ICUS NEWSLETTER

International Center for Urban Safety Engineering

Institute of Industrial Science
The University of Tokyo

VOLUME 7 NUMBER 1
APRIL-JUNE 2007

IMPORTANCE OF TECHNICAL AND SOCIAL PROBLEMS TO PREVENT FALSE STRUCTURES FOR URBAN SAFETY

By

*Taketo UOMOTO**

INTRODUCTION

In November 2005, a big shock struck Japanese society through newspapers, radios and TV programs. Mr. Hidetsugu Aneha, a first-class certified architect confessed that he faked records to make substandard buildings look like they met Japan's anti-earthquake requirements. He mentioned that he began faking earthquake safety data around 1998, when a developer asked him to cut costs by reducing the amount of steel reinforcement below the compulsory minimum in a Tokyo apartment project. The newspapers mentioned that at least 99 structures which he designed may collapse even in a moderate earthquake.

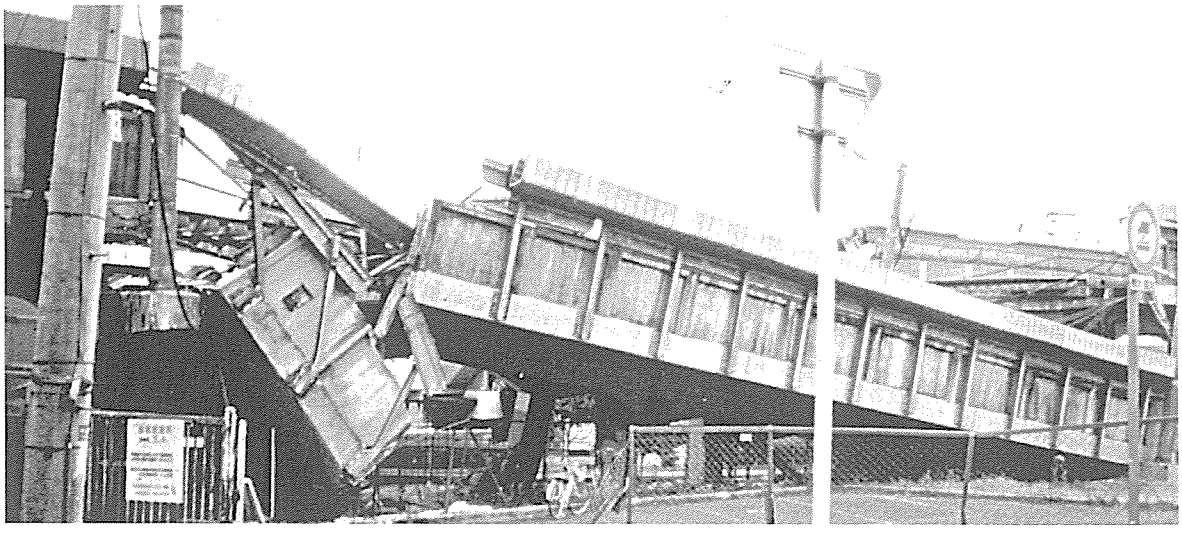
Such news had never been reported in Japan. The people, who bought houses paying large amounts of money, lost everything except the commitment to return the bank loan. If such a disaster was caused by a natural hazard (earthquake, tsunami, flood, fire, etc.), Japanese people and government would surely try to help the victims by all means. But in this faked design case, it is not easy to persuade the people of our country to support the victims.

PROBLEMS RELATED TO FALSE WORKS

The problems related to false works reported by newspapers, magazines, etc. can be classified as follows:

- Group 1: Mistakes by engineers and workers
- Group 2: False works due to insufficient knowledge
- Group 3: Intentional false works knowing that they are difficult to be detected

It is difficult to eliminate all problems belonging to Group 1. Any

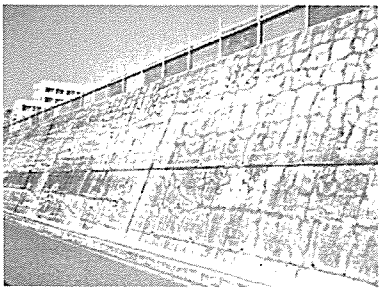


Collapsed RC bridge due to the 1995 Kobe Earthquake

Corrosion of steel due to the use of sea sand as fine aggregate

person can make a mistake but this is of particular concern for engineers. Considering this, most of the specifications, guides, instructions and books are published showing both how to prevent mistakes and how to check the accuracy of the results. If we look at some of the books, we can easily find data showing the percentage of "error" based on numerous data surveyed from many construction works. As an example, the design codes give the standard error in bar arrangements, form arrangements, etc.

Workers and engineers, especially those without sufficient knowledge and experience, may easily create problems belonging to Group 2. In 1960's and 1970's, chloride induced corrosion of steel reinforcing bars due to sea water were reported by researchers, but concrete engineers were not much concerned about the chloride contained in sea sand which was used as fine aggregate. As a result, many important concrete structures, such as railway bridges in the western part of Honshu, deteriorated within 20-30 years, as shown in the picture on the upper left corner of this page. In the late 1980's when evidences of "alkali-aggregate reaction of concrete structures" were reported to the Japanese concrete society, neither concrete engineers nor concrete researchers believed in the problem. Most civil engineers and concrete engineers in Japan thought that alkali-aggregate reaction did not occur in our country. Teachers and professors teaching concrete technology explained that no problems of alkali-aggregate reaction have been reported in Japan that far.



Cracks on retaining wall due to the use of reactive aggregates

As a result, many concrete structures which used reactive aggregate extensively cracked even when provided with steel reinforcement. The figure above is an example of this.

The "Aneha" problem is the typical example of Group 3. Maybe it was not such from the beginning, but as the system consistently failed to detect Mr. Aneha's faulty works, he may have realized the system flaws and how to take advantage of them. Similar problems are "addition of water" to ready mixed concrete at the site, lack of bond length of anchoring bars for anti-falling apparatus, etc. The details of these problems are explained in the following section.

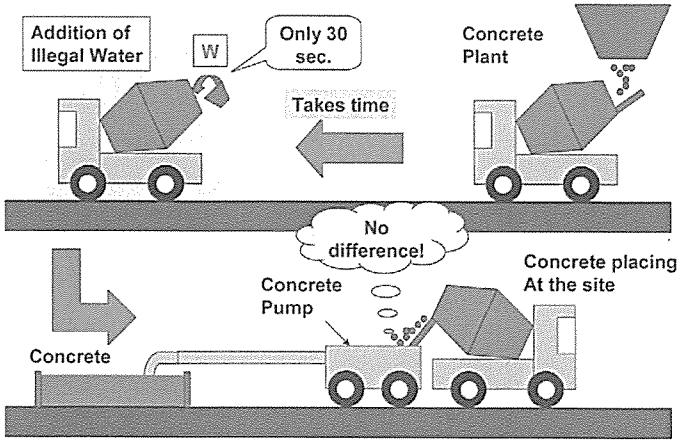
PROBLEMS OF "WATER ADDITION" AND "ANCHORING BARS"

Addition of illegal water to ready mixed concrete

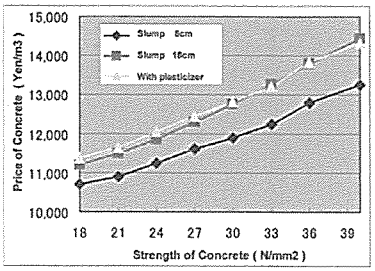
Addition of water to ready mixed concrete has been strictly prohibited in Japan. But due to several reasons, such false works can be found at some of the construction sites. As shown in the figure below, when ready mixed concrete is carried from the concrete plant to the site, it often takes more than 30 minutes due to traffic conditions. As a result, the concrete slump reduces due to the evaporation of mixing water especially in hot climate. Since 1970's, it is common to use concrete pumps to cast the concrete in place. The pumpability of concrete is mainly governed by the fluidity and segregation resistivity of concrete. Generally speaking, it is easier to convey the concrete with higher slump to the casting place than lower slump concrete. To increase the slump of transferred concrete, addition of water is the easiest and it does not imply any additional cost. Addition of such illegal water to concrete can be done within 30 seconds without being discovered by the engineers at the site. Even when additional water is added to the conveyed concrete, it is difficult to find out the amount by regular inspection methods.

As shown in the figure on the upper left corner of next page, if we have to increase the slump of concrete from 8cm to 18cm, with the same concrete strength, the cost increment will be about ¥1000 per cubic meter. This is about 8% for a concrete of 30N/mm2 strength even when plasticizer is used. This cost increment is not affordable by the client nor by the constructor. On the other hand, water addition increases the slump at no cost, but reduces the concrete strength about 15% and also the concrete durability.

Considering these evidences, the



Illegal addition of water to ready mixed concrete



Price versus strength of concrete with different slumps (2003)

Ministry of Construction introduced a method to inspect the water content of concrete by Non-Destructive Testing (NDT) since 2003. Although the NDT measuring apparatus is not always accurate enough, such a system may reduce the "illegal addition of water" to certain extent.

Anchor bolts for seismic safety

When the 1995 Kobe Earthquake occurred, many bridge piers were destroyed due to enormous force acting on the structures and many bridge girders fell off from the piers by the seismic force as shown in the cover of this newsletter issue. The cars on the bridge easily fell down from the bridge even after the earthquake.

To prevent such a disaster several types of apparatuses, such as the ones shown in the photos on the upper right corner of the page, were installed to the existing piers to prevent the falling of the bridge girders and maintain the structures for a longer period of time.

To install such apparatuses, anchor bolts must be embedded into the existing piers by coring the concrete to the specified depth. The existing structures have been used for as long as 50 years and design drawings are not available in some cases. Even when design drawings are still available, the bar arrangements in the actual structure may not coincide well with the drawings.

When drilling is done, there is a high possibility that the core drill may hit the embedded steel bars. What did the workers do in this case? They behaved in two ways as shown in the figure on the right:

1) Stop the drilling at the depth of the steel bars.
2) Drill the concrete and steel to the specified depth.

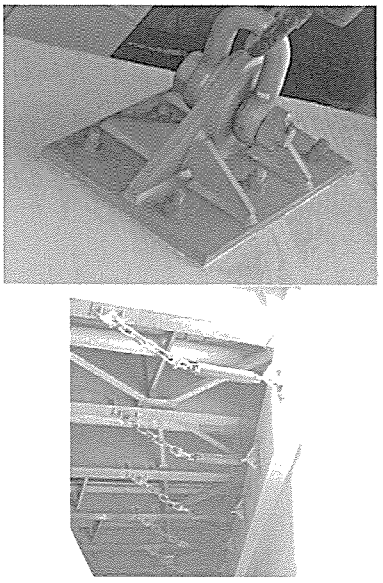
As a result, some anchored bolts lack bond length, and some reinforcing bars in the structures were cut. In Case 1, anchor bolts may not be strong enough against seismic forces, and the pier strength is reduced to form cracks in Case 2.

The Ministry of Construction mentioned that about 2% of the whole anchor bolts used in road bridges had problems so far and they asked the contractors to reinstall the false anchor bolts. To prevent such problems, inspection must be done properly. One of the most effective method is to utilize NDT. The inspection must be done before and after the installation of anchor bolts. Ultrasonic method may be useful to inspect the length of bolts and electromagnetic method may be useful to detect the steel bars in concrete before drilling.

SYSTEMS TO BE SETUP

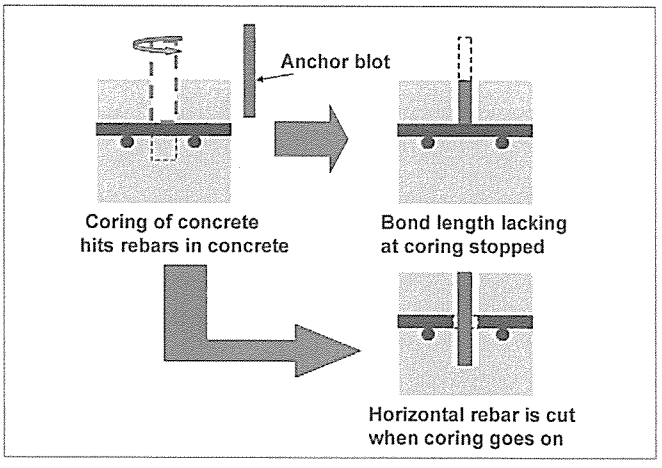
As explained above, many problems are occurring at the site. Until now, the systems being used in our country are all based on Japanese culture and ethics in the believe that people will not try to do bad things, unless by accident. But the evidences presented above gave a big warning to our culture: ethics is no longer sufficient and "learning makes a good man better and an ill man worse". A new system must be studied not only from a technical point of view but also by incorporating the systems related to law, economics, insurance, etc.

Civil engineers have been working to offer better facilities to make the human society comfortable. "Safety", "Serviceability", "Durability", and "Esthetics" are the major requirements of the structures through out their service life. To deal with the problem, civil engineers have been working to offer better and safer structures to the society. But the efforts we have been making may not be enough. Maybe we have to widen our field to study not only technical problems but also insurance, law, economics, etc. in order to discover and eliminate faked works which may not have been revealed yet.



Apparatus to prevent the fall of bridge girders

** Professor,*
Shibaura Institute of Technology and Former ICUS Director

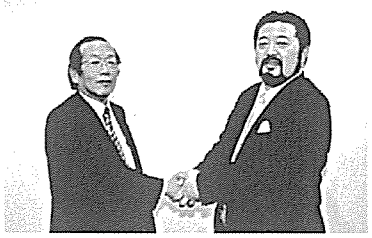


Drilling concrete to install anchor bolts

Prof. Meguro appointed ICUS Director

It is with a great honor and deep sense of commitment that I accept the appointment as ICUS Director following Prof. Uomoto's retirement from the University of Tokyo. I would like to take this opportunity to extend our center gratitude and especially my own for his great leadership under which ICUS has grown and become a leading institution addressing urban safety issues by carrying out advanced research, disseminating information, and also by helping create a network of experts in the field.

I have had the great opportunity to be a founding member of ICUS predecessor, the International Center for Disaster-Mitigation Engineering and also ICUS itself. During these 17 years of involvement with both centers, many disasters have occurred worldwide and I have had several opportunities to visit the affected sites and have a direct contact with those situations. These experiences have helped me to realize the importance of urban safety and its issues. During this period, I have also been very lucky to build a worldwide network of outstanding experts who share the same concerns and have enriched my understanding of the problems with their opinions.



Prof. Meguro receives the post of ICUS Director from Prof. Uomoto.

To all ICUS network members, I would like to thank very much for your support until now. We, at ICUS, are really looking forward to continuing and starting collaborative activities together. Please do not hesitate to contact us and we will try to assist you and do our best in spite of the limitations of our human resources.

(By K. Meguro)

12th Open Lecture was held

The 12th ICUS Open Lecture was held at IIS and attended by approximately 130 participants. The title of the lecture was "ICUS Activities to Achieve a Safer Urban Environment -Past achievements and future directions-." ICUS was established in April 2001 with the objective of promoting fundamental and collaborative research, networking and information dissemination related to various aspects of urban safety engineering towards creating a safe urban environment in the 21st century. In this Open Lecture, achievements of the first six years of ICUS and its focus for the future were discussed.

Dr. Ooka gave the welcome speech after which the following presentations were given:

- Prof. Taketo Uomoto, Shibaura Institute of Technology and Former ICUS Director, "Urban Safety and Concrete"
- Prof. Yoshifumi Yasuoka, IIS, the University of Tokyo, "Observation and Assessment of the Urban Environment and Disasters"
- Prof. Kimiro Meguro, ICUS Director, "Towards Urban Safety, Hard and Soft Approaches- from a Domestic and International Viewpoint"

Professors T. Uomoto, Y. Yasuoka, and K. Meguro delivering their lectures

Additionally, video messages from three ICUS network members were displayed:

- Dr. Dushmanta Dutta, Lecturer, Monash University, Australia
- Dr. Tan Kiang Hwee, Associate Professor, National University of Singapore
- Prof. Mehedi Ansary, Bangladesh University of Engineering and Technology

The closing remarks were given by Prof. Yasuoka. After the Open Lecture a small party was held and attended by approximately 60 people.

(By P. Mayorca)

ICUS Open House

ICUS joined the IIS Open House which was held for three days, from May 31 to June 2. In this event, our institute is open to experts and the public to share its research outcomes with the visitors. Overall 6,000 people visited Komaba research campus. A theme of the ICUS was "Towards the Establishment of a Sustainable Urban System." All laboratory members participated and displayed their panels showing their research activities. Topics included diagnosis, repair, and strengthening of concrete, earth, and underground structures, diffusion of contaminants in urban areas, need of disaster resilient water cycle systems for sustainable societies, analysis of traffic jam, the challenge to integrate countermeasures to achieve earthquake disaster resilient urban systems, and others. The open house was also an opportunity to introduce the 2006 Annual Report as well as RNUS and BNUS activities. Reports and newsletters were handed to visitors. Almost 200 people visited ICUS exhibition. An ICUS Quiz was prepared following the success of last year issue. About 90 people participated in the quiz and got prizes such as photo stands, picture books, ICUS special calendars, small bags, and key holders.

Open House attendees of all ages participated in ICUS Quiz

(By R. Kuwano)

A Woman Died in Roller Coaster Accident

A woman was killed and 19 other people were injured when a roller coaster derailed on May 5, 2007. The six-car stand-up roller coaster derailed and bumped into the guard rail at Expoland in Suita, Osaka Prefecture.

The accident was caused when a wheel axle on the second coaster broke. Expoland carries out routine visual checks on the roller coaster every February under legal guidelines, and usually disassembles and inspects the ride on a voluntary basis around the same time. But the axle had not been replaced since the roller coaster was introduced in March 1992. Other amusement parks that use coasters have regularly inspected or replaced axles.

According to Japanese Industrial Standards (JIS), ultrasonic or magnetic-particle inspections should be conducted on coaster axles at least once a year. Many amusement parks fail to conduct these nondestructive inspections. As a result the Ministry of Land, Infrastructure and Transport, through prefectural governments, asked amusement parks nationwide to conduct an emergency checkup of their roller coasters by May 18, 2007.

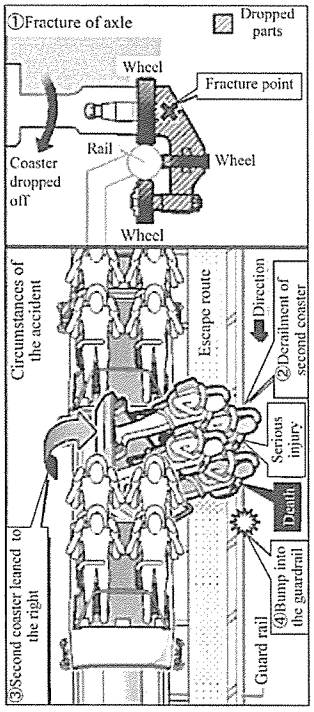
Ultrasonic and magnetic-particle methods are commonly used to inspect the parts of coasters. Ultrasonic method can be used to detect inner defect. The probe emits ultrasonic from one end of the wheel axle and then the bottom echo is detected. If there is a defect in the axle, flaw echoes reflect from defects before the bottom echo.

Magnetic-particle inspection can be used to detect surface-breaking or near-surface cracks. If the ferromagnetic material has no defect, most of the magnetic flux is concentrated below the material's surface. However, if a defect, which interacts with the magnetic field, is present, the flux is distorted locally and 'leaks' from the surface of the specimen in the region of the flaw. Fine magnetic particles, applied to the surface of the specimen, are attracted to the area of flux leakage, creating a visible indication of the defect.

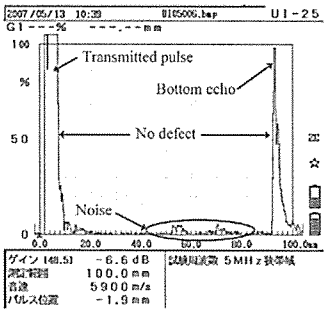
According to the report from Japan Building Equipment and Elevator Center Foundation, 26 people were killed and 255 people were injured by amusement equipments such as roller coasters or swings from 1977 to 2006.

The Ministry of Land, Infrastructure and Transport is now preparing detailed inspection guidelines for amusement facilities to prevent such accidents. After this, periodical nondestructive inspections or permanent certified staff may be required at all amusement parks. It is argued that it is too costly and not suitable to have such strict regulations for low speed coasters.

(By H. Kanada, Inspection and Measurement Division, Nippon Steel Techno Research Corporation)

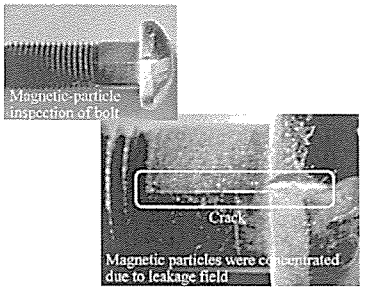


Summary of the accident (reproduced with permission of Asahi Shimbun)



Ultrasonic waveform (no defect)

Magnetic-particle inspection of axle



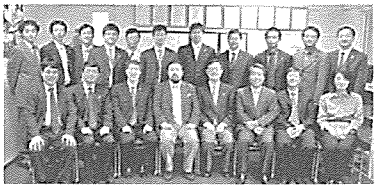
Magnetic-particle pattern

Delegation from Tsinghua University visits ICUS

On June 29, 2007, a delegation of 13 representatives belonging to various Chinese governmental and academic institutions, led by Prof. Weicheng Fan, visited ICUS in order to sign the Memorandum of Understanding (MOU) between ICUS and the Center for Public Safety Research, Tsinghua University, for promoting research and education activities in the field of Urban Safety Engineering. These centers will be hosting the Eighth International Symposium on "New Technologies for Urban Safety of Mega Cities in Asia" next year. The signature of this MOU will strengthen the relationship between these two parties and bolster collaborative activities in the region.

(By R. Ooka)

MOU exchange



Delegation of Tsinghua University during its visit to ICUS

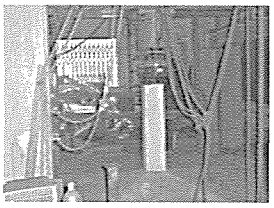
BNUS Activities

For the last few months, Bangladesh Network Office for Urban Safety (BNUS) is involved in the community awareness program. Recently, BNUS members attended a workshop on 'Mason Training and Hollow Block Laying' organized by the Housing and Building Research Institute, Ministry of Works, Government of Bangladesh. It was expected to increase the quality of construction at the community level.

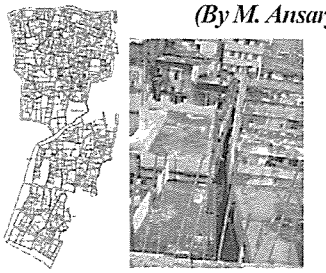
Around 60% of buildings in Bangladesh are masonry structures. At present, BNUS is planning to undertake a project to assess the vulnerability of un-reinforced masonry structures (URM) in the cities of Bangladesh. To carry out this project, BNUS is planning to use the existing Universal Testing Machine (UTM) and the Compression Testing Machine (CTM) of the BUET. The UTM capacity is 1800kN (400kips) and gauge constant is 0.2 mm; the capacity of CTM is 700kN (160kips) and gauge constant is 0.2 mm. Using UTM and CTM, shear strength, joint strength, failure mode, etc. of masonry panels will be evaluated.

BNUS is also developing the earthquake evacuation plan for the Ward No. 68, Old Dhaka, the most dense and vulnerable part of Dhaka city. Old Dhaka is seismically vulnerable due to its high population density, narrow road networks, unplanned development, vulnerable structures, low preparedness, etc. To have an effective evacuation plan, vulnerability data of the existing buildings in the target area have been collected. A GIS based evacuation plan will be generated based on the existing site condition, i.e. buildings, road network system, evacuation places, etc., applying different evacuation techniques. The whole area will be segregated into different groups according to the vulnerability and capacity of evacuation places. Finally, a 3D elevation model of the area showing the escape route and the shortest path to the evacuation site from each specified group will be prepared.

(By M. Ansary)



Compression Testing Machine

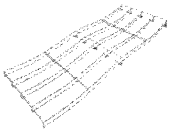


Study area map and typical road channel with nearby buildings

RNUS Activities

Inspection of Fired Factory in Rayong Province

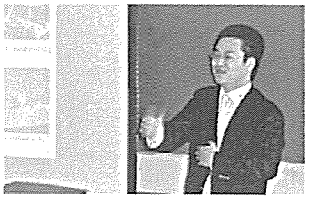
RNUS researchers, in collaboration with King Mongkut's Institute of Technology North Bangkok, inspected a fire affected factory in Rayong Province (Eastern part of Thailand). The compressive strength of concrete in column was evaluated with a Schmidt's Hammer and ultrasonic wave propagation technique. Samples from the roof truss in the fire affected zone were taken and tested to evaluate its residual tensile capacity. The loading capacity of the structure then was confirmed by numerical analysis.



Measurement of ultrasonic wave propagation velocity in RCcolumn at fire affected zone (left) and roof truss numerical simulation result (right)

RNUS Seminar

The RNUS seminar on 'Remote Sensing and Traffic Management for Urban Safety' was held on May 10, 2007. Two instructors from the University of Tokyo kindly delivered lectures to AIT students and researchers.



Dr. Takeuchi delivering his lecture

Dr. Wataru Takeuchi gave the lecture entitled 'Remote Sensing of Environment and Disaster over Asia with IIS/AIT Satellite Network' which clearly illustrates how remote sensing techniques can be applied to various field such as agriculture and flood protection.

Dr. Shinji Tanaka delivered the talk entitled "ITS Technologies and Researches for Urban Traffic Management" which illustrates several measures that can be applied to improve the traffic safety with some easy-to-understand simulation.

(By R. Sahamitmongkol)

Research Committee on BCM suitable for Japanese Society is launched

The Research Committee 58 (RC-58) was launched on April 1st, 2007 for a two-year period. The topic of this committee is "Business Continuity Management (BCM) Systems Suitable for Japanese Society". Business are faced with many threats to the continuance of their trade. Therefore, preparing organizations to actively plan to avert those threats or to reduce their effects, the so-called BCM, has been getting increasing attention. Traditional BCM models have been mainly developed for western developed countries. However, Japan is confronted with particular situations such as the high likelihood of natural disasters, high population density, and also its own cultural background. Therefore, this RC-58 is intended to explore suitable BCM systems for Japan.

To this end, approximately 15 companies from various sectors of Japanese society have joined the research committee. However, additional participants are still welcomed. For additional information regarding RC-58 please visit: http://icus.iis.u-tokyo.ac.jp/index-j.htm.

(By P. Mayorca)

Changes in ICUS staff

FAREWELL TO THREE ICUS MEMBERS

Professor Taketo Uomoto, Visiting Professor Reiko Amano and Dr. Hisashi Kanada retired from ICUS on March 31st, 2007.

Prof. Uomoto is a founding member of ICUS and its director for six years. He retired from the University of Tokyo and became a Professor at the Shibaura Institute of Technology. He is currently an ICUS Advisor Researcher.

Visiting Prof. Amano joined ICUS in March 2003. She has been actively involved in the development of water screens for fire protection, disaster manuals for various institutions and a website to promote public facilities retrofitting. Prof. Amano is currently an ICUS Researcher.

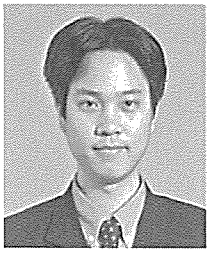
Dr. Kanada became an ICUS member in August 2005. During his stay, he continued his research on Non-Destructive Test Methods for concrete structures. In addition, he was in charge of the edition of reports, the secretariat of the Research Committee 39, and also participated in joint activities between ICUS and the University of Tokyo Hospital.

We would like to thank them all for their great contribution to our center and wish them all the best.

WELCOME TO DR. WORAKANCHANA

Dr. Kawin Worakanchana joined ICUS as project researcher from April 1, 2007. He obtained his Ph.D. degree from the University of Tokyo in September 2005 and was a Ph.D. fellow at Meguro laboratory before joining ICUS.

His research interest includes the numerical simulation of structural fracture and collapse behavior under earthquake and fault action. He received the Excellent Young Researcher Award during the Fifth International Symposium on New Technologies for Urban Safety of Mega Cities in Asia.



Dr. Kawin Worakanchana

His doctoral research involves the study of the failure mechanism of concrete structures under fault-induced ground surface rupture and deformation. He developed the Voronoi Applied Element Method (VAEM). Compared to previous Applied Element Method, the VAEM element shape is random therefore it can better fit non-rectangular domains, reduce the crack directional bias and allow element size variation. VAEM was used to study the behavior of dams, soil deposits, buildings and concrete pipes under fault action.

Recently, he is involved in the development of the 3-D AEM for modeling unreinforced and retrofitted masonry structures using PP-band.

(By K. Meguro)

ICUS Activities

- *Prof. Meguro traveled to Bangkok, Thailand together with Dr. Tanaka from May 9 to 11 to visit RNUS offices and meet Prof. Worsak and Prof. Hanaoka at AIT.*
- *Prof. Meguro visited Jakarta, Indonesia from June 20 to 23 to attend the 3th Association of Pacific Rim Universities / Association of East Asian Research Universities Research Symposium "Earthquake Hazards around the Pacific Rim".*
- *Dr. Ooka visited Helsinki, Finland from June 9 to 14 to attend Clima 2007 and Roomvent 2007.*
- *Dr. Ooka traveled to Los Angeles, USA from June 23 to 28 to attend the 2007 Annual Meeting of the American Society of Heating, Refrigerating and Air-Conditioning Engineers.*
- *Dr. Ooka visited Cairns, Australia from June 30 to July 5 to join the 12th International Conference on Wind Engineering.*
- *Dr. Kato stayed at AIT for his research work and teaching duties at RNUS from April 17 to May 15. He officially finished his appointment at AIT on May 15.*
- *Dr. Tanaka visited Berkeley, USA from June 24 to 30 to attend the World Conference on Transport Research Society.*
- *Dr. Sahamitmongkol stayed at AIT for his research work and teaching duties at RNUS from April 2 to May 28 and from June 4 to July 26.*
- *A meeting to explain the objectives and scope of the Research Committee 58 was held on April 25.*
- *The 12th Open Lecture was held on April 25. Its topic was "ICUS Activities to Achieve a Safer Urban Environment -Past achievements and future directions-".*
- *A student seminar attended by all ICUS laboratory members was held on May 29.*
- *ICUS participated on IIS Open House from May 31 to June 2.*
- *ICUS members participated in the Highway Watching Tour which was carried out on May 23 under the leadership of the Metropolitan Expressway Co., Ltd.*
- *The Research Committee 58 (RC-58) held its first meeting on June 19. The objective of the meeting was to introduce the working methodology and to exchange opinions regarding the topics of interest.*
- *A delegation of scholars from Tsinghua University led by Prof. Weicheng Fan visited ICUS on June 29.*

Awards

- *Prof. Meguro received the "Continuing International Contribution Award" from the Japan Society of Civil Engineering on May 25, 2007 for his continuous efforts towards disaster mitigation worldwide.*
- *Dr. Ooka received the "Award of Excellency in Research" at the International Conference on Sustainable Building Asia (SB07 Seoul) on June 28, 2007 for the paper "Design of the Outdoor Thermal Environment for a Sustainable Riverside Housing Complex Using a Coupled Simulation of CFD and Radiation Transfer."*

Editor's Note

There was a big step in ICUS this April. Prof. Uomoto, the former director of ICUS, retired and Prof. Meguro was appointed as the new director. Both have devoted themselves to ICUS growth for the past six years, from its very beginning. It is certain that their continuous contributions has led ICUS to the current situation, active research work by members and associates, and extensive network established in Asia. However, in spite of the fact that engineers/researchers have made enormous efforts so far, there seem to be still many pitfalls in the urban safety.

Prof. Uomoto pointed out in the main article of this newsletter the problem of the false works and structures. This is a severe warning that relying on the engineers' ethics may not be always effective. I am afraid to say that this concern is not only in the field of urban engineering. Recently, it has been revealed that the safety in food was also threatened. Fujiya, one of the biggest confectionary makers in Japan, used old expired dairy goods for making cakes. A meat shop called Meathope sold false beef disguised with pork and chicken.

Apart from these man-made disasters, nature often shows us big energy beyond our control. Even in the recent months, there have been several incidents which have shaken us, the Noto Hanto Earthquake in March, the explosion of a spa facility due to the leakage of natural gas in the center of Tokyo in June, and the Niigataken Chuetsu-oki Earthquake in July. We cannot completely prevent casualties from flooding or slope failure caused by every year's typhoons and heavy rain. All of these unfortunately kill people and each time we learn a lesson. They also make us realize again that we can never spare efforts in seeking urban safety.

(By R. Kuwano)

If you would like to contribute an article to ICUS newsletter or have any comment or suggestion, please contact the editorial committee at icus@iis.u-tokyo.ac.jp.

PRINTED MATTER

International Center for Urban Safety Engineering, ICUS
Institute of Industrial Science, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
Tel: (+81-3)5452-6472, Fax: (+81-3)5452-6476
E-mail: icus@iis.u-tokyo.ac.jp
http://icus.iis.u-tokyo.ac.jp/

International Center for
Urban Safety Engineering