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Estimation of Primary Compression Index (Cc) Using Physical Properties of Pontianak Soft Clay

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ABSTRACT : Primary compressibility parameters of the soil can be evaluated by laboratories tests for samples, which are time consuming and costly. Estimation of the Compression Index using the physical properties of the soil is fast and easy. Some researchers present a linear correlation between c_c value and physical soil properties such water content, liquid limit and void ratio. In this paper linear regression method is used to correlate physical properties of Pontianak soil to obtain Compression Index. Correlation between compressibility index as dependent variable and void ratio, water content, liquid limit respectively as independent variables is presented. Empirical equations proposed by some researchers depending on the correlation between water content and liquid limit are under estimate the value of c_c compare with the laboratory tests results.

KEYWORDS: Primary compression index, linear regression, soft clay

I. INTRODUCTION

Estimation compressibility parameter for undisturbed soil using soil properties such as water content, liquid limit and void ratio is possible to be done. This correlation can also be useful for checking of quality control which needs easy and faster ways. Compressibility index of Pontianak soil from field and then to be tested at laboratory will be compared with several existing equations suggested by some researchers.

II. LITERATURE RIVIEW

Primary Compression Index (Cc)

The capability of soils to bear loading are differ depending on the soil types. Generally, fine-grained soils have a relatively smaller capacity in bearing of load than the coarser grained soil. Hence, fine grained soils therefore have a greater degree of compressibility. Values of primary compression index (c_c) vary from different type of soils. Table 1 below indicates c_c values of several kinds of soils.

Table 1. Primary Compression Index (c_c) for several kinds of soils

Kind of Soil	Cc
Dense Sand Loose Sand	0.0005 – 0.01 0.025 – 0.05
Firm Clay Stiff Clay	0.03 – 0.06 0.06 – 0.15
Medium – Soft Clay	0.15 – 1.0
Organic Soil Rock	1.0 – 4.5 0

Correlation Between Compression Index (c_c) , Void Ratio(e_o), Water content (W_n) and Liquid Limit (W_L)

There are some correlations between primary compression index (c_c) and soil properties such as void ratio, water content and liquid limit. Nishida (1956) derives theoretically linear correlation for all kind of undisturbed clay as showed in equation below :

$$c_c = 0.54\,(e_o - 0.35) \qquad (1)$$

and other : $$c_c = 0.0054\,(2.6\,W_n - 35) \qquad (2)$$

From more than 700 clays located in USA and Greece , Azzouz (1976) presented correlation as follows :

$$c_c = 0.4\,(e_o - 0.25) \qquad (3)$$

and other : $$c_c = 0.01\,(W_n - 5) \qquad (4)$$

Hough (1957) derived equations for cohesive soil, silt, clay, silty clay and inorganic soil. This equation correlated with pore ratio (e_o) and also water content.

$$c_c = 0.4049\,(e_o - 0.3216) \qquad (5)$$

and other : $$c_c = 0.0102\,(W_n - 9.15) \qquad (6)$$

Rendon-Herrero (1980) collected around 94 samples of America's clay and present equation below.

$$c_c = 0.30\ (e_o - 0.27) \qquad (7)$$

Serajuddin (1987) gave a linear equation for 130 alluvial clay and silt in Bangladesh as given in the following equation.

$$c_c = 0.0102\ (W_n - 9.15) \qquad (8)$$

Terzhagi and Peck (1967) present a linear correlation between primary compression index (c_c) and liquid limit (W_L) as ilustrated in the following equation.

$$c_c = 0.009\ (W_L - 10) \qquad (9)$$

For all parameters c_c, e_o, Wn and WL is primary compression index, pore ratio,water content and liquid limit respectively.

In addition, another correlation for disturbed clay sample or remoulding, Skempton (1944) gave a linear correlation using liquid limit.

$$c_c' = 0.007\ (W_L - 7) \qquad (10)$$

Koppula (1981) and Wroth et al. (1978) propose a correlation using plasticity index for primary compressive strength of remoulding clay.

$$c_c' = 1.325\ I_p \qquad (11)$$

Linear Regression Method

Linear regression is a simple method to analyze data and take conclusion afterwards. By using spreadsheets program (Excel for windows) data base can be easily calculated. Trend line linearly indicate between independent variable (c_c) and dependent variables (e_o, W_n,W_L). Coefficient of determination (R^2) indicates a correlation each other. Ratio coefficient regression to standard error is T-value indicating validity of equation. Practically, T-value more than 2.0 hints a valid equation.

III. DATA COLLECTING

Main data for calculation and analysis came from soil investigation of expanded runway project of Supadio airport in Pontianak, Indonesia. There are 10 boreholes along at left and right of existing runway having 2.250 m length and 30 m width. It will be extended 2.550 m length and 45 m width. From each borehole two samples were taken hence there are 20 samples for testing at laboratory. Detail data from soil investigation results for the project is shown in Table 2.

STA	No. of sample	Depth (m)	γ (kN/m3)	σ i kPa	Wn (%)	W_L (%)	Wp (%)	Ip (%)	I_L	eo	Cc
0+072	1	9.30	14.23	132.34	75.79	35.23	25.81	9.42	5.31	1.887	0.829
	2	20.30	14.33	290.90	49.85	49.38	26.38	23.00	1.02	1.390	0.738
0+303	1	3.30	15.43	50.92	69.17	48.79	30.64	18.15	2.12	1.811	0.803
	2	12.30	18.25	224.48	34.86	24.90	14.66	10.24	1.97	0.910	0.349
0+639	1	9.30	15.64	145.45	68.83	48.29	26.23	22.06	1.93	1.850	0.663
	2	20.30	15.66	317.90	60.38	62.46	32.79	29.67	0.93	1.791	1.663
1+054	1	3.30	14.74	48.64	81.55	48.73	27.53	21.20	2.55	2.321	1.236
	2	12.30	15.82	194.59	71.80	54.89	28.97	25.92	1.65	1.886	0.436
1+435	1	6.30	16.33	102.88	66.96	51.52	26.64	24.88	1.62	1.522	0.653
	2	15.30	15.88	242.96	66.00	49.12	29.55	19.57	1.86	1.748	0.872
1+773	1	9.30	16.03	149.08	90.96	53.44	26.86	26.58	2.41	2.258	0.866
	2	18.30	18.54	339.28	35.59	22.62	19.08	3.54	4.66	0.884	0.279
2+106	1	3.30	14.23	46.96	86.42	54.02	38.44	15.58	3.08	7.114	0.993
	2	12.30	16.21	199.38	49.59	55.13	29.11	26.02	0.79	1.610	1.196
2+250	1	6.30	14.4	90.72	83.01	52.27	28.50	23.77	2.29	2.351	1.013
	2	15.30	17.19	263.01	43.83	46.46	25.55	20.91	0.87	1.178	0.488
2+400	1	12.30	13.93	171.34	56.82	17.10	14.62	2.48	17.02	1.444	0.556
	2	20.30	14.64	297.19	50.14	46.16	25.71	20.45	1.19	1.347	0.511
2+550	1	9.30	16.87	156.89	54.10	51.96	24.87	27.09	1.08	1.308	0.452
	2	18.30	16.28	297.92	52.31	39.08	22.91	16.17	1.82	1.347	0.511
	Max	20.30	18.54	339.28	90.96	62.46	38.44	29.67	17.02	7.114	1.663
	Min	3.30	13.93	46.96	34.86	17.10	14.62	2.48	0.79	0.884	0.279
	Avg	11.85	15.73	188.14	62.40	45.58	26.24	19.34	2.81	1.898	0.755

Table 2. Data from soil investigation of expanded runway project at Supadio airport

IV. DISCUSSION FOR ANALYSIS RESULTS

Primary Compression Index (Cc) from Equations

The results for primary compression index (c_c) from laboratory testing and that from some equations above is shown in Table 3. Nishida (1956), Azzouz (1976) and Hough (1957) gave two results for c_c values. Left one of coulomb is based void ratio and other is based from water content. Rendon-Herrero (1980) only give linear correlation between c_c and void ratio and Seradjuddin (1987) uses water content to get c_c value whereas only Terzhagi and Peck (1967) propose correlation of c_c based on liquid limit.

Table 3. Values of c_c from laboratory test using some equations

Location	Lab.	Nishida		Azzouz		Hough		Rendon-Herrero	Seradjuddin	Terzhagi
	Cc	Cc	Cc	Cc	Cc	Cc	Cc	Cc	Cc	Cc
0+072	0.829	0.830	0.875	0.655	0.708	0.634	0.680	0.485	0.680	0.227
	0.738	0.562	0.511	0.456	0.449	0.433	0.415	0.336	0.415	0.354
0+303	0.803	0.789	0.782	0.624	0.642	0.603	0.612	0.462	0.612	0.349
	0.349	0.302	0.300	0.264	0.299	0.238	0.262	0.192	0.262	0.134
0+639	0.663	0.810	0.777	0.640	0.638	0.619	0.609	0.474	0.609	0.345
	1.663	0.778	0.659	0.616	0.554	0.595	0.523	0.456	0.523	0.472
1+054	1.236	1.064	0.956	0.828	0.766	0.810	0.738	0.615	0.738	0.349
	0.436	0.829	0.819	0.654	0.668	0.633	0.639	0.485	0.639	0.404
1+435	0.653	0.633	0.751	0.509	0.620	0.486	0.590	0.376	0.590	0.374
	0.872	0.755	0.738	0.599	0.610	0.578	0.580	0.443	0.580	0.352
1+773	0.866	1.030	1.088	0.803	0.860	0.784	0.834	0.596	0.834	0.391
	0.279	0.288	0.311	0.254	0.306	0.228	0.270	0.184	0.270	0.114
2+106	0.993	3.653	1.024	2.746	0.814	2.750	0.788	2.053	0.788	0.396
	1.196	0.680	0.507	0.544	0.446	0.522	0.412	0.402	0.412	0.406
2+250	1.013	1.081	0.976	0.840	0.780	0.822	0.753	0.624	0.753	0.380
	0.488	0.447	0.426	0.371	0.388	0.347	0.354	0.272	0.354	0.328
2+400	0.556	0.591	0.609	0.478	0.518	0.454	0.486	0.352	0.486	0.064
	0.511	0.538	0.515	0.439	0.451	0.415	0.418	0.323	0.418	0.325
2+550	0.452	0.517	0.571	0.423	0.491	0.399	0.458	0.311	0.458	0.378
	0.511	0.538	0.545	0.439	0.473	0.415	0.440	0.323	0.440	0.262
Max	1.663	3.653	1.088	2.746	0.860	2.750	0.834	2.053	0.834	0.472
Min	0.279	0.288	0.300	0.254	0.299	0.228	0.262	0.184	0.262	0.064
Average	0.755	0.836	0.687	0.659	0.574	0.638	0.543	0.488	0.543	0.320

c_c values from correlation using parameter of void ratio show higher than water content for three equations Nishida (1956), Azzouz (1976) and Hough (1957) whereas Rendon-Herrero (1980) and Seradjuddin (1987) gave different trend. Furthermore, Terzhagi and Peck's equation based liquid limit gives the smallest of c_c value. From Table 1 above that average value of c_c for Pontianak Soil is 0.755 and classified as soft soil in ranging from 0.15 to 1.0 for medium-soft soil in grouping.

Linear Regression of Laboratory Data

By using linear regression, analysis and validation for Pontianak soft soil is done and new equation for soil model is found. There are three kind of equations will be showed. Firstly, it is based on void ratio. Secondly, it is based on water content and the last one is a correlation between c_c values and liquid limits. The correlation between cc and different types of physical properties are shown in Figures 1, 2, 3.

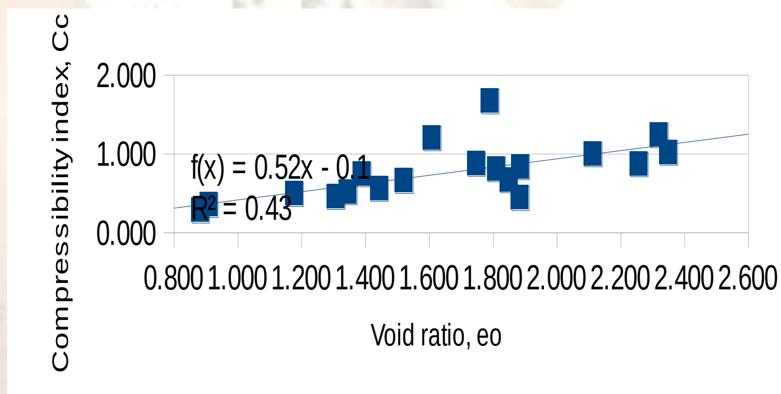

Figure 1. c_c versus. e_o

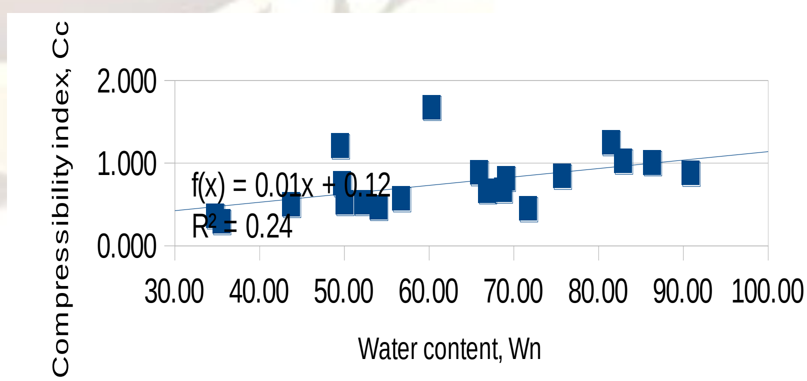

Figure 2. c_c versus. W_n

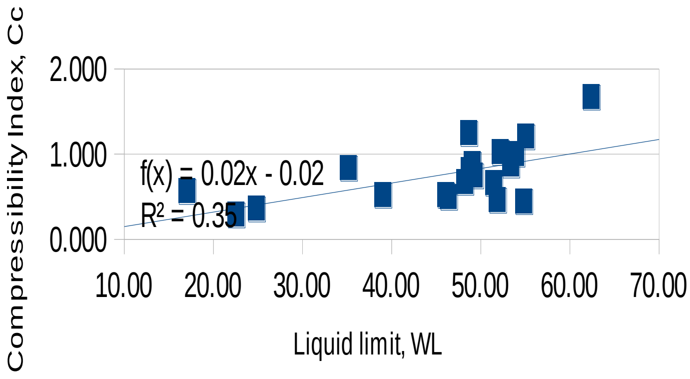

Figure 3. c_c versus W_L

Correlation between Compression index (c_c) and Void ratio (e_o) uses linear regression as depicted in Figure 1. with cofficient of determination $R^2 = 0.427$ gives equation:

$$c_c = 0.5217\ e_o - 0.10428 \quad (12.a)$$
$$= 0.5217\ (e_o - 0.20) \quad (12.b)$$

Furthermore, in Figure 2. for coefficient of determination $R^2 = 0.238$ gives equation:

$$c_c = 0.0102\ W_n + 0.11807 \quad (13.a)$$
$$= 0.0102\ (W_n + 11.57) \quad (13.b)$$

Figure 3. presents a linear correlation between compression index (c_c) and Liquid limit taking coefficient of determination $R^2 = 0.349$ gives equation:

$$c_c = 0.01706\ W_L - 0.02209 \quad (14.a)$$
$$= 0.01706\ (W_L - 1.30) \quad (14.b)$$

From coefficient of determination (R^2) above that all equations give low correlation and the worst is the correlation between c_c and water content (W_n). In addition, constant or intercept for the equation between c_c and W_n having positive value are different than other which are negative signs. Table 4 right column gives new equations as alternative equations using linear regression analysis.

Table 4. Comparison of equations

Researchers	Existing equations	Alternative equations
Nishida (1956)	$c_c = 0.54\ (e_o - 0.35)$ $c_c = 0.01404(W_n - 13.46)$	$c_c = 0.5217\ (e_o - 0.2)$ $c_c = 0.0102\ (W_n + 11.57)$ $c_c = 0.01706\ (W_L - 1.29)$
Azzouz (1976)	$c_c = 0.4\ (e_o - 0.25)$ $c_c = 0.01\ (W_n - 5)$	
Hough (1957)	$c_c = 0.4049\ (e_o - 0.3216)$ $c_c = 0.0102\ (W_n - 9.15)$	
Rendon-Herrero (1980)	$c_c = 0.3\ (e_o - 0.27)$	
Seradjuddin (1987)	$c_c = 0.0102\ (W_n - 9.15)$	
Terzhagi-Peck (1967)	$c_c = 0.009\ (W_L - 10)$	

CONCLUSIONS

Based on compression index (c_c) at laboratory testing for Pontianak soil which average of c_c value is 0.755 and the values ranging from 0.279 to 1.663 indicates as soft clay. Compression index values using independent variables such as water content and liquid limit are under estimated compared laboratory testing whereas void ratio is shown better result. Coefficients of determination (R^2) for three grouping from regression analysis are below 0.5. Hence, they indicate as low correlation between c_c and independent variables void ratio, water content, liquid limit respectively. Large number of sample is more needed for further analysis in other to present valid equations having high correlation.

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