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The Environmental Load Characteristic Analysis of LCA-based IPC Girder Bridge

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Abstract. The carbon emission amount of the Republic of Korea ranks 8th in the world including China and the US and accordingly, the government announced its emission reduction plan by 37% compared to BAU (8.51 million tons) by 2030. As a result of the emission trading scheme that has been implemented since 2015, efforts are being made to reduce environmental load. Accordingly, this study analyzed the material-specific environmental load distribution and environmental impact category for 60 IPC girder bridges of national road constructions in Korea by utilizing the life cycle assessment (LCA) method. The analysis result was found to be in the order of ready-mixed concrete (RMC) (64.00%), rebar (9.1%), timber (7.8%) and plywood (5.6%). As for environmental impact category-specific result, it was found to be in the order of global warming (50.60%), abiotic resource depletion (32.20%), photochemical oxidant creation (POC) (10.10%) and human toxicity (HT) (7.10%), thereby considered to be helpful when selecting the form of bridge while considering environmental load during the planning and design phases.

1. Introduction

1.1. Background

At the 21st United Nations Climate Change Conference (COP21) held in Paris in December 2015, the Paris Agreement, a new climate system containing temperature elevation goal, reduction implementation review and climate management fund for developing countries, was signed. Contrary to 1997 Kyoto Protocol that demanded greenhouse gas reduction obligation only for developed countries, it is the first international climate agreement that must be observed by 195 countries, and it substitutes the Kyoto Protocol system that expires in 2020 [1].

The Paris Agreement includes the effort to limit global mean temperature even lower than before industrialization by 2100 [2]. Forecasting greenhouse gas emission to reach the peak by 2030, it presented 'carbon neutral' goal for reaching the equilibrium of greenhouse gas emission and absorption by reducing greenhouse gas through forest greenification, carbon capture & storage and energy technology.

At present time where environmental issue is a global concern, various efforts are being demanded in Korea's construction sector that occupies 40% of the country's total energy consumption [3]. Ultimately, construction industry requires eco-friendly approaches such as eco-friendly material use &

construction method and maximization of heavy equipment energy consumption to solve such issue [3, 4]. Accordingly, Ministry of Environment has been measuring the amount of carbon being discharged by companies by performing product-specific LCA through "carbon labeling" system and in construction industry, environmental impact assessment studies in construction area have been conducted based on LCA method since the late '90s [1].
However, this study analyzed material & construction-specific environmental load characteristics by analyzing 60 IPC (Incrementally Prestressed Concrete) girder bridges.

1.2. Scope & Method

In this study, detailed breakdown information on IPC girder bridges of national road construction in Korea was collected first before computing the materials used for each construction based on breakdown system analysis. Upon quantifying the amount of emission and resources used throughout the product life cycle, the environmental load was computed by using LCA analysis, an environmental impact assessment method for comprehensively assessing their impact on the environment. In this study, the environmental load is composed of eight impacts categorize, namely, abiotic resource depletion (ARD), acidification (AD), Eutrophication (EU), global warming (GW), ozone depletion (OD), photochemical oxidant creation (POC), terrestrial eco-toxicity (TET) and human toxicity (HT), albeit their measurement unit varies. Since there is the need to compare them at equivalent level, environmental impact assessment indexes were assessed through eco-point unit that has been converted through the process of classification, characterization, normalization and weighting [1, 5]. In addition, representative construction types were computed to explain the total environmental load of IPC girder bridges upon identifying major material-specific environmental load to deduce the environmental load characteristics of representative construction types through the eco-point distribution. Fig.1 represents the method and process of the research. The research process starts with the collection of information for further analysis of IPC girder bridge environmental load, analysis of material-specific environmental and through to the deduction of environmental load characteristics.

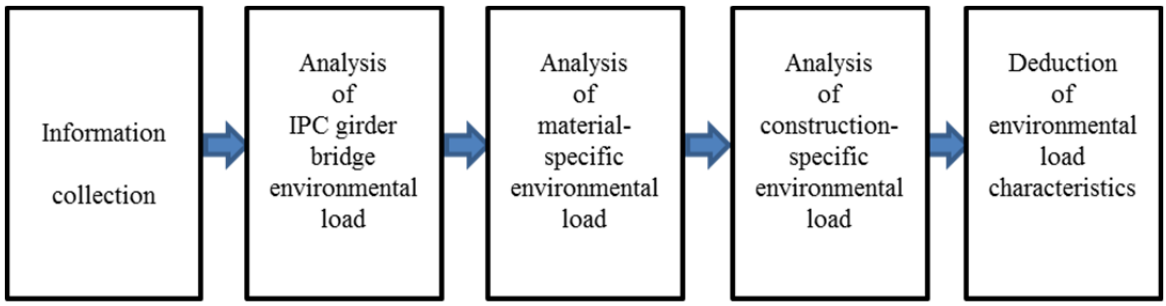

Figure 1. Method and process of the Research.

In this study, environmental load was computed from the energy consumption occurring while equipment operation and materials used during the construction phase. Basically, environmental load occurring during the construction phase can be computed if it is connected with LCI DB that can be described as a quantification of environmental load occurring when extracting, transporting and processing raw materials based on the BOQ (Bill of Quantity) prepared through breakdown information. In this study a method was applied by first calculating breakdown cost based on detailed statement before converting resources and energy used into environmental load. In addition, some of the items that have been applied as actual construction cost and items applied as project-specific actual construction cost are very different. Accordingly, National Construction Project Design Guideline and Standard of Estimate were used to apply items of same construction type to calculate energy used while operating equipment and resources used for the same construction type.

2. Analysis of IPC girder bridge environmental load characteristics

2.1. IPC girder bridge

IPC (Incrementally Prestressed Concrete Girder) bridge is a multi-step tension type prestressed concrete girder bridge that allows minimum girder height and maximum span up to 60m, while having the advantage of being able to lower the height of existing girder or reduce cross-section area by allowing incremental implementation of prestressing by considering weight increase during construction step. IPC Girder Bridge is cheaper in construction cost as compared to that of conventional structural steel girder because of its lower girder height & weight and long-span construction, and makes repair & reinforcement easy when needed by using unbounded prestressing strand inside PC girder, thereby allowing maintenance & repair cost-savings [6].

2.2. Characteristics of data

To analyze the environmental load characteristics of IPC Girder Bridge, LCA analysis was performed for 60 IPC beam bridge cases. The number of bridges analyzed in this study is 60, and the distribution of bridge span length was 30-45m. In addition, they were divided into 25m 6.67%, 30m 30.00%, 35m 10.00%, 40m 38.33%, 45m 15.00%. In terms of the cut-off level indicating the LCI DB amount percentage of Girder Bridge; it was found to be within 70.26-96.33%, 85.01% mean and standard deviation. For analyzing environmental load upon reviewing various cases of IPC girder bridge, "Facility-specific Carbon Emission Estimation Guideline" presented by Ministry of Land, Transport and Maritime Affaires was applied in this study. This criteria states that "While ensuring over 90% of cut-off level based on material cost when estimating greenhouse gas emission at construction step, assessor may adjust and decide considering the characteristics of project.", and that "In the case where cut-off level 90% is not achieved when applying both domestic & foreign DB, achievement of at least 80% is required to officially proclaim that carbon emission has been estimated, in which case analysis rate must be clearly presented." [7].

2.3. Distribution of environmental load

As for the distribution of construction-specific environmental load, it can be said that 'material', 'IPC GIRDER' and 'non-shrinkage concrete' occupy about 90% of the total environmental load. Mould had the least percentage weight of 3.97%. Accordingly, it is thought that the key point of reducing environmental load will be how to control the amount of materials during designing since the majority of environmental load occurs due to RMC and metal products used while constructing IPC Girder Bridge. Fig. 2 depicts the distribution of construction-specific and material-specific environmental load. The left side figure represents the distribution of construction environmental load while the right side figure depicts the material-specific environmental load.

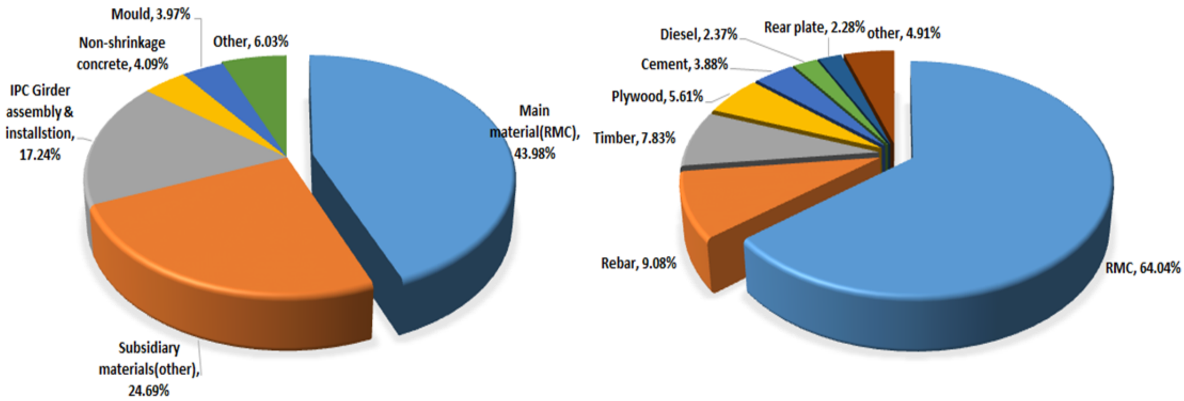

Figure 2. Distribution of construction- & material-specific environmental load.

As for the distribution of material-specific environmental load of IPC girder bridge, RMC occupied the highest percentage with 64.04%, followed by rebar with 9.08%, timber with 7.83%, plywood with 5.61%, cement with 3.88%, diesel with 2.37%, rear plate with 2.28% and other with 4.91%.

2.4. Distribution of 8 major impact categories

As for the distribution of 8 major impact category-specific environmental load, it was found to be in the order of GW with 50.60%, ARD with 32.0%, POC with 10.1%, HT with 7.1%, TET with 2.8%, EU with 1.8%, AD with 1.6% and OD with 0.5%. Fig. 3 is the graphical representation of the distribution of 8 major impact categories. From fig.3, the eco-point distribution of GW and ARD represents 82.60% among the 8 major impact categories. Ultimately, it can be known that RMC, metal products and equipment fuel used while constructing IPC girder bridge discharge much environmental pollutants.

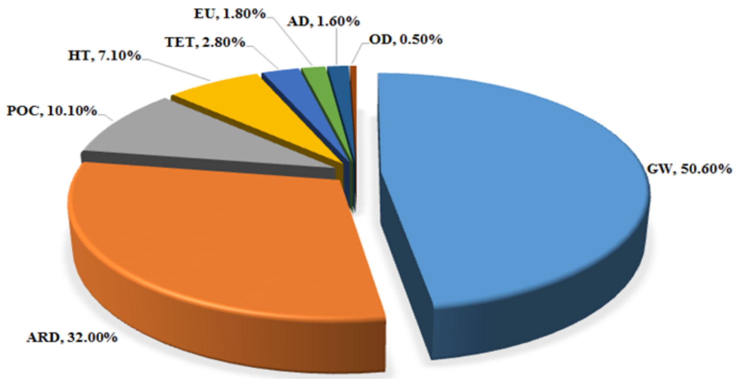

Figure 3. Distribution of 8 major impact categories.

In regards to the representative materials with much environmental loads, namely, RMC (64.04%), rebar (9.08%) and timber (7.83%), their major pollutants were researched. As shown in Table 1, the result showed GW (47.41%), ARD (28.74%) and POC (12.82%) to be the major pollutants of RMC. In the case of rebar, GW (51.73%), ARD (39.02%) and POC (4.53%) were deduced, while GW (75.73%), ARD (18.56%) and AD (2.50%) for timber.

Table 1. Eco-point of Material-specific Major Pollutant.

Material	Weighting								
	ARD	AD	EU	GW	OD	POC	TET	HT	Sum
	Eco-point	Eco-point	Eco-point	Eco-point	Eco-point	Eco-point	Eco-point	Eco-point	Eco-point
RMC	3.969E+01	1.869E+00	6.960E-01	6.547E+01	8.038E-01	1.771E+01	6.084E-01	1.125E+01	1.381E+02
	28.74%	1.35%	0.50%	47.41%	0.58%	12.82%	0.44%	8.15%	100.00%
Rebar	8.108E+00	1.894E-01	1.473E-03	1.075E+01	2.935E-02	9.413E-01	1.863E-01	5.737E-01	2.078E+01
	39.02%	0.91%	0.01%	51.73%	0.14%	4.53%	0.90%	2.76%	100.00%
Timber	3.646E+00	4.910E-01	1.038E-01	1.488E+01	1.537E-02	6.914E-02	4.313E-02	3.997E-01	1.965E+01
	18.56%	2.50%	0.53%	75.73%	0.08%	0.35%	0.22%	2.03%	100.00%

3. Conclusion

This study was conducted as an advanced study for establishing a model considering environmental load during the planning and design phases by analyzing the environmental load characteristics of IPC Girder Bridge. The result showed that material-specific environmental load of IPC Girder Bridge was in the order of RMC 64.00%, rebar 9.10%, timber 7.80%, plywood 5.6%, with cement as 3.9% and diesel 2.4%. As for the construction types that can describe environmental load that occurs while constructing IPC girder bridge, 'materials', 'IPC GIRDER' and 'non-shrinkage concrete' occupy about 90% of total environmental load, while GW and ARD were shown as environmental load on earth. In addition, it was not possible to obtain 16.84% of LCA among total construction materials since there are many materials used in construction industry that are not commonly used in other industries. It is thought that conducting a follow-up study after sufficiently obtain LCI DB with supplemented information of construction industry materials will be helpful in establishing a model that assists in making rational decisions considering environmental load during the planning and design phases based on high quality IPC girder bridge environmental load characteristics.

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