Muhammed Alamgir, S.M. Tariqul Islam, Mahmudul Hasan, N.J. Pollen (Eds.)
ISBN: 978-984-35-7297-4

Full Paper of the WasteSafe 2025 – 9th International Conference on
Sustainable Solutions for Waste Management in Developing Countries
22-23 February 2025, Dhaka, Bangladesh

EVALUATING THE WASTE GENERATION RATE IN CONSTRUCTION ACTIVITIES: A CASE STUDY OF CHATTOGRAM CITY

Arka Prava Das[1] and Fatema Tuj Jahara[2]

[1,2]Department of Civil Engineering, Southern University Bangladesh

ABSTRACT

Construction and demolition (C&D) waste is generated during the construction, renovation, and demolition of buildings or structures. These wastes include materials such as concrete, bricks, wood and lumber, roofing, drywall, landscape, and other wastes. The main objective of this study is to know the waste generation rate (WGR) of construction activities in Chattogram city. The results revealed that WGR is approximately 40.29 kg/m² for construction activities in the financial year (FY) of September 2021 to March 2022. A total of 2785.8801 tons of waste were generated in Chattogram city, of which the largest proportions were concrete (81.15%). The present study also finds out the management of construction waste in Chattogram City. Concrete mortar waste is sold approximately 25% & 75% is transported to landfill, where 100% metal flows to the industry to produce new metal products & 100% brick is converted to coarse aggregate. Additionally, the study highlights the need for improved waste management practices and policies to enhance recycling and reduce landfill dependency. It also suggests potential areas for future research, such as the environmental impact of C&D waste and the economic benefits of recycling initiatives. The findings aim to contribute to sustainable construction practices in urban areas.

INTRODUCTION

The volume and composition of construction debris generated during building, restoration, and demolition activities provide substantial environmental challenges. This trash comprises items such as concrete, wood, metals, and toxic compounds, all of which can cause pollution and resource depletion if not handled properly. Effective construction waste management strategies, such as the "3R" principle (reduce, reuse, and recycle), are critical to reducing environmental effect. However, many impoverished countries experience low recycling rates. For example, China recycles less than 5% of its construction and demolition trash, compared to 70-95% in industrialized countries such as the United States and Germany(Wu et al., 2014). Government laws, public education, and stakeholder involvement are vital for improving waste management practices and promoting sustainability in the construction sector(Z. Ding et al., 2016)

In recent years, landfill loading and operations have been heavily burdened with construction and demolition (C&D) waste (*Waste | Environmental Protection Department*, n.d.). According to Eurostat, around 2 billion tons of waste is produced annually in the European Union, with 31% being construction waste (*Waste Statistics - Statistics Explained*, n.d.). In China, 29% of the world's municipal solid waste is generated, with 40% of it comprising construction waste (*Solid Waste in China - Statistics & Facts | Statista*, n.d.). A study reported that 3158 tons of material waste were disposed of daily at landfills, which accounts for 23% of the total solid waste generated in Hong Kong (*Solid Waste in China - Statistics & Facts | Statista*, n.d.).

Construction waste generation has become a serious concern due to its direct influence on the environment while also impacting the efficiency of this business. Building activity has a significant environmental impact, including air pollution, noise pollution, and water contamination. The most significant and negative environmental impact is caused by incineration, which emits pollutants into the air. Contractors have to bear the loss because of additional overhead costs and delays and loss of efficiency due to further time spent for cleaning.

Construction and demolition waste (CDW) accounts for 30% to 40% of the total waste in China. Typically, CDW is randomly dumped or landfilled, with an average recycling rate of only about 5%. Annually, China produces more than 1.5 billion tons of CDW, leading to severe environmental and social issues, and this amount has been increasing rapidly, particularly after 2009 (Huang et al., 2018) In China, East China

contributes the largest ratios to construction waste (37%) and demolition waste (27%), followed by Middle and Southwest China (14%) and South China (25%) in construction waste (Zhao et al., 2011). The waste management pattern in Sylhet city, Bangladesh, covering an area of 26.50 km² with a population of 1 million, is alarming. In 2017, solid waste generation reached about 260 tons per day, 2.5 times higher than in 2004, with 52% collected door-to-door, 22% using community bins, and the rest dumped in open places (Iqbal, 2017).

In Malaysia, the waste generation rate varies with construction methods: conventional methods generate 9.88 tons per 100 m², mixed-construction methods generate 3.29 tons per 100 m², and demolition projects generate 104.28 tons per 100 m² (Mah et al., 2016). In the UK, construction and demolition waste amounts to around 120 million tons per year, including an estimated 13 million tons of unused material, with responsibilities to minimize waste lying with clients, contractors, suppliers, and designers (*UK Statistics on Waste - Data.Gov.Uk*, n.d.). In the Lisbon Metropolitan Area (LMA), CDW management is vital for urban development. CDW generation in 2006 and 2007 was estimated based on construction activity and waste movements, showing 954 tons per day and a per capita rate of 0.60 tons per year in Lisbon (De Melo et al., 2011)

In this study, a proportion of different types of construction waste was estimated in Chattogram city, Bangladesh. 10 projects were primarily selected for calculating total waste generation rate. Also, an observation was done to check any management techniques (reuse/recycle/resell/dump) are followed in Chattogram city

Construction and Demolition (C & D) Waste

Construction waste is described as reasonably clean, heterogeneous building materials resulting from different construction processes. Construction and demolition wastes (C&DW) include detritus from the construction, renovation, and demolition of bridges, roads, and buildings (*Construction Waste - Wikipedia*, n.d.)

There are two types of C&D waste generally Inert and Non-inert construction & demolition waste. Inert C&D comprises of soil and mixed fragments, mortar and bricks, and non-inert materials are metal, timber, plastic, glass and residual. Also, the C&D waste can be categorized into hazardous and non-hazardous which is shown.

Table 1Classification of Construction & Demolition waste

Hazardous	Non-hazardous
Insulation and asbestos materials	Insulation and asbestos materials
Soil and stones	Wood - untreated
Dredging spoil	Glass - uncontaminated
Gypsum materials	Plastic - excludes packaging waste
Concrete, bricks, tiles and ceramics in mixtures	Concrete
Cables containing oil, coal tar and other hazardous substances	Concrete, bricks, tiles and ceramics in mixtures

ISBN: 978-984-35-7297-4

METHODOLOGY

In this section, the whole framework was mentioned in a nutshell. It was a long process but the total workflow can be described in this flow chart:

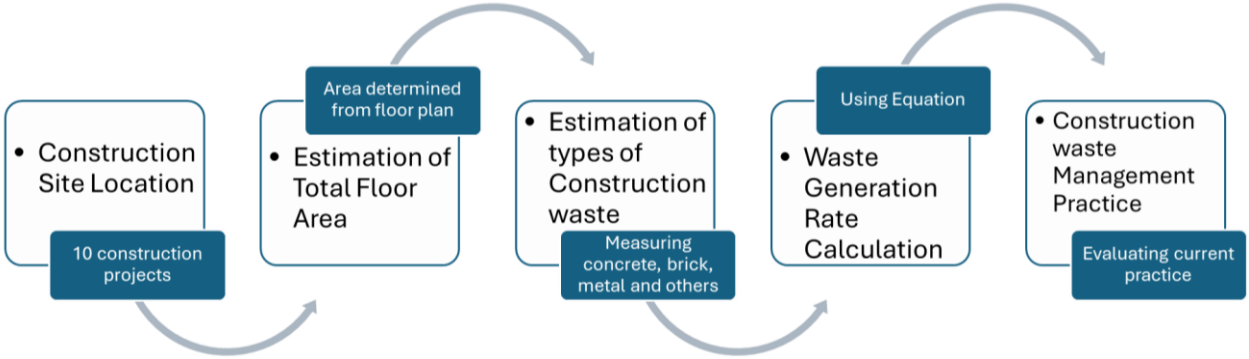

Figure 1 Flowchart of Construction Waste Estimation and Management Process

Among the construction sites, nine of them were residential buildings and one of them was a commercial building. The construction areas are scattered around the main Chattogram City and located in the main areas of Agrabad, Khulsi and 2No. Gate.

The main target was to calculate the total amount of waste created in the process. The calculations were simple. Buckets of known weight and volume were chosen. The materials were collected and then separated. With a weighing scale, weights of waste were calculated.

To integrate the data, following equation was used (T. Ding & Xiao, 2014; Islam et al., 2019)
:

$$Q = \sum_{k=1}^{n} \sum_{j=1}^{m} A_i \, WGR_{jk} \qquad (1)$$

Where,
Q = total quantity of C & D waste generated in a region
A_i = total amount of C & D activity in a region (m^2)
WGR_{jk} = waste generation rate of j^{th} type of waste material from k^{th} type of building
m = number of primary materials
n = number of different types of buildings

RESULTS

After calculating each material, waste amount values are inserting in a scatter plot to estimate the waste generation rate, WGR through regression analysis which are presented in following figures:

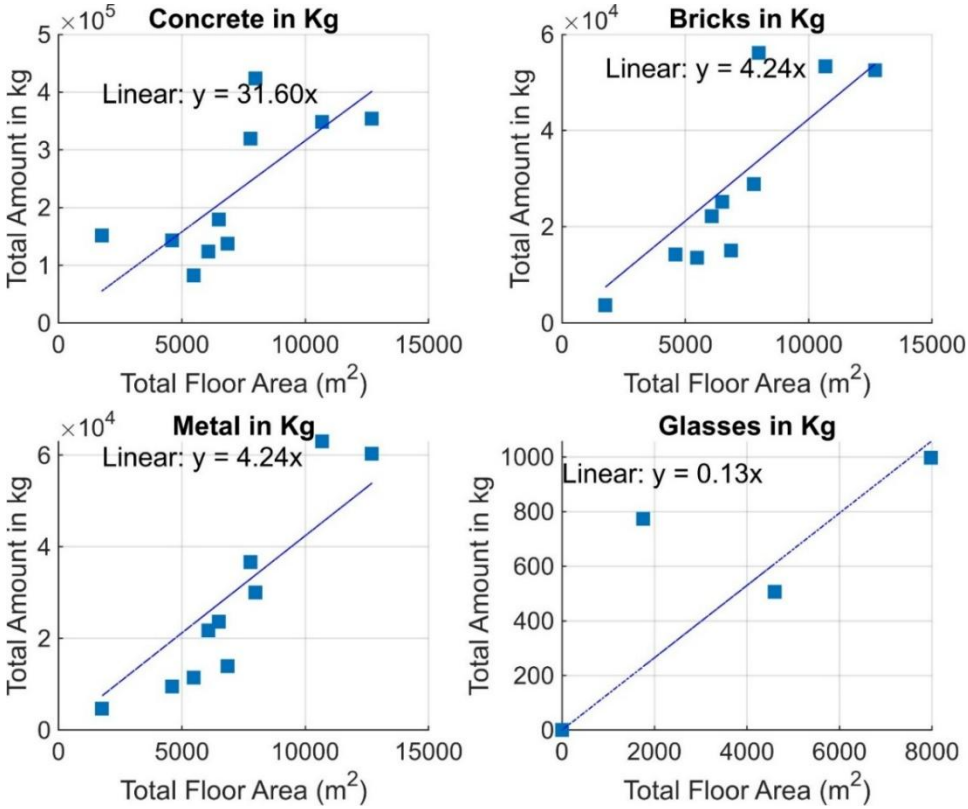

Figure 1 Analysis of waste generation of different materials

In the first row of the figure, it is seen. concrete waste is maximum for all the buildings as it is the primary constituent in a building construction. Also, there is a positive relation between floor area and total amount of concrete wasted. A lot of bricks are wasted in the process of building making. In the bottom row, it is visible that there is a significant loss of metals in the production which are used in framework or shuttering. Glass waste is very less as it is generally used in commercial buildings only.

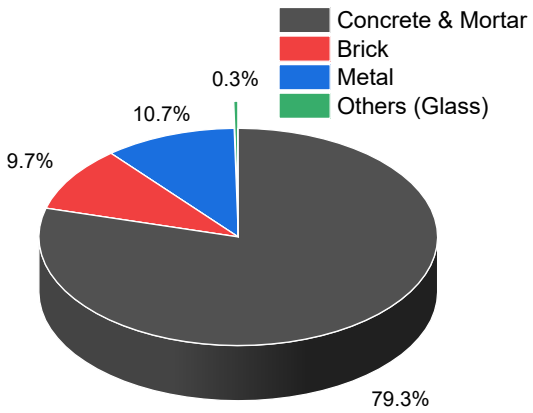

Figure 3 Distribution of Construction Waste Materials

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The largest percentage of waste was found from concrete and mortar and metal, brick and glasses comprise the other constituents which can be shown in figure 3.

The waste generation rate here can be defined as the slopes of the above-mentioned graphs. So, total waste generation rate from our experiment is tabulated in table 2

Table 2 Waste generation rates for the experiments

Primary Waste materials	Waste Generation Rate (kg/m^2)
Concrete	31.60
Bricks	4.24
Metals	4.24
Others (Mainly Glasses)	0.13

The total Waste Generation rate for construction in the time of September 2021 to March 2022 was found to be 40.21 kg/m^2.

From the total floor area and the amount, total quantity of waste produced by the 12 construction sites was calculated using the equation 1 and tabulated below in Table 3:

Table 3 Total Waste generated

Primary Waste materials	Total Amount in Tons
Concrete	2263.43
Bricks	274.81
Metals	244.81
Others (Mainly Glasses)	9

Total amount of waste activity found in our experiment was about 2800 tons.
Among 10 project concrete mortars, 25% are being sold & the remaining 75% are being transported to landfill. Flow the metal industry to produce new metal products. Brick 100% converted to coarse aggregate. 100% brick of 10 projects are converted into coarse aggregates. An explanation of the use of the materials is shown in table 4

Table 4 C&D Waste Management in Chattogram city

Construction Waste Types	**Waste Management**	**Quantity**
Concrete mortar	25% is sold & 75% is transported to landfill	565.86 Ton out of 2263.43 Ton (25%)
Metal	Flow the metal industry to produce new metal products.	274.9 Ton
Brick	100% converted to coarse aggregate.	244.81 Ton

The WGR estimated in this study agreed with the values estimated in other countries like Spain, China, India (Chennai), & Malaysia. The WGR Calculated, maximum construction WGR found 40.21 kg/m2 in Chattogram (Bangladesh), 80 to 114 kg/m2 in Spain & 32.9 to 98.8kg/m2 in Malaysia. The comparison can be shown in the table 5

Table 5 Comparison of Chattogram City's Construction waste generation rate with other countries

Country	WGR (kg/m²) Construction	Year of Data	Reference
Malaysia	32.9 to 98.8	2016	(Mah et al., 2016)
Chennai, India	60	2013	(V G & Kalidindi, 2017)
Spain	114.47	2010	(Mália et al., 2013)
Spain	80	2013	(Mercader-Moyano & Ramírez-de-Arellano-Agudo, 2013)
Dhaka, Bangladesh	63.74	2016	(Islam et al., 2019)
Chattogram, Bangladesh	40.21	09/2021-03/2022)	This Study

In the figure 4, the percentage distribution of various construction waste materials across eight countries:

Kuwait, USA, Norway, Spain, Portugal, China, Bangladesh (Dhaka), and Bangladesh (Chittagong) was illustrated. The y-axis represents the percentage of waste materials, with categories including Metal, Concrete, Mortar, Brick/Block, Ceramic, Timber, and Others. The chart shows that concrete is the most predominant construction waste material in all listed countries, followed by significant proportions of brick/block and mortar in some regions.

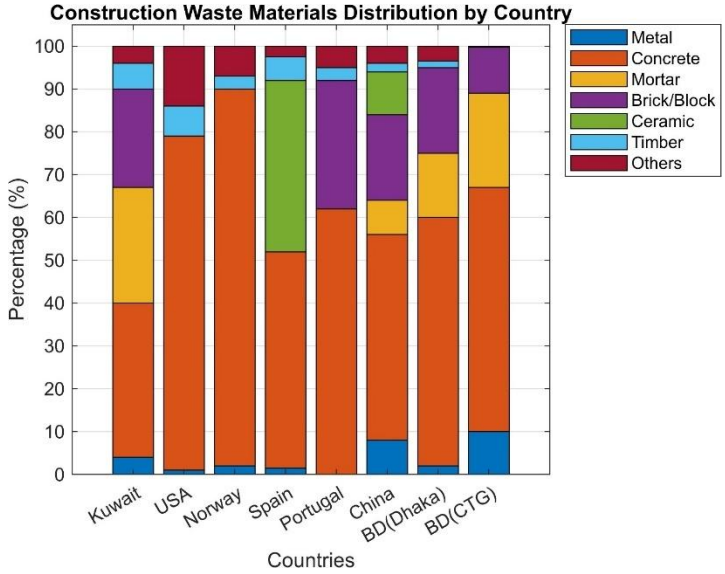

Figure 4 Construction Waste Materials Distribution by Country

In the next graph in the figure 5, total landfilling and recycling percentages of waste across countries like France, UK, Italy, Spain, Belgium, Germany, China, and Bangladesh. It highlights high recycling rates in countries like the UK and Germany, contrasting with low recycling and high landfilling rates in China and Bangladesh. It means, better waste management policies should be implemented in Bangladesh. Also, European countries have a good rate of recycling which is a good practice for Sustainable development goals.

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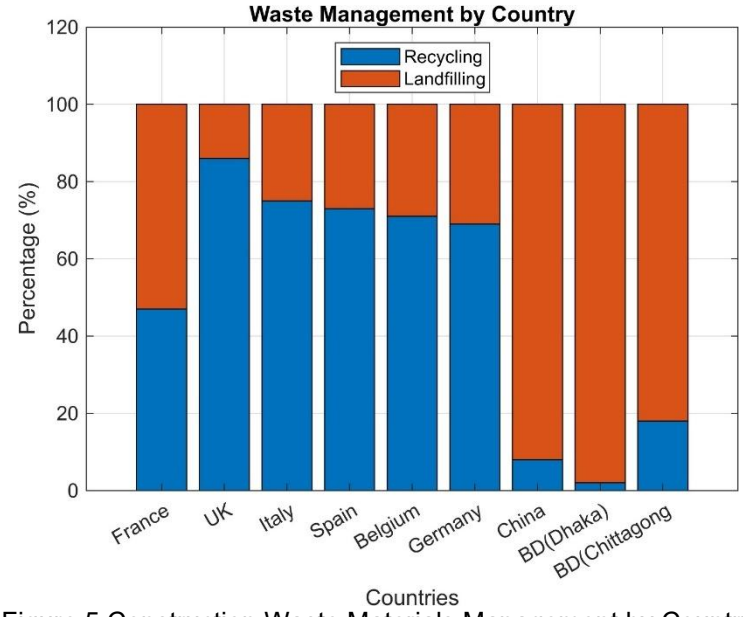

Figure 5 Construction Waste Materials Management by Country

CONCLUSIONS

C&D waste can significantly contribute to the national economy by reducing natural resource use and meeting material needs in construction projects. However, increased urbanization will lead to more waste, potentially polluting the environment if not managed effectively. Government action is crucial at both policy and administrative levels, including formulation, implementation, management, monitoring, and law enforcement.

In a study of 10 projects in Chattogram city, the construction waste generation rate was found to be 40.29 kg/m², with concrete mortar waste at 31.94 kg/m². The total construction waste in Chattogram is 2785.8801 tons, comprising 81.15% concrete mortar, 8.68% metal, and 9.77% brick waste. The study concluded that 25% of concrete mortar waste is sold, 75% is landfilled, and 100% of metal and brick waste is recycled or repurposed.

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