on DRR in various organizations, and policy makers. Representative persons from UN/ISDR, IG-WRDRR, IAWE, UNESCAP, WMO, ADRC, BDPC, SEEDS and APEC-WW presented current status and activities for WRDRR in the Asia-Pacific region. Future collaborative action plans were intensively discussed and implemented. As one output of the Pre-conference event, the Chairman of IG-WRDRR, Prof. Yukio Tamura, submitted a message to the 4AMCDRR.

Report on "The 7th International Advance School on Wind Engineering" (IAS 7)

Date : December 6-8, 2010
Venue : CSIR Science Centre, New Delhi, India

The 7th International Advance School on Wind Engineering" was held at CSIR Science Centre, New Delhi, India from 6th to 8th December 2010. It was co-hosted by Global Centre of Excellence Programme, Tokyo Polytechnic University (TPU), Japan, Central Building Research Institute (CBRI), Roorkee and Indian Society for Wind Engineering (ISWE), Roorkee. It was inaugurated by Prof. Yukio Tamura, Tokyo Polytechnic University, Japan. Prof. Prem Krishna, Vice President, INAE & Chairman RC, CBRI, Roorkee, India graced the occasion and presented his views on the state of Wind Engineering in India. Prof. S. K. Bhattacharyya, Director, Central Building Research Institute, Roorkee, India presided over the function and briefed the gathering about the research activities of CSIR-CBRI. Dr. A. K. Mittal, Course Coordinator, Scientist CBRI and Hon. Sec. ISWE presented an overview of the activities of ISWE being carried out.

The dignitaries released the lecture notes proceedings containing the lectures of all the eminent speakers.

Experts in Wind Engineering from various countries all over the world were invited to discuss the new areas of research that are being taken up in their respective countries and also to address the issues concerning the Indian designers and practice engineers.

The lecturers and the titles of their lectures were as follows:

Yukio Tamura (Tokyo Polytechnic University, Japan)

1. Efficient observations of random fields - Meaning of POD
2. Suppression of wind-induced responses of buildings - Damping devices
3. Damping in buildings and estimation techniques

Chii-ming Cheng (Tamkang University, Taiwan)

1. Aerodynamic databases for tall buildings
2. Aero-data based wind resistant design of tall buildings
3. e-wind: An integrated engineering solution package for wind sensitive buildings and structures

Chris Letchford (University of Tasmania, Australia)

1. Windborne debris in horizontal winds and applications to impact testing
2. Climatology of extreme wind speeds
3. Topographic effects on gust wind speed

Partha Sarkar (Iowa State University, USA)

1. Interference effect of surrounding buildings on wind loads
2. Aerodynamic loads and response of slender structures in time domain
3. Rain-wind induced and dry cable vibration of stay cables

Michael Kasperski (Ruhr University, Germany)

1. Specification of the design value of aerodynamic coefficient
2. Estimation of the design wind speed
3. Identification of effective pressure distribution

YouLin Xu (The Hong Kong Polytechnic University, Hong Kong)

1. Wind and structural health monitoring of long span bridges
2. Typhoon wind simulation and design wind speed

Ted Stathopoulos (Concordia University, Canada)

1. Understanding wind codes and standards: Fundamentals behind their provisions I
2. Understanding wind codes and standards: Fundamentals behind their provisions II
3. Understanding wind codes and standards: Fundamentals behind their provisions III

Prem Krishna (Indian Institute of Technology, Roorkee, India)

1. Proposed revisions in the Indian Wind Loading Code. Part I-Revisions
2. Proposed revisions in the Indian Wind Loading Code. Part II-Implications in design
3. Proposed revisions in the Indian Wind Loading Code. Part III-Research needs

A large number of delegates from Govt. and private sectors were benefited from the IAS7. About 50

Photo 1. Inauguration by lighting of lamp by dignitaries

Photo 2. Release of the proceedings of lecture notes

Photo 3. Dignitaries and faculty members

Photo 4. Participants of IAS7

participants which included Engineers/Professionals from many organizations like Consulting Engineering Services, Mahagun India Pvt. Ltd., Mehro consultants, Construction Catalysers Pvt. Ltd., NTPC, Jaypee Associates Ltd., RWDI Consulting Engineers, HUDCO and CBRI attended the programme. Faculty members from IIT Kanpur, IT-BHU Varanasi, NIT Trichy, NIT Surathkal, NIT Durgapur and research scholars also participated in this course.

This school was preceded by a 3 day workshop cum training course on "Seismic and Wind Resistant Design of Building Structures" jointly organized by CBRI, Roorkee and ISWE, Roorkee at the same venue from Dec 3 to Dec 5, 2010. This course was inaugurated by Prof. Michael Kasperski, Ruhr University, Bucham, Germany who was the Chief Guest of the Function. Prof. S. K. Bhattacharyya, Director, Central Building Research Institute, Roorkee, India was the Guest of Honor.

Eminent speakers like Prof. Prem Krishna, Prof. S.K. Bhattacharyya, Prof. P.D. Porey, Dr. N. Lakshmanan, Dr. S. Arunachalam, Prof. P.K. Pande, Prof. D.K. Paul, Prof. Abhay Gupta, Prof. Y. Singh, Dr. Naveen Kwatra and Dr. Achal Mittal delivered lectures and shared their experiences. They discussed on the basics of Wind Engineering and the recent developments on the design concepts regarding wind and earthquake engineering.

Finally, the closing ceremony was held on 8th December, in which Prof. Yukio Tamura, Tokyo Polytechnic

Photo 5. Certificates distribution to the participants

University, Japan, distributed the certificates to the participants. Prof. P.D. Porey, President, ISWE presided over the function and emphasized the need of similar activities in future also. Dr. Achal Kr. Mittal, Course coordinator and scientist, CBRI conducted the event and proposed a vote of thanks to faculty, participants, sponsorors (DST, CSIR etc.), press and the organizing team. GCOE

A feedback study was carried out by the organizers at the end of the event. From this study, it was found that IAS7 was highly appreciated by the participants and expressed that there should be more of such courses dealing with the multi-hazard approach especially in earthquake and wind engineering. Also more international collaborative activities in the form of projects, visits of research scholars, workshops, seminars, conferences, etc, should be rigorously pursued.

Photo 6. Lecturers and Participants of IAS7

The 2nd Joint Workshop between CARDC and TPU

The 2nd joint workshop between the China Aerodynamics Research & Development Center (CARDC) and Tokyo Polytechnic University (TPU) was held during the period from August 16 to 18, 2010 at a hotel in Mianyang City, Sichuan, Republic of China. The primary purpose of this workshop was to promote greater mutual understanding through the free exchange of information on the current status of wind engineering research and to make an agreement for collaborative research. The 10 persons in the Chinese delegation and the 3 persons in the Japanese delegation, Prof. Y. Tamura, M. Ohba and Y. Yoshie, participated in the workshop. On the first day, the workshop started with an opening speech by Prof. Sun Haisheng. TPU presented their scientific research results on seven topics and CARDC on three topics. On the second day, TPU joined a technical tour of the CARDC research facilities. The 8m×6m wind tunnel had measuring sections of 4m×3m and 8m×6m and a large fan motor of 7800 Kw. It was not permitted to take photographs inside because it was a military facility. After the technical tour, we discussed the research cooperation in detail and finally signed an agreement for a cooperative project for wind tunnel tests on large-scale and small-scale building models. The research project will be composed of three stages: Air flow characteristics assessment, Experimental surface pressure measurement on Texas Tech University Model, and External/internal pressure and flow field measurement on a TPU suggested model. The test model in the 8m×6m wind tunnel will be constructed as large as possible according to the restrictions of the testing situation.

Figure 1. 8m×6m wind tunnel

Photo 1. Participants of the workshop

Report on the 5th Korea-Japan Joint Seminar on Wind Engineering (JaWEiK5)

The 5th Korea-Japan Joint Seminar on Wind Engineering (JaWEiK5) was held at the POSCO Center Art Hall on September 6, 2010 in Seoul, Korea. This joint seminar was carried out with the cooperation of the Japan Association of Wind Engineering (JAWE), the Wind Engineering Institute of Korea (WEIK) and the Global COE Program, Tokyo Polytechnic University. The first JaWEiK was held in 2005 and has been organized every year since then. President Jong-Rak Kim (President of WEIK) gave the opening address and explained the importance of the discussion about the theme of this year's JaWEiK as "Bluff body aerodynamics and flow mechanics for large size structures". There were 12 presentations as follows:

Prof. Shirato (Kyoto University): "Turbulence scale effect on spanwise correlation of gust force"

Prof. Ho-Kyung Kim(Seoul National University): "Aerodynamic stabilizing measures of a cable-stayed bridge in construction"

Prof. Sungsu Lee (Chungbuk National University): "Development of WindRisk (R); a tool for regional windstorm risk assessment"

Dr. Seogcheol Kim(BOOLT simulation):"CFD simulations of wind flows around buildings and terrains"

Dr. Young-Min Kim (DAEWOO Institute of Construction Technology): "Wind engineering on the Busan-Geoje fixed link bridges"

Prof. Kawai (Kyoto University): "Wake structure behind a 3D square prism in shallow boundary layer flow"

Mr. Choongmo Koo (Tohoku University): "Discussion of design wind loads on cylindrical storage tanks"

Prof. Hayashi (Kyoto University): "Turbulent structure in high wind"

Dr. Takeuchi (Kyusyu University): "Unsteady wind forces on a body subjected to short-rising gust"

Assoc. Prof. Yoshida (Tokyo Polytechnic University): "Field measurement of Jeju World Cup Stadium roof and system identification"

Dr. Wonsul Kim (TPU): "Interference effects on local peak pressures on two adjacent tall buildings"

Prof. Matsui (TPU): "Generation of time history of design wind speeds using typhoon model and empirical wind characteristics"

At the end of the JaWEiK, President Hiromasa Kawai (President of JAWE) gave a closing address and emphasized the significance of the information exchange on wind engineering during the engineer of JAWE and WEIK.

Photo 1. Group Photo

Photo 2. Explanation of the derivation of "JaWEiK" by Prof. Tamura

The 2nd International Workshop on Equivalent Static Wind Loading and Technical tour

Date : November 29, 11:00-18:00
Venue : Tokyo Polytechnic University, Atsugi,Japan

'The 2nd International Workshop on Equivalent Static Wind Loading' was held at the Atsugi Campus of Tokyo Polytechnic University. This workshop was a part of the activities under the NFSC (National Natural Science Foundation of China) – JST (Japan Science and Technology Agency) Cooperative Research Project. The research groups in the wind engineering field of Tokyo Polytechnic University, Tongji University, and Beijing Jiaotong University participated in this workshop. After the workshop, a technical tour of the WERC facilities for the guests from China was also conducted. This workshop is planned with the aims of information exchanges on cutting-edge research and exchange of opinions for collaborations among 3 research groups. From Tongji University and Beijing Jiaotong University, 5 professors joined the workshop. At the beginning of the workshop, Prof. Yukio Tamura (Director of Global COE program, TPU) introduced the concept of this workshop. After that, 5 topics from TPU, 5 topics from Tongji University, 3 topics from Beijing Jiaotong University, 1 topic from the Wind Engineering Research Center, and 1 topic from Kanagawa University were reported. In addition, a technical tour of experimental facilities in WERC was conducted. In this tour, 4 wind tunnels, a cladding-test facility, a tornado-like flow simulator, and an experimental solar panel system were introduced. Through these academic events, active exchanges of opinions and information were accomplished. The following are the titles and speakers on the research topics of the joint workshop.

- Some Progress about Field Observation and Numerical Simulation of Tropical Cyclones nearby Southeast coastlines of China, *Lin Zhao (Tongji University)*
- An application of typhoon models to setting design wind speed time histories, *Masahiro Matsui (Tokyo Polytechnic University)*
- On the design wind speed in hilly regions for wind resistant design of bridges, *Shuyang Cao (Tongji University)*

- Parameters of turbulent wind in Beijing, *Qing-shan Yang (Beijing Jiaotong University)*
- Universal Equivalent Static Wind Load for a terminal building, *Akira Katsumura (Wind Engineering Institute)*
- Universal ESWL of plane truss roofs, *Bo Chen (Beijing Jiaotong University)*
- Generalized peak factor and its application to stationary random processes in wind engineering applications, *Nadaraja Pillai (Tokyo Polytechnic University)*
- Aerodynamic characteristics of tall building models with various unconventional configurations, *Yukio Tamura (Tokyo Polytechnic University)*
- Static Wind Loading on Buildings: Comparative Study of Major Asia-Pacific Codes and Standards, *Yaojun Ge (Tongji University)*
- Interference effect on local peak pressure between two high-rise buildings with different shapes, *Wonsul Kim (Tokyo Polytechnics University)*
- Wind Force and Response Characteristics of a Slender Beam with Angle Cross-section, *Takeshi Ohkuma (Kanagawa University)*
- Energy transformation mechanism of coupled bending torsional flutter, *Zujun Liu (Tongji University)*
- Aerodynamic flutter control for typical bridge girder sections under self-excited wind loading, *Yongxin Yang (Tongji University)*
- Investigation of Fetch Effect on Wind Pressures on Low-rise Building, *YongChul Kim (Tokyo Polytechnic University)*
- Rough wall treatment by SST k-ω turbulence model, *Jian Zhang(Beijing Jiaotong University)*

Photo 1. Group Photo (Reception dinner)

Interference effects on local peak pressures of two adjacent tall buildings

Wonsul Kim , Yukio Tamura, Akihito Yoshida

1 INTRODUCTION

Most wind load codes have been derived for isolated buildings. However, wind loads on tall buildings surrounded by other tall buildings in real environments may be quite different from those on isolated tall building. Surrounding tall buildings can either increase or decrease not only overall wind loads on a building but also local peak pressures acting on the building cladding. Unfortunately, few codes have referred to wind-induced interference effects on wind loads on buildings (AS/NZS 1170.2, 2002; AIJ, 2004). These codes only briefly accommodate wind load effects of neighboring tall buildings, mainly dealing with shielding effects, which is beneficial to the building structural system and claddings. Because there are a large number of variables involved, such as building size and shape, relative locations of interfering building(s), wind directions, upstream terrain conditions and so on, it is difficult to consider all parameters in codes.

The main aim of this study is to tackle the problem of interference for 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 different height ratios and various wind directions for an urban exposure condition.

2 WIND-TUNNEL EXPERIMENTS

2.1 Pressure measurements

Wind tunnel experiments on a high-rise building model with various arrangements and height ratios of an adjacent building were carried out in a Boundary Layer Wind Tunnel located at Tokyo Polytechnic University, Japan as shown in Figure 1. For this study, the flow of the atmospheric boundary layer in the wind tunnel was interpreted as a geometrical scale of approximately 1:400. The approach flow represented an urban wind exposure using the spire-roughness technique with a power law exponent of 0.27. The wind speed and the turbulence intensity at the height of the model (principal building) were 8.2 m/s and 20%, respectively.

The considered experimental models comprised two buildings: the pressure model, referred to as the principal building, and the other model, referred to as the interfering building. Figure 2 shows the coordinated system indicating the different locations of the interfering building and wind directions. The center-to-center spacing between them was varied by Sx longitudinally and Sy laterally. Table 1 shows cases of the experimental models used in this study.

The fluctuating wind pressures on the building faces were simultaneously sampled every 0.00128 seconds and the sampling period was 7.5 seconds for each sample. The data were digitally low-pass filtered at 300 Hz. For each test case, 15 samples of 10-min length in full-scale conversion were analyzed. The tubing effects were numerically compensated by the gain and phase-shift

Figure 1. Experimental models in wind tunnel

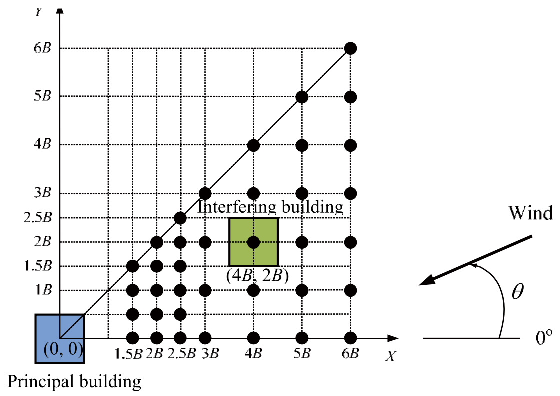


Figure 2. Coordinated system indicating different locations of interfering building and wind directions.

Table 1. Experimental models

Experimental models	Dimensions (mm) (B×D×H)	Height ratios (H_r=H_{ib}/H)	Locations	Wind directions
Principal building	70×70×280	1	1	0° – 355° (5° steps)
Interfering building	70×70×140	0.5	37	0° – 355° (5° steps)
	70×70×196	0.7	4	
	70×70×280	1	37	
	70×70×420	1.5	37	
	70×70×560	2	4	

∗ H and H_{ib} are height of principal building and interfering building, respectively

characteristics of the pressure measuring system. The pressure data were filtered by means of a moving average filter corresponding to 0.2sec in full scale. Further, the maximum and minimum peak pressure coefficients were calculated by the Cook & Mayne method.

2.2 Simultaneous pressure measurement and flow visualization

To obtain further information and understanding on the interference mechanism for enhanced local peak pressures on the principal building with interfering building of Hr=1, flow fields around two buildings for worst wind directions in tandem and oblique arrangements have been investigated by simultaneous pressure measurements and flow visualization using dynamic particle image velocimetry (DPIV) in wind tunnel of Shimizu Institute of Technology, Japan. As shown in Figure 3, this system consisted of a high-speed digital video camera, a double pulse Nd: YAG laser and a particle generator. The fluctuating wind pressures and the image of particle were simultaneously sampled every 0.0001 seconds and the sampling periods were 7.5 seconds and 6 seconds for each sample, respectively. Tracer particles were discharged from downstream of the principal building and then circulated in the wind tunnel. The particles were illuminated by a pulsed laser light sheet. The image was captured in digital memory using a computerized data acquisition system for a field of view of 276mm×207mm.

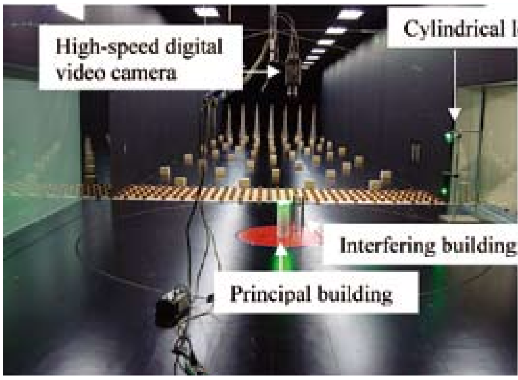


Figure 3. Simultaneous pressure measurement and flow visualization in wind tunnel.

3 RESULTS AND DISCUSSIONS

3.1 Effects of building arrangement

The minimum negative peak pressure coefficient ($\check{C}_p$) for all measurement points on the principal building and all wind directions can be expressed by:

$$\check{C}_p = \min_{i,j,\theta}\left[\check{C}_p(i,j,\theta)\right] \qquad (1)$$

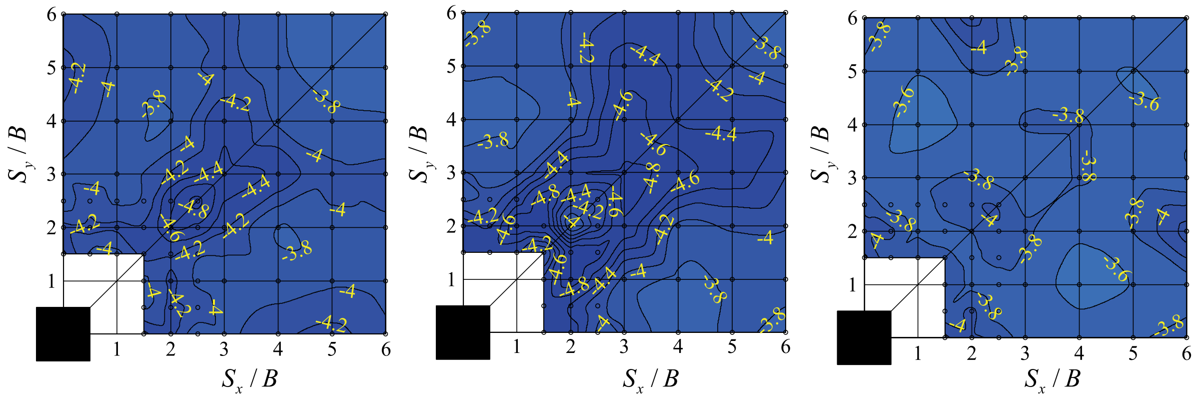
Figure 4 shows the contour of $\check{C}_p$ on the principal building for interfering buildings of different height ratios and various locations, and $\check{C}_p$ on the isolated building was -3.7. From Figure 4, $\check{C}_p$ on the principal building was decreased and expanded with increase in height ratio of the interfering building.

Another interesting observation was that $\check{C}_p$ for *Hr*=1 and 1.5 significantly decreased when the interfering building was located in oblique arrangement. However, it should be noted that the critical locations of the interfering building vary with increase in height ratio. Interference effects of $\hat{C}_p$ on the principal building were also investigated in this study.

However, the results show that $\hat{C}_p$ on the principal building for interfering building of different height ratios and various locations was similar to that an isolated building.

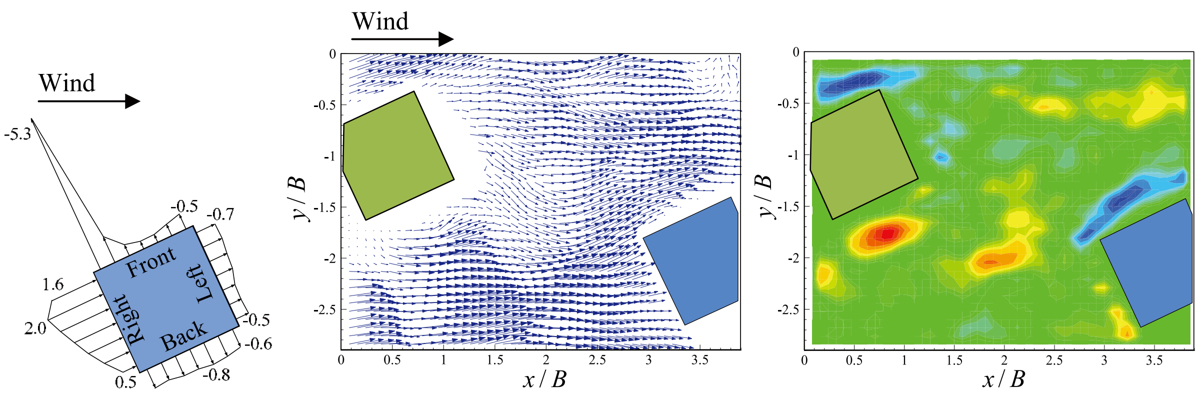
3.2 Flow pattern in oblique arrangement

Figure 5 shows the instantaneous pressure coefficients



(a) Height ratio (*Hr*) = 0.5 (b) Height ratio (*Hr*) = 1 (c) Height ratio (*Hr*) = 1.5

Figure 4. Contour of $\check{C}_p$ on principal building for interfering building of various height ratios and locations ($\check{C}_p$ (Isolated) = -3.7).



(a) Pressure coefficients (b) Velocity vector field (c) Vorticity field

Figure 5. Instantaneous pressure coefficients on principal building with interfering building of Hr=1, velocity vector and vorticity fields for wind direction θ=65o in oblique arrangement (Minimum vorticity and increment of vorticity contour are 100 and 100s-1, respectively).

on the principal building with interfering building of *Hr*=1, velocity vector and vorticity fields around two buildings in oblique arrangement with (Sx,Sy)=(2.5B,2.5B) for wind direction θ=65^o when the smallest minimum peak pressure coefficient on the principal building occurs. From Figure 5(b) and (c), the strong shear layer generated by the interfering building directly hit the principal building, leading to increased momentum at the upper face (front wall) of the principal building. This rose to a high pressure coefficient near the leading edge of the upper face of the principal building, as shown in Figure 5(a). Furthermore, it is inferred that some changes of wind directions (55^o≤ θ ≤ 85^o) could lead to an obvious decrease in minimum peak pressure coefficients acting on the principal building.

4 CONCLUSIONS

A detailed and comprehensive study of wind-induced interference effects on buildings has been carried out. Based on the results of these detailed experiments that consider various relevant parameters, general guidelines for limiting conditions have been formulated and critical interference effect situations identified.

5 REFERENCES

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[2] AS/NZS 1170.2 (2002). “Structural design actions, part 2: Wind actions”, Australian/New Zealand Standard.

Experimental and numerical studies on convective heat transfer from urban canopy and its dependence on urban parameters.

Sivaraja Subramania Pillai ,Ryuchiro Yoshie,Chung Jaeong

INTRODUCTION

A Weather Research Forecasting (WRF) model coupled with an Urban Canopy Model (UCM) is an effective tool for the prediction of urban heat island phenomena. In this UCM, local convective heat transfer from an urban canopy and its dependence on urban parameters such as building coverage ratio and variations of building height are not explicitly modeled. The aim of this research is to clarify the local convective heat transfer coefficients, which depend on urban parameters, and to incorporate the results into the UCM with the help of experimental and numerical simulation results.

SINGLE LAYER URBAN CANOPY MODEL

In the single layer Urban Canopy Model (Kusaka et al. 2001) in the WRF, the heat fluxes from the canyon surfaces were modeled by equations 1 and 2.

$$H_W = C_W(T_W - T_S) \quad (1)$$

$$H_G = C_G(T_G - T_S) \quad (2)$$

$$C_W = C_G = 7.51\, U_S^{0.78} \quad (U_S > 5\text{m s}^{-1})$$
$$C_W = C_G = 6.45+4.18\, U_S \quad (U_S \le 5\text{m s}^{-1}) \quad (3)$$

Where H_W, C_W, T_W are heat flux, heat transfer coefficient and wall temperature, respectively. H_G, C_G, T_G are heat flux, heat transfer coefficient and ground temperature, respectively. US and TS are velocity and temperature inside the canopy, respectively. In this single layer UCM, the convective heat transfer coefficient from wall and ground depends only on the velocity inside the canopy, as shown in equation (3). But this cannot be justified since other urban parameters also contribute to the heat transfer coefficient. Moreover, this model can not distinguish between convective heat transfer coefficients on different wall surfaces, i.e., windward, leeward and side walls. Therefore, to clarify this issue, wind tunnel experiments and CFD simulation with a low-Re- k-ε model has been carried out. Based on the experiment and CFD results, the convective heat transfer coefficient and heat flux from the urban canopy will be modified with respect to urban parameters like building coverage ratio and variations of building height, which will be incorporated into the UCM.

WIND TUNNEL EXPERIMENT

The experimental setup consisted of an aluminum block array to model different cases of urban canopy. The building coverage ratios (hereafter referred to as BCR) were varied as 25.0%, 11.1% and 6.3%, with both uniform- and non-uniform-height buildings. The inflow velocity and air temperature at the wind tunnel inlet were uniformly maintained at 1.9m/s and 7.8oC, respectively, throughout the cross section. The floor temperature was maintained at 53oC to simulate the unstable thermal environment. These conditions were adopted for all experimental cases. Figure 1 (left) and (right) shows the vertical profiles of mean wind velocity component U and mean temperature T at the measuring section for uniform- and non-uniform-height case, respectively. It has been observed that velocity decreases and temperature increases with increase in BCR in the roughness sub-layer. The boundary layer is higher for the non-uniform-height cases than for the uniform-height cases.

CFD SIMULATION & RESULTS

CFD simulation was conducted with a low Reynolds number k-ε model (Abe, Nagano and Kondoh, 1994) because of its good prediction accuracy of turbulent heat transfer in a separating and reattaching flow. CFD results showed good agreement with the experimental results for all cases. Thus it has been considered that the CFD simulations were appropriate for further investigations regarding heat transfer from canyon surfaces.

The heat flux from various urban canyon surfaces like ground; roof; and windward, leeward and side walls varies with change in building coverage ratio and variation in building height. Figure 2 (left) and (right) shows the heat flux from individual canyon surfaces for BCR 25% and 6.3%, respectively. The heat flux from the canyon surfaces for the 6.3% case is higher than that for the 25% case. Heat flux from the roof is higher than from the windward wall for the 25% case, which is the reverse of the 6.3% case. This is because of the change in flow pattern in the canopy. The 6.3% case falls in the isolated roughness flow category, whereas the 25% case exhibits skimming flow. More fresh air (which enhances heat transfer) contact on all canyon surfaces for isolated roughness flow than skimming flow may be the reason for the above behavior.

From the simulation results, it has been observed that the heat flux varies among canyon surfaces, viz. ground, roof, side wall, windward wall, and leeward wall, depends on urban parameters like building coverage ratio and variations in building height of the urban canopy. Based on the CFD results, the convective heat transfer coefficient and heat flux from the urban canopy will be modified with respect to the urban parameters, which will be incorporated in the Urban Canopy Model (UCM) of the Weather Research Forecasting (WRF) model.

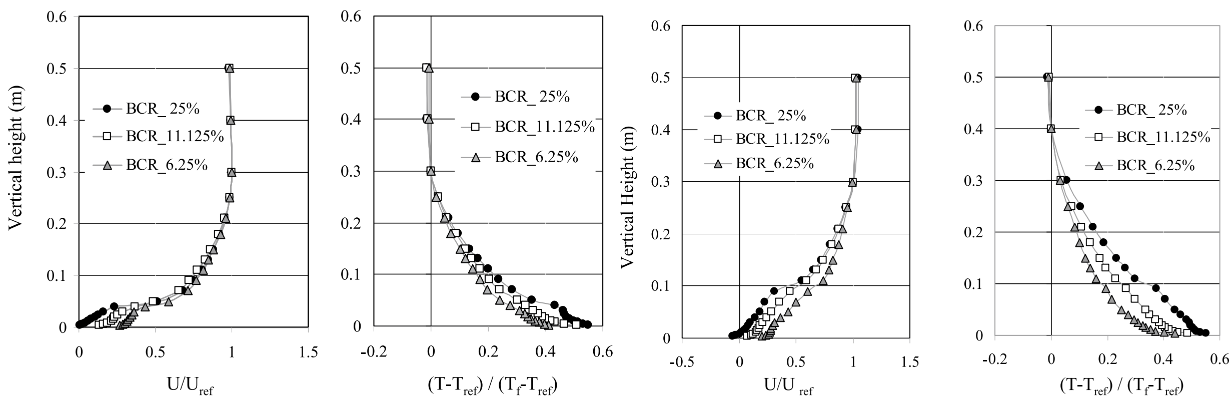

Figure1. (left): Mean velocity and temperature profiles for uniform-height cases
Figure1. (right): Mean velocity and temperature profiles for non-uniform-height cases

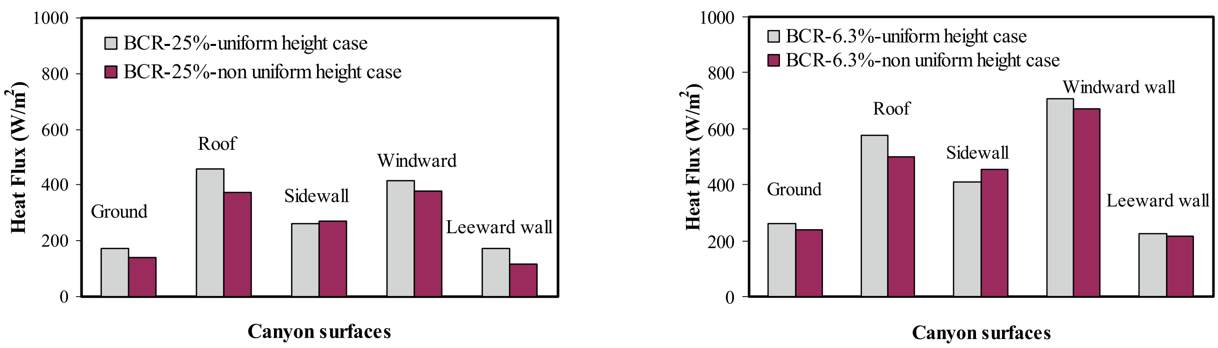

Figure 2. Left: Heat flux (W/m2) for canyon surfaces –BCR 25% uniform & non-uniform cases
Right: Heat flux (W/m2) for canyon surfaces –BCR 6.3% uniform & non-uniform cases

GCOE Program TPU

New Frontier of Education and Research in Wind Engineering

Executors of the Global COE Program
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Director

Yukio Tamura	Professor	Director of Global COE Program	yukio@arch.t-kougei.ac.jp
Ahsan Kareem	Professor	Technology related to EVO	kareem@nd.edu
Masaaki Ohba	Professor	Design method for natural/cross ventilation	ohba@arch.t-kougei.ac.jp
Ryuichiro Yoshie	Professor	Heat exhaust and air pollution in urban area	yoshie@arch.t-kougei.ac.jp
Kunio Mizutani	Professor	Natural ventilation dehumidifying system	mizutani@arch.t-kougei.ac.jp
Takeshi Ohkuma	Guest Professor	Wind resistant design method	ohkuma@kanagawa-u.ac.jp
Masahiro Matsui	Professor	Engineering simulator for tornado-like flow	matsui@arch.t-kougei.ac.jp
Akihito Yoshida	Associate Professor	Development of wind response monitoring network	yoshida@arch.t-kougei.ac.jp
Yoshiro Morita	Associate Professor	Wind Resistant Structural System	morita@arch.t-kougei.ac.jp

Wind Engineering Research Center
Graduate School of Engineering
Tokyo Polytechnic University

1583 Iiyama, Atsugi, Kanagawa, Japan 243-0297
TEL:046-242-9548 FAX:046-242-9514
URL：http://www.wind.arch.t-kougei.ac.jp/

ISBN 978-4-902713-43-5