Estimation of Life Cycle Impact of Bridges

Nagoya University Student Member ○ Laxman SUNUWAR
Nagoya University Fellow Yoshito ITOH
Nagoya University Student Member Hiroki NAGATA

1. Introduction

The bridge type during preliminary design process has to be decided carefully including various criteria for selection. Recently there is growing concern of degrading global environmental due to emissions of greenhouse gases from different anthropogenic activities. Construction of bridge is one such activity causing depletion of natural resources and emission of greenhouse gases like carbon dioxide (CO_2). Environmental impact of construction stage of bridge was considered as one of selection factors of bridge types in the study by Itoh et al.[1].

This study considers the environmental impact of bridge for life cycle consisting of construction, maintenance and rehabilitation and finally up to demolition and replacement stage as shown in Fig. 1. CO_2 emission is taken as the indicator of environmental impact in this study.

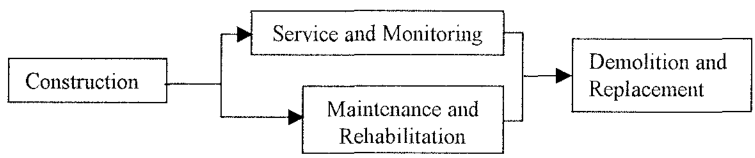

Fig.1 Life Cycle Stages of Bridges Considered for Life Cycle Impact

2. Estimation of Life Cycle Impact

2.1 Construction Stage

Various construction materials are used to build the bridge during construction stage. Productions of these materials at various stages cause emissions in different ways. Such embodied emissions are compiled in the research of PWRI [4]. Using this database and estimated amount of construction materials and equipment which are planned to be used in the construction process, total CO_2 emission is estimated with a computer program prepared in C++ language. Among various materials used in the construction, calculation of environmental impact of concrete and steel are made. In the case of concrete superstructure and substructure, concrete, reinforcement, prestressing cables and moulds are considered. Different types of steel are considered in case of steel superstructure. It has been found that by considering these materials more than 90% of environmental impact of materials are evaluated [4].

2.2 Service and Monitoring Stage

Service stage is the time when the bridge can be used by the vehicle traffic. During this stage, the emission due to use of fossil fuels by moving vehicles over the bridge is the main part of impact. Since the bridge is built for running the vehicle, the emissions from vehicle is inevitable and cannot be controlled by Civil Engineering measures. This part of life cycle impact is thus not included in this study.

2.3 Maintenance/Rehabilitation/Strengthening Stage

The maintenance and rehabilitation activities carried for restoration of the bridge in its serviceable condition consumes construction materials and equipment. This stage is within the service stage. The problem in estimation of the environmental impact from this stage is that the frequency and extent of maintenance activities are very difficult to predict. In this study, it is proposed to consider only major items of maintenance like maintenance of pavement, expansion joint and painting of girders and piers for the calculations of environmental impact in this stage. Maintenance data of two bridges of Nagoya City showed that these items covered more than 70% of total annual maintenance cost. The service life of bridge is considered as 60 years in this study. The study by Kitada et al.[2] at Hanshin Expressway also showed that the major maintenance items contributing most part of maintenance cost are pavement, expansion joint and painting.

2.4 Demolition and Replacement Stage

The bridge has to be demolished and replaced with another bridge when it becomes obsolete either functionally or structurally. The impact of bridge at this stage depends upon the efficiency of recycling option that will be followed for the demolished material. The life cycle impact will be reduced significantly if the construction materials used in the old bridge can be reused in building new bridge as well as for other construction and maintenance purposes. It has been found that since steel can be recycled more efficiently than concrete, steel bridges are preferred over concrete bridges with respect to decreasing the environmental impact [1].

3. Numerical Example and Preliminary Result

The environmental impact of a 215m long 5-span post-tension T-girder bridge is estimated assuming the maintenance to be carried out regularly in annual basis to minimize the major rehabilitation and strengthening activities. The rehabilitation of bridge deck at 20 and 40 years is assumed and the pier is assumed to be retrofitted in the middle of service life [3]. The details of assumed maintenance and rehabilitation strategy is shown in Table 1. With this assumption, the proportions of environmental impact for different life cycle stages of a bridge are estimated to be 70.7 % in construction stage, and 29.3% in maintenance, rehabilitation and strengthening stage. Figure 2 shows the cumulative plot of CO_2 emissions in the life cycle of the bridge during construction and maintenance activities. It shows the steady increase in the life cycle impact, as the bridge is being older. The proportions of life cycle impact of construction and maintenance stages of bridge life cycle stages are shown in Fig. 3. This shows that if the vehicular emission is excluded from the life cycle impact, the greater portion of impact is from the construction stage than maintenance stage. In this example the former is more than two folds of the latter one. However, there is possibility that, if frequent maintenance has to be carried out in any bridge, then the environmental impact from maintenance activities can be comparable to new construction. The above trend also shows that if the service life is extended by continuous maintenance and rehabilitation avoiding reconstruction, the life cycle impact is also reduced.

Table 1 Average Maintenance/Rehabilitation/Strengthening Schedules with Resources Used

Maintenance Types	Types of Resources	Concrete	Steel	Asphalt Concrete
Annual Maintenance	Pavement	-	-	48.71 tons
	Expansion Joint	-	422 kg	-
Rehabilitation at 20th and 40th year: Deck slab overlay of 30mm	Deck	78 m^3	-	-
Strengthening at 30th year: Retrofitting of Piers with 6mm steel plate bonding	Substructure	-	35.3 tons	-

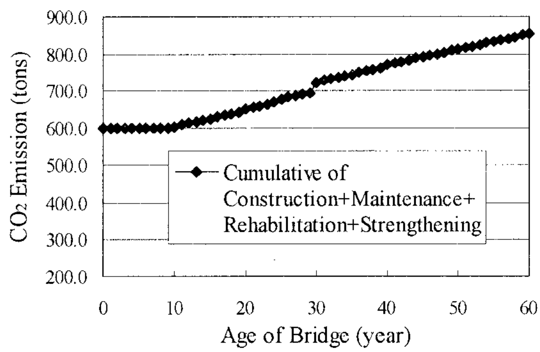

Fig. 2 Pattern of Life Cycle Environmental Impact of Bridge

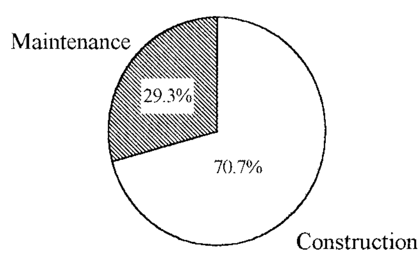

Fig. 3 Relative Share of Life Cycle Impact of Construction and Maintenance

4. Conclusion

The cumulative method of estimation of life cycle impact of bridge is proposed and illustrated with numerical example. From the preliminary result it can be said that when emissions from vehicle traffic is excluded, construction stage contributes greater portion of environmental impact than maintenance stage. So there is potential of reduction of environmental impact by appropriate selection of construction materials as well as construction methods in the construction stage. Another possible method to reduce the life cycle impact is to increase the service life of the bridge.

References:

(1) Itoh, Y., Hirano, T., Nagata, H., Hammad, A., Nishido, T., and Kashima, A. (1996). Study on Bridge Type Selection System Considering Environmental Impact, *Journal of Construction Management and Engineering*, JSCE, No 553/VI-33, 187-199 (in Japanese).

(2) Kitada, T., Seki, K., Matsukura, T., Nishioka, T, and Iwasaki, K. (1996). Maintenance, Service Life and Total Cost of Steel Bridges in Urban Elevated Highways, *Bridge Management 3*, E & FN Spon, London.

(3) Public Works Research Institute (1997). *Investigations on Minimum Maintenance Bridge*, Ministry of Construction, Tsukuba (in Japanese).

(4) Public Works Research Institute (1994). *Report on Calculation Method and Investigation of Resources, Energy Consumption and Environmental Impact (2)*, Ministry of Construction, Tsukuba (in Japanese).