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International Center for Urban Safety Engineering



Institute of Industrial Science
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PROTECTING BUILDINGS AGAINST MULTIPLE HAZARDS

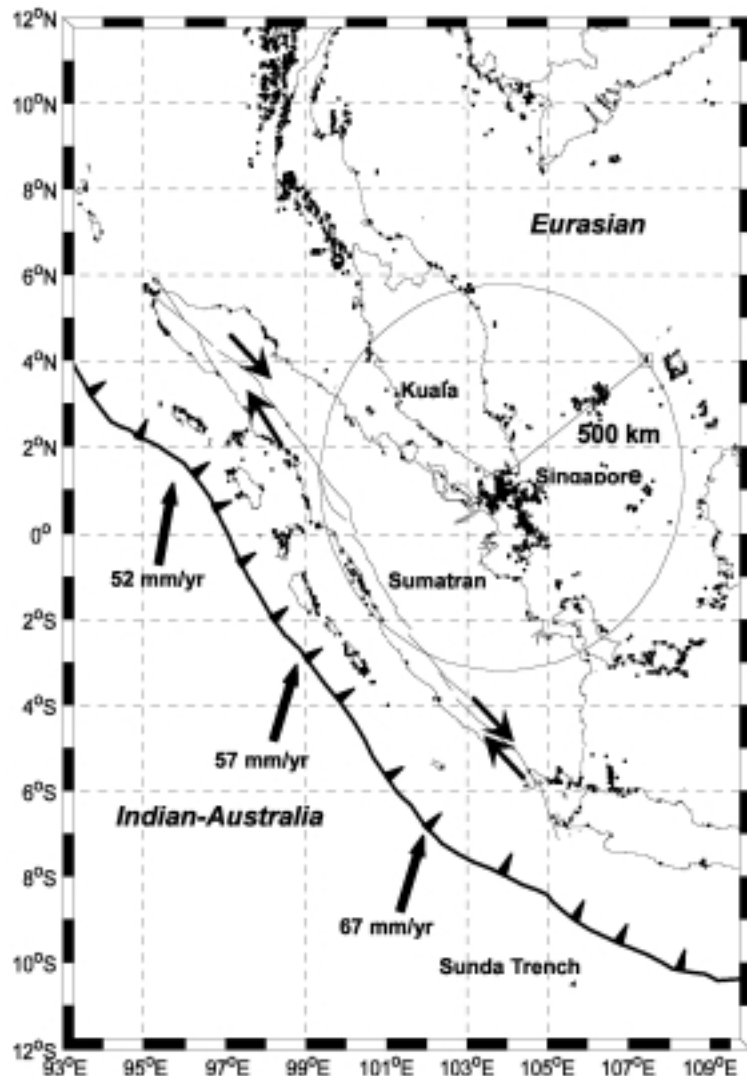
By

Tso-Chien PAN*

Effects of Long-Distance Major Earthquakes

Although Singapore is believed to be located within the stable Sunda plate with mild winds, it is about 350 km away from an active earthquake belt, comprising the Great Sumatra Fault and the subduction zone of Sunda Trench, as shown in the sight figure. Singapore has never experienced any earthquake damage, and hence buildings are generally not designed against the horizontal earthquake loadings. However, tremors caused by distant Sumatra earthquakes have been felt in Singapore for many years.

The largest subduction earthquake that has occurred in the Sunda trench is the great 1833 event with an estimated M_w between 8.8 and 9.2. The earthquake, with an average M_w of 9.0 at an epicentral distance of 723 km, is thus selected for a recent study as the maximum credible earthquake (MCE), the figure at the top of next page, that the Sumatra subduction zone is capable of generating. The larger of the two horizontal components of



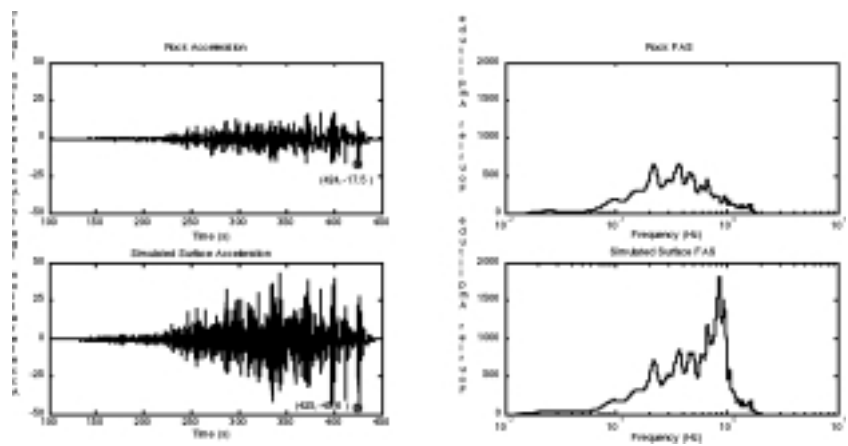
Seismotectonics of Sumatra region

the synthetic MCE ground motions is used in the convolution process to obtain the surface accelerations at a soft soil site. The seismic response of a typical high-rise residential building in Singapore to the synthetic MCE ground motions at a soft soil site has recently been investigated.

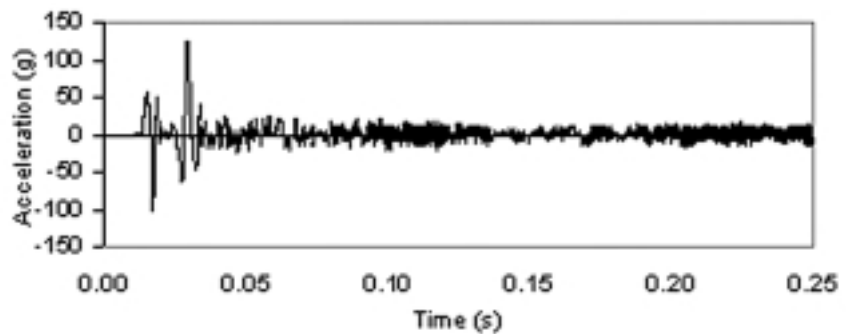
The typical high-rise residential building is a 15-storey, reinforced concrete (RC) building. The overall height of the building is 42.8 m, with the first storey of 3.6 m and the others 2.8 m. The dimensions of the floor plan are 94.5 m in the longitudinal direction and 11 m in the transverse direction. The lateral load resistant system of the typical building is a RC frame-shear wall dual system. The frame system consists of a series of two-bay frames spanned in the transverse direction, with 3 m spacing between frames along the longitudinal direction. The maximum base shear force resulting from the soft soil site response to the MCE event is about 14% of the total building dead weight. This maximum base shear force ratio exceeds the notional horizontal load specified in the local building code as 1.5% of the characteristic dead weight of a building.

Effects of Explosion-Induced Ground Shocks

As part of the national effort to intensify the land use of the land-scarce country, Singapore has explored the possibility of using underground facilities for various purposes. One of initiatives is to move the surface ammunition storages underground, which will reduce the precious land surrounding the surface storages that have been sterilized for safety reasons. As a result, the dynamic response of building structures to explosion-induced ground motions (EIGMs) or ground shocks that may result from underground explosions has been investigated. The results are discussed in terms of the dynamic failure of RC buildings subjected to



Acceleration time-histories and Fourier spectra for the maximum credible earthquake at rock and soft soil sites



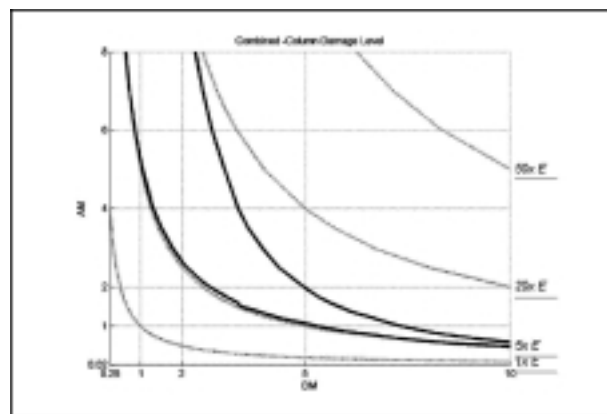
Horizontal acceleration time history of a simulated EIGM

ground shocks, which in turn affects the minimum radial distance within which no residential buildings should be erected.

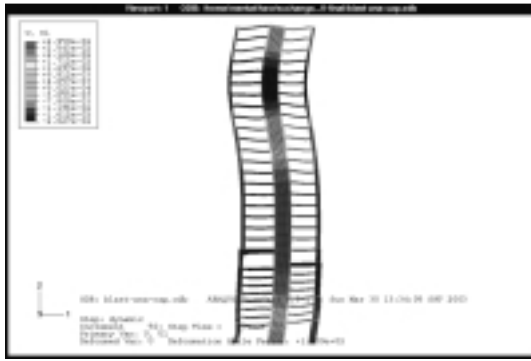
A non-seismically designed 6-storey RC frame was subjected to a simulated EIGM. The simulated EIGM for the horizontal ground motion at a distance from the explosion source is shown in the second figure. The simulated EIGM has a peak ground acceleration of 124 g and a predominant frequency of about 200 Hz. To understand the effects of the duration and the input

impulse of EIGMs, duration multipliers (DM) and amplitude multipliers (AM) were applied on the above EIGM. Both shear failure and joint failure were investigated for the first storey interior column where the maximum shear stress occurred.

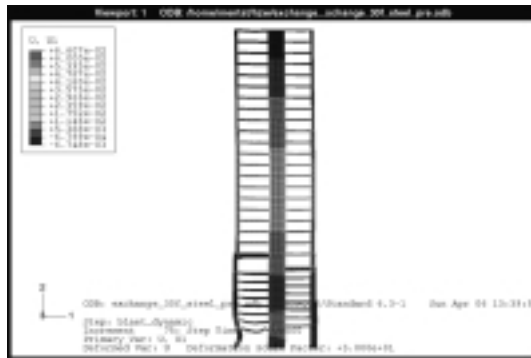
Combinations of DM and AM can lead to joint and/or shear failure during the forced vibration (Phase I) or the free vibration (Phase II). The damage level for the first storey column is presented in the figure below. One bold line shows the boundary between the moderate and



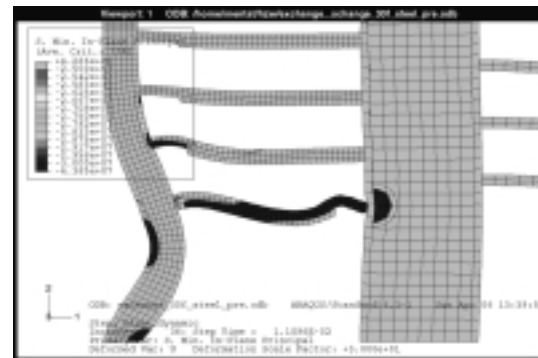
Zones of failure patterns for different response phases



Deformation and stress distributions of a long standoff case



Deformation and stress distributions of a short standoff case



the severe damage levels for Phase I, Severe (I). The other bold line shows the boundary between the moderate and the severe damage levels for Phase II, Severe (II). Iso-impulse lines are shown as dotted lines in the background. Therefore, it can be seen that the damage level computed based on the damage index defined for seismically design buildings does not reflect adequately the shear failure and joint failure caused by scaled EIGMs.

Effects of External Blast Loading

Recent terrorist bomb attacks around the world have demonstrated the ferocity, cruelty and unpredictability of the hazards posed by terrorism. Instead of trying to predict the next terror attack, it appears to be more important to protect critical assets like waterworks, seaports, airports, major buildings, etc. The transient dynamic response of a high-rise commercial building to a postulated external explosion load resulting from a vehicle bomb at the ground level near the building has been investigated.

The high-rise commercial building selected for the study is a 30-storey RC structure with frames and a shear wall core. For a long standoff distance, the local damage index based on curvature is used to evaluate the flexural performance of structural elements under blast load. The second and the third storey beams were found nearly in complete failure. Severe damage appeared in columns on the first and the second storeys and in the beams at the fourth and the fifth storeys, as shown in the top figure.

For a short standoff distance, The second figure shows that partial collapse or moderate damage may appear in the columns on the first and the second storeys. The beams at the second and the third storeys were destroyed completely. Compared with the long standoff case, damage in the short standoff case was more localized.

Multiple-Hazard Protection of Buildings

In summary, in protecting building structures in Singapore, there is a need to investigate

systematically the effects of multiple hazards which may include both natural and man-made events. The multiple hazards that have been investigated so far comprising the effects of long-distance major Sumatra earthquakes, explosion induced ground motions, and blast induced overpressure. The dynamic response of the non-seismically designed building structures in Singapore to these postulated multiple hazards has shown a variety of different characteristics. This will pose a challenge to structural engineers who must strike a balance between safety and economy in designing a building structure to resist the multiple hazards which may result from both natural and man-made events. It is important to realize that the dynamic effects of these events have drastically different loading characteristics as well as frequency of occurrence.

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ICUS organized International Symposium on New Technologies for Urban Safety of Mega Cities in Asia

The recent developments of various advanced technologies including Remote sensing (RS), GIS, GPS and other computational tools have generated scopes and motivation to focus on devising appropriate methodologies for management and maintenance of urban buildings, infrastructures, mitigation of urban disasters and environmental problems for sustainable development of the Asian Mega Cities with adequate safety and security. With the realization and recognition of the importance of advanced tools in urban safety, the International Center for Urban Safety Engineering (ICUS) of the Institute of Industrial Science and the 21st Century COE Program entitled "Center of Excellence for Sustainable Urban Regeneration" of the University of Tokyo organized an international symposium during October 30-31, 2003 on New Technologies for Urban Safety of Mega Cities in Asia. The symposium, held at the Sanjo-kaikan conference hall of the Hongo campus of the University of Tokyo, was attended by 126 participants from 13 countries around the world. This was the second international symposium organized by ICUS on the same theme after the very successful first international symposium held in Bangkok on October 28, 2002.

The two-day long program of the symposium was arranged in 12 technical sessions including two plenary sessions, where one keynote speech and six special lectures were delivered by invited distinguished academicians and researchers from several Asian countries. The symposium was inaugurated by Prof. Shin-ichiro Ohgaki, Dean of the Faculty of Engineering, University of Tokyo



Symposium Staff

and it was followed by the Keynote speech of Prof. Worsak Kanok-Nukulchai, Dean of the School of Civil Engineering, Asian Institute of Technology (AIT), Thailand. The other invited speakers for the plenary sessions were Dr. Sudhir Misra, IIT Kanpur, India; Prof. T.-C. Pan, Nanyang Technological University, Singapore; Prof. W.C. Fan, University of Science and Technology, China; Dr. Suvit Vibulshresth, GISTDA, Thailand; Dr. Pennung Warnitchai and Prof.

Tawatchai Tingsanchali of AIT.

A total of 72 papers were presented in the ten technical sessions, some of which were held in parallel, covering a wide range of issues in the areas of urban safety including earthquake, fire, water management, infrastructure management, disaster mitigation and environmental problems. Several presentations were made on newly developed advanced tools



Participants at the symposium

and methodologies for addressing these issues. The active participation of the audience in discussions that followed each of the presentations was noteworthy and that brought out many urgent issues to the attention of the participants. The discussions raised a very important question of how the new advanced technologies can be effectively used for urban safety in developing countries of Asia, where financial resources and technical know-how are limited. Several speakers pointed out the

need of collaborative research among the researchers of developed and developing countries for developing low-cost and locally adaptive technologies and capacity building for new technologies to tackle the urgent issues towards urban safety. This point was addressed by Prof. Yoshifumi Yasuoka of ICUS in his closing remarks by highlighting the purpose of this symposium for developing a network for future collaboration and focus of ICUS on collaborative research projects

with colleagues from Asian countries. A network office of ICUS has been already established at AIT for coordinating such activities in the region.

The proceedings of the symposium have been already published both in hardcopy and digital formats. The digital format of the proceedings is now available on the home page of ICUS. If you are interested in obtaining a hardcopy of the proceedings, please contact ICUS.

ICUS Activities Record

Some of the international activities carried out by ICUS faculty members during the period of July-December 2003 besides 2nd ICUS International Symposium.

Professor Uomoto visited Sydney, Australia during July 20-24 for participation in 10th ISO/TC71 Committee.

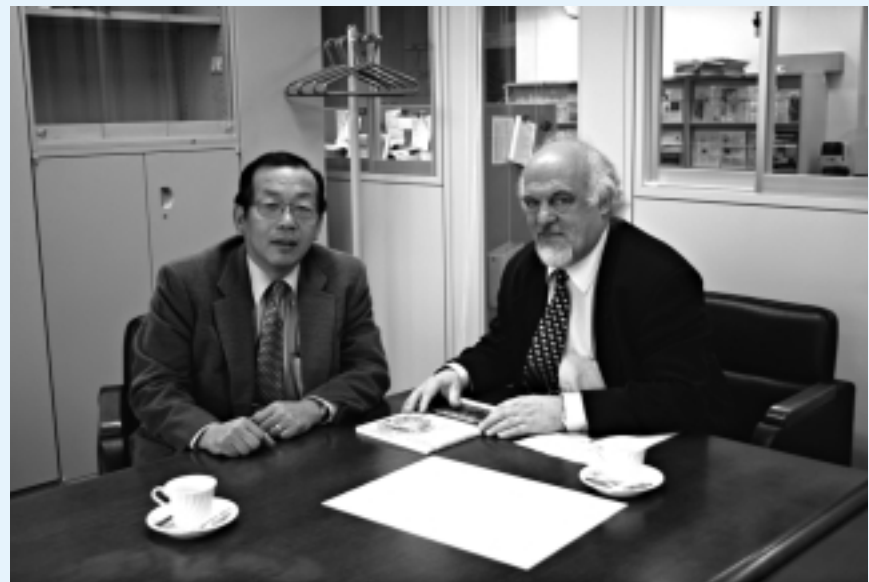
Professor Uomoto attended International Symposium on Non-Destructive Testing in Civil Engineering held at Berlin in Germany during September 14-21

Professor Yasuoka participated in the International Symposium for Commemorating, Tenth Anniversary of Korean Society for Geo-spatial Information System, held at Seol, Korea on 26 September.

Professor Yasuoka and Dr. Endo attended the Asian Conference on Remote Sensing 2003 at Busan, Korea during November 5-7.

Dr. Meguro visited Istanbul, Turkey during October 5-9 for participation in Turkey Disaster emergency measure study project.

Dr. Meguro visited Teheran,



Prof. Andre Ozer(right) and Prof. Uomoto(left)

Iran during December 20-26 for participation in Iran National Earthquake prevention of disasters and administrative plan investigation for big earthquake in Tehran

Dr. Ooka attached 5th International Conference on Urban Climate held at Lodz, Poland during September 1-5.

Ms. Yoshimura attached 28th Annual Hazards Research and Applications Workshop held at Denver, U.S.A. during July 13-18.

Ms. Yoshimura visited Berkly, U.S.A. during for participation in a

scholarship program for young researchers supported by the U.S.-Japan Cooperative Program on Urban Earthquake Disaster Mitigation.

Visitor to ICUS

During the period of October - December, 2003, ICUS received the following visitors.

-Prof. Jianhua Lin, Vice-President of Peking University(November 28)

-Prof. Dr. Andre Ozer, University of Liege(December 12)

Highlights of Recent Activities of RNUS

The Regional Network Office for Urban Safety (RNUS) of ICUS at AIT has been expanding its collaborative research and academic activities with researchers of AIT and other organizations in Asia. During the last three months from October to December, 2003, RNUS has successfully organized various activities including one seminar and two workshops. It has received a research grant for a research project on flood modeling in the Mekong River Basin.

Seminar on Water Resources in the 21st Century

RNUS and Water Engineering and Management field of AIT jointly organized a seminar on "Water Resources in the 21st Century under Climate Change Scenarios". Held on 14 November, the event gave a venue for the discussion of issues on water resources under high stress and climate change. It was graced by Guest Speaker Associate Professor Dr. Taikan Oki of the University of Tokyo, an internationally-renowned researcher in the field of land-atmosphere interaction, variation of global climate, global water resources analysis, virtual water, and isotope analysis. He was joined at seminar by his two colleagues from the University of Tokyo, Associate Prof. Dr. Shinjiro Kanae and Research Fellow Mr. Kei Yoshimura, who have been actively involved in various projects including the GEWEX, GLASS, GSWP, and the IAHS PUB. The workshop was rated highly by participants that included visiting scholars from Japan, researchers from Thammasat University (Thailand), representatives from Thai Meteorological Division (TMD) and faculty members, staff and students from AIT.



The three speakers of the Seminar

Workshop on Collaboration between Yamanashi University and Research Organizations in Thailand

RNUS assisted the University of Yamanashi, Japan in organizing activities of the Workshop on "Collaborative Research and Education Program of the University of Yamanashi COE with Thai Organizations and AIT" that was held on 25 November, 2003 at the Conference Center of AIT. The objective of the workshop was to establish a strong tie for research collaboration between the he University of Yamanashi, Japan

and various water-related Thai organizations through AIT. The one-day activity was graced by Prof. Kuniyoshi Takeuchi of the Yamanashi University, who introduced the "UY COE Research and Education on Integrated River Basin Management in Asian Monsoon Region" and Prof. Kengo Sunada who talked about the Fuji River Basin. Several experts from AIT and Thai organizations presented papers on hydrology and water resources in Thailand, water use management, water quality and solid waste management, among other topics.



A snapshot during the workshop

Third International Workshop of WSSI

RNUS spearheaded the organization of the 3rd International Workshop of the World Seismic Safety Initiative (WSSI) on "Seismic Risk Management for Countries of the Asia Pacific Region" at the Miracle Grand Hotel in Bangkok during 7-8 December, 2003. WSSI is an undertaking of the International Association for Earthquake Engineering (IAEE) in support of the International Decade for Natural Disaster Reduction (IDNDR) of the United Nations. Since its inception in 1992, WSSI has been working with many countries around the world through its programs. To utilize and share the experiences learnt over the past ten or more years, WSSI 2003 was organized to allow participants to: 1) learn from countries where WSSI programs have made positive difference in terms of risk mitigation and management; 2) learn from countries where WSSI programs have not made any



The workshop participants pose for a group photo

major impact in terms of risk mitigation efforts, and 3) develop a plan in consultation with all the attending countries about what WSSI should do for the next five years and where they should focus their human and financial resources. The workshop was attended by over 55 representatives from 19 countries.

Research Project on Urban Flood Modeling in Mekong River Basin

RNUS has received a financial grant from the Engineering Consultants NEWJEC Inc. of

Japan to conduct a research project entitled "Urban Flood Inundation Modeling in Mekong River Basin Using a Physically Based Surface-River Model". The main scope of the project includes conducting research for improvement of an existing physically based distributed model for urban flood inundation simulation and its application and verification in the Lower Mekong basin. The project work aims at regional development and cooperation. This one and half year duration project has started from December, 2003.

3rd International Symposium on Urban Safety Engineering on October 18-19, 2004

On October 18-19, 2004, 3rd International Symposium on Urban Safety Engineering will be held at Deli, Agra. Dr. Sudhir Misra, Associate Professor of IIT(Indian

Institute of Technology) is a secretariat of this symposium(sud@iitk.ac.in). Application of registration and submission of abstract will start in April, 2004. Reader can see the

following URL page for the information of this symposium (<http://icus-incede.iis.u-tokyo.ac.jp/isus04/index.htm>). Further details will be updated soon.

ICUS Activities Recognized

Mr. Shirase, Mr. Okuyama, Mr. Sugiyama and Mr. Kaneda working with Professor Uomoto, and Mr. Oda and Ms. Kan-no and

Ms. Yoshimura working with Dr. Meguro, won a prize for the excellent presentation at the 2003 Annual meeting of Japan

Society of Civil Engineers held at Tokushima in September.

Editor's Note

I took charge of the secretariat of ICUS second international symposium. This was good and a severe experience for me.

There were some first and adventurous things at this international symposium. First of all, it was the first event that I was the secretariat of an international symposium although I am very lazy. I think that this choosing was a strategy of ICUS head for educating me.

Moreover, it was the first time to have recruited general speakers widely. I thought we cannot make the wide discussions concerning urban safety engineering if the speakers were selected by only ICUS staffs

as in the first international symposium.

It was necessary to make First Circular by April last year to recruit general speakers widely. However, I am not good at English. When I was embarrassed, Dr. Dutta made it instead of me.

Then, the papers recruitment started. Fortunately, many mails of registrations and the inquiries gathered. Unfortunately, I could not afford processed them all. Ms. Sharvani who was the secretary of ICUS received those all instead of me. I wish to express my gratitude to her sincerely.

After papers gather, it was necessary to make the symposium program. When I was nonplused, Dr. Endo and Ms. Yoshimura made the program instead of me.

At this symposium, I thought that I wanted to invite a lot of speakers. It is necessary to think about the arrangement of the budget for that, and to secure the rooms for stay. Ms. Ochi, Ms. Yoshimoto, and Ms. Fujita who are the secretary of ICUS did all those works. Moreover, they prepared the symposium hall.

Because the symposium ended safely, I was deeply relieved. I noticed only the work that I had done was to have worried, when I thought calmly. No matter how I wish, I cannot express my gratitude to all staffs of this symposium. However, it is uncertain whether ICUS head's strategy succeeded or not.

(by Ryozo Ooka)

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