TO DEVELOP A CORRELATION BETWEEN CBR AND DYNAMIC CONE PENETRATION VALUE

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Abstract: In this paper, a brief practical review is presented on Correlation between CBR and dynamic cone penetration value. In India, California Bearing Ratio (CBR) value of sub grade is used often for design of flexible pavements. In practice, only limited number of such tests could be performed because of high unit cost and time required for such testing. As a result, in many cases, it is difficult to reveal detailed variations in the CBR values, over the length of roads. In such cases if the estimation of the CBR could be done on the basis of some tests which are quick to perform, less time consuming and cheap, then it will be easy to get the information about the strength of subgrade over the length of roads and also will be helpful and important specially for low volume roads being constructed under Pradhan Mantri Gram Sadak Yojana (PMGSY) scheme over different states of India presently, to develop large scale connections of rural India within a short period of time. By considering this aspect, a number of investigators in the past made their investigations in this field and developed different methods for determining the CBR value on the basis of results of low cost, less time consuming and easy to perform tests. The dynamic cone penetrometer (DCP) has been widely used for estimating the strength of soils. Also, the California bearing ratio (CBR) test is the test most widely used in highway pavement design all over the world. An attempt has been made to obtain relationship between DCP and CBR values for fine grained soils. In the first part of the investigation laboratory experiments were carried out by single test method. The purpose of the research was to establish whether any correlation exists between the CBR and penetration depth of the DCP for various types of fine grained soils. In the second part of the investigation field CBR tests were carried out developing a test set-up in the laboratory using five types of soils. The DCP tests were conducted in the same soil to find out the relationship between field DCP value and field CBR value. The results of the research indicate that a good correlation exists between CBR and penetration depth of the DCP for each of the material tested. These relationships are useful to obtain appropriate design inputs for analysis on the basis of field DCP tests conducted during evaluation of in-service pavements.
Keywords: CBR, Dynamic Cone penetration, Correlation, investigation.

I. INTRODUCTION

Traditionally the design of either kind of pavement is based on the strength of the compacted soil in the pavement, called subgrade. The design of the pavement layers laid over the subgrade soil starts off with the determination of subgrade strength and the traffic volume which is to be carried. The design of pavement is very much dependent on the subgrade strength of soil. Design criteria mainly needs thickness of layers. Weaker subgrade needs thicker layers whereas stronger subgrade needs thinner pavement layers. The Indian Road Congress (IRC) provides the exact procedures for the pavement layers design which based upon the subgrade strength. The strength of a subgrade soil is normally expressed in terms of the California Bearing Ratio (CBR). Due to variable nature of soil, the subgrade strength changes inconsistently, as a result engineers face so many difficulties or challenges during the design of a pavement. The subgrade strength is very much dependent on moisture content. As the subgrade is intended to variation of moisture due to flood, precipitations or all other climatic changes, so it is necessary to enable or understand the subgrade according to the variation of moisture. The CBR is the only test which can figure out the strength of a subgrade. By this test we can compare the strength of different subgrade materials .The CBR test is done in a standard manner by which one can find out or design the strength or thickness of subgrade layer. CBR value is inversely proportional to thickness of the pavement layer. If the subgrade is stronger, the higher is the CBR value, so lesser thickness is required and vice-versa.

II. NEED FOR PRESENT STUDY

Pavement structure design is based on three factors: loading (projected traffic), paving material properties (strength, aging, environmental effects, etc.), and subgrade support. But many uncertainties exist in pavement design. Even after a road is opened to traffic, the engineer cannot verify the accuracy of the traffic projection until the project has been through its design life. During the design stage, the engineer selects a subgrade support value based on a few samples taken from the project site and some engineering assumptions. The engineer controls paving material properties through quality assurance/quality control (QA/QC) programs during construction. Most states use density of the in-place subgrade and unbound base for construction quality control. However, density is not a load-bearing indicator. Also, in most cases, thickness of the unbound base layer is not monitored closely. Experience shows that it is very costly to repair a failed pavement caused by poor base or subgrade quality. Therefore it is very important and beneficial to verify and improve, if needed, the quality of the base and subgrade prior to paving operations and to provide engineers an opportunity to reevaluate and modify pavement structure design during paving operations. Pavement performance depends greatly upon the quality and uniformity of materials incorporated into the pavement structure. Careful monitoring of material quality and the dimensions of pavement layers during construction improves overall compliance with specifications as well as in-service performance of the pavement. The Dynamic Cone Penetrometer (DCP) provides a quick and simple field test method for evaluating the in-situ stiffness of base and subgrade layers, and DCP testing has been used in many countries and some states for subgrade evaluation. The greatest advantage offered by the DCP is its ability to penetrate underlying layers and accurately locate zones of weakness within the pavement system. This quick and dirty method can measure soil properties to a depth of 3 ft (0.91m).

III. OBJECTIVE AND SCOPE OF THE STUDY

- Develop and implement a procedure for using the DCP as an acceptance criterion for subgrade and unbound base material.
- Develop a threshold, based on DCP readings, for unsuitable material.
- Establish stiffness parameters, based on DCP readings, for pavement design and rehabilitation
- To develop correlation between CBR (California bearing ratio) and DCPT (Dynamic cone penetration test) for different soils (Clayey, silt and Sandy Soil) at different levels of compaction.
- To study the effect of compaction on correlation between CBR and DCPT value
- To compare the results with the correlation given in IRC 37: 2012
- Log10 CBR = 2.465-1.12Log10 N
- To find out the error percent between the relation developed and the relation given in the IRC 37:2012
- To evaluate the strength of sub-grade in terms of CBR value

IV. LITERATURE REVIEW

Deepika.Chukka, Chakravarthi.V.K conducted an experiment to develop relationship equations between DCPT index to Index and engineering properties of few sub grades with low plasticity characteristics. The tests include determination of DCP index in field and engineering properties in the lab. Studies are extended for both pre monsoon and post monsoon periods to know the effect of moisture on all properties. M. M. E. Zumrawi conducted an experiment to predict the field CBR of different types of soils. Since CBR can't be easily measured in the field, prediction of CBR from other simple tests such as Dynamic Cone Penetration (DCP) and soil properties is a valuable alternative. Various soils have been compacted at different initial state conditions (i.e. water content and dry density) then using laboratory and field equipment to enable the measurement of unsoaked CBR and DCP of these soils. Comparison of the measured and predicted values of unsoaked CBR and DCP using the developed equation clearly indicates the validity of this equation.

Er Younis Farooq, Prof Ajay K Duggal, Asif Farooq conducted an experiment on the CBR method and with these CBR values which are obtained by conventional method and Dynamic Cone Penetration (DCP) values are correlated to find the conventional CBR value by using DCP in the field. So, with the help of this relationship, it will be easy to get information about the strength of sub grade over the length of road.

Dr. Dilip Kumar Talukdar conducted an experiment to correlate CBR value with other soil parameters. It can also be used for determination of sub grade reaction of soil by using correlation. It is one of the most important engineering properties of soil for design of sub grade of rural roads. CBR value of soil may depends on many factors like maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), type of soil, permeability of soil etc.

K.A.K.Karuna Prema and A.G.H.J.Edirisinghe, conducted an experiment to develop relation between dynamic cone penetration(DCP) and other soil parameters that are used in road construction and maintenance work.

In this study, a series of tests were carried out in a laboratory under controlled conditions. The standard proctor compaction test was carried out for each soil sample to find out the dry density/moisture content relationship. Then, DCP test was carried out by varying the moisture content and the dry density. Samples were compacted manually to obtain the pre determined conditions. The unsoaked CBR and soaked CBR tests were also carried out under the same conditions.

V. EXPERIMENTAL INVESTIGATION

5.1 Determination of Liquid and Plastic Limit

To determine the Atterberg's limits (Liquid Limit & Plastic Limit) as per IS 2720 Part 5-1985. The objective of the Atterberg limits test is to obtain basic index information about the soil used to estimate strength and settlement characteristics. It is the primary form of classification for cohesive soils. Fine-grained soil is tested to determine the liquid and plastic limits, which are moisture contents that define boundaries between material consistency states. These standardized tests produce comparable numbers used for soil identification, classification and correlations to strength. The liquid (LL) and plastic (PL) limits define the water content boundaries between non-plastic, plastic and viscous fluid states. The plasticity index (PI) defines the complete range of plastic state. Consistency is meant the relative ease with which soil can be deformed.

Consistency denotes the degree of firmness of the soil which may be termed as soft, firm, stiff or hard. Soil passes through 4 states of consistency. In 1911, Swedish Agriculturist Atterberg divided the entire range from liquid to solid state into 4 stages.

- Liquid state
- Plastic state
- Semi solid state
- Solid state

5.2 Factors Affecting Compaction

Compaction is measured in terms of the dry density achieved. This is found to be a function of (a) the water content (b) the compactive effort applied to the soil, and (c) the nature of the soil. These effects are briefly discussed below

The effect of water content on compaction:

The shearing resistance to relative movement of the soil particles is large at low water contents. As the water content increases, it becomes relatively easier to disturb the soil structure, and the dry density achieved with a given compactive effort increases. However if the dry density is plotted against the water content for a given compactive effort, it will be seen that the dry density reaches a peak, after which any further increase in water content results in a lower dry density. From the dry density / water content curve, we can determine two quantities; the maximum dry density, and the optimum water content at which this maximum dry density is achieved.

The effect of variations in compactive effort:

Both the maximum dry density and the optimum water content are found to depend on the compactive effort used. Increasing the compactive effort increases the maximum dry density, but reduces the optimum water content. The air void ratio at the peak density remains very much the same. It may be seen that, at high water contents, there is little to be gained by increasing the compactive effort beyond a certain point.

The effect of soil type on compaction:

The highest dry densities are produced in well-graded coarse-grained soils, with smooth rounded particles. Uniform sands give a much flatter curve, and a lower maximum dry density. Clayey soils have much higher optimum water contents, and consequently lower maximum dry densities. The effect of increasing the compactive effort is also much greater in the case of clayey soils. Figures 5.1 and 5.2 show typical results of compaction tests for different soils and different moisture contents.

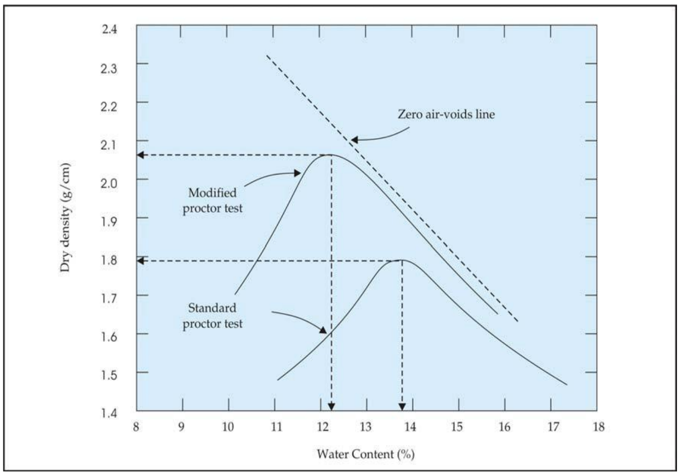


Figure 5.1: Modified Proctor Test Curve (Dry Density vs Moisture Content)

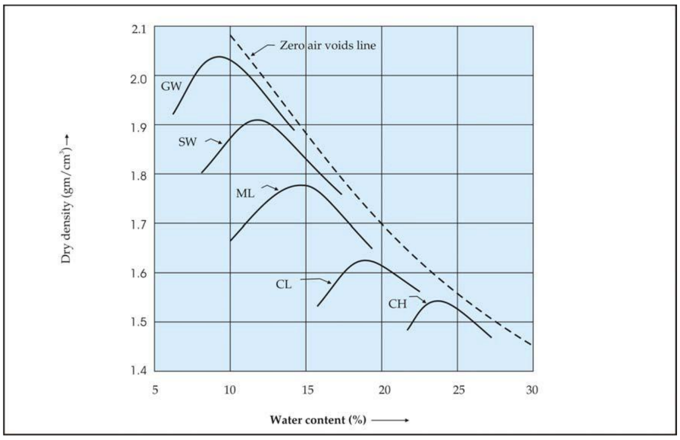


Figure 5.2: Compaction Curve for a Range of Soil Types

Specifications for Granular Sub-Base (GSB)

The material to be used for the sub-base are sand, moorum, gravel crushed stone, crushed slag, granulated slag, crushed concrete, brick metal and kankar, etc. The material shall be free from organic or other deleterious material. The material shall have 9 percent fines value of 50 KN or more (for sample in soaked condition) when tested in compliance with BS: 812. If water absorption value is greater than 2%, the soundness test shall be carried out on the material delivered at the site as per IS: 383-1970. The CBR requirement for sub-base layer should be at least 15% when tested in soaked condition. The material for sub-base shall be preferably non-plastic. Otherwise, the plasticity index (PI) of material passing 425 μ m sieve shall be less than 6 and liquid limit less than 25%. The material shall conform one of the gradations specified in Table 5.1 In case of un-surfaced roads, the PI value of the gravel should not exceed 9%.

Table 5.1: Gradation requirement for coarse graded granular sub-base

Sieve Size (mm)	(Percent by weight passing (By wet sieve analysis)		
	Grading – I	Grading – II	Grading – III
75	100	-	-
53	-	100	-
26.5	55-75	50-80	100
4.75	10-30	15-35	25-45
2.36	-	-	-
0.425	-	-	-
0.07	<10	<10	<10

Specifications for base and surface course

As per the MoRD specifications, the gradation requirements for gravel/soil-aggregates in base and surface course of a gravel road were given in Table and Table respectively. Any of the three gradations given in Table for base course can be adopted depending upon the availability of materials. The CBR requirement for base and surface courses is 30% when tested in 4-day soaked condition. These gradations and CBR requirements are recommended in case the gravel surface is sealed by chip sealing or surface dressing

Table 5.2: Grading requirement for surface course

Sieve Size, mm	Percentage passing by Mass
26.5	100
19	97 – 100
4.75	41 – 71
0.425	12 – 28
0.075	9 – 16

Gravel for base courses should have very small portions of fine materials (silt and clay) and a relatively larger top-sized aggregate for strength and durability. Surface-gravel should have a relatively higher percentage of fines (silt and clay) and relatively smaller top sized aggregate, so as to readily shed off water falling on the surface of the gravel road. The percentages of gravel, sand and fines (silt and clay) in the gradations A, B and C were given in Table 5.3.

Table 5.3: Composition of material for base course

Composition	Grading A	Grading B	Grading C
Gravel	53 to 67%	47 to 61 %	41 to 53%
Sand	25 to 43%	31 to 49%	31 to 55%
Silt and Clay	4 to 8%	4 to 8%	4 to 8%

When a single naturally occurring material does not meet any of the specified gradations, 'processing' will have to be resorted to, by blending two or more materials to achieve the required grading. Where gravel meeting the requirements in respect of grading as per the above is not available within economical leads or cannot economically be processed, gravel or soil-aggregate mixtures meeting the following requirements for base and wearing/surfacing course can be used (including processing if required).

Gravel base and surface/wearing courses

Table 5.4 shows the soil specifications for base course and Table shows the soil specifications for wearing course.

Table 5.4: Specifications for base course

Composition	Grading A	Grading B	Grading C
Gravel	53 to 67%	47 to 61 %	41 to 53%
Sand	25 to 43%	31 to 49%	31 to 55%
Silt and Clay	4 to 8%	4 to 8%	4 to 8%

Table 5.5: Specifications for wearing/surface course

Percent retained on IS 4.7 5mm sieve and passing 80 mm in size (percent gravel)	50-70%
Percent retained on IS 75 µ m sieve and passing 4.75 mm in size (percent sand)	25-40%
Percent passing IS 75 µ m (percent silt and clay)	8-15%

VI. RESULTS AND DISCUSSION

6.1 Properties of different soils

Table 6.1: Comparison of Gravel Content for Different Type of Soils

Type of Soil	Gravel Content
SC	4.9
SC	2.1
SM	38.8
CI	7
CL	0

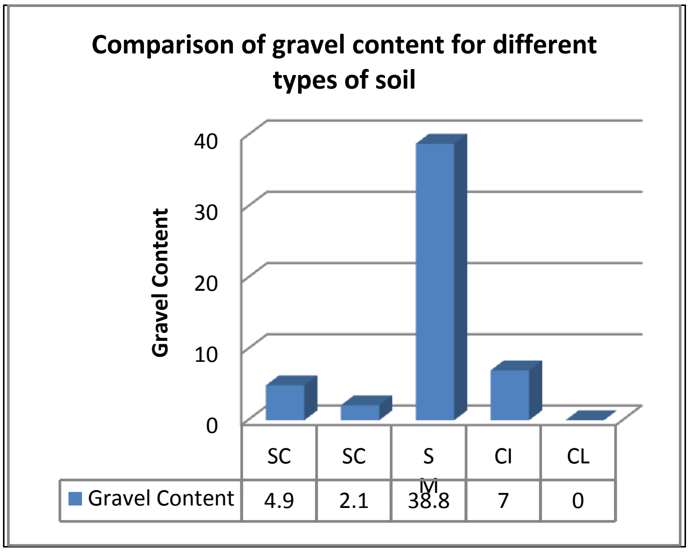


Figure 6.1: Comparison of gravel content for different types of soil

Table 6.2: Comparison of Silt & Clay Content For Different Type of Soils

Type of Soil	Silt & Clay Content
SC	57.5
SC	46.9
SM	6.8
CI	63
CL	55

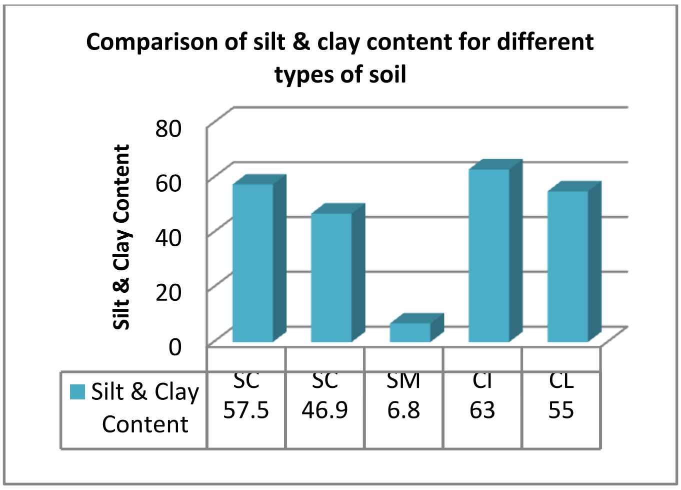
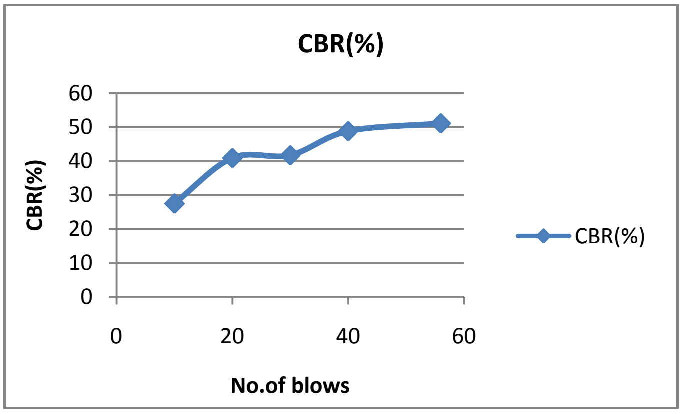


Figure 6.2: Comparison of Silt & Clay Content For Different Type of Soils

Comparison of CBR for different soils at different compaction levels

CBR for SC soil at different compaction levels

No. of blows	CBR (%)
10	27.5
20	40.9
30	41.7
40	48.8
56	51.1



CBR for SC soil at different compaction levels

VII. CONCLUSIONS

- For existing conditions, the in situ DCPT can be conducted for determination of field CBR value for in situ density.
- The logarithmic models are considered to be more suitable for use than any other models.
- As we are expecting that the equation which is given in IRC-37-2012 for finding insuit CBR is not suitable for every type of soil and moisture content. As CBR value may changes with the variation in moisture content and types of soils.
- The analysis of the laboratory work confirmed that a good estimate of CBR could be made from the DCP.
- The CBR value of uniform soils having similar characteristics can be determined quickly and with adequate accuracy using the DCPT results.
- Dynamic Cone Penetration Test can be effectively used to identify number of pavement layers, thickness of each layer and strength of each layer in terms of CBR for rural roads.
- California Bearing Ratio Test results and Penetration resistance observations from DCP test shows that CBR value increase with decrease in DCP values.
- The soaked CBR values of uniform soils which has similar characteristics can be determined quickly and will have adequate accuracy using DCP test results.

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