ESTIMATION OF CALIFORNIA BEARING RATIO (CBR) FROM INDEX PROPERTIES AND COMPACTION CHARACTERISTICS OF COARSE GRAINED SOIL

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ABSTRACT; *California bearing ratio (CBR) is a useful method to assess the strength of different pavement layers by comparing them with the strength of standard crushed rock and it is represented in percentage. Usually CBR value is used to determine the thickness of pavement layers and also to evaluate the stiffness modulus and shear strength of subgrade material. CBR test is quite time consuming, expensive and tedious tes,t but it is necessary to perform multiple tests throughout the length of pavement in order to get proper idea about subgrade strength. In this regard many researchers have developed prediction models to correlate CBR value with index properties of soil to save budget and time. This research is an effort to correlate CBR value with classification test parameters/index properties of granular soil taken from different regions of Pakistan. Prediction of CBR value is based upon relatively simple and less costly tests like sieve analysis and modified proctor test. Parameters like Particle sizes at 30%, 50% and 60% passing (D_{30}, D_{50}, D_{60}), coefficient of uniformity (Cu), optimum moisture content (OMC) and modified proctor maximum dry density (MDD) are used in different combinations to develop seven prediction models using multiple linear regression analysis. Out of seven prediction models, model-2 showed highest regression coefficient (R^2 = 0.88) and validation of model 1, 2 and 3 represented percentage error $\pm$11.9, $\pm$14.1 and $\pm$16.1 respectively. This research is only limited to granular soils (SP, SW), so the correlations developed in this research can give better estimates only for granular soils.*

Keywords: California bearing ratio, CBR, Regression, Model, prediction

1. INTRODUCTION

A strong foundation is always required for the construction of all kinds of engineering projects, especially those involving large quantities of earth works like pavements, runways and pavement embankments etc. Bearing capacity, swell pressure and settlement of different layers of pavements should be within tolerable limits. Therefore, it is necessary to have reliable methods to access the engineering properties of such projects. California bearing ratio (CBR) is one of the methods to assess the strength of different pavement layers by comparing them with the strength of standard crushed rock and it is represented in percentage. Usually CBR value is used to determine the thickness of pavement layers and also to evaluate the stiffness modulus and shear strength of subgrade material. Different soil types give different CBR values and this test can be performed in lab as well as in the field.

CBR test is quite time consuming, expensive and tedious test but it is necessary to perform multiple tests throughout the length of pavement in order to get a proper idea about strength of subgrade material. Many researchers developed prediction models to correlate CBR value with index properties of soil to save budget and time. As mentioned earlier, CBR value is mostly dependent on index properties of soil so, many investigators have conducted studies to understand the effect of soil type and soil characteristics on CBR value and also correlated CBR value with the index properties/classification test parameters.

Breytenbach (2009) did research work to develop prediction models for estimation of CBR value using natural road construction materials in South Africa [1]. Ferede (2010) developed correlations to predict CBR value using D_{60}, OMC and MDD for granular soils and LL, PL, PI and F200 for fine grained soils [2]. And many other investigators like (Taskiran, 2010; Venkatasubramanian and Dhinakaran, 2011; Patel and Desai, 2010; Yildrim and Gunaydin, 2011; Talukdar, 2014; Singh, Reddy and Yadu, 2011; McGough, 2010 etc) [3, 4, 5, 6, 7, 8, 9,] developed prediction models based upon index properties of soil. Present research is an effort to develop prediction models based upon grain size distribution (D_{60}, D_{50} and C_u) and compaction characteristics (OMC and MDD) for coarse grained soil.

2. MATERIALS AND METHODS

The major source of soil samples were from local deposits of cohesion less soils of varying gradation namely Ravi, Chanab and Lawerencepur Sand. A total of sixty soil samples of varying gradation were prepared by mixing above mentioned soils in different proportions, most of the samples lie in SP and SW category as per USCS classification. Three major tests were performed on each sample, grain size distribution, modified proctor and soaked California Bearing Ratio (CBR) test. One point and three point CBR tests were performed on few samples in order to determine a correction factor to convert the one point CBR values into three point CBR values for simplicity, than only one point CBR tests are performed on rest of the samples. The results summary shown in table 2.1 is the outcome of above mentioned laboratory tests.

Outcomes of the laboratory tests are analyzed to develop regression models for the predict California bearing ratio. Multiple linear regression analysis is performed by considering CBR value as dependent variable and D50, D60, Cu, MDD and OMC as independent variables using Statistical package for the social sciences (SPSS) software. Total seven different correlations are developed using independent variables in different combinations. Then a comparison is made between predicted and experimental results of CBR value using same data. In order to check the validity of developed prediction models, experimental data is collected from Geotechnical Engineering Laboratory of Civil

Engineering Department, University of Engineering and Technology Lahore.

Table 2.1: Summary of test results

	GSD			Modified Proctor		CBR
Range of results	D30	D50	D60	OMC	MDD	CBR value
	Mm	mm	Mm	%	kN/m^3	%
Max.	1.1	2.3	2.8	16.6	21.92	35
Min.	0.17	0.22	0.25	8.1	17.64	8

3. RESULTS AND DISCUSSIONS

Results summary of the experimental study is shown in table 2.1, outcomes of the laboratory tests are initially analyzed to develop regression models for the prediction of California bearing ratio using simple linear regression analysis on Excel as shown below in figures 1 to 6. Linear relationship among CBR value and various parameters used are displayed below.

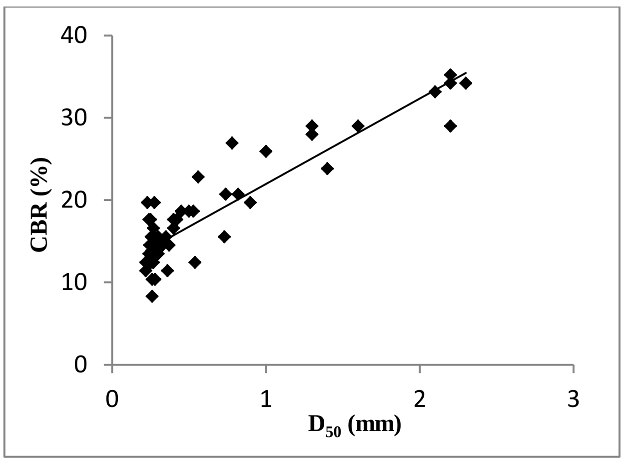

Figure 1: D_{50} verses Soaked CBR value

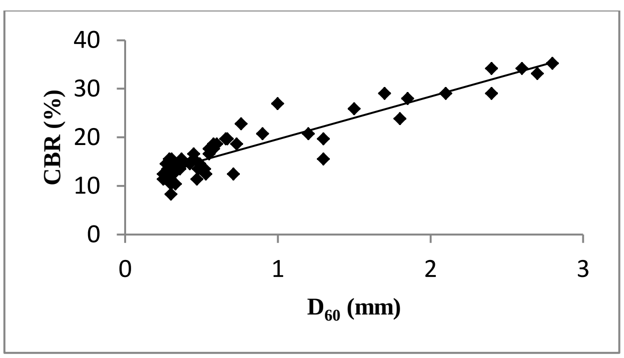

Figure 2: D_{60} verses Soaked CBR value

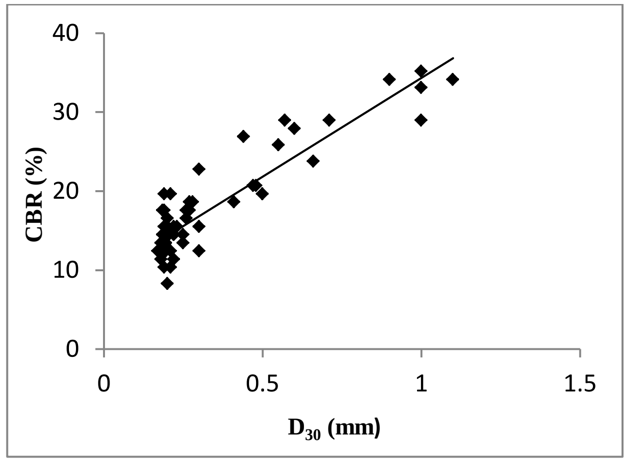

Figure 3: D_{30} verses Soaked CBR value

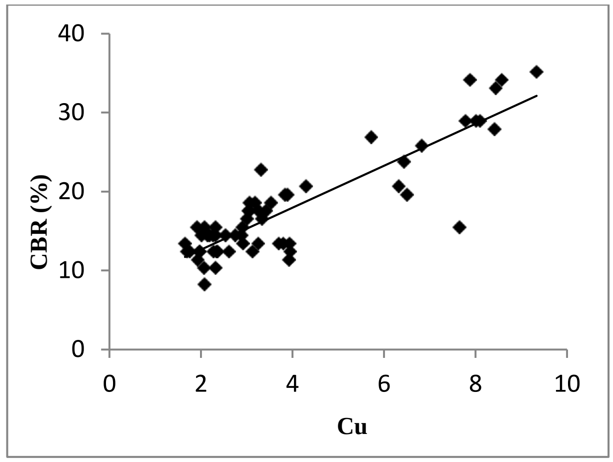

Figure 4: Cu verses Soaked CBR value

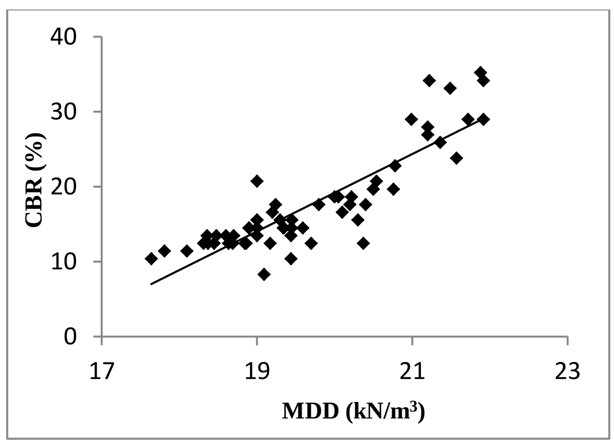

Figure 5: Maximum dry density verses Soaked CBR value

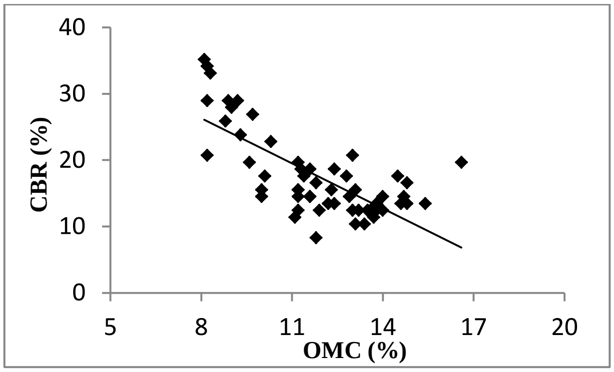

Figure 6: Optimum moisture content verses Soaked CBR value

Then multiple linear regression analysis is performed by considering CBR value as dependent variable and D_{50}, D_{60}, Cu, MDD and OMC as independent variables using Statistical package for the social sciences (SPSS) software. Total seven different correlations are developed using independent variables in different combinations, developed models are given below in table 2.2.

Table 2.2: Developed prediction models

Eq.	Developed Prediction models	R^2
1	$CBR = 7.351D_{50} + 0.883C_u + 9.879$	0.84
2	$CBR = 6.368D_{60} + 1.773MDD - 22.242$	0.88
3	$CBR = 1.51C_u + 2.697MDD - 41.383$	0.83
4	$CBR = 2.27C_u - 0.53OMC + 15.069$	0.78
5	$CBR = 8.451D_{60} - 0.134OMC + 12.656$	0.86
6	$CBR = 6.141D_{50} + 0.264C_u + 2.157MDD - 29.492$	0.87
7	$CBR = 8.76D_{60} + 10.834$	0.86

A comparison is made between experimental and predicted CBR values only for model 1, 2 and 3 to get an idea about percentage error/deviation in predicted CBR values. This comparison is presented below in figure 7, 8 and 9.

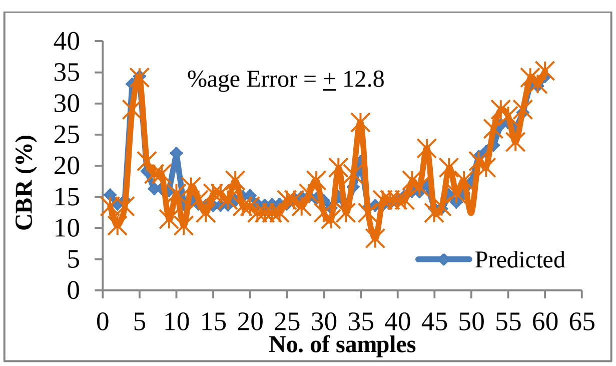

Figure 7: Comparison between predicted and experimental results for Model-1

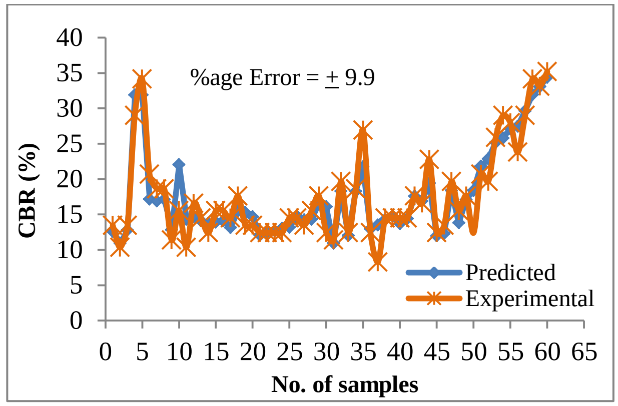

Figure 8: Comparison between predicted and experimental results for Model-2

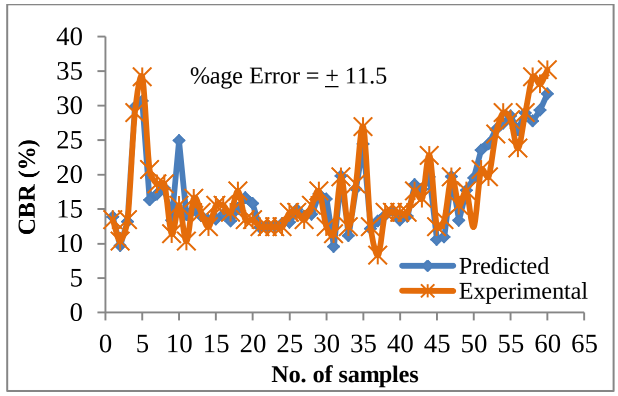

Figure 9: Comparison between predicted and experimental results for Model-3

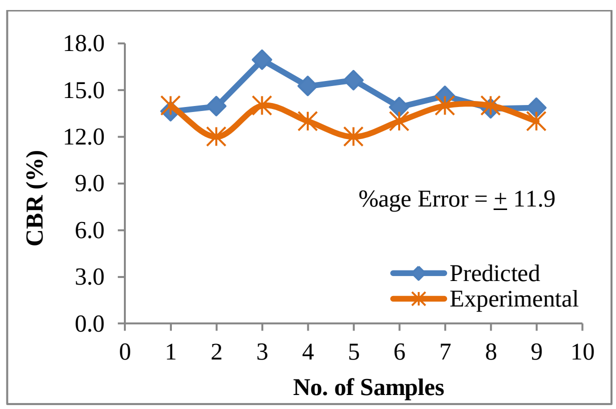

Figure 10: Comparison between predicted and experimental results using validation data for Model-1

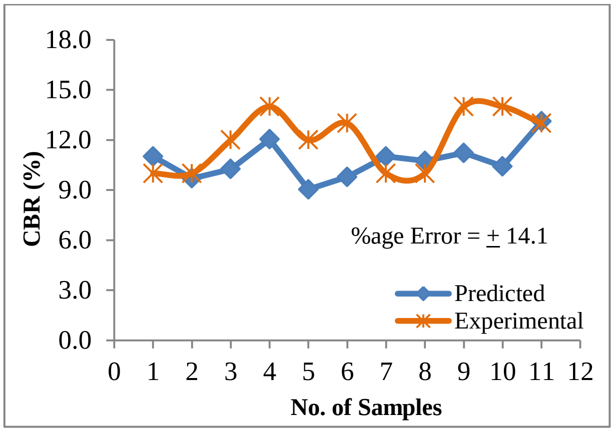

Figure 11: Comparison between predicted and experimental results using validation data for Model-2

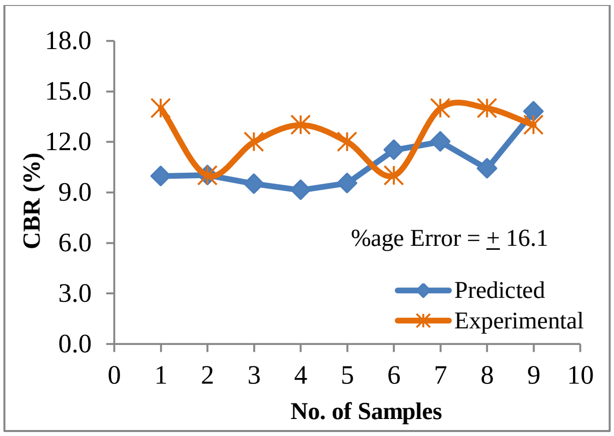

Figure 12: Comparison between predicted and experimental results using validation data for Model-3

Validity of developed prediction models is checked by using validation data of soil properties from Geotechnical Engineering Laboratory of Civil Engineering Department, University of Engineering and Technology Lahore and this database was not used in development of prediction models. The results of experimental and predicted soaked CBR values are presented in Figure 10, 11 and 12 for prediction model 1, 2 and 3. This comparison is representing a close relationship between experimental and predicted results and their corresponding percentage error is shown within presented figures. Therefore CBR value can only be predicted with the help of developed prediction models using good engineering judgment and experience.

4. CONCLUSIONS

Following conclusions are drawn from presented research work

1. It is concluded in this research that there is good relationship between index properties/classification test parameters and soaked CBR values for coarse grained soil. Therefore it is observed that CBR value increases with increase in grain size and modified proctor maximum dry density and decreases with increase in optimum moisture content.
2. Prediction Models developed using simple linear regression analysis showed good R^2 value but these relationships are relatively less reliable in comparison with multiple linear regression models.
3. Prediction Model-2 developed using multiple linear regression analysis represented relatively good performance by showing highest R^2 value of 0.88.
4. Validation of model 1, 2 and 3 represented percentage error $\pm$11.9, $\pm$14.1 and $\pm$16.1 respectively and these errors generally fall within relatively reasonable range.
5. This research is only limited to granular soils (SP, SW) so; the correlations developed in this research can give better estimates only for granular soils.

5. REFRENCES

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