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Origins of Construction and Demolition Waste Generation in the Sri Lankan Construction Industry

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Abstract: C&D waste management is an area where attention needs to be paid for as the construction industry is considered to be one of the key solid waste generators. Mainly, C&D waste get generated through the new construction, renovation of buildings, and through the demolition of buildings and structures. Hence, it is necessary to manage the C&D waste. In order to manage the C&D waste, it is necessary to identify the types and origins of waste. Thus, the aim of the paper is to identify the types of C&D waste and their origins of generation. This paper critically reviews secondary data and findings of eight case studies under the qualitative approach. Through the case study findings, it was evident that plywood, concrete, cement, steel offcuts, blocks bricks, sand, soil, wood, polythene and food waste as the main types of C&D waste in Sri Lankan construction sites. Further, design changes, transport, human mistakes, quality of works, client changes and mismatches in required materials are identified as the key origins for C&D waste generation in Sri Lankan construction sites. Therefore, to achieve the aim of the paper, types of C&D waste materials and origins of C&D waste generation were identified.

Keywords: Construction and Demolition (C&D) waste, Waste Materials, Waste Management, Sri Lankan Construction Industry

Introduction

Construction industry being one of the largest industries, make a considerable contribution to the Gross National Product (Elgizawy et al.2016; Sapuay, 2016). Further, Elgizawy et al. (2016) have stated that as bigger portion of solid waste generation is through the construction industry attention is being paid to C&D waste management (Banihashemi et al., 2018; Hao et al., 2007). Moreover, out of the generated C&D waste, nearly 10-30% are dumped in landfills causing number of environmental, social and economical problems (Agamuthu 2008; Wang et al., 2010).

According to Coelho and Brito (2012), due to the generation of C&D waste, ecological damages, land depletion, scarcities in land resources and pollutions take place. Furthermore, unsustainability in the construction industry is largely due to the massive C&D waste generation (Elgizawy et al., 2016).Thus, Lingard et al., (2000) have said that through proper C&D waste management adveres impacts of C&D waste can be overcomed.

In order to overcome the adverse impacts and to have proper C&D waste management, strategies need to be implemented (Magalhaes et al., 2017). Further, policies and regulations needs to be implemented by the government to manage C&D waste (Oluwole & Olaniran, 2013). In order to manage the C&D waste, it is necessary to identify the types and origins of waste generation. Hence, this paper focuses on the C&D waste types and their origins of generation in the Sri Lankan construction industry.

Literature Review

Definitions of C&D waste

When considering about the C&D waste, different authors have given different definitions for the C&D waste. In simple, all types of waste generated as a result of construction activities are identified as C&D waste (Hsiao et al., 2002). Further, Yuan and Shen (2011) have defined Solid waste that is generated due to construction

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activities as C&D waste. Moreover, many authors have defined C&D waste that is generated in construction, repair of buildings, maintenance and demolition (Christensen & Andersen, 2011; Ghosh & Ghosh, 2016; Kofoworola & Gheewala, 2008).

Origins of C&D Waste

C&D waste get generated due to the errors in design, lack of knowledge in material handling, poor material planning decisions and due to changes in building design (Yeheyis, et al., 2013). Furthermore, when the required data for the selection of construction method, inadequate knowledge in sequential order of construction activities, C&D waste get generated. Moreover, procurement issues, transportation issues, material storage issues, handling of material issues, issues in site operation, residual issues, weather issues and vandalism issues have resulted in the generation of C&D waste (Begum et al., 2006; Gavilan& Bernold, 1994; Osmani, et al.,2008).

Changes in design during the construction, incomplete documents to start construction, poor quality assurance and quality control in specifications have resulted in the generation of waste (Bossink & Brouwers, 1996). Further, lack of awareness in environmental protection and selection of structures, inadequate management skills, and inadequate training on waste management are the reasons for the generation of C&D waste (Wang et al., 2008). Moreover, Magalhaes et al. (2017) explained that construction planning and designing decisions also lead to the C&D waste generation.

Composition of C&D waste

C&D waste comprises of ceramics, concrete, electrical wiring ,bricks, tiles, wood, tar and tarred products, glass, hazardous components plastic, asphalt, metals soil and dredged soil, mixed C&D, insulation materials, and gypsum based materials (Ghosh & Ghosh, 2016). Further, Hsiao et al. (2002) have stated that, C&D waste consists of sand, stone, pottery and porcelain, dirt brick, glass, tile, concrete, remaining mud, asphalt, concrete, timber, plastic, bamboo, paper, and metal. Moreover, Wang et al. (2008) have stated that out of the generated C&D waste, 95% can be recycled while remaining 5% is unrecyclable. Similarly, Shen et al. (2004) have said that C&D waste comprise of building debris, earth, steel, timber concrete, rubble, and mixed site clearance materials. In addition to that, soil, gravel, pieces of concrete, lime-cast, dressed stone, porcelain, concrete, wood, metal ferrous (Steel), metal Non ferrous (Copper, Aluminum), masonry (bricks and mortar), plastic (PVC pipes, plastic films for packaging, wall coverings), glass, ceramic tiles, insulation material (mineral wool insulation, Styrofoam), drywall or gypsum board, filling material (gravel, sand and soil), paper and cardboard, marble and granite (Elgizawy et al., 2016; Shen et al.,2004).

C&D Waste Management in Sri Lankan Construction Industry

In the Sri Lankan context, no specific regulation is available for the management of C&D waste and C&D waste is classified under solid waste (Karunasena, et al., 2012). Further, Jayawardane (1992) has stated that, in the Sri Lankan construction industry, wastages of resources like plant, labour, and space are beyond reasonable limits. Moreover, the author has identified that the waste generated in the construction sites of Sri Lanka as a considerable problem to be addressed. In addition to that, according to Kulatunga et al. (2006), wastage of materials in Sri Lankan construction sites are beyond the acceptable limit (as cited by Jayawardena, 1994). As per Jayawardane and Gunawardena (1998) in the current context, operations of the construction industry are regulated by the Institute for Construction Training and Development (ICTAD). In Sri Lanka, the value added of construction activities grew by 3.1 percent in 2017 and a number of large scale residential and mixed development projects and infrastructure projects have contributed to the growth in the construction activities (Central Bank of Sri Lanka, 2017).

In carrying out construction activities, materials are the largest input into the construction activities where it leads to the generation of waste (Rameezdeen, et al., 2004). Further, Kulatunga et al. (2006) have stated that, there is a significant impact on the cost of waste in the Sri Lankan construction industry. In addition to that, Karunasena et al. (2012) have stated that, although landfilling is considered to be the least preferred option in waste process, in Sri Lankan context landfilling has become the first option to manage C&D waste. Table 1 shows the C&D material wastage in Sri Lanka

Table 1.: Material wastage in Sri Lanka

Material	Material Waste as a Percentage
Sand	25
Lime	20
Cement	14
Bricks	14
Ceramic Tiles	10
Timber (Formwork)	10
Rubble	7
Steel (Reinforcement)	7
Cement blocks	6
Paint	5
Asbestos sheets	3

Source : Rameezdeen et al. (2004)

According to Rameezdeen et al. (2004), the main causes for C&D waste in Sri Lanka are, cutting waste which takes place due to cutting of materials in different sizes and uneconomical shapes and management waste which take place as a result of incorrect decision making and lack of supervision. Furthermore, as a result of the Tsunami disaster which took place in the year 2004, 450, 000 tonnes of building waste were generated in Sri Lanka and a post Tsunami programe called Construction Waste Management (COWAM) project was initiated to manage C&D waste in Sri Lanka (Karunasena, et al. 2009,2012). Although COWAM project was initiated to manage C&D waste, due to the lack of technology, funds, unfamiliarity and unawareness of recycled building materials, building waste recycling projects have not been implemented in Sri Lanka (Karunasena, et al., 2009) . Therefore, considering all the above discussed facts, it is clear that C&D waste management in the Sri Lankan context is still in a primary stage.

Methodology

Journal articles, books, conference proceedings related to C&D waste types, origins were reffered to collect data. Following the literature review, for the data collection case study strategy under the qualitative approach was used. Under the qualitative approach, eight (08) case studies were carried out and details of the cases are shown in Table 2. Moreover, semi structured interviews were carried out with twenty seven (27) respondents and respondents details are shown in Table 3 . Selected cases were under the building construction CS2 grade in Construction Industry Development Authority (CIDA).

Table 2 : Case Study Details

Criteria	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H
Cost of the project (Billion)	4	0.28	1.2	0.76	1.89	40	0.4	3.08
Duration of the project (Months)	36	18	18	18	24	26	18	20

Table 3 : Profile of the interviewees

Profession	Code	Interviewee from each case	Experience
Project Manager	PM	PM-C	26years
		PM-E	18years
Planning Engineer	PE	PE-A	7 years
		PE-B	5 years
		PE-F	13 years
		PE-H	4 ½ years
Site Engineer	SE	SE-C	4 years
		SE-D	6 years
		SE-F	3 years
		SE-G	5 ½ years
		SE-H	3 ½ years
Safety Officer	SO	SO-A	7 years
		SO-B	5 years
		SO-C	8 years
		SO-D	4 ½ years
		SO-E	4 years
		SO-F	12 years
		SO-G	2 ½ years
		SO-H	8 years
Mason	MA	MA-E	1 ½ years
Store Keeper	SK	SK-B	1 year
Labourer	LA	LA-A	10 months
		LA-C	1 year
		LA-D	1 ½ years
		LA-F	1 ½ years
		LA-G	8 months
		LA-F	1 year

Results and Discussion

Types of C&D Waste Materials

In the construction industry, C&D waste management is a critical issue that needs to be addressed. Following Table 4 shows the C&D waste composition according to the case study findings.

Table 4: Waste Types and their Source of Generation

Type of Waste	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H
Plywood	√	√	√	√	√	√	√	√
Concrete	√	√	√	√	√	√	√	√
Cement	√	√	√	√	√	√	√	√
Steel/ Offcuts	√	√	√	√	√	√	√	√
Blocks	√				√	√		√
Bricks		√	√	√			√	√
Sand	√			√	√		√	
Soil		√	√					√
Wood waste	√	√	√		√	√	√	√
Polythene	√	√	√			√	√	
Cardboard	√					√		

Plastic/ PVC	√				√	√		
Paper		√						
Aggregate	√							
Tile offcuts			√					
Concrete nails					√			
MEP waste	√							
Wire nails					√			
Welding rods					√			
Tool wastage					√			
Food waste	√	√	√		√	√	√	

When analysing the C&D waste in the construction industry, as per the case study findings, there are C&D waste types like plywood, concrete, steel offcuts, blocks, bricks, sand , aggregate, cement, soil, MEP waste, wood waste (2x2, 2x4), polythene, cardboard, plastic, PVC, paper, tile offcuts, concrete nails, wire nails, welding rods, tool wastage and food waste. In the study, almost all the respondents have identified concrete, plywood, cement, and steel offcuts as the main type of C&D waste in their sites. Moreover, two (02) to three (03) respondent from each case have identified, cardboard, plastic, PVC, paper, tile offcuts, concrete nails, wire nails, welding rods in their C&D waste composition. In addition to that, respondents PM-C of case C stated that, in their site, during the foundation stage, there were unusable weak soil and in piling stage, there were bentonite contaminated soil. So these soil types are unable to use for the backfillings in the site and due to that reason they are removed from the site as waste.

Waste Origins

C&D waste can get generated due to number of reasons. Table 5 shows the origins of waste generation.

Table 5 : Waste Origins

Origins of Waste	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H
Design changes	√	√	√	√	√	√	√	√
Transport	√	√	√	√	√	√	√	√
Human Mistakes	√	√	√	√		√	√	√
Quality of works	√			√	√	√	√	√
Client Changes	√		√			√		√
Mismatches in required materials		√	√		√	√	√	√
Labour skills	√				√	√		√
Weather Condition		√			√			
End of product life		√					√	
Negligence					√	√	√	
Material handling					√	√		√
Changes by Architect and Engineer			√					
Poor Supervision							√	

C&D waste in the constructon industry gets generated due to a number of reasons. As per the case study findings, main reasons to generate C&D waste are design changes and transportation. In addition to that, there

are other reasons which lead to C&D waste generation and they are, client changes, human mistakes, quality of work, labour skills, weather condition, end of product life cycle, mismatch in required materials for the construction activities, changes carried out by the engineer and architect, negligence, material handling and poor supervision.

Respondents PM-C from the case C stated that, waste get generated due to client, architect, and structural engineer changes. Respondent, further stated that,

> "*in the stage of ducts establishment, there will be chances of ducts start to crossover each other. In such scenario, there will be difficulties in taking the minimum height between the floors. So in order to overcome the issue, sometimes beam needs to be drilled or needs to be break. So it creates waste".*

In addition to that, he also explained, "*tile and ceramic wastages can occur due to transport*". Furthermore, respondent SE-D stated that, when the bricks are brought into the basement of the site, they need to be transported to the upper flows of the site. For the transport of bricks, hand transport method is used. In the process of brick transportation, at first bricks are unloaded to the site basement. Then from the basement, bricks are put into the hoist. From the hoist, bricks are transported to the upper floors. So in this instance of brick transportation, brick is nearly transported 4 times before they are being used for construction. Hence, brick waste get generated during the transportation process. Moreover, respondent SE-D also stated that, sand waste get generated in the process of transportation from the basement of the site to the upper stories of the building.

Respondent SE-C and respondent PM-E explained that, waste get generated due to the mismatch in materials required and materials available. They elaborated this scenario through the example of steel bar. For a specific work, required steel bar size is 10m and the available steel bar sizes are 6m and 12m. So it ultimately generates a steel offcut of 2m which is a waste from that specific activity. Furthermore, respondent PM-E stated that,

> *"if we specify the supplier that, for a specific work, required bar size is 7.1m and asked them to provide the quantities, then there will be no any wastage. But, to do a procurement as such, at least 20 tons of steel bars from the same size need to be ordered".*

As per the findings, weather condition is another reason for waste generation. Respondent SO-E of case E stated that, "*sand wastages and steel corrosion take place due to weather conditions".* In the site, sand is collected in an open yard, and due to rain, sand can get washed away by creating a waste. Further, respondent SO-E also explained that, due to weather conditions, steel get rusted and sometimes it creates waste. Most of the time, such steels are reused after doing the wire brushing.

Respondent SO-E also stated that, C&D waste get generated from the material handling methods. When there is a slab construction, measurements and quantities are taken before hand. There may be changes in the quantities and measurements. That means, there may be excess materials. In such instances, excess can be used for fillings in the floors or to prepare drains. Such activities need to be preplanned in the material handling stage and in material purchasing stage. Similarly, SO-E also said that, waste like plywood get generated as a result of the end of the product life cycle. Normally in the site plywoods are used for 4-5 times and when they get mixed with water, layers of the plywood get loose and it leads to wastages.

Respondent PE-F said that waste get generated due to human mistakes and due to the negligence. When there are calculation errors in the stage of procurement, there are wastages. For example, where concrete is purchased, due to the errors in volume calculation, there can be excess quantity of concrete. Respondent further elaborated that,

> "*if such thing take place in the site, it is being sent back to the main batching plant and they are being reused. In this site, for the construction, high grading concrete like grade 50 to 70 are being used.*

These concrete can be degraded by mixing with sand. So it can be used for domestic construction, as 20 grade concrete is being used for domestic construction".

Conclusions

Construction industry being one of the key contributors in solid waste generation, C&D waste needs to be managed in a systematic way. Thus, attention is paid to manage C&D waste to reduce adverse impacts such as environmental pollution, issues in social and economic aspects. To eliminate the C&D waste, it is necessary to identify the types and origins of C&D waste generation. Hence, this paper has discussed types and origins of C&D waste. The study revealed that, main type of C&D waste is plywood, concrete, cement and steel/ offcuts while design changes, transportation, human mistakes and quality of works as the main origins of waste generation. Therefore, the aim of the paper which was to identify the C&D waste types and its origins of waste generation were achieved. Further, the generated waste is transported away from the site through waste collectors and recyclers and finally the waste is dumped into landfills. Thus, elimination of C&D waste through a concept like zero waste is a precise solution to overcome from the C&D waste issue.

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