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Experimental Study on Development of Correlation between CBR & Dynamic Cone Penetration Test

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Abstract:
CBR (California bearing ratio), gives realistic results which aids the design process of new flexible pavements as well as the restoration of existing pavements all over the world. The conventional CBR test procedure has always been time consuming, relatively expensive and has generally low repeatability. The repeatability has been found extremely low when it comes to sensitive soils like Lacustrine soils, locally known as Kerawa soils in North India. All these hindrances indicate that the present study should be carried out using Dynamic Cone Penetrometer (DCP). The DCP has been widely used to evaluate the in-situ strength of undisturbed soil and compacted sub-grade materials. The present study aims at developing a correlation of DCP test values with the CBR test values for Lacustrine (sedimentary upland) soil formations so that a quick assessment of road sub-grades can be made. Analysis of experimental data indicated that there is a very good relationship of the measured soil strength (i.e., unsoaked California Bearing value and Dynamic cone penetration values) with the soil initial state factor as described by the combination of initial dry density, water content and void ratio. Comparison of measured and predicted values of soaked CBR and DCP using the developed equation clearly indicate the validity.

Keywords: Dynamic Cone Penetrometer (DCP); Standard Proctor Test; California bearing ratio (CBR); Sub-grade soil material; Lacustrine and Kerawa soils.

I. INTRODUCTION

The projects of road and infrastructure development have always been of great concern for the government of Jammu & Kashmir. The government allocates huge funds to various concerned departments like R&B (Roads and Buildings), PMGSY (Pradhan Mantri Gram Sadak Yojna) and other corporations for planning, construction, execution, development and maintenance of various road related projects within the state of J&K. The emphasis is led on the timely completion of projects which becomes a major concern for all the executing agencies. Subgrade is the native material underneath a constructed road, pavement or railway (US: railroad) track. It is also called formation level. Subgrades are commonly compacted before the construction of a road, pavement or railway track, and are sometimes stabilized by the addition of asphalt, lime, Portland cement or other modifiers. The Dynamic Cone Penetration Test (DCPT) is a widely-used and very simple test for evaluating soil compactness and load-bearing capacity and thus can be successfully for estimating the strength of soil. CBR is the **ratio of force per unit area** required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the **corresponding penetration** of a standard material. Tests are carried out on natural or compacted soils in water soaked or un-soaked conditions

II. FIELD INVESTIGATIONS

The in place field investigations involved conducting DCP and core cutter tests at different selected locations across valley. On the whole, 17 soil samples were tested which include 8 samples of Alluvial soil deposits and 7 samples of Lacustrine soils. Lacustrine samples were collected from eastern side of river Jhelum in Pampore region (Alluvial), Budgam which possesses loose soil and mostly denuded Karewas and Pattan area (Karewas) of Kashmir valley. The Alluvial soil has also been collected from Rambagh and GogjiBagh area. Various field tests were conducted on these samples and the results obtained have been tabulated below. The field tests incuded identification of bulk density, dry density and moisture content at site.

Table-1 RESULTS OF BULK DENSITY, DRY DENSITY AND NATURAL MOISTURE FOR SAMPLE 1

SITE NO: 1	FLOOD CHANNEL, RAMBAGH NEAR NEW CONVENT SCHOOL	
GPS CO-ORDINATES	N- 34°03'25.4''	Elevtion- 1606 m
	E- 074°48'36.5''	Accuracy- 6.2 m
Bulk density, ρ (gm/cc)	AVERAGE M.C %	DRY DENSITY, P_D (GM/CC)
1.51	13.90	1.33

Table-2 RESULTS OF DCPT TEST FOR SAMPLE 1

SITE NO: 1	DYNAMIC CONE PENETROMETER TEST (DCPT)		
BLOW NO	INITIAL READING (CM)	FINAL READING (CM)	PENETRATION (CM)
1ST	6.5	13.4	6.9
2ND	13.4	24.2	10.8
3RD	24.2	28.6	4.4
4TH	28.6	31.1	2.5
5TH	31.1	33.2	2.1

Table-3 RESULTS OF BULK DENSITY, DRY DENSITY AND NATURAL MOISTURE FOR SAMPLE 2

SITE NO: 2	FLOOD CHANNEL BEHIND KGP CAMPUS	
GPS CO-ORDINATES	N- 34`03'27.3''	Elevation- 1608 m
	E- 74`48'40.5''	Accuracy- 5.8 m
Bulk density, ρ (gm/cc)	AVERAGE M.C %	DRY DENSITY,
1.73	12.69	1.54

Table-4 RESULTS OF DCPT TEST FOR SAMPLE 2

SITE NO: 2	DYNAMIC CONE PENETROMETER TEST (DCPT)		
BLOW NO.	INITIAL READING (CM)	FINAL READING (CM)	PENETRATION (CM)
1ST	6.0	8.0	2.0
2ND	8.0	9.6	1.6
3RD	9.6	11.0	1.4
4TH	11.0	12.0	1.0
5TH	12.0	13.5	1.5

III. LABORATORY INVESTIGATIONS

Disturbed and undisturbed soil samples retrieved from the field exploration were subjected to following tests for determination of engineering properties. The tests conducted are

A. IDENTIFICATION/CLASSIFICATION TESTS

1) Gradation test:

Soil gradation is a classification of a coarse-grained soil that ranks the soil based on the different particle sizes contained in the soil. These tests were performed to establish the particle size distribution of soil samples.

2) Specific Gravity:

Specific gravity G is defined as the ratio of the weight of an equal volume of distilled waters at that temperature both weights taken in air. These tests were performed on disturbed/undisturbed samples of soil to ascertain the general nature of soil in terms of its geological origin and mineralogy.

3) Consistency test:

Soil consistency is the resistance of a soil at various moisture contents to mechanical stresses or manipulations. Liquid limit is defined as the percentage moisture content at which a soil changes with decreasing wetness from liquid to plastic consistency or with increasing wetness from plastic to liquid consistency. Plastic limit is the percentage moisture content at which a soil changes with decreasing wetness from the plastic to the semi- solid consistency or with increasing wetness from the semi-solid to the plastic consistency.

4) Moisture content test and Natural Bulk density:

These tests were performed on undisturbed samples retrieved from field. Density of soil is generally ascertained by collecting the undisturbed field sample in core cutter and subsequently measuring its bulk density. Moisture content of each sample was determined by Oven drying method.

B. STRANDARD PROCTOR TEST

These tests was performed on disturbed soil samples collected from various field locations to determine the optimum moisture content and maximum dry density of soil sample. The tests provide a relationship between water content and dry density.

C. CALIFORNIA BEARING RATIO TEST

It is the **ratio of force per unit area** required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the **corresponding penetration** of a standard material. These tests were performed on undisturbed as well as on disturbed field samples. These tests are performed for evaluating the suitability of the subgrade and material used in sub-base and base of a flexible pavement.

Table.5. RESULTS OF LIQUID LIMIT FOR SOIL SAMPLE 1

SITE NO 1		LIQUID LIMIT		
NO. OF BLOWS (N)	DISH NO.	EMPTY DISH WT (GM)	DISH+ DRY SAMPLE (GM)	MOISTURE CONTENT (M.C %)
12	206	25.62	42.30	41.43
26	309	20.29	36.30	38.29
36	13	24.13	41.74	36.68
42	307	20.53	50.23	35.93

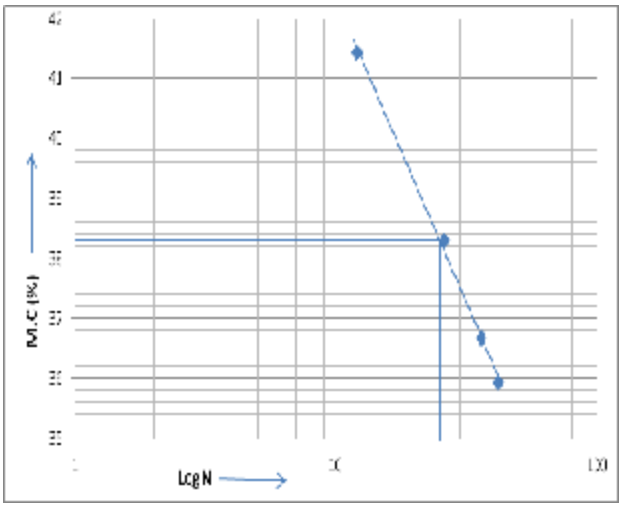

FIGURE. 1. FLOW CURVE FOR SAMPLE 1

LIQUID LIMIT = 38.3 % (FOR N = 25 BLOWS)

Table.6. RESULTS OF PLASTIC LIMIT FOR SOIL SAMPLE 1

PLASTIC LIMIT.	D/NO	EMPTY DISH WT. (GM)	DISH+ DRY SAMPLE (GM)	M.C (%)
	68	18.62	30.33	26.44

Table.7. RESULTS OF LIQUID LIMIT FOR SOIL SAMPLE 6

SITE NO: 2		LIQUID LIMIT			
NO. OF BLOW (N)	DISH NO.	EMPTY DISH W (GM)	DISH+ SAMPLE (GM)	DISH+ DRY SAMPLE	MOISTURE CONTENT MC(%)
14	24	24.76	68.31	55.00	44.02
25	412	20.96	44.72	38.04	39.11
36	307	20.53	55.90	46.78	34.74
44	110	27.47	61.20	53.18	31.20

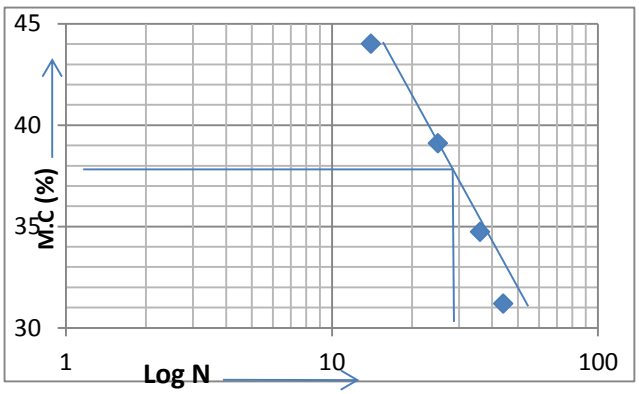

FIGURE. 2. FLOW CURVE FOR SAMPLE 2

LIQUID LIMIT = 38.0% (FOR N = 25 BLOWS)

Table.8. RESULTS OF PLASTIC LIMIT FOR SOIL SAMPLE 2

PLASTIC LIMIT:	EMPTY DISH WT. (GM)	DISH+ DRY SAMPLE (GM)	M.C (%)
	28.91	47.22	25.83

TABLE.9. RESULTS OF CBR_{US} FOR SAMPLE 1

SITE NO: 1						CBR OF UNSOAKED REMOULDED SAMPLE				
PENETRATION IN MM	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
DIAL GUAGE READINGS	0.2	0.4	1.0	1.1	1.3	1.4	2.0	2.1	2.2	2.3
NO. OF DIVISIONS	2	4	5	6	8	9	10	11	12	13

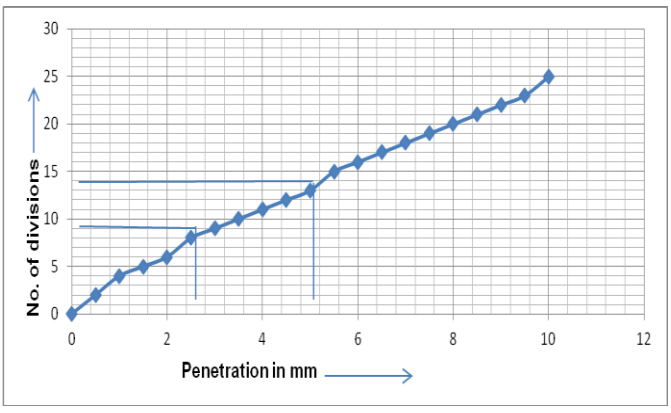

FIGURE. 3. LOAD PENETRATION CURVE (CBR_{US}) FOR SAMPLE 1

Least count= 1.22

CBR AT 2.5= 1.22×8/13.7 = 0.71

CBR AT 5.0 = 1.22×13/20.55 = 0.77

CBR VALUE = 0.74

Table.10. Results of cbr_{us} FOR SAMPLE 2

SITE NO: 2						CBR OF UNSOAKED REMOULDED SAMPLE					
PENETRAT IN MM	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	10
DIAL GUA READINGS	3.2	6.1	9.2	12.1	14.2	16.1	17.3	19	20.2	21.4	33.2
NO. OF DIVISIONS	17	32	47	61	72	81	88	96	102	109	167

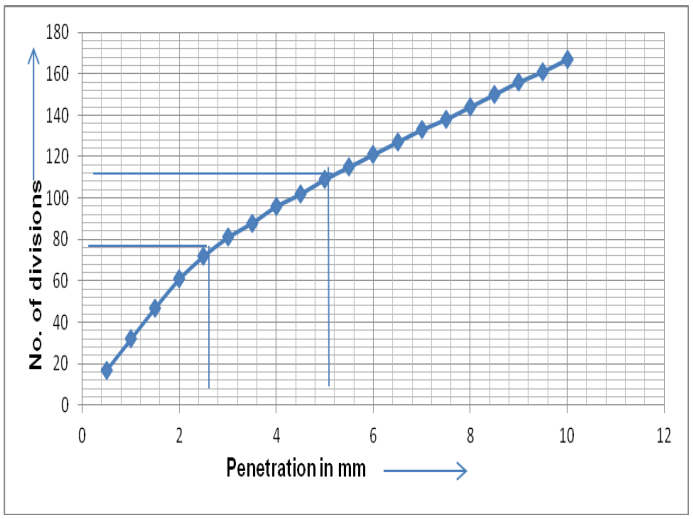

FIGURE. 4. LOAD PENETRATION CURVE (CBR_{US}) FOR SAMPLE 2

Least count= 1.22
CBR AT 2.5 = 1.22×72/13.70= 6.41
CBR AT 5.0 = 1.22×109/20.55= 6.47
CBR VALUE = 6.44

IV. CONCLUSION

The present study aims at identifying the correlation between CBR and DCPT to facilitate quick evaluation of road sub-grade properties. This study showed that the DCP is the most simple and inexpensive test and is preferred to predict the in-situ CBR for the different pavement layers. The following conclusions can be summed up from the present study:

1) The CBR value of uniform soils having similar characteristics can be determined quickly with adequate accuracy using the DCP test results.
2) Once the correlation is established between CBRindex (for tests conducted under different conditions and compaction level or in-situ density), the soaked CBR value in the field can be determined very quickly by conducting the in-situ DCP test for existing conditions, using the CBR indexvalue for that particular condition.
3) For construction of new embankments or strengthening of existing pavements, DCPT will be a very useful tool for evaluating the strength of sub grade in terms of CBR value.
4) It can be helpful in enhancing highway construction quality control, ensuring long-term pavement performance, stability and achieving more uniform structural property.
5) California Bearing Ratio test results and Penetration resistance observations from DCP test shows that CBR-value increase with decrease in DCP test values.

V. FUTURE SCOPE

Although above equations have been proposed considering limited data from 17 different sites from Kashmir Valley, however, these equations can be used as basis for further studies on subject matter and strengthen the data thereof. It is proposed that further field and laboratory experimental studies may be encouraged on the topic so that reliability of above proposed equations may be improved upon and the proposed equations may be readily used to estimate various pavement system design parameters like in place density of sub-grade, undisturbed California Bearing ratio, soaked California Bearing ratio. In present study, relatively more emphasis has been placed on evaluation of undisturbed CBR through DCP correlations because inherently the lacustrine soils in Kashmir valley are very sensitive to remoulding. Such soils are relatively consolidated and largely present a cemented disposition. Effect of in -place soaking in such soil is very minimal due to their very low permeability and high degree of consolidation. As such indirect measure of in -place and un-soaked CBR, using above established correlation, is a reliable measure of sub -grade strength, in particular.

VI. REFRENCES

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