Correlation Studies between Consolidation Properties and Some Index Properties for Dhaka-Chittagong Highway Soil

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Abstract

Collection of undisturbed soil samples is a very hard task either due to time constraint or heterogeneity of soil deposits or huge cost in collection process. So in most cases adequate and well-founded data on soil compressibility are not available. In the laboratory, 14 undisturbed soil samples from Dhaka-Chittagong expressway PPP design project were tested and analysed. The moisture contents of these samples were fully intact and collected from various depths. This paper suggests correlations between compression index with liquid limit, in situ water content, in situ void ratio and plasticity index. This paper also suggests correlation between swelling index and plasticity index. Based on consolidation pressure-void ratio equations, analyses were performed and results have been verified using the values of coefficient of determination (R^2). The correlated equations were compared with the equations already developed for various clays. Values of R^2 have been found 0.9805, 0.8997, 0.8864, 0.8619 and 0.8196 for the correlation between C_C-LL, C_C-W (%), C_C-PI, C_C-e_O and C_S-PI respectively.

Keywords: Consolidation, Correlation, Plasticity Index, Void Ratio, Water Content.

1. INTRODUCTION

It is obvious that Karl Terzaghi was the guiding spirit in the development of soil mechanics and geotechnical engineering throughout the world. The publication of Erdbaumechanik auf Bodenphysikalisher Grundlage (1925) by Terzaghi gave birth to a new era in the advancement of soil mechanics. It was Terzaghi who introduced the index tests. Atterberg played an important role by categorizing seven qualitative limits that determines how water content dominates cohesive soil behavior. Finally Casagrande standardize those indices according to engineering properties and they have been used universally essential for any site investigation. Less dependency has been put on the results of index test and evaluation of any soil for an engineer has become easy after the development of testing methods both in laboratory and in the field. According to Atterberg, the moisture content at the point of transition from semisolid to plastic state is the plastic limit and from plastic to liquid state is the liquid limit. These parameters are also known as Atterberg limits which establishes direct approach to make quantitative correlations between index parameters with other soil properties. It helps most importantly in the case of evaluating the quality of soil which will be used as engineering purposes. These procedures are used as a framework against various test results which can be judged for their consistency and reliability. But site investigation, sampling and testing soil are always preferred and best for the results.

Liquid limit is the assessment of the water content at which the soil begins to flow and the plastic limit test is the evaluation of the brittle/ductile transformation of the soil sample (Whyte, 1982; Haigh et al. 2013). The Atterberg limit provides values for plasticity index which is the difference between liquid limit and plastic limit of a soil. This can be empirically correlated against many soil properties and design. According to Casagrande, A-line which classifies soils into clays and silts based on a correlation between soil type and a combination of liquid limit and plasticity index (Casagrande, 1947). In Bangladesh, the research works on this topic are not to be noted well since there is no established valid correlation between soil parameters has been developed. Based on experiment we suggest various correlations which enable to determine index properties. This will reduce experimental time and cost, most importantly predict the soil type and behavior of soils of Bangladesh.

2. MATERIALS AND METHODS

The soil samples are collected from Dhaka-Chittagong expressway PPP design project. Total 14 samples from various locations of the project were tested experimentally in the laboratory. Although collection of undisturbed soil samples is a very hard task either due to time constraint or heterogeneity of soil deposits or huge cost in collection process but experimented samples were undisturbed, collected from various depths and places in Dhaka-Chittagong highway. The natural moisture content was fully intact. Soil parameters, found from the laboratory tests, are shown in table 1.

In the laboratory, one dimensional consolidation test of soil has been conducted for all the collected soil samples. Applied loads are respectively 250 gm, 500 gm, 1 kg, 2 kg, 4 kg, 8 kg and 16 kg. For unloading, we removed 8 kg from the given loads. The values for compression index (C_C), swelling index (C_S) and pre consolidation pressure (P_C) have been found from the void ratio-pressure curve (e vs. log P). Standard test to determine liquid limit, plastic limit, specific gravity and moisture content has also been done in the laboratory. Soil samples were kept in the desiccator for further tests so that they could not get in touch with air by any chance.

Table 1. Experimental values of the soil parameters used in correlation

Test no.	Specific gravity, G_S	Moisture content, W (%)	In situ void ratio, e_o	Compression index, C_C	Swelling index, C_S	Liquid limit, LL	Plastic limit, PL	Plasticity index, PI
1	2.67	28.954	0.703	0.316	0.021	43.762	24.62	19.142
2	2.6	30.3	0.722	0.324	0.022	36.205	12.059	24.146
3	2.64	28.44	0.668	0.247	0.018	38.163	20.91	17.253
4	2.6	42.355	1.149	0.530	0.026	67.097	27.15	39.947
5	2.68	29.02	0.874	0.279	0.015	41.182	29.1	12.082
6	2.631	29.78	0.760	0.260	0.019	38.547	24.12	14.427
7	2.626	29.95	0.895	0.333	0.022	45.932	18.45	27.482
8	2.602	29.12	0.742	0.306	0.018	47.528	24.344	23.184
9	2.574	34.99	0.817	0.306	0.017	44.708	23.789	20.919
10	2.634	25.2	0.640	0.329	0.02	33.73	11.733	21.997
11	2.673	33.87	0.945	0.346	0.019	48.588	30.926	17.662
12	2.657	45.85	1.195	0.534	0.028	66.612	22.326	44.286
13	2.623	28.96	0.733	0.279	0.017	41.594	22.902	18.692
14	2.654	34.28	0.878	0.242	0.018	37.576	25.19	12.386

3. RESULTS AND DISCUSSION

3.1. Correlation between compression index (C_C) and liquid limit (LL)

In Figure 1, compression index (C_C) vs. liquid limit (LL) graph has been plotted. The value for R^2 has been found 0.9805. It presents that there is strong correlation between C_C and LL. Comparing our equation with Skempton (1944), shows very close relationship. The correlated equation is given below:

$$C_C = 0.01(LL - 13.61) \tag{1}$$

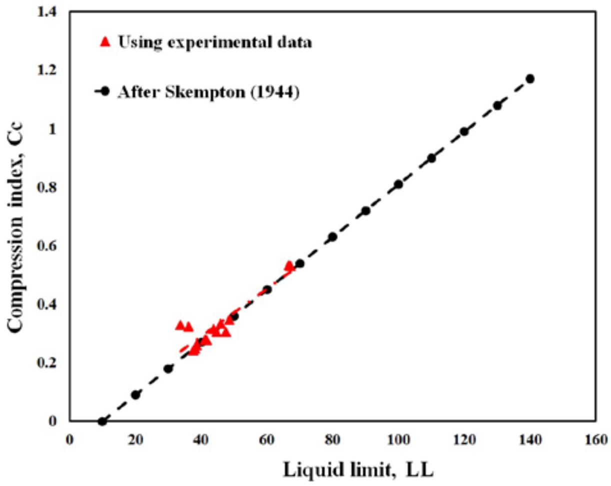

Figure 1. Correlation between C_C and LL

3.2. Correlation between compression index (C_C) and water content (W, %)

In Figure 2, compression index (C_C) vs. water content (W, %) graph has been plotted. The value for R^2 has been found 0.8997, which lies between acceptable ranges and hence it presents a strong correlation. The equation we have got is close to the equation derived for Chicago clays. The correlated equation is given below:

$$C_C = 0.0158W - 0.179 \tag{2}$$

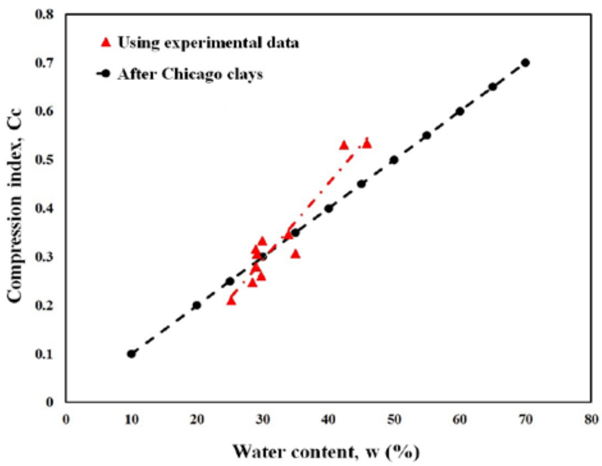

Figure 2. Correlation between C_C and W (%)

3.3. Correlation between compression index (C_C) and void ratio (e_o)

In Figure 3, compression index (C_C) vs. in situ void ratio (e_o) graph has been plotted. The R^2 value has been found 0.8619 which shows moderate relation between the two variables. The correlated equation was compared with the equation given by Nishida (1956). Experimental values have been deviated from Nishida's equation line as he proposed his equation for pure clay soil where our equation is for clay mixed with silt and sand by some amount. The correlated equation is given below:

$$C_C = 0.5562e_o - 0.1453 \quad (3)$$

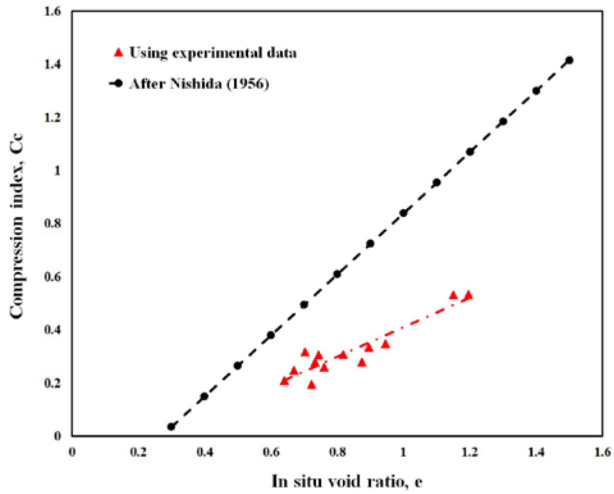

Figure 3. Correlation between C_C and e_o

3.4. Correlation between compression index (C_C) and plasticity index (PI)

In the figure 4, compression index (C_C) vs. plasticity index (PI) graph has been plotted. The value for R^2 has been found 0.8864 which indicates a strong relationship between the variables. The equation also seems to be closely matched with equation given by Kulhawy and Mayne (1990) where they took average specific gravity value 2.7. The correlated equation is given below:

$$C_C = 0.0091PI + 0.128 \quad (4)$$

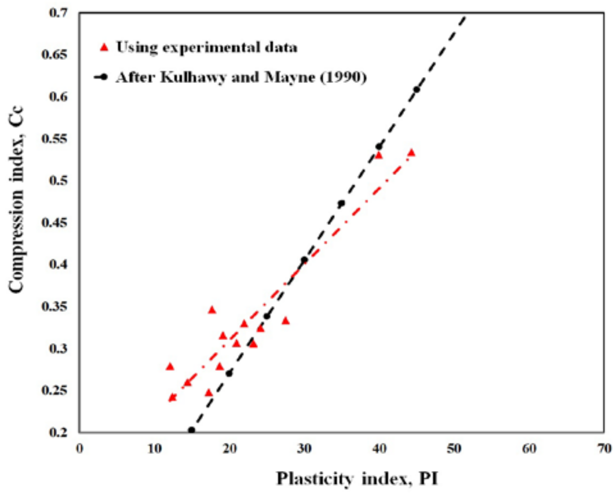

Figure 4. Correlation between C_C and PI

3.5. Correlation between swelling index (C_S) and plasticity index (PI)

In Figure 5, swelling index (C_S) vs. plasticity index (PI) graph has been plotted. The R^2 value has been found 0.8196, shows moderate relation between two variables. The equation derived from experimental values compared with the equation given by Kulhawy and Mayne (1990), shows some deviation as it was given for modified cam clay model but our results were from real field data where soil may be mixed with some impurities. The correlated equation is given below:

$$C_S = 0.0003PI + 0.0125 \quad (5)$$

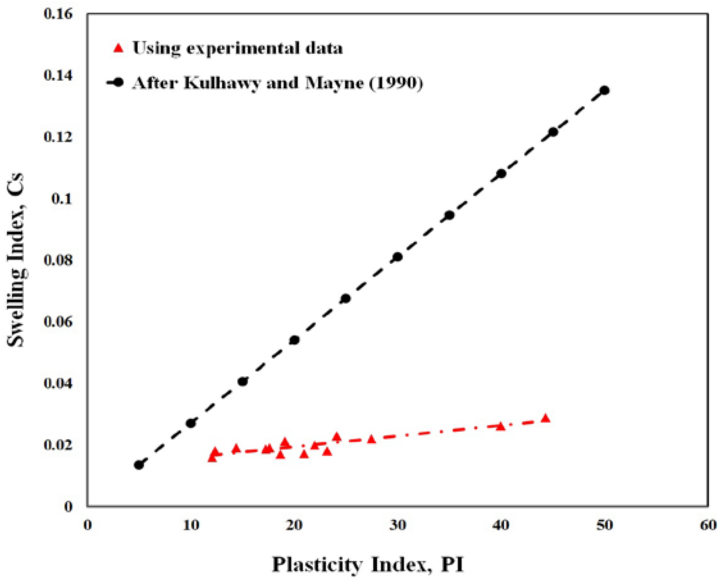

Figure 5. Correlation between C_S and PI

Summary of the results are shown in table 2.

Table 2. Correlated equations with their respective R^2 value

Sl no.	Correlated Equation	R^2	Compared Equation
1.	Cc = 0.01(LL-13.61)	0.9805	Skempton(1994): Cc = 0.009(LL-10)
2.	Cc = 0.0158W-0.179	0.8997	Chicago clay: Cc = 0.01W+3E-16
3.	Cc = 0.5562e_0-0.1453	0.8619	Nishida(1956): Cc = 1.15e_0-0.3105
4.	Cc = 0.009(PI+0.128)	0.8864	Kulhawy and Mayne(1990): Cc = 0.0135PI-2E-16
5.	C_S = 0.0003PI + 0.0125	0.8196	Kulhawy and Mayne(1990): C_S = 0.0027PI – 4E-17

4. CONCLUSION

From this research, the following conclusions can be drawn:

- The compression index (Cc) has been found to be exclusive functions of liquid limit, water content and void ratio, the equation being identical with that derived by Skempton, Nishida and for Chicago clays respectively.

- Equations derived in terms of liquid limit, water content and void ratio formed a basis for prediction of compression index (Cc) without carrying out any consolidation test.
- These findings can be used for predicting parameters without conducting either consolidation or Atterberg limit tests.
- This study shows a good correlation between plasticity index and compression index and plasticity index and swelling index.
- These equations can be used to determine the soil parameters of Bangladesh.

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