Categorization and Quantification of Construction Waste of Commercial Buildings in Iraq

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Abstract. The construction sector has a significant and direct relationship with the development and growth of countries. Meanwhile, the population growth and the massive expansion of buildings and infrastructure projects keep up with living standards, generating more construction waste. Knowing the categorization for the CDW is very important to get better information about the waste and to have a proper plan to manage these wastes during the construction process. This study aims to categorize and quantify the CDW produced during the construction of a commercial building in Iraq, with a total floor area of 900 m^2 (A three-story building with 300 m^2 for each story). Data acquisition for this study took approximately two years. It concludes that soil waste represents 86.75% of total waste produced during the construction of the building, with the remaining 13.25 % mainly composed of brick (47.03%), followed by concrete (19.27%), mortar (10.65%), ceramics and marble (6.68%), gypsum (4.88%), steel (3.08%), wood (2.37%), and subbase (2.02%).

Keywords: Construction waste; materials; generation; building; project; Iraq.

1. INTRODUCTION

Construction and demolition waste (CDW) generation have created severe local and global problems. As stated by Tareq [1], all countries are facing a construction waste problem due to the rapid growth of construction projects. More particularly, Iraq is suffering from vast amounts of CDW and leakage, which is needful in the construction stages of a building. Illegal dumping sites have increased this problem, led to environmental pollution, and increased project costs. According to Alajeeli and Kaabi [2] the increase in construction activities in the last fifty years has generated a similar growth in the quantity of CDW. This expansion and deficient landfill areas in civilized zones have led to severe environmental requirements. As Nikakhtar [3] concluded, CDW may be categorized according to several properties, such as type, proportion, etc. Most of the classifications aim to divide the waste into similar categories. The expected points through these categorizations are material loss, rubble, and drawings.

According to Koskela [4], waste refers to materials and waste originating from the different resources required in the construction process. In this sense, Almusawi [5] observes that some waste is generated during the implementation of non-critical stages that consume more funds but do not add significant value to the final project. Formoso [6] conclude that correctly classifying the waste into different and appropriate categories may significantly contribute to reusing this waste. Muhwezi [7] reported that a widespread habit in Uganda is to increase by approximately 5% of the budget assigned to the materials of a project to consider the extra materials required due to the waste generated. This shows a need for more consideration and environmental awareness, since CDW could be minimized with a proper study during the planning and design stages. Most of the project's cost is associated with materials, which must be organized appropriately.

Hoornweg [8] noted that world countries generate nearly 1.3 billion tons of construction waste annually, increasing to 2.2 billion tons by 2025. Within thirty years, construction waste will be doubled in developing countries. According to the Iraqi ministry of planning [9], the Iraqi population reached 40 million inhabitants at the end of 2020, and at least 5 million housing units are required to solve the housing problem in the country. Moreover, another report for the same Ministry [10] asserted that the CDW generated in Iraq in 2020 was 7,254,856.80 tons. The number of construction projects in Iraq has significantly and rapidly increased in the last years, both residential and public buildings, which generates more CDW. Hence, there is a significant and severe problem since more landfills are required to deposit the enormous amounts of CDW generated nowadays.

2. CLASSIFICATION OF CDW

The composition of CDW may differ from one country to another, depending on the construction method used. In Iraq, concrete structures are used primarily in commercial buildings, with partitions made with bricks or blocks joined with cement mortar and covered with renders of cement or gypsum. Facades are commonly covered with porcelain tiles, marble, or Styrofoam, and false ceilings are made with gypsum boards. Changing the style of construction will change the type of waste produced. Many researchers work on the categorization of CDW. Lau and Nagapan [11, 12] determined that housing construction creates different kinds of waste, such as timber, cartoons, concrete, steel, blocks, roof tiles, packaging boxes, plastics, and other materials. Also, as explained by Obaid [13], CDW comprises different types of waste, such as solid waste or that obtained from deconstruction, execution, extension, rehabilitation, and dismantling buildings, streets and highways, bridges,

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and infrastructure projects. Additionally, different materials can be found, such as asphalt, concrete, bricks, timber, glass, aluminum, reinforcement steel bars, packaging waste, pipes, isolation, and cables... Although the structure of all these waste materials varies, all they have in common is that their minimization, reutilization, and recycling are beneficial for the environment, as they reduce the consumption of raw materials and the waste deposited in landfills.

Raval [14] investigated the type and percentages of CDW generated during building construction in Ahmedabad, Gujarat, India. The authors reported the following amounts of waste produced: 29,268 kg of steel, 6,770 bags of cement, 486,444 kg of sand, 680,228 kg of coarse aggregate, 1,569 kg of admixture, which implies 4.5%, 6.5%, 16.5%, 14% and 15% of the CDW produced, respectively. Similarly, in a study conducted in Iraq, Tareq [1] concluded that the waste percentages for cement, sand, gravel, subbase, brick, and concrete were 13%, 18%, 15%, 5.5%, 15%, and 7%, respectively. In a study done in Batu Pahat, Malaysia [15], the CDW generated in two construction sites (A and B) were analyzed. The most significant waste in site A was wood, which contributed 49% of the volume of the CDW, followed by bricks (16%). Waste was generated due to aspects such as incorrect cutting of materials or the demolition of areas that needed to be built appropriately. Similarly, carelessness when pouring concrete led to 6% of waste, while 4% of waste was reported in steel reinforcement bars. At site B, the waste was mainly generated from scaffolding and formwork; 26% of the CDW was brick waste; 9% was obtained from concrete, 1% from reinforcement steel bars, and there was also a waste of raw materials used during the construction of the building, such as cement, sand, or gravel. The waste of packaging (cardboard, paper, and plastic) filled the construction,site area accounting for 15%.

Bossnik and Brouwers [16] reported the following percentages after analyzing the CDW of buildings constructed in the Netherlands: stone tablets 29%, concrete piles 17%, concrete 13%, sand-lime elements 11%, Roof-tiles 10%, mortar 8%, packing 7%, sand-lime bricks 3 % and metal and wood 2%. These percentages significantly differ from those reported by Almusawi [5], who investigated the CDW percentages originated in a building constructed in Kuwait, where an average composition of 35.4% concrete waste, 19.2% bricks and tiles, and 14.2% steel reinforcement bars, together with small quantities of other materials, were reported. Also, dismantling old buildings generated 70% of concrete,cement , and 20 % steel reinforcement bars. Faridah [17] analyzed the waste generated in 30 different construction sites located in Seberang Perai (Malaysia), and observed that concrete was the most significant waste generated (12.32%), followed by metals (9.62%), bricks (6.54%), plastic (0.43%), wood (69.10%) and other (2%). Other works developed in Iran by Asgari [18] demonstrated that the CDW generated in the constructions analyzed in Tehran were composed of concrete (19%), bricks (10%), metals (0.75%), and others (70%). In contrast, the statistics processed waste annually generated in Yazd city in Iran Mohsen [19] stated that the waste of cement and concrete, bricks, metals, tiles, glass, plastic, and timber is nearly 38, 20, 17, 14, 5, 3, and 3%, respectively. The study conducted by John [20] in Brazil concluded that the CDW analyzed included mineral waste (65%), timber (13%), plastic (8%), and other materials (14%). In the same manner, Rashidul [21] indicated that waste was generated in Dhaka city in Bangladesh with the three most significant amounts of concrete (60%), bricks (21%), and mortar (9%).

In Summary, the type, quantity, and composition of the CDW generated differ from one site to another depending on factors such as the project and style of work. However, the existing studies agree that material waste is analyzed at a certain point during all the construction processes. Additionally, identifying and adequately classifying the CDW generated in the building site is of great interest since that will facilitate its reduction, reutilization, recovery, and recycling. For all these reasons, this work aims to analyze the CDW generated during the construction of a commercial building in Diwaniyah (Iraq).

3. EXPERIMENTAL WORK

A commercial building located in Diwaniyah city, the mid-Furat area of Iraq, was selected for this study. The work included the excavation and construction of a new commercial building. As plotted in Figure 1, the building is located in the city center. The facility consists of three floors with a total built area of 900 m^2. The materials used to construct different parts of the building and the expected waste generated are summarized in Table 1.

Table 1: Details of the building analyzed.

Activity	Details	Type of waste
Type of structure	Concrete	Concrete waste
Partitions	Brick and cement mortar	Broken bricks and mortar
Flooring	Porcelain and marble	Broken tiles and marble
Outside finishing	Marble and Styrofoam	Broken marbles and Styrofoam
Wall finishing	Cement mortar and gypsum	Cement and gypsum
Plumbing and water	PVC pipes	PVC pipes
Electrical network	Isolated copper wires	Copper and PVC insulation
Roofing	Concrete tile	Broken concrete tiles
Finishing	False ceiling	Plastic false ceiling
Doors	PVC and Aluminum	PVC and Aluminum
Windows	Aluminum	Aluminum

Figure 1: Location of the building in Diwaniyah city (Iraq).

3.1 Construction Waste Inventory

The construction of the commercial building is nowadays 100% complete. During its construction, an inventory was made to account for the volume and mass of waste generated during the following stages: foundations excavation, concrete structure work, masonry, plastering, floor and roof tiles, covering the outside of buildings, and MEP (mechanical, electrical and plumbing) work. Datasheets were developed to register the mass of CDW generated. The volumes of the different types of waste (sand, concrete, brick, steel, etc...) were determined, and using their density, their mass was calculated. Some work, such as the manufacture of doors and windows, was developed outside the construction work site, so this article did not include the corresponding waste generated. Figure 2 (A, B, C, D, E, F, G, H, I, J, K, and L) shows different building construction stages and various types of waste generated during the construction process.

Figure 2: Construction stages and waste generated during building construction.

4. RESULTS AND DISCUSSION

4.1 Construction Waste Characterization

Tables 2 and 3 summarize the quantities of CDW generated during the construction of the building, while Figures 3 and 4 show the corresponding amounts of CDW. As observed from Table 2, 86.75% of total waste was generated during the soil excavation, and the other activities were responsible for less than 14%. Table 3 shows the percentages after removing the percentage associated with the soil waste. As observed, brick waste accounts for 47.03%, concrete for 19.27%, mortar for 10.65%, ceramic materials, and marble for 6.68%,

gypsum for 4.88 %, and other materials represent 12% of the waste generated during the construction of the building. According to the obtained results, during the two years of construction of this commercial building, 395,553.20 kg of CDW were generated, including soil, and 52,410.40 kg without including the soil). This implied a ratio of 439.50 and 58.23 kg/m^2, respectively. The large volume of CDW generated during the construction of this commercial building could be reduced by employing less traditional construction techniques, which would imply a more efficient use of the available materials and equipment.

The classification and quantification of the CDW generated during the construction of the selected building will allow for estimating the waste generated in future constructions, facilitating its reuse and recycling. This contributes to a circular economy since it provides essential data that can be used to reduce the amount of waste simply landfilled and the consumption of natural raw materials

Table 2: Amounts and percentages of the CDW generated during the construction of the building with excavation.

Waste Material	Quantity, kg	Percentage %	Waste Material	Quantity, kg	Percentage %
Soil (Excavation)	343,142.8	86.75	PVC	342.0	0.09
Brick	24,650.0	6.23	Plastic	304.6	0.08
Concrete	10,100.0	2.55	Steel can	295.0	0.07
Mortar	5,584.0	1.41	Cartoon	225.0	0.06
Ceramic and marble	3,500.0	0.88	Aluminum	160.0	0.04
Gypsum	2,558.0	0.65	Paint	165.0	0.04
Steel	1,992.0	0.50	Styrofoam	129.2	0.03
Wood	1,240.0	0.31	Cooper	70.0	0.02
Subbase	1,058.4	0.27	Fibers	37.2	0.01
Total Quantity, kg	**395,553.15**				

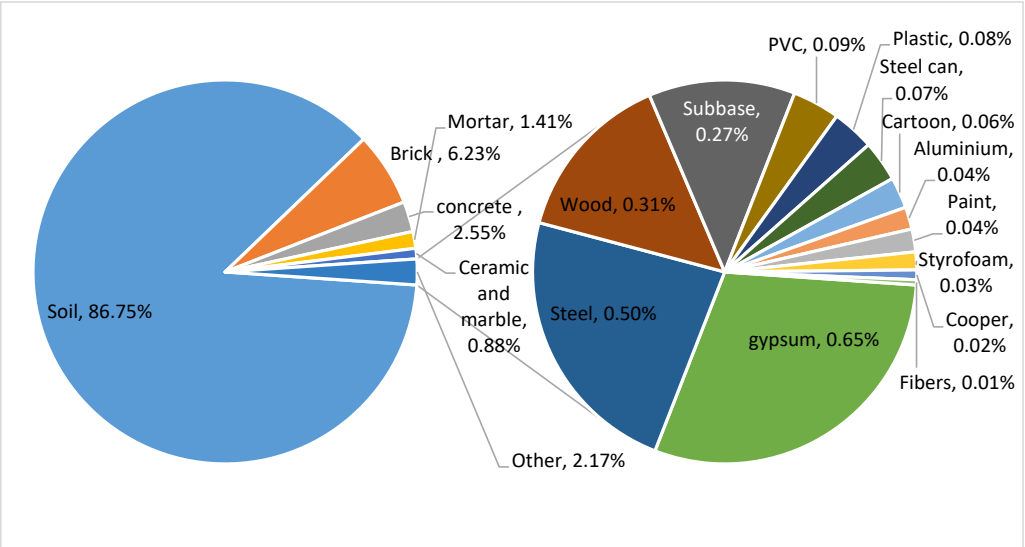

Figure 3: Percentage of the different types of CDW generated during building construction.

Table 3: Amounts and percentages of the CDW generated during the building construction without excavation.

Waste Material	Quantity, kg	Percentage %	Waste Material	Quantity, kg	Percentage %
Brick	24,650.0	47.03%	Plastic	304.6	0.58%
Concrete	10,100.0	19.27%	Steel can	295.0	0.56%
Mortar	5,584.0	10.65%	Cartoon	225.0	0.43%
Ceramic and marble	3,500.0	6.68%	Aluminum	160.0	0.31%
Gypsum	2,558.0	4.88%	Paint	165.0	0.31%
Steel	1,992.0	3.80%	Styrofoam	129.2	0.25%
Wood	1,240.0	2.37%	Cooper	70.0	0.13%
Subbase	1,058.4	2.02%	Fibers	37.2	0.07%
PVC	342.0	0.65%	-	-	-
Total Quantity, kg	**52,410.35**				

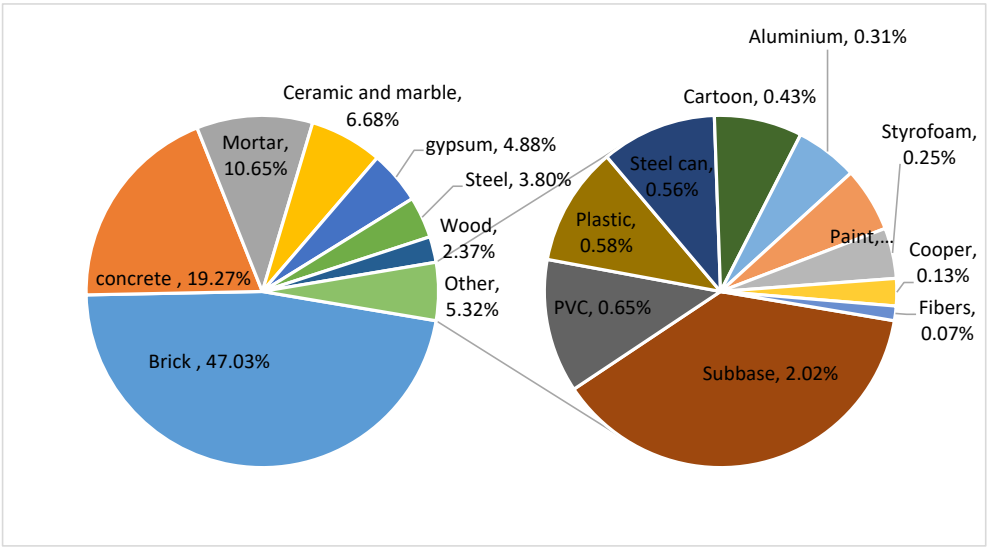

Figure 4: Percentage of the different types of CDW generated during the construction of the building without excavation work.

5. CONCLUSIONS

This study analyzed the waste generated during the construction of a commercial building. According to the obtained results, the following conclusions have been reached:

- Construction activities produce several types of CDW, such as soil, concrete, bricks, PVC, plastic, mortar, copper, iron, or steel.
- In the commercial building analyzed (900 m^2 built), 439.50 kg/m^2 (with soil) and 58.23 kg/m^2 (without soil) of CDW were generated.
- The waste that originated outside the construction site, such as that generated during the manufacture of carpentry, could not be quantified.
- The excavation work generated the highest amount of waste (86.75%). This could be reused in other building sites.
- Brick and concrete were the most significant waste materials (64.3%) apart from the soil. If properly separated, these inert waste materials could be reused to fill subbases or roads in other construction sites.

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