ISSN: 2277-9655
[Daljeet Singh* *et al.*, 6(7): July, 2017] Impact Factor: 4.116
IC™ Value: 3.00 CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EFFECT OF FIELD MOISTURE CONTENT ON PENETRATION INDEX VALUE OF DYNAMIC CONE PENETROMETER IN ALLUVIAL SOIL SUBGRADES

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DOI: 10.5281/zenodo.827508

ABSTRACT

Dynamic Cone Penetrometer is an ideal instrument for testing subgrade and embankment compaction and it in-situ California Bearing Ratio (CBR). The Dynamic Cone Penetration Index (DCPI) value has valid correlation with CBR. The relation has higher value of coefficient of determination, denoted as R^2, for non-cohesive soils dry soils. The fine grained alluvial soils having some Plasticity Index (PI) value shows the lower R^2 value. The Various alluvial soil samples having PI value from 0 to 10 were tested for finding the moisture correction factor so that DCPI values can be correlated with In-situ CBR at different field moisture conditions.

Keywords: ***DCP, CBR, DCPI, PI, Field Moisture Content and Correction Factor.***

I. INTRODUCTION

Performance of flexible pavement greatly depends upon the accurate evaluation of subgrade strength. To ensure the subgrade and embankment has achieved the design CBR, one has to cut the core and soak it for 4 to 7 days in still water and test it in laboratory for its CBR or remold the sample in cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick. 2. Spacer disc 148 mm in dia and 47.7 mm in height along with handles. The samples are then tested as per IS 2720 Part 16 [1] As per revised Indian Road Congress **(**IRC: 37**) [**2**]** subgrade soil should be non**-**expensive in nature having CBR more than 8**%.** but most of the roads constructed prior to this code of practice do not conform to this further more due lack of awareness on the part of field engineers it is considered that some plasticity is considered helpful in compaction and easy to maintain profile leads to long term complications. The procedure to ensure in-situ CBR as described above is very complicated and time consuming, more over repeat-ability and reproduce-ability of the test procedure is very low. Keeping the importance of in-situ CBR in view the various government agencies and individual researchers tried to find the in-situ CBR through alternative testing procedures the most prominent are direct in-situ CBR as per IS 2720 Part-31 [3], Light Weight Falling Deflectometer ASTM [4] and Dynamic Cone Penetrometer IRC [5]. All these methods have their own implications as DCP Test is not suitable for soils have large particle size, ideal non-cohesive fine-grained soils are rarely available in actual field conditions for that most of researchers have developed correlations. The DCPI results are moisture sensitive To make the use of DCP for wider range of soils, the effect of moisture on DCPI is studied and efforts are made to find the possible correlation with other properties such as Plasticity index, field moisture content and DCPI and CBR. For this purpose, a 16 KM stretch of Ludhiana to Malerkotla State Highway No 11 passing through state of Punjab (India) as shown in Figure-1, is tested for various in-situ and laboratory tests.

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[Daljeet Singh* *et al.*, 6(7): July, 2017]
IC™ Value: 3.00
ISSN: 2277-9655
Impact Factor: 4.116
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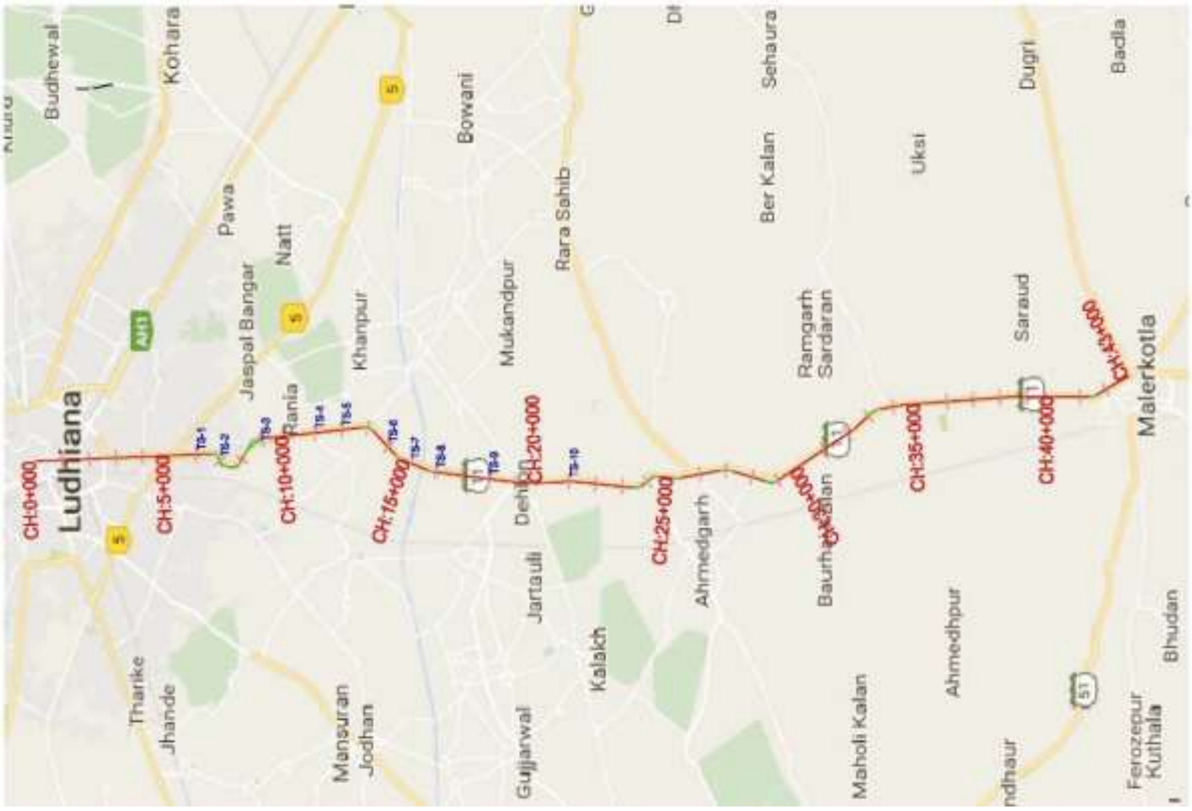

Figure-1 Key Plan Showing the Location of Testing Location on Ludhiana Malerkotla Section of Punjab SH -11

II. REVIEW OF LITERATURE

Performance of soil subgrade of a flexible pavement is influenced by several factors. Kolisoja [6] have demonstrated that in addition to grain size distribution and degree of compaction, water content with mineralogy had effects on the deformation properties. Ekblad [7] have shown that the resilient modulus is inversely proportional to the content of fines (grain size < 0.075 mm). He proved that the rise of water content decreases more the stiffness of the materials with high contents of fines. If the content of fines is small then the bigger grains can contact each other and distribute the load, while the fines fill the empty voids between grains. As the content of fines increases, the bigger grains do not necessarily contact each other to distribute the load Kolisoja [8]. As a result, there is a decrease in the deformation modulus. Besides water content and grain size distribution, one of the most important factors of permanent deformation is the degree of compaction of the material. Lekarp has demonstrated that the degree of compaction has an even stronger effect on the permanent deformations than on the resilient deformations Lekarp et al. [9]. van Niekirk [10] has addressed the fact that the degree of compaction has a more important effect on the permanent deformation than the grain size distribution. Uthus [11] demonstrates that the dry density, the degree of saturation and the stress level seem to be key parameters for determining the permanent deformation behaviour, but mineralogy, fines content and grain size distribution are also of importance.

Correlations with DCPI and CBR

Webster et al. [12] have reported the development of a relationship between the CBR and the penetration rate (DCPI) expressed in mm per Equation (1) by the U.S. Army Corps of Engineers for a wide range of granular and cohesive materials. they also found that that the effects of soil moisture content and dry density influence both CBR and DCP test values in similar ways hence not considered for the correlation where moisture and density is kept constant.

$$\text{Log CBR} = 2.465 - 1.12 \text{ Log (DCPI)} \quad (1)$$

This correlation was adopted by many researchers for their work with different soils and reported similar results, prominent and relevant to the present problem is (2) given by Livneh et al. [14] with granular and cohesive soil.

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$$\text{Log(CBR)} = 2.45\text{-}1.12 \log(\text{DCPI}) \quad (2)$$

Webster et al. [13] developed a much similar correlation relation (3) after conducting tests on various soils.

$$\text{Log(CBR)} = 2.46\text{-}1.12 \log(\text{DCPI}) \quad (3)$$

Ese, et al. [14] carried out a detailed field and laboratory testing with DCPT, for evaluating low volume roads having gravel base course and established (4).

$$\text{Log CBR}_{(lab)} = 2.438\text{-}1.065^{*}\log(\text{DCPI})_{field} \quad (4)$$

Daljeet Singh et al. [15] studied fifteen different soil in road subgrades using DCPT, grain size and Atterberg's limits in laboratory and actual field conditions at optimum moisture content and developed a CBR prediction model (5)

$$\text{CBR} = 43.73\text{-}1.043\text{N}\text{-}0.717\text{LL}\text{-}0.149\text{PL}+5.39\text{D}_{60} \quad (5)$$

With R^2 =0.995 and a standard error of 0.407

The model is very useful for verification of CBR during construction only as the field moisture conditions at OMC can only be at the time of construction or at any specific period of time after rainy season. The field moisture conditions remain changing rapidly.

As the review of previous works indicates

i) DCPI and Index Properties Grain Size and Plasticity Index have definite correlation with CBR of soil.

ii) The model developed by Daljeet Singh et al [15] is useful for verification of CBR during construction only as the field moisture conditions at OMC can only be at the time of construction. Verification of sub grade CBR for rehabilitation, upgradation or post construction evaluation purposes is not possible as the CBR and DCPI are moisture sensitive Amini, F [16].

iii) The previous researchers have primarily investigated relation of a particular parameter with CBR. The effect of other parameters if studied is only at a particular moisture content un-soaked or soaked conditions. To investigate in-situ CBR it is essential to study the effect of moisture on DCPI and CBR.

hence, it is felt performance of soil subgrade under flexible pavement layers can be anticipated with the help of DCPT apparatus by applying suitable moisture correction factor to the available prediction model (5).

III. MATERIALS AND METHODS

To investigate the effect of field moisture content on the DCPI a 16 KM long widened and strengthened from two lane to four lane dual carriage of SH 11 from Ludhiana to Malerkotla is investigated. The selected stretch has the advantage of having different alluvial soils subgrade with variable field moisture content. The research methodology is based upon the assessment of in-situ subgrade strength at optimum moisture content and worst moisture conditions. The in-situ soil strength can be measured directly from the response of the soil to applied loads or correlated to several equipment's penetration resistance. The various available techniques that can be used to measure the direct response of the soil when subjected to loads are static plate test, LWD, Benkelman Beam, Geo Gauge, time domain reflectometry and other means. In this study Standard Dynamic Cone Penetrometer (DCPT) apparatus is used. Other soil properties such as dry density, grain size, liquid limit and plastic limit and effect of moisture content is used. The Dynamic Cone Penetrometer (DCP) consists of a guiding rod fitted with a cone at the tip and is operated by dropping an 8 kg mass from a specified height. The DCP test is conducted as per standard procedure IRC-Special Publication [5] and ASTM [4] The penetration index given by DCP can be correlated to the CBR and density of a particular soil at a particular moisture content. The other soil parameters are also used to fine tune the results and enhance the usability to a wider range of soil type. This tests are conducted upto significant depth of influence of wheel load. Many researchers and agencies have developed the relationships between in-situ tests with Dynamic Cone Penetration Index (DCPI) versus CBR. To find the effect of moisture content on DCPI and mould CBR, samples are tested at different moisture content to develop correlations. The soils are grouped based upon their Plasticity Index (PI) value into three groups.

IV. RESULTS AND DISCUSSION

The CBR of soil is determined at selected location using the standard CBR test procedure and verified using DCPT apparatus using predication model (5). Since this equation gives the CBR of soil at OMC hence correction factor for moisture are developed for three different categories of soil based upon their Plasticity Index. Group A for non-plastic soils PI Value 0, Group B for PI value 1 to 4 and Group C for PI value 5 to 7. The graphs are plotted

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to find the correlation equations and and coefficient of determination as given below.

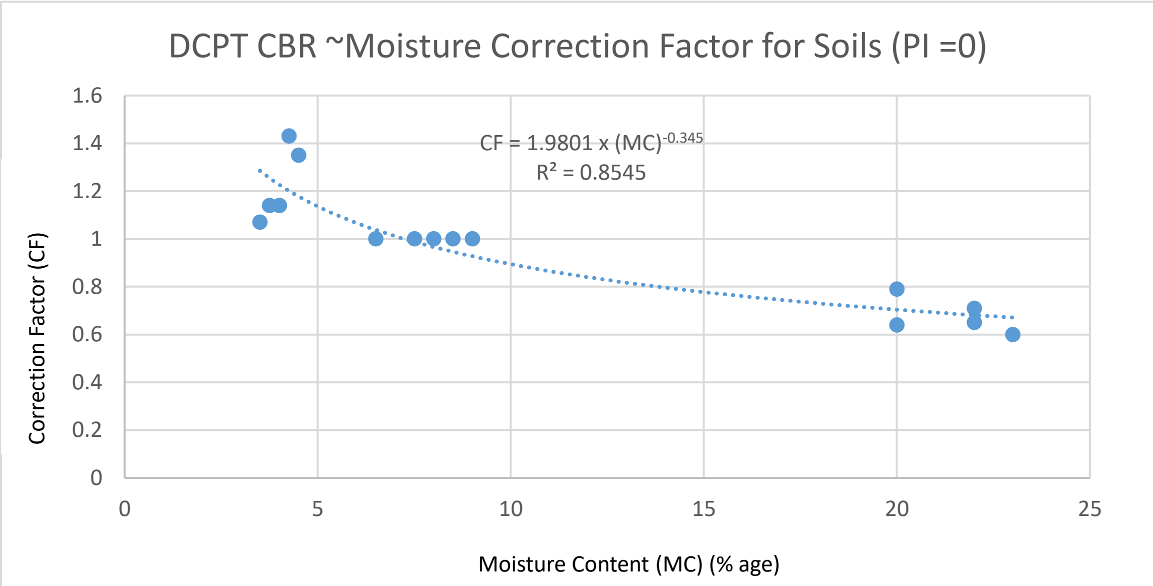

Figure- 3: DCPT CBR Moisture Correction Factor Relationship for Non-Plastic Soils (PI=0)

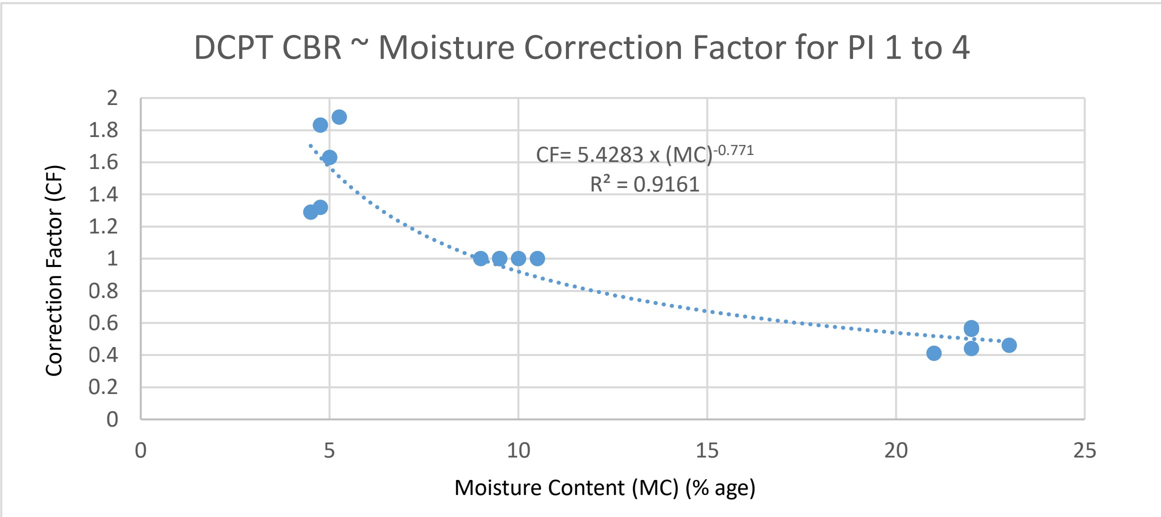

Figure- 4: DCPT CBR Moisture Correction Factor Relationship for Plastic Soils (PI value 1 to 4)

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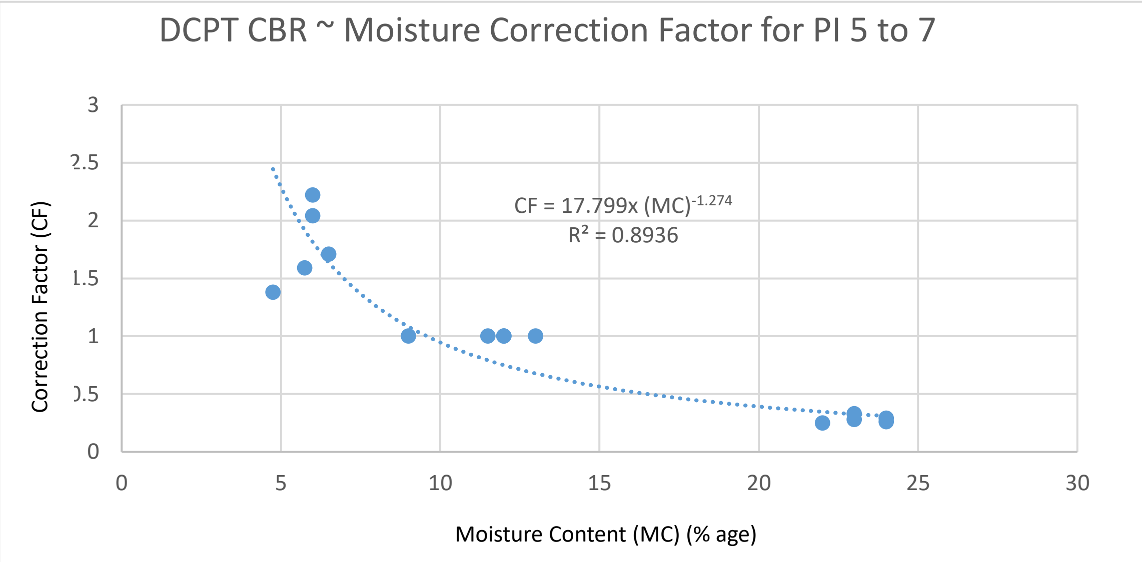

Figure- 5: DCPT CBR Moisture Correction Factor Relationship for Plastic Soils (PI value 5 to 7)

The correction factor (CF) for non-plastic soils can derived from the equation

$$CF = 1.9801 \times (MC)^{-0.345} \quad (13)$$

having $R^2 = 0.8545$

Similarly, for PI value 1 to 4 and 5 to 7 the following equations can be used respectively.

$$CF= 5.4283 \times (MC)^{-0.771} \quad (14)$$

having $R^2 = 0.9161$

And

$$CF = 17.799x\ (MC)^{-1.274} \quad (15)$$

with $R^2 = 0.8936$

The results obtained from the above equations are in accordance with correction factors used for Benkelman Beam deflection procedure defined in IRC [17].

V. FIELD VERIFICATION OF RESULTS

To verify the applicability of established relationships to moisture correction in field application 15 samples from different locations were taken and tested for their properties as detailed in Table-1. The grain size of the samples varies from D_{60} From 0.925 mm to 0.045, Plasticity Index from Non Plastic to PI upto 7 and moisture content from 3.5% to 22% since the sample are taken from the subgrade of road constructed under the strict supervision of international engineering consultant firm and reputed construction agency the in-situ compaction is nearly 97 to 98 percent of maximum dry density (modified).

Table: 1 Properties of different subgrade soils along with percentage error in Estimated and Laboratory CBR in saturated condition.

Sample Ref.	D_{60} mm	LL	PL	PI	Γd insitu kN/m³	N mm/ blow	MC %	C.F. (Divisible)	Esti. Sat. CBR	CBR$_{Lab}$ (Saturated)	Error %
S1	0.925	15	15	NP	18.6	6.33	3.5	1.29	22.6	23.4	**3.42**
S2	0.515	16	16	NP	18.24	10	7.5	0.99	22.4	21.7	**-3.23**
S3	0.35	17	17	NP	18.57	20	22	0.68	14.8	15.2	**2.63**
S4	0.209	18	18	NP	17.52	16.67	8.5	0.95	12.5	12.6	**0.79**

S5	0.172	18	18	NP	17.16	10	4.5	1.18	15.8	16.6	**4.82**
S6	0.176	19	18	1	16.47	13.67	9	1	14.1	13.9	**-1.44**
S7	0.166	20	18	2	18.42	13.67	9.5	0.96	13.9	13.6	**-2.21**
S8	0.126	21	18	3	18.93	21	21	0.52	9.2	9.6	**4.17**
S9	0.101	22	18	4	18.42	20	22	0.5	9.9	10.4	**4.81**
S10	0.206	23	19	4	16.83	12.66	9.5	0.96	12.8	12.3	**-4.07**
S11	0.084	23	18	5	18.24	12	11.5	0.79	15.8	15.2	**-3.95**
S12	0.058	24	18	6	17.37	14.33	12	0.75	12.3	11.8	**-4.24**
S13	0.058	24	18	6	17.37	3	6	1.82	11.6	11.9	**2.52**
S14	0.416	24	18	6	20.04	4	4.75	2.45	8.9	9.3	**4.3**
S15	0.045	25	18	7	16.8	11.66	13	0.68	16.5	15.8	**-4.43**

The results shown in the table indicates that percentage error in estimation of CBR are within the ± 5% range, hence can be very useful for rapid quality assurance in field applications.

VI. CONCLUSION

From the present study, the followings conclusions are drawn:

1. The DCPI values are influenced by the field moisture content in general.
2. The moisture cotenant have significant effect in case of fine grained plastic soils.
3. DCPI can be very useful to evaluate the in-situ CBR of subgrade and embankment layers of alluvial soils if sufficient data such as grain size, Atterberg and field moisture etc. with reasonable accuracy is available.
4. DCPI have very good repeatability and reproducibility subject to the conditions that other parameters affecting it are taken into consideration.
5. Moisture correction factors once established for particular range of soil can be very useful for speedy testing of subgrade and embankment layers for desired strength parameters such as CBR.

VII. ACKNOWLEDGEMENTS

Authors are very thankful for the cooperation of staff and faculty of Guru Nanak Dev Engineering College Ludhiana, Punjab, Engineers of Public Works department Punjab, Field Engineers of Execution Agencies for their cooperation and sharing valuable information without which this work was not possible.

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CITE AN ARTICLE

Singh, Daljeet , J. N. Jha, and K. S. Gill. "EFFECT OF FIELD MOISTURE CONTENT ON PENETRATION INDEX VALUE OF DYNAMIC CONE PENETROMETER IN ALLUVIAL SOIL SUBGRADES." ***INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*** **6.7 (2017): 327-33. Web. 15 July 2017.**