VOL. 12, NO. 2, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PREDICTION OF SETTLEMENT RATIO OF COMPRESSIBLE SOIL UNDER EMBANKMENT LOAD USING EMPIRICAL CORELATION AND LINEAR REGRESSION

Putu Tantri K. Sari and Yudhi Lastiasih
Civil Engineering Department, Institute Technologi of Sepuluh Nopember, Surabaya, Indonesia
E-Mail: tantri@ce.its.ac.id

ABSTRACT

The major part of this paper is on challenges to predicting the ratio of settlement under the toe of embankment (a), outer side embankment (b) and the center of embankment (c). This study uses several variables such as the depth and characteristic of soft soil layer in accordance with the soft soil in Surabaya Indonesia, the width of embankment and the height of embankment. Those variable uses to compare the ratio of settlement depend on those variables. This research was conducted by several empirical approaches to obtain the value of compression index (Cc). The swelling index (Cs) of the soil is made of variation between 1/5-1/10 Cc. The results obtained from this study are the settlement ratio of a/c with soil depth of 10 meters is 0.22 and the soil depth of 20 meters is 0.27. The settlement ratio of b/c if the soil depth of 10 meters is 0.87 and the soil depth of 20 meters is 0.82. The study results showed that the empirical formula of ratio (a/c) is y = 0.0047x + 0.1729; ratio (b/c) is y = -0.0046x +0.9121.

Keywords: settlement ratio, compressible soil, compression index, soil settlement.

1. INTRODUCTION

The development of settlement calculation under an embankment is usually taken as granted that the maximum settlement occurs in the center is the priority of soil settlement calculation under embankment. The settlement at the toe of embankment is always assumed as zero value which means that there is no settlement under the toe embankment. Whereas, soil settlement can occur in areas affected by embankment where not appropriate under embankment. The possibility of the settlement value under the toe embankment can be found from the stress increase under the embankment toe due to the embankment load itself.

The one dimensional settlement empirical formula shows that the stress increase could impact the magnitude of soil settlement [1]. It can be concluded that the settlement that occurs right at the toe embankment is not always zero. The settlement has occurred on the relocation construction of Porong Highway in Surabaya Indonesia. Soil compression occurred in the housing area resident residing a few meters away from the outerside of embankment. The conditions proved that the settlement does not only occur in the area just under the embankment load, but also in the surrounding area.

A road construction code in Japan stated that the compression ratio in the outer side of embankment and in the toe of embankment with the center embankment is not 0. Those ratios were obtained based on the soil condition in Japan. In that code shows that the compression ratio of subgrade at the toe of embankment is 0.2 x Settlement Consolidation in the center of embankment (0.2Sc), while the compression ratio side in outer side of embankment is 0.8Sc. [2] Conducted a study to determine the compression ratio toe and outer side of embankment with the center of embankment. The study obtained the settlement ratio for the toe of embankment towards the center of the embankment is 0.2Sc (10 meters of soft soil depth) and 0.25Sc (20 meters of soft soil depth). The settlement ratio for the outer side of embankment with the center of embankment is 0.86Sc (10 meters of soft soil depth) and 0.81Sc (20 meters of soft soil depth). However, this study was restricted to the comparison of the value of Coefficient Swelling (Cs) = 1/8 x Coefficient Consolidation (Cc) only.

However, further research is needed to determine the magnitude of the soil settlement under the embankment and also to compare the settlement ratio under the toe and outer side of embankment with the center embankment using a more various soil condition (The ratio of Cc and Cs are 1/5 - 1/10). The amount ratio is then compared between several variables that are type of soil, the depth of soft soil, embankment height and embankment width. This research was conducted by several empirical approach to obtain the value Coefficient Consolidation / compression index (Cc). The value of index compression is required by the geotechnical to determine the amount of compression of a soft clay soil. The value of compression is needed to do a lot of designing. An empirical approach in this study is then adjusted to the soft soil in Surabaya and surrounding areas.

Lots of empirical formula for compression index formulation approach has been tested on soft clay soils in some developing countries. The empirical formulations derived from correlate the soil consistency values and soil characteristics which are more easily tested in the laboratory. Some predictions formulation of empirically based from Liquid limit value has been tested [3-5], based from Plasticity Index has been tested [6-7]; based from Shrinkage Index has been tested [8].

Other formulas also been extensively tested in several countries, among others: [9] who tested Chicago clay, Brazilian clay, Clay Motley from the city of San Paulo and USA clay as well as in Greece based on the value of water content, void ratio and Liquid Limit; [10]

conducted tests on clay in the North Atlantic based on the value of plasticity index. Not only those, dozens of other formulations have also been developed to correlate the characteristic value of void ratio, specific Gravity and water content. Some of these formulations are developed by [9, 11-15]. The formula offered to the entire soft clay. This study will use several formula of compression index that have been developed previously.

The purpose of this study is to determine the magnitude of soil settlement ratio that occurs under the toe embankment and under the outer-side embankment with the maximum amount of settlement that occurs at the middle of the embankment. Results of this study was to obtain empirical formula using linear regression methods to determine the compression ratio of subgrade beneath embankment on the various types of soil subgrade with empirical approach and several variations of compressible soil depth, embankment height variations and variations in the width of the road embankment. The results of this study are expected to be one of the designer references in order to avoid damage to structures on the embankment and surround the embankment constructed area.

2. MATERIAL AND METHODS

This study is conducted by some variation of the data for comparisons that is:

a) Embankment height variations (3 meters; 5 meters and 7 meters)
b) The depth variation of compressible soil (10 - 20 meters)
c) Width variation of embankment road (20 m, 30 m and 40 meters)
d) Variations value of compression index (Cc) using empirical formula by [14, 16, 17].

(This study uses the embankment with only 1 slope ratio which is 1: 1)

By using the variations above, and then analyzed it to determine the magnitude of the soil subgrade stress increase due to the embankment load. The calculation of the vertical stress increase is conducted to determine the magnitude of soil compression. The calculation of the vertical stress increase is performed by the method of superposition and graph to obtain the factor influence measurement [18]

Empirical formulations to obtain the value of plasticity index (Cc) were used in this study are:

$Cc = 0006\ LL + 0.13\ eo2 - 0.13$ (by [16] on the soft clay in Surabaya and surrounding areas)

$Cc = 1.15\ (eo - 0.35)$ (by [17] on all types of clay)

$Cc = 0.75\ (eo - 0.50)$ (by [14] for the type of soil that has a low plasticity value).

3 empirical formula used above is considered to represent all types of soft clay. The value of Cc is used by the empirical formula above is varied between 0.3 until 1.2. By using the value of Cc is then performed calculations to determine the amount of compression subgrade beneath the embankment using Terzaghi one dimensional consolidation by assuming the entire soil type are over-consolidated clay (OC) soil by the condition po + Δp> pc.

Besides using the empirical formula mentioned above, the Cc values of soil subgrade were also use the data contained in Surabaya. The analyses using those data were done by 466 soil samples at 77 borehole at 25 locations in Surabaya. Soil data used for this study was obtained from Soil and Rock Mechanics Laboratory, Department of Civil Engineering ITS, Surabaya, Indonesia. The results of the compression index (Cc) and void ratio (eo) can be seen in Figure-1.

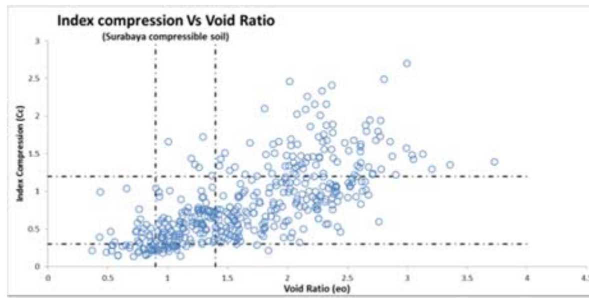

Figure-1. Compression index and void ratio in Surabaya area.

3. ANALYIS AND DISCUSSIONS

a. Initial analyzes of the compression ratio of subgrade

The analysis using the above-mentioned variations made to obtain the settlement ratio of the subgrade on the toe of embankment and the outer side of embankment with the settlement in the center of embankment. The analyses carried out on various conditions and produce relatively the same conclusion (Figures 2 and 3), namely:

- At the toe of embankment: the more the soil compressible depth the greater the compression ratio. Conversely, at the outer side of embankment: the more the soil compressible depth the less the compression ratio. These trends occur in all the wide embankment are analyzed.
- The higher the embankment, the greater the compression ratio are occurred. The ratio at the toe of embankment is not too great difference when compared with the ratio on the outer side of embankment.
- The wider the road embankment, the smaller the compression ratio is occurred, but the difference is not too significant.

The analysis on the chart shows that the magnitude of soil settlement in the toe of embankment is not zero, while the magnitude of soil settlement under the outer side of embankment is not the same as the settlement in the center embankment. Based on the compression ratio in the above figure can be seen that there is a difference between the ratio of the amount of each variety used. For

VOL. 12, NO. 2, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

that, it needs further analysis to determine how big the influence of the variation data to the amount of compression ratio that occurred.

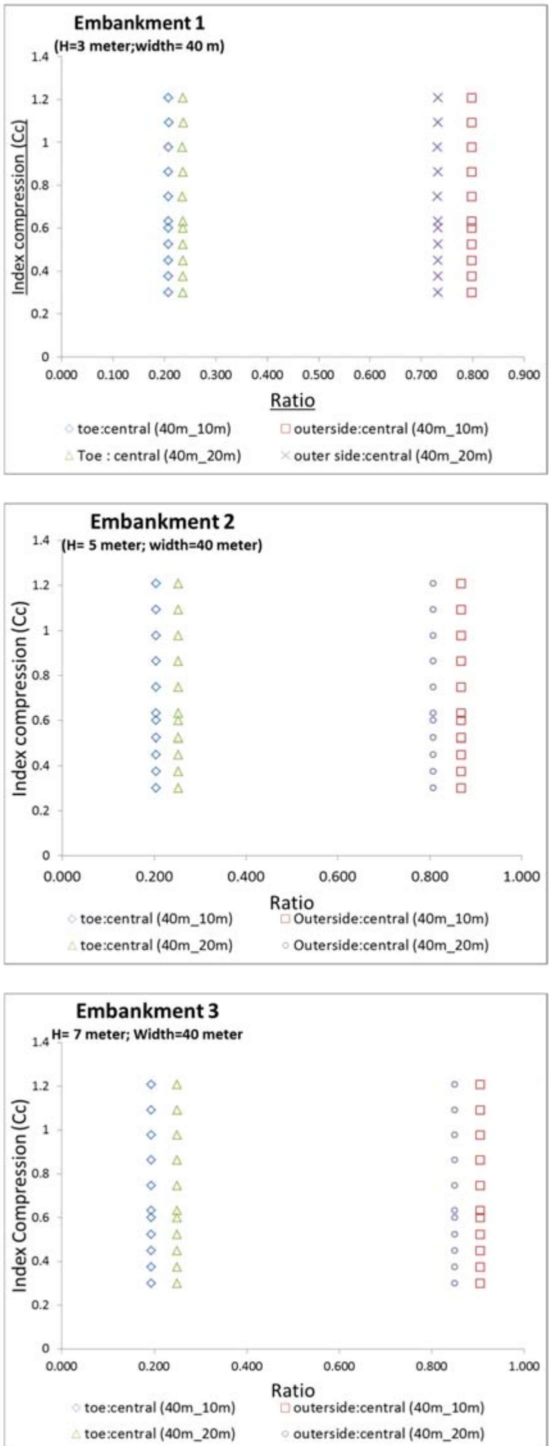

Figure-2. Results analysis of the compression ratio in the soil under embankment with a width 40 meters (a) 3 meters embankment height; (b) 5 meters embankment height; (c) 7 meters embankment height.

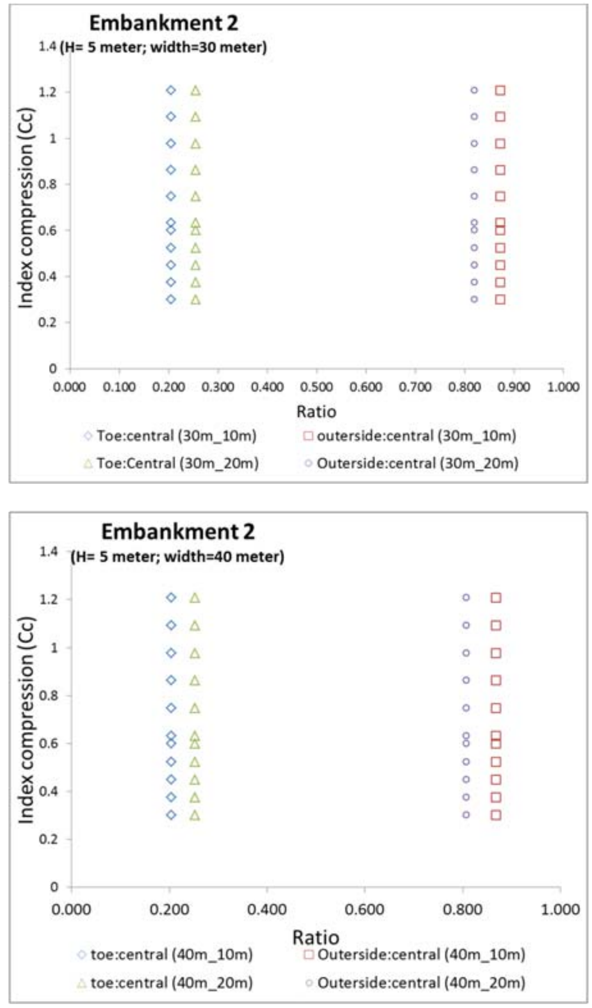

Figure-3. Result analyses of soil compression under embankment load in embankment height 5 meter; (a). Embankment width = 30 meter; (b) Embankment width = 40 meter (b) Analysis of soil compression ratio under the embankment load.

The calculation of settlement ratio is done as much as 396 trials. The trial of calculations and analysis is done by using three variations of elevation and two variations of soil compression depth. In each of these variations, the calculations were carried out in five void ratio variations and 11 variations of Cc / Cs ratio. Trend graph analysis results with diverse variety used can be seen in Figure-5 and Figure 6 with captions can be seen in Figure-4.

VOL. 12, NO. 2, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

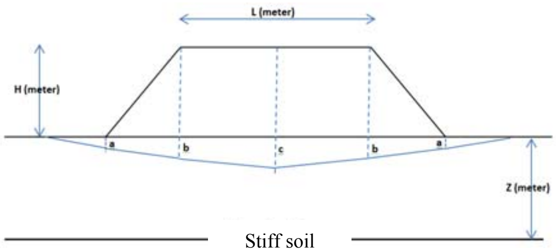

Figure-4. Description symbol for the analysis of soil compression ratio under embankment load.

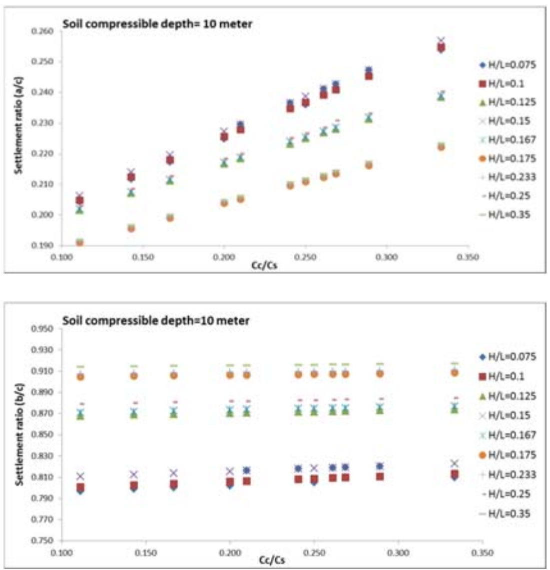

Figure-5. Compression ratio of 10 meter soil compressible depth.

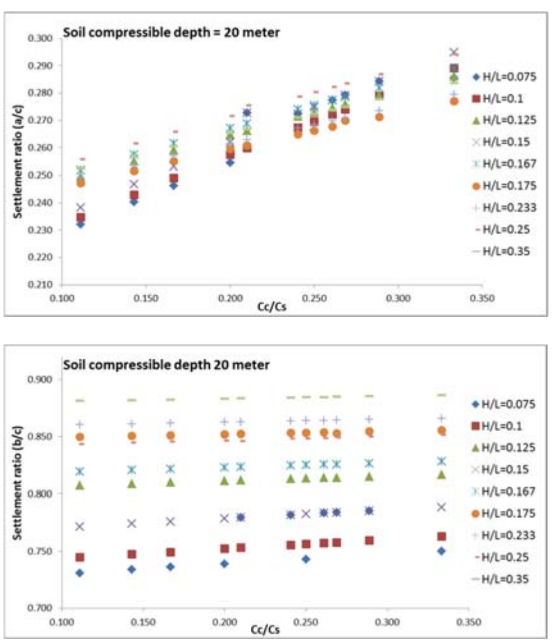

Figure-6. Compression ratio of 20 meter soil compressible depth.

Sari and Lastiasih (2015) in his research states that the greater L then the a/c and b/c will be smaller; The larger the Z then a/c greater; b/c getting smaller; The greater the H then the a/c will be smaller; b/c even greater. Similar results were also obtained in this study. The same Trend of graph was obtained on soft soil depth (Z) of 20 meters as shown in Figure-10.

The amount of settlement ratio under the embankment has relatively different results on each parameter soil conditions. However, the compression ratio difference is not very big. On the condition Z = 10 meters, the settlement ratio a/c is varied between 0.19 to 0.24.The compression ratio with a various conditions has coefficient variation (Cv) is between 4-6%. The magnitude of Cv of soil settlement ratio analysis under the embankment with a vary of conditions can be seen in Table-1.

Table-1. The compression ratio of the subgrade under embankment based on the coefficient of variation (CV) for all variations of soil data were used.

H/L	Z=10 meter			
	a/c	CV	b/c	CV
0.08	0.23	6.39	0.81	1.09
0.10	0.23	6.16	0.81	0.45
0.13	0.22	4.74	0.87	0.20
0.15	0.23	6.18	0.82	0.42
0.17	0.22	4.75	0.87	0.19
0.18	0.21	4.28	0.91	0.12
0.23	0.21	4.29	0.91	0.11
0.25	0.22	4.80	0.88	0.18
0.35	0.21	4.30	0.92	0.10
Total	**0.22**	4.48	**0.87**	4.78

H/L	Z=20 meter			
	a/c	CV	b/c	CV
0.08	0.26	6.67	0.76	2.96
0.10	0.26	5.89	0.75	0.69
0.13	0.27	3.89	0.81	0.33
0.15	0.27	6.02	0.78	0.63
0.17	0.27	3.91	0.82	0.31
0.18	0.26	3.26	0.85	0.19
0.23	0.26	3.24	0.86	0.19
0.25	0.28	3.96	0.85	0.28
0.35	0.27	3.28	0.88	0.16
Total	**0.27**	1.50	**0.82**	5.38

Based on the table above it can be seen that the magnitude of the settlement ratio in the toe of embankment to the center of embankment (a/c) is 0.22 and the magnitude of settlement ratio in the outer side of embankment to the center of embankment (b/c) was 0.87 for the depth of soft ground 10 meters (Figure-7). However if the soft soil depth is 20 meters, the ratio settlement of a/c is 0.27 and the b/c was 0.82 (Figure-8). Based on the analysis above is produced the equation y = 0.0047x + 0.1729 (for the ratio a/c) and y = -0.0046x +0.9121 (for the ratio b/c), where y = ratio and x = depth of soft ground is incompressible. The graph to obtain these equations can be seen in Figure-9.

VOL. 12, NO. 2, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

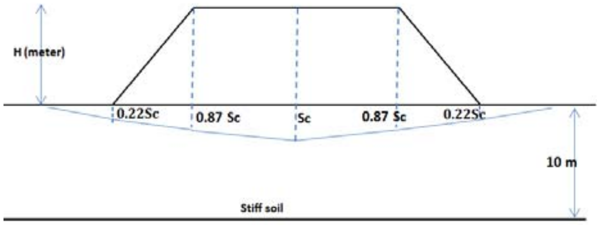

Figure-7. Settlement ratio of 10 meter compressible soil under the embankment load.

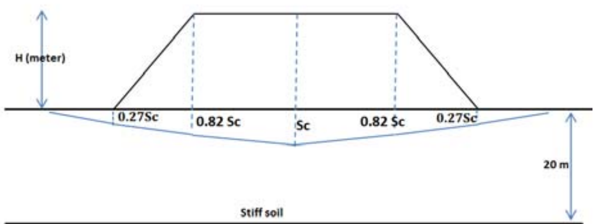

Figure-8. Settlement ratio of 10 meter compressible soil under the embankment load.

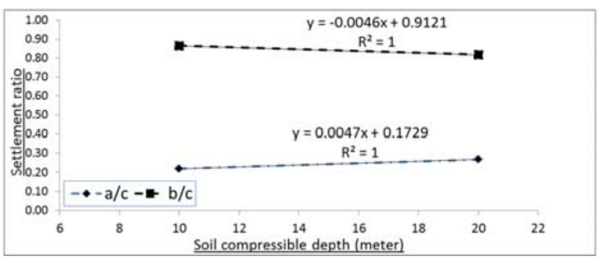

Figure-9. Empirical formula of settlement ratio in vary condition.

4. CONCLUSIONS

Based on the result mentioned above, then obtained some conclusion namely:

- The magnitude of soil subgrade settlement under the toe embankment is not zero it means that the soil settlement in the surrounding area close by the embankment load is also not zero. Need to beware especially if the embankment constructed near the densely populated.
- The settlement ratio of soil subgrade under the toe embankment to the center embankment is 0.22 for 10 meter compressible depth and 0.27 for 20 meter compressible depth.
- The settlement ratio of soil subgrade under the outer side of embankment to the center embankment is 0.87 for 10 meter compressible depth and 0.82 for 20 meter compressible depth.

The results of this study are the settlement ratio in the several locations under embankment to obtain an empirical formula. Further research needs to be conducted to verify the empirical formula obtained in this study with the magnitude of the compression ratio in the field using geotechnical instruments. There should also be analyzed the settlement ratio of the soil subgrade under embankment when using PVD as a soil improvement.

REFERENCES

[1] Terzaghi K. 1943. Theoretical Soil Mechanics. John Wiley and Sons, New York.

[2] Sari P.T.K, Lastiasih Y. 2015. The empirical correlation using linear regression of settlement ratio under embankment load for Surabaya compressible soil. Digital Proceeding of ICOCEE-CAPPADOCIA2015.

[3] Skempton A.W. 1944. Notes on the Compressibility of Clays. J. Geo. Soc. London (C: parts 1&2), 100, 119-135.

[4] Karl Terzaghi, Ralph Peck. 1967. Soil Mechanics in Engineering Practice, 2nd Edition. John Wiley, New York.

[5] Bowles J.W. 1979. Physical and Geotechnical Properties of Soils. New York: McGraw Hill.

[6] Jian-Hua Yin. 1999. Properties and Behaviour of Hong Kong Marine Deposits with Different Clay Contents. Canadian Geotechnical Journal. 36: 1085-1095.

[7] Amitnath and Dedalal S.S. 2004. The role of plasticity index in predicting Compression Index behaviour of clays. Electronic Journal of Geotechnical engineering http://www. ejge.com/2004/Per0466/Ppr0466.htmm.

[8] Sridharan A and Nagaraj H.B. 2001. Compressibility behaviour of remolded fine-grained soils and correlation with index properties. Canadian Geotechnical Engineering Journal. (38): 1139-1154.

[9] Azzouz A.S., R. J. Krizek and R. B. Corotis. 1976. Regression Analysis of Soil Compressibility Soils and Foundations. 16(2): 19-29.

[10] V.A. Nacci, M.C. Wang, K.R. Demars. 1975. Engineering behavior of calcareous soils. Civil Engineering in the Oceans III, ASCE, Newark.

[11] C. P. Wroth D. M. 1978. Wood The correlation of index properties with some basic engineering properties of soils. Canadian Geotechnical Journal. 15(2): 137-145.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

[12] Nagaraj T and Murthy B.1986. Prediction of Compressibility of Over consolidated Uncemented Soils. J. Geotech. Engrg. 10.1061/ (ASCE) 0733-9410112: 4(484): 484-488.

[13] V.M. Cozzolino. 1961. Statistical forecasting of compression index. The 5th International Conference on Soil Mechanics and Foundation Engineering, Paris.

[14] G. B. Sowers. 1970. Introductory Soil Mechanics and Foundations. Macmillan Co., New York, 1951, 3rd edition.

[15] Moran, Proctor, Mueser, and Rutledge. 1958. Study of deep soil stabilization by vertical sand drains. Report to Bureau of Yards and Docks, Department of the Navy, Washington, D.C.

[16] Kosasih A., Mochtar I.B. 1996. Pengaruh Kadar Air, Angka Pori, dan Batas Cair Tanah Lempung Terhadap Indeks Pemampatan Konsolidasi Cc dan Indeks Pengembangan Cs. Master Thesis, Program Pasca Sarjana, teknik Sipil ITS.

[17] Nishida Y. 1956. A Brief Note on the Compression Index of Soil. Journal of Soil Mechanics and. Foundation Division, American Society y of Civil Engineers. 82(3): 1

[18] Osterberg J. O. 1957. Introduction of the symposium on vane shear testing of soils. Am. Soc. Testing Mater. Spec. Tech. Publ. 193: 1-7.