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Global warming potential and energy consumption of temporary works in building construction: A case study in Hong Kong

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ABSTRACT

The importance of the building industry on environmental impacts, especially global warming potential (GWP) impact due to greenhouse gases emissions is undisputed. Thus, significant efforts have been devoted to minimize environmental impacts and waste management problems from building construction globally. Numerous studies have particularly focused on assessing the environmental impacts of buildings based on materials, construction processes and whole building systems. However, less attention has been given on some critical features, especially on temporary works (e.g., hoarding system). But the temporary works also consume considerable amounts of materials and generate significant amounts of waste due to its short service life time. Therefore, this study evaluated the environmental impacts of hoarding systems as a case study in Hong Kong with the aim to identify the areas of impacts reduction and improvements in its waste management system. A case-specific structured questionnaire survey was conducted to the relevant stakeholders to identify the essential materials, and construction, deconstruction and waste management processes of hoarding systems, whereas life cycle assessment was employed to assess the associated environmental impacts. The findings demonstrated that more than 3 tonnes of CO_2 eq GWP and 39 GJ of non-renewable energy consumption impacts were associated with 1 m of hoarding construction. This is mainly due to the use of large amounts of steel products and concrete in the construction of the hoarding system. This results and analysis can help the building industry to identify the opportunity for reducing environmental impacts, and facilitate resource-efficient and effective design of hoarding systems.

1. Introduction

The construction industry is responsible for substantial natural resources diminution, and further induces burden to the environment by generating a considerable amount of wastes. For example, the industry consumes approximately 60% of the earth raw materials [1] and produces 50% of its waste [2]. In terms of materials, the annual consumption is about 25 gigatonnes of concrete (more than 3.5 tonnes per capita) [3] and about 16% of the total iron and steel production globally [4]. The steel and iron industry and the cement industry emits 7% and 5–10% respectively of the carbon globally [5,6].

As one of the largest consumers of natural resources, the building sector is also the largest contributor of environmental impacts [7]. Buildings are responsible for about 40% of the total energy consumption [8] and 36% of the total CO_2 emission worldwide [9]. Therefore, increasing attention has been devoted in the building sector to minimize environmental impacts globally [10].

The selection of sustainable construction materials and energy efficient construction methods during the design stage can minimize the environmental impacts from buildings significantly [11,12]. Much focus is being paid on the construction stage to minimize greenhouse gases (GHGs) emissions from building construction [13]. The construction industry and building sector require tools that can help to quantify and reduce resources consumption and environmental impacts, as well as to support decision making process. Life cycle assessment (LCA) is a recognized and widely used technique to evaluate the environmental impacts of the construction sector [14], and is also increasingly becoming as an early-stage design-decision support tool for buildings [15] which is essential for sustainable cities development [16].

In the building construction industry, LCA has been employed in numerous diverse areas and scales ranging from assessments to comparisons, and building materials/components to whole building systems analysis [17–20]. Several LCA studies have been focused on the improvements of environmental performance of the built environments. For example, Ghose et al. [21] investigated the environmental impacts

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of building refurbishments using consequential LCA by considering the resource constraints and marginal suppliers of construction materials using market information in New Zealand. In addition, several reviews have identified the trends of existing studies and future potential in this research arena. For instances, a systematic review was conducted on energy consumption of buildings based on LCA using bibliometric analysis by Zeng and Chini [22]. Li et al. [23] provides a comprehensive review on the assessment of sustainable refurbishment strategies for residential buildings in high-density city. Some other reviews have been found on identifying the valuable insights and most effective measures for reducing impacts from buildings [17,18,24,25].

Moreover, numerous case-specific LCA studies have been conducted to evaluate the carbon footprint [8,26–28], embodied energy [10,22], and a wide range of environmental impacts [7,29,30] throughout the world, including in China [10], South Korea [26,29], USA [22], Hong Kong [31], Sweden [32], the UK [15], the Netherlands [7], New Zealand [21] and Australia [33].

Most of the LCA studies have commonly focused on building materials or the operation of buildings with much less attention on temporary works during construction. For example, environmental impacts of building construction were evaluated by a few studies in Hong Kong [30,31]. But the evaluations in all of the previous studies were carried out without considering the impacts due to such temporary works (including the construction, deconstruction and end-of-life waste treatment systems). However, different construction activities or processes may show different environmental impacts. Hoarding (or covered walkway) is a temporary structure erected to secure the construction site and protect pedestrians from falling debris from the construction works above the pedestrian walkways. This is particular important for construction in crowded metropolitan areas like Hong Kong (a picture of hoarding system in Hong Kong is given in Section 2). So far, the environmental impacts for hoarding systems (including the construction and demolition) have not been critically studied both in Hong Kong and other parts of the world. Therefore, this study comprehensively evaluated the environmental impacts of the construction (including demolition) of the hoarding systems using Hong Kong as a case study to represent other similar densely populated cities. Hoarding system was specifically highlighted in this study as the system is an integral and important part of building construction in Hong Kong, and can contribute significantly to the total environmental impacts of the building construction due to its short service life span and considerable material usage and waste generation. In addition, the study identified the areas of possible reduction in impacts from hoarding construction and improvements in waste management after end-of-life of the hoarding system using LCA techniques.

2. Overview of hoarding system in Hong Kong

In Hong Kong, the construction of hoarding/covered walkway is governed by the Buildings Ordinance and associated Regulations. Applications for erect hoarding/ covered walkway permits under the Building (Planning) Regulations (B(P)R) are approved by the Buildings Department (BD). Hoardings/covered walkways should be constructed in accordance with the Code of Practice [34]. References should be made to the Practice Note for Authorized Persons, Registered Structure Engineers and Registered Geotechnical Engineers (PNAP) APP-23 [35] and the requirements of the Transport Department (TD) and the Highways Department (HyD).

Fig. 1 shows a typical section of catch platforms and covered walkways made of steel given in the Code of Practice for Demolition of Buildings [34]. The figure shows the requirements on dimensions of the hoarding/covered walkway structure. It can be seen that the concrete footings are placed under the footpath surface. Typical counterweights used in Hong Kong are shown in Fig. 2, which are horizontal concrete counterweights acting as barriers between columns. With reference to APP-23, the concrete counterweights (plinth) shall not be more than 250 mm in thickness across the width of footpath and not more than 1000 mm in height, and the minimum clear spacing between two concrete counterweights shall not be less than 1100 mm [35].

In Hong Kong, hoarding/covered walkways are assembled on-site in-situally and are mostly custom designed in response to different site conditions such as the width of pavement, street furniture and traffic signs requirements, and provisions and trees. According to the Code of Practice [34], the minimum clear width of the covered walkway on footpath depends on the existing pavement width of the footpath as shown in Table 1. The maximum width of the gantry is 6000 mm and the maximum clear spacing between two columns is 2400 mm. According to the requirements of TD and HyD [35], the obstruction to the existing traffic signs, traffic provisions, trees and utility pit cover should be avoided. The hoardings/covered walkways currently adopted in Hong Kong provide flexibility to accommodate site characteristics.

3. Methodology

3.1. Case-specific questionnaire survey

A case-specific and structured questionnaire survey was conducted in this study in order to collect the practical information of hoarding construction and deconstruction (including the waste management practices) in Hong Kong from the relevant professionals (given in Supplementary Information). The information and data gathered from this survey were used as a basis of this study. In the first part of the-survey, the information regarding the types of waste generated from horading construction, current waste management strategies, and potential waste minimization methods were collected. In the second part, the relevant necessary life cycle inventory (LCI) data (including the types and sources of materials used for hoarding construction, composition of hoarding systems, transport distances of materials and wastes, etc.) for conducting LCA was collected for assessing the environmental impacts associated with hoarding construction and waste management (shown in Tables 2 and 3, and Fig. 3). Finally, potential scopes for impacts and waste reduction were identified (Fig. 3).

3.2. Life cycle assessment of hoarding system

In order to assess the environmental impacts of hoarding construction in Hong Kong, LCA techniques according to ISO [36,37] was used in this study.

3.2.1. Scope of the study

The 'cradle-to-grave' system boundary was considered in this LCA, with the functional unit of 1 m of hoarding systems (Fig. 3). The current (existing) waste management system is the materials used for the hoarding construction would become waste/scrapes after the demolition of the hoarding systems. The waste, in particular, the concrete counterweights, would be disposed of at public fills, and most of the steel would be sold to scrape dealers for recycling in a steel smelter. An alternate system (proposed system in the study) is that different percentages of the steel materials used in the hoarding system would be directly reused in other sites.

3.2.2. Assumptions taken in this study

Due to the lack of some necessary information, several assumptions were made in this LCA, including:

(i) Energy (e.g., electricity) consumption data for welding was not taken into account due to the unavailability of data. However, other energy (e.g., diesel consumption by crane) was considered. (ii) The average transport distance was assumed be 20 km in average for transport of concrete from batching plants to hoarding construction sites based on our previous studies.

(iii) According to the Hong Kong Merchandise Trade Statistics