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ESTIMATING MATERIAL WASTE IN THE BUILDING CONSTRUCTION IN Egypt

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ملخص
تواجه مصر هذه الايام في مجال البناء استهلاك كميات كبيرة من الموارد الطبيعية مما يولد كميات كبيرة من النفايات ، على سبيل المثال بلغت كمية النفايات التي أنتجت في عام 2000 (11مليون طن) من قطاع التشييد ، فإن كمية النفايات المتولدة عن صناعة البناء والتخلص منها لاحقا في مدافن النفايات أصبحت تشكل مخاوف متزايدة .وعلى الرغم من أن التخلص من مدافن النفايات من مواد البناء لا يزال الخيار الاكثر تفضيلا من قبل العديد من شركات الانشاءات ، فإن أكثر من (75٪) من مواد نفايات البناء لديها إمكانية إعادة الاستخدام أو إعادة التدوير.

إن القيادة في تصميم الطاقة والبيئة إحدى أنظمة التقييم المستخدمة الاكثر قبولا والمعترف بها على نطاق واسع مما تعطي مكانة هامة لادارة مخلفات البناء في الموقع ضمن نظام تصنيفها .وهناك الآن اتجاه متزايد نحو تنفيذ تقنيات مستدامة لإدارة النفايات .ومع ذلك ، نادرا ما تعرضت فعالية هذه الطرق في صناعة البناء والتشييد لتحليل شامل

Abstract
Nowadays, in Egypt The construction industry, however, consumes large amounts of natural resources and generates large amounts of material wastes, e.g. the amount of material waste produced in the year 2000 was 11 million tons from the construction sector (Statistics Canada, 2000). Thus, the amount of waste generated by the construction industry and its subsequent disposal at landfills are becoming growing concerns. Although landfill disposal of construction waste materials is still the most preferred option by many construction companies, more than 75% of construction waste materials have the potential for reuse or recycling (Nobe, 2007).

Leadership in Energy and Environmental Design (LEED), one of the most accepted and widely recognized sustainable building rating systems (Syal et al., 2007), gives an important place to on-site construction waste management within its rating system; and, there now exists a growing trend towards the implementation of sustainable waste management techniques. However, the effectiveness of these methods in the construction industry has rarely been subjected to comprehensive analysis.

Key words: construction waste, waste management, waste percentage, Waste materials, Waste cost.

1. Introduction
The severity of the construction waste problem can be identified from studies performed in different parts of the world on building waste material quantities. Skoyles (1976) identified thirty-seven building materials having material wastages from 2 to 15% of the weight of the designed amount of material. Bossink and Brouwers (1996) identified wastages of materials ranging from 1-10% of weight of the purchased material quantities, based on a study in Netherlands. Another study, based on the construction projects in Australia, indicated material wastage to be 2.5-22% of the total material purchased

(Forsythe and Marsden, 1999). Pinto (1989) revealed that material wastes ranged from 1-10, 2% of its designed weights, based on the building construction industry in Brazil.

Although the percentages of waste from construction materials are different from region to region, the important finding is that the quantity of construction waste generation is significant, irrespective of the location. Evidently, the type of construction, construction technology and the rules and regulations imposed by local authorities can have an impact on material wastages.

There are evidence that the generation of construction waste has been increasing over the years, creating a series of problems in various regions of Canada. The construction waste portion was approximately equal to 35% of the total municipal solid waste generation in 2001 (CCA, 2001). Being a growing industry and due to high construction activities in Alberta, as the statistics in Figure 1.1 confirm, there was a rapid increase of construction and demolition waste generation over the period of 2000 to 2006. It is estimated that, in Alberta, 30-40% of C&D waste is coming from new constructions. However, the reported landfill disposal of construction waste materials has slightly dropped over time, reaching 22% (Alberta Environment, 2006) from 27% in 2003 (Verduga, 2004).

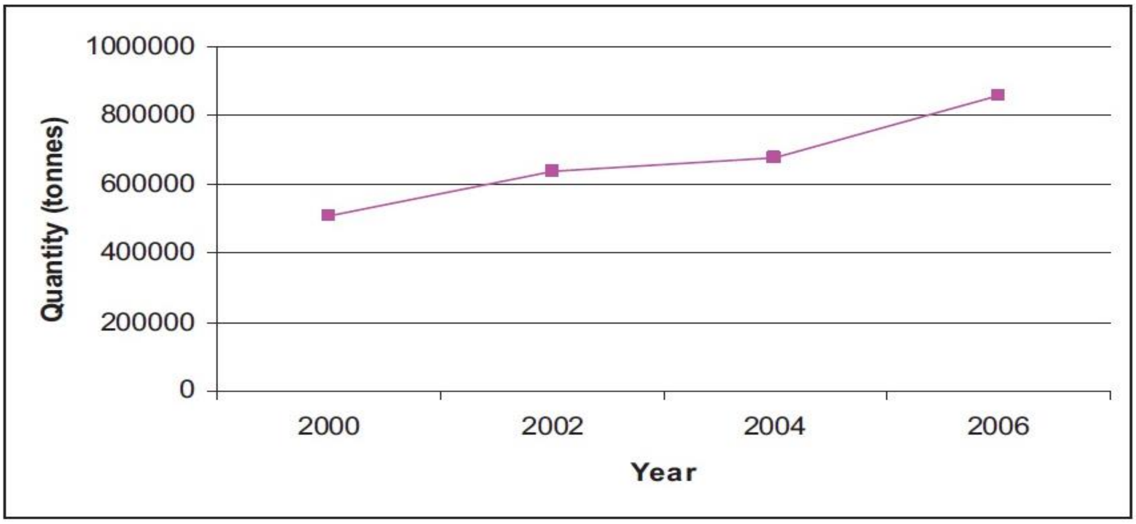

Figure 1: Construction and Demolition Waste Generation in Alberta
(Data Adopted from Alberta Environment, 2010)

Moreover, in Egypt, very few recorded data kept from regular feedback on previous projects are available to predict the accurate amounts and types of wastes generated during construction operations. Contractors tend to know roughly how much waste they will create during a given project according to previous experience. This fact favorably agrees with the study conducted by Chua D.K.H. et al, 2001 that contractors behavior have no clear rules while delivering a bidding decision as these decisions are commonly based upon intuition and past experience.

Related problems such as insufficient sources of natural materials, the energy needed to assemble the products and materials, and the negative impact on the environment due to illegal dumping of solid waste are directly affected by the increasing construction materials waste generation rates. Site visits, interviews, and literature surveys -concerning the construction industry in Egypt- revealed that no documented data base for previous projects are found

Within the reach of project managers of various construction companies. However, an increasing number of construction companies are applying actions to improve their projects' performance by eliminating different waste categories in construction.

3. Construction Waste Characterization and Composition

The US army characterized the construction and demolition waste (in its CERL Technical report, 1999) into two components: (1) composition and (2) quantity. The composition of the waste is defined by the type of included constituent components. The quantity of C & D waste is based either on the volume or weight of the debris. Table (2-1) presents the common components of Construction and Demolition activities as suggested by the US army (CERL technical Report,1999).

Nesmith, 1993 divided the total construction and demolition waste stream into three major categories:

1 Concrete, asphalt, and rubble make up about 50% of the C & D waste stream by weight;

2 (25%) is attributed to wood (including site vegetation), lumber, and manufactured wood products; and

3 The remaining 25% consisting of metals, packaging, gypsum drywall, and other miscellaneous materials.

A Brazilian study conducted by Hamassaki et al. (1994) reported that recycling materials found in Construction / Demolition wastes includes mainly two groups:

Cemented materials: including concrete, masonry, mortar more cement, lime sand and coarse aggregate (about 60% by weight); Ceramic materials: wall tile, floor tile, bricks, clay pipes and others (about 25% by weight).

A third group about 15% by weight is non-recycling (by this proposed process) materials as gypsum, soil, metal pieces, paper, plastic, organic materials, glass and others.

Regarding the fact that construction waste does not typically have the same composition as demolition waste, Bossink et al (1996) carried out a study on construction waste indicating that it is an important topic to quantify and analyze despite their lower volumes in comparison with Demolition waste because: Construction waste contains a relative big amount of chemical waste (Lanting 1993).

Construction waste is more difficult to recycle due to high levels of contamination and a large degree of heterogeneity (Brooks et al., 1994). Prevention of construction waste is preferable to recycling of demolition waste.

A cost reduction caused by preventing the generation of construction waste is of direct benefit for most of the participants that work on a construction project. Bossink (1996) summarized in Table (2 - 2) some studies conducted in Brazil to determine construction waste of specific materials and percentage of total purchased construction materials (by weight).

To the contrary to Lanting (1993), the US army reported in its CERL Report (1999) that C&D waste varies according to the type of project and the method of Construction and Demolition.

Demolition debris is more likely to contribute materials contaminated by undesirable components and/or potentially toxic substances such as lead paints, stains and adhesives.

Prior research conducted by Betts (1993) indicated that C&D waste composition varies widely by season, location and type of project. C&D waste generally consist of asphalt, concrete, brick, dirt, wood, metal, wallboard, roofing and insulation materials, plastics, cardboard, glass and miscellaneous trash.

Yost and Lund (1997) estimated that by weight or by volume, wood, dry wall and cardboard combined make up between 60 and 80 percent of job site waste in construction projects.

2. Material Waste Identification / Quantification In The Egyptian Construction Industry

The "Egyptian Contractors' Union" has classified the contractors in the Egyptian Construction Industry into six classes (law no. 104 - 1992) according to their capital budget, years of experience and some other administrative conditions. The highest class is category "A" with capital budget over 10m L.E.and not less than 10 years of experience in building various kinds of projects in Egypt.

A sample of 24 contractors among 125 of category "A" participated in providing the required data. The sample included 8 public sector contractors (one contributed with 13 branches all over the country), 15 private sector contractors and one foreign contractor. The criterion of choosing a sample of this category was based on using contractors having similar conditions of human resources force, construction technologies, and experience. This was besides their willingness to participate in the study. Contractors in this category represent the leading competitors in the building and construction market, they have the motive to obtain and analyze the information related to materials waste amounts and its causes in order to minimize these amounts to reduce the overall projects costs. Appendix A includes a full list of the sample of contractors who participated in the questionnaire.

It was aimed to obtain data related to a large number of materials and from a sample of contractors located in different cities all over the country in order to diagnose the real conditions of the Egyptian Construction Industry. Preliminary interviews were carried out on various on-going field projects for the sample of contractors under study prior to the formal questionnaire. The main objective was to pinpoint the most frequent waste categories according to the projects ‘members' perceptions. The upcoming points gives examples of the waste types that are caused and affected directly or indirectly by non-value-adding activities, which probably consume the overall projects' money and time as reported by the site engineers.

The most frequent on-site waste categories Waste Types

- Waste due to transportation deficiencies
- Waste due to organizational systems
- Waste due to construction operations
- Waste due to defects
- Waste due to people movements
- Waste due to rework and/or slow performance
- Waste due to lack of transparency

- Waste due to Theft-vandalism-unpredicted weather conditions-war- recession.
- Waste due to overproduction
- Waste due to wait periods

About 85% of the sample responded positively to the survey, while the rest provided useful data only to the questions concerning the causes of material waste generation. It should be noted that these results represent the experts' opinion as provided in the questionnaires, while results from other studies may include site-measured data. The answers of the survey were grouped for each of the four previously mentioned categories separately. These involved both quantitative and qualitative data on material wastes and the causes of its generation.

Table (3-1) presents the average percentages of waste in materials for each company during construction operations as well as the standard deviation for the provided data. Some figures in table (3-1) were not obtained due to data collection problems, while others seemed to be unreliable such as those provided by contractor C10. The list of contractors who participated in the study and provided the presented data are listed in Appendix A. There was a large variation of waste indices found for some materials such as timber formworks (2-50%), and sand (2-20%). This variation might be due to the lack of accuracy in estimating the average percentages of waste in materials due to the absence of:

A waste management plan prior to the execution phase. Regular feedback through kept records (database) about waste rates and their causes from previous projects.

Wooden shutters (timber formworks): The various types of formworks contributed the highest waste rates (13% in average). Each type was used according to the specified number of using times to obtain the required quality of fair face structural element. The maximum and minimum percentages of waste rates among the Companies under study ranged between (2-50%) as indicated in table (3-1). This data was based on the experience of the contractors. The study on timber formworks regarded this material as a non-consumable material that aids in building but does not contribute to the final structure. Therefore the calculation procedure of its waste is different from those consumable materials. According to the experts opinion the various types of timber frameworks are generally used as indicated by the manufacturing company, then finally it is used in secondary works. The timber formworks waste has a low negative impact on the environment as it is sold at the end of the project to scrap dealers in lots to be re-used in minor jobs. Due to the variation of the types of timber formworks in the Egyptian market and accordingly the difficulty in calculating its waste percentages accurately, this material will be excluded from the 2nd phase of the study.

Sand and gravel with an average waste of 9% & 6% respectively were within the Reasonable percentages despite the large deviation in the data provided by the contractors. Although sand and gravel as raw materials contribute a low percentage of the projects ‘final cost, its leftover on site causes great pollution to the environment.

Reinforcing steel (R. steel) with an average waste percentage of 5% which is considered a low rate of consumption. This is due to its high cost in any contract which forces the contractor to highly monitor its waste percentages. The study revealed that one of the main causes of waste in R. steel was the poor structural design in terms of standardization and detailing causing non-optimized cutting of bars. Also waste caused by late working designs, and substitution of bars was highly addressed by the site engineers. Moreover, problems related to poor handling of steel bars especially in tight site conditions resulted in large disorganized stocks and ending up with considerable waste.

Aiming to minimize this waste in R.steel bars, some site engineers and project managers recommended purchasing pre-assembled steel reinforcement bars to optimize the cutting of bars and reduce the waste. Another intensive recent study, conducted by Talaat ,2003, succeeded to develop a computer software program RCD-1 that can be used in producing re-bar detailed drawings and bending lists of reinforced concrete structures. Talaat's system was aiming to reduce human errors and repetitive work since the drawings are produced automatically. In addition, proper detailed drawings and bending lists would lead to the reduction of the total amount of used steel bars and to minimi`ze the site fabrication waste of re-bar.

Tiles and Masonry wastes ranged from 2-15% for masonry and 2-10% for tiles according to their types. In general, the study revealed that most problems related to this type of waste was caused due to poor handling, storage and transportation deficits, as well as low performance of some working trades. This finding favorably agrees with a study conducted by Thomas H.R. (2002), who argued that a distinct absence of construction equipment, especially small lifting devices used for material handling is among the factors leading to low construction performance in developing countries. In addition, insufficient planning of the site layout was among the main causes of waste that can be easily eliminated. However, due to the great variance in the types of these materials, the generalization of presented figures is not highly recommended. Accordingly, these types of materials will not be considered in a further step of the study.

Ready mix concrete (premix concrete) presented one of the lowest average waste percentages 4%. This waste was measured in all sites by monitoring the difference between the purchased amount (actually delivered to site amount) and the actually used amount from the as-built drawings without considering the amounts of waste in the batch plants. The study reported that some suppliers deliver quantities of material smaller than what is paid for. Some site engineers often order an additional allowance of material in order to avoid interruptions in the pouring process. Also the extra thickness of slabs due to the poor execution of the concrete formworks was one of the main causes of ready mix concrete wastes.

Cement results presented in Table (3-1) included only those amounts used as mortar and cast-in place concrete (in sites where ready-mix concrete was not used). As cement is considered one of the basic binding and expensive materials in the bill of quantity, its average waste 5% was within the reasonable indices. The excessive thickness of plaster was reported as one of the major causes of cement waste. This was partially due to the lack of experience within some labors (untrained labor or low cost labor) that were awarded their tasks on daily basis as well as management deficits. This deficiency also led to high amounts of mortar wastage during plastering.

Table (3 -1): Actual % of waste in materials as percentages of Total purchased amount (by weight)

Code of project	Ready Mix Concrete	Sand	Masonry Various Types	Reinforcing Steel	Cement	Tiles Various Types	Timber Frameworks	Gravel (Lime Stone)
P1	2	5	5	4	2	2	2	
P2	5	15	15	6	5	3	15	10
P3		10	5	3	4	5	10	
P4		10	5	2	5	5		
P5		10	2	2	4		7	
P6		6	4	3	3	2		
P7		5	8	3	5	5	10	
P6	5	5	8	5	5		2	
P7		10	8	5	7	3	15	
P8	4	4	4	4	4	4	4	4
P9	7	12	6	8	5	5	10	10
P10				5	7	7		
P11		10	7	8	5	4	10	
P 12	2	5	7	5	4	2		2
P 13	5	20	7	5	5	5	10	7
P 14	2	3	3	8	5	5		
P 15		9	4	2		3	5	3
P 16	1	10	7	3	5	8	10	2
P 17		20	5	7	5	10	30	
P 18		10	4	4	5	5	10	5
P 19				5		10	2	
P 20	4	8	6	4	5	5		6
P 21	2	10	2	5	7	3	15	5
P 22	3	3	4	4	1	3	3	3
P 23	3	10	10	7	7	5	25	10
P 24	3	10	10	10	7	5	40	10
P 25		2	5	2	1	5	50	2
P 26	10	10	10	10	10	10	10	10
P 27	3	8	6	5	4	3	16	5
P 28	5	5	5	5	5	5	10	5
Stand. Dev.	2	4	3	2	2	2	12	3
Average	4	9	6	5	5	5	13	6

Studies have been conducted in some developing countries on construction waste quantities to determine the materials waste rates. Although it is not possible to establish a direct comparison between results of local studies and others undertaken in foreign countries due to the difference in construction techniques, culture, and work procedures, it was found useful to present the absolute results of these studies together in Table (3-2). The aim was to get a better feeling on the reliability of the gathered data representing the Egyptian Construction Industry. The presented results include four studies conducted in Brazil. The 1st study was carried out by Pinto, 1989 based only on one site during the structuring, walling and plastering phases through the analysis of fiscal documents of the construction. The 2nd presents results of experimental studies described by Pinto, 1990. The 3rd was an in-depth study conducted by Soibleman et al. (1994) that presented the average results obtained in five construction sites. The last Brazilian study is conducted by Souza et al, (1999), presents the average wastage rates measured at about 63 new building sites. The table also included the results of a study developed by Skoyles (1976) in England as well as a research project in the Netherlands by Bossink & Brouwers (1996).

The results of the data gathered on the Egyptian Construction Industry developed by Ragab et al (2001), and Garas et al (2004) are also presented in Table (3-2). It should be denoted that these last results represent the experts' opinion gathered through interviews and questionnaires in 2 different studies in Egypt, whereas data from other studies may include site-measured data. The average percentages of wastes in the 2 Egyptian studies for most of the materials under study are consistent. When comparing these results with those of the Brazilian studies, a great difference between the values is recognized although Brazil is considered a developing country. While those results of studies conducted in the UK and the Netherlands more or less agree to an extent with those of the Egyptian studies. In Egypt, reinforcing steel and cement contributes one of the highest costing items in the contractors' bill of quantity resulting in great efforts- on the contractors' behalf- to reduce its waste

Table (3-2): Construction Wastes of Specific Material as percentage of Total purchased Amount

	Brazil		UK		Netherlands		Egypt		
Construction Materials	Pinto	Pinto	Soibelman	Souze	Skyles	Bossink	Ragab	Garas	Ahmed El Desouky
	1989	1990	1994	1999	1976	1994	2001	2001	2018
Concrete	1.3	1.5	13.2	9.0	2.0	3.0	3.2	4.0	5
Sand	39.0	28.0	45.7	-	-	1.0	7.2	9.0	8
Masonry (Bricks)	12.7	13.0	23.0	13.0	12.0	6.0	5.9	6.0	35
Reinforcing Steel	26.2	26.0	19.0	11.0	5.0	-	3.9	5.0	6
Cement	33.1	33.0	84.1	-	-	-	3.8	5.0	10
Tiles (Various types)	-	7.5_9.5	27.0	13.0	8.0	10.0	5.1	5.0	10
Wooden Shutters	-	47.5	-	-	-	-	-	13.0	20
Gravel (lime stone)	-	102.0	-	-	-	-	5.5	6.0	6
Mortar	101.9	68.0	91.3	42.0	5.0	10.0	5.8	-	20
Cables									3
Marble									10

4. Conclusions and recommendations:

The results of materials waste percentages in the Egyptian Construction Industry gathered in phase 1 are consistent to those developed by Ragab et al (2001) & Garas et al (2004) . While comparing the absolute values of these 2 Egyptian studies with those of other countries, a great difference between the values is recognized due to the different procedures of gathering the data as well as the variation in the building traditions.

- Uncompleted designs, changes to design, substitution of materials, late information, unnecessary people movements, and untrained labor were among the highest dominant causes of materials waste generation in the Egyptian Construction Industry.
- While ignorance of specifications, waiting (idle) resources, bureaucracy, and theft actions were of least effect on materials waste amounts.
- The study in phase 2 is limited to the three prevailing types of projects: "Residential", "Non Residential or Building", and "Engineering". The 3 types are built inside the application case base under one major concept called "Materials Waste Estimation",
- Although small case base with 15 case, it is expected that it will increase gradually. This will be achieved by adding (retaining) the new case (using the "query as case" option) that fits the users' requirements to the case base.
- Problems related to projects of type Residential "PR' which consist of repetitive units and typical floors are almost similar to each other. They only differ in the on-site management level according to the experience of the members of the teamwork and the conditions of each site. This makes each project regarded as a new experience.
- The attributes' values in each case are not reliable on any theoretical basis, but they reflect absolute data related to the conditions of each specific case according to its conditions provided from the project documents. So, comparing between cases is not acceptable as each case provides a unique experience.

It is recommended that future work on material waste minimization would cover the following areas:

1- To integrate other building materials in the study after identifying their effect on the overall project cost.
2- To collect data on materials waste percentages and its causes using site- measured data.
3- To enlarge the structure of the decision support tool application such that it consists of one main concept on materials waste study, which includes inside it three separate sub-concepts one for each of the prevailing type of projects (Residential- Building-Engineering) to increase the size of the case base.
4- It is recommended to consider a factor that takes the inflation rates into account while building the budget attributes of the projects in the case base. This factor would allow the program to update its budgets regularly according to the year of execution of the project,
5- It is highly recommended to make this application available for contracting companies to integrate all the cases of various projects inside it to be used as a decision-supporting tool, as well as a learning tool for estimating and minimizing the amount of waste in materials.

6- In a wider scale this application can be used nationally among Public sector contractors to extend the case base with various types of projects and experiences that would show clearly the defects in various areas in the Egyptian Construction Industry and make possible actions to improve it.

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