Shear strength parameters of peat soil of district of Asahan by direct shear test

Roesyanto* and A. S. Ritonga

*Civil Engineering Department, Universitas Sumatera Utara, Medan, Indonesia

Email: roesyanto@usu.ac.id

Abstract. Peat is a wetland ecosystem characterized by the accumulation of organic matter happens for a long time. This accumulation occurs because of the slow decomposition rate compared to the rate of accumulation of organic found in the wetland forest. The purposes of this study were to determine the index properties, to classify the peat soil classification, to obtain the optimum water content and maximum dry unit weight, $\gamma_d$ by Standard Proctor test, and to examine the shear strength of peat soil by direct shear test. The peat soil had water content, $w$ of 726.34 % and a specific gravity, $G_s$ of 1.302. Based on ASTM D4427-92, the classification of peat soil was high ash peat and highly acidic. Based on the Standard Proctor test, the optimum water content obtained was 34% and the maximum dry unit weight was 0.518 gr/cm$^3$. The Standard Proctor test increased the value of the dry unit weight of the undisturbed soil samples from 0.154 gr/cm$^3$ to 0.556 gr/cm$^3$. The original internal friction angle, $\phi$ and cohesion, $c$ were 0.595° and 0.019 MPa while the Standard Proctor test resulted in 3.539° of internal friction angle, $\phi$ and 0.020 MPa of cohesion, $c$.

1. Introduction

The formation of peat in some coastal areas of Indonesia is estimated to have started since the late glacial era, around 3,000 - 5,000 years ago. The process of forming inland peat is even longer, which is around 10,000 years ago. Like other tropical peatlands, peat in Indonesia is formed by the accumulation of tropical vegetation residues that are rich in lignin and cellulose. Because of the slow decomposition process, the peat, branches, and roots of the large plant can still be found in the peat swamp ecosystem. Similar to compost, peat is a soil that contains a significant amount of organic substances [1-5].

The determination process causes peat soils to have physical and engineering properties that do not benefit civilian buildings that are on peat soil. These physical properties include water content, $w$ which reaches 900%, the weight of the soil volume is quite small (0.8 - 1.04 gr / cm$^3$), large pore numbers range from 5-15, and high organic content > 75% [6]. The unfavorable physical properties automatically affect the engineering behavior of peat soil. Peat soil has a very low carrying capacity of 57 kPa [3] and large compression is uneven so that many civil buildings are damaged by this behavior [7].

The shear strength of a soil mass is the internal resistance per unit area that the soil can resist failure. The shear strength parameters of soil are internal friction angle, $\phi$ and cohesion, $c$ [8]. Direct shear testing and compaction testing are important to do on peat soil to find the shear strength value of
peat soil to calculate the carrying capacity of peat soil. The results of the direct shear test are in the form of internal friction angles and cohesion values. This experiment can be applied in the world of work, namely to calculate the carrying capacity of peat soil, geotechnical building planning and so on. The purposes of this study were to determine the index properties, to classify the peat soil classification, to obtain the optimum water content and maximum dry unit weight by Standard Proctor test, and to examine the shear strength of peat soil by direct shear test.

2. Methodology
This research used an experimental method which was carried out in the Laboratory of Soil Mechanics, Civil Engineering Department, the University of Sumatera Utara for index properties, and compaction tests. The direct shear test was conducted in the Soil Mechanics Laboratory, Civil Engineering Department, Politeknik Negeri Medan. The research specimens were peat soil which was obtained from Pertahanan Village, Sub-District of Sei Kepayang, District of Asahan, Sumatera Utara province. These samples were assumed to be representative of peat soil that was in the district of Asahan district, Sumatera Utara province.

2.1. Total samples in the research
There were 32 soil samples in the research in which one sample was used for the determination of ash content and organic content based on ASTM D2947-87 [9]. Then 11 samples were employed for index properties of peat soil. Next, 5 samples were compacted in the Standard Proctor test, and afterwards, 15 samples were utilized for the direct shear test based on SNI 3420:2016 [10]. The index properties of peat soil were shown in Table 1.

2.2. Testing implementation
Standard Proctor test was conducted to obtain the optimum water content and the maximum dry unit weight. Mineral element tests were carried out in Balai Riset dan Standarisasi Industri (BARISTAND) Medan. Then, a direct shear tests was performed to determine the shear strength parameters of peat soil. The direct shear test equipment is strain-controlled type, a constant rate of shear displacement is applied to one half of the box. The resisting shear force of the peat soil corresponding to any shear displacement was measured by a proving ring. Two types of soil samples can be got during subsurface exploration, undisturbed and disturbed samples. The shear strength determination of original soil by using direct shear test must use undisturbed samples. The computations would be presented in the form of tables, graphs, and interpretations. The research flow diagram was seen in Figure 1.
3. Result and Discussion

3.1. Index properties

Index properties of peat soil were shown in Table 1.

| No. | Test                          | Result            | Physical properties of normal peat soil |
|-----|-------------------------------|-------------------|----------------------------------------|
| 1   | Water content (w)             | 726.340%          | 100-1300%                              |
| 2   | Specific gravity (Gs)         | 1.302             | 1.250-1.800                            |
| 3   | Void ratio (e)                | 3.672             | 5-15                                   |
| 4   | Wet unit weight ($\gamma_w$)  | 1 gr/cm$^3$       |                                        |
| 5   | Dry unit weight ($\gamma_d$)  | 0.154 gr/cm$^3$   |                                        |

3.2. Classification of peat soil
The classification of peat soil was displayed in Table 2.

**Table 2. Classification of peat soil.**

| No | Test              | Result     | Peat classification based on ASTM D 4427-92 (2002) [
|----|------------------|------------|------------------------------------------------------|
| 1  | Ash content      | 45.302%    | High ash-peat                                        |
| 2  | Organic content  | 54.968%    |                                                      |
| 3  | Acidity (pH)     | 4          | Highly acidic                                        |

**3.3. Mineral elements**

Mineral elements of peat soil were presented in Table 3.

**Table 3. Mineral elements of peat soil.**

| Mineral Composition | Unit | Result |
|---------------------|------|--------|
| Calcium (CaO)       | %    | 0.290  |
| Ferum (Fe₂O₃)       | %    | 0.400  |
| Silica (SiO₂)       | %    | 0.020  |
| Alumunium (Al₂O₃)   | %    | 0.030  |
| Magnesium (MgO)     | %    | 0.160  |
| Potassium (K₂O)     | %    | 1.580  |
| Natrium (Na₂O)      | %    | 0.610  |

**3.4. Shear strength parameters of peat soil**

The shear strength parameters of peat soil were determined by the direct shear test and the results were shown in Table 4. Correlation between dry unit weight and relative compaction R, the relationship between internal friction angle and relative compaction R, and the connection between cohesion and relative compaction were presented in Figures 2, 3, 4 respectively.

**Table 4. Shear strength parameters of peat soil.**

| No | Sample       | Dry Unit Weight (γ_d) | Relative Compaction (R) | Internal friction angle (φ) | Cohesion (c) |
|----|--------------|-----------------------|-------------------------|-----------------------------|--------------|
|    |              | (gr/cm)               | (%)                     | (º)                         | (Mpa)        |
| 1  | Disturbed 107% | 0.556                 | 107.000                 | 3.539                       | 0.020        |
| 2  | Disturbed 106% | 0.549                 | 106.000                 | 3.244                       | 0.020        |
| 3  | Disturbed 103% | 0.533                 | 103.000                 | 2.212                       | 0.020        |
| 4  | Disturbed     | 0.177                 | 35.000                  | 0.295                       | 0.019        |
| 5  | Undisturbed   | 0.154                 | 30.000                  |                             | 0.019        |

(γ_d) max (100%) Standard Proctor = 0.518 gr/cm³
Figure 2. Correlation of dry unit weight against relative compaction (R).

It was shown in Figure 2 that the greater the relative compaction the higher the value of the dry unit weight of peat soil.

Figure 3. Correlation of relative compaction (R) against friction angle of peat soil.

Figure 3 explained that as relative compaction, R raised, the internal friction angle increased.

Figure 4. Correlation of relative compaction, R against the cohesion, c of peat soil.
Figure 4 revealed that the cohesion, c values of peat soil were not improved by compaction of peat soil.

4. Conclusion
1. Peat soil of Pertahanan village, sub-district of Sei Kepayang, district of Asahan, Sumatera Utara province had 72.36% water content and specific gravity, G_s, of 1.302.
2. Based on ASTM D4427-92 (2002), the peat soil of Pertahanan village, sub-district Sei Kepayang, district of Asahan was classified as high ash-peat due to ash content of 45.302 % and had organic content of 54.968% and was classified as highly acidic peat due to pH of 4 that was smaller than pH of 4.5.
3. Based on the Standard Proctor test, the optimum water content obtained was 34% and the maximum dry unit weight was 0.518 gr/cm^3.
4. The original undisturbed peat soil sample had an internal friction angle, $\phi$ of 0.295° and cohesion, c of 0.019 MPa. Standard Proctor test increased angle of internal friction, $\phi$ to 3.539° and cohesion, c to 0.020 MPa.
5. It can be concluded that compaction according to the Standard Proctor test gave insignificant effect to the shear strength of these peat soil.

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