Lifecycle Environmental Impact of Bridge Types with New Technologies

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1. Introduction

Lifecycle studies aiming reduction of various lifecycle burdens are being more important in recent years in the design of civil engineering infrastructures. Lifecycle cost is normally considered main parameter of lifecycle performances. However, human society's concern for sustainable development is giving more importance to the environmental impact and energy issues. Various new technologies are developed in bridge engineering in the form of Minimized Girder Bridges[1)], Minimum Maintenance Bridges[4)] and so on in order to minimize the lifecycle cost by reducing the maintenance requirements. This study presents the comparative analysis of bridge types with new technologies and conventional bridges with respect to lifecycle environmental impact.

2. Lifecycle Environmental Impact of Bridge

Various types of environmental effects are caused due to bridge construction and maintenance activities like natural resources depletion, local air pollution, land-use change, global environmental impacts and so on. Since global warming is considered as the main threat to human society, global environmental impact is one important environmental effect from developmental activities. Emission of greenhouse gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and so on are resulted during different bridge lifecycle activities. These emissions are consequence of various activities that are dependent upon the consumption of natural resources and industrial activities consuming fossil fuels and energy. Since CO_2 is a major greenhouse gas, it is taken as the indicator of environmental impact in this study. The total CO_2 emission is found by accumulating emissions from various materials and equipment fuels. The volume and weight of materials are found on the basis of design manuals and interview with practicing bridge engineers. The duration of construction equipment used in various construction, maintenance and demolition activities are taken from various databases. The unit CO_2 emission values are taken from the study by PWRI (1994)[3)] and JSCE (1997)[2)]. As various uncertain parameters are involved in the bridge lifecycle the absolute value of the lifecycle environmental impact has slight meaning by accuracy perspective but it is considered to be useful for comparing of several alternatives when consistent assumptions are made. Furthermore, this comparison also gives direction to future research and development.

3. Comparison Example of Lifecycle Environmental Impact

Minimized Girder Bridge and Minimum Maintenance Bridge are compared with conventional bridge type. The Minimized Girder Bridge is designed and constructed as a new bridge type in various parts of Japan. The Minimum Maintenance Bridge is conceptualized at PWRI for a service life of 200 years[4)]. The conventional bridge is Steel Non-Composite I-Girder bridge. The span length and width of all three bridge types are 30m and 11.5 m respectively. Table 1 shows the main features assumed in various bridge types. The main improvements of Minimized Girder Bridge over conventional bridge are less number of girders and adoption of PC deck. Since PC deck is used with improved girders it is assumed to have same service life of Minimum maintenance Bridge. The Minimum Maintenance Bridge has several improvements over conventional bridge to reduce the maintenance requirements such as improved painting, durable type of expansion joint, rubber bearing, deck slab with coated reinforcement to prevent corrosion and so on. The bridge is assumed to be located at coastal area with medium traffic.

Since there is only slight difference between the substructures of each bridge, only environmental impacts from superstructures are considered in this study. To compare the lifecycle performance, the environmental impact from construction stage of conventional is given a value of unity. The environmental impact value is calculated for every 5 years interval up to 200 years. The relative index value is calculated by following equation:

$$RI = I(n)/I_i(0) \quad (1)$$

Where, RI = relative index value; I(n) = cumulative environmental impact value for the n-th year; and $I_i(0)$ = environmental impact from the construction of conventional bridge.

Table 1 Various Features of Conventional Bridge and New Bridge Types

	Conventional Bridge	Minimized Girder Bridge	Minimum Maintenance Bridge
Number of Girders	5	2	5
Replacement cycle (year)	60	200	200
Deck	RC Deck	PC Deck	RC Deck (coated reinforcement)
Painting	Ordinary paint	Ordinary paint	Zinc galvanization
Expansion joint	Normal type	Normal type	Durable type
Bearing	Steel bearing	Steel bearing	Rubber bearing

Figure 1 shows the relative index values of three bridge types considered in preliminary calculation. In comparison to conventional bridge and Minimum Maintenance Bridge, Minimized Girder Bridge has less environmental impact from the construction stage. The reduction in number of girders has resulted less weight of superstructure and hence less environmental impact from Minimized Girder Bridge.

At the end of analysis period the relative index values for Minimized Girder Bridge and Minimum Maintenance Bridge are only 48% and 37% of conventional bridge type respectively. The conventional bridge is reconstructed at every 60 years while the two new bridge types are considered to last for 200 years. This is how the bridge types with new technologies are preferable from lower lifecycle environmental impact also.

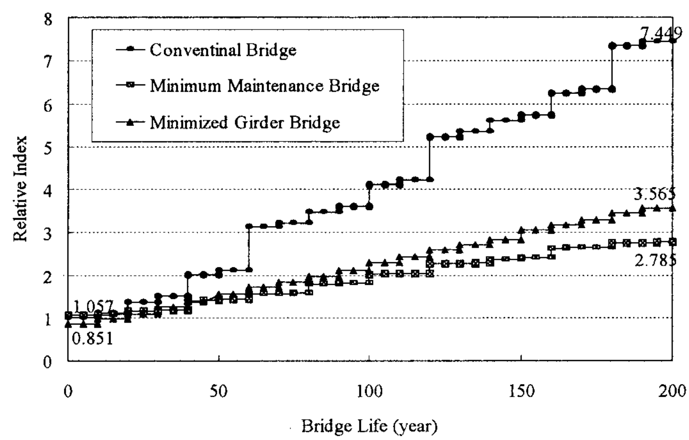

Fig. 1 Comparison of Lifecycle Environmental Impacts

4. Conclusions

Conventional bridge, Minimized Girder Bridge and Minimum Maintenance Bridge are compared with respect to lifecycle environmental impact. The preliminary result at this stage shows that the lifecycle environmental impacts of bridge types with new technologies are lower than the conventional bridge. Besides lower lifecycle cost, new bridge types are preferable also due to lower lifecycle environmental impact over conventional bridge.

References:

1) Japan Association of Steel Bridge Construction (1998). *Change in bridge type* (in Japanese).

2) Japan Society of Civil Engineers: JSCE (1997). *Report on lifecycle analysis of environmental impact*, JSCE Committee on LCA of Environmental Impact (in Japanese).

3) Public Works Research Institute: PWRI (1994). *Development of computational techniques and realities examination of resources, energy consumption and environmental hazards*, Report of PWRI (in Japanese).

4) Public Works Research Institute: PWRI (1997). *Investigations on minimum maintenance bridge*, Report of PWRI (in Japanese).