ANALYSIS OF CALIFORNIA BEARING RATIO BASED ON STATE PARAMETER APPROACH

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ABSTRACT

The sub-grade is the bottom most layer, most often naturally occurring at any given location. This in-situ soil acts as sub-grade in most of the cases. The design and performance of a pavement depend essentially on the strength of the sub-grade soil. Accordingly, enough care has to be exercised while preparing the sub-grade so as to form a uniform support base. The California bearing ratio (CBR) is often used to assess sub-grade strength. The comparison of the strength of the soil in relation to the standard crushed rock expressed as percentage signifies the CBR of the soil. The higher the CBR value the lower will be the pavement thickness. Highways form essential basis for strengthening the infrastructure of any nation to facilitate effective transportation for its economic advancement.

In order to design the pavement CBR value of the sub-grade and other base courses is a prerequisite and is often determined based on elaborate experimental procedures. It is therefore necessary to develop a framework to estimate the CBR value based on parameters which are easily determinable from routine preliminary investigations. An attempt has been made to develop a framework for estimating the CBR based on experimental results on different soils based on state parameter approach. The state parameter refers to the compacted state in relation to the liquid limit sate of respective soils. The approach proposed incorporates compacted density and other index properties.

KEYWORDS: Regional Soils, California Bearing Ratio, State Parameter, Analysis, Prediction.

1 INTRODUCTION

1.1 General

Most of the pavement design guidelines are based on the assumption that aggregates are important ingredients of pavement structures. However, the availability of good quality aggregates may be a constraint in many instances in the construction and may not be economically feasible including consideration of availability and transportation. Due to the excessive investment and maintenance cost, researchers are striving to introduce appropriate design methods and building materials for cost effective infrastructure development. Sometimes soil characteristics can be improved by the locally available admixtures so as to meet the design requirements of the intended project. In view of rapid industrialization and need for advancement of economy, a lot of emphasis is being laid on infrastructure development for safe and efficient transport of raw materials and industrial produce. Therefore, development of road network is regarded as an index of economic, social and commercial progress of a particular country. Being a major infrastructure of transportation is Highways, in this aspect Sustainable and cost-effective highway construction can be achieved with the help of exact soil sub grade information. In the design of highway pavement, the California Bearing Ratio (CBR) value can be treated as important parameter in the strength assessment of the pavement sub grade. An attempt has been made in the present work to bring out the correlations of CBR with soil index properties. These types of correlations can help the designer to choose appropriate CBR value and cross verify the CBR value obtained from the laboratory testing. Along with the soil test data, some of the existing correlations are made use for further improvement of the correlations. Existing correlations for CBR are made use to validate the laboratory CBR values. Conventionally, CBR can be determined both in the laboratory as well as in the field. For a road project, a large number of soil samples need to be tested, making determination of soaked CBR of the soils a laborious and time-consuming task. Hence, many researchers in the past have suggested quick methods for estimating CBR of the soils through other soil parameters that are easily determinable [5].

1.2 Scope of the present study

The physical properties most often reflect the classification of soils and do not represent the in-situ characteristic features based on which the actual response of the system depends. For example, two soils with same physical properties with different unit weights might behave quite differently. Hence, it is thought that any prediction methodology should be based on both physical and in-situ characteristics for meaningful application of the model in real practice.

1.3 Soils Types used in the investigation

The soil types considered in the present investigation represent wide spectrum of fine grained soils usually encountered in practice in this region. The fine fraction varies from 16% - 72 %. The liquid limit values vary from 20 - 33%. Apart from the classification tests, the compaction and CBR tests were conducted on 14 different types of soils. In yet another series of tests, the influence of coarse fraction in the CBR values on drilled cuttings obtained from an actual field situation.

1.4 Proposed Empirical Model

The model proposed takes into cognizance the liquid limit void ratio, percentage fine fraction, modified liquid limit, by appropriately taking into account, the relative influence of fine fraction on liquid limit together with void ratio at compact state to bring out the correlation with the experimentally determined CBR values. The model proposed has been applied to other soil data and the result thus compared underlines the importance of the model proposed.

2 BACKGROUND INFORMATION

2.1 Introduction

Indian road network consists of 33 lakh km and is second largest in the world. India has large and extensive transportation system. About 65% of freight and 80% passenger traffic is carried by the roads. Number of vehicles has been growing at an average pace of 10.16% per annum over the last five years [19]. Geotechnical engineering should play one of the most important roles in early stage of Planning and Design of Infrastructure, due to the fact that incorrect geotechnics can result in unreasonably high cost. For the design of pavement CBR value is one of the important parameters.CBR value can be measured directly in the laboratory test in accordance with IS-2720 (part 16) on soil sample acquired from site. Civil engineers always encounter difficulties in obtaining representative CBR value for design of pavement. CBR value is affected by the type of soil and different soil properties. An attempt has been made to correlate the CBR with soil properties. It can be the alternate method for the time-consuming tests. These tests are much economical and rapid than CBR test.

2.2 CBR and Index Properties

A method is proposed for correlating CBR values with the Liquid Limit, Plastic Limit, Plasticity Index, Optimum Moisture Content, and Maximum Dry Density of cohesive soils of various zones of Surat city of Gujarat state. These tests are much more economical and rapid than CBR test. The correlation is used for determining CBR value using basic soil properties for no of samples at 100m interval & checked by few CBR test representing a similar range of CBR [19].

CBR values are correlated with the liquid limit, plastic limit, plasticity index, OMC, Maximum dry density, UCC values of various soils taken from in and around three different districts in Tamil Nadu namely Thanjavur, Tiruchirapalli and Pudukkottai districts using Artificial Neural Network. The results of these analyses are compared with experimental results. Multiple linear regression based model for CBR prediction performs better than neural network based model in the present study [25]. The predicted and tested values of CBR of various soils have been used to check the applicability and limitations of available methods and are presented in this paper [4]. Attempts have been made by several research workers to develop suitable correlation between CBR value of compacted soils at Optimum Moisture Content (OMC) and result of some simple field tests [9], [12] or different simple soil characteristics. In this section

The study aims at developing regression-based models for predicting soaked CBR value for fine-grained subgrade soils in terms of grain size analysis, LL, PL, MDD and OMC. [21] A few investigators [19], [27] in the past developed models for estimating the CBR value on the basis of low cost, less time consumption and easiness to perform tests. Other investigators [25] [27] used soft computing systems like Artificial Neural Networks for correlating CBR values with LL, PL, PI, OMC, MDD and Unconfined Compressive (UCC) strength values of various soils. Comparison of the measured and predicted values of un-soaked CBR and DCP using the developed equation clearly indicates the validity of this equation [13].

The soil classification and compaction parameters are routinely determined for in-situ and borrow soils used in the construction. In the present study, soaked value of the CBR of fine grained soils is correlated with classification and compaction parameters [5]. [23] have developed empirical equations/ models for CBR prediction from basic soil properties. Recently, [21] have critically reviewed some of correlations and models developed by predecessors and have proposed a simple correlation equation for predicting of soaked CBR of compacted soils

3 BASIC CONSIDERATIONS

The both fine grained and coarse-grained soils have much in common as the members of the same family of particulate materials; they exhibit dissimilar and different behaviors.

3.1 The Effect of Coarse Fraction

Several attempts have been made both empirical and rational in the past to model and predict the compressibility behaviour of fine grained soils using their liquid limit as the parameter and it is determined only on soil fraction passing 425 microns. Hence this parameter alone can’t adequately account for the presence of particles coarser than 425 micron. This forms the limitation of the predictive methods when applying to natural soils containing particles coarser than 425 microns [24].

3.2 Modified liquid limit

Liquid limit reflects the physicochemical potential of fine-grained soils. Generally there is an agreement that the liquid limit depends on the base exchange capacity and the specific surface of the fine-grained soil [7]. The addition of coarse particles will reduce the specific surface proportionately. However in their investigation only sand particles finer than 425 micron could be used, to account for the specifications in liquid limit determination. It becomes logical to examine the influence of particles coarser than 425 micron on liquid limit before extending the method to predict the behavior of natural soils. This aspect has been appropriately considered and explained by [24].

$$w_{mL} = w_L \times F$$

3.3 Modified Plasticity index

In the similar lines, it is attempted in the present investigation to examine the influence of coarse particles. On engineering behaviour by considering the modified plasticity index as defined by

$$I_{MP} = I_P \times F$$

This seems to be logical in the sense that the consistency limits are found out for fraction finer than 425 micron size where as the engineering is affected by the coarser particles as well.

3.4 Need for Reference State

A reference state-stress paths of the reconstituted soil in relation to which analysis of soil behaviour can be pursued appears to be advantageous since the stress history, time and cementation effects are subdued in the undisturbed state of the natural deposit. If the reference path can be identified, which is independent to as above said factors effects it would serve the purpose of identifying the dominance of any of the aforesaid factors controlling the soil behaviour considering the undisturbed state and the overburden pressure.

3.4.1 Reference Stress-State Path

Several attempts to establish the Intrinsic State Line (ISL), [14] have been made with reference to an intrinsic state parameter (e/e$_L$) and its variation with effective stress for reconstituted clays.

The relationship can be expressed as:

$$\left\{\frac{w}{w_L}\right\} = \left\{\frac{e}{e_L}\right\} = a - b\ \ \log \sigma c + c \log\left\{\frac{\sigma c}{\sigma}\right\}$$

For the data analyzed a = 1.22 to 1.23 and b = 0.24 to 0.28, c = 0.04 to 0.05.

Subsequently [3] proposed void index parameter and consequently Intrinsic compression Line (ICL) to analyze the compressibility and shear strength response of natural soil. It was recognized and explicitly stated by [3] that both ISL and ICL are identical for the range of soils examined. Further examination of these independently developed approaches [15] in the present context possibly reinforces the systematic analysis of data of natural soils in their soft and stiff conditions.

It has been shown [14] that the one-dimensional compression paths of uncemented residual soils starting at the liquid limit water content follow a path defined by the equation

$$\frac{e}{e_L} = 1.23 - 0.276 \log\left(\sigma'_v\right)$$

This has been adopted for estimating the saturated compression behavior of remolded soils.

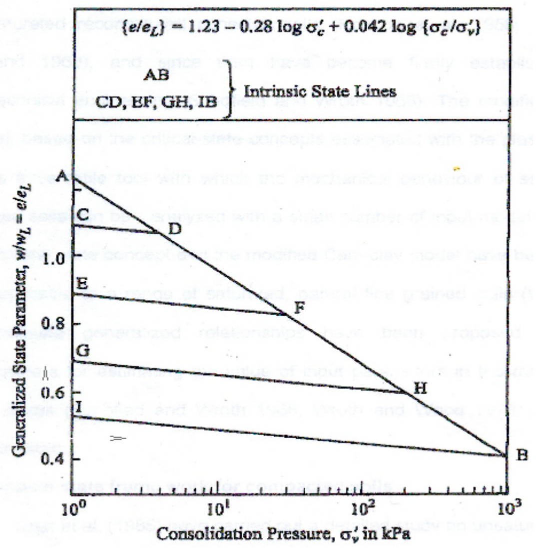

Figure 1 Intrinsic compression and recompression lines using e$_L$ as reference parameter

3.5 Compression Path from Compacted State

It has been noticed that [16] that the samples compressed from partly saturated state would be on the right hand side of the Normal compression line and the compression path of compacted soils are placed on left hand side of the Normal compression line. Hence, there is increasing recognition that the Normal compression Line which is devoid of stress, time and environmental factors i.e. when compressed from the slurry or loose state would form the basis for the reference path. The partly saturated or cemented soils states would fall on the right hand side of normal compression line and due to de-cementation or inundation the state would fall on to the Normal compression Line. On the other hand, if the soil is compacted, owing to interlocking of the particles the state of the soil would be on the left hand side of the Normal compression Line. Once the stress level reaches the magnitude equal to yielding in compression the state would once again merge with the Normal compression Line. Therefore, the degree of compactness or degree of bonding can be estimated from the relative positioning of the initial states of the soil. Smoke of these features explained can be seen from the Figure 2

3.6 California Bearing Ratio Test

California Bearing Ratio test is carried out as it is a measure of stability of soil in order to evaluate strength of the sub-grade material for flexible pavement design. In view of the fact involving soils of tropical region in the preparation of sub grade attempt has been made to correlate the C.B.R Value with modified plasticity index.

The relationship between C.B.R value and modified plasticity index is given below. The data includes the C.B.R values of other soils tested in the laboratory. It may be seen (Figure 3) that the relationship is a power function with a correlation coefficient of 0.96. As modified plasticity index increase the C.B.R value decreases as a power function given by the following expression.

$$CBR = 26.53\left(I_{MP}\right)^{-0.6324}$$

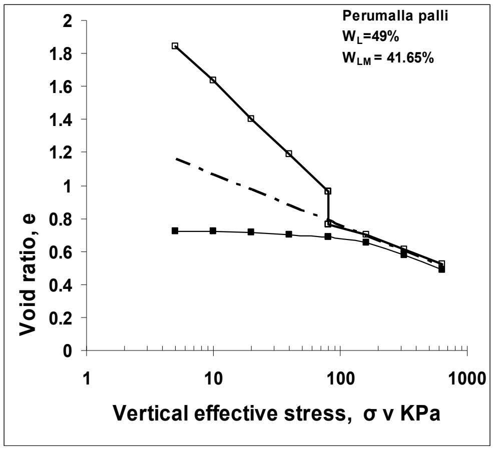

Figure 2 Soil state vs. Externally applied pressure

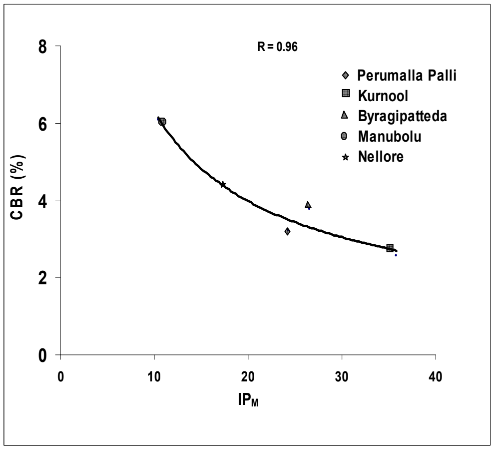

Figure 3 Empirical Relationship between CBR and Modified Plasticity Index for the samples studied (O. Sreedhara, 2007)

3.7 Remarks:

It is brought out in the preceding sections that, any experimental programme that is contemplated the following points should be kept in mind:

1. The tropical soils constitute varying grain size distribution characteristics. Accordingly, the effect of coarse fraction has to be appropriately taken into account while analyzing the test results.
2. The functional relationships are generally developed relating consistency limits to engineering behavior. But the consistency limits are found out using soil fraction passing 425 micron sieve size. Therefore, the consistencies limits need to be modified appropriately, taking into account the percentage Fine fraction.
3. The soil states exist quite varyingly encompassing unsaturated state, partly saturated state, normally consolidated state, compacted state, over consolidated state. The behavior of soils can be analyzed using a reference state in order to understand the behavior of soil more comprehensively in relation to each other.

4. EXPERIMENTAL INVESTIGATIONS

In order to develop a framework, a carefully planned experimental work has been devised which take into account wide spectrum of variations in terms of inherent grain size, plasticity characteristics that is normally encountered in practice. For the purpose of the present study, the soil samples from 14 different locations have been selected.

The soil properties are presented in Table 1-2. It may be noticed from the tables that the Fine fraction varies from 22-72%. The plasticity as represented by Plasticity Index ranges from 11-17%. The relative portions of the samples in plasticity chart are shown in figure 4. It is of interest to know that though the soil grain size has wide variation, the plasticity index range is relatively less. This is typical of the soils normally found in the region.

4.1 Test Results and Analysis

The CBR Test Results are shown in relation to the material index properties in terms of liquid limit, modified liquid limit, plasticity index and modified plasticity index as also with respect to state parameter represented by initial void ratio and e/e_L. These parameters are evaluated as shown in Table 3-4. The variation of CBR with various material parameters are brought out in Figures 5-11.

4.2 Variation of CBR with Liquid Limit

A closer examination of these variations turns out that the CBR bears no relationship with liquid limit, as wide scatter in the variation may be observed in Figure 5 However, when the variation of CBR is represented in terms of modified liquid limit which takes in to account the fine fraction of the soil sample which for which liquid limit is determined, it is noticed that the variation is linear with a regression coefficient of 0.664 as shown in Figure 6. This relationship indicates that there is effect of fine fraction on CBR value. The CBR value decreases with increase in Modified Liquid Limit. However, the regression coefficient of 0.664 indicates that it's other parameters which are to be taken into account in order to develop more defined functional relationship.

4.3 Variation of CBR with Plasticity Index:

An attempt has been made to observe the variation of CBR with plasticity index. Accordingly, the relationship between CBR and plasticity index is shown in Figure 7. For the soils under consideration, it may be noticed that there is no definite relationship between plasticity index and CBR value as is indicated by wide scatter in the variation. The results are transformed on to modified plasticity index as represented in Figure 8. It may be once again noticed that there is wide scatter and doesn't indicate any functional relation.

4.4 Variation of CBR with Initial Void Ratio:

Further, an attempt has been made to observe the variation of CBR with state parameter which is represented by the initial void ratio. Accordingly, the relationship between CBR and initial void ratio is shown in Figure 9. For the soils under consideration, it may be noticed that there is no definite relationship between initial void ratio and CBR value as is indicated by wide scatter in the variation. The same results are transformed on to e_L, as represented in Figure 10. It may be once again noticed that there is a linear relation of CBR with void ratio at liquid limit. However, the regression coefficient is as low as 0.664, indicating further analysis. Consequently, it was thought to compare the present state of the soil in relation to its loosest state which would bring about degree of compactness leading to better representation of the current state of soil. The figure 11 shows the variation of CBR relative to e/e_L parameter. It is of interest to note that the relationship is very close to linear variation with regression coefficient of 0.942.

Table 1 Soil Properties

Sl. No	Description	Value						
		Sample Numbers						
		1	2	3	4	5	6	7
1.	Gravel (%)	27.80	41.30	14.10	2.10	17.00	16.50	14.60
2.	Sand (%)	49.50	28.60	52.60	60.00	51.60	57.40	51.70
3.	Silt + Clay (%)	22.70	30.10	33.30	37.90	31.40	26.10	33.70
4.	Liquid Limit (%)	20.00	28.00	30.00	21.00	25.00	29.00	33.00
5.	Plastic Limit (%)	-	14.00	15.00	-	14.00	15.00	16.00
6.	Plasticity Index (%)	NP	14.00	15.00	NP	11.00	14.00	17.00
7.	IS Classification	SM	GC	SC	SM	SC	SC	SC
8.	Free Swell Index (%)	20.00	30.00	40.00	30.00	10.00	20.00	30.00
9.	Degree of Expansion	Low	Low	Low	Low	Low	Low	Low
10.	Maximum dry density, (KN/m^3)	21.19	20.80	20.2	20.8	21.19	20.6	20.6
11.	Optimum moisture content (%)	8.00	6.00	8.00	8.00	8.00	8.00	8.00
12.	CBR, (%) *(as per IS 2720, Part 16,*	30.134	8.218	18.263	21.002	20.089	24.655	30.134

Table 2 Soil Properties

Sl. No	Description	Value						
		Sample Numbers						
		8	9	10	11	12	13	14
1.	Gravel (%)	0.60	6.10	3.60	4.80	69.00	11.50	5.60
2.	Sand (%)	27.70	42.30	73.30	57.50	12.70	72.30	64.00
3.	Silt + Clay (%)	71.70	51.60	23.10	37.70	18.30	16.20	30.40
4.	Liquid Limit (%)	23.00	29.00	27.00	30.00	30.00	30.00	31.00
5.	Plastic Limit (%)	13.00	14.00	14.00	15.00	15.00	16.00	16.00
6.	Plasticity Index (%)	10.00	15.00	13.00	15.00	15.00	14.00	15.00
7.	IS Classification	CL	CL	SC	SC	GC	SC	SC
8.	Free Swell Index (%)	20.00	40.00	10.00	40.00	40.00	10.00	30.00
9.	Degree of Expansion	Low	Low	Low	Low	Low	Low	Low
10.	Maximum dry density, (KN/m^3) *(as per IS 2720, Part 8, 1983)*	20.9	20.6	19.8	20.9	20.6	20.2	20.2
11.	Optimum moisture content (%) *(as per IS 2720, Part 8, 1983)*	8.00	8.00	9.00	9.00	8.00	9.00	8.00
12.	CBR, (%) *(as per IS 2720, Part 16, 1983)*	10.958	5.479	3.653	58.441	15.980	52.049	63.007

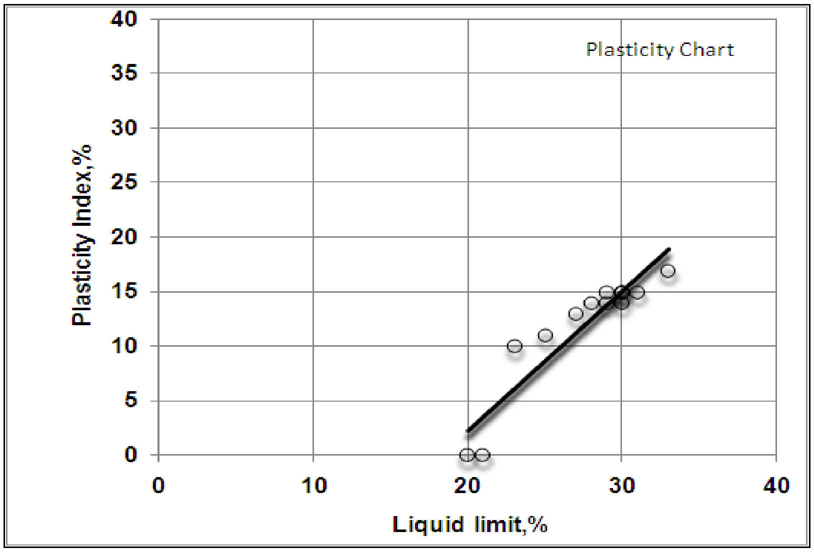

Figure 4 Relative positioning of samples tested on plasticity chart

Table 3 CBR values in relation to Material Properties

Sample Numbers	CBR, %	Liquid Limit, %	Modified Liquid Limit, %	Plasticity Index, %	Modified Plasticity Index, MPI, %	e	e_L	$\frac{e}{e_L}$
1	30.13	20	6.6	-	-	0.3557	0.1756	2.0262
2	8.22	28	11.004	14	5.502	0.3500	0.2927	1.1957
3	18.26	30	12.06	15	6.03	0.4402	0.3208	1.3722
4	21.00	21	11.424	-	-	0.5482	0.3039	1.8041
5	20.09	25	10.5	11	4.62	0.5124	0.2793	1.8347
6	24.65	29	11.107	14	5.362	0.5349	0.2954	1.8106
7	10.96	33	12.144	17	6.256	0.5372	0.3230	1.6629
8	5.48	23	18.147	10	7.89	0.6332	0.4827	1.3118
9	3.65	29	16.414	15	8.49	0.5301	0.4366	1.2142
10	58.44	27	8.019	13	3.861	0.6541	0.2133	3.0666
11	15.98	30	13.71	15	6.855	0.5233	0.3647	1.4349
12	52.05	30	6.27	15	3.135	0.5275	0.1668	3.1628
13	63.01	30	6.54	14	3.052	0.5660	0.1740	3.2534
14	15.07	31	11.253	15	5.445	0.5521	0.2993	1.8445

Table 4 Evaluation of index parameters

S. No	Description	Functional Relation	Remarks
1	Modified Liquid Limit	MLL, $w_{ML}= w_L \times F$	F=percent fine fraction (ie <425 microns)
2	Modified Plasticity Index	MPI, $I_{MP}= I_P X f$	
3	Void ratio	$e=\frac{G\gamma_w}{\gamma_d}-1$	-
4	Void ratio at Liquid Limit	$e_L=\frac{w_L G}{S_r}\ ;\ \ S_r=1$	w_L=liquid limit water content

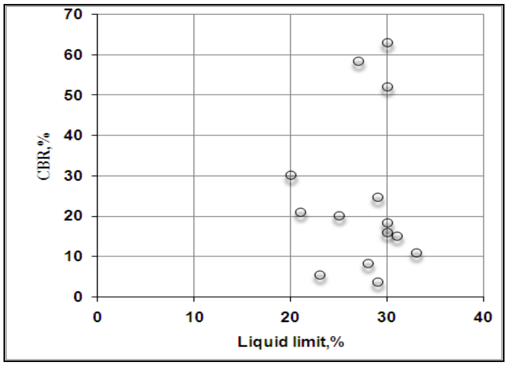

Figure 5 Variation of CBR with Liquid Limit Values

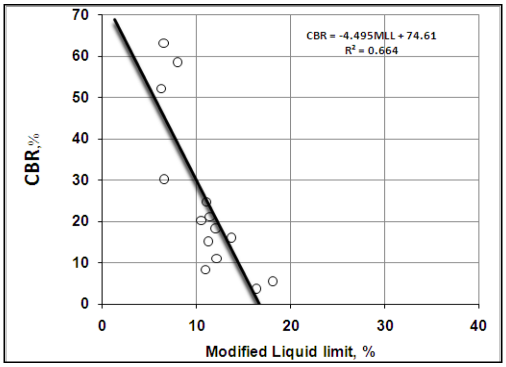

Figure 6 Variation of CBR with Modified Liquid Limit Values

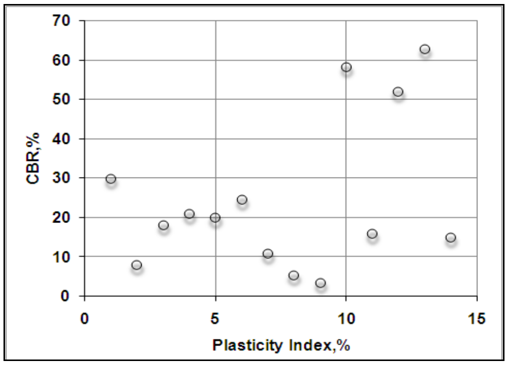

Figure 7 Variation of CBR with Plasticity Index Values

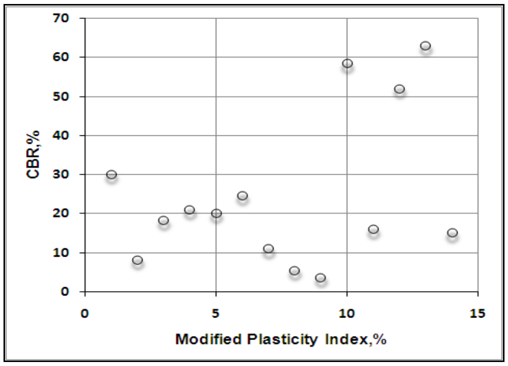

Figure 8 Variation of CBR with Modified Plasticity Index Values

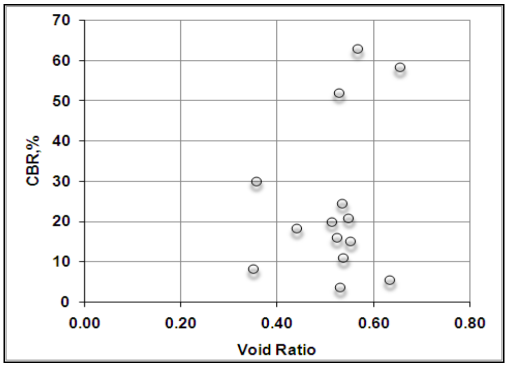

Figure 9 Variation of CBR with Initial Void Ratio Values

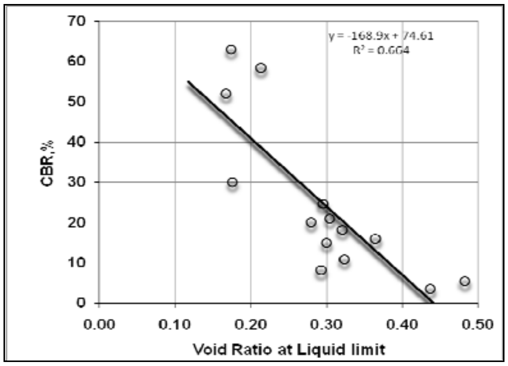

Figure 10 Variation of CBR with Void Ratio at Liquid Limit Values

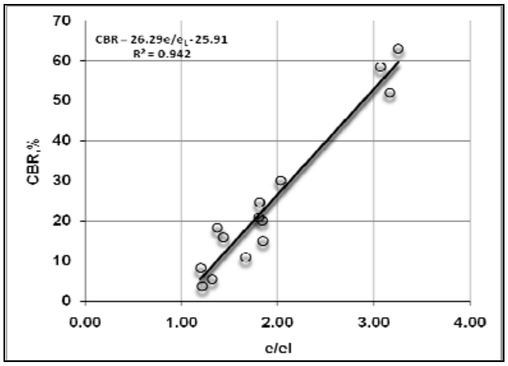

Figure 11 Variation of CBR with e/e_L

4.5 Framework for Assessment of CBR.

Based on the detailed analysis presented, it is possible to propose the following framework for assessment of CBR value.

Step-1 : Determine the liquid limit of soil

Step-2 : Determine the normal Compression line as given by [14] to locate the current state of soil.

Step-3 : Determine the compaction properties and find out the void ratio corresponding to optimum moisture content

Step-4 : Determine e/e_L

Step-5 : Determine CBR from following functional relation

$$CBR,\% = A\frac{e}{e_L} + B$$

Where A=26.29: B= -25.91

The constants A and B can be refined by considering more number of samples in order to make to applicable to wide variety of soils.

5.0 CONCLUDING AND REMARKS

Most of the basic models suggested for prediction of CBR value are based on index parameters without proper relation to the state parameter. The physical properties most often reflect the classification of soils and do not represent the in-situ characteristic features based on which the actual response of the system depends. For example, two soils with same physical properties with different unit weights might behave quite differently. Hence, it is thought that any prediction methodology should be based on both physical and in-situ characteristics for meaningful application of the model in real practice

Based on the present investigation, the following specific concluding remarks may be made:

1. The model proposed takes into cognizance the liquid limit void ratio, percentage fine fraction, modified liquid limit, by appropriately taking in to account the relative influence of fine fraction on liquid limit together with void ratio at compact state to bring out the correlation with the experimentally determined CBR values. The model proposed has been applied to other soil data and the result thus compared underlines the importance of the model proposed.
2. The grain size distribution curves for the samples under study indicate wide variation in the grain size.
3. The positioning of soil samples on plasticity chart indicate the soil are scattered around A-line indicating the soils selected are mostly clayey.
4. The fine fraction varies from 22-72%. The plasticity as represented by plasticity index ranges from 11-17%. It is of interest to know that though the soil grain size has wide variation, the plasticity index range is relatively less. This is typical of the soils normally found in the region.
5. The test results of compaction are scattered over a range of maximum dry densities. A closer examination reveals that the scatter is on account of the grain size distribution and plasticity characteristics.
6. A closer examination of the test results turns out that the CBR bears no relationship with liquid limit, as wide scatter in the variation is observed. However, when the variation of CBR is represented in terms of modified liquid limit which takes in to account the fine fraction of the soil sample for which liquid limit is determined, it is noticed that the variation is linear with a regression coefficient of 0.664. This relationship indicates that there is effect of fine fraction on CBR value.
7. An attempt has been made to observe the variation of CBR with plasticity index. For the soils under consideration, it is noticed that there is no definite relationship between plasticity index and CBR value as is indicated by wide scatter in the variation. The results are transformed on to modified plasticity index and is once again noticed that there is wide scatter and doesn’t indicate any functional relation.
8. Further, an attempt has been made to observe the variation of CBR with state parameter which is represented by the initial void ratio. For the soils under consideration, it may be noticed that there is no definite relationship between initial void ratio and CBR value as is indicated by wide scatter in the variation. It is once again noticed that there is a linear relation of CBR with void ratio at liquid limit. However, the regression coefficient is as low as 0.664, indicating further analysis.
9. Consequently, it is observed that the variation of CBR relative to e/e_l parameter is quite in close agreement with the linear relation. The parameter e/e_l compares the present state of the soil in relation to its loosest state which would bring about degree of compactness leading to better representation of the current state of soil.

REFERENCES

[1]. Abdolreza Osouli, Sajjad Salam, Goran Othmanawny, Erol Tutumluer, Sheila Beshears, Heather Shoup and Mathew Eck, (2017). “ Results of Soaked and Unsoaked California Bearing Rate Tests on Unbound Aggregates with varying Amounts of Fines and Dust Ratio”, Transportation Research Record : Journal of the Transportation Research Board, Volume 2655

[2]. Ammu John, Anju Joson, Jesu Venia, Krishna Chandran B, Prof Anniamma Chacko (Mar, 2017). “Correlation of CBR Value with Properties of Red Soil”, International Research Journal of Engineering and Technology, Volume:04 Issue: 03

[3]. Burland, J.B. (1990), “On the compressibility and Shear Strength of Natural clays”. Geotechnique, 40(3): 29-378.

[4]. Datta, T., and Chottopadhayay, "Correlation between CBR and Index Properties of Soil," Paper No. A-350, In Proceedings of Indian Geotechnical Conference, December 15-17, 2011.

[5]. Deepak Yadav, P.K. Jain & Rakesh Kumar (2014), “Prediction of Soaked CBR of Fine Grained Soils from Classification and Compaction Parameters”, International Journal of Advanced Engineering Research

and Studies E-ISSN2249–8974 Int. J. Adv. Engg., Res. Studies/III/IV/April-June, 2014/119-121.

[6]. Essien Udo, Charles Kennedy, (June, 2016), “Characterization and Model Prediction of CBR Parameters of Stabilized Ebidang Residual Soils, Akwa Ibom State, Nigeria”, International Journal of Scientific Engineering and Applied Science, Volume 2, Issue 6.

[7]. Farrar, D. M., Coleman, J.D. (1967), “The correlation of Surface Area with other properties of Nineteen British Clay Soils”, Journal of Soil Science, Vol:18, No:1

[8]. Guruprasad Jadhav, Vishwajeet Biradar, Prof. Md. Khaja Moniuddin, (2016), “ Relation Between C.B.R Values and Geotechnical Properties of Expansive Soil”, International Journal for Scientific Research and Development Vol.4, Issue 1, 2016

[9]. Karunaprema, K.A.K. and Edirisinghe, A.G.H.J. (2002), “A Laboratory study to establish some useful relationship for the case of Dynamic Cone Penetration”, Electronic journal of Geotechnical Engineering. Vol.7

[10]. Kesharwani R.S, Sahu A.K, Khan N.U., (April, 2016), “CBR Value of Sandy Subgrade Blended with Coarse Aggregate”, Int. J. of GEOMATE, April, 2016, Vol. 10, No. 2(Sl. No. 20), pp. 1743-1750 Geotech., Const. Mat. and Env., ISSN: 2186-2982(P), 2186-2990(0), Japan.

[11]. Khillare, P.S., Dr. Damgir, R. M., Sandeep L. Hake., (October, 2016), “ CBR Determination on Subgrade Soil by Replacement of Additives”, International Journal of New Innovations in Engineering and Technology, Volume 6 Issue 1-October 2016, ISSN: 2319-6319

[12]. Kumar, P., et el (2000), “An Indigenous Impact Tester for measuring In situ CBR of Pavement Materials”, Highway Research Bulletin, IRC, No 63, 13-22

[13]. M. M. E. Zumrawi (2014), “Prediction of In-situ CBR of Subgrade Cohesive Soils from Dynamic Cone Penetrometer and Soil Properties”, IACSIT International Journal of Engineering and Technology, Vol. 6, No. 5, October 2014.

[14]. Nagaraj, T. S. & Srinivasa Murthy B. R., Vatsala, A., (1994). “Analysis and prediction of soil behavior”, Wiley Eastern, New Delhi, p.294.

[15]. Nagaraj, T. S., Nagendra Prasad, K., Chandra Reddy, V. M. & Govinda Reddy, N. (1998). “Analysis of residual tropical soil behaviour. The Geotechnics of hard soils and soft rocks”, Evangelista & Picarelli (eds), Balkema: 715 -723.

[16]. Nagendra Prasad. K., Manohara Reddy. R., Chandra. B., Harsha Vardhan Reddy. M. (2013)’ “Compression Behaviour of Natural Soils”, International Journal of Civil Engineering and Technology (IJCIET) Volume 4, Issue 3, May - June (2013), pp. 80-91.

[17]. Naveen B shirur, Shahbaz Dandin, Vivek Patil (2017), “Establishing Relationship between CBR Value and Physical Properties of Soil”, International Journal of Engineering Research in Mechanical and Civil Engineering, Special Issue.

[18]. O. Sreedhara, (2007), “Analysis and Predication of Behaviour of Compacted Soils, Ph.D., Thesis submitted to Sri Venkateswara University, 2007.

[19]. Patel, Rashmi S. 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

[20]. Rabi Das, Raja Saha, Minhaj Aktar Mollah, Abhirup Sadhukhan, Jhilik Das, Shayantani Dutta, (April, 2017), “ Comparative Studies of CBR Value of Soil Sample using various Ground Improvement Materials”, International Research Journal of Engineering and Technology, Volume:04 Issue: 04

[21]. Ramasubbarao, G.V. and Siva Sankar, G. (2013), “Predicting Soaked CBR Value of Fine Grained Soils Using Index and Compaction Characteristics”. Jordan Journal of Civil Engineering, Volume 7, No. 3, 2013

[22]. Saklecha P. P, Katpatal Y. B, Rathore S. S., Agarawal D. K, (2011), “Spatial Correlation of Mechanical Properties of Subgrade Soil for Foundation Characterization”, International Journal of Computer Application, Volume 36 - No.11

[23]. Sathawara Jigar K., Patel A.K. (2013), “Comparison between soaked and

unsoaked CBR". International journal of advanced engineering research and studies., vol 2, issue 3, pp 132-135,

[24]. Srinivasa Murthy, B.R., Nagaraj, T.S.& Bindu Madhava, (1987). "Influence of coarse particles on Compressibility soils, prediction and performance in geotechnical engineering" / Calgary / 17-19 June 1987.

[25]. Venkatasubramanian, C. and Dhinakaran, G., "ANN Model for Predciting CBR from Index Properties of Soil," International Journal of Civil and Structural Engineering, Vol. 2, Issue 2, 2011, pp. 614-620.

[26]. Vishal Chandrakar, R K Yadav, (November, 2016), " Study of Correlation of CBR Value with Engineering Properties and Index properties of Coarse Grained Soil", International Research Journal of Engineering and Technology, Volume:03 Issue: 11

[27]. Yildrim, B. and Gunaydin, O. "Estimation of CBR by soft computing systems," Expert Systems with Applications, ELSEVIER, 38, 2011, pp. 6381-6391.

[28]. Zohib Shahzad Janjua, Jagdish Chand, (October 2016), "Correlation of CBR with Index Properties of Soil", International Journal of Civil Engineering and Technology, Volume 7, Issue 5, September-October 206, pp. 57-62.