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Author(s)	SUTOH, A.; MARUYAMA, O.; TANAKA, H. et al.
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PROBABILISIC MODEL FOR DAMAGE ACCUMULATION IN CONCRETE TUNNEL LINING USING INSPECTION DATA

A. SUTOH[1*], O. MARUYAMA[1], H. TANAKA[2], and T. SATO[3]

[1]*Dept. of Urban and Civil Engineering, Tokyo City University, Japan*
[2]*Dept. of Applied Analysis and Complex Dynamical Systems, Kyoto University, Japan*
[3]*Civil Engineering Research Institute for Cold Region, Japan*

ABSTRACT

This paper propose to the stochastic damage accumulation model of concrete tunnel lining based upon actual inspection data, in order to carry out strategic maintenance and to rationalize life cycle cost analysis for cold region tunnel structures. The evaluation value of deteriorating or damage accumulating tunnel concrete lining structures are non-stationary stochastic processes, and these structures are essentially time dependent reliability problems. For the tunnel management system in Japan, evaluations of the concrete tunnel linings are categorized into several ranks. And, a methodology to identify the Markovian transition probability matrix, which is presented to forecast the degradation process of concrete tunnel linings for actual maintenance procedures. The proposed the damage accumulation model is based upon a stochastic differential equation driven by a Poisson white noise, whose solution process, a damage accumulation.

Keywords: Deterioration model, Stochastic differential equation, Tunnel lining.

1. INTRODUCTION

This paper proposes to select of the tunnel lining deterioration models based upon actual inspection data in order to carry out strategic maintenance and to rationalize life cycle cost analysis for tunnel structures. The deterioration of conventional construction method road tunnel lining is non-stationary stochastic processes, and reliability problems of such structures are essentially different of time-independent reliability problems. While the forecasting model of deterioration is one of the central takes in infrastructure asset management, it is often the cases where are few data stocks available for estimating the deterioration forecasting model (See Fig. 1). In this paper, it will be developed to the efficient tunnel maintenance of tunnel lining. Firstly, performance function of the deterioration evaluation value, the methodology of predicting of deterioration is discussed of the stochastic methods of tunnel lining. Secondly, a method is developed to identify degrading process of tunnel lining concrete using inspected data of existing aged tunnels in Hokkaido. The stochastic model of deterioration and/or degrading process is described by the Ito stochastic differential equation.

* Corresponding author: Email: a.sudou@iwata-gr.co.jp

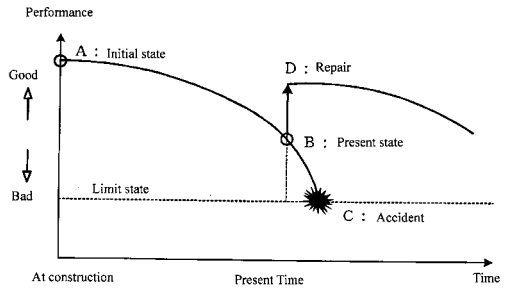

Figure 1: Life cycle cost for performance.

2. STOCHASTIC MODEL OF TUNNEL CONCRETE DEGRADING PROCESS

2.1. Basic Model of Ito Stochastic Equation

The present problem is the estimation and/or identification of the deterioration process of the tunnel lining. The deterioration process of tunnel lining is represented by the Ito stochastic differential equation in Baxter and Rennie (1996).

Here, the deterioration rate or evaluation value $X(t)$ or the performance functions $Q(t_i)$ of the tunnel lining represented by the Ito stochastic differential equation as follows.

$$dX(t) = \beta X(t)dt + \sigma X(t)dW_1(t) \qquad (1)$$

where, β :the constant drift parameter, σ : the constant volatility parameter or the volatility function $P(t_i)$, $W_1(t)$: the wiener process (See Fig. 2).

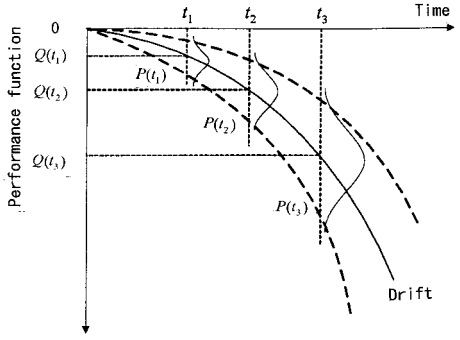

Figure2: Degrading process of tunnel lining.

2.2. Modified Model of Ito Stochastic Equation

In the second place, for the prediction of the individual structure of tunnel lining concrete, a probabilistic approach using the own historical repair data is proposed. And , assume that the performances of tunnel lining recovers immediately after each repair process, so that $Z_i(t)$ becomes discontinuous and returns to vertically at a repair time (Madanat, S. 1997).

$$dZ(t) = \beta Z(t)dt + \sigma Z(t)dW_1(t) + \sum_{i>1} \{Z_1^* - Z_2^*\} l(t - t_1^*) \qquad (4)$$

where, I :the Dirac measure.

The repair of degrading is one of the central actions in infrastructural asset management, it is often the cases where are few existing records available for estimating the degrading forecasting model.

2.3. Identification of the Degrading Process

Inspected data from existing tunnels in Hokkaido are used for the identification of Ito stochastic differential equation. Inspection data of conventional construction method road tunnel has been carried out last several decades, such as crack width, crack length and crack expanse of 182 tunnels. The results summarized as degrading ratio from 0.0(no damage) to 1.0 (critical damage).

Figure 3 shows a degrading ratio of conventional construction method type in terms of tunnel age and the reproduced degrading process by using identified general solution of Ito stochastic differential equation as follows

Conventional type: $X(t)trend = 0.0805e^{0.0197t}$ (5)

Above mentioned reason, these results indicate degrading process of a group of tunnel. Therefore, it is observed that these results are satisfactory for the degrading process of the tunnel lining concrete.

Here, the using the degrading ratio of conventional construction method type inspection data are divided 4 periods, in which divided the 10~20 years, 21~30 years, 31~40 years, 41~50 years.

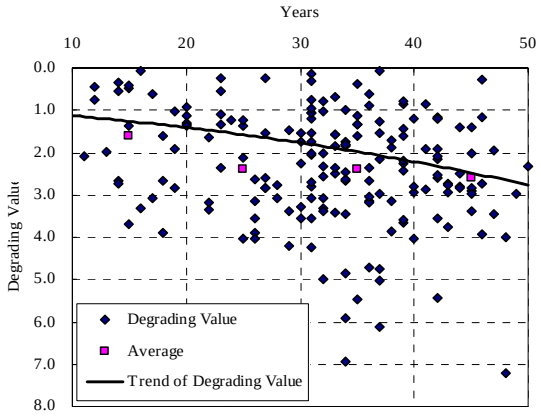

Figure3: Degrading and Average Value of Tunnel Lining.

In the figure 4 shows an increase of the volatility or distribution average of conventional construction method type in terms of tunnel age and the reproduced degrading process by using identified Ito stochastic differential equation. Therefore, the tunnel lining crack evaluation results represented by the Ito stochastic differential equation were generally correct to results of detailed inspection at site. Especially, in the Ito stochastic differential equation, the variance or distribution of considered repair effect is log-normal distribution (see Figure 4).

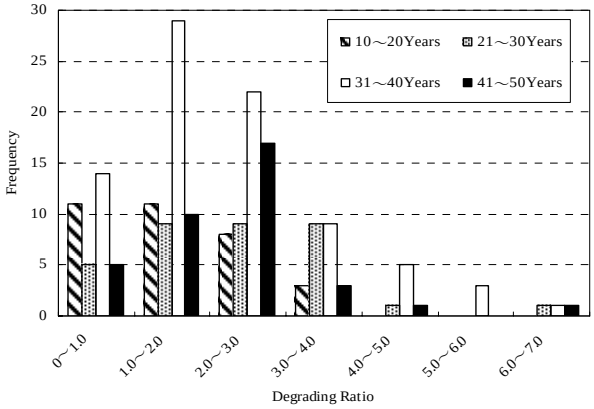

Figure 4: Distribution of Degrading.

3. ESTIMATION OF DEGRADING PROCESS

While the forecasting of degrading process is one of the important things in infrastructure asset management, a procedure is developed to estimatie of degrading process of tunnel lining concrete using inspected data of existing aged tunnels in Hokkaido. Table 1 shows the reproduced degrading process by using identified general solution of Ito stochastic differential equation. Here, the using the degrading ratio of conventional construction method type inspection data are divided 4 periods, in which divided the 21~30 years, 31~40 years, 41~50 years. These results indicate degrading process of group tunnels.

Table 1 Identified Parameters

T(year)	β	σ
20	0.0379	0.0458
30	0.0382	0.0395
40	0.0288	0.0282

4. CONCLUSIONS

The proposed degrading process of tunnel lining concrete described by the Ito stochastic differential equation was identifed by the inspected data of existing aged tunnels. And, it should be mentioned that most of the aged tunnels have repaired at certain period. Therefore, the basic examples of the repair effect are demonstrated based on the official records from existing aged tunnels.

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