Committee Report : JCI- TC114A

Technical Committee on Improvement of Quality of Concrete Structures Based on Database

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Abstract

This committee has developed a method for practical study of the quality assurance of newly-built structures and performance assurance of existing structures, mainly using a database. With regard to newly-built structures, advancement and extension of the crack containment system, using the database by the Yamaguchi Prefectural Government which has been operating since 2007, was set as a main objective of this study, and the system employed by the Yamaguchi Prefectural Government has been developed to the stage where it can be applied to the quality of roads to be restored in the Tohoku District. In addition, collection of pioneering examples and sharing of information concerning the maintenance management system using the database were also carried out. Further, in order to identify a future direction, while specific precedents about database utilization were analyzed in detail and findings were properly organized, discussion about how to use these findings was in progress. This paper describes the gist of the discussion by the Technical Committee, as well as summaries of the progress papers.

Keywords: quality assurance, crack containment, performance assurance, database, maintenance management system

1. Introduction

It is needless to say that the durability of concrete structures which are mainly used for infrastructure is important for the sound continuous development of our country. In our country with such a variety of environmental actions, although it is difficult to construct high-quality structures where cracks are contained in all seasons, and also to ensure good performance for structures to fulfill their functions for a period of 50, 100, or more years, every stakeholder should challenge them.

A unique temperature crack containment system has been operated by the Yamaguchi Prefectural Government since 2007. The reason why the Yamaguchi Prefectural Government

Table 1: Committee Members

Chairperson	Takahiro TAMURA	Tokuyama College of Technology
Vice-Chairperson	Takahumi NOGUCHI	The University of Tokyo
Secretary-General, WG2 Secretary	Akira HOSODA	Yokohama National University
WG1 Convener	Hideaki NAKAMURA	Yamaguchi University
WG1 Secretary	Makoto NINOMIYA	Yamaguchi Prefectural Government
WG2 Convener	Ichiro IWAKI	Nihon University
WG3 Convener	Tetsuya ISHIDA	The University of Tokyo
WG3 Secretary	Tetsushi KANDA	Kajima Corporation
WG3 Secretary	Yasushi TANAKA	Nagaoka University of Technology
Members	Minoru ABA	Hachinohe Institute of Technology
	Junichi ABE	Asano Concrete Co., Ltd.
	Kazumasa INOUE	Takenaka Corporation
	Yasuhiro INOUE	The Kansai Electric Power Co., Inc.
	Hiroshi UEDA	Railway Technical Research Institute
	Toshiharu KISHI	Institute of Industrial Science, The University of Tokyo
	Minoru KUNIEDA	Gifu University
	Shusuke KUROIWA	Taisei Corporation
	Kaoru KOBAYASHI	East Japan Railway Company
	Tatsuhiko SAEKI	Niigata University
	Noboru SAKATA	Kajima Corporation
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	Katsuyuki HORIE	Kanagawa Prefectural Government
	Miho MAKATAYAMA	National Institute for Land and Infrastructure Management
	Akira MARUYAMA	ISS
	Toshiaki MIZOBUCHI	Hosei University
	Masaki MUTO	Building Research Institute
	Toru YAMAJI	The Port and Airport Research Institute
	Tsutomu YAMAMOTO	Tokyo Metro Co., Ltd.
	Takashi MASUI	Metropolitan Expressway Company Limited
	Satoshi NAKANO	Fukuyama Consultants.Co.,Ltd.
	Akihiko TAKAHASHI	Mutsu Survey & Planning
	Makoto TANIMURA	Taiheiyo Cement Corporation
	Hiroshi MATSUDA	Nagasaki University

Table 2: Table of contents of committee report (proposal)

WG1 (Advancement/extension of crack containment/quality assurance systems for newly-built structures, using a database)

Chapter 1 Introduction
Chapter 2 Analysis of crack containment system by Yamaguchi Prefectural Government
- 2.1 Outline of crack containment system by Yamaguchi Prefectural Government; Results of crack containment; problems with the system
- 2.2 "Objectives" and "Means" for crack containment and quality assurance in Yamaguchi Prefectural Government
- 2.3 Improvement of surface quality (mass transfer resistance, visual evaluation) by the system of the Yamaguchi Prefectural Government
- 2.4 Mechanism for ensuring "Compliance with basic points of construction"
  - 2.4.1 Role of construction status tracking check sheet
  - 2.4.2 Supervisor's role in quality assurance
- 2.5 Feedback of findings obtained with crack containment system by Yamaguchi Prefectural Government to JSCE Standard Specifications for Concrete Structures, etc.

Chapter 3 Advancement of crack containment system by Yamaguchi Prefectural Government
- 3.1 Process of transition from crack containment system to quality assurance guide
- 3.2 How the improvement of the placement log and future concreting practice record should be
- 3.3 Importance of data on ready-mixed concrete, and combination with concrete practice record
- 3.4 New database system proposal
- 3.5 Assured durability of concrete structure, and part of the structure where water is circulating
- 3.6 From concrete practice record to progress record of maintenance management

Chapter 4 Extending to other local governments and business operators
- 4.1 Extension of quality assurance system by Yamaguchi Prefectural Government to other local governments and business operators, and its problems
- 4.2 Application of quality assurance system by Yamaguchi Prefectural Government to roads to be restored, and roads used for revitalizing areas stricken by the Great East Japan Earthquake
- 4.3 Management and operation of future database in JSCE

Chapter 5 Conclusion

WG2 (Sharing of good examples of maintenance systems using databases such as maintenance management systems by local governments)

Chapter 1 Introduction
Chapter 2 Changes, current situation and future vision of asset management in this country
Chapter 3 Good examples of maintenance management system by local governments/business operators
- 3.1 Current situation, problems and vision of asset management by Aomori Prefectural Government
- 3.2 Problems and vision for Michimori (Road Guardian) System by Nagasaki Prefectural Government, and its sustainable development
- 3.3 Maintenance management of structures and human resource development in Kagawa Prefectural Government
- 3.4 Maintenance management model and practice for municipalities in Fukushima Prefectural Government
- 3.5 Approach by Chubu District

Chapter 4 Utilization and necessity of database for maintenance management
- 4.1 Chloride ion monitoring
- 4.2 Necessity and construction of narrow and deep database

WG3 (Detailed analysis and utilization of database)

(commissioning party) started the construction of a system was because the construction industry in the prefecture could not satisfy the demands of the commissioning party. The dissatisfaction and distrust of the commissioning party seems to have surfaced because crack problems place a heavy burden on building constructors regarding cost control and construction schedule control. The Yamaguchi Prefectural Government will tackle this problem head on, utilize a database where data for real structures has been accumulated, and try to solve the problem by industry-government-academia "cooperation."

Crack problems are also those of construction management. Considering that it is

important to thoroughly analyze the Yamaguchi Prefectural Government's management system, and extend it to other local governments and business operators, JCI set up "a technical committee concerning the quality assurance of concrete structures, mainly using a database" (chairperson: Takahiro Tamura, professor at Tokuyama College of Technology), which has been operating for the last two years since 2011. **Table 1** shows the constitution of the Committee. This committee, which shares a common understanding that the utilization of a database is important with regard to not only quality assurance of newly-built structures, but also performance assurance of existing structures, undertook free and intensive study and discussion, mainly using a "database" which is a means to an end. This paper describes a summary of the study carried out by this committee, and reports of its progress.

2. Table of contents of committee report

This committee undertook its activities by setting up three WGs. These three WGs are as follows:

(1) WG1 (Advancement/Extension of Crack Containment/Quality Assurance Systems for Newly-built Structures, using a Database)

(2) WG2 (Sharing of Good Examples of Maintenance System using a Database, such as Maintenance Management Systems by Local Governments)

(3) WG3 (Detailed Analysis and Utilization of Database)

However, these three WGs were not independent of one another. When they were held, all the committee members were able to participate in any of the WGs, and broadly share information and findings.

WG1, which closely worked together with the Technical Committee "Extension of Concrete Structures Quality Assurance Method based on Placement Log to Chugoku District" (chairperson: Professor Takahiro Tamura; Secretary: Hideaki Nakamura, professor of Yamaguchi University) whose activities were started in 2011 by JCI Chugoku Branch, tackled the analysis, advancement, and extension of the Crack Containment System by the Yamaguchi Prefectural Government.

Table 2 shows the table of contents of the Committee Report (draft). The Committee has a wide variety of activities which contain a leading-edge study concerning practical quality assurance, etc., a study on good examples of maintenance management by local governments, etc., and examples of utilizing databases in the civil engineering and architectural fields.

WG1 thoroughly analyzed the Crack Containment System by the Yamaguchi Prefectural

Government, and especially discussed in detail a mechanism in which "compliance with basic points of construction", which greatly contributes to quality assurance of concrete structures, should be ensured as a system. The system of the Yamaguchi Prefectural Government is being transformed from a crack containment system to a quality assurance system for whole structures, and extended to other local governments, etc., little by little. The content of a new database and system necessary for doing so were also discussed.

Construction of roads to be restored and roads used for revitalizing the Tohoku District will start in full swing from 2013. In a very severe environment where a large amount of snow-melting agent is sprayed, and under many difficult conditions relating to terms of work, materials, human resources, etc., an enormous number of structures will be constructed. In order to ensure the quality of these restored roads, it was decided to utilize some of the quality assurance system of the Yamaguchi Prefectural Government, as a result of the activities of this committee. The summary was also discussed.

In order to share good examples of maintenance management systems in local governments, business operators, etc., WG2 invited people responsible for such systems to deliver lectures, and prepared summaries of these lectures. In addition, it also presented the newest study results and previous, precious study results which should be carried over into the future concerning examples of utilizing databases in maintenance management in the civil engineering field, databases necessary for the future, and so on.

WG3 reviewed the utilization of the findings obtained from a detailed analysis of databases in the civil engineering and architectural fields, and examples of the database expected to be developed and utilized especially in the architectural field in the future.

On September 12 (Tue.) 2013, the committee will hold a symposium where results will be reported in Tokyo. Since there are many on-going practical studies, the symposium will present new information concerning quality assurance projects for roads to be restored in Tohoku and the crack containment system of the Yamaguchi Prefectural Government, as well as the presentation of maintenance management systems by local governments, etc., which many people may be interested in.

3. Reviewing matters in WG1 (advancement/extension of crack containment and quality assurance systems for newly-built structures, using a database)

Here, a summary of the crack containment and quality assurance systems by the Yamaguchi Prefectural Government and their future, as well as a summary of the extension of quality assurance to roads to be restored, will be discussed.

3.1 Summary, results and problems of the system of the Yamaguchi Prefectural Government

"The concrete crack containment system" which is implemented through industry-government-academia cooperation as shown in **Fig. 1**, has been operated by the Yamaguchi Prefectural Government since 2007. This system is one constructed based on the results of a trial construction of real structures carried out for 2 years since 2005, and it has the following original mechanism:

A contractor prepares "a concrete placement log" where detailed data for materials employed for each lift, data on construction status and cracks, etc., are recorded, and submits it to an ordering party (Yamaguchi Prefectural Government).

The Prefectural Government has released all relevant data such as this "concrete placement log," "data on crack containment measures" which is a standard for operation, etc., on its website, and such data are shared by all persons concerned such as designers, ordering parties, contractors, material manufacturers and researchers.

It will be possible to review practical and reasonable crack containment measures without relying on numerical analysis by utilizing data for structures built on the ground where a future structure is to be erected.

In addition, with regard to our attitude towards cracks, cracks which require no repair are permitted, and crack containment measures are expected to be chosen taking account of economic efficiency (which is aimed at keeping costs down as much as possible) and workability. For this reason, the term "containment" rather than "prevention" or "control" is used in the system.

The containment measures consist of three elements as shown in **Fig. 2**, and they are expected to be implemented with the cooperation of the designer, contractor, material supplier and ordering party.

This effort gradually came to attract attention from researchers, and in 2009, JSC's "Subcommittee Studying the Verification System for Concrete Quality/Durability of the Surface Layer of Structures" subcommittee" (chairperson: Toshiharu Kishi, professor at Institute of Industrial Science, University of Tokyo) inspected the quality, etc., of the surface layers of structures before and after their operation, and confirmed that an improvement was seen in the quality of the surface layers due to the containment measures[1]. In addition, Tamura, et al. and Hosoda, et al. analyzed placement log databases, and reported the results[2],

3).

Although the number of data accumulated for 6 years since 2007 when the operation started, exceeds 1,000, it has not led to the participation of the municipalities in the prefecture. The structures in the prefecture are built by the same constructors, the same material (ready-mixed concrete) is used, and it is advantageous to share data. So, these municipalities are encouraged to participate in the system.

On the other hand, trial runs to prepare placement logs for ordering parties in prefectures other than Yamaguchi Prefecture were carried out in cooperation with researchers, contractors and ordering parties who were interested in the system through the activities they were involved in at this committee, and the committee was able to receive data from not only Yamaguchi Prefectural Government but also other prefectural governments, which are released in the "guest corner" of the website. Now, the committee received data within the prefecture from JR West Japan and the MLIT, and data outside the prefecture from Gunma Prefectural Government. A gradual expansion of the system can be expected.

The operation standard "Crack Containment Measure Data" started to be revised in 2012, and original revision items were supposed to (1) reflect analytical results from accumulated data, (2) develop the content so that it may be expressed in the form of easy-to-understand criteria, and (3) extend the quality assurance of concrete cracks, but not to limit cracks.

The committee discussed this revision in order to further develop the potential of the system, and it proposed to extend the scope, which was limited to RC structures, to PC structures which are superstructures, and to consider water treatment which greatly influences durability after placement in service.

Further, the role of ordering parties in quality assurance, and the importance of technical capabilities were proactively discussed. The system is based on the cooperation of industry (designers/material suppliers/contractors), government (ordering parties) and academia (researchers), and to establish this cooperation, ordering parties also need to have the required technical strength, and properly fulfill their roles. However, there were many personnel who have not reached a satisfactory level, and so an effective training method was also discussed in the committee.

Moreover, since there is a tendency to fall into a situation where "the end justifies the means," that is, the means is carried out although the purpose is not understood at the start of system operation, the committee also discussed how to avoid not becoming what is called a "how-to", in which only the means is shown.

Thus, as for the operation criteria, since discussions and reviews which are aimed at

advancement of the system have been carried out as much as possible, revision work is a little bit behind schedule, and the revised version is due to be published in 2013.

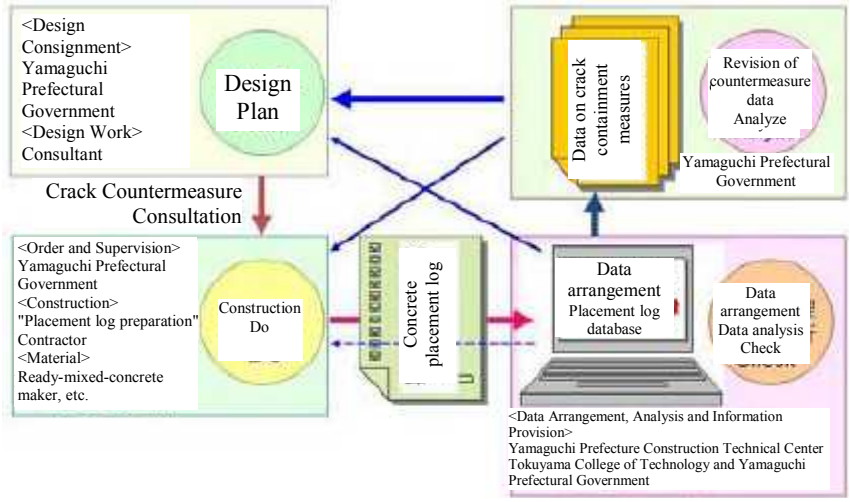

Fig. 1: Concrete crack containment system by Yamaguchi Prefectural Government

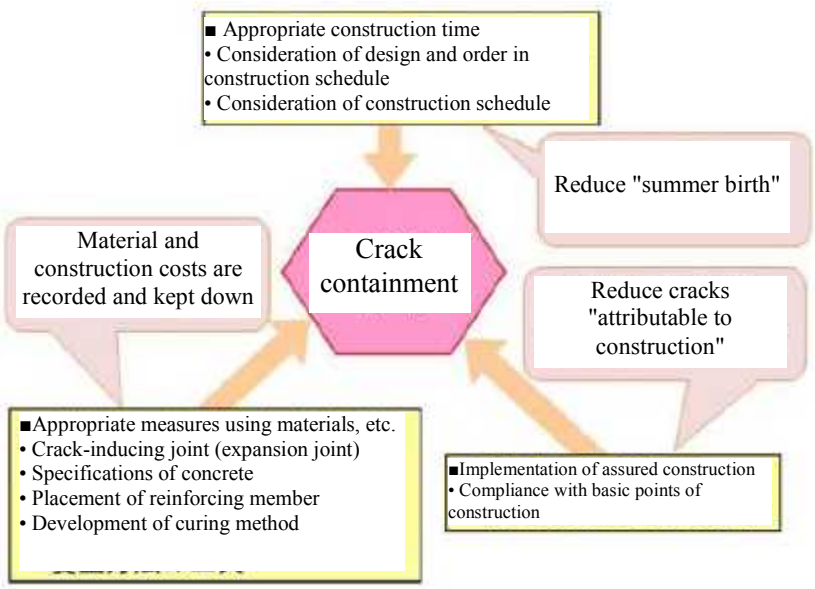

Fig. 2: Crack containment measures by Yamaguchi Prefectural Government

3.2 Advancement of database system by Yamaguchi Prefectural Government

Yamaguchi Prefectural Government constructed a database for providing crack containment in 2007. In this database, the construction status of a structure targeted for crack containment was arranged for each lift where concrete was placed, and 1060 data were stored as of the end of March, 2013. An outline of the stored data is shown below:

- Structure information

  Structure size, rebar work, drawing of concrete placement lift, temperature measurement position, etc.

- Concrete placement information

  Date and time, concrete used, strength, transportation status, placement status, curing status, etc.

- Crack information

  Crack summary, occurrence status, follow-up status, etc.

In this activity, according to the idea that any effort to contain cracks will result in better quality assurance, mainly bridge-substructures, box culverts, etc., have so far been subject to discussion, but an increase of target portions including superstructures, the review of data items, and the review of data formats, etc., have been implemented.

Further, the database system itself which stores such data has been reconstructed, although it is yet to be completed. In the reconstruction of the database system, in order to try to not only enhance the search function but also quality assurance for restored roads in the Tohoku District, which enables not merely the Yamaguchi Prefectural Government but also other local governments, business operators, etc., to use data, information such as location information (latitude, longitude, etc.), prefecture name, and structure management agency has been added as data items.

Further, it is necessary to prepare all required data items in advance in a conventional relational database. To add new data items, the design of the database needs to be changed, but it is not easy to do so. It seems that data items differ for each local government, business operator, etc., and thus the conventional relational database cannot apply to such differences. So in this activity, utilization of an XML database has been considered. Since such an XML database has extendibility and flexibility that can freely add or change required data items when needed, its extension to other local governments and business operators is possible. Further, handling when data items will increase in future can also be made relatively easy.

3.3 Extension to other local governments and business operators, etc.

It was attempted to extend the quality assurance system constructed by the Yamaguchi Prefectural Government to other local governments, business operators, etc., with the cooperation of all players involved. Placement logs were submitted to the guest corner of the database of Yamaguchi Prefectural Government with regard to structures of JR West Japan,

the Ministry of Land, Infrastructure, Transport and Tourism, and the Gunma Prefectural Government. In Yokohama City, supervisors tried to track the construction status at the time of placement by using the construction status tracking check sheet employed by the Yamaguchi Prefectural Government. The placement logs of structures in Yokohama City are also likely to be submitted to the guest corner in 2013.

In the Tohoku District, the construction of restored roads, and roads for revitalizing that district, has been gaining momentum. During a very limited work period, as well as with many limitations such as material supply and human resources, many bridges will be constructed in an environment where a large amount of snow-melting agent is sprayed. In 2012, the Tohoku Regional Bureau and core member of this committee repeatedly consulted each other, and from 2013 on, they have been promoting the quality assurance of restored roads, and roads for revitalizing the Tohoku District, while applying the essentials of the quality assurance system employed by the Yamaguchi Prefectural Government.

With regard to substructures, guaranteed quality and proper water treatment are key principles in compliance with the basic points of construction. With regard to superstructures, under circumstances where the deterioration of existing structures is notable, it will be a challenge to fulfill quality assurance in combination with all measures such as design, construction, materials and inspection.

A preliminary inspection of the quality of a group of bridges under construction on the Sendai-Shiogama Road was conducted on April 10, 2013. A detailed inspection on the surface quality of bridges, etc., will be conducted from May 31 until June 1, and it will develop into a specific quality assurance project.

Many attempts will be made to ensure the quality of bridges on restored roads and roads for revitalizing the Tohoku District. Tracking the initial quality of structures, and compiling a database of performance after service placement in each environment, will result in many findings for the high durability of structures. Because of this effort, we consider that the quality assurance system will extend across the country, and this effort will continue for a long time.

4. Examination by WG2 (Sharing of good examples of maintenance systems using databases, such as maintenance management systems by local governments)

WG2 analyzed good examples of maintenance management systems by local governments, and shared its findings. As shown in **Table 2**, WG2 analyzed maintenance

management systems employed by municipalities in Aomori, Nagasaki, Kagawa and Fukushima Prefectures, the Chubu District, etc. Here, we will describe the outlines of maintenance management by municipalities in Fukushima. In addition, this paper will give a summary of the discussion of what a database required for performance assurance of a future structure should be.

4.1 Good example of maintenance system of self-governing body and undertaker

Although longer life bridge maintenance projects schedules are now being formulated in municipalities across the country, unlike the national/prefectural governments, it is difficult to use a method of aiming at LCC optimization on the assumption of deterioration. Fukushima Prefecture consists of the following 3 regions: Hamadori, Nakadori and Aizu, which differ in terrestrial phenomena and climatic conditions, and municipalities are completely different from one another in financial capability and technical strength. Therefore, 4 models have been created as shown in **Fig. 3**. The main feature is simple preventive maintenance which focuses attention on water action.

Since Fukushima City Government, for example, has many bridges under its management, and there are also personnel with rich technical strength, its bridge management is equal to that of the national/prefectural government.

Tamura City is a large city with a population of about 40,000, which was founded after the merger of five municipalities (4 towns and 1 village) in 2005. Since technical personnel in the municipalities were gathered together due to the merger, the city government trained them as in-house engineers, and a system where they can conduct basic bridge inspection/diagnosis was prepared.

Minami-Aizu-machi is a town with a population of about 18,000, and one of the largest municipalities in Japan, which was founded after the merger of four municipalities (1 town and 3 villages) in 2006, and which has been depopulating and aging. The town government is examining how to train mainly the local construction industry in each area (Tajima, Nango, Ina, Tateiwa) as a bridge guardian, and carry out maintenance management of bridges.

Then, how about Hirata-mura? The government of this small village with a population of about 7,000, located in the Abukuma Highlands, is promoting a road-making/bridge guardian project through industry-academia-government-private coordination ahead of any other municipalities in the country.

Thus, from now on, it is indispensable to develop a model which utilizes regional specialties (advantages), and it seems that a longer life infrastructure in the region will be

realized if such small good examples are promulgated laterally across the country from now on.

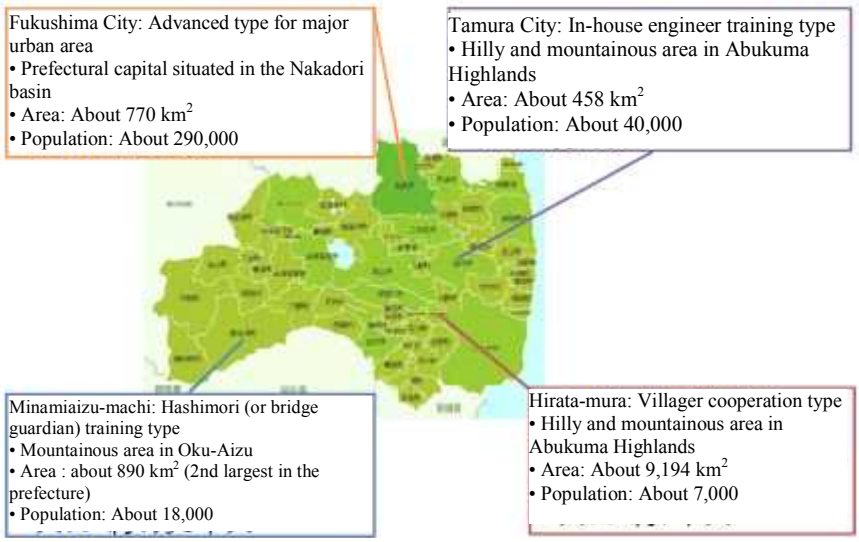

Fig. 3: Good examples of maintenance management where regional features (advantages) are utilized

4.2 Utilization and necessity of database in maintenance management

If the compilation of a database based on the collection of visual inspection data for all the bridges managed by the national and prefectural governments is considered as the construction of a wide database with little depth, it is also important to construct a narrow database with depth. Therefore, if important structures which are exposed to a harsh environment are inspected with regard to environmental actions and structural conditions from various perspectives, and a database is compiled, high performance evaluation and precise prediction of deterioration are possible, and as a result, when maintaining and managing not only such bridges but also many other bridges which are in a less severe environment, it is possible to obtain useful findings.

This committee performed a detailed inspection on Kuretsubo Bridge, and compiled a database. The bridge was built in a salt damage environment (on Route 7 in the Atsumi Area in Yamagata Prefecture) in 1965. It was replaced 34 years after coming into service, and since then 15 years has passed.

5. Examination by WG3 (detailed analysis and utilization of database)

WG3 was mainly concerned with examining how to improve the quality of newly-built

structures by utilizing a database at the time of construction, and how to utilize such information for maintenance management, from both the technological and system points of view. While using several specific examples, WG3 discussed how a database should be, and how to implement and operate it for society, in order to establish, manage and run quality infrastructure facilities and building property. This paper presents part of the results instead of reporting activities by WG3.

5.1 Findings obtained from analysis of database by Yamaguchi Prefectural Government

Data for very precious real structures are stored in the database constructed by the crack containment system by the Yamaguchi Prefectural Government. The database has been released, and this committee also worked on analysis from some viewpoints.

Fig. 4 shows a temperature crack probability curve obtained by utilizing the Yamaguchi Prefectural Government database, and implementing a 3D temperature stress analysis with regard to the vertical wall and breast wall on the bridge abutment. Compared to the curve shown in JCI's "2008 Guidelines for Mass Concrete Crack Containment"[4], the curves of the group of structures are placed further left. Curves obtained from both the standard analysis using placement log data as input values without modification, and the identification analysis where input values were adjusted for the temperature history measured on the actual structure, are shown. In Yamaguchi Prefecture where compliance with the basic points of construction was satisfied as a system, when the minimum crack index exceeded 1.0, there was a tendency that almost no cracks occurred. The reliability of the data in the database is high, and it is thought that the results implicitly show that the temperature stress analysis technique is highly reliable.

Fig 5 shows the crack width predicted from the result of the temperature stress analysis by using the calculation formula for crack width in the above guidelines, and the actual measured value at the maximum crack width on the structure of the Yamaguchi Prefectural Government. Although the data used as the basis of the crack width calculation formula in the above guidelines are distributed near the 1:1 straight line in the figure, the data for the real structure are not necessarily so. In many cases, the crack width of a real structure is narrower compared to the predicted value, and thus it seems that the crack containment measures employed by the Yamaguchi Prefectural Government are effective. In future, these data will be used for improving the accuracy of the crack width calculation formula.

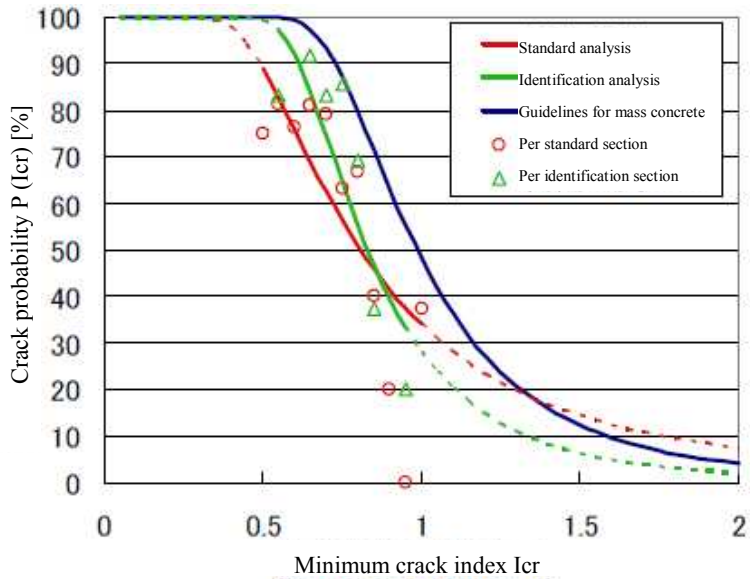

Fig. 4: Temperature crack probability curve

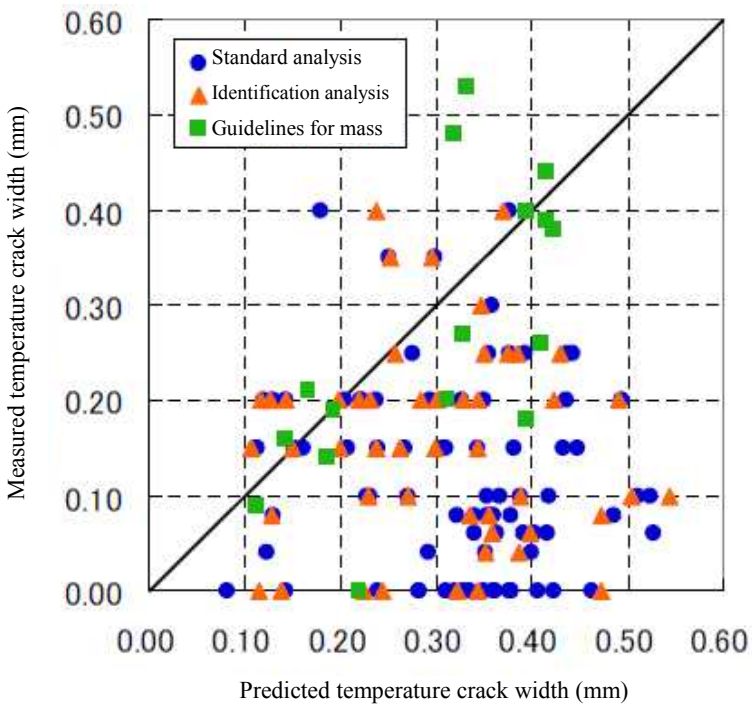

Fig. 5: Comparison between predicted and measured values in temperature crack width

5.2 Examples of utilizing database in civil engineering field

One example of utilizing the database in the civil engineering field reviewed by WG3 is related to the countermeasures against salt damage in the Niigata Prefectural Government.

On the coast of the Japan Sea, salt damage to bridges has become more acute, and how to maintain and manage deteriorated bridges has been a problem requiring resolution. In Niigata Prefecture, an effort has been made to utilize construction records and inspection log data in

the process of examining such measures[5].

Fig. 6 shows changes in the total amount of new construction costs and maintenance/operation costs of bridges that deteriorated in maritime areas in Niigata Prefecture because of salt damage. Almost all the bridges were repaired by the patch repair method and the surface coating method, since the cost of repair for each event is not high in these methods. However, since almost every bridge re-deteriorated at intervals of several to ten years, and such repair had to be repeated, the repair cost for the bridge up to the present was almost half the construction cost for a post-tensioned PC bridge, and about twice for a pre-tensioned PC bridge. In case of a pre-tensioned bridge, the repair cost is higher because cover is small. In addition, it was confirmed that bridges built after the 1990s and for which countermeasures to salt damage such as retention of cover were taken, have not deteriorated up to now.

In the case of Bridge C, a pre-tensioned PC bridge, a different repair method was used from span to span. **Fig. 7** shows changes in the total amount of money for Bridge C repair per span. The total amount of money up to the present has almost been the same regardless of which repair method was used. In the case of bridges for which the patch repair method or the anti-corrosive material application method was used, there are many spans where corrosion cracks or exfoliations are occurring at present because of re-deterioration. On the other hand, no damage has been observed at present in any span where the electrolytic protection method was applied.

It is obvious that these analysis results are useful to take measures in the future. It is important to analyze data after collecting past data and compiling a database, when problems which take a lot of time to be examined, such as bridge maintenance management, urgently need to be solved.

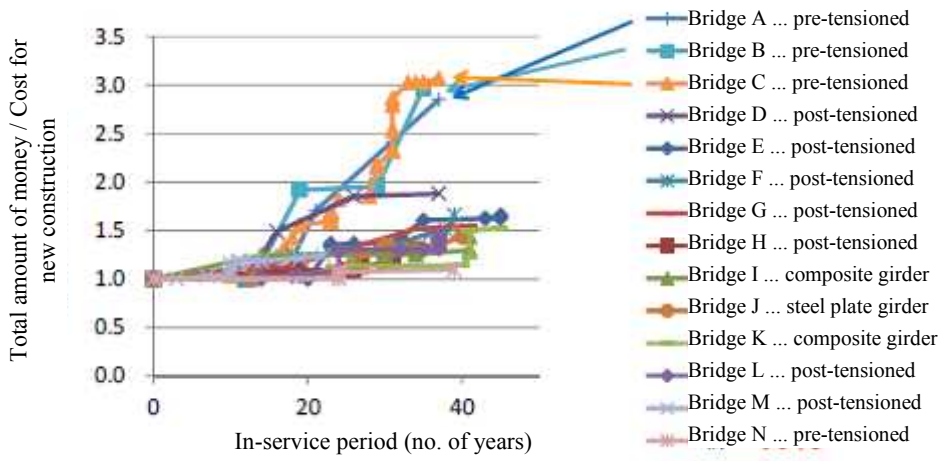

Fig. 6: Changes of total amount of money spent on bridges deteriorated by salt damage, located within 150 m or less from the seashore (only Bridge L is in a mountainous area)

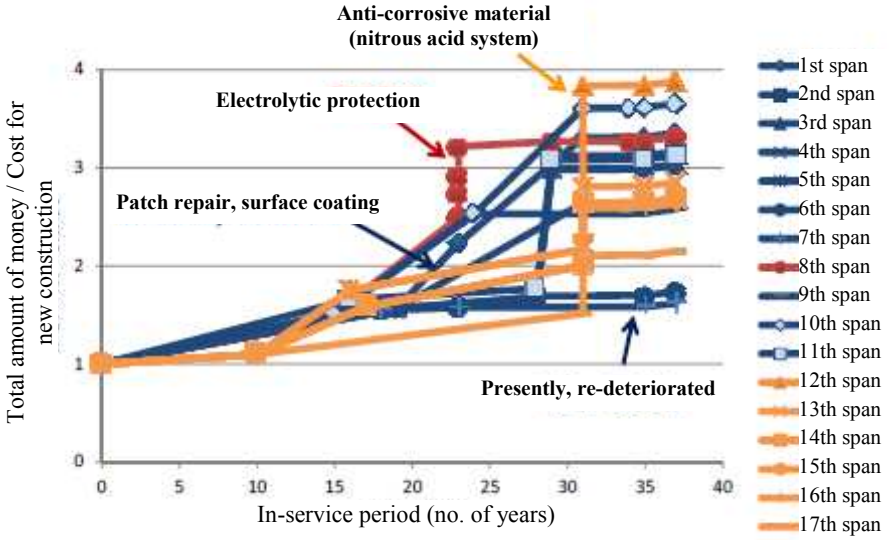

Fig. 7: Changes of total amount of money per span in Bridge C

5.3 Utilizing a database in the architectural field

Since there are a very broad array of work items in construction work, under the present circumstances, it is difficult to collect data only focusing on RC skeleton work as shown in the case of Yamaguchi Prefecture. In addition, the main works are private, and there is strict confidentiality that applies to each building. Therefore, even if data can be collected and such data are released through the construction of a database for utilizing them significantly in an academic/practical fashion, there remain many problems to be solved. On the other hand, there is a strong public concern for the durability and maintenance management of structures, and it has been more and more important to accumulate construction data comparable to a

maternity record, which prove the quality of skeleton work, and data comparable to a clinical record, including aging deterioration and maintenance data which are used for maintenance management. Yamaguchi Prefectural Government's progressive approach offers much to be learned.

For these reasons, with a view to accumulating and utilizing construction data on RC skeletons in the architectural field, WG3 investigated and reviewed the following four points: i) tracking the actual condition of skeleton construction records by contractors; ii) proposing how construction records should be in order to contribute to the higher quality of skeletons, including reduced cracks and secured cover thickness; iii) seeking possible data collection and utilization with BIM representing computerized construction which is proceeding at a rapid rate [BIM (Building Information Model) is defined as a digital model characterized by having attribute information on a structure, such as specifications/performance of materials/ members, as well as 3D shape information on such a structure created on a computer[6),7)].]; iv) tracking the idea, development and current status of a construction & maintenance logbook comparable to a clinical record for the structure, which is proceeding under a governmental initiative.

We shall describe BIM in iii) as an example of examined results. Great effort by the contractor is required to record and organize construction information. However, since data can be easily added to the digital model by inputting them to a smart phone or automatically collecting them through a sensor or the like, for instance[8)], the spread of BIM may rapidly lead to the construction of a database comparable to a maternity record and a clinical record even in the architectural field, although it applies to each individual structure. **Fig. 8** shows construction data collection and its integrated image.

Fig. 8: Construction data collection and integrated image by use of BIM

6. Conclusion

In order to achieve the construction of longer-life concrete structures in society, reliable initial quality, reliable performance during an in-service period, and database analysis and utilization are required as shown in **Fig. 9**.

Whenever this committee held discussions, every member recognized how important it was to achieve reliable quality/performance of structures, and to foster human resources in that process and enhance technical strength which must become more accessible. However, everybody confirmed that a database, which is a means, is also very important, and to construct and utilize such a significant database, outstanding strategies, tactics, our commitment, and our determination to continue are required.

There are many real-world projects which have started in the wake of this committee's activities, and thus we would like to continue trying hard to realize the philosophy that was discussed in this committee.

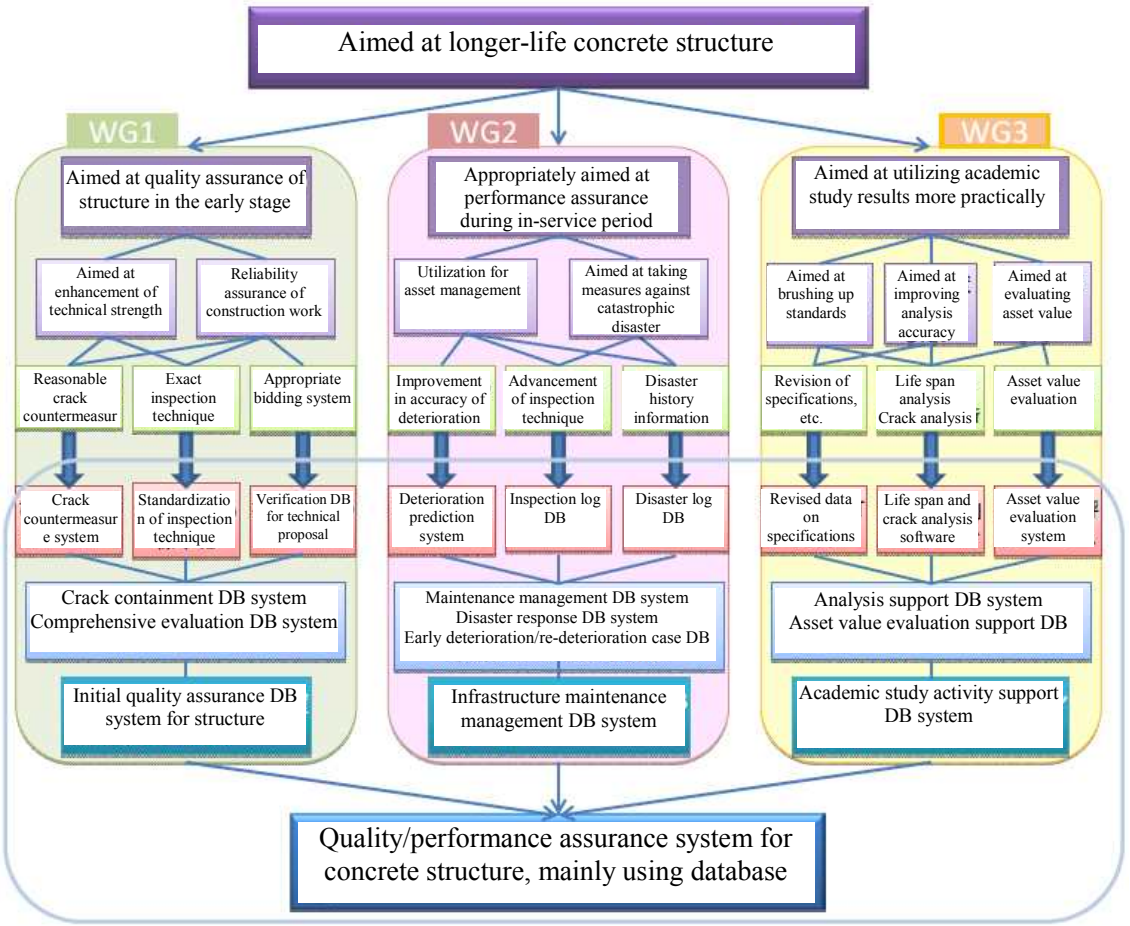

Figure 9: Quality/performance assurance system for concrete structure, mainly using database

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