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Causes of Construction Waste in the Building Projects within India – An Analytical Study

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Abstract - *With the migration of rural population to the urban centers or cities, there is a greater and increased pressure upon the infrastructure of the cities, as such. The increased rate of urbanization has resulted in the development of the infrastructure that includes various construction activities. These construction activities involve the construction of various civil structures like roads, culverts, overhead water tanks, drains and buildings. This paper focuses on the analytical study of the causes of construction waste generated during the construction of buildings. Based on the earlier studies, various causes of construction waste are identified and listed. A set of questionnaire is prepared and put forth in front of various stakeholders involved in the building construction industry, that includes designers/architects, contractors and sub-contractors, if any and supervisors. Then the relevant data is extracted from this information and analyzed followed by results, conclusion and recommendations.*

***Key Words*: Construction waste, Construction waste management.**

1. INTRODUCTION

Wastes are unwanted or discarded materials [1] and [2]. Waste is an unwanted product that may be generated on the site of construction [3].

Waste is one of the major problems in the construction industry. Many researchers and practitioners mentions that there are lot of activities during design and construction phases that are quite wasteful. Waste is generated during different stages of the project starting from planning and designing till the construction of the building [4]. Furthermore, it was suggested that waste produced during design, operational, procurement and material handling [5]. Majorly these processes eats a lot of resources in the form of time and efforts resulting in the loss of material, delay in timely completion and execution of superfluous work. This direct impact of waste on productivity of the project results in the loss of revenue. The physical waste of construction contributes to about 10 percent of the total landfill from municipal solid waste which generates the need for waste minimization methods to regulate the waste generation at various levels [6]. According to Building Material & Technology Promotion Council under Ministry of Housing & Urban Affairs, Govt. of India (2018) approximately 100 million tonnes of waste is generated annually from the construction industry nation wide. In order to avoid or minimize the waste generation, its root causes have to be identified.

2. RESEARCH AIM AND OBJECTIVES

The aim of this research paper is to study the causes of construction waste in the residential buildings. In order to accomplish the aim the following objectives have to be attained:

1. To thoroughly understand the background of the related topics by reviewing the earlier researches upon the related topics of Construction Waste, Types of Construction Waste, Construction Waste Management.
2. Identifying the different types of causes of Construction Waste.
3. To rank the causes for Construction Waste generation in order of its significance.

Giving the conclusions based upon the research and recommendations to the Architects, construction professionals and researchers.

3. RESEARCH METHODOLOGY

The research methodology prepared for achieving the research objectives comprises of collection of data from the various sources like academic journals, conference proceedings, dissertations and thesis and government publications. This data fulfills the first objective of understanding the background. In order to achieve the second objective, the earlier research works are studied and the different types of causes or source of construction waste are identified. For achieving the third objective, a set of well-structured questionnaire is carried out for a set of stakeholders that includes architects, engineers, contractors and clients. The questionnaire is prepared as such to draw out responses from the stakeholders by placing closed ended questions that fetches suggested answers on an ordinal scale and the data is analyzed.

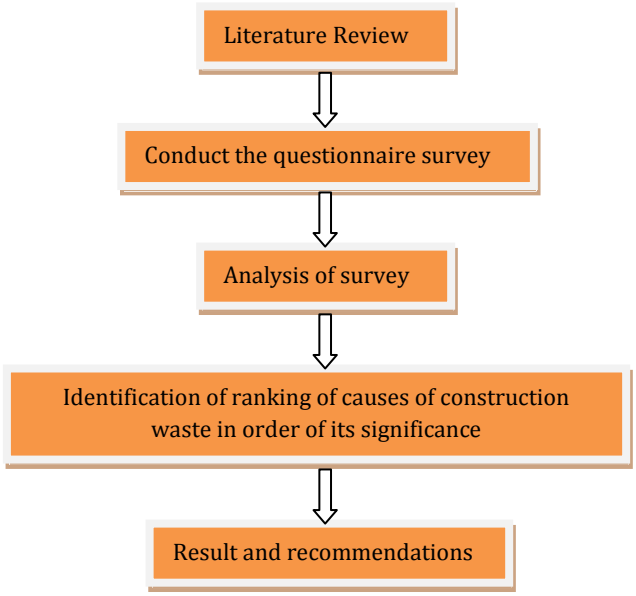

Fig -1: Research Methodology

4. CONSTRUCTION WASTE

Construction waste is the one that is produced during various activities like cleaning of sites for the construction of new building or infrastructure and their construction itself [7]. The Construction Waste was defined as the outgrowth product that is generated and subsequently removed out of the sites comprising construction, renovation, demolition activities or the sites holding construction activities of buildings and civil engineering structures [8]. Construction Waste can be classified into two types – 1. Tangible or Physical and 2. Intangible or Non- Physical.

4.1 TANGIBLE OR PHYSICAL WASTE

Physical Waste can be defined as the blend of inert and non-inert materials produced from the construction, excavation, demolition, renovation and other sites in relation with civil construction [9]. In a similar manner, [10] and [11] defined Construction Waste as the waste that comes from construction, demolition or renovation activities or the waste that are generated due to land excavation, site clearance or dressing, civil structures and building structures and other infrastructure facilities like road construction, etc.

4.2 INTANGIBLE OR NON-PHYSICAL WASTE

This category of waste adds no value to the project and its related stakeholders. These wastes are apparently not seen as such but contributes to the loss of resources in the form of time, money or work labour. These are also termed as Non-Physical or Indirect Wastes. Waste was explained as any activity done by human beings that consumes resources and add no value like mistake that needs to be rectified, production of unwanted items, execution of unnecessary processes, useless movement of employees on the site and unnecessary waiting for the completion of one activity in order to execute next activity [12]. Also waste was defined as the usage of equipment, materials, labour and revenue in larger quantities due to any inefficiency [13]. Accordingly in construction, the waste of materials on the site is not the only concern but there are various other activities that gathers attention like overproduction of some component, waiting time for the completion of one activity presiding the another one, handling of materials, method of processing, inventories and movement of employees or workers [14].

5. CONSTRUCTION WASTE MANAGEMENT

Construction waste management in literal sense means that some kind of management plan or policy has to be implemented in order to manage the waste produced in the construction activity. For the same purpose, a model of 3R's of management is adopted, that is based on the ascending order of most desirable or preference hierarchy. That is, the one policy that is most preferred comes first and the least preferred comes the last. The 3R's of the management model are – Reduce, Reuse and Recycle.

Fig -2: 3R's Waste management model
Source : *www.finleysgreenleapforward.org*

Reduce :- This waste management method applies at an early stage of the project and that is the design stage. It is the wisdom of the designer or the architect that comes into play, by identifying the potential wastes that can be minimized at the design level. For example by adopting the standard sizes of the building materials, flexibility in the design of different spaces taking consideration of changing usage and deconstruction of the building. This is the most desirable method in the hierarchy of construction waste management that could add the best in managing the construction waste.

Reuse :- This waste management method applies to those waste that has some salvage value and can be put to use again on the same site or may be at another site. Before opting for recycling the waste, it is assessed for its salvage value, means its usability in the project. Sometimes its very

useful to be reused. Other options could be its sale for other projects or can be put into charitable use.

Recycle :- After adopting the methods of reduce and reuse, in order to prevent the wastage, comes the method of recycling in waste management hierarchy. The maximum debris is aimed at putting it for recycling, in order to cut down the cost of disposal.

Dispose :- Though the waste management model is popularly known as 3R's waste management model, yet it has one more component in its hierarchy, which is the least desirable option and that is the disposal. It is due to the fact that the usable value of the waste is zero and could pose threat to the environment.

6. CAUSES OF CONSTRUCTION WASTE

Construction waste originates from various sources throughout the life cycle of construction projects, from inception through to construction and demolition [10]. According to previous studies, the origins of construction waste can be classified into the following ten categories: contractual, design, procurement, transportation, on-site management and planning, material storage, material handling, site operations, residual, and other causes [15,16 and 17]. These origins are shown in Table 1.0 below.

Table -1.0: Origins and causes of construction waste

Origins of waste	Causes of waste (cause code)
Contractual	• Errors in contract documents (C1) • Contract documents incomplete at commencement of construction (C2)
Design	• Design changes (C3) • Design and detailing complexity (C4) • Design and construction detail errors (C5) • Unclear/unsuitable specification (C6) • Poor coordination and communication (late information, last minute client requirements, slow drawing revision and distribution) (C7) • Selection of low-quality products (C8) • Lack of attention to standard sizes available in the market (C9) • Designers' unfamiliarity with alternative products (C10)
Procurement	• Ordering errors (i.e., ordering items not in compliance with specification) (C11) • Over allowances (i.e., difficulties to order small quantities) (C12) • Supplier errors (C13) • Purchased products that do not comply with specification (C14)
Transportation	• Damage during transportation (C15) • Difficulties for delivery vehicles accessing construction sites (C16) • Insufficient protection during unloading (C17) • Inefficient methods of unloading (C18)
On-site Management and planning	• Lack of on-site waste management plans (C19) • Improper planning for required quantities (C20) • Delays in passing information on types and sizes of materials and components to be used (C21) • Lack of on-site material control (C22) • Lack of supervision (C23)
Material storage	• Inappropriate site storage space leading to damage or deterioration (C24) • Improper storage methods (C25) • Materials stored far away from point of application (C26)
Material handling	• Materials supplied in loose form (C27) • On-site transportation methods from storage to the point of application (C28) • Inadequate material handling (C29) • Damages during transportation (C30) • Unfriendly attitude of project team and labourers (C31)
Site operation	• Accidents due to negligence (C32) • Unused materials and products (C33) • Equipment malfunction (C34) • Poor craftsmanship (C35) • Use of wrong materials resulting in their disposal (C36) • Time pressure (C37) • Poor work ethics (C38)
Residual	• Waste from application processes (i.e., over-preparation

	of mortar) (C39) • Off-cuts from cutting materials to length (C40) • Waste from cutting uneconomical shapes (C41) • Packaging (C42)
Other	• Weather (C43) • Vandalism (C44) • Theft (C45)

Note : *Taken from the early studies of Osmani et al., 2008; Kulatunga et al., 2006; Gavilan and Bernold, 1994 except the code assigned*

7. RESULTS AND ANALYSIS

The respondents to the questionnaire survey were architects, project managers and building construction contractors. The total number of respondents were 63.The data collected from the questionnaire survey was analyzed and based upon the analysis, the different causes of construction waste were ranked according to their significance. Since the questionnaire survey resulted in the quantitative type of data, it was analyzed statistically. In this study, the data was analyzed with the help of the software application Microsoft Excel 2010.

A set of 45 multiple choice questions against their respective causes of construction waste with their corresponding cause code (Table 1.0) were asked. Each question was given with five option as 1,2,3,4 and 5, in which option 1 being assigned the least significance, 2 as low significance, 3 being neutral, 4 as high and 5 with highest significance. The data collected was put into the excel chart as number of respondents with their selected option of importance level against each question code (Fig 3) :

	Importance lev. 1	Importance lev. 2	Importance lev. 3	Importance lev. 4	Importance lev. 5
C1	12	27	18	0	6
C2	15	12	21	6	9
C3	6	6	15	21	15
C4	3	12	33	15	0
C5	6	18	12	15	12
C6	3	15	18	15	12
C7	6	6	18	24	9
C8	9	9	15	18	12
C9	9	18	15	12	9
C10	3	9	21	18	12
C11	6	18	12	18	9
C12	12	12	12	21	6
C13	12	9	18	18	6
C14	12	9	27	12	3
C15	3	24	18	9	9
C16	0	12	33	15	3
C17	6	12	21	15	9
C18	3	18	15	21	6
C19	0	15	12	24	12
C20	9	9	18	21	6
C21	6	15	15	24	3
C22	6	15	18	18	6
C23	6	12	24	9	12
C24	6	12	24	6	15
C25	3	15	21	15	9
C26	6	12	21	18	6
C27	12	18	12	15	6
C28	9	12	24	15	3
C29	15	18	6	12	12
C30	9	15	12	15	12
C31	9	15	18	12	9
C32	12	9	12	27	3
C33	9	9	15	27	3
C34	15	9	12	18	9
C35	18	12	9	21	3
C36	6	18	21	15	3
C37	6	9	18	15	15
C38	6	18	15	18	6
C39	9	12	18	15	9
C40	9	6	12	33	3
C41	3	12	24	15	9
C42	12	9	18	18	6
C43	6	18	18	12	9
C44	12	12	18	6	15
C45	3	18	24	12	6

Fig -3: Respondents data chart

Then with the help of in-built rank formula in Microsoft excel2010 application, rank for each cause code was calculated and assigned (Fig 4) :

	Total	Rank
C1	150	45
C2	171	43
C3	222	1
C4	186	30
C5	198	12
C6	207	6
C7	213	4
C8	204	7
C9	183	37
C10	216	3
C11	195	17
C12	186	30
C13	186	30
C14	174	41
C15	186	30
C16	198	12
C17	198	12
C18	198	12
C19	222	1
C20	195	17
C21	192	22
C22	192	22
C23	198	12
C24	201	10
C25	201	10
C26	195	17
C27	174	41
C28	180	38
C29	177	40
C30	195	17
C31	186	30
C32	189	25
C33	195	17
C34	186	30
C35	168	44
C36	180	38
C37	213	4
C38	189	25
C39	192	22
C40	204	7
C41	204	7
C42	186	30
C43	189	25
C44	189	25
C45	189	25

Fig -4: Rank chart

The rank assigned to each cause code is depicted graphically in the graphical chart below (Fig 5) :

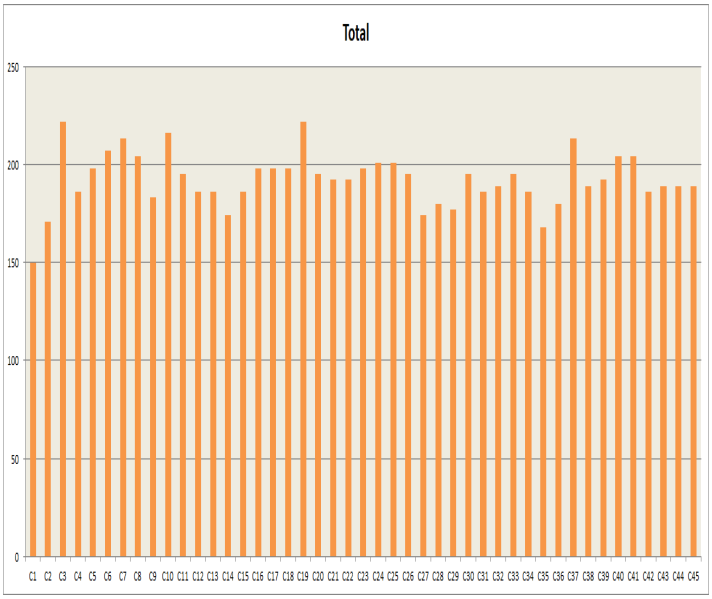

Fig -5: Rank chart- graphical representation

The highest rank assigned is 1 and the lowest assigned is 45. The top five rank assigned in descending order, that is rank with highest value as 1st and so on, are : 1, 3, 4, 6 and 7. The top five mentioned rank with their corresponding cause code and respective cause of construction waste is given in Table-2.0 below.

Table -2.0: Top five ranked causes of construction waste

Rank	Cause code	Cause of construction waste
1	C3 C19	• Design changes • Lack of on-site waste management plans
3	C10	• Designers' unfamiliarity with alternative products
4	C7 C37	• Poor coordination and communication (late information, last minute client requirements, slow drawing revision and distribution) • Time pressure
6	C6	• Unclear/unsuitable specification
7	C8 C40 C41	• Selection of low-quality products • Off-cuts from cutting materials to length • Waste from cutting uneconomical shapes

There are nine causes of construction waste, that are ranked at top five out of forty five causes of construction waste. They include :

Design changes : Last minute design changes can lead to the wastage of resources and any design changes during construction phase will lead to the generation of construction waste substantially. This could be avoided by finalizing the complete design prior to the construction.

Lack of on-site waste management plans : Without any proper management plan for controlling waste at the construction site would definitely promote to the construction waste generation. A proper and site specific waste management plan is much needed in order to avert such kind of wastages.

Designers' unfamiliarity with alternative products : The designers must possess a comprehensive knowledge of the products used in the construction, so that in case of unavailability of any product, a relevant alternative product could be suggested. A thorough survey of available products within the market used in construction is necessary for avoiding such problems, during the design phase of the construction project.

Poor coordination and communication: Any late information, last minute client requirements, slow drawing revision and distribution, which is a result of poor coordination and communication between the agencies involved in the construction project, would contribute to the generation of construction waste and wastage of other resources. Timely communication along with the proper coordination between various project stakeholders like the client/clients, designers, contractors, sub-contractors, construction manager/managers, project managers and indirect stakeholders like different government agencies or regulating authorities, NGOs (social organizations), environmentalists, etc., is must to avoid these kind of waste generation causes.

Time pressure : Time is one of the most important factor in the successful completion of any construction project, its mismanagement could lead to create pressure on overall machinery of the construction project. This would result in a chaotic condition, where in order to meet the deadlines, the quality of work would be compromised resulting in the generation of construction waste. A specialized project management plan should be prepared and executed by the specialists, that would include a proper time management schedule also. By adopting such an expertise, these time pressure related causes can be avoided.

Unclear/unsuitable specification : During design phase of the project all the suitable specifications must be mentioned clearly. Unclear or unsuitable specification of any material or product leads to the state of bewilderment. This could result in the use of wrong or unsuitable material or product within the construction and thereby generation of waste. All the specifications must be laid off by the experts before the construction phase of the project in order to avoid such waste generating causes.

Selection of low-quality products : Low-quality products would not sustain longer and could lead to earlier damage. This would result in the construction waste generation. Only products mentioned in specifications list by experts should be utilized in the project. This practice could avert such waste generating causes.

Off-cuts from cutting materials to length : Using material after cutting it to the desired or required length at the construction site leads to its wastage and adds up to the construction waste. Care should be taken, while designing, about the available lengths and other measurements of the materials to be used in the construction project. Such planned design could help in avoiding such wastes.

Waste from cutting uneconomical shapes : Use of irregular shapes in the construction would lead to a lot of wastage. Designers should try to avoid using complex and irregular shapes within their designs, as it would lead to a lot of wastage during its erection or construction. And it would also result in escalation of construction cost. So that would be uneconomical too. Designer's wisdom and innovation could help in eliminating such waste generating causes.

8. CONCLUSION

Topics like construction waste, types of construction waste and construction waste management are understood through literature review. Different causes of construction waste are identified and classified. Through quantitative survey, data for ranking the identified causes of construction waste is obtained and then analyzed with the help of Microsoft excel 2010 software application. Using rank formula within Microsoft excel 2010, different ranks are calculated and assigned to the identified causes of construction waste. The top five ranked nine causes of construction waste are identified and discussed along with their remedial measures. It is highly advisable to all the designers, contractors and construction managers to follow the mentioned remedial measures in order to avoid the generation of construction wastes.

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