Wind Effects

New Frontier of Education and Research in Wind Engineering

Bulletin

Vol.11 April 2009

Wind Engineering Research Center
Graduate School of Engineering
Tokyo Polytechnic University

INDEX

The post-evaluation results of the 21st Century COE programs

Yukio Tamura, Professor, Program Director

The 21st Century COE Program "Wind Effects on Buildings and Urban Environment", which is the predecessor of the current Global COE Program "New Frontier of Education and Research in Wind Engineering", ended its five year term in March 2008 as previously reported. The post-evaluation results of the 21st Century COE programs were officially published under the name of Dr. Reona Ezaki, Chairman of the 21st Century COE Program, from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan in December 2008. I am very pleased to inform you that our TPU 21st Century COE Program received the top ranked evaluation "THE INITIAL PURPOSE HAS BEEN SUFFICIENTLY ACHIEVED". The following comments are attached: "With respect to the overall achievements resulting from the establishment of the apex center of research and education, it is evaluated that the project has been well promoted with the effective collaboration of the members of the TPU Wind Engineering Research Center (WERC). Steady progress and promotion of the program has been achieved, promoting center-to-center-based collaborative actions including enterprising research exchanges with various overseas research and education centers/institutes and establishment of the APEC Wind Engineering Network. It is highly evaluated that the purpose of the program, aimed at taking the international initiative in wind engineering education, research and social contribution, has been fully achieved. A significant increase in the numbers of PhD candidates and doctoral degree awardees was achieved during the COE term, and considering their employment condition, it is sufficiently evaluated that the program contributed significantly to education and training of young researchers and talents including Asian students. Research products achieved by the COE program have been reflected in revision works and in development of domestic and international design codes/standards, and have contributed to the establishment of environmental evaluation methods. Thus, advanced and fruitful research results have been produced by the three research projects: wind resistant design, natural/cross ventilation, and air-pollution/wind environment. Focusing on post-COE activities, the TPU WERC has been planning to establish an Engineering Virtual Organization (EVO) in order to realize a more advanced center-to-center-based global-level collaborative wind engineering community. The TPU WERC has also been strengthening its relations with the private sector, and the TPU foundation and faculty members have created well organized relationships that promise durable and effective development of research and education programs."

Incidentally, nine of twenty-three programs in the category of "Engineering," including Mechanical Engineering, Civil Engineering, Building Engineering and other Engineering fields, received the same top ranked evaluation "THE INITIAL PURPOSE HAS BEEN SUFFICIENTLY ACHIEVED". In the "Post Evaluation of the 21st Century COE Program," which appeared in the home-page (http://www.jsps.go.jp/j-21coe/08_jigo/index.html) of the Japan Society for the Promotion of Science (JSPS), our TPU 21st Century COE Program is jointly introduced with those of Tohoku University and Tokyo Institute of Technology as three constructive and strategic model programs in the category of "Engineering". As we informed you before, the mid-term evaluation conducted by MEXT in 2005 gave us the highest ranked evaluation, and listed our program as one of the six most excellent programs of the entire 105 COE Programs in the five categories including "Engineering". These highest evaluations owe a great deal to the kind collaboration and keen support given to us. On behalf of all the members of the TPU WERC, I would like to express our sincere appreciation to all of you.

Now our program has evolved from the 21st Century COE Program to the Global COE Program, and with the collaboration of the University of Notre Dame, we have been pioneering some new trials including construction of the EVO. With respect to the basic policy that provides the motivation for studies on prevention of wind disaster, natural ventilation, air pollution and the wind environment, based on "affection for human beings", "affection for global resources", and "affection for atmospheric environment", respectively, we would like to pursue our targets "New Frontier of Education and Research in Wind Engineering". The final goals are to promote global level advances in the quality of wind engineering education and research and to create safe and secure societies all over the world.

New curricula for the School of Architecture, Graduate School of Engineering

The School of Architecture, Tokyo Polytechnic University revised its curricula in 2008 to facilitate systematic study and research of a wide variety of important wind engineering issues. These new curricula have started in April 2009, and in 2010 the School of Architecture will be changed to the School of Architecture and Wind Engineering. We will enhance wind engineering curricula and related subjects and promote a small-scale but unique postgraduate education program. We would like to introduce our new curricula for the School of Architecture as follows:

Formation and system of subjects in educational program

The School of Architecture is divided into four disciplines: (1) Architectural Structure Engineering, (2) Construction Methods & Architectural History, (3) Architectural Planning & Design, and (4) Architectural Environmental Engineering. Figure 1 shows the educational program of "structural and environmental engineering fields" that compose our wind engineering course.

1) Master Course

The wind engineering course is divided roughly into the structural field (left side of Figure 1) and the environmental field (right side of Figure 1).

The first half of the first year of the Master course (M1) is a period for acquiring the basics required for extensive study of wind engineering, such as mathematics, fluid dynamics, and meteorology. In the latter half of M1, students are required to take compulsory courses, such as structural analysis and building vibrations from the structural field, and heat transfer, ventilation and moisture from the environmental field, regardless of their future career options.

From the second year of the Master course (M2), the structural field and the environmental field are more clearly divided, and students are required to acquire specialized learning and experiment techniques applicable to each field and to perform research in preparation for their Master's dissertation.

In addition, an Engineering Virtual Organization that consists of Tokyo Polytechnic University, the University of Notre Dame (U.S.A.), and Wind Engineering Research Institutes in various countries will provide knowledge databases and lectures through the Web, and support self-study.

Moreover, students will develop a sense of morality as engineers and contribute to elementary school education and junior high school education by working as teaching assistants (TA) or as instructors for children's science classes. They will also develop the ability to convey the science of engineering in an easy-to-understand manner.

Through the Master course, a special lecture on wind engineering will be implemented and domestic and overseas researchers and practitioners who are active in the wind engineering field will deliver lectures on advanced or topical themes. Students will gain enhanced international awareness through research exchange with overseas researchers.

2) PhD Course

In the first year of the PhD course (D1), core courses are provided in the structural and environmental fields. Based on the basics acquired during the first stage of the PhD course, students will develop advanced expertise or expertise that is helpful in practice, and improve their scholastic techniques as experts in each field. In principle, classes will be held in English so that students will develop a sense of internationalism and an ability to discuss topics in English. Intensive courses (special issues of wind engineering I to IV) will be given to students in D2 and D3 by more than 20 guest professors invited from overseas. Master course students and working people can also audit the courses.

In addition, open seminars, international advanced schools, intensive courses for overseas students in PhD courses, and short-term overseas training will be promoted as part of these educational programs so that students can select various advanced specialized subjects according to their career options. An opportunity to get in touch with overseas researchers will be created through internships with overseas research institutes or participation in joint international research. Students will also receive support for their career paths and independence through participation in joint research with private research institutes.

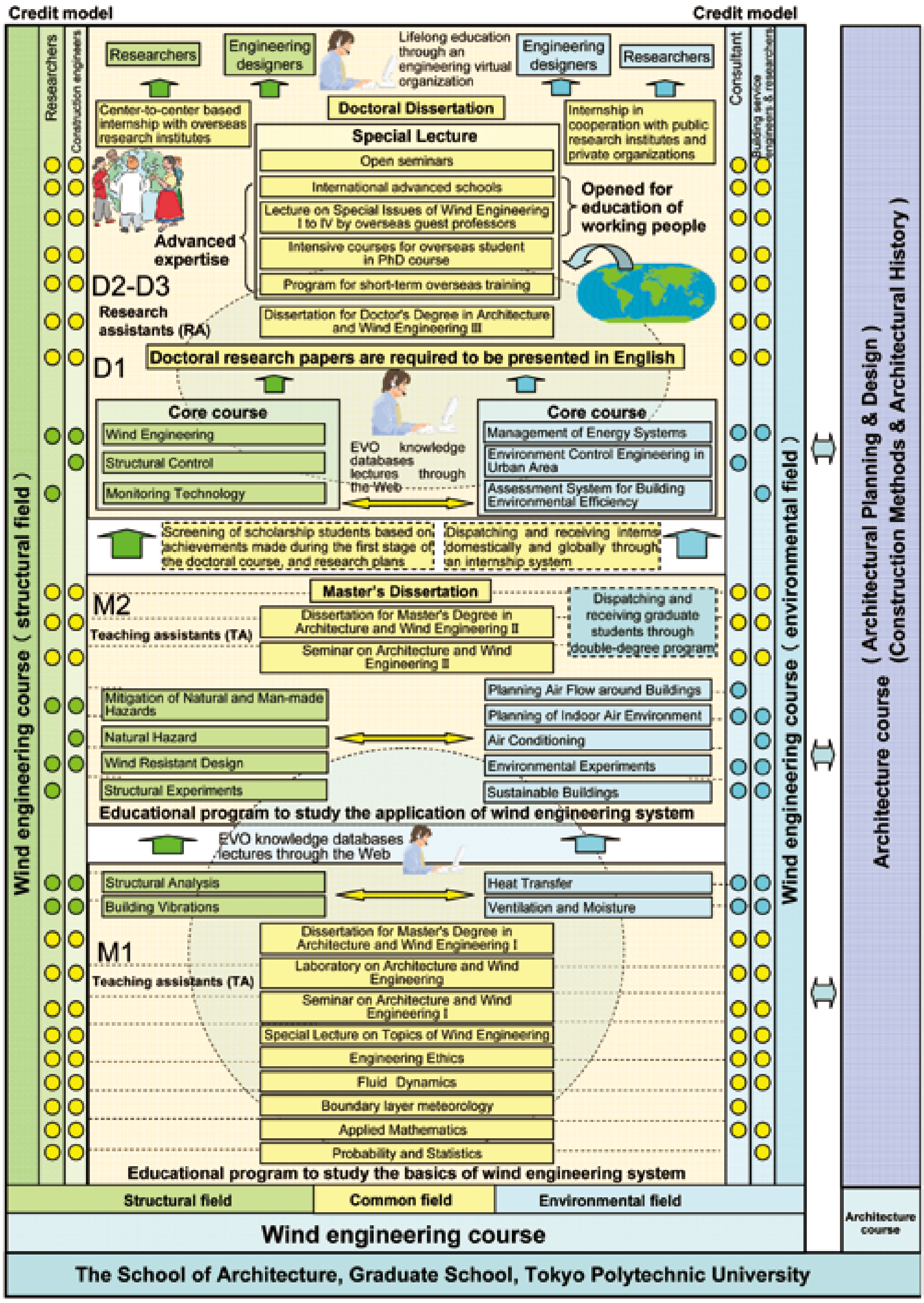

Figure 1. Education program of wind engineering course

Overview of Climate Chamber

Based on the Global COE Program, a climate chamber was constructed as a testing facility in the field of ventilation.

The exterior of the chamber measured about 5 meters wide, 11 meters long, and 3 meters high. The interior measured 3.7 meters wide, 4 to 6 meters deep, and 2.7 meters high, and also incorporated a foyer and a fan room.

The chamber's temperature could be set between 20°C and 35°C (±0.5°C) and its humidity could be set between 40% and 70% (±2%). In addition, the wind velocity could be controlled within the range of 0.1 m/s to 2.0 m/s.

A closed circuit wind tunnel was provided so that the wind from the Fan Room flowed towards the Foyer through the Measuring Area, and returned to the Fan Room through a 1-meter-wide Corridor.

To control the wind velocity, the rotational frequency of 48 plug fans with DC motors could be controlled by the use of inverters. Thus, a wind of the same velocity could be blown through the wind tunnel, or the wind velocity could be varied from side to side as well as vertically.

In the future, we plan to simulate the fluctuation of natural wind by controlling the rotational frequency of the motors via a PC.

As a major application, we plan to measure human physiological and physical responses such as human thermal sensation and the amount of perspiration when the temperature, humidity or air flow changes. Through this application, we plan to clarify the relationship between comfort and temperature, and between humidity and wind velocity during ventilation, where this relationship can now only be confirmed through actual measurement.

We also plan to apply the results of our study to the Global COE Program, such as in the development of human body heat balance models in consideration of skin temperature fluctuation, perspiration and transpiration through the fluctuation of ventilating air; the development of a dehumidifying air conditioning system using natural ventilation and radiation panels in consideration of the climate of the APEC region; and verification of the comfort of heat sensation.

Photo 1. Interior of laboratory inside climate chamber

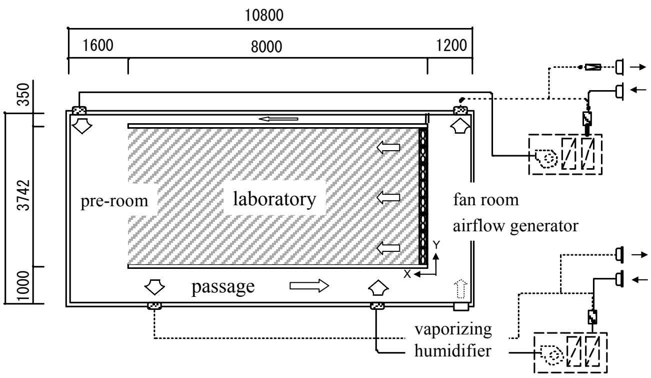

Figure 1. Plan view of Climate Chamber

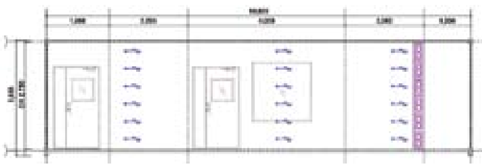

Figure 2. Section plan of Climate Chamber

Photo 2. Outer appearance of climate chamber and the fan room

TPU-TKU Wind Engineering Joint Workshop

Date: August 27,2008
Venue: Tokyo Polytecnic University, Atsugi, Japan

On August 27, 2008, the TPU-TKU Wind Engineering Joint Workshop was held jointly by the Tokyo Polytechnic University Global COE Program and the Tamkang University Wind Engineering Research Center (Taiwan) at Tokyo Polytechnic University. The Tamkang University Wind Engineering Research Center is the foremost wind engineering research center in Taiwan with ten staff members (four professors, five associate professors and one post-doctoral researcher), and three wind tunnel facilities. The aim of the workshop was to exchange information on the latest research activities of the wind engineering research groups of Tokyo Polytechnic University and Tamkang University and to share opinions on mutual cooperation. Eleven persons including students from Tamkang University participated in the workshop. After visiting experimental facilities in the morning, the workshop was held in the afternoon. The workshop started with an introduction of the Global COE Program by Professor Tamura, followed by an introduction of the Tamkang University Wind Engineering Research Center by Professor C.M.Cheng and a special lecture by Guest Professor Alan Jeary (University of Western Sydney) of the Global COE Program. Four research papers were presented by Tamkang University and three research papers were presented by Tokyo Polytechnic University. This was followed by an active exchange of opinions.

Participants

Participation Report on the Sixth International Colloquium on Bluff Body Aerodynamics and Applications (BBAA6)

The sixth International Colloquium on Bluff Body Aerodynamics and Applications(BBAA6)was held in Milano, Italy from July 20 to July 24, 2008. It was organized by the Research Center for Wind Engineering (CIRIVE) of Politecnico di Milano and hosted at Campus Bovisa Politecnico by the Faculty of Industrial Engineering. The series of BBAA was initialized by JAWE and the host country was rotated among the three global regional organizations of International Association for Wind Engineering (IAWE). The sixth BBAA was hosted by the Europe-Africa Region and chaired by Prof. Giorgio Diana of Politecnico di Milano. Totally 146 people attended this symposium and 115 papers, including 33 posters, were presented.

Open ceremony

Effect of porosity on net pressure on roof panel

Vu Thanh Trung, Ph.D student, TPU
Yukio Tamura, Professor, TPU
Akihito Yoshida, Associate Professor, TPU

1. INTRODUCTION

Roof panels with holes provide a solution to reducing temperature inside a building. Wind load on these roof panels depends on the difference between the upper and lower surface pressures. It is therefore important to be able to assess the effect of porosity on net pressures. Porosity allows air to flow across a roof panel tending to reduce mean pressures and to attenuate peak pressures, both of which reduce the total wind loading on the roof panel. The purpose of this study was to quantify the attenuation of wind loads on a porous roof panel as compared to that of wind loads acting on a similar non-porous roof panel in the same external flow field.

2. EXPERIMENT

A model (200mm high (H)×470mm wide (B)×710mm deep (D)) with roof panels was tested in a Boundary Layer Wind Tunnel, 2.2m wide by 1.8m high, in Tokyo Polytechnic University, Japan. The length and velocity scales were 1/50 and 1/4, respectively. Terrain category III (power law index 0.2) in AIJ-RFLB (2004) was chosen for the tests. The turbulence intensity at height 200mm was 0.26 and the wind speed was 7m/s. There were 3 test model cases to consider the effect of roof panel porosities (0%, 5% and 10%) with a total of 41 wind direction angles (0° to 360° in 10° steps and four wind directions angles: 45°, 135°, 225° and 315°). The model had sixteen roof panels one of which was porous with 128 holes, while four had pressure taps (A, B, C and D) (see Figure 1).

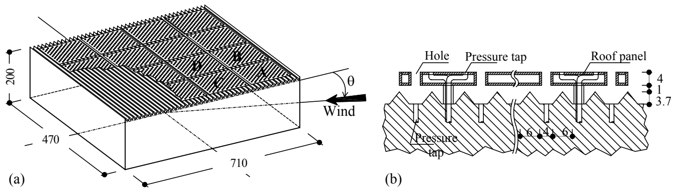

Figure 1. Test model (all dimensions in mm): (a) Geometry of test model; (b) Detail of roof section.

3. DATA ANALYSIS

The net pressure coefficient on the roof panel due to the combined effect of the upper and lower roof panel surfaces is

$$C_{p,net}(i,t) = C_{p,u}(i,t) - C_{p,l}(i,t) \qquad (1)$$

where $C_{p,u}(i,t)$ and $C_{p,l}(i,t)$ are wind pressure coefficients at measurement tap i at time t on the upper and lower surfaces of the roof panel, respectively; and $C_{p,net}(i,t)$ is the net wind pressure coefficient at measurement tap i at time t of the roof panels.

The time history of wind force coefficients was obtained by integrating the near-simultaneous pressure signals at all tap locations over both roof panel surfaces. The wind pressure coefficients and the net wind force coefficients were defined as positive in the vertically downward direction.

4. RESULTS AND DISCUSSION

Figure 2 shows the distributions of maximum peak net wind pressure coefficients ($\hat{C}_{p,net}$) on roof panels A,

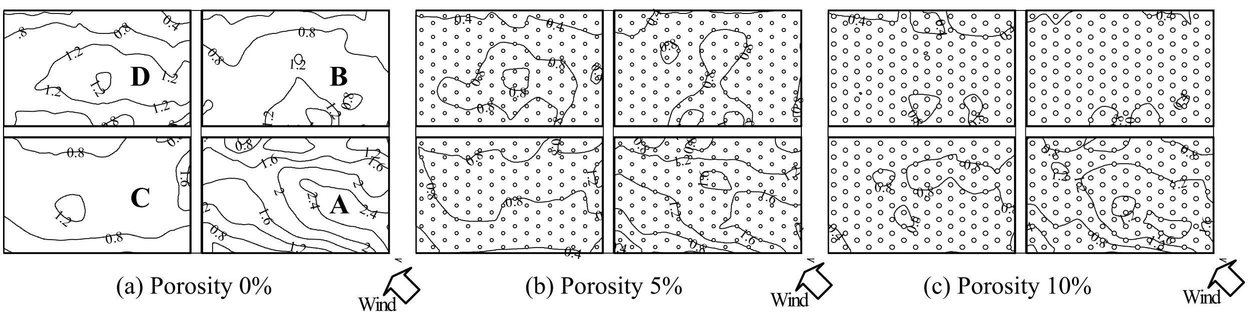

Figure 2. Distributions of $\hat{C}_{p,net}$ at wind direction angle $\theta = 45°$

B, C and D for wind direction angle 45°. Generally, the pressure coefficients of the outer roof panels are always higher than those of the inner ones. Of these four roof panels, roof panel D had the lowest values. The values of $\hat{C}_{p,net}$ for 0% porosity were up to 50% and 100% higher than those for 5% and 10% porosities, respectively.

For wind direction angle 45°, $\hat{C}_{p,net}$ varied from 0.4 to 2.4. The pressures on roof panel A were higher than those on roof panels B, C and D due to conical vortices. The values of $\hat{C}_{p,net}$ for roof panels B and C were similar.

Figure 3 depicts variations of maximum peak and minimum peak net wind force coefficients ($\hat{C}_{F,net}$, $\breve{C}_{F,net}$) for roof panels A and B for all wind direction angles. Generally, the net wind force coefficients for 0% porosity were the highest and those for 10% porosity were the lowest. The values of $\hat{C}_{F,net}$ were about 41% lower for 5% porosity and about 64% lower for 10% porosity than those for 0% porosity. These numbers were 37% and 49% for $\hat{C}_{F,net}$.

For the maximum peak values, there was a strong dependence between $\hat{C}_{F,net}$ and wind direction angles with a rapid change of these values for wind direction angles from 0° to 180°. The largest values of $\hat{C}_{F,net}$ for roof panels A and B were 0.89 and 0.78, respectively, corresponding to 0% porosity.

For the minimum peak values, the difference between the values of $\breve{C}_{F,net}$ for 5% and 10% porosities was small. The ranges of values of $\breve{C}_{F,net}$ were from -0.48 to -0.06 and from -0.39 to -0.04 for 5% and 10% porosities, respectively. The minimum peak values for 0% porosity also depended strongly on the wind direction angles, ranging from -0.84 to -0.17. Values of $\breve{C}_{F,net}$ for roof panel A for 0% porosity changed quickly for wind directions angles from 0° to 180°.

5. CONCLUDING REMARKS

The effect of porosity on net pressures on the roof panels was investigated.

The maximum peak and minimum peak distributions over the surfaces of the roof panel were measured for several wind direction angles as well as for different porosities. Four roof panels had high-pressure fluctuations at wind direction angles from 0° to 180°.

From the analysis of results obtained in the tests, the pressures on the roof panels with 0% porosity were higher than those with 5% and 10% porosities. The porosities of the roof panels were most effective in reducing wind load on them.

ACKNOWLEDGEMENTS

This study was funded by the Ministry of Education, Culture, Sports, Science and Technology, Japan, through the Global Century Center of Excellence Program, 2008-2012, which is gratefully acknowledged.

REFERENCES

1) H.J. Gerhardt and C. Kramer, Wind loads on wind-permeable building facades, Jnl. Wind Eng. and Ind. Aerodynamics, 11(1983)1-20.
2) J.C.K. Cheung and W.H. Melbourne, Wind loading on a porous roof, Jnl. Wind Eng. and Ind. Aerodynamics, 29(1988)19-28.
3) AIJ-RFLB (2004), AIJ Recommendations for Loads on Buildings, Architectural Institute of Japan.

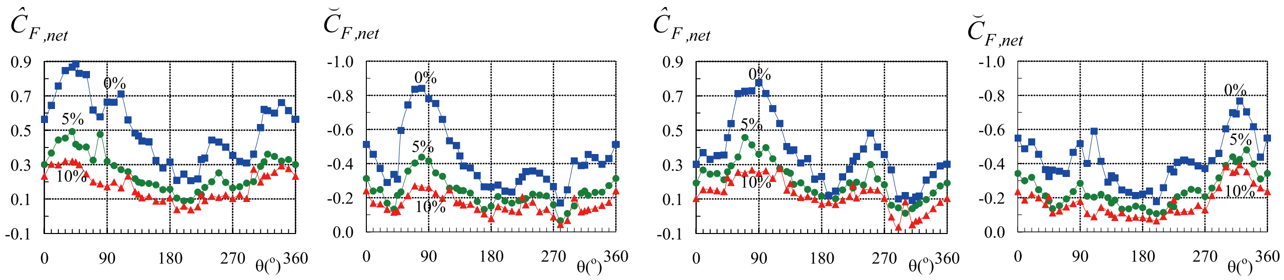

Figure 3. Variations of $\hat{C}_{F,net}$ and $\breve{C}_{F,net}$ of panels A and B with wind direction angles

Advective and turbulent fluxes of pollutants within urban canopy

Klára Bezpalcová

Complex processes like the dispersion of car exhaust in street canyons or the dispersion of accidental releases of harmful substances in built-up areas are not yet fully understood. For a better insight of the driving phenomena it is helpful to study flow and dispersion of pollutants within an idealised urban setting first. The study of dispersion through large idealised arrays of building-like obstacles is an important method of obtaining a better understanding of dispersion through a real urban environment. We examined flow and passive tracer dispersion within 18 different configuration of the idealised urban area layouts during our experiment.

Experimental set-up

The experiment was carried out in the Boundary Layer Wind Tunnel at Wind Engineering Center of Tokyo Polytechnic University, Atsugi, Japan. The 14 m long facility provides test section with 1.2 m in width and 1 m in height. The researcher team of Wind Engineering Center of Tokyo Polytechnic University has developed new method for simultaneous measurement of velocity and concentration by the means of thermo-anemometry and flame ionization detection of the tracer gas (Yoshie et al., 2007). This set-up allows deriving turbulent fluxes related to the momentum and concentration. The flow measurement was conducted using a thermo-anemometer with split-fibre probe and constant temperature adjustment module. The concentration measurements were performed by fast flame ionisation detector.

The idealised urban canopy set-ups consisted of sharp edged wooden prism of side 70 mm and heights varied from 30 to 110mm. They were arranged in the regular aligned or staggered arrays with different obstacle spacing of 16, 25, and 34% as shown in Fig.1. Different building height distributions were also applied as shown in Fig.2. The basic cases with the uniform building height were complemented with set-ups, where the building heights follow a normal distribution with mean value 70mm=1H and standard deviation 0.17H and 0.33H, respectively (see Fig.3). The individual elements were randomly distributed. The arrangement parameters are shown in Table 1. The ground-level point source of the tracer gas ethylene (C_2H_4) was located in the wake of the cube at coordinates x=-5.43H, y=0, and z=0. The location was the same for all set-ups. The emission rate of the tracer gas was 300 cc/min, i.e. 18 l per hour. The scale of the model and of the modelled boundary layer was 1:400, i.e. the average building height would be equivalent to 28 m in the full scale. The approach boundary layer was described in Bezpalcova (2007) and it modelled atmospheric boundary layer above moderately rough terrain.

Vertical fluxes of passive pollutant

The ventilation of the urban canopy can be divided to the horizontal and vertical transport of pollution. Less dense and aligned set-ups allow higher wind speeds at the street level compared to denser and staggered set-ups and therefore the horizontal transport is enhanced in these cases. However, smaller concentrations at lower elevations in the case of the denser and staggered set-ups were observed. This is caused by the enhanced vertical transport of passive tracer. The vertical wind speed component and the concentration of passive tracer gas were measured simultaneously at one place to obtain the normalised vertical advective and turbulent fluxes WC*/UH•100 and w'c*'/UH•100, respectively. The turbulent, advective, and total vertical fluxes, as well as, a contribution of the turbulent to the total flux inside the urban canopy and above are shown in Fig.4 and 5, respectively. Inside the urban canopy the magnitude of the advective vertical flux is mainly influenced by individual buildings. The mean vertical velocity is negative in the windward regions and positive in the leeward regions of individual buildings following the well-know street canyon vortex layout (Oke, 1987). Therefore, the sign of the advective vertical transport is given. The biggest values of advective flux were obtained for denser set-ups (bold lines in Fig.4) and staggered set-ups (lower row of figures). The advective transport is predominant in the plume centreline, where the contribution of the turbulent flux to total flux approaches zero. However, the turbulent transport becomes important at the plume edges, where the concentration signal is highly intermittent with very small mean value there. Therefore, the advective flux is also very small. Nonetheless, the peak concentration values are significant and coincident with certain flow patterns resulting into significant values of turbulent vertical transport.

The turbulent transport reaches the same magnitude as the advective transport at the roof top level and higher, where the mean value of vertical velocity and also the advective vertical flux approaches zero. The vertical transport of pollution is enhanced at height of 1.5H for set-ups with non-uniform building height (red and orange colours in Fig.5). The magnitudes of both advective and turbulent transports are higher in the case of staggered set-ups with higher packing densities (bold lines in lower row in Fig.5). The contribution of the turbulent flux is significant for all set-ups.

Conclusion

Pollutant dispersion within an urban canopy is very complicated process. We have chosen an idealised canopy created by regularly placed cubes to simplify the situation. The comparison of the advective and turbulent fluxes within 18 different arrangements of idealised urban canopies has shown prevailing advective transport, but significant contribution of the turbulent transport at the edge of the plume and above the roof top level. The strongest downward and upward advective transport of the passive contaminant was found at building windward and leeward positions, respectively.

REFERENCES

Bezpalcová, K, Newly implemented method for the boundary layer formation in a wind tunnel, Wind Effects News, Vol. 17, 2007

Cheng, H. and Castro, I. P., Near wall flow over urban-like roughness, Boundary layer Meteorology, 105, pp.411-432, 2002

Oke, T. R., Boundary Layer Climates, Routledge, London, 1987

Yoshie, R., Tanaka, H. and Shirasawa, T., Technique for Simultaneously Measuring Fluctuating Velocity, Temperature and Concentration in Non-isothermal Flow, Proceedings of the 12th International Conference on Wind Engineering, Cairns, Australia, pp.1399-1406, 2007

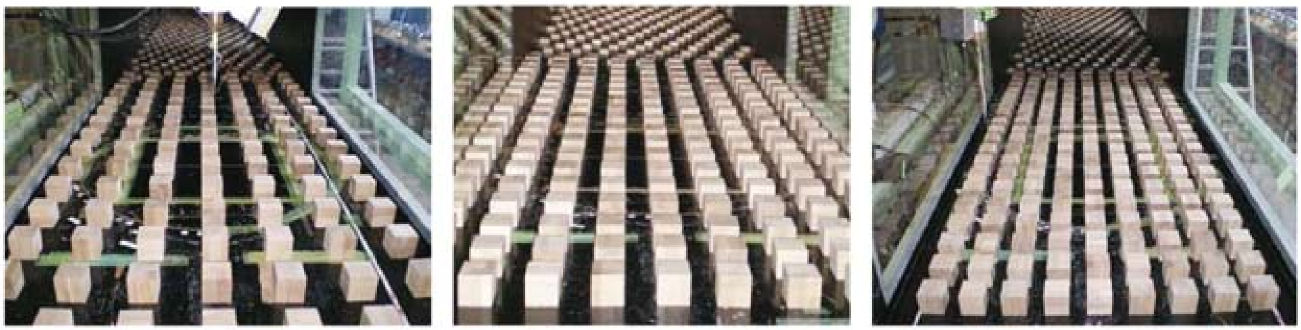

Figure 1. Idealised urban canopies with uniform building height and 16% (left), 25% (centre), and 34% (right) building coverage ratio

Figure 2. Idealised urban canopies with non-uniform building height. Standard deviation of building heights is 0.17H and 0.33H in the left and right figure, respectively

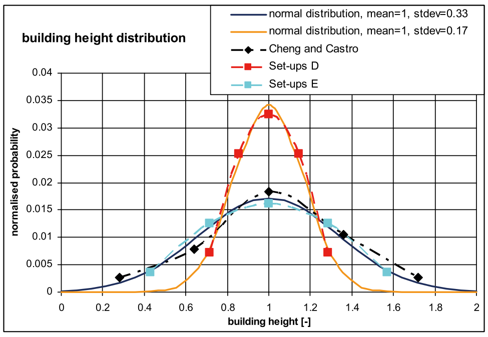

Figure 3. Normal distribution of the building heights.

Table 1. Experimental conditions.

Packing density	16%	16%	25%	25%	34%	34%
Arrangement	Aligned	Staggered	Aligned	Staggered	Aligned	Staggered
Height deviation						
uniform height	C_16_A	C_16_S	C_25_A	C_25_S	C_34_A	C_34_S
height σ=0.17	D_16_A	D_16_S	D_25_A	D_25_S	D_34_A	D_34_S
height σ=0.33	E_16_A	E_16_S	E_25_A	E_25_S	E_34_A	E_34_S

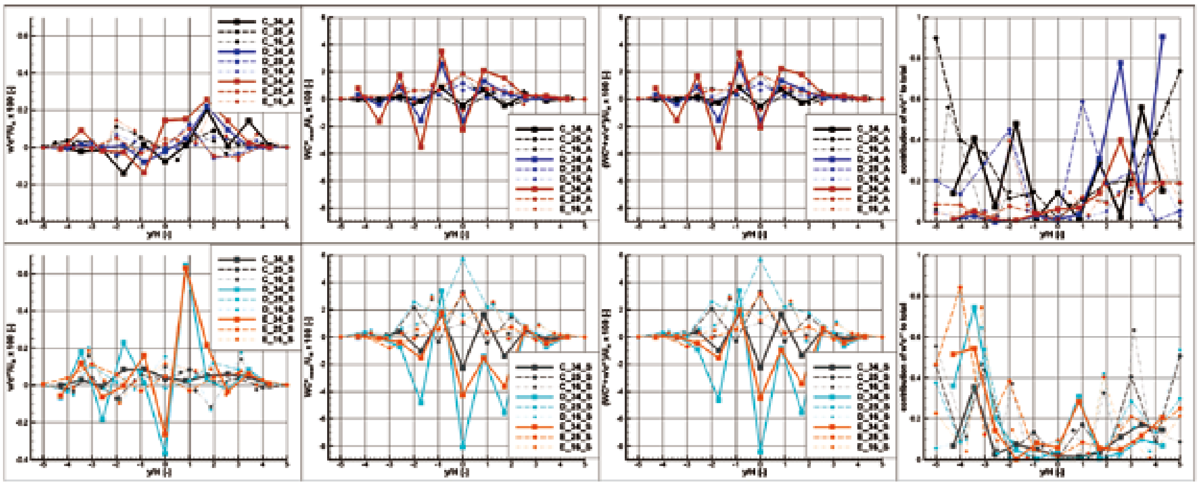

Figure 4. Horizontal profiles of normalised vertical turbulent flux (first column), advective flux (second column), total flux (third column), and contribution of the turbulent flux to the total flux (fourth column) in the middle of the fourth t street canyon behind the source at height 0.29 H.

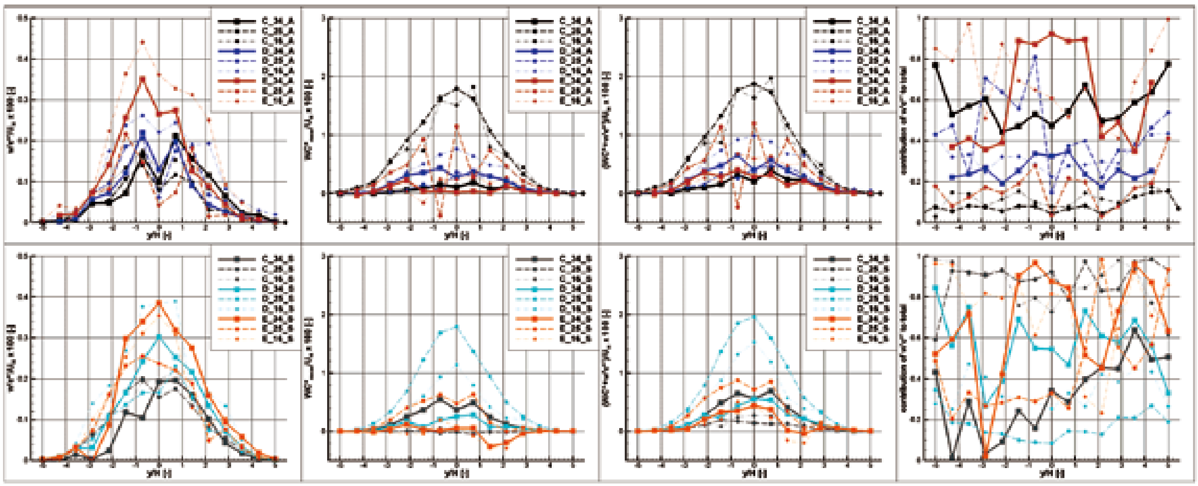

Figure 5. Horizontal profiles of normalised vertical turbulent flux (first column), advective flux (second column), total flux (third column), and contribution of the turbulent flux to the total flux (fourth column) in the middle of the fourth t street canyon behind the source at height 1.5 H.

GCOE Program TPU

New Frontier of Education and Research in Wind Engineering

Executors of the Global COE Program
New Frontier of Education and Research in Wind Engineering

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
Takashi Ohno	Professor	Wind resistant construction	oono@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	Invited Professor	Wind resistant design method	ohkuma@arch.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

Wind Engineering Research Center
Graduate School of Engineering
Tokyo Polytechnic University

1583 Iiyama, Atsugi, Kanagawa, Japan 243-0297

TEL & FAX：+81-046-242-9658

URL：http://www.wind.arch.t-kougei.ac.jp/

ISBN 4-902713-33-6