Construction and Building Materials 186 (2018) 1154–1160

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

GHG mitigation of railway concrete products using eco-concrete and surface protection agent

Cheul-Kyu Lee [a], Jae-Young Lee [a,*], Il-Wha Lee [b], Yong-Ki Kim [a]

[a] *Transportation Environmental Research Team, Korea Railroad Research Institute, 176 Cheoldo bakmulkwan-ro, Uiwang-si, Gyeonggi-do 16105, Republic of Korea*
[b] *Advanced Infrastructure Team, Korea Railroad Research Institute, 176 Cheoldo bakmulkwan-ro, Uiwang-si, Gyeonggi-do 16105, Republic of Korea*

HIGHLIGHTS

- GHG saving effect of the eco-concrete in railway was calculated with LCA analysis.
- Concrete deterioration preventive agent were applied and physical performance tested.
- Life cycle GHG reduction by eco-concrete and anti-deterioration agent was calculated.

ARTICLE INFO

Article history:
Received 21 February 2018
Received in revised form 6 August 2018
Accepted 10 August 2018
Available online 14 August 2018

Keywords:
Railway
Concrete
Furnace slag
Surface protection agent
GHG mitigation

ABSTRACT

This study investigated the life cycle greenhouse gases (GHG) mitigation effect of railway infrastructure through the application of an eco-concrete, using ground granulated blast furnace (GGBF) slag and electric arc furnace (EAF) slag as alternative materials in railway sleeper, and a concrete surface protection agent in railway track. A simplified life cycle assessment method was applied to compare GHG emissions and an instrumental analysis as well as a physical performance test were carried out to identify the protection mechanism between the agent and concrete along with field tests. From this study, it was found that two different approaches might contribute substantially to mitigate GHG emissions from railway infrastructure. The surface protection agent with an anti-deterioration function showed high possibility of increasing lifespan of the concrete structure and the use of alternative materials, such as furnace slag, reduced the concrete consumption by more than 20% (w/w). It was estimated that the potential GHG mitigation effects from the surface protection agent and eco-concrete technology applied to a railway concrete track were at least 27 ton CO_2 eq. per km a year and 11.1 kg of CO_2 eq. per 1 sleeper, respectively.

1. Introduction

Buildings and construction account for about 30% of global energy-related GHG emissions [1]. In order to lower greenhouse gas (GHG) emissions and improve energy efficiency in buildings and construction, eco-design using life cycle assessment (LCA) is widely employed considering its life cycle environmental aspects [2–5]. Since concrete has been used the most widely as a construction material in roads, buildings, bridges and other infrastructures, it is important to evaluate the environmental impacts of this material, considering the GHG emissions and the impacts on climate change it generates [6,7]. Concrete, the most consumed material by humans after water, has recently been under scrutiny for the environmental impacts associated with its production [8].

Steel slag is widely used as a supplementary cementitious material in order to reduce GHG emissions and increase material efficiency throughout the cement industry [9]. Ferreira analyzed technical requirements and environmental impacts derived from the application of electric arc furnace (EAF) slag as a pavement aggregate. It has been revealed that EAF slag shows excellent mechanical properties that improve the skid resistance of the pavement and reduce the risk of aquaplaning due to higher permeability [10]. It has been also found that lower environmental impacts can be expected compared to the case with natural aggregate from the LCA analysis. Balaguera investigated potential environmental benefits for the use of alternatives in road construction with the LCA concept [11].

Another solution of lowering GHG emissions for buildings and construction is to extend their lifespan as much as possible by

---

* Corresponding author.
E-mail address: iyoung@krri.re.kr (J.-Y. Lee).

https://doi.org/10.1016/j.conbuildmat.2018.08.046

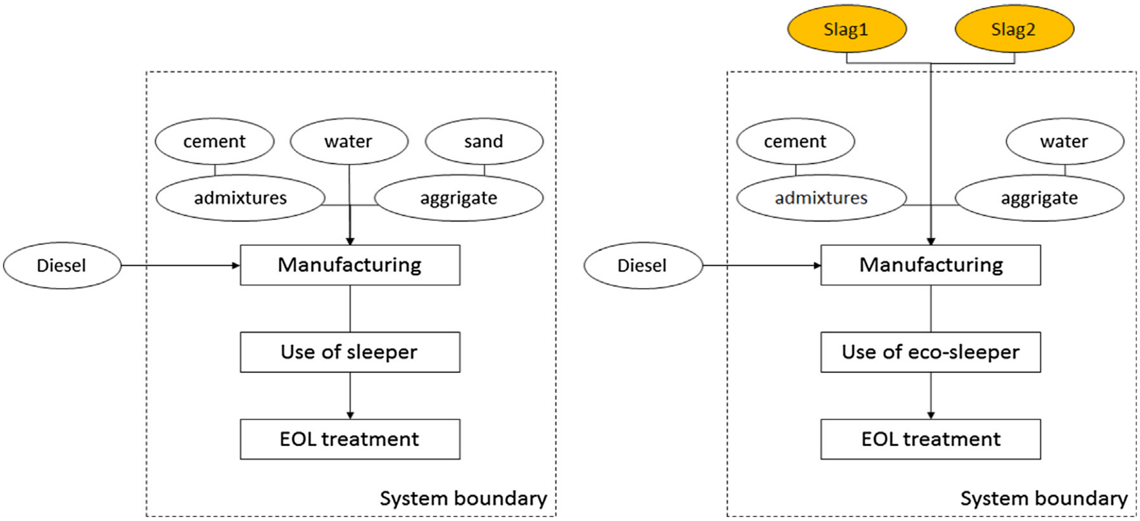

Fig. 1. System boundary between eco-sleeper (R) and conventional sleeper (L).

preventing deterioration of the concrete structure. Pan comprehensively reviewed concrete surface treatment studies and noted the advantages and drawbacks of each treatment [12,13]. Wang proposed a life-cycle design (LCD) method, combining traditional design with green design, for concrete structures to promote the long-term performance of a structure [14].

Railway infrastructures demand massive materials for construction and have long lifespan so that most of the GHGs are generated at the construction stage, whereas rolling stock consumes a large amount of electricity during its operation stage [15]. From several LCA studies regarding railway infrastructure, it has been also found that concrete is one of the main contributors of GHG emissions [16–18]. In order to decrease GHG emissions released from the use of concrete in railway infrastructure, it is very important to consider an application of the eco-concrete using supplementary materials and a deterioration protection agent which is helpful for lengthening its life span. However, most previous studies to apply furnace slags in the railway industry have focused on analyzing the physical performance without the consideration of environmental impacts [19–21]. The aim of this study was to investigate GHG mitigation effects using a LCA methodology from the application of furnace slags and a concrete surface protection agent in railway concrete structures.

Table 1
Materials and energy input for manufacturing a sleeper.

Input	Unit	Sleeper	Eco-sleeper
Cement	Kg	45.32	34.81
GGBF	Kg	–	17.94
Water	Kg	13.6	13.7
Sand	Kg	72.2	
EFA	Kg	–	104.3
Aggregate	Kg	118.1	102.0
Admixtures	Kg	0.815	0.373
Total	Kg	250.035	273.123
Diesel	L	2	2

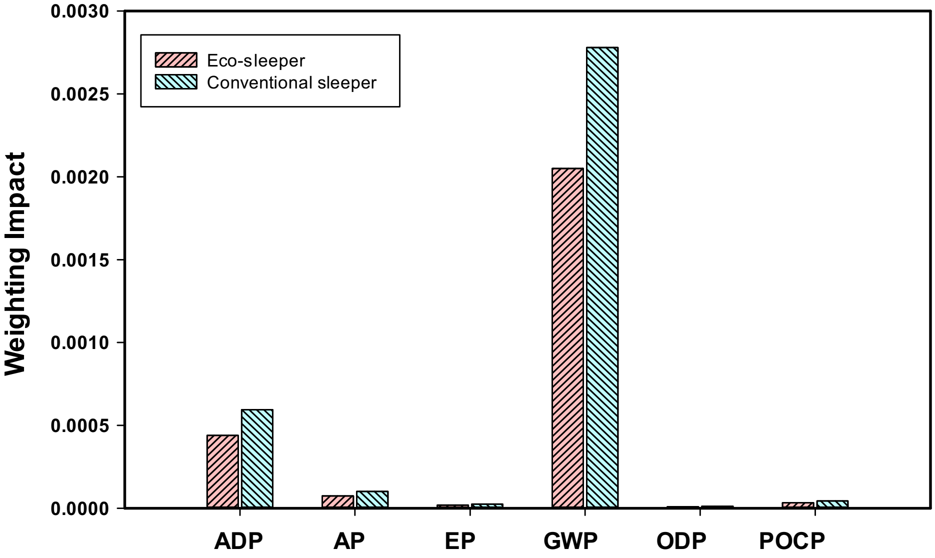

Fig. 2. Life cycle impact assessment between conventional sleeper and eco-sleeper (ADP: abiotic resource depletion potential, AP: acidification potential, EP: eutrophication potential, GWP: global warming potential, ODP: ozone layer depletion potential, POCP: photochemical ozone creation potential).