Instituting relationship between California Bearing Ratio value and Physical properties of Soil by Regression analysis

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Abstract : In pavement design, the most important parameter used is the California Bearing Ratio (CBR) of subgrade soil. All along the road stretch, we encounter soil differing in its basic properties and CBR strength at different locations. Therefore the thickness of flexible pavement varies with the change in CBR of subgrade soil. As the determination of CBR of soils at different locations in a single project area gets too late since it requires 4 days soaking period. Soil CBR mainly depends on soil basic properties like Gradation, Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI), Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). Additionally we know that CBR of soil has a direct linear relationship with soil property like Maximum Dry Density (MDD).In the present study, an attempt is made to relate the basic properties of various soil to its CBR value. A statistical regression analysis has been carried out and simple as well as multiple linear regression equations have been developed to predict the CBR from its basic properties. This facilitates the pavement designer to arrive at the CBR values in less time, which otherwise requires minimum four days for simulating the worst field condition by soaking. Soil was selected from different locations of Anekal Taluk, keeping in mind to study the variation for different types of soil. Accordingly, the soil selected were classified as per BIS classification, with CBR values ranging from 1 % to 18%

Index Terms **- California Bearing Ratio, Liquid Limit, Plastic Limit, Plasticity Index, Maximum Dry Density, Optimum Moisture Content, Specific Gravity, Regression analysis, SLRA, MLRA.**

I. INTRODUCTION

General

Soil acts as the foundation material for all Civil Engineering structures. Soil, formed as a disintegration of rocks over years of weathering, is very variable and its behavior cannot be predicted commonly over areas. During the construction of roads, Civil engineers experience these complex problems of variability, which if they fail to tackle, may lead to serious failures. Thus the knowledge of soil, its properties and its performance as a road material takes importance in the design and construction of pavements. California Bearing Ratio (CBR) test is used to determine the strength of the subgrade for pavement design. Pavement crust thickness purely depends on subgrade CBR. If the CBR value is less the crust thickness will be more and vice-versa. Crust thickness is inversely proportional to subgrade CBR.

CBR is an empirical method whose test is conducted as per IS 2720 Part - 16. It is conducted at the optimum moisture content which gives the Maximum dry density. The test results are obtained after soaking for 96 hours to simulate the worst condition in field. Thus it becomes imperative for one to wait for a period of 4 days to arrive at the CBR values. However the soil properties determination such as the index properties and compaction results are easier to determine and require less time to arrive at the results. In this background it was felt that, it would be convenient if the CBR of any soil could be predicted knowing its basic properties.

In this work an attempt is made to co-relate the various properties of soil to its CBR strength after studying the basic nature of various soils collected from various regions of Anekal taluk. Many investigators, who have worked in the past, have proposed various mathematical equations to predict the soaked CBR. Using statistical method i.e. by using simple and multiple regressions, an equation is developed thus predicting the CBR in a shorter duration of time.

Objectives of Present Study

a. To characterize the different soil selected based on their index properties.
b. To determine the inter-relationship between CBR and other properties of soil.
c. To compare predicted result and laboratory result using existing statistical models.
d. To develop simple and multiple linear regression equations to relate the various properties with CBR strength of soil.

II. LITERATURE REVIEW

1. **Dilip Kumar and Talukadar[12]**

This study was developed based on index properties of soil by using Microsoft Excel software. The soil sample was collected from Nagon district, Assam, India. Totally sixteen type of soil samples were collected in different area. The statistical analysis was done by using simple and simple and multiple linear regression analysis. In this study the analysis done is mainly on t-distribution and variation of level of significance.

He finally concluded that the CBR value of fine grained soil is well significant in OMC, MDD and PI. He also concluded that when CBR value decreases the PI value increases.

CBR = 0.127 LL - 0.1598 PI + 1.405 MDD - 0.259 OMC + 4.618.....Eqn. 1

2. **Yildrim and Gunaydin (2011)[13]**

This equation was developed by using simple linear regression analysis and neural network to estimate the CBR based on grain size analysis, such that % gravel and % fines (75µ) by SLRA. They concluded that as the % gravel increase the CBR also increases and as % of fines decreases the CBR decreases.

CBR = 0.2353 G + 3.0798.....Eqn. 2

CBR = - 0.1805 F + 18.508.....Eqn. 3

3. **Patel Rashmi and Desai M.D[1]**

In this paper, soil samples were collected from Surat region. Two samples each from north zone, south-east zone, south zone, south zone and west zone were collected. The soil consists of sand, clay and silt. These soil samples were tested for MDD, OMC, LL, PI and CBR (soaked and un-soaked) and correlated using Microsoft Excel software. It showed linear trend line between MDD, OMC, PI, LL and soaked and un-soaked CBR. They finally concluded that soaked value has 2.5% standard error and un-soaked value has 3.5% of standard error. So best fit for regression equation were as follows.

$CBR_{unsoaked}$ = 17.009 – 0.0696 * IP – 0.296 * MDD + 0.0648 * OMC.....Eqn. 4

CBR_{soaked} = 43.907 – 0.093 * IP – 18.78 * MDD – 0.3081 * OMC.....Eqn. 5

4. **Ramasubberao G.V and Shivasankar G[3]**

This study aimed at developing regression model for predicting soaked CBR value for fine grained soil based on grain size analysis, LL, PI, MDD and OMC. By simple regression analysis and multiple regression analysis, they studied some range of soils with Gravel = 0 - 24%, Sand = 0 - 40.14%, Silt and Clay = 50 - 100%, MDD = 1.25 - 1.85 g/cc, OMC = 12.35 - 35.4%, LL = 24.6 - 94% and PL = 11.9 - 36%.

Soaked CBR = 0.8 - 5.86%. Microsoft excel was used for developing relationship.

CBR = 0.064 * F + 0.082 * S + 0.033 * G – 0.069 * LL + 0.157 * PL – 1.81 * MDD – 0.061 * OMC.....Eqn. 6

And they finally concluded that SLRA best fit curve MDD. And MLRA is R^2 value 0.92 and the lowest error is 0.97.

III. PRESENT INVESTIGATION

Sample Collection

It is observed that soil of different nature is encountered on a highway alignment which spread over several kilometers. Keeping this in mind, it was found that a wide variation of soil has to be studied in order to arrive at more versatile co-relations which have more application.

Accordingly, five different types of soil samples were selected for the present study. It ranged from fine grained soil to coarse grained soil which was collected from about 1m to 1.5m depth below ground level. Soils selected were spread over various regions of Anekal taluk.

Laboratory Analysis

The list of laboratory tests which were conducted are given below

a. Wet sieve analysis
b. Specific gravity
c. Liquid Limit
d. Plastic Limit
e. Modified Proctor Test
f. California Bearing Ratio (CBR) Test

Statistics Regression Analysis

Regression analysis acts a vital tool in reduction process of any big data. In the present study, Microsoft Excel tool for statistical analysis is used. This analysis consists of two types of regression analysis

1. Simple Linear Regression Analysis (SLRA)
2. Multiple Linear Regression- Analysis (MLRA)

1. Simple Linear Regression Analysis (SLRA)

It is one of the statistics analysis methods where the correlation is between dependent variable (y) with respect to one of the independent variable (x). The present study considers the dependent variable is CBR and independent variables are any of the basic index properties such as LL or P.I or MDD or OMC..

2. Multiple Linear Regression Analysis (MLRA)

It is also statistical analysis method where correlation is between dependent variable with respect to two or more independent variables. Again here, the dependent variable considered is CBR and independent variables are the basic index properties such as LL, PI, MDD and OMC taken together. Following are the important significance tests for co-efficient in a regression model –

a. Standard R^2 Value
b. t - distribution Test
c. F and F - ratio Test
d. p - value
e. Regression coefficient

Laboratory Test Results

The various tests as mentioned above have been conducted for the five soil samples collected and the data has been consolidated as below.

Table 1: Consolidated results of laboratory tests conducted on the nine different soil sample

SAMPLE NO	1	2	3	4	5
GRAVEL, %	2.8	3.0	2.6	5.52	12.4
SAND, %	6.2	45.2	70.7	38.6	53.4
SILT and CLAY, %	91	51.8	26.7	55.88	34.2
SPECIFIC GRAVITY	2.56	2.6	2.63	2.72	2.72
LL, %	49.2	43.1	38.1	34.1	28.2
PL, %	18.6	19.0	20.1	21.5	23.6
PI, %	30.6	24.1	17.7	12.6	4.6
CLASSIFICATION OF SOIL	CI	CI	CI	CL	ML
OMC, %	18.50	12	15.20	13.20	12.10
MDD, g/cc	1.69	1.85	1.82	1.96	1.90
CBR, %	1.81	6.2	8.2	9.15	14.6

IV. DATA ANALYSIS

General

The data as obtained in the laboratory is analyzed statistically to arrive at simple and multiple linear relations which could be useful in predicting the strength of the soil by assessing the basic properties for a variety of soils.

Comparison between Existing Model Result and Experimental Result

Several researchers have worked in this area and based on their study have formulated different equation for predicting CBR from various index and basic properties. In the present section an attempt is made to compare the results obtained experimentally with the existing models as suggested by a few researchers. Out of the various models available the following have been discussed based on the similarity in soil conditions to the present study.

Comparison with NCHRP model

This model was developed by NCHRP in U.S.A. It mainly advises design of rehabilitation and new pavement design. Its correlation is between CBR and index properties of soil. In this equation, mainly percentage of plastic index and percentage of 75µ passing soil are taken as dependent variables.

$$CBR = \frac{75}{1+0.728(w * PI)} \quad \text{.....Eqn.7}$$

Where, w = Percentage of passing 75µ sieve in decimal.

This equation is tested with the values in the present study as obtained in the laboratory, and compared with the actual laboratory results. The following table 2 gives the obtained and Predicted CBR from NCHRP equation.

Table 2: Values of obtained CBR and NCHRP predicted CBR

SAMPLE NO.	Obtained CBR	(NCHRP) Predicted CBR
1	1.81	3.525
2	6.2	7.434
3	8.2	13.193
4	9.15	9.146
5	14.6	34.965

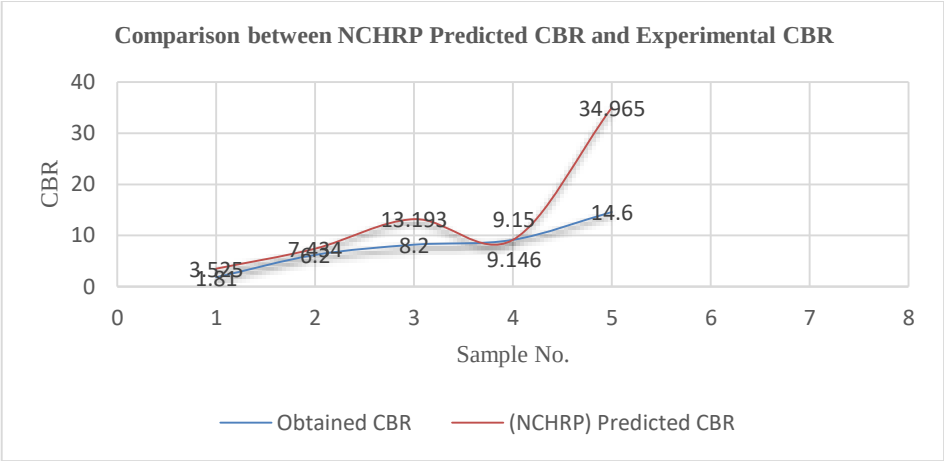

Fig. 1: Comparison between BCHRP Predicted CBR and Experimental CBR

Comparison with Model developed by Yildrim and Gunaydin (2011)

As seen in the model developed by Yildrim and Gunaydin in 2011, the gradation is taken as major contributor and relation is developed using its percentage of gravel and percentage of fines. They have developed a simple liner regression model depending on percentage of gravel and its R^2 value is 0.86 as shown below.

$$CBR = 0.2353\ G + 3.0798 \quad \text{.....Eqn.8}$$

Where, G = percentage coarser fraction.

Table 3: Values of obtained and predicted CBR by Yildrim and Gunaydin

Sample No.	Obtained CBR	Predicted CBR
1	1.81	3.738
2	6.2	3.785
3	8.2	3.691
4	9.15	4.378
5	14.6	5.997

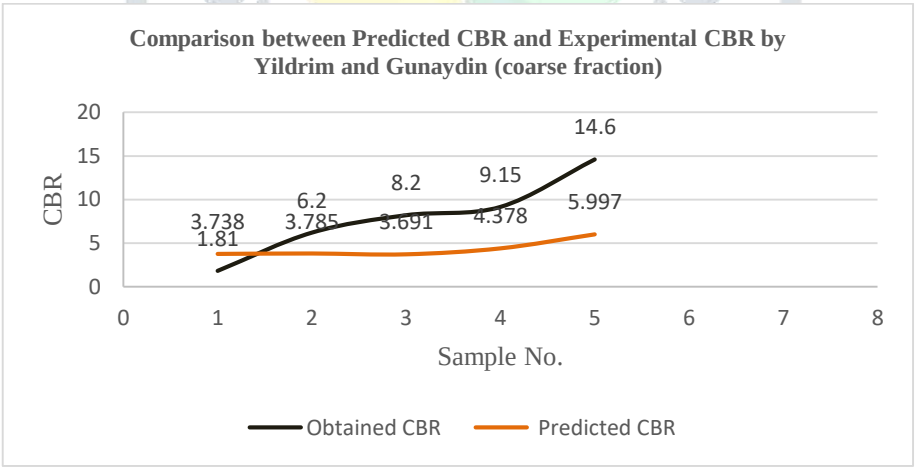

Fig.2: Comparison between Predicted CBR and Experimental CBR by Yildrim and Gunaydin (coarse fraction)

SIMPLE LINEAR REGRESSION (SLRA)

1) Relation between PI and CBR

Table 4: SLRA between PI and CBR

Regression Statistics	
Regression, R-value	0.981
R^2 value	0.964
Adjusted R^2	0.952

Standard error (SE)					1.0184	
Number of soil sample observation					5	
ANOVA						
		Df	**SS**	**MS**	**F**	**F Significance**
Regression		1	83.366	83.366	80.380	0.0029
Residual		3	3.111	1.0371		
Total		4	86.478			
	Coefficient	**SE**	**t - stat**	**P - value**	**Lower 95%**	**Upper 95%**
INTERCEPT	16.123	1.0148	15.888	0.000542	12.89341	19.352
PI	-0.453	0.050	-8.965	0.002928	-0.61475	-0.2926

Table 5: SLRA between Experimental CBR and Predicted CBR using PI

Observation	Experiment CBR	Predicted CBR
1	1.81	2.235
2	6.2	5.189
3	8.2	8.092
4	9.15	10.40
5	14.6	14.036

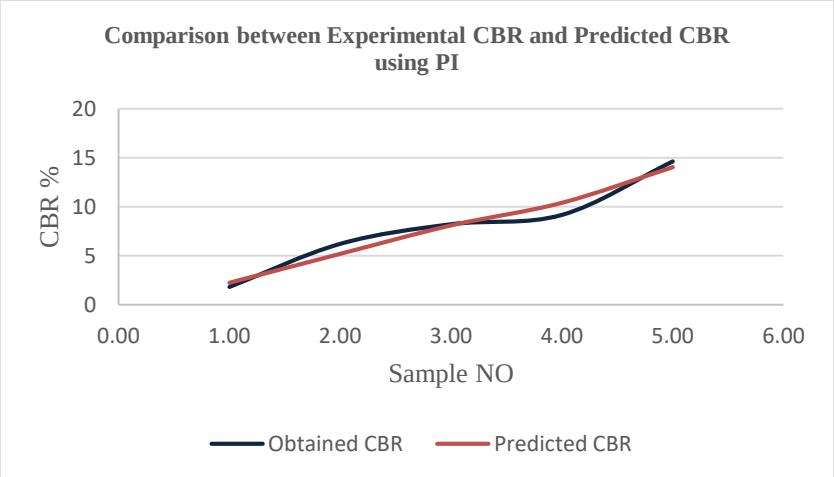

Fig.3: Comparison between Experimental CBR and Predicted CBR using PI

CBR= 16.123 - 0.453* PI.....Eqn. 9

From the above result, the correlation between CBR and PI, R^2 value is 0.964. It indicates that it is the best fitted linear curve. It means that linear relationship is well significant. The standard error is found to be 1.0184.

The degree of freedom v_1 is 1 and v_2 is 3. The 95% of significant level is 10.13. The obtained F value is 80.381. Hence the obtained value is more than tabulated value, Thus it is safe critical region. The F significance is 0.0029, its level of significance is 95% and the F value is <5%. The assumption of confidence level is correct.

Then coming to the student t-distribution concept the coefficient of correlation and PI coefficient is 15.888 and -8.965, the 95% of level of significance tabulated value is 3.182. Hence it is safe in terms of critical region. It means that obtained value is more than tabulated value.

The P value is 0.000542 and 0.002928; it is less than 5%. The critical region of probability value is within the critical region. It means that good strength of relation.

The coefficient of correlation is 16.123 and -0.453; it is within the lower and upper 95%. In the equation above the PI coefficient is inversely proportional to the coefficient of relation.

From the above Fig. 3, the experimental and predicted CBR values are almost in equal or in line. Therefore we conclude that the equation is of good strength.

2) Simple linear Regression between LL and CBR

Table 6: SLRA between LL and CBR

Regression statistics					
Regression, R-value					0.982
R^2 value					0.964
Adjusted R^2					0.952
(SE)					1.008
Number of soil sample observation					5
ANOVA					
	df	**SS**	**MS**	**F**	**F Significance**
Regression	1	83.4253	83.4253	81.9780	0.0028
Residual	3	3.0530	1.0177		
Total	4	86.478			
	COEFFICIENT	**SE**	**t - stat**	**P - value**	**Lower 95%**	**Upper 95%**
INTERCEPT	29.771	2.447	12.165	0.001	21.982	37.559
LL	-0.565	0.062	-9.054	0.003	-0.764	-0.366

Table 7: SLRA between Experimental CBR and Predicted CBR using LL

LL		
Observation	**Experiment CBR**	**Predicted CBR**
1	1.81	1.973
2	6.2	5.4195
3	8.2	8.2445
4	9.15	10.5045
5	14.6	13.838

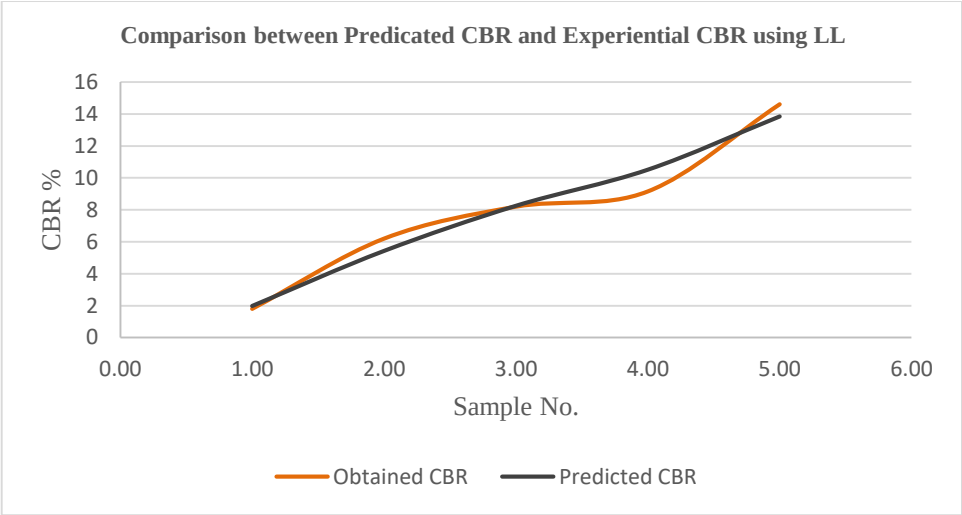

Fig. 4: Comparison between Predicated CBR and Experiential CBR using LL

CBR = 29.771– (0.565* LL).....Eqn. 10

The relation of CBR and LL has R^2 value of 0.964. Hence it is a significant relation. The adjusted R^2 value is 0.964; it satisfies the criteria. It means that linear relationship is well significant

Then, coming to F test, the degree of freedom v_1 is 1 and v_2 is 3. The standard 95% level of significance value 10.13 and obtained F value is 81.9780, the obtained value is more than tabulated value. The F critical regions are safe and F significance 0.0028; it is less than 5%. The assumption of confidence level is correct.

Then student T distribution test, the critical value is 12.165 and -9.054; the standard tabulated 95% significance value is 3.18. The obtained value is more than tabulated value and the critical region is within the limit. The probability value in this relation is 0.001 and 0.003. It is <5%, the level of significance is >95%. This implies good strength in this relation. Observe that the coefficient is within the limit of upper and lower 95%.

In the above Fig. 4, observe that sample No. 2 and 4 is having a very little variation between experimental CBR and predicted CBR. Finally it is concluded that, this relation is satisfactory for all kinds of soil.

3) Simple linear Regression between MDD and CBR

Table 8: SLRA between MDD and CBR

Regression statistics					
Regression, R-value					0.766
R^2 value					0.587
Adjusted R^2					0.449
(SE)					3.452
Number of soil sample observation					5
ANOVA					
	Df	**SS**	**MS**	**F**	**F Significance**
Regression	1	50.721	50.721	4.255	0.131
Residual	3	35.757	11.919		
Total	4	86.478			
	COEFFICIENT	**SE**	**t - stat**	**P - value**	**Lower 95%**	**Upper 95%**
INTERCEPT	-56.929	31.509	-1.807	0.169	-157.20	43.347
MDD	35.207	17.067	2.063	0.131	-19.108	89.521

Table 9: SLRA between Experimental CBR and Predicted CBR using MDD

MDD		
Observation	**Experiment CBR**	**Predicted CBR**
1	1.81	2.570
2	6.2	8.203
3	8.2	7.147
4	9.15	12.076
5	14.6	9.964

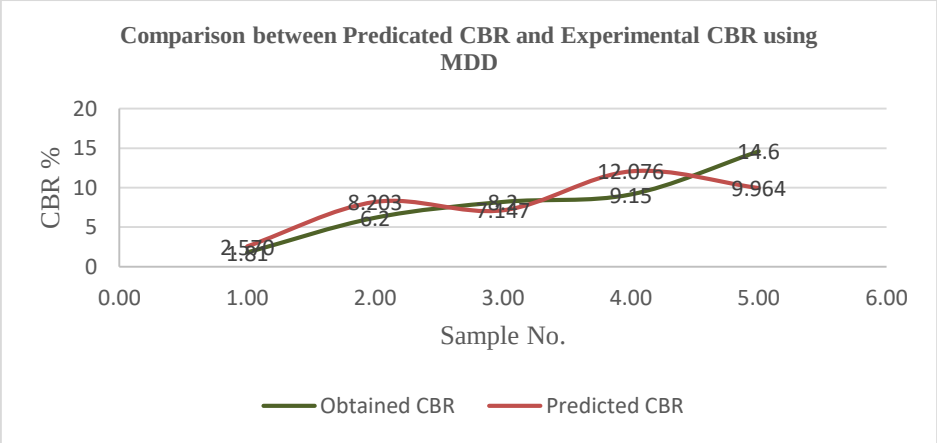

Fig. 5: Comparison between Predicated CBR and Experimental CBR using MDD

CBR = - 56.929+ (35.207* MDD).....Eqn. 11

In this correlation between MDD and CBR, the dependent variable is CBR and independent variable is MDD. The standard R^2 value is 0.587; it is very low when it is compared with PI and LL variables. So the equation is of medium strength.

The variation of predicted CBR result is not linear, and the adjustable R^2 is 0.449. Adjustment of correct and incorrect value is not sufficient. F distribution test has degree of freedom v_1 and v_2 is 1 and 3. F distribution value 4.255 and the standard tabulated value is 10.13. The assumption of confidence level is correct. The F significance is also just safe (0.131>5%). This Coefficient is rejected since it is not safe.

In t-distribution test, the obtained values are -1.807 and 2.063. And the standard tabulated value is 3.182. Hence critical region of correlation coefficient is not safe and MDD critical value is also not safe. p- Value coefficient of correlation is 0.169> 5%. Hence this coefficient is rejected and MDD coefficient is also not satisfactory (i.e. > 5%). The coefficient of correlation is within the lower and upper 95%.

In the above Fig. 5, it denotes that there is more variation in CBR values of sample No.4 and 5. Finally, we strictly conclude that this relation between MDD and CBR is rejected.

4) Simple linear Regression between OMC and CBR

Table 10: SLRA between OMC and CBR

Regression statistics					
Regression, R-value					0.7388
R^2 value					0.5458
Adjusted R^2					0.3944
(SE)					3.6183
Number of soil sample observation					5
ANOVA					
	Df	**SS**	**MS**	**F**	**F Significance**

Regression		1	47.2016	47.2016	3.6053	0.1538
Residual		3	39.2767	13.0922		
Total		4	86.4783			
	COEFFICIENT	**SE**	**t-stat**	**P-value**	**Lower 95%**	**Upper 95%**
INTERCEPT	25.8814	9.5595	2.7074	0.0733	-4.541	56.3042
OMC	-1.2598	0.6635	-1.8988	0.1538	-3.371	0.8517

Table 11: SLRA between Experimental CBR and Predicted CBR using OMC

OMC		
Observation	**Experiment CBR**	**Predicted CBR**
1	1.81	2.574
2	6.2	10.763
3	8.2	6.732
4	9.15	9.25
5	14.6	10.637

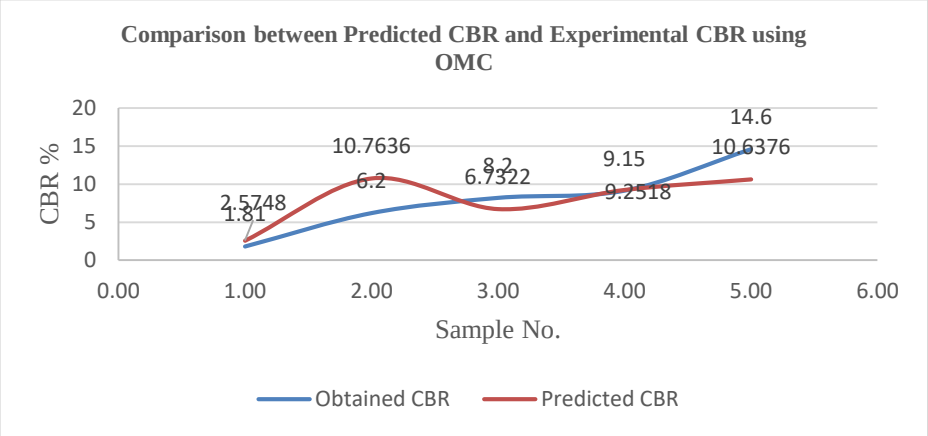

Fig. 6: Comparison between Predicted CBR and Experimental CBR using OMC

CBR = 25.8814- (1.2598*OMC).....Eqn. 12

This relation is Correlation between OMC and CBR. The R^2 value is 0.545and is same as MDD's R^2. The adjusted R^2 is 0.394 is lower than above MDD result.

F-test critical value is 3.605 and standard 95 % significant value is 10.13. Hence it is satisfactory under critical zone. The F significance value is 0.1538>5%. The level of significance is not safe. The t-distribution test value is 2.7074and --1.8988. 95% level of significance tabulated value is 3.19. The null hypothesis is rejected. The critical region is also not safe.

From the probability value, it is observed that it is 0.0733 and 0.1538 which is >5%. The coefficient of regression is in between upper and lower 95 %. Hence this equation can be accepted based on this criteria.

In the above Fig. 6, the comparison between experiment and predicted CBR is done. Except for sample numbers 2 & 5, other results satisfy.

MULTIPLE LINEAR REGRESSION ANAYSIS (MLRA)

1) MLRA between OMC, MDD and CBR

Table 12: MLRA between OMC, MDD and CBR

Regression statistics	
Regression, R-value	0.785
R^2 value	0.616

Adjusted R^2						0.231
(SE)						4.077
Number of soil sample observation						5.000
ANOVA						
		df	**SS**	**MS**	**F**	**F Significance**
Regression		2.000	53.241	26.620	1.602	0.384
Residual		2.000	33.237	16.619		
Total		4.000	86.478			
	COEFFICIENT	**SE**	**t-stat**	**P-value**	**Lower 95%**	**Upper 95%**
INTERCEPT	-26.246	87.140	-0.301	0.792	-401.177	348.685
OMC	-0.546	1.401	-0.389	0.735	-6.573	5.482
MDD	22.768	37.769	0.603	0.608	-139.73	185.275

Table 13: MLRA between Experimental CBR and Predicted CBR using MDD & OMC

MDD & OMC		
Observation	**Experiment CBR**	**Predicted CBR**
1	1.81	2.140
2	6.2	9.329
3	8.2	6.900
4	9.15	11.179
5	14.6	10.413

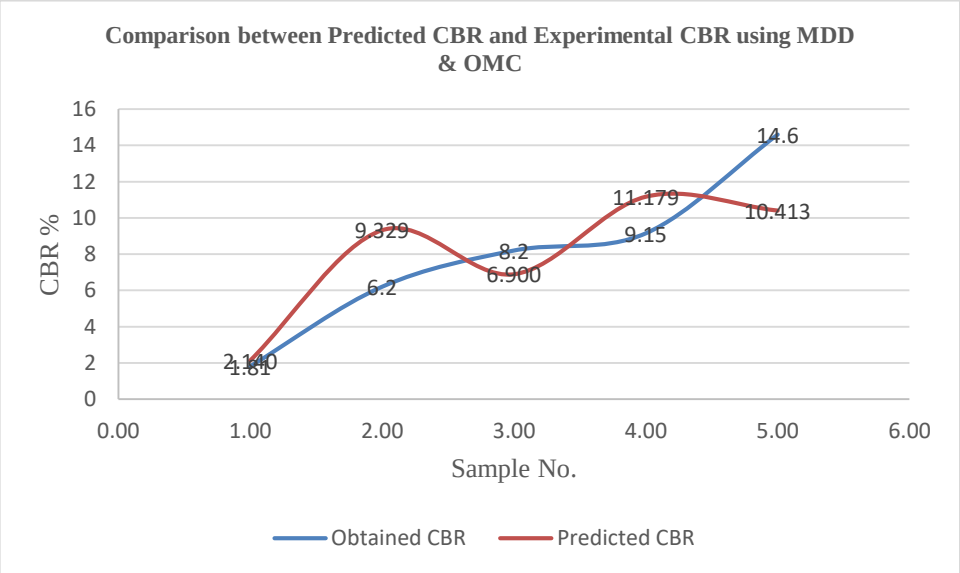

Fig. 7: Comparison between Predicted CBR and Experimental CBR using MDD & OMC

CBR = -26.246- (0.546* OMC) + (22.768* MDD).....Eqn. 13

In multiple linear analysis, dependent variable is CBR and independent variables are MDD and OMC. These are correlated by using Microsoft Excel. The level of significance is 95%. Obtained statistical result of R^2 value is 0.616 which means it is a medium fitted regression curve. The adjusted R^2 is 0.231 which is not a good adjusted variation of CBR result, the standard error is 4.077 is more when compared with simple linear regression analysis.

In this correlation, F-distribution test value is 1.602, the degree of freedom V1 and V2 is 2 & 2 corresponding to 95% level of significance and tabulated value is 19.00.

Since obtained value is less than tabulated value, it is a valid result. The level of significance, 0.384 which is very much greater than 5%, hence this relation is not best fitted.

Then coming to t-statistics, from the above table result of t value is -0.301. t values w.r.t to OMC and MDD are -0.389 and 0.603. In 95% of level of significance, standard tabulated value of degree of freedom is 2 corresponding to 4.303. The obtained t value is less than the tabulated value. Hence the critical region is not safe.

Then, P value is greater than 5%; the regression coefficient is not accepted and this equation has not got good MLRA result. From coefficient in table, OMC has negative value -0.546 and MDD is positive sign, indicating that MDD increases and OMC decreases. It means that the linear relation exists between the independent variables. In this coefficient between lower and upper 95% the coefficient is satisfactory.

From the above Fig. 7, the soil sample 2, 4 & 5 the CBR increases it effect that MDD is almost same but OMC varies, finally conclude that it is not a good fit regression line.

2) MLRA between OMC, MDD, PI and CBR

Table 14: MLRA between OMC, MDD, PI and CBR

Regression statistics						
Regression, R-value						0.999
R^2 value						0.999
Adjusted R^2						0.995
(SE)						0.335
Number of soil sample observation						5
ANOVA						
		df	**SS**	**MS**	**F**	**F Significance**
Regression		3.000	86.366	28.789	256.498	0.046
Residual		1.000	0.112	0.112		
Total		4.000	86.478			
	COEFFICIENT	**SE**	**t-stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	55.763	8.606	6.479	0.097	-53.592	165.118
OMC	-0.594	0.115	-5.161	0.122	-2.058	0.869
MDD	-16.667	3.860	-4.317	0.145	-65.719	32.385
PI	-0.479	0.028	-17.179	0.037	-0.834	-0.125

Table 15: MLRA between Experimental CBR and Predicted CBR using MDD, OMC and PI

MDD, OMC & PI		
Observation	**Experiment CBR**	**Predicted CBR**
1	1.81	1.938
2	6.2	6.196
3	8.2	7.914
4	9.15	9.213
5	14.6	14.700

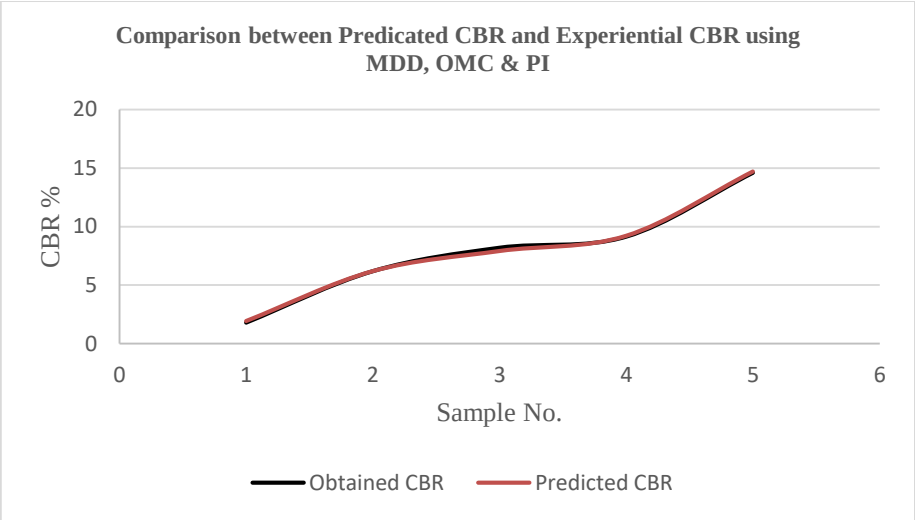

Fig. 8: Comparison between Predicated CBR and Experiential CBR using MDD, OMC & PI

CBR = 55.763-(0.594* OMC) - (16.667* MDD) – (0.479* PI).....Eqn. 14

The correlation between the dependent variable CBR and the independent variable is OMC, MDD & PI. The R^2 value is 0.999, best fitted for regression line and also gives good strength in this equation and adjusted R^2 value is 0.997. In this value, it is very near to 1 which means very good adjusted positive and negative variation of result.

Then coming to the student-t distribution, by just observing the values 6.479, -5.161, -4.317 and -17.179 respectively, corresponding to the 95% level of significance standard tabulated value. The degree of freedomV_1 is 1 and V_2 is 1 and t-value is 12.706. By just observing MDD and PI, the t-value is less than the statistical table value. The coefficients are rejected.

The F-distribution value is 256.498 with respect to the 95% level of significance. The degree of freedom V_1 and V_2 is 3 and 1 with respect to the tabulated value is 224.58. Since obtained values are greater than the tabulated values, results are satisfactory. The level of significance is 0.046 which is less than 5% is sufficient for F-distribution in this equation.

Then coming to the probability value, observe the coefficient of correlation of MDD and PI value is greater than 5% from the above table. Hence it is not satisfied, but PI probability value is 3.6% which is less than 5%. There is one more criteria called P-value, suppose P-value is between 10-15%, it is weak strength of coefficient. Hence, it is rejected in this PI is having very good strength probability value.

Above Fig.8, the predicted and experimented CBR in all sample result are satisfactory. Finally concluded that it is best fitted for independent variables Of MDD, OMC and PI are accepted in this equation.

3) MLRA between OMC, MDD, LL and CBR

Table 16: MLRA between OMC, MDD, LL and CBR

Regression statistics						
Regression, R-value						1.000
R^2 value						1.000
Adjusted R^2						1.000
(SE)						0.027
Number of soil sample observation						5.000
ANOVA						
		df	**SS**	**MS**	**F**	**F Significance**
Regression		3.000	86.478	28.826	38951.294	0.004
Residual		1.000	0.001	0.001		
Total		4.000	86.478			
	COEFFICIENT	**SE**	**t-stat**	**P-value**	**Lower 95%**	**Upper 95%**

Intercept	74.801	0.752	99.471	0.006	65.246	84.356
OMC	-0.545	0.009	-58.284	0.011	-0.664	-0.426
MDD	-18.840	0.319	-58.969	0.011	-22.899	-14.780
LL	-0.631	0.003	-211.92	0.003	-0.669	-0.593

Table 17: MLRA between Experimental CBR and Predicted CBR using MDD, OMC and LL

MDD,OMC,LL		
Observation	**Experiment CBR**	**Predicted CBR**
1	1.81	1.820
2	6.2	6.199
3	8.2	8.177
4	9.15	9.155
5	14.6	14.609

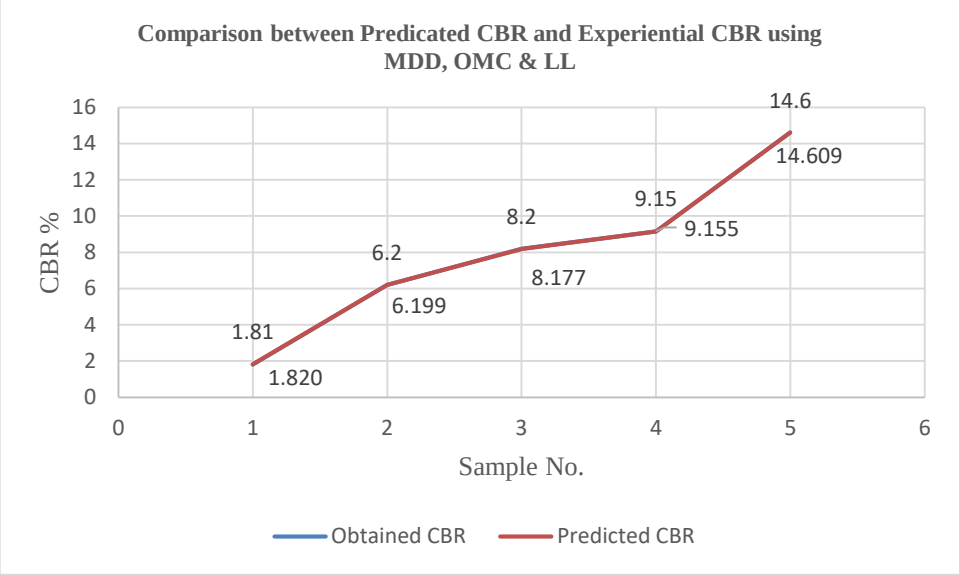

Fig. 9: Comparison between Predicated CBR and Experiential CBR using MDD, OMC & LL

CBR = 74.801- (0.545* OMC) - (18.840* MDD) – (0.631* LL).....Eqn. 15

In this relation, dependent and independent variable is CBR, OMC, MDD and LL. This relation R^2 obtained 1.0, best fitted correlation curve. The adjusted R^2 value is 1.0 which is best adjusted variation of result.

The F-distribution obtained value is 38951.294 in 95% significance of degree of freedom V_1 and V_2 is 3 and 1 with correspondent standard tabulated value is 215.71. Hence, the obtained value is more than the standard tabulated value. The F-critical region lies within safety. The F-significance is 0.004 which is less than 5% and the best fitted equation. The student t-test of the MDD, LL & OMC i.e. -58.969, -211.92 and -58.284 which is more than the tabulated value 12.706. It satisfies the critical region.

P-value is very good strength of coefficient in this equation.

The coefficient arrives between lower and upper 95% which is satisfactory.

Just observe above Fig.9, there is no variation between experimented and predicted CBR values. Finally concluding that from this it is satisfactory best correlation for CBR.

V. DISCUSSION AND CONCLUSION

1. When compared with NCHRP prediction equation for CBR, using index properties obtained in the present study, it did not show much similarity and the difference seemed to be more for coarser fraction. It can hence be concluded that such Regression analysis gives better results for finer fractions as the variability is lesser. The existing NCHRP equation model better fits our laboratory results for finer fractions, $\text{CBR} = \frac{75}{1+0.706\,(w * PI)}$
2. Again when compared to Yildrin and Gunaydin's Models and Dr. Dhilipkumar Talukdar, the variability is found to be more and hence cannot be considered.
3. The mathematical model depends on accurate laboratory results and independent variables.

4. This gives an understanding that for such comparisons the simple regression considering only one parameter such as only gradation to predict CBR may not be justified.
5. It is observed that most of these studies have been limited their findings to arriving at Regression co-efficient (R^2-value) and based their conclusions on that which seems to be inappropriate. Hence in the present study, after the equation has been developed, more statistical analysis has been dealt with by way of statistical analysis and significance tests for the co-efficient.
6. Based on the t-test and F-test values, it is seem that the more than Simple linear equations developed, the MLRA is more accurate with the experimental values. Hence the Multiple linear Regression equations developed in the present study relating OMC, MDD, PI with CBR is more appropriate and can be effectively used.
7. Also the MLR equations relating MDD, OMC and LL with CBR seems to be close to the experimental results.
8. However, the last equation developed in the present study relating MDD, OMC and LL gives the most accurate results when validated with the laboratory results. In MLRA, best fit predicted CBR equation is CBR = 74.801- (0.545* OMC) - (18.840* MDD) – (0.631* LL). The R^2 value is 1.0, this result is equal to laboratory results. Hence these equations can be conveniently used for predicting CBR. This indeed gives the CBR instantaneously which is practically very useful and saves lot of time and effort.

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