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Investigations on Effects of Maintenance Frequencies in Life Cycle Environmental Impact of Bridges

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1. Introduction

Recently there is growing concern over the life cycle of infrastructures. The problem of global warming is drawing attention of construction sector to investigate the environmental impacts from the construction and maintenance activities [3]. Maintenance stage of transportation infrastructures such as bridge is characterized by various uncertainties in maintenance activities to be carried out. This study considers various scenarios of bridge maintenance activities to investigate the relative proportions of impact from maintenance activities to total lifecycle environmental impact. The amount of carbon dioxide (CO_2) emissions is used as an indicator for the environmental impact.

2. Bridge Maintenance and Rehabilitation

Various maintenance and rehabilitation activities are carried out during service life of the bridge to keep it in serviceable condition. The maintenance requirements depend upon the deterioration rate of bridge elements that will be the effect of traffic condition, material type, quality of construction, surrounding environment and so on. Therefore it is quite difficult to get exact relations between various parameters of bridge deterioration and maintenance activities needed. So in this study, major bridge maintenance activities and their frequencies are taken based on the interviews with bridge maintenance engineers from Nagoya City and similar previous study[2]. The most frequent, average and least frequent values are considered for each maintenance activity corresponding to fast, average and slow deterioration rates of bridge elements from the results of the interviews.

3. Life Cycle Environmental Impact Evaluation System

A lifecycle impact evaluation system is prepared to estimate the total CO_2 emissions of the bridge lifecycle by extending bridge type selection system prepared for construction stage. The details of the bridge type selection system are given in reference (1). Fig. 1 shows the structure of the system prepared. Total CO_2 emission from construction stage is found with the bridge type selection system. From the superstructure and substructure processing of construction stage, the material usage and equipment usage during maintenance stage is calculated with the assumed maintenance frequency. Total CO_2 emission from maintenance stage is found out by multiplying these material and equipment usage values with unit CO_2 emissions available in reference (3).

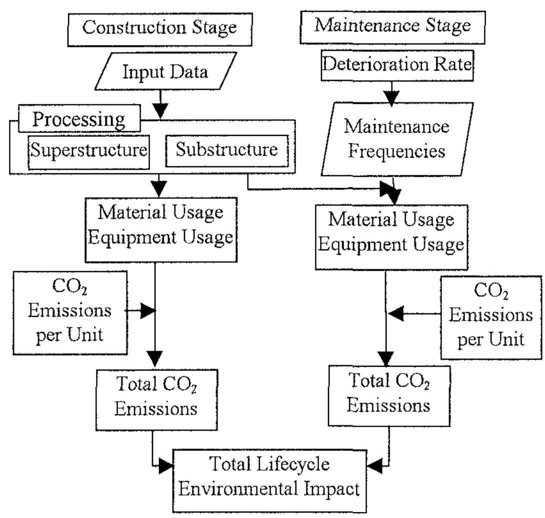

Fig. 1. Structure of the Life Cycle Impact Evaluation System

4. Example Application of the System

The system is used to show an example calculations of lifecycle environmental impacts for a bridge having a length of 215m and width 12m. Two bridge types Prestressed Concrete (PC) Simple Post-tension T-Girder Bridge and Continuous Steel Box Plate Box Girder Bridge are considered in the example calculations. These candidate bridge types are obtained for the given conditions by the system. Table 1 shows the most common bridge maintenance activities with corresponding frequencies. Similar maintenance activities were found to be contributing most part of lifecycle costs in the steel bridges of urban elevated expressways [2]. Lifecycle

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environmental impacts are estimated for seven different scenarios assuming the maintenance frequencies are distributed normally as shown in Fig. 2. It shows the normal curve assumed for the case of deck rehabilitation as depicted in Table 1 with points considered and corresponding probability on the ordinate. Similar curves are assumed for other maintenance activities with mean values and standard deviations shown in column 3 of Table 1. Figs. 3(a) and 3(b) show the contributions of environmental impact from construction, maintenance and demolition stage to the total life cycle environmental impact at seven points. The points considered are at *m-3s, m-2s, m-s, m, m+s, m+2s, m+3s*. Here *m* is the mean frequency value and *s* is the standard deviation of the frequency. The service life of bridge is assumed to be 60 years. In case of PC Simple Post-tension T-Girder Bridge, the maintenance stage is contributing about 41% impact in slow deterioration rate and 70% in high deterioration rate. In case of Steel Box Plate Girder Bridge, the environmental impacts from maintenance activities varied from 32% to 68%. The environmental impact from demolition stage is found very low in comparison to construction and maintenance stages.

Table 1. Major Bridge Maintenance Activities and Frequencies

Maintenance Activities (1)	Frequency Range (years) (2)	Proposed Distribution (3)
Pavement Replacement	5-20	N (12, 3)
Superstructure Painting	5-20	N (10,2.5)
Deck Rehabilitation	15-25	N (20, 2.5)
Deck Replacement	30-50	N (40, 5)
Expansion Joint Replacement	5-20	N (12, 3)
Support and Bearings Replacement	20-30	N (25, 2.5)

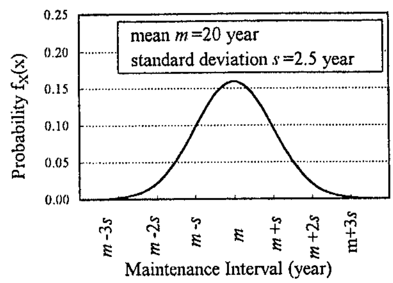
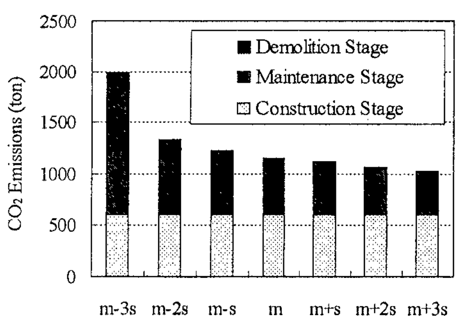
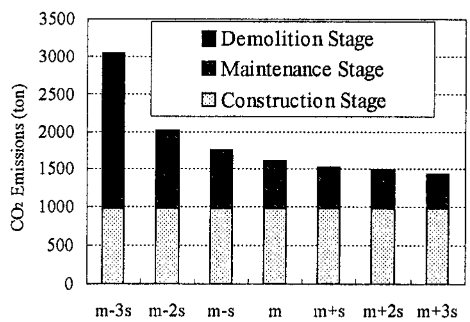


Fig. 2. Normal Distribution Considered for Maintenance Frequency



(a) PC Simple Post-tension T-Girder Bridge



(b) Steel Continuous Box Plate Girder Bridge

Fig. 3. Proportions of Life Cycle Impact from Varying Maintenance Frequencies

5. Conclusions

This study considered contributions of environmental impact from the maintenance stage to the life cycle environmental impact of bridges. It is observed that the maintenance stage is contributing the same order of environmental impact as of construction stage depending upon the maintenance frequencies of various activities.

References:

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