

Prediction of Consolidation Characteristics from Index Properties

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Abstract. Compression index and coefficient of consolidation are two most important parameters in obtaining the consolidation characteristics of cohesive soil. Considerable time and effort are required to obtain these parameters from the oedometer test. Therefore, this study aims to correlate these two parameters with the index properties. Five remoulded samples are tested for their physical properties as well as their consolidation characteristics. The results show good relationship was obtained for the liquid limit and the compression index while the coefficient of consolidation is best correlated with the plastic limit. Multiple regression analysis was performed to improve the prediction. Liquid limit is best coupled with specific gravity to estimate the compression index while plastic limit and plastic index can be used to best predict the coefficient of consolidation.

1 Introduction

Geotechnical investigation is required before constructing any structure for a safe and economic design which include surface and subsurface exploration of the site. Lack of knowledge about the compressibility of soil that is important in the design of the building and infrastructure may lead to the construction fault which is costly in materials and efforts. Compressibility of the soil is its capacity to decrease in volume under pressure and is indicated by soil characteristic likes compression index (C_c) and coefficient of consolidation (C_v). Compression index is used for settlement estimation while coefficient of consolidation is used to predict the time required for a given amount of compression to take place.

The prediction of magnitude and the rate of consolidation settlements in consolidation theory is important for serviceability of structure founded on a compressible soil layer. The consolidation characteristics can be obtained by conducting a one-dimensional consolidation test using oedometer apparatus. However, the determination of coefficient of consolidation and compression index of soil from oedometer test require considerable time

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and effort. Therefore, several attempts have been made to predict the value of compression index and coefficient of consolidation from empirical correlation linked with the index properties which are relatively easier and faster [1-9]. Skempton [1] is the first to correlate the compression index of remoulded clay with index properties. Table 1 shows different correlations to predict compression index reported in the literature. Comparing to compression index prediction, there are limited studies that have been made in the past to predict the coefficient of consolidation. Table 2 shows various approximations to predict C_v .

Table 1. Compression index equation by various authors

References	Equations	Samples
Skempton [1]	$C_c = 0.007(LL-10)$	Remoulded Clays
Terzaghi and Peck [2]	$C_c = 0.009(LL -10)$	Normally consolidated, Moderate sensitivity
Wroth and Wood [3]	$C_c = 0.0135PI$	All remoulded, normally consolidated clays
Vinod and Bindu [4]	$C_c = 0.0055(LL - 1.8364)$	High plastic clays
Widodo and Ibrahim [5]	$C_c = 0.01706(LL-1.30)$	Soft Clays

LL= Liquid limit, G_s = Specific gravity, PI = Plastic index

Table 2. Coefficient of consolidation approximations by various authors

References	Equation	Samples
Sridharan and Nagaraj [6]	$C_v = 3 / (100IS^{3.54})$ (m^2 / s)	Remoulded soils
Solanki and Desai [7]	$C_v = 7.7525PI^{-3.1021}$ (cm^2 / s)	Normally consolidated soils
Soibam et al. [8]	$C_v = 4X10^{-7}-4x10^9 LL$ (m^2 / s)	Soft clays
Jadhav [9]	$C_v = 128.7/3.54IS + 0.0002$ (cm^2 / s)	Clays with wide range of liquid limit

IS = Shrinkage index

2 Materials and methods

Five cohesive soil samples were selected in the present study and have been evaluated for their physical properties. The index properties tests were carried out according to BS:1997-part 2, 1990. The LL test was carried out with fall cone test while plastic limit, PL test was carried with rolling thread method. The summary of the soil properties is shown in Table 3. The LL of the five samples ranges from 29 % to 46 % with PI ranges from 8 -18. The one-dimensional consolidation tests for five remoulded soil were performed accordance to BS1377: Part 5: 1990 with oedometer equipment. The samples were hand remoulded at their respective liquid limit. The samples were loaded to 800 kPa with four increment stage. From the oedometer data, the void ratio curve on a semi-log has been plotted where the tangent of linear portion of the pressure is a value of compression index, C_c . The coefficient of consolidation, C_v was calculated using Taylor's Method obtained from the plot of square root time-deformation curve. Due to small different in C_v values for each loading stage, the value of C_v presented here is obtained from loading at 200 kPa. Index

properties are correlated with C_c and C_v to determine the best correlated parameter using simple linear regression. In addition, multiple regression analysis was conducted to determine two most controlling variables in predicting the C_c and C_v .

Table 3. Summary of Soil Properties

Sample no.		1	2	3	4	5
Specific gravity, G_s (mg/m ³)		2.56	2.55	2.57	2.58	2.52
	Liquid Limit, LL	35	38	29	46	36
	Atterberg Plastic Limit, PL	22	24	21	28	24
Limits (%)	Plasticity index, PI	13	14	8	18	12
Particle Size Distribution (%)	Clay	12.69	12.24	5.94	16.76	13.96
	Silt	51.49	55.67	61.81	52.40	54.45
	Sand	35.82	32.09	32.25	30.84	31.59
Classification of soil		CIS	CI	CL	MI	CI

* CIS: Sandy Clay of Intermediate Plasticity; CI: Clay of Intermediate Plasticity; CL: Clay of Low Plasticity; MI: Silt of Intermediate Plasticity

3 Result of consolidation characteristics

The results of oedometer test for five tested samples in terms of compression index and coefficient of consolidation are shown in Table 4. The C_c ranges from 0.19 to 0.28 while C_v ranges from 0.3 to 0.48. Table 4. Four index properties are used to correlate with the LL and the results is shown in Fig. 1. All of the results show the increase of C_c with the increase of index properties except the fine content, F%. From the single regression analysis, the liquid limit is best correlated with the compression index:

$$C_c = 0.0062LL + 0.0165 \tag{1}$$

Similar findings are obtained by other researchers as can be seen in Table 1. Modest relationships are obtained for fine particles, plastic index and plastic limit. Skempton's equation [1] was used to predict the results, and the differences are 27%, 2%, 30%, 10%, and 24% respectively compared with sample no. 1 to 5.

Table 4. Oedometer results

Sample	1	2	3	4	5
C_c	0.24	0.2	0.19	0.28	0.25
C_v (m ² /yr)	0.36	0.35	0.48	0.3	0.4

Subsequent multiple regression analysis shows that the correlation of LL and C_c can be further improved with the addition of another index property which is the specific gravity, G_s as shown in Eq. (2) in which the coefficient of determination, R^2 is 0.998.

$$C_c = 0.27 GS - 0.005LL - 0.26 \tag{2}$$

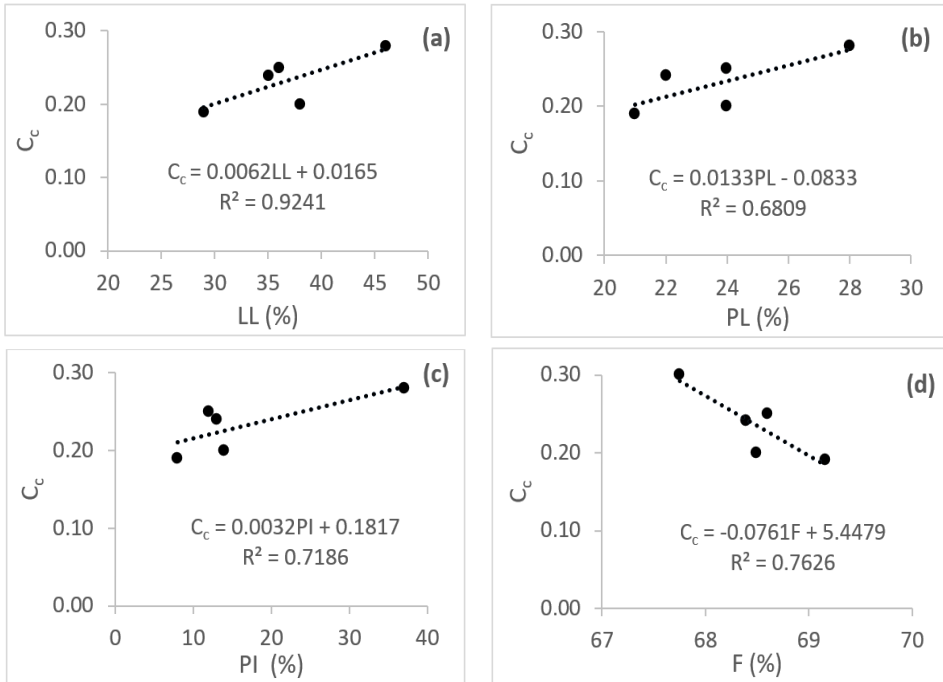


Fig. 1. a) LL vs C_c , b) PL vs C_c , c) PI vs C_c , and d) F vs C_c

Figure 2 shows the C_v value is best correlated with the PI. The relationship of C_v and PI is shown in Eq. (3). Solanki and Desai [7] reported the similar finding. The correlation with F% is not satisfactory with low degree of relationship. Generally, C_v decreases with the increase of the index property. Through multiple regression analysis, LL and PI can be used to best estimate the coefficient of consolidation as shown in Eq. (4) with $R^2= 0.994$.

$$C_v = 0.6155 - 0.0183PI \quad \text{in m}^2/\text{yr} \quad (3)$$

$$C_v = 0.451 + 0.011LL - 0.0367PI \quad \text{in m}^2/\text{yr} \quad (4)$$

4 Conclusions

Five cohesive samples were remoulded and subjected to one dimensional consolidation test. The compression index was found to be best correlated with the liquid limit while and the coefficient of consolidation was best correlated with the plastic index. Further multiple regression analysis showed that the specific gravity and liquid limit are best coupled in predicting the compression index. While best correlation was obtained using liquid limit and plastic index to estimate the coefficient of consolidation.

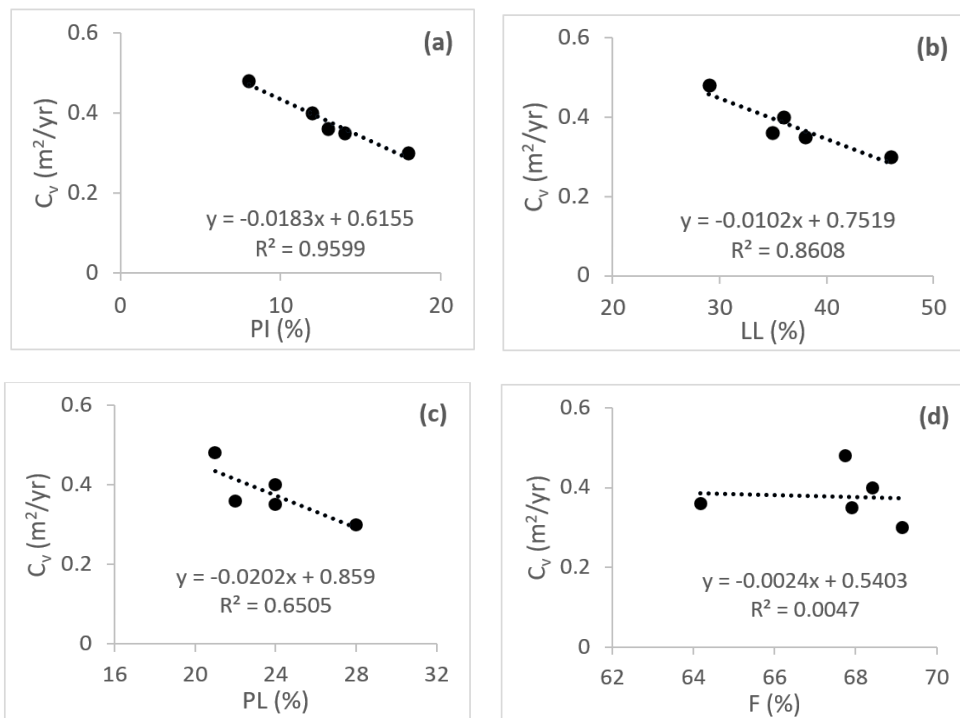


Fig. 2. a) LL vs C_v , b) PL vs C_v , c) PI vs C_v , and d) F vs C_v

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