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Concrete Recycling in Egypt for Construction Applications: A technical and Financial Feasibility Model

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***Abstract*—**The construction industry is a very dynamic field. Every day new technologies and methods are developed to fasten the process and increase its efficiency. Hence, if a project uses fewer resources it will be more efficient.

This paper examines the recycling of concrete construction and demolition (C&D) waste to reuse it as aggregates in on-site applications for construction projects in Egypt and possibly in the Middle East. The study focuses on a stationary plant setting. The machinery set-up used in the plant is analyzed technically and financially.

The findings are gathered and grouped to obtain a comprehensive cost-benefit financial model to demonstrate the feasibility of establishing and operating a concrete recycling plant. Furthermore, a detailed business plan including the time and hierarchy is proposed.

***Keywords*—**Construction wastes, recycling, sustainability, financial model, concrete recycling, concrete life cycle.

I. Introduction

As the resources of the world are getting more limited every day, engineers and researchers should start thinking of many ways to acquire new resources, recycle their old, or efficiently use the current. The average annual consumption for each human being is 1 ton of concrete in the modern world [11]. The consumption for aggregates is rapidly increasing as people are increasing, thus building more shelters.

In fact, concepts like cradle to cradle are now very important in the understanding of suitability and concrete life cycle. As shown in Fig. 1, Cradle to cradle is basically designing the materials to acquire many life cycles. In other words, the product is reused over and over again [6]. For example the construction debris can be recycled to be used again as concrete aggregates, similar materials can be recycled the same way.

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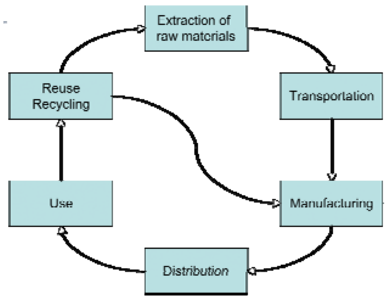

Fig. 1 Cradle-to-Cradle Approach

Although many contractors get scared from putting recycled aggregates into their concrete mixes, this may have a huge impact on the cost of the project without sacrificing the quality if properly used [11]. Many researches were performed to compare the characteristics of concrete containing recycled concrete aggregates (RCA) versus concrete with normal aggregates (NA). Research showed that when replacing 20-30% of the NA by RCA in the concrete mix, minor effects was noticed in the compressive strength [1].

Such study and others shows that recycled aggregates are suitable for construction. Hence, construction developers are proceeding with building plants to recycle concrete wastes. This approach could if properly applied be environmentally friendly and less costly with great financial benefit to all parties. The developer will make profit from recycled aggregates, contactors will also benefit by buying the same quality aggregates with cheaper prices. In this paper the cost of collecting and processing, construction debris waste is analyzed. The purpose for this paper is to provide a technical and financial to study the possibility of recycling concrete waste in Egypt and other similar developing countries.

II. Review of the Literature

In order to proceed with the research, the background, history and recent studies should be studied first. This will aid us in the methodology to start from where other researchers have stopped. In the literature review, some of the researches in this industry are analyzed. There are national and international papers. Some of them will focus on the construction waste in general and its quantity and others will focus on the techniques and machines used to recycle them.

A. Amount of Construction Waste and Actions Taken Nationally (Egypt)

In the construction industry there exits many factors that lead to waste. In the beginning we need to take some measurements and quantities for those wastes. Waste can be produced from suppliers, contractors and sometimes owners.

In a paper that was part of a PhD research, the authors state that “timber frameworks (2-50%), and sand (2-20%)” “Timber frameworks with an average waste of 13% and sand with an average 9% showed the highest percentages of waste among all materials. While other materials such as reinforcing steel with an average of 5%, cement 5%, and concrete 4%” [4]. This paper surveyed the top 35 contractors in Egypt based on their size of capital and experience according to the classification of the Egyptian Union for Building and Construction Contractors [10].

The following are estimates of the construction concrete waste produced in Egypt every year: Egypt's total annual production of cement = 36,200,000 metric tons.

“- Total quantity of cement exported (approximately) = 5,000,000 metric tons.

- Total quantity of cement consumed in local market = 33,200,000 metric tons.

- Approximate quantity of cement used for structure concretes (assumed as 50% of total cement consumed in the local market) = 16,600,000 metric tons.”

With some calculation based of the survey the waste can be measured. From the survey in the thesis the concrete was approximately 2-3%. The following is applied if each meter cube concrete contains approximately (1/3 metric ton) of cement = 330 kg cement. Thus, from above: 16,600,000 metric tons of cement (for structure concrete) produces about (16,600,000 ÷ 0.33) = 50,303,000 cubic meters of structure concrete [9].

The thesis performed by Eng. Kamel surveyed the reasons that prevented contactors from recycling. The author performed a survey and its results were as follows: “64% of the participating firms stated that the lack of experiences, lack of know-how and the environmental and economic concerns are the main problems and/or reasons that hinder the recycling industry of concrete, 62% of the participants mentioned that the lack of management and economic models are major problems. However, 100% of the participants stated that the absence of codes of practices is the main problem” [9].

In addition Eng Kamel has researched in the effect of the contract type of the project. The results were as follows: “84% of the participating firms have mentioned that the unit price contract would be more acceptable; whereas, 16% have mentioned that the contract type would make no effect on the choice of recycled aggregate when compared to the conventional aggregate.” [11].

In the UK, there is good potential to increase resource efficiency in construction and reduce waste. The government has set a strategy in 2007 to reduce C&D wastes. In the UK, the construction industry is a major source of waste. It consumes over 400 million tons of resources. The construction, demolition and excavation (CD&E) sector contributes to the generation of waste more than any other sector. It produces around 1.7 million tons. It contributes to the GDP by 9-10%.

B. Actions Taken towards Waste Management Internationally:

In the states, in 1998, an initiative called LEED v1.0 was established to preserve the environment. It followed the formation of U.S. Green Building Council (USGBC) in 1993. In less than a year after its formation, the committee focused solely on this topic to establish initial findings [3].

After extensive modifications, in March 2000, the LEED Green building rating system version 2.0 was released. Now it is called the LEED Green Building Rating System for New Commercial Construction and Major Renovations, or LEED-NC [9].

III. Methodology

Construction waste has a critical and major contribution to the world’s total wastes. It is our duty to create ways to reuse this waste. Part of this waste is the concrete waste, which can be in many forms.

A. Data Collection

To begin, the process will be analyzed based on other researches that were made by researchers in the same field. Thenceforward, the process will be divided into smaller processes. They will be priced based on machine cost, labor, rent, etc. Then this cost of the final product, which is concrete aggregates, will be compared with the price of the new material.

There are many types of equipment to be used, however in this paper the focus will be on stationary plants. The data will be collected from various suppliers who produce the necessary crushing equipment for this type of project. The suppliers are from many countries, like China, United Kingdom and Australia

Other expenses are gathered through a number of surveys with professors and experienced engineers working in the field of construction and concrete recycling in Egypt. In addition, all these data are verified and peer reviewed by several construction management and mechanical engineering professors at the American University in Cairo.

IV. Data Findings and Results

In this part the equipment will be analyzed financially and technically. The pricing is found in the next section with more details and numerical justifications. The estimates given in this paper are strictly confidential and could not be verified using different sources. The sources used in this paper are extensive interviews with site engineers in similar plants and equipment suppliers’ representatives. The data obtained and the brand is confidential to this study, as the manufacturers do not accept to reveal their market prices. This is very common practice in the field of the construction industry for confidentiality purposes.

A. Type of Concrete Recycling Plant

There are two types of concrete recycling, closed and open. The following diagrams illustrate both. The closed system, in Fig. 2, is the most recommended one. The open system, in Fig. 3, has only one advantage, it operates with greater capacity. However the same basic equipment is used for both systems. Moreover, an advantage for the closed system is having a well-defined maximum aggregate size and this can lead to larger variations in the size of the end product, especially when the input size variations are large [8].

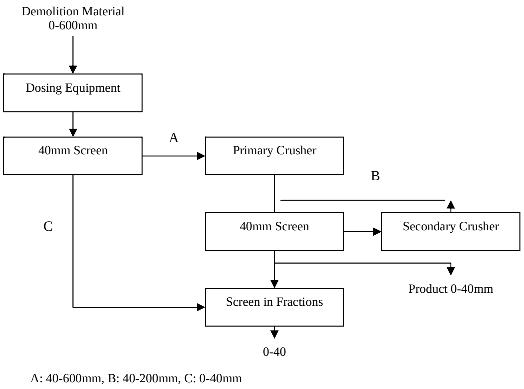

Fig. 2 Flow-chart of typical plant for production of recycled aggregate from concrete debris which is free foreign matter (Closed system) [8]

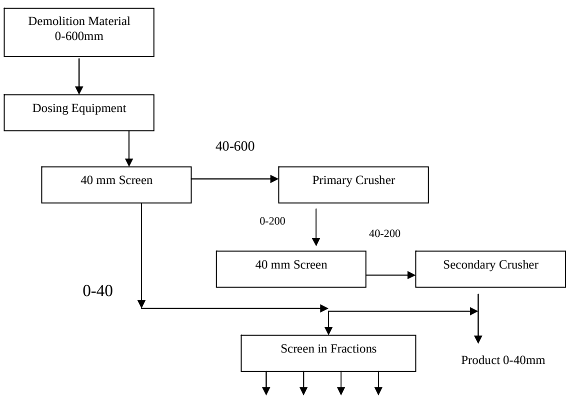

Fig. 3 Flow-chart of typical plant for production of recycled aggregate from concrete debris which is free foreign matter (Closed system) [8]

B. Comparison of Crusher Types

The crushers needed for this project are categorized into three main types [2]:

1. Jaw Crusher
2. Impact Crusher
3. Cone Crusher

A Dutch investigation was made in order to compare the performance of crushers when crushing old concrete. The results can be summarized as follows: jaw crusher is the best choice to provide the best grain size distribution of recycled aggregates for concrete production. The cone crusher is best used as secondary crusher with 200mm maximum feeding size. Impact crushers are best used in projects related to road construction. They provide a better grain-size distribution and are less sensitive to obstacles that cannot be crushed like steel or iron [7].

However jaw crushers produce better grain-sized distribution than impact crushers because jaw crushers crush smaller proportions of the original aggregate particles in the old concrete. On the other hand, impact crushers will crush old mortar thus produce lower quality aggregate. In addition, another economical disadvantage for the impact crushers is its high wear and tear. Therefore it needs relatively higher maintenance cost [2].

The study proved that all crushers approximately produce the same percentage of cubical particles in cubical aggregates and that the quality improves with secondary crushing [7].

C. Site Layout

The layout may differ according to the project needs. Another factor that may limit the site is the area available to construct the plant. In this case study the area is assumed to be sufficient for the model; hence, there is no limitation. The governing factor for the site layout is the recycling process itself. The process is visually described in Fig. 4 and as follows:

- Construction Waste Transportation and Stockpiling: Collecting the concrete waste from different sites. This process requires the operation of heavy hauling equipment.
- Sorting Process: This process involves sorting the materials and removing the unnecessary waste like large pieces of steel, wood, gypsum, etc. However this is not the final sorting process, as minor unnecessary materials will be removed later.
- Crushing: this stage is divided into two processes, primary and secondary. The primary crushing breaks the large blocks into smaller ones, the secondary crushing crushes them into much smaller particles to get the desired size.
- Magnetic Separator: All the iron, metal and steel components are removed mechanically by a permanent magnetic separator.
- Washing, Screening or air sifting: This is the final stage where the aggregates get ready to be sold. They are screened according to size and washed by recycled water to remove all the fines from them. This process in executed between the primary and secondary crushing.
- Manual removing: at this stage all the aggregate is almost finished, however one worker is responsible to manually remove any non-aggregate material.

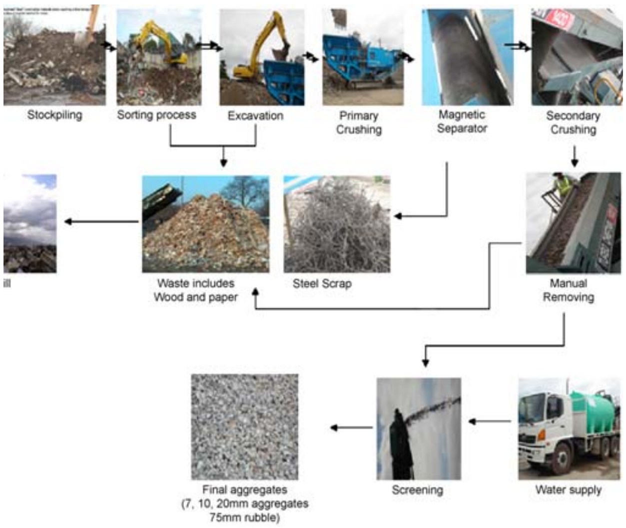

Fig. 4 Concrete recycling process [12]

D. Equipment Pricing

The plant can have a wide range of capacity, usually ranging from 200 Tone per Hour (TPH) to 800 or more TPH. This is applicable by combining one or more sets of crushers. In this paper the capacity for the plant will be 800TPH as shown in Fig. 4.

According to many suppliers in China and other countries the prices of the equipment are listed in Table I. Professors at the American University in Cairo approved these prices. Also the sea freight is added to the FOB prices. The currency used throughout this paper is US dollars (USD).

E. Labor

For the plant to work efficiently labor is highly needed, thus they should have a sufficient plan. This plan must have the amount of labor needed, their salaries, efficiency, etc. The labor in Egypt is divided into three categories, normal labor, semi skilled labor and skilled labor [5]. To initiate the concrete recycling plant, there are many processes where a labor must be there to either operate a machine or do any other task. The processes are divided into stations or tasks as follows; pre-handling, feeder, manual filtering, primary crusher, secondary crusher, screening, monitor, post handling, transportation. For the feeder three semi-skilled labors need to be hired to operate the machine and make sure it is maintained. For the manual filtering six normal-skilled labors should be hired to remove undesired materials from the concrete. For the pre-handling process three highly skilled workers should be hired, as they will operate a loader the primary and secondary crushing six semi-skilled workers should be hired. For the screening three semi-skilled workers are needed, six skilled labor for post-handling and transportation as they will need to have driving skills. Therefore the total number of skilled labor is nine, the semiskilled is twelve and the normal is six. Moreover, there should be two resident engineers who monitor the entire process and work in shifts.

TABLE I
RECYCLING EQUIPMENT PRICES

Name	Qty	FOB (USD)	
		Unit Price	Total Price
Vibrating Feeder	1	33,500	33,500
Jaw Crusher	1	274,000	274,000
Impact Crusher	2	115,000	230,000
Impact Crusher	2	50,000	100,000
Feeder	2	3,500	7,000
Vibrating Screen	4	25,000	100,000
Belt conveyors	1	23,000	23,000
	2	19,000	38,000
	4	10,000	40,000
	2	9,000	18,000
	2	17,600	35,200
	6	7,200	43,200
	1	5,400	5,400
Control panel	1	35,000	35,000
Steel structure	1	26,000	26,000
FOB		**1,008,300**	
Sea Freight 15%		**151,245**	
Total		**1,159,545**	

F. Other Financial Aspects

In order to have a comprehensive well-established financial plan many other financial aspects should be considered, like inflation, depreciation, salary increase, installments, initial investment, efficiency of labor, working days per year, the working hours per day and price of construction waste.

According to the statistical website trading economics, the inflation in Egypt is 10.15 percent in September 2013 [4]. The salary increase is between 10-12 percent. In this model the depreciation is assumed to be linear and the salvage value is 50% after 10 years. The initial investment will be divided into equal installments in the first 5 years. According to experts in the field the efficiency of the labor is assumed to be 75 percent. The number of working calendar days is assumed to be 250 days. The working hours per day are 10 hours. The price to buy the construction waste is $2 per ton in order to motivate contractors in Egypt to recycle. Last but not least, as stated before the average price of normal aggregates is $10/ton. Using all these data, a model will be created to calculate the expected revenue/expense and profit loss projections for the 10-year period of time. Nevertheless, in the fourth year another plant is planned to operate to increase the revenues. All this will be presented in the business model data analysis section.

IV. Business Model Data Analysis

The business model is the main part of this paper as it concludes and gathers all the data collected. It should be the recommendation to propose to construction investors for this project and prove that it will be profitable to them. In addition, many investors should expect a lot of governmental support, as this will decrease the construction waste thrown in the streets and dumpsites. In Table II, the projected income statement for 10-year period is presented. The break-even (BEP) is expected to be in Year 2 of the project. In Year 5, the second plant will be operating and this explains the sudden increase in the revenues. All the revenues and expenses are subject to inflations and salary increases.

The installments are paid equally for 5 years for the first and second plant. The installments for the first plan end at year 5; however the installments for plant 2 begin at year 5 and ends at year 10. Therefore, the installment is doubled in year 5 (Fig. 5). This reflected on the sudden increase in the expenses. The geographical locations of the plants will be distributed across the region to be easily accessed by construction debris sellers. This will help maximize the construction debris collection.

TABLE II
10 Year Income Statement Projection

800 TPH Capacity	US Dollars (Millions)									
Income Statement	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Revenues	4.04	4.45	4.91	5.42	11.96	13.2	14.56	16.06	17.71	19.53
Cost of Good sold	3.20	3.53	3.89	4.29	9.47	10.45	11.53	12.72	14.03	15.47
Gross Profit	0.84	0.92	1.02	1.12	2.49	2.77	3.02	3.343.86	4.06	28.45
Operating Expense										
Total Salaries	0.14	0.15	0.17	0.18	0.41	0.45	0.50	0.55	0.61	0.66
Total Depreciation	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Rent	0.14	0.16	0.18	0.21	0.5	0.57	0.66	0.760.87	1.00	7.04
Utilities	0.14	0.15	0.17	0.19	0.21	0.23	0.25	0.28	0.31	0.34
Initial Investment 1st Plant	0.48	0.48	0.48	0.48	0.48					
2nd Plant					0.48	0.48	0.48	0.48	0.48	0.48
Total Expenses	0.91	0.96	1.01	1.08	2.09	1.74	1.90	2.07	2.27	2.01
Net Profit	(0.07)	(0.03)	0.005	0.39	0.99	1.12	1.26	1.4	2.05	2.06
Profit margin	-4.74%	0.42%	5.48%	10.39%	15.10%	57.69%	60.01%	61.81%	63.10%	111.22%

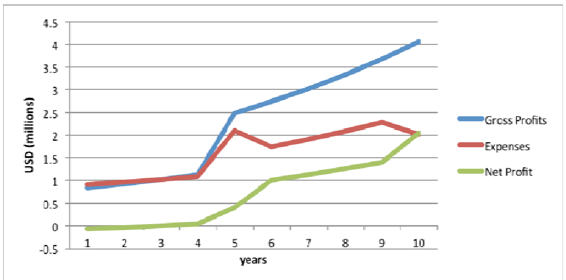

Fig. 5 Profit Projections

V. Conclusion and Recommendation

After conducting the study, several conclusions and recommendations can be stated.

The cradle-to-cradle concept is introduced which states that the materials can always enter again the manufacturing cycle and be reused. This saves a lot of energy, resources, and the environment. The main material recycled in this study is concrete debris. The complete set-up from an industrial point of view is presented including the definite types of machines, which can be used to initiate a concrete recycling plant. The main equipment that should be used is identified as the primary and secondary crushing, material hauling and screening.

From an economic point of view, it is demonstrated that, as internationally feasible, the process can be implemented in Egypt and generate profits from the second year of operation. Moreover, the initial set-up can expand to operate with an extension plant in year 4 with no losses, after the break-even point at Year 2.

In the future, studies can focus on the analysis of the recycling of other materials, like granite, bricks, gypsum, etc. In addition, other studies researches can be initiated to optimize the process for higher profits by changing the variables included in the production process; such as capacity rate, initial investments, types of plants, and strategy for execution.

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