T Abukhader et al. Int. Journal of Engineering Precious Research and Application
www.ijpera.com
ISSN : 2456-2734, Vol. 2, Issue 1, April 2017, pp.09-13

RESEARCH ARTICLE OPEN ACCESS

Evaluation of Construction Waste Impacts on Energy Consumption and the CO_2 Emissions

T Abukhader and O Damdelen
School of Engineering, Faculty of Civil Engineering, Girne American University, Girne American University, University Drive, PO Box 5, 99428 Karmi Campus, Karaoglanoglu, Kyrenia / Cyprus

ABSTRACT
This paper will identify the negative long-term impacts of energy consumed, to reduce the construction waste short-term impacts. Construction waste contributes a great share of the total generated waste, the current construction waste problem resolutions, have more complications on the environment, the energy consumed to manufacture, transport, fabricate, recycle and recover or damp, release CO2 emissions. Environmentally, these emissions have negative impacts on long-term more than the construction waste accumulation itself. The paper will review several kinds of literature to calculate the total released CO2 emissions from a villa project, the calculations will consider the emissions released due to the energy consumed, from manufacturing till the completion of the waste treatment process. The study will only examine the project from the footings works up to the plaster completion; the finishes stage will not be considered due to several parameters, which will be mentioned later in the study.

I. INTRODUCTION

Poor waste management and its impacts environmentally, financially and socially are common global problems. Due to the fact that, construction activities considered as the main solid waste generation source. Based on Eurostat report on 2014, 33.5% of the total waste in Europe generated from construction activities, and if compared to the Chinese or Indian population growth and their urban development the figures will be much greater. Many countries managed to recycle and recover construction waste; the values could reach even more than 90% in some countries, but the problem is more complicated than it seems to be. The energy consumed to manufacture the building materials, as well as the energy consumed to transport and fabricate, should be considered. Adding to that, the energy consumed to transport the waste from the construction sites, segregate and recycle or damp to the landfill areas also should be considered. Ignoring the financial aspects, this study will focus on the environmental impacts of the consumed energy, to demonstrate that waste generation prevention techniques, are more beneficial than improving recycle and recovery processes.

1.1 History and background:

The improvement of waste management strategies and techniques is a global demand; many types of researches proposed several techniques to improve the recycling process, since the implementation of the first systematic waste management concept in London by Corbyan Morris in 1782, the waste management received many improvements. The interest in waste management knowledge and improvement increased, due to the negative impacts of the waste generated from various human activities. The first waste management plans mainly proposed to deal with the municipal waste, to reduce the public health problems on short terms. The environmental issues caused by poor waste treatment and its long-term effects on the human were unknown, until the discovery of the negative impacts of Co2 emissions. These environmental challenges and their social financial consequences require a continuous improvement for the waste management strategies and its effectiveness. Industrial and construction wastes were negligible before due to its small quantities, compared to the municipal waste. The growing communities increased the urbanization demand on construction industry; accordingly, the construction became the main waste generation source. Many proposals introduced to reduce the waste quantities like recycling; Recycling techniques improved successfully to recover glass, plastic, wood and paper so far, the manufactured products using recycled components are commonly accepted by consumers. The commercial viability of recycling these types of waste material encouraged bigger investment in this industry, which reflected positively to sort out part of the problem. But the case is different with construction waste since the main component in the waste is concrete, bricks and tiles all mixed together, So far, the recycled aggregates from these components are not attractive commercially or physically. The recycled aggregates mainly used in roads and backfilling works; this study will evaluate construction waste recycling negative environmental impacts.

II. RESEARCH METHODOLOGY

The study will use actual villa project, the concrete, bricks, and plaster quantities will be calculated. Accordingly, based on the waste will be the calculation, the energy consumed to manufacture that wasted material will be calculated in the pre-delivery stage1. Adding to that the energy consumed to fabricate at the site, segregate, transfer and recycle in the post-delivery stage2. The total Co2 emissions released will be calculated based on the total consumed energy in both stages. Eventually, The figures of the total consumed energy and the Co2 emissions to be used, to evaluate how negative is recycling process environmentally compared to its advantages. This study to focus on the materials composed of cement only due to the harmful effects of cement industry.

2.1 Project Briefing:

The project is private villa contains, 5bed rooms, sitting-dinning area, kitchen, and service area. The villa located in Dubai, and its constructed on a plot with an area of 570 m2, ground + 1st floor + roof, the villa total build up area is 410m2; the project total duration is 18 months.

2.2 Quantities Breakdown:

The following tables 1 and 2 prepared based on the approved bill of quantities, in addition to that the actual quantities taken from the concrete delivery receipts:

Table.1 (Substructure concrete quantities)

No.	Substructure	Unit	Theoretical quantities	Actual quantities	Waste
1	PCC. 10 cm thick concrete	M3	15	17	2
2	RCC. For neck Columns	M3	3	5	2
3	RCC. For Footings	M3	36	42	6
4	RCC. For Tie Beams	M3	13	18	5
5	Slab On Grade 10cm thick RCC	M3	24	32	8

Table.2 (superstructure concrete quantities)

No.	Superstructure	Unit	Theoretical quantities	Actual quantities	Waste
1	RCC. For Columns	M3	24	30	6
2	RCC. For Slab 33 cm Th. (including blocks)	M3	81	86	5
3	RCC. For Solid Slab	M3	10	11	1
4	RCC. For Drop Beams	M3	19	24	5
5	RCC. For Hidden Beams	M3	25	26	1
6	RCC. For Domes, Sections & Slop Area	M3	76	87	11
7	Other RCC elements	M3	11	17	6

The total proposed concrete quantity for this specified project is 337M3 and the total actual is 395M3, the difference between these quantities is 58M3, which is forming 17.2% waste in the reinforced concrete item only.

Table.3 (Block plaster quantities)

No.	Item description	Unit	Theoretical quantities	Actual quantities	Waste
1	Concrete blocks CMU	No.	7,775	8,865	1,088
2	Cement Plaster 2.5cm thickness	M3	35	54	19

All the theoretical quantities in table.3 calculated from the project documents, the actual quantities calculated based on site delivery notes and daily project reports.

2.3 Energy consumption calculations (stage1):

2.3.1 Concrete:

The energy calculation will consider the extraction and transportation of the raw material, adding to that the energy consumed by the batching plant. Further to that, the energy consumed to transport it to the site, the energy to transfer out of the site and to recycle will be added as well.

The used mix is C40 to achieve compressive strength of 40Mpa,the weight of 1M3 concrete is = 2,388 Kg, and will contain: Cement = 400kg, Water = 160kg, Fine aggregate = 660kg, Coarse aggregate 20mm = 701kg, Coarse aggregate 10 mm = 467 kg. The total wasted cement is 400kg * 58M3 =23,200 Kg, total energy consumed to manufacture 1kg of cement is 3.35MJ/kg (Stripple, 2001,LCI Data). So 23,200 kg * 3.35MJ/kg = 77,720 MJ is the total energy lost by cement waste.

The total weight of aggregates in concrete waste = 58M3 * 1828kg/M3 = 106,024 kg, the total energy required to produce 1kg of aggregates is 0.067 MJ/kg (Stripple, 2001), so the total wasted energy in aggregates is 0.067MJ/kg * 106,024 kg = 7,104 MJ.

2.3.2 Concrete Block:

The mix design for 1M3 of concrete block mortar contains: 240kg cement, 1200 kg aggregates, 715kg sand. 1M3 of this mortar can manufacture 160 block with size of 20X20X40 cm. total block waste =1088pcs/160 = 6.8M3 *240= 1632 kg cement. Energy consumed =1632kg *3.35MJ/kg = 5,467 MJ.
Total energy consumed for aggregates =1200+715=(1915kg/M3 * 6.8M3) * 0.067MJ/kg = 872MJ
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2.3.3 Plaster:
The total weight of 1M3 of cement sand plaster mortar is approximately 2184 Kg, the mix design will be cement =325 kg, sand =1495kg, water =364 kg. The energy consumed to manufacture the cement waste in plaster is 325kg/M3 * 19M3 = 6175kg * 3.35MJ/kg = 20,686 MJ.
The total sand waste weight in the plaster is =1495kg/M3 * 19M3 = 28,405 kg, and the total energy lost due to sand waste =28,405 kg * 0.067 MJ/kg = 1,903 MJ.

2.3.4 Co2 emissions:
The total energy consumed to manufacture the wasted materials is = 77,720MJ + 7,104MJ + 5,467MJ + 872MJ + 20,686MJ + 1,903MJ = **113,752MJ**. The diesel is the most common fuel to operate heavy equipment and machinery in Dubai, the Co2 emissions can be calculated based on the total energy consumed and the fuel type. To generate 1GJ of energy from diesel fuel, 74.1 kg/GJ of Co2 emissions will be released (Quaschning, 2013), accordingly, 113, 752MJ = 113.752GJ * 74.1Kg/GJ = **8,429Kg**of Co2, is the total emissions from wasted material in stage 1 (pre-delivery).

2.5 Co2 emissions calculations (stage2):
At stage 1, the embodied energy calculated for the concrete and aggregates separately. At this stage the energy and emissions to deliver, mix, clean, segregate and recycle or transfer to the landfill to be calculated. The project is located in Dubai land area, 20 Km away from the batching plant and 50 Km from the landfill; the recycling plant is also located near the landfill. The block factory and the cement sand supplier are also located near the concrete batching plant.

2.5.1 Transport:
The cement and aggregates supplied to the batching plant from remote areas, for this study the approximate distance will be assumed to be 50Km, the total wasted concrete 58M3 consist of 23,200Kg of cement and 106,024Kg of aggregates.

The total weight = 129,224Kg =129 Ton, the diesel heavy truck with capacity of 40ton are the common transporters. The 40ton truck can actually load up to 34tom maximum, and the Co2 emissions are 0.87Kg/Km based on US - EPA 2001 Guide.

Accordingly, 129ton/34ton=3.79 means that 4 heavy trucks required to transport the raw material to the concrete batching plant, 50Km * 0.87Kg/Km * 4= 174Kg of Co2 emissions released. To transport the 58M3 wasted concrete to the site if every concrete mixer capacity is 8M3, approximately 7 mixers required to transport the concrete to the site, 20Km * 0.87Kg/Km * 7 =121.8Kg of Co2 emissions released. To shift the concrete, plaster and block waste from the site to the recycling plant/landfill, the Co2 emissions will be calculated as, 58M3 + 19M3 + (1088*0.2*0.2*0.4) = 94.4M3 * 2.4ton/M3 ~ 227 ton, heavy truck can load 34ton, 227ton/34ton ~ 7 truck required means, 50Km * 0.87Kg/Km * 7= 304.5Kg Co2 emissions released to transport the waste out of the site. Chart.4. Total Co2 emission by transport =174+121.8+304.5 ~600Kg

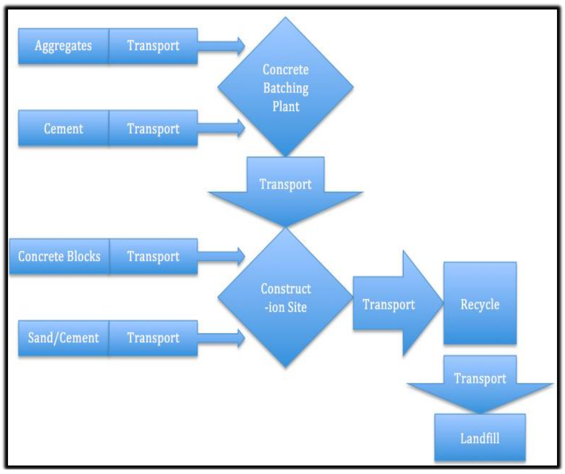

Chart.4 (Material flow diagram)

2.5.2 Mixing and Manufacturing:
To mix 1M3 of concrete, the batching plant will consume 33MJ/M3, if the plant operated by electricity (Rydh et al., 2002), accordingly, the Co2 emissions 1.5Kg/M3. The total energy consumed to mix the wasted concrete = 58M3 * 33MJ/M3 = 1914MJ. The Co2 emissions = 58M3 * 1.5 Kg/M3 = 87Kg of Co2 emissions. Block manufacturing plant will release 0.08Kg of Co2 per concrete block (CO2List, 2016), so, 1088Pcs *0.08 Kg/Pc ~87Kg of Co2 emissions. The total emissions by mix/manufacturing = 87+87= 174Kg.

2.5.3 Housekeeping
The wasted concrete, cement sand plaster, and

bricks cut pieces, required special housekeeping techniques and practices. The safety records showed extensive machinery works, a total of 420 working hours, participating of Bobcat, backhoe, and Concrete breaker. The total Co2 emissions = 9.33 MT~ 9,330Kg calculated using Project Emission Estimator PE-2. Table.5.

Table.5 (Co2 emissions by equipment used for cleaning)

Division	Fuel Rate	Equipment Description	Number Used	Hours	Emissions	Gallons Used
38	0.8039	Bobcat	1	270	2.2242 MT	217.0635
35	2.8248	Rubber Tired Hoe	1	180	5.2103 MT	508.4712
24	1.543	Concrete Breaker	1	120	1.8974 MT	185.1624

2.5.4 Recycling:

The total waste transferred from the site is 94.4M3 = 227ton, if the total quantity will be recycled, the process will release Co2 emissions as 0.6Kg/ton (Wilburn and Goonan, 1998). And the total will be 227Ton * 0.6Kg/Ton ~ 136Kg of Co2 emissions.

III. CONCLUSION:

Based on the research calculations, the waste generated in the initial construction stages could consume a huge amount of energy. The total released Co2 emissions due to that is 18,669Kg ~ 18.67Ton. According to the national ready mix concrete association (NRMCA), the ideal Co2 emissions for concrete structures = 550Kg per square meter. If the whole villa project will release 410M2 * 550Kg/M2 = 225,500Kg ~225.5Ton, means that approximately 8% of the total allowed emissions generated by concrete waste only. Since the concrete recycling process in the best cases is a result of cosmeticsolution for the generated waste due to the poor designs and practices. Further to that, the recycled aggregates uses are limited to some secondary activities, and it's not financially viable, so the concrete recycling can only be used to reduce the existing waste in a landfill, to reduce its area.

The great impacts caused by the additional Co2 emissions due to the concrete waste calls for an urgent action plan for the future projects since the recycling as a remedial solution can't be adopted. Legislation and Co2 quotas should be strictly applied, as well as, the adoption of low-waste design techniques are the future for better environmental practices. The technological enhancement for the construction materials also is the key to improving the industry as a whole.

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