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Quantification of Construction Waste: Egypt Case Study

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Abstract

As the world is shifting towards sustainability in construction, C&D waste quantity estimates will be of ultimate importance in seeking to determine the necessary capacity of the recycling facilities and for companies seeking to offer processing or recycling of recovered items. Assessing the right quantity of C&D waste is rather complex and many researches focused on providing reliable estimates to C&D waste generation rates.

Currently in Egypt, despite the emerging interest in sustainability and efficient waste management, there is very limited research on the quantity of waste resulting from construction activities. Unfortunately, waste is still seen as an unfavorable byproduct of construction activities rather than an opportunity to benefit from.

The study aims to assess the various quantification methodologies present in the literature highlighting the benefits and deficiencies in each of them. The study provides a construction waste analysis for two LEED certified projects in Egypt and two medium scale residential projects and assesses the Construction waste Index for all of them. The index obtained for the two LEED certified projects were about 0.025 t/m^2 and 0.026 t/ m^2 whereas the index obtained for the medium scale projects was of 0.115 t/m^2 in average. The CW index for this small to medium projects is 4 times as big as the ones calculated for large scale projects. The index analyzed for the different projects will help provide a basis for comparison for different types of projects in Egypt and facilitates the estimation and prediction of waste generation for future projects which in turn improves the process of waste management

Keywords: Construction Waste, Construction Waste Index (CWI), Waste Generation Rates, Waste in Egypt

1. INTRODUCTION

Construction and demolition waste is not new worldwide and has started booming as population increased and accordingly their housing needs increased. As time progressed, and as a result of the fast urbanization and the construction boom that happened almost worldwide during the 1990s, the amount of C&D waste generated which was traditionally landfilled started increasing to uncontrollable levels. In the US, estimates by the Environmental Protection Agency (USEPA) indicated that approximately 136 million tons of building-related construction waste was generated in 1996 [1].Another study stated that construction waste constitutes about 29% of the solid-waste stream in the USA [2] In Canada, 35% of the space in landfills is taken up with construction waste, and over 50% of waste in a typical UK landfill could be construction waste [3]. Similarly, studies of Australian landfills have revealed that construction activity generated about 20–30% of all deposited wastes [4].

Egypt in particular, is undergoing increasing population, vast urbanization, and changing consumption patterns that resulted in the generation of huge amounts of solid waste which is considered as the most perceptible environmental problem in the area. Figure 1 demonstrates the distribution of municipal solid waste in Egypt highlighting a large quantity of construction and demolition waste reaching almost half of the total municipal solid waste

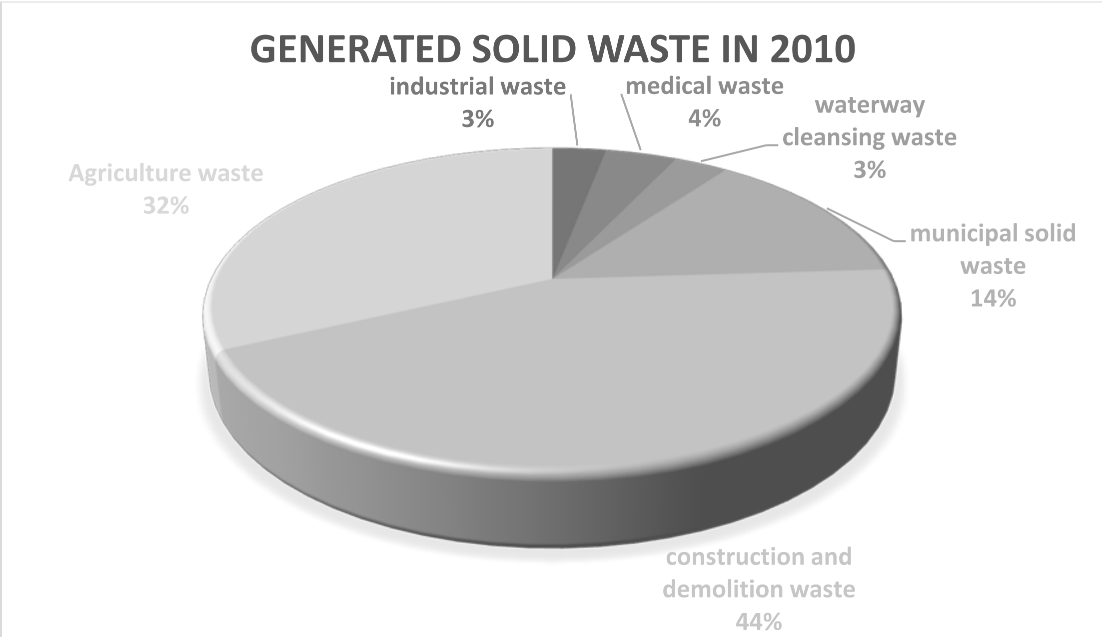

Fig 1: Generated Solid Waste in Egypt in 2010 [5]

The increasing amount of solid waste draws significant attention worldwide and in Egypt to try to mitigate the environmental effects of waste accumulation in landfills through waste reduction, recovery, reuse and recycling. Given the limited landfill space, and the increasing costs of effective environmental protection of landfill, it became obvious that action to reuse or recycle C&D waste is becoming critical, especially that natural resources are also depleting causing a real threat to all countries.

Construction and demolition wastes is defined as: “Wastes from buildings and other structures are classified as demolition wastes. Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes” [6]. Construction and demolition wastes can be classified into physical waste and non-physical waste. The physical waste is defined as loss of materials which are damaged, cannot be repaired nor used or over-ordering of materials which will not be used. However, the non-physical wastes are related to cost overrun and delay in construction projects [7] which is not the focus of this paper. The generation of construction waste in particular can be attributed to six main stages or sources such as design, procurement, handling of materials, operation and residual sources [8] and is considered one of the largest amounts of waste in the solid waste stream, and represents a real threat to all countries.

To design an effective waste management program, it is most important to know how much waste must be managed and what is the waste composed of in order to properly assign the truck capacities and the landfill space required as well as the amount of materials which can be recovered for future use and recycling.

The accurate estimation of the type and quantities of construction and demolition waste has the following benefits:

- Effective planning of waste management on site
- Increased motivation of applying waste reduction, recycling and recovery techniques
- More accurate estimation of the cost and benefits of waste management from the economic and environmental points of view.

- Generating a material log where the material produced from recycling as well as the raw materials to be purchased are accounted for

In addition to accurately assessing the quantity of waste generated, tracking the total waste generated every year and estimating the future generation rates will be an imperative indicator for sustainable waste management.

The quantities of construction and demolition waste produced are difficult to estimate and are variable in composition, in Egypt in particular, most of C&D wastes have always been recognized as inert materials and were not considered a big environmental threat until the overall quantity of solid waste increased to uncontrollable levels and the landfill spaces became very limited. Accurately estimating the quantity of construction waste generated is not easy specially in Egypt because many of the buildings are unplanned like in slum areas and it is very common that local contractors and developers do not have proper construction waste management systems, or registrations of waste on site, therefore there is no track record of the amount of waste generated. Moreover the skills and level of training and experience of the site workers play an important role in the quantity of materials wasted and whether any waste reductions plans are implemented on site or not.

This justifies the lack of detailed statistics and information about the composition of C&D waste, or any forecast into the amounts and types of C& D wastes resulting which makes this study of great significance

2. LITTERTAURE REVIEW

This section summarizes work previously done in quantifying C&D waste worldwide which helps to assess these trials and evaluate its benefits and deficiencies.

2.1 HISTORY OF QUANTIFICATION

The purpose of this section is to present the major studies performed worldwide to quantify C&D waste and highlight their advantages and drawbacks and areas of improvements to be able to reach a quantification methodology which can be most applicable to Egypt.

The most straightforward method of quantifying construction waste is to track the waste when sort it, perform visual characterization and monitor it to identify the different waste materials resulting and weigh them [9], [10]. This process is quite difficult because it requires close inspection and monitoring which consumes lots of time and is challenging specially for heavy loads like C&D waste and for large scale projects which have tons of materials wasted from construction works.

Lau et al, 2008 proposed a waste quantity estimation model based on physical layout of dumped waste (stockpiled, gathered, scattered, and stacked) [11]

Some of the layouts of dumped wastes take the form of stockpiled waste, where the waste are accumulated in the form of rectangular base pyramidal shape (Fig. 2). The volume (Vs) of a stockpiled waste was taken as Vs = 1/3 (B x L x H). For gathered waste, it was assumed to take the form of rectangular prism (Fig. 2) on the ground surface. The volume of gathered waste (Vg) was taken as Vg = L x B x H.

Fig 2: stockpiled waste and gathered waste respectively [11]

Scattered waste can be divided into two categories. The first consists of waste with similar size, such as broken bricks, cement bricks and roof tiles. The second consists of waste with large variation in size, such as off cuts of steel roofing sheet, off cuts of gypsum or plaster board. For scattered waste with similar size, samples are chosen and weighed. The average weight per sample multiplied by the number of samples gives the total weight of the scattered waste

For stacked waste, it was measured in a similar manner as scattered waste. The average weight is assumed to be uniform for the whole stack. The number of samples in the stack were counted. This value was then multiplied by the average weight per sample to obtain the total weight of the stack. This method was applied except where there is a large variation between sample sizes. In that case, the stacked waste was sorted out into similar sizes before the method was applied.

This method provides a rough estimate of waste quantity generated in terms of weight, for a particular layout. The weight is determined through the product of the waste estimated volume based on its form and estimated unit weight. This quantification concept is not accurate and not reliable as the form of waste dumped is not a representation of the actual quantity of its components and does not take into consideration that in most cases construction waste is comingled waste of different shape and size.

Cochran and Townsend (2010) utilized an alternative methodology for estimating C&D generation rates in the United States based on materials flow analysis (MFA) [12]. The MFA approach uses historic national production and usage data for a material (e.g., tons of concrete or wood used in building construction in a year) together with data on average material lifetimes to estimate construction and demolition waste (CDW) generation rate for that component.

The material flow analysis approach can be used throughout the lifecycle of a building for construction, renovation and demolition. It necessitates however the close monitoring of how materials flow through each stage as shown in fig 3

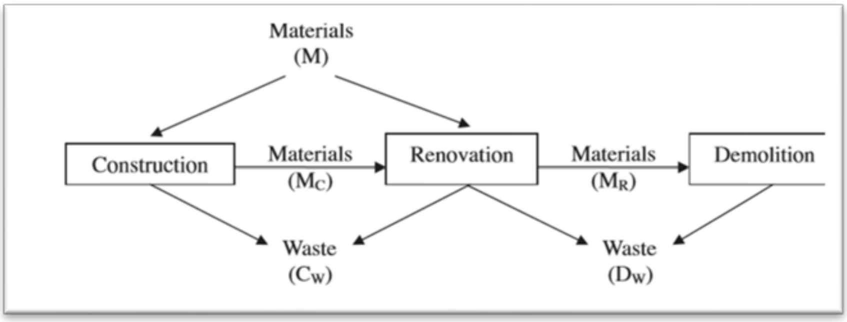

Fig 3: Flow of materials throughout the building lifetime [12]

This study is based on the concept of service life where each material has an estimated service life depending on their durability and use and this can be obtained from building life cycle assessments and construction material databases. Drawbacks of the MFA is that it overestimates the amount of material demolished and relies totally on the assumptions of service life of components which might not be very accurate in some cases . Because of the long and extremely variable lifetimes of buildings, roads, and other structures, the material flows method was determined to be infeasible for C&D debris. Moreover it assumes that all structures will be demolished and accordingly all materials will be either disposed or recycled, it does not account for materials discarded before being used due to defects for example or for not complying with the specifications and for materials that are left on site uncollected after being demolished which are not disposed nor recycled

In general, the total floor area has been widely used for CDW estimation mainly in high density urban areas such as China or Hong Kong where dwellings are sold by gross floor area [13], [14]

Estimating the amount of waste generation per building area is estimated based on the following two concepts:

$W = A \times G$ where A= area of building constructed, demolished or renovated during one year (m^2)

G= average waste generated per building area (kg/m^2)

Or

$W = (C/B) \times G$ where C= cost of building construction, demolition or renovation per year

B= average cost of construction, demolition or renovation per building area ($\$/m^2$)

All the above trials to quantify waste focused on waste generation index calculation which facilitates waste quantification on project level as well as municipalities and even national level. This index calculation can be obtained based on the different methodologies as shown in fig 4

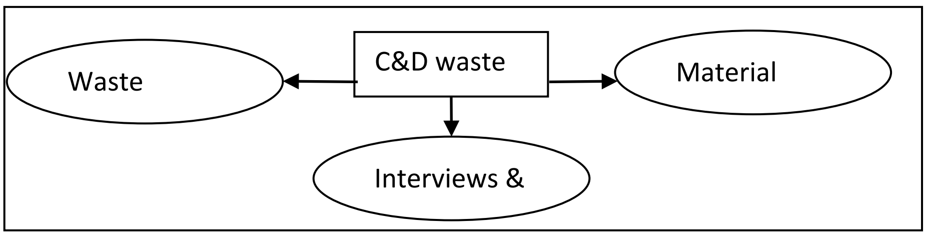

Fig 4: methodologies to obtain waste quantity index

The field monitoring approach relies on collecting actual data by regular visual inspection, waste sorting and keeping tape measurements and truck load records. This approach is time consuming and requires too much space and manpower because of its big size and weight. Another easier method is conducting interviews and questionnaires at different sites with professionals and project managers. This method is not very accurate because there might be discrepancies between contractor's delivery records and measurement of finished work. The third possible way is based on the material balance principle which uses pre-existing data for a material or product and bases the material generation index on average material or product lifetimes. This requires less time and manpower and allows for large scale investigations however is not very applicable in Egypt as material databases in Egypt are not well established and can sometimes be not reliable since the construction industry in Egypt is in most cases unplanned like in urban areas and slum areas. Moreover records of material life cycle and durability in Egypt is not well kept and can't be reliable enough for waste quantification estimation

3. EGYPT CASE STUDY

Based on the literature review and the different methodologies to obtain waste index it was noted that the most generic construction waste quantity estimation that can be applicable to Egypt is waste weight per built up area calculation. The amount of waste resulting from construction works can be easily recorded based on loading capacity of waste hauling trucks and keeping record of how many trucks are needed per week as follows:

Construction waste quantity for the whole project = weight of hauling trucks x number of trucks per week x number of weeks of a project

The construction waste index (CWI) is calculated as follows:

$$CWI = \frac{\text{Construction waste quantity (tons)}}{\text{Built up area (m}^2\text{)}}$$

CWI gives an overview of the quantity of construction waste and the percentage waste of each material as the quantity of raw materials or material inflow to the construction process is known during procurement and the amount of waste for each material can also be obtained by waste segregation and weighing. CWI is applied on 4 different projects in Egypt and the results are evaluated in section 3.1 and 3.2 of this paper

3.1 LEED CERTIFIED MEGA PROJECTS IN EGYPT

As previously discussed construction waste quantity estimation in Egypt is not an easy process since many of the construction projects in Egypt are randomly planned and as most of the wastes are not dumped in designated areas. However, this paper focuses on applying the CWI on two LEED certified projects done in Egypt, they are both office buildings of the same project's duration and constructed by the same contractor. These types of projects are considered major projects, involving good planning, following the best construction techniques and keeping a detailed waste tracking records.

The first project is the Credit Agricole Bank new head office in new Cairo. This project has a built up area of 24654.6 m2 comprising of two basements, ground floor and three typical floors. The structure was divided into two above ground wings; each consists of four floors connected by a central hall through interior bridges, highly developed building facades, and a cantilevered roof providing shade and protection to the entrance.

The second project is Dar el Handasa new headquarter in smart village, Giza where the built up area is 44307.4m2 comprising one basement, ground floor and four typical floors. The premises were designed as an equilateral triangle. A large glass atrium serves a double function, allowing daylight to penetrate and moderating between the exterior and the air-conditioned interior. The open space layout on each floor suits flexible office space arrangements and lets the maximum light into the work area. Communication bridges between work spaces also pass through the atrium.

Table 1 shows a comparison between both projects and their description

Project Name	Credit Agricole Bank New head Office in New Cairo, Egypt	Dar el Handasa new Headquarter smart village Giza, Egypt
		
Project duration	36 months	36 months
Project size (area , number of floors)	Building comprises two basements, ground floor and three typical floors.	Building comprises one basements, ground floor and Four typical floors.
Built up area	24654.6 m2	44307.4 m2
Type of Cons. Waste	Wood (trim-lumber-sheet materials), Masonry ,Cardboard & Packing boxes , Paper and newsprint Metals , Insulation (waterproofing membrane) & (mineral fiber blanket), Plastic bottles & bags , Beverage containers , Organics	Wood (trim-lumber-sheet materials), Masonry ,Cardboard & Packing boxes , Paper and newsprint Metals , Insulation (waterproofing membrane) & (mineral fiber blanket), Plastic bottles & bags , Beverage containers , Organics
Waste quantity (Ton)	612.74	1,165

Calculating the Construction waste Index for each project is as follows:

Credit Agricole: 612.74/24654.6 = 0.025 t/m^2

Dar El handasa: 1165/44307.4= 0.026t/ m^2

Both projects being of the same scale, constructed by the same contractor using the same construction techniques have the same Construction Waste Index. Dar el Handasa is shown to have almost double the quantity of waste because it is a larger size project. Segregating the waste once produced facilitates the sorting and weighing process and allows to accurately estimate the composition of the waste which facilitates the process of recycling later on to achieve a more sustainable waste management as shown in table 2.

Table 2 shows the quantity of each waste material for both projects

Waste quantity per type (ton)	Credit Agricole	Dar el Handasa
wood	293.85	175.65
masonry	80.01	552.28
Cardboard	20.88	26.67
Paper and packing boxes	10.04	11.7
Plastics	7.85	9.94
Piping (PVC + metal)	2.09	11
metals	7.64	33.78
plastic bags	19.68	23.28
containers	7.03	9.41
flooring	0.48	1.06
polysterene	0.74	0.99
Organics	29.48	35.58
gypsum boards	17.2	127.82
Glass	0.09	0.25
Insulation	1.3	2.76
steel	114.38	142.83

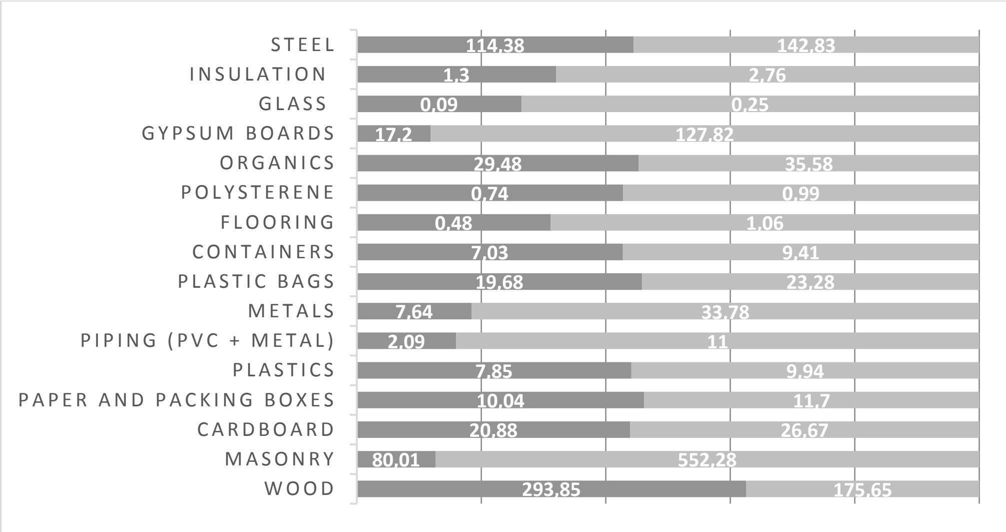

Fig 5: A representation of the waste quantity per material type in both projects

The quantity of Masonry waste, metal waste and gypsum boards waste in Dar el Handasa project is remarkably higher, this is due to the fact that Dar el Handasa is an office building, and accordingly it uses larger quantities of gypsum boards in office partitions. The difference in quantity of waste per material type can be attributed to a difference in design and usage of the building

3.2 MEDIUM SIZED PROJECTS IN EGYPT

As a comparison to the two LEED certified projects presented in section 3.1 of this paper, two small to medium scale residential projects in new Cairo were also analyzed. Both projects are residential Villas comprising 1 basement, 2 floors and a roof.

Villa A has a built up area of 1490 m^2 and a total construction waste quantity of 163.9 Tons

Villa B has a built up area of 1540 m^2 and a total construction waste quantity of 184.8 tons

Table 3 is used to show the CW index formulated for both projects:

	Villa A	**Villa B**
Built up area	1490	1540
Total Quantity of CW	163.9	184.8
CW Index	**0.11**	**0.12**

The CW index for this small to medium projects is approximately four times larger than the ones calculated for large scale projects in section 3.1 of this paper. This is justifiable since waste reduction measures in such small scaled residential projects is not applicable, the workers are less skilled than in large scale projects and the management of the project is usually done by the contractor himself. Accordingly monitoring and waste track records are deficient causing a large amount of waste and a large Construction waste index as compared to larger well managed projects.

4. CONCLUSION

Waste quantity calculation is an imperative tool for effective waste management. Estimation of the quantity of waste generated from construction, renovation and demolition activities has many benefits on the scale of the project itself and even on the national scale. It provides a log or a platform for the types and quantities of wasted materials that can be reused or recycled hence preserving natural resources, it also helps estimate future waste generation rates which leads to better environmental protection in terms of forecasting landfills capacities and recycling plants capacities needed. Although Studies are always ongoing worldwide to provide the most accurate quantification techniques, Egypt is still in the first steps of establishing an effective quantification technique for construction waste. This study analyzed some of the techniques available in the literature and helped formulate a waste index for construction activities in Egypt based on the weight of waste resulting in relation to the foot print of the project. This index was applied on two LEED certified mega scale projects and two medium size projects; The index obtained for the two LEED certified projects was about 0.025 t/m^2 and 0.026 t/m^2 whereas the index obtained for the medium scale projects was about 0.115 t/m^2 in average. The CW index for these small to medium projects is approximately four times larger than the ones calculated for large scale projects which is justifiable since the techniques of construction, the level of material track record and monitoring are important factors in assessing the quantity of waste resulting. Construction waste management in Egypt is still developing and needs lots of research specially in the area of construction waste quantification

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