RATIONAL MAINTENANCE SYSTEM FOR CONCRETE BRIDGES DETARIORATED BY SALT ATTACK ON THE COAST OF JAPAN SEA

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ABSTRACT**:** Because many concrete bridges has been already started to corrode in the coastal area of Niigata prefecture, we tried to establish rational management system to minimize the maintenance cost. As a first step, we started to increase the number of well-trained engineers for the inspection of concrete bridges. As a second step, we developed web-database system which stores inspection data. Tablet PC was selected as input device. Through the trial test, we found that our system enables us to reduce inspection cost significantly. As a third step, past data is collected and analyzed to achieve actual maintenance cost. Then, the life cycle cost of each repairing method is discussed.

KEYWORDS: tablet PC, life cycle cost, salt attack

1. INTRODUCTION

In Japanese coastal area, concrete bridges, which were constructed in 1960's and 1970's, are now deteriorated by salt attack as shown in Figure1. High concentration of chloride ion accelerates corrosion of reinforcing materials inside concrete structures. Reduction of the amount of reinforcing materials leads to strength reduction. Corrosion product causes cracks and spalling of concrete. Therefore, repair, strengthening or re-construction is required to keep the function of deteriorated concrete bridge.

Because hundreds of thousands of bridges become over 50 years within the next decade in Japan

Figure1 an example of deteriorated PC bridge beam affected by salt attack in Niigata pref., Japan (constructed in 1975)

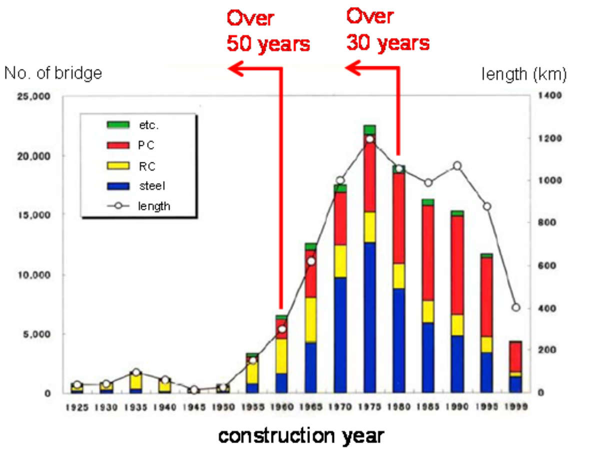


Figure2 history of the number of constructed bridges in Japan (bridge length > 15m) (refer to Figure2, there are 600 thousands bridges which are longer than 2m in Japan), rational management system should be developed and supplied to reduce the cost for management of these bridges. This problem is serious especially in Niigata prefecture which locates along Japan Sea (see Figure3), because many concrete bridges has been already started to corrode in this area.

Objective of this study is to find the answer to this problem. In this paper, we introduce our activities to solve this problem.

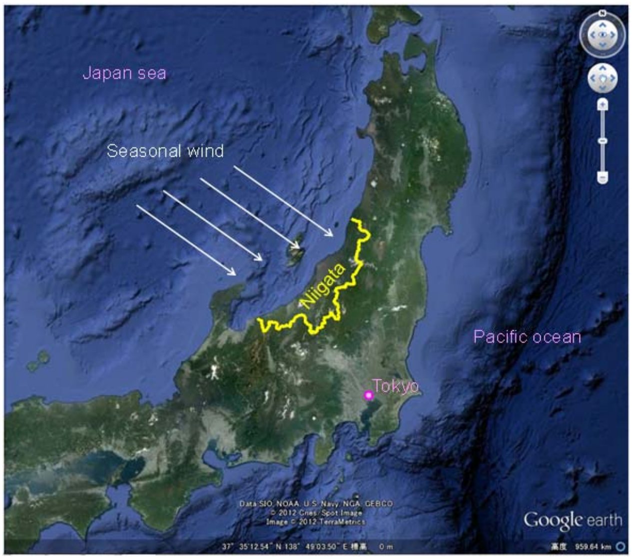


Figure3 location of Niigata pref. in Japan

2. EDUCATION OF INSPECTORS

2.1 Budget shortfall in local municipalities

As shown in Figure4, more than half of bridges belong to local municipalities in Japan, but local municipalities are now under financial pressure due to aging of population and economic recession. Consequently, the budget for bridge maintenance tends to be reduced severely. On average, visual inspection costs about 500 thousands yen per one bridge. On the other hand, budget is only 80 thousands yen per year for each bridge on average. The budget includes inspection, repairing and renewal cost. That is, present maintenance system has been failed in Japanese municipalities. At least inspection cost should be reduced to solve this problem.

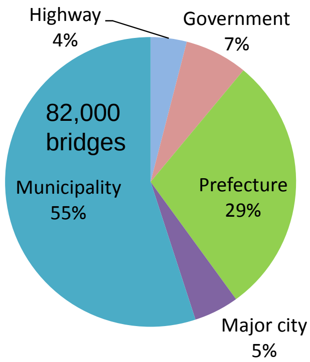
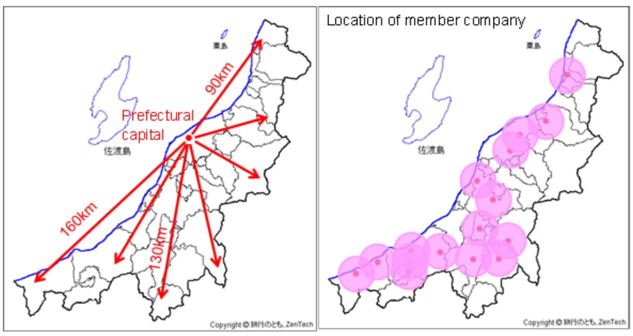


Figure4 number of bridges in each road administrator (bridge length > 15m)

2.2 Problems in present inspection system

We considered the way to reduce the inspection cost. At present, number of engineers who can make a correct diagnosis is limit. Therefore, each engineer inspects many bridges. Because every inspector now lives in prefectural capital, they sometimes drive hundreds kilometers each way to inspect one bridge as shown in Figure5 (a). If well trained engineers live all over the prefecture, both travel distance and inspection cost will be reduced as shown in Figure5 (b).



(a) present system (b) proposed system

Figure5 the locations where inspectors live and the area where each inspector covers in Niigata pref.

2.3 Education of engineers

To realize the proposed system shown in Figure5 (b), we started to educate engineers who work at regional company in 2006. 16 regional companies participated the study group named Niigata pref. Concrete Maintenance study group (NCM study group). So far technical lectures have been held 19 times. Contents of lectures include field study and the study for qualifying test (Figure6).

(a) field study (b) lecture for qualifying test

Figure6 examples of educating activities in NCM study group

3. SIMPLE AND EASY INSPECTION SYSTEM

3.1 Management of inspection data

It is time-consuming work to make the inspection report. Figure7 shows an example of inspection report according to the form prescribed in Niigata prefecture. Other than inspection results, inspector must collect many relating data according to defined format. This report should be prepared for every bridge.

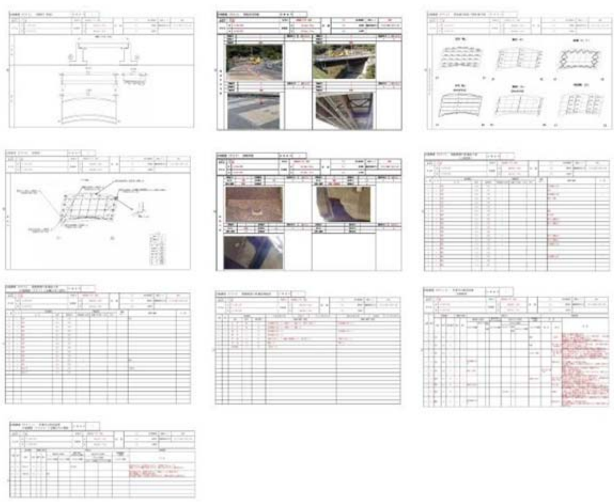


Figure7 an example of inspection report according to the form prescribed in Niigata pref.

Figure8 shows how inspection data flows in present system. Inspectors write inspection results by hand at field site. Then, they input inspection data at their office. Prepared report is submitted to the road administrator. As the next step, road administrator orders making database from submitted reports as another job. Obviously, this process is wasteful. We considered that web database system enables us to eliminate reporting process. We also considered that the inspection with tablet PC enables us to make the database automatically as shown in Figure8. It is clear that we can save much time and cost if our proposed system is put into practice. Therefore, we tried to establish web database system with tablet PC for visual inspection of concrete bridges.

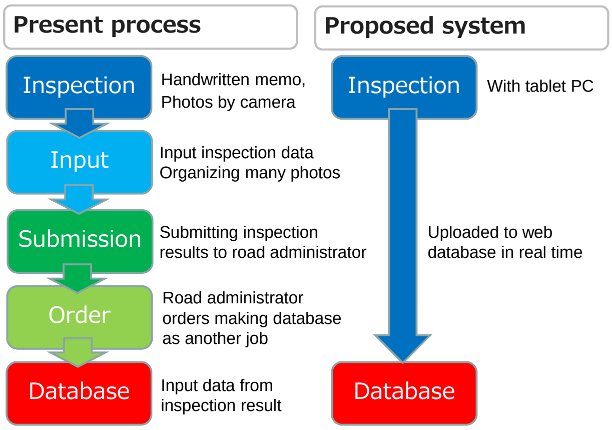


Figure8 flow of inspection data

3.2 Web database system with tablet PC

Figure9 shows the inspection system developed in this study. Wireless tablet PC is selected as data input device in our database system because tablet PC enables us to input inspection data at field site. iPad was selected as tablet PC device while FileMaker was used as database software in this study. Mac OS X server was used as web server. During inspection, tablet PC is connected to web server via mobile telephone network. Inspection data is uploaded to web database in real time. Road administrators are able to browse recorded data any time from the outside via broadband line.

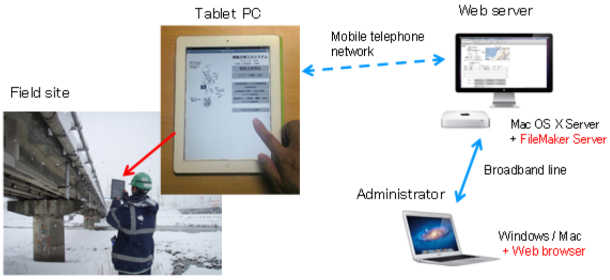


Figure9 developed inspection system in this study

Figure10 shows the display screen image for searching the bridge to be inspected. GPS data is obtained from tablet PC or Wi-Fi router by tapping upper left button. Once GPS data is obtained, neighbor bridges are searched and displayed on the middle of the screen. Then, we can select the target bridge by tapping the name of the bridge from the list.

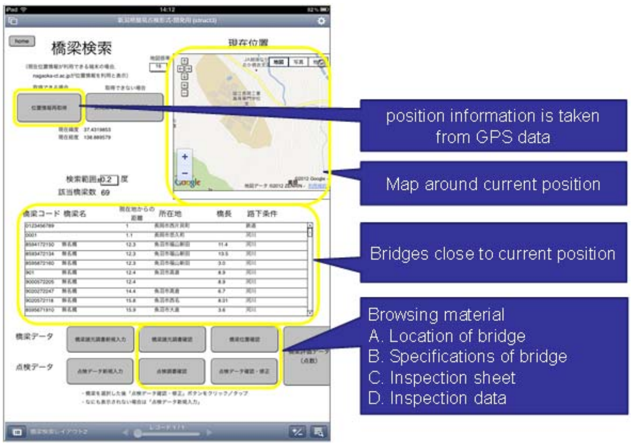


Figure10 display screen image for searching the bridge

Figure11 shows the display screen image for input of inspection data. We designed inspection screen according to the manual prescribed by Niigata prefectural government. In this case, check items consist of the type of structural member and the type of deterioration.

Tablet PC has camera function. Figure12 shows how to use camera function in our database system. Picture frame is already prepared in our database. By tapping picture frame, camera software runs immediately. Captured picture is uploaded into picture frame automatically. This function relieves us of organizing photos.

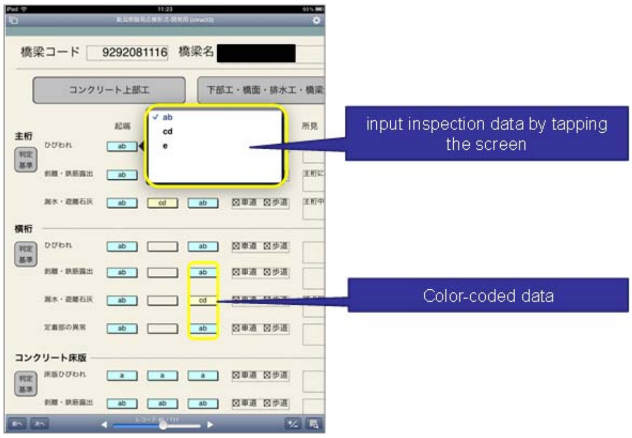


Figure11 display screen image for input of inspection data

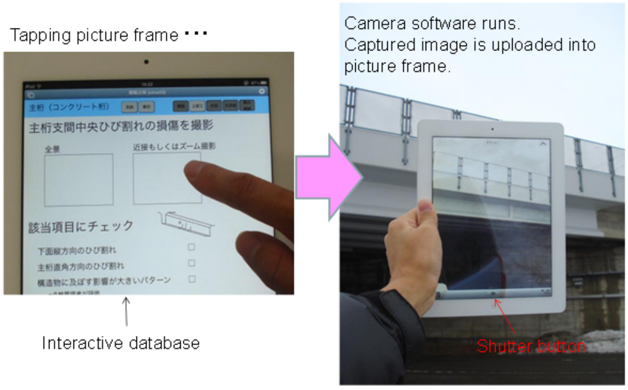


Figure12 display screen image for taking pictures

We carried out trial test several times on site to improve our database system. Through the trial survey, it is confirmed that developed database system is able to reduce working time (inspection and making report) by half.

3.3 Simple and easy inspection

Inspection work should be simple and easy because many engineers participate in our inspection system. On the other hand, the quality of inspection will drop if the inspection manual is too simplified. Therefore, we decided not to change present inspection manual. Instead of that, we modified screen design from table form (Figure11) to dialogue form (Figure13). This modification relieves inspectors of reading and memorizing the inspection manual. Inspectors have only to answer the questions from tablet PC step by step. Thus, we succeeded to simplify the inspection work.

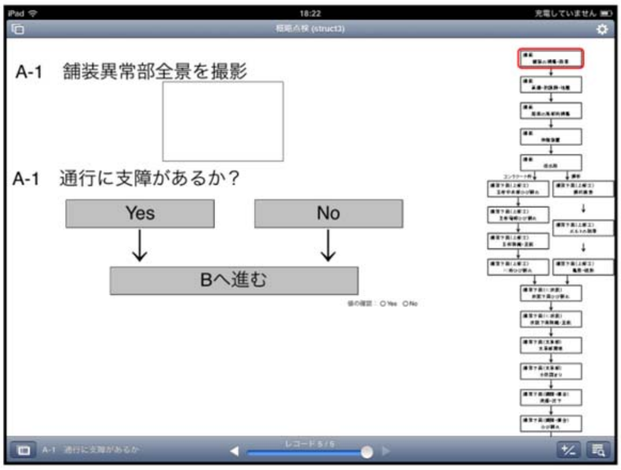


Figure13 modified screen design (dialogue form)

4. ANALYSIS OF PAST REPAIRING DATA

4.1 Background

Collecting inspection data is not sufficient for rational maintenance in coastal area. We have to study what is best way to manage coastal bridges suffered by salt attack. Figure14 shows examples of re-deteriorated concrete bridges on the coast of Niigata prefecture. These bridges were repaired with patching and painting repair method several years ago. It is clear that the repair was not effective. So far no study has ever tried to clear actual durability of repaired bridges. The purpose here is to clear the effect of repair in bridges suffered by salt attack.

Figure14 re-deteriorated PC bridges in Niigata pref.

4.2 Method for investigation

Because inspection data had not been stored until recently, it is impossible to evaluate the durability of repaired bridges quantitatively. Instead, we collected construction cost and repair cost stored in road administrator office. Then, we calculated actual maintenance cost for each bridge. As shown in Figure15, National route 8, 18 and 345 were surveyed in this study. The value of currency changes day by day. Therefore, construction cost and repair cost was converted to present value with Corporate Goods Price Index (CGPI) as shown in Figure16.

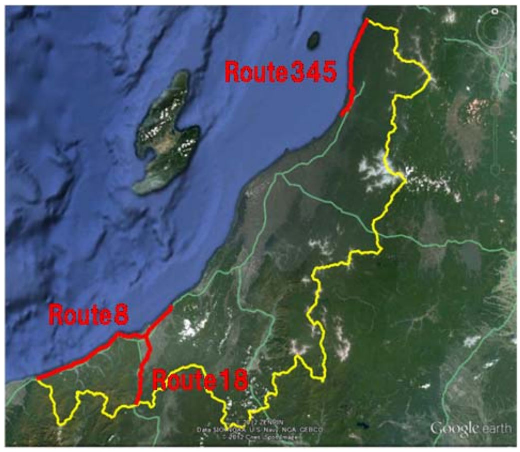


Figure15 surveyed national route

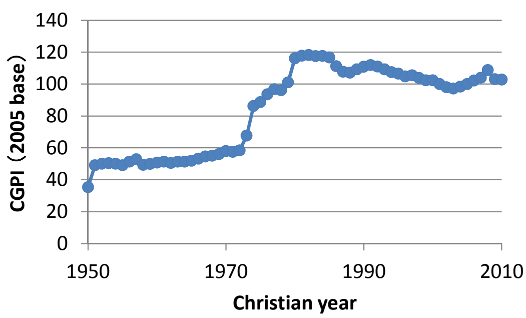


Figure16 Corporate Goods Price Index used for converting to present value

4.3 Influence of distance from coastal line on total cost

Figure 17 shows the growth of total cost of steel girder bridges which locate more than 500 m apart from coastal line. In this figure, total cost is divided by initial construction cost to compare with other bridges. Seismic strengthening and slab strengthening for load increase are not included to the total cost because these repairs do not relate to chloride deterioration. Most bridges have not been repaired except for periodical repaint. Therefore, total cost stays low value in every bridge. It is clear that 500 m is enough distance to avoid salt attack in Niigata prefecture.

Figure18 shows the growth of total cost of concrete and steel bridges which locate less than 150 m from coastal line. Every bridge in this figure is suffered by chloride attack. These bridges were repaired by patching and painting repair method several times. Therefore, total cost reaches twice of construction cost in most cases. In case of A, B and C bridge, total cost exceeds 3.5 times of initial cost. These bridges are pre-tensioned PC bridges. The reason of higher repair cost in pre-tensioned PC bridges is remained to be solved.

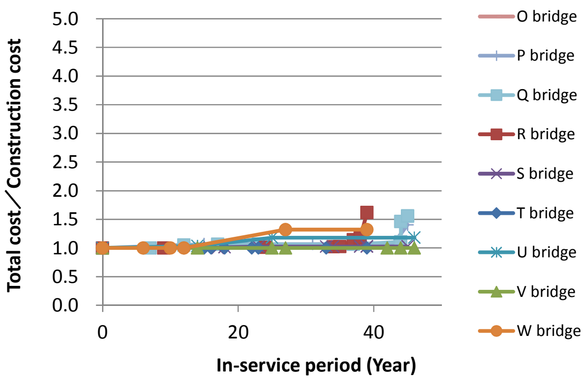


Figure17 the growth of total cost of steel girder bridges (more than 500 m apart from coastal line)

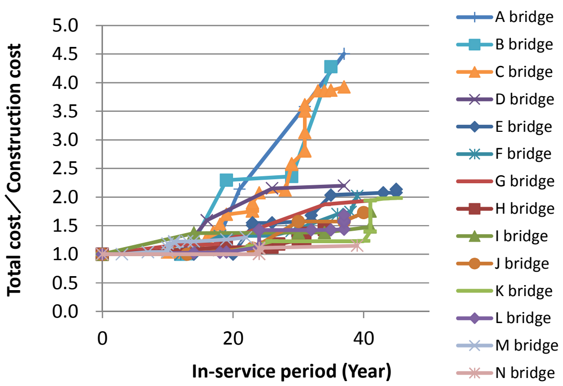


Figure18 the growth of total cost of concrete and steel bridges (less than 150 m from coastal line)

4.4 Comparison of repairing method

In case of B bridge, two types of repairing methods were used. As shown in Figure19 (a), patching and painting repairs were applied except 8th span. 8th span was repaired by cathodic protection. Total cost of each span is compared in Figure20. Cathodic protection was applied 23 years after construction. Although cost of cathodic protection is higher than patching and painting repairs, maintenance cost after repair is cheap and re-deterioration has not occur until now in 8th span. On the other hand,

(a) patching and painting (7th span)

(b) cathodic protection (8th span)

Figure19 repair method in B bridge

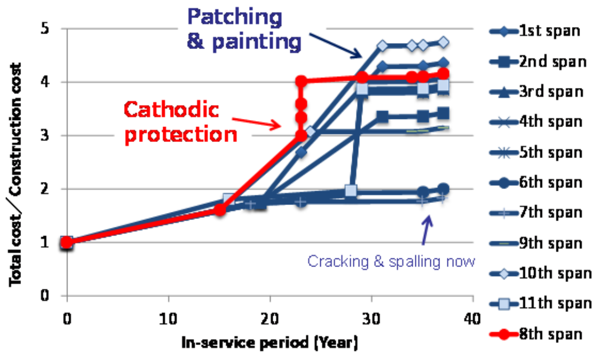


Figure20 the growth of total cost of each span in B bridge

re-deterioration is repeated in case of patching and painting repairs in every span. As a result, total cost is similar in both repair methods at present. Because the history of cathodic protection in Japan is not long, the durability of cathodic protection should be verified in future to make rational maintenance strategy in coastal area.

5. CONCLUSIONS

To minimize the maintenance cost of bridges deteriorated by salt attack in Niigata prefecture, Japan, we started to educate engineers who work in regional companies as a first step. As a second step, we developed web database system which succeeded to reduce inspection cost. Finally, total costs of bridges deteriorated by salt attack were analyzed for rational maintenance strategy. We are now close to our goal.

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