

Prediction of CBR Value of Stabilized Black Cotton Soil use for Road Construction

Ravindra D Nalawade, Pradip D Jadhao

Abstract: Black cotton soils of India are categorized as expansive soil due to Montmorillonite mineral. Replacement of expansive soil with non expansive material, then transport longer distance causes environmental degradation and uneconomical. Stabilization of clay soil is more effective and eco-friendly option when the soil is used for construction purpose. Stabilization is the process of improving the properties of soil by changing its gradation. Expansive soil is with varies additive, makes an improvement of connections between granules and reduces the expansibility and contractility of soil. California Bearing Ratio (CBR) is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. Stronger the subgrade lesser the thickness of road pavement layers, and hence reduction cost of project. In this work attempt has been made to understand to estimate the effect of stabilizer on liquid, plastic limit Maximum dry density and optimum moisture content properties of black cotton soil, in order to determine the suitability of stabilizer in the treatment of black cotton soil for sub grade stabilization in road construction. Main objective of the present study was to develop regression based model for estimating CBR, considering other properties of a soil so that developed models were used to predict the CBR from other properties. It has been observed from lab test stabilizer alter the properties of soil by reduce the plasticity characteristics and improve load carrying capacity. Regression analysis shows that good agreement with experimentation results.

Index Terms: Black cotton soil, Plasticity, Compaction, California bearing ratio, Stastical model. Regression analysis,

I.INTRODUCTION

Black cotton soil is one of expansive soil of world having grey to black colour. Expansive soil have more specific surface area and cation exchange capacity due to clay content (Nalbantoglu 2001,2004). Change in volume large extent due to presence or absence of water content exhibit high swelling pressure on the structure lay above this soil (Osinubi 2000). Stabilization of expansive soil by different stabilizer is one of the better option for minimize the problems of expansive soils. Stabilization is the process of improving the properties of soil by changing its gradation. Expansive soil is with varies additive, makes an improvement of connections between granules and reduces the expansibility and contractility of soil. soil stabilization of black cotton soil by lime is economical alternative (Nalawade and Jadhao 2019). To reduce the volume change behaviour and to improve the strength due to stabilization of expansive soil with various additives stated by many researchers.

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II.SUBGRADE STRENGTH

Subgrade strength is most important parameters in design of road pavement and CBR value is key test to identify strength, stiffness, and resistance properties of subgrade material. (A.Athanasopoulou 2014). Soaked CBR value measures of existence of field condition of pavement (A.Athanasopoulou 2014). The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. Stronger the subgrade lesser the thickness of road pavement layers, and hence reduction cost of project (Pravin Kumar 2013).

As per Indian Road Congress (IRC) codes design of different layers of pavement depends on four days soaked CBR value of laboratory or field soil sample tested for strength of subgrade, which occurs below the pavement layers and act as foundation. For design of flexible pavement, stiffness value of subgrade tested with particular water content and density should be use for deciding overall thickness of pavement (Zhang 2009). Indian Road Congress has specified the design procedure for design of flexible pavement based on CBR values and the pavement thickness related to cumulative number of standards axles to be carried out for different subgrade strength To avoid rutting problem, Preferably the stiff and higher strength of subgrade is required. However, for black cotton soil, low strength, change of volume behaviour and expansiveness creates a problem. It has been seen that for construction roads more attention has been given to finishing top layer and aggregate course and less attention on strength of the sub-grade soil. To enhance the properties for strength and durability of soft soil subgrade require large volume of natural aggregates above the weak subgrade. Soil stabilization of sub-grade which is natural soil layer foundation under the road pavement and enhancement of weak soil subgrade is more beneficial approach than placing huge amount of valuable aggregates in road sub base and base course section to fulfil the structural design criteria. The California Bearing Ratio (CBR) test is performing to measure the pressure required to penetrate soil sample by a plunger of standard area to the pressure necessary to attain an equal penetration of a standard material. to evaluate the probable strength of sub grade, sub base, and base course material for design new construction flexible pavement has to be based on the samples set at optimum moisture content of Proctor compaction.

III.LITTERUE REVIEW

Shailendra Singh (2013). In this paper an attempt has been made to stabilize the soil using lime. Experimental work has been carried out with 4 % and 6 % of lime content.

The experimental work is based on different percentages of lime content in soil on tests for soil Liquid limit, Plastic limit, O.M.C., M.D.D, Bulk density and Dry density, C.B.R. test, Grain size analysis and Swelling pressure. It was found that the engineering properties of black cotton soil substantially improved by addition of lime. Nadgouda, K. A. (2010). Research shows the improvement of the properties of soil, by optimum lime content which was found to be within the range of 3.5% to 4.5%, these values are found to be in good agreement with work carried out by other researchers. Stabilization of black cotton soil occurs, when the hydrated lime reacts with the clay particles and pozzolanic reaction take place causes the plastic nature of the soil decreases and the stiffness of the soil increases. Bozbey, Demir, (2016). The experiment investigation conducted under this work, in which Coarse and fine soil was mixed with 4, 6, 9 % of lime. Test results for 4% of lime at 56 days curing, shows stress is 300 kpa, for 6%, 600 kpa and 9% 1000 kpa coarse soil. Fine grained soil stress is 600 kPa for 4 %, 1600 kPa for 6% and for 9% is 1800 kPa. The result confirmed that soil pulverization level affects the coarse soil pulverization and hence lower strength and elastic modulus. Dilip Kumar Talukdar (2014) shows a relationship between soaked CBR value with MDD, OMC, LL, PL and PI of soil sample collected from different locations Assam, India. Correlation coefficient (R^2) of each of these properties with CBR is determined and their significance is tested by using statistical t- test. Finally a linear multiple regression model was developed for determination of CBR value involving the above mentioned soil parameter. Jadhav, Biradar and Md Khaja Moniuddin (2016) The study was undertaken to develop regression based models to estimate CBR values for coarse and fine grained soils. Many of the linear relationships between index properties and CBR and UCS of the samples were observed using simple and multiple linear regression analysis and also predictive equation estimating CBR from the index properties results of soil. Based on experimental results and SLRA, there is no significant relation exists to predict CBR value from liquid limit and plastic limit. The model developed by SLRA for good correlation can be obtained from the model developed using MLRA by showing R^2 value of 0.72. From the correlation analysis it is clear that, large variation can be observed between experimental and predicted CBR value particularly in case of high compressible clays (CH).

IV. MATERIALS AND METHODOLOGY

Black cotton soil was collected from Pune, Maharashtra. The soil was taken from 1 meter below the ground level. The laboratory tests were carried out to determine the properties of untreated soil sample then stabilizer is added into in the soil and tests were conducted to determine the effect on the plasticity behaviour of soil, compaction behaviour studied through proctor test, and California bearing ratio (CBR) tests conducted to check the enhancement of strength for different percentage of stabilizer. The first part of this research is to estimate the effect of stabilizer on liquid, plastic limit Maximum dry density and optimum moisture content properties of black cotton soil, in order to determine the suitability of stabilizer in the treatment of black cotton soil for sub grade stabilization in road construction. The second phase of the present study was to develop regression based model for estimating CBR, considering other properties of a soil so

that developed models were used to predict the CBR from other properties.

• Liquid limit and plastic limit (IS: 2720 (Part V) –1985)

Liquid limit (LL or WL) is defined as soil changes from plastic to liquid but, the conversion from plastic to liquid actions is gradual over a range of water contents. The plastic limit (PL) The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface at a moisture content where its behavior is plastic, and thread breaks apart at a to a 3 mm diameter.

The plasticity index is the variation between the liquid and the plastic limit and indicates plastic behaviour of soil for range of water contents.

• Standard Proctor Test.

Observation of the correlation between the moisture content and density of soil compacted in a mould as per prescribed by IS 2720, Part VII - 1980. Graphical representation of the dry density to moisture content plot to establish the compaction characteristics. From the peak point of the compaction curve h MDD and OMC is determined.

• California Bearing Ratio

IS: 2720 part 16 (1979) explain the procedure for conducting CBR test was conducted at optimum moisture content of corresponding sample to measure the pressure required to penetrate soil sample by a plunger. The were conducted in soaked condition for 4 days.

V. RESULTS AND DISCUSSION

Experimental lab test results for various percentage of stabilizer content in soil sample as follows.

i) Plasticity Characertersics:

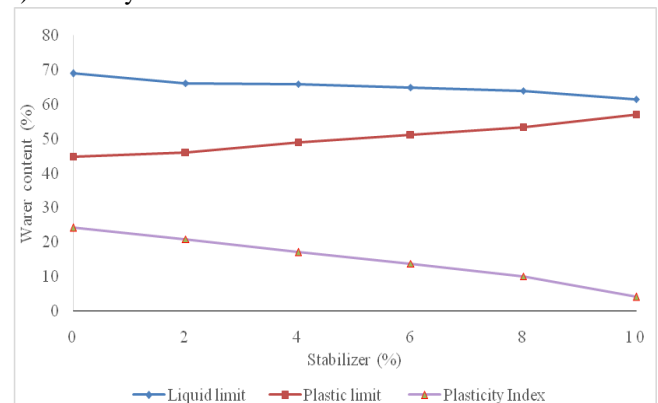


Figure. 1 variations of liquid, Plastic limit and plasticity index

Results indicates that with increase in stabilizer content, Liquid limit increases, Plastic Limit and Plasticity index decreases.

ii) Compaction Characertersics:

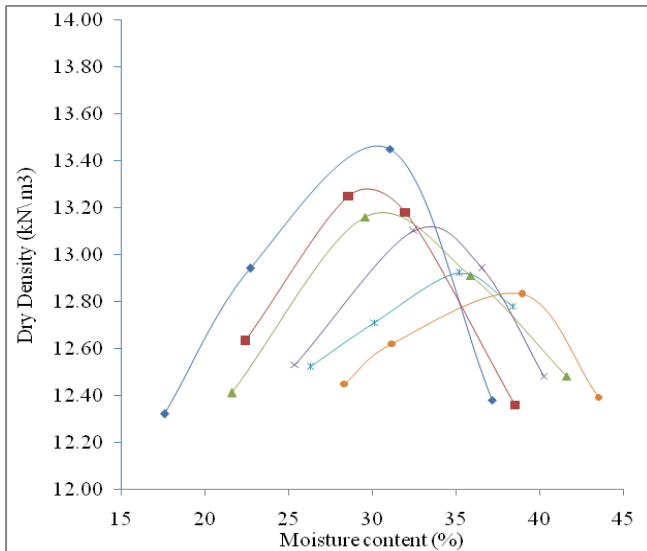


Figure. 2 Compaction curve for various stabilizer content

After compaction test conducted, a plot of dry density and moisture content to establish the compaction characteristics. From the peak point of the compaction curve MDD and OMC is determined. it was found that addition of stabilizer percentage from 2 to 10 % MDD decrease, OMC increases

iii) Strength Characteristics:

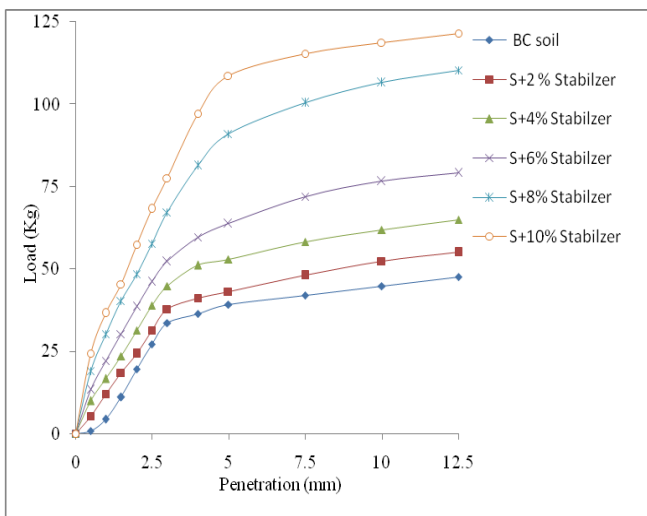


Figure. 3 Load peneretration curve for stabilizer content

CBR tests on the samples were performed at optimum moisture content obtained from Proctor compaction test and sample soaked in water for a period of four days before testing. From the test conducted it was found that addition of stabilizer percentage from 2 to 10 % increses and CBR increases. Strength gain increase by 26.11%, 63.69%, 97.45%, 182.16% and 236.94% for 2,4,6,8,10% respectively.

Follwing table shows variations of properties for different percentage of stabilizer content of stabilized soil.

Table. 1 Properties of stabilized soil

Sl. No	Stabilizer Content (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (%)
1	2	61	57.82	3.21	1.28	39.2	1.98
2	4	60	59.05	1.85	1.27	40.5	2.57

3	6	58.5	61.42	1.30	1.26	41.7	3.10
4	8	57	61.92	0.75	1.25	43.1	4.43
5	10	56	63.11	0.42	1.25	44.3	5.29

Table. 2 % changes in properties of stabilized soil

Sl. No	Geotechnical properties	2 (%)	4 (%)	6 (%)	8 (%)	10 (%)
1	Liquid Limit	-4.13	-4.34	-5.79	-7.24	-10.86
2	Plastic Limit	2.69	9.20	14.33	18.96	27.34
3	Plasticity Index	-13.30	-29.25	-43.22	-58.06	-83.05
4	OMC	6.29	6.29	17.10	20.77	23.44
5	MDD	-0.89	-1.79	-2.23	-3.65	-4.32
6	CBR)	26.11	63.69	97.45	182.16	236.94

After experimental work is done then next part of the work was to develop regression based models for estimating CBR value of black cotton soil, considering other properties of a soil so that developed models would be use to evaluate the CBR value with known other properties of soil. As CBR test is laborious and time consuming and the results, every so often are not accurate of testing of samples in laboratory due to skill of the technicians. To defeat these problems, correlation of CBR value statistically with the liquid limit (LL). Plastic limit (PL), plasticity index (PI), maximum dry density (MDD) and optimum moisture content (OMC) of soil, because these tests are easy and can be done in short period.

• Statistical Model:

A statistical model is a class of mathematical model represents idealize form the data-generating process and illustrate a set of probability distributions.

• Regression Analysis:

Regression analysis is a statistical process for estimating the relations amongst variables and helps to realize how the classic value of the dependent variable alters to the independent variables is diverse, while the other independent variables are said unchanging. Linear regression focus on the restrictive probability distribution of Y given X. Linear models which depend on their unknown parameters are easier to fit than models which are non-linearly connected to their parameters and as the statistical properties of the resulting estimators are easier to determine and has numerous practical uses. Multiple regressions utilized to predict the value of a variable based on the two or more other variables and expansion of simple linear regression to anticipate the value of a variable base on the value of two or more other variables. The variable to predict is known as the dependent variable and the variables to calculate the value of the dependent variable is said the independent variable. Multiple regressions let to decide the overall fit of variance explain of the model and the relative involvement of each of the predictors to the total variance explained.

• SLRA statistical Models to predict the CBR

i) Model summary of CBR V/S liquid limit:

Prediction of CBR Value of Stabilized Black Cotton Soil Use for Road Construction

Table.3 Anova output for liquid limit

Type	DF	SS	MS	F	Significance F
Regression	1	91.71	91.71	32.42	0.004
Residual	4	11.31	2.82	--	---

Table : Coefficients for independent variables

Type	Coeff.	Stand. Error	t Stat	P value	Lower 95%	Upper 95%
Intercept	119.4	19.6	6.06	0.00	64.74	174.09
X Variable	-1.71	0.30	-5.6	0.00	-2.55	-0.87

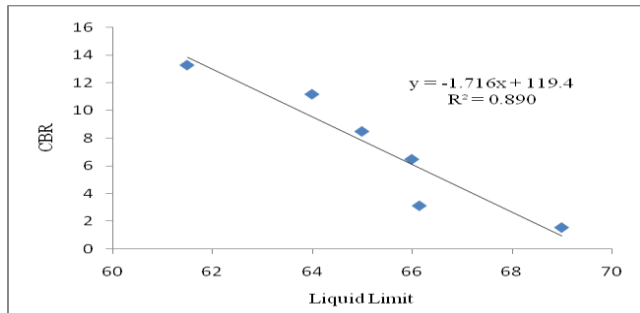


Figure. 4 Correlation between CBR and Liquid limit

ii) Model summary of CBR V/S Plastic limit:

Table.4 Anova output for plastic limit

Type	DF	SS	MS	F	Significance F
Regression	1	101.5	101.5	270.5	7.99 E-05
Residual	4	1.50	0.37	--	---

Table 5 : Coefficients for independent variables

Type	Coeff.	Stand. Error	t Stat	P value	Lower 95%	Upper 95%
Intercept	41.26	2.96	13.9	0.00	49.5	33.03
X Variable	0.96	0.058	16.4	7.99	0.80	1.13

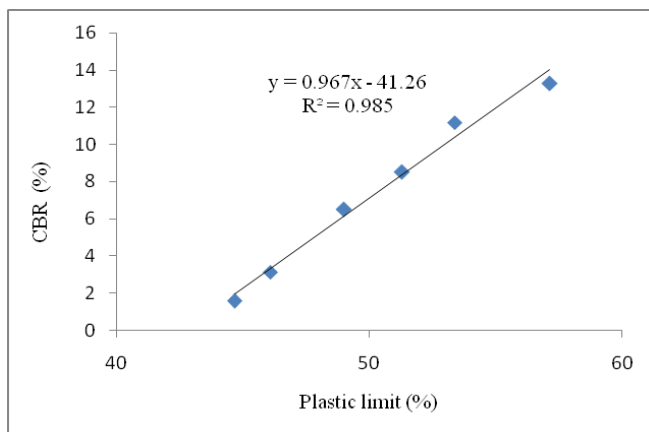


Figure. 5 Correlation between CBR and Plastic limit

iii) Model summary of CBR V/S Plastic limit:

Table.6 Anova output for plasticity index

Type	DF	SS	MS	F	Significance F
Regression	1	81.10	81.10	14.80	--
Residual	4	21.91	5.47	--	---

Table.7 : Coefficients for independent variables

Type	Coeff.	Stand. Error	t Stat	P value	Lower 95%	Upper 95%
Intercept	12.65	1.67	7.55	0.00	8.00	17.30
X Variable	0.28	0.07	3.84	0.01	0.49	0.08

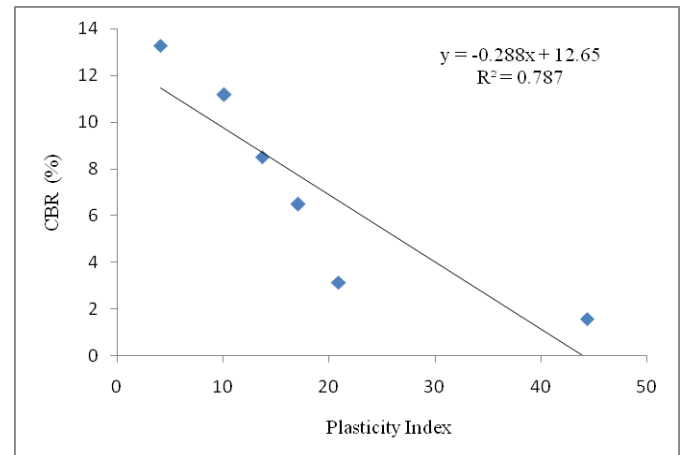


Figure. 6 Correlation between CBR and plasticity index

iv) Model summary of CBR V/S Maximum dry density:
SLRA analysis of correlation between CBR properties of stabilized soil with MDD and OMC as shown below.

Table.8 Anova output for Maximum dry density

Type	DF	SS	MS	F	Significance F
Regression	1	96.70	96.70	61.16	0.00
Residual	4	6.32	1.58	--	---

Table.9 : Coefficients for independent variables

Type	Coeff.	Stand. Error	t Stat	P value	Lower 95%	Upper 95%
Intercept	276.6	34.43	8.03	0.00	181.0	372.20
X Variable	205.7	26.31	7.82	0.00	278.8	132.7

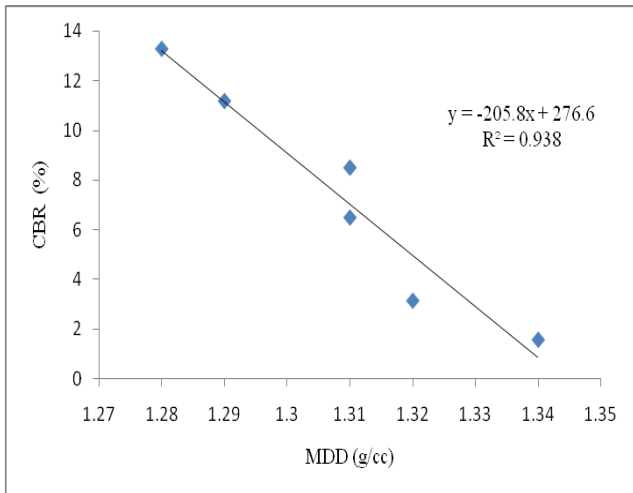


Figure. 7 Correlation between CBR and MDD

v) Model summary of CBR V/S optimum moisture content:

Table.10 Anova output for OMC

Type	DF	SS	MS	F	Significance F
Regression	1	95.53	95.53	50.97	0.00
Residual	4	7.49	1.87	--	---

Table.11 : Coefficients for independent variables

Type	Coeff.	Stand. Error	t Stat	P value	Lower 95%	Upper 95%
Intercept	44.80	7.32	6.11	0.00	65.15	---
X Variable	1.49	0.20	7.13	0.00	0.91	2.07

SLRA analysis developed models representation of correlation between CBR with other properties of stabilized soil like LL, PL, PI, MDD and OMC presents (R^2) values were 0.89, 0.98, 0.78, 0.93, 0.92 respectively indicates very close to 1 indicates very good agreement.

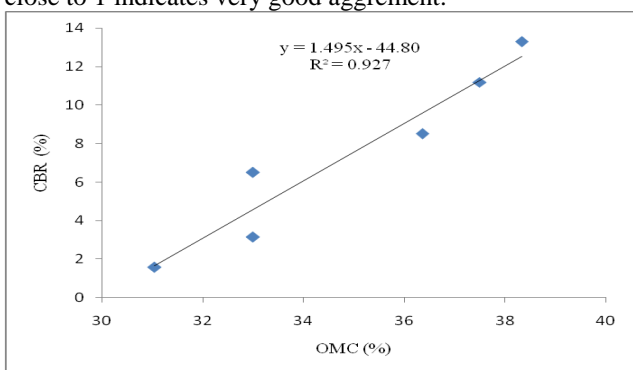


Figure. 8 Correlation between CBR and OMC

Table.12 : R^2 for different soil properties

Properties	LL	PL	PI	MDD	OMC
R^2	0.890	0.985	0.787	0.927	0.938
Level of Significance	0.00	7.9 e-05	0.018	0.002	0.001

From Table 12, it is observed that CBR value has significant correlation with LL, PL, PI, MDD and OMC.

•MLRA statistical Model to predict the CBR

Multiple regressions utilized to predict the value of a variable based on the two or more other variables. Multiple regression technique used to predict the values of California Bearing Ratio and for validating the equation with the help of experimental results. To establish a relation of CBR value of soil with other properties, a multiple linear regression model was developed and the mathematical relationship is developed to predict the CBR value from LL, PL, PI, MDD and OMC shown below.

$$\text{CBR} = 0.9816 \text{ LL} + 0.8921 \text{ PL} - 0.056 \text{ PI} - 67.393 \text{ MDD} + 0.222 \text{ OMC} - 20.11.$$

Table.13: Experimental and Predicated CBR values

Sl. No.	Stabilizer content (%)	Experimental Value (%)	Predicated value (%)	Variations (%)
1	2	13.61	13.608	0.014
2	4	14.71	14.762	- 0.315
3	6	16.36	16.375	- 0.092
4	8	16.45	16.364	0.522
5	10	16.74	16.729	0.065

VI.CONCLUSION

As per experimental results from determination of the various properties of stabilized soil the it has been seen that, improvement of weak properties of soil due to addition of stabilizer content for 2, 4, 6, 8 and 10%, and following conclusions were drawn.

Due to addition of stabilizer content the liquid limit decreases to 4.13%, 4.34%, 5.79%, 7.24% and 10.83% respectively. Plastic limit shows decrease trend like, 2.69%, 9.20%, 14.33%, 18.96% and 27.34% respectively.

As the stabilizer content increases, plasticity index decreasing trend by 13.30%, 29.25%, 43.22%, 58.06% and 83.05% respectively.

After addition of stabilizer, maximum dry density of stabilized soil slight decreases due to light weight of stabilizer material and observed values are 0.89%, 1.79%, 2.23%, 3.65% and 4.32%.

Optimum moisture content shown increases by 6.29%, 6.29%, 17.10%, 20.77%, 23.44% due to more water required for chemical reaction of soil with stabilizer.

California Bearing Ratio (CBR) for stabilized samples increased considerably by addition of stabilizer content and investigation shows that untreated soil value was 1.57 and stabilized soil values are 1.98, 2.57, 3.10, 4.43 and 5.29.

Statistical models developed by regression analysis to predict the CBR value from other properties indicates very good agreement with experimental investigations.

Models summary of correlation between CBR and LL, PL, PI, MDD and OMC presents (R^2) values are 0.89, 0.98, 0.78, 0.93, 0.92 respectively indicates very close to 1.

Multiple linear regression model developed for mathematical relationship to predict the CBR value from other properties indicates very small variations as compare to actual experimental value of CBR tests.

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