Correlation of CBR with Index Properties of Soil of Kolar Region (Bhopal) using Regression Analysis

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ABSTRACT*: In design of roads and pavements, engineering properties of soil plays a very important role. These properties are valid and most of the cases unpredictable, because soil is a heterogeneous material. The engineering properties such as CBR, Liquid Limit, Plastic Limit, Maximum Dry Density, Optimum Moisture Content, Plasticity Index and % Fines are being tested and measured for different properties of roads constrictions, which is a very time consuming and depending on laborites.*

In view of developing a well proven co relation between these dependents and independents properties of soil, it will be good for engineers to make immediate decision based on very few properties. This research is of correlation of CBR with index properties of soil is specially of a Bhopal Kolar Region.

The findings of the research are tested on regression method using NCSS software, where it is found that in case of simple linear regression analysis, six model equation have been evolved and in case of multiple regression three model equation have been evolved. All these are proven on the regression value not below then 0.8.The model equation are matched with other researches being done.

The outcome of the research is proven on mathematical modeling using practically determent value of CBR, Liquid Limit, Plastic Limit, Maximum Dry Density, Optimum Moisture Content, Plasticity Index and % Fines.

KEYWORDS: **CBR CORRELATION, INDEX PROPERTY OF SOIL, REGRESSION ANALYSIS, LINEAR AND NON LINEAR, PROPERTIES OF SOIL OF KOLAR.**

1. INTRODUCTION

During the recent past, majority of the countries including India, have their primary focus on Infrastructure advancement and development. As a result, the focus was mainly on the development of road network as it is well established that economy follows the lines of transportation. Mobility and accessibility have been targeted simultaneously while improving the urban as well as rural road networks. Improving economy, ever increasing population coupled with ever increasing demand for the personalized travel has resulted in increased stress on the road networks.

The popular option of flexible pavement uses CBR as the sole soil parameter for design. It is well known that the CBR indicates the comparative strength of sub grade soil to the strength of standard crushed rock expressed as percentage value. CBR is usually sensitive with regard to the soil compaction levels and the care with which the sample is prepared and the test is being carried out. The test procedure is being laid out by the California Division of Highways during 1930 and still being used now.

As like CBR value indicates the strength of soil, the index properties of soil indicates the basic engineering characteristics of the soil. In other words it can be said that Index properties are those properties which are not are indicative to the engineering properties of soil such as bearing capacity, shear strength, permeability, slope stability, compressibility properties and so on.

There is innumerable variety of natural soil. So, for easy classification, the soils which exhibit similar behavior are grouped together. There are number of methods to identify a soil type. These methods can either be field method or laboratory method. The type of soil diagnoses by field methods is approximate identification. For accurate in0iu the laboratory certain test are carried out in order to classify the soil. These tests are known as classification tests. The numerical results obtained on the basis of such tests are termed as Index Property of soil.

Index properties are divided into two types:

- Soil Grain Properties.
- Soil Aggregate Properties.

These properties can be determined from disturbed samples while the soil aggregate properties depend on the soil history, mode of soil formation and in general soil structure.

Since, sometime engineering structures are constructed on undisturbed deposits of soil. Hence soil aggregate properties are of great engineering importance.

It is with this background that the present study was taken up for a particular soil which is a non-expansive fine grained soil. Specific reasons for taking up this study have been explained in the following section.

In contrast with CBR test, the tests like Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI), Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are less challenging and proven to be correlated with CBR of the given soil.

In view of accurate and optimum analysis of CBR in correlation with engineering properties of soil, regression method is considered best to evaluate the engineering properties of soil.

1.1 Description of StudyArea

The area selected for this research work is Kolar region (Bhopal), India. This is one of the densest areas and future scope of development is quite high. The present infrastructure of this area requires a lot of improvement. The locations selected for this research work has been spotted in the map.

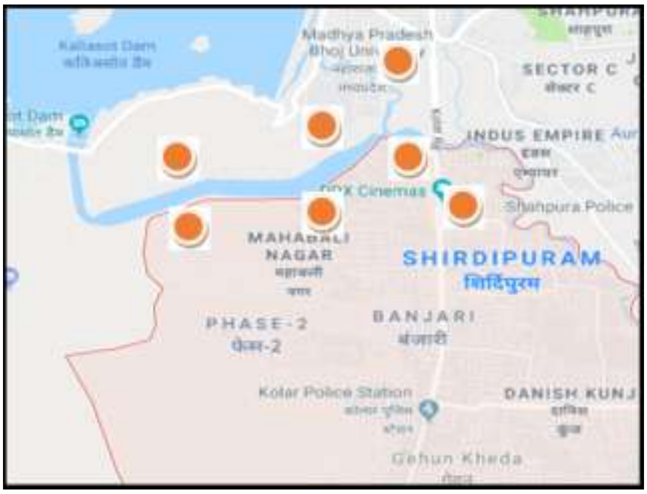

Fig-1: Site Selection Map-1

1.2 Research Objectives

The objectives of the research work presented in this dissertation concern itself with

- The study of index and engineering properties for classification of the soil at the Kolar Region (Bhopal).
- To develop correlation between California Bearing Ratio (CBR) and the Soil Index properties for a particular soil collected from Kolar Region, (Bhopal).
- Evaluating new model and equations by using regression method for prediction of CBR and index properties.

1.3 STUDY SCOPE

- This research work is limited to establishing the correlation between Index properties and CBR of the soil collected from Kolar Region, Bhopal of about 12-15 km area only.

2. METHODOLOGY

Majority of Indian highways are flexible in nature by choice. As a principle, majority of the flexible pavement design philosophies use sub-grade California Bearing Ratio (CBR) as the sole soil related parameter for design. The California Bearing Ration (CBR) parameter is considered empirical in nature and represents the relative penetration resistance offered by the soil at a standard penetration value is the corresponding penetration resistance offered by the standard crushed aggregate particles. CBR varies with respect to the moisture levels in the soil, density at which it is being tested as well as the type of the soil in general.

It is well known that CBR test is tedious and needs time and resources to conduct the test. Small changes in moisture and compaction levels might affect the CBR drastically. In addition, the margin of error in conducting this test, either in lab or in the field, is very small. Simple Index and other properties like Liquid Limit (LL), Plastic Limit (PL), Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), if correlated with CBR might help the designed with more accurate and consistent CBR value being obtained for further use in pavement design as these tests are found to be relatively simple, less tedious with better reproducibility and less costly too.

It is with this background that the current research activity is taken up to correlate the above mentioned properties with CBR value of the sub-grade with multiple samples being taken to improve the reproducibility.

The steps of methodology adopted is been mentioned below;

- Identification of the research area & its objectives.
- The review of literature of the past researchers with gaps being identified for further study.
- Site area selection for the research study.
- Collection of soil samples.
- Experimental work done for the research work and its outcomes.
- Validation of results.
- Establishment of the correlation between index properties of the soil and the CBR.
- Validation of the model developed.
- Conclusion and recommendation.

After the thorough review of literature and experiments performed on the samples, the correlation of CBR with soil index properties is established by using regression analysis. The software used for the evolution of model and equation with the help of regression analysis is NCSS DATA ANALYSIS.

3. Experimental Works

All laboratory tests are performed with Indian Standards and precautions are taken while performing the test to maintain the validation of outcomes.

3.1Soil Sample Collection

The area has been surveyed visually to different locations and seven places were identified on the basis of their future scope of development and need of infrastructure development. The disturbed soil samples are collected for laboratory investigation.

3.2PREPARING THE SOIL

The samples retrieved from the site contain lot of waste material and impurities which will affect the test results and the motive of soil testing will be completely failed. So, it is necessary to prepare the soil before testing. The preparation of soil involves air drying, pulverizing and oven drying.

3.3 LABORATORY TEST

The samples retrieved from the concerning site area are kept in laboratory for different test by which the soil index properties and CBR values can be obtained. The laboratory test performed is generally divided into two categories:

(i) Index Properties Test

(ii) Engineering Properties Test.

3.3.1 INDEX PROPERTIES TEST

As a construction material, soil behaves very differently comparing with other construction materials like steel and concrete as these materials are manufactured with proper specification and control. But soil is formed naturally so the factors involved in the formation of soil vary a lot.

The properties of soil fully depend on the type of formation, loading history, structure and composition. Soil possesses the variable nature so, it is necessary to examine the index properties which are essential to evaluate the engineering properties of soil like shear strength, compressibility, permeability, compaction characteristics before using it as a construction material.

3.3.2 ENGINEERING PROPERTIES TESTS

The engineering properties of soil help in determine the strength. These properties can be determined by performing either field or laboratory test. For testing the strength Tri-Axial Test, CBR Test, Unconfined Compressive Strength Test, Modified Compaction Test can be performed in laboratory.

4. Results and Discussion:

The results of different tests performed on different soil samples retrieve from various locations were analyzed and correlated with CBR using Single Regression Analysis and Multiple Regression Analysis. The software used for the evolution of model and equation with the help of regression analysis is NCSS DATA ANALYSIS.

4.1 Single Linear Regression Analysis:

The single linear regression analysis is performed for predicting the value of one dependent variable by using one independent variable. In this research work the dependent variable is CBR value of soil and liquid limit, plastic limit, plasticity index, maximum dry density, optimum moisture content and % fines are independent variables. Different combinations prevail for adopting best correlations:

Model 1: Correlation between CBR and Liquid Limit (L.L.)

The equation evolved after correlating CBR with Liquid Limit is expressed by the following linear equation with the correlation coefficients:

CBR = (11.7464) + (-0.1346 * L.L.)

R^2 = 0.9238, Soil Sample (n) = 7

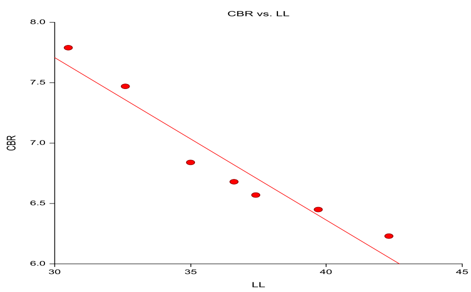

Fig-2: Correlation of CBR with L.L

Model 2: Correlation between CBR and Plastic Limit (P.L.)

The equation evolved after correlating CBR with Liquid Limit is expressed by the following linear equation with the correlation coefficients:

CBR == (12.5380) + (-0.1948 * P.L.)

R^2 = 0.9344, Soil Sample (n) = 7

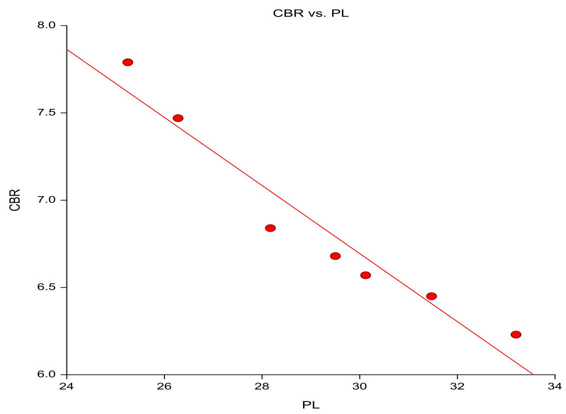

Fig-3: Correlation of CBR with P.L.

Model 3: Correlation between CBR and Plasticity Index (P.I.)

The equation evolved after correlating CBR with Plasticity Index is expressed by the following linear equation with the correlation coefficients:

CBR = (9.8860) + (-0.4225 * P.I.)

R^2 = 0.0174, Soil Sample n = 7

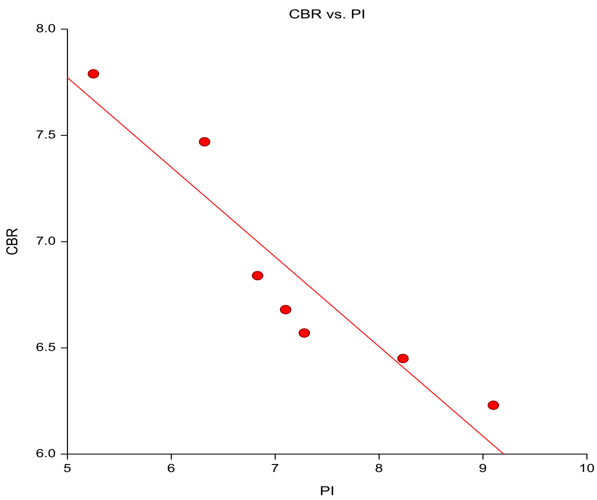

Fig-4: Correlation of CBR with P.I.

Model 4: Correlation between CBR and Maximum Dry Density (M.D.D.)

The equation evolved after correlating CBR with Maximum Dry Density is expressed by the following linear equation with the correlation coefficients:

CBR = (-29.4669)+ (23.3408) MDD

R^2 = 0.9715, Soil Sample (n) = 7

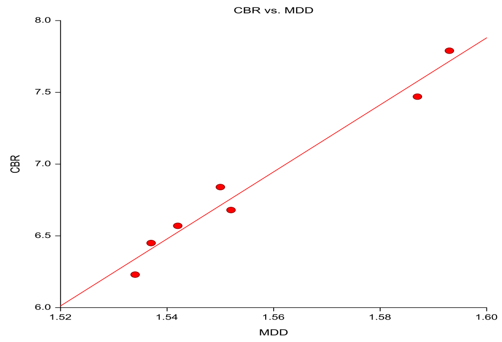

Fig-5: Correlation of CBR with M.D.D

Model 5: Correlation between CBR and Optimum Moisture Content (O.M.C.)

The equation evolved after correlating CBR with Optimum Moisture Content is expressed by the following linear equation with the correlation coefficients:

CBR = (13.0634) + (-0.4617) OMC

R^2 = 0.3114, Soil Site Sample (n) = 7

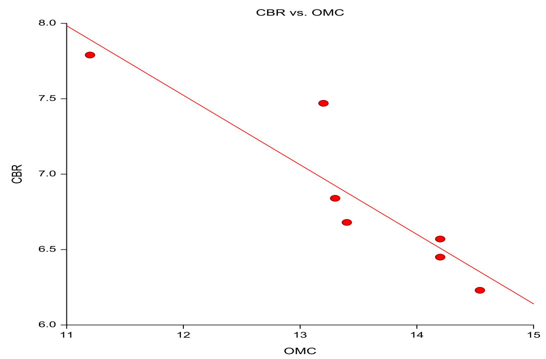

Fig-6 Correlation of CBR with O.M.C.

Model 6: Correlation between CBR and % Fines:

The equation evolved after correlating CBR with Liquid Limit is expressed by the following linear equation with the correlation coefficients:

CBR = (49.348) + (0.4339 * % Fines.)

R^2 = 0.9016, n = 7

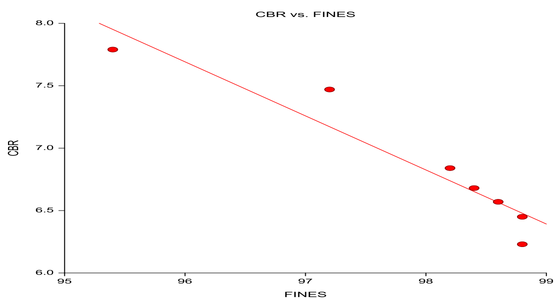

Fig. 5.6 Correlation of CBR with % FINES

4.2 Multiple Linear Regression Analysis:

The multiple linear regression analysis is performed for predicting the value of one dependent variable by using one or more than one independent variable. By performing several attempts with multiple regression analysis on different combinations of index properties to correlate with CBR, three suited models are evolved. The models are shown below:

Model A: Correlation between CBR with PL and PI:

The equation evolved after correlating CBR with Plastic Limit and Plasticity Index is expressed by the following linear equation with the correlation coefficients:

CBR =13.234019059677 + 0.125268407635355 * PI - 0.249450136400544 * PL

R^2 = 0.9020, Soil Sample (n) = 7

Model B: Correlation between CBR with LL, PL and OMC:

The equation evolved after correlating CBR with Liquid Limit Plastic Limit and Optimum Moisture Content is expressed by the following linear equation with the correlation coefficients:

CBR = 14.9487520391241 + 0.314713663412211 * LL - 0.575824630736887 * PL - 0.203291575105211 * OMC

R^2 = 0.9669, Soil Sample (n) = 7

Model C: Correlation between CBR with LL PI and MDD:

The equation evolved after correlating CBR with Liquid Limit is expressed by the following linear equation with the correlation coefficients:

CBR = -16.5156819186858 - 0.038800108815463 * LL - 0.0264688148664365 * PI + 16.0463729595013 * MDD

R^2 = 0.9889, Soil Sample (n) = 7

5. Validation of Developed Correlation:

The results obtained by performing laboratory tests and by adopting correlation for prediction of CBR are mentioned below:

Sample No.(n)	% Fines	L.L. (%)	P.L.(%)	M.D.D.(g/cc)	O.M.C(%)	ACTUAL CBR	PREDICTED CBR
S1	97.2	32.6	26.28	1.587	13.2	7.47	7.54
S2	95.4	30.5	25.25	1.593	11.2	7.79	7.74
S3	98.8	39.7	31.47	1.537	14.2	6.45	6.60
S4	98.4	36.6	29.5	1.552	13.4	6.68	6.81
S5	98.2	35	28.17	1.55	13.3	6.84	6.85
S6	98.6	37.4	30.12	1.542	14.2	6.57	6.59
S7	98.8	42.3	33.2	1.534	14.54	6.23	6.22

Table 1: Validation of Actual CBR & Predicted CBR

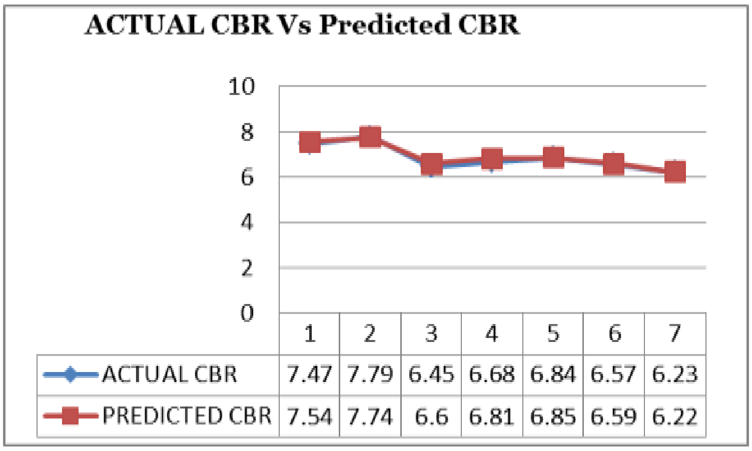

Fig. 5.7 Actual CBR with Predicted CBR

6.1 Conclusions

This research work is conducted in order to evolve a localized correlation between CBR value and index properties of soil of Kolar Region(Bhopal). Accordingly, the required laboratory tests were conducted on the soil samples collected from seven different locations of Kolar region. Using the single and multiple regressions on obtained test results a correlation has been developed that helps in predicting CBR value in terms of %Fines, L.L, P.L., P.I, M.D.D, O.M.C.

The suitability of developed correlation is also checked by conducting a separate control test results. From the results of this research work following conclusion can be made:

1. Six single linear regression models has been generated, where CBR value is dependent variable and Liquid Limit (L.L.), Plastic Limit (P.L.), Maximum Dry Density (M.D.D.), Optimum Moisture Content (O.M.C.), Plasticity Index (P.I.) and %Fines are independent variable.
2. The each single regression model equation has been discussed under:

Model 1: Correlation between CBR and Liquid Limit (L.L.):

CBR = (11.7464) + (-0.1346 * L.L.)

R^2 = 0.9238, Soil Sample (n) = 7

Model 2: Correlation between CBR and Plastic Limit (P.L.):

CBR = (12.5380) + (-0.1948 * P.L.)

R^2 = 0.9344, Soil Sample (n) = 7

Model 3: Correlation between CBR and Plasticity Index (P.I.):

CBR = (9.8860) + (-0.4225 * P.I.)

R^2 = 0.0174, Soil Sample n = 7

Model 4: Correlation between CBR and Maximum Dry Density (M.D.D.):

CBR = (-29.4669) + (23.3408) MDD

R^2 = 0.9715, Soil Sample (n) = 7

Model 5: Correlation between CBR and Optimum Moisture Content (O.M.C.)

CBR = (13.0634) + (-0.4617) OMC

R^2 = 0.3114, Soil Sample (n) = 7

Model 6: Correlation between CBR and % Fines:

CBR = (49.348) + (0.4339 * % Fines.)

R^2 = 0.9016, Soil Sample (n) = 7.

3. After several multiple regression attempts to establish a correlation between CBR with Index properties three best suited models have been developed.

Model A: Correlation between CBR with PL and PI:

CBR =13.234019059677 + 0.125268407635355 * PI - 0.249450136400544 * PL

R^2 = 0.9020, Soil Sample (n) = 7

Model B: Correlation between CBR with LL, PL and OMC:

CBR = 14.9487520391241 + 0.314713663412211 * LL - 0.575824630736887 * PL - 0.203291575105211 * OMC

R^2 = 0.9669, Soil Sample (n) = 7

Model C: Correlation between CBR with LL PI and MDD:

CBR = -16.5156819186858 - 0.038800108815463 * LL - 0.0264688148664365 * PI + 16.0463729595013 * MDD

R^2 = 0.9889, Soil Sample (n) = 7.

4. Among the single linear regression analysis the correlation between **CBR** and **Maximum Dry Density MDD** has resulted the following relationship:

CBR = (-29.4669) + (23.3408) MDD

R^2 = 0.9715, Soil Sample (n) = 7

5. Relatively an improved correlation than the single regression is obtained when multiple regression is used as given below:

CBR = -16.5156819186858 - 0.038800108815463 * LL - 0.0264688148664365 * PI + 16.0463729595013 * MDD R^2 = 0.9889, Soil Sample (n) = 7

6. For preliminary design of roads, the above correlation might be used, if the predicted CBR value is within the range of 6.23% to 10.7.79%. Otherwise, a detailed laboratory test should be carried out to obtain the actual CBR value.

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Prof.(Dr.) J.P. Tegar is presently working as professor of Department of Civil and Environmental Engineering at National Institute of Technical Teachers Training and Research, Bhopal, (M.P.). He has received his Bachelor of Engineering degree in Civil Engineering from Jiwaji University, Gwalior and M.Tech from MANIT, Bhopal. He has also completed his Ph.d from B.U., Bhopal. He is a great researcher and academician; he has published number of research papers in National and International Journals. Prof. (Dr.) J.P.Tegar has also worked with many foreign universities and also technically assisted World Bank Project.