Wind Effects

Wind Effects on Buildings and Urban Environment

Bulletin

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Wind Engineering Research Center
Graduate School of Engineering
Tokyo Polytechnic University

INDEX

Report on First International Symposium on Wind Effects on Buildings and Urban Environment (ISWE1)

Date: March 8 to 9, 2004
Venue: Main hall at Science Council of Japan
Supported by The Science Council of Japan / Architectural Institute of Japan / The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan / Japan Association for Wind Engineering

An international symposium on Wind Effects on Buildings and Urban Environment (ISWE1) was held in Tokyo on 8th and 9th March 2004 with sponsorship from the 21st Century Center of Excellence (COE) program at the Graduate School of Engineering, Tokyo Polytechnic University (TPU). The symposium participants, 200 persons in total, came from Australia, Canada, China, Italy, Taiwan, the UK and the US, as well as Japan, and all contributed to the discussions.

On 8th March, Dr. Ken-ich Honda, president of TPU, welcomed the participants and emphasized the significance of the 21st COE program in TPU and the situation of full backup from TPU. He also hoped the conference to be fruitful one.

As an introduction to the COE program in TPU, Professor Yukio Tamura, the leader of the program, discussed the whole range of issues on wind effects and the importance of solving them. Professor Y. Tamura, Professor Masaaki Ohba and Professor Nobuyuki Kobayashi explained the main three projects that constitute the COE program: wind hazard mitigation, natural/cross ventilation and combatting indoor/outdoor air pollution. The participants showed great interest in this COE program, and there were many questions and discussions related to multipass effects on GPS monitoring systems, a new research field called engineering public health and natural ventilation and diffusion of fire smoke.

Then, high quality lectures were given by invited lecturers from in and outside Japan on the latest knowledge in each field of wind engineering, and questions and answers were exchanged.

Dr. Manabu Ito, Emeritus Professor of the University of Tokyo (Chairman of IABSE), described changes of the methods of old Japan for wind resistant design for a huge bridge, and introduced the role of the Japan Association for Wind Engineering. Professor Hiroshi Akiyama, (Nihon University, president of Architectural Institute), introduced energy-oriented analysis, which treats aseismic design and wind resistant design of high-rise buildings from an energy viewpoint. Professor Shuzo Murakami, Keio University, president of the Society of Heating, Air-conditioning & Sanitary Engineers of Japan, compared the abundant turbulent flow models with examples of calculations about the numerical fluid calculation technique, which predicts a local wind for wind power energy evaluation.

Professor Chris Baker, the UK, Birmingham University, considered a wide range of problems concerning wind engineering, from weak wind to strong wind, and emphasized information exchange in the wind engineering and other fields. From Professor Shinsuke Kato, University of Tokyo, gave a detailed description of the hybrid ventilation technique and demonstrated its validity. Professor Robert Meroney, the U.S., Colorado State University, described problems such as the shape of an atrium used as a boundary condition for the open air, based on many examples in which human damage in case of a fire is mainly due to smoke. Professor Kenny C. S. Kwok, Hong Kong University of Science and Technology, introduced field measurement techniques and problems of the dynamic characteristics of high-rise buildings under various oscillating conditions, such as with a crane, with human power, under micro tremors, and under wind excitation,

Prof. Honda (President of TPU)

Prof. Tamura (COE Leader)

with many examples. Professor Bogusz Bienkiewicz (president of the American Association for Wind Engineering, the U.S., Colorado State University) introduced various kinds of strong wind disaster examples, subsequent investigation techniques, etc. in the Missouri-Kansas tornado in May 2003. Professor Jun Kanda, Tokyo University, described a statistical method for the non-Gauss distribution of fluctuating wind pressures.

On the 9th of March, the symposium was opened with a lecture from Professor Masaru Matsumoto (Kyoto University, Japan Association for Wind Engineering chairman). He made synoptic review of the aerodynamic properties of a basic 2-dimensional bluff body and a box girder for a bridge. He also indicated some problems left to be solved. Professor You-Lin Xu (Hong Kong Polytechnic University) showed the results of an analysis using a new technique of an empirical mode decomposition regarding the unsteady nature of wind speeds.

Professor Giovanni Solari (president of International Association for Wind Engineering, Genova University, Italy) examined the fatigue damage evaluation method by wind response under buffeting or vortex shedding excitation. It was very unfortunate that Professor Ahsan Kareem (U.S. Notre Dame university) canceled his participation. A substitute presentation was made by Professor Tamura with Professor Kareem's lecture slides, which introduced the newest knowledge on 3-D Gust Loading Factor method.

Dr. John D. Holmes (Australia, JDH Consulting head) described the aerodynamic handling of flying objects under strong wind, which are the main reasons for wind disasters, and a method of evaluating their orbits. It was stated that data on flying objects accompanying a fire are prepared for in relation to fire-fighting. Professor Chii-Ming Cheng (Taiwan, Tamkang University) introduced the aerodynamic database and knowledge base, which can be used for wind resistant design of high-rise buildings of various horizontal sections.

Professor Alan P.Jeary (Australia, University of Western Sydney) emphasized the importance of evaluating damping to the wind response of a structure, and he described the amplitude dependence of the damping mechanism. Professor Ted Stathopoulos (Canada, Concordia University) discussed the latest knowledge on wind-induced dispersion of exhaust from rooftop stacks. Professor Hiromasa Kawai (Kyoto University, Disaster Prevention Research Institute) described a wind tunnel experiment result on the characteristics of wind pressure acting on a double skin facade where there are insufficient design data, and he introduced the influence of an opening position.

In closing, Professor G. Solari made a speech, in which he made some proposals. He stated his desire to advance cooperation relations between IAWE and the COE program, and gave his blessing to this symposium.

The exchanges among excellent researchers and the active discussions with them were very significant experiences for the COE research members of TPU. It was hoped that this symposium would be a good stimulus for the COE program, and help it to achieve to produce excellent research and educational results.

Speakers and Invited Lecturers

Ken-ichi Honda (President of TPU)
Yukio Tamura (COE Leader, TPU)
Masaaki Ohba (TPU)
Nobuyuki Kobayashi (TPU)
Manabu Ito (Chairman of IABSE, The University of Tokyo, Japan)
Hiroshi Akiyama (President of Architectural Institute, Nihon University, Japan)
Shuzo Murakami (President of the Society of Heating, Air-conditioning & Sanitary Engineers of Japan, Keio University, Japan)
Chris Baker (The University of Birmingham, U.K.)
Shinsuke Kato (The University of Tokyo, Japan)
Robert Meroney (Colorado State University, USA)
Kenny C.S. Kwok (Hong Kong University of Science & Technology, Hong Kong)
Bogusz Bienkiewicz (Colorado State University, President of the American Association for Wind Engineering, USA)
Jun Kanda (The University of Tokyo, Japan)
Masaru Matsumoto (Japan Association for Wind Engineering chairman, Kyoto University, Japan)
You-Lin Xu (The Hong Kong Polytechnic University, Hong Kong)
Giovanni Solari (President of International Association for Wind Engineering, Genova University, Italy)
Ahsan Kareem (University of Notre Dame, USA) (Substitute presentation by Professor Yukio Tamura)
John D. Holmes (JDH Consulting Mentone, Australia)
Chii-Ming Cheng (Tamkang University, Taiwan)
Alan P. Jeary (University of Western Sydney, Australia)
Ted Stathopoulos (Concordia University, Canada)
Hiromasa Kawai (Kyoto University, Disaster Prevention Research Institute, Japan)

Annual Reports of COE Research Projects

Project 1 : Wind Hazard Mitigation

The objective of research project 1 is to promote and develop many wind engineering technologies to contribute towards mitigating wind hazards. The subjects being dealt with are wind disaster investigation, evaluation of design wind speed, a wind response monitoring system for buildings during strong winds, a natural hazard prevention system for urban buildings, a reliable wind resistant design method, a wind resistant self-sufficient housing system, etc.

Wind disaster investigation

Post-disaster investigations were conducted on Typhoon 0314 (Maemi) at Miyakojima Island, Japan and the southern part of Korea. The disaster of Typhoon 0315 (Choi-wan) at Hachijojima Island was also investigated. Historical wind disasters were studied as investigations of aerodynamic forces on a five-story pagoda and the wind climate at the time. The disaster at Miyakojima is briefly discussed below.

On September 11, 2003 Typhoon 0314 (Maemi) struck Miyakojima Island in the southern part of the Ryukyu Island chain, causing serious damage. The typhoon was closest to Miyakojima Island at 03:00 to 04:00(JST) September 11, when it passed the east part of the island. The moving direction changed from the northwest to the north-northeast. At the weather observatory in Miyakojima Island, the maximum mean wind speed was 34.8m/s (03:10, JST), and the maximum instantaneous wind speed was 74.1m/s (03:12, JST). The 912.0hPa lowest atmospheric pressure at sea level was recorded at 04:12 JST when the eye of the typhoon passed. These records are comparable to remarkable records from the past: the 10th highest instantaneous wind speed, and the 8th lowest sea level pressure recorded at a meteorological observatory in Japan.

The housing in Miyakojima Island is mostly of reinforced concrete construction. This is because of the lessons learnt from serious damage from three past major typhoons (the 1st on September 15th, 1959, the second on September 5-6, 1966, and the third on September 22-23, 1968). As a result, there was some damage to only very old wooden buildings, and this was mainly to roofs of large-span buildings such as gymnasiums (Photo 1 & 2).

The most serious damage to life in the land was due to breakages of 882 electric power poles and 1031 telephone lines (overlap counting permitted). Electrical power failure affected many basic facilities such as water supply lines. There was a breakdown in the power supply over 80% of the island just after the typhoon passed. Although power was restored in 50% of the area within two days, it required two weeks for full recovery.

There were 7 wind power systems in the island, and damage was observed at all of them. 3 of them collapsed (Photo 3). The rest received some damage at their blades or nacelles (Photo 4).

Photo 1. Damaged roof of a gymnasium

Photo 2. Damage to wall by a missile

Photo 3. Collapse of wind power plant

Photo 4. Damages to blades of a wind power plant

Design wind speed

For close evaluation of design wind speeds in extratropical regions, tropical and extratropical cyclones should be taken into account separately from seasonal winds. Sometimes a cyclone simulation technique is used for this purpose. Some improvements were developed for evaluating directional properties of extreme winds as well as wind speeds. A POD-based typhoon pressure model was proposed that reproduced correlations between all typhoon pressure parameters. A database-assisted surface wind evaluation method was also proposed. The proposed techniques were used to generate virtual typhoons in Monte-Carlo simulations. Wind directionality effects were studied using the improved simulation method, and a concept for deriving directional factors was proposed.

Wind response monitoring

Basic studies were carried out to investigate the characteristics of RTK-GPS. With the RTK-GPS, measurements were conducted of wind-induced response of a high-rise steel tower. Integrity monitoring was also developed by hybrid use of RTK-GPS and FEM analysis. A WEB page was established for the public to access response data obtained by RTK-GPS. The feasibility of a multi-measurement system for wind-induced response of urban buildings was investigated using RTK-GPS.

System identification

Wind responses are very sensitive to a buildingís damping. Therefore, observation analysis, as well as data analysis by collection of analytical results, is carried out. An empirical formula of the attenuation constant is proposed for each classification of building structure. The damping factor, however, varies a lot and is overestimated in many cases, generally depending on the analysis method. Since building vibrations that include two or more modes show complicated characteristics, it is important to use the appropriate analysis method.

Various traditional techniques for estimating the damping ratio and the natural frequency were investigated using building models and full-scale measurement data. A frequency domain decomposition method (FDD) was introduced for accurately estimating the damping ratio. A multi-DOF RD technique was developed for estimating dynamic characteristics.

The vibration modes obtained by FDD from observation records and FEM analysis at a building's completion are shown in Table 1. In the FEM analysis, the building's stiffness was estimated only for the members of the main structure. As a result, the FEM results are evaluated as slightly smaller than the FDD values. The stiffness of the building's exterior walls was therefore added so that the first vibration mode was nearly identical to the actual value. As a result, satisfactory agreement was obtained up to the sixth vibration mode.

Wind resistant design of tiled roofs

The Building Standard Law of Japan and the related Enforcement were revised in 1998 and 2000, respectively. As a result, the basic idea of structural design of roofs was changed. In the old Enforcement, only the primitive specification for roofing was prescribed. In the new one, examination with calculation for structural safety of the applied roofing method is required. To cope with this situation, standard testing methods for evaluating structural performance were established with related industrial associations. However, the design wind forces for roofing members have not yet improved due to lack of appropriate data.

Main results obtained until now are as follows.

1. Characteristics of wind pressure/force on a roof tile have been examined in relation to tile shape, position on a roof and effects of tile-lift.
2. A negative peak wind force may occur with a mechanism wherein the wind pressure on the back of a tile (internal pressure) cannot follow a rapid and extreme change of wind pressure on the surface of the tile (external pressure).
3. The power spectral density of the internal pressure is similar to that of the external pressure and their coherence is high in a lower frequency region.

Wind resistant self-sufficient housing system

In most countries of Southeast Asia, which are subjects of this study, many residences suffer damage every year due to typhoons and so on. For many areas of these countries,

Table 1. Mode shapes and their natural frequencies for a CFT building obtained by FEM analysis and FDD

Mode								
Frequency (Hz)	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8
FEM	0.74	0.82	1.02	1.92	2.18	2.45	-	-
Tuned FEM	0.76	0.87	1.15	2.14	2.53	3.02	3.85	4.26
FDD	0.76	0.86	1.11	2.23	2.47	2.94	3.85	4.26

energy and drinking water supplies, which are the most fundamental life resources, are insufficient. These countries frequently suffer strong winds, but they are blessed with plenty of rainwater and sunlight. With development of an ecological house, environmentally symbiotic housing, the future use of energy and other resources is being considered.

The purpose of this study is to develop a building system and construction method for residences that will not only survive strong winds like typhoons, but also obtain energy and drinking water from the wind, solar radiation and rainwater. This will save large-scale infrastructure for distribution, creating a housing system that is independent and self-sufficient.

The main works for this research in 2003 are as follows.

1. General data of weather in the Southeast Asia area are being collected from the Japanese Meteorological Agency.
2. Basic data on the production system and the typical residential building system are being collected from books and published reports.
3. Several data on government organizations and regulations related to building systems and residential construction methods are being collected from researchers and from published reports in this area.
4. General data about the culture and typical life-style are being collected from Japanese guidebooks.

Project 2 : Natural Ventilation

With the increasing seriousness of environmental problems caused by global warming, definite technologies need to be developed to establish a sustainable society. Attention is now focused on effective utilization of natural ventilation to reduce energy consumption for ventilation, heating and cooling of buildings. However, in order to effectively promote the utilization of natural ventilation, many technological problems must be solved, such as establishing a reliable method for predicting ventilation flow rate as a basic technique. Research project 2 is now developing a natural ventilation design method. The annual research results obtained in 2003 are as follows.

Organization of the 1st International Workshop on Natural Ventilation

To promote greater international collaborative work, the First International Workshop on Natural Ventilation was held on October 31 and November 1, 2003, at the Tokyo Polytechnic University, as shown in Photo 1. The workshop was organized under the auspices of the Tokyo Polytechnic University, the Tokyo University of Science, and the Building Research Institute. The following six persons were invited from overseas to participate in the workshop as chairman and guest speakers: Professor Per Heiselberg (Aalborg University, Denmark), Assistant Professor Yuguo Li (The University of Hong Kong, China), Professor David Etheridge (University of Nottingham, United Kingdom), Professor Qingyan Chen (Purdue University, U.S.A.), Professor Mats Sandberg (University of Gävle, Sweden), and Dr. Martin Liddament (VEETECH Co., Ltd., United Kingdom). A group of specialists from Japan, including the following four lecturers, participated and presented speeches in the workshop: Professor Shinsuke Kato (Institute of Industrial Science, University of Tokyo), Senior Researcher Takao Sawachi (Building Research Institute), Professor Takashi Kurabuchi (Tokyo University of Science), and Professor Masaaki Ohba (Tokyo Polytechnic University). The contents of the lectures on natural ventilation could be classified into four fields, consisting of practical ventilation design procedure, experimental approach, numerical simulations, and ventilation modeling. There were far more participants than originally expected. In all, 119 persons participated in the workshop from a wide area including engineers and technical staff, research staff, and students

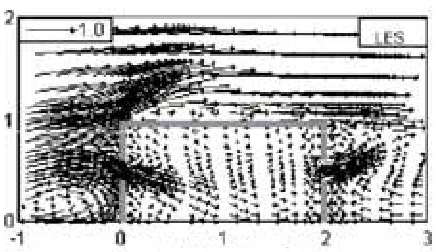
The International Workshop offered the opportunity to exchange information on the state-of-the-art in natural ventilation study and to introduce attractive features of ventilation study to young researchers and students. We are planning to organize this type of international workshop again in future to expand and promote international collaborative works among researchers beyond national borders and to contribute further to the advancement and the development of ventilation study.

Photo 1. Workshop hall on natural ventilation

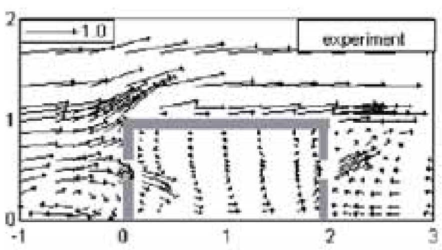
Analysis of complicated airflow structure at inflow opening for an isolated building model

The analysis of LES and wind tunnel experiments was conducted to understand the complicated airflow structure inside and outside a building. In particular, ventilation airflow is characterized by rapid acceleration and rapid deceleration in the vicinity of inflow openings. It is considered difficult to apply an eddy viscosity model such as the k-ε model to this situation. We chose instead to use Large Eddy Simulation (LES) where the Smagorinsky coefficient is regarded as constant (C_s = 0.13). Figure 1 compares the wind velocity vectors in the vertical symmetrical cross-section with wind direction set to 0°. The features of the velocity vector in the experiment were re-circulation at the front edge of the roof surface, extensive re-circulation at the lower portion of the windward surface, and sudden downfall of the inflow. The analysis of LES indicates that the primary cause of the downfall of inflow lies in the pressure gradient due to the re-circulation at the lower portion of the windward surface.

To elucidate the mechanism of total pressure loss, the shape of a virtual flow tube passing through the inflow opening was calculated by tracing the trajectories of passive markers. When the wind direction is 45°, no turbulent kinetic energy is produced at the windward corner. When the wind direction is set to 60° as shown in Figure 2, the stream tube changes to a flow along the wall surface and then reaches the opening. A significant amount of turbulent kinetic energy is produced, and this suggests that it occurs where the airflow passes through this portion and causes total pressure loss.

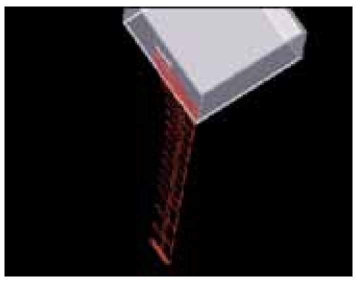


(1) LES result

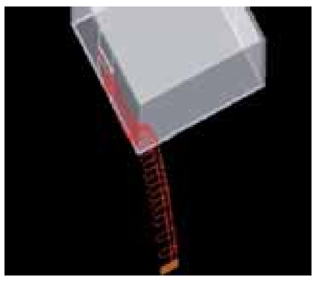


(2) Experiment

Figure 1. Comparison of velocity vector distribution by LES and experiment



(1) Wind direction 45°



(2) Wind direction 60°

Figure 2. Shape of stream tube in the vicinity of inflow opening at wind direction of 45° and 60°

Formation of high-precision cross-ventilation model

The currently used method for calculating ventilation flow rates is directed to infiltration rates. It is based on data of pressure loss at the opening under windless conditions. The discharge coefficient at the opening is highly dependent on wind direction angle, whereas the influence of wind direction is not taken into account in the ventilation calculation formula currently available. The conventional orifice flow model calculates ventilation flow rates by the following equation (1), assuming a constant discharge coefficient, C_d, independent of the approaching flow angles:

$$Q = C_d A \sqrt{\frac{2}{\rho}(P_W - P_R)} \quad (1)$$

where P_W and P_R are wind pressure and room pressure, respectively, and. Q and A are ventilation flow rate and opening area, respectively.

Based on our study results, a local dynamic similarity model was proposed (Kurabuchi and Ohba, 2002, 2004). This model expresses the relative pressure balance between the cross-ventilation driving pressure and the interfering cross-flow dynamic pressure in the vicinity of the opening. When the ratio of these two parameters concurs, it is considered that ventilation phenomena may be dynamically similar to each other at the inflow opening even when the magnitude of the ventilation driving force or the interfering cross-flow dynamic pressure differs.

The discharge coefficients were measured for various wind directions using a suction type ventilation model. The regression expressions of P_R*-C_d in Figure 3 are as follows:

$$C_d = 0.68\left(\frac{P_R^*}{-4.5}\right)^{0.133} \qquad (-4.5 \le P_R^*) \quad (2)$$

where

$$P_R^* = \frac{P_R - P_W}{\Delta P} \quad (3)$$

$$\Delta P = P_T - P_W \quad (4)$$

In the local dynamic similarity model we can choose C_d suitable to various wind directions by equation (2).

The prediction accuracy for ventilation flow rates with these models was evaluated for a basic opening in an inflow surface. The estimation results are compared in Figure 4. The ventilation flow rates were measured by a tracer gas method. The conventional orifice flow model, keeping C_d fixed, could not obtain good prediction accuracy even if the wind direction was normal to the opening. The local dynamic similarity model indicated better prediction accuracy than that with the conventional orifice flow model even when the discharge coefficient greatly decreased with change in wind direction.

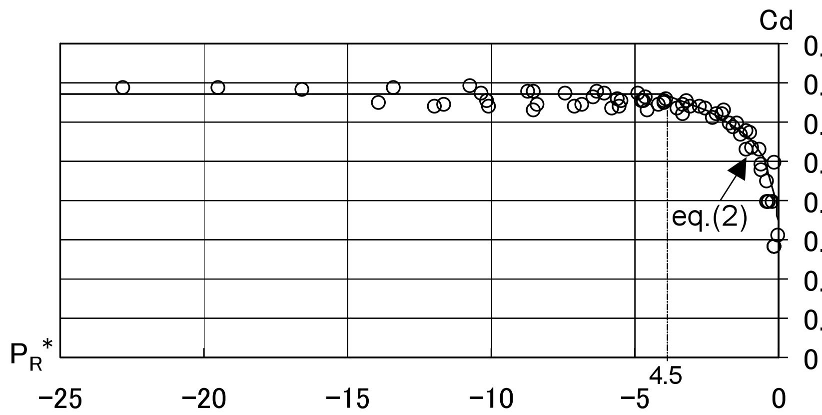


Figure 3. Discharge coefficient curves for basic opening

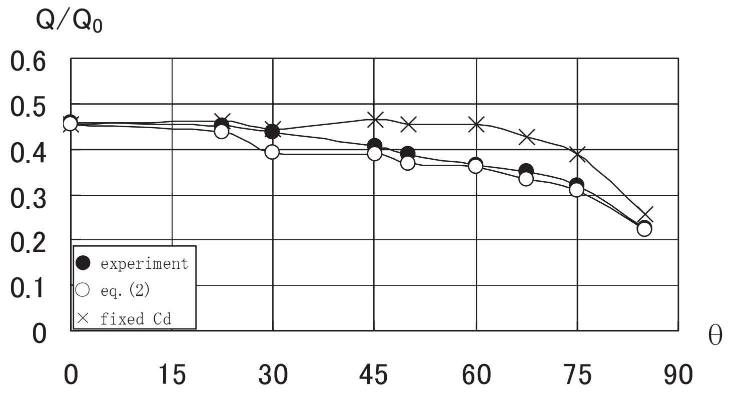


Figure 4. Comparison of conventional orifice flow model with local dynamic similarity model for prediction of ventilation flow rate at central opening

Project 3 : Control of Indoor / Outdoor Air Pollution

Air pollution in urban areas poses a serious threat to mankind. Dispersion of pollutants in city areas, street canyons and residential areas is an important area of research. Although various regulations are in force, the problem is still acute. Indoor air pollution is another area that needs to be addressed. Indoor air pollution, such as sick house syndrome, sick building syndrome and damp buildings are very common problems nowadays. Hence, there is need for immediate measures and a policy to control the air pollution menace, in both inside and outside air environments. The aim of Project 3 is to obtain new knowledge on ways of reducing air pollution and to develop risk assessment systems. This will contribute much to human safety and healthy, and, will help to alleviate environmental deterioration in developing countries where a large amount of pollutants are exhausted into the atmosphere. The project is categorized into two areas: (i) outdoor air environment and (ii) indoor air environment.

Objectives of research in outdoor air pollution

To develop a comparatively simple and inexpensive high-response concentration measurement system with multipoint measurements

To develop a numerical model for contaminant dispersion around buildings and urban areas

To suggest a pollutant removal and control method for occupied spaces in urban areas

To propose a risk assessment method for outdoor air quality and environment

Objectives of research in indoor air pollution

To develop a fundamental model for predicting emission, ad-/desorption and chemical reaction of VOCs (Indoor Air Chemistry)

To develop a numerical model for predicting microorganism growth and MVOC emission taking into account the influence of moisture and temperature (Indoor Air Biology)

To develop a procedure for coupled analysis of flow, temperature, moisture and pollutants (Indoor Air Physics)

To establish a paradigm for the integrated design of the indoor environment that takes into account the Indoor Air Chemistry, Biology and Physics (Engineering Public Health)

Progress of research in outdoor air pollution

Development of Concentration Measurement System;

A concentration measurement system using an image-processing technique with laser light and a line scan camera has been developed, and confirmed in principle that the system can measure instantaneous concentration.

Database for Flow and Contaminant Diffusion Fields in Urban Areas (Wind Tunnel Experiment);

Three dimensional air flow measurements a using split-film probe are in execution and concentration will also be measured using a high-response FID detector.

Progress of research in indoor air pollution

Indoor Air Chemistry;

A flat-plate test chamber has been developed and ozone deposition velocity is being measured for various building materials.

Measurements of ozone concentration distribution in a model room with 2D flow field were completed.

Indoor Air Biology:

The experimental setup was completed and the growth responses of fungi is being measured for various building materials taking into account the influence of moisture and temperature.

Indoor Air Physics;

Coupled simulation of emission, diffusion, ad-/desorption and chemical reaction (uni-molecular reaction) based on CFD simulation was carried out, and the predictive accuracy was verified by comparison with experimental data.

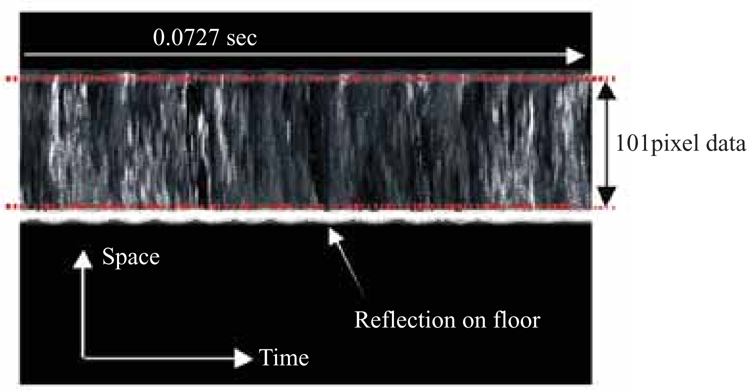


Photo 1. Image data of line scan camera

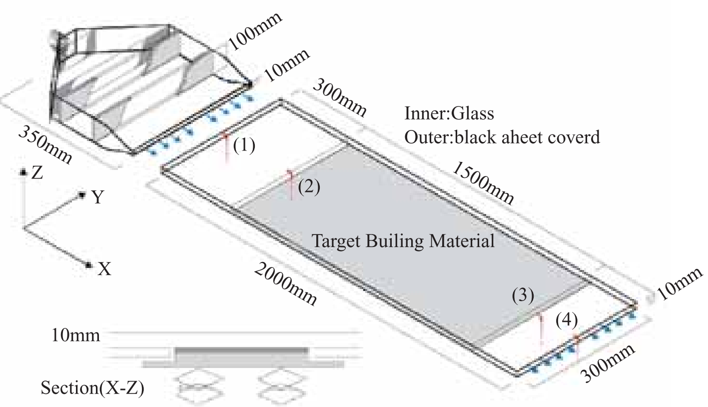


Photo 2. Flat plate test chamber for measurement of ozone deposition

Wind Pressure Coefficients on Gable Roof of Low-rise Buildings

Yong Quan, COE Researcher

In order to build a database, a series of pressure measurement wind tunnel tests were performed on gable roofs of low-rise buildings. The buildings had heights of 3 ~ 18m, depth/breadth ratios of 1~4 and roof pitches of 0°~ 45°, as shown in Figure 1. The tests were performed in a simulated suburban terrain with a length scale of 1/50 in TPU's boundary wind tunnel. The effects of roof pitch, height and depth of buildings and wind direction angle on wind pressure coefficients of gable roofs were analyzed and some conclusions were drawn concerning pressure coefficients on gable roofs.

To check the veracity of our wind tunnel test data, average wind pressure coefficients on the center axes of the gable roofs with wind direction angle of 90° were compared with those given by Holmes, as shown in Figure 2. There was a little difference between the two results because of the different depths of the test models.

The average value, RMS value, maximum and minimum values of wind pressure coefficients on the gable roofs were compared for different model heights, model depths, roof pitches and wind direction angles. The following conclusions were drawn on their effect on the pressure coefficients:

Effect of model heights. When wind direction angle was 90°, with increasing height of models, mean, minimum and maximum wind pressure coefficients on the windward roofs decreased and RMS values increased. However, on the leeward roof, maximum values and RMS values changed little at the same time.

Effect of roof pitch. When wind direction angle was 90°, mean wind pressures on the windward roof with pitch of 45° were positive and decreased with decreasing roof pitch. When the roof pitch was less than 30°, the mean wind pressures on the windward roof were negative. The minimum wind pressure on the whole roof decreased with decreasing roof pitch. At the same time, the maximum pressures on the windward roof decreased and those on the leeward roof increased.

Eeffect of model depth. When the wind direction angle was 90°, with increase in depth, the mean value of wind pressure coefficients on the whole roof, minimum values on the leeward roof and RMS on the windward roof, decreased. When wind direction angle was 0°, the depth of the roof on the leeward direction had little effect on the wind pressure coefficients near the ridge on the upwind part.

Eeffect of wind direction angle. The minimum wind pressure coefficients on the gable roof didn't appear when the wind direction was perpendicular to the ridge or along the ridge, but when it was oblique. When the roof pitch was small, the minimum pressure coefficient on the whole roof appeared at the windward corner of the roof when the wind direction angle was 30°. When the roof was steep, the minimum pressure coefficient appeared on the leeward roof near the windward gable end and it increased with increasing depth.

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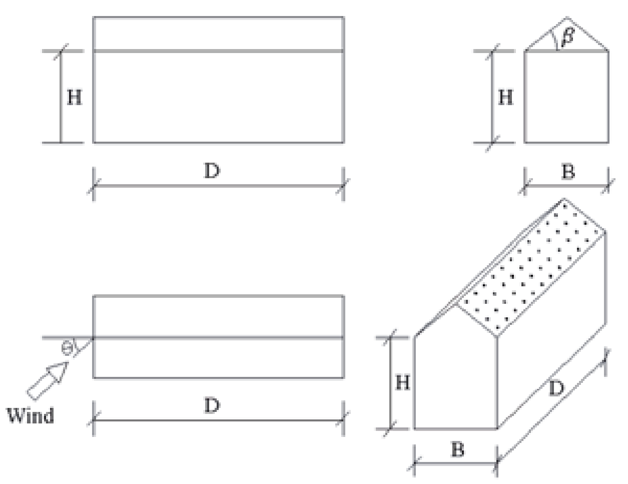

Test models' parameter (length unit: cm)

Model No.	B	D	H	β(°)	Note
1~6	16	24	6~36	26.7	Building heights are 1,2,3,4,5 or 6 floors
7~12	16	16~64	12	26.7	B/D=1/1, 1/1.5, 1/2, 1/2.5, 1/3, 1/3.5 or 1/4
13~18	16	24	12	45~0	Pitch=0°, 4.8°, 18.4°, 21.8°, 26.6°, 30° or 45°

Figure 1. Testing models

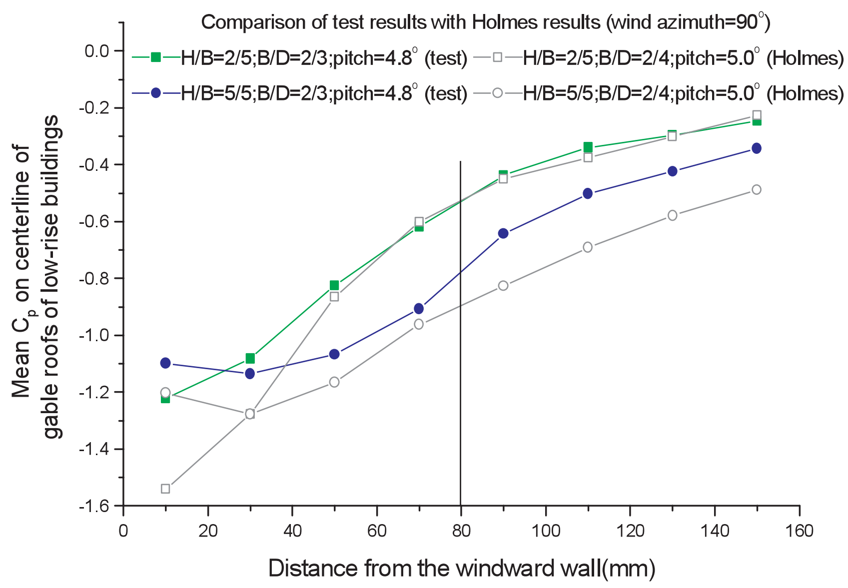

Figure 2. Comparison with Holmes' test results

Fluctuating Flow Field Pressure Measurements Behind 2-D Perforated Plates

Subhash C. Yaragal, COE Researcher

Separating and reattaching flows are encountered in diverse situations. The wake behind an immersed body is of basic importance in applications to problems of turbulent wind interaction between structures, and the dispersal of pollutants. The oldest applications have been in agricultural shelter areas. Windbreaks or shelterbelts are used to reduce wind erosion, protect growing plants, manage snow, and improve irrigation efficiency. Although not widely recognized, but of great technical significance, is the fact that pressure fluctuations away from flow boundaries can differ substantially from those measured at flow boundaries. The pressure fluctuation measurements pose experimental difficulties, particularly for measurements within the flow. Presented here is the construction, calibration and measurements made by a suitable static pressure probe. The study attempts to measure and correlate the fluctuating pressures in the flow field for different perforation levels of a normal plate.

The facility used is a suction-type low-speed wind tunnel with speed control provision. The solid/perforated plate is of steel. The step height above the splitter plate (which is of 10 mm thick Perspex) is 12mm for all cases. The configuration spanned the tunnel width and was held in mid-stream. A suitable number of 3 mm circular holes were drilled in stainless steel plates to produce different perforation levels [0% (no openings), 10%, 20%, 30% and 40%].

It is essential to exercise a lot of care in fabricating a microphone based static pressure probe. Basically, the problems stem from the need to account for the effects of the tube and the width of the air gap in front of the microphone diaphragm. The signal obtained with the probe is generally dominated by the resonant frequencies, unless the system is critically damped, in which case the signal to noise ratio suffers. By careful construction, the resonances can be shifted to higher frequencies. The static pressure fluctuations were measured with a 3.175 mm diameter B and K condenser microphone (Model No. 4138) based probe tube.

The static pressure probe used was very similar to the one used by Arndt and Nilsen (1971). The geometric details of the probe are shown in Figure 1. The locations of the pressure sensing holes were strategically determined such that the effect of the nose and holder assembly was nullified for the probe microphone unit. The output of the microphone was fed into a B and K model 2462 cathode follower built-in preamplifier and the root-mean-square (rms) values of the fluctuating signal were measured with a B and K model 2120 measuring amplifier/frequency analyzer.

This built up microphone was calibrated against a standard microphone in an anechoic chamber, as shown in Figure 2. Preliminary calibration runs of the probe microphone clearly showed a peak in the response at about 1500 Hz. This frequency agreed well with the predicted resonance frequency for organ type of resonance of the probe tube. The resonance peak was reduced by placing glass wool as a damping material between the transducer face and the static holes. The response of the probe with modifications was found to agree well with the that of a standard microphone and was found to be flat within 2 dB over a frequency range of 20 Hz to 1500 Hz. The directional sensitivity of the probe microphone with respect to the sound source was also checked and up to 15 to 20 degrees tilt, very small changes in the readings were observed.

The study reveals that the maximum coefficient of fluctuating pressure in the flow field bears a constant ratio with base pressure coefficient and the perforation level for the models studied. From the data analysis it is found that the ratio $[C_p^{'} \max / \{-C_{pb}(1-\eta)\}]$ appears to be constant and equal to 0.32.

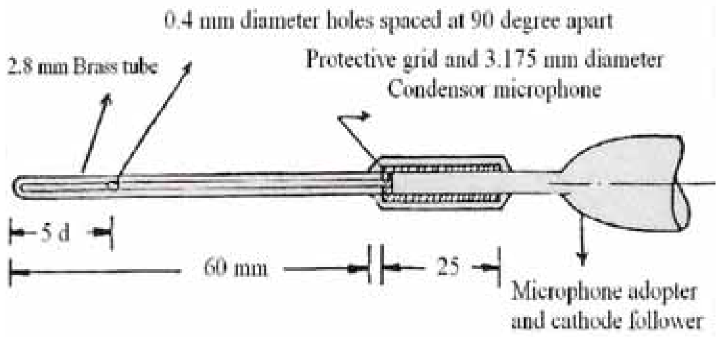

Figure 1. Geometry of probe microphone

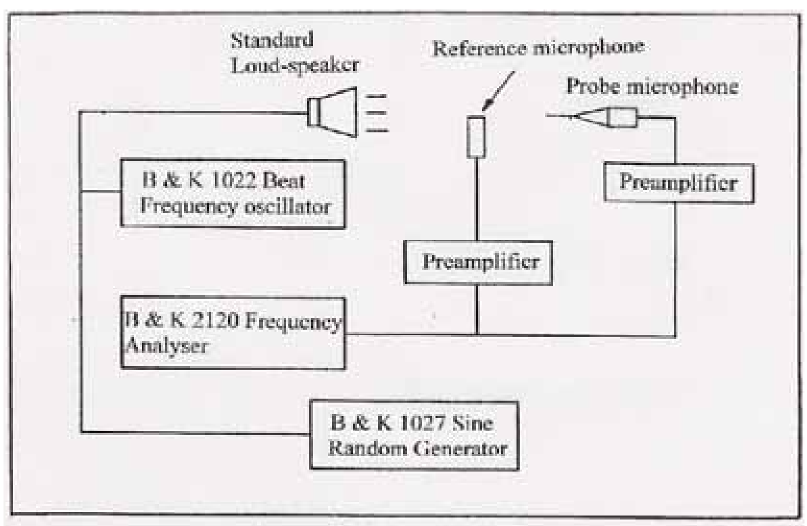

Figure 2. Probe microphone calibration set-up

Announcement

COE Workshop "Numerical Simulation of the Turbulent Boundary Layer"

Date: October 22, 2004
Venue: Tokyo(under consideration)

The COE program organized this workshop to create an opportunity to exchange new information on numerical simulation of turbulent boundary layer. Two topics will be mainly involved: simulation of the turbulent boundary layer as generating inflow turbulence for wind engineering applications, and CFD study of atmospheric turbulence.

Please confirm the details of this workshop at **http://www.arch.t-kougei.co.jp/COE/CFD2004E**

[Invited Lecturers]
S.Iizuka (National Institute of Advanced Industrial Science and Technology)
T. Ishihara (University of Tokyo)
H. Kataoka (Obayashi Corporation)
K. Kondo (Kajima Corporation)
T. Maruyama (Kyoto University)
A. Mochida (Tohoku University)
K. Nozawa (Shimizu Corporation)
T. Tamura (Tokyo Institute of Technology)
Y. Tominaga (Niigata Institute of Technology)
M.Tsubokura(The University of Electro-Communications)
T. Uchida (Kyushu University)

WERC International Symposium on Architectural Wind Engineering "Activity Report of Wind Engineering Research Center, TPU"

Date: November 18, 2004
Venue: Wind Engineering Research Center (WERC), Tokyo Polytechnic University, Atsugi, Japan

The international symposium entitled WERC International Symposium on Architectural Wind Engineering will be held with the support of the Ministry of Education, Culture, Science and Technology (MEXT) of Japan.

The symposium has the following purposes:
- to report the activities of the Wind Engineering Research Center, TPU
- to promote its achievements as an international, academic and industrial cooperation research center

Please confirm the details of this workshop at **http://www.arch.t-kougei.co.jp/COE/WERCIS**

Workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (APEC-WW)

Date: November 19 and 20, 2004
Venue: Tokyo Polytechnic University, Atsugi, Japan

A two-day workshop entitled APEC Wind Workshop (APEC-WW) will be held with the support of the COE Program with possible participation of researchers and engineers from Australia, China, Hong Kong in China, India, Indonesia, Iran, Israel, Japan, Jordan, Korea, Malaysia, New Zealand, the Philippines, Singapore, Sultanate of Oman, Taiwan, Thailand, Vietnam, etc.

The APEC-WW has two purposes:
- to harmonize the structural loading standards/codes in the APEC area; and
- to harmonize the bylaws/specifications on wind environmental problems in the APEC area.

The former is to reach a common understanding on wind loading, and to collaborate in developing methods and technologies for wind hazard mitigation in the APEC area.

The latter is to discuss bylaws/specifications for wind environmental assessment related to pedestrian level winds due to construction of tall buildings, and air-pollution problems outside/inside buildings.

Please confirm the details of this workshop at **http://www.arch.t-kougei.co.jp/COE/APECWW**

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Wind Effects on Buildings and Urban Environment

Diretor

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