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Institute of Industrial Science
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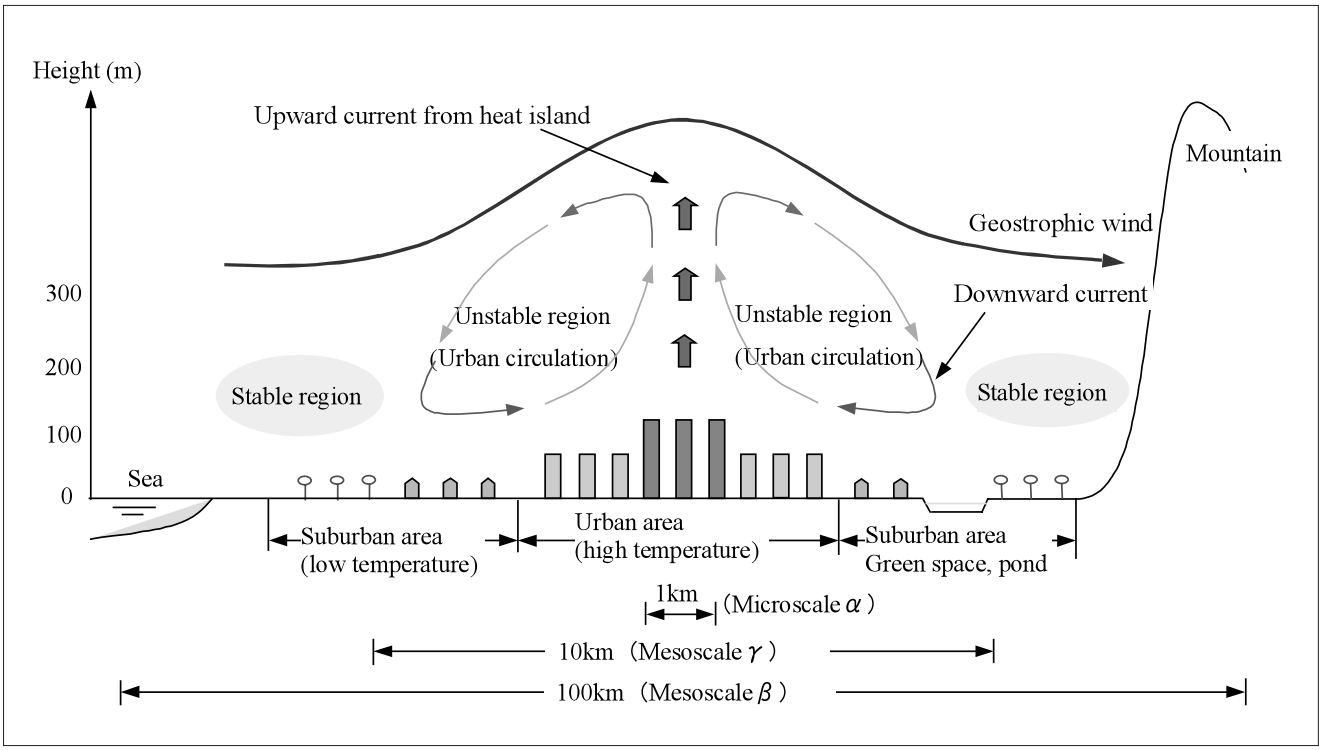
Urban Warming and its Control

by
Ryozo OOKA

Rapid urbanization has significantly affected the urban climate and is at least partly responsible for the phenomenon, which is being termed *'urban heat island'*. It refers to localized small regions of relatively higher temperature created in the neighborhood of urban centers on account of the massive consumption of energy and lack of appropriate heat sinks. These local changes caused in the urban environment, cannot be captured using normal meteorological methods, and have been described to extend over a range of 10 ~ 100 km horizontally and 100 ~ 1,000 m vertically in a large city such as Tokyo.

A brief description of factors leading to the emergence of heat island and the steps that may be taken to control the phenomena is given here along with the research effort made being for analytical modeling. Appropriate examples for the Tokyo metropolis are included.

The figure below is a schematic representation of the model that can be used to describe



Schematic model for creation of urban heat island

the emergence of heat islands. It can be seen that warmed air in the urban area rises through buoyancy, is cooled in the upper reaches of the atmosphere, and descends into the surrounding suburbs. Also, the air currents descending further converge in the metropolis, generating so-called urban circulating currents.

The figure at the bottom left shows the growth of urbanized area in Tokyo in the last about a hundred years. The radius in the Tokyo metropolitan area can be seen to have expanded to about 50km from 5km over the period. The variation in the air temperature during the same period is also given in the figure at the bottom right, and it can be seen that the mean air temperature measured at a height of 1.5 m above the ground has risen by as much as about 2°C. It may also be noted that the number of tropical nights (summer nights following days when lowest temperature is higher than 25°C) in Tokyo rose from less than three in the 1920s to more than thirteen in the 1980s.

Factors leading to urban warming

Increase in artificial heat release in urban areas, decrease in evaporation from land, heat storage by urban construction materials, decrease in heat exchange with the atmosphere due to urban structures and the greenhouse effect due to presence of fine dust and atmospheric contaminants can be listed as some of the factors that lead to formation of urban heat islands. It may be noted that artificial waste heat in three wards in the Metropolitan Tokyo reached approximately 700,000 Gcal/y/km^2 in 1986, which is more than the incident solar heat radiation (approx. 650,000 Gcal/year/km^2). Also, urbanization leads to a loss of permeable areas such as green space, marshland, rivers, ponds, etc. which affects the consumption of latent heat by evaporation from the land surface, causing the surface temperature in urban area to rise higher than in the suburbs.

Controlling urban warming

As can be seen from the above, warming of the atmosphere in the neighbourhood of mega-cities such as Tokyo is advancing at a far faster pace than the global warming. Thus, unless steps are taken immediately, it is almost certain that the problem will acquire a very serious dimension in the future. The following could be considered as steps that could help control emergence of heat islands:

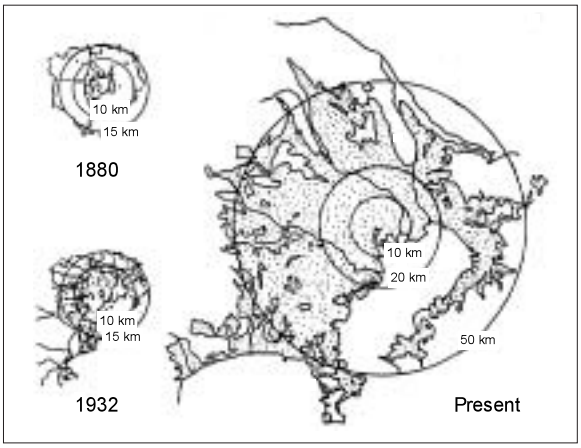
a) Reduction in artificial heat releases by promotion of appropriate energy saving systems,
b) Promotion of evaporation from land surfaces using appropriate construction materials,
c) Promotion of heat absorption by heat sinks,
d) Promotion of heat exchange between the urban structures and the atmosphere achieved by improvement in the ventilation performance of the urban area by the suitable arrangement of building, and,
e) Control of atmospheric contaminants

Implementation of plans incorporating 'Ventilation paths' in Struttgart, Germany, is an example of layout of buildings to facilitate ventilation.

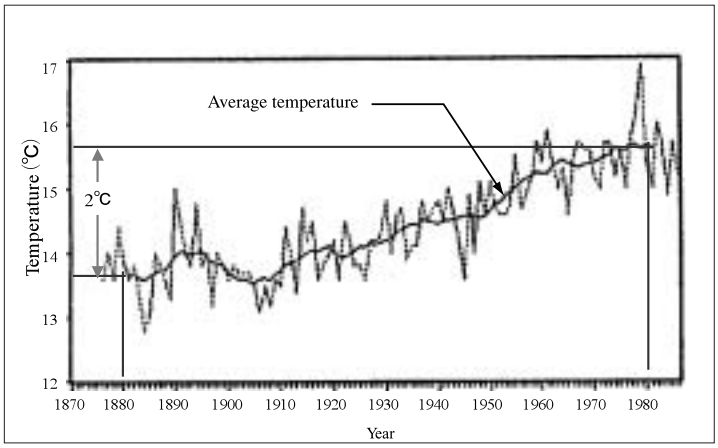
Numerical climate models for urban warming

Although the control methods against urban warming mentioned above, have a reasonably sound qualitative basis, given the extremely complex inter-relationship between the various variables, it is very difficult to quantitatively evaluate the effect of each method through empirical and experimental studies alone. Thus, one of the ways to study the problem is formulation of appropriate analytical climate models for the purpose.

An analytical hydrostatic model taking into account the different factors that affect the microclimate in the neighbourhood of mega-cities has been used to study the variations in temperature. It is likely that such techniques based on the numerical climate model may become a powerful tool from the viewpoint of synthetic environment assessment technology, including studies for air pollution, etc. The model uses



Urbanization of Tokyo over the last 120 years



Increase in air temperature in Tokyo

fundamental principles of heat, mass and momentum transfer, thermodynamics, water vapor and mass and radiation heat transfer to study local climate changes.

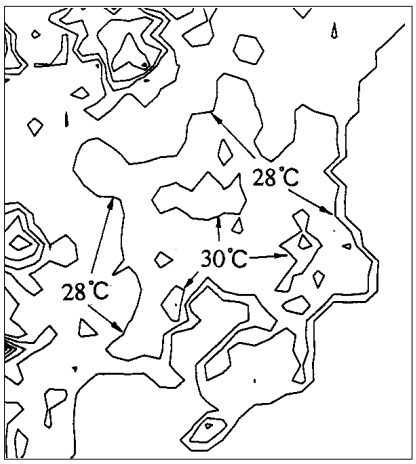
The figures below show the results for the simulated studies of changes in the microclimate in the Tokyo metropolitan area, over the last about hundred years. The effects of factors such as land use, and heat releases are incorporated in the model. Whereas the figure (a) shows the simulated distribution of ground surface temperature in the present day Tokyo area for late afternoon on a summer day in August, a similar distribution for the area during the Edo era, about 150 years is shown in Figure (b). It can be seen that that whereas the peak temperature of about 34°C, is observed in the central part of the present day Tokyo, the maximum in only about 30°C for the Edo period Tokyo. It may also be noted that the temperature in the suburban areas has remained at the same level of about 28°C. It is of interest to study these variations in temperature in light of the urbanization of the Tokyo metropolis that has depicted earlier. A plot of the ground surface temperature of the Kanto district recorded during the summer using the artificial satellite (NOAA-AVHRR) is also shown for reference, and clearly shows a high temperature region in the central part, which has the maximum concentration of buildings, and urban infrastructure, compared to the suburban area.

Though the results do provide an estimate to the warming in the Tokyo region that has been observed, there is an apparent need to refine the model to obtain better quantitative estimates. A better modeling of the complicated air-flow and temperature field in the neighbourhood of urban structures could possibly help to improve the model.

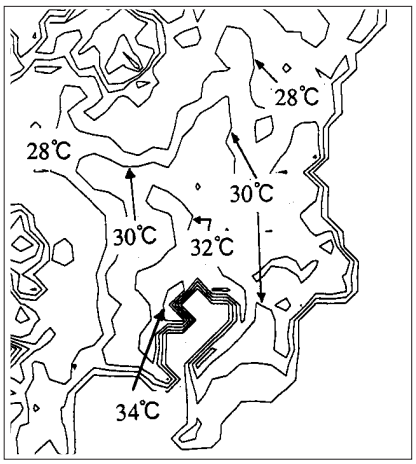
Concluding remarks

The phenomenon of generation of heat islands as a result of urbanization and resulting consumption of energy has been demonstrated above along with the results from a numerical simulation.

It can be seen that the model presented can simulate climatic changes considering geographical features over a range of 10 to 100 kilometers, though more effort is required to improve the accuracy.

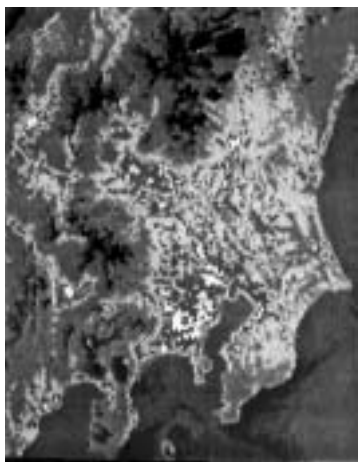


(a) Present



(b) About 130 years ago

Changes in the temperature patterns in the Tokyo metropolis



Ground Surface temperature in Tokyo region (NOAA-AVHRR)

ICUS Activities Recognised

Mr. T. Sugiyama and Mr. K. Miyamoto of the Uomoto Laboratory bagged Prizes for excellent presentation at the 2002 Annual Meeting of the Japan Concrete Institute. Mr. Sugiyama is a research engineer in the Uomoto Laboratory and works for the Master Builders Technologies. Mr. Miyamoto is a graduate student of the Shibaura Institute of Technology.

Mr. Sugiyama also won an award for his presentation in the 2002 Annual Meeting of the Japan Cement Association.

Mr. Y. Ishizeki, Mr. Y. Hosokawa, Mr. T. Nishimura and Prof. T. Uomoto won the Development of New Technology Award for their work on development of high quality shotcrete in May 2002 from the Japan Concrete Institute. Mr. Ishizeki and Mr. Hosokawa are employed with Kumagai Gumi Company and Taiheiyo Cement Corporation, respectively, and are research engineers at the Uomoto Laboratory. Mr. Nishimura is a Technical Associate at the Institute of Industrial Science.

Foreign graduate students Mr. Bishnu Hari Pandey (Nepal) and Ms. Paola Mayorca (Peru) working with Dr. K.Meguro, Associate Professor, ICUS, earned a Recognition for their presentations at the 4th International Summer Symposium of the Japan Society of Civil Engineers held on August 3, 2002, at Kyoto.

Expert Systems in Visual Inspection of Concrete Structures

The end of the Second World War saw the onset of a major construction boom in Japan, and concrete was used extensively in the construction of buildings, bridges, etc. The figure at the bottom left, with the data for bridge construction shows an example of the construction boom. Indeed, the structures built during that time, are all more than 35-40 years old, and have begun to show signs of deterioration to varying degrees. It is clear from the figure that the structures that need inspection and maintenance are likely to increase at a very rapid rate from now.

Another representation relating the maintenance required and the life in service is given in the figure at the bottom right. It shows that whereas some bridges may require maintenance and repair as early as 10 years after construction, more than 50% need repairs in about 50-60 years of service.

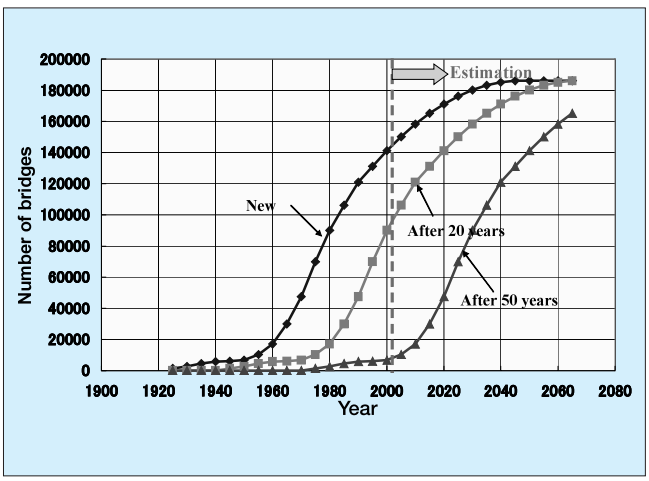
Though the figures show the examples of only bridges, the pattern is similar for other structures, such as buildings, etc. also. Information in a report compiled by the Ministries of Construction, Transportation and Agriculture and Fisheries in 2000 showed that about 40% of the concrete structures have been repaired after a service life of about 50 years.

Now, no matter what the *'design life'* of the structures built in the post-war construction boom was, given the cost of dismantling and building new ones, leaving the technical problems of working in congested urban environments apart, it is only likely they will be expected to remain serviceable for as long as possible, even as long as say 100 years. This clearly outlines a mammoth task for the engineers in terms of carrying out inspection of structures and repair/strengthening works in existing structures. The high level of public awareness and concern for safety of structures should also not be lost sight of. The following picture is a clipping from the Press warning of the consequences of overlooking 'dangerous' (deteriorated) concrete structures, and describing developments including new inspection systems and the examination introduced by the JCI.

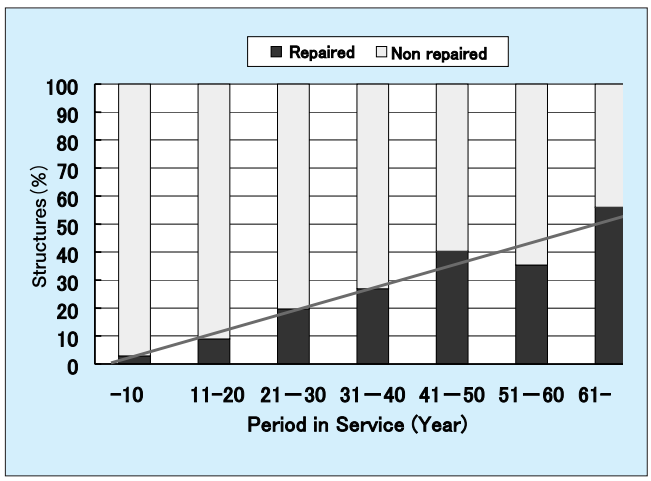

危ない構造物 見逃すな
コンクリート劣化の新システム
診断士の試験も

Press reports (February,2000)

Structures, both in the private and public sectors, are periodically inspected to ensure that they are serviceable, and to look for signs of deterioration and distress. The possibility of injury to not only the users but also 'third parties' by way of spalling of concrete, etc. is also kept in mind during these inspections. Depending upon the degree of importance, location and environment of the structure, the inspection may use different nondestructive testing tools, or be simply visual. In fact, in most cases, a detailed inspection using appropriate tools is carried out in cases (only) when visual inspection shows a need. Even in cases when a decision has to be made regarding carrying out repair and/or strengthening the structure, visual inspection is usually the first step.



(a)



(b)

Representation of progressive aging of bridges and required increased attention for older structures

(a) *(b)*

Sample displays for software to aid in inspection of structures

Though visual inspection yields excellent data but the subjectivity in the results sometimes makes it's reliability quite poor. Not only different inspectors may view a certain degree of cracking as 'serious' or 'routine' depending upon personal judgment, but their understanding and interpretation could also depend on their professional backgrounds, i.e. whether they are essentially trained in repair systems of cracks or they are structural engineers.

Further, the life-span of a structure is quite long, and not only it is difficult for the same person to continue to inspect the structure, but his own 'evaluation' undergoes substantial changes with age and experience.

Though the Japan Concrete Institute has instituted professional examinations to bring about some standardization in the area of inspection of concrete structures, it is important that other avenues for better standardization and utilization of results from visual inspection are explored.

In this context, Dr. Taketo Uomoto, Director ICUS, and Professor at the Institute of Industrial Science, University of Tokyo, has led an effort on the possibility of using personal computer based expert systems in visual inspections, and formulated a basic outline of the system about two years ago.

The system is being developed to introduce a certain degree to uniformity and objectivity in testing and evaluation, and enable an engineer with only a marginal understanding of the deterioration processes in concrete to carry out routine inspections. The interactive system guides the inspector through inspection process using the built-in data for commonly encountered deterioration. The adjoining figures are samples from the displays on the computer screen during the execution of the software developed. Figures (a) and (b) abore are examples of kind of assistance the system offers to the inspector and prompts him with questions about the environment of the structure, extent of cracking, etc. The adjoining figure shows an example of the 'diagnosis' made by the expert system on the basis of the data fed in during the course of the inspection. The results are given in terms on an 'overall index' which gives the possibility of a certain mechanism

Sample display of 'diagnosis' using the software

of deterioration operating.

At present, Professor Uomoto is leading a team of researchers, including engineers drawn from ten consulting and construction companies, to develop a practical expert system for a scientific collection and analysis of data from bridges, tunnels and wharfs.

Though it is hoped that the required software will be ready in another year, it is likely to take some more time before the package is translated in English, etc. and is available for use in other countries.

(Sudhir Misra)

Editor's Note: Readers may also note that Vol 1 No 4 of our Newsletter also carried a related article on Maintenance of concrete infrastructure.

3rd ICUS Open Lecture

The phenomenon of global warming has been recognized for quite sometime now, and has been studied by scientists and environmentalists from the point of pollution and pollution control, rising sea levels, and environmental conservation. Recently, however, research effort is also being directed to study different aspects of the 'Heat Island' phenomenon, which essentially refers to creation of localized pockets of heat in the neighborhood of major urban centers.

The theme for the 3rd Open Lecture organized by ICUS scheduled for September was delayed and held on October 7, 2002, at IIS, Komaba-II Campus, University of Tokyo was "Urban Heat Environment - The Risk of Heat Island". The theme had been chosen to draw wider attention to the problem and the directions in current research. About 80 engineers and scientists from various organizations listened to presentations by Prof.R. Ooka of the ICUS and three other eminent researchers.

At the outset, Prof. Y. Yasuoka provided a brief overview of the Open Lecture, and thanked the speakers and participants for taking time out of their schedules and coming to IIS for the event. He then invited the speakers to make their presentations.

Dr. Ryozo Ooka, Associate Professor, ICUS, Institute of Industrial Science, University of Tokyo, made a presentation dealing with the issue of urban warming and methods that could adopted during architectural design and urban planning to control the development of heat islands. He also gave a summary of the current projects in his research group dealing with microclimate modeling and application of advanced technologies for the mitigation of urban heat conditions.

Prof. Takehiko Mikami, Department of Geography, Tokyo Metropolitan University, gave a lecture on "Investigation of Urban Heat Island in Tokyo metropolis Based on the Ground Monitoring System". His presentation was based on data collected and the evidence available to show the growing Heat Island phenomenon in the Tokyo metropolitan region, and emphasized the importance of developing a network system for accurate monitoring of parameters related to Heat Islands, in order to better understand the changes in urban micro climate on account of urbanization.

Mr. Kohtaro Takemura, Advisor, Water Resource Environment Technology Center, made a presentation titled "Global Warming and Urban Disaster", and discussed the present trend in water related natural disasters such as flood and draught. His presentation focused on the situation in Japan in relation to the changes in microclimate by urbanization, and global warming. Mr. Takemura also put forward the mission of the government and government agencies in mitigation of damage by these disasters.

Prof. Yutaka Inaba, Department of Epidemology and Environmental Health, Juntendo University School of Medicine, presented a talk on "Mortality rate due to heat disorder by place of occurrence using vital statistics in Japan". His presentation contained the statistics about the mortality rate by heat disorder over the last about 40 years collected during hot days in Osaka, Tokyo and Nagoya. Prof. Inaba observed that the mortality rate was markedly high among the persons over 65 years old and those 0 to 4 years old, and did not show a gender bias. However, in the other age groups and places of occurrences, mortality rate for women was lower than that for men. Further, the mortality rate from 1990 to 1999 was higher than that from 1959 to 1968, while the age-adjusted mortality rate remained the same. significant Positive correlations were observed between the mortality rate of heat disorder and the annual peak temperature as well as the occurrence of hot days in Tokyo, Nagoya and Osaka.

Through comments and questions on each of the presentations, the audience expressed their interest in the various issues. At the end of the Open Lecture Prof. Y. Yasuoka thanked the speakers for the excellent presentations, and invited them to join the participants for informal interaction.

A view of audience at the Open Lecture

ICUS/INCEDE Activity Record

Prof. T. Uomoto attended the International Congress on Challenges of concrete Construction held at Dundee, UK from 5th to 11th September, and also attended the meeting of the ISO panel TC 71 on Concrete.

Prof. K. Meguro attended the Earthquake Related Insurance and Financial Risk Management and the 27th Annual Hazards Research and Applications Workshop during 3rd to 8th July and 14th to 19th July, respectively. The Conferences were held at St. Petersburg Russia and Boulder USA, and highlighted the need to involve professionals from sectors such as banking, finance, insurance, etc. in developing a comprehensive approach to disaster mitigation.

Prof. R.Ooka participated in the Landscape Frontier 2002 held at Kita Kyushyu in Japan from Sept 30th to Oct 3rd.

Dr. D.Dutta participated in the International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences 2002 held from 25th to 28th August at Hanoi in Vietnam.

Dr. S. Ochi participated in The 2nd Regional Seminar on Geo-Informatics for Asian Eco-System Management (India) from 10th to 12th September, organized by the Asian Institute of Technology (AIT) and the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) at the Indian Institute of Remote Sensing, Dehradun, India. 23 resource persons and 39 participants from India, Japan, Malaysia, Nepal, Thailand and Vietnam attended the seminar.

Dr. S. Ochi also participated in the MAP Asia 2002 at Bangkok, Thailand from 7th to 9th August. More than 500 delegates from over 30 countries attended the conference held at the initiative of the AIT, the Centre for Spatial Database Management and Solutions (CSDMS), India, and the Geo-Informatics and Space Technology Development Agency (GISTDA), Thailand. Professor S. Murai, Emeritus Pro. of the University of Tokyo was awarded the "Life Time Achievement Award" for his contributions in the field of remote sensing by the organizing committee.

Professor Uomoto (Right, Front) with some other Japanese delegates

Visitor to ICUS/INCEDE

Dr. Seok-Kyun Park, Associate Professor, Department of Civil Engineering, Taejon University, South Korea visited ICUS, IIS on July 31st.

Prof. Park specializes in nondestructive testing of concrete structures and is a former graduate student of the Department of Civil Engineering. at the University of Tokyo. He completed his D.Engg in 1996 on application of radars for monitoring of concrete structures, under the supervision of Professor Taketo Uomoto.

ICUS personnel

Ms Yuriko Ochi and Ms Eiko Yoshimoto joined as Secretaries at the ICUS in September.

Dr. Sudhir Misra joined as Visiting Professor on July 15th for about a year from the Department of Civil Engineering, Indian Institute of Technology, Kanpur India. This is his second stint at ICUS after a brief stay last year. During this stay here, Dr. Misra will work closely with Prof. Uomoto and participate in teaching and research activities. He will also devote part of his time to work with a sub-committee of the Japan Society of Civil Engineers translation with the responsibility of publishing the English translation of the Japanese standard specification for design and construction of concrete structures. Dr Misra is an alumnus of the Tokyo University and worked during his graduate studies here (1984-1989) with Prof. Uomoto.

Welcome to ICUS.

Ms.Yuriko Ochi

Ms.Eiko Yoshimoto

Editor's Note

During late July and August, the University of Tokyo observes summer vacation, and this year it was a very hot and humid period with the temperatures reaching more than 33°C even in the beginning of July. I used the vacations this year to visit Hida-Takayama with my students in August and attend an International conference in Dundee, Scotland in September.

Hida-Takayama, one of the historical cities in Japan, is set in picturesque setting and has architecture and culture quite different from Tokyo. Located on the west side of Japan North Alps and known for the heavy snow falls in winter, the city of Takayama is just like Kyoto, with old houses still being used. Such houses having sloping roofs are to be found only in a small limited area and are built using the traditional "Gassho-zukuri" (literally meaning 'made in the manner of folded hands') method. I hope the following photograph conveys the idea.

Weather in Dundee in September was quite cool and the temperature difference with Tokyo was more than 15°C!!. I had the opportunity to have dinner in Gramis Castle, where H.E. Queen Elizabeth spent her younger days. The castle is beautiful and I enjoyed the bug pipes at the welcome and nice drinks and traditional food - indeed an experience that we cannot have in our country.

At the moment, we are busy preparing to hold an International Symposium and to open a network office in Bangkok, Thailand. At the end of September, we bid farewell to our secretary, Ms. Murakami, who left Japan to join her family in Shanghai. New secretaries, Ms. E.Yoshimoto and Ms. Y.Ochi have joined ICUS during this period, and I am sure we will be able to keep you posted on the latest developments here.

(Taketo Uomoto)

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