Correlation of Plasticity Index and Compression Index of Soil

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Abstract- Foundation of any structure on a compressible soil layer leads to its settlement. The amount of settlement is related to the compression index C_c or coefficient of volume change m_v. Knowledge of the rate at which the compression of the soil takes place is essential from design consideration. The behavior of the soil is an important element which always concerned in the civil engineering. The properties of the soil such as plasticity, compressibility or strength of the soil always affect the design in the construction. The determination of compression index from consolidation tests is expensive, cumbersome and time consuming since it takes a maximum of 3 weeks to complete a typical consolidation test. Because of these factors, several attempts have been made in the past to predict the Compression Index using index properties which are relatively easier to determine and take lesser time to obtain in the laboratory. Index properties of the soil such as Atterberg limits and moisture content are basic properties of the soils; therefore it is possible to use these index properties to predict the compression index of the soil. The aim of this research paper is to know the relationship between physical properties and the mechanical properties of the soil. Linear Regression is a statistical tool for the investigation of relationships between dependent variable and independent variables. The commonly used regression equation is used to develop the model. 44 laboratory tests results, which were conducted in this office laboratory, on the soil samples collected from various river valley projects were used in this study. On the basis of these test results a model has been developed between Compression Index (C_c) and Plasticity Index (PI) by using the linear regression analysis. This model has been discussed in this Research Paper.

Keywords – Compression Index, Plasticity Index

I .INTRODUCTION

Foundation of any structure on a compressible soil layer leads to its settlement. The amount of settlement is related to the compression index C_c or coefficient of volume change m_v. Knowledge of the rate at which the compression of the soil takes place is essential from design consideration. The behaviour of the soil is an important element which always concerned in the civil engineering. The properties of the soil such as plasticity, compressibility or strength of the soil always affect the design in the construction.

Lack of understanding of the properties of the soil can lead to the construction errors that are costly in effort and material. The suitability of a soil for a particular use should be determined based on its engineering characteristics and not on visual inspection or apparent similarity to other soils. The determination of compression index from consolidation tests is expensive, cumbersome and time consuming since it takes a maximum of 3 weeks to complete a typical consolidation test. A lot of maturity and skill is required on the part of the Engineer in interpreting the results for application to the conditions in the field. Because of these factors, several attempts have been made in the past to predict the Compression Index using index properties which are relatively easier to determine and take lesser time to obtain in the laboratory. Index properties of the soil such as Atterberg limits and moisture content are basic properties of the soils; therefore it is possible to use these index properties to predict the compression index of the soil. The aim of this research is to know the relationship between physical properties and the mechanical properties of the soil. Physical properties refer to Atterberg limit test to determine Plasticity Index (PI).The Atterberg limit test is simple and rapid test. Meanwhile mechanical properties refer to One Dimensional Consolidation Test to determine the Compression Index (C_c).The One Dimensional Consolidation Test is a complex, time consuming and expensive test if compared to the other soil tests.

II. LITERATURE REVIEW

The capability of soil to bear loadings is different depending on the type of soil. Generally, fine grained soils have a relative smaller capacity in bearing of load than the coarser grained soils. Hence fine grained soils therefore have greater degree of compressibility. Values of compression index C_c vary for different type of soils. Table 1 below indicates compression index C_c valves of several kind of soils:

Kind of soil	**compression index C_c**
Dense sand	0.0005- 0.01
Loose sand	0.025- 0.05
Firm clay	0.03- 0.06
Stiff clay	0.06- 0.15
Medium soft clay	0.15- 1.0
Organic soil	1.0-4.5

Table No:1 Primary Compression Index (C_c) for several kind of Soils

In literature several correlations have been proposed whereby compressibility characteristic like compression index have been evaluated using liquid limit, natural moisture content(W_n), initial void ratio (e_o), plasticity index, specific gravity, void ration at liquid limit and several other properties of soil.

Skempton (1944) conducted consolidation test on a number of clays collected from different locations and gave the following equation for the compression index for a remolded sample:

Skempton model $C_c = 0.007 (w_L - 10\%)$

Terzaghi and Peck (1967) have given that for an ordinary clay of medium to low sensitivity, the value of C_c corresponding to field conditions is roughly equal to 1.3 times values of Skempton model ,which is :

Terzaghi and Peck model $C_c = 0.009 (w_L - 10\%)$

Nishida (1956) derives theoretically linear correlation for all kind of undisturbed clays as showed in equation below:

Nishida model $C_c = 0.54 (e_o - 0.35)$

Similarly Azzouz (1976) presented correlation as:

Azzouz model $C_c = 0.4\ (e_o - 0.25)$

Rendon- Herrero (1980) collected around 94 samples of America's clay and presented the following equation:

Rendon- Herrero model $C_c = 0.3\ (e_o - 0.27)$

Serajjudin (1987) gave a linear equation for 130 alluvial clay and silt in Bangladesh by using moisture content (W_n):

Serajjudin model $C_c = 0.0102\ (W_n - 9.15)$

Koppula (1981) and Wroth et al. (1978) propose a correlation using plasticity index for remoulding clays:

Koppula Wroth model $C_c = 1.325\ PI$

Similarly Sridharan and Nagaraj (2000) have given: $C_c = 0.014(PI+3.6)$

These equations were obtained by research conducted on soil from the country of origin of the researchers, in most of the cases and when used in other countries, these equations either over estimate or underestimate the C_c.

III.ESTIMATION

Analysis of all types of geotechnical problems requires all relevant soil properties. These soil properties are either measured by testing in the field or in the laboratory or estimated.as all the properties of the soil are difficult to evaluate with available testing facilities, available budget, expert manpower and in the given period of time, some of the properties have to be estimated from another test data. These estimates are made mostly from available basic test data of index properties and insitu test results. However, a design engineer must always be careful while using such an estimated data as such correlation has always their own limitations. How a dishonest correlation can confuse and may lead to faulty design is given in Fig.1. Special kind of soils like soft clays, ocean clays, dispersive, organic, cemented soils do not always follow correlations derived for normal type of soils. The same special care should be taken for the soils in the remote areas where no prior experience has been gained. Major problem in estimation of soil properties is its complexity. Its behaviour is not like steel or other material. Soil has been formed in a very very long period of time by various environmental, geological and chemical processes. Many of these processes are still continue and they are still modifying the soil properties. Due to these natural processes, all the soil properties vary in different directions. Even under most sophisticated and controls laboratory, soil properties exhibit variability. Different type of tests conducted on same soil for unknown reasons may also give different results because each test has its own worthiness and limitations. The variability is affected with the use of results obtained from different type of field and laboratory tests because of their boundary conditions and loading pattern. This variability increases in manifold while using data from estimation.

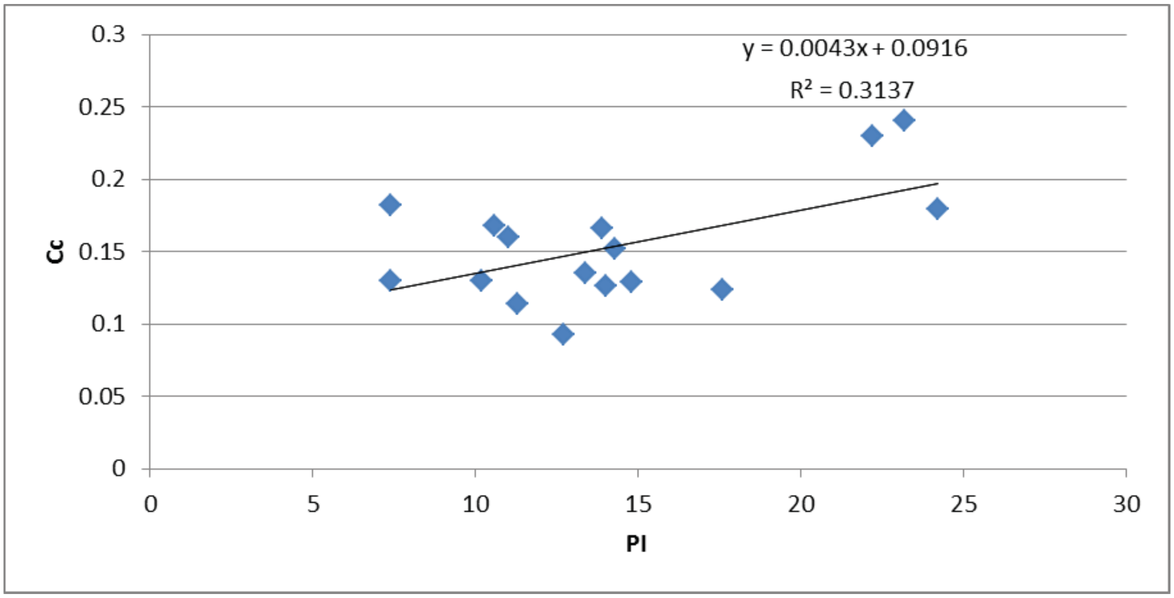

Figure 1: Dishonest correlation

IV.LINEAR REGRESSION AND SOIL EMPIRICAL MODELS

Linear Regression is a statistical tool for the investigation of relationships between dependent variable and independent variables. The dependent variables are used to predict the independent variables; the aim of linear regression is to find the value of intercept and slope of the line that best predicts independent variables from dependent variables. The form of the regression equation is commonly written as:

$$Y = MX + C$$

where Y is the independent variable, X is the dependent variable; M and C are the slope and intercept of the regression equation respectively. The regression procedure finds estimates of the C and M by a minimization process. This minimization is done by minimizing the sum of squares of the vertical distances between the data points and the best-fit line in X-Y space (Bartlett and Lee, 2004). Assessment of regression relationships can be done through estimation of coefficient of determination, (R^2). For example an R^2 value of 0.5 means that 50 percent of the variation in the independent variable is being explained by the dependent variable. The values of R^2 range between 0.0 and 1.0. An R^2 value of 0.0 means that there is no correlation between the variables, an R^2 value of 1 means that there is a perfect correlation between the variables. Haan (1994) stated that, the quality of a regression relationship depends on the ability of the relationship to predict the dependent variable for observation on the independent variables that were not used in estimating the regression coefficients.

Many researchers in the field of geotechnical engineering have used linear regression to establish empirical models between soil parameters. Yoon et al. (2004) proposed best regression models for predicting compression index using natural water content, liquid limit and void ratio for Korean coastal area.

Recently Abasi et al (2012) used regression analysis to predict the compression behavior of normally consolidated fine grained soil and concluded that, the proposed empirical models predict the compression index accurately in comparison with the existing equations.

Yildirim and Gunaydin (2011) also estimated the California Bearing Ratio (CBR) of soils from different parts of Turkey using regression analysis. He concluded that, the correlation equations obtained as a result of regression analyses are in satisfactory agreement with the test results and recommended that the proposed correlations will be useful for a preliminary design of a project where there is a financial limitation and limited time. It is evident in literature that prediction of compression index with regression analysis has proved to be successful and widely accepted.

V. MATERIALS AND METHODS

The data used for the study consist of current and past laboratory results of soils samples collected from various river valley projects in India during the various geotechnical investigations conducted in different locations within the study area. The data consisted of about 44 laboratory results which were conducted in the CSMRS, New Delhi Soil Laboratories under the same conditions. The tests included Atterberg Limits (Liquid Limit LL, Plastic Limit PL), moisture content, particle size distribution (wet seiving) and one dimensional consolidation tests.

The liquid limit (LL) was determined by the Casagrande method as specified by IS: 2720 (Part 5)The liquid limit tests were carried out to obtain a minimum of five points for plotting the curve, the test was conducted on soil samples passing 425μm. The plastic limit (PL) was determined by the rolling thread method as outlined in IS code. The Plasticity Index (PI) is calculated as LL – PL. The Particle size analysis was conducted according to IS: 2720 (Part 4) by wet sieving method. The one dimensional consolidation tests were performed in accordance with IS: 2720- Part 15, with the oedeometer equipment. The moisture content (MC) was determined by the oven drying method, the moisture content of the soil sample was express as a percentage of its dry mass. A summary of the laboratory results are presented in the enclosed Table 1, since the data was from different geotechnical investigation reports; it was carefully scrutinized to eliminate any outliers and errors.
Linear regression was used to establish empirical models between the compression index and the Plasticity index. A graph of compression index was plotted against the Plasticity index and the coefficient of determination R^2 was used to determine the quality of the relationships; the higher the value of R^2, the higher the quality of the relationship between the variables.

Table-1: Summary of Laboratory Test Results

Sample No	LL	PL	PI	C_C	Classification	Sample No	LL	PL	PI	C_C	Classification
Soil/1	46.6	21.7	24.9	0.265	CI	Soil/23	31.1	19.6	11.5	0.150	CI
Soil/2	45.0	24.4	20.6	0.169	CI	Soil/24	31.9	18.2	13.7	0.166	CL
Soil/3	42.5	22.6	19.9	0.213	CI	Soil/25	29.5	18.4	11.1	0.176	CL
Soil/4	43.1	21.5	21.6	0.219	CI	Soil/26	29.1	17.8	11.3	0114	GC
Soil/5	44.7	21.1	23.6	0.133	CI	Soil/27	42.6	20.4	22.2	0.230	CI
Soil/6	30.0	19.6	10.4	0.133	CL	Soil/28	44.1	20.9	23.2	0.240	CI
Soil/7	59.7	30.3	29.4	0.259	CH	Soil/29	45.8	21.6	24.2	0.179	CI

Soil/8	45.8	26.6	19.2	0.208	CI	Soil/30	35.6	20.8	14.8	0.129	CI
Soil/9	53.0	24.4	28.6	0.270	CH	Soil/31	27.1	16.1	11.0	0.160	GC
Soil/10	47.6	22.8	24.8	0.276	CI	Soil/32	28.6	15.9	12.7	0.093	SC
Soil/11	36.0	20.0	16.0	0.120	SC	Soil/33	33.9	19.9	14.0	0.126	CL
Soil/12	39.4	17.9	21.5	0.106	CI	Soil/34	34.2	19.9	14.3	0.152	CL
Soil/13	46.0	20.4	25.6	0.226	CI	Soil/35	34.8	20.9	13.9	0.166	CL- CI
Soil/14	37.0	20.0	17.0	0.20	CI	Soil/36	24.7	14.1	10.6	0.168	CL
Soil/15	45.5	18.6	26.9	0.320	CI	Soil/37	34.0	16.4	17.6	0.124	CL
Soil/16	50.0	22.5	27.5	0.380	CI-CH	Soil/38	25.3	17.9	7.4	0.182	CL-ML
Soil/17	46.5	17.3	29.2	0.350	CI	Soil/39	30.6	17.2	13.4	0.135	CL
Soil/18	20.5	14.6	5.9	0.102	CL	Soil/40	25.5	18.1	7.4	0.130	CL-ML
Soil/19	28.7	22.6	6.1	0.092	SM-SC	Soil/41	27.8	17.6	10.2	0.130	CL
Soil/20	43.4	24.7	18.5	0.170	ML-CL	Soil/42	27.0	16.9	10.1	0.200	CL
Soil/21	30.7	21.0	9.7	0.160	CI	Soil/43	30.5	17.0	13.5	0.173	CL
Soil/22	44.0	25.7	18.3	0.150	CL	Soil/44	31.3	16.9	14.4	0.114	CL

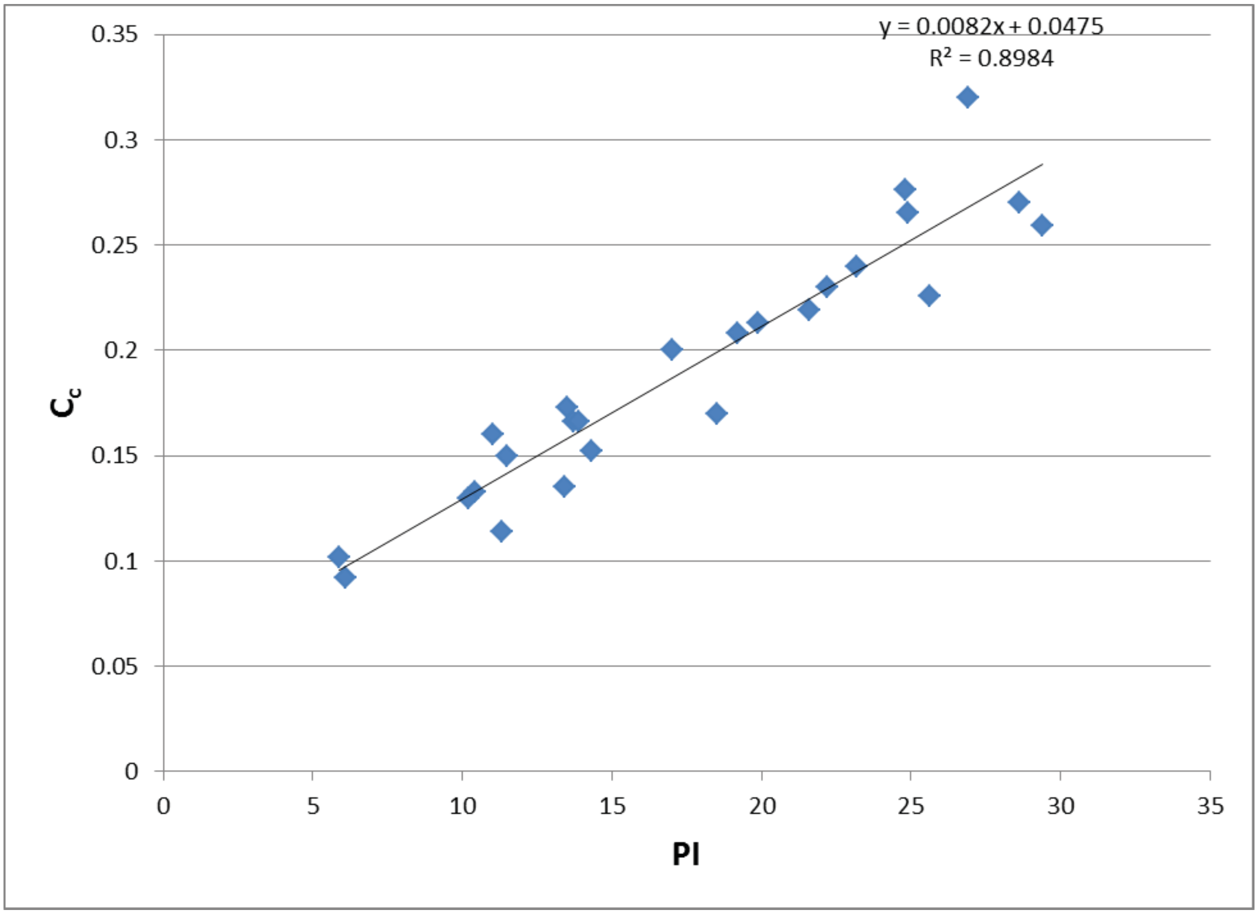

Figure 2: Compression Index and Plasticity Index

VI. RESULTS AND DISCUSSIONS

Linear regression analysis of the compression index and the Plasticity Index is presented in a graphical form in Figure 2 .The summary of the regression analysis is:

Independent variable	Empirical Model	Coefficient of Determination R^2
Plasticity Index-PI	$C_c = 0.0082$ PI + 0.0475	0.898

The graphs indicate there is a significant level of correlation. This means that there is high correlation between compression index and plasticity index. From the graph presented in Figure 2, it is clear that plasticity index increases with an increase in compression index. Plasticity is the property by which the material can undergo large amount of deformations; clay soil exhibits this property to a greater degree with high liquid limit. That is why soil containing high liquid limit, possess high compression index. More than 80% of the compression index can be predicted by PI. The limitations of this model are that it is applicable for the values of C_c in the range of o to 035 where as for the values of PI in the range of 5 to 30.

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