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Characterizing the generation and management of a new construction waste in China: glass curtain wall

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Abstract

Massive construction and demolition waste is generated in China's rapid development. Within this kind of waste, glass material produced form the widely applied curtain wall system contributes a lot. Currently, the majority of waste glass curtain wall is simply disposed in landfills or dumping, which not only significantly threats the scarcity of land resources, but also raises risks for surrounding environment and human health. However, there is relatively little work in China which focuses on the management of glass curtain wall waste produced from demolition and reconstruction sites. Therefore, this study systematically reviews current application and further development of glass curtain wall system in Shenzhen city (a mega city of China), and then analyzes the compositions and characteristics of the generation of waste glass curtain wall. The results show that the total gross surface area of buildings that use glass curtain wall system has approximately reached to 3 million m^2 in the region (Nanshan district in Shenzhen). It also indicates that there is around 2 kg of waste which could be produced from the construction of glass curtain wall per m^2 and will generate more than 6000 tons of glass curtain wall waste, including the whole life cycle from manufactory and construction. In additional, several recommendations to sound management of the waste glass curtain wall are proposed based on the further review of the management strategies and process methods employed in developed counties. Overall, the findings in this study could be helpful to contribute valuable knowledge and methods to the environmental management and waste recycling in China.

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Keywords: Glass curtain wall; Construction waste Management; waste recycling; environmental management

1. Introduction

The gross domestic product (GDP) of China has reached 57 trillion yuan by 2013, within which the number contributed by construction industry is 16 trillion yuan [1]. As one of the national pillar industries, construction industry develops rapidly along with the further urbanization. To be specific, due to glass curtain wall have advantages of lightness (12% of traditional masonry and 10% of concrete), high transparency property and beautiful appearance, it

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has got a quick development and wide application since it emerged in China in 1980s, and becomes one of the best choice for the outer shield structure in high-rise and super high-rise buildings [2].

Recently in China, however, only less than 10% of construction and demolition (C&D) waste was recycled while the majority of waste remain to be simply landfilled or just to be dumped, glass curtain wall waste [3]. At present, the technology of glass curtain wall has been widely used. It is imperative for us to recognize that the material life is as short as 10 to 20 years which is obviously shorter than other construction material and many glass-wall buildings are facing the situation of being demolished [4]. The newly built buildings adopted glass curtain wall with large scale in 1990s need a large number of replacement which generate enormous GCWW and cause resource waste and environment issues.

Owing to the significance of C&D waste, including GCWW, the investigation has long been attractive to researchers as well as practitioners. Tam et al.(2009) found that rapid urbanization has not only contributed to an increasing use of non-renewable resources, but has also led to the generation of significant amount of construction and demolition (C&D) waste and its associated environmental concerns [5]. At the same time, this rapid growth has resulted in enormous pressure on the ecosystem due to a large amount of energy required.

And glass curtain wall industry is one of the resource-intensive industries. Energy use is a major source of GHG emission, causing environmental problems, which is a serious question given that extreme weather conditions are spreading rapidly across China [6]. Continually rising energy consumption and highly-positioned energy intensity have not only sounded the alarm for Chinese energy security, but also increased the pressure on whether or not China should bear more responsibility in cutting emissions in the post Kyoto-protocol era [7]. Hence, cutting energy consumption has become a matter of urgency in China

When considering GCWW management measures for saving energy and resource, it is necessary to understand the amount, composition, and flows of the generated waste as precisely as possible within a given geographic area [8].Previously, foreign studies have been undertaken to investigate the suitability of glass curtain wall materials. M.Samuel introduces a new direct technique for recycling aluminium scrap with low energy consumption and cost without intervening metallurgical processes and experimental results show that the direct technique for recycling aluminium provides high productivity and about 80% green density [9]. These studies investigated the properties of the waste glass aggregate and tried to find the optimum percentage of waste glass that can be used as aggregate without any effect on the properties of the produced concrete [10,11].

Although these prior literatures enhance our knowledge, they mainly focused on the composition, weight, generation rate and management measures of C&D waste separately, with few focusing on GCWW holistically. Besides, in many cities of China, including Shenzhen, there is lack of regular statistics on the quantities of demolition waste, which presents a major barrier to the development of effective management measures [12].Moreover, there is a pressing need to understand the composition, quantities and weight of GCWW .It is therefore imperative to identify the a new GCWW management measures to replace the traditional mode which is featured with high resources wasting.

The analysis is based on empirical investigations of GCWW in Shenzhen city of south China and the aim of this research is to propose recommendations for improving the performance of GCWW management. The remainder of this paper is organized in four stages, the first of which is to provide methodologies for investigating GCWW and the second stage is conducting waste sorting and weighing at two site in Shenzhen (a construction project and a demolition project) and doing interview about the recycling potential of GCWW, while the third and fourth stages respectively analysed the data and provide results and discussions.

2. Method and data collection

When investigating GCWW, its normally approach is classifying GCWW into different categories. A review indicates that there are four measures are adopted when charactering the waste generation rates, namely (a) percentage of material purchased, (b) percentage of material required by the design, (c) kg/m2 of GFA, or (d) m3/m2 of GFA [13]. This study adopted the measures to calculate the material loss rate in construction period by (a) (b) and waste generation rate by (c), while using two common methodologies for investigating GCWW: (i) using ‘hard’ measures such as on-site sorting and weighing and or truck load records, and (ii) using ‘soft’ measures such as questionnaire and/or interviews with construction employees and government officials.

Field surveys were carried out to estimate the total surface area of glass-wall buildings in Nanshan District. And the research was conducted between October 2014 and March 2015 on two construction and demolition projects (A and B) in Shenzhen, a coastal city in South China adjacent to Hong Kong. Before the waste in project A and B was weighed, physical sorting of the waste was carried out. It is observed that different GCWW such as glass, steel, aluminium and stone, more or less, were generated along with different C&D procedures. For the on-site waste measuring exercises, the research team was equipped with tools including (1) buckets with the net weight and volume already known, (2) a weighing scale. Different types of C&D wastes were weighted bucket by bucket and recorded in inventory forms. GFA of the area was calculated from the floor drawings provided by the site managers. The manufacturing process and energy consumption of glass industry and the GCWW management measures were questioned and interviewed with glass practitioners, constructors and government officials.

2.1. Estimation of surface area of glass curtain wall for a single buildings

The Nanshan District is a high-tech district with 510.948 km² in Shenzhen, Guangdong province in China. In 2013, Nanshan District's GDP totaled 320.657 billion yuan. The Nanshan district has 31,299 buildings with an average GFA (gross floor area) of 2683 m² per buildings[4]. In this research, the glass curtain wall building's type is identified in frame supported glass curtain wall and full glass curtain wall. The surface of glass curtain wall used in a single building is calculated by (Eq. (1)).

$$S_x = GFA_x \times \partial_x \quad (1)$$

Where S_x refers the surface area of glass curtain wall of a single building. GFA_x refers gross floor area, the index (∂_x)refers the ratio between the surface area of glass curtain wall and GFA, and x refers to two different building types(frame supported glass curtain wall and full glass curtain wall).

2.2. Calculation of weight of glass curtain wall materials for single new construction building

The weight of GCWW for single new construction building could be calculated by equation (2).

$$W_n = S_n \times \rho \times G_i \quad (2)$$

Where W_n refers weight of GCWW for new construction building,S_n refers the glass curtain wall surface of a single building, ρ refers the surface density of glass curtain wall(about 30kg/㎡)， G_i refers generation index of GCWW (see Table 1) and i refers different materials used in glass curtain wall including glass, steel, aluminium and stone.

2.3. Calculation of weight of GCWW of single demolition project and the total weight

The weight of GCWW of single demolition project could be calculated by equation (3)

$$W_d = S_d \times G_i \quad (3)$$

$$W_t = W_n + W_d \quad (4)$$

Where W_d refers weight of GCWW of single demolition project, $S_d$refers the glass curtain wall surface of a single building and G_i refers generation index of GCWW (see Table 2), i refers different materials used in glass curtain wall including glass, steel, aluminium and stone, W_t refers weight of GCWW of all of the buildings in Nanshan District.

3. Results and discussions

This section analyses and discusses the major findings revealed by the study, including the result of total surface of glass-wall buildings in Nanshan District, comparison of the generation and composition of GCWW amongst the two projects(A&B), and the present GCWW recycling potential values. In addition, GCWW management measures in China are also compared with that in foreign developed countries.

Fig.1. Nanshan District and some glass curtain wall buildings

3.1 The surface area of glass curtain wall buildings in Nanshan District

From our previous investigation, it is estimated that there are more than 80 glass curtain wall buildings with 20 to 30 buildings being constructed among numerous buildings in Nanshan District (See Fig.1).

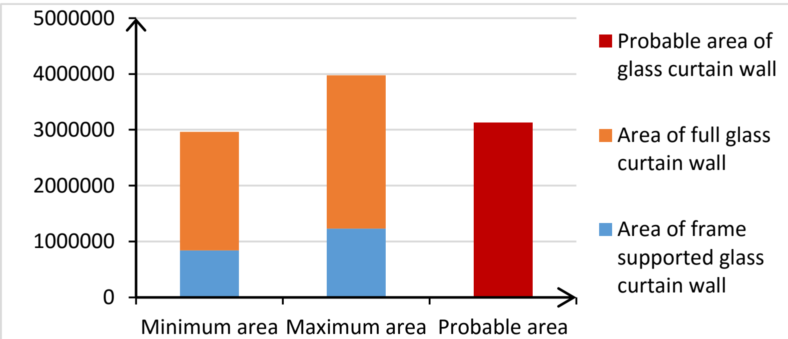

Fig.2. Estimation of surface area of glass curtain wall buildings in Nanshan District (㎡)

The research estimated the probable surface area of glass curtain wall used in construction. Fig.2 clearly shows the surface of two different types' area of glass curtain wall. Totally an area of 3.1 million square meters of glass curtain wall is estimated in Nanshan District. Surface area of frame supported glass curtain wall should be about 980,000 square meters (32% by area), surface area of full glass curtain wall should be about 2.12 million square meters (68%).it is predicted that there will be 8 million square meters of glass curtain wall by 2025 if the trend continues and escalates.

3.2 Generation and composition of GCWW

Table 1 shows the materials purchased and required in a construction project A. The loss of material generated from freight and installation. It is estimated that there would be about 0.09 kg/㎡ GCWW generated from construction process.

Table 1. Glass curtain wall materials provided and used in construction project A

Materials	Purchased (kg)	Required(kg)	Material loss rate
Glass	1 074 000	1 021 320	4.9%
Steel	93 000	90 327	2.8%
Aluminium	412 500	391 660	5.1%
Stone	98 000	96 740	1.3%

Table 2 shows the GCWW generated from a demolition project B. On-site sorting and weighting from provides more credible data when investigating GCWW. Because the specificity of glass-wall buildings, almost all of the glass curtain walls are demolished and it is estimated that there would be about 1.92 kg/㎡ GCWW generated from demolition process. And 2.01 kg/㎡ with a total of more than 6000 tons GCWW is supposed to be generated during the life cycle of one project.

Table 2. GCWW in demolition project B

Materials	Weight of generation (kg)	Waste generation rate(kg/㎡)
Glass	306 750	1.22
Steel	26 405	0.11
Aluminium	114 495	0.46
Stone	33 600	0.13

3.3 Recycling potential of GCWW

Table 3 illustrates the environmental influences of glass curtain wall industry. Recently in China, however, more than 90% of GCWW remains simply to be landfilled or just to be dumped from questionnaire and interviews. This does not fulfil the related requirements specified in policies of resource recycling [14].

Table 3. CO_2 emission and energy consumption of main materials of glass curtain wall

Materials	Energy consumption (MJ)	CO_2 emission (kgCO2 / t)
Glass	505	1 870
Steel	37 200	6 470
Aluminium	45	1 430

To reduce the recyclable GCWW being landfilled or dumped, GCWW could be used as a raw material in the manufacture of construction materials and for the compliance with its own recycling target

4. Conclusion and recommendations

This research improves the understanding of GCWW in the Shenzhen's construction and demolition sector. The research revealed around 2.01 kg/m2 GCWW in Shenzhen. GCWW for main materials including glass, steel, aluminium and stone waste were investigated individually. It was found that glass outweighed any other material as the main sources of GCWW in Shenzhen. GCWW management measures were also compared with foreign developed countries and it was found that GCWW should not only remain simply to be landfilled or dumped. Rapidly developing city like Shenzhen will be rapidly renewed again in the future. The huge generation of GCWW and crude management measures are new problems to which little attention has been paid but which should not be ignored. Or else, this situation will potentially result in a series of serious issues such as a peak in the generation of GCWW.

Based on the above findings and discussions, it is able to make recommendations for improving GCWW management in Shenzhen.

- Technology is the basis of recycling utilization of construction and demolition waste, including the research and development of comprehensive utilization techniques and the innovations in the reform of GCWW management system and mechanism.
- Glass curtain wall industry is energy-intensive and production technology should be promoted to decrease the CO_2 emissions and energy consumptions.
- Although Shenzhen have been implementing construction and demolition waste recycling very well, the overall recycling rate of GCWW is still not high. The main reason is unstandardized policies and classification systems for glass waste. The foreign measures provide a better solution for the management and unified policies and management measures of glass waste recycling are needed.
- Financial support from the government is required to reduce the initial high investment costs for using managing and using waste concrete materials.

Findings from the research will improve the creditability of statistics that are available for understanding GCWW in China, and the waste generation rate revealed will serve as valuable quantitative information for benchmarking different construction and demolition waste practices. Finally, the recommendations presented could be helpful for the construction and demolition industry when considering improving the performance of GCWW.

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References

1. NBSC, 2014. Available at: http://data.stats.gov.cn/workspace/index;jsessionid¼472F31C505EE5881D26929410F8BB362F?m=hgnd.
2. Dong B. Glass curtain wall is the best choice for exterior walls of high-rise buildings [J].Doors &Windows, 2014(04): 22-23.
3. Wu, H., et al., An innovative approach to managing demolition waste via GIS (geographic information system): a case study in Shenzhen city, China. Journal of Cleaner Production, 2015.
4. Wu X. The existing problems and the development directions of modern glass curtain wall. Heilongjiang science and technology information, 2010(30): 284.
5. Tam V.W.Y., Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. Journal of Cleaner Production, 2009. 17(7): 688-702.
6. Wang Z., et al., Regional total factor energy efficiency: An empirical analysis of industrial sector in China. Applied Energy, 2012. 97: 115-123.

7. Andrews-Speed, P., China's ongoing energy efficiency drive: Origins, progress and prospects. EnergyPolicy,2009.37(4): 1331-1344.
8. Gallardo, A., et al., Methodology to design a municipal solid waste generation and composition map: A case study. Waste Management, 2014. 34(11): 1920-1931.
9. Samuel, M., A new technique for recycling aluminium scrap. Journal of Materials Processing Technology, 2003. 135(1): 117-124.
10. Corinaldesi, V., et al., Reuse of ground waste glass as aggregate for mortars. Waste Management, 2005. 25(2): 197-201.
11. Idir, R., M. Cyr and A. Tagnit-Hamou, Use of fine glass as ASR inhibitor in glass aggregate mortars. Construction and Building Materials, 2010. 24(7): 1309-1312.
12. Yuan, H., A SWOT analysis of successful construction waste management. Journal of Cleaner Production, 2013. 39:1-8.
13. Lu, W., et al., An empirical investigation of construction and demolition waste generation rates in Shenzhen city, South China. Waste Management, 2011. 31(4): 680-687.
14. Li, J., et al., A model for estimating construction waste generation index for building project in China. Resources, *Conservation and Recycling,* 2013. 74: 20-26.