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COMPARISON OF CBR AND DCPI CORRELATIONS ON SOILS USING ASTM

C Lavanya[1] and Batchu Ramanjaneyulu[2]

[1]*Professor in Civil Engineering, GRIET Hyderabad-500090, Telangana, India*

[2]*Assistant Professor, CVR College of Engineering Hyderabad - 501510, Telangana, India*

Abstract

California Bearing Ratio (CBR) plays a pivotal role in the design of flexible pavement as it indicates the strength of pavement subgrade material and decides pavement thickness. It is cumbersome to evaluate CBR value proximately every time. Development of correlations between CBR and Dynamic Cone Penetration Index (DCPI) on soils will ease the testing work of highway design engineers in evaluation of subgrade CBR value. Research is being in progression to test the reliability of this correlation. The present study is focused to bring out the reliability of CBR and DCPI correlation on Indian soils such as black cotton soils and murrum soils. The correlations published in ASTM-D-6951 were considered for comparison of the test results. Dynamic cone penetrometer tests were conducted for three different soils like black cotton soil, murrum and sandy soil along with laboratory CBR tests. A comparison study is made between laboratory CBR and CBR values obtained from the DCPI value and also, between CBR values obtained by using the correlations published in ASTM D 6951. Percentage reduction in CBR value obtained from ASTM is compared with that of laboratory CBR value. The percentage change in CBR of clay showed more compared to the granular soils. The correlations developed are verified and proposed for sustainable engineering practice point of view.

Keywords: *CBR, DCPI, Correlation, Soil*

1. Introduction

California Bearing Ratio (CBR) value plays a crucial role in the design of flexible pavements or for the rehabilitation of existing pavements. The effectiveness of CBR value is very important for the evaluation of strength of subgrade materials and to ensure the lifespan of pavements. Dynamic Cone Penetration test is an in-situ test which is used to evaluate the resistance of soil towards the penetration. This test was first developed by Scala in Australia in 1956. The model of DCPT which is being used currently is modified by Transvaal Roads Department, South Africa in 1998. The traditional methods to evaluate the properties of soils consists of many laboratory tests which include complex procedures. DCP test was developed as an alternative method for these methods. Due to its ease of carrying the apparatus, simple and clear process, this test brings down the efforts and cost of evaluating subgrade soil properties. CBR value can be assessed in the form of correlation from Dynamic Cone Penetration Index (DCPI) which is obtained from DCP test.

Construction of flexible pavement over a black cotton soil subgrade with CBR approach as defined by IRC 37-2001 is the most appropriate method [1]. As per IRC, pavement is designed for various thicknesses by taking CBR value into consideration. Flexible pavements have been found to be more cost-effective for lower traffic volumes. The thickness of the pavement varies as the CBR value changes. Pavement thickness decreases when CBR increases and vice versa [2]. It is critical to assess and identify the reasons of flexible pavement failures, as well as to choose the most appropriate and effective treatment and maintenance [3].

The performance of flexible pavement (IRC-37 2012) continues to deteriorate after flooding, according to a study of the circumstances before and after floods. Increased pavement thickness reduces the likelihood of road degradation. Rutting of the pavement may be minimized as the thickness of each layer increases [4]. The goal of laboratory and field testing on a fine-grained material was to identify correlations between the materials density, moisture content, laboratory and field stiffness characteristics. The laboratory and field moduli were reasonably well-correlated to their respective moisture contents at the time of testing with DCPT [5].

With three uncemented soil groups like poorly graded sand (SP), silty sand (SM), and well-graded sand with silt (SW-SM) compacted in a big container, the Soil Stiffness Gauge (SSG), Dynamic Cone Penetrometer (DCP), Plate Load Test (PLT) and California Bearing Ratio (CBR) were performed and the relationship obtained between CBR and DPI showed a similar trend although at a given DPI it produces significantly larger CBR values. For all the soils considered, the void ratio is linearly proportional to the DPI divided by the median particle size while the angle of internal friction is inversely proportional [6].

Dynamic Cone Penetrometer (DCP) is a valid way of determining SPT blow count N60 values, which are employed in a variety of geotechnical correlations for soil property evaluation. The DCP is more sensitive than the SPT to variations with the depth of soil [7]. Correlations between DPI and engineering characteristics of sandy soils with a high correlation coefficient are found effective [8]. Use of dynamic cone penetrometer in subgrade and subbase is widely accepted. The DCP might be the sole instrument capable of detecting and confirming and identifying soil locations with low quality [9]. Existing roads also must be assessed for layer thickness and strength in relation to the California Bearing Ratio (CBR). The Dynamic Cone Penetrometer is one of the most common and straightforward devices for assessing road pavement layer thickness and strength [10].

This paper is probing towards reliability study of correlations that fetch CBR values keeping DCPI as base in three different soils. Comparison is made between numerical variation of CBR values from ASTM D 6951 to that of laboratory CBR.

2. Experimental Investigation

2.1. Materials Used

Soils used in the present study were collected from different districts from Telangana state of India.

Sample 1 was collected from Bachupally, Medchal-Malkajgiri district which is a non-plastic soil and classified as SP as per Indian Standard Soil Classification System. Sample 2 was collected from Patancheru, Sanagreddy district which is also non-plastic and is classified as SW-SC. Sample 3 was collected from Gundala, Nalgonda district in the state of Telangana, India and is classified as CH. Third sample is having high plasticity index of 40% and free swell index value is 220%. Laboratory tests were conducted on these soil samples as per the Indian standard (IS) code of practices [11-15] as mentioned in Table 1. Basic laboratory tests were conducted on all the three soil samples and the properties are presented in Table 2.

Table 1. IS Code for Tests Conducted

Name of the Test	IS Code of Practice
Grain Size Analysis	IS: 2720 (Part-IV): 1985
Liquid Limit and Plastic Limit	IS: 2720 (Part-V): 1985
Compaction	IS: 2720 (Part-VIII): 1980
California Bearing Ratio	IS: 2720 (Part-XVI): 1987
Coefficient of Permeability	IS: 2720 (Part-XVII): 1986

Table 2. Properties of Soil Samples

Soil Properties	Sample 1	Sample 2	Sample 3
Grain size analysis			
Gravel (%)	11	17	4
Sand (%)	85	78	33
Silt and Clay (%)	4	5	63
Consistency Limits			
Liquid Limit (%)	NP	25	75
Plastic Limit (%)	NP	NP	35
Plasticity Index	NP	NP	40
IS Classification	SP	SW-SC	CH
Maximum Dry Density (kN/m3)	20	17	14
Optimum Moisture Content (%)	12	12	18
Coefficient of Permeability, k (cm/sec)	0.35×10^{-4}	0.59×10^{-5}	0.53×10^{-7}
California Bearing Ratio (%)	8.8	7.5	2.0

2.2. Dynamic Cone Penetration Test

The dynamic cone penetration test (DCPT) was designed to evaluate the properties of flexible pavement and subgrade soils [16]. The traditional method for determining the strength and stiffness of subgrade soils involve a core sampling procedure and a lengthy laboratory testing program that includes resilient modulus, Marshall tests, and other methods. Better knowledge of the DCPT data can minimize the work and cost of evaluating pavement and subgrade soils greatly due to its economy and simplicity.

The dynamic cone penetrometer consists of two shafts. The upper shaft is linked with lower shaft with an anvil. It has a metal hammer of mass 8kg. A cone is attached to the lower shaft which has 60^0 apex angle. Tip of the cone is placed on the soil sample by holding the shaft at the upper end. The blows were given by dropping 8kg hammer from a height of 575mm on to a soil. The penetration depth is noted for every blow of hammer. This procedure was carried out until the desired depth is reached. Soil samples were prepared at their OMC and tested. Number of blows required for the penetration of DCPT up to 300mm is recorded.

3. Results and Discussion

3.1. Test Results

Variation of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) is shown in Fig.1 for all the three different soils. It is observed that the MDD for SP soil is more when compared to SW-SC and CH soils and more OMC is observed in CH soil as compared to the other two soils SW-SC and SP. Fig. 2 shows the variation of California Bearing Ratio (CBR) Value for SP, SW-SC and CH soils. It can be noticed that the CBR value for SP soil is about 4.4 times more when compared with that of CH soil and for SW-SC it was about 3.75 times more than that of CH soil.

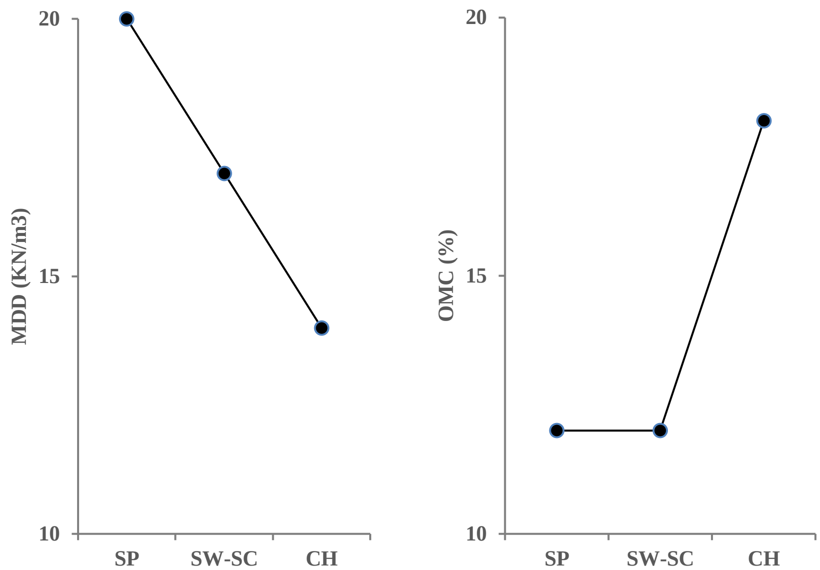

Fig. 1. Variation of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for three different soils.

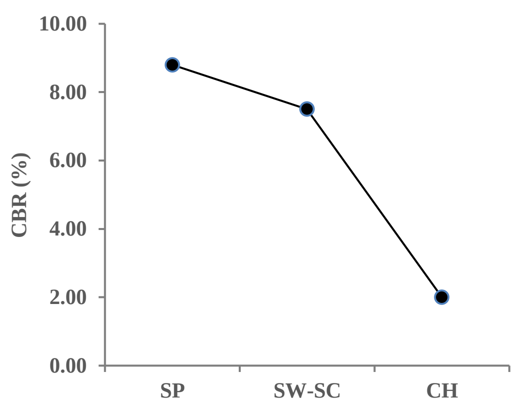

Fig. 2. Variation of California Bearing Ratio (CBR) Value for three different soils.

The results of DCPT in the form of number of blows and the respective penetration in mm are shown in Fig. 3. Curves presented in Fig.3, show linear variation for SP, SW-SC and CH soils. It is observed that the number of blows required for CH soil is less when compared to that of SP and SW-SC soils for the same penetration. Variation of Dynamic Cone Penetration Index (DCPI) value with number of blows is shown in Fig. 4. DCPI is the ratio of penetration value to that of number of blows. From Fig.4, it is observed that as the number of blows increases, the DCPI is increasing and this increase is noticed up to 1 to 2 blows, thereafter the DCPI is decreasing. In case of CH soil, the decrease in DCPI is drastic, but in case of SP and SW-SC soils after 2 blows, the variation in DCPI is negligible.

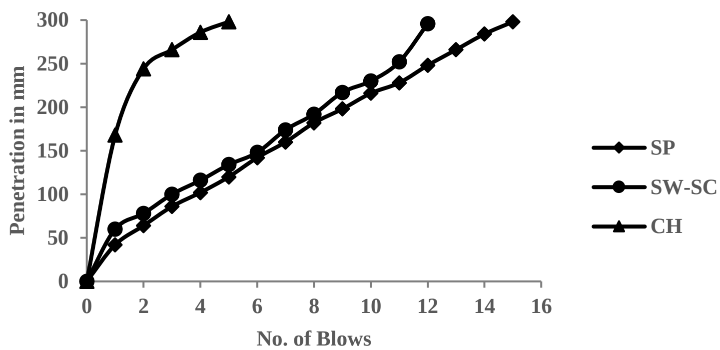

Fig. 3. Number of blows versus Penetration (mm) for SP, SW-SC and CH soils.

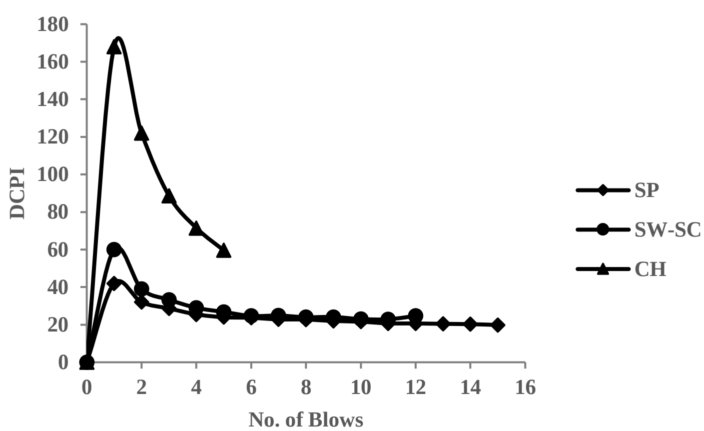

Fig. 4. Number of blows versus DCPI for SP, SW-SC and CH soils.

CBR value is calculated from the DCPI value by using correlation as per the ASTM D 6951. The correlation used to estimate CBR as per the ASTM D 6951 is as follows.

$$CBR=292/[DCPI]^{1.12}$$

Figs. 5 show the CBR value obtained from DCPI by using ASTM correlations for SP, SW-SC and CH soils. It is observed that the CBR value obtained from ASTM is similar for SP, SW-SC and CH soils. For clay soil with high plasticity, CBR value is less when compared to that of SP and SW-SC for the respective number of blows.

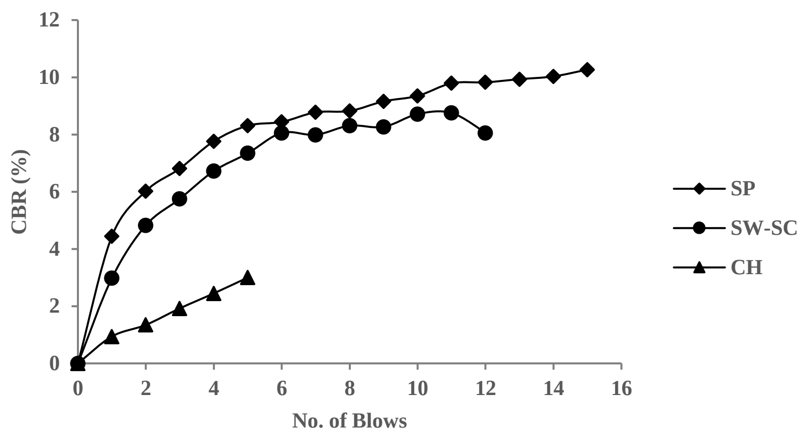

Fig. 5. CBR from DCPI Value as per ASTM D 6951 for SP, SW-SC and CH soils.

CBR value obtained from the ASTM is compared with the laboratory CBR value for SP, SW - SC and CH soils. It is observed that the CBR value obtained from laboratory test is little higher when compared with the CBR value obtained from ASTM correlations. The marginal difference between laboratory CBR and CBR value from ASTM was 3.18% for SP soil. Whereas for SW-SC soil, the variation is about 4.67% ASTM approach. For CH soil the percentage difference is 3.50%.

4. Conclusions

CBR and Dynamic Cone Penetration Index (DCPI) correlations are very helpful in flexible pavements. Laboratory CBR and CBR from the correlations as per ASTM D 6951 is studied for SP, SW-SC and CH soils. ASTM correlation show the similar CBR value when calculated by using DCPI. CBR value obtained from the ASTM is compared with the laboratory CBR value for SP, SW-SC and CH soils. The laboratory CBR value is more when compared with the CBR value obtained from ASTM correlation for SP, SW-SC and CH soils. Percentage difference between laboratory CBR and CBR value obtained from ASTM is about 3.24% for SP soil, 4.73% for SW-SC and 3.5% for CH soil.

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