THE MEASURE TOWARD MAINTENACE BY NEW TECHNOLOGY FOR EXPRESSWAY BRIDGE IN JAPAN

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Abstract

The bridges in the expressway that the *NEXCO* group manages are more than 13,500 in Japan, old bridges where the use period exceeds 40 years are more than 15%. The maintenance of the bridge will become important more and more for us in the future, because old bridges will rapidly increase. This report is technical new approaches in *NEXCO* of the maintenance for the old expressway bridges that increases in Japan, in this text around the bridge management and the corrosion measures of steel bridges.

Introduction

The greater part of expressways in Japan is constructed and managed in expressway Ltd. that privatized from the public corporation from 2005. *NEXCO* group (*East Nippon Expressway Co. Ltd.*, *Central Nippon Expressway Co. Ltd.* and *West Nippon Expressway Co. Ltd.*) has managed the expressway between cities excluding the expressway in the capitals and Kansai area etc. The extension of the expressway that the *NEXCO* group manages exceeds 8300km, use during about 20 years (As of 2008) on the average, and also includes the route that reached in 45years.

The total bridge extension is about 15% (1,250km), and about 13,500 bridges. In the kind of the superstructure, steel bridges is about 40%, concrete bridges is about 60%, and RC and PC are almost in halves of a concrete bridge. And then, new structural form like corrugated steel-web bridges are developed in recent years, and they are constructed a lot. The construction time and the number of bridges of bridge types are indicated in Figure-1.

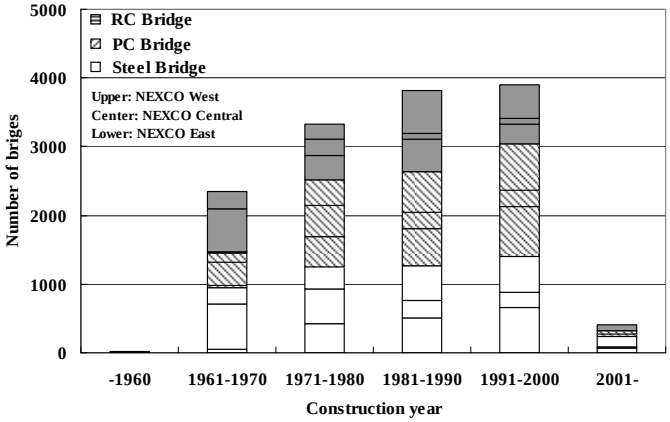

Fig.1 Relationship between number of bridges and construction year of bridge types (2003)

The bridge maintenance is one of the important missions of *NEXCO*. It goes in the control of maintenance of a great number of these bridges as about 1,000 technical engineers

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in the organization of about 100. Especially, a social noteworthy level concerning the safety of the bridge has risen further, because the bridge collapsed accidents and the breaking bridge member accidents happen inside and outside the country in recent years. Therefore, we should maintain safe bridges attempting efficiency improvement of maintenance works, because it will increase more and more in future, even though number of engineers will be limited. In the text, it is described that technical new approaches of bridge maintenance in the expressway that *NEXCO* manages around the bridge management and the corrosion measures of steel bridges.

Approach of Bridge Management

It is indispensable to manage the Asset management technique to do the maintenance management of a great number of bridges. *Japan Highway Public Corporation* (*JH*) started operation examination of Bridge Management System (hereafter, BMS) from 2001 based on the basic policy of "*Technical Committee Concerning the Deterioration Prediction and the Evaluation of Bridges*" composed by an inside and outside specialist. The main functions demanded from BMS are 1) grasp of road property, 2) grasp of deterioration parts of structure, 3) deterioration prediction and soundness evaluation of bridges, 4) selection of optimal repair and reinforcement method, 5) calculation of repair or reinforcement cost. We brought the principle of *NEXCO-BMS* in this committee, constructed the system to 2002-2004 based on it, and began the operation of *NEXCO-BMS* from 2004.

(1) Outline of *NEXCO-BMS*

The bridge management system is used making efficient maintenance management plan such as repair or retrofit method, repair construction time based on appropriate soundness evaluation and long-term deterioration prediction of members that composes bridge (Figure-2). In *NEXCO-BMS*, the soundness of bridge member is divided into five stages of grade 1-5 by progress of deterioration mechanism. And, it is evaluated by inspection results. The soundness deformation grade and the remedial measures in BMS are shown in Table-1. *NEXCO-BMS* is prediction of each member that composes bridge according to each deterioration mechanisms. It is prediction function in system default based on the theory concerning

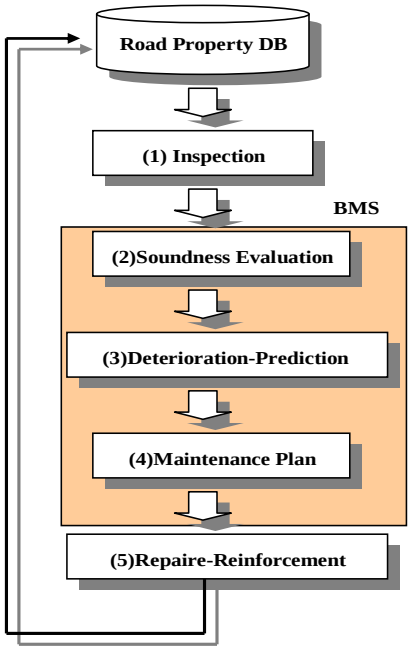


Fig.2 Object of using BMS

technological domestic deterioration predictions (Table-2). The soundness based on these deterioration predictions should be calibrated by the inspection results of an individual bridge (Figure-3), and accurate deterioration members can be understood.

Table-1 Deformation grade and remedial measure

Grade	Progress of deterioration	Performance of structure (e.g. load bearing capacity)	Management range	Type of remedial measure	Deteriration phase(refer to specifications*)
1	No problematic deterioration	No progress of deterioration	Standard control range	No remedial measures are taken	Incubation
2	Minor deterioration	Deterioration progresses but no reduction in load bearing capacity		Preventive maintenane	
3	Deterioration occurs	Deterioration progresses considerably, and reduction in load bearing capacity demands monitoring	Control range	Repair or retrofit	Propagation and acceleration
4	Large deterioration	Load bearing capacity decreases and required limit is likely to be reached	Management limit	Retrofit	Critical state of deterioration
5	Critical deterioration	Load bearing capacity decreases to a serious level and there may arise safety concerns in the short run	Management limit is exceeded	Large-scale remedial measures	

*** JSCE: Standard specification for design and construction of concrete structure -maintenance**

Table-2 Deterioration mechanism and deterioration prediction formula

Deterioration mechanism	Deterioration prediction formula	Remark
Cabonation	Carbonated thickness (formula of Japan Society of Civil Engineers (JSCE)), corrosion of steel member	Interpolated from the results of detailed inspection
Chroride attack	Chroride ion concentration (formula of JSCE), corrosion of steel member	Interpolated from the results of detailed inspection
Fatigue (RC Slab)	Degree of fatigue damage (Matsui's formula)	Related to free lime content inspection
Frost damage	If deformation becomes apparent, detailed inspections are conducted regularly	Deterioration prediction formula will be established
Chemical erosion	If deformation becomes apparent, detailed inspections are conducted regularly	Deterioration prediction formula will be established
Alkali-silica reaction (ASR)	If deformation becomes apparent, detailed inspections are conducted regularly	Deterioration prediction formula will be established
Fatigue (main member of a steel bridge)	Fatigue assessment formula (Japan Raod Association (JRA))	

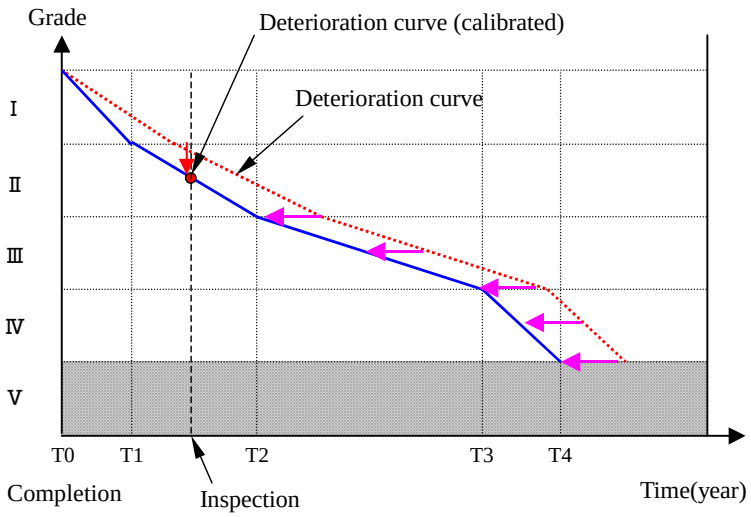


Fig.3 Calibration of deterioration curve

(2) Present situation and view in the future of *NEXCO-BMS*

The most important point in *NEXCO-BMS* is an appropriate soundness evaluation and calibration works by the inspection. When we analyzed the data of BMS in 2006, we understood the accuracy of the soundness evaluation was not good according to inspector's engineer level. Therefore, we analyze the soundness evaluation result by the professional skill person whom we can trust, and we are examining the rule that can do accuracy evaluation by general engineer.

Now we chiefly use the functions of *NEXCO-BMS*, such as property information, bridge parameter, deterioration bridges data base. For instance, when we search for object bridges of the urgent inspection and thinking bridge inspection plan and others, we are using it.

We will analyze accumulated correction BMS data, and make the deterioration curves of structure, design time, each using conditions such as traffic, deterioration environment such as coming flying salinities and anti-freezing agents and others in near future. It is scheduled to improve the accuracy, to reflect it in decision of repair and retrofit plan of fiscal, mid/long-term bridge maintenance management vision, and the research and development technical target by *NEXCO-BMS* in the future.

Approach of corrosion measures

The total cost of corrosion measures such as painting repair was about 5-6 billion yen/year on these 10years average in *NEXCO* group (2005). In future, maintenance works of corrosion measure will increase, because old bridge will be so. Therefore we should develop efficiency maintenance management technology, as minimal life cycle cost technology, efficiency inspection method and so on. Here, new technical approaches for the maintenance management system of painting, control of going into of deterioration factor for corrosion measures and repair of partial corrosion damage in *NEXCO* are described.

(1) Maintenance management system of painting

We use basically the heavy anti-corrosion painting system for the method of anti-corrosion of a present steel bridge in *NEXCO*. To do maintenance management of the painting of steel bridge, we use Paint View System that paint film deterioration diagnostic system by the image data processing. At one time, we had judged painting maintenance based on a local vague judgment. This system is used for quantitative judgment of painting maintenance (Figure-4). The principle of this system extracts the deterioration part by light and darkness of image, and we understand quantitatively the soundness of the paint film from the deterioration area rate and the diameter in the deterioration part. This system has also records record of past soundness and painting history etc. (Figure-5 and Table-4).

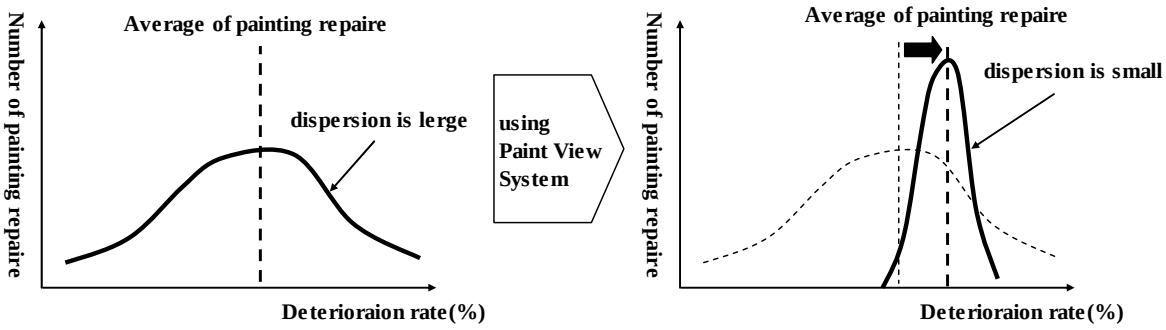


Fig.4 Concept of using Paint View System

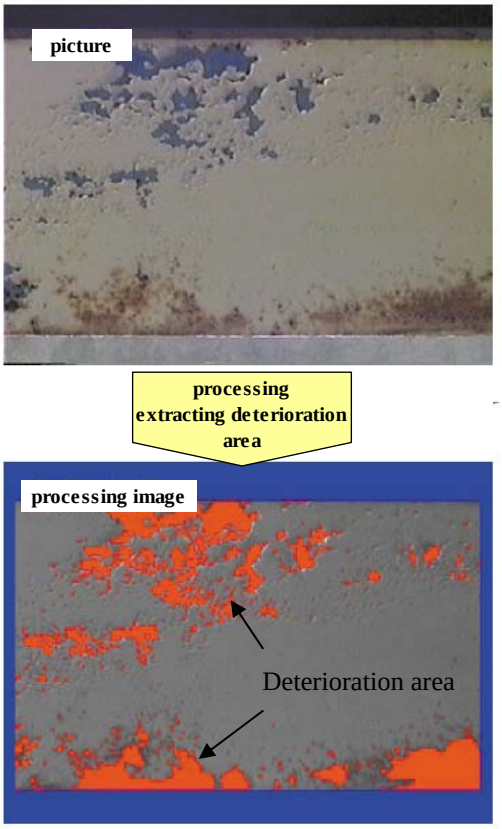


Fig.5 Image processing by Paint View System

Table-4 Soundness evaluation of painting

diameter of rust(mm) / deterioration rate(%)	10 over	5 - 10	3 - 5	3 - 1	1 - 0.05	under 0.05
5 over	E	E	E	E	E	E
2 - 5	E	E	D	D	D	D
1.5 - 2	E	D	D	D	D	D
1 - 1.5	D	D	D	D	C	C
0.5 - 1	D	D	C	C	C	C
0.3 - 0.5	D	C	C	C	B	B
under 0.3	C	C	B	B	B	A

A: Good, B: Not bad, C: Observation, D: Continuous observation, E: Need repaire painting

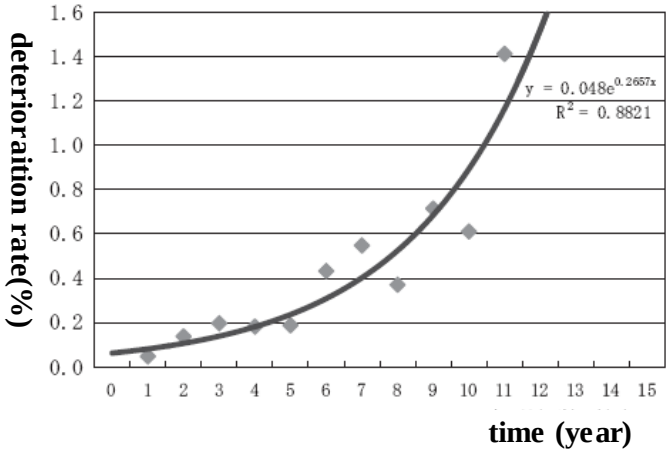


Fig.6 Deterioration curve of painting (Steel bridge of *NEXCO*, phthalic resin coating paint)

We think that the deterioration forecast becomes possible by these accumulations of the quantitative data in the bridges in future (Figure-6). We are researching also concerning the deterioration prediction of painting of the standard painting system of *NEXCO* by acceleration test and long-term atmospheric exposure test that uses test piece. By these continuous investigations, we come to be able to use this system as one of maintenance management plan tool of the bridge as well as BMS in the future.

(2) Control of going into of deterioration factor for corrosion measures (Water leak measures at expansion joint)

There are a lot of corrosion damage cases of steel bridges around the expansion joint. The gathering such as water, dust and sand at around the expansion joint influences the promotion of deterioration. In addition, the influence of water leak including the chloride ion is remarkable, because we use a lot of anti-freezing agent for the traffic securing in winter in recent years (50t/km or more is used in part). Therefore, the expansion joint that we have used adopts non-water-leak system so far (Figure-7), and the effect is seen in a lot of it. But, the water leak is seen partially for a short time in old expansion joint putting non-water-leak system after. To solve this problem, we are studying the method of evaluating the performance of non-water-leak of expansion joint (Figure-8). This research has aimed to get rid of using present detail standard, to evaluate the product that satisfies the demand performance as a system, and to promote technological development of new non-water-leak system that we can use in repair work. Moreover, we use recently the extension slab system that the position of expansion joint is moved to ground, because we avoid the water leak from the expansion joint (Figure-9~10).

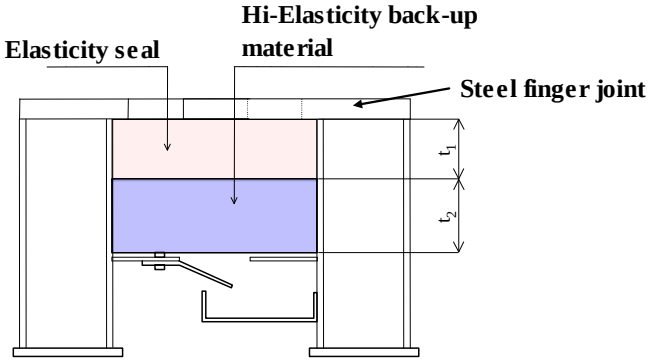
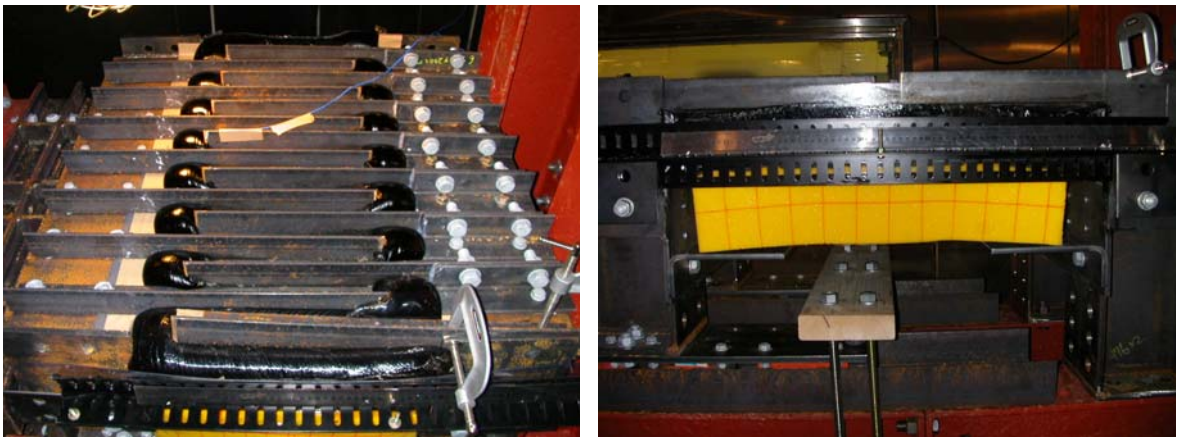


Fig.7 Non-water-leak system of expansion joint



(a) compression in high temperature(+50C.) **(b) tension in low temperature(-10C.)**

Fig8. Performance confirmation test of non-water-leak system of expansion joint

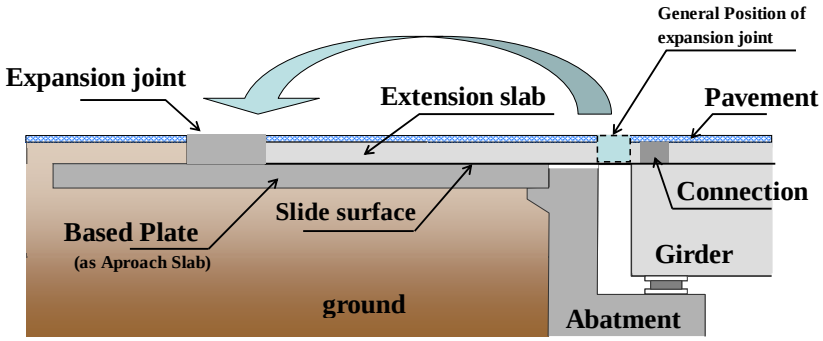


Fig.9 Extension slab system

Fig.10 Extension slab system at Bridge of *NEXCO*

(3) Repair of partial corrosion damage

A partial corrosion damage of the steel member laying in concrete like *Kisogawa* bridge in Japan is not few. We grasped that there was no broken corrosion, but rust and negligible corrosion were in part by the infiltration of water to the space, though in the urgent inspection that we did last year (Figure-11). We should continuously inspect such a structure in the future. The development of more efficient inspection method is advancing also.

Fig.11 Inspection of steel member in concrete at bridge of *NEXCO*
(Mono arch Lohse bridge)

As for the method of repairing the above-mentioned damage, exchanging member or making up steel plate reinforcement, etc. were generally used. However, such a repair might be difficult the repair construction, for the construction reason such as securing the work space in height and structural reasons of closed section member etc. We need a repair method that is good construction works, and is good in life cycle cost securing certain safety in such a condition. Therefore, we are developing a new repairing method of corrosion damage that uses carbon fiber sheets, it is light and good construction works. We had executed the pilot repairing construction at *Asarigawa* Bridge in *Cyuo* Expressway last year after doing various basic experiments (Figure-12~13). We are expected one of the important repair technologies to negligible corrosion in the future, though we will investigate continuously to evaluate durability etc.

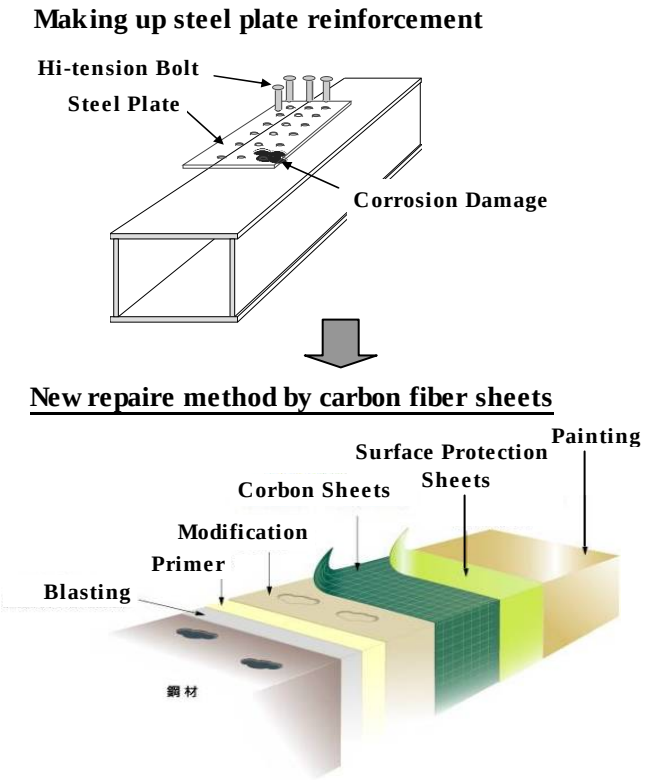


fig.12 Repair method by carbon fiber sheets

fig.13 Repair by carbon fiber sheets at *Asarigawa* bridge of *Chuo* expressway

Conclusion

An active discussion about the ideal way of the maintenance of the bridge used now is done from the viewpoint of excellent maintenance of the infrastructure in recent years. The important point are 1) a lot of bridges constructed at the high economic growth period age, and it will receive "Update time" all together in the near future, 2) the deterioration factor of the bridge is not the same and complex, and is including the compound deterioration, 3) the restriction of the road budget, especially an enough securing the maintenance management budget must be difficult, 4) engineer's lack for inspection and repair of bridge and incompleteness framework etc.

This is not an exception in *NEXCO*. There are rather more problems by special requirement, heavy traffic, scattering a lot of anti-freezing agent, and lack of the maintenance cost and engineer, addition of new corporate objective such as further safety and comfort after privatization etc. Our mission that maintains the expressway network that is indispensable for support an economic of our country, and maintain the people's comfortable lives whole country doesn't change in the future. Especially the bridge is located on an important structure, because the influence is large if it damages and repair work is difficult. In this text, it reported on technical approach of expressway bridge

maintenance of this background in *NEXCO* from BMS and the corrosion measures. We work similarly about slab, concrete deterioration, bearing, and expansion joint etc., and we are making an effort for realization making bridge long-lived. If this report becomes reference of other road administrators who have similar problems, it is great.

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