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Compression Index Correlation that Best Fits Clay Deposits in Nigeria

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Abstract: - Soil samples collected from 16 clay deposits across Nigeria were tested for consolidation. Compression index were calculated from the consolidation results. The values of compression index from the experimental results were then compared with those obtained using seven different empirical correlations from literature. The experimental values were correlated with values obtained from each of the considered empirical correlations. Coefficient of determination (R^2) was used as evaluation criteria to check for the empirical correlation that best fits the considered clay deposits. Observation of the results showed that the empirical correlation, proposed by Azzuoz et al for Chicago clays has the highest R^2 of 66.25 % , and therefore found to best fits the clay deposits considered.

Keywords: **-** *Clay deposit; Coefficient of determination*; *Compression Index; Compression Index Correlation; Consolidation.*

I. INTRODUCTION

Soil tends to retain the effects of stress changes that have occurred in its geological past. Stress history deals with the pressure an undisturbed clay deposit has ever encountered in its geologic past. This pressure has very significant influence on the compressibility of a particular clay deposit on the application of a structural load [1-3]. A clay deposit can be categorized as under-consolidated clay deposit, if the existing surcharge pressure is higher than the pressure the clay has ever encountered in its geologic history; normally consolidated, if the existing surcharge pressure is equal to the pressure the clay has ever encountered in its geologic history; and over-consolidated or pre-consolidated, if the existing surcharge pressure is less than the pressure the clay has ever encountered in its geologic history. Preconsolidation pressure is the maximum vertical overburden stress that a particular soil sample has sustained in the past.

Casagrande [4] was the first to evolve a graphical method of determining the preconsolidation pressure of a clay deposit using the graph of void ratio-effective stress represented on a semi-logarithmic graph. The graph consists of a recompression curve with a slope called recompression index C_r, and a virgin compression curve whose slope is known as the compression index C_c. These indices are very essential as they are used mainly to evaluate the magnitude of consolidation settlement. Due to the long period of time required to carry out consolidation test, numerous researchers have evolved empirical relationships to evaluate these indices.

II. SOME EMPIRICAL CORRELATIONS FOR COMPRESSION INDEX

Many studies have been conducted with the sole aim of finding less time demanding methods of estimating consolidation indices. Most of these studies, evolved around finding empirical relationships, using easily determined soil properties, to evaluate these indices. Azzouz *et al* [5] carried out many consolidation tests on Chicago clays, organic soils and Brazilian clays to obtain large number of data which was used to evolve an empirical relationship given by:

$$c_c = 0.01w_n\ ;\ for\ Chicago\ clay\ deposits \qquad (1)$$

$$C_c = 0.208e_0 + 0.0083;\ \ for\ Chicago\ clay\ deposits \qquad (2)$$

$$C_c = 0.0115w_n\ ;\ for\ organic\ soils \qquad (3)$$

$$C_c = 0.0046(LL - 9)\ ;\ for\ Brazilian\ clays \qquad (4)$$

where
C_c = compressive index; w_n = natural moisture content; e_0 = initial void ratio; and LL = liquid limit.

Wroth and Wood [6] also carried out study on the correlation of compressive index with some basic engineering properties of some soils and evolves an empirical correlation given by:

$$C_c = 0.5G_s\left(\frac{PI}{100}\right) \qquad (5)$$

where

G_s and PI are specific gravity and plasticity index respectively.

Rendon-Herrero [7] studied a wide variety of clay deposits and evolved an empirical relationship, termed the universal compression index equation which is expressed as:

$$C_c = 0.141 G_s^{1.2} \left(\frac{1+e_0}{G_s}\right)^{2.38} \quad (6)$$

Leroueil *et al* [8] carried out both laboratory and field study on the preconsolidation pressures on marine clay deposits at Gloucester. Their study employed the various methods available in literature for the measurement of preconsolidation pressures to estimate the preconsolidation pressure of a marine clay deposit in Gloucester. The results obtained were than compared with that mobilized in-situ below the center of a test embankment. It was discovered that special techniques of measurement such as constant rate of strain, controlled gradient, single-stage loading and anisotropic triaxial consolidation tend to overestimate the in-situ preconsolidation pressure. However, the conventional oedometer test using a load increment ratio of 0.5 and a reloading schedule of 24 hours applied to a good quality undisturbed samples produced preconsolidation pressures that compared best with the in-situ values.

A similar study carried out by Nagaraj and Murthy [9], expressed compressive index as function of liquid limit and specific gravity:

$$C_c = 0.2343 \left(\frac{LL}{100}\right) G_s \quad (7)$$

Amit and DeDalal [10], using artificial soil samples, prepared were by mixing varying proportions to obtain fifty numbers of different plasticity index, developed separately, regression equations between C_c and w_l, e_0, I_p. A relationship given below was then obtained as a relationship between compression index and plasticity index.

$$C_c = 0.015 I_p - 0.0198 \quad (8)$$

This relationship, according to the researcher holds for remolded clays.

Rao *et al* [11] investigated the choice of appropriate parameters among the compositional factors (liquid limit, plasticity index, initial moisture content and dry density) for prediction of compression index. The author carried out study on fifteen soil samples with wide ranges of liquid limit, plasticity index, dry density and initial moisture content. Regression models were then developed relating compression index with liquid limit, plasticity index, initial moisture content and dry density separately and also for various combinations of these four parameters. The applicability of the proposed regression models were tested by comparing predicted and observed compression index values for 180 test data collected from literature. Result showed that only three regression models relating compression index with liquid limit, dry density and moisture content were found to be better among all the models.

Bujang *et al* [12] investigates the effect of stress history on the volume change characteristic of unsaturated residual soils. Their study focused on the effect of stress history with regard to the matric suction (u_a-u_w). It was observed that the void ratio of the soil could either increase (swell) or decrease (collapse), depending on the stress history of the soil.

Large number of datasets was obtained from the consolidation tests conducted on alluvial deposits of south Gujarat region of India by Solanki and Desai [13]. They used soil index and consolidation test data to derive empirical correlations for preconsolidation pressure and over consolidation ratio for alluvial deposits. The correlation relations are:

$$p_c = 137.924 - 0.179 p_0 - 30.48 \left({}^{e}/_{e_l}\right) \frac{kN}{m^2}; \ \ with\ R^2 = 0.7478 \quad (9)$$

$$OCR = 1.85 - 0.007 p_0 - 0.255 \left({}^{e}/_{e_l}\right); \ \ with\ R^2 = 0.793 \quad (10)$$

where

e = void ratio; e_l = void ratio at liquid limit; p_c = preconsolidation pressure in kN/m^2; p_0 = existing overburden pressure in kN/m^2.

Narra [14] studied the influence of different consolidation curve models on the initial void ratio values and through which one can obtain preconsolidation stress. This is to check the trend between the consolidation curve models and the deviation in preconsolidation stresses. Three different oedometer tests were carried out on undisturbed, disturbed and disturbed re-wetted clay samples. The curves were fitted using two different curve models (Assouline and Van Genuchten models) and the graphical calculation of the preconsolidation stress was done using two different methods (Casagrande and Silva methods). The curve models are applied on the compaction data obtained from the soil. A good consolidation curve fit to the data was verified for a wide range of applied stresses including stresses less than the preconsolidation stress. Wide differences in the initial void ratio values ranging between 0.003 and 0.423 were observed with different curve models and with which a huge difference in preconsolidation stresses ranging between 0 and 57 kPa was observed. It was therefore concluded that the preconsolidation value obtained depends mainly on the curve fitting model and also on the calculating method. The research also showed the dependence of preconsolidation stress over the void ratio measured at 1kpa.

Solanki *et al* [15] studied some ten alluvial deposits in Gujarat state of India to obtain enough datasets which was used for correlation of various consolidation index properties. Based on the test data of the studied area the following relations were derived:

$$OCR = 1.85 - 0.007p_0 - 0.225(^{e}/_{e_l}); \quad R^2 = 0.793 \qquad (11)$$
$$C_v = 10^8 w_l^{-6.7591} \frac{cm^2}{sec}; \quad R^2 = 0.7867 \qquad (12)$$
$$C_v = 7.7525 I_p^{-3.1025} \frac{cm^2}{sec}; \quad R^2 = 0.9156 \qquad (13)$$
$$C_c = 0.0032w_l + 0.0004; \quad R^2 = 0.7806 \qquad (14)$$
$$C_c = 0.002w_l + 0.001I_p + 0.037; \quad R^2 = 0.8674 \qquad (15)$$

III. METHODOLOGY

Undisturbed samples of clay soils, collected from 16 different deposits across Nigeria were tested for consolidation. Compression index were then determined from the consolidation results. The values of the compression index from the experimental results were then compared with those obtained using seven (7) different correlations (as shown on table 1) to check which one best fits the tested Nigerian clay deposits. The comparison was made using correlation between the experimental results viz a vis the values from the empirical correlations by these authors. Coefficient of determination (R^2), determined graphically, was used as evaluation criteria to check for the correlation that best fits the considered clay deposits. Fig.1 shows the distribution of the sample collection points across Nigeria. Figs 1 and 2 show some of the plotted graphs for the determination of R^2, while table 1 shows summary of the results.

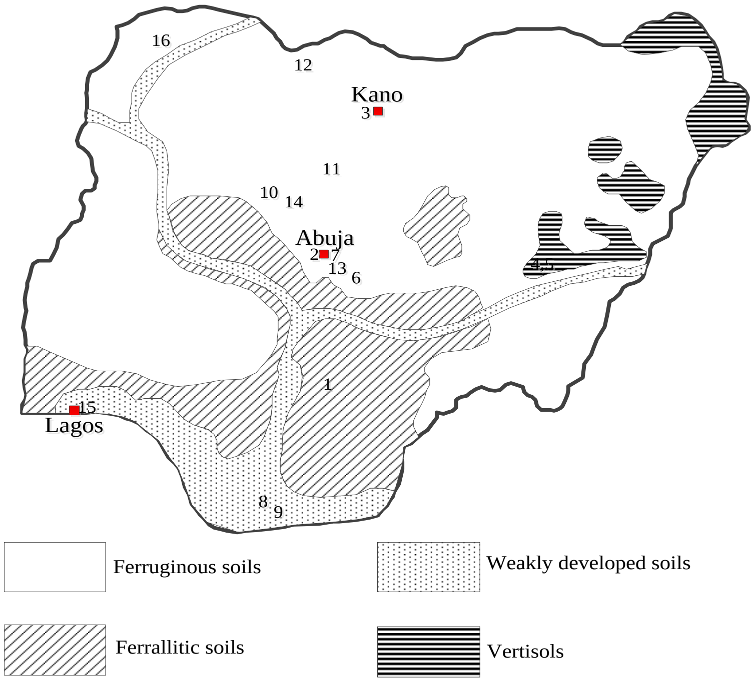

Fig.1: *Soil groups in Nigeria (sample collection points are shown with numbers)*

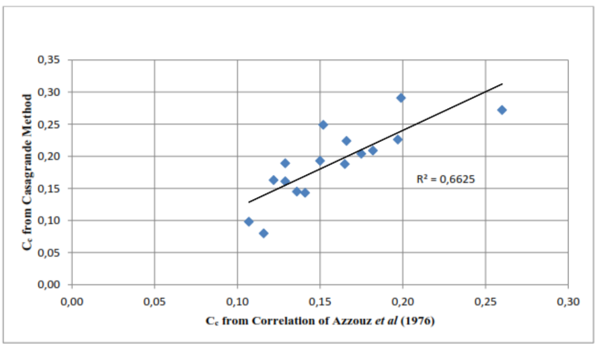

Fig. 2: R^2 for C_c from Azzouz *et al* [5] correlation

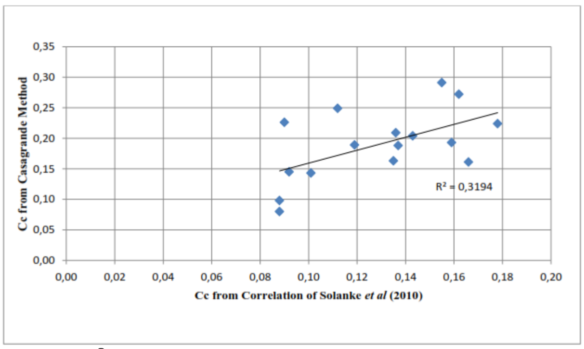

Fig. 3: R^2 for C_c from Solanke *et al* [15] correlation

IV. RESULT AND DISCUSSION

The result of the study is presented in table 1. From the result, it is observed that the least value of for R^2 of 16.03 % was obtained from the empirical correlation by Amit and DeDalal [10]. R^2 of 18.23 and 31.94 % were obtained from the correlations by Wroth and Wood [6] and Solanke *et al* [15] respectively, while the correlations of Skempton [16], Azzouz *et al* [5] for Brazilian clay and Nagaraj and Murthy [9], gives R^2 values of 42.06, 42.23 and 43.99 % respectively. The highest R^2 value of 66.25 % was obtained from the empirical correlation of Azzouz *et al* [5] for Chicago clay.

Table 1: Compression Index from experimental and the considered correlations

Soil sample	Compression Index from:							
	Experiment Using Casagrande	Wroth and Wood [6]	Azzouz *et al* [5] Chicago clay	Azzouz *et al* [5] Brazil clay	Nagaraj and Murthy [9]	Amit and DeDalal [10]	Skempton [16]	Solanke *et al* [15]
1	0.204	0.281	0.175	0.153	0.258	0.304	0.291	0.143
2	0.188	0.267	0.165	0.141	0.238	0.292	0.266	0.137
3	0.098	0.109	0.107	0.055	0.124	0.111	0.099	0.088
4	0.193	0.332	0.150	0.178	0.280	0.379	0.340	0.159
5	0.161	0.377	0.129	0.186	0.293	0.427	0.356	0.166
6	0.189	0.228	0.129	0.108	0.198	0.243	0.202	0.119
7	0.291	0.289	0.199	0.179	0.291	0.315	0.341	0.155
8	0.163	0.265	0.122	0.138	0.236	0.288	0.260	0.135
9	0.249	0.188	0.152	0.098	0.182	0.199	0.183	0.112
10	0.224	0.452	0.166	0.206	0.336	0.489	0.393	0.178
11	0.209	0.181	0.182	0.156	0.267	0.184	0.296	0.136
12	0.145	0.102	0.136	0.068	0.147	0.096	0.123	0.092
13	0.272	0.213	0.260	0.210	0.344	0.217	0.401	0.162
14	0.143	0.109	0.141	0.087	0.166	0.109	0.161	0.101
15	0.226	-	0.197	0.081	0.161	-	0.149	0.090
16	0.080	0.142	0.116	0.050	0.121	0.144	0.089	0.088
R^2		0.1823	0.6625	0.4223	0.4399	0.1603	0.4206	0.3194

V. CONCLUSION

Possibility of the use of some of the existing empirical correlations for the determination of compressive index of clay deposits in Nigeria was considered, using coefficient of determination (R^2). Result of the study showed that the correlation by Azzuoz *et al* for Chicago clays has the highest R^2 of 66.25 %, and therefore adjudged to best fits the studied clay deposits.

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