SETTLEMENT IN THE NOTHERN PART OF BEKASI REGENCY, WEST JAVA PROVINCE, BASED ON CONE PENETRATION TEST DATA

Siti Nadia Jatsiah[1], Ismawan[1], Nur Khoirullah[1], and Tulus Pramudyo[2]
[1]Faculty of Geological Engineering, Universitas Padjadjaran, Sumedang, West Java
[2]*Pusat Air Tanah dan Geologi Tata Lingkungan*, Bandung, West Java
Corresponding author : nadiajatsiah@gmail.com

ABSTRACT

In the nothern part of Bekasi Regency, the soil layers are dominated with alluvial deposit, especially clay and silt deposit. It makes the potential of the settlement in this area is getting higher. In this research, Cone Penetration Test (CPT) have been done to determine the soil layers from the surface till the 20 meters depth and to identify other soil properties, such as unit weight, compression index, swelling index, void ratio, etc. This research aims to analyze the total settlement in the northern part of Bekasi Regency based on CPT data. The total settlement is calculated by using the theory of One-Dimensional Primary Consolidation based on CPT data. The research area shows that the highest result of total settlement calculation is in the northern part of research area which directly adjacent to the Java Sea. It can be happened because the clay layers in northern part is way thicker than the other area.

Keyword: Consolidation, clay, settlement

INTRODUCTION

Based on In SAR data from 2016-2021, Bekasi Regency has experienced settlement 0.133 – 5.99 cm (Pramudyo et al., 2022). Settlement occurs in deposits that haven't consolidated completely. In Bekasi, the materials are dominated by alluvial deposits, namely sediments that haven't done lithification process (Fuji et al., 2017).

Based on the Karawang Regional Geological Map (Achdan & Sudana, 1992), the research area is dominated by sediments composed of clay and silt. On the other hand, settlement due to the consolidation process itself generally occurs in clay and silt soils. Therefore, Cone Penetration Test (CPT) was carried out in order to identify soil layers to a maximum depth of 20 meters, so that settlement could be carried out to a maximum depth of 20 meters in Northern Bekasi Regency, West Java.
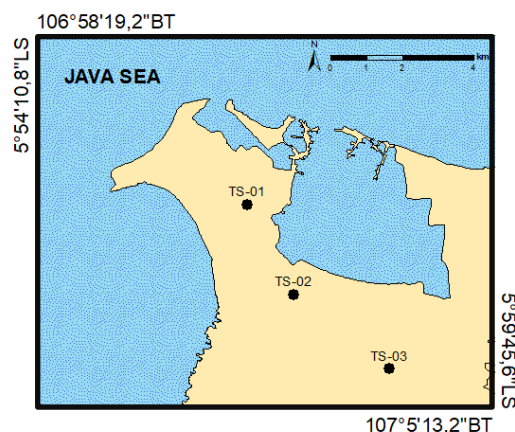

Figure 1. Research Area

RESEARCH METHOD

In this research, CPT (**SNI 2827:2008**) was carried out at 3 observation points located in the northern part of Bekasi Regency, West Java with a depth of 20 meters.

To identify the type of soil, it is obtained based on the soil behavior type index or Ic (Robertson, 1990) with the following formula:

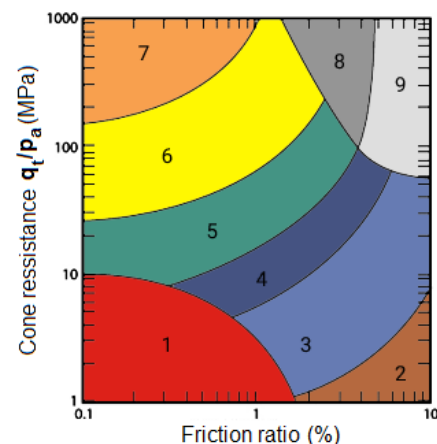$$Ic = ((3,47 - logQt)^2 + logFr + 1,22)^2)^{0.5} \quad (1)$$

Figure 2. Soil Type (Robertson, 1990)

Where :

Ic = Soil Behavio2ur Type Index

Qt = Normalized Cone Resistance (Mpa)

Fr = Normalized Friction Ratio (%)

1. Sensitive fine grained
2. Clay – organic soil
3. Clays: clay to silty clay
4. Silt mixtures: clayey silty sand to sandy silt
5. Sand mixtures: silty sand to sandy silt
6. Sands: clean sands to silty sands

31

7. Dense sand to gravelly sand
8. Stiff sand to clayey sand*
9. Stiff fine grained*

(*) overconsolidated or cemented

Based on CPT data, it can be converted into other soil properties, such as unit weight, compression index (Cc), swelling index (Cs), effective overburden stress, and void ratio.

Unit Weight

Unit weight can be determined by using dimensionless CPT (q_c/p_s) and *friction ratio* (Rf = (f_s/q_c) x 100%) (p_s = 1 atm = 0,01 Mpa) (Robertson & Cabal, 2010).

$$\frac{\gamma}{\gamma_w} = 0{,}27\left(logR_f\right) + 0{,}36\left(\log\left(\frac{q_c}{p_s}\right)\right) + 1{,}236 \dots(2)$$

Where :

Rf = friction ratio

γ = Unit Weight of Soil

γw = Unit Weight of Water

Compression Index

Compression index shows the compressibility of the soil, so the value of Cc will be different for each type of soil (Azzouz et al., 1976).

$$Cc = 0{,}014(PI + 3{,}6)\dots\dots\dots\dots\dots(3)$$

Where:

PI = plasticity index

Swelling Index

Swelling index is calculated when the natural load is unloaded or it can be called as recompression and it depends on the basic soil properties, Liquid Limit (LL) (Kordnaeij et al., 2015).

$$Cs = (0{,}0007 \, x \, LL) + 0{,}0062\dots\dots\dots(3)$$

Where:

LL = Liquid Limit

Effective Overburdes Stress

Effective overburden stress is come from vertical effective stress and also consider the load from soil and water around (Hardiyatmo, 2002).

$$p_o{'} = \Sigma\, \gamma\, . \Delta h \dots\dots\dots\dots\dots\dots\dots\dots(4)$$

legends :

γ = unit weight

h = depth

Void Ratio

Void ratio is the ratio of pore volume with grain volume, which very important to the calculation of the total settlement (Azzouz et al., 1976)

$$Cc = 1{,}15(e_0 – 0{,}35)\dots\dots\dots\dots\dots\dots\dots(5)$$

Where :

Cc = compression index

e_0 = void ratio

Overconsolidation Ratio

Overconsolidation ratio is used to determine wether the soil is normally consolidated or overconsolidated and it is important to calculate the total settlement. If the OCR > 1, the soil is overconsolidated, if 1<OCR<0, the soil id normally consolidated (Hardiyatmo, 2002).

$$OCR = \frac{p_c}{p'_o}\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(6)$$

Total Settlement

To calculate the total settlement, this research using theory of Terzaghi's One-Dimensional Primary Consolidation (Das, 2013).

• Normally Consolidated,

$$S_c = \frac{c_c H}{1 + e_o}\log\left(\frac{p'_o + \Delta p'}{\sigma'_o}\right)$$

• Overconsolidated,

If $(p'_o + \Delta p' \leq p'_c)$,

$$S_c = \frac{c_s H}{1 + e_o}\log\left(\frac{p'_o + \Delta p'}{p'_o}\right)$$

If $(p'_o + \Delta p' > p'_c)$,

$$S_c = \frac{c_s H}{1 + e_o}\log\frac{p'_c}{p'_o} + \frac{c_c H}{1 + e_o}\log\left(\frac{p'_o + \Delta p'}{p'_o}\right)$$

RESULT AND DISCUSSION

This research was conducted in northern part of Bekasi Regency that adjacent directly to the Java Sea.

Geotechnical Condition

Geothecnical Map of Karawang (Sutarto & Djadja, 1991), shows that the research area is dominated with the deposit of clay and silt (Fig. 2). In the subsurface, the soil layers also shows that the material is dominated with deposit of clay and silt (Fig. 3), so it makes the research area have bigger potential of settlement.
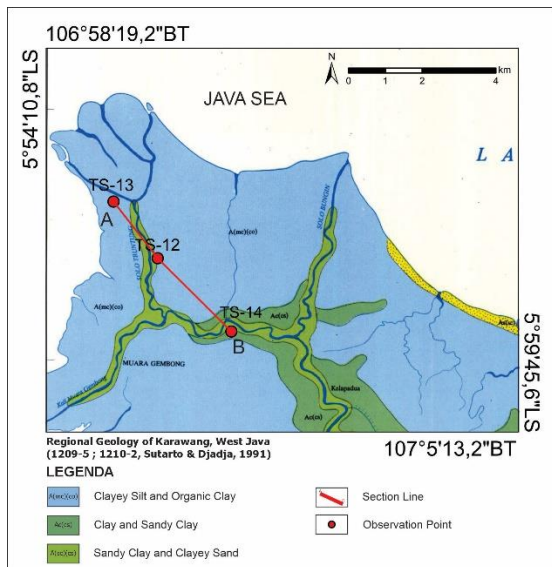
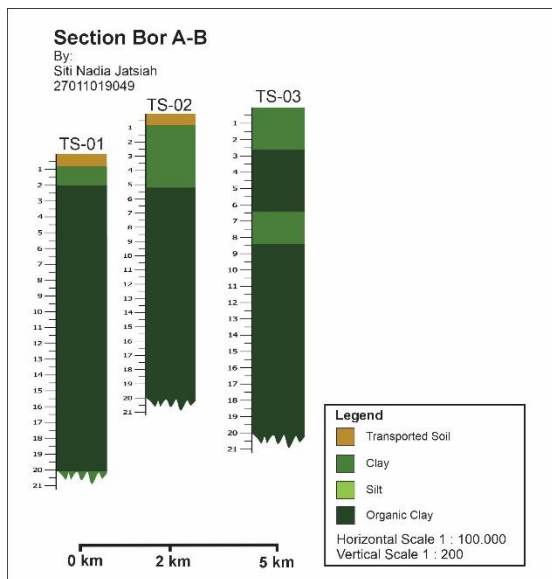**Figure 3.** Geotechnical Map of Karawang (Sutarto & Djadja, 1991)

Figure 4. Section Bor A-B

Total Settlement

From the results of total settlement calculation using Rocscience Settle3 software, the total settelement is around 2,3 – 2,8 meters (Fig. 6).
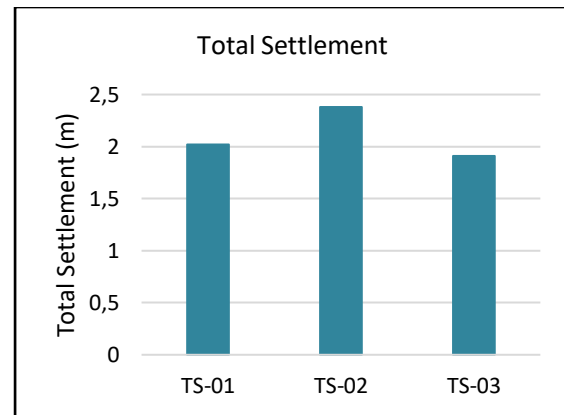

Figure 5. Total Settlement in Research Area

TS-01

Based on CPT data, in 20 meters, TS-01 contain 3 layers of soil, including transported soil 0,8 meters, clay 4,4 meters, and organic clay 14,8 meters. The total settlement at TS-01 shown in Fig. 4.
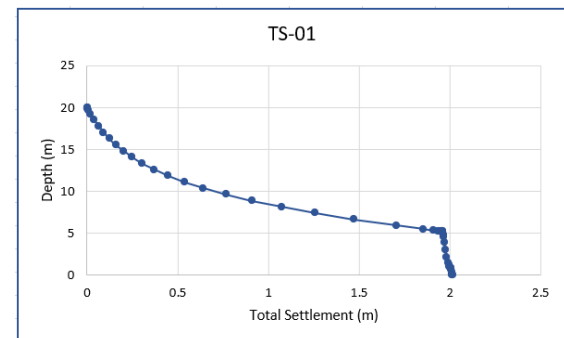

Figure 6. Graphic of Settlement in TS-01

Table 1. Total Settlement of TS-01

Thickness (m)	Layers	Total Settlement (m)	Total (m)
0.8	Transported soil	0.01	
4.4	Clay	0.05	
14.8	Organic Clay	1.96	

TS-02

Based on CPT data, in 20 meters, TS-02 also contain 3 layers of soil, including transported soil 0,8 meters, clay 1,2 meters, and organic clay 18 meters. The total settlement at TS-02 shown in Fig. 5.
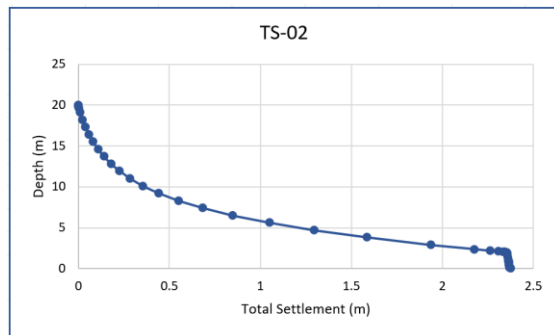
33

Figure 7. Graphic of Settlement in TS-02

Table 2. Total Settlement of TS-02

Thickness (m)	Layers	Total Settlement (m)	Total (m)
0.8	Transported soil	0.01	
1.2	Clay	0.01	
18	Organic Clay	2.36	

TS-03

Based on CPT data, in 20 meters, TS-03 contain 4 layers of soil, including clay I 2,6 meters, organic clay I 3,8 meters, clay II 2 meters, and organic clay 11,6 meters. The total settlement at TS-03 shown in Fig. 5.
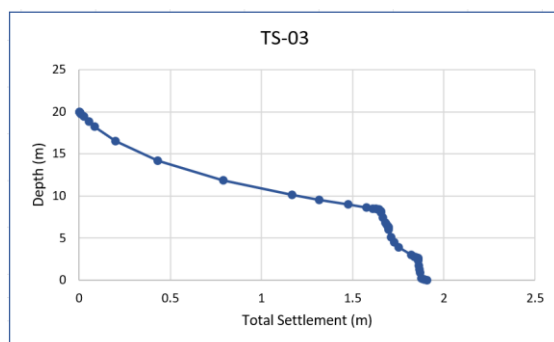

Figure 8. Graphic of Settlement in TS-03

Table 3. Total Settlement of TS-03

Thickness (m)	Layers	Total Settlement (m)	Total (m)
2.6	Clay I	0.05	
3.8	Organic Clay I	0.16	
2	Clay II	0.04	
11.6	Organic Clay II	1.65	

CONCLUSION

From the subsurface condition of each observation points, there are some thick layers of clay and organic clay that also have larger total settlement value. TS-02 has the largest settlement with total settlement 2,38 meters, which we can see that TS-02 has organic clay with 18 meters thickness. Meanwhile, in TS-03 has total settlement 1.91 meters with layer of organic soil 11,6 meters. So we can conclude that thickness and type of soil will effect the total settlement value.

ACKNOWLEDGEMENT

REFERENCES

Anonim. (2008). Standar Nasional Indonesia (SNI) : Cara Uji Penetrasi Lapangan dengan Alat Sondir. In Badan Standardisasi Nasional.

Azzouz, A., J, R., Krizek, & Corotis, R. (1976). Regression Analysis od Soil Compressibility. Soil and Foundations, 16(2), 19–29.

Das, B. M., & Sobhan, K. (2013). *Principles of Geotechnical Engineering 8th Edition.* Stanford: Cengage Learning.

Fuji, R., Pratikso, & Soedarsono*. (2017). Pengaruh Amblesan Tanah (Land Subsidences) Terhadap Perubahan Luas Genangan Air Pada Dataran Alluvial Kota Semarang Bagian Timur*. Prosiding SNST Ke-8, 1–6.

Hardiyatmo, H. C. (2002). *Mekanika Tanah I.* Yogyakarta: Gajda Mada University Press.

Kordnaeij, A., Kalantary, F., Kordtabar, B., & Mola-Abasi, H. (2015). Prediction of recompression index using GMDH-type neural network based on geotechnical soil properties. Soils and Foundations, 55(6), 1335–1345. https://doi.org/10.1016/j.sandf.2015.10.001

Pramudyo, T., Wiyono, Widyaningrum, R., Fitriasi, T., Marwanto, E., Mulyadi, D., Sabingan, & Sahidin, D. (2002). *Penyelidikan Geologi Teknik Potensi*

Penurunan Tanah Daerah Bekasi dan Sekitarnya, Provinsi Jawa Barat.

Robertson. (1990). *Guidelines For Interpretation of CPTU Test Data For Determination of Consolidation and Permeability Parameters of Soils.* Columbia: ConeTec Investigation Ltd.

Robertson, P., & Cabal, K. (2010). Estimating Soil Unit Weight from CPT. 2nd International Symposium on Cone Penetration Testing.

APPENDIX