Report on the conference of Taiwan bridges management and real time monitoring

A Brief History of Taiwan Bridges management and Real Time Monitoring:
From 921 Chi Chi Earthquake to 88 Typhoon

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1. Introduction

Following the fall of the bridge in Nanfangao in eastern Taiwan on September 30, the Ministry of Transportation in Taiwan asked the Chinese Institute of Civil and Hydraulic Engineering (hereinafter referred to as "CICHE") its accident survey and requested to hold a conference for local road managers to raise awareness on the current status and issues of bridge maintenance. On conferencing, CICHE made a request to the Japan Society of Civil Engineers (hereinafter referred to as "JSCE") to provide a topic on the current situation of disaster prevention and maintenance for bridges in Japan. To meet this requirement, I have participated in this conference. Originally JSCE has concluded agreements with overseas society of civil engineers as part of international exchange activities and regularly carries out technical exchanges, information exchanges, disaster surveys, etc.

Prior to the conference, I have made a courtesy call and a brief discussion on the Ministry of Transportation, the promoter of the conference, and the CECI, the largest construction consultant company, one of the sponsors of the conference.

This report will state on this matter.

2. Journey

(1) Thursday, November 14, 2019

- Departure Haneda Airport 9:20 Arrival Taipei Songshan Airport 12:40
- Visit place
  -CICHE 13: 30-13: 50
  -Ministry of Transportation 14: 00-15: 30 (under CICHE's conduct)
  -CECI 16: 00-17: 30 (under CICHE's conduct)
- Banquet: Ministry of Transport, CICHE, CICE, New Taipei City Government

(2) Friday, November 15, 2019

- Conference
  -Location 1101 International Conference Hall, Chang-Yung Fa Foundation
  -Hours 9: 00-17: 30
  -Organizer: CICHE
  -Sponsor Taiwan Construction Research Institute, National Taipei University of Technology, Taiwan Institute of Steel Construction, CICE, Sanlien Technology Corporation (hereinafter referred to as "Sanlien")
- Banquet: CICHE, CICE, Sanlien

(3) Saturday, November 16, 2019

- Departure Taipei Songshan Airport 13:30　Arrival Haneda Airport 17:30

3. Report on activities

(1) Courtesy visit and brief discussion

a) Ministry of Transportation

After greeting Mr. Ten, the director of highway motc., we exchanged opinions with a young engineer in a seminar room. The main contents are described below. (Figure-1)

- I have seen a video of working while holding on to the rope at high altitude inspection, but is it true?

→ Inspector have to check elements by close visual inspection. However, element at places where man lift or snooper cannot reach is inspected like this way. As pointed out, inspection way is not good for the safety and workability. So, now, we are considering the use of UAVs and inspection robots.

- How to respond to sudden events like the case of falling this bridge

→ It is not possible to give an appropriate answer because there is no information on the cause, but it is suggested that the behavior of the bridge be monitored by consistent observation, for example, monitoring, and that the system be equipped to notify abnormal behavior to a road manager as soon as possible. Now, we are trying to adopt such kind of system.

- Taiwan is close to the sea and is often damaged by salt. Do you have some comments to deal with this issue?

→ For concrete structures, increase the cover of the reinforcing bar than usual, and for steel structures, apply a coating that is superior in rust prevention and weather resistance.

After their questions, in turn, I asked that. “What kind of effort or attempt do you do for young engineers to be interested in the bridge as the Ministry of Transportation?”

There was no answer, however, I found that holding this conference itself was this answer.

In addition, as mentioned in the question above, they share the awareness of the crisis regarding the falling bridge, and Mr. Song, the next chairman of CICHE said that we have started real time monitoring of bridge using optical fiber and have achieved certain results and were ready for introducing information to them.

b) CECI

This company, the largest construction consultant company in Taiwan, founded in 1969, has been involved in the first highway, high-speed rail and subway systems. And its activities are not limited to Taiwan, but also extend overseas, such as Indonesia, Philippines, Hong Kong, etc. After the introduction of the company overview and business overview DVD in Japanese, the question-and-answer session was followed. The main contents are described below. (Figure-2)

- What is the motivation for the bridge management system using 3D images and the bridge disaster management platform system?

→ This is an action that images future social situations, especially infrastructure. The bridge management system is considered to be necessary from the point of increasing number of aging bridges. The platform system is an approach based on the belief that there are many natural disasters from geographical features in Taiwan and it is necessary to appropriately deal with them. Especially, it is important to provide detour information in case of emergency.

- It requires much information to develop this kind of system. You aren't an infra manager. So how do you obtain or collect data or information?

→ We recognize the importance of information and data. And we are a private consultant, but have much data such as, data of bridges designed in-house over the past 50 years (40% of bridges in Taiwan are designed by this company), data obtained through our own inspection business work, sensor company data, government open data, satellite data, etc. And now we want bridge condition data, so ask road managers to supply it.

- What kind of business model will you draw as a result of system development?

→ There is a lease contract system, but we are considering contracting the inspection business from road managers based on our system. And furthermore we will aim to extend this business to overseas.

c) Banquet

At a banquet, Prof. Wang, the current chairman of CICHE, and Mr. Chu, commissioner of New Taipei City Government Public Works Department, along with engineers mentioned before, showed me hospitality. Although the participants belong to each

organization, they all knew each other and exchanged opinions if they had the opportunity like this. Especially, Mr. Chu has participated even though the diet is sitting and very busy. It seems to me that he values this connection extremely and takes an interest in a rare guest from Japan. There were discussions on the importance of other infrastructure management such as sewerage after friendly self-introduction.

When asked about the status of the investigation regarding the accident, they stated that there was no information to tell because the investigation was in operation and that the site has been already cleaned up.

(2) Conference

a) Date and time

November 15, 2019, 9: 00-17: 30 (including breaks)

b) Number of participants

Approximately 300 (half are engineers and half are local administrators)

c) Topics

At the conference, the presentation materials and explanations were given in Taiwanese, so I could somehow understand the outline thanks to interpreter and by inference from Taiwanese character. (Figure-3, 4)

Prof. Liang-Jenq Leu [President of Taiwan Construction Research Institute]

Optimizing bridge design and applying machine learning for bridge management

- The effect can be confirmed by measuring the natural period before and after reinforcement.
- Introduction of the Golden Gate Bridge in San Francisco and the Brooklyn Bridge in New York, they have constructed such a wonderful bridge without any advanced tools that we use now. This was due to a sophisticated design and construction method under the growing socio-economic condition in the United States at that time, followed by proper maintenance. Even though environmental degradation, these wonderful bridges are still in use at present time with suitable and consistent maintenance.
- The application of AI has recently been used in traffic guidance, but has been delayed in civil engineering. It lags far behind the finance and telecommunications sectors.
- The machine learning in the use of AI by Random Forest tree modus operandi is possible to reduce the inspection cost. For example, a model is constructed based on the inspection data at two points (1992 and two years later in 1994), and the bridge condition in two years later (1996) is predicted. In this model, inspection

data is based on NBI (FHWA). Note that the accuracy of prediction depends on the data used in the model, and the accuracy can be improved by using a wider range of deterioration level (up to 9level), and as a result, the frequency of inspection can be reduced. This will lead to lower costs. This can be a support tool for human inspection work.

Prof. Yu-Chi Sung [National Taipei University of Technology]

Bridge health monitoring

- Necessity of measurement and monitoring is increasing by this fall bridge accident
- Sensors and its data without evaluation criteria are meaningless.
- It is necessary to look at bridges from the short-term and long-term perspectives, as with human health examinations.
- Setting of monitoring items according to the erection step for suspension bridges such as cable-stayed bridges and extra-dosed bridges
- Construction of model being modified or adjusted by loading test and its application for bridge maintenance
- The deterioration can be grasped by measuring the frequency of the cable over time for a long time.
- As a future goal, we will construct an automatic monitoring system, such as from detecting damage to informing it to us as soon as possible, and make use of it in disaster prevention.

Mr. Patrice Marc Pelletier [Deputy Chief Executive of OSMOS Group]

Mr. Lin [Sanlien Engineer]

Real Time Bridge Monitoring System

- Introduction of SHM of OSMOS France system, which is being implemented all over the world that could be applied to infrastructure in Taiwan near future

Prof. Han [National Taiwan University]

Current status and potential of UAV technology in bridge inspection

- By combining the characteristics of UAV technology, GNSS and shooting technology, it can be a more effective technology.
- Construction of 3D model is based on photo data from multiple directions by UAV. Inspection is possible without going to the site by using this model.
- In this model, using deterioration, defect and corrosion data from captured images
- Modeling (mapping) by laser scanning can have the data of coordinate of component, but such level of accuracy is not required for maintenance.
- UAV imaging is an excellent technology, but it remains some problems (1) the amount of light in taking images (2) the movable space in taking images and the

distance to the subject (3) acquisition of satellite radio waves (4) operation capabilities and licenses of the UAV.

Mr. Lin, Yew-Tsang [CICE Chief Engineer]

Development of bridge disaster management platform system and its application

- The goal is to link and use bridge condition data 28,000 bridges in Taiwan.
- Incorporates fault and ground information (boring data) into this system
- Using the InSAR analysis data, we can grasp the ground displacement (such as uplift) at any cross section.
- On this platform system, we use 47 types of information.
- Expectation for a decision-making tool to prepare a complex disasters (typhoon, serious rain, landslides, etc.)
- We want to respond to natural disasters and man-made disasters due to lack of engineer.

Mr. Ping-Hsun Huang [CICE Associate Vice President Civil Engineering Group]

Reinforcement of existing bridges to extend their life in Taiwan

- Summary of typhoon and earthquake damage
- Damage factor analysis by environment and human
- Geographical features, (1) Land area where humans can live is small and few plains. (2)High potential for damage. Rainfall, river gradient, soil grain size (3) Faults are distributed and active in various places.
- According to inspection manual, we are rated on numerical scale of 1 to 4 (with 4 being a severe condition). The item is consist of Degree of deterioration, Extend of deterioration, Relevancy to safe and Urgency.
- The problem of regular inspection, (1) Frequency is high (every two year), there are many items, the cost (2) Reliability Second-generation inspection problem such as the difference between this time and previous time
- Classification of bridge life cycle costs: initial cost, inspection cost, predictable cost, unpredictable cost (earthquake and typhoon), cost due to system / revision of law
- Cost reduction by preventive maintenance
- Reinforcement according to the revised seismic specification (concrete rolling, seismic distribution, seismic isolation)

e) My presentation

Presentation materials and explanations in English are translated into Taiwanese and introduced. Therefore, it took twice as much time, and as a result, about only half of the prepared materials were introduced. (Figure-5)

- Introduction

Environment and deterioration factors: Aging, Increased traffic volume for heavy vehicle, Increased spraying of deicing agents, Intrinsic salt, ASR and Potential problems in bridges designed based on old standards (insufficient PC grout)

- Body

Inspection: Type and purpose, Close visual inspection by law, Labor saving challenge
Monitoring: Role, application scenarios, and examples of monitoring
SMH: Overview, purpose, utilization of database

- Conclusion

The importance of process itself and maintenance cycle, the integration of human and ICT technologies and the role of skilled engineer

f) Conclusion and discussion

Chairman Dyi-Wei Chang [National Council of Structural Engineers Associations, R.O.C. (Taiwan) President]

Proposal of bridge safety maintenance business Scheme in Taiwan

- Introduction of natural disasters based on geographical conditions in Taiwan
- Earthquakes and typhoons are likely to land. The subsequent rainfall leads to a raging stream due to the steep river gradient, causing landslides and flooding of the river.
- There are natural disasters and man-made disasters.
- Preparing a White Paper on Natural Disasters after the 921 Chi Chi Earthquake: Committee consisting of scholars and local government officials
- Proposal of bridge safety policy: cost, securing human resources
- There is a commemorative ceremony such as opening ceremony and the beginning of crossing for the new bridge, but there is no such memorable ceremony for reinforcement. More attention is needed.
- Introduction of bridge disasters and accidents: examples of other countries
- The ground is loosened after the earthquake, and landslides are likely to occur. Problem of compound disaster (earthquake, rain, landslide)
- Fatigue problem
- The timing of alarm generation (threshold setting) is very important in the case of the Shinkansen earthquake notification system in Japan.

After the above explanation, all the presenters came on stage, and a whole discussion including all participant on the venue was held under the chairman of Chang.

- Please tell us about the inspection modus operandi of underwater structures.

→ At present, the technology is not yet sufficiently developed and is under development and trial.

- How do you check the condition of cables?

→ It is based on close visual inspection. At this inspection, we have to survey the vicinity of the fixing device not only cable itself. Also, confirm that the cable tension is not loosened by the tapping sound.

- The run of illegal heavy vehicle may be considered as a factor of this fall bridge. On the other hand, we have a case that a road manager permits the heavy vehicle over design load run. How do you think this situation? And how much heavy vehicle can run on road?

→ In Japan, by 25tf heavy vehicle can run without permission. Considering the effect on the bridge, there is no problem if vehicle runs based on permitted conditions. But, it is a problem if the vehicles run daily without any restrictions.

g) Technical exhibition

A technical exhibition was held in the break room, the same floor as the conference hall.

CECI

There was a panel that supplemented the bridge disaster platform system described at the conference. There was an introduction of a system that periodically measures ground displacement using InSAR technology and predicts damage to infrastructure due to typhoons and serious rain.

Sanlien

Along with the monitoring system using optical fiber that was explained at the conference, there was an introduction of bridge displacement monitoring using an accelerometer. The accelerometer uses the technology of a Japanese precision machine maker (SEIKO EPSON), and there were also explanations from engineers from Japan.

4. Finally

The 921 serious earthquake in the title is a magnitude 7. 7 earthquake that occurred near the Chichi Township in Nantou County in central Taiwan on September 21, 1999, with about 2,400 people died and missing, and about 15, 000 houses completely or semi-destructed. The damage to buildings, roads, etc., as well as sediment-related disasters, was severe. The typhoon 88 landed and crossed Taiwan on August 7 due to typhoon MORAKOT (No. 8) that occurred on August 3, 2009, and passed Taiwan on August 8. The typhoon caused serious rainfall for three days, almost equivalent to the world record, and caused landslides and flood disasters mainly in the central and southern part. Investigation teams have been dispatched from Japanese academic societies to introduce this disaster. In Taiwan, various measures have been taken to raise awareness about disaster prevention. On the other hand, although the investigation of this bridge

accident is currently in operation, it seems to be different from the previous two factors. This issue is very close to what Japan is currently working on.

During this business trip, the most interesting issue is the development of the bridge disaster management platform system consolidating various kinds of data for support infra managers to make a decision in emergency. And this work is implemented by not an infra manager but a private consultant company from collecting necessary data to designing system. This is an amazing entrepreneurship.

In addition, although the schedule was very severe, I could see streets, towns, buildings and structures through the window on my way to destinations by car. This precious experience widens my knowledge as well as participation in conference. (Figure-6, 7)

Finally, I appreciate for Ministry of Transportation, CICHE and JSCE to give precious opportunity to participate this conference and to get to know many distinguished Taiwanese engineers. This Report ends with acknowledgment.

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