APPLICATION AND VALIDATION OF REGRESSION ANALYSIS IN THE PREDICTION OF STABILITY VALUE IN COLD BITUMINOUS EMULSION MIX

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ABSTRACT

Regression analysis is one of the statistical technique which is used for estimating the relationship between various variables. For establishing the relationship between a dependent variable and independent variable regression analysis is used. The Regression analysis with one dependent variable and two or more independent variable is called as multiple regression analysis. It is required to establish a relationship between variables in many civil engineering practical problems. In this study, Marshall Stability test results of cold bituminous emulsion mix are analyzed and the relation between stability values and values of air void with different variables is established. Emulsion content, Aluminum dross, and Cement content these three variables are considered as an independent variable. In this study, total thirty different combinations are analyzed. Comparison between actual stability values and predicted stability values shows that there is very little error and prepared model can be used effectively.

Keywords: Cold Bituminous Emulsion Mix, Marshall Stability Value, Ordinary Portland Cement, Regression Analysis.

I. INTRODUCTION

1.1 Regression Analysis

Regression analysis is a technique that allows finding a functional relationship (model or equation) between dependent variables and independent variables. If only one dependent variable is consideredthen the regression analysis is called univariate regression; while if two or more dependent variables are considered then the regression is called multivariate regression. There are two main types of regression analysis techniques depending upon the number of independent variables the simple linear regression and the multiple linear regression.

1.1.1. Simple linear regression

The simple linear regression has an equation of the form

$$Y = a + bX + E$$

Where Y is the dependent variable, X is the independent variable, a andb are the regression coefficients or regression parameters, and E is an errortoaccountforthediscrepancybetweenpredicteddata.

1.1.2 Multiple linear regression

The multiple linear regression, or univariate multiple regression, is the generalization of the simple linear regression model. The model in multiple linear regression allows more than one predictor variable.

$$Y = a + bX1 + cX2 + \ldots + zXn + E$$

Where Y is the dependentvariable, X_1; X_2; …X_n are the independent variables with n as the number of variables a, b, z are the regression coefficients, and E is an error to account for the discrepancy between predicted data and the observed data.

1.1.3 Coefficient of determination (R^2)

The coefficient of determination R^2can be used for determine the quality of fit of the linear model to a given set of observed data. The value of R^2 varies between 0 and 1. For a multiple linear regression model, the adjusted coefficient of determination is defined in terms of R^2 as

$$R^2adj = 1 - (1-R^2)\frac{n-1}{n-k}$$

Where k is the number of regression coefficients

N. Fumo et al. (2015) used regression analysis technique for prediction of energy consumption in buildings. In this study, both simple as well as multiple regression analysis types were used. The relationship between electricity with different independent variables like temperature, gross domestic product etc. was determined. R. Jafarzadeh et al. (2014) used regression analysis methodology for establishing construction cost models for seismic retrofit of confined masonry buildings. In this study, total 183 cases were analyzed for establishing the regression model. Total four variables were considered viz. total floor area, seismic weight indicator, floor and roof diaphragm type, and mortar quality. David J. Lowe et al. (2006) also used multiple regression analysis for predict construction cost. In this work, total 286 sets of data were analyzed. Gross internal floor area (GIFA), function, duration, mechanical installations, and piling these variables were considered for establishing the model.

1.2 **CBEM**

Cold bituminous emulsion mix (CBEM) is a mixture of aggregates, emulsion and filler at ambient temperature. For improving the coating ability premix water is also used for preparing CBEMs. Now a days for constructing low volume flexible pavements roads use of cold mix increased. Especially in rural road construction cold mix is used as a major material. Use of cold mix has many environmental and ecological advantages. Emission of CO_2 gas can be reduced by using cold mix because in this technology heating of aggregate and bitumen is not required. However, these mixes have some inferior characteristics such as weak earlier-life mechanical properties and high porosity compared with hot mixes. Hence for improving the performance of cold mix it is necessary to use some admixture or additives as a filler. In previous studies (Ahmed et al. 2016, Ali Behnood et. al, 2015) different additives are used as a filler in the cold mix for example, ordinary Portland cement, lime fly ash etc. In all cases it is observed that, there is significant improvement in properties of cold mix. In the case of pavement material, Marshall Stability values and % air voids values this two parameters are deciding factors. Marshall Stability and % air voids % this two factors are depends on many variables for example binder content, filler content etc.

In this work, multiple regression analysis is used for establishing the relationship between stability value and % air voids with emulsion content and filler content. For data analysis, results of Marshall Stability test are used. Two separate models are prepared one for stability value and one for % air voids. Total 30 different combinations were analyzed. Table 1.1 shows details of two models.

Table 1.1:- Details of Regression models.

Model No.	Dependent Variable	Dependent Variables
1	Marshall Stability value	% Emulsion, % ordinary Portland cement, % Aluminum dross
2	% Air Voids	% Emulsion, % ordinary Portland cement, % Aluminum dross

II. MATERIALS

2.1 Aggregates

The aggregates used in this work were crushed basalt. Specific gravity of coarse aggregate is 2.86, Specific gravity of fine aggregate is 2.8 and 2.58 of dust. For determining the gradation of aggregate MORTH specification was used. Figure shows the gradation of aggregate which was selected for present study.

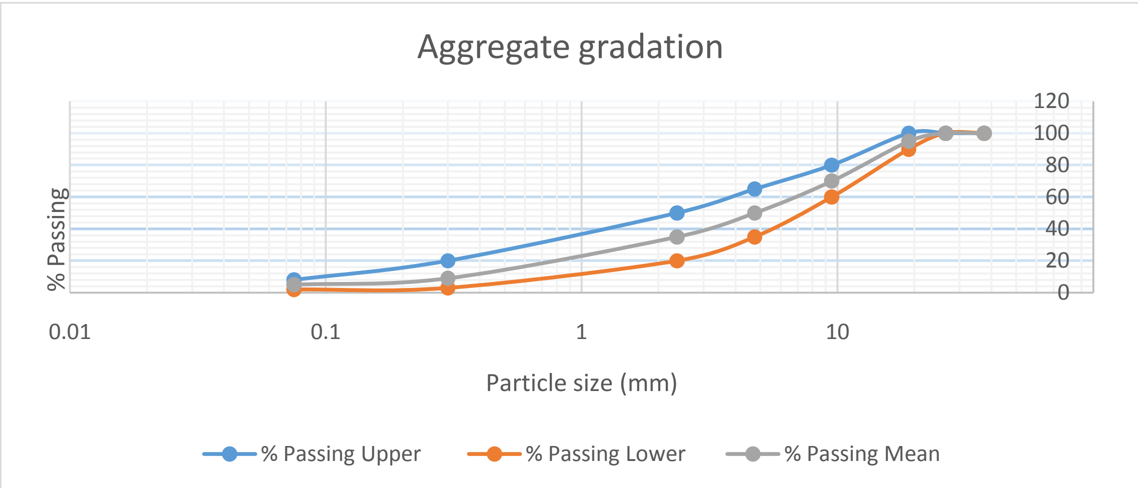

Figure 2.1Aggregate gradation

2.2 Binder

A commercial cationic setting bituminous emulsion was used to manufacture the CBEMs. Particle charge test, Viscosity test, Specific gravity test etc. were performed on emulsion for identify the type and grade of emulsion. All tests were carried out according to IRC: SP: 100-2014 Test results are shown in Table 2.1.

Table 2.1 Test result of Emulsion:-

Sr. No.	Test	Result
1	Residue	0.03%
2	Viscosity	136 sec
3	Coagulation of emulsion	Nil
4	Particle charge	+ve
5	Residue by evaporation	65%
6	Specific gravity	1.01

Results shows that, the grade of emulsion which is used in the study is rapid setting (RS-2). Emulsion was used in 7.5% to 9% depending on the percentage of cement and aluminum dross.

2.3 Cement

53 grade Ordinary Portland cement (OPC) was used for modifying the CBEMs. Cement is replaced with aggregate passing 0.075 mm in 1% to 3% with increment of 1%. Specific gravity cement was 3.15.

2.4 Aluminum dross

Aluminum dross which was brought from Ahmednagar is used as 2nd material for modifying the CBEMs. Aluminum dross is replaced with aggregate passing 0.3 mm and retained on 0.075 mm in 1% to 3% with increment of 1%. Specific gravity aluminum dross was 2.39.

2.5. Sample preparation:-

Different sizes of aggregates are blended to achieve the specified aggregate gradation. About 1100gm of graded aggregates are made wet uniformly with optimum water content. The different percentage of bitumen emulsion, say 5 percent by weight of aggregate, are then added to the aggregates and mixed for 1-2 minutes for achieving uniform binder coating. The mixture is dried for about 1 -2 hours using a fan. The cold mix is then kept in oven at 40°C for 2 hours. The cold mix is then transferred into the Marshall mould with a filter paper on base plate and compacted with 50 blows of Marshall hammer on both faces. Similarly, the Marshall specimen are prepared with optimum water content and bitumen emulsion contents of 5, 6, 7, 8 and 9 percent by weight of aggregates. The Marshall specimens are then extracted from the mould after 24 hours and cured in air oven at 40°C for 72 hours before subjecting to different Marshall Stability Tests. Marshall specimen are subjected to different tests viz. bulk density, stability and flow values. Marshall stability and flow values are determined in dry state at25°C. Different properties of the mixes are determined and other design parameters like voids content, voids filled with binder etc. are calculated.

III. EXPERIMENTAL DATA

3.1 Marshall Test:-

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm per minute. The Marshall stability of the mix is defined as the maximum load carried by the specimen at the specified standard test temperature. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. In the Marshall test method of mix design three compacted samples were prepared for each binder content. All the compacted specimens are subject to the following tests: bulk density determination, stability and flow test and density and voids analysis.

Figure 3.1 Marshall Stability test set up

IV. TEST RESULTS

Following table shows Stability values and % Air voids of different combinations of cold bituminous emulsion mixes.

Table 4.1 Stability and % Air voids values for different mixes.

Sr. No.	Premix Water Content (%)	Emulsion Content (%)	Aluminum Dross (%)	Cement (%)	Air Voids (Vv %)	Stability (KN)
1	3	7.5	0	0	4.36	14.36
2	3	8	0	0	3.37	14.88
3	3	8.5	0	0	2.58	14.10
4	3	7.5	1	0	4.71	17.2
5	3	8	1	0	3.45	15.8
6	3	8.5	1	0	3.35	15.54
7	3	7.5	0	1	4.84	15.16
8	3	8	0	1	4.09	16.1
9	3	8.5	0	1	3.38	15.4
10	3	7.5	2	0	5.57	17.9
11	3	8	2	0	4.19	17.9
12	3	8.5	2	0	4.00	18.10
13	3	7.5	0	2	5.55	15.8
14	3	8	0	2	5.17	17.2
15	3	8.5	0	2	4.01	16.7
16	3	7.5	3	0	6.14	18.30
17	3	8	3	0	4.94	19.80
18	3	8.5	3	0	4.55	17.20
19	3	9	3	0	3.95	18.20
20	3	7.5	0	3	6.07	16.80
21	3	8	0	3	5.69	18.10
22	3	8.5	0	3	4.78	16.20
23	3	9	0	3	3.93	16.20
24	3	7.68	0	0	4.00	14.52
25	3	7.78	1	0	3.99	16.42
26	3	8.5	2	0	3.99	18.30
27	3	8.7	3	0	3.96	17.50
28	3	8.06	0	1	4.00	15.02
29	3	8.55	0	2	4.12	17.20
30	3	9.1	0	3	3.94	15.36

V. DATA ANALYSIS

In this study, total thirty different combinations of cold bituminous emulsion mixes are analyzed. The relation between Stability values with Emulsion content, Aluminum dross content and ordinary Portland cement content is determined. Also, the relation between % air voids values with Emulsion content, Aluminum dross content and ordinary Portland cement content is determined. For determining this relationship multiple regression analysis is used. Microsoft Excel 2013 and Statistical Package for the Social Sciences (SPSS) this two software are used for data analysis.

Regression Statistics	
Multiple R	0.9714 59
R Square	0.9437 34
Adjusted R Square	0.9372 41
Standard Error	0.2126 24
Observations	30

Table 5.1 Data analysis results for % Air Voids model

	Coefficients
Intercept	15.17628441
X Variable 1	-1.474921856
X Variable 2	0.60168698
X Variable 3	0.723493212

Table 5.2 Values of coefficients in % Air Voids model

	Coefficients
Intercept	19.13829967
X Variable 1	-0.541857974
X Variable 2	1.320796129
X Variable 3	0.735516286

Table 5.3 Data analysis results for Stability model

Regression Statistics	
Multiple R	0.855506444
R Square	0.731891276
Adjusted R Square	0.700955654
Standard Error	0.772384312
Observations	30

Table 5.4 Values of coefficients in Stability model

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VI. REGRESSION MODEL

By using results of data analysis two models are prepared.

6.1 % Air voids model:-

% Air Voids = $15.17 - 1.47(X_1) + 0.60(X_2) + 0.72(X_3)$

6.2 Stability model:-

Stability = $19.13 - 0.54(X_1) + 1.32(X_2) + 0.73(X_3)$

Where,

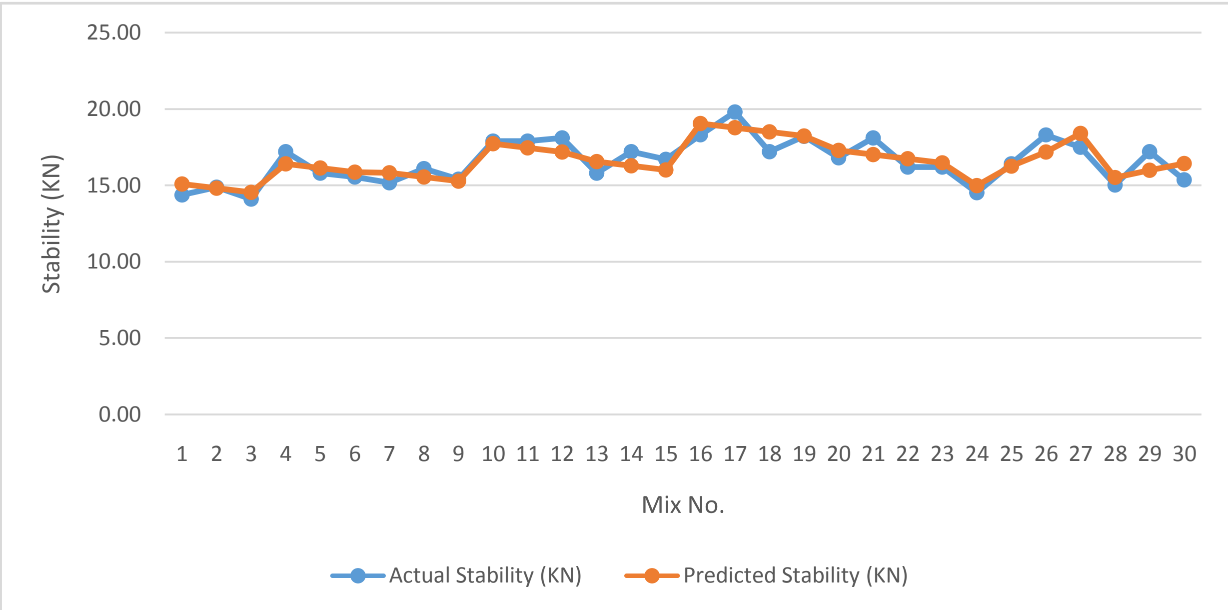
X_1 = % Emulsion content in CBEMs

X_2 = % Aluminum dross

X_3 = % Ordinary Portland Cement.

6.1 Validation of Model:-

Following Figure shows actual stability values and predicted stability values. It is observed that predicted



stability values are coincide with actual stability values.

Figure 6.1 Comparison between actual and predicted stability values.

VII. CONCLUSION

1. Results of Marshall Stability test shows that there is a significant improvement in the stability values after adding the Aluminum dross and ordinary Portland cement.

2. Stability values of cold bituminous emulsion mixes containing aluminum dross have slightly greater values of stability as compare to mix containing ordinary Portland cement. Hence it is possible to replace ordinary Portland cement with aluminum dross in cold bituminous emulsion mixes.

3. Results of R square test shows that there is a strong relationship between stability values and emulsion, aluminum dross and ordinary Portland cement content. Hence results of Marshall Stability test can be used for multiple regression analysis.

4. After comparing actual stability values with predicted stability values it is observed that there is little difference between this two values and mostly predicted stability values coincide with actual stability values.

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