ICUS NEWSLETTER

International Center for Urban Safety Engineering

Institute of Industrial Science
The University of Tokyo

VOLUME 5 NUMBER 3
OCTOBER-DECEMBER 2005

FROM GROUND SHOCKS TO AIR BLASTS: MULTIPLE-HAZARDS PROTECTION OF BUILDINGS

By

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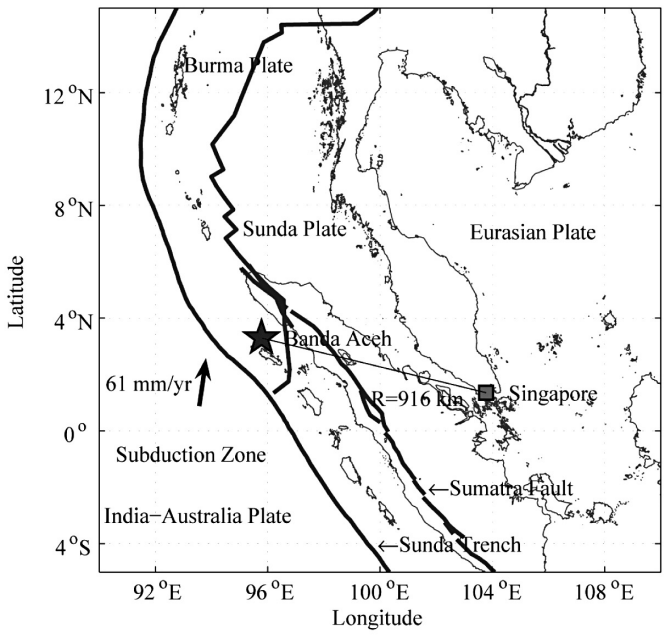
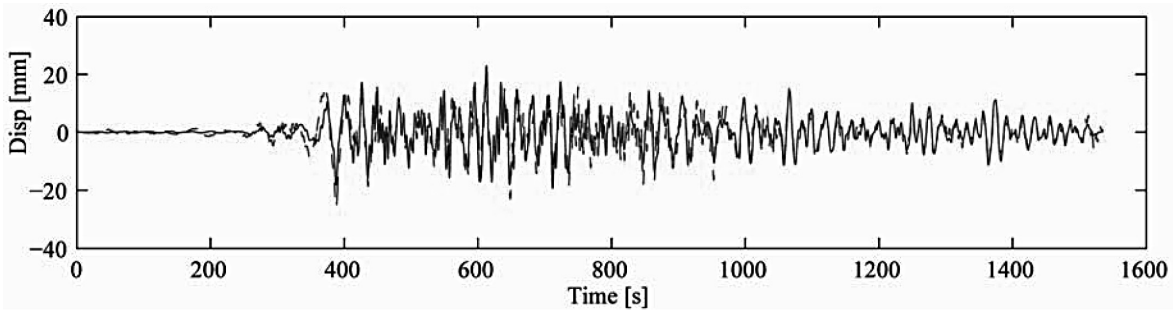
Reflecting the rapid economic growth and development, many high-rise buildings and complex infrastructure systems have been constructed in recent decades in almost all Mega Cities of Asia. Of concern is the high concentration of population and commercial activities taking place in these cities. Therefore, the consequences of even a moderate disaster may be enormous in these cities. Recent technological development has motivated the devising of new methodologies for sustainable development of Asian Mega Cities with adequate safety and security. The importance of using advanced tools in urban safety has been recognized by the International Center for Urban Safety Engineering (ICUS). This is the motivation for ICUS to organize a series of symposium in the Asian Region. These symposiums encourage trilateral communication among researchers, practitioners and policy- makers, whereby the epicenter of this is evidently human lives. Any improvement of urban safety serves to better protect the core of a community – human lives.



Map of epicenter

Republic Plaza



Numerically determined displacement compared with recorded displacement

The Fourth International Symposium on New Technologies for Urban Safety of Mega Cities in Asia (USMCA 2005) was held in Nanyang Technological University, Singapore, during October 18-19, 2005. It was co-organized by Protective Technology Research Center, Nanyang Technological University, Singapore, and ICUS, IIS, University of Tokyo, Japan. About 100 participants from various countries were present. The countries included Australia, Thailand, Bangladesh, China, Japan and Singapore. The participants included engineering researchers, defence scientists, design engineers and members of government organizations. The variation of the participant's background supports the philosophy of ICUS's intent for these symposiums. For this symposium, the areas discussed include safety assessment and monitoring of existing infrastructure, threat reduction and consequence management, structures subjected to seismic, shock and impact loads, environmental impact assessment of urbanization, tsunamis, flood and environmental risk assessments. During the symposium, the two co-chairmen of the symposium, Prof. Kimiro Meguro and Prof. Pan Tso-Chien, were interviewed by the Channel News Asia Television Station. During the interview, both the co-chairmen emphasized the need for the balance between engineering solutions and the enforcement of these solutions.

Within the Singapore community, the concerns about urban safety include: (a) the response of buildings subjected to far-field earthquake ground motions; (b) damage assessment of buildings subjected to ground shocks; and (c) blast response of buildings.

FAR-FIELD EARTHQUAKE MOTIONS

Singapore is located in a low seismicity region of Sunda plate. The Sumatran fault and the Sumatran subduction zone, are located more than 350 km away. While earthquakes have never posed any real problems for Singapore, previous large earthquakes have induced tremors felt in Singapore. Like other mega cities, the lack of free surface land has prompted the construction of taller buildings. These taller and flexible buildings may respond more significantly to long period, far-field earthquake ground motions.

On 26 December 2004, the Great Sumatra-Andaman Islands Earthquake (Mw = 9.0) occurred off the northwest coast of Sumatra, Indonesia. The epicenter of this earthquake is about 916 km west-northwest from Singapore (figure in previous page).

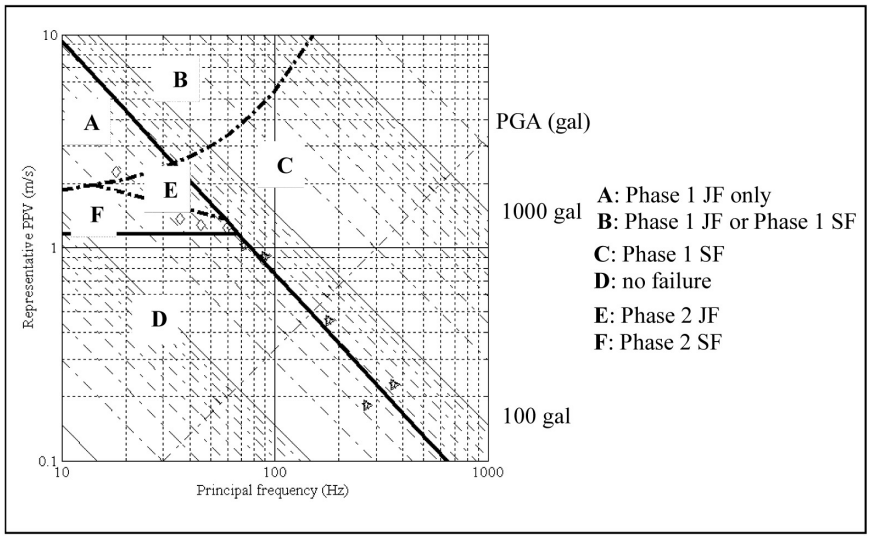
Since 1996, one of the tallest buildings in Singapore, the Republic Plaza shown in previous page has been instrumented to study buildings responses due to winds and far-field earthquakes. The Republic Plaza is a 66-storey, 280 m high tower consisting of a frame-tube structural system with a central core wall, in turn connected to a ring of external columns by a horizontal steel framing system at every floor. From ambient vibration tests, the predominant frequencies of the building are found to be 0.19 Hz and 0.20 Hz, in the two horizontal directions.

Accelerometers are installed at the basement level and the roof level, along the two principle directions of the building. The accelerometers recorded the building vibration during the Great Sumatra-Andaman Islands earthquake. The ground signals recorded at the basement were used as the input to the finite element model of the Republic Plaza. When subjected to this input ground motion, the response results obtained numerically were compared with the recorded responses shown in above figure. At the roof level, the displacement response obtained by the numerical method is reasonably similar to that of the recorded response.

GROUND SHOCKS

Most mega cities have limited free space. Singapore's national effort is to intensify its land use. This has prompted under-ground space development, leading to the housing of ammunition storages underground. As a result, ground shocks due to accidental underground explosions and their effects on surrounding buildings are investigated.

Ground shock characteristics can be segmented into two parts: the major shock duration (Phase 1) and the ensuing duration (Phase 2). It was shown that the high frequency nature of a ground shock leads to a large shear force with small deformation during Phase 1, followed by significant deformation during Phase 2. In Phase 2, the responses of global modes are significant, and this would possibly cause beam-column joint failure.



Damage characteristics of a 6-storey RC frame to ground shocks

For non-seismically designed beam-column sub-assemblies, it has been experimentally observed that the beam-column joints may fail at an inter-storey drift ratio of about 3 % of the storey height.

A non-seismically designed 6-storey reinforced concrete (RC) frame was subjected to a simulated ground shock. For the simulated ground shock, the peak ground acceleration (PGA) is 124 gal, the peak particle velocity (PPV) is 0.9 m/s and principal frequency is about 200 Hz. By considering the failure mechanisms of flexural failure (FF), diagonal shear failure (SF) and joint failure (JF), the damage for the 6-storey RC frame subjected to the simulate ground shock was assessed.

A parametric study was undertaken which involved the scaling of the PGA, PPV and principal frequency of the simulated ground shock. The characteristics of the scaled ground shock leading to the various failure mechanisms, are shown in the above Figure.

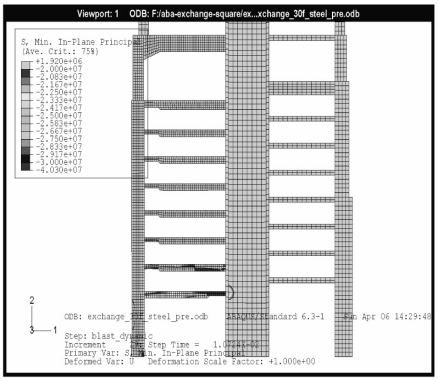
AIR BLASTS

Effects of an air blast explosion on a high-rise commercial RC building resulting from a vehicle bomb at the ground level area, were investigated. The objective was to investigate the effect of standoff distance on building damage. The high-rise commercial building selected for the study was a 30-storey RC structure with frames and a shear wall core.

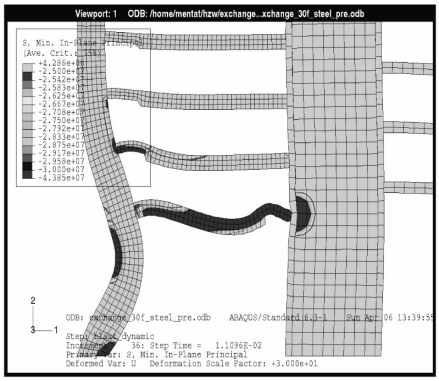
For a long standoff distance case, the deformation was concentrated at the ground column and the beams of the second and the third storeys. The beam deformation was focused at its ends where local damages occurred like as the figure below.

However, for a short standoff distance, the dynamic deformation was localized at the blastloaded columns spanning the first and the third storeys. The beams connected with these columns might thus be damaged. Large residual deformations were observed for the blast-loaded columns and the beams connected to them. Thus, the beams connected to these columns might be damaged as shown in the figure.

Compared with the case of long standoff distance, the global response hardly existed in the short standoff distance case. Furthermore, compared with the case of long standoff distance, the damage in the case of short standoff distance was more localized.



Stresses and deformation for short standoff



Stresses and deformation for long standoff

CONCLUSIONS

In summary, there is a need to investigate systematically the effects of multiple hazards which may include both natural and man-made events. In this article, the multiple hazards investigated comprised the effects of long-distance major Sumatra earthquakes, ground shocks, and air blasts. The dynamic response of the non-seismically designed building structures in Singapore to these multiple hazards has shown varying characteristics.

This will pose a challenge to the engineering community who must strike a balance between safety and economy in designing and constructing a building structure to resist multiple hazards. The consequences from any extreme event of multiple hazards could be devastating to mega-cities due to the high concentration of population and also the high-value of commercial and financial activities. However, it is important to realize that the dynamic effects of these events have varying characteristics and frequency of occurrence.

** Director, Protective Technology Research Centre, Nanyang Technological University, Singapore*

4th International Symposium on New Technologies for Urban Safety of Mega Cities in Asia at NTU, Singapore

On October 18-19, 4th International Symposium on New Technologies for Urban Safety of Mega Cities in Asia was held at Nanyang Executive Centre, Nanyang Technological University, Singapore. The symposium was co-organized by ICUS and Protective Technology Research Centre, School of Civil and Environmental Engineering, Nanyang Technological University, Singapore, and sponsored by Center for Sustainable Urban Regeneration, The University of Tokyo, 21st Century Center of Excellence Program, Ministry of Home Affairs (Singapore), Shimizu Corporation, CPG Corporation Pte Ltd. and Surbana International Consultants Pte Ltd..

Seven keynote papers and 63 technical papers were presented. 97 delegates from 12 countries participated in the symposium.

This symposium provided a platform for sharing knowledge and forming a network among the Asian researchers. The number of participants are increasing and the quality of papers are improving at each new symposium. The next symposium will be held at Phuket, Thailand on December 16-17, 2006. Further details will be announced soon.

(by H.Kanada)

Number of participants per country

Country	Number of participants	Country	Number of participants
Singapore	43	Australia	2
Japan	31	Iran	2
China	5	Bangladesh	1
Thailand	4	Indonesia	1
Taiwan	3	Nigeria	1
India	3	Vietnam	1
		Total	97

Number of presentation

Session name	Number of presentation
Keynote	2
Plenary	5
Safety Assessment and Monitoring of Existing Infrastructure	11
Threat Reduction and Consequence Management	6
Maintenance, Retrofitting and Rehabilitation of Structures	6
Design and Assessment of Structures for Seismic, Shock and Impact Loads	15
Environment Impact Assessment of Urbanisation	6
Tsunamis, Floods and Environmental Risk Assessment	6
Advanced Technologies for Assessment of Urban Safety	8
Planning and Development of Urban Infrastructure	5
Total	70

Symposium participants pose for a group photo

RNUS Activities

RNUS Seminar

On October 20, RNUS organized another RNUS seminar on 'Advanced Technology for Urban Safety – Against Disaster and Hazardous Environment'. Four professors from the University of Tokyo were invited to give the presentation. The presenters were Prof. T. Uomoto, Prof. R. Amano, Prof. K. Meguro,and AssociateProf.R.Ooka.

The content of this seminar covers technologies applicable to prevent various types of disaster and to evaluate hazardous environmental condition. There were approximately 80 audiences in this seminar. Not only staffs and students of AIT but those from other institutes and engineers from construction companies also joined this event.

Field Trip to New Airport

RNUS held the field trip to the new international airport of Thailand on October19,2005.The name of this new airport were conferred by H.M. the King as Suvarnabhumi or "GoldenLand" on September 29, 2000 and a foundation stone laying ceremony was held on January19,2002.

Prof.W. Kanok-Nukulchai gave a present to Prof. T. Uomoto

Dr.Tokuda:Chief of Thai Obayashi Corp in Suvarnabhumi Airport

The field trip which was led by Dr. Tokuda began with a brief introduction about the airport construction and ended with a visit to the construction of runways and terminals.

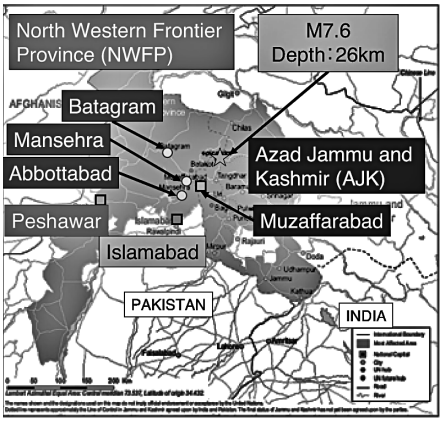
Suvarnabhumi airport has an approximate area of 8,000 acres and is located around 25 km to the east from the downtown Bangkok.

There are two 60-m wide parallel runways (4,000 and 3,700 m. respectively). Two parallel taxiways were designed to accommodate simultaneous departures and arrivals. The annual passenger capacity is expected to be 45 million at opening day and 100 million upon attaining the full capacity.

(by R. Sahamitmongkol)

Pakistan and India was Struck by a M 7.6 Earthquake on October 8, 2005

On October 8, 2005, at 3:50 (UTC), a magnitude 7.6 earthquake, with a focal depth of 26 km, struck the North of Pakistan and North West of India. Most damaged area is North Western Frontier Province (NWFP), and Azad Jammu and Kashmir (AJK) in Pakistan. Many cities, towns and villages were heavily damaged.



Map of Damaged Area (UN OCHA Relief Web)

The statistics of human casualties and structural damage are provided in the following tables. Due to this earthquake, approximately 75,000 people and 77,000 were killed and injured, respectively. Mainly all types of masonry structures were damaged during this earthquake.

This earthquake occurred in a mountainous area like the 2004 Mid-Niigata Prefecture Earthquake, Japan. So the geo-related damage was widespread. Many roads were broken and damaged. Therefore, many people living in mountainous area were isolated and could not evacuate and get foods and tents. Military carried affected people to refugee camps or medical centers by helicopters. They made temporary heliports at riverbeds and fields and used them.

One of the features of this earthquake damage was that public buildings, especially school buildings had heavy damage near the epicenter. So many students and teachers were affected (see upper right table). School buildings located not near the epicenter had also cracks in the walls. As the earthquake occurred during school time, students ran away from classrooms without their textbook, bags etc. After the earthquake, the students did not return to the schools due to three reasons: "Students do not want to come to school"; "Their parents do not send them to school"; and "Teachers do not want to go to school". So it is necessary to provide psychological support to both students and teachers and construct emergency building for schools.

(by Shinya Kondo, Researcher of Disaster Reduction and Human Renovation Institution)

Casualties in Pakistan and India (as of November 20, 2005 by UN OCHA Relief Web)

	Pakistan	India	Total
Injured	69,392	7,510	76,902
Dead	73,320	1,307	74,627

Damaged buildings in Pakistan (as of November 20, 2005 by UN OCHA Relief Web)

Pakistan	Total Units	Completely Damaged
AJK	244,980	204,940
NWFP	542,603	195,222

Casualties at schools in AJK, Pakistan (as of November 20, 2005 by UN OCHA Relief Web)

	Enrolled	Died
Students	204,023	24,491
Teachers	3,099	173

Damaged school buildings in AJK, Pakistan (as of November 20, 2005 by UN OCHA Relief Web)

	Total schools	Collapsed	Dangerous	Major repairs required	Minor repairs required
AJK	4,472	3,076	1,024	247	125

Many public buildings were collapsed (Muzaffarabad)

Many large land slides were observed (Muzaffarabad)

Temporary heliport set at dry riverbed (Alai)

Pancake collapse of building (Abbottabad)

Due to fear of earthquake, both students and teachers dislike attending school even if the structural damage were not so severe (Mansehra)

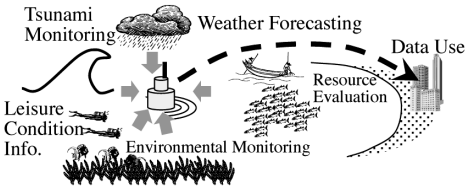
Potential of Coastal Industry in Tsunami Disaster Reduction

A year has passed since the huge tsunami generated by a M9.0 earthquake off Sumatra devastated Indian Ocean rim countries. The number of victims by this event was reported as over 300,000. However, the number is still unconfirmed even after one year due to lack of proper identity check and a large number of dead bodies being carried away by huge waves. Affected countries are seeking a reasonable approach to improve their preparedness against tsunami disaster to avoid the same consequence in the future.

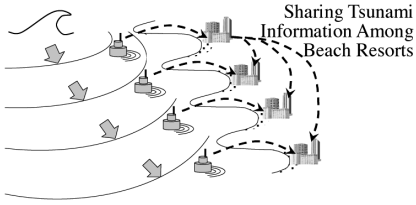
Most straightforward approach for tsunami disaster reduction would be setting back from the coast line. However, it is not always an acceptable solution for everyone.

As shown in photos, their livelihood is inseparably linked to ocean. Beach front location which allows guests good access to water pleasure, nice ocean view and comfortable sound of waves is an indispensable factor for resort hotels. Fishers tend to live just next to shore line. They use beach as a dock to maintain fishing boats and equipments, an yard to process the catch and meeting space with neighbors for fishers. With this reality, tsunami warning system (TWS) can be a most practical solution.

Meguro Lab., IIS, The University of Tokyo has proposed a sustainable



Concept of Sustainable Tsunami Warning System using Multi-Purpose Maritime Observation



Networked Multipurpose Buoy System

TWS concept using Multi-Purpose Observation Buoy Network. Important characteristics of this system are its simplicity, economical efficiency and daily-usability. Indian Ocean rim countries have less resource of technologies, researchers and experiences of tsunami disasters compared with Pacific Ocean rim countries. So, it is important for monitoring tsunami which occurs in around 100-year period continuously without any interruptions to develop a scheme to use and maintain the monitoring system on daily basis. Industries inherent in coastal area have strong need to collect various kinds of information as shown in middle figure above.Promotion of coastal industries and continuous tsunami monitoring can be accomplished by adding tsunami monitoring function on the system collecting daily use information.

Minimum unit of the system is one or two multi-purpose observation buoys operated by one beach society. The cost to maintain the system should be shared by the beach society, who will receive the most benefit from the system. When many beach societies install the system and join the multi-purpose observation buoy network beyond the administrative or international boundary, it must be possible to gather marine information needed on daily basis in much larger scale and to get more advantage before tsunami arrival even in case of transoceanic tsunami.

Understanding and cooperation of local leading industries and governments are essential to implement this kind of plan. We had opportunities to talk with resort hotel owners, managers and local government officers in our field surveys. It was found that hotel owners and managers who did not receive physical damage on their properties but suffered from decline of guests with harmful rumors tends to have a strong interests on our concept. We wish to implement our concept in cooperation with those local stakeholders and contribute to the tsunami disaster safety in their countries.

For further information: see ICUS Report, Report on the 2004 Sumatra Earthquake and Tsunami Disaster, 2005- 01.

(by Masasuke Takashima, Lecturer of FujiTokoha University)

left: resort beach in PhiphiIs., Thailand right: a fishing village in Trincomalee, Sri Lanka

INTER MAINTECH 2005

Inter Maintech 2005 was held from November 15 to 18 at Tokyo International Exhibition Center. This is the only trade show in Japan which focuses on diagnosis and repair as well as maintenance related management technology from industrial facilities to social-capital infrastructure related facilities such as concrete and steel structures.

ICUS set up booth and presented the following research topics;

1. *Diagnosis software for concrete structures (concrete bridges, piled piers, tunnels)*
2. *Development of new technique to detect deleterious substances of concrete using NIR spectral imaging system*
3. *Online monitoring system for aging concrete bridges*

Booth of ICUS

Over 400 specialists visited our booth and were interested in exhibits. Various publications from ICUS were also distributed there. Stock ran out due to heavy demand of ICUS publications.

ICUS will make a presentation at The 10 Earthquake Technology EXPO scheduled to take place at PACIFICO YOKOHAMA from February 2 to 3, 2006.Please come and visit our booth.

(by H. Kanada)

Open Campus of IIS Chiba Experiment Station

The Institute of Industrial Science (IIS) of the University of Tokyo organized an open house at its Chiba Experiment Station on November 11, 2005. There were 651 participants in this event.

ICUS also participated in this event and presented its research activities. The ICUS topic was "Towards Safety Improvement in Mega Cities." Research associate of ICUS, Dr. Endo guided and explained the research works to the participants.

Elementary school students from near the experiment station visited the facilities. They listened to Dr. Endo intently. They attended and drew picture on concrete block at the Uomoto laboratory.

Professor Uomoto, the head of Chiba Experiment Station gave a special lecture on "Urban Safety on Concrete."

(by R. Ooka)

Guidance by Dr. Endo

Special lecture by Prof. Uomoto

ICUS New Staff

ICUS is glad to welcome its new staff, Dr. Raktipong Sahamitmongkol who joined ICUS as Researcher from October 1st, 2005.

He received his Ph.D degree from the school of civil engineering, the University of Tokyo in September, 2005. During his doctoral study, he also got the outstanding presentation award at the annual meetings of Japan Concrete Institute (JCI) and Japan Society of Civil Engineering (JSCE). His research interests are the usage of expansive agent to prevent cracking or to control cracking condition in RC structure.

In his research, it was found that the expansive additive with suitable reinforcement not only induces beforehand the compressive stress in concrete, but it can also enhance the ductile behavior of concrete. As a result, the cracking of RC structure can be effectively prevented. This technique is proved advantageous to elongate the service life of important infrastructure.

Dr. Raktipong Sahamitmongkol

He has been assigned to station at the Regional Network for Urban Safety (RNUS) which locates in the Asian Institute of Technology (AIT), Thailand to activate more collaborative research with other Thai organizations.

Recently, he started more research program including the study about the application of ferrocement to protect the structural element in building from bomb blasting, bridge inspection in Bangkok Metropolitan Area, and the application of NDT to inspect the condition of concrete structure.

(by T. Uomoto)

ICUS Activities

- *Project team was formed to consider the role of The University of Tokyo Hospital in a time of disaster. The joint working group meetings are regularly convened.*
- *All ICUS members participated in the 4th International Symposium on New Technologies for Urban Safety of Mega Cities in Asia at NTU, Singapore (Oct 18-19).*
- *Second student seminar was held and 25 students in ICUS reported their current research results (Dec 9).*
- *Prof. Uomoto attended RNUS Seminar at AIT (Oct 20-21) and 13th general meeting and working of ISO/TC71 in Seoul (Nov 27-30).*
- *Prof. Amano attended RNUS Seminar at AIT (Oct 20-21).*
- *Prof. Meguro attended RNUS Seminar at AIT (Oct 20-21), World Seismic Safety Initiative board meeting in Singapore and visited Islamabad to investigate the damage due to northern Pakistan earthquake (Oct 22-Nov 1).*
- *Dr. Ooka attended RNUS Seminar at AIT (Oct 20-21), International Symposium on Sustainable Development of Asia City Environment 2005 in China (Nov 23-27).*
- *Dr. Oki attended The Second Post-GAME Planning Workshop in Thailand (Nov 4-7) and The Second Post-GAME Planning Meeting in Thailand (Nov 19- 24).*
- *Dr. Kato stayed at Asian Institute of Technology for his research work and teaching duties at RNUS (Sep 19-Dec 9) and attended a conference on Durability of Reinforced Concrete under Combined Mechanical and Climatic Loads in China (Oct 26-31) and visited Vietnam Institute for Building Science & Technology to exchange views (Nov 10-13).*
- *Dr. Yoshimura attended RNUS Seminar at AIT (Oct 20-21).*
- *Dr. Sahamitmongkol stayed at Asian Institute of Technology for his research work and teaching duties at RNUS (Oct 5- Dec 18).*

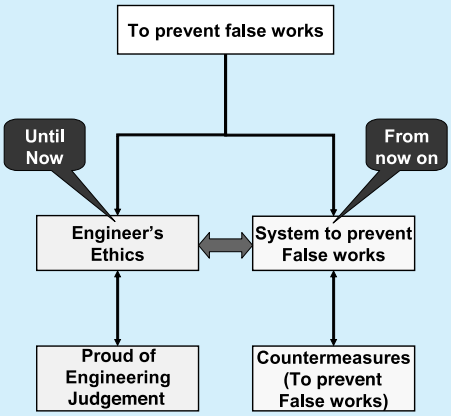
Awards

Three graduate students; D. Itoh, T. Nanjyo (Meguro lab.) and N. Takeshita (Kato lab.) won the excellent presentation award at 60th annual meeting of Japan Society of Civil Engineers (Dec 26).

Editor's Note

In November 2005, a big shock struck Japanese society through newspapers, radio and TV. 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. In the committee of Japanese parliament, he mentioned that he began faking earthquake safety data around 1998, when a developer asked him to reduce costs by decreasing the amount of steel reinforcements below the compulsory minimum in a Tokyo apartment project. He mentioned that he was under heavy pressure from the developer to reduce steel reinforcements. Initially he refused the request because of his pride as a first-class certified architect. But considering the reduction in construction cost and pressure from the developer, altimately he succumbed. The newspapers mentioned that at leat 88 structures (as of December 28, 2005) which he has designed may collapse in a moderate earthquake tremor.

Keio Presso Inn, Gotanda has been closed for demolition due to lack of adequate earthquake resistance



Such news were never reported in Japan until now. The person, who bought the houses paying a large amount of money, lost everything except the loan which was lent to him by the banks. If such a disaster is caused by the natural hazards (earthquake, tsunami, flood, fire, etc.), people and Japanese government may try to help the victims by all means. But in this faked design case, it may not be easy to request the people of our country to support the victims.

The systems now being used in our country are all based on Japanese culture and ethics that people will not try to do things bad, unless by accident. But this news gave us a big warning to our culture: Ethics is no longer efficient and "Learning makes a good man better and an ill man worse" (See the above figure). "Safety" is now becoming one of the most important requirements in urban area, and ICUS has been working to prevent and reduce the natural disasters for more than 5 years. May be we at ICUS have to widen our researches to man made disasters, not only natural hazards and terrorism but also to the faked works which have not been exposed yet.

(by T.Uomoto)

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