EFFECT OF RESIDUAL SERVICE LIFE AND LIFETIME OF REPAIR METHODS ON THE CHOICE OF REPAIR OPTIONS

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1. Introduction

Enormous amount of money is investing for the rehabilitation of infrastructure like bridges by the government. Efficiently manage the infrastructure system thus become critical issue to the engineers and decision makers. This study will provide some light on the choice problem between same type of repairing having different costs based on residual service life of structure and life time of repairing and thus efficiently manage the structure.

2. Reliability based failure

The structural performance function of state 'z' for corrosion initiation of reinforcing steel and crack width are shown below.

$$z = C_{\lim} - C(x,t) \tag{1}$$

$$z = w_d - w_c \tag{2}$$

Equations 1 and 2 can be generalized as load –capacity model shown in Eq. 3.

$$Performance = Strength - Load = A - B \tag{3}$$

where C_{lim} and w_d are the threshold chloride concentration and maximum allowable crack width, $C(x,t)$ is chloride ion concentration (kg/m^3) [1] [2] and w_c is the crack width (mm) as reference [3].

Reliability index can be determined using load-capacity model.

$$\beta = \frac{1}{V_z} = \frac{\mu_z}{\sigma_z} = \frac{\mu_{\ln A} - \mu_{\ln B}}{\sqrt{\sigma_{\ln A}^2 + \sigma_{\ln B}^2}} \tag{4}$$

V_z is the coefficient of variation of performance function z. All random variables are taken as log-normal distribution. Thus μ_{lnA}, μ_{lnB}, σ_{lnA} and σ_{lnB} are the mean of strength, load and standard deviation of strength, load respectively.

$$P_f(t) = \phi(-\beta) \tag{5}$$

The performance of deteriorating structure is characterized by probability of failure $P_f(t)$ or damage over the interval [0, T] as shown in Eq. 5 where ϕ is the standard normal cumulative distribution function.

The state or reliability of structure thus comes to as follow.

$$R(t) = 1 - P_f(t) \tag{6}$$

The time to initiation of corrosion is referred as t_i and t_{cr} is named as time to reach allowable crack. Thus, the study reports the failure time as the summation of both the times indicated above.

$$t_f = t_i + t_{cr} \tag{7}$$

It is assumed that when $R(t)$ < 0.8 structure needs repair.

3. Random variables

The random variables need to predict crack width w_c is same as in reference [3]. Chloride ingress is computed using equation stated in reference [1] [2] with folloing random variables in table 1.

Table 1. Random variables

Parameter	Case 1	Case2
Cover depth, x (cm)	4 (0.1)	6 (0.1)
Hydraulic Permeability, k (m/s)	1e^{-14} (0.1)	1e^{-14} (0.1)
Saturation Degree, S (%)	80 (0.1)	80 (0.1)

Mean (COV)

These two cases are analyzed to see the effect of residual service life.

4. Life cycle cost

LCC plays key role in maintaining the infrastructure and provides necessary information to the manager or owner. In this study LCC is computed in the following way.

$$LCC = \sum_{t=0}^{T} (AgingCost + DelayCost + RepairCost)$$

Aging cost and delay cost are carried by the owner and road user and they are the functions of probability of failure and age of structure as well as traffic volume respectively.

4.1 Repair cost

This cost is provided by the owner due to repair when the performance goes down below the required.

$$Repair\ Cost = 0 \qquad ....u = 0 \tag{8}$$

$$Repair\ Cost = \left[\begin{array}{l} Fixed\ Cost + \\ \left(unit\ Cost \times area \times P(f)_{t_{i-1}} \times \Delta x_{t_i} \right) \end{array} \right] \times \frac{t_{RSL}}{t_{Repair}} \qquad ....u = 1 \tag{9}$$

where *unit cost* is the cost of repair for unit area,

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$P(f)_{t_{i-1}}$ is the failure probability just before repair, Δx_{t_i} is the change of state done by repair i at time t, t_{RSL} is the residual service life in years, t_{Repair} is the life time of repair material.

The following table shows the type of repair methods and their costs.

Table 2. Cost of repairing

Types	Fixed Cost ($)	Variable Cost ($/m^2)	Life time (yrs.)	Effect of repairing
RM1-Cathodic Protection-1	6870	97	20	Threshold Cl^- increased by 1.5 times
RM2-Cathodic Protection-2	6870	150	35	Threshold Cl^- increased by 1.5 times

5. Results and Discussion

5.1 Effect of residual service life

Figure 1 shows the state dynamics for case 1 and 2. Case 2 has high durability in respect of cover depth that requires less number of repairs. It is found from figure 2 that for each repairing time, RSL is greater for case 1 than that of case 2.

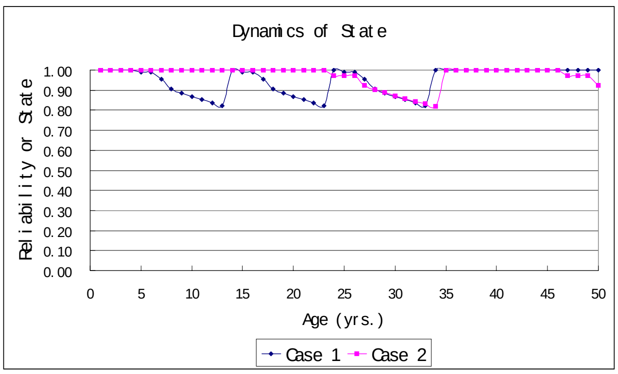

Fig.1. Effect of cover depth on state dynamics

5.2 Effect of life time or repairing

Figure 2 and 3 show the comparison between repair options for case 1 and 2 respectively. In figure 5 RM2 has higher value than RM1 due to high variable cost of RM2, but figure 2 shows opposite. This is due to RSL and lifetime of repair option. For case 2 lifetime of both the repair options is larger than RSL so total cost depends on the cost of repairing. For case 1 lifetime of RM1 is shorter than RSL for first 2 time of repairing where lifetime of RM2 is almost same or greater than RSL.

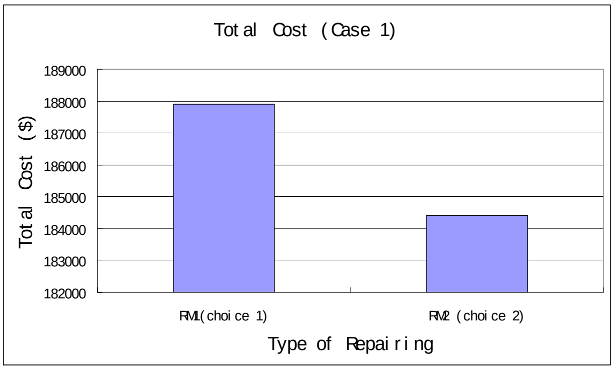

Fig.2. Effect of repair methods on total cost (case 1)

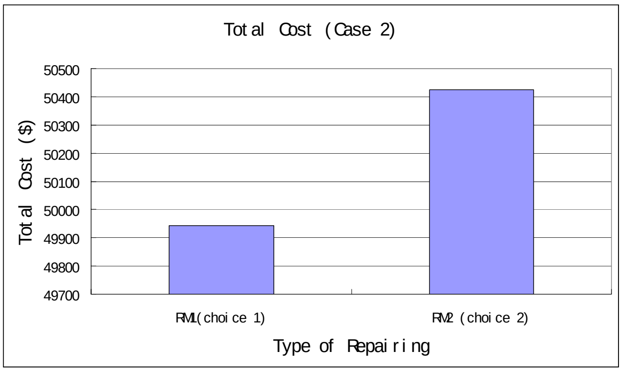

Fig.3. Effect of repair methods on total cost (case 2)

6. Conclusions

1. High durability of structure cause less number of repair as well as it costs less LCC.
2. Residual service life of structure and lifetime of repairing play important role in selecting repair options.
3. Cost of repair is not only factor that control the choice of repair options.

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