CHULALONGKORN UNIVERSITY

Summary Report

Thailand

Verification Survey with the Private Sector for Disseminating Japanese Technologies for Improving Bridge Maintenance with Concrete Crack Measurement System

January 2018

Japan International Cooperation Agency

KUMONOS Corporation

1. BACKGROUND

Thailand is one of the most developed countries in the ASEAN region. In Thailand, infrastructures have been intensively constructed since the 1980's, and the government still focuses on new constructions. On the other hand, the existing infrastructures have been gradually aged and increased, and it is concerned that maintenance works for the existing structures are insufficient due to fiscal limitations.

Under such circumstances, the "Bridge Maintenance Management System (BMMS) was established by Department of Highways (DOH) in collaboration with Kasetstart University in 2012, which is expected to give more reliable explanations to the government when a budget request for road and bridge maintenance with continuous updates.

For more efficient and effective operation of the system and bridge maintenance, accuracy of inspection result is one of critical factors to understand the soundness of structures and to determine necessary rehabilitation and budgetary plans. However the precision of inspection results for bridge inspection is still low in Thailand since the damage is inspected by direct visual check and hand sketch / photographs. Moreover it is necessary to make policy and budget makers aware of the importance of maintenance since bridge inspections have not conducted sufficiently and properly due to the lack of budget.

It is concerned in Thailand that the lack of proper maintenance may result in critical social problems such as increase of traffic accidents and economic loss like Japan and the USA. Therefore the effort toward implementation of "Preventive Maintenance" is one of key subjects for appropriate bridge management in Thailand.

2. OUTLINE OF THE PILOT SURVEY FOR DISSEMINATING SME'S TECHNOLOGIES

(1) Purpose

The purpose of this Survey is to prove that the remote crack inspection system of "KUMONOS" is applicable, useful and can contribute to execute appropriate infrastructure asset management in Thailand.

The expected effects are as follows:

- To enhance the technical level of bridge inspection;
- To improve the existing method of bridge maintenance;
- To increase awareness on the importance of appropriate infrastructure asset management among the concerned parties.

(2) Activities

Activity1: Infrastructure and Crack Inspection using KUMONOS

- Six bridges were inspected using KUMONOS by Thai engineers together with Japanese experts. The knowledge and know-how were basically transferred to Thai engineers through the lectures and on the job training. Prior site survey was executed to select appropriate six bridges for the Pilot Survey (for the duration between November 2016 and March 2017).
- Two inspection teams were formulated for the Pilot Survey and consisted of Japanese trainers and Thai engineers.
- The inspection was executed at three different times in Bangkok area and/or rural area. Each inspection has been completed within 2 weeks.

Activity2: Verification of Bridge Maintenance and Management System utilizing KUMONOS

- The inspection results have been saved in the database of the current Bridge Maintenance and Management System (BMMS) in DOH for further updates of the system and future monitoring and analysis of cracks and other defects.
- Preliminary rehabilitation plan and deterioration prediction of main girder have been prepared based on the obtained crack information during the Pilot Survey.

Activity3: Evaluation of KUMONOS in Bridge Maintenance and Management in Thailand

- The usefulness of KUMONOS in bridge maintenance in Thailand has been assessed in the evaluation meeting on 16th October 2017, which was composed of Chulalongnkorn University (CU) personnel, Burapha University (BU) personnel and DOH personnel.

Activity4: Dissemination of KUMONOS

1) Seminars for personnel related to infrastructure maintenance and management

- In order to encourage the involved engineers/personnel on bridge maintenance in Thailand to recognize the importance of accurate deterioration identification and prediction in infrastructure asset management as well as the advantages of KUMONOS, the technical seminars were held on 30th May and 7th November 2017.

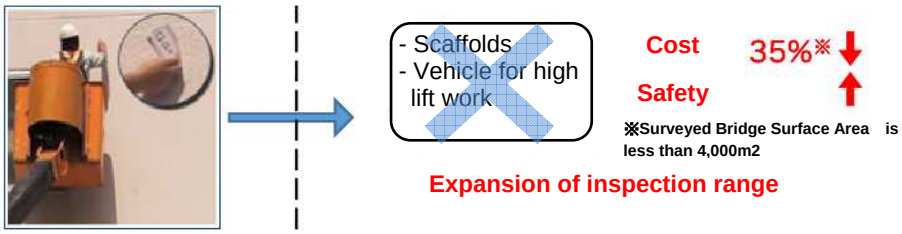
2) Seminars for Professors of Technical Colleges

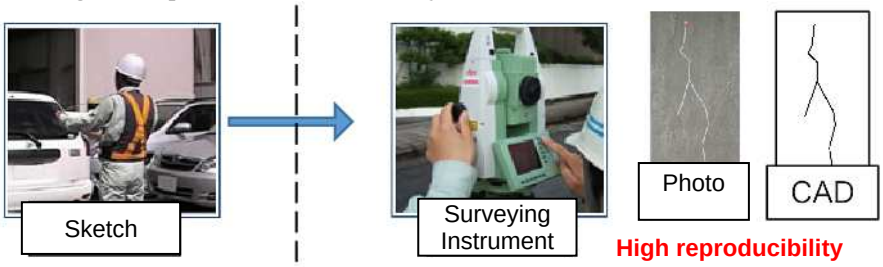
- Educational seminars were held to share the experience in Japan as well as practical knowledge and skills on KUMONOS to professors of technical colleges in Thailand.
- The colleges are then expected to raise engineers who can use KUMONOS on site.

Activity5: Technical Support for Establishment of KUMONOS Guidelines

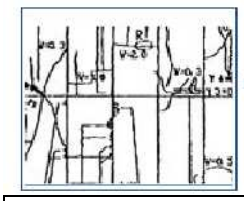
- Technical support was provided to Suranaree Technical College and Bureau of Vocational Education for establishing a teaching guideline and program of KUMONOS.

(3) Information of Product/ Technology to be Provided

<table>
<tr><td>Product Name</td><td>Concrete Crack Measurement System ”KUMONOS”</td></tr>
<tr><td>Components</td><td>・Total Station（measuring distance and angle）
・Built-in crack scale
・Analysis software</td></tr>
<tr><td>Features</td><td>① Noncontact measurement from
0.4 mm of crack width can be measured at 100 meters away without scaffolds.
＜Measurable crack width due to distance＞
<table>
<tr><td>Distance (m)</td><td>1.5</td><td>5</td><td>10</td><td>20</td><td>50</td><td>100</td></tr>
<tr><td>Measurable width (mm)</td><td>0.01</td><td>0.02</td><td>0.04</td><td>0.09</td><td>0.22</td><td>0.44</td></tr>
</table>
② Accurate crack inspection by surveying instrument
Cracks width, shape, and location (3D coordinates) can be accurately measured / obtained from distant locations by surveying instruments with a built-in crack scale and a high magnification of telescope (x42).
③ Quantitative monitoring of crack growth
Crack growth can be quantitatively monitored from the results of periodical inspections since the 3D coordinates of cracks can be obtained and stored by the KUMONOS.
④ Compensation of collimation angle
By the KUMONOS, the collimation angle can be automatically compensated and the accurate crack width can be obtained.
⑤ Automatic plotting of inspection results
The KUMONOS office software automatically converts the acquired measurement data (3D coordinates, width and shape) to the Auto CAD data and creates the plotted drawings.</td></tr>
<tr><td>Advantages</td><td>【Comparison with the direct visual inspection】
Advantage 1：Unnecessity of direct visual inspection
 

・More efficient inspection is possible since vehicles for high lift work and scaffolds are unnecessary as the direct visual inspection
・Safety during inspection works can be improved since works at high place is unnecessary.
・KUMONOS is applicable to the inaccessible structures located on busy streets, rivers etc.
Advantage 2：Improvement of the accuracy
 

・Variations in inspection results due by the sketching can be avoided by application of the KUMONOS.
・The accuracy of inspection results is highly improved since the crack location and shape can be obtained in 3D coordinates.</td></tr>
</table>

Advantages	**Advantage 3：Improvement of work efficiency**  Analog Data ⇒Digitization 30%※ Shortening of the inspection period ※Surveyed Bridge Surface Area is less than 4,000m2 ・The step for producing digital data from manuscript sketches is unnecessary and this can achieve about 30 % of inspection . **【Comparison with crack measuring method by digital camera】** **Advantage 1：Low load in analysis of measurement results** High Resolution Photographs High load Mass data storage Small data size ※Maximum data size ; 10kByte / file + Automatic analysis and creation of CAD drawings by dedicated software ・Data processing is fast due to small data size ・Inspection results can be checked on site though automatic plot by KUMONOS and oversights can be avoided. **Advantage 2：High measurement accuracy** Unclear outlines on photographs Measurement errors due to unclear outlines High accuracy ・Measurement results are quite reliable since crack width is measured by overlapping crack gauge on cracks through telescope. ・Measurable crack width is smaller than the conventional measurement method by digital camera. **Advantage 3：Measurement from an oblique angle** ※Photography from the front is necessary Severe applicable conditions Automatic compensation of collimation angle ※Crack width is accurately measured from the angle and/or distance between surveying instrument and cracks Measurement from an oblique angle is possible ・Crack width can be accurately measured even from an oblique angle since collimation angle is automatically compensated in the KUMONOS.
Sales	Sales : 145 units / Inspection services : more than 1,000 sites in Japan Sales : 22 units / Inspection services : 6 sites (inc. demonstration) in other countries
Size	Size（H×W×L）：34.5cm×22.6cm×20.3cm、Weight：5.8 kg
Installation location	The KUMONOS system is portable and unnecessary to be left on the site.
Transported instruments	6 units

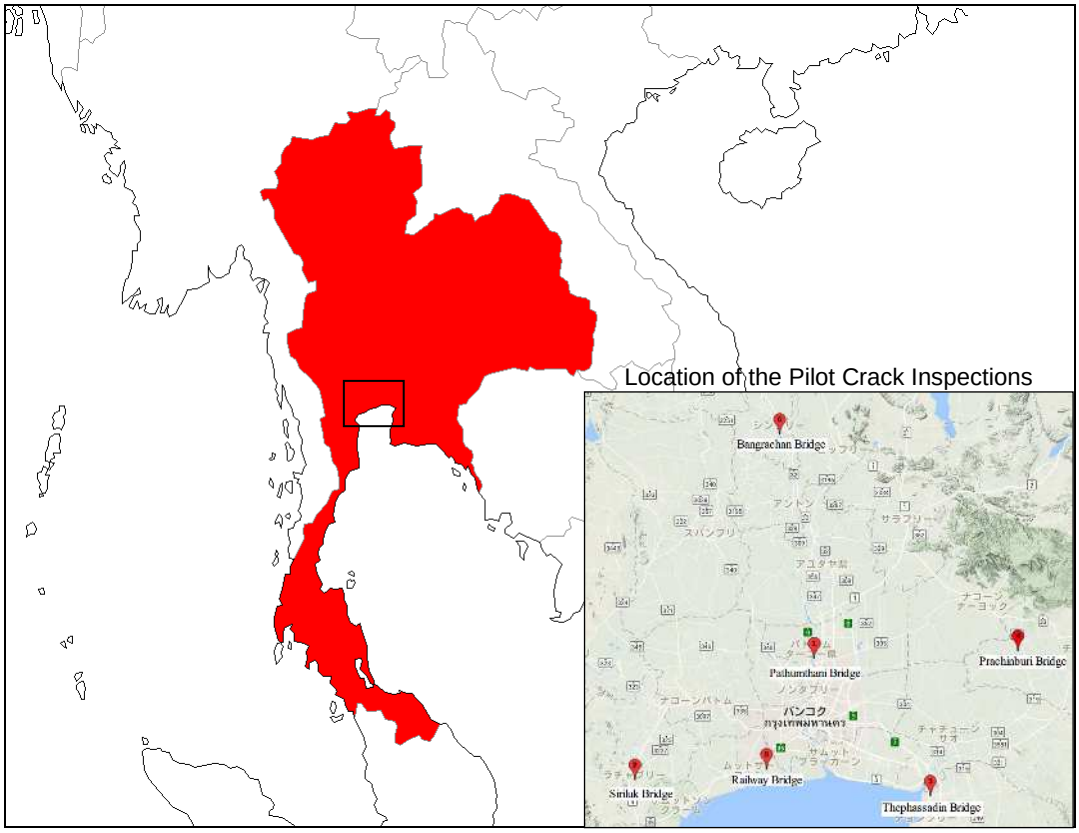
(4) Counterpart Organization

Chulalongkorn University (Counterpart Organization)

Bureau of Bridge Construction, Department of Highways (Supporting Organization)

(5) Target Area and Beneficiaries

Target Area: Bangkok area, rural area far from Bangkok as shown in the below figure.



Source: http://www.craftmap.box-i.net/ and Google Map

Figure. 1 Target Area and Location of Pilot Inspections

Beneficiaries: Parties related to operation, maintenance and management of road bridges in Thailand (government agencies, local private enterprises, and local university/research institutes)

(6) Duration

One year six months from September 2016 to February 2018.

(7) Progress Schedule

Table. 1 Survey Progress Schedule

Survey Item	2016				2017												2018	
	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
1. Implementation Plan & Data Collection																		
2. Pilot Crack Inspection																		
2-1 Preparations																		
2-2 Procurement of Survey Equipment																		
2-3 Pilot Crack Inspection																		
3. Verification of Bridge Maintenance																		
3-1 Input Pilot Survey Data to the Existing BMMS																		
3-2 Simulatin by Survey Data																		
3-3 Analysis, Evaluation																		
4. Promotion of KUMONOS																		
4-1 Technical Seminar																		
4-2 Lecture at Technical College																		
4-3 Support on Establishment of Guidelines																		
5. Business Plan for KUMONOS																		
5-1 Market Research																		
5-2 Business Matching with Local Companies																		
5-3 Preparation of Business Implementation Plan																		

Thailand (Plan) Thailand (Actual)
Japan (Plan) Japan (Actual)

Source: JICA Survey Team

(8) Manning Schedule

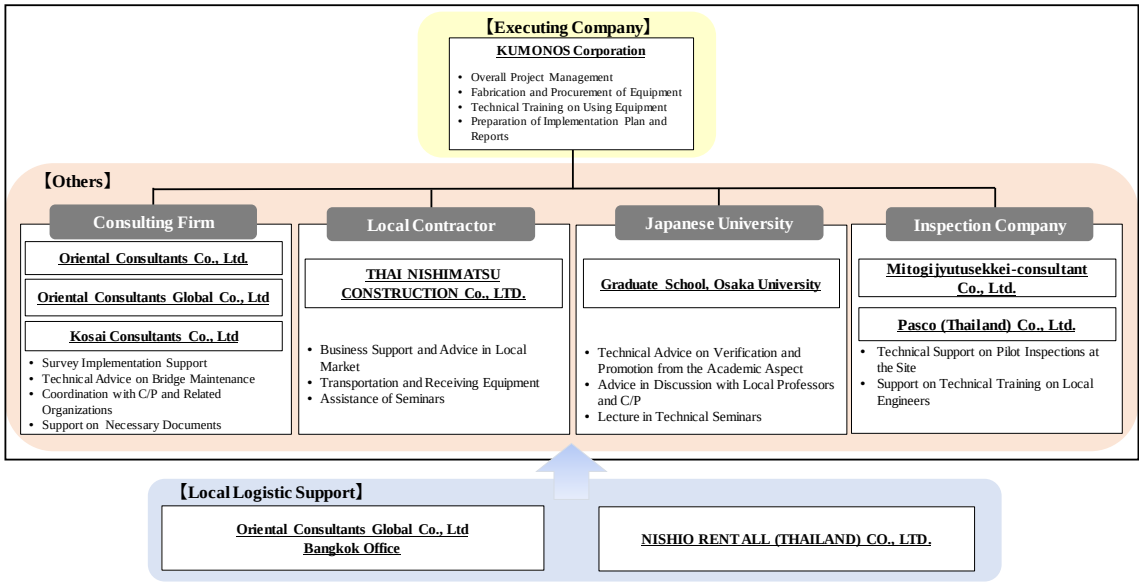
Position	Name	Organization	Item	2016 Sep	2016 Oct	2016 Nov	2016 Dec	2017 Jan	2017 Feb	2017 Mar	2017 Apr	2017 May	2017 Jun	2017 Jul	2017 Aug	2017 Sep	2017 Oct	2017 Nov	2017 Dec	2018 Jan	2018 Feb	Total(days) Oversea	Total(days) Domestic	Total man-month Oversea	Total man-month Domestic
Team Leader	Kazuhide Nakaniwa	KUMONOS Corporation	Plan	1 7		7 1	1		1		1		1 9 1				2 10		2			33	12	1.10	0.60
			Actual	1 6		1			1 4		1	1	1 4 3		1	1	1	1 3 2	3 1	1		26	15	0.87	0.75
Technical Adviser	Seiji Fujita	KUMONOS Corporation	Plan	1		7 1	1		1 6		1		1	1			1 4		2			22	10	0.73	0.50
			Actual	1	1 7			1	1 2	2 1	1	1 3	3		1	1		1 3 2				26	27	0.87	1.35
Deputy Team Leader/Senior Technical Trainer1	Makoto Narukawa	KUMONOS Corporation	Plan	3 7	6 18 2	7 2		2	3 21	3 10 5		5 27 4		3 28 1		3 20 2		3 4				142	52	4.73	2.60
			Actual	3 8	3	11 3		1 4 1 1 7 2		2 2	3 1 1	1	3 2	2 4		1 2 7 1		1	10 2 10 2	1		74	33	2.47	1.65
Senior Technical Trainer2	Akihiko Miyamoto	KUMONOS Corporation	Plan			1 7 1			4 25	2 10 2		3 21	2	3 21	1							84	23	2.80	1.15
			Actual		3	1 7			1 6	2 13 3		3 17 3	14 2	14	2	6		3 2 7 2				83	30	2.77	1.50
Coordinator	Daisuke Nishi	KUMONOS Corporation	Plan	3 7	3	3 7 1	3	5	3 7	5 10 5		5 9 4			5	5 14 5		10				54	65	1.80	3.25
			Actual	3 10 5	16	3 7 11	13	14 4 5	11 8	13	5 5 5	13	7 15	10	7 7	10	3 10 7 8	11	5 3			74	187	2.47	9.35
Dissemination Activities	Natsuki Nakagawa	KUMONOS Corporation	Plan	3 7	3	3 7 1	7 3		2	5 10 3		4 9 5			5	5 14 5		8				54	55	1.80	2.75
			Actual	4 10 5	14	3 7 11	5	8	11 7	7 7 3	7	13	7 15	8	5	1	2 5	7	5 3	4		56	133	1.87	6.65
Technical Trainer	Yusuke Nagase	KUMONOS Corporation	Plan																			0	0	0.00	0.00
			Actual									1 15	2 13 2	12	4							40	9	1.33	0.45
Chief Adviser	Hidetoshi Nakano	Oriental Consultants	Plan	3 7			7 3		2			2	1	7	3		9	5	3 4			34	23	1.13	1.15
			Actual	3 5 1				3 3	3 2				2	3 6		1	2 8 2 4	4	2			33	23.7	1.10	1.18
Senior Adviser	Yingyongrattanakul Narentorn	Oriental Consultants Global	Plan			7			7			6				2	5					25	5	0.83	0.25
			Actual			7						8					2 10		6			33	0	1.10	0.00
Bridge Maintenance	Yusuke Suzuki	Oriental Consultants Global	Plan			5 6			5 22 2			3 26 2		3 23 2	5		6	8				75	42	2.50	2.10
			Actual						2 3				3				2 13.5		2.5			7	23	0.23	1.15
Bridge Maintenance2	Yasuhisa Suganuma	Oriental Consultants Global	Plan																			0	0	0.00	0.00
			Actual								6	1.5 14	13 8	12 6		5						45	20.5	1.50	1.03
		Kosai Consultants	Plan																			0	0	0.00	0.00
			Actual															4	9			0	13	0.00	0.65
Domestic Adviser	Nobuyoshi Yabuki	Graduate School, Osaka University	Plan	1		4		1	1		1	2 4			2		10	1				18	9	0.60	0.45
			Actual						1 4 1	1	1 3	4 1			1		3 4 1					12	13	0.40	0.65
Local Adviser / Coordinator	Toyoshige Furusono	THAI NISHIMATSU CONSTRUCTION	Plan																			0	0	0.00	0.00
			Actual																			0	0	0.00	0.00
Local Adviser / Coordinator2	Yuji Maruoka	THAI NISHIMATSU CONSTRUCTION	Plan	5			5	5	20		5	20		20		10		4				0	94	0.00	4.70
			Actual	5	1	4 1.5		2	4	1.5	6	13	13	11	11	3	9	7	2			0	94	0.00	4.70
Senior Technical Trainer3	Shinichi Yamada	Mitogijyutusekkei-Consultant	Plan						21				19		19							59	0	1.97	0.00
			Actual									2.5	17 2	13 3	12	2.5		2				44	10	1.47	0.50
Senior Technical Trainer4	Kritsada Pethsen	PASCO(Thailand)	Plan						24				20		20							64	0	2.13	0.00
			Actual									17	10	5	14							10	36	0.33	1.80
KUMONOS Corporation, Man・Month Total(Plan)																								12.97	10.85
KUMONOS Corporation, Man・Month Total(Actual)																								12.63	21.70
Others, Man・Month Total(Plan)																								9.17	8.65
Others, Man・Month Total(Actual)																								6.13	11.66
Total Man・Month(Plan)																								22.13	19.50
Total Man・Month(Actual)																								18.77	33.36

Oversea　Domestic

Source: JICA Survey Team

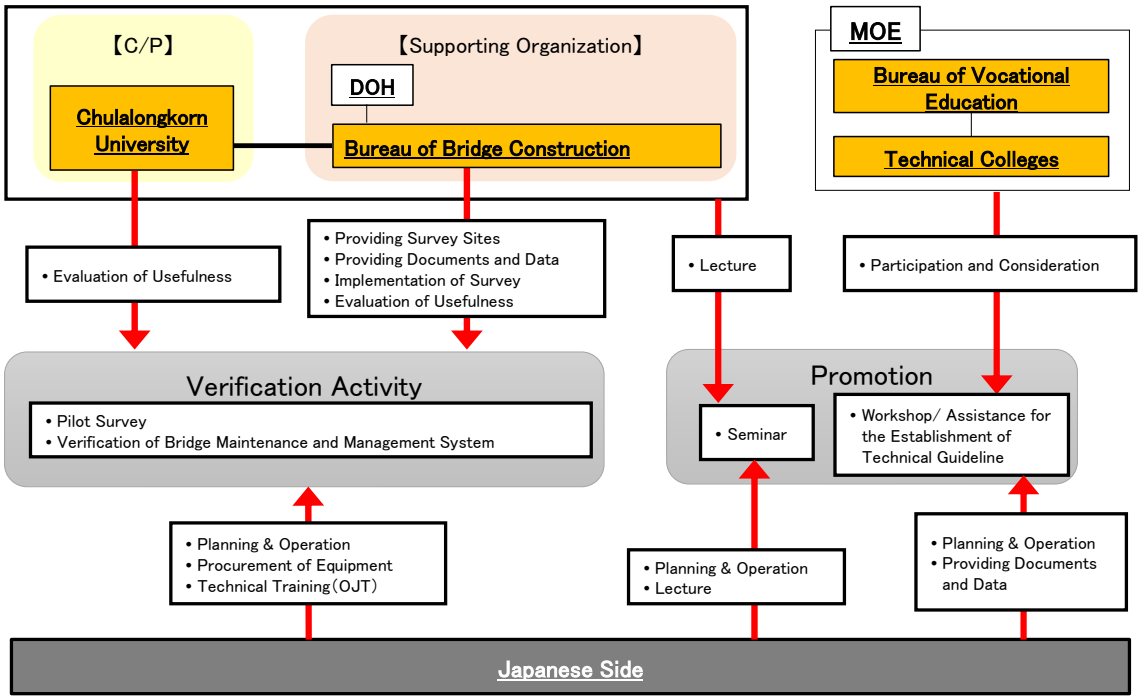
Figure. 2 Manning Schedule

(9) Implementation System



Source: JICA Survey Team

Figure. 3 Survey Implementation Organization (Japan Side)



Source: JICA Survey Team

Figure. 4 Survey Implementation Organization (Thai Side)

3. ACHIEVEMENT OF THE SURVEY

(1) Outputs and Outcomes of the Survey

i. Outputs of the pilot survey

Six bridges for the pilot survey have been selected out of 25 bridges nominated by DOH, based on the prior site survey which was executed in the duration between November 2016 and March 2017. Prior to the pilot survey, the technical training was conducted for CU students and DOH engineers separately.

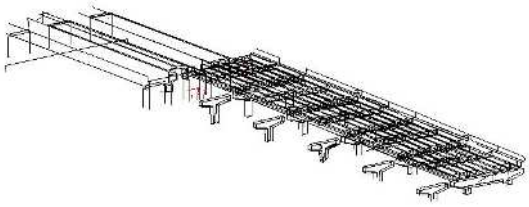
Table.2 List of target bridges

No	Name of bridge	Province	Survey duration
1	Pathumthani Bridge	Pathumthani	May 24 to June 9, 2017
2	Siriluk Bridge	Ratchaburi	May 24 to June 9, 2017
3	Bang Pakong Bridge	Chachengsao	June 28 to July 7, 2017
4	Prachinburi Bridge	Prachinburi	June 28 to July 7, 2017
5	Railway Bridge	Samutsakorn	August 1 to 11, 2017
6	Bangrachan Bridge	Singburi	August 1 to 11, 2017

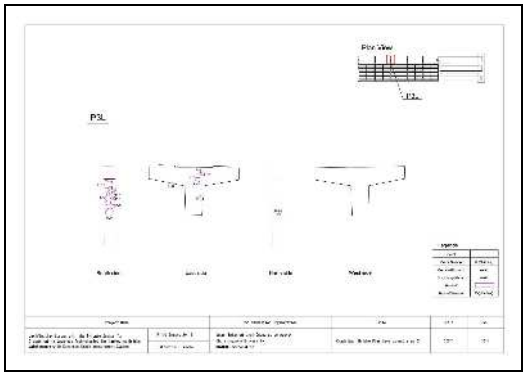
Source: JICA Survey Team

The pilot survey of six bridges listed above was carried out by two joint teams of Thai and Japanese engineers on May, June and August 2017. These bridges were constructed in different years, and so, different stages of degradation have been surveyed. In case of Pathumtani Bridge, 3D laser scanning was also carried out. The pilot survey with KUMONOS has demonstrated accurate measurement of cracks including those which the present methods are not able to capture. Advantage of KUMONOS which works from a distance has been evidentially displayed. It has showed a great contrast with the classical survey carried out from an elevating work platform or scaffoldings, which was often hampered by electric cables closely extended along the bridge.

KUMONOS survey data has been saved in the database of the present BMMS as attached files, in the form of drawings in DWG format, PDF data of 2D and 3D drawings, and a crack list. KUMONOS data saved in BMMS would be useful for future analysis of degradation by comparing it with then inspection results of the bridge. Nevertheless, KUMONOS would be utilized in much better way to select a remedy measure, prepare a cost estimate and prioritize measures to be taken, if the present BMMS adapts necessary modification. In cooperation with CU, DOH and IMMS which are very positive to improve the present system, necessary changes with adequate crack parameters and analysis method will be proposed.



[3D drawing]



[Drawing of a pier]

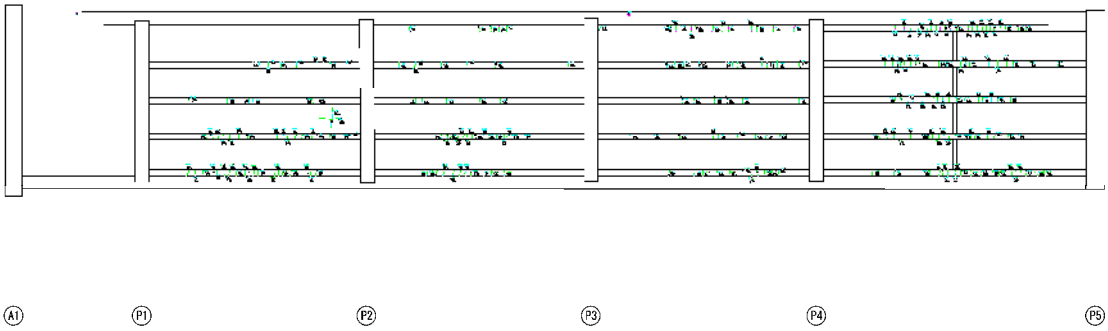
Source: JICA Survey Team

Figure. 5 Survey outputs (Pathumthani Bridge)

ii. Simulation for data utilization

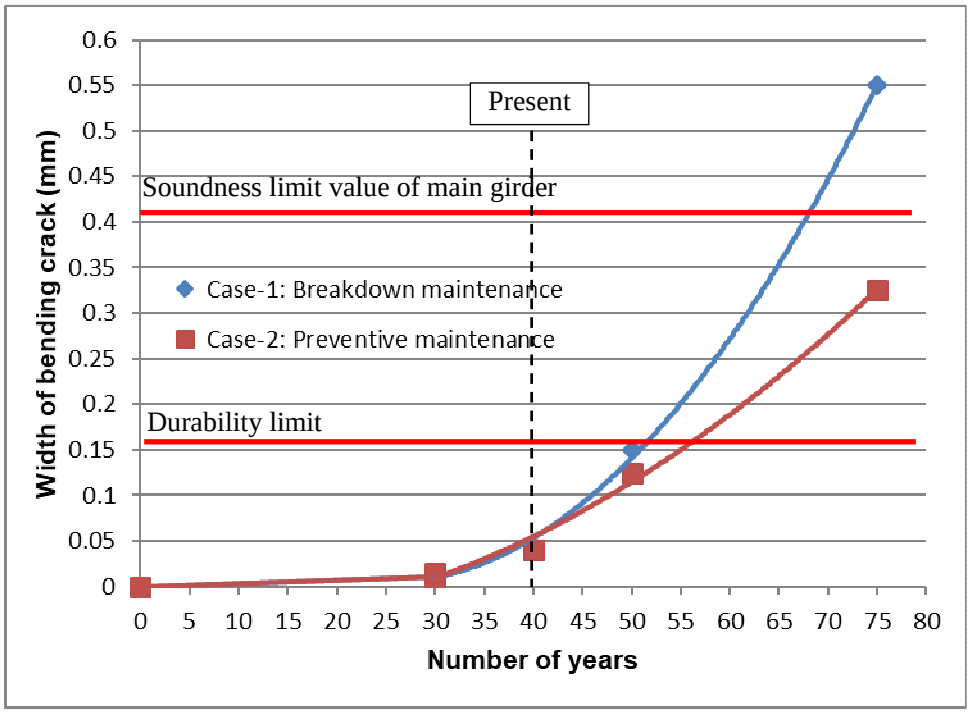
In order to demonstrate data utilization, Bang Pakong Bridge which sustains more number of cracks was chosen as a pilot bridge for the simulation. The main girders have sustained bending cracks predominantly in the middle of the span, and no stain nor deflection/deformation to alarming extent has been observed. Majority of those cracks are observed 0.04mm in width. Live load is suspected as main cause of the cracks. In Japan, it is commonly recognized that a crack more than 0.2mm in width requires remedy measures. In case of Bang Pakong Bridge, only 2% out of all the cracks on the main girders fall into this category.

Accurate coordinates of a crack surveyed with KUMONOS materializes deterioration prediction by analyzing crack data measured at least in three different times. The limited data from the one-time pilot survey should not be enough for the prediction. Yet, simple simulation was demonstrated to estimate future development of the bending cracks in two different cases; one is the case when corrective maintenance was adapted, and in other case, preventive maintenance was taken up. The simulation has shown drastic difference between the results in the two cases. As indicated on Figure.7, taken the corrective maintenance approach, the bridge becomes require major repair 25 years from now, whereas it keeps good health even after 35 years by following the preventive maintenance approach.



Source: JICA Survey Team

Figure. 6 Cracks sustained on main girders of Bang Pakong Bridge (A1 Abutment - P5 Pier) (Horizontal projection)



Source: JICA Survey Team

Figure. 7 Simulation for development of crack on main girders of Bang Pakong Bridge (A1 Abutment - P5 Pier)

iii. Utility verification of KUMONOS

The advantage of KUMONOS, which is to measure cracks accurately from a distance, has been well shared among the agencies concerned through implementation of the pilot survey. The verification meeting organized on October 16, 2017 with experts and students from CU and BU as well as officials from DOH including the director of the Bridge

Construction Bureau presented a comparison between the present and proposed methods of crack measurement as shown below. A number of positive feedbacks from the experts, students and officials from CU, BU as well as DOH have been received during the meeting. The feedback showed high expectation to KUMONOS to improve data accuracy and the database so as to support informed decision and budget appropriation.

Table.3 Comparison between KUMONOS and conventional method in Thailand

Aspect	Conventional method in Thailand	KUMONOS
Accuracy	Low	High
Measured crack information	Drawn by human	Generated by software
Human error	Many	Few (require trained personnel)
Time for inspection	Quick	Require time especially for the 1st time
Time for data processing	Recorded and stored by Human	Converted and generated by software
Cost for inspection	Cheap for rough inspection but may have extra-cost for measuring crack in height (i.e. scaffolding)	Expensive (Device)
Cost for data producing	Cheap	Expensive (Software)
Crack Database	Difficult to track	Easy to track

Source: JICA Survey Team based on CU's presentation material

In order for effective utilization of KUMONOS in infrastructure maintenance and management, technology and know-how need to be transferred to engineers who conduct bridge inspection on daily basis. As remarked by CU students, it was felt easy to learn the operation of KUMONOS for those who were used to operate Total Station. A good example is the two CU students who took part of the pilot survey and learnt operation of KUMONOS. After three times of experience during the pilot survey, they have become capable to carry out crack measurement with KUMONOS by themselves. . Their capacity obtained has been categorized in Level 2 of the KUMONOS Corporation (KC) technical standard and successfully reached up to the target level. Similarly, operation of KUMONOS would be learnt by engineers through on the job training.

iv. Dissemination on importance of maintenance and management

The two seminars organized jointly by CU and KC have raised up awareness on infrastructure maintenance and management. It was felt that the participants have been highly interested in infrastructure maintenance technology. The first seminar organized on

May 30, 2017 at CU targeted entities in technical background. Better maintenance and management system to be developed with KUMONOS was explained to 46 participants. Conscious of the importance of the government initiatives, the second seminar on November 7, 2017 at the Embassy of Japan in Thailand invited participants also from the government authorities. Including chiefs of state divisions associating with policy and planning, as well as presidents and board members of private enterprises, more than seventy participants attended the seminar. In this seminar, five Japanese enterprises, which are Hanshin Expressway Co., Ltd, Kanamori Co., Ltd, Metropolitan Expressway Co., Ltd, Oriental Consultants Co., Ltd and KC, gave presentations which focused on theory and experience of infrastructure maintenance implemented by the respective enterprise.

The questionnaire from the participants indicated that the similar challenges on infrastructure management have been found all over the country. Most of those challenges are associating with three categories; ‘organization and human resource’, ‘financial resource’ and ‘technology’. Many positive feedback filled in the questionnaire indicates that the technology of KUMONOS to cope with the existing challenges in Thailand have already been understood and shared among the participants.

(2) Self-reliant and Continual Activities to be conducted by Counterpart Organization

The KUMONOS equipment provided to CU would be continuously utilized in teaching curriculum of the university. To undergraduate students, it is proposed to teach operation of KUMONOS as a tool for quality control of construction in the course. Graduate students would focus on data management technology with KUMONOS. The civil engineering graduates who learn importance of infrastructure maintenance and management with KUMONOS would take significant roles to cope with development issues and challenges in Thailand in near future.

CU is very positive to continue advanced study and research on adaptation of KUMONOS in bridge maintenance and management, and the research target would be extended to different types of infrastructure, such as buildings, dams and ports. CU has an interest in establishing ‘Crack Analysis Center’ which helps to process crack data and advises the government appropriate measures to be taken against damages by analyzing data and identifying cause of cracks.

4. FUTURE PROSPECTS

(1) Impact and Effect on the Concerned Development Issues through Business Development of the Product/ Technology in the Surveyed Country

i. Improved reliability on the maintenance and management system

KUMONOS materializes high accuracy for measurement of cracks and other degradation and damages. Accurate and reproducible data from KUMONOS makes it possible to estimate development of degradation over time, and planned out appropriate timing and type of remedy measure. The deterioration prediction is in such a way useful and efficient to scientifically make a decision for infrastructure maintenance and management, yet with the present method, it has been difficult to produce it. The survey of Bhumibol Bridge carried out on October 11, 2017 upon request from DRR was a good example to demonstrate how KUMONOS functioned to access chronological development of cracks. It has confirmed that the cracks have not been developed since the year of 2013 when KC has surveyed the same cracks during the project feasibility survey.

KUMONOS drastically reduces survey cost which was largely spent for elevating work platforms and scaffoldings. In case of Japan, KUMONOS has achieved 35% reduction of total survey cost. It would cope with the current challenges of insufficient coverage of inspection. KUMONOS also expands the area of inspection, which have been never reachable before. The survey of Rama VIII Bridge carried out on March 14, 2017 after receiving a survey approval from BMA was an amazing demonstration for this advantage. KUMONOS has taken measurement of the cracks sustained on its main tower of 160 meter in height.

[Railway Bridge]

[Rama VIII Bridge]

Source: JICA Survey Team

Figure. 8 Survey of Railway Bridge and Rama VIII Bridge

ii. Enhancement of preventive maintenance approach

Importance of preventive maintenance and management has already been shared among many people in Thailand, including those who are involved in policy making and planning on maintenance and management in the Government. The two seminars organized have further disseminated the concept of preventive maintenance. Nonetheless, the preventive maintenance approach needs accurate survey data and a reliable database. KUMONS

provides advanced technology required for preventive maintenance approach, which works in the present infrastructure maintenance and management system in Thailand.

(2) Lessons Learned and Recommendation through the Survey

i. Sustainable education for engineers

Implementation of the survey with KUMONOS requires engineer who are able to operate KUMONOS. Whereas graduates of CU will take important roles in policy making and planning in agencies concerned, the engineers who carry out the KUMONOS survey on site need to be trained in technical college. The collaboration with Suranaree Technical College where the training program was organized from March 20 to 23, 2017 needs to be continued in sustainable basis. The KUMONOS training curriculum has been already drafted by lecturers during the program in the college.

CU's initiatives for continuous study and research on adaptation of the new technology in infrastructure maintenance and management, and establishment of Crack Analysis Center would bring tremendous benefits for institutionalization of sustainable maintenance cycle - inspection, analysis and remedy measure - for bridge and other infrastructure.

ii. Institutionalization of preventive maintenance approach

In some bridges, concrete spalled off the surface has been left in a risk of falling down over busy traffic. And in other cases, any anticorrosive has not been applied for steel reinforcement bars exposed. Importance of regular inspection and necessary repair on time is commonly understood, but in reality, it has not been strictly practiced due to the current limitation of financial and human resources as well as technology. While KUMONOS technology provides solution to such ground reality, the endeavor to disseminating the preventive maintenance approach needs to be continued in order to institutionalize the preventive maintenance system through initiatives of the government authority.

Last but not least, we would like to express our appreciation to all the entities involved in the survey. This survey would not be materialized without cooperation with C/P namely CU, and also the government agencies including DOH, private enterprises and academic institutes which have supported the survey.

ATTACHMENT: OUTLINE OF THE SURVEY

Thailand

Verification Survey with the Private Sector for Disseminating Japanese technologies for Improving Bridge Maintenance with Concrete Crack Measurement System

KUMONOS Corporation

Concerned Development Issues in Thailand

Establishment of implementation system for preventive maintenance of infrastructures

- Measures for only surfaced serious deterioration can be taken because of chronic lack of maintenance budget
- Accuracy, quality and quantity of inspection are insufficient so that the suitable repair plan can not be established

Implemented Activities in the Survey

- Transfer of inspection methods and know-how of utilizing inspection data through pilot measurements for road bridges by KUMONOS in order to grasp and manage deterioration states properly
- Promotion for dissemination of KUMONOS by holding technical seminars to introduce the concept of preventive maintenance and improve the accuracy of inspections
- Preparation of the detailed plan for business promotion in Thailand

Proposed Products/Technologies

Remote crack inspection system of "KUMONOS"

- **Realization of the non-contact inspection from a distance**
  - **Cost reduction by omitting equipment for approaching cracks**
  - **Expansion of inspection coverage**
- **Accurate record of location of damage/deterioration by 3D coordinates and quantitative monitoring of crack growth**
- **Automatic creation of CAD drawings using the dedicated software**

Survey Overview

Name of Counterpart:
Chulalongkorn University
Survey duration: Sep 2016~Feb 2018
Survey Area: Bridges in Thailand

Expected Outcomes for Thailand

- Promoting the development of maintenance system by improving the awareness of importance of maintenance
- Improvement of accuracy of soundness analysis and selection of suitable timing/method for rehabilitation by utilizing the inspection method which has high accuracy, high reproducibility and low operation cost

Expected Outcomes for Japan

Present states

- Overseas sales : 22 sets

Future plan

- Development of market and establishment of sales structure in Thailand
- Securing and training of measurement engineers of KUMONOS, and establishment of order-receiving structure for measurement works
- Application to other infrastructures, and business prospects to neighboring countries/regions