Chapter X

Life-Cycle Cost Evaluation of Bridge Structures Considering Seismic Risk

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Abstract

This chapter introduces a life-cycle cost (LCC) analysis of bridge structures considering seismic risk. Recently, LCC has been paid attention as a possible and promising method to achieve a rational maintenance program. In general, LCC consists of initial cost, maintenance cost, and renewal cost. However, when considering LCC in the region that often suffers from natural hazards such as typhoons and earthquakes, it is necessary to account for the effects of such natural hazards. Using the probability of damage occurrence, LCC can be calculated for the bridge structures with earthquake excitations. The LCC analysis method proposed in this chapter can be applied to optimal maintenance planning by using genetic algorithms and can be extended to the life-cycle cost analysis of road network.
Introduction

Many existing bridges in Japan are suffering from damage and deterioration of materials due to heavy traffics and aging. In the future, it is evident that serious social problems will arise as the number of damaged bridges increases. Considering the present social and economic situation of Japan, it is urgent and important to establish an optimal maintenance strategy for such existing bridges so as to ensure their safety in satisfactory levels. Life-cycle cost (LCC) has been paid attention as a possible and promising method to achieve a rational maintenance program (Frangopol & Furuta, 2001). LCC of bridges consists of initial construction cost, maintenance cost, and failure cost (renewal cost, user cost, social and environmental costs and so on). In usual, LCC analysis considers the damage and deterioration of materials and structures (Furuta, Nose, Dogaki, & Frangopol, 2002). However, in the region that often suffers from natural hazards such as typhoons and earthquakes, it is necessary to account for the effects of such natural hazards.

In this chapter, based on the seismic risk analysis, LCC is evaluated focusing on the effects of earthquakes that are major natural disasters in Japan (Japan Society of Civil Engineers, 1996). At first, LCC analysis is formulated to consider the social and economical effects due to the collapse of structures occurred by the earthquakes as well as the minimization of maintenance cost (Furuta & Koyama, 2003). The loss by the collapse of structures due to the earthquake can be defined in terms of an expected cost and introduced into the evaluation of LCC. The LCC analysis method proposed can be applied to optimal maintenance planning by using genetic algorithm (GA) and can be extended to LCC analysis of road network (Furuta, Kameda, Fukuda, & Frangopol, 2004; Liu, & Frangopol, 2004a, 2004b).

Life-Cycle Formulation Including Seismic Risk

In general, life-cycle cost is defined in terms of initial construction cost, maintenance cost, and replacement cost. As the initial cost, only pier is considered here, because the sufficient data for the whole bridge is not available. Seismic risk includes both losses due to earthquake and user cost (Furuta, Koyama, Ohi, & Sugimoto, 2005).

\[
LCC = C_i + \sum P_d(a) \cdot C_d(a) + C_m(DI, a) + UC(DI, a) 
\]

(1)

\[
P_d(a) = P_h \cdot P(DI, a) 
\]

(2)

where \(C_i\): initial construction cost, \(P_d(a)\): probability of seismic damage occurrence, \(C_d(a)\): seismic loss, \(C_m(DI, a)\): maintenance cost, \(UC(DI, a)\): user cost, \(P_h(a)\): earthquake occurrence probability, \(P(DI, a)\): seismic damage probability, \(a\): maximum acceleration, \(DI\): damage index.
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