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Waste Minimization of Construction Materials on A Bridge Site (Cement and Reinforcement Steel) - A Regression and Correlation Analysis

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*Abstract— **According to the new production philosophy, waste should be understood as the output of any inefficiency that results in the use of resources in larger quantities than those estimated as necessary for the production of an item. Waste indicates both, the incidence of resource and energy losses and the 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 generate direct or indirect costs, but do not add any value to the product from the point of view of the client. So the need of wastage minimization arises. The paper deals with analysis of the wastage in cement and reinforcement steel at a bridge construction site. The analysis of wastage is already done by mathematical method and this paper involves analysis by Correlation and Regression using SPSS16 software. The factors which had major effect on the material wastage were identified and analyzed based on Correlation & Regression using SPSS16 (Statistical Package for Social Sciences version 16) software. The study suggests ways to reduce wastage based on the mentioned mathematical model and its results are verified using SPSS. This paper is written in continuation to my previous paper. In this analysis we are concentrating on how some results can be obtained using SPSS software which was not used previously.***

Index Terms— **Wastage Minimization, Cement, Reinforcement Steel, Correlation, Regression.**

I. INTRODUCTION

It is seen that in executing major Civil Engineering projects there happen to be wastages related to materials used for construction. 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 materials 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 in this area to have control over the economy of the project cost. It is observed that, 5 –10 percent of construction materials end up as waste on construction sites. It is reported that construction waste constitutes 26% of the total amount of waste produced in the Netherlands and 29% of the solid-waste stream in the USA [1]. About one third of the waste contribution is done by construction industries, wherein these materials add to the cost of the project. R. Navon, M.ASCE and O.Berkovich stated in their paper that as materials constitute a major portion of the project's total cost, effective control and management can increase the productivity by 6% [2]. Wastage of materials though inevitable can be reduced to a lesser value, if the materials that form bulk of the project cost structure; it is to be efficiently monitored. This waste if minimized will help not only in reduction of project cost but also benefit the environment [3]. Minimizing waste is an opportunity to increase profits. The best way to reduce wastage is to not create it, firstly [4]. Various reasons that involve wastage include multiple materials handling, poor inventory control, untrained labour, rework and time related wastage (like in case of cement storage). Gavilan and Bernold15 organized the sources of construction waste under six categories: (i) design; (ii) procurement; (iii) handling of materials; (iv) operation; (v) residual related; and (vi) others [5]. SPSS (Statistical Package for the Social Sciences) 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) Out of the above mentioned list of various versions of the software highlighted versions will be worked upon in the later part of the thesis to generate a correlation analysis and regression equations. For the case history mentioned below, analysis of wastage for different methods of concreting is done by mathematical calculation by Regression and correlation method. The outcome is compared with analysis done by SPSS software.

II. METHODOLOGY

First, bridge site is identified where ongoing project is in process and site layout is prepared to locate areas of work going on, its accessibility and distance between that place and the store, stores records regarding orders delivered and its utilization , excess/ deficit, if any. The RMC/ concrete records are worked out against the estimated quantities as per approved drawing of components. The work involved construction of flyover with eight piers of which at present seven are completed. Data is compared to find wastages at stages to find the same in components (i.e. footings, piers, pier caps, box girders). We then use Correlation and Regression analyses to wastage causing various factors and compare the results using mathematical model. For An Ongoing Project **"Construction of Flyover Bridge Interconnecting Both Campus Of BEG (Bombay Engg Group) Near Holkar Bridge, Pune,"**

Details of project are as follows:

Name of the work: Construction Of Flyover Bridge Interconnecting both campuses of BEG (Bombay Engg Group) near Holkar Bridge, Pune

Client: Pune Municipal Corporation (PMC)

Consultant and Structural Consultant: C.V Kand Consultant Pvt Ltd

Contractor: J.M. Mhatre

Project cost: Rs 7, 22, 34,968.41

Date of Commencement: 07 June 2010

Number of piers: 8(7 completed, Pier 5 to be constructed)

Foundations: open foundations

Span: 5 nos of 25m and 2 spans of 20m

Girders: 5 nos of Box Girders and 2 voided slabs

Work Completed: 40% (as on 30 September, 2011)

For this project, the factors affecting wastage in cement were considered for different methods of placement of concrete and for reinforcement steel were rated based on a **Questionnaire Survey**. The different methods are, placing the concrete to required point using: i) pump ii) buckets & iii) using chutes made of GI sheets, such that the concrete directly flows into the required place. One can see the wastage being different for each of the methods.

1. **Concrete Pumps**: They are used for concreting in PSC Box girders (i.e. soffit slabs, web and deck slabs) at elevated points above ground level.
2. **Concreting by buckets**: This method is used for concreting of piers and pier caps above ground level. A crane holds the bucket above the point to be concreted.
3. **Concreting by chutes**: This is generally done for footings of piers at lower points w.r.t ground level wherein an inclined channel directly leads concrete dumped by transit mixer to required position.

Factors identified for **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. **Changes in design at initial stages (DC)**: This factor can cause wastage because the design is not complete at the start of the construction activity for a project or due to error in contract. The contractors who buy the cement are not aware of the design that leads to wastage.
2. **Record keeping mistakes (RM)**: The records if not properly maintained will lead to wrong estimation of quantity of materials in stock and cause wastage. At times, receipts are misplaced. This is due to lack of commitment of personnel involved in record keeping.
3. **Absence of authorities (A)**: Authorities are required to be present for works no matter how insignificant to supervise the labor.
4. **Over ordering (O)**: Procuring excess quantity that gets wasted due to wrong interpretation of drawings also causes wastage.
5. **Unskilled labour (UL)**: This factor can also lead to wastage due to unskilled labour involved in construction of larger quantity of work like in case of piers or box girders.
6. **Transit losses (TL)**: Wastage occurs due to transit loss where time is a factor and due to traffic conditions the concrete delivered is not fresh.
7. **Excess handling (H)**: concrete once prepared should be handled as minimum and applied to the prepared surface as soon as possible as excess handling leads to wastage.

For **reinforcement steel**, instead of absence of authorities, transit loss, and over ordering: theft, cut pieces that cannot be used and short supply were added.

1. **Theft (T)**: This factor also leads to wastage where usually cut pieces are stolen.
2. **Cut 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.
3. **Short supply (SS)**: If the steel bars are less in stock it leads to wastage.

According to the ratings received, each of the factors is correlated with wastage in cement for chutes, buckets and pumps and also for wastage in reinforcement steel independently. The same tables/ ratings are used to formulate a linear regression equation to find out the combined effect on the wastage in cement and reinforcement steel. **The software used in this case is SPSS16 (Statistical package for Social Sciences version 16).**

The Questionnaire survey was done from following persons namely: Mr. Prashant Narkhede (Proj Manager-J.M.Mhatre), Mr. Gokul Wadile (Site engineer-J.M.Mhatre), Mr. Prasad Borole (Site Engineer – Simplex Infraprojects), Mr. Aditya Kale (Structural Engineer – Simplex Infraprojects), Mr. Rahul Bhalerao (Managing Partner – Manoja Sthapatya), Mr. Shelar- (site Engineer, T & T Group), Mr. Amit Gandhi (Design Engineer-Technogem Pvt Ltd)

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

Sr No	wastage	DC (1)	RM (2)	A (3)	O (4)	UL (5)	TL (6)	H (7)
1	4.94	4	5	6	3	3	3	4
2	4.49	2	3	5	2	5	4	6
3	4.94	4	4	5	3	2	4	6
4	10.95	2	8	5	4	6	6	9
5	14.64	5	7	6	5	6	5	8
6	4.49	2	9	7	3	6	3	7
7	4.25	3	6	6	3	5	3	9

A) CORRELATION USING SPSS16

Correlation is shown for one factor for wastage in cement and the results interpreted using the software. Similarly, one for wastage in reinforcement steel is correlated using SPSS and results are interpreted for all the factors.

I. Wastage in cement

This is divided into three methods of placement of concrete i.e. by chutes, buckets and pumps. The ratings are compared against actual wastage in each of the placement methods. Following table shows the actual wastage in cement by chutes. The following calculations are based on mathematical calculation and as per the design drawings.

Table II: Actual Wastage in Cement (Kg) By Method of Chutes in Footing and Pier

Sr No	Description	Cement Theoretical Qnty calculated (kg)	Qnty Ordered calculated (kg)	Excess (kg)	% excess
1	Pier 1	951.54	998.53	46.99	4.94
2	Pier 2	175.92	183.82	7.90	4.49
3	Pier 3	951.54	998.53	46.99	4.94
4	Pier 4	71.01	78.78	7.77	10.95
5	Pier 5	**Work not started**			
6	Pier 6	71.01	81.41	10.40	14.64
7	Pier 7	175.92	183.82	7.90	4.49
8	Pier 8	1070.48	1116.01	45.52	4.252
Total		**3467.42**	**3640.9**	**173.4**	**6.95**

a) Correlation for wastage in cement by method of using chutes

Chutes were used for concreting of **footings and part of pier up to ground level.**

Table III: Data for Analysis of Wastage in Cement by Chutes

Sr No	wastage	DC (1)	RM (2)	A (3)	O (4)	UL (5)	TL (6)	H (7)
1	4.94	4	5	6	3	3	3	4
2	4.49	2	3	5	2	5	4	6
3	4.94	4	4	5	3	2	4	6
4	10.95	2	8	5	4	6	6	9
5	14.64	5	7	6	5	6	5	8
6	4.49	2	9	7	3	6	3	7
7	4.25	3	6	6	3	5	3	9

The output from SPSS software is as shown in Table IV using data from Table III

Table IV: SPSS16 Output for Correlation between Wastage and Design Changes for Method of Chutes

Correlations

		wastage	Design changes
Wastage	Pearson Correlation	1	.407
	Sig. (2-tailed)		.365
	N	7	7
Design changes	Pearson Correlation	.407	1
	Sig. (2-tailed)	.365	
	N	7	7

1. **Correlation between wastage in cement and design changes**

r = 0.407 i.e. correlation is medium strong positive correlation among wastage in cement and design changes factor within fairly average certainty.

2. **Correlation between wastage and record keeping mistakes**

r = 0.405 i.e. correlation is medium strong positive among wastage in cement and recording mistakes factor within fairly average certainty.

3. **Correlation between wastage and absence of authorities during works**

r = -0.105 i.e. correlation is very weak positive between wastage and absence of authorities for method of chutes concreting with high degree of uncertainty.

4. **Correlation between wastage and over-ordering of concrete**

r = 0.925 i.e. correlation is positive and very strong between wastage and over ordering for method of chutes concreting.

5. **Correlation between wastage and unskilled labour**

r = 0.485 i.e. correlation is medium strong positive between wastage and unskilled labour for method of chutes concreting with average certainty level.

6. **Correlation between wastage and Loss due to transport/ application**

r = 0.798 i.e. correlation is strong positive between wastage and Loss due to transport/ application for method of chutes concreting with fair certainty level.

7. **Correlation between wastage and excessive handling of materials**

r = 0.459 i.e. correlation is medium positive between wastage and handling of materials for method of chutes concreting with fair certainty level.

INTERPRETATION:

For method of chutes concreting, over ordering (r = 0.925) has strong positive correlation with wastage and absence of authorities(r= -0.105) has negative correlation with wastage.

b) Correlation for wastage in cement by method of using buckets

Concreting by buckets was done for piers, abutments and pier-caps. The table is arrived at by combining the actual wastage and rating obtained from the questionnaire survey. SPSS16 outputs are generated and then interpreted.

Table V: Actual Wastage in Cement by Buckets in Piers and Pier Caps

Sr No	Description	Cement Theoretical Qnty calculated (kg)	Qnty Ordered calculated (kg)	Excess (kg)	% excess
1	Pier 1	1142.379	1202.584	60.206	5.40
2	Pier 2	1153.069	1201.410	48.341	4.43
3	Pier 3	1254.344	1286.506	32.163	2.56
4	Pier 4	1762.112	1849.353	87.241	4.95
5	Pier 5	**Work not started**			
6	Pier 6	1574.097	1642.056	67.959	4.48
7	Pier 7	1696.564	1727.401	30.837	2.13
8	Pier 8	897.177	924.677	27.499	3.07
Total		**3467.42**	**9743.377**	**240.35**	**Avg: 2.96**

Sr No	wastage	DC (1)	RM (2)	A (3)	O (4)	UL (5)	TL (6)	H (7)
1	5.4	4.0	5.0	6.0	3.0	3.0	3.0	4.0
2	4.43	2.0	3.0	5.0	2.0	5.0	4.0	6.0
3	2.56	4.0	4.0	5.0	3.0	2.0	4.0	6.0
4	4.95	2.0	8.0	5.0	4.0	6.0	6.0	9.0
5	4.48	5.0	7.0	6.0	5.0	6.0	5.0	8.0
6	2.13	2.0	9.0	7.0	3.0	6.0	3.0	7.0
7	3.07	3.0	6.0	6.0	3.0	5.0	3.0	9.0

Table VI: Rating Of Variables for Actual Wastage in Cement by Method of Bucket Concreting

1. Correlation between wastage and design changes

r = 0.168 i.e. correlation is positive and very weak between wastage and design changes for method of bucket concreting with low certainty.

2. correlation between wastage and record keeping mistakes

r = - 0.186 i.e. correlation is negative and weak between wastage and record keeping mistakes for method of bucket concreting with low certainty.

3. Correlation between wastage and absence of authorities

r = - 0.365 i.e. correlation is negative and weak between wastage and absence of authorities for method of bucket concreting with low certainty.

4. Correlation between wastage and absence between over ordering

r = 0.244 i.e. correlation is positive and weak between wastage and over ordering for method of bucket concreting with low certainty.

5. Correlation between wastage and unskilled labour

r = -.066 i.e. correlation is positive and very weak between wastage and unskilled labour for method of bucket concreting with high degree of uncertainty.

6. Correlation between wastage and Loss due to transport/ application

r = 0.432 i.e. correlation is positive and medium between wastage and Loss due to transport/ application for method of bucket concreting with fair certainty.

7. Correlation between wastage and handling

r = -0.193 i.e. correlation is negative and very weak between wastage and excess handling for method of bucket concreting with high degree of uncertainty.

INTERPRETATION:

For method of bucket concreting, transit loss/ application loss (r = 0.432) has medium positive correlation with wastage and absence of authorities (r = -0.365) has negative weak correlation with wastage.

c) Correlation for wastage in cement by method of pumps

The method of concreting by pumps was done for box-girders spans varying from 20m to 25m in span.The SPSS16 software directly give us the output for correlation analysis.

Table VII: Actual Wastage in Cement by Pumps for Spans

Sr No	Description	cement Theoretical Qnty calculated (kg)	Qnty ordered as calculated (kg)	Excess qnty (kg)	% excess
1	Span P1-P2	11725.30	11929.25	203.94	1.74
2	Span P3-P4	2251.61	2292.45	40.84	1.81
3	Span P7-P8	11856.40	12141.51	285.11	2.40
Total		**25833.31**	**26363.21**	**529.90**	**Avg: 1.99**

Table VIII: Rating Of Variables for Method of Pump Concreting and Actual Wastage

Sr No	wastage	DC (1)	RM (2)	A (3)	O (4)	UL (5)	TL (6)	H (7)
1	1.74	4	4	5	3	2	4	6
2	1.81	2	8	5	4	6	6	9
3	2.4	5	7	6	5	6	5	8

1. Correlation between wastage and design changes

r = 0.689, there is medium positive correlation between wastage and design changes in method of pump concreting with fair degree of certainty.

2. **Correlation between wastage and record keeping mistakes**

r = 0.369 i.e. correlation is negative and very weak between wastage and record keeping mistakes in the method of pump concreting with low certainty level.

3. **Correlation between wastage and absence of authorities**

r = 0.995 i.e. correlation is positive and very strong between wastage and absence of authorities in the method of pump concreting with very high degree of certainty.

4. **Correlation between wastage and absence between over ordering**

r =0.91, correlation is positive and very strong between wastage and over ordering in method of pump concreting with high degree of certainty.

5. **Correlation between wastage and unskilled labour**

r = 0.581 i.e. correlation is positive and moderately strong between wastage and unskilled labor in the method of pump concreting with fair certainty level.

6. **Correlation between wastage and transit or application loss**

r = 0.097 i.e. correlation is negative and moderately strong between wastage and Loss due to transport/ application in the method of pump concreting with high degree of uncertainty.

7. **Correlation between wastage and handling**

r = 0.283 i.e. correlation is positive and very strong between wastage and excess handling for method of pump concreting with low certainty level.

INTERPRETATION:

For method of pumped concreting, over ordering (r = 0.910) has strong positive correlation with wastage and absence of authorities (r=0.995) has very strong positive correlation with wastage.

III. Wastage in Reinforcement Steel

The variables that affect wastage in reinforcement steel are:

1. Design changes.(DC)
2. Record keeping mistakes.(RM)
3. Cut pieces that cannot be reused.(CP)
4. Theft.(T)
5. Unskilled labour.(UL)
6. Short supply.(SS)
7. Rework.(RW)

Following table is obtained by the ratings as given in the Questionnaire survey for the above listed factors. Only HYSD bars were used

Table IX: Ratings for Wastage in Reinforcement Steel from Questionnaire Survey.

Sr No	DC (1)	RM (2)	CP (3)	T (4)	UL (5)	SS (6)	RW (7)
1	3	6	3	1	1	2	1
2	2	5	5	1	1	2	1
3	3	7	5	2	1	2	1
4	1	6	3	1	1	1	1
5	1	5	3	2	1	1	2
6	1	4	5	2	2	1	1
7	2	6	4	1	1	1	1

Table X: Wastage in Reinforcement Steel for All Footings, Piers, Pier Caps and Spans

Sr No	Description	Theory qnty (kg)	Actual qnty (kg)	Wastage (kg)	% Wastage
1	8mm	4187.84	4246.22	58.38	1.39
2	10mm	13976.56	14238.28	261.72	1.87
3	12mm	14661.69	14934.26	272.58	1.86
4	16mm	26348.18	26724.09	375.91	1.43
5	20mm	34935.68	35592.82	657.14	1.88
6	25mm	36501.94	37175.98	674.05	1.85
7	32mm	4974.46	5072.23	97.77	1.97
Total Weight In Kg		135170.96	137568.51	2339.16	1.75

1. Correlation for wastage in reinforcement steel

The table taken for analysis is as shown. The same is used for regression analysis for wastage in steel. It is obtained by combining the actual wastage in reinforcement steel and ratings above. SPSS16 is used and the results interpreted.

Table XI: Ratings for Actual Wastage for R/F Steel

Sr no	Wastage	DC (1)	RM (2)	CP (3)	T (4)	UL (5)	SS (6)	RW (7)
1	1.39	3	6	3	1	1	2	1
2	1.87	2	5	5	1	1	2	1
3	1.86	3	7	5	2	1	2	1
4	1.43	1	6	3	1	1	1	1
5	1.88	1	5	3	2	1	1	2
6	1.85	1	4	5	2	2	1	1
7	1.97	2	6	4	1	1	1	1

The output from SPSS software is as shown in Table XII using data from Table XI

Table XII: SPSS16 Output for Correlation between Wastage and Record Keeping Mistakes for Reinforcement Steel

Correlations

		wastage	Design changes
Wastage	Pearson Correlation	1	**-.126**
	Sig. (2-tailed)		.788
	N	7	7
Design changes	Pearson Correlation	**-.126**	1
	Sig. (2-tailed)	.788	
	N	7	7

1. **Correlation between wastage and design changes.**

   r= -0.126, the correlation is negative and very weak with very low degree of certainty for wastage in steel and design changes.
2. **Correlation between wastage and record keeping mistakes.**

   r= -0.246, the correlation is negative and very weak with very low degree of certainty for wastage in steel and record keeping mistakes.
3. **Correlation between wastage and unused cut pieces**

   r= 0.622, the correlation is negative and very weak with very low degree of certainty for wastage in steel and cut pieces.
4. **Correlation between wastage and theft**

   r= 0.449, the correlation is negative and very weak with very low degree of certainty for wastage in steel and theft.
5. **Correlation between wastage and unskilled labour**

   r= 0.187, the correlation is negative and very weak with very low degree of certainty for wastage in steel and unskilled labour.
6. **Correlation between wastage and short supply**

   r= -0.172, the correlation is negative and very weak with very low degree of certainty for wastage in steel and short supply.
7. **Correlation between wastage and rework.**

   r= 0.243, the correlation is negative and very weak with very low degree of certainty for wastage in steel and rework.

INTERPRETATION:

For wastage in reinforcement steel, cut pieces (r = 0.662) has a medium positive correlation with r/f steel wastage.

B) REGRESSION ANALYSIS USING SPSS16

Here an 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.

I. Wastage in cement

a. Regression for wastage in cement by method of chutes

The data table is same as used in correlation analysis of wastage in cement using chutes. Refer table III. The output from SPSS software is as shown in Table XIII

Table XIII: SPSS16 Output for Correlation between Wastage in Cement for Method of Chutes

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	**-2.041**	.000		.	.
	Design changes	**2.479**	.000	.728	.	.
	Record keeping mistakes	**.750**	.000	.392	.	.
	Absence of authorities	**-2.271**	.000	-.415	.	.
	Unskilled labour	**1.752**	.000	.680	.	.
	Transit loss	**1.218**	.000	.340	.	.
	Excessive handling	**-.493**	.000	-.218	.	.

Wastage in chutes method= -2.041 + 2.479(design changes) -0.75 (record keeping mistakes) – 2.271 (absence of authorities) +1.752 (unskilled labour) +1.218(transit loss) -0.493 (handling)

Regression equation for chute concreting for wastage in cement

INTERPRETATION

This equation shows us that design changes are a main factor that affects wastage linearly, i.e. as design changes it affects the wastage 2.479 times. The factor of over ordering is excluded from this analysis.

Verification

From table III, wastage for chutes placement of concrete cement is worked out using rating as given for 5th reading that shows maximum value of wastage (14.64)

Wastage in cement using chutes= = -2.041 – 2.479(5) -0.75 (7) – 2.271 (6) +1.752 (6) +1.218(5) -0.493 (8)

= 14.636~ 14.64

Hence verified.

b. Regression for wastage in cement by method of buckets

The data for this analysis is same as for correlation analysis for wastage in cement using buckets. Refer table VI. The output from SPSS software is formulated in an equation as below.

Wastage in cement using buckets= 93.889 + 3.402 (design changes)+3.631(record mistakes)-16.838 (absence of authorities) +4.102(unskilled labour) – 7.64 (transit loss) -2.153 (handling)

Regression equation for bucket concreting for wastage in cement

INTERPRETATION

The regression analysis for bucket concreting shows unskilled labour (4.102) to be a main factor that affects wastage in cement linearly. The regression coefficient of absence of authorities being very high does not imply that by increasing absence of authorities on site we can reduce wastage to a great extent but instead that if there is no supervision on site that could result in short supply of materials on site(as indicated by the negative sign).

Verification

From table 6, wastage for bucket placement of concrete cement is worked out using rating as given for 4th reading that shows maximum value of wastage (4.95)

Wastage in cement using buckets= = 93.889 + 3.402 (2) +3.631 (8) -16.838 (5) + 4.102(6) – 7.64 (6) -2.153(9)

= 4.946~ 4.95

Hence verified

B.Regression for wastage in cement by method of pumps

The data is same as for correlation analysis of wastage in cement for pumped concrete. Refer Table 8.

Wastage in concrete using pumps= -1.467+ 0.613 (absence of authorities) + 0.023(handling)

Regression equation for pumped concreting for wastage in cement

INTERPRETATION

This regression equation shows us that absence of authorities (0.613) causes wastage in concreting by means of pumps. Other variables like design changes, record keeping mistakes, over ordering, unskilled labour & transit losses are excluded from the analysis. This is due to size of sample set being less than the number of variables (3<7). A larger database will give better accuracy in the results.

Verification

From table 8, wastage for pumped concrete cement is worked out using rating as given for 2nd reading that shows maximum value of wastage (1.81)

Wastage in concrete using pumps = -1.467+ 0.613 (5) + 0.023(9)

= 1.805~1.81

Hence verified

Following table gives the summary of regression analysis for wastage in cement using chutes, buckets and pumped concrete.

IV.WASTAGE IN REINFORCEMENT STEEL

Data is same as used for correlation analysis for wastage in reinforcement steel. Refer table 10. The output is as follow

Table XIV: SPSS16 Output for Regression for Wastage in Reinforcement Steel

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	**1.678**	.000		.	.
	Design changes	**.242**	.000	.923	.	.
	Record keeping	**-.126**	.000	-.521	.	.
	Cut pieces	**.298**	.000	1.263	.	.
	Unskilled labour	**-.428**	.000	-.686	.	.
	Alt short supply	**-.524**	.000	-1.187	.	.
	Rework	**.324**	.000	.519	.	.

a. Dependent Variable: wastage

Wastage in reinforcement steel = 1.678+ .242(design change) -0.126(recordkeeping) +0.298(cut pieces) -0.428(unskilled labour) – 0.524(short supply)+0.324 (rework)

Regression equation for r/f steel

INTERPRETATION

This regression equation identifies rework (0.324) and cut pieces (0.298) to be the main wastage causing factors, which if controlled can lead to effective waste minimization in r/f steel. The factor, theft is excluded from analysis.

For minimizing r/f wastage, more importance is to be given for Bar Bending Schedule (BBS) and in selection of length of bars where cutting of respective bars of varying lengths should be so combined so as to have maximum utilization of total length of r/f bar.

Verification

From table XI, wastage for r/f steel is worked out using rating as given for 7th reading that shows maximum value of wastage (1.97)

Wastage in reinforcement steel =1.678 + 0.242(2) -0.126(6) + 0.298(4) -0.428(1) – 0.524(1) +0.324 (1)

= 1.97 =1.97

Hence verified.

The following table gives us a summary of the factors affecting wastage in cement by chutes, buckets and pumps and also for r/f steel by Correlation & Regression Analysis using SPSS16.

Table XV: Summary of the Results Obtained By Correlation and Regression for Wastage in Cement (By Chutes, Buckets and Pumps) and Wastage in Reinforcement Steel.

Cement wastage								
FOR CORRELATION								
Sr No	**Method of concrete placement**	**Factors causing wastage in cement**						
		Design Changes (1)	**Record Keeping Mistake (2)**	**Absence Of authorities (3)**	**Over Order (4)**	**Unskilled labour (5)**	**Transit Loss (6)**	**Handling (7)**
A	By chutes	0.407	0.405	-0.105	**0.925**	0.485	0.798	0.459
B	By bucket	0.168	-0.186	-0.365	0.244	0.066	**0.432**	-0.193
C	By pump	0.689	0.369	**0.995**	0.910	0.581	0.097	0.283
FOR REGRESSION								
A	By chutes	**2.479**	0.750	-2.271	-	1.752	1.218	-0.493
B	By bucket	3.402	3.631	-16.838	-	**4.102**	-7.640	-2.153
C	By pump	-	-	**0.613**	-	-	-	0.023
Reinforcement steel wastage								
FOR CORRELATION								
		Design Changes (1)	**Record Keeping Mistake (2)**	**Cut pieces (3)**	**Theft (4)**	**Unskilled Labour (5)**	**Alternate Short Supply (6)**	**Rework (7)**
For reinforcement Steel		-0.126	-0.246	**0.622**	0.449	0.187	-0.172	0.243
FOR REGRESSION								
For reinforcement Steel		0.242	-0.126	0.298	-	-0.428	-0.524	**0.324**

In case the whole project was done by chutes concreting the wastage = **-2.041 + 2.479(design changes) -0.75 (record keeping mistakes) – 2.271 (absence of authorities) +1.752 (unskilled labour) +1.218(transit loss) -0.493 (handling)**

=

V. FINDINGS

By method of correlation, over ordering and absence of authorities, transit loss and absence of authorities and handling, over ordering are the factors that have more correlation with total cement wastage by chutes, buckets and pump respectively. Wastage in cement identifies absence of authorities and unskilled labour as main factors for regression analysis for all the three methods of placement of concrete. Wastage in reinforcement steel shows medium positive correlation between cut-pieces and total wastage. For regression, rework and cut pieces are identified as major factors. Through this analysis, we can say that controlling these factors will give us minimum wastage in cement and reinforcement steel for construction of bridge projects. The verification also tallies with the original value which is covered for each of the cases.

VI. INFERENCES

This proves that the use of software matches with the mathematical calculations. Hence it is suggested that the SPSS16 software can be used for bridge projects where we can forecast the wastage in advance based on overall variables for the project. The choice of variables will vary from site to site, Parameters chosen and hence may require suitable adjustments/ modifications for project.

VII. CONCLUSION

From the results obtained from the Correlation and Regression analysis using SPSS16 software, we are able to get the different factors and its % contribution in the overall wastages and if this methodology is applied in the forthcoming construction of bridges, it is quite possible to predict the likely wastages which may occur in the project. The Planning Engineer can take adequate steps in advance to take care of factors which have major contribution in overall wastages such as absence of authorities, excess handling of materials, concrete placement methods for different conditions, etc. This may vary on account of site conditions, number and height of piers, number of pre- stressed girders used in each span, manpower and machinery conditions. This in turn, gives variation in different weightage in the coefficients obtained by the Correlation and Regression analysis. However, this will enable the Engineers to concentrate on those factors and plan the works respectively. The limitation to this project is the small dataset as contractors generally hesitant to reveal quantities of materials used. But, for larger dataset one can predict the coefficients more accurately.

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