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Geotechnical Investigation of Different Soil Samples Using Regression Analysis

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Abstract - *For safe and economic design of civil engineering structures, geotechnical investigation is very essential for finding and analyzing ground parameters. The process of determining geotechnical properties is too expensive, time consuming, cumbersome and needs a lot of experiments for getting undisturbed samples of soil from ground or field. In laboratory it is very difficult to mould the sample at a required in-situ density, carrying out CBR test consumes much time and even more expensive. In case the soil available is not in quality, then mix appropriate additives with soil and resulting strength of soil is examined by CBR value, which is clumsy. In order to overcome these troubles, other methods like simple and multiple regression based equation have been developed for CBR value arithmetically with liquid limit, plastic limit, plastic index, maximum dry density, optimum moisture content of soil, as these tests are simple and can be completed with less time period. Equations were determined through multiple regression using matlab software from sample data available.*

***Key Words*: Regression, CBR, Density, Geotechnical properties, plastic index, soil**

1.INTRODUCTION

All civil engineering works have a robust relationship with soil. To make a structure strong and safe, a strong stratum of soil or rock is very essential. The entire structure may become weak and even collapse if the soil is in poor condition to withstand the load. Hence, to ensure safety of a structure, geotechnical properties of soil on which it is to be constructed is analyzed in depth. Behavior of soil cannot be predicted as soil conditions vary from place to place. Hence characteristics of soil must be properly studied for safe design and life of structure. For safe and economical design of civil engineering structure, determination of ground parameters are very important in geotechnical investigation. One of the soil parameters that are required for the calculation of foundation settlement is compression index, however this process requires longer time, expensive, cumbersome and also much undisturbed soil samples from the field. To mitigate these difficulties, equations have been developed by researchers to predict compression index which are relatively easier to conduct in the laboratory. [1] Bearing capacity of soil is determined by using Terzaghi's equation. By making use of Terzaghi's equation, many researchers are focused on contribution of cohesion and angle of internal friction to bearing capacity of soil. [2] Standard penetration test (SPT) and Cone penetration test (CPT) are the most commonly used insitu tests to delineate soil stratigraphy and determine the geotechnical engineering properties of subsurface soils. [3] In highway design, pavement thickness is affected due to subgrade strength. Subgrade strength is determined by using CBR test. It is a long-drawn-out test and challenging, hence for relating CBR value a method is suggested. In the current study, various soil samples were collected from different locations. Laboratory tests like specific gravity, CBR, Atterberg limit etc. were performed on these samples. Using simple and multiple regression analysis, various linear relationships between index properties and CBR of samples were examined. Also predictive equation estimating CBR from experimental index values were produced. [4] To avoid foundation and superstructure failures, geotechnical properties of soil on which it is to be constructed must be well understood. [5]In laboratory CBR value can be directly measured in accordance with IS2720-PART XVI. [6] The thickness of subgrade is mainly depends on CBR value, if CBR is higher, then designed thickness of sub-grade is thinner and vice-versa. [7] Compression index is one of the parameter that is used in settlement estimation. If CC value is higher, then larger will be settlement. [8]

1.1 Experimental Evaluation

CBR test procedure: Soil specimens each of about 7Kg must be compacted so that their compacted densities range from 95% to 100% generally with 10,30 and 65 blows. Take the weight of empty mould. Now add water to the first specimen(compact it in five layer by giving 10 blows per layer). After compaction, remove the collar and level the surface. Take sample for determination of moisture content. Take the weight of mould + compacted specimen. Now place the mould in the soaking tank for four days. Take other samples and apply different blows and repeat the whole process. After four days, measure the swell reading and find %age swell. Remove the mould from the tank and allow water to drain. Then place the specimen under the penetration piston and place surcharge load of 10lb. Apply the value and note the penetration load values. Draw the graph between the %age CBR and Dry density, and find the value of CBR at required degree of compaction.

Table -1: Proportions of data's collected

ID	Industrial wastes/by-products			Stabilizing material		ID	Industrial wastes/by-products			Stabilizing material	
	WFS	Fly ash	Red mud	Cement	Lime		WFS	Fly ash	Red mud	Cement	Lime
S1	100	0	0	0	0	S29	95	0	0	0	5
S2	95	0	0	5	0	S30	90	5	0	0	5
S3	90	5	0	5	0	S31	85	10	0	0	5
S4	85	10	0	5	0	S32	80	15	0	0	5
S5	80	15	0	5	0	S33	75	20	0	0	5
S6	75	20	0	5	0	S34	70	25	0	0	5
S7	70	25	0	5	0	S35	65	30	0	0	5
S8	65	30	0	5	0	S36	60	35	0	0	5
S9	60	35	0	5	0	S37	55	40	0	0	5
S10	55	40	0	5	0	S38	90	0	5	0	5
S11	90	0	5	5	0	S39	85	5	5	0	5
S12	85	5	5	5	0	S40	80	10	5	0	5
S13	80	10	5	5	0	S41	75	15	5	0	5
S14	75	15	5	5	0	S42	70	20	5	0	5
S15	70	20	5	5	0	S43	65	25	5	0	5
S16	65	25	5	5	0	S44	50	30	5	0	5
S17	50	30	5	5	0	S45	55	35	5	0	5
S18	55	35	5	5	0	S46	50	40	5	0	5
S19	50	40	5	5	0	S47	85	0	10	0	5
S20	85	0	10	5	0	S48	80	5	10	0	5
S21	80	5	10	5	0	S49	75	10	10	0	5
S22	75	10	10	5	0	S50	70	15	10	0	5
S23	70	15	10	5	0	S51	65	20	10	0	5
S24	65	20	10	5	0	S52	60	25	10	0	5
S25	60	25	10	5	0	S53	55	30	10	0	5
S26	55	30	10	5	0	S54	50	35	10	0	5
S27	50	35	10	5	0	S55	45	40	10	0	5
S28	45	40	10	5	0						

ID	CBR (%)	OMC (%)	Density (g/cc)	ID	CBR (%)	OMC (%)	Density (g/cc)
S1	11	10.8	1.778	S29	28	11.4	1.798
S2	40	11.18	1.816	S30	35	11.58	1.875
S3	52	11.6	1.858	S31	42	12	1.885
S4	61	12	1.882	S32	48	12.4	1.889
S5	71	12.4	1.891	S33	51	12.8	1.898
S6	78	12.6	1.842	S34	52	13	1.871
S7	81	13	1.789	S35	49	14	1.795
S8	76	13.5	1.742	S36	43	14.8	1.735
S9	68	14	1.722	S37	34	15.2	1.710
S10	58	14.8	1.692	S38	26	11.6	1.829
S11	36	12	1.829	S39	35	12.8	1.840

S12	53	13.2	1.842	S40	43	13.4	1.864
S13	68	13.4	1.858	S41	51	13.8	1.893
S14	77	14	1.86	S42	56	14.0	1.884
S15	82	14.2	1.865	S43	54	14	1.825
S16	81	14.6	1.852	S44	50	14.4	1.734
S17	75	15	1.868	S45	44	15	1.718
S18	68	15.4	1.814	S46	36	15.2	1.650
S19	60	16	1.808	S47	21	12	1.815
S20	26	12	1.7910	S48	30	12.9	1.840
S21	48	12.4	1.824	S49	41	14	1.884
S22	64	12.8	1.885	S50	49	14.2	1.895
S23	72	13	1.918	S51	48	14.6	1.885
S24	70	14	1.891	S52	45	14.8	1.875
S25	63	14.8	1.818	S53	40	15	1.840
S26	54	15.2	1.785	S54	35	15.8	1.770
S27	43	15.8	1.735	S55	28	16	1.715
S28	30	16.2	1.710				

Table-2 : Results of data's collected

1.2 Result and Discussion

1.2.1 Equations Framed Based on Data's Available

1.2.1.1Equation For California Bearing Ratio

The equation arrived using the from the regression analysis to predict approximate CBR value of the sample is,

CBR = 127.07-1.1607(WFS)-0.9080(FA)-2.0496(RM) +8.6908(C) +4.7694(L)

In the equation, the input values should be substituted as percentage. That is, if the fly ash percentage is 60%, substitute FA=60. Figure shows the scattered plot of the data points corresponding to the CBR value determined experimentally and predicted using regression equation.

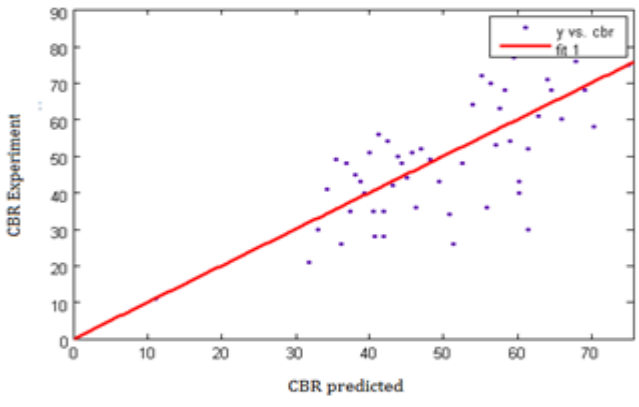

Chart-1: CBR Experiment vs CBR predicted

Equation for Maximum Dry Density

The equation arrived using the from the regression analysis to predict approximate MDD value of the sample is,

MDD = 2.5810-0.0080(WFS)-0.0111(FA)-0.0070(RM) +0.0115(C)+0.0123(L)

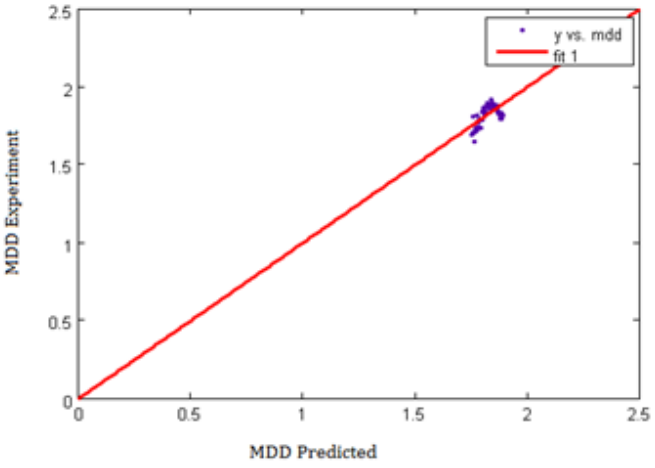

Chart-2: MDD experiment Vs MDD predicted

Equation for Optimum Moisture Content

The equation arrived using the from the regression analysis to predict approximate OMC value of the sample is,

OMC = 15.13230.0433(WFS)+0.0480(FA)+0.0858(RM) +0.0330(C)+0.0481(L)

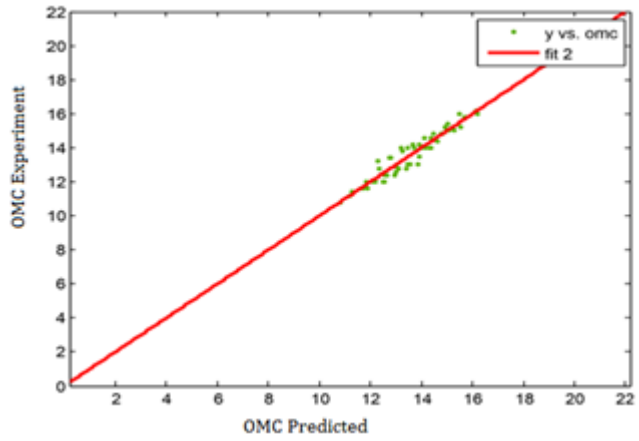

Chart-3: OMC experiment vs OMC predicted

Equations Framed Based On Index Properties of Soil

Simple Linear Regression Analysis (SLRA)

Simple Linear Regression Analysis (SLRA) was conducted by taking into account soaked CBR value as dependent variable and liquid limit, plastic limit, plasticity index, shrinkage limit, maximum dry density and optimum moisture content are considered as independent variables. Hence correlation between individual soil characteristics and soaked CBR value were developed.

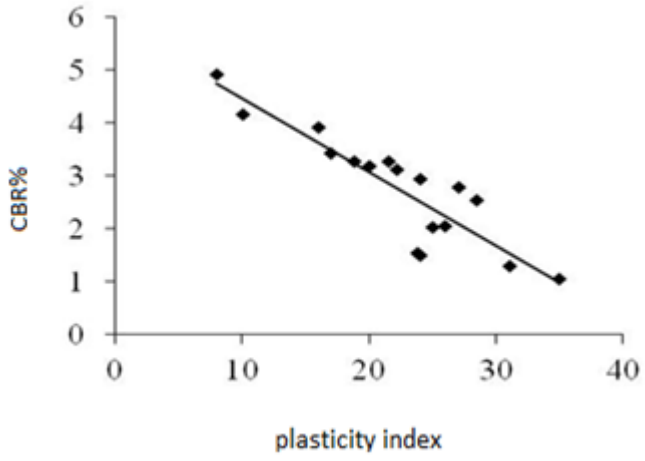

Chart-3: Correlation between plasticity index and CBR

Sample number 1, 14 and 17 are not taken into account as these soils are non-plastic (NP) in nature, so regression analysis is executed by making use of seventeen numbers of samples. The coefficient correlation was found to be 0.72. Liquid limit and plastic limit has only lower influence on CBR value, according to their soil properties. Whereas plasticity index has a greater influence on CBR value. This indicate that there is a good relationship exists between CBR values of soils those are plastic in nature.

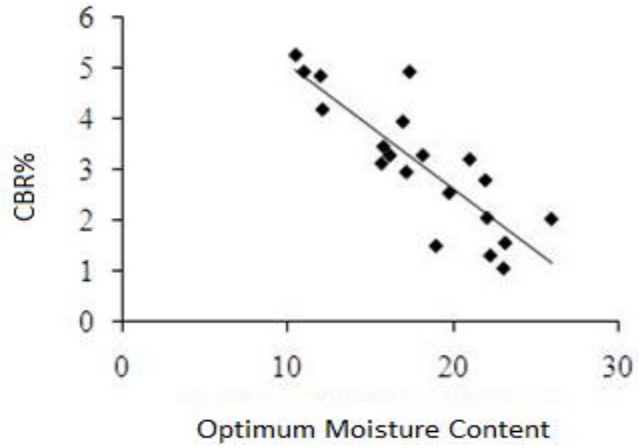

Chart-4: Correlation between Optimum moisture content and CBR

In the above figure 3 the moisture content increases with the decrease in CBR value. The correlation coefficient R2 =0.70, indicating a reasonable fit to the data is the soaked CBR value for the developed model. It indicates the optimum moisture content increases with the increase in CBR value.

Multiple Linear Regression Analysis (MLRA)

The soil properties are taken as independent variable while the soaked CBR value is taken as dependent variable. It can be expressed as given: Soaked CBR = f (MDD, OMC, LL, PL, PI) Equations,

1. CBR = 5.09477 + 0.022566 (SI) + 0.10939 (SL) - 0.09323 (LL)
2. CBR = 5.813 – 0.007826 (LL) + 0.12097 (PL)
3. CBR = -4.8353 – 1.56856 (OMC) + 4.6351 (MDD)
4. CBR= -3.2353-0.06939 (PI) + 2.8 (MDD)
5. CBR= 6.5452 – 0.07703(OMC) - 0.10395 (PI)

Where, CBR= California Bearing Ratio, PI= Plasticity Index, OMC= Optimum Moisture Content, LL=Liquid Limit, PL= Plastic Limit, SL= Shrinkage Limit, MDD= Maximum Dry Density.

The multiple variable regression analysis is shown in equation 1,2,3,4 and 5. The correlation of all the parameters with CBR value is included in these equations. The CBR value is directly affected by the three parameters, plasticity index, maximum dry density and optimum moisture content. The correlation between CBR and optimum moisture content and maximum dry density is shown in equation 3. From figure 4, it is observed that the experimental soaked CBR values are close to predicted values. The correlation coefficient (R2) =0.82 indicating a reasonable fit to all types of soil is the CBR value for the developed model.

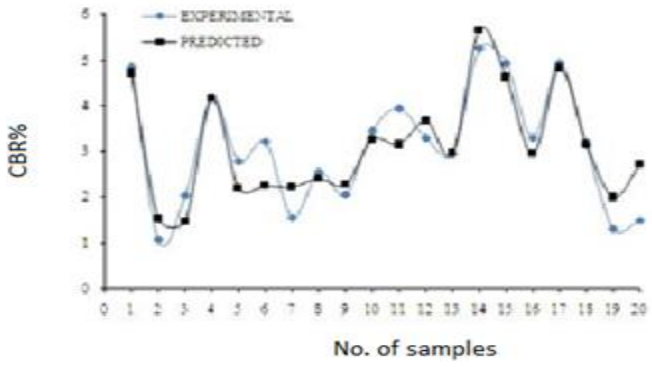

Chart-5: Comparison between experimental and predicted CBR value obtained from equation3

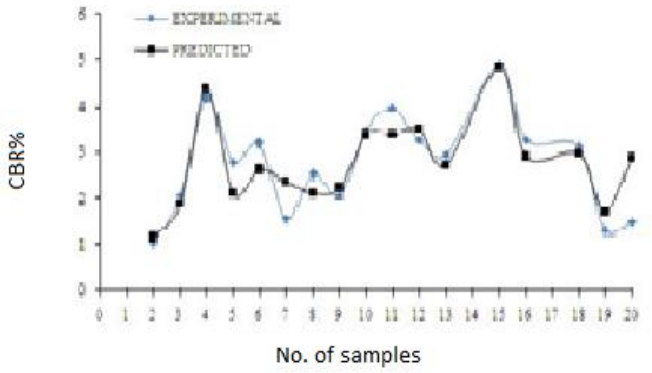

Chart-6: Comparison between experimental and predicted CBR value obtained from equation 4

From simple linear regression analysis (SLRA), it is known that CBR value decreases with increase in plasticity index and also increases with increase in maximum dry density. The coefficient of correlation R2 for plasticity index and maximum dry density are 0.72 and 0.78 respectively from SLRA. Hence a trail is made to form a correlation between CBR from plasticity index and maximum dry density. From the correlation coefficient R2=0.76, the conclusion can be made from figure 5 that CBR value prediction model based on MLRA are quite near to experimental values.

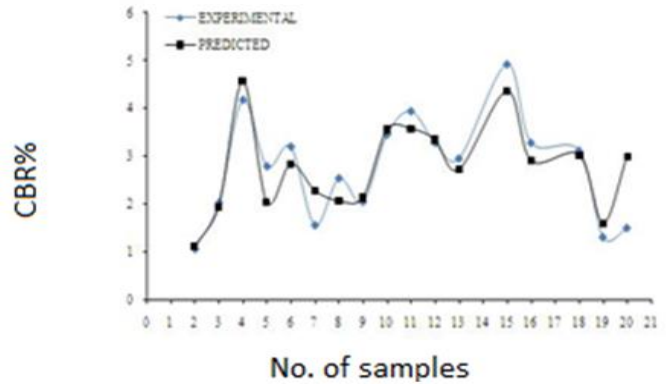

Chart-7: Comparison between experimental and predicted CBR value obtained from equation 5

The effect of moisture content and plasticity index on CBR value of soil samples collected for investigation shown in the above figure 6. From simple linear regression analysis (SLRA) it is known that CBR decreases with increase in moisture content and CBR value decreases with increase in plasticity index. The coefficient of correlation R2 for plasticity index and optimum moisture content are 0.72 and 0.71 respectively. A trail is made to form correlation between CBR value with these two variables using multiple linear regression analysis as shown in equation-5 and R2 value found to be 0.75. Therefore MLRA holds good for these two parameters is the conclusion.

3. CONCLUSIONS

The project was conducted to find an equation between CBR, OMC, MD and the percentage of highway materials within the scope of study. Accordingly, the required data base was obtained from different locations. Using the obtained test results a multivariate non-linear regression equations were developed and a relationship was established. The equations will be useful not only for individuals but also for the government agencies, who are involved in building construction and other structure in the study area. The cost and time required for doing tests will be saved. The result indicates that there is a good relation between the observed geotechnical property value and predicted value. Hence for preliminary design purpose the developed equation can be used to predict CBR, OMC& MDD value with good accuracy.

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