# Optimal Research on Effect- Cost-Life of Bridge Preventive Based on the Particle Swarm Optimization

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**Keywords:** Bridge Engineering; Bridge preventive maintenance; Effect- Cost-Life; Optimization; Multiple Egression; MATLAB.

**Abstract:** This paper constructs the optimization model of bridge based on Particle Swarm Optimization and the effect of preventive maintenance, maintenance cost, durability and prolonging the service life of the three objective integrated control. To establish a bridge of preventive maintenance life cycle cost model and to build a bridge deterioration preventing and curing cycle mathematical model based on extended maintenance durability, it introduces the SPSS software to calculate the curing effect on the durability life prolonging, the multivariate regression equation of life and maintenance cost, and application MATLAB to achieve optimization algorithm of information, in order to realize the three big targets of integrated optimization control bridge prevention maintenance, that providing a set of reliable, suitable theory system on maintenance time and cost options for the bridge preventive maintenance.

## 1. Introduction

The construction of the bridge is the premise, in the development of bridge maintenance management is the guarantee of healthy development of the bridge, the implementation of preventive maintenance of the bridge, is beneficial to reduce life cycle cost, delay bridge repair and overhaul period, improving the quality of the bridge service, extend the service life of the bridge, and the maintenance of the prevention first and prevention &treatment combination principle of work, have less effect on the traffic, provides a good environment, create a good social and economic benefits.

In this paper can solve at the right time to implement the preventive maintenance measures with the least amount of maintenance cost, to keep Bridges good operation state and design service life and can avoid major bridge repair or replace the huge cost and traffic the significant influence on the society. This article is seeking to establish a can truly realize the maximization of the curing effect of bridge preventive maintenance, maximum service life and maintenance cost minimization optimization model of the integrated control of the three objectives, forming a bridge effect of the implementation of preventive maintenance optimization is reliable, applicable evaluation system.

## 2. Bridge preventive maintenance

### 2.1 Concept of bridge preventive maintenance

Bridge preventive maintenance to ensure the durability of bridge design service life period of predetermined maintenance measures should be taken, by its basic principle is at the right time to take the appropriate measures of the bridge, the bridge's ability to maintain the established function, core idea is to require the best cost effective maintenance measures, emphasized the planning of maintenance and management. Preventive maintenance measures of Bridges can be divided into two kinds: during the design phase to determine the operating period of scheduled maintenance measures should be taken.

  DOI: 10.25236/iccse.18.008

## 2.2 Full life cycle cost model for bridge preventive maintenance

The preventive maintenance project of bridges is featured by simple engineering contents, short operation period and complex process. According to engineering characteristics of preventive maintenance, costs closely related to the preventive maintenance project are selected from the cost constitution elements of construction projects to establish cost structure of the preventive maintenance project.

According to the effect model of multiple preventive maintenance, when preventive maintenance activity is used to the degraded bridges, durability status of the original bridge member is $d_0$, and the degradation rate is $\alpha$; the durability index increases by $\gamma_1$ after implementing the first time of preventive maintenance at $t_{P1}$, and corresponding cost is $C_1$. Then, the durability index continues to degrade at $\theta$, the maintenance effect disappears at $t_{P1}+t_{PD}$ and the degradation rate is restored to $\alpha$; the second time of preventive maintenance is applied at $t_{P1}+t_P$, the structure durability index increases by $\gamma_2$, and corresponding cost is $C_2$, and so on. The number of total times that preventive maintenance has been carried out when the bridge reaches its service life is $n$, and the calculation model for costs of preventive maintenance in life cycle of the bridge member under the condition of considering time value of funds is :

$$C(t_{P1},t_P)=\sum_{i=1}^{n(t_{p1},t_p)} C_i(t_{P1},t_P)\frac{1}{(1+r)^{t_{p1}+(n-1)t_p}} \qquad (1)$$

Where:

$C_p(t_1,t_n)$ - Total costs of preventive maintenance of bridges;

Cp(t1,tn) - Total costs of preventive maintenance of bridges;

n(tp1,tp) - The number of times that preventive maintenance is carried out in life cycle of bridges; All these parameters are related to starting time tp1 and time interval tp of preventive maintenance

r - Social discount rate (%), the expenditure of preventive maintenance projects comes from the maintenance costs. Different from investment of the construction project, the value of social discount rate shall be lower than the construction project.

## 2.3 Basis for establishment of optimization model of particle swarm optimization

This paper tries to find a method for determining the best time for preventive maintenance which can achieve three targets including maximized maintenance effects and service life and minimized maintenance costs. The criterion of arranging preventive maintenance of bridges in the life cycle is meeting the requirements of structure durability in the life cycle, and ensuring that the maintenance costs in its life cycle is minimized at the same time.

Due to the fact it is difficult to quantify the maintenance effects in optimization of actual preventive maintenance project, so it always carries out analysis and optimization on service life and maintenance costs, and there are few mathematical models involving the goal of maintenance effects.

In order to study the quantification equation of maintenance effects, this paper establishes a multivariate function relation $Q=f(C,\ \mathrm{t}_{\mathrm{ext}})$ between the maintenance effects and durable life extension years and the maintenance costs, uses $SPSS$ software to analyze the multiple regression of maintenance effects to durable life extension years and maintenance costs. $SPSS$ is to carry out linear or nonlinear regression analysis through fitting a group of observation values with the least square method.

This tool can be used to analyze how a single dependent variable is affected by one or more independent variable(s). Based on the analysis data, the multiple regression equation of maintenance effect to durability life extension years and maintenance cost is established as follows:

$$Q = \alpha C + \beta t_{ext} + \gamma C t_{ext} + \phi C^2 + \varphi t_{ext}^2 + \lambda \quad (2)$$

## 3. Engineering Case

Take Dongzhai New Bridge of some Province as an example, it is located in K339+034 section of Ningwu-Baijiatan Provincial Highway with a total length of 93.01m. Superstructure of it is a 4×20m I beam made by prestressed concrete and its substructure is column piers with 0# abutment as gravity abutment and 4# abutment as ribbed slab abutment to enlarge the foundation.

Design load of this bridge is Highway-I. Practical subject results can be confirmed according to preventive maintenance timing of the bridge with knowledges that the implementation cycle of regular surface protective coating of bridge concrete members is 13 years and the first implementation is 6 years since the design working time of the bridge.Now using models in above sections to make assessment on implementation effect of bridge preventive maintenance.

(1) The concrete surface organic organosilane penetrant method will be used to isolate concrete from corrosive mediums and improve concrete durability. The maintenance effect of the method lasts for 10 years, and after the effect disappears, the components are degraded according to the carbonation regularity of the original concrete.

The measured carbonation depth of this bridge is 8.4mm. According to the estimation model of carbonation coefficient in *Standard for Durability Assessment of Concrete Structures* , the carbonation remains $x_0$ at this time is 14.83mm and the time for rebars starting to corrode is 33.6 years. At this point, the durability limit is reached, and 16.4 years are left compared with the objective of 50-year service life of the bridge and preventive maintenance measures are required.

(2) Durability life extension and maintenance cost $t_{ext}$ $C_p(t_1, t_n)$

The environment in which the bridge is located is a typical inland climate and the environmental conditions have no significant change in estimated service life, i.e. $\beta_1 = \beta_2 = \beta_n$, $t_1$ has a value range of 11-23 in this case and $n$ has a value range of 1,2 ..., the extension life of preventive maintenance is calculated according to formulas(1),(2).

The actual area of this bridge painted with organosilane penetrant is 2264 $m^2$ . The project cost includes the direct engineering fee, the construction measurement fee, the enterprise management fee, and the integrated unit price of other fees of about 180 yuan / $m^2$, so the single time of preventive maintenance C = 479,520 yuan, that is, the preventive maintenance cost for each time.

As the project is a maintenance project, the funding source is maintenance fee. Different from the investment in construction projects, the social discount rate should be lower than that of the construction project. So here we take the 1-year fixed interest rate 3% as the reference value.

(4) Multiple regression equation of maintenance effect on the durability life extension term and maintenance cost

The implementation effect of preventive maintenance is assessed according to the project's expected implementation objectives100%≥Q≥97%.

The calculated results are shown in Table 1.

By *SPSS* regression analysis, it can be concluded that:

$$\alpha = 4.221 \quad \beta = 0 \quad \gamma = 0 \quad \phi = 0 \quad \varphi = -0.011 \quad \lambda = 98.076$$

The following regression equations are obtained for the maintenance effects on the durability life extension term and maintenance cost:

$$Q = 4.221T - 0.011C^2 + 98.076$$

(5) The best time selection of particle swarm optimization

In the case, the regression equation of maintenance effect ondurability life extension termand maintenance cost is established by using the method of regression, and the quantization ofdurability life extension termand maintenance cost of the maintenance effect is completed.

The optimization model is established. With programming, the optimal solution is obtained by applying particle swarm optimization iteration.We can see that the first preventive maintenance time is the fifteenth year and the interval of 5.5 years is the most reasonable preventive maintenance time.

Table 1 Data sheet of maintenance effect on the durability life extension term and maintenance cost

| No. | $Q$ | $T$ | $C$ | $TC$ | $T^2$ | $C^2$ |
|---|---|---|---|---|---|---|
| 1 | 100 | 19.3 | 84.5 | 1630.85 | 372.49 | 7140.25 |
| 2 | 100 | 20.2 | 86.4 | 1745.28 | 408.04 | 7464.96 |
| 3 | 99 | 18.4 | 82.7 | 1521.68 | 338.56 | 6839.29 |
| 4 | 99 | 19.3 | 84.5 | 1630.85 | 372.49 | 7140.25 |
| 5 | 99 | 20.2 | 86.4 | 1745.28 | 408.04 | 7464.96 |
| 6 | 98 | 17.5 | 80.9 | 1415.75 | 306.25 | 6544.81 |
| 7 | 98 | 18.4 | 82.7 | 1521.68 | 338.56 | 6839.29 |
| 8 | 98 | 19.3 | 84.5 | 1630.85 | 372.49 | 7140.25 |
| 9 | 98 | 20.2 | 86.4 | 1745.28 | 408.04 | 7464.96 |
| 10 | 97 | 16.6 | 79.2 | 1314.72 | 275.56 | 6272.64 |
| 11 | 97 | 17.5 | 80.9 | 1415.75 | 306.25 | 6544.81 |
| 12 | 97 | 18.4 | 82.7 | 1521.68 | 338.56 | 6839.29 |
| 13 | 97 | 19.3 | 84.5 | 1630.85 | 372.49 | 7140.25 |
| 14 | 97 | 20.2 | 86.4 | 1745.28 | 408.04 | 7464.96 |

## 4. Conclusion

The particle swarm algorithm is introduced into the effect of preventive maintenance and maintenance cost, durability, longevity of the integrated control of the three objectives optimization model, using SPSS software to calculate the curing effect of fixed number of year of the durability life extension and maintenance cost of multivariate regression equation, for preventive maintenance time and cost of decision provides a strong practicability, high reliability, the method of theoretical system and to perfect our country bridge preventive maintenance has very important practical significance.

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