Wind Effects

Wind Effects on Buildings and Urban Environment

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INDEX

Mid-term Evaluation by the Ministry of Education, Culture, Science and Technology

Yukio Tamura, Professor, Program Director

On May 11, 2005, a hearing for mid-term evaluation was held at the Japan Society for the Promotion of Science, and I attended the hearing together with President Nobuyuki Kobayashi, Professors Masaaki Ohba and Ryuichiro Yoshie. In the evaluation sub-committee for specialized fields comprising 20 committee members, I gave explanations for 15 minutes as a program leader. The details of the explanations are given below.

At first, points of "intensive support by president" were emphasized as follows.

Guidelines of study and education in the graduate schools of Tokyo Polytechnic University

Study in the graduate schools of Tokyo Polytechnic University are led by several research centers organized by forefront research groups. This is a different system from those seen in national universities, where graduate schools are simply placed above faculties. Our system is advantageous in that the limited resources of study and education can be efficiently utilized and operated. Under the general principle of study and education for graduate schools, excellent wind engineering research staff, who engage in the architectural environment and structure fields, have been appointed, and we have applied for a grant-in-aid for large-scale study such as "Wind Engineering Research Center", which serves as a scientific frontier for the promotion of studies by MEXT (Ministry of Education, Culture, Science and Technology). We have consequently recorded excellent scientific achievements, as proven by the acquisition of prizes from scientific associations inside and outside the country, and this has further resulted in fervent activities to build up a forefront research center based on the 21st Century COE Program.

Support for the 21st Century COE Program in Tokyo Polytechnic University

For good promotion of the program under the leadership of the President, "The COE Management and Operation Committee" was organized in the university. This is an organization for management and operation comprising the President (chairman), managing director, executive director, dean of graduate school of engineering, chief professor of department of architecture, head of educational affairs, and COE program director. The committee is responsible for problems such as confirmation of advancement of COE program, planning support operation by the university, and enactment of regulations relating to COE. The committee is held every 3 months and plays an important role in promoting the COE program.

In order to evaluate the activities of the entire operation of the COE program and study and educational activities, the "Advisory Board", which includes experts from third parties, has been organized. Opinions have been collected from specialists inside and outside the country who have extensive knowledge and experience in activities of study and education. These experts include the President of the International Association of Wind Engineering and the President of the Japan Society of Wind Engineering. This board studies the validity of the present policy for promoting the program and the validity of the future plan. The Advisory Board meeting is held annually. Promotion activities for the COE program by the program leader and study and educational activities by the staff are discussed and valuable advice is offered.

Further efforts are also made by the university to activate the COE program. More concretely, the activities include: (A) remission of university tuition in doctoral course; (B) APEC Wind Hazard Mitigation Center; and (C) organizing of COE support office with specialist staff. The staff and the funds required for support are provided by the university via a special budget.

Next, 8 points of "outstanding achievement" are explained as follows.

Development of research center with prospect for future study system on center-to-center basis

It is predicted that the existing study system based on individual research centers is being shifted to an international and more tightly organized study system on a center-to-center basis. In view of this trend, cooperative studies, organizing of workshops, and conclusion of an agreement for personnel interchange have been promoted and held with about 20 institutions including Nottingham University (United Kingdom) Tongji University and the Structure Anti-Disaster Center (China) etc., which exist as centers of study and education around the world. By making efforts through buildup of the APEC Wind Engineering Network, we shall continuously develop activities – not merely to establish a global level research center but also to serve as a "hub" for connecting centers around the world.

Emphasis on education –training and education of young engineers and researchers, particularly in Asia

In Asian countries, there are serious problems of frequent disasters due to typhoons or cyclones, and problems of air pollution and energy consumption due to rapid urbanization and concentration of populations in cities. Thus, researchers and engineers should be trained and educated from the international viewpoint, and this is being accomplished by the APEC short-term fellowship, internship of PhD students, lectures given in the English language, etc.

Continuing organization of international conferences and open seminars, and improvement of research education through international exchange

After the adoption of the COE program, 7 international meetings have been held (710 participants in total; 109 participants from overseas). Furthermore, 27 COE Open Seminars have been organized, and 39 lectures were given (about 700 participants in total; about 200 participants from overseas). In total, about 1400 researchers and students have participated in the seminar. The latest study achievements were widely circulated among researchers and students by these meetings and seminars. This improves the quality of education and research, and also provides the chance for young researchers and engineers to exchange information with excellent researchers inside and outside the country.

First-rate achievements on study

Superior research results have been produced, such as "the development of high-precision prediction model for ventilation flow rate (March 2004)", "universal equivalent static wind load distribution (July 2004)", "the study on the combination of wind load (July 2004)", etc. These results have affected trends of study inside and outside Japan, and made great contributions to society by being adopted for domestic guidelines and international standards.

Announcement of experimental data, research materials, IT contents, etc., and prompt reflection in education

Experimental data, research materials and reports on the investigation of disasters are publicly presented on a website so that the study results can be shared throughout the world via the Internet. The information is also propagated through News Letters in Japanese (issued 4 times annually) and Bulletins in the English language (twice annually). It is also attempted to reflect the study results in lectures to graduate students.

Cooperation with enterprises

Cooperation with enterprises and other research organizations are very important from the viewpoint of learning through practice and for identifying social trends and seeds of studies. This is also very important as a part of our contribution to society as specialists in wind engineering and for the consolidation of the economic basis of post-COE programs. Positive efforts are being made to conclude a basic agreement on long-term cooperative research with enterprises and advanced consultant activities for practical projects. They are based on the premise that these activities will have significant meaning for study and their results will be open to the public.

Selection of purposes and themes based on love for human beings, earth resources, and air environment

Motivation for studies on prevention of wind disaster, natural ventilation, air pollution and the wind environment are based on "love for human beings", "love for global resources", and "love for atmospheric environment", respectively. All these are based on "love" on human beings and the earth. With this awareness, we will be able to set up a meaningful goal, to create good ideas and to continue our efforts toward accomplishment of the study. We consider this to be an important impetus for education in wind engineering.

Evaluation of study from international viewpoint

An external evaluation meeting of persons comprising the Advisory Board of 7 members, including the world's leading scholars and researchers such as the President of the International Association of Wind Engineering (IAWE), and the coordinator of IAWE in the U.S., is held in March each year. International evaluation is provided on our study, education and other activities in the COE program. These results are utilized for execution of future activities.

After explanations have been made, the members of the evaluation sub-committee in specialized fields asked questions and made comments on organic cooperation of study and education activities between our research groups, i.e. for wind disaster and for the wind environment.

The evaluation results were notified to us in October and were also publicly announced on the web page of the Japan Society for the Promotion of Science (http://www.jsps.go.jp/j-21coe/05_chukan/index. html). The present program was jugged as "The program has been carried out as initially planned, and the objectives of the program will be attainable by continuing the current efforts". Our program was reported as a remarkable achievement, and the highest evaluation was granted.

In future, we will continue our efforts in study and education to solve problems such as prevention of wind disaster on buildings in urban areas, natural ventilation, diffusion of contaminants, and problems relating to air flow in cities and buildings. Furthermore, we aim to build the world's top center of study and education in wind engineering. Our final goal is to provide feedback from our study to the public and to contribute to the welfare of human beings and society. In this respect, we expect sincere and thoughtful cooperation from you all.

Report on the 2nd International Symposium on Wind Effects on Buildings and Urban Environment (ISWE2)

Date :	September 15, 2005
Venue :	Sheraton Walker Hill Hotel in Seoul, Korea
Co-Organized by :	Wind Engineering Institute of Korea (WEIK)
	The 21st century COE program at Tokyo Polytechnic University
Supported by :	Japan Association for Wind Engineering

An international symposium on Wind Effects on Buildings and Urban Environment (ISWE2) was held in Seoul on September 15, 2005. This symposium was organized by the Wind Engineering Institute of Korea (WEIK) and the 21st century COE program of Tokyo Polytechnic University (TPU) and supported by the Japan Association for Wind Engineering (JAWE).

At the opening, Prof. Yukio Tamura (21st century COE program leader of TPU) welcomed the participants and expressed his gratitude to professor Young-Duk Kim, president of WEIK and co-organizer of the symposium.

Venue: Sheraton Walker Hill Hotel

The morning session was chaired by Professor Hiromasa Kawai, Kyoto University. The first presentation was made by Dr. Ahmad K. Abdelrazaq (Samsung, Korea), and entitled "New paradigm in tall building planning and design". He showed recent high-rise building construction projects in Asia and their structural characteristics and wind loads. Many examples of aerodynamic devices and vibration dampers were shown. A comment from the audience pointed out the problem that the dampers required some space, whereas in Japan elasto-plastic dampers, which can be set in walls, were often adopted instead of tuned mass dampers. Professor J. C. K. Cheung (Monash University, Australia) presented "Model scale effect of topography on wind tunnel testing for buildings". Although it was an important practical issue, validation by wind tunnel tests for topography was sometimes difficult. This interested everyone and led to some discussion. Some of comments were that a numerical approach would be remarkable and that even isolated high-rise buildings could affect buildings 800m leeward.

Professor Chris Letchford (Texas Tech University, US) showed "Thunderstorm effects on buildings". He used pulsed jets to simulate downbursts in the laboratory kinematically. Downbursts were such local meteorological disturbances that there were not enough observation records and more full scale data needs to be accumulated.

Dr. Tim Reinhold (Institute for Business and Home Safety, US) presented "Wind loads on low-rise buildings: Is one set of pressure coefficients sufficient for all types of terrain exposures?" By showing many examples of wind induced damage, he focused on problems with the wind design method.

In the afternoon, sessions were chaired by Professor Kangpyo Cho (Wonkwang University, Korea). Professor Young-Duk Kim (Kwandong University, Korea) presented

The symposium site

"An experimental study on the noise of thin columns induced by wind". He measured acoustic pressure level from a variety of shaped prisms immersed in wind. The relation between Strouhal number and girth was pointed out.

Professor Masaru Matsumoto (Kyoto University, Japan) presented "Karman vortex shedding and its effects on bluff body aerodynamics". He discussed the effects of Karman vortex on galloping oscillation. He showed that suppression of the Karman vortex led to galloping arise.

Professor Elizabeth English (Louisiana State University, US) presented "Current research on the trajectories of wind-borne debris: simulation, verification and application". She illustrated the flying trajectories of wind bone debris that caused serious damage under high wind conditions.

Presentations from seven worldwide active wind engineering researchers led to very fruitful discussions. This symposium was held in conjunction with the sixth Asia-Pacific Association for Wind Engineering (APCWE-VI). (Masahiro Matsui)

Professor Yukio Tamura stated the welcome

Dr. Ahmad K. Abdelrazaq

Professor J.C.K. Cheung

Professor Chris Letchford

Dr. Tim Reinhold

Professor Young-Duk Kim

Professor Masaru Matsumoto

Professor Elizabeth English

Report on the 1st Korea-Japan Joint Meeting on Wind Engineering

Date : September 15, 2005
Venue : Sheraton walker Hill Hotel in Seoul, Korea
Co-Organized by : Wind Enginering Institute of Korea(WEIK),Japan Association for Wind Engineering(JAWE)

The 1st Korea-Japan Joint Meeting on Wind Engineering (JaWEiK1)was held as a joint hosting of the Japan Association for Wind Engineering (JAWE) and the Wind Engineering Institute of Korea (WEIK) on September 15th, 2005 at Sheraton Walkerhill Hotel, Seoul, Korea. The aim of JaWEiK was to share information on wind engineering between wind engineers of Japan and Korea. The main topic of this JaWEiK1 was "Workshop on Wind Load Codes for Buildings and Bridges" and there were 4 presentations as follows:

Yukio Tamura, Hiromasa Kawai, Yasushi Uematsu, Hisashi Okada, Takeshi Ohkuma, "Wind resistant design of buildings in Japan"

Young-Cheol Ha, "Wind load provisions of the 2005 version of the Korean Building Code–Structural and tentative plans for future revision"

Hiroshi Sato, "Wind resistant design methods for bridges in Japan"

Heeduck Kim, "Wind resistant design for bridges in Korea"

After this meeting, a Steering Meeting organized by representatives of both countries was held to discuss the future program. As a result, it was decided that this JaWEiK would be held regularly, and that the next meeting would be held as a satellite meeting of an annual meeting of JAWE in Japan next year.

(Akihito Yoshida)

Report on the 2nd International Workshop on Natural Ventilation

Date: December 1 and 2, 2005
Venue: AIJ Hall
Organized by: National Institute for Land and Infrastructure Management (NILIM), Building Research Institute (BRI), The 21st Century COE Program "Wind Effects on Buildings and Urban Environment" Tokyo Polytechnic University, Tokyo University of Science
Supported by: Architectural Institute of Japan (AIJ), Institute for Building Environment and Energy Conservation (IBEC), Consortium for Building Research and Development

On December 1-2, 2005, "The Second International Workshop on Natural Ventilation" was held at the AIJ Hall. This workshop was organized under the joint auspices of four organizations: NILIM, BRI, Tokyo University of Science and Tokyo Polytechnic University COE Program. Its aim was to present and share the latest information on natural ventilation, and to express opinions on further studies and practices in this field.

Prior to the opening of the workshop, Dr. Hiroyuki Yamanouchi (BRI) welcomed all participants, and explained the spirit and scope of the workshop.

At the beginning of the morning session on the first day, a keynote speech was given by Dr. Richard Aynsley In the speech, he introduced the basic concept of "Indoor Wind Speed Coefficients", which is to easily evaluate the general influence on natural ventilation of various factors, and also discussed comfort conditions for naturally ventilated spaces. Then, Dr. Nigel Wright, Dr. Takao Sawachi, and Dr. Tomoyuki Endo presented subjects relating to wind pressure and airflow characteristics. They discussed the analysis of unsteady flow of natural ventilation based on DES, the influence of adjacent buildings on the wind pressure analyzed using the "Wind Shadow" concept, the accuracy of wind pressure predicted by CFD analysis with different RANS models, and a method for coupling the "Local Dynamic Similarity Model" with CFD analysis.

In the afternoon session, Professor Heiselberg and Professor Ted Stathopoulos reviewed the latest study on natural ventilation, such as limitations in applying the orifice equation, the method for measuring the discharge coefficient of a full-scale window, and the internal pressure coefficient during natural ventilation. Next, there were presentations by Professor Takashi Kurabuchi, Dr. Hisashi Kotani, Professor James Axley, and Professor Masaaki Ohba regarding modeling of natural ventilation phenomena. Several useful solutions were proposed to problems impairing the modeling of natural ventilation phenomena, i.e. changes of discharge coefficient caused by porosity, changes of discharge coefficient with approaching flow angle or opening position, and conservation of mechanical energy.

President Nobuyuki Kobayashi (TPU) concluded the first day's sessions, and indicated his expectation of further development toward establishment of standards on natural ventilation design and on their application for further social development.

The second day began with the opening speech by Dr. Akira Muragishi (NILIM). In the morning session of the second day, a panel discussion entitled "Natural Ventilation for Passive Cooling and Its Regional Feasibility" was held. Professor Shuzo Murakami acted as the coordinator, and the panelists included: Dr. Martin Liddament, Mr. Katashi Matsunawa, Dr. Aynsly, Professor Stathopoulos, Professor Axley, Professor Yuguo Li and Professor Heiselberg. Dr. Liddament started the panel discussion with his keynote speech, and each panelist presented standards on natural ventilation design for their respective country and introduced design examples. Then, in response to questions from the audience, active discussion took place with subjects concentrated on appropriate design methods for opening sizes for natural ventilation, how to link users to natural ventilation, and the cost of natural ventilation.

In the afternoon session of the second day, there were presentations on problems of exhaust heat. Professor Li, Professor Tatsuo Nagai and Dr. Shigeki Nishizawa presented a simple design method for night cooling to provide thermal mass effect, the results of a study using an

Second day's panel discussion

First day's lecture

optimization technique to determine the relation between window opening behavior of occupants in a room and air-conditioning, and the results of a full-scale building model experiment on heat and contaminant distribution during cross-ventilation. Next, on the subject of single-sided opening ventilation, Professor Shinsuke Kato and Professor Toshio Yamanaka introduced a wind tunnel experiment on the effects of a projection installed at an opening and circulating airflow in a room on ventilation flow rate, and CFD analysis and experiments on the influence of fluctuating wind pressure on ventilation flow rate.

As described above, forefront studies on natural ventilation were presented by 7 foreign speakers and 11 Japanese speakers, and there was active discussion among the 196 participants in this workshop. (Tomonbu Goto)

Speakers and Invited Lecturers

Richard Aynsley (Delta T Corporation, USA)
Nigel Wright (University of Nottingham, UK)
Takao Sawachi (National Institute for Land and Infrastructure Management, Japan)
Tomoyuki Endo (Tokyo University of Science, Japan)
Per Heiselberg (Aalborg University, Denmark)
Ted Stathopoulos (Concordia University, Canada)
Takashi Kurabuchi (Tokyo University of Science, Japan)
Hisashi Kotani (Osaka University, Japan)
James Axley (Yale University, USA)
Masaaki Ohba (Tokyo Polytechnic University, Japan)
Shuzo Murakami (Keio University, President of AIJ, Japan)
Martin Liddament (VEETECH Ltd., UK)
Katashi Matsunawa (Nikken Sekkei Ltd., Japan)
Yuguo Li (University of Hong Kong, China, Hong Kong)
Tatsuo Nagai (Tokyo University of Science, Japan)
Shigeki Nishizawa (Building Research Institute, Japan)
Shinsuke Kato (The University of Tokyo, Japan)
Toshio Yamanaka (Osaka University, Japan)

Report on the 2nd Workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (2nd APEC-WW)

Date : December 5 and 6, 2005

Venue : The Hong Kong University of Science and Technology (HKUST)

The 2nd workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (2nd APEC-WW) was held at the Hong Kong University of Science and Technology (HKUST) on December 5th and 6th, 2005. It was co-hosted by the CLP Power Wind/Wave Tunnel Facility of the HKUST & the 21st Century Center of Excellence (COE) program of Tokyo Polytechnic University. The 2nd APEC-WW followed the spirit set in the 1st APEC-WW, which was held at TPU in Japan in 2004. The purpose of the APEC-WW was to harmonize structural loading standards/codes and bylaws/specifications on wind environmental problems in the APEC area. The workshop participants, about 40 persons in total including 28 delegates from 14 APEC countries, contributed to the discussions.

On December 5, Prof. Kenny C.S. Kwok of HKUST welcomed the participants and emphasized the significance of collaboration, harmonization, and exchange of information on wind loading and wind environment related codes and recommendations in APEC countries. Then, along with the concept of this workshop, reports from 14 countries were presented by the delegates

All participants

Prof. Kenny Kwok stated the welcome

and active discussions took place. On December 6, semi-closed workshops were held to promote more detailed discussions. Participants were separated in two special sessions, i.e. wind loadings and wind environment. In the session on wind loading, design wind loads for three example buildings (Example 1 - A steel-framed warehouse in an urban area, Example 2 - A medium-height office building in a tropical city, Example 3 - A tall building in a city centre) based on the structural loading code of each country were compared and discussed. In the session on wind environment, air ventilation assessment systems in Hong Kong (AVAS), and specifications for outdoor and indoor air qualities and wind power generation were discussed. As a result of the two-day workshop, resolutions for wind loading and wind environment were made and approved. The next workshop will be held in India. After the workshop, a technical tour at the CLP Power Wind/Wave Tunnel Facility of the HKUST was held. The participants admired the large, splendid wind tunnel. The 21st century COE program will continuously support the workshop. It is hoped that this activity will contribute to solving wind related problems in APEC countries.

(Ryuichiro Yoshie)

Invited Article

Development of CFD Simulations in Support of Air Quality Studies

Alan Huber

National Atmospheric and Oceanic Administration, Atmospheric Sciences Modeling Division, in partnership with US Environmental Protection Agency, RTP, NC

Overview

Computational Fluid Dynamics (CFD) simulations of pollutant concentrations within roadway and building microenvironments is feasible using high performance computing CFD models are emerging as a promising technology for such assessments, in part due to the advancing power of computational hardware and software. The results of CFD simulations can both be directly used to better understand specific case studies as well as be used to support the development of better-simplified algorithms that may be generally applied to complex situations. However, the tools are not well evaluated for air quality modeling and best-practice methodologies have not been established. A program has been ongoing over the past few years at the US EPA in collaboration with Fluent, Inc scientists to develop applications using the Fluent CFD software and work toward establishing best practices. Unlike most currently used regulatory air quality models, CFD simulations are able to treat for topographical details such as terrain variations and building structures in urban areas as well as local aerodynamics and turbulence. CFD simulations have the potential to yield more accurate solutions than existing regulatory air quality models because CFD models solve the fundamental physics equations including the effects of detailed three-dimensional geometry and local environmental conditions. Development and application of CFD simulations are being advanced through case studies for simulating air pollutant concentrations from sources within open fields and within complex urban building environments. CFD developments are being evaluated by comparing with both wind tunnel model and field measurements. Additional information about these ongoing developments is covered by Huber et al. (2005) and Tang et al. (2005).

Prior to September 11, 2001 developments of CFD were begun to support air quality applications assessing the impact from usual sources of pollution. There is a need to properly develop the application of CFD methods in support of air quality studies involving pollution sources near buildings at industrial sites and roadways. While this original work continues, following September 11, 2001 there was a need to model the transport of potential emissions from “ground zero” at the New York World Trade Center (WTC) area. Much has been learned and developed over the past few years through research and development.

Originally the plans were to develop CFD applications under a more modest progression of urban complexity. Rising to the need to study lower Manhattan, which is one of the most complex urban building environments on earth, presented great challenges. By learning to overcome many of these challenges, future more common modeling of air quality in urban building environments should be easier. Plume dispersion in the absence of buildings is generally simulated with standard plume dispersion models for point and line source pollutant emissions. The development of CFD methods and applications in urban building environments is critical when it is important to accurately estimate potential human exposures to local sources of a toxic contaminant. In the absence of being able to measure everything we need to know in the field, finely resolved numerical models are necessary to fully understand relationships between local pollutant sources and air concentrations along their pathways to exposure. CFD simulations have great potential for supporting both urban air quality and homeland security studies.

Software

FLUENT, which is a general purpose computational fluid dynamics code that solves the governing equations for the conservation of mass, momentum, energy, and scalars such as a pollutant, is being used. The codes multiphase models, moving domain models, and turbulence models are being applied. Developing quality mesh for the complex array of buildings found in lower Manhattan has been particularly challenging. The process is much smoother for idealized building shapes where the model may be developed directly though the GAMBIT code. Computational Engineering International (CEI) mesh and Visualization software is also being used. Setting up a CFD model of an urban area requires a building database. Buildings for the New York City studies were developed from a database licensed with Vexcel Corporation.

Atmospheric Boundary Layer

For atmospheric flows the segregated solver using implicit discretization is being used. In general, second order calculations are being used. Initial developments are working with the steady-state solutions for the Reynolds-Averaged Navier-Stokes (RANS) governing equations for momentum. The realizable k-ε turbulence modeling option is presently the default. There are several other k-ε options that are being evaluated for future application. In the future higher order turbulence closure models including Reynolds Stress Models (RSM) and Large Eddy Simulation (LES) within the framework of unsteady solutions will be evaluated.

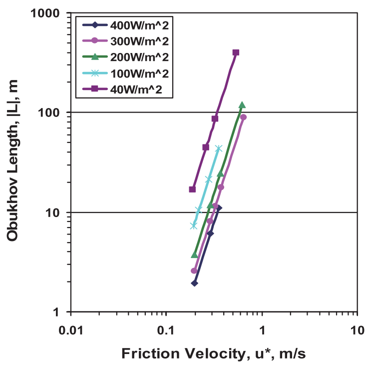

Figure 1. Monin-Obukhov theory applied to a range of case studies

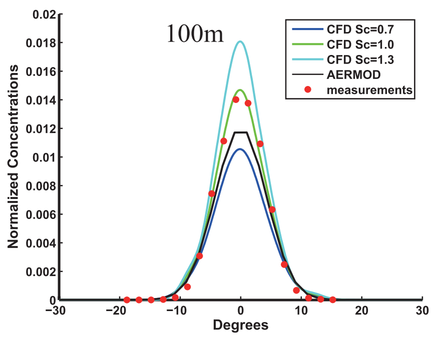

Figure 2. Example Project Prairie Grass case.

Simulation of the atmospheric boundary layer is critical to modeling plume dispersion. Boundary layer turbulence can be simulated as characterized by surface roughness (characterized by z_0 and surface stress u_*) and surface heat flux (characterized by the Obukhov length L). The "law of the wall" is applied to develop an atmospheric boundary layer oncoming as boundary conditions to the study zone with buildings. No work has yet been started to evaluate strongly stable stratified flow. Figure 1 presents a summary of simulated Obukhov length (L, m) versus surface friction velocity that result from a range of simulations. These results are found to compare well with Monin-Obukhov theory. Figure 2 presents example comparisons of the crosswind profiles of normalized concentrations compared with field measurements from project Prairie Grass (Barad, 1958), demonstrating comparability with the measurements and the AERMOD regulatory plume model (Cimorelli et al., 2005). Three turbulent Schmidt Numbers are being evaluated.

Simulations from WTC Studies

CFD applications have been under development to reconstruct the dust/smoke plume following the events at the New York City World Trade Center on September 11, 2001. The scope of the reconstruction has 3 stages:

a) the plume following airplane impact but prior to the collapse of the towers

b) during and immediately following the tower collapse

c) the days following September 11 when emissions from "ground zero" could be significant.

Parts b) and c) are the key developments and briefly presented in this summary. A large amount of momentum and kinetic energy is generated by the collapsing tower. During the collapse potential energy is being converted to kinetic energy. The flow impingement created by a collapsing tower creates vortex structures which transport gaseous constituents and particulate matter radially outward from the base of the towers. These materials were dispersed though lower Manhattan into the surrounding Metropolitan area. Nearby the collapsed towers the material was transported radially in all directions. However, this radial impulse created by the collapsed tower is short lived and soon the material is caught by the prevailing winds. Figure 3 presents an example near surface (H= 5 m above ground) wind field. Immediately following the completion of the collapse (T= 15 s) an impulse radiating out from the tower base is shown. Maximum velocities of 30-40 m/s range were short lived. Figure 4 presents an example of the smoke and

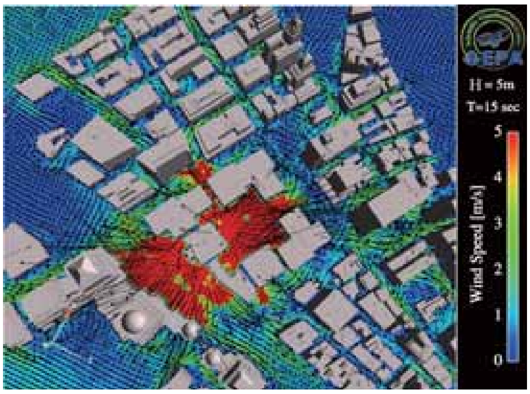

Figure 3. Surface winds immediately following the building collapse.

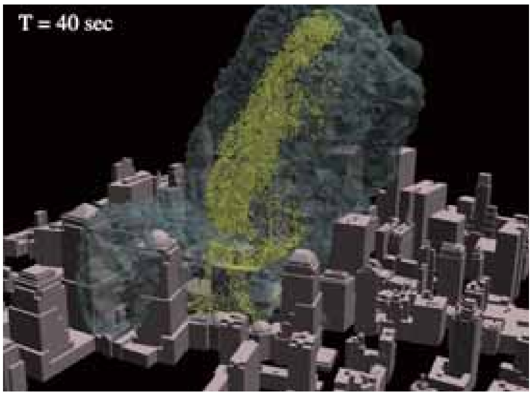

Figure 4. Example visualization of outer boundary of smoke and of a particle cloud immediately following the building collapse.

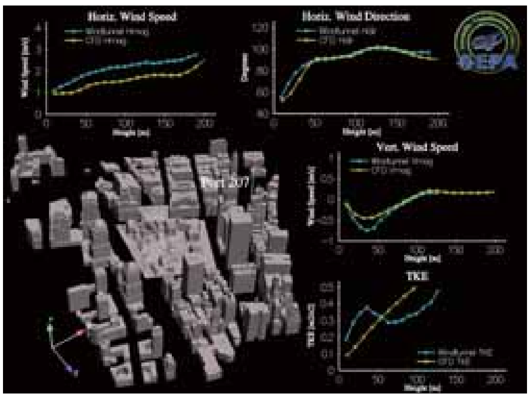

Figure 5. Example comparisons between CFD model and wind tunnel model vertical profiles of horizontal wind. speed and direction, vertical wind speed, and TKE for Westerly winds case. (Wind tunnel measurements provided by Dr Steven Perry, US EPA)

small particle plume following the collapse of the North Tower. The suspended particles are concentrated in the central core of the plume since they disperse less rapidly relative to the smoke as outlined by the grey shading. Figure 5 presents a comparison of horizontal wind speed, horizontal wind direction, vertical wind speed, and TKE for a vertical profile at Port 207 located as the green pole in the figure. Note that degree on the wind direction scale represents direction toward which the wind vector points (West winds are reported as 90 degrees). This is for a Westerly winds case. The horizontal wind speed and direction match well. There are some zones with strong wind shear and which are well matched. A comparison with all the wind tunnel model measurements is being made. Additional information of the numerical and wind tunnel modeling support for the WTC studies can be found in Huber et al. (2004) and Perry et al. (2004).

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Study on Evaluation of Thermal Comfort in Wind-Driven Ventilation Environment

Masaaki Ohba, Professor
Yukari Iino, Researcher

The cross-ventilation is a phenomena of very complicated turbulence flow because of the interaction of the internal flow with the envelope flow. The cross-ventilation airflow through the upwind opening turns steeply downward near the opening inside a room. The pressures near the opening exhibit reversible and irreversible changes of energy between dynamic pressure and static pressure associated with extreme deformation of airflows. Project 2 have successfully identified the mechanism of the interaction between inside and outside airflows through simultaneous use of experiments and CFD, and established a high-precision model of estimating ventilation flow rates for past several years. The proposed model improved the prediction accuracy of ventilation flow rates compared to the traditional orifice flow model in a wide range of wind directions.

It is important not only to evaluate wind-driven ventilation environment quantitatively but also to evaluate the thermal comfort of occupants from the qualitative aspect of the airflow and from the thermal viewpoint. From now on, the project is aiming a new target to establish the evaluation of thermal comfort of occupants in wind-driven ventilation environment from the qualitative aspect of airflow, as shown in Figure 1.

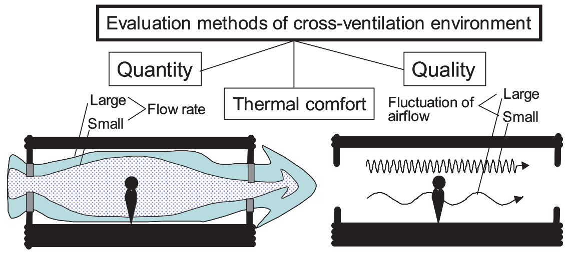

Figure 1 Evaluation of cross-ventilation environment

In humid areas with high summer temperature, effective cross-ventilation can greatly improve the thermal comfort of occupants. However, the method to evaluate the thermal comfort in the cross-ventilation environment is not firmly established. Multilateral evaluations are requested to attain a design guideline for the comfortable cross-ventilation environment.

In the summer of 2005, the airflow features through the window configurations were measured at a training institute using four ultrasonic anemometers. Figure 2 illustrates power spectrum curves for three types of airflows. The cross-ventilation flow indicated lower power spectrum than external airflow because the air velocity decelerated inside a room. Figure 3 illustrates the ratios of power spectrum in the frequency ranges under these opening conditions. The upwind window was equipped with insect screen, lace curtain, fabric curtain or their combinations. The major contributions to the energy spectra of cross-ventilation are revealed in the frequency range less than 0.1 Hz. The window with insect-screen

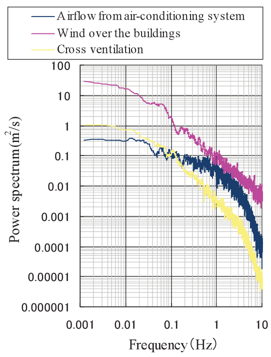

Figure 2 Power spectra for three types of airflows

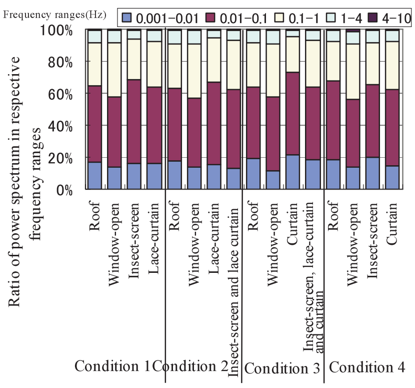

Figure 3 Ratios of power spectrum in frequency rages

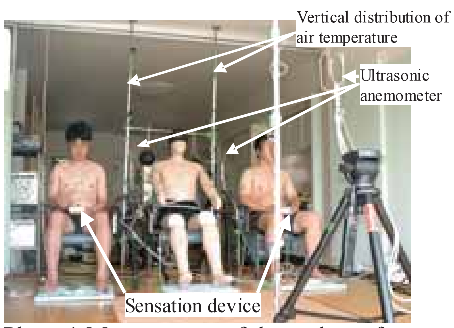

Photo 1 Measurement of thermal comfort at a condominium

and lace-curtain indicated higher ratio of power spectrum than other window configurations. The characteristic length scale of eddies through the room became gradually smaller at internal points.

In the summer of 2005, the convective heat transfer coefficients on human body and thermal comfort of occupants in the cross-ventilation environment were investigated at a condominium as shown in Photo 1. Two adult persons and thermal mannequin took sitting position on chairs under three types of airflows that are driven by wind force, air-conditioner unit or electric fan. The occupants voted their feelings on airflow, feelings on warmth and chilliness and how they felt about thermal comfort during the experiment. The thermal loss and convective heat transfer coefficients at 17 points on skin surface was simultaneously measured using thermal mannequin. The relation between the thermal environment indices such as PMV and SET* and the thermal sensation votes by the occupants were investigated. It is expected that the general guideline of thermal comfort in cross-ventilation environment can be obtained by modifying the current thermal environment indices.

Research on Design Wind Speeds

Masahiro Matsui, Associate Professor

"Wind hazard mitigation" is one of the projects of the 21st century COE program "Wind effects on buildings and urban environment". I am in charge of research on design wind speeds and evaluation of strong winds in this project.

Although it is very important in the wind resistant design to set the design wind speed, it is very difficult to evaluate it from the limited meteorological observation record. Therefore, it is necessary to model strong wind phenomena to achieve a more reasonable evaluation. Some ongoing researches are shown as follows.

Evaluation of design wind speed using typhoon simulation technique

In Japan, due to their high wind speeds and large influence areas, typhoons are the dominant wind climates generating strong winds that need to be taken into account in wind resistant design. However, they often do not pass near metrological stations, so severe wind damage may occur without large wind speeds being observed. In order to improve the instability of the statistical data (sampling error), a typhoon simulation method was adopted for evaluating strong winds caused by typhoons. Figure 1 outlines this typhoon simulation method. The pressure fields of typhoons are modeled by several parameters: central pressure depth, radius to maximum winds, moving speed, etc. The non-exceedance probability of strong wind in the target area is evaluated by generating virtual typhoons according to the results of statistical analysis of pressure field parameters. In the present study, some improvements were developed to improve the accuracy of typhoon simulation and to evaluate directional properties of extreme winds as well as wind speeds. A proper orthogonal decomposition (POD) based typhoon pressure model was proposed that reproduced correlations between

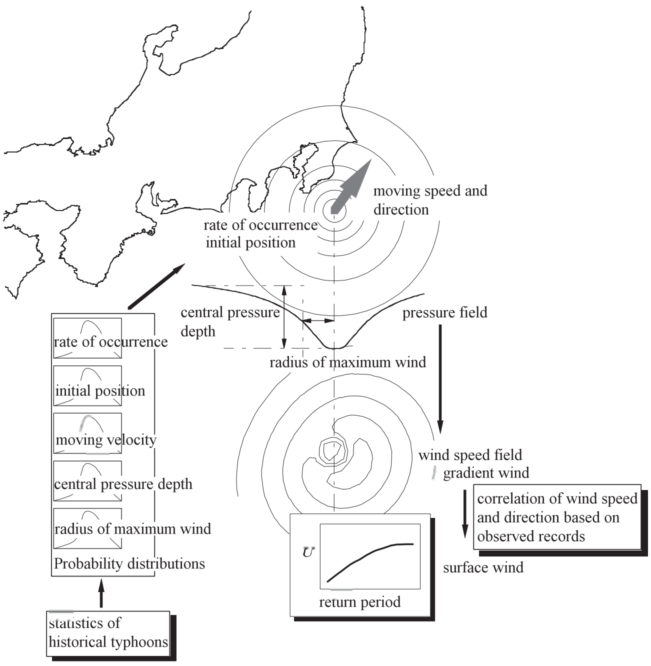

Figure 1 Outline of typhoon simulation

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 then studied using this improved simulation method. A concept for deriving a directional factor was also proposed.

Wind disaster investigation

To mitigate wind-induced damage to buildings and other structures, we need to learn from past major disasters. A disaster results from interaction between wind climates and structures. We need to know not only the characteristics of each factor but also know how they interact with each other. Field study enables us to investigate the comprehensive relations between meteorological and mechanical factors. Since the COE program began, a lot of field investigations have been conducted, e.g. wind damage in Miyakojima Island in 2003, many typhoon landings and tornadoes in Saga and Hokkaido prefectures in 2004, and gust damage in Akita prefecture in 2005. Typhoons induced the most damage of all wind climates, not only due to wind strength but also to the extent of the affected areas. Tornadoes and downbursts also occur sometimes and also require attention.

Development of tornado-like flow simulator

Tornadoes and downbursts are such local events that it is very unusual to catch theit resulting wind speeds at meteorological stations. Therefore, a device has been developed that generates a tornado-like flow in the laboratory, and resulting wind velocity distributions have been measured. Experiments have revealed some characteristics: the size of the core of the cyclostrophic flow affected by ground surface roughness and the maximum wind speeds generated close to the ground. The experimental results can be related to the evaluation of wind speeds of local weather disturbance. Research is continuing with a view to utilizing these experimental results in wind resistant design.

Figure 2 Tornado in Mombetsu, Hokkaido and related damage (Photo by Eiji Yamamoto, Marusa-kusunoki Industrial Co.)

Figure 3 Flow visualization of tornado-like flow

Wind Effects on Large Span Space Structures

Zhihong Zhang, COE researcher; Yukio Tamura, Professor

Wind-tunnel tests and wind-induced vibration analysis on reticulated spherical domes

the Wind Engineering Research Center of Tokyo Polytechnic University to determine the wind effects on large-span structures. Twelve models were tested for two terrain types (urban and suburban), as shown in Figs. 1 and 2. The models had rise-to-span ratios of 1/3 and 1/5, and wall-height-to-span ratios of 0, 1/6, 1/3, 1/2, 2/3 and 1. The wind pressure distributions on spherical domes, including mean and standard deviation, are presented, as well as the effects on

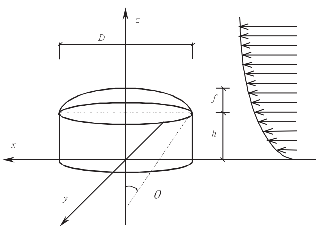

Figure 1 Dome model geometry

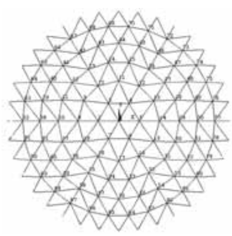

Figure 2 Number of taps

wind pressure distribution of wall-height-to-span ratio, rise-to-span ratio, terrain type and Reynolds number. The emphasis of this paper is on wind-induced vibration analysis. A new way is proposed for determining the special mode that contributes most to wind effects. This mode contributes not only mostly to background response but also significantly to the resonant part.

In order to find out this special mode, we checked the correlation coefficient between the dominant modes and the dominant frequency of the principal coordinates obtained by Proper Orthogonal Decomposition of the fluctuating pressure fields acting on the dome model and the mode shapes and the natural frequencies of the dome structures obtained by FEM analysis. Fig. 3 shows the 91st and 93rd modes of a K6-6 reticulated spherical shell (rise-to-span ratio 1/5, span 30m). The 91st mode integrally rises up. It should be pointed out that this mode is usually speculated to be the 'fundamental mode' of the whole structure. However, its order depends upon structure type, rise-to-span ratio, boundary conditions and so on. The 92nd mode is integrally a torsional mode and the 93rd mode is an anti-symmetric mode of the whole structure. Fig. 4 shows the natural frequency. Fig. 5 shows the correlation between POD modes and vibration modes. The peak value is at the 91st order, which is very interesting.

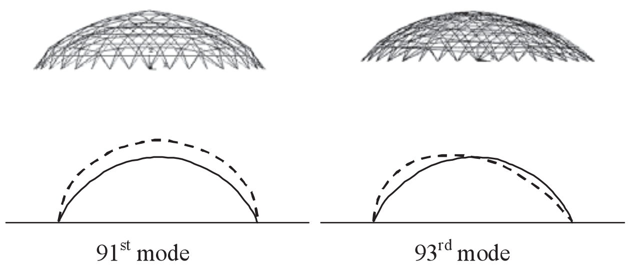

Figure 3 91st and 93rd mode shape

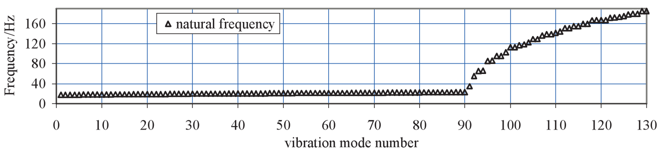

Figure 4 Natural frequency of K6-6

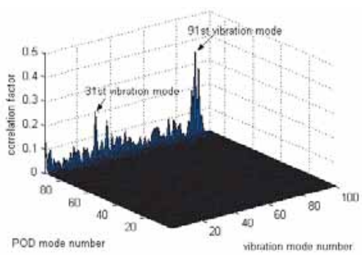

Figure 5 Correlation between POD mode and Vibration mode

Aeroelastic wind tunnel test on cable dome

The cable dome was realized for the practical gymnastics and the fencing arenas for the Summer Olympics in Seoul, Korea in 1986. Due to its lightness and attractive geometry, more cable domes were constructed around the world, such as the Redbird Arena, the Sun Coast Dome and, the largest one, the "Georgia Dome" for the Atlanta Olympic Games in 1996.

An aeroelastic model of a Geiger-type cable dome has been fabricated in the wind engineering research center of Tokyo Polytechnic University, and a series of structural tests on this model including construction analysis, modal test, structural tests subject to harmonic excitation and earthquake load, and wind tunnel tests have been carried out. The model's structural design is described in detail. The similarity requirement based on dimensional analysis is discussed, including Froude number, Cauchy number and Scruton number. The required structural tests are conducted on the aeroelastic model. Dynamic instability subject to harmonic excitation like a degree of freedom hardening system is verified. Nonlinear modal interaction occurs when the shaking table dowels at 29Hz. Some statistical results of wind tunnel tests are presented, and the possibility of aeroelastic instability of the cable dome is discussed.

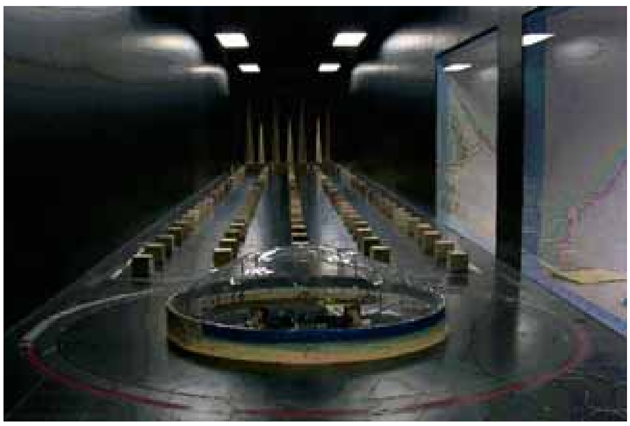

Figure 6 Cable dome model in the wind tunnel

The Fourth International Symposium on Computational Wind Engineering (CWE2006)

Data: July 16-19, 2006
Venue: PACIFICO YOKOHAMA, Yokohama, Japan
Co-Convened by: Japan Association for Wind Engineering
The 21st Century COE Program, Tokyo Polytechnic University

For more details, please check: http://www.wind.arch.t-kougei.ac.jp/cwe2006/index.html

Key Dates:

4-page Extended Abstracts due	March 31, 2006
Early Registration	May 31, 2006
Symposium	July 16-19 2006
Notification of Selected Papers	September 30, 2006
Full papers due (selected papers)	December 31, 2006

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