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Estimation of building-related construction and demolition waste in Shanghai

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ABSTRACT

One methodology is proposed to estimate the quantification and composition of building-related construction and demolition (C&D) waste in a fast developing region like Shanghai, PR China. The varieties of structure types and building waste intensities due to the requirement of progressive building design and structure codes in different decades are considered in this regional C&D waste estimation study. It is concluded that approximately 13.71 million tons of C&D waste was generated in 2012 in Shanghai, of which more than 80% of this C&D waste was concrete, bricks and blocks. Analysis from this study can be applied to facilitate C&D waste governors and researchers the duty of formulating precise policies and specifications. As a matter of fact, at least a half of the enormous amount of C&D waste could be recycled if implementing proper recycling technologies and measures. The appropriate managements would be economically and environmentally beneficial to Shanghai where the per capita per year output of C&D waste has been as high as 842 kg in 2010.

1. Introduction

As the rapid development of building industry in PR China, huge quantities of construction and demolition (C&D) waste are generated. Along with a speedy increase of Gross Domestic Product (GDP), in the last decade, PR China has been the country with the largest production of C&D waste in the world (Xiao et al., 2012c). However, at present, most of the C&D waste is delivered to suburban or rural areas for simple disposal of landfill. Thus, C&D waste has become an important issue not only for its cost efficiency but also due to its adverse effect on the environment (Trankler et al., 1996). The large amount of C&D waste is a big challenge to the sustainable development of many large countries and regions, including PR China, and has already led to an increasing interest in recycling (Formoso et al., 2002; Tam and Tam, 2006; Xiao et al., 2012a).

In order to promote the sustainability of the building industry, plenty of regulations focusing on reducing or recycling the C&D waste have been carried out in many countries and regions such as the EU countries (Symonds Group Ltd., 1999), the US (USEPA, 2009) and Hong Kong (Hong Kong government, 2005). In recent years, intensive measures to encourage C&D waste reduction and recycling in PR China have also been put forward (China government, 2005). However, reliable information on the expected quantities of the C&D waste accumulated is important in order to establish reasonable policies as well as to propose alternative solutions. Many organizations and researchers throughout the world have been aware of this issue and focused on the estimation of C&D waste accumulation.

In the US, Franklin Associates (1998) estimated the building-related C&D waste generated was 136 million tons in 1996 and USEPA (2009) concluded the total building-related C&D waste was almost 170 million tons in 2003, with 39% coming from residential and 61% from nonresidential sources. For regions like Florida, Cochran et al. (2007) estimated that approximately 3.75 million tons of building-related C&D waste were generated in 2000, and demonstrated that concrete was the major component of the waste, representing a 56%.

In Europe, Bossink and Brouwers (1996) firstly quantified the waste generation during several residential construction projects in the Netherlands. Researchers in other countries such as Greece (Fatta et al., 2003), Norway (Bergsdal et al., 2007), Portugal (Coelho and de Brito, 2011) and Spain (Solís-Guzmán et al., 2009; Sáez et al., 2012) also took effective efforts to determine C&D waste quantification due to the deficiency of reliable or official data from the local governments. Recently, Llatas (2011) and Mália et al. (2013) also carried out studies to propose C&D indicators to estimate the amount of C&D waste for the EU, since the EU legislation lacked tools to implement C&D waste prevention and recycling measures.

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In Asia, quantification of C&D waste was first noticed in Hong Kong where a series of investigations reported by Poon (1997), Poon et al. (2001, 2004) and Tam et al. (2007) assessed the C&D waste. Seo and Hwang (1999) estimated that the amount of C&D waste in Seoul, the capital city of South Korea, was about 8.63 million tons in the year 1999 and would follow an increasing trend in the later years. The statistics figures were also available in some other countries like Kuwait, Thailand and Israel (Kartam et al., 2004; Kofoworola and Gheewala, 2009; Katz and Baum, 2011). In the mainland of China, Lu et al. (2011) and Li et al. (2013) conducted significant studies separately in Shenzhen city, south part of China. Though the demolition waste was not taken into consideration, both of the investigations presented a waste generation index during construction activity, which was an important factor in calculating the amount of construction waste. The important information cited from the previous researches is summarized and listed in Table 1, which can be used to compare C&D waste generation in different countries or regions.

However, the consideration on C&D waste generation amount has been fairly neglected in Shanghai, a big city located in eastern part of PR China. In fact, as a result of past, undeveloped technology and economy, numerous residential or nonresidential buildings in Shanghai that were constructed around 20–30 years ago or before, cannot satisfy the requirements of aseismic performance and accommodate to the rapid urban development. Structure codes in PR China have also been updated several times in the past 30 years, and the demand of urban planning led to massive demolishment of old houses, factories and even groups of new constructed buildings in Shanghai. Therefore, there is a pressing need to understand the generation of both C&D waste in this fast developing region and some further work should be taken to obtain the accurate accumulation of C&D waste generated per year in Shanghai.

The primary purpose of this study is to provide a specific analysis for the quantification and composition of C&D waste in Shanghai, PR China. Some discussion about the waste index per capita per year and lessons for the recycling management in this region will also be offered and introduced. In fact, the proposed estimation methodology will also be practical to evaluate the accumulation of C&D waste for other regions with rapid development.

2. Methodology

2.1. Approach

Two main methodologies have been used to estimate building-related C&D waste generation in the recent years. One popular method at present is the materials flow (or materials balance) analyses. It calculates the amount of materials that come into service and predicts the amount of those materials come out of service, i.e., C&D waste. The USEPA adopted the materials flow method to characterize municipal solid waste in the US since the late 1960s (USEPA, 2006). Cochran and Townsend (2010) first took advantage of this approach for the C&D waste generation and composition estimation area for the US. For the materials flow analyses, the historical construction material production data of the country or region is needed and data sources inevitably play a significant

Table 1
Previous studies on C&D waste generation in different countries and regions.

Country or region	Year	Types of buildings	Types of waste	C&D waste conclusions
US[a]	1996	Residential and nonresidential	Construction and demolition waste	136 million tons, with 43% coming from residential and 57% from nonresidential
US[b]	2003	Residential and nonresidential	Construction and demolition waste	170 million tons, with 39% coming from residential and 61% from nonresidential sources
Florida in US[c]	2000	Residential and nonresidential	Construction and demolition waste	3.75 million tons and concrete was the major component of the waste representing 56%
Netherlands[d]	1996	Residential	Construction waste	1–10% of the building materials delivered on site becomes waste, with an average of 9%
Greece[e]	2000	Residential and nonresidential	Construction and demolition waste	Exceed 3.9 million tons with about 656 kg per capita
Norway[f]	2002	Residential and nonresidential	Construction and demolition waste	1.256 million tons generated and the major is concrete and bricks, accounting for 67%
Portugal[g]	2008	Residential and nonresidential	Construction and demolition waste	186 kg/person/year, with commercial buildings account for 13% and public works around 15%
Spain[h]	2009	Residential and nonresidential	Construction and demolition waste	New construction: 0.3076 m^3/m^2 demolition: 1.2676 m^3/m^2
Seoul in Korea[i]	1999	Residential and nonresidential	Construction and demolition waste	8.63 million tons in the year 1999 and following an increasing trend
Hong Kong[j]	1998	Residential and nonresidential	Construction and demolition waste	32 710 tons of C&D waste generated per day and waste concrete occupies the most
Shenzhen in Mainland China[k]	2009	Residential and nonresidential	Construction waste	Waste generation rates ranged from 3.275 to 8.791 kg/m^2 and miscellaneous waste, timber, and concrete were the three largest components
Shenzhen in Mainland China[l]	2009	Residential and nonresidential	Construction waste	Waste generation per gross floor area is 40.7 kg/m^2, and concrete waste is the major contributor, accounting for 43.5%

[a] Franklin Associates (1998).
[b] US Environmental Protection Agency (USEPA) (2009).
[c] Cochran et al. (2007).
[d] Bossink and Brouwers (1996).
[e] Fatta et al. (2003).
[f] Bergsdal et al. (2007).
[g] Coelho and de Brito (2011).
[h] Solís-Guzmán et al. (2009).
[i] Seo and Hwang (1999).
[j] Poon et al. (2001).
[k] Lu et al. (2011).
[l] Li et al. (2013).