Development of OSWMP strategy for Minimization of Construction Waste by a Case Study

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Abstract:
Growth in Construction projects leads to an increase in material waste, and these wastes are strewn into landfills. There are a few papers that measure the quantification of waste at newly constructed sites, and these wastes are measured in kg. This research paper tries to find out the material waste at each stage, from the foundation to the finishing stage. The percentage waste at each stage had been calculated, and that helped minimise the waste at the next stage. Strategies are framed, such as an on-site waste minimization plan (OSWMP) and a manual for waste minimization, to minimise waste in construction projects. Finally, the strategies were effectively applied and validated at the construction site, and the difference in cost had been calculated.

Keywords: Construction waste; Construction waste minimization; On-site waste minimization plan; Manual book for waste minimization**.**

1. INTRODUCTION

The large number of construction projects in India, on the one hand, and the country's inadequate system for managing construction waste (also known as CWM), on the other hand, have contributed to the country's growing construction waste problem in recent years. However, practices of Construction Waste Minimization and implementation of low-waste construction technologies in the Indian construction sector are still at a low level compared to those of some developed nations, including the United States, the United Kingdom, and Australia (Lu and Yuan, 2010). The inadequate monitoring and management of building waste in India can be characterised by a number of different features. For instance, contractors are unable to comply with Construction Waste Management procedures and laws due to a lack of specificity. When building something, it's not a top priority to solve for environmental management issues like reducing construction waste. There is a common lack of understanding among industry shareholders regarding the reduction of waste in construction and the protection of the environment. The vast majority of building projects in India do not have comprehensive waste management plans at the level of the project.

The lack of proper management on the construction site results in trash being produced there. Existing literature on the subject of construction waste minimization covers a wide variety of topics, including measures for minimising construction waste, on-site construction waste sorting, construction waste recycling and disposal, and forecasting construction waste generation at each level (Wang et al., 2011, Hao et al., 2007, Formoso et al., 2002). However, there is only a small amount of research that can be used to help with the strategic planning of construction waste minimization. Studies have revealed that the construction industry plays a significant part in economic development in both developing and developed nations around the world. Furthermore, the construction industry consumes up to sixty percent of all raw materials mined from the earth (Lomberaand prea, 2010). According to the findings of a study that was carried out by the World Watch Institute, the raw material that is used for building construction uses up to forty percent of stones, twenty-five percent of aggregates, twenty-five percent of timber, and sixteen percent of all of the water that is used annually around the world (Dimoudi and Tompa, 2008). The amounts of raw materials that are utilised in the construction industry are one of the primary factors that determine the amount of waste generated by this sector (Kourmpanis et al., 2008; Wang et al., 2004). As a result, this sector is responsible for a major share of the total amount of garbage generated in the construction industry worldwide.

A. Waste in Construction Industry

Generation of Construction Waste are from three sources,

- Newly construction site
- Renovation site
- Demolition site

These wastes are directly strewn to landfill. If the waste is properly monitored and controlled, very minimum waste can be sent to dumpsite. Refuse, Reduce, Reuse, Recycle and Retreat are few methods that can be followed to minimize or control the waste in construction site. Construction waste are obtained during building process such as cement, fine aggregate, coarse aggregate, brick, tile etc.

B. Construction waste affect Environment

Liyin et al., 2006 narrates the environmental problems includes,

- Decreasing landfill space as a result of increasing quantities of these discarded materials.
- The depleted building materials.
- The rise in contamination from landfills, which caused severe adverse health effects.
- Damage to the environment.
- The increase in energy consumption for transportation and the production of new materials rather than the production of energy-intensive materials deposited.

2. LITERATURE REVIEW

Thomas Wilson P. M., (2016), explains the significance of the 3R concept (Reduce, Reuse, and Recycle) for refuse management in the construction industry. The author concludes that waste minimization and waste management programmes for site engineers are in their infancy in India and that the waste management hierarchy of specific construction waste regulation should be implemented.

According to the findings of Harish P. Gayakward and colleagues (2021), there is no accurate assessment of the quantity of garbage generated in India. This is due to the fact that engineers focus less on this issue. In addition, the author advised making use of recycled materials in new building, along with precise recycling criteria, provided that the pricing were competitive.

An analytical approach for evaluating the cost of construction waste was developed by Siti Akhar Mahayuddin and her colleagues (2013). Construction waste is the primary factor in the overall cost of building. (that is, thirty percent of the total material purchased).

Through the analysis of semi-structured interviews, Zhang Xiaoling et al. (2020) give a discussion on important low waste technologies that have been adopted and the implemented LWT's in both the design and cost stages of the research. The author draws a conclusion by advocating for an increased utilisation of LWT in the development of a set of design and technological tool kits for the purpose of enhancing construction waste management in industries.

The research conducted by Effie Papargyropoulou and her colleagues (2011) concentrated on the construction industry to investigate the current state of waste management and the extent of environmentally responsible practises on construction sites. Interviews were used to investigate how individuals felt about waste management and how they responded to it. The author also investigated this. The results indicate that both the industry's awareness of waste management and the commitment to improving it are quite low, which is very frustrating in construction organisations.

Effie Papargyropoulou and colleagues (2011) focused their research on the construction industry to investigate the current situation of waste management and the extent of sustainable practises on construction sites. Interviews were used to investigate not only the contractors' attitudes but also their responses on trash management. The results demonstrate that both the industry's awareness of waste management and the commitment to improving it are extremely low in construction enterprises. This is quite distressing.

According to Sumit Arora and colleagues (2015), the natural resources have a finite amount of availability and will run out at some point in the future. Restricting and regulating the production of waste that is unneeded on building sites is one way to contribute to the conservation of natural resources. Construction waste can be reduced to a minimum by the implementation of an appropriate waste management plan throughout the life cycle.

According to Muniyappan. K et al., (2020), the costs of the materials make up between 65% and 75% of the total cost of the project. In order to determine which areas of the Tanjavur site generate the most garbage, a questionnaire was developed and distributed to the site's engineers. Bricks, cement, timber, concrete, metals, and glasses are the types of items that are thrown away on building sites. The RII approach was used to analyse the respondents. The author arrives at the conclusion that an efficient waste management system is the procedure that needs to be followed in order to regulate all of the garbage in a newly constructed site.

Hongping Yuan (2013) carried out a SWOT analysis in order to have a better understanding of the current state of construction waste management (CWM) and to discover the CWM's internal and external conditions. According to the findings, one of the strengths is the high level of awareness that the local government has towards the promotion of CWM. Some of the weaknesses include incomplete rules connected to CWM, insufficient reduction of waste from construction, and a lack of systematic planning. The opportunity exists in the form of a good chance to develop CWM practise, while the threat comes in the form of restricted landfills for the management of waste generated by construction projects.

In their study on waste management, Swarna Swetha Kolaventi et al. (2019) discovered four approaches: the quantification of waste by wastivity, the grouping of influence factors (IFs) by factor analysis, the ranking of IFs by comparable importance index, and the assessment of attitude by concordance among construction crew. The results are the predicted levels of wastivity for concrete (4.14%) and steel (1.62%). There is a quantifiable range of attitudes held by workers in regard to trash management, as well as a predisposition on the part of policy architects to gravitate towards procedures that incorporate the training of personnel in effective waste management.

Hongping Yuan (2017) identified five shortcomings in the practises of waste management. These drawbacks are as follows: an immature regulatory environment for managing trash; no one takes the leading position; a lack of fundamental data; inadequate attention paid; and a decrease in the number of recycling factories. The author suggested that the government should take the initiative to improve waste management practises, effective trash disposal charging fees, design-out-waste, and waste sorting at the source, all of which can greatly contribute to improved waste management.

The key sources of site waste creation have been identified by Ekanayake, L.L., and Ofori, G. (2004), and a model has been established to evaluate construction designs from the point of view of the generation of waste materials. Waste was generated at the site primarily through the processes of design, operation, and material handling. The Building Waste Assessment Score Model (BWAS) was derived from the evaluations given by respondents using a 5-point Likert scale, which then generated weights for the building's subsystems. The remaining six attributes—the designer's lack of familiarity with alternative products; the complexity of the drawings; the absence of information in the drawings; errors in contract documents; and the selection of low-quality products—were deemed to not be significant contributors to the generation of waste on the site.

A group-based incentive reward programme was given by Chen, Z., Li, H., and Wong, C.T.C., (2002). This programme motivates workers to reduce unnecessary wastes of construction materials on site and had been validated at sites. IRP automatically captures historical data of consumed materials, monitors material consumption in two groups, and transmits automatically transformed data to head office. It also tracks real-time data of building materials on site and transforms data automatically. This keeps an automatic record of the amount of material consumed and contributes to the reduction of waste.

3. CONSTRUCTION WASTE REDUCTION APPROACHES

Osmani (2012) Latest research in the field of construction waste management and minimization can be broadly categorized as follows,

- Quantification of construction waste and source evaluation.
- Waste minimization strategies.
- Designing out waste.
- On-site waste sorting methods and its techniques.
- Data collection models development, including flows of wastes and waste management mapping, to help handling of on-site waste.
- On-site waste auditing development and assessment tools
- Effect of legislation on waste management practices.
- Improvements of on-site waste management practices.
- Reduce, Reuse and recycle waste in construction.
- Benefits of waste minimization in construction.
- Waste minimization manuals, including guides for designers.
- Attitudes towards construction waste minimization.
- Comparative waste management studies.

A. Scope of the Research & Objective

To make the study more detailed, wide and achievable, surveys and study is limited within the defined boundary. The scope of study is limited in Tanjavur. Total residential builtup area is 10,400 and 12,800 Sq.ft. type of apartment building which is located at Tanjavur, Tamilnadu, India.

- To estimate the quantity of waste generation at each stage in a newly construction site.
- To frame strategy and validate at construction sites to find out the material waste generation.
- To compare planned vs actual waste and cost at construction site.

4. RESEARCH METHODOLOGY

Following methodology were implemented to complete the research work.

Case 1, Case study was carried out to identify the waste and the generation of waste at each stage, all related data were collected from the construction site such as Bill of quantities, Job cost ledger, reconciliation statement every fortnight, material calculation and planned waste. Planned waste vs achieved waste had been compared at each stage and the

reasons for the waste had been noted. In order to reduce the waste in construction site, techniques had been framed such as On-Site Waste Minimization Plan (OSWMP) and Manual book.

Case 2, in construction site was instructed to follow the Manual book's advice and OSWMP, these were prepared with the help of reasons for waste, interviews from the experts, respondents from the questionnaire etc. The techniques were validated throughout the construction, planned vs achieved were compared at each stage. From the analysis, the cost savings and profit maximization had been arrived.

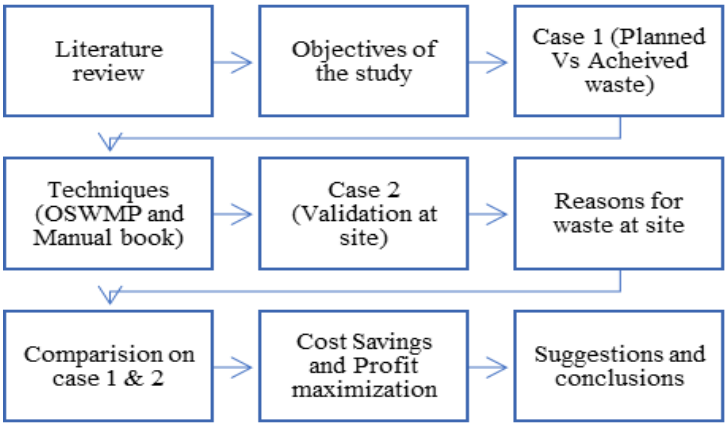

Fig 1: Research methodology

5. Findings and Discussion of Case studies

Two construction sites featuring medium cost high rise residential buildings in Tanjavur were selected.

A. Case study 1:

A construction site of S+4 floors with the builtup area of 10,400 sq.ft were selected at Tanjavur and the data required for the research such as Bill of quantities, Calculation of materials, Planned waste, Reconciliation statement, job cost ledger etc.. were collected from the site at each stage. A regular site inspection was conducted and the reports were reviewed every week to find out the quantity of construction waste. Calculation of cost were divided in to two ways, lab our cost and material cost. Material cost is around Rs. 1, 38, 00, 000/-

Table 1 Construction materials cost in %

Materials	% On Material cost
Cement	12.74
Fine Aggregate	13.86
Coarse Aggregate	5.50
Steel	14.93
Brick	8.48
Tile	12.12
Paint	7.70
Electrical	11.29
Plumbing	2.87
Wood	10.45
Others	3.07

Reconciliation is the process of comparing the standard data with actual data after considering data relating to variances. This ensures the accuracy and validity of financial information. This helps to provide credibility to the financial statements and ensures that all revenue and cost of revenue being charges to the financial statements is being charged to the proper project.

Table 2 Reconciliation statement case 1

S.No	Description	Cement in Bags	M.Sand in Cft.	20mm Metal in Cft.	Bricks

1	Stock received	5294	26240	16000	172500
2	Stock at site	565	2680	991	4460
3	Actual usage	4728	23559	15009	171320
4	Theoretical	4358	22616	14145	155865
5	Variation Qty	-370	-943	-864	-15455
6	Variation %	-8.49	-4.17	-6.10	-9.91
7	Rate/unit	380	80	50	7
	Total wastage	-140762	-75516	-43200	-108185

i. Planned Vs Actual waste

Planned waste is the assumed (standard) waste taken from the literatures and IS codes. Actual waste is the achieved waste from construction site measured at each stage. Difference in percentage of waste had been arrived from the planned waste calculated (theoretical-without wastage)) vs achieved waste obtained (actual). Based on the quantity of waste, the wastage amount had been identified. Hence the overall wastage amount for the below given materials are Rs. 4,74, 134/- Whereas the material cost for (Cement, sand, aggregate, tile, and brick) is Rs. 70, 59, 220 is 6.71%.

Table 3 overall wastage amount case 1

S.No	Item	Plan waste %	Act waste %	Diff %	Qty waste	Wastage Amount
1	Cement	3.0	8.50	-5.5	370 bags	140743
2	F.A	2.5	4.17	-1.67	944 cft	75516
3	C.A	4.0	6.11	-2.11	864 cft	43200
4	Brick	4.0	9.92	-5.92	15455 nos	108185
5	Tile	4.0	6.83	-2.83	2366 nos	106470
					Total	**474134**

B. Case study 2

A construction site of S+5 with the builtup area of 12, 500 sqft were selected at Tanjavur and the data required for the research such as Bill of quantities, Calculation of materials, planned waste, Reconciliation statement, job cost ledger etc. were collected from the site at each stage. A regular site inspection was conducted and the reports were reviewed every week to find out the quantity of construction waste. Calculation of cost were splitted in to two ways, labour cost and material cost. The material cost is around Rs. 1, 57, 50, 000.

This table 4 clearly shows the stocks recived at site, actual and theoretical usage and its difference in quantity and percentage. Finally, the total wastage had been calculated.

Table 4 received stocks detail on site 2

Materials	% on Material cost
Cement	13.01
Fine Aggregate	12.45
Coarse Aggregate	5.93
Steel	13.36
Brick	8.53
Tile	13.1
Paint	7.9
Electrical	12.01
Plumbing	2.9
Wood	8.68
Others	2.13

i. Reconciliation statement

Table 5 Reconciliation statement case 1

S. No	Description	Cement in Bags	M.Sand in Cft	20mm Metal in Cft	Bricks
1	Stock received	7800	27000	24000	220600
2	Stock at site	96	172	355	306
3	Actual usage	7704	26828	23645	220294

4	Theoretical	7253	25956	22606	211117
5	Variation Qty	450	872	1039	9177
6	Variation %	6.2	3.36	4.60	4.35
7	Rate/unit	380	80	50	7
	Total wastage	-171000	-69760	-51950	-64239

Reconciliation is the process of comparing the standard data with actual data after considering data relating to variances. This ensures the accuracy and validity of financial information. This helps to provide credibility to the financial statements and ensures that all revenue and cost of revenue being charges to the financial statements is being charged to the proper project.

ii. Planned Vs Actual Waste Case 2

Planned waste is the assumed (standard) waste taken from the literatures and codes. Actual waste is the achieved waste from construction site measured at each stage. Difference in percentage of waste had been arrived from the planned waste calculated (theoretical-without wastage) vs achieved waste obtained (actual). Based on the quantity of waste, the wastage amount had been identified. Hence the overall wastage amount for the below given materials are Rs. 4, 54, 232/- Whereas the material cost for (Cement, sand, aggregate, tile and brick) is Rs. 83, 50, 650/- is 5.43%.

Table 6 overall wastage amount case 2

S.No	Item	Plan waste %	Act waste %	Diff %	Qty waste	Wastage Amount
1	Cement	3.0	6.2	-3.2	ags	171038
2	F. A	2.5	3.36	-0.86	Cft	69760
3	C.A	4.0	4.60	-0.6	cft	51950
4	Brick	4.0	4.35	-0.35	nos	64239
5	Tile	4.0	5.19	-1.19	nos	97245
				TOTAL		454232

6. RESULTS AND DISCUSSIONS

The construction business is a major part in universal economy. As the construction industry increases, the construction waste also increases with the same growing intensity. Least importance given for waste minimization in India leads to generation of enormous amounts of material waste in construction annually. Reducing project waste, project cost deviation are the major problems affecting Indian construction sector. From the case study 1 survey, it was found that, the materials are wasted because of no proper waste minimization techniques used. The construction waste per sq.ft had been calculated as Rs. 45/sq.ft.

Case 1:

- Built-up Area = 10, 400 sq.ft
- Wastage amount = Rs. 4, 74, 134/-
- Material cost = Rs. 70, 59, 220/-
- (Cement, F.A, C.A, Tile, Brick)
- Waste/sq.ft = Rs. 45/sq.ft
- % Waste on material cost = 6.71%

In case study 2, On site waste minimization plan and the manual prepared were properly followed with a good waste management monitoring team. The waste was Rs. 36/sq.ft.

Case 2:

- Builtup Area = 12, 500 sq.ft
- Wastage amount = Rs. 4, 54, 232/-
- Material cost = Rs. 83, 50, 650 /-
- (Cement, F.A, C.A, Tile, Brick)
- Waste/sq.ft = Rs. 36/sq.ft
- % Waste on material cost = 5.43%

It clearly shows, Rs. 10/sq.ft can be saved by using this technique. If the waste of Rs.36/sq.ft is applied to case 1, 10400 sq.ft building, 10400 sq.ft x 36/sq.ft = Rs. 3, 74, 400/-.

Table 7 Cost comparison of case studies

Item	Wastage Amt	Material cost	Waste/sft	Qty waste	Wastage Amount
Case 1	474134	7059220	45	Cft	474134
Case 2	454232	8350650	36	cft	454232
Case 1 Assumed			36	nos	374400
		Difference in Rs.			**99734/-**

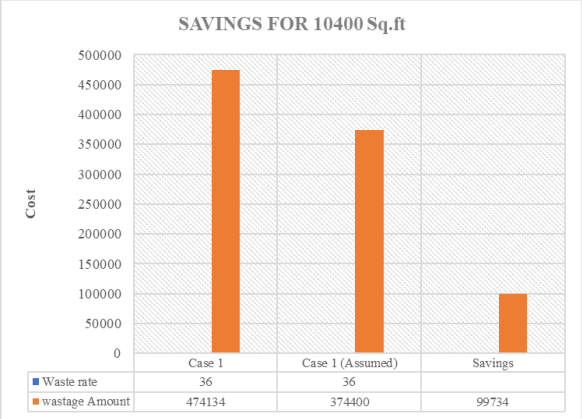

Fig. 1. Cost minimizaton comparison

The difference in cost saving (Rs. 4, 74, 134 – Rs. 3, 74, 400) is Rs. 99, 734/- for around 10400 sft building. If this technique is used in bigger projects, the contactors will be benefited much. Hence by using onsite waste minimization plan and Manual book for waste minimization, the benefits such as waste reduction, maximizing profit, less waste to landfill, reducing extraction of new materials can be achieved.

7. CONCLUSION

The expansion of construction projects leads to an increase in refuse materials, which are then disposed of in landfills. In this research work minimising waste in construction projects, on-site waste minimization plan (OSWMP) and a manual for waste minimization are formulated and implemented the strategies were successfully implemented and validated on the construction two site, and the cost differential was determined. Both the case studies were proved that the suggested method effectively minimizes the total building cost of the building.

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