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Laboratory Assessment To Correlate DCP And Optimum Moisture Content With Strength Characteristic Of Subgrade

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ABSTRACT

In this research a laboratory investigation has been performed on the soil from different locations of Gujarat, India to Correlate Optimum moisture content (OMC) Dynamic Cone Penetration (DCP) test values with strength parameters of subgrade. In-situ condition has been made in laboratory using bigger testing mould and various tests like Liquid Limit, Plastic limit as well as CBR, PBT, UCS and DCP were carried out on repetitive samples of Maximum Dry Densities achieved through modified proctor effect in soaked condition. The empirical correlations have been developed among test results using multiple variable linear regression procedure. The formulations are formalized using other sets of tests data. The developed empirical correlations may be beneficial to approximate time consuming strength characteristic as well as physical properties at various locations within area under consideration using simple and rapid DCP test.

Keyword- CBR, DCP, OMC, MDD, PBT, Subgrade, UCS.

I. INTRODUCTION

The quality of the road or runways depends to a large extent on the strength and shear characteristics of subgrade material. To execute optimistic Pavement design, an accurate and representative material characterization technique is essential; such technique would be more acceptable if it is simple, rapid and economic. The evaluation of subgrade strength is an important for the highway pavement at time of design, construction and service stages.

The use of CBR or K-Value is mandatory parameters for pavement design, to approximate the CBR or K-value for the subgrade soil. The laboratory determination of CBR value and K-value tests require significant effort, in strength determination of subgrade, initially the California Bearing Ratio (CBR) test was developed by the California Division of Highway. The CBR is a measure of shearing resistance of material under controlled density & moisture condition, it is a ratio of the force per unit area required to penetrate a soil mass with a standard circular piston of 50 mm diameter at the rate of 1.25 mm/min to that required for the corresponding penetration of a standard material. The CBR value obtained is an integral part of several flexible pavement design method, as per the test method standard one CBR test will take minimum 7 days

The Plate Bearing Test (PBT) is one of the most important tests to determine the stiffness of road subgrade. The PBT teat measures deformation under rigid plate for various loading conditions. The test is expensive and long duration. The PBT test is used to get modulus of subgrade reaction (K-value) of subgrade which is important parameter to design rigid pavement and raft footing.

The unconfined compression strength of sub grade soil is a load per unit area at which an unconfined cylindrical specimen of soil will fail in simple compression test, Test is lengthy and precise and need experienced engineer to conduct, UCS test gives the shear strength of the soil that is useful parameters for computing Safe bearing Capacity of soil as well as strength of soil.

In view of present pavement design procedures, it reflect that there is a need of performing direct monitoring of stiffness of subgrade to design, construction and operation period which demands rapid & easy way to verify subgrade strength parameters, It become easier to evaluate the strength parameters by correlating the results of PBT, CBR, UCS & DCP in soaked as well as Unsoaked condition.

This paper is aims to develop linear correlations between DCP and other subgrade soil parameter such as CBR, UCS, KPBT etc. in both soaked and unsoaked condition for direct determination of these parameters from DCP results. The Dynamic Cone Penetrometer Test is a Portable Equipment that measures Penetration resistance by cone penetration with blows count of hammer; it is designed for the rapid insitu measurement of subgrade. So the use of Dynamic cone penetrometer is the faster and the easier way to estimate the strength parameters. (Harison, J.R., 1983 – 1987, Kleyn, E.G., 1975, Livneh, M. 1987, Rodrigo Salgadi, Sungmin Yoon, 2003, Talal Ao-Referal & Al Suhaibani, 1996).

II. EXPERIMENTAL Investigation and setup

2.1. Gradation and Determination of Index Properties

As a test samples, various soils belongs to different locations of Gujarat were collected ,The index properties of the selected soils samples were determined as shown in Table -1 and Grain Size analysis results were depicted in FIGURE 1. (IS-2720-P-4, IS-2720-P-5, IS-1498, IS-2720- P-3). Wet sieve analysis is conducted to determine the percentage by weight coarser than 425 micron (C) One kilogram of oven dried soil sample is taken in a 425 micron I.S. sieve and washed under a jet of water until the wash water became clear. The material retained on the sieve is collected and dried in oven for 24 h. The dried soil sample is weighted accurately and the value of C is determined (Table-1) (IS-2720-P-4)

Based on the experimental study, analysis is done to develop the correlation for CBR, KPBT and UCS with plasticity/gradation characteristics. The generalization for natural soils can be made by accounting for the presence of coarser fraction and modifying the liquid limit as

$W_{LM} = W_L (1- C/100)$ ------------------- (1)

Where, W_{LM} = Modified Liquid limit (%),

W_L= Liquid Limit (%)

C = Fraction of soil coarser than 425 micron (%)

In the present study, Modified liquid limit has been used as the characteristic property of the soil and presented in table-1.

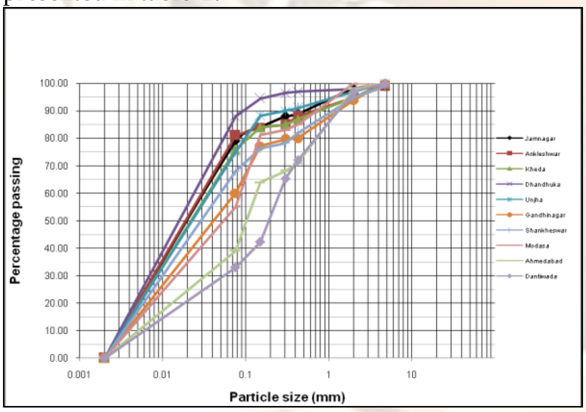

Fig. 1: Grain Size analysis

2.2. Test Set Up For Investigation Using Plate Bearing Test (PBT)

The investigation was carried out on prototype cylindrical mould of 490 mm diameter and 490 mm height made of 10 mm thick steel plate. The mould was stiffened by 12 mm thick and 40 mm wide steel ring at bottom and top. The photograph of mould and Reaction frame are shown in figure 2.

Fig. 2. The photograph of mould and Reaction frame

A base plate of 25 mm thickness was prepared to fix the cylindrical mould. It is stiffened by 4 mm wide and 2 mm thick steel plate. At the bottom of the base plate for soaking of the sample, 6 mm diameter holes were drilled at uniform spacing. During soaking top soil surface was closed by perforated steel plate,

which is properly clamped with mould to prevent swelling or particles displacement of soil. It was placed in steel water tank of larger size by means of crane so that sample in mould got saturated uniformly during soaking are as shown in figure 3.

Fig. 3. Mould with saturation tank

The diameter of the test mould for the sample satisfies the recommendation for the experimental set up and the test procedure as per the Indian standard that is the diameter of the loading plate should be approximately one fifth of the diameter of the sample specimen mould in order to overcome the effect due to the confining of the boundary. (IS-1498, IS-1888, IS-9214).PBT was conducted on samples prepared in the test mould. Weight of sample required filling the mould of an inner diameter of 490 mm and a sample depth of 400 mm was determined. Total soil was filled in five equal layers by static efforts using compression testing machine specially developed as shown in figure 4.

Fig. 4. Compression testing machine for static Compression of sample in mould

The load was applied on the circular plate of diameter 10.5 cm and thickness of 15 mm by manually operated jack fitted on reaction frame .The load was applied without impact, fluctuation or eccentricity. Initially a seating load of 0.007 MPa was applied and released before the actual test was started. The loads were applied in convenient increment and measured by proving ring of capacity 50 KN or more and settlement of Plate for each increment were measured by two nos. of dial gauge (0.01 mm accuracy) placed at diametrically opposite ends of the plate. The settlements were measured until the rate of settlement becomes less than 0.025 mm per minute. This procedure was continued up to the total settlement became 1.75 mm or more three tests were performed and average of three results are presented in Table-1 Similar tests were performed for the each type of soil for M.D.D. in soaked and unsoaked condition . The results of the test are used in calculation of K-value (Coefficient of subgrade reaction) and presented in the Table-1.

2.1. Test Set Up For Investigation Using Dynamic Cone Penetrometer (DCP)

DCP test were performed using cylindrical mould at the same densities and moisture content in soaked and unsoaked condition as were done in the case of test using PBT. FIGURE 5 shows test set up for DCP specially developed with digital facilities for blows count and penetration measurement and also mechanical arrangement for hammer falling. In DCP test the 8 kg hammer were dropped through the height of 575 mm on the anvil hammer was dropped by mechanical pulling arrangement, anvil was connected with rod attached by 60 degree cone of 20 mm diameter was kept on the top of the soil surface. In the DCP test, observation were made of number of blows corresponding to penetration of cone through digital display The penetration test using DCP was performed up to 300 mm depth; the penetration resistance was obtained that was the ratio of the total penetration to the corresponding number of blows. Similar tests were performed for M.D.D. for each type of soil in soaked and unsoaked condition. The results of the test were observed and are noted in the Table-1.

Fig. 5. Dynamic Cone Penetrometer

2.3. California Bearing Ratio Test (CBR)

CBR tests were performed on soaked soil samples as per the test procedure stipulated in Indian standard.(IS-2720-P-16) In the CBR test, load and penetration reading of 50 mm plunger were observed at a rate of 1.25 mm/minute, the load for 2.5 mm and 5 mm were observed, the load was expressed as a percentage of standard load value at a respective deformation level. CBR test were conducted at the same densities and moisture contents for soaked and unsoaked sample as were performed using PBT and DCP. Test results of CBR are tabulated in Table-1.

2.1. Unconfined Compressive Strength (UCS)

UCS tests were performed on soaked soil samples as per the test procedure stipulated in Indian standard.(IS-2720-P-10) The maximum load that can be transmitted to the sub soil depends upon the resistance of the underlying soil. To measure the resistance of the soil by compressibility or shearing deformation, unconfined compression test is the load required per unit area to fail the unconfined soil specimen by application of compressive pressure. UCS test were conducted at the same densities and moisture contents as were performed using PBT, CBR and DCP. Test results of UCS are tabulated in Table-1.

Table 1 results Obtained From Experimental Investigation

Sample No.	Gravel	Coarse Sand	Fine Sand	Silt + Clay content	Group of Soil	modified LL(W_{LM})	PI	MDD (KN/m^3)	OMC	Soaked CBR	Soaked K_{PBT} (N/mm2 /mm)	Soaked UCS ($N/m m^2$)	Soaked DCP (mm/blows)
S1	0	15	30	55	CL	19.52	11	19.9	10.2	8.9	0.205	1.72	2.18
S2	0	29	32	39	SC	20.59	8	20.9	8.7	15.05	0.828	2.48	1.72
S3	4	48	7	41	SC	21.08	10	20.8	9.6	11.9	0.569	2.06	1.97
S4	4	2	74	20	SM	22.08	NP	20.6	8	9.5	0.359	1.7	2.08
S5	6	38	8	48	SC	22.08	11	20.5	9.7	10	0.458	1.78	2.03
S6	3	5	45	47	SM-SC	24.36	7	20.4	7.5	8.5	0.195	1.56	2.22
S7	2	5	51	42	SC	24.64	7	20.2	9.7	8.3	0.181	1.53	2.29
S8	4	25	15	56	CL	24.75	12	20.3	10	8.1	0.179	1.5	2.32
S9	6	18	28	48	SC	25.16	13	20.1	10	7.8	0.168	1.46	2.39
S10	2	15	31	52	CL	26.25	14	19.9	10.4	6.6	0.102	1.28	2.65
S11	7	13	17	63	CI	26.64	15	19.9	12.5	6.5	0.093	1.27	2.68
S12	1	5	9	85	CL-ML	26.73	7	19.8	10	5.9	0.088	1.2	2.84
S13	0	2	9	89	CL-ML	26.88	7	19.7	9.8	5.8	0.081	1.18	2.93
S14	0	0	37	63	CL	27.2	11	19.6	10.1	5.5	0.08	1.14	3.02
S15	4	10	61	25	SC	28.12	17	19.5	10.4	5	0.075	1.08	3.21
S16	4	7	30	59	CI	28.44	14	19.4	10.6	4.9	0.069	1.06	3.22
S17	0	18	10	72	CI	29.82	20	19.4	12.8	4.6	0.062	1.01	3.35
S18	3	12	19	66	CI	29.82	20	19.4	11	4.6	0.062	1.02	3.34
S19	2	0	31	67	CI	29.88	13	19.4	10.5	4.5	0.058	0.98	3.72
S20	5	15	5	75	CI	29.92	22	19.3	11.6	4.6	0.066	1.03	3.35
S21	0	0	20	80	CI	33.06	15	19.1	10.7	3.9	0.054	0.91	3.72
S22	0	18	34	48	SC	33.12	27	19.3	10.4	4.2	0.056	0.96	3.55
S23	1	2	9	88	CI	34.92	14	18.9	13	3.59	0.052	0.93	4

III. Results And Discussion

Assessment of soil focused on observations obtained by CBR, PBT, UCS, and DCP tests in soaked condition. Here attempt has been made to develop correlation between various strength parameters. These relationships help civil engineers to estimate various parameters of soil. The linear and multiple variable regression analysis have been adapted to evaluated relation between strength parameters. Development of correlation between results of various tests in soaked condition is done in following way.

3.1. Prediction of CBR from OMC and DCP

A relation between CBR, OMC and DCP is determined from Experimental Investigation is expressed by Equation No. – 2

$$\mathbf{CBR = -4.005080963*10^{-2}\ OMC - 3.973639631\ DCP + 18.48488815} \quad (2)$$

A plot between actual and predicted value CBR values is shown in fig. 6

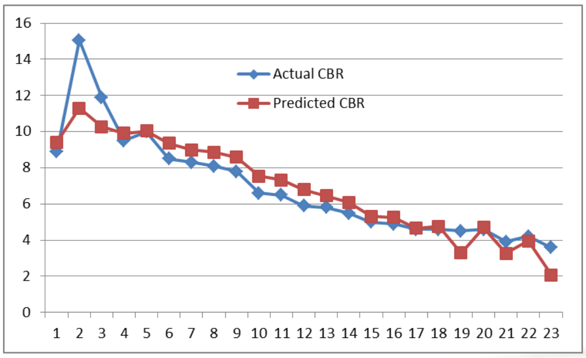

Fig. 6 plot between actual and predicted value CBR Values

3.2. Prediction of K_{PBT} from OMC and DCP

A relation between K_{PBT}, OMC and DCP is determined from Experimental Investigation is expressed by Equation No. – 3

$$K_{PBT} = -4.471015161*10^{-3}\ \text{OMC} - 2.238789275*10^{-1}\ \text{DCP} + 8.566696399*10^{-1} \qquad (3)$$

A plot between actual and predicted value K_{PBT} values is shown in fig. 7

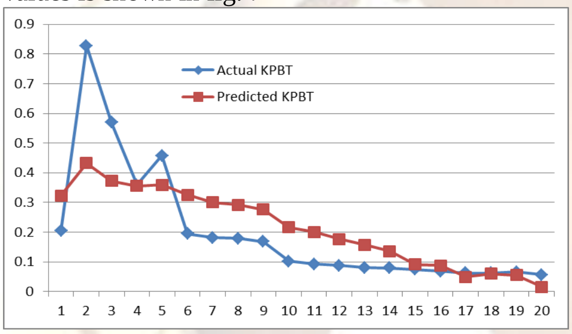

Fig. 7 plot between actual and predicted value K_{PBT} Values

3.3. Prediction of UCS from OMC and DCP

A relation between UCS, OMC and DCP is determined from Experimental Investigation is expressed by Equation No. –4

UCS = 1.317196471*10-3 OMC - 5.688606326*10-1 DCP + 2.929493599 (4)

A plot between actual and predicted value UCS values is shown in fig. 8

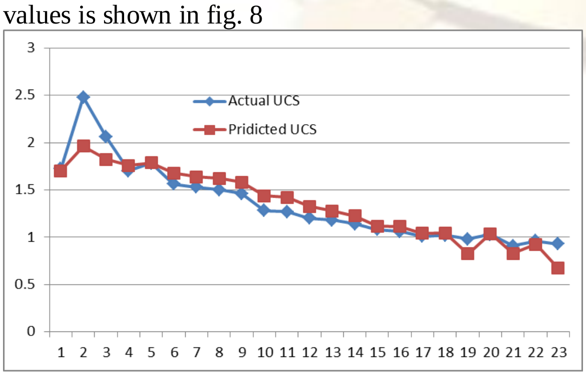

Fig. 8 plot between actual and predicted value UCS Values

3.4. Prediction of MDD from OMC and DCP

A relation between MDD, OMC and DCP is determined from Experimental Investigation is expressed by Equation No. – 5

MDD = -4.961797748*10-2 OMC - 7.509231951*10-1 DCP + 22.4658343 (5)

A plot between actual and predicted value KPBT values is shown in fig. 9

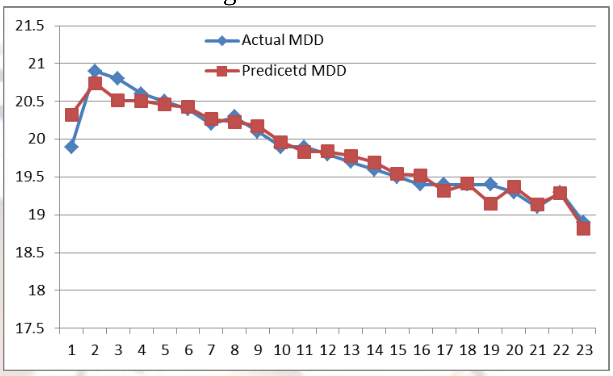

Fig. 8 plot between actual and predicted value MDD Values

IV. CONCLUSION

The above experimental analysis was done to develop the co relations between various tests like MDD, OMC, KPBT.UCS, CBR and DCP of soil in soaked condition. The correlations developed are very useful to the civil engineer in estimating strength parameters of various soils. These correlations will helpful for quick determination of strength parameter for subgrade. Based on experimental results the following conclusions are drawn. In short we can say that the relations between MDD, KPBT,UCS, CBR with DCP results are in form of z = ax+by, where Z denote the values of KPBT, UCS, MDD and CBR and x & y represent the OMC & DCP respectively where a & b are constant.

a) With increase in Maximum Dry Density of soil, Penetration resistance observations from DCP decrease.
b) Results of Coefficient of subgrade reaction K-value from Plate bearing Test and Penetration resistance observations from DCP test shows that K-value increase with decrease in DCP values.
c) Results of Unconfined Compression Test and Penetration resistance observations from DCP test shows that UCS increases with decrease in DCP values.
d) Results of DCP decreases as modified liquid limit increases.
e) Graph between actual and Predicted K_{PBT} shows that correlations are not reliable for less value of $K_{PBT.}$

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