Improvement of the Selection Criteria for Residual Soil to be Used as Road Pavement Material

S. S. I. Kodagoda, J. A.D.N.A. Jayasooriya, W. M. J. K. Wendakoon and M. Jegathees
Central Engineering Consultancy Bureau, Sri Lanka

ABSTRACT: Attempts were made to narrow down the accepted range of soil samples for California Bearing Ratio (CBR) in quality controlling works of road pavement through initial basic tests so that the probability of satisfying the CBR criteria is increased. Variation of CBR of Sri Lankan residual soil with respect to index properties such as gradation characteristics, Atterberg limits, Maximum Proctor density and optimum moisture content (OMC) was studied aiming at deriving relationships for prediction of CBR. Relationships reported in literature for predicting CBR were assessed and found to be less applicable for Sri Lankan residual soil. Some relationships have been identified which could be highly applicable to a specific geographical terrain. This paper summarizes the findings of above study which can be utilized for prediction of CBR and also for improvement of the selection criteria of pavement material.

1 INTRODUCTION

1.1 *Use and importance of CBR as a parameter for design and quality controlling of road pavements*

CBR value of a soil is a measure of its resistance to shearing triggered by wheel load. Being a parameter conveniently determined in laboratories of various environments, CBR has been widely used for pavement material classification since earlier days. Design procedures for pavements also have been developed based on this parameter which led to incorporation of this as a vital parameter of quality controlling in many guidelines and specifications worldwide. Though more advanced methods of pavement design are in use from mechanistic-empirical design to those involving other parameters such as layer coefficients, resilient modulus and sub grade reaction, the simplicity of conducting the CBR test still demands its inclusion in the design and quality controlling procedures, especially in Sri Lankan context as a country struggling to compromise cost to high technical advances. Since CBR is a direct measurement of the type of resistance to be determined, value of this parameter is never to be underestimated

1.2 *Adoptability of international standards and guidelines for local pavement quality controlling works*

Many technically advanced countries have developed guidelines and specifications for quality controlling of pavement that include CBR as a controlling parameter. Based on these, local guidelines have been established by other countries including Sri Lanka which usually adopt ICTAD guidelines. In addition to CBR values, some other criteria for basic soil properties including gradation characteristics and Atterberg limits are inserted aiming at achieving a durable pavement. Also some inexpensive tests such as Maximum Dry Density (MDD) have been defined as initial screens. Difficulties during adoption of these guidelines for local quality controlling works are given below with suggestions to overcome the problems.

1.2.1 *Low probability of satisfying the CBR criterion of soil samples that full fill other recommended requirements*

It has been observed that, though the index properties of soil samples tested for upper and lower layers of sub base satisfy the given requirements of recommended guidelines, the criterion for CBR is not met in many instances. A recent study has shown that the number of samples agreeing the CBR criteria can be considerably low as 50% of the total samples satisfying the other criterion. Findings for a group of soil samples are presented in Fig. 1which shows only 14 out of 31 samples satisfy the CBR criteria. Therefore a considerable time and resources are wasted on investigating on these non complying material as the common practice is to assume that when MDD, PI, LL and particle size requirements are met, it will satisfy the CBR requirements as well (Suvetha et al 2011) Thus investigating the methods of prediction of CBR and establishing valid criteria will be of immense use.

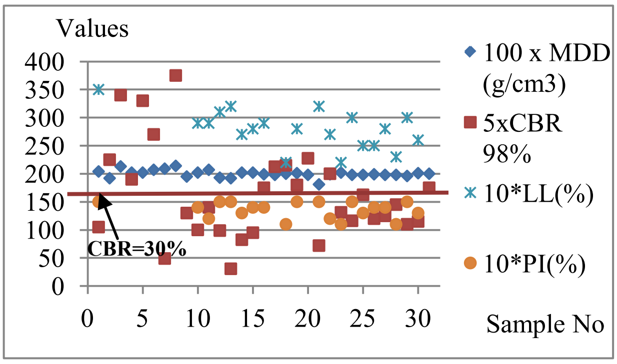

Fig. 1 Variation of CBR of soil samples that full fill other Upper sub-base requirements according to the ICTAD specification

1.2.2 *Gradation curves of soil samples with high CBR do not fall within the recommended envelope*

In a study conducted for a group of residual soil samples as shown in Fig. 2., it is found out that gradation curve of 45% of soil samples with high CBR values lie outside the upper limit of the recommended curves. Most of them are low or non plastic thus deem to create durable pavements.

Therefore further research of the material properties incorporated with Repeated Load Triaxial test (RLT) can be conducted for recommending these materials for base layers of road pavements

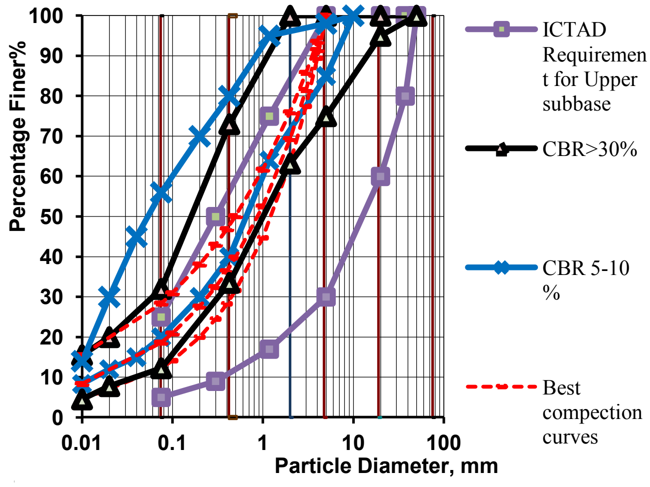

Fig. 2 Standard and Observed Curves

2 PREDICTION OF CBR THROUGH BASIC PROPERTIES

2.1 *Relationships in literature*

Literature reveals that in various parts of the world researchers have developed certain relationships to predict CBR with index properties such as MDD, OMC, LL, PI and w(75 mm passing x PI). Equations developed by De Graft et al(1969), Agrawal et al (1970), NCRHP (2001), Roy et. al(2008), Afeez Adefemi Bello(2012) and Patel. et al (2010), are reported in Table 1.

Table 1. Accuracy of prediction CBR using the existing relationships

	Cohesive soil												Cohessionless soil
References and equations	Agrawal et. al(1970)	De Graft-Johnson et.al(1969)	Patel et. al(2010)	Roy et.al(2008)	Datta et. al(2011)	NCRHP(2001)			Afeez et. al 2012	Afeez et. al 2012	Afeez et. al 2012	NCRHP(2011)
Percentage Of Accuracy Of Prediction	CBR=2-16Log(OMC)+0.07LL	CBR=35*((P2.0mm*100)/LL*(logPI/100))-8	CBR (SOAKED)=43.907-0.093(PI)-18.78 (MDD) -0.3081(OMC)	Log (CBR) = Log (γd max/ γw)-Log (OMC).	CBR=-0.889(Wlm)+45.616	CBR= 75/(1+0.728(wPI)	CBR=31591/(OMC)$^{2.89}$	CBR=824.1/(P200mm)$^{1.08}$	CBR=0.22(LL)+28.87	CBR= 1.04(PL)+13.56	CBR=50.28(MDD)-70.22	CBR=28.09*(D60)$^{0.338}$
within 10%	9.2	1.5	4.6	13.8	10.8	14.5	6.2	7.7	6.2	3.1	4.6	9.1
under estimates <50%	15.4	0.0	52.3	13.8	1.5	10.4	3.1	4.6	3.1	13.8	1.5	54.55
Overestimates>150%	18.5	52.3	1.5	12.3	35.4	2.0	41.5	20.0	46.2	36.9	24.6	9.09

2.2 *Comparison of actual and predicted CBR*

A data set of 65 residual soil samples obtained from specific geographical regions of Sri Lanka was used for the study. CBR values were derived using the equations given in Table 1. Comparison of the derived values and the actual values was done and the accuracy of prediction obtained is presented in table 01.

It is found out that the percentage of prediction within 10% of actual value was less than 15% for all the methods. Also it is noted that methods used OMC as a parameter for prediction produced comparatively better results.

3 VARIATION OF CBR WITH RESPECT TO INDEX PROPERTIES

Variation of CBR with respect to other index properties such as 75mm passing, Coefficient of Uniformity(C_U), Coefficient of Curvature(C_c), Liquid Limit (LL), Plasticity Index (PI), MDD, and OMC was studied aiming at obtaining relationships that can be used for prediction of CBR. 60 soil samples belonging to some specific geographical regions were used for the study. Results are presented in Fig 03.As shown, envelopes could be drawn for variation with OMC, MDD, 75mm passing, and w. The CBR values used here were for 98% MDD compaction done according to ASSHTO: T 193-99(2007) standard.

Also the gradation curve envelopes for CBR ranges was established and plotted with recommended envelopes and compaction curves as shown in Fig. 02.

4 DEVELOPMENT OF A HYPOTHESIS FOR PREDICTION OF CBR AND ANALYSIS

Residual soil samples of a specific geographical region can possess many similar physical and chemical properties as the main influencing factors namely parent rock features, and climate are common. Therefore variation of CBR with respect to OMC was studied according to its geographical location. As such material Group 1 which contained residual soil samples from a specific geographical region and tested under same controlled environment was separated and the plot fitted to a curve with R^2= 0.76 as shown in Fig. 04. Properties of this material set are reported in Table 2.

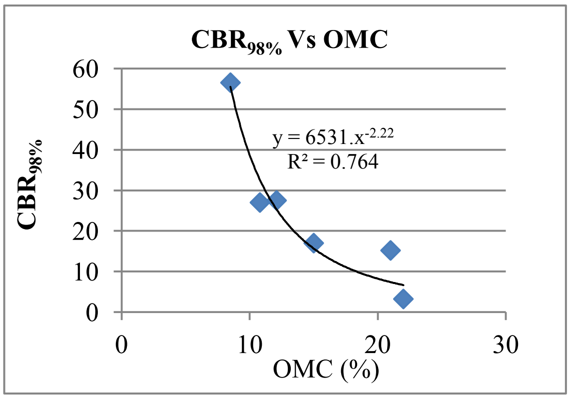

Fig. 4 CBR Variation with OMC

5 RELATIONHIP BETWEEN GRADATION CURVES AND CBR AND NEED FOR FURTHER RESEARCH

Gradation curves of 50% of soil samples with high CBR values lie outside the upper limit of the recommended curves and thus making them unsuitable to be used as road sub base layers. Most of

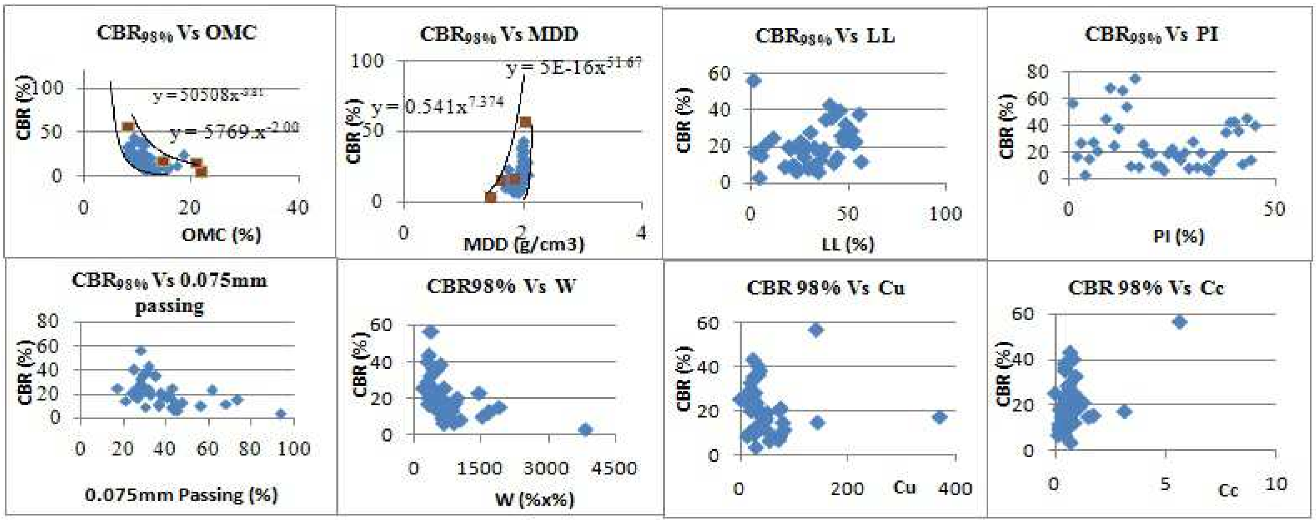

Fig. 3 CBR Variation with Index Properties for Sri Lankan Residual Soil belonging to some specific geographical regions

Group	ID	Visual Description	Soil Classification	Gradation Φ 10%	Gradation Φ 30%	Gradation Φ 60%	0.075mm Passing	Atterberg Limits LL	Atterberg Limits PI	Modified Proctor OMC (%)	Modified Proctor MDD (g/cm³)	CBR 98%
1	A	Yellowish brown	Clayey sand	0.003	0.090	0.450	28.01	28	14	8.5	2.04	56.5
1	B	Reddish brown	Clayey sand	0.001	0.034	0.370	40.48	46	22	15	1.86	17.0
1	C	Yellowish brown	Silty sand	0.010	0.188	0.668	19.34	cbd	cbd	10.8	1.99	27.0
1	D	White to brown	Elastic Silt	0.001	0.005	0.029	93.58	80	41	22	1.46	3.25
1	E	Brown	Elastic Silt with sand	0.001	0.009	0.047	73.78	65	26	21	1.64	15.2
1	F	Yellow black	Silty sand	0.049	0.166	0.430	16.84	cbd	cbd	12.1	1.9	27.5

Table 2 Properties of Group 1 material

them are low or non plastic as shown in Table- 2, thus deem to create durable pavements. Also as reported by Arnold et al (2007) for some soil types the best compaction curve can be different from Tailbot coefficient (n) =0.5which is known as Fullers curve and n=0.3-0.5 can be adopted. Therefore further research including RLT is recommended for checking the suitability of this material for sub base layers of pavements.

6 CONCLUSIONS

Relationships established for predicting CBR with index properties for soil types in other countries are not valid for the Sri Lankan residual soil in the specific geographical regions studied. Relationships involved with OMC yielded comparatively acceptable results. OMC and MDD provided narrow envelopes for predicting CBR.

For residual soil in a specific geographical region, a relationship between CBR and OMC could be found with R^2= 0.76. Therefore further research can be conducted for establishing a criterion based on OMC as an initial screening test for CBR based on geographical regions, to increase the probability of satisfying the criteria and thus to expedite the road pavement construction works.

Further research involving RLT test have to be conducted for recommending the upper curve of the gradation envelopes to allow the use of some residual soil samples with high CBR values for road sub base layers.

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