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Effects of aggregate reuse for overpass reconstruction-extension projects on energy conservation and greenhouse gas reduction: A case study from Shanghai City

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A B S T R A C T

Currently urban overpasses (new-construction, reconstruction and extension) are being constructed on a large scale in China. While the construction projects are beneficial to the economic and social development, they have also caused serious ecological and environmental problems. On one hand, the final disposal of construction wastes requires a large amount of land, and the extraction of virgin aggregate destroys the local ecological environment. On the other hand, the energy consumption and the greenhouse gas (GHG) emissions during the entire life cycle are massive. To reduce the ecological and environmental impacts and to improve the resource use efficiency during the overpass construction, it is necessary to change the traditional linear resource use mode (aggregate–buildings–garbage) into a circular mode (aggregate–buildings–reused/regenerated aggregate–buildings). Using the life cycle inventory (LCI) method, the energy consumption and the GHG emissions are investigated for two different kinds of reconstruction and extension projects for overpasses in Shanghai City, using virgin and regenerated aggregates, respectively. Through that, the actual energy conservation and the GHG reduction benefits from using the regenerated aggregate are determined. Important first-hand data on the extraction of aggregate, the regeneration of aggregate, and the demolition of the discarded overpass, in a real situation, are gathered. The results show that, for the life cycle of aggregate, the energy consumption and the GHG emissions from reused aggregate can be reduced to 45.27% and 43.91%, respectively, compared to the virgin aggregate. For the life cycle of road concrete, the figures mentioned above would be 3.48% and 1.33%, respectively. In order to reduce the total energy consumption and GHG emissions from the reconstruction and extension projects of the overpasses, it is essential to find a way to reduce the amount of cement used, as well as the energy consumed and the GHG emitted during the cement production.

1. Introduction

According to the National Development and Reform Commission's annual October report on the utilization of resources, the construction wastes generated in 2013 in China, was about 1.0 billion tons (Qin, 2014). In Shanghai, the amount of construction wastes generated was up to 110.12 million tons in 2012, accounting for 94% of the total solid wastes (Shanghai Statistical Yearbook, 2014). The contribution of the wastes from road reconstruction, to the total waste generated, is expected to increase steadily.

On one hand, the final disposal of construction wastes requires a large amount of land, and the extraction of the virgin aggregate destroys the local ecological environment. On the other hand, the energy consumption and the greenhouse gas (GHG) emissions during its entire life cycle are massive. To reduce the ecological and environmental impacts and to improve the resource use efficiency during the construction of an urban overpass, it is necessary to change the traditional linear resource use mode (aggregate–buildings–garbage) into a circular mode (aggregate–buildings–reused/regenerated aggregate–buildings).

Extensive research on the life cycle assessment (LCA) of the

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construction of the ground–level roads and overpasses has been carried out across the world. Table 1 lists some studies of ground–level road or bridge construction projects.

Extensive research on the LCA of the construction of the ground-level roads and overpasses has been carried out in China, by Liu et al. (2007, 2009), Shang et al. (2010), Pang (2011), Pan (2011), Xu (2012), etc. However, at present, for urban road reconstruction and extension projects in China, especially those involving the reuse of aggregate in overpass projects, studies on benefits such as energy conservation and GHG reduction, based on the LCI and true process data, are few. This study considered a stretch of the Pudong Middle Ring overpass in Shanghai as a case study, and based on the LCI, utilized the measured data, field survey data and the literature data, comprehensively, to determine the energy consumption, the GHG emissions and their differences for two kinds of reconstruction and extension projects, using virgin and regenerated aggregate, respectively. Meanwhile, the production of virgin and regenerated aggregate was evaluated, and several relevant first-hand process data, which are usually difficult to obtain, were gathered.

2. Definition of goal and scope

2.1. Goal of study

The study focuses on the following four goals:

(1) Quantifying and systematically comparing the life cycle energy consumption and the GHG emissions in two kinds of overpass reconstruction and extension projects, using virgin and regenerated aggregate.
(2) Quantifying and systematically comparing the life cycle energy consumption and the GHG emissions from virgin and regenerated aggregates.
(3) Determining the actual extent of energy conservation and GHG emission reduction due to the reuse of aggregate generated from the site of overpass demolished.
(4) Gathering more accurate data to support the recycling of road concrete waste and the ecological construction of overpasses.

2.2. System boundary and functional unit

2.2.1. Boundary and functional unit for the life cycle system of overpass

Overpass construction is a complex systemic project, which involves a series of intermediate products and unit processes. Keeping in mind the study goal, time limitations and the data availability, this study considered an overpass as a product system. Generally, the life cycle of a building can be divided into five stages: the production of building materials, the transportation of building materials, construction of the building, use of the building (operation and maintenance) and demolition of the building (Yan, 2011; Zhou, 2012). Given that this study aimed to compare the differences in the two scenarios, one using virgin aggregate and the other using regenerated aggregate, the differences in the energy consumption and GHG emissions during the construction and operational stages of the overpass may be redundant. Hence, these two stages were omitted from this study.

The main raw materials used in the construction of overpass in Shanghai include cement, aggregate gravel, and rebar. Based on the investigation of the overpass construction in Shanghai, its life cycle boundary overpass using virgin aggregate was determined as shown in Fig. 1. Except for the parts in the dotted boxes, others were considered. So, the nine stages that were considered are:

STAGE 1. The extraction of virgin aggregate;

STAGE 2. the transportation of virgin aggregate from the site of extraction to the storage site for sale;

STAGE 3. the transportation of virgin aggregate from the site of storage to the concrete mixing station;

STAGE 4. cement production;

STAGE 5. the transportation of cement from the retail stores to the concrete mixing station;

STAGE 6. production of the concrete at mixing station;

STAGE 7. transportation of the concrete to the sites of the overpass construction;

STAGE 8. demolition of the deteriorated overpass;

Table 1
The quantitative analysis of carbon emissions of construction projects such as road and bridge.

Author	Country	Life cycle thinking			Research objects			
		Process LCA	Hybrid LCA	Economic input and output I/O	Pavement materials	Road	Building	Bridge
Mroueh (2000)	Finland	×				×		
Stripple (2001)	Sweden	×				×		
Nisbet (2000)	America	×			×			
Park et al. (2003)	Korea		×			×		
Treloar et al. (2004)	Australian		×			×		
Keoleian et al. (2005)	America	×						×
ARI (2006)	Canada	×			×			
Birgisdottir et al. (2006)	Denmark	×				×		
Liu et al. (2007)	China	×						×
Kendall et al. (2008)	America		×					×
Garraín and Vidal (2008)	Brazil			×			×	
Huang et al. (2009a).	England	×				×		
Huang et al. (2009b)	England	×				×		
Liu et al. (2009)	China		×					×
Chang et al. (2010)	China			×			×	
White et al. (2010)	America	×			×			
Weiland and Muench (2010)	America	×			×			
Milachowski et al. (2011).	Germany	×				×		
Loijos (2011)	America	×				×		
Cass and Mukherjee (2011)	America		×			×		
Huang et al. (2013)	India	×				×		
Melanta et al. (2012)	America	×				×		

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