Management and Minimization of Construction Waste for Residential Site.

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Abstract - Past research into the causes of waste in construction projects indicate that waste can arise at any stage of the construction process right from inception, design, planning, actual construction, etc. to operation of the built facility. Waste in the construction industry has been the subject of several research projects around the world in recent years. It is commonly acknowledged that a very high level of waste exists in construction. Waste indicates both, the incidence of resources and energy losses and execution of unnecessary work. It generates additional cost to the product but does not add value to it. Therefore waste should be defined as any losses produced by activities that generates direct and indirect cost, but do not add any value to the product from point of view of client. Since construction has a major and direct influence on many other industries by means of both purchasing inputs and providing the products to all other industries, eliminating or reducing waste could yield great cost savings to the society. This paper identifies the sources and causes of generation of construction wastes, especially cement and steel, on construction sites. The main tools for the collection of data included questionnaires, interviews and available data from construction sites. This study is an attempt to find the main causes of construction waste, which may be Method of Storage, Material Handling, Documentation, Workmanship, Planning and Controlling and Procurement, Variation in Design, etc. The factors which has major effect on the material wastage are identified and analyzed based on Correlation & Regression analysis using SPSS16 (Statistical Package for Social Sciences Version 16) software. In this study an attempt is made to suggest ways to reduce construction waste, based on the analysis by Correlation and Regression using SPSS16 software. By using these identified sources and causes, construction industry players may become aware of how the waste is generated and how this can be avoided. It will give a great benefit for not only the construction industry but also the country in terms of economic, social and most importantly, protection of the environment.

Index Terms – Management, Minimization, Construction Waste, Cement, Reinforcement Steel, Correlation, Regression.

1 INTRODUCTION

The construction industry plays a vital role in meeting the needs of society and enhancing quality of human life. Nowadays, the construction industry faces many challenges with issues related to construction waste. During the past two decades, the amount of waste has increased significantly, due to the increase in the standard of living, changes in consumption habits, as well as the natural increase in population. Thus, construction waste has become a serious problem in many countries. Numerous reports and studies have investigated issues on waste which lead to negative impact to the environment, cost, productivity, time, social and economy. In addition, these issues contribute to a reduction value of construction productivity and reduce the performance of overall projects. The wastes, produced on construction sites, are in physical form and non physical form. The physical waste are mainly from broken concrete, bricks, metals, packaging waste, etc. Whereas the nonphysical wastes are cost overruns and time delays in construction projects. Construction material wastages can be defined as the difference between the value of materials delivered and accepted on site and those properly used as specified and accurately measured in the work, after deducting the cost saving of substituted materials transferred elsewhere in which unnecessary cost and time may be incurred by material wastage. Generally, the material cost contributes to about 40% of the total construction cost of which cement and steel account for 60% of that cost. Hence it is necessary to curb wastages for these materials to control the economy of the project cost. Study specified that Malaysia also has faced construction waste problems in line with the rapid development of construction sector. With increasing demand of infrastructure projects, residential development projects, large amounts of construction waste are being produced in Malaysia. These conditions may give a huge impact on project costs and time due to physical and non-physical waste for construction industry .They identified various factors causing construction waste in Malaysia. In this study author identified and detected factors contributed to the generation of construction waste. This will help researchers and construction industry players to understand the main factors contributing to physical and nonphysical waste generation. Mapping technique was applied for identification works and interview was conducted to detect the physical and non-physical waste. Waste is a product or material that is unwanted. Construction waste clustered into two groups namely the physical and non-physical waste. This paper had identified significant factors contributing to physical and non-physical waste in construction projects based on (1) Design, (2) Handling, (3)Worker, (4)Management, (5)Site Condition, (6)Procurement, (7)External Factor. By identifying the significant factors in construction process, construction players are able to notice the best ways to apply new practice for reducing material waste, time delay and cost overrun in any project.The study assessed the forms, causes and factors incidental to waste and measures to effectively control construction waste. The research showed that most of the firms do not calculate waste indices which could assist them to determine the amount of waste that could be generated on sites. The main results of two research studies carried out in Brazil. Some typical figures for the waste of some key construction materials were provided, and the main causes of waste in the sector were discussed. The main causes of waste in the industry and propose guidelines for preventing its incidence. Considering that material waste is an important issue for the construction industry, waste is defined as the loss of any kind of resources-materials, time (labor and equipment) and capital produced by activities that generate direct or indirect costs but do not add any value to the final product from the point of view of the client. The previous studies about the sources of waste examined and the recommended measures to minimize the waste. The significance of these causes and frequency of implementation of adequate measures in the UAE construction sites were examined. The various causes of material waste and waste minimization practices implemented in UAE construction sites. The perceptions of contractors on the benefits of waste minimization have also been investigated. The main direct causes of material waste in the UAE construction sites were: workers' lack of awareness; poor design resulting in excessive off-cuts; and the rework and variations. The indirect causes of material waste were found to be the lack of

legal and contractual incentives. The author reported on a study to assess the level of contribution of some waste minimization measures to waste reduction, and the level of practice of such measures in the Ghanaian construction industry. Consultants perceive purchasing raw materials that are just sufficient, using materials before expiry dates, use of more efficient construction equipment and good coordination between store and construction personnel to avoid over-ordering as the measures that highly contribute to waste minimization and also those highly practiced. Study observed that, 5 –10 percent of construction materials end up as waste on construction sites. It was reported that waste typically accounts for between 15 and 30% of urban waste. Waste can be categorized according to its source - the stage in which the root causes of waste occurs. Waste rates in the Dutch construction industry identified the main sources of waste in construction as design, procurement, material handling, operation and residual. Sources of waste identified from the processing preceding construction such as materials manufacturing, design, material supply, and planning, as well as from the construction stage. Waste can affect success of construction project significantly. More specifically, it has major impact on construction cost, construction time, and productivity and sustainability aspects. The study made analysis of wastage in cement and reinforcement steel at a bridge construction site. The analysis of wastage was done by mathematical method of correlation and regression using SPSS16 software. The factors which had major effect on the material wastage were identified and analyzed based on the correlation and regression using SPSS16 (Statistical Package for Social Sciences Version16). SPSS software is a computer application that provides statistical analysis of data. It allows for in-depth data access and preparation, analytical reporting, graphics and modeling. It can be used in Planning Department and for survey authoring and deployment (IBM SPSS Data Collection), data mining (IBM SPSS Modeler), text analytics, statistical analysis, and collaboration and deployment (batch and automated scoring services) Add-on modules provide additional capabilities. The available modules referred are: SPSS Regression - Logistic regression, ordinal regression, multinomial logistic regression, and mixed models, SPSS Correlation- Partial correlation, bivariate correlation, SPSS Decision Trees creates classification and decision trees for identifying groups and predicting behavior. SPSS, Forecasting ANOVA (Analysis of Variance) and ANCOVA (Analysis of Covariance) are the softwares that could be used. For the case history mentioned below, SPSS software is used for analysis of wastage of cement and wastage of steel.

2 METHODOLOGY

From literature review following methodology is defined for the study. (1)The significant factors lead to generation of wastage of cement and wastage of steel are find out from literature survey, site visit and interviews. (2)The Residential site is identified where r.c.c work and brickwork is in progress on the site. Out which about 50-60%of work is completed. The stores records regarding orders delivered and its utilization, excess/ deficit are collected from site. The concrete quantity records are worked out as against the estimated quantities as per approved drawing. (3)The significant factors causing wastage in cement and steel are considered and ratings are given as per a 10 point scale from the questionnaire survey. Then we use SPSS 16 Software for correlation analysis and regression analysis for wastages of cement and wastages of steel and various factors leads to wastage for the ongoing residential project. The site chosen for the study is Eira Project, Punawale, Dist. Pune.

Details of projects are as follows:

(1) Name of the work: Eira Project, Punawale, Dist. Pune.
(2) Name of owner: Rainbow Associates
(3) Name of Architect: M/s Laxman Thite and Associates
(4) Plot area: 10000 sq. m.
(5) Construction area: 16,730 sq.m.
(6) Stage of Construction: R.C.C framed work, Brickwork, plaster, and flooring work,
(7) No. of buildings: 2
(8) Project cost: INR 55 Crores
(9) Work completed: 55 %

Factors leading to wastage in cement are set to the sample (also the abbreviations are used in tables) size (i.e. seven) and they are listed as below:

1. Variations in the design while construction is in progress (DC):

Frequent design changes are the main contributor for waste generation. The waste arises at the construction site due to the changes made by the clients at the verge of completion of projects. When the first design drawing is approved by both parties (contractors and client), the contractor begins the construction works at site, while the construction work is in progress, the sudden requirement of the client will complicate the near completion work and end up with rework. The built structure has to be demolished and need to be constructed again as to the requirement of the new design drawing.

2. Storage (ST):

Wrong material storage, is highest key cause of construction waste generation. This problem is always connected with the improper storing methods. The wrong storage occurs because of inappropriate protection strategy. For examples, cements have to store under a shade and save place. Without proper protection, the materials end up as waste. Proper storage of material are very necessary for avoid the construction waste generation. Beside that, the wrong material storage also contributes to the non-physical waste. If the cement spoils at site due to improper storage by worker, then this leads to shortage of material during construction. Insufficient stock of construction materials, will lead to stoppage of construction works at site. The manpower of waiting workers during supply and payment of hourly salary always will end ups as waste.

3. Material Handling (MH) :

The concrete once prepared, should be handled as minimum and applied to the prepared surface as soon as possible as excess handling leads to wastage.

4. Record keeping Mistake (RM):

The records if not properly maintained will lead to wrong estimation of quantity of materials in stock and cause wastage. Also due to receipts are misplaced. This is due to lack of commitment of personnel involved in record keeping.

5. Poor workmanship (PW):

Unskilled workers tend to make more mistakes due to lack of skills and poor working attitude. Mistakes during concreting works can cause rework. The Poor workmanship occurs due to untrained labourers, lack of skills and poor working attitude. Such workers often make mistakes at work place. They always generated material waste.

6. Planning And Controlling (PC):

Without detailed planning of construction process, requirement

and material storage facilities can lead to the generation waste. Less attention paid to workers during material handling on site causing waste.

7. Procurement error (P):

Procuring excess quantity that gets wasted due to wrong interpretation of drawings causing wastage. Sometimes poor ordering of materials does not fit in terms of quality and last ends up as material waste.

For reinforcement steel, instead of planning and controlling (PC), storage (ST), material handling (MH) and procurement error (P), following factors are added.

1. Cutting uneconomical pieces (CP): This is a major factor causing wastage. Standard Length of reinforcement bars are available in market and if the cutting length schedule is such that the complete length is not utilized leads to wastage.
2. Vandalism (V): This factor also leads to wastage where usually cut pieces are stolen.
3. Short supply (SS): If the steel bars are less in stock it leads to wastage.
4. Site management (SM): Less attention paid to workers during cutting bar as per schedule on site causing waste.

According to the ratings received from project team, each of the factors is correlated with wastage in cement and also for wastage in reinforcement steel independently. The tables / ratings are used to formulate a linear regression equation to find out the combined effect on the wastage in cement and effect on the wastage in reinforcement steel by using SPSS16 software. Survey was carried out through questionnaire duly filled in from Project Manager, Senior Engineer, Site Engineers, Structural Engineer and Managing Partner of the project mentioned above.

3 ANALYSIS AND DISCUSSION

The summary of information gathered is represented from Table I to Table IV

Table I: Actual Wastage in Cement (in bags):

Sr. No	Description	Cement Theoretical Qty. (in bags)	Cement Executed Qty. (in bags)	Excess (in bags)	Excess (in %)
1	Footing	1556.62	1591.00	34.38	2.21
2	Plinth beam	219.21	230.00	10.79	4.92
3	Column	2980.88	3122.00	141.12	4.73
4	Slab and beam	6923.42	7481.00	558.00	8.05
5	Lift raft	556.80	580.00	23.20	4.20
6	Lift Pardi	99.71	104.00	4.29	4.30

Table II: Ratings Given As Per a 10 Point Scale for the Questionnaire Survey for Cement Wastage

Sr. No	Wastage (%)	DC (1)	ST (2)	MH (3)	RM (4)	PW (5)	PC (6)	P (7)
1	2.21	1	4	2	1	6	3	4
2	4.92	2	4	4	3	6	5	5
3	4.73	2	4	7	4	7	6	3
4	8.05	1	5	5	2	9	4	5
5	4.20	1	5	2	1	6	5	5
6	4.30	1	5	4	1	7	6	4

Table III: Actual Wastage in steel (MT):

Sr. No	Description	Steel Theoretical Qty. (in MT)	Steel Executed Qty. (inMT)	Excess (in MT)	Excess (in %)
1	8mm	63.25	65.64	2.39	3.80
2	10mm	24.05	24.90	0.85	3.56
3	12mm	33.02	34.77	1.75	5.29
4	16mm	42.62	44.44	1.82	4.28
5	20mm	19.38	20.12	0.74	3.79
6	25mm	6.04	6.20	0.16	2.56

Table IV: Ratings given on 10 Point Scale based on questionnaire survey for steel wastage

Sr. No	Wastage (in %)	DC (1)	PW (2)	CP (3)	SM (4)	SS (5)	V (6)	RM (7)
1	3.80	1	6	4	4	2	1	3
2	3.56	2	5	6	2	3	3	2
3	5.29	1	7	6	3	2	4	1
4	4.28	2	6	8	3	3	3	1
5	3.79	1	3	7	2	2	2	1
6	2.56	1	2	3	2	2	4	2

Using the input data given in Table II, the correlations are given as follows

1. Correlation between wastage in cement and design changes (DC)

r = 0.038 i.e. correlation is positive and very week among wastage in cement and design changes factor.

2. Correlation between wastage in cement and storage (ST)

r = 0.453 i.e. correlation is positive and medium strong among wastage in cement and storage factor.

3. Correlation between wastage in cement and material handling (MH)

r = 0.526 i.e. correlation is positive and medium strong among wastage in cement and material handling factor

4. Correlation between wastage in cement and Record keeping Mistake (RM)

r = 0.308 i.e. correlation is positive and medium strong among wastage in cement and Recordkeeping mistake factor

5. Correlation between wastage in cement and poor workmanship (PW)

r = 0.860 i.e. correlation is positive and very strong among wastage in cement and poor workmanship factor.

6. Correlation between wastage in cement and planning and controlling (PC)

r = 0.118 i.e. correlation is positive and week among wastage in cement and planning and controlling factor.

7. Correlation between wastage in cement and Procurement error (P)

r = 0.384 i.e. correlation is positive and medium strong among wastage in cement and Procurement error factor.

INTERPRETATION: Poor workmanship has strong positive correlation with wastage in cement (r = 0.860) and design changes has very week correlation with wastage in cement. (r = 0.038).

Correlation for wastage in steel

Using the input data from Table IV for SPSS 16 software, following correlation observed between various factors and wastage in steel.

Table VI: SPSS16 Output for Correlation between Wastage of steel and poor workmanship (PM):

Correlations

	Wastage	Poor Workmanship
Wastage - Persons Correlation	1	0.838
Sig. (2-tailed)		0.037
N	6	6
Poor workmanship- Persons Correlation	0.838	1
Sig. (2-tailed)	0.037	
N	6	6

Using the input data given in Table IV, the correlations are given as follows:

1. Correlation between wastage in steel and design changes (DC):

r = 0.035 i.e. correlation is positive and very week among wastage in steel and design changes factor.

2. Correlation between wastage in steel and poor workmanship (PW):

r = 0.838 i.e. correlation is positive and very strong among wastage in steel and poor workmanship factor.

3. Correlation between wastage in steel and Cutting uneconomical pieces(CP):

r = 0.580 i.e. correlation is positive and medium strong among wastage in steel and Cutting uneconomical pieces.

4. Correlation between wastage in steel and site management(SM)

r = 0.451 i.e. correlation is positive and medium strong among wastage in steel and site management factor.

5. Correlation between wastage in steel and short supply(SS):

r = 0.035 i.e. correlation is positive and very week among wastage in steel and short supply factor.

6. Correlation between wastage in steel and Vandalism(V)

r = 0.065 i.e. correlation is positive and very week among wastage in steel and Vandalism factor

7. Correlation between wastage in steel and Recordkeeping Mistake (RM):

r = -0.492 i.e. correlation is negative and very week with very low degree of certainty for wastage in steel and recordkeeping mistake factor

INTERPRETATION: Poor workmanship has strong positive correlation with wastage in steel (r = 0.838) and record keeping mistake has negative correlation i.e. very week correlation with wastage in steel. (r=-0.492)

B) REGRESSION ANALYSIS USING SPSS16:

In this analysis equation is formed considering all the factors that affect the dependent variable simultaneously. The ratings taken for analysis are the same as that used in the correlation analysis.

1. Wastage in cement

The data table is same as used in correlation analysis of wastage in cement. Refer Table II. The output from SPSS software is as shown in Table VII

Table VII: SPSS16 Output for Regression analysis of Wastage of cement and other factors:

Coefficients

Model	Unstandardized Coefficients		standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	-12.452	0.00		-	-
Storage	0.784	0.00	0.227	-	-
Recordkeeping mistake	0.752	0.00	0.503	-	-
Poor workmanship	1.060	0.00	0.655	-	-
Planning and controlling	0.082	0.00	0.051	-	-
Procurement Error	1.042	0.00	0.449	-	-

Regression equation for wastage in cement is as below

Wastage in cement = (-) 12.452+0.784(storage) + 0.752(Record keeping mistake) + 1.060(Poor workmanship) + 0.082(Planning and controlling) + 1.042(Procurement error)

INTERPRETATION: This equation shows us that Poor workmanship is a main factor that affects wastage linearly, i.e. as Poor workmanship it affects the wastage in cement 1.060 times. The factor of Variations in the design while construction is in progress (DC) and material handling (MH) is excluded from this analysis.

Verification:

From Table VII, wastage for cement is worked out using rating as given for 4th reading that shows maximum value of wastage (8.05)

Wastage in cement =8.05

= (-) 12.452 + 0.784*(5) + 0.752*(2) + 1.06*(9) + 0.082*(4) +

1.042*(5)
=8.05~ 8.05
Hence above equation is verified.

1. Wastage in steel

The data table is same as used in correlation analysis of wastage in steel. Refer Table IV. The output from SPSS software is as shown in Table VIII

Table VIII: SPSS16 Output for Regression analysis of Wastage of steel and other factors:
Coefficients

Model	Unstandarized Coefficients		Standarized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	4.212	0.00		-	-
Design Changes	-0.616	0.00	-0.355	-	-
Poor Workmanship	0.503	0.00	1.089	-	-
Site management	-0.293	0.00	-0.267	-	-
Vandalism	-0.109	0.00	-0.141	-	-
Recordkeeping mistake	-0.510	0.00	-0.465	-	-

Regression equation for wastage in steel is as below

Wastage in steel = 4.212 (-) 0.616 (Design changes) + 0.503 (Poor workmanship) (-) 0.293 (site management) (-) 0.109 (Vandalism) (-) 0.510 (Record keeping mistake).

INTERPRETATION: This equation shows us that Poor workmanship is a main factor that affects wastage linearly, i.e. as Poor workmanship it affects the wastage in steel 0.503 times. The factor cutting into uneconomical pieces (CP) and short supply (SS) is excluded from this analysis.

Verification:

From table VII, wastage for steel is worked out using rating as given for 3rd reading that shows maximum value of wastage (5.29)

Wastage in steel =5.29
=4.212- 0.616*(1) + 0.503*(7) - 0.293*(3) - 0.109*(4) - 0.510*(1)
=5.29~ 5.29
Hence above is verified.

4 RESULTS

Table XI: Summary of Results obtained by Correlation and Regression for Wastage in Cement.

Wastage in Cement		
Factor	Correlation	Regression
Variations in design while construction is in progress (DC)	0.038	-
Storage (ST)	0.452	0.784
Material Hadling (MH)	0.526	-
Recordkeeping Mistakes (RM)	0.308	0.752
Poor Workmanship (PW)	0.860	1.06
Planning and Controlling (PC)	0.118	0.082
Procurement Error (P)	0.384	1.042

Table XII: Summary of Results obtained by Correlation and Regression for Wastage in Reinforcement Steel.

Wastage in Steel		
Factor	Correlation	Regression
Variations in design while construction is in progress (DC)	0.035	- 0.616
Poor Workmanship (PW)	0.838	0.503
Cutting uneconomical shapes (CP)	0.580	-
Site Management (SM)	0.451	-0.293
Short Supply (SS)	0.035	-
Vandalism (V)	0.065	-0.109
Recordkeeping Mistake (RM)	- 0.492	-0.510

By method of correlation, poor workmanship have strong correlation with cement wastage and other factors such as material handling, storage, recordkeeping mistake and procurement error have medium positive correlation with total cement wastage. In case of regression analysis, poor workmanship identifies as main factors for wastage of cement. Wastage in reinforcement has strong correlation with poor workmanship and medium positive correlation with cutting uneconomical pieces, and site management. For regression, poor workmanship identified major factors. Through this analysis, we can say that controlling these factors will give us minimum wastage in cement and reinforcement steel.

5 CONCLUSION

From the results obtained from the Correlation and Regression Analysis using SPSS16 software, it is concluded that it is possible to obtain the different factors and their contribution in the overall construction wastes. If this methodology is applied, it is quite possible to predict the likely wastages which may occur in the residential project. The Planning Engineer can take adequate steps, in advance, to take care of factors, which have major impact / contribution in overall construction wastes, such poor workmanship, material handling, storage, record keeping mistake and procurement error and cutting uneconomical shapes. This may vary on account of site conditions on different construction sites / projects. It gives variation in different weightages in the coefficients obtained by the Correlation and Regression analysis. However, this will helps the Engineers to concentrate on those factors and

plan the works respectively. The limitation to this project is the small dataset as contractors generally unwilling / hesitates to provide data regarding construction material used and actual waste generated during execution of a project on construction site.

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