Resources, Conservation and Recycling 74 (2013) 20–26

Contents lists available at SciVerse ScienceDirect

Resources, Conservation and Recycling

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

A model for estimating construction waste generation index for building project in China

Jingru Li*, Zhikun Ding, Xuming Mi, Jiayuan Wang

College of Civil Engineering, Shenzhen University, Shenzhen 518060, China

ARTICLE INFO

Article history:
Received 7 October 2012
Received in revised form 17 February 2013
Accepted 20 February 2013

Keywords:
Waste generation per gross floor area (WGA)
The amount of construction waste
Material waste rate (MWR)
Building
China

ABSTRACT

The increasing construction and demolition (C&D) waste causes both cost inefficiency and environmental pollution. Many countries have developed regulations to minimize C&D waste. Implementation of these regulations requires an understanding of the magnitude and material composition of waste stream. Construction waste generation index is a useful tool for estimating the amount of construction waste and can be used as a benchmark to enhance the sustainable performance of construction industry. This paper presents a model for quantifying waste generation per gross floor area (WGA) based on mass balance principle for building construction in China. WGAs for major types of material are estimated using purchased amount of major materials and their material waste rate (MWR). The WGA for minor quantities of materials is estimated together as a percentage of total construction waste. The model is applied to a newly constructed residential building in Shenzhen city of South China. The WGA of this project is 40.7 kg/m^2, and concrete waste is the largest contributor to the index. Comparisons with transportation records in site, empirical index in China and data in other economies reveal that the proposed model is valid and practical. The proposed model can be used to setup a benchmark WGA for Chinese construction industry by carrying out large-scale investigations in the future.

1. Introduction

Construction and demolition (C&D) waste has become an important issue not only from the perspective of cost efficiency but also due to its adverse effect on the environment. In an attempt to protect the environment and to improve sustainability of the construction industry, many countries and regions have developed various regulations and initiatives to minimize C&D waste. In the United Kingdom, the Code for Sustainable Homes makes on-site waste minimization, sorting and recycling obligatory (United Kingdom Government – Department for communities and Local Government, 2006). Several regulations have existed to control C&D waste in Hong Kong (Tam and Tam, 2008a). As an example, waste management plan is compulsory for all construction projects in Hong Kong since 2003 (Tam, 2008b). The Brazilian Environmental Protection Agency published Resolution 307 in 2002, which requires all local authorities to prepare and execute plans for the sustainable management of C&D waste (Brazilian Government-Environmental Protection Agency, 2002). In mainland China, the Administration of Urban Construction Garbage was promulgated in 2005 to promote a series of local regulations on C&D waste management (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2005).

However, implementation of these provisions requires an understanding of the magnitude and material composition of the waste stream (Cochran and Townsend, 2010). A construction waste management plan, for example, requires contractors to estimate the quantity of total construction waste and its main components at the planning phase, which will facilitate waste reduction, reusing and recycling during the construction process.

A number of researchers were aware of this situation and concentrated on quantification of C&D waste in various countries (Llatas, 2011). These studies can be divided into two categories: studies that determine an overall C&D waste generation amount in a region (e.g. Bergsdal et al., 2007; Cochran et al., 2007; Franklin Associates, 1998; Kofoworola and Gheewala, 2009; Yost and Halstead, 1996) and those that measure C&D waste generation index at project sites (e.g. Bossink and Brouwers, 1996; Formoso et al., 2002; Poon et al., 2004a; Skoyles, 1976). In the second category, most of researchers discussed the construction waste generation index as estimation of this index is more difficult than demolition waste generation index.

The construction waste generation index is identified as a meaningful tool to promote construction waste management. It can be applied to predict the amount of construction waste generated in a project, which will assist project stakeholders to prepare appropriate waste management plans. Comparing the index between

* Corresponding author. Tel.: +86 755 26732840; fax: +86 755 26732850.
E-mail address: lijr2000@szu.edu.cn (J. Li).

0921-3449/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.resconrec.2013.02.015

different projects can help project stakeholders to gain more insight about their construction waste management performance and to review the effectiveness of construction waste management practices. Moreover, the amount of construction waste generated in a region or a country can also be estimated by employing the index and construction area (Cochran et al., 2007).

However, the consideration on construction waste management is fairly negligible in mainland China. Low awareness of sustainable construction accounts for the deficiency of data about the amount of construction waste either at a macroscopic level or a microscopic level. A widely cited construction waste generation index, 50–60 kg/m^2, was provided by Lu (1999) based on empirical estimation without detailed interpretation. However, the waste generation index will vary in a wide range with construction technology, structure type, building occupancy, and especially management level (Li et al., 2010). The above empirical index reveals limited information for project stakeholders for understanding the magnitude and composition of construction waste and preparing an appropriate construction waste management plan. In particular, the culture and common practices of the construction industry in China may not be entirely similar to other economies. Thus, an approach to the measurement of a construction waste generation index for the Chinese construction industry should be investigated.

Given the situation, the objective of this research is to present a practical and simple model for measuring the construction waste generation index for building projects in China. The study is structured in four parts. The first part includes a literature review on the quantification of construction waste. The second section describes the approach to measuring the waste generation index for building construction. Then, the method is illustrated using a newly constructed residential building project in Shenzhen, China. Finally, all the findings are discussed in detail and conclusions are drawn.

2. Reviews

2.1. Main construction waste generation indexes

Amounts of construction waste generation have received significant attention because this information is a prerequisite to developing appropriate solutions for managing waste. A variety of researchers have developed different methodologies to quantify construction waste. As mentioned above, these studies can be divided into two categories: studies that determine an overall waste generation amount in a region and those that measure the waste generation index at a project site.

Of the second category, some studies investigated material waste rates (MWR), which are the percentages of waste material to purchased material or required by the design, to indicate the waste generation level of construction projects. For an example, Skoyles (1976) measured the MWR of major materials in UK and found the percentages of waste materials ranged from 2 to 15%, on average double the losses generally assumed. Enshassi (1996) found from a study in the Gaza strip that the materials loss was approximately 3.6–11%. Formoso et al. (2002) indicated that the waste rate of materials in the Brazilian building industry was fairly high and varied widely across different projects. Bossink and Brouwers (1996) revealed that approximately 1–10% of the purchased construction materials (by weight) was left as waste. In Hong Kong, Poon et al. (2004b) identified the material waste levels of various trades for public housing and private residential buildings. Tam et al. (2007) investigated waste levels of five major types of construction material in terms of subcontracting arrangements and project types.

Other studies derived a waste generation index using the volume or quantity of waste generated per gross floor area (WGA). Poon et al. (2004a) calculated the WGAs for two public housing construction sites as 0.14 m^3/m^2 and 0.21 m^3/m^2. In China, Lu et al. (2011) performed a total of five measurement exercises to investigate the WGAs of four typical trades. Llatas (2011) developed a model to estimate WGA and applied to a dwelling project in Spain. A WGA of 0.1388 m^3/m^2 was obtained from the case study. Another study in Spain derived a WGA as 0.1075 m^3/m^2 from a newly constructed residential building that generated waste of approximately 172.2 m^3 on a total of 1600 m^2 floor area (Solís-Guzmún et al., 2009).

2.2. Measurement method of these construction waste generation indexes

In addition to different units of measure, the above studies also adopted varied approaches to measuring construction waste generation indexes. They reached their objectives using three different approaches: (1) field monitoring; (2) interviews and (3) material balance.

The first approach collects data by conducting field monitoring because direct records of construction waste amounts are generally unavailable at sites. Skoyles (1976) and Enshassi (1996) measured the MWR by comparing contractors' records of delivery with measurements of finished work. Formoso et al. (2002) investigated the occurrence of material waste in Brazil by direct observation of sites. Bossink and Brouwers (1996) sorted and weighed all construction waste materials at five housing construction sites. This method was also adopted by Lu et al. (2011). Poon et al. (2004a) conducted regular site observations at construction sites and collected data by visual inspection, tape measurements and truck load records. The quantities of waste were calculated by multiplying the truck volume and the total number of trucks used for waste disposal.

Apart from this type of 'hard' method for measuring waste, 'soft' methods, such as questionnaire surveys and interviews, have also been adopted (Lu et al., 2011). For example, Poon et al. (2004b) identified the waste levels of various trades based on site observations and interviews with professionals. Tam et al. (2007) collected the waste levels of five major types of construction material from interviews with project managers.

Another approach quantifies the construction waste generation index based on the material balance principle. This approach considers the fact that after the building materials are delivered to the site, part of the materials are incorporated into the building structure during construction, and the remainder is discarded as wreckage waste or package waste on site (Cochran and Townsend, 2010). Solís-Guzmún et al. (2009) identified three categories of waste in the construction process: demolished, wreckage and package waste. They quantified these three types of waste by multiplying the quantities of material used in structural elements with the corresponding transformation coefficients. The material used in each structural elements is obtained from the budget document. These coefficients were estimated from the Andalusian Construction Costs Database and the guidelines of an expert team. Llatas (2011) further applied the approach to quantify the amount of waste expected in each building element according to the European Waste List.

To quantify construction waste by carrying out field observation, on-site sorting, weighing and monitoring related documents is a relatively accurate method but requires a great deal of time and human resources. This approach requires field monitoring to continue until the end of construction activity in order to obtain the total quantity of waste generated on the site. This requirement is one key reason that only a few sample construction sites were investigated in previous researches (Bossink and Brouwers, 1996; Poon et al., 2004a). Furthermore, our previous experimental research also found that on-site sorting and weighing occupy too