Site Characterization of Marine Clay Consolidation Ratio on Kamal Muara Area, Northern Jakarta

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Abstract. Northern Jakarta coastal area is formed by some marine clay layers which has high compression as sedimentary soil. Land subsidence can occur due to several factors, such as load of building, excessive groundwater exploitation and normally consolidation process. Consolidation is a process of soil compacting due to the compression. The compression process of the soil occurs when soil receives the load from its above structure which makes a reduction of pore water pressure. Then, the dissipation of groundwater is followed by compaction of the volume of soil. A significant level of land subsidence in the coastal areas of Jakarta especially in Kamal Muara can lead to failure of building structures built on sedimentary clay soils. Therefore, research on the level of compression of sedimentary soils in the coastal areas of Jakarta needs to be done. This research is conducting by laboratory tests on UDS (undisturbed) soil samples taken by drilling a depth 50 meter point. The method used is the conso compression index lidation test for further analysis of the parameters of Pc, Cr, and OCR. Testing result shows the level of marine clay soil of coastal sediment clay in Kamal Muara North Jakarta is under consolidation.

Keywords: compression index, pre-consolidation pressure, over consolidation ratio

1. Introduction

Land subsidence is a phenomenon for Jakarta, the capital city of Indonesia, indicates the damage to the building structure. In last 30 years, the subsidence occurs reached 20 – 200 cm at several places, with settlement rates reached 1 – 15 cm/years [1], [2], [3]. Land subsidence can cause by groundwater extraction, load of constructions (settlement of high compression soil), natural consolidation of alluvium soil, and earthquake forces such as broken plates of the earth [5]. From the previous study [4] groundwater extraction was the major factor caused land subsidence in urban area. However, it need to be considered that marine clay causing land subsidence due to consolidation as alluvial layers. Measurements of land subsidence using GPS measured over 3 years since 2007 [2] indicate that in the Kapuk Muara (PIKA) area in Figure 1, land subsidence that occurred in 2007-2008 reached 0.18 m per year which was then reduced to 0.11 m in 2008-2009 and 0.07 m in 2009-2010 It becomes important thing to investigate the soil characteristics in compression and the level of over consolidation ratio (OCR), so that we can learn the soil behavior for designing the foundation structure of the building which taking into account the land subsidence. Based on data of Department of Mines and Energy DKI Jakarta Province in 2012 critical condition of shallow groundwater conservation (0-40m) excluding Penjaringan areas.

Figure 1. Land Subsidence measurement using GPS in part coastal areas of Jakarta (Source: Abidin, 2008)

2. Methods

Location of research is conducted in Kamal Muara, Penjaringan, North Jakarta (Figure 2). This location is adjacent to the location where is determined by the Department of Mines and Energy DKI Jakarta Province to install extensometer testing instrument up to 300 meters depth. From previous study indicates that deep groundwater extraction (40 - 300 m) is not a major factor causing land subsidence. Geological condition of the Penjaringan area shows that the zone is dominated by embankment and alluvium (Al) which is soft soil with high moisture content. This research is using one-dimensional consolidation testing by laboratory procedure performed in a consolidometer or oedometer was first suggested by Terzaghi [5]. The bore hole up to 50 meter was drilled to determine the SPT value and take undisturbed sample (UDS) of soil from Kamal Muara. The location shown in Figure 2,

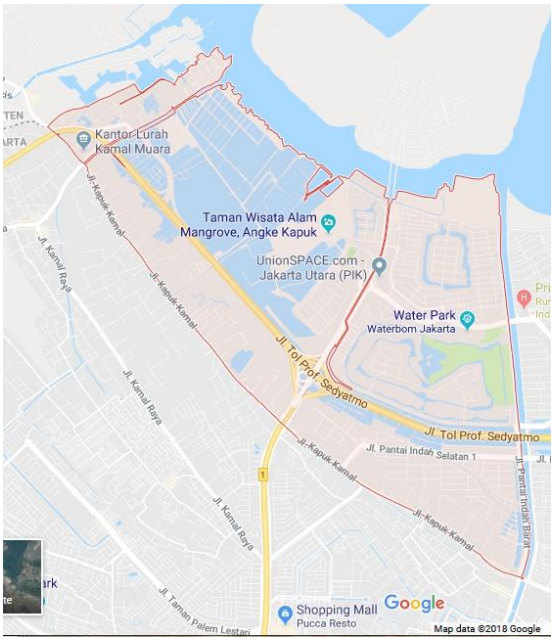

Figure 2. Research Location, Kamal Muara Penjaringan, Northern Jakarta (Source: Google Maps)

The soil specimen is placed inside a metal ring with two porous stones, one at the top of the specimen and another at the bottom. The specimens are 64 mm in diameter and 20 mm thick. The load on the specimen is applied through a lever arm, and compression is measured by a

micrometer dial gauge. The specimen is kept under water during the test, to make sure that the specimen is in the saturated condition. Each load is kept for minimum 18 hours. Doing the loading procedure until effective stress is zero (Po), then reloading procedure. The objective of this result is to find the pre consolidation pressure of a specimen (Pc), the re-compression index (Cr), and the over consolidation ratio (OCR) parameters of the soil samples.

Pre-consolidation pressure of a specimen or past maximum vertical effective stress, Pc, is the maximum vertical effective stress that a soil was subjected to in the past. Pre-consolidation pressure is determined by simple graphic plotting *e-log a'* graphic, suggested by Casagrande [6] [7], from laboratory testing result of consolidation test.

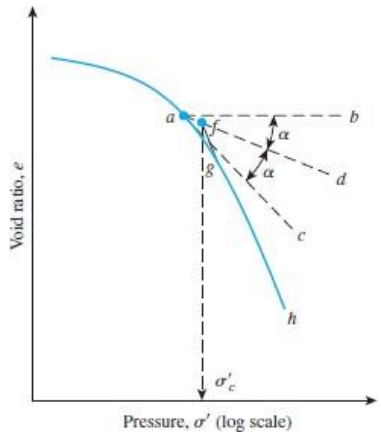

Figure 3. Preconsolidation pressure graphs (Casagrande, 1936)

Recompression index or unloading/reloading index, Cr, is the average slope of the unloading/reloading curves in a plot of the logarithm of vertical effective stress versus void ratio. There are some relationships between simple soil tests and consolidation settlement parameters are given below.

Typical range of values

C_c = 0.1 to 0.8
C_r = 0.015 to 0.35; also, $C_r \approx C_c/5$ to $C_c/10$
C_α/C_c = 0.03 to 0.08

Empirical relationships	**Reference**
$C_c = 0.009\ (LL - 10)$	Terzaghi and Peck, 1967
$C_c = 0.40(e_o - 0.25)$	Azzouz et al., 1976
$C_c = 0.01(w - 5)$	Azzouz et al., 1976
$C_c = 0.37(e_o + 0.003\ LL - 0.34)$	Azzouz et al., 1976
$C_c = 0.00234\ LL\ G_s$	Nagaraj and Murthy, 1986
$C_r = 0.15(e_o + 0.007)$	Azzouz et al., 1976
$C_r = 0.003(w + 7)$	Azzouz et al., 1976
$C_r = 0.126(e_o + 0.003\ LL - 0.06)$	Azzouz et al., 1976
$C_r = 0.000463\ LL\ G_s$	Nagaraj and Murthy, 1985
$C_c = 1.35$ PI (remolded clays)	Schofield and Wroth, 1968

w is the natural water content (%), LL is the liquid limit (%), e_o is the initial void ratio, and PI is the plasticity index.

Figure 4. Variation of Cc and Cr

Thus, over consolidation ratio, OCR, is the ratio by which the current vertical effective stress in the soil was exceeded in the past. The degree of over consolidation, called over consolidation ratio, is defined as:

$$OCR = \frac{\sigma_c'}{\sigma_0'} \quad (1)$$

where σ_c' =Pc =pre consolidation pressure
σ_o' =present effective vertical pressure

3. Results

Laboratory testing result of physical properties of Kamal Muara sedimentary soil is showed in table below:

Table 1. Result of Physical Index Properties

Depth (m)	Unit Weight (kN/m^3)	Moisture Content (%)	Void Ratio (e)
4.00-4.50	15.24	78.66	1.20
5.50-6.00	14.41	101.98	1.47
7.00-7.50	14.49	101.60	1.47
9.00-9.50	14.53	106.05	1.54
40.00-40.50	16.22	23.30	0.38
41.50-42.00	18.14	41.05	0.75
43.50-44.00	18.22	82.49	1.5
44.50-45.00	18.21	38.47	0.70

It is clearly seen that soil has high moisture content. Correlation between the moisture content and void ratio showed in the table below: Rate of Consolidation in each layer as follow:

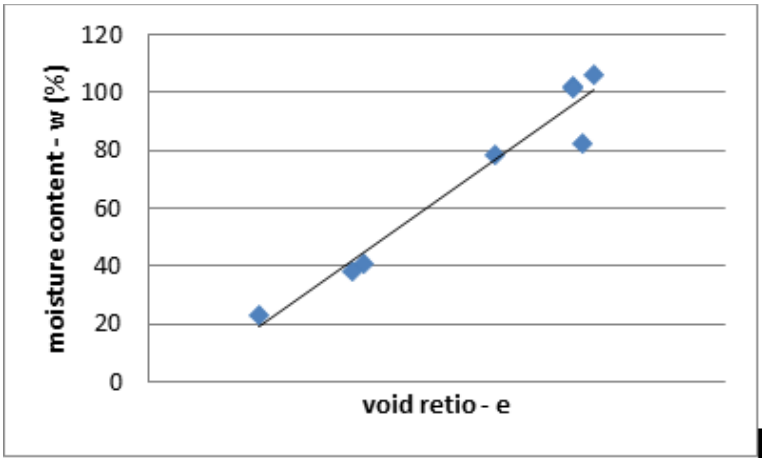

Figure 5. Correlation of moisture content versus void ratio

4. Discussion

As shown in Table 2, the soil layer bellow 4.5 m are under consolidation rate, it can be seen from Table 2 as follow

Table 2. Result of Consolidation Rate

Depth (m)	Po (kN/m^2)	Pc (kN/m^2)	OCR	Consolidation Rate
4.00-4.50	0.11	0.79	7.18	over consolidation
5.50-6.00	0.18	0.17	0.94	under consolidation
7.00-7.50	0.21	0.19	0.91	under consolidation
9.00-9.50	0.26	0.19	0.73	under consolidation
40.00-40.50	0.75	0.45	0.60	under consolidation
41.50-42.00	1,02	0.62	0.61	under consolidation
43.50-44.00				under consolidation
44.50-45.00	1,57	0.34	0.22	under consolidation

And the estimation of recompression index or unloading/reloading index, Cr for each layer are vary that can be be seen from the table below:

Table 3. Result of recompression index - Cr

Depth (m)	e_o	w (%)	Cr (graph)	Cr (#1)	Cr (# 2)
4.00-4.50	0.0012	78.66	0.008542	0.001229	0.031146
5.50-6.00	0.0015	101.98	0.016380	0.001270	0.032079
7.00-7.50	0.0015	101.60	0.005163	0.001270	0.032063
9.00-9.50	0.0015	106.05	0.051495	0.001281	0.032242
40.00-40.50	0.0004	23.30	0.110286	0.001106	0.028932
41.50-42.00	0.0007	41.05	0.05175	0.001161	0.029642
43.50-44.00	0.0015	82.49	0.054307	0.001275	0.031299
44.50-45.00	0.0007	38.47	0.067816	0.001155	0.029539

5. Conclusion

Land subsidence has been identified as one of major geological hazards of Jakarta. Based on the result of laboratory testing show the level of marine clay compressibility index of coastal sediment clay in Kamal Muara North Jakarta are under consolidation so that in certain areas the land subsidence that occurs is still ongoing due to the consolidation process from the land. Land subsidence occurring in the area of Penjaringan and Pademangan areas is estimated to be in the conservation of shallow ground water (0 - 40 m) which is in the level under consolidation. The surfece layer up to 4,5 m shows that the zone is dominated by embankment with overconsolidation level.

Acknowledgements

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