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RESEARCH ARTICLE

CONSOLIDATION PARAMETERS EVALUATION OF COHESIVE SOIL IN LIANGANGGAM, KALIMANTAN INDONESIA USING CPT DATA

***Putu Tantri K. Sari, Noor Endah and Dwiaji Ari Yogyanta**

Civil Engineering Department, Institute Technologi of SepuluhNopember, Surabaya, 60111, Indonesia

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ABSTRACT

The cone penetration test (CPT) has emerged as most widely used for obtaining soil profile and soil properties. In several studies showed that CPT data can also be used for the soil settlement calculation. However these calculations have a different parameter for each location. The main objective of this study was to compare and evaluate the results of settlement using laboratory testing data and consolidation measurement using CPT data of soft clay soil in some area in Indonesia. Furthermore, this study also conducted to find the parameter of CPT settlement (αm) that appropriate with the soil condition in this study area and also to analyze the value the horizontal coefficient (Ch) of PVD installation that installed in the field. The Pre-loading with trial embankment of soil subgrade is considered in this study. This study uses a several field soil data CPT test, consolidation laboratory test and settlement plate measurement. The area of study in this research is in access road construction project of Trisakti harbor in Lianganggam, Kalimantan, Indonesia. The results obtained from this study are the horizontal coefficient of PVD (Ch) for the soil in this area is measures as 5 times higher than the vertical coefficient of PVD (Cv) measurement from laboratory data. In addition, the appropriate parameter of settlement using CPT data (α) is 2.77 obtained by back calculation method in trial embankment and settlement plate result. These results are slightly different from the results of similar research but at a different location in another country.

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INTRODUCTION

The calculation of clay soil settlement under the building structure and the building transport load are more developed. The calculation of soil settlement was first developed by Terzaghi (1929) in a scientific publication on world engineering conference in Tokyo. The results of the analysis consist of five specific areas, two of them are:

- Condense the results of the test borings to a geological profile
- Determine the physical properties for a few typical samples

The two point mentioned above are look effortless and simple but that is the most important thing in the calculation of soil settlement. To obtain a soil layer property are in accordance with the type of soil at any depth whereas the soil layer is heterogeneous. A very heterogeneous soil layer would be extremely difficult to know the characteristics of the soil each layer carefully in the laboratory.

****Corresponding author:*** **Putu Tantri K. Sari**
Civil Engineering Department, Institute Technologi of SepuluhNopember, Surabaya, 60111, Indonesia

The laboratory test in every depth to obtain compression parameter are generally takes time and cost. Because the cost relatively expensive and the testing are time consuming then the engineers commonly use empirical formula to obtain the consolidation parameters. The empirical formulation with the lack data and using the several assumptions causes the calculation results do not correspond to the actual conditions in the field. Thus then developed the settlement consolidation formula using data compression soil in the field. Peck (1994) attempted to develop the use of field data for the settlement consolidation calculation. Field soil testing such as cone penetration test (CPT), standard penetration test (SPT), dilatometer test, pressure meter test is frequently performed in the field to obtain soil parameters in accordance with the natural conditions in the field which is considered more accurate. So the uses of soil testing field, by some researchers are considered very necessary to improved. Thus that can be correlated as the analysis results of testing in the laboratory and can be more appropriate to the actual conditions in the field. Mitchell et al (1978) identified several reasons for the importance of the use of testing in the field, namely:

- To determine properties of the soil that cannot be easily sampled in the undisturbed state such as sea bed sediments, organic soil deposits, sands, etc.
- To avoid some of the difficulties and uncertainties in laboratory testing such as sample disturbance, proper simulation of in situ stresses, temperature, chemical and biological environments

In recent decades, the use of a soil testing in the field, namely Cone Penetration Test (CPT) as one of the main testing in the field are more and more develops. CPT method has 3 main areas at any depth layer of soil under review: tip stress (qc), sleeve friction (fs) and pore pressure. Results of analysis of CPT in the field are then developed by several researchers to obtain a correlation value of soil property as derived from laboratory testing. Begemann (1965), Sanglerat et al (1974), Schmertmann (1978), Douglas and Olsen (1981) and many more, obtained soil classification parameters of the data CPT; Senneset and Janbu (1985), Sandven (1990) obtained soil friction angle parameter of the data CPT; Khulway and Mayne (1990), Abu-farsakh (2003, 2007) obtained a parameter constrained modulus (M) of the data CPT and many other studies to obtain soil parameters such as laboratory test results from the test results CPT in the field. Recent study result by Abu-farsakh (2003) showed a good correlation between the compression parameters obtained from the data CPT and field testing data. The results of the analysis provide αm coefficient of 3.58 in Louisiana soil. The study was later developed by Rohit (2007) with the main focus on cohesive soils in Louisiana to estimate the consolidation parameters and predict total and time rate of embankment settlement with field data using CPT. Another study conducted by Jones and Rust (1995) obtained results αm coefficient value of 2.75 ± 0.55 on alluvial clay soil in South Africa. With the amount research on the relationship of consolidation parameters from CPT data performed on cohesive soils in other states and there are advantages CPT data usage based on the description above, it is necessary to continue the study about the soft clay soil in several area in Indonesia. This study is the beginning of a larger research plan with the topic of settlement prediction using CPT data in Indonesia. The location taken in this study is only 1 location in 1island in Indonesia.The main objective of this study was to compare and evaluate the results of settlement with the results of laboratory testing and data consolidation in CPT data soft clay soil in Lianganggam, Kalimantan, Indonesia.

MATERILAS AND METHODS

Field Data Measurement

This study was conducted in Lianganggam district in Kalimantan, where the most characteristic of soil subgrade is compressible clay soil. The study begins with the soil subgrade data collection in the field. At this road construction site there are 5 CPT data and 4 Boring-N SPT data test. The clay compressible soil depth along the 13 km road construction area is varying between 7 to 34 meters with details of the location area is as follows:

- KM 10 + 300 - KM 11 + 500 with compressible ground depth of 34 m
- KM 11+500 - KM 13+800 with compressible ground depth of 28 m
- KM 13+800 - KM 15+500 with compressible ground depth of 27 m
- KM 15+500 - KM 19+000 with compressible ground depth of 7 m
- KM 19+000 - KM 23+300 with compressible ground depth of 13 m

Laboratory tests were also carried out to obtain soil data parameters in the field. The result of the laboratory test is then used to calculate the compression of the soil subgrade data using 1-D compression formula by Terzhagi. The compression calculation results are then compared with the settlement result that occurred in the field using the settlement plate data from the trial embankment. Trial embankment performed on KM 14 + 125. The field data and laboratory data used in this analysis refers to Field data at KM 13 + 800 - 15 + 500 with a depth of compressed soft soil is 27 meters. Flowchart method used in this research is can be seen in Figure 1.

Consolidation parameter of cohesive soil from CPT measurement

The Cone Penetration Test (CPT) test became one of the most widely used field tests for soil profiles and soil physical properties. This test can also estimate the parameters required for compression calculations generally obtained from laboratory tests. To obtain the compression parameters from the laboratory tests done by Oedometer or triaxial test which is time consuming and expensive to do, thus allowing a limitation on the number of tests to be performed. In the Cone Penetration Test (CPT) test, (Qc) every 20 cm interval which can later be correlated to the required parameters in the compression prediction. If soil and pore water in the soil pore space is assumed to compress, the total volume change in the soil due to the load (preloading) will result from forcing the pore water out of the soil. The condition is known as consolidation. In the process of removal of pore water from the soil, the soil granules are rearranged to become more stable and dense as well as decreasing volume and compressing (Holtz and Kovac, 1981). Due to a stress change that results in compression, the first analysis is to calculate the vertical stresses in the soil layer. Load changes in soil elements such as loads (preloading) on the surface can be estimated using the elastic approach (Poulos and Davis, 1974) or by using a plastic approach (Janbu 1967). Strain (ε) occurring from a layer (H) will result in the compression formula as follows:

$$Sc = \varepsilon \cdot H \qquad \text{……………………(1)}$$

This strain depends on the overburden effective stress pressure (σv_o) and distribution pressure ($\Delta\sigma_v$). Generally, the stress-strain relationship is obtained from a one dimensional consolidation test using an Oedometer or triaxial test, which applies in the Terzaghi consolidation equation as follows:

$$Sc = mv \cdot \Delta\sigma v \cdot H \qquad \text{.................................(2)}$$

Where mv is the coefficient of volume change obtained from the equation:

$$m_v = \frac{\varepsilon_v}{\sigma_v} \qquad \text{……………………(3)}$$

The inverse measurement of mv is referred to as the constrained modulus (M) / odometric modulus (D) with the following equation:

$$M = \frac{\sigma_v}{\varepsilon_v} = \frac{1}{m_v} \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

So compression can also be formulated:

$$S_c = \frac{\Delta\sigma_v.H}{M} \qquad \ldots\ldots\ldots\ldots\ldots(5)$$

The M value can be obtained from the correlation of the conus value (qc) of the soil test based on CPT field data. Based on research on the relation of compressibility with the value of conus value (qc), the value of modulus constrained (M) for soil with low cohesion (sand) according to Buisman (1940, 1941) as follows:

$$M = \frac{1}{m_v} = 1.5\ q_c \qquad \ldots\ldots\ldots\ldots\ldots(6)$$

For the cohesive soil, according to Sanglerat (1972) the coefficient of 1.5 is replaced by α which depends on the characteristic of the soil as follows:

$$M = \alpha_m . q_c \qquad \ldots\ldots\ldots\ldots\ldots(7)$$

Sanglerat test results (1972) are then summarized in a Table which can be seen in Table 1.

Table 1. Sanglerat (1972) ~m coefficient

Criteria	αm	Soil Type
qc < 0.7 MPa	3 <αm< 8	Clay of low plasticity (CL)
0.7 < qc < 2 MPa	2 <αm< 5	
qc > 2 MPa	1 <αm< 2.5	
qc < 2 MPa	3 <αm< 6	Silts of low plasticity (ML)
qc > 2 MPa	1 <αm< 2	
qc < 2 MPa	2 <αm< 6	Highly plastic silts and clay (MH CH)
qc < 2 MPa	1 <αm< 2	
qc < 1.2 MPa	2 <αm< 8	Organic Loam (OL)
qc < 0.7 MPa		Peat and Organic clay (Pt, OH)
50<wc< 100	1.5 <αm< 4	
100 <wc< 200	1 <αm< 1.5	
wc> 200	0.4 <αm< 1	
2 < qc < 3 MPa	2 <αm< 4	Chalks
qc > 3 MPa	1.5 <αm< 3	
qc < 5 MPa	αm = 2	Sands
qc > 10 MPa	αm = 1.5	

RESULTS AND DISCUSSION

Trial embankment observation Result

The result of trial embankment observation is used to compare the settlement prediction in the field. The settlement measured in the field is based on Settlement Plate reading data. In this study, the data used is the result of Settlement Plate at KM 14 + 125 due to it has reached 5.7 months (171 days) and has not experienced settlement happened again, so it can be concluded that the settlement in this location has been done with almost 100% degree of consolidation. The settlement magnitude due to stage construction of embankment load from the settlement plate result is 531 cm. The observation result of trial embankment can be seen in Figure 2

Determination of Coefficient Horizontal Consolidation (Ch) in Field: The Cv measured in the study location is 2 x 10^{-4} cm^2/ sec. This Cv value is obtained from the test data in the laboratory. However, the existing Cv value data is only consist with 4 data at 27 meter soft clay soil depth.

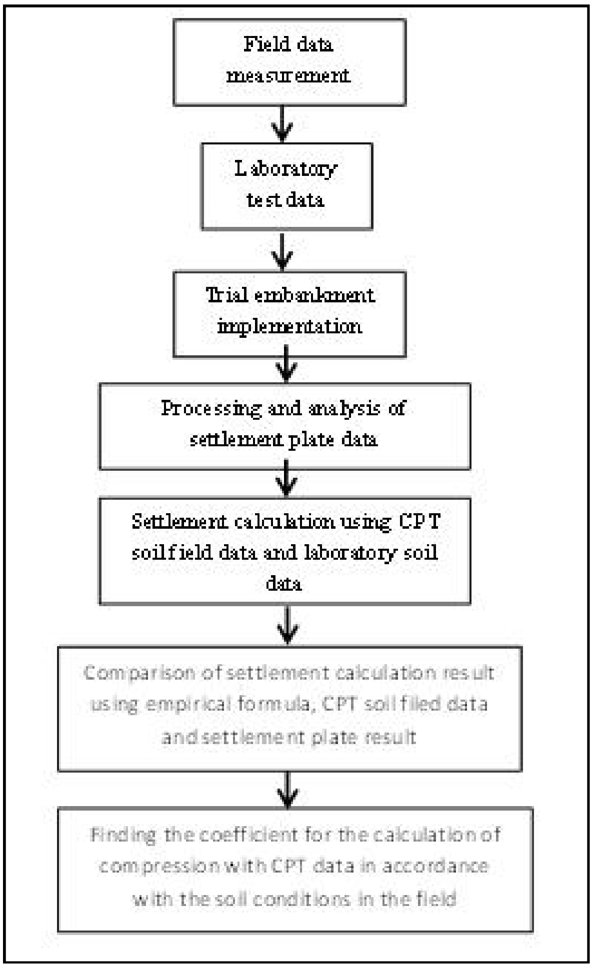

Figure 1. Flow Chart of Research

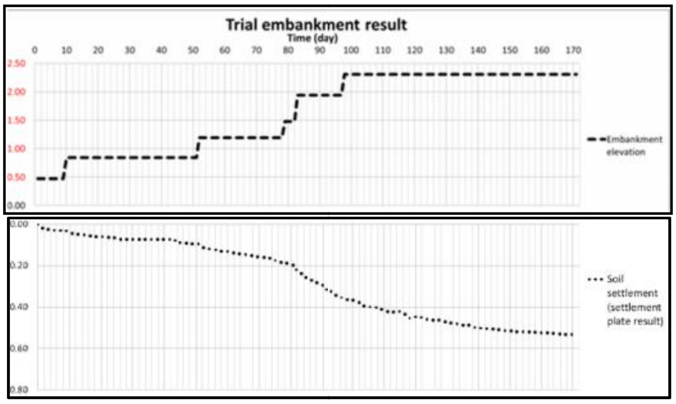

Figure 2. Settlement Plate Result in The Field

This condition may result in a Cv value that is less appropriate to the soil conditions in the field. This is one of the most common problems in Indonesia where soil consolidation data is minimal. But in this study, the value of Cv used is in accordance with the existing data. The results of the Settlement Plate readings in the field can be plotted by fitting curve into the stage construction embankment load graph using Terzaghi formulation based on laboratory data to find out the value of horizontal consolidation coefficient (Ch) occurring in the field. The Ch value can be tried several times (in example 4 xCv, 5x Cv, 6x Cvetc) to find the constant value of settlement during and after the stage embankment construction process and find a settlement magnitude that is almost equal to the settlement magnitude in the field. In the calculation of staged embankment construction in accordance with the data of embankment trial obtained the value of Ch in the field is 5x Cv as in Figure 3.

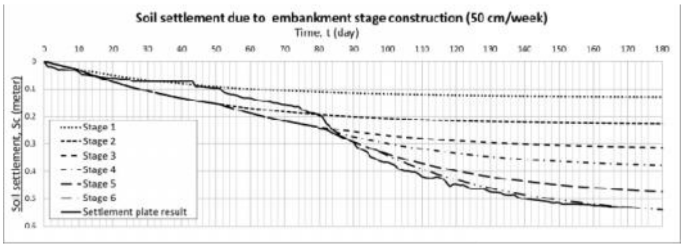

Figure 3. Comparison of compression result calculation with 1D empirical formula by Terzhagi (Ch = 5Cv) on the result of settlement plate in the field

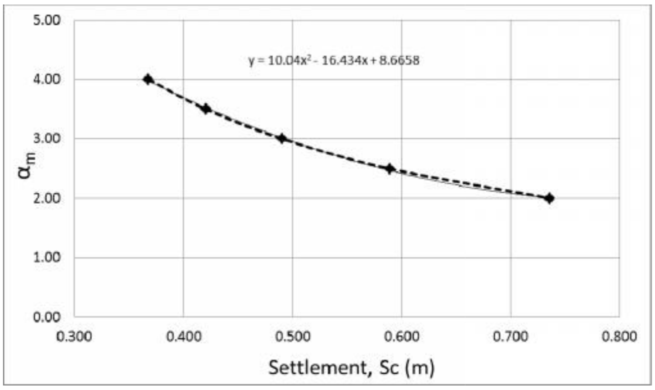

Figure 4. Graph of the coefficient value ~m and compression

Determination of Coefficient of Constrained Modulus (αm) in Field: In settlement calculation due to stage construction of embankment load, it can be assumed that the coefficient of constrained modulus (αm) at settlement calculation based on CPT data is not necessarily the same as in field. After obtaining the Ch field value from the previous calculation, then the real coefficient modulus (αm) in the field can be calculated by trying different αm value (for example 3.5, 3, 2.5, and 2). With the value of αm, then a settlement magnitude prediction (Sc) can be made by graph between the αm value and the settlement magnitute as shown in Figure 4. The graph above obtained equation to calculate the value of αm in the field. To obtain compression of 0,531 m, then the value of αm obtained 2,77. According to Sanglerat (1972), the price of αm for low-plastic clay type with a value of qc<0.7 Mpa is not less than 3 (Table 1), therefore, the αm price of Sanglerat is not appropriate with the condition of subgrade soil in the location of this study area.

Settlement calculation using laboratory test data

Calculation of compression using laboratory test data conducted with the formulation of Terzaghi consolidation. The results of the settlement calculation with this formula show slightly different results with the measuring settlement plate result in the field. The condition may be caused by the compression index values obtained from the laboratory tests less appropriate with the soil conditions in the field. Sampling for soil testing in the laboratory was done every 4 meter depth. The depth may be too large to have a precise calculation of compression results that are less precise. The result of a large percentage of the compression of soil to the embankment load based on the Terzaghi formula can be seen in Figure 5. The major differences between the results of laboratory testing with the Terzaghi formula and the settlement plate results can be seen in Figure 5.

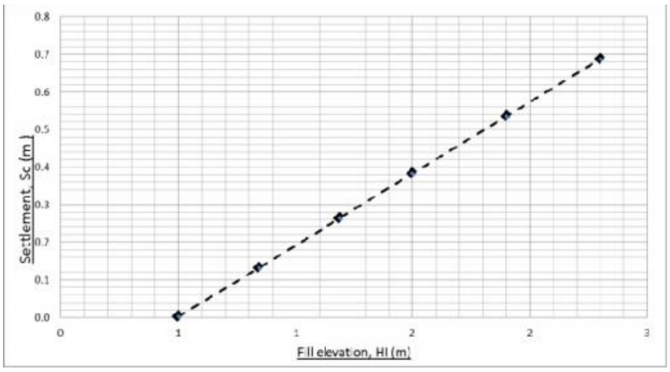

Figure 5. Soil Settlement measurement under embankment load using laboratory test data

Conclusion

In conclution, the Chmeasured in the project Trisakti-Liang Anggang port access road construction based on the compression test result of the trial embankment is 5 times the price of Cv. The αm measured in the appropriate field in port access project of Trisakti-Liang Anggang port for calculation based on Sondir's data is 2.77. The coefficient value is slightly different from the pre-existing test results. The resulting value in this study is slightly lower than the results of existing research. The result is certainly caused by soil conditions in each region so that the coefficient value is still not generalizable for all existing locations.

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