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Maintenance of Concrete Infrastructure - A New Challenge for Civil Engineers -

by
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Civil Engineers have been traditionally involved in design and construction of infrastructure - road networks, buildings, bridges, industries, or any other structure. Even as engineers have endeavored to develop innovative design methods, materials and construction techniques, a lot more needs to be done. Shown below are clippings from the local press expressing alarm at some of the deterioration observed in concrete structures. Also shown is a now well-known collapse of a section of the Hanshin expressway, after the Kobe earthquake of January 26, 1995. Such failures of engineered structures and the public outcry associated with that, only highlight the effort that still needs to be put in to create a safe environment.

Now, creating a safe urban environment needs,

- a better understanding of the forces of nature,
- building the structures in a manner that their performance remains satisfactory during the service life, and,
- methods to evaluate and strengthen existing structures in terms of their ability to withstand loads. Initiation of appropriate maintenance action is a necessary corollary to this.

Traditionally, a civil engineer is trained to deal with forces of nature in terms of structural loads and adopt appropriate tools for design and construction. A new dimension

Warning of safety problems of concrete structures in Japan (left) and failure of Hanshin Expressway due to Kobe Earthquake of 1995

- nondestructive testing and evaluation of existing structures, initiating appropriate maintenance action, understanding environmental conditions in terms of 'loads', and trying to better understand the performance of structures over the period of time, is being added to the responsibilities of a civil engineer.

Efforts are being made all over the world to train civil engineers for the new role, and given Japan's vulnerability to earthquakes,typhoons, etc. the issue has been taken up on war footing here. This article briefly discusses some of the actions being taken, citing examples in the area of concrete structures.

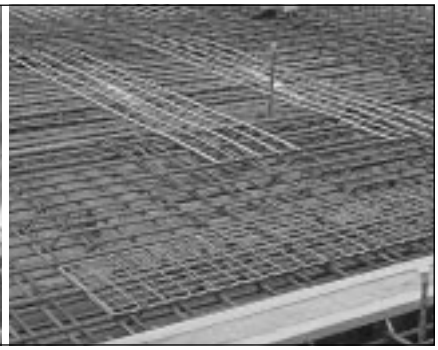
Developments in concrete engineering

Though concrete has been used in the last 50 years in various structures - bridges, tunnels, nuclear power plants, dams, roads, and of course buildings, better construction materials and techniques along with an improved understanding of its mechanical behavior, has only widened its applications as a construction material.

Use of *fibre-reinforced plastic materials*, as a possible replacement for steel reinforcement in cases where corrosion could not be allowed, or in external prestressing especially in the case of repair of deteriorated structures, is an example of use of alternative construction materials for specialized use. There have also been advances in the use of concrete reinforced with short discrete fibres when cracking in concrete needs to be controlled and to improve the post-cracking load-carrying capacity of concrete. Airport runways and tunnel linings are examples where *fibre-reinforced concrete* has been often successfully used.

High performance self-consolidating concrete is another development that has contributed to improve the quality of concrete construction, especially in areas where it would otherwise be extremely difficult to ensure adequate vibration and consolidation of concrete. Though use of such concretes is still less than 5%, it is increasing rapidly. The figure above shows an example of shotcreting using automated equipment, and utilization of FRP rods in conjunction with conventional reinforcement in a parking lot (where presence of steel reinforcement hampers the working of operating equipments).

Shotcreting using automated equipment

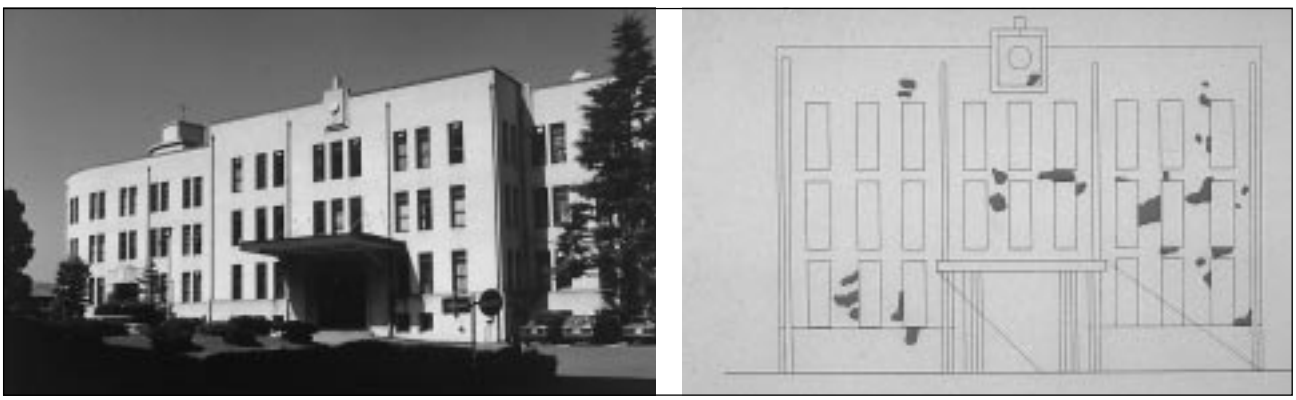


Use of FRP rods along with conventional steel reinforcement

Development in nondestructive testing and evaluation methods

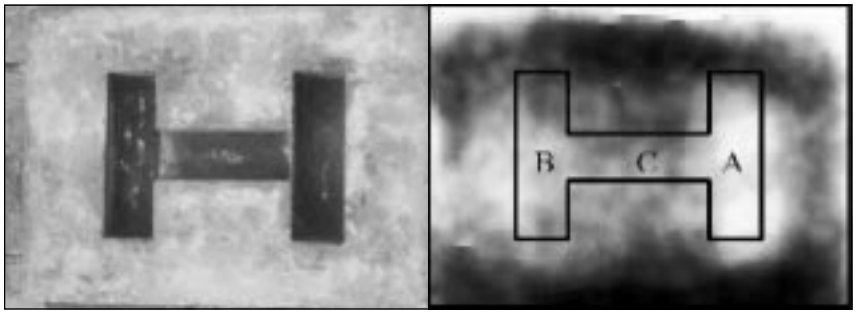
The construction of structures at any time reflects the state-of-art in design and construction at that time, and the construction during the 50s and 60s in Japan is no exception. These structures were built with only limited knowledge of the effect of different environmental conditions. Viewed in that light, it is not surprising that a lot of these structures have begun to show signs of deterioration. Efforts are being made to develop new techniques for an accurate assessment of the levels of deterioration, so that corrective steps, as may be required, can be initiated.

Given that concrete structures are often quite large, it is important to narrow down smaller areas, which could be used for 'representative' testing. Use of *infrared theremography* is emerging as a valuable tool in this area. An example of a photographic and thermographic images of a building is shown below. The presence of air pockets under the



Application of infrared thermography in non-destructive testing and evaluation of buildings

surface causes a difference in the heat absorption and conductivity characteristics of the concrete leading to a difference in the surface temperatures in portions with voids and delaminations, which is captured in a thermographic image. The technique can also be used to indentify areas that may have voids behind an apparently smooth concrete surface. The two figures in righthand side show examples where infrared theremography has been used to 'look' at an H-shaped void in a 150 mm thick concrete block. It may also be pointed out that in this study, the depth of the void (in the regions A, B and C, the thickness of the concrete behind the smooth surface), is varying, and that is also reflected in the varying 'clarity' with which the void is mapped.



Use of infrared thermography to detect voids hidden bihind smooth concrete surfaces

Development of repair and rehabilitation methods

Minor repair and maintenance action are often undertaken locally and with locally available materials and expertise. However, in addition to such minor actions, formal rehabilitation works are needed when it is desired to extend the service life or upgrade the performance level of the structure, or at the time of change in the (design) loading for the structure, or during post-event (e.g. earthquake) rehabilitation. In such cases, it is important that the following are carefully examined:

- extent of removal of concrete required (all loose concrete, or that contaminated with chlorides, etc., should be removed)
- need to provide additional reinforcement
- properties of the material to be used and method of repair
- compatibility of the repair material with the parent concrete
- behaviour of the repaired (composite) structural member under the action of loads

In the last about 15-20 years, several method have been developed largely on a 'trial and error' basis. From among those documented in literature, the following methods have perhaps been more commonly used:

- reinforcement with a steel plate
- reinforcement with continuous fibre-reinforced plastic sheets
- application of (cementitious or epoxy based) repair mortar or concrete by shotcreting
- jacketing the affected members or increasing the cross-section

The figures below show examples of using external prestressing cables as a means for strengthening beams in a bridge deck and an example of using flexible sheets made of continuous fibres woven in two directions around columns in several layers and applying binder material in much the same manner as making a rigid cast in the case of a plaster used by doctors during the period of allowing broken bones to repair!!

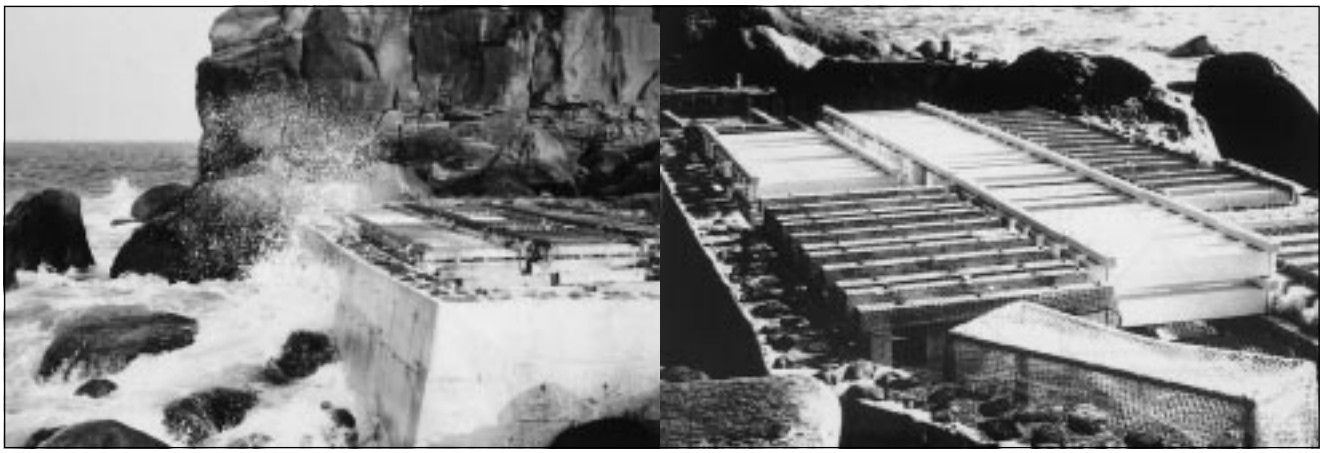
An extensive repair material evaluation programme involving more than 15 companies is presently in progress. The figure on the next page is a view of the exposure site where specimens prepared under varying conditions and using different materials are being tested to test the durability of repair materials.

Steps by professional bodies

The Japan Society of Civil Engineers and the Japan Concrete Institute are among the several professional bodies in Japan, that have taken steps in the recent past in response to the new responsibilities that civil engineers are being asked to shoulder - whether they work for construction companies, government and semi-government organization, or consulting organizations. Several publications brought out in the last ten years dealing with testing and use of new materials and techniques. This shows the importance being placed on development of specifications and standardization of use of new materials and methods.

Using external prestressing for strengthening structures

Jacketing of columns with continuous fibre sheets for strengthing structures



Two photographs of the Izu exposure site showing a bird's eye view and the specimens in place

Design of new structures

In the Standard Specification for Design and Construction of Concrete Structures (JSCE) presently in force, a performance based durability design approach has been adopted. Most standards in the world lay down limits for parameters, such as, the maximum flexural crack width, grade of concrete used and cover to the reinforcement, which are known to play a part in the susceptibility of a structure to future deterioration. However, the new approach suggested in the Japanese standards provides a framework to model deterioration processes in a manner that during the service life of the structure, a predetermined level of deterioration is not exceeded.

In other words, as recognition of the fact that concrete structures are not maintenance free, a certain amount of deterioration has been 'allowed'. Now, on the basis of quantitatively defined parameters, a certain critical level of (acceptable) deterioration has been fixed (A_{lim}). Thus, the designer is required to check that the extent of likely deterioration during the service life of the structure, A_d, (called 'designed deterioration', because, that is the amount or extent of deterioration, estimated to occur over the sevice-life at the time of design) does not exceed this critical level. Further, the extent of difference between the designed deterioration and the critical deterioration needs to be related to level of importance of the structure. In other words, it should be ensured that,

$$\gamma_i \frac{A_d}{A_{lim}} < 1.0$$

where, γ_i is a coefficient representing the importance of the structure. It may be taken to be 1.0 in most cases, but may be increased to 1.1 in case of important structures.

Efforts are now being made to publish some of the important standards in English, to enable non-Japanese speaking professionals better understand the thinking among Japanese designers, and promote a fruitful exchange of ideas. It is hoped that the volumes will be available for wider circulation by May 2003.

Introduction of professional examination

As mentioned above, an understanding of nondestructive testing and evaluation is fast becoming very important for practicing civil engineers. The work involves a knowledge of the deterioration mechanism operating in concrete under different conditions, awareness of the various tests available, and a clear understanding of the limitations associated with different tests. With a view to impart the required professionalism and promote awareness among the engineers, in 2001 the Japan Concrete Institute introduced an examination to 'qualify or license' engineers in the area. This exermination has been called the *'concrete shindan shi test'*. Interstingly the japanese *(kanji)* character used for *shindan* are the same as used in the term '*kenko* (health) *shindan* (chek up)!!'

In other words, the effort is directed to creating awareness towards the fact that,

(a) much like our health, concrete structures should be subject to a regular check up, so that any symptoms of deterioration, can be caught early and appropriately rectified, and,

(b) such examination and decisions for further action should be carried out by appropriately qualified personnel.

Concluding remarks

Repair and rehabilitation of concrete structures has become a multi-billion dollar industry in the world, and all out effort is required to ensure that not only new structures are designed and constructed with adequate care, even the existing structures are appropriately modified to be safe. Some of the steps taken in Japan in this direction have been briefly discussed here. However it is clear that closer cooperation between researchers and designers in the world would go a long way in a more effective utilization of the limited resources.

Editor's note: Readers may also refer to an extended version of this article at our website (http://icus-incede.iis.u-tokyo.ac.jp).

2nd ICUS/INCEDE Open Lecture

The second ICUS/INCEDE Open Lecture was held on January 24, 2002 at the Institute of Industrial Science of the University of Tokyo with major focus on issues to be considered in urban safety. It was attended about 100 participants from Tokyo and its neighboring cities.

There were four speakers in the lecture. Two of them were renowned Japanese technocrats; Dr. Tsuneo Katayama, the Director General of National Institute of Earth Science and Disaster Prevention and Prof. Shunji Murai of Keio University, both of them are also Professor Emeritus of the University of Tokyo. Other two speakers were Profs. T. Takahashi and M. Setojima, both are the visiting professors at ICUS/INCEDE.

Dr. Katayama presented a lecture on the purpose of earthquake disaster prevention research in Japan in which he elaborated the history of earthquake disaster prevention research in Japan and its expected future development.

In his talk, Prof. Murai presented a proposal to wealthy urban planning the role of space information technology. He covered various aspects of this proposal during the talked and emphasized that role of space information technology was important to estimate and realize the proposal.

Dr. M. Setojima spoke on evaluation of urban environment using remote sensing technology in which the importance of evaluation of landscape was emphasized and remote sensing technology was expected as a powerful tool for such evaluation.

Prof. T. Takahashi presented on administration for earthquake disaster prevention of Japan. He talked in detail the various countermeasure taken by Japanese Government towards disaster prevention.

The following two articles summarize the talks of Dr. Katayama and Prof. Murai in this lecture.

(R. Ooka)

Dr. T. Katayama (left) and Prof. S. Murai during their talks in the 2nd ICUS Open Lecture

Smallness Can Be a Culture

by Dr. Tsuneo Katayama

ICUS/INCEDE is small, and I know that the INCEDE part of it is even smaller. Encountered with such a difficult problem as disaster mitigation in developing nations, one often feels that it is almost impossible to single-handedly do anything significant.

Although almost six years have passed since I left INCEDE, I strongly remembered those days in which we worked so hard to internationally establish INCEDE. It is true that the work was hard because the organization was small. But don't be discouraged.

We saw very recently that a single individual can change the future of a nation. Aung San Suu Kyi, leader of the pro-democracy movement of Myanmar, has been released after a year and seven months under house arrest. It has already been 12 years since Suu Kyis National League for Democracy won the general election by a landslide in 1990, but the generals refused to cede power. Now neighboring countries clearly suggest that the only way for Myanmar to develop of its situation is to adopt democracy.

Smallness is undoubtedly one of the important attributes of the Japanese culture and I do believe that it is also one of the vital characteristics of ICUS/INCEDE.

You can do whatever you believe is right, because ICUS is small, and you can strongly show your identity, because you work in a small organization. Shortcomings can be made into strong points. Best wishes for the bright future of ICUS/INCEDE.

Safety vs. Disaster

by Prof. Shunji Murai

As a former professor of Intitute of Industrial Science, the University of Tokyo, first of all, I congratulate ICUS/INCEDE for a good start with the well organized team works.

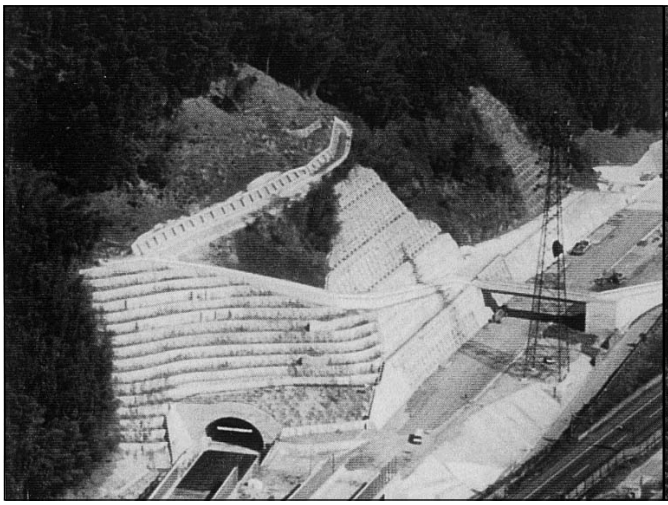
I would like to propose my viewpoints with respect to safety vs. disaster for the consideration of future direction. As different from the existing definition, I think that disaster will be a negative effect incurred before and after a natural phenomenon or a human activity. In other words, disaster is a negative change. Therefore in my view, if an urban planning and design was not done properly that resulted in traffic jam, ugly city landscape, dirty streets, etc., it is a disaster.

On the other hand, safety in my definition will be a positive effect to be guaranteed for future. Regardless of safety or danger in the current condition, it could become safety if one can guarantee the future. In spite of my view, safety is considered by many people to be in the condition of no danger. My thought is that it should be a positive promise. Therefore a safe city will be environmentally healthy, beautifully scenic, making people happy and comfortable, free from fear, etc.

As I deliver this lecture at ICUS workshop in January this year, most of the Japanese cities are a disaster with spider nets of electric poles and not a safety to me. The reclaimed coast, which replaced a beautiful beach, is a disaster and not a safety to me. I hope that the readers may understand my view points.

I wish all the best for ICUS and I am sure that ICUS is not a disaster but a safety to all. Lastly, I myself should be careful that I do not become a disaster but a safety.

The photographs presented below are kindly provied by the Green Bench Research Group-Chairman: Prof. Shunji Murai



February 1995: The construction with steep slopes was a disaster

April 1998: The slope was not yet safe in spite of the plantation of trees instead of grasses

September 1998: The slope was much improved with trees growing

August 1999: Green Bench Method certified how to change from disaster to safety condition

International Symposium on
NEW TECHNOLOGIES FOR URBAN SAFETY OF MEGA CITIES IN ASIA

This one-day symposium is being organized by the Center (ICUS) at the Grand Pacific Hotel, Bangkok, in collaboration with the Asian Institute of Technology (AIT), Thailand, on October 28, 2002. The objective is to create awareness towards issues related to urban safety engineering and disseminate information about use of latest techniques such as Remote Sensing, GIS, GPS and other computational tools, in creating databases and inventories of urban infrastructure. Additional information about the schedule, and other details will be available at the center website (http://icus-incede.iis.u-tokyo.ac.jp).

Tenth International Conference on Structural Faults and Repair

An International Conference on Structual Faults and Repair will be held in Commonwealth Institute Kensington, London, UK during July 1 - 3, 2003. It is organized by University of Edinburgh.

The main theme of this conference is extending the life of bridges, concrete, composites, buildings and civil structures. The deadline of the abstract (within 200 words) is August 31, 2002.

The adress for futher information is as follows. Prof. M. C. Forde, School of Civil and Environmental Engineering, University of Edinburgh, The King's Buildings, Edinburgh EH9 3JN, Scotland, UK FAX +44-131-452-8596, E-mail : m.c.forde@ed.ac.uk.

The Fifth International Conference on Urban Climate (ICUC-5)

The Fifth International Conference on Urban Climate (ICUC-5) is going to be held in Lodz, Poland during September 1 - 5, 2003. It is organized by the International Association for Urban Climate (IAUC) and the University of Lodz in co-operation with the World Meteorological Organization.

ICUC-5 is the continuation of a series of similar conferences starting in Kyoto, Japan in 1989, followed by those in Dakha, Bangladesh in 1993, Essen, Germany in 1996, and Sydney, Australia in 1999. The success of this series helped to create a cohesive international community of urban climatologists that led to the formation of the IAUC (http://www.geography.ohio-state.edu/UrbanClimate/) in 2000. ICUC-5 is the first conference to be organised by the new Association.

The aims of the conference remain as before, to provide an international forum where the world's urban climatologists can meet to showcase and discuss modern developments in research, and the application of climatic knowledge to the design of better cities. ICUC-5 wishes to cater to the interests of a diverse community of meteorologists, climatologists, hydrologists, ecologists, engineers, architects and planners and others interested in these topics.

The futher details of this conference information are available in web site http://www.geo.uni.lodz.pl/~icuc5.

The United Nations World Disaster Reduction Campaign
Disaster Reduction for Sustainable Mountain Development

As every year since the early nineties, the United Nations is organizing a World Disaster Reduction Campaign, which culminates on International Disaster Reduction Day, the second Wednesday of October,9 Octorber this year. The World Disaster Reduction Campaigns are organized by the Secretariat of the International Strategy for Disaster Reduction, located in Geneva, Switzerland.

The first aim of the 2002 World Disaster Reduction Campaign is therefore to increase globale awareness of successful disaster reduction efforts in mountain areas so that vulnerable mountain populations can benefit from already existing experiences. The second aim of the 2002 Campain is to raise awareness more generally on disaster reduction, so that past and new solutions in vulnerability and risk reduction can be explained and shared.

Visitors to ICUS

Some of the visitors to ICUS/INCEDE during Jan. - Mar. 2002;

** Prof. D. K. Paul, Department of Civil Engineering, Indian Institute of Technology (Feb. 19).*

** Dr. Pennung Warnitchai, School of Civil Engineering, Asian Institute of Technology, Thailand (Mar. 21-22)*

** Dr. Somnuk Tangtermsirikul, Sirindhorn International Institute of Technology, Thammasat University, Thailand (Mar. 21-22)*

** Dr. Marek Rebow, Institue of Heat Engineering, Warsaw University of Technology, Poland (Mar. 26)*

ACTIVITY RECORDS

During the period of January-March, 2002, ICUS staff have participanted in various international research activities including filed surveys, conferences and project meetings. Some of those are listed:

Prof. Yasuoka visited AIT to participate in a research meeting. (Mar. 21-23)

Prof. Meguro visited New York to study the on-going rehabiliation activities aftermath of the WTC disaster. (Feb. 24-Mar. 3)

Dr. Dutta visited Switzerland to attend the international conference on Flood Estimation in Bern. (Mar. 4-9)

Dr. Dutta also visited Thailand to participate in a field survey for flood modeling. (Mar. 13-17)

Editor's Note

As a research center, ICUS/INCEDE is involved in various research activities towards urban safety. The word safety has a broad meaning. There is no doubt that it is most important to protect a human life from natural disasters, such as earthquakes, floods, etc., which is dealt with in the conventional disaster-prevention engineering field. However, that is not enough to secure safety for a society. There are equally important other issues to be dealt with to attain that. For example, in recent years the global environmental problem has become a very serious issue. This problem has occurred because the human activities exceed the environmental capacity of the earth. This has caused many adversed effects, such as climate change on an earth scale, broader-scale air pollution, sea pollution, a change of ecosystem, exhaustion of natural resources and energy, etc. These phenomena are threatening the safety of human beings after all. The similar thing has occurred also in urban scale. In order to secure urban safety, we must pay attention not only to natural disasters but also to environmental and social problems widely.

ICUS/INCEDE has been developed and reorganized from INCEDE with the aim of carrying out intense research for tackling various issues towards urban safety covering such broad aspects.

As ICUS/INCEDE is a small research organization, it is impossible for it to tackle all these problems alone. However, We want to aim at such a large target. Moreover, in order to tackle such large research domains, cooperation of many people related with these problems is expected.

(R. Ooka)

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