Towards Safer Urban Cities and Environment in the 21st Century

International Center for Urban Safety Engineering

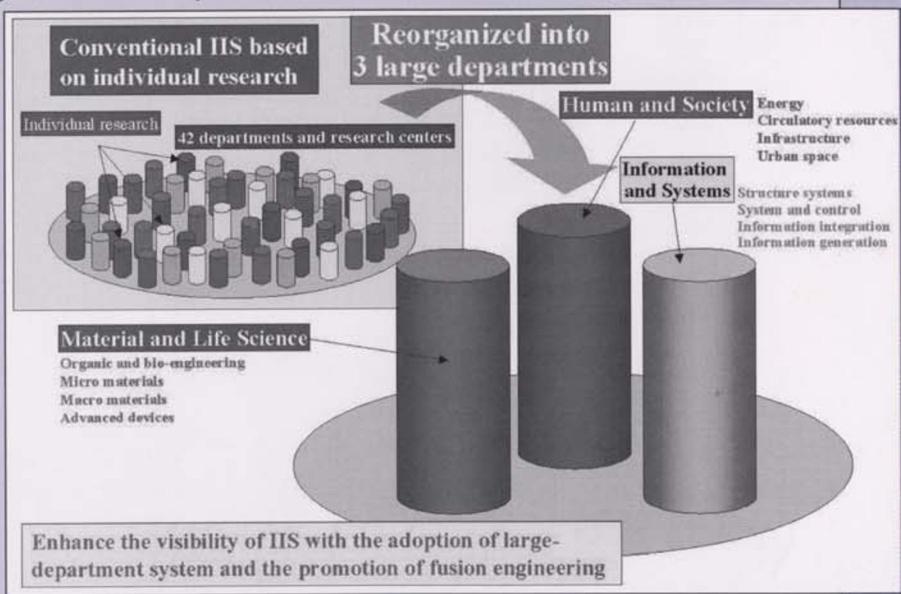
ICUS/INCEDE

Institute of Industrial Science
The University of Tokyo

Establishment of ICUS/INCEDE

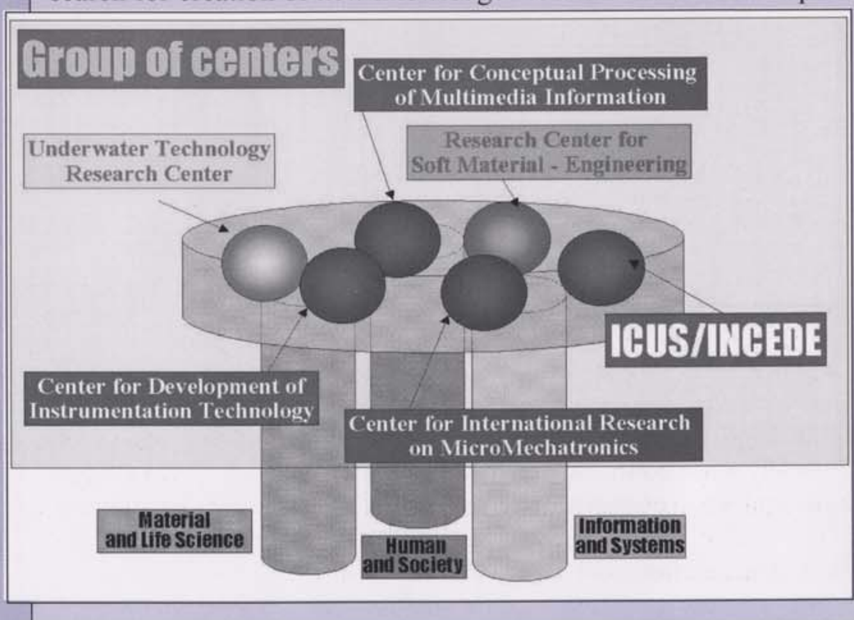
Restructuring of the Institute of Industrial Science

The Institute of Industrial Science (IIS), University of Tokyo was founded in 1949 as the second engineering college of the University of Tokyo and is considered to be the largest research institute attached to a University in Japan. Covering almost all the engineering fields, it has been carrying out various industry oriented scientific research with the focus on application of its research results in the industry. The institute consisted of 42 research departments and several research centers whose characteristics differ from similar departments in the main campus of the University of Tokyo at Hongo. IIS has been reporting its creative research achievements on advanced scientific technology. At the same time, it also pays great attention to public evaluation. Its achievements have been highly evaluated by all international, industrial and academic panels. However, in order to continue to be the frontier institute in the rapidly changing 21st century, it is necessary for IIS to form rational organizations and systems. Towards realization of that goal, IIS has been seeking a suitable management and structural reform so that it can respond dynamically to the public requirements as well as to the new challenging issues of the society. As a result, all the conventional organizations of IIS are completely restructured. Three large departments have been formed, namely: **Departments of Material and Life Science**, **Human and Society** and **Information and Systems**, enabling the combination of various research fields. The new system allows researchers to freely implement research activities in their own ways.



Strategy for the formation of research centers at IIS

Towards becoming an international engineering research institute, IIS is carrying out the so-called "Research for creation of new knowledge" to contribute to the improvement in social activity of the human beings in the next generation. This frontier exploitation, based on important researches which have been cultivated so far, is due to be realized by achieving functional strengthening of attached centers. Anticipating the social needs, group of research centers (i.e. Research strategy organizations), which perform research on important domains, are established with experts from various departments. These research centers are designed to promote the research at IIS and also to make the public recognize their activities, so that IIS can play an important role in international as well as in domestic research network.

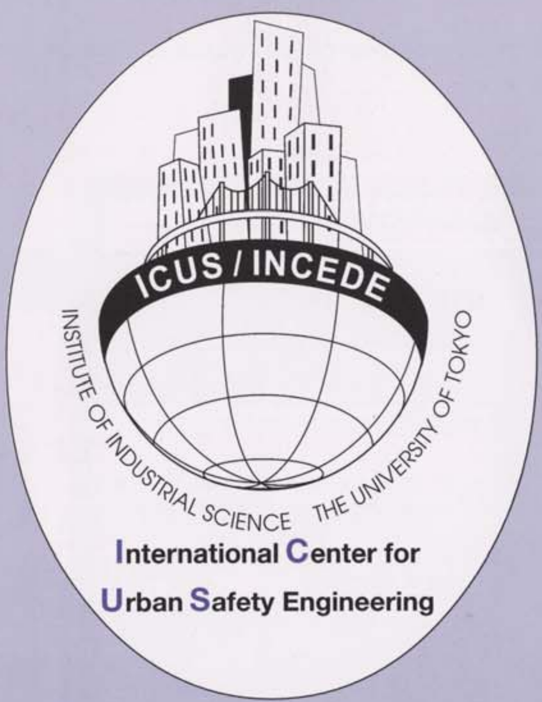


TOWARDS SAFER URBAN CITIES IN THE 21ST CENTURY

Research on Safety of Urban Infrastructure by University Researchers, From International Viewpoint

The International Center for Urban Safety Engineering (ICUS/INCEDE) was created at the IIS in response to a need of a center for studying urban safety engineering including maintenance and management of urban infrastructure from an international viewpoint. Based on the research results accumulated until now at IIS, comprehensive research activities are being implemented towards the realization of safer cities in the 21st century. Within the ICUS/INCEDE, three divisions have been created, namely: ***Sustainable Engineering***, ***Urban Safety and Disaster Mitigation*** and ***Infrastructure Information Dynamics Departments***.

Sustainable Engineering Division will target development of new technologies for maintenance management and for the evaluation of structural safety, considering the deterioration of both material and structure. ***Urban Safety and Disaster Mitigation Division*** will develop management technologies to ensure the structural safety of urban infrastructure during natural disasters such as earthquake, flood, etc. and their safety for use at the time of a disaster. The role of ***Infrastructure Information Dynamics Division*** is to develop and evaluate technologies for monitoring information of urban infrastructure, ensuring their safety for daily use and in case of emergency.



Main research themes of the 3 divisions

Sustainable Engineering

- Deterioration mechanism of existing structures
- Nondestructive testing technology for evaluation of deterioration
- Retrofitting and strengthening of structures based on mechanism of deterioration
- Standard specification for design, construction and maintenance

Urban Safety and Disaster Mitigation

- Urban safety and disaster mitigation strategy
- Development of a universal disaster environment simulator
- Disaster countermeasures for urban lifeline systems
- Use of earthquake-predicting information from an engineering viewpoint

Infrastructure Information Dynamics

- Remote sensing/geographic information system
- Information network of urban infrastructure
- Space data analysis
- Urban warming/comprehensive environmental assessment

The International Center for Urban Safety Engineering (ICUS/INCEDE) was established in March 2001 after the International Center for Disaster-Mitigation Engineering (INCEDE) had completed its designated period of ten years. The abbreviation of the English name of the new center is set to ICUS/INCEDE, which shows that it is the inheritor of the internationally well-known INCEDE. With the network built by INCEDE and the cooperation of its members, ICUS is determined to comprehensively carry out research on safety of urban infrastructure. The main objective of ICUS/INCEDE is to study the urban safety engineering, which includes maintenance and management of urban infrastructure from an international viewpoint.

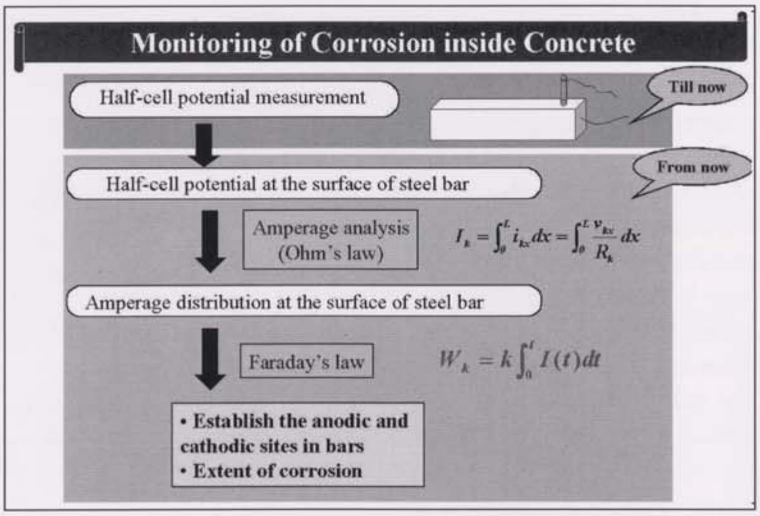
Sustainable Engineering Division

This division performs research on the maintenance management technology including development of suitable inspection methods for evaluation of structure safety and repair and reinforcement methods for deteriorated structures and infrastructural components, taking into account the degradation in performance of the materials *per se* and the structures as a whole.

Inspection and Prediction Methods for Corroded Portion of Reinforcing Steel Bars Embedded in Concrete Structures

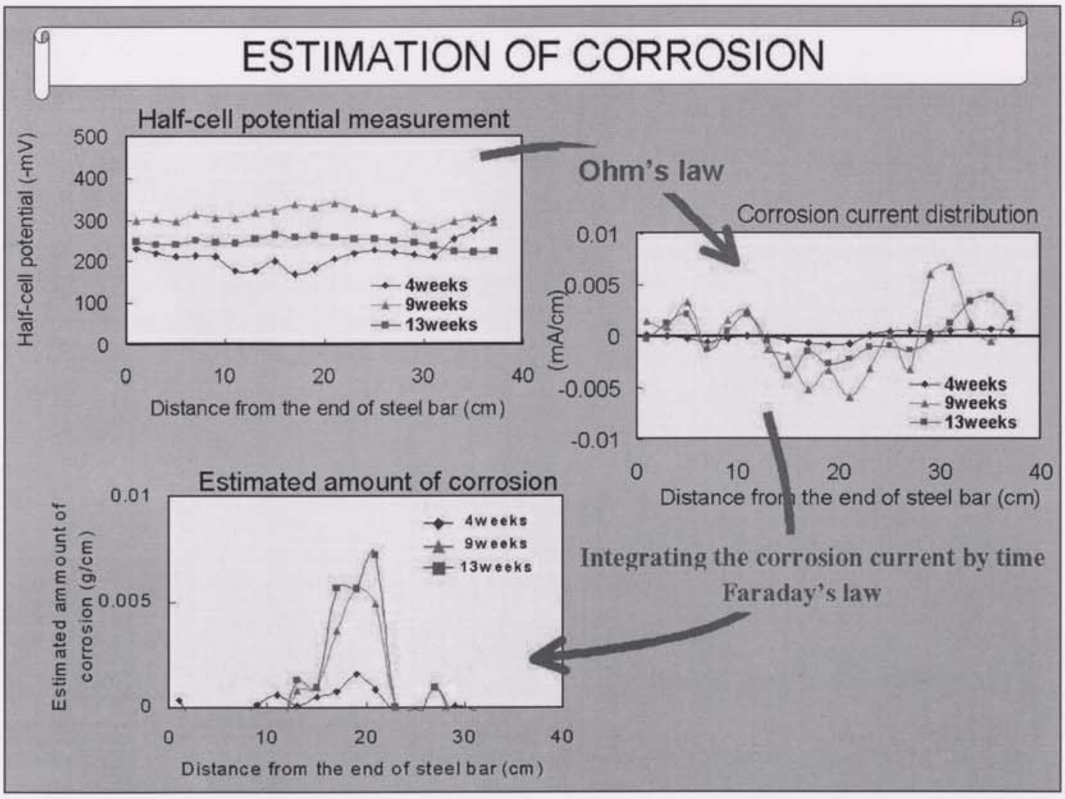
Half-cell potential measurement is one of the nondestructive methods to evaluate corrosion of steel bar embedded in concrete. The following table shows the assessment of corrosion as per ASTM.

Half-cell potential E(mV, CSE)	Probability of corrosion
-200mV < E	No corrosion (90%)
-200mV<=E<=-350mV	Unknown
E<-350mV	Corrosion (90%)



Now, the relationship between corrosion and half-cell potential still has not been clarified in details. In order to solve this problem, it is necessary to use the electrochemical theories to supplement nondestructive measurements. Distribution of corrosion current can be estimated using half-cell potential measurements and Ohm's law. Further, the total amount of corrosion can be estimated by integrating cumulative corrosion current and using Faraday's law.

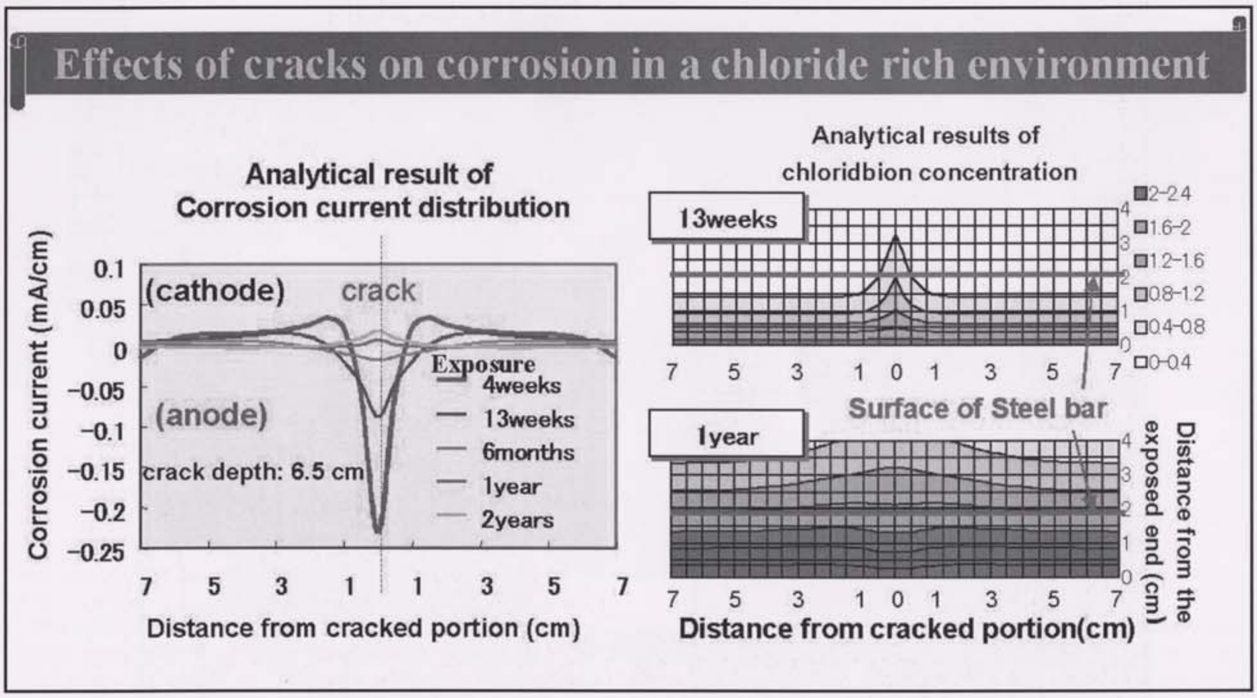
Using these electrochemical theories, it is possible to know the progress of the corrosion from the time-dependent measurement of half-cell potential from time to time.



When the cracks are formed in concrete structure built in coastal areas, chloride ion can easily penetrate towards the surface of steel bar in concrete through these cracks. This causes corrosion of steel reinforcing bars. It is therefore very important to estimate the effect of cracks on corrosion of the steel reinforcing bars when designing concrete structure in marine environments. It could be possible to predict long term corrosion activity in marine structures by applying the kind of electrochemical tools outlined above along with diffusion models to estimate chloride penetration in concrete.

Example:

From the prediction analysis of corrosion in cracked concrete in chloride environment, the difference of chloride content largely affects the corrosion of steel bar embedded in concrete at the initial stage. However, as time passes, the chloride content at any surface becomes the same and the explicit effect of the existence of cracks becomes matter. Now, in order to keep the performance of concrete against chloride environment, it is necessary to design the structure with adequate cover thickness to the bars. Other options such as use of surface coating materials on the surface of concrete or the use of epoxy coated bars, or the use of non-corrosive FRP rods as reinforcing material, need to be considered.

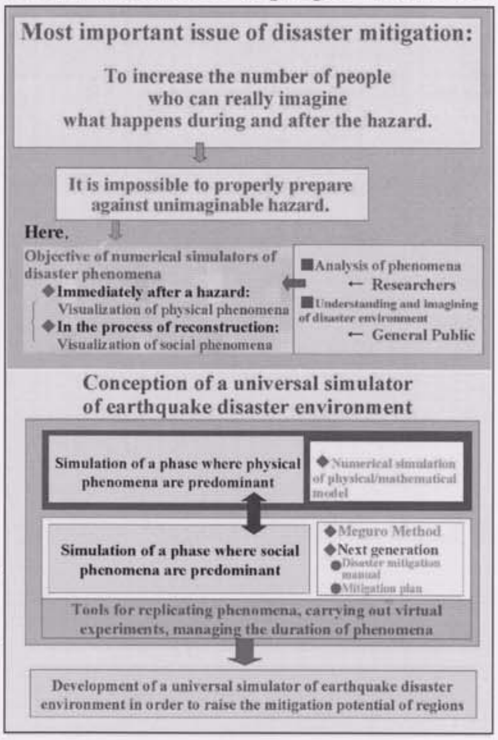


Urban Safety and Disaster Mitigation Division

This team develops tools to estimate the structural safety of urban infrastructure in case of disasters such as earthquake or flood. This research aims to improve the situation of both developed countries, whose societies are characterized by low economic growth rate, aging, low birthrate and developing countries which have problems of sustainable development.

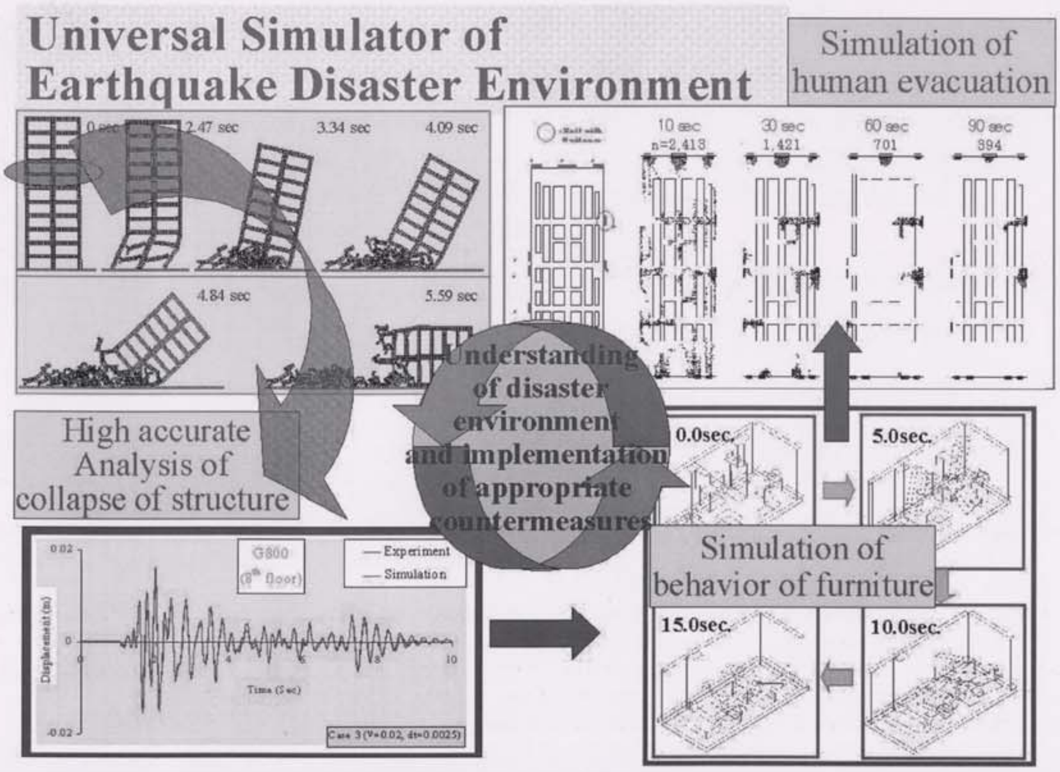
Development of a Universal Simulator of Earthquake Disaster Environment

The most important issue of disaster mitigation is to increase the number of people who can actually comprehend the events during and after a hazard. It is impossible to properly prepare against an unimaginable situation. The essential mission of us, disaster experts, is to reduce the number of people who will be affected by an earthquake because of insufficient preparedness due to disability to imagine the disaster situation. This is the reason why numerical simulators are meaningful, as they can help people to imagine the real disaster situation by giving visual images of the disaster environment based on physical and social backgrounds.



Numerical simulations have several advantages. They assist experts and common people to study and understand various phenomena better by replicating them. They can serve as virtual experimental tools when real experiments are dangerous, phenomenon scales are too large or too small, or there are restrictions on material parameters or boundary conditions. Finally, numerical simulations can manage the duration of phenomena for better observation in cases when phenomena takes too long or too short time.

The figure below shows a universal simulator system which enables the visualization of the collapse of structure, behavior of furniture inside the structures and human evacuation during an earthquake. This model is the basis of a universal simulator of earthquake disaster environment whose final objective is to simulate total process of earthquake disaster including post-earthquake activities such as reconstruction.

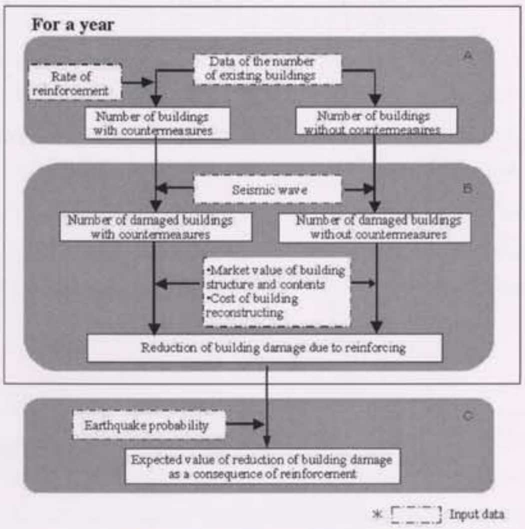


Research on Use of Earthquake Prediction Information From Engineering Viewpoint

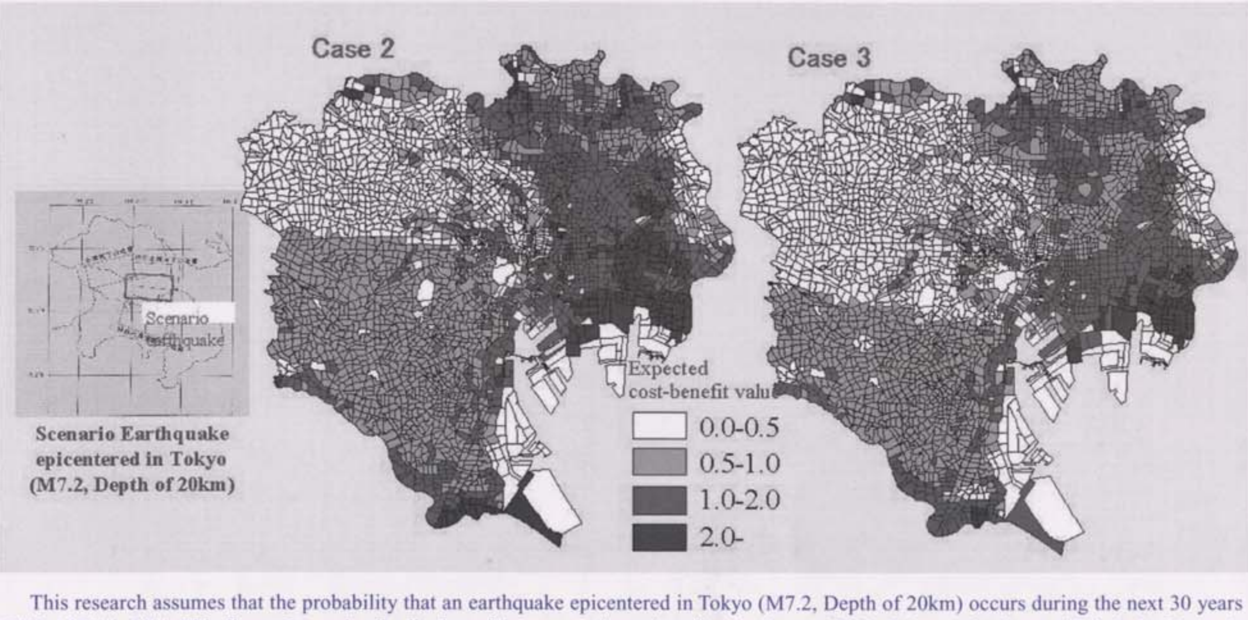
In Japan, research on earthquake prediction started in 1965. Tokai area, which is under potential risk of an earthquake, has a system to announce earthquake prediction information and to provide countermeasures. However, if prediction fails, the countermeasures of this system will bring huge social effects because it was designed under the assumption that an earthquake could be predicted with high accuracy. The social negative impact due to an inaccurate prediction is estimated in 720 billion Japanese Yen per day. This type of prediction system makes it difficult for society to accept a failed prediction and it does not encourage the release of uncertain information.

The Earthquake Research Promotion Institute, Ministry of Education, Science, Culture and Sports of Japan, reported the possibility of large earthquakes such as the Tokai earthquake and Miyagiken-oki earthquake within the next 30, 50 or 100 years. In order to use such information effectively, the ongoing research should focus not only on the prediction accuracy but also on the effective use of uncertain prediction information.

Earthquake prediction is classified in long-term, mid-term, short-term and immediate prediction according to the time duration of prediction. We try to make effective use of these information for the purpose of disaster mitigation focusing on the long-term predictions which have relatively higher possibilities of being successful. Kobe earthquake of 1995 showed us that reducing building damage by reinforcing existing weak structures could minimize both victims and economic loss. We propose to quantify the effect of reinforcement by calculating the expected building damage cost reduction as a consequence of reinforcement using earthquake probability data and damage estimation. The flowchart of this research is shown in the adjoining figure.



The flowchart of the study



Scenario Earthquake epicentered in Tokyo (M7.2, Depth of 20km)

This research assumes that the probability that an earthquake epicentered in Tokyo (M7.2, Depth of 20km) occurs during the next 30 years (2001-2030) is 30%. This figure shows the distribution of the expected cost-benefit value in case 25% of the wooden houses built in the 23 wards of Tokyo city before 1970 are reinforced. The expected cost-benefit value is calculated using the expected reduction of the building damage cost which can be estimated by using fragility curves and real estate data. The time when reinforcement is carried out has influence on the cost-benefit value. Thus, 3 cases were considered. Case 1, case 2 and case 3 correspond to the situations in which reinforcement is carried out from 2010 to 2015, from 2010 to 2020 and from 2010 to 2030, respectively. The results of cases 2 and 3, which are shown in this figure, indicate that the cost-benefit value varies according to the regions.

Our team is proposing a new system by which the Government pays part of the repair and reconstruction cost in case that a building/house, which is properly reinforced before an earthquake, is damaged by an earthquake. In order to apply this system to their facilities, Government and private companies should establish priorities. The research described in the previous paragraphs provide basic information for this purpose. Moreover, it can assist the building users to decide when reinforcing should be carried out according to the zone where they are living, expected earthquake occurrence data and accuracy of the earthquake prediction information.

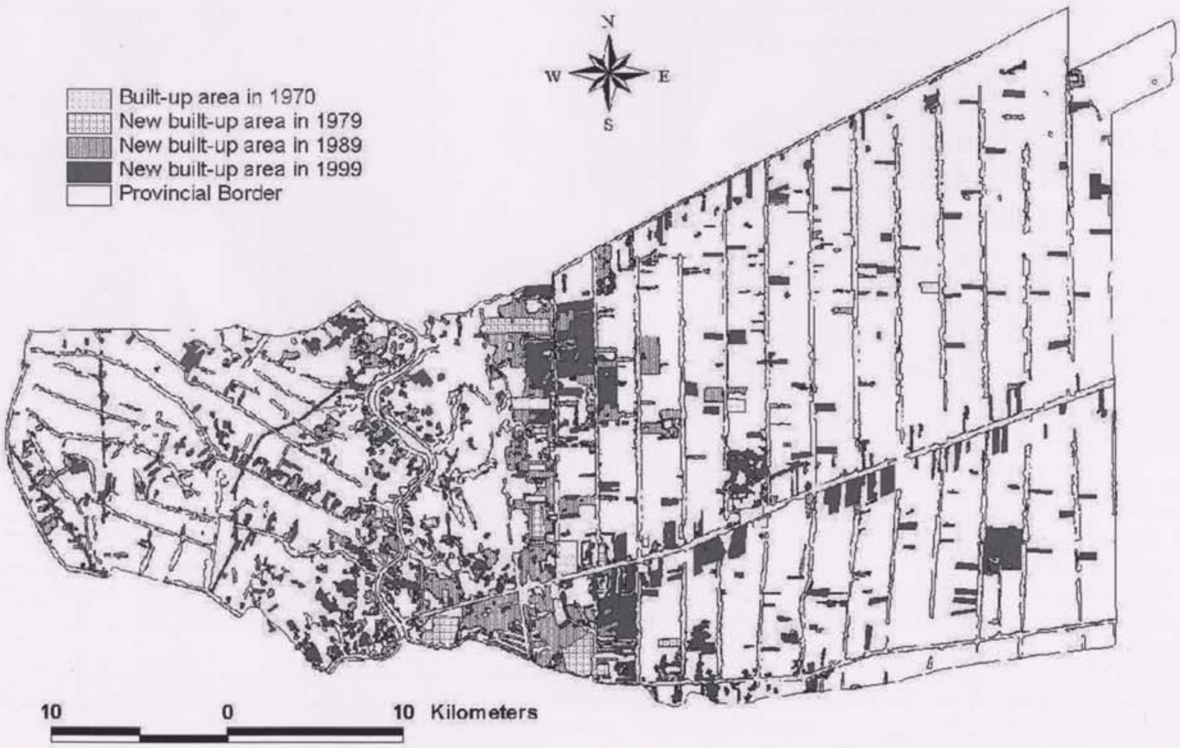
Infrastructure Information Dynamics Division

The roles of Infrastructure Information Dynamics Division are monitoring the natural environmental conditions and the soundness of existing structures, which can be considered to be important factors affecting the safety management of urban infrastructures, and to study the countermeasures when above conditions exceed the allowable threshold so that the loss or impact on society is minimized. At the same time, the research on how to properly decide these thresholds is also currently underway. As for the scale of the target system, this research is divided into the safety employment area of a structure unit and the safety reservation of the whole society. The former is mainly the monitoring using ground apparatus while the latter uses satellite technology, such as remote sensing as the main means of monitoring.

Assessment of Urban Development with Remote Sensing and Geographic Information System

Rapid urban development in Asian countries has provided a more comfortable life to the people of the region. However, it has also given rise to serious concerns including environmental degradation, unsustainable growth and safety. For example, in Japan, in recent years we have experienced cases of severe degradation. Falling of concrete blocks in tunnels or under highway bridges are examples of such degradation. Similar kind of problems may arise in the cities in Asia. One of the problems to assess sustainability and safety of urban infrastructure and to prevent them from urban disasters is the lack of data and information on urban development and urban structures.

The objective of the study is to investigate spatial data analysis methods for assessing sustainability and safety of Asian cities by combining remote sensing and geographic information system (GIS). An example below demonstrates the assessment of urban growth around Pathum Thani area near Bangkok, Thailand from satellite data. It shows the rapid expansion of built-up areas around Bangkok and indicates the changes in population, environment and other social factors. Spatial analysis with remote sensing and GIS enables us to measure spatial and temporal structures of urban areas, and further to integrate different characteristics including environment, disaster or socio-economic factors to assess urban sustainability and safety.

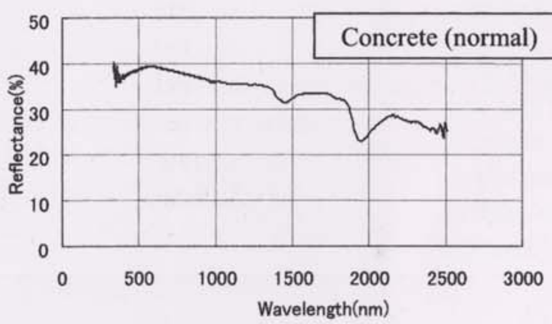


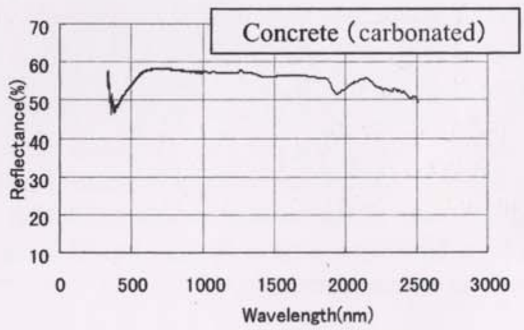
Urban Development in Pathum Thani area near Bangkok (1970-1999)

Assessment of Concrete Degradation with Hyper-spectral Measurement

Concrete is one of the basic materials supporting our life, and therefore its proper management is of high priority for the maintenance of urban infrastructure. As shown in the accidents where blocks of concrete block fell in tunnels or under bridges in Japan, degradation of artificial constructions is on the increase in most of urban areas, and therefore, it is important to develop an efficient inspection method for concrete degradation urgently.

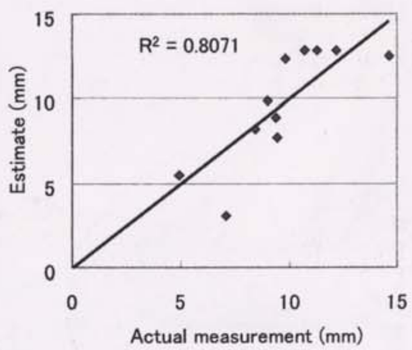
This study aims at the development of a nondestructive inspection method with hyper-spectral measurement to assess concrete degradation due to carbonation, chloride induced corrosion and sulfate degradation. The figures below illustrate the difference in spectral characteristics for normal concrete and concrete degraded due to carbonation. It can be seen that spectral signature is quite different in mid-infrared spectral range. Also the statistical analysis shows very high correlation between the spectral reflectance at specific wavelengths and the degradation depth of concrete, and the result indicates the possibility of concrete degradation assessment with hyper-spectral measurement. Hyper-spectral measurement is one of the most advanced remote sensing methods, and it may provide us with an efficient monitoring method of urban sustainability and safety over wide areas by use of automobiles, vehicles and satellites.





Upper: Spectral characteristics of normal and carbonated concrete. Spectral differences are clear at the two specific wavelengths.

Right: Comparison between the estimated and the observed carbonation depth.



Infrastructure Information Dynamics Division (II)

Urban Warming and Its Control Technique

1. Urbanization and urban warming

Rapid urban development has caused significant changes in urban climate which is peculiar phenomena in urban area represented by urban heat island. Thereby, it is recognized widely now that various environmental problems such as urban warming, regional air pollution and increase of ozone concentration, etc. are caused. Figure 1 shows the ground surface temperature of the Kanto district in the summer measured by artificial satellite (NOAA-AVHRR). High temperature region can be recognized in the urban area compared with suburban area. Figure 2 illustrates urbanization in Tokyo metropolitan area in the last one hundred years (Ojima 1991). Increase of air temperature during the same period is given in Figure 3. The radius in the Tokyo metropolitan area will be expanded to 50km from 5km in about 100 years, and the mean air temperature at a height of 1.5 m has been rising by about 2°C. Warming of large cities, such as Tokyo is advancing by several times the speed of the global warming.

2. Various control methods against urban warming

When the concentration of population and a function in urban area continues with the present condition and the urban warming advances, it is expected that the urban environmental aggravation becomes a serious problem. The various control methods are proposed against urban warming. For example, the reduction of artificial heat releases by the promotion of the energy saving system, the control of artificial heat releases to atmosphere using large-scale heat sinks such as river, underground and sea water, the improvement in the ventilation performance of the urban area by the suitable arrangement of building and the promotion of the evaporation from the earth surface by proper arrangement of permeable area such as green area, river and ponds, etc. Although the above control methods against urban warming are devised at present in every direction, it is very difficult for evaluating the effect of each method correctly since a host of factors are involved in urban climate intricately. Establishment of the synthetic environmental assessment, which includes the various factors based on the numerical analysis is required strongly.

1) T. Ojima, Changing Tokyo Metropolitan Area and its Heat Island Model, Energy and Buildings, 15, 191-203, 1991.

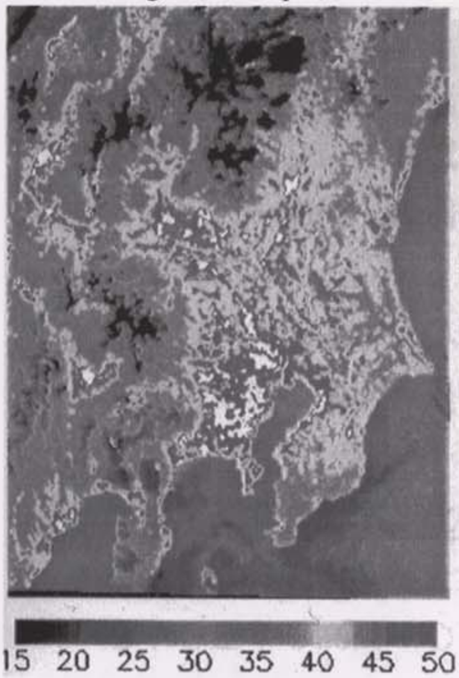


Figure 1. Ground surface temperature (NOAA-AVHRR)

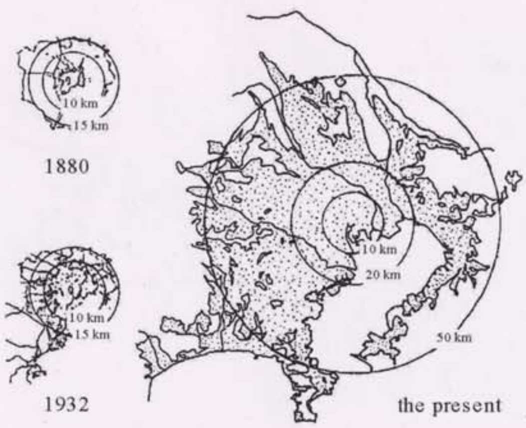


Figure 2. Progress of Urbanization in Tokyo (Ojima 1991)

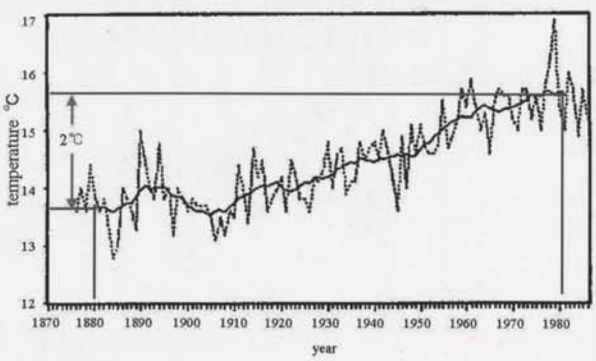


Figure 3. Increase of air temperature in Tokyo (at a height of 1.5 meter)

3. Prediction of urban warming using numerical climate model

a. Numerical climate model for a synthesis environmental assessment

It is expected that the environmental prediction technique based on the numerical climate model may become a useful tool from the viewpoint of synthetic environmental-assessment technology. The models based on the hydrostatic model, which has progressed for the prediction of local climate in the meteorological field are used in such a simulation, in many cases. These local climate models also involves the transportation equations of momentum, potential temperature, water vapor and mass and the radiation heat transfer formula. The model developed by Mellor and Yamada is a typical one.

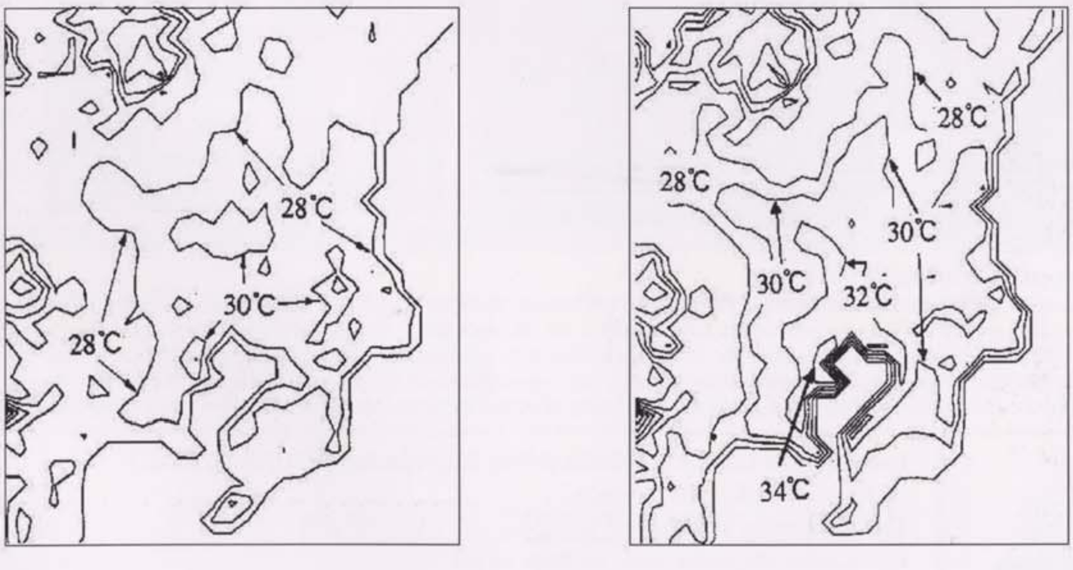
b. Effect of urbanization on climatic change in Tokyo metropolitan area-comparison between in the present and Edo era

Figure 4 shows distributions of ground surface temperature during Edo era (Tenpo period, 1830-1844) and recent period (1995). In the analysis for the present Tokyo, a maximum temperature (about 34°C) appears in a central part of Tokyo compared to the 30°C recorded in the 1830s. This result clearly reflects changes in the land use pattern, land covering accompanied by the present land use, artificial heat releases, etc. (Figure 4 (2)) and is in agreement with a past survey result generally. These results well explain urban warming accompanied by urbanization.

c. Future subject of comprehensive environmental-assessment technology

Numerical models incorporating the effects of geographical features have been successfully used to simulate the changes in climatic conditions over large areas. The studies have also been found useful in analysis of phenomenon of air pollution, etc.

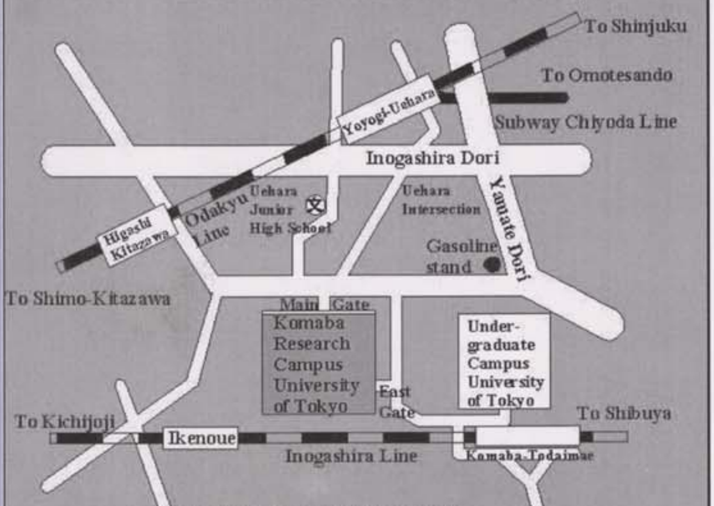
In order to analyze the urban climate phenomenon further in greater detail, it is important that nesting (or any other suitable technique) be used to incorporate the effect of the complicated flow and temperature fields in an urban canopy in the climatic model and a finer grid size (than the present 2km) is made possible.



(1) the Edo era (2) the present (1995)

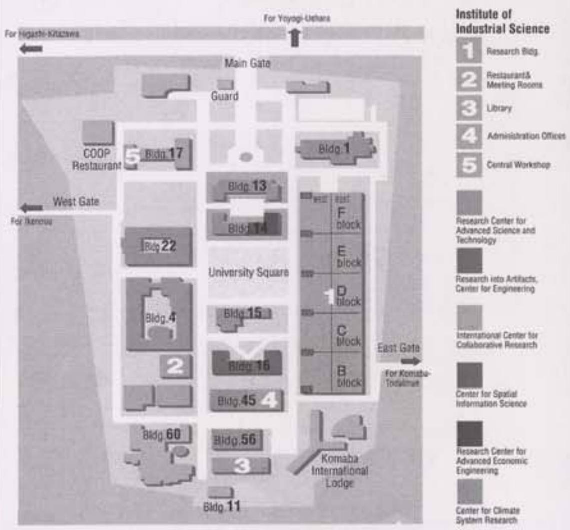
Figure 4 Distributions of ground surface temperature (3:00 p.m., in summer season)

Access to Komaba Research Campus



Walking distance to the Campus:
From Higashi-Kitazawa station (Odakyu Line): 7 min.
From Komaba-Todaimae station (Inogashira Line): 10 min.
From Ikenoue station (Inogashira Line): 10 min.
From Yoyogi-Uehara station (Odakyu Line/Chiyoda Line): 12 min.

Inside Map of Komaba Research Campus



Meaning of ICUS/INCEDE Logo:

Centralization of population in urban areas is increasing worldwide. In order to realize a safe urban environment for the inhabitants, proper preparation and maintenance of urban infrastructure are indispensable. The upper part of the Logo with rows of buildings represents the buildings and infrastructures for human activities in urban areas. The lower part means the earth environment underneath these facilities. With the combination of these parts, the Logo represents the objective of ICUS/INCEDE to develop tools and technologies for solving the problems for realization of safety of urban infrastructures from the viewpoint of earth environment.

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INSTITUTE OF INDUSTRIAL SCIENCE THE UNIVERSITY OF TOKYO

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