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Comparative environmental evaluation of construction waste management through different waste sorting systems in Hong Kong

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A B S T R A C T

This study aimed to compare the environmental performance of building construction waste management (CWM) systems in Hong Kong. Life cycle assessment (LCA) approach was applied to evaluate the performance of CWM systems holistically based on primary data collected from two real building construction sites and secondary data obtained from the literature. Different waste recovery rates were applied based on compositions and material flow to assess the influence on the environmental performance of CWM systems. The system boundary includes all stages of the life cycle of building construction waste (including transportation, sorting, public fill or landfill disposal, recovery and reuse, and transformation and valorization into secondary products). A substitutional LCA approach was applied for capturing the environmental gains due to the utilizations of recovered materials. The results showed that the CWM system by using off-site sorting and direct landfilling resulted in significant environmental impacts. However, a considerable net environmental benefit was observed through an on-site sorting system. For example, about 18–30 kg CO_2 eq. greenhouse gases (GHGs) emission were induced for managing 1 t of construction waste through off-site sorting and direct landfilling, whereas significant GHGs emission could be potentially avoided (considered as a credit −126 to −182 kg CO_2 eq.) for an on-site sorting system due to the higher recycling potential. Although the environmental benefits mainly depend on the waste compositions and their sortability, the analysis conducted in this study can serve as guidelines to design an effective and resource-efficient building CWM system.

1. Introduction

A considerable amount of construction and demolition (C&D) waste is generated globally. So far, the majority of the C&D waste is landfilled without any further treatment (Bovea and Powell, 2016). Nevertheless, C&D waste could be reused as raw materials for the manufacturing of secondary materials/products (Rodrigues et al., 2013). Recycling and reusing of C&D materials has a twofold beneficial effect of avoiding landfill disposal and conserving non-renewable natural resources (Vieira and Pereira, 2015). Thus, high priority has been given to C&D waste minimization from both waste management and resource efficiency perspectives (Pacheco-Torgal et al., 2013).

The management of C&D waste has received increasing attentions from both practitioners and researchers worldwide, as resource efficient management is a challenging issue globally (Lu and Yuan, 2011; Yuan and Shen, 2011). However, C&D waste is not effectively managed in many countries (Cheng and Ma, 2013). There are substantial opportunities for improving C&D waste management in terms of technical, environmental and economic points of views (Bovea and Powell, 2016).

The effective and efficient minimization of building construction waste is a challenging issue (Tam, 2008; Wu et al., 2016). Waste sorting is considered one of the most effective measures for waste minimization and materials recovery (Saez et al., 2013). During the waste sorting process, different waste fractions are sorted and recovered before the residuals are sent for disposal (Lu and Yuan, 2012). But most building construction participants are reluctant to conduct on-site waste sorting in Hong Kong (Poon et al., 2013). In addition, Yu et al. (2013) showed that the use of waste reduction practices on building construction sites in Hong Kong is still not common even after the implementation of construction waste disposal charging scheme. In order to support the decision making process on the selection of effective and resource-efficient CWM, the evaluation of environmental performance of CWM through different sorting systems using life cycle assessment (LCA) technique is therefore necessary.

The LCA approach following the guidelines provided by ISO 14040-44 has increasingly been used to identify strategies that

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may improve the environmental performance of waste management systems (ISO, 2006a, 2006b). Recently, LCA techniques have been widely applied to the C&D waste management sector, especially for materials recovery and reuse (e.g., Hossain et al., 2016a, 2016b; Butera et al., 2015; Dahlbo et al., 2015; Kucukvar et al., 2016).

Mercante et al. (2012) conducted an LCA study on C&D waste management systems with emphasis on inert waste processing and treatment facilities. An overview of C&D waste management using LCA was conducted by Yeheyis et al. (2013). Dahlbo et al. (2015) assessed the environmental and economic performance of the common C&D waste management system in Finland in order to identify the recycling potential of materials to meet the overall EU target (70%) by 2020. Butera et al. (2015) assessed the environmental performance of utilizing C&D waste as road based materials. A review on the application of LCA methodology to overall C&D waste management, recycling and applications was conducted by Bovea and Powell (2016). Mastrucci et al. (2016) used the LCA approach to develop a framework of building material stocks and the potential environmental impact of end-of-life of buildings at the urban scale as a supporting decision tool. Rodrigues et al. (2013) assessed the mineralogical and physico-chemical properties of recycled aggregates generated from C&D waste. In addition, Neto et al. (2016) analyzed the economic viability of different types of processing (e.g., sorting) in C&D waste recycling platforms.

From the above review of the literature, most studies assessed the environmental performance of materials recycling and utilizations for secondary applications. But little has been done on assessing the use of different waste sorting strategies on the environmental performance of building CWM systems. To bridge this research gap, this study focuses on evaluating the environmental performance of different building CWM systems incorporating different sorting strategies using Hong Kong as a case study.

2. Construction waste management systems in Hong Kong

A huge amount of C&D waste is generated each year in Hong Kong. According to the Hong Kong Environment Protection Department (HKEPD), about 58,000 tonnes per day of C&D waste was generated in 2014, of which 93% was delivered to public fill reception facilities (for land reclamation), and 7% was sent to landfills (for landfill disposal), and the latter made up 27% of the total landfilled waste in Hong Kong (HKEPD, 2015). As a result, the management of this kind of waste is becoming a serious problem in Hong Kong because both of the disposal outlets (public fills and landfills) are running out.

In Hong Kong, C&D waste is categorized into inert (such as soil, sand, bricks and concrete, which is disposed of at public fills for land reclamation) and non-inert materials (e.g., wood and timber, bamboo, plastics, glass, paper, and other materials, which is disposed of at landfills) (Poon et al., 2001). Usually, C&D waste is a mixture of inert and non-inert construction materials, thus waste sorting is a good practice before it is disposed of in landfills or public fills, respectively (Lu and Yuan, 2012). Three strategies can be used for CWM, i.e., off-site sorting, on-site sorting and direct landfilling (without sorting). The typical C&D waste management structure in Hong Kong is shown in Fig. 1.

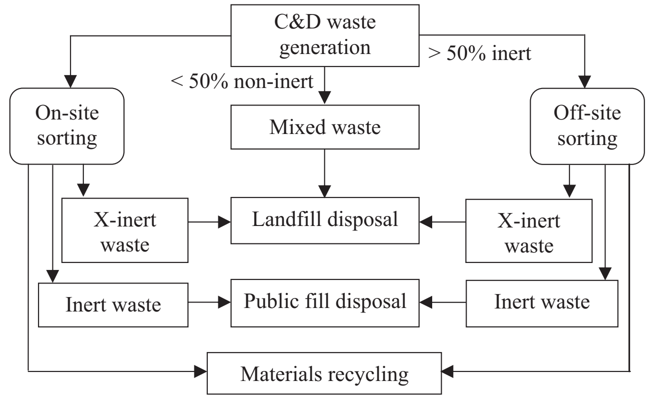

Fig. 1. C&D waste management structure in Hong Kong.

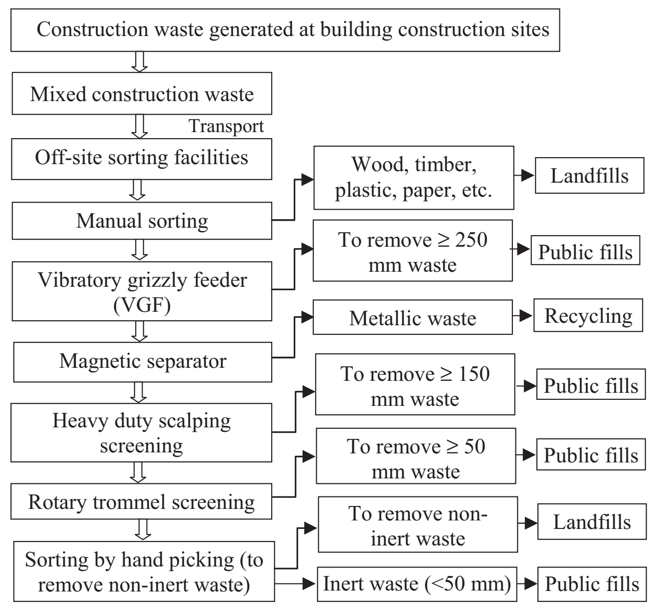

Fig. 2. Building CWM through off-site sorting in Hong Kong.

2.1. Building CWM system through off-site sorting

In Hong Kong, the most common form of waste sorting of building construction waste is by off-site sorting (Lu and Yuan, 2012). The off-site sorting process is presented in Fig. 2. First, contractors send mixed waste materials from construction sites to off-site sorting facilities, in which inert and non-inert waste materials are separated. However, the sorting facilities only accept construction waste which contains more than 50% of inert materials (by weight) with the purpose of maximizing its service efficiency (Lu and Yuan, 2012). After receiving by the sorting facilities, the mixed waste goes through several manual and mechanical processes (Fig. 2). The separated inert and non-inert waste fractions are then disposed of at public fill sites and landfill sites, respectively.

2.2. Building CWM system through on-site sorting

On-site sorting is considered as an effective approach to manage building construction waste, as it could increase the reuse and recycling rates and reduce associated disposal costs (Poon et al., 2001; Hao et al., 2008; Wang et al., 2010). When implementing on-site sorting, the workers separate the generated building waste at source in order to prevent waste being mixed. Yuan et al. (2013) described several on-site management strategies for sorting building construction waste: (i) recyclable waste such as paper, cardboard, plastics and aluminum cans are collected and transferred to designated recycling bins, (ii) inert waste is collected and transported to a designated area after some preliminary source separation on each construction floor, (iii) other non-inert waste