STUDY ON AN EFFECTIVE BRIDGE MANAGEMENT METHOD FOR LOCAL GOVERNMENT

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***ABSTRACT*:** In this study, it aims at considering an effective management method of bridges for comparatively small local government like a city or a town. Specifically, the management effect of waterproofing system effective in the preventive maintenance for reinforced concrete slab (RC slab) was confirmed by the numerical simulation of actual bridges. In numerical simulation, deterioration prediction of RC slab using waterproofing system was modeled. And the management effect of waterproofing system by the difference in plan years is evaluated by numerical simulation on maintenance cost of RC slab in which management levels differ.

KEYWORDS: bridge management, preventive maintenance, local government, reinforced concrete slab (RC slab), waterproofing system

1. INTRODUCTION

In Japan, some bridges improved intensively at rapid economic growth are superannuated. And, the soundness of bridge is falling sharply by various deterioration, such as corrosion, fatigue, Alkali-Silica Reaction (ASR). Many bridge engineers have appealed against the necessity for preventive maintenance in consideration of such the present condition of bridge management. The preventive maintenance is carrying out periodical inspection, predicting the soundness of bridges in the future, and performing preventive measure before deterioration arises. By this preventive maintenance, a bridge can realize extension of life-span and reduction of life cycle cost. However, in local government, the measure of preventive maintenance is behind for reason of insufficiency of budget and engineers.

In this study, it aims at considering an effective management method of bridges for comparatively small local government like a city or a town.

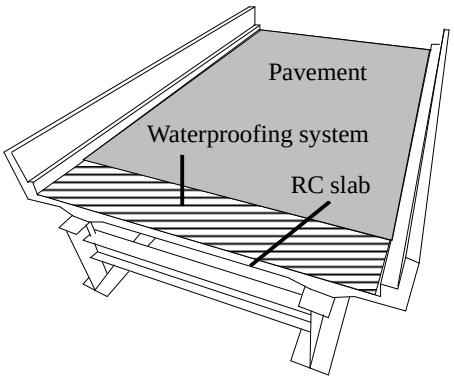


Fig.1. The waterproofing system of RC slab

Especially, the effect of the waterproofing system was examined for management of reinforced concrete slab (RC slab) in Fig.1. First of all, the deterioration prediction of RC slab using the waterproofing system was modeled. And, a life cycle cost in these scenarios was also calculated. Secondary, the management effect of waterproofing system effective in the preventive maintenance for RC slab was confirmed by the numerical simulation of actual bridges. Finally, the management effect of waterproofing system by the difference in plan years

is evaluated by numerical simulation on maintenance cost of RC slab in which management levels differ.

2. DETERIORATION AND COST MODEL OF REINFORCED CONCRETE SLAB USING WATERPROOFING SYSTEM

2.1 The maintenance scenarios

In bridge management, some maintenance scenarios are set up in consideration of traffic environment and importance of road network. For example, the over bridge of expressway or railway in which social influence becomes large when use becomes impossible is set to preventive maintenance scenario, and performs management by comparatively high level. This study defined two preventive maintenance scenarios from which type differs for local government. For example, the preventive maintenance scenario of high management level is applied to the overpass bridge such as expressway or railway, and the preventive maintenance scenario of standard management level is applied to general bridges. In this research, the concept which applies these two types of preventive maintenance scenario is confirmed by the numerical simulation by real bridges.

2.2 Soundness and deterioration model of RC slab

First of all, this research defines the soundness of RC slab as shown in Table 1. The soundness of RC slab was set up in five phase, such as the damage incubation phase (Grade 5 to 4), the damage progress phase (Grade 4 to 3), the first half of damage accelerated phase (Grade 3 to 2), the second half of damage accelerated phase (Grade 2 to 1), and the damage deterioration phase (Grade 1 to 0). Secondary, the deterioration model of RC slab was set up as the period holding these soundness as shown in Table 2. The deterioration model of RC slab with the waterproofing system is set up to each of two different deterioration models. Generally, the deterioration speed of RC slab becomes slow by applying waterproofing system. At the deterioration model proposed by this study, the effect of waterproofing system is expressed by setting up the longer period holding the soundness in damage accelerated phase.

2.3 Maintenance cost include waterproofing system of RC slab

The repair method corresponding to each soundness and its cost are shown in Table 3. In this study, the deterioration speed of RC slab becomes slow by application of the waterproofing system in the first half of damage accelerated phase and the second half of damage accelerated phase. Therefore, repair cost is the sum total of repair cost in each soundness phase and waterproofing system cost. The repair method in the first half of damage accelerated phase is the steel plate bonding method, and it set the repair unit price to 35,700 [JPY/m^2]. And, the repair method in the second half of damage accelerated phase is the steel plate bonding and overlay method, and it set the repair unit price to 63,900 [JPY/m^2]. The installation cost of the waterproofing system was estimated as 2,200 [JPY/m^2].

3. NUMERICAL SIMULATIONS

3.1 The basic information of real bridges

The basic information of 6 real bridges, which are in Ibaraki Prefecture, Japan to examine the effect of waterproofing system of RC slab, is shown in the Table 4. All the bridges are built before 2000 year, and there are various bridges over railway, expressway, river, and so on. The inspection of these bridges are carried out in 2010 year, and the soundness of RC slab is judged to be the grade 5, Grade 4, and Grade 3. Moreover, the deterioration model of RC slab set up Type1 and Type2.

Table 1. The definition of soundness of RC slab

Phase of soundness of RC slab	The situation of deterioration
Damage incubation phase (Grade 5 to 4)	There is no crack. Or there are small cracks of one way.
Damage progress phase (Grade 4 to 3)	There are cracks of the bridge transverse direction with growth. Or there are cracks of the bridge longitudinal direction.
First half of damage accelerated phase (Grade 3 to 2)	The crack with the shape of lattice occurs. And the number of cracks increases.
Second half of damage accelerated phase (Grade 2 to 1)	There are many cracks with the shape of lattice. And there is leakage or free lime.
Damage deterioration phase (Grade 1 to 0)	There is the lack of slab concrete. Or there is steel rod exposure.

Table 2. The deterioration model of RC slab

The deterioration model of RC slab		The period holding soundness (Year)				
		Grade 5 to 4	Grade 4 to 3	Grade 3 to 2	Grade 2 to 1	Grade 1 to 0
Type1	without waterproofing system	3	4	11	11	8
	with waterproofing system	3	4	13	13	8
Type2	without waterproofing system	4	5	13	13	9
	with waterproofing system	4	5	15	15	9

Table 3. Maintenance cost of RC slab

Soundness of RC slab	Repair Method	Cost (JPY/m^2)
Damage incubation phase (Grade 5 to 4)	Observation	0
Damage progress phase (Grade 4 to 3)	Grouting	3,200
First half of damage accelerated phase (Grade 3 to 2)	Steel plate bonding	35,700
Second half of damage accelerated phase (Grade 2 to 1)	Steel plate bonding and overlay	63,900
Damage deterioration phase (Grade 1 to 0)	Replacing	66,700

Table 4. The basic information of 6 real bridges for verification

Bridge	Construction year	Length of bridge (m)	Effective width (m)	Intersection situation	Inspection year (soundness of RC slab)	The deterioration model of RC slab
A	1975	21.6	19.0	Railway	2010 (Grade 5)	Type1
B	1993	68.8	11.5	Expressway	2010 (Grade 3)	Type2
C	1980	43.0	9.5	Expressway	2010 (Grade 5)	Type1
D	1990	39.0	6.5	Road	2010 (Grade 4)	Type2
E	1982	25.0	5.0	Road	2010 (Grade 5)	Type1
F	1970	19.7	5.5	River	2010 (Grade 3)	Type2

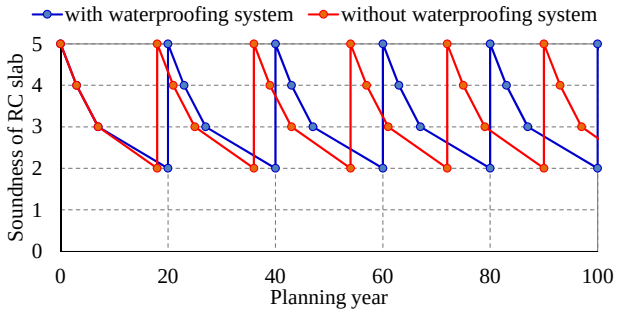
Table 5. The rule of change of maintenance scenario

Case No	The preventive maintenance scenario	
	High management level (bridge)	Standard management level (bridge)
Case1	A, B, C, D, E, F	Nothing
Case2	A, B, C, D, E	F
Case3	A, B, C, D	E, F
Case4	A, B, C	D, E, F
Case5	A, B	C, D, E, F
Case6	A	B, C, D, E, F
Case7	Nothing	A, B, C, D, E, F

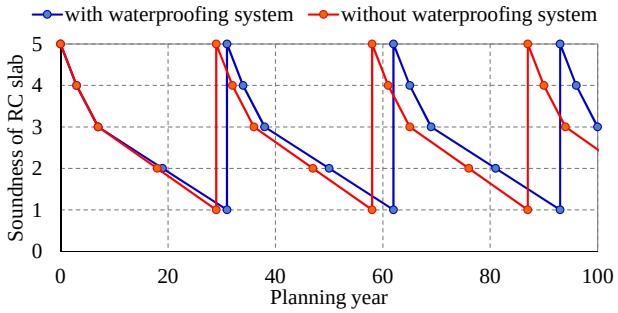
3.2 The calculation condition of numerical simulations

The usefulness of the waterproofing system of RC slab for local government is discussed through numerical simulations. This study defined two preventive maintenance scenarios from which type differs for local government. These are the preventive maintenance scenario of high management level and preventive maintenance scenario of standard management level. In this numerical simulations, these scenarios are changed regularly, and the usefulness of the waterproofing system of RC slab of six real bridges is investigated.

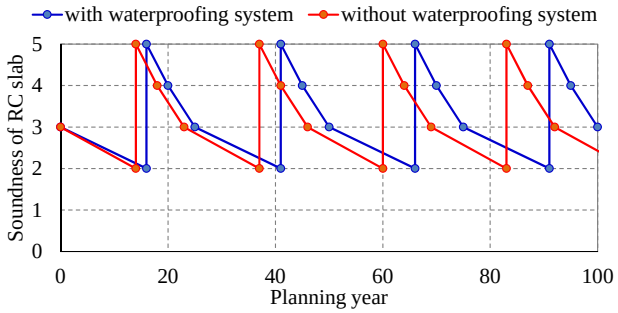
Concretely, the preventive maintenance scenario of high management level is the scenario repaired when the soundness of RC slab amounts to Grade 2, and the preventive maintenance scenario of standard management level is the scenario repaired when the soundness of RC slab amounts to Grade 1. In addition, the waterproofing system of RC slab is constructed at the same time repair to each soundness is carried out.



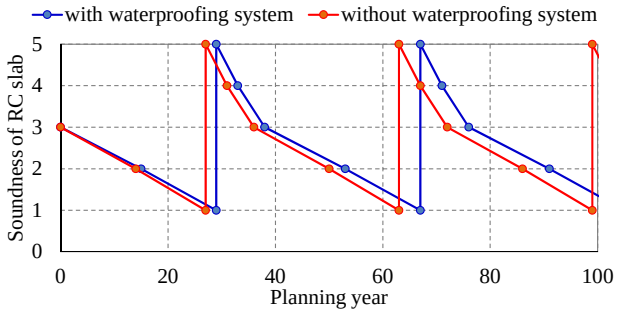
(a) High management level (Bridge A)



(b) Standard management level (Bridge A)



(c) High management level (Bridge B)



(d) Standard management level (Bridge B)

Fig.2. Simulation result of deterioration of RC slab

The rule of change of scenario is shown in Table 5. The scenario of Case 1 repairs all the bridges in the preventive maintenance scenario of high management level. On the other hand, the scenario of Case 7 repairs all the bridges in the preventive maintenance scenario of standard management level. Furthermore, in each case, both the life cycle cost at the time of applying the waterproofing system and the life cycle cost when not applying the waterproofing system estimate. Three patterns in 50 years, 80 years, and 100 years were set up during the calculation of life cycle cost.

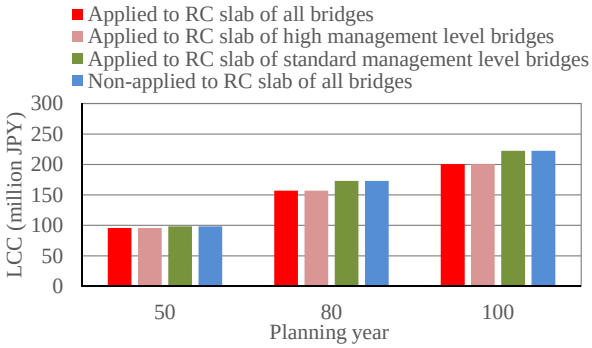


Fig.3. Calculation result of LCC in Case1

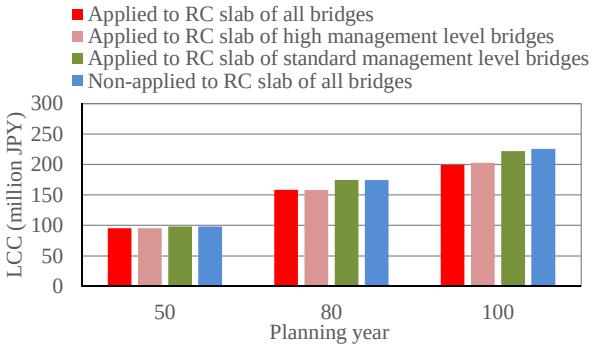


Fig.4. Calculation result of LCC in Case2

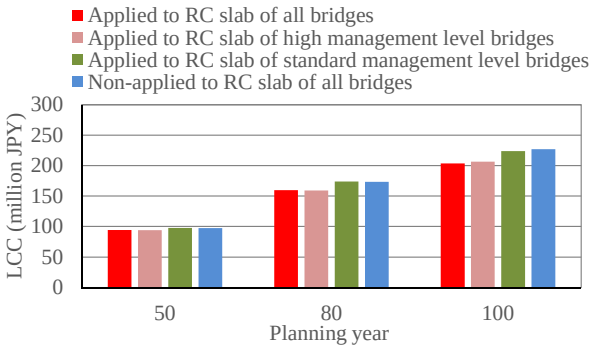


Fig.5. Calculation result of LCC in Case3

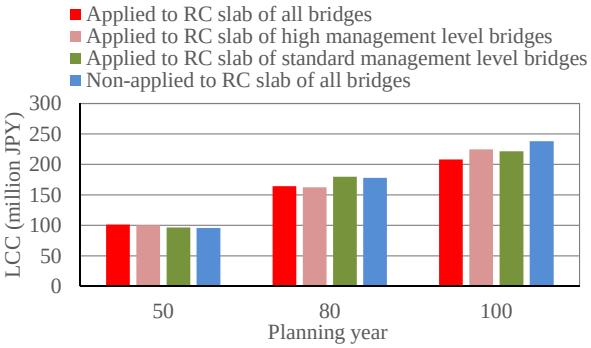


Fig.6. Calculation result of LCC in Case4

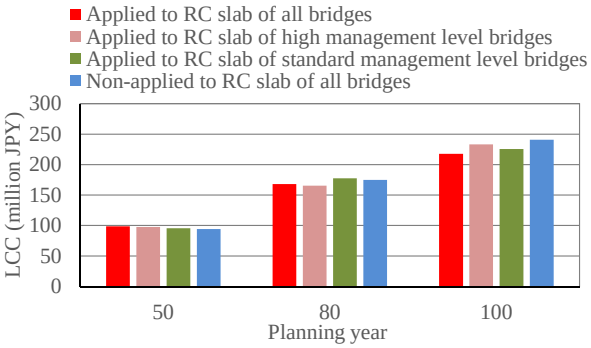


Fig.7. Calculation result of LCC in Case5

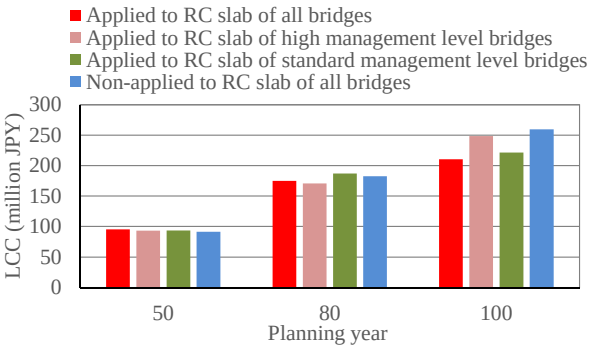


Fig.8. Calculation result of LCC in Case6

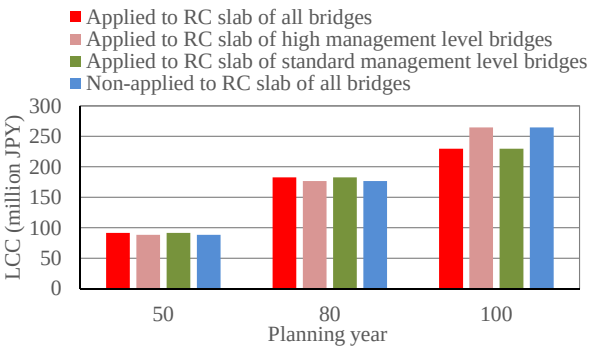


Fig.9. Calculation result of LCC in Case7

3.3 The result of numerical simulations and verification

First of all, the simulation result of deterioration of RC slab in bridge A and bridge B is shown in Fig.2. Fig.2 (a) and (c) shows the preventive maintenance scenario of high management level which repairs when the soundness of RC slab amounts to Grade 2, and Fig.2 (b) and (d) shows the preventive maintenance scenario of standard management level which repairs when the soundness of RC slab amounts to Grade 1. The durability of RC slab is improving by applying the waterproofing system in both of maintenance scenarios. Moreover, bridge A is having set up deterioration of Type1, and its deterioration is slightly earlier than bridge B. The

waterproofing system is raising the durability of RC slab of both of bridges.

Next, the calculation result of LCC of each cases is shown in Figs. 3 to 9. The effect of waterproofing system cannot be highly estimated in all cases when the simulation planning year is 50 years. However, the effect of waterproofing system appears notably when the simulation planning year are 80 years or 100 years. Moreover, in Case1 to Case3, the LCC of RC slab which has preventive maintenance scenario of high management level is cheap. On the other hand, in Case5 to Case7, the LCC of RC slab which has preventive maintenance scenario of standard management level is cheap. Therefore, when RC slab in which the soundness differs was maintained by a fixed management level in local government, it confirmed that the life cycle cost was reduced by applying the waterproofing system to RC slab of many bridges.

4. CONCLUSIONS

The following conclusions may be made from this study:

1) The waterproofing system is effective in delaying deterioration of RC slab. This effect can be confirmed in the preventive maintenance scenario both of high management level and standard management level.

2) According to the difference in the maintenance scenario or the plan period of RC slab, there was some suitable applicable condition in using the waterproofing system of RC slab. For example, the planning year is more considered for a long time, the effect of waterproofing system more appears notably.

3) The waterproofing system of RC slab is effective as the method of reducing Life Cycle Cost. Therefore, the waterproofing system is applicable as the effective management technique of local government.

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