Waste Material Management on Building Construction in Sri Lanka; Mitigation of Concrete Waste Factor and Cost Effect During Construction Stage

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Abstract— Material waste is one of the most important factors which effect the contractor directly by reducing profit and effect to the employer by increasing project cost. As a result, the majority of building projects have planned to address in multiple levels to reduce these wastes. Concrete debris is one of the waste materials in construction that costs the project's stakeholders the most. When compared to other material wastes, the volume of waste concrete generates as a primary component of the construction is disproportionately high in Sri Lankan construction projects. Most countries are currently working to reduce concrete waste while pursuing sustainable growth. As a result, traditional methods used to reduce concrete waste have not been effective over time. The aim of this research study is to achieve waste material management in building construction in Sri Lanka, mitigation of concrete waste factors, and cost-effective during the construction stage. To achieve the aim, a comprehensive literature review, semi- structured interviews and a questionnaire were conducted to gather data through both qualitative and quantitative procedures. The empirical findings revealed that concrete waste has a positive relationship with project cost. Precast elements, lean construction techniques, 3R concept, and a few more others were identified to minimize concrete waste, which reduces the project cost in the Sri Lankan construction industry. These research findings deliver beneficial evidence to the practitioners with an indepth understanding of the important necessity for the construction industry and thereby benefiting to reduce the project cost in construction projects.

Keywords— **Cost effectiveness, Concrete waste, Building Construction**

I. INTRODUCTION

According to Ramya & Viswanathan (2019), from throughout the world, the cost of building materials calculates for 50% to 60% of the whole project cost. With the process of planning, carrying out, and controlling the field and the official activities in construction organizations, material management principles on building construction sites are a crucial role in the sector. The availability of resources is a major component in the success of a building project, in addition to the quality and quantity of the construction activity. Each project activity calls for a specific number of resources (Ali-Khan et al 2019). Concrete is a building material that is used all over the world and requires a lot of raw ingredients. With little to no environmental oversight, this concrete is frequently classified as waste and destroyed (Vefago & Avellaneda 2013).

Concrete is frequently used in a variety of building structures, and the technology employed in concrete construction directly affects the construction quality of the concrete structure itself, which is crucial to the stability of the building structure (Guo 2021). According to Perera & Amarathunga (2018), the majority of this material waste, which requires special attention, is "Wasting Concrete". The expense incurred by the employer due to this concrete waste results in wasteful spending. There is concrete waste in materials in building construction as an in-built situation. Accordingly, the objectives of this research are to identify waste material management in building construction in Sri Lanka; mitigation of concrete waste factor, and cost effect during the construction stage. Objectives were listed as 1) To examine concrete waste in building construction and its effect on the cost. 2) To identify the current situation of concrete management strategies on building construction sites in Sri Lanka. 3) To propose appropriate recommendations for effective concrete waste management.

II. LITERATURE REVIEW *A. Material Management Process*

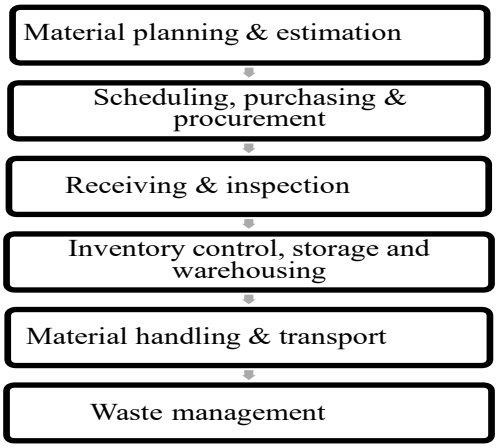

Figure 1: Process of Material Management Participant Source: (Abeysinghe 2020)

The word "material management" refers to the inability of industrial organizations to regulate the type, amount,

location, transportation, and timing of the numerous commodities utilized in production. Planning, directing, and organizing those actions that are concerned with the materials and inventory needs starting at the point where they are introduced into the production process is known as material management (Ashika 2019).

B. Functions in Material Management Process According to Homaid (2002), the administration of construction materials, particularly for large projects, is a crucial and complex task that requires significant improvement. Contrary to construction, the function is thoroughly studied in manufacturing, and there are sophisticated formal systems and methodologies for carrying it out.

1. Planning

According to Patel Chetna M Vyas & Vishvakarma Mahavidyalaya ADPatel (2011), the Bills of Quantities (BOQ) created by the client are the most common basis for planning out the project, however, companies may have two major levels of planning: the levels of micro and macro. The four main forms of planning that are done on construction sites are time, money, material, and labor. The planning should be updated as often as possible to ensure that the work is going according to schedule.

2. Procurement

According to Kasim, Anumba & Dainty (2005), procurement involves organizing the purchasing process, sending delivery schedules to suppliers, and checking in to make sure that providers meet their deadlines. According to Bizuneh & Asteway (2016), the phrase "procurement" refers to a considerably wider range of activities, including purchasing, budgeting for, and managing supplies, managing inventories, managing traffic, and transportation, inspecting incoming items, disposing of excess and obsolete materials, and managing inventory.

3. Receiving & Inspection

According to the statement that they are the receipts from the external divisions and internal divisions, the system of receipt may be broadly classified into two types. Before the material is transported to the premises, the receiving process starts. The three documents needed for the receiving process are the purchase order, a copy of the supplier advice, and the consignment note *(*Abeysinghe 2020). In accordance with Wang (2008), the currently used tracking and management techniques for the inspection in material testing laboratories involve manual recording on paper-based documentation. When handling inspection results, information gathered through such time-consuming techniques is unreliable and inefficient.

4. Material Handling

According to Cavalline & Charlotte (2022), the notion of material handling encompasses all activities involving the movement, storage, preservation, and control of goods and materials during manufacturing, warehousing, distribution, use, and disposal. A range of manual, semi-automated, and automated equipment and technologies are integrated into the material handling process to support the logistics and supply chain. Effective material handling is defined by Kasim et al (2005), as the use of the proper method, amount, material, place, time, sequence, position, condition, and cost. The processing, storing, and management of the building materials are involved.

C. Waste Management

Construction waste is defined as any material, other than earth materials, that needs to be transported to construction sites from other places or that must be used on the site itself for landfilling, incineration, recycling, reusing, or composting in contrast to the project's intended specific purpose due to material change excess, nonuse, or noncompliance with specifications, or because it is a byproduct of the construction process. Building material waste also refers to the difference between the value of materials that have been delivered and accepted on site and those that have been properly used as specified and accurately measured in the work, after deducting the cost savings of substitute materials transferred elsewhere, where the material waste may result in an increase in unnecessary expense and time (Bekr 2014).

According to Kulatunga et al (2005), there are two types of building material waste that can be happened in the construction stage. They are direct and indirect types of waste. The majority of the time, the cost of direct waste is not the cost of the material itself but is instead followed by the cost of removal and disposal.

D. Cost Effect of Concrete Waste Material Management According to Perera & Amarathunga (2018), the majority of countries have discovered a number of methods to reduce the amount of wasted concrete where all project participants can work together. For the Employer's budget, the cost associated with this concrete waste immediately results in an extra expense. Therefore, waste has been used in concrete as a safe and cost-effective means of disposal. Utilizing waste products preserves the environment's cleanliness while also conserving natural resources and landfill space (Vasoya & Varia 2015).

According to the Noh, Azree & Mydin (2018), the 3R Program is an appropriate and cost-effective choice that recognizes the three crucial waste minimization tactics of reduce, recycle, and reuse. However, waste reduction is the most sought strategy by many nations since it offers an efficient and practical solution that reduces the majority of waste-related issues and makes it feasible to recycle 90% of the construction and demolition waste.

III. RESEARCH METHODOLOGY

According to Wijethunga (2020), the field of methodology is the study of methodical technique, which is a set of structured steps used to perform research. The methodology element of any research is the most crucial one since it offers some understanding of both specific scientific results and the nature of human activity in general. To achieve the objectives of the research, data employing qualitative and quantitative methodologies were collected using a literature review, semi-structured interviews, and a questionnaire survey.

Table 1: Population and sampling

Data Collection	Population	Sample	Sampling Techniques	Reference
Questionnaire	Quantity Surveyor Civil Engineer Project Manager Site Engineer	33	Simple Random Sampling	(Senarathna & Perera 2021)
Semi-Structured Interviews	Civil Engineer Quantity Surveyor Project Manager	10	Purposive sampling	(Perera & Amarathunga 2018)

Qualitative analysis depends on the knowledge and viewpoint of the individual as well as the explanation and application of the theory, both of which seem to be very individualized. Quantitative analysis is the examination of a social or human issue that the current community is currently dealing with. It is centered on challenging a theory or hypothesis that only has a few variables, is quantified using data, and is examined using humorous methods to support these theories (Surendra, Manoj & Madhav 2016).

Research questionnaire and semi-structured interviews conducted as the data collection of this research area.

The objectives of this research have been achieved through a survey questionnaire distributed to a simple random sample of populations in industry professionals. The collected data from the questionnaire analyze using the frequency analyzing method. The content analyzing method used for gathered data from the semi-structured interviews.

Table 2: Data collection methods and research objectives

Item	Objective	Data Collection Method	Data Analyzing Method
1	To examine concrete waste management in building construction and its effect on the cost.	Questionnaire Semi-Structured Interview Literature Review	Frequency Analysis (By tables & charts) Content Analysis
2	To identify the current situation of concrete waste management strategies on building construction sites in Sri Lanka	Questionnaire Semi-Structured Interview Literature Review	Frequency Analysis (By tables & charts) Content Analysis
3	To propose appropriate recommendations for effective concrete waste management.	Questionnaire Semi-Structured interview	Frequency Analysis (By tables & charts) Content Analysis

IV. RESEARCH FINDINGS

This research study has a quantitative and qualitative analysis. It is a mixed-method approach. Frequency analysis and content analysis methods for the responses of professionals that were sampled. Quantitative data collected from the questionnaire survey are analyzed by frequency analysis and qualitative data collected from the literature reviews in chapter 02 and semi-structured interviews are analyzed by content analysis. There are 33 people who responded to the full questionnaire survey out of 45 distributions, and 10 industry experts were interviewed using semi-structured interviews to gather the data for the analysis.

Due to the differences in their experience levels and how it affected their industry expertise, responses from beginners to seniors were required. A person's ability to think can vary depending on their experience. There are some different opinions from professionals for concrete waste management.

A. To examine concrete waste in building construction and its effect on the cost

In accordance with, Shahab et al (2021), utilizing these wastes as substitutes for typical concrete elements is one way they may be used. This is because foamed concrete has a low strength requirement, making it a suitable medium for absorbing these wastes in a significant volume. According to the frequency analysis, Figure 2, the superstructure is the element that is mostly consuming concrete waste in building construction. It is 69.70% of the respondents have experienced this.

Table 3: Most concrete waste elements in building construction

Construction Element	Respondents
Super Structure	23
Foundation	10

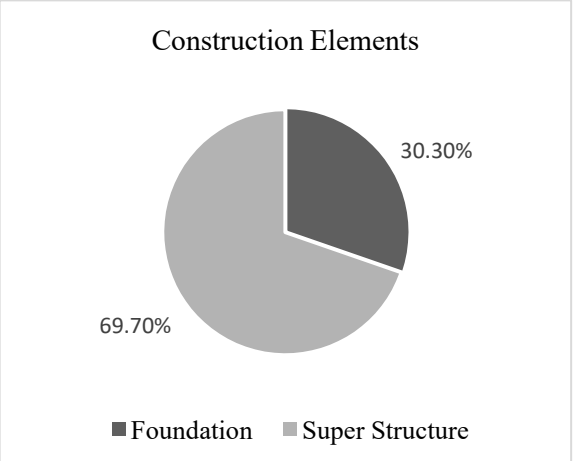

Figure 2: Most concrete waste elements in building construction

When considering the deep foundation and shallow foundation, deep foundation consumes more concrete waste than shallow foundation in building constructions as per the expert professions experience. There are 87.9% of experts proved it through the questionnaire survey. There are 12.1% professionals have experienced the shallow foundation as consuming the most concrete waste. Among the slabs, beams, columns, and walls in the superstructure, there are slabs take the highest percentage of the most concrete

waste-consuming element of the superstructure. It is 63.60%. The least percentage of concrete waste consume by the beams and columns in the superstructure is 6.10 %. According to the semi-structured interviews which conducted with industrial experts, the five out of ten were obtained by opinion was no, which is any experience during construction time to manage waste come from execution of work. Other five experts in the industry answered yes that confirming there should reduce the waste in construction. When considering the literature review, during the construction phase, there are two forms of waste that can occur. These wastes come in both direct and indirect forms. The majority of the time, the cost of direct waste is followed by the cost of removal and disposal rather than the cost of the substance. By preventing direct waste, simple financial gains can be attained. to (Kulatunga et al 2005).

B. To identify the current situation of concrete waste management strategies in building construction sites of Sri Lanka

There are some common strategies in concrete waste management in the construction sites in Sri Lanka. In accordance with the questionnaire data, reduction is the suitable concrete waste management in the construction stage among the 3R concept. The experts in the industry opinioned re-use as the minimum percentage of using in the 3R concept. According to the semi structured interviews, 3R concept is the most common practice that using in the industry to mitigate the concrete during the construction period. According to the experts' opinions through the semi structured interviews, there is a sub-contractor payment certification for waste disposal management, such as for construction material, and solid waste. There are two divided parts such as steel waste, time waste and concrete waste. There should be disposed under the approved phase such as, Steel has a rescheduled value. At that time, they can sell and balance them take by the pay a per tip and concrete waste also can be disposed and they pay per tip. The wasted concrete used for the landfilling and road construction projects as ABC (Aggregate Base Course).

Industry professionals in the industry stated that, using BIM is the suitable strategy in the concrete waste management but it should be applied in the design stage. Guerraa, Leiteb & Faust (2020), illustrated, building information modeling has grown in popularity as a tool for controlling construction waste; its data-richness, visualization, and simulation capabilities offer an opportunity to enhance costeffective trash recycling and reduce project-level planning.

When considering the above content analysis, BIM is one of the modern strategies which implemented in the industry to mitigate concrete waste factor because of the system of proper accurate estimating quantities and the possibility to improve efficient waste recycling at a lower cost by using BIM.

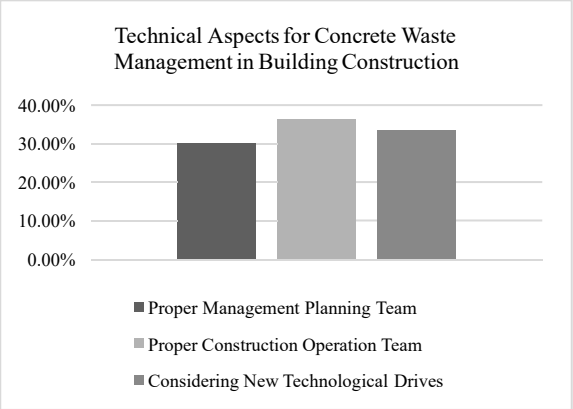

Figure 3: Technical aspects for concrete waste management in building construction

Industry professionals emphasized the proper construction operation team is the suitable technical aspect for concrete waste management in building construction.

There are suitable suggestions are discussed below, according to the identified strategies; 3R concept, Using BIM and identifying technical aspects of concrete waste management in current situation in Sri Lanka.

C. To propose appropriate recommendations for effective concrete waste management

As the final objective analysis of this research, there are 93.8%, from the professionals who received the questionnaire stated that a requirement of an appropriate concrete waste management system for a cost identifiable concept. There are 30 experts out of 33 respondents. When considering the data of the questionnaire, the most suitable approach in the design stage, under mitigating concrete is to apply precast elements to the project. There are 59.4% of industry professionals agree with that approach.

The industry experts specified that, the most important one is daily working target in the site activities and concrete requirement per day for that targeting work. As a suggestion, there should be used skilled, trained technical staff under proper supervision. By using proper technologies, it occurs to reduce the concrete waste and increasing the profit of the project. Furthermore, industry professionals stated that if it is better reducing the wastage in site level and it possible to maximize the project profit.

The experts emphasized that concrete wastage can reduce with implementing BIM applications. The construction team can get real concrete volumes with BIM applications. It helps to the concrete ordering process and inventory management system. Furthermore, need to have a proper plan and a team whom having knowledge on new technological aspects. Due to the financial crisis there need to manage the waste in properly. According to the situation, there must have proper risk management system to forecast the risk combine with the wastage. Also need to automate. Improvement of monitoring system, data collection and much more technology base advancement and there can recycle the concrete into

aggregates and reuse as road base material and reuse in recycled aggregate concrete production are possible suggestion for effective concrete waste management.

In accordance with the above analysis, appropriate recommendations are identified for effective concrete waste management. 3R Concept (reduce, recycle and re-use), Lean Concept, Lean Engineering, De-Construction (demolished and re-construction), Increasing lifetime of concrete hardening by using chemicals, Proper planning of concrete handling and planning extra volumes of concrete (with the same grade) for precast elements, improving monitoring system in site activities and using skilled manpower are the suitable recommendations for mitigate the concrete waste factor and cost effect during the construction stage.

There is a correlation between concrete waste and project cost in the Sri Lankan construction industry, according to the results of both frequency (tables and charts) and content analysis.

The generation of concrete waste within a project can be caused by several significant factors, including changing client requirements during construction activities, a lack of coordination between stakeholders and the design team, a lack of communication, improper delivery methods and storage space on the project site, handling attitudes of the labor force, improper proportion mixing and the addition of admixtures, and a few others. These sources of concrete waste have a direct impact on the cost, a key project criterion. The price is related to the causes of waste and includes things like additional labor costs sand the requirement for the project owner to reorder concrete.

V. CONCLUSION AND RECOMMENDATION

The outlined objectives have been met, as further discussed in the conclusion. The recommendations are to fill the gap regarding the Waste Material Management in Building Construction in Sri Lanka, Mitigation of Concrete Waste Factor, and Cost Effect during Construction Stage. The limitation in this chapter demonstrates the narrow regions that provided support for this investigation.

As per the opinions of industry professionals, there are different types of concrete waste that could be identified, by content analysis, in the building construction sites in the execution of project work such as remaining concrete at pump cars on site, formwork alignment, and ordering issues, lack of knowledge and experience of labor and the team. When considering the frequency analysis, super structure is the mostly consume concrete waste element than foundation. When contemplating foundation, deep foundation consumes highest concrete wastage than the shallow foundation. As per the analysis, slabs are the most concrete wasting element of super structure. Furthermore objective 01 examined lack of following waste management procedure is a main cause of concrete waste and Simple financial gains can be made by avoiding direct waste. In accordance with the project's characteristics, reducing concrete waste can reduce the amount of materials wasted on site, which can effectively increase project profit. By completing objective 02, there are identified concrete waste management strategies in the current practice and the main strategy is the 3R concept. Reducing and re-use are the most common answers which identified from the 3R concepts. Tam in (2008), has stated the three major strategies for reducing waste are known as the "3Rs": reuse, recycling, and reduction. To minimize the quantity of construction trash generated on-site, coordination is essential between all parties involved in the design and building process. Building Information and the Lean concept are another important strategy. The daily working goal for site activities and the specific requirements for each day's work on that goal setting is the most crucial. It is recommended to hire technical staff that is skilled, trained, and well-supervised. By implementing the right technologies, the project's profit is increased while less concrete waste is produced.

Providing training programs, rewarding those who are willing to apply modern procedures within their contracting organizations, and educating professionals and all other parties involved in the building business about eliminating concrete waste management practices. Utilizing value engineering approaches, lean building methods, recycling of concrete, usage of precast concrete components, and other strategies can help decrease waste of other types of materials, such as cement and reinforcements, while simultaneously lowering waste of concrete.

By giving the necessary direction and outlining the benefits that the project will receive from reducing concrete waste, it is possible to change the unfavorable attitudes that workers and other construction professionals have about the adoption of new techniques. When considering the suggestions, it is necessary to suggest in the construction stage within Sri Lanka's construction industry that leads to reduce the effect of project cost, and that it is also beneficial to move towards the sustainable developments through protecting the environment.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

ABC	Aggregate Base Course
BIM	Building Information Modeling
BOQ	Bills of Quantities

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