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Regression Model for Predicting Soaked CBR from UCC

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ABSTRACT. *Flexible pavement is a multi-layered structure with a subgrade layer acting as the pavement structure's foundation. The performance and strength of soil for its use as a subgrade are ascertained by its California Bearing Ratio (CBR) value. CBR test is a technically extensive and labour-intensive mechanism that could cause delays in carrying out construction projects, which would raise the construction cost. Therefore, highway engineers need to design a predictive model for quick assessment of the CBR of subgrade soil. In this research, eight specimens of disturbed soil were obtained from Rawalpindi Division, Pakistan. All soil samples were subjected to laboratory testing and categorized according to the AASHTO soil Classification System. The specimens were subjected to soaked CBR, and unconfined compression tests based on Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) values, acquired from the Modified Proctor Compaction test. An empirical correlation between soaked CBR and unconfined compressive strength test is developed by the Suitable Trend-Line Method in Microsoft excel. From the single linear regression model, the value of the coefficient of correlation is found (0.98) indicating a very good correlation between soaked CBR and UCC strength test.*

Keywords: Regression Model, Correlation Coefficient, California Bearing Ratio (CBR), UCC strength.

1. INTRODUCTION

The transportation systems usually act as a backbone of a country. The Road network covers a large portion of the transportation system, as most of the freight is transported through roads. One of the primary elements in road networks is the pavement. The strength of subgrade material affects how well the road pavement performs under loadings. Subgrade serves as a suitable foundation of the pavement structure, which is a compacted layer of natural local soil deposit from the borrow pits. The subgrade, which may be a natural soil deposit or a compacted fill material, ultimately receives the load from the moving vehicles on the road surface. B.Ramanjaneyulu (2016) and BT Nguyen (2015) observed it to be quite challenging to get undisturbed soil samples for laboratory testing so the determination of geotechnical properties must rely on the results of field tests, and in other scenarios, expensive and extended field testing makes it necessary to obtain properties from a limited number of field tests. Further, the use of heavy machinery and expensive equipment for the testing of soil comes at a significant expense. C Lavanya (2021) suggested that the CBR test value is used for designing the flexible pavement but the determination of CBR is a very lengthy and laborious process. As a result, fewer test sites are used, and the least CBR value is chosen as a compromise for any region with a nearly identical geological origin but possibly different soil properties. Because of this, the flexible pavement's overlay thickness increases, which ultimately raise the cost of construction. N.A Saputra (2020) developed a correlation of CBR and UCC in Palangka Raya for the laterite soils as Heap Material and found the coefficient of correlation is 0.90. SK Alam (2020) proposed prediction models for the soaked CBR and the un-soaked CBR by utilizing ANN model, genetic expression programming, and the kriging method, where fine-grained soil is used for these models. From the results, it was concluded that the ANN, GEP, and kriging methodologies could be efficiently applied to correctly determine the soaked and un-soaked CBR through soil index properties.

In the past, many UCS predictive models have been designed by DP Khatri (2019), F Iqbal (2018), H.B. Nagaraj (2018), H Malhotra (2018), J Maity (2012), Ravichandra A H (2019), DK Talukdar (2014), Venkatasubramanian C

(2013), and Z. U. Rehman (2017) to determine the value of CBR from soil physical properties, i.e. Plastic limit, Liquid limit, maximum dry density, plastic index, and OMC. SM Lakshmi (2020) made efforts through (SLRA) simple Linear Regression Analysis to correlate the unsoaked CBR value with the soil UCC strength to estimate the unsoaked value of CBR based on unconfined compression strength UCC of soil and also, examined the impact of different moisture content upon UCC and unsoaked CBR. NB Shirur (2014) carried out the laboratory tests like P.L, L.L, S.L, P.I, MDD, and OMC and developed a method to correlate the CBR with soil index properties and derived MLRA relationship as CBR= -4.8353– 1.56856(OMC) +4.6351(MDD) where the coefficient of correlation ($R2=0.82$) which indicates a good relation for prediction of CBR from soil compaction characteristics.

The parameters like shear strength and stiffness modulus of the subgrade, determined from the (CBR) test are employed for flexible pavement design of highways, runways, airports, village roads, etc. Foundation for the pavement material is provided by subgrade and to reach full strength, subgrade soil should be densely compacted. The strength of the subgrade materials is related to CBR value. Compared to the UCC test, the CBR test requires more time, effort, and fatigue. In some cases, a huge number of CBR test results are needed for road projects. By using these correlations we may reduce the reliance on CBR testing in laboratories. So the purpose of this research is to design a predictive model for soaked CBR from the UCC strength test.

2. EXPERIMENTAL WORK

Eight locally available disturbed soil samples were taken from various regions of the Rawalpindi division including Attock, Chakwal, Jhelum, and Rawalpindi districts. Various laboratory experiments were conducted to identify the index properties of soil including liquid limit test AASHTO T 89 - 2006, wet sieve analysis AASHTO T 11 - 2020, and plastic limit test AASHTO T 90 - 2006, and all the soil specimens were classified according to AASHTO M 145 soil classifications system. A modified Proctor Compaction Test (MPCT) was additionally carried out to find out the MDD and OMC values of soil specimens. All samples for soaked CBR and UCC tests were prepared based on MDD and OMC obtained from MPCT. Finally, an empirical correlation was developed to estimate the value of soaked CBR of soil on the basis of the UCC strength test by using SLRA.

3. RESULTS ND DISCUSSION

Laboratory test results including Atterberg's limit test and wet sieve analysis are listed below in table 1. L.L ranges from 27.35 to 33.96, P.L ranges from 19.40 to 21.20, and P.I ranges from 7.51 to 12.76 for each different soil sample.

3.1 Soil Classification

All soil specimens are classified based on the index properties according to the AASHTO Classifications system. RWP-1, RWP-2, CHK-3, and ATK-5 are classified as A-4 soils CHK-4 as A-6, ATK6 as A-3, JMR-7 as A-6 and JMR-8 as A-2-4 soil, and the results are given below in Table 1.

Table -1: Laboratory test results & AASHTO Classification

Soil Sample ID	Grain Size Analysis			Atterberg's Limits			AASHTO Soil Classif.	Compaction Characteristics		UCC	Soaked CBR
	Percent Passing %			LL	PL	PI		OMC	MDD	q_u	
	#10	#40	#200	%	%	%		%	Ib/ft3	(kpa)	%
RWP-1	95.5	89.5	66	29.96	19.40	10.60	A-4	13	121.2	444	3.26
RWP-2	99	95	78	28.74	19.85	8.89	A-4	11.8	122.3	437	5.37
CHK-3	100	91.5	59.5	27.35	19.84	7.51	A-4	10	117.75	195	8.48
CHK-4	88	84	81	33.96	21.20	12.76	A-6	14.95	119	443	4.15
ATK-5	95.5	75.67	63.67	30.22	19.92	10.30	A-4	12.5	119.94	417	6.92
ATK-6	76	25.67	9	NP	NP	NP	A-3	9.3	134.68	198	9.3
JMR-7	97	91	74	31.51	20.51	11	A-6	9	121.89	148	2.18
JMR-8	95	92	27	NP	NP	NP	A-2-4	10.3	129.29	391	10.78

3.2 Modified Proctor Compaction Test (MPCT)

MPCT was carried out on the soil samples as per AASHTO T 180 - 2009. MDD and OMC were determined from MPCT for the 8 different soil specimens and the final outcomes of the MPCT are listed in Table 1. Fig. 1 depicts the relation between dry density (ρd) and moisture content (w) obtained for soil samples from MPCT.

3.3 Unconfined Compressive Strength Test

Eight different soil samples were laboratory tested for their UCC strength as per AASHTO T 208. Soil specimens for UCC tests were prepared at 95% relative compaction of MDD obtained from MPCT. The point at which failure of the soil specimen occurs is referred to as the UCC strength which shows in fig.2. The outcomes of the UCC test are listed in Table 1.

3.4 California Bearing Ratio (CBR) Test

Soaked CBR AASHTO T-193-2007 tests were carried out on each soil sample based on the maximum dry density

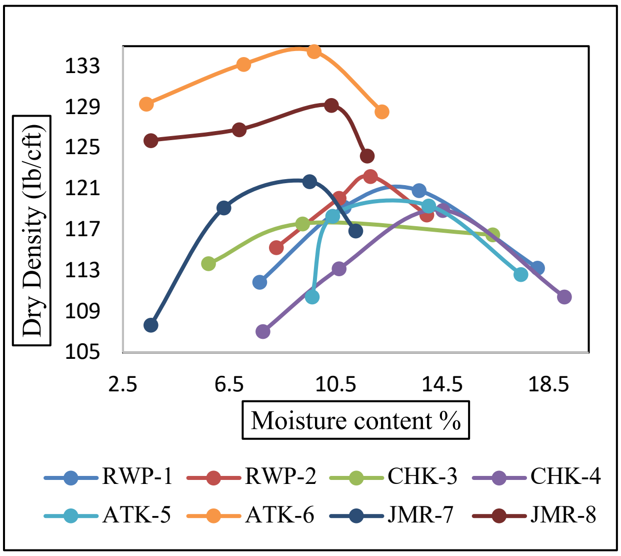

Fig -1: Moisture content versus dry density

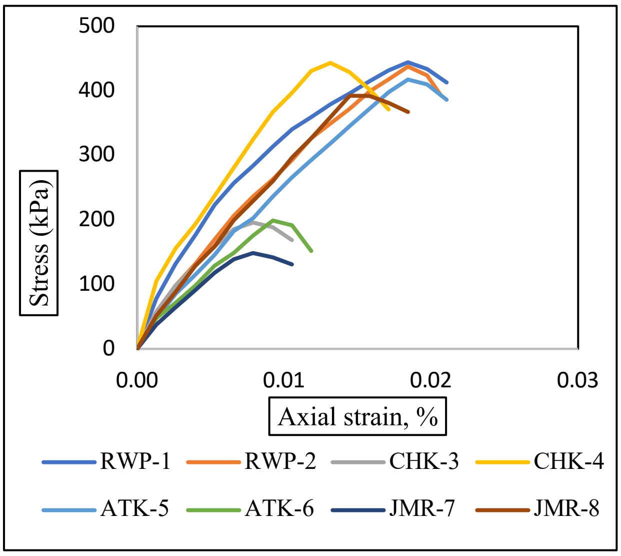

Fig -2: Stress, axial-strain curves for UCC

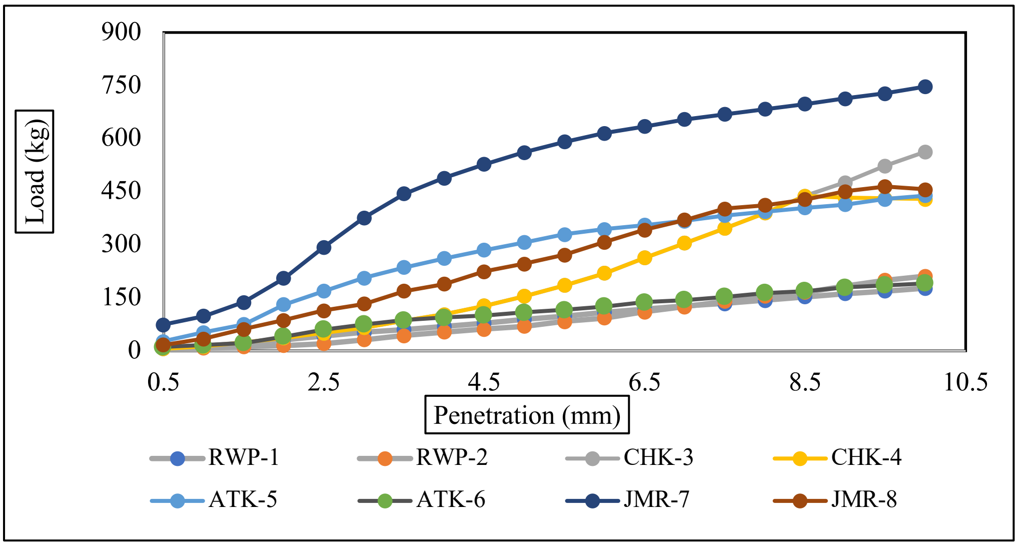

Fig -3: Load versus penetration curves for soaked CBR.

values acquired from MPCT, the soil samples were made for 95% relative compaction for soaked CBR testing. Fig.3 depicts the curve of load penetration acquired from soaked CBR for all the samples and the outcomes of soaked CBR tests are given in Table 1. From the penetration versus load curve plotted for the soaked CBR test, it can be seen from curves that soil specimens RWP-2, CHK-3, and ATK-6 show a similar penetration versus load curve.

3.5 Correlation of soaked CBR from with soil UCC

In this investigation, an attempt is devised to correlate the soaked CBR of the subgrade with its unconfined compression strength with help of the Suitable Trend-Line Method in Microsoft excel. Fig.4 shows a correlation between soaked CBR and UCC strength.

The 2nd Order Polynomial Regression Equation (1) given below is used to find the empirical correlation between the UCC Strength and soaked CBR value for subgrade soils from Fig. 4.

$$\text{Soaked CBR} = -0.0005(UCC)2 + 0.3277(UCC) - 34.441 \quad (R2=0.9813) \qquad (01)$$

The above second-order polynomial equation shows that there exists a very strong correlation between the UCC strength and soaked CBR since the coefficient of correlation (R) value is 0.9813, which is extremely near to + 1.0. As a result, eq. 01 can be used to estimate value of soaked CBR.

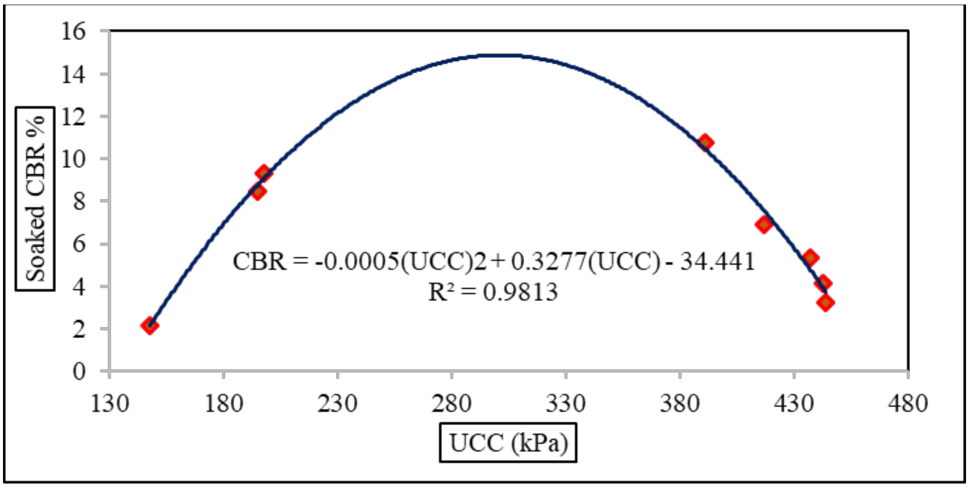

Fig -4: Correlation between soaked CBR and UCC strength

3. CONCLUSIONS

The 2nd order Polynomial Regression eq. for subgrade between CBR and UCC Strength is;

$$\text{Soaked CBR} = -0.0005(UCC)2 + 0.3277(UCC) - 34.441 \quad (R2 = 0.9813)$$

The soaked CBR value and the UCC strength of subgrade soil exhibit a strong correlation, as indicated by the coefficient of correlation (R) value being extremely close to +1.0. Consequently, it may be inferred from the aforementioned findings that since performing a laboratory-soaked CBR test is more effortful, time-taking, and exhausting than conducting a UCC test, the above second-order polynomial regression equation relieves the requirement to perform the laboratory CBR test by just predicting the CBR value from the UCC strength.

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REFERENCES

[1] B.Ramanjaneyulu, E. C. (December 2016,). A STUDY TO CORRELATE FIELD AND LABORATORY TEST RESULTS OF c-ϕ SOILS. Indian Geotechnical Conference, (pp. pp,1-4). Chennai.

[2] Bao Thach Nguyen, A. M. (2015). Prediction of California Bearing Ratio from Physical Properties of Fine-Grained Soils. International Journal of Civil, Structural, Construction and Architectural Engineering Vol:9, pp 1-6.

[3] C Lavanya, N. D. (2021). SLRA and MLRA Based Correlations of Geotechnical Parameters of Fine-Grained Soils. IOP Conf. Series: Materials Science and Engineering (pp. pp 1-12). IOP.

[4] Dhruba Paudel Khatri, I. P. (2019). Correlation of California Bearing Ratio with Index Properties of Sub-Grade Soil: A Case Study On-Road Thankot Chitlang Road. Proceedings of IOE Graduate Conference, (pp. 2350-8906). ISSN: 2350-8914.

[5] Faisal Iqbal, A. K. (2018). Co-Relationship between California Bearing Ratio and Index Properties of Jamshoro Soil. Mehran University Research Journal of Engineering and Technology, pp.177-190.

[6] H.B. Nagaraj, M. S. (2018). Influence of clay mineralogy on the relationship of CBR of fine-grained soils

with their index and engineering properties. Transportation Geotechnics,https://doi.org/10.1016/j.trgeo.2018.02.004, pp 29–38.

[7] Heena Malhotra, J. S. (2018). Correlation of CBR Values with Soil Index Properties by Regression Model using Soft Computing Techniques. International Journal of Emerging Science and Engineering (IJESE), 2319–6378.

[8] Maity, B. C. (2012). Prediction of CBR of Different Groups of Alluvial Soils for Design of Flexible Pavements. Proceedings of the International Symposium (pp. pp 833-847). Kolkata: DOI 10.1007/978-81-322-0757-3_55, # Springer India 2013.

[9] Norseta Ajie Saputra, a. R. (2020). The Correlation Between CBR (California Bearing Ratio) and UCS (Unconfined Compression Strength) Laterite Soils in Palangka Raya as Heap Material. International Conference on Environment and Technology (pp. PP 1-9). doi:10.1088/1755-1315/469/1/012093.

[10] Ravichandra A H, S. K. (2019). PREDICTION OF CBR VALUE BY USING INDEX PROPERTIES OF SOIL. International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 07, pp 1-7.

[11] S. Muthu Lakshmi ⇑, M. A. (2020). Correlating unsoaked CBR with UCC strength for SC and SP soil. Proceedings provide the materials science community with a fast and flexible route to the publication of research presented at national and international scientific conferences in the field of materials science., 2214-7853.

[12] Sk Kamrul Alam, A. M. (2020). Prediction of CBR Value of Fine-Grained Soils of Bengal Basin by Genetic Expression Programming, Artificial Neural Network, and Kriging Method. JOURNAL GEOLOGICAL SOCIETY OF INDIA, pp.190-196.

[13] Talukdar, D. D. (2014). A Study of Correlation Between California Bearing Ratio (CBR) Value With Other Properties of Soil. International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 1.

[14] Venkatasubramanian C., D. G. (2013). ANN model for predicting CBR from index properties of soils. International Journal of Civil & Structural Engineering, pp 614-620.

[15] Z. U. Rehman, U. K. (2017). Soils, Prediction of CBR Value from Index Properties of different. Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan, Vol. 22 No pp 1-7.

[16] AASHTO M 145. (n.d.). Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.

[17] AASHTO T 11. (n.d.). Standard Method of Test for Materials Finer Than 75-μm (#200) Sieve in Mineral Aggregates by Washing.

[18] AASHTO T 180. (n.d.). Standard Method of Test for Moisture-Density Relation of Soils Using a 4.45-kg (10-lb.) Rammer and a 457-mm (18-in.) Drop.

[19] AASHTO T 208. (n.d.). Standard Method of Test for Unconfined Compressive Strength of Cohesive Soil.

[20] AASHTO T 88. (2007). Standard Method of Test for Particle Size Analysis of Soils.

[21] AASHTO T 89. (n.d.). Standard Method of Test for Determining the Liquid Limit of Soils.

[22] AASHTO T 90. (n.d.). Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils.

[23] AASHTO T-193-2007. (n.d.). Standard Method of Test for Determining the soaked CBR of Soils.

[24] N. B Shirur and S. G Hiremath, “Establishing Relationship between Cbr Value and Physical Properties of Soil,” IOSR J. Mech. Civ. Eng., vol. 11, no. 5, pp. 26–30, 2014, doi: 10.9790/1684-11512630.