

CORRELATION BETWEEN CBR VALUES AND PLASTICITY INDEX OF SOIL FOR KOLKATA REGION

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Abstract - California bearing ratio test is an empirical one and results of such test are widely used in design of flexible pavement. But In practice, determination of California bearing ratio (CBR) value in laboratory is laborious and time-consuming. Furthermore, Improper handling and poor quality of testing conditions in hurriedly established field laboratories for temporary purpose in sites or poor quality of skill of the technicians testing the soil samples in the laboratory may not give accurate results. As a result only limited number of CBR test could be performed for kilometer length of the proposed road to be constructed, for preparation of detailed project report (DPR) needed which may not be sufficient to map the field variation, and they may have very negative impact on the quality of the construction. So evaluation of CBR value of soil subgrade on the basis of simple, cheap and less time-consuming tests may be helpful for Geotechnical Engineer for checking the accuracy of laboratory tested CBR value. In the present investigation, an attempt has been made to develop a framework for prediction of CBR value from Percentage Finer and Plasticity Index for the alluvial clayey soils which cover a large part of Indo-Gangetic plain. For this purpose, a very large number of test results on soil samples collected from different sites in Kolkata been used. The correlation is established in the form of an equation of CBR as a function of Percentage Finer and Plasticity Index by the method of graphical analysis and the reliability of the proposed method have been checked for large number of tested values.

Key Words: CBR CORRELATION, INDEX PROPERTY OF SOIL, GANGETIC

INTRODUCTION

Large amount of roads connecting remotest villages in rural India with the existing network of road is being done through different scheme, like Pradhan Mantri Gram Sadak Yojana. For such roads, local soils are used as constructional material for sub-grade construction. Alluvial soils due to their modes of formation are very erratic and properties of such soil vary greatly along different directions. In West Bengal, Ganga enters near Rajmahal, flows to Bangladesh, in the name of Padma, leaving the original river to flow through the district of Murshidabad, from north to sea, remaining as eastern border of the districts, of Hooghly, Howrah and Purba Meidnipur and western border of the districts of Nadia, North and South 24 Parganas. In India, the river is more recognized as Hooghly River. In all these districts, the

top soils are alluvial and these soils generally support the rural roads, being constructed. Further to conduct a CBR test, representative soil sample has to be collected from location selected, from which a remolded specimen has to be prepared at predetermined optimum moisture content with standard proctor compaction. To obtain soaked CBR value of a soil sample, it takes more time making CBR test expensive, time consuming and laborious. Improper handling and poor quality of testing conditions in hurriedly established field laboratories for temporary purpose in sites may also hamper the accuracy of the test results. Again, only limited number of CBR test could be performed for kilometer length of the proposed road to be constructed. Such limited number of CBR test results may not reveal the variation of CBR values over the length of the road to enable lucid, economic, and safe construction. This is particularly true for road construction on alluvial soils which by nature of their development are extremely erratic in nature, In such cases, only limited number of CBR test values along the alignment of the road, makes difficult for Highway Engineers to incorporate the in-situ variation of soil properties of subgrade along the length of the road properly and also take rational steps to identify and rectify the local weakness present at any location if any, along the length of the road.

Available Correlations:

Available correlations in present literature may be grouped into two classes. In one class, simple field test results are correlated with CBR value, while in second class different simple fast and easy to perform laboratory test result have been correlated with CBR value of the soil. These correlations are described below

AVAILABLE CORRELATIONS BETWEEN CBR AND SIMPLE FIELD TEST RESULT.

The Dynamic Cone Penetrometer is an instrument which is designed for the measurement of the structural properties of the existing road pavement. The Dynamic Cone Penetrometer is quick and easy to use, portable and suitable for use in locations where access may be difficult. A typical test takes only a few minutes and therefore the instrument provides a very efficient method of obtaining information.

Therefore, correlations between CBR value and DCP value have been proposed by different researchers in different times, so that, CBR value can be obtained very easily by knowing the Dynamic Cone Penetration value.

A. In 1975, Kleyn, proposed a correlation between CBR value and DCP value. He proposed:

$$\log(\text{CBR}) = 2.62 - 1.27 \log(\text{DCP})$$

B. In 1987, Livneh made his research on Granular and cohesive soil and proposed a correlation between CBR value and DCP value. He proposed:

$$\log(\text{CBR}) = 2.56 - 1.16 \log(\text{DCP})$$

C. In 1987, Harison also carried out his research on Granular and cohesive soil and proposed a correlation. He proposed:

$$\log(\text{CBR}) = 2.55 - 1.14 \log(\text{DCP})$$

D. In 1992, Livneh et al. made elaborate study on CBR on Granular and cohesive soil and proposed a correlation as below.

$$\log(\text{CBR}) = 2.45 - 1.12 \log(\text{DCP})$$

E. Later in 1992, Webster et al. carried out research on CBR on different types of soil and proposed that:

$$\log(\text{CBR}) = 2.46 - 1.12 \log(\text{DCP})$$

F. In 1995, Ese et al. proposed an another correlation. They carried out detailed study on aggregate base course and proposed that:

$$\log(\text{CBR}) = 2.44 - 1.07 \log(\text{DCP})$$

G. In 1998, North Carolina Department of Transportation (NCDOT) proposed a correlation between CBR value and DCP value. They used aggregate base course and cohesive soils for their research. They suggested:

$$\text{Log}(\text{CBR}) = 2.60 - 1.07 \log(\text{DCP})$$

H. In 1999, Coons reported work on Piedmont residual soil and proposed that:

$$\text{Log}(\text{CBR}) = 2.53 - 1.14 \log(\text{DCP})$$

I. Karunaprema and Edirisinghe (in 2002) investigated for similar relationship for Clayey gravel and silty gravel of Sri Lanka and proposed a correlation between Dynamic Cone Penetration (DCP) value and CBR value.

They proposed:

$$\text{Log}(\text{CBR}_{\text{unsoaked}}) = 1.966 - 0.667 \text{LogDCP}$$

$$\text{CBR}_{\text{unsoaked}} - \text{CBR}_{\text{soaked}} = 67.12 - 1.48W - 30.64 \text{DCP}^{1/W}$$

J. In 2009, Sahoo et al. proposed a correlation between CBR value and DCP value. He proposed

$$\text{CBR} = 67.687(\text{DCP})^{-1.1029}$$

K. In 2010, Gupta, Kumar and Rastogi conducted experiment to find a correlation between CBR value and DCP value. Their field evaluation was carried out on thin bituminous surfaced granular pavements constructed under PMGSY programme in Uttar Pradesh and Uttarakhand states of India. They proposed

$$\text{CBR} = 35.476(\text{DCP})^{-1.28}$$

L. In 2012, Desalegn, made his research to find the correlation between Cone Penetrometer (DCP) with CBR values that best suit the type of soils in Ethiopia. Accordingly, several laboratory tests and field tests he proposed a correlation

$$\log(\text{CBR}) = 2.954 - 1.496 \log(\text{DCPI})$$

The relation obtained from statistical analysis has an R^2 value of 0.943.

The results of the statistical analysis show that good correlation does exist between the dynamic cone penetration indexes (DCPI) and unsoaked CBR values.

Correlations with Clegg Impact Value (CIV).

One simple device for the measurement of strength and stiffness of soil layers is the Clegg Impact Tester. The Clegg Impact value (CIV) given by the machine is the resistance offered by the top soil of about 25 cm thickness against a falling hammer of standard weight.

The Clegg Impact soil Tester is commonly used in Britain.

As the CIV too is a measure of soil strength, research works were carried out to examine the possibility of correlating the same with CBR values and these correlations are found.

A. In 1995, Venkataraman et al. developed an equation, based on his experiments, conducted on soil mixtures with different combination of Sand and Gravel.

$$\text{CBR}(\%) = 1.3728(\text{CIV}) + 0.868$$

The above Equation has a correlation coefficient (r) = 0.9

This equation shows a very good result for Laterite or Lateritic soil.

B. Later, In 2000, Kumar **et. al.** proposed an another correlation which shows a very good result for Alluvial Soil, B.C .Soil, Gravel, Moorum etc. He proposed:

$$CBR = 0.0039[CIV]^{1.94}$$

C. To find a better result for all types of soil, **Omar et. al.** proposed an another correlation in **2002**.

$$CBR = 0.169[CIV] + 1.695$$

D. Later, in **2003**, **Chandrasekhar et. al.** proposed an another correlation for Lateritic soil .They developed the equation based on his laboratory test result of soils which was collected from Tirupati Town. He proposed that:

$$CBR(\%) = 1.1242(CIV) - 0.3466$$

AVAILABLE CORRELATIONS BETWEEN CBR AND SIMPLE LABORATORY TESTS

A. In **2008**, **Vinod and Cletus** gives a correlation between CBR and Liquid Limit of soil. He had done a lot of experiment to develop the equation. He collected a large number of Lateritic soil sample from different part of South India (Thiruvananthapuram, kollam etc).

He proposed that:

$$CBR = - 0.889 (W_{LM}) + 45.616$$

Where,

$$W_{LM} = \text{Modified Liquid Limit} = LL (1 - C/100)$$

LL = Liquid Limit of soil passing 425 micron sieve (in percent).

C = fraction of soil coarser than 425 Micron sieve (in percent).

B. In 2010, **Ferede Proposed** a simple correlation to predict the soaked CBR value for **Silty-Clay. He proposed:**

$$\ln CBR = 4.175 - 0.029*LL - 0.009* P_{200}$$

Where, P_{200} = Percentage of soil particle which is passing 200micron Sieve

C. In **2001**, **Transportation Research Board** recommend a co relation formulae to estimate the values of Plasticity Index.

According to this formulae For materials with plasticity Index(I_p) ,greater than zero, a weighted plasticity index ,termed I_{pw} is used where,

$$\text{weighted plasticity index} = I_{pw} = I_p * P_{200}$$

I_p = Plasticity Index of soil in percent.

P_{200} = Percentage Passing 200 micron sieve.

Now,

when, weighted plasticity index(I_{pw}) = 0

$$\text{Then, } CBR = 28.09(D_{60})^{0.358}$$

And, when soils exhibits some plasticity and containing more than 12 Percent fines(i.e. I_p is greater than zero)

$$\text{Then, } CBR = 75 / [1 + 0.728(I_{pw})]$$

This equation is best suited for Lateritic soils or Laterite soils

D. In 2004, Shukla and Kukalyekar proposed an another correlation to predict the CBR value from Optimum Moisture Content and Maximum Dry Density . They proposed that:

$$CBR_{(SOAKED)} = -2.97 - 0.1162 * OMC + 12.9853 * MDD$$

$$CBR_{(UNSOAKED)} = -5.71 - 0.2235 * OMC + 24.9717 * MDD$$

E. In **2006**, **Kin** proposed a correlation to predict soaked CBR values from Optimum Moisture Content (OMC) and Maximum Dry Density(MDD). He proposed :

$$CBR = OMC * (MDD/19.3)^{20}$$

F. In **2009**, **Roy et. el.** Proposed an another correlation to predict the soaked CBR value from Optimum Moisture Content (OMC) and Maximum Dry Density(MDD). He proposed that :

$$\text{Log}[CBR] = \text{Log}[MDD/\text{UNIT WEIGHT OF WATER}] - \text{Log}[OMC]$$

G. In 2010, **Ferede** Proposed an another correlation to predict the soaked CBR value **for Granular Soils .He proposed:**

$$CBR = - 27.998 + 0.029 * OMC^2 + 4.796 * MDD^4$$

H. In **2010**, **Patel&Desai**, proposed an another correlation to determine the value of soaked and unsoaked CBR For Fine Grained Soil. He proposed:

$$CBR_{\text{unsoaked}} = 17.009 - 0.0696PI - 0.296MDD + 0.0648OMC$$

$$CBR_{\text{soaked}} = 43.907 - 0.093PI - 18.78MDD - 0.3081OMC$$

I. U.C.Saboo ,M.G.Kalpna Rani and A.S.Bisbt (in2010),proposed an another correlation .They tested Thirty four different types of soil sample in the Laboratoy to evaluate different properties.

Based on these results, they made a best possible correlation. They Proposed:

$$\text{CBR} = 7.88 * \text{MDD} - 0.17 * P_{0.075} - 0.07 * w_{LL} + 5.07$$

Where,

$P_{0.075}$ = Percent Passing 75 micron IS sieve.

w_{LL} = Weighted Liquid Limit = $LL * (P_{425} / 100)$.

$P_{0.425}$ = Percent Passing 425 micron IS sieve

In **1970**,Based on the research on 48 soil samples of fine grained soils found in India, **Agarwal and Ghanekar** had tried to develop a correlations between CBR values and either liquid limit, plastic limit or Plasticity index but could not find any significant relationship between them.However ,they found a better correlation of CBR with optimum moisture content(W_{opt}) and liquid limit (LL).They suggested that:

$$\text{CBR} = 2.0 - 16.0 * \log (W_{opt}) + 0.07 * LL$$

Need for further Study:

From the review of literature, it is observed that studies on the prediction of CBR value by correlating the CBR with easily determinable soil parameter have been made to some extent. Such correlation being empirical in nature, may give reliable results only for the region from which such soil data for correlation were collected. Further majority of correlation are for CBR in unsoaked condition while in design of flexible pavement, CBR value in soaked condition, are used.

Stressing on the need for alternate method for CBR test, Sikder (2003) indicated that possible variation in pavement thickness, resulting from an error in estimation of CBR value, may lead to unnecessary wastage of capital investment. Similarly the non-identification of the weak sport along the alignment of proposed road which is possible when only limited number of CBR test are conducted in conventional manner, may lead to short life of the road.

Reliability of any prediction depends primarily on the relative importance of the factor in controlling the magnitude of the output. In search of the best correlation for CBR, the most important parameter influencing the value of

CBR should be identified. This was studied by Kaur et el (2011), following innovative technique proposed by Garson (1991). They have indicated that PI followed by LL are the most important factor influencing the value of CBR, other parameter like maximum dry density, fine fraction, sand fraction etc, have influence but of much lesser significance

In view of the above discussion, a study was undertaken for finding the correlation between soaked CBR value and PI and Percentage Finer of the soils from alluvial plain and validity of the correlation developed is tested by comparing the predicted value of CBR(soaked) into tested value of CBR(Soaked).

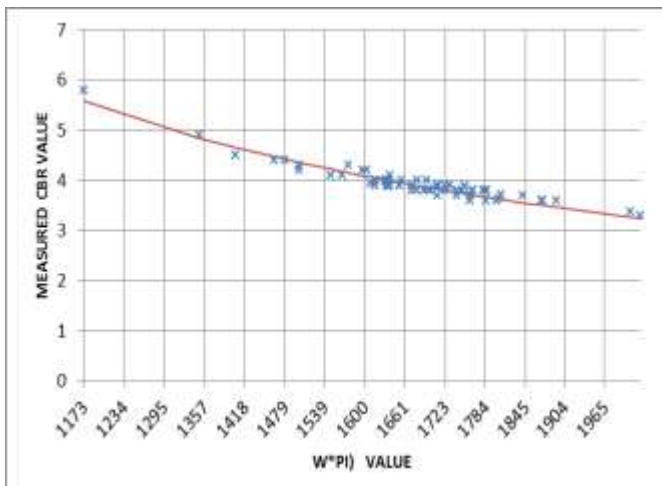
Development of Relationship Between CBR(Soaked) and Index Properties.

To develop the relationship a large number of test results on fine-grained soil samples are collected from different sites in West Bengal. . All the data are divided into two parts, one part is used to develop the prediction model and another part is used to check the validity of the proposed correlations. Here the test results of High Plastic soil(PI value is greater than 17) are used.

For each group of soils the observed values of CBR are plotted against ($W * PI$) of the soil. Where W is percentage of soil passing 75μ and PI is plasticity index of soil. From the relationship the trend of variation of CBR value with the change of ($W * PI$) value was noted . Now, efforts are made to establish a best fit curve that can fit the point as closely as possible. The equation of best fit curve is developed for necessary co relation.

Analysis of soil for Kolkata Region:

Here mainly the High Plastic soils found and it is also divided into CI and CH Group. To find the accurate result only the data of CI Group soil are used for the research work. From the chosen data($W * PI$) values are plotted against CBR(soaked) value to develop a best fitted curve which is shown in figure



Now, from the plotted points the best fit curve is found. And the equation of the best fit curve is calculated. The equation of the best fit curve

$$CBR(\text{soaked}) = 6550 / (W * PI)$$

Checking The Validity Of The Correlation

$$CBR(\text{soaked}) = 6550 / (W * PI)$$

W	PI	LL	M.CBR	P.CBR	ERROR
90.5	18	43	3.62	4.1	13.4
90.3	18	42.9	3.62	4.09	13
89.9	18	41.6	3.63	4.04	11.3
100	18	41.2	3.25	3.63	11.7
85	18	41	4.1	4.25	3.62
85	18	44	4.06	4.25	4.64
84	18	41	4.1	4.3	4.85
87	18	41	3.9	4.15	6.43
84	18	40	4	4.3	7.47
91	18	37	3.64	3.97	9.02
87	18	42	3.8	4.15	9.23
89	18	43	3.7	4.06	9.66
82	18	40	4	4.4	10.1
88	18	43	3.7	4.1	10.9
94	18	37	3.46	3.84	11
91.3	18	36.7	3.51	3.93	12.1
90	18	36.8	3.54	3.97	12.1
79	19	37	4.1	4.33	5.62
78	19	37	4.1	4.39	6.98
86	19	40	3.7	3.98	7.51
85	19	42	3.7	4.02	8.78

94	19	38	3.28	3.64	11
93	19	38	3.28	3.68	12.2
91.8	19	40	3.3	3.73	12.9
92	19	39	3.28	3.72	13.4
100	19	42.3	3.1	3.4	9.78
100	19	39.6	3.02	3.4	12.7
81.1	19	46.2	3.97	4.15	4.6
70.2	20	39.5	4.36	4.75	8.91
87	20	44	3.6	3.74	3.77
82	20	36	3.8	3.96	4.3
85	20	43	3.6	3.82	6.21
80	20	37	3.8	4.06	6.91
92	20	49.8	3.3	3.53	7.05
78	20	37	3.8	4.17	9.65
100	20	43.9	2.93	3.25	10.9
92	20	49.8	3.1	3.53	14
89	20	49	3.28	3.58	9.15
81	21	37.5	3.62	3.9	7.61
86.9	21	45.7	3.38	3.61	6.91
82.7	21	42.1	3.34	3.76	12.6
83	21	41	3.6	3.73	3.59
92	21	42	3.1	3.36	8.53
90	21	50	3.16	3.44	8.83
84	21	41	3.3	3.68	11.7
93	21	50	2.98	3.33	11.7
93	21	50	2.98	3.33	11.8
92	21	42	3	3.36	12.2
92	21	50	3	3.36	12.2
77.5	21	43.9	3.49	3.96	13.4
83.7	21	43.6	3.26	3.63	11.3
83.8	22	43.5	3.18	3.61	13.5
85.6	22	43.8	3.1	3.53	13.9
92	22	40	3	3.21	7.05
83.5	22	44	3.2	3.54	10.6

Note: M.CBR and P.CBR represents Measured and Predicted Soaked CBR Value.

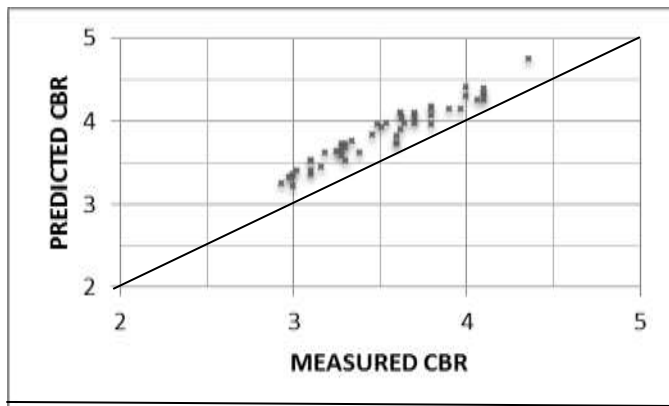


Fig: Measured and Predicted Soaked CBR Values are plotted.

CONCLUSION:

Considering the CBR value test of soil is laborious and time consuming, it can be emphasized that the use of other properties for estimating CBR value such as Liquid Limit, Plastic Limit, Grain size analysis which is obtained from low cost and less time consuming test can be used. In the present study it is observed that the predicted values of CBR are closer to the measured values of CBR. This model predicts the soaked CBR values from grain size analysis and PI Value of soil. This will be help full for Geotechnical Engineer to predict the soaked CBR value and also will be helpful for checking the reliability of laboratory tested CBR value.

REFERENCES

1. Agarwal, K.B. & Ghanekar, K.D. (1970): Prediction of CBR from Plasticity Characteristics of Soil. Proceeding of 2nd South-east Asian Conference on Soil Engineering, Singapore. June 11-15, Bangkok: Asian Institute of Technology, 571-576.
2. Black, W.P.M. (1962): A Method of Estimating the CBR of Cohesive Soils from Plasticity Data. Geo technique. Vol.12, 271 - 272.
3. Central Road Research Institute (1990), "Document on Rural Road Development in India", Vol. II, CRRI, New Delhi.
4. Chattopadhyay BC and Maity J,(2012) "Prediction Of CBR Of Different Groups Of Alluvial Soils For Design Of Flexible Pavements", International Symposium On On Engineering Under Uncertainty: Safety Assessment And Management, January 4 To 6, 2012. Paper No. CNP 028
5. Kin MW (2006) California bearing ratio correlation with soil index properties. Master's thesis, Faculty of Civil Engineering, University of Technology, Malaysia

6. Kaur, S., Ubboveja, and Agarwal, A. (2011), "Artificial Neural Network Modelling For Prediction Of CBR, "Indian Highways, Vol.39, No.1, pp.31-38

7. National Cooperative Highway Research Program (2002), "Guide for mechanistic and empirical - design for new and rehabilitated pavement structures, Final document. In :Appendix CC-1: Correlation of CBR values with Soil Index Properties", West University Avenue Champaign, Illinois, USA.

8. Patel, S.R. and Desai, M.D. 2010. CBR Predicted by Index Properties for Alluvial Soils of South Gujarat, Dec. 16-18, 79-82, Proceedings of Indian Geotechnical Conference-2010, India.

9. Srinivasa Rao, K. (2004). Correlation between CBR and Group Index. Proceedings of the Indian Geotechnical Conference. Warangal, 477-480

10. Sikdar, P.K. (2003), "Pradhan Mantri Gram Sadak Yojan, striving for Quality and Economy", Indian Highways, IRC, New Delhi, vol 31, No 6, pp 77-91

11. Shukla, S.K. and Kukalyekar, M.P. (2004), "Development of CBR Correlations for the Compacted Fly Ash." Proceedings of the Indian Geotechnical Conference Wanrangal, pp. 53-56

12. Sahoo, U. C. and Reddy, K. S. (2009). Subgrade strength characterization for low volume roads in India, Proc., of International Conference on Pavement Engineering, ICPE-2009, College of Engineering and Technology, B.P.U.T. Bhubaneswar, 86-93.