Effect of compaction and direct shear test values on peat soil of Batubara Regency, Sumatera Utara Province

Roesyanto* and Vini Rizki Eka Putri
Civil Engineering Department, University of Sumatera Utara, Medan 20155, Indonesia.

*E-mail: roesyanto@usu.ac.id

Abstract. Peat soil is an organic soil and is usually found in low-lying areas where the water table is near the ground surface. The peat Soil has very large water reserves, high compression and has a low carrying capacity. This study aims to ascertain the index properties, to classify the peat soil classification according to ASTM 4427-92 (2002), to get the optimum water content and maximum dry unit weight by Standard Proctor test, and to analyze the shear strength of peat soil by direct shear test. The peat soil had water content (w) of 752.833 % and specific gravity (G_s) of 1.533. According to ASTM 4427-92 (2002), the peat soil was classified as high-ash peat with more than 15 % ash and as slightly acidic peat with a pH between 4.5 and 6.5. From the Standard Proctor test, the peat soil had an optimum water content of 37.235 % and 0.474 gr/cm^3 maximum dry unit weight (γ_dmax). The Standard Proctor test increased the value of the dry unit weight (γ_d) of 0.169 gr/cm^3 to 0.519 gr/cm^3. The original internal friction angles (φ) and cohesion (c) were 0.885º and 0.015 MPa respectively while the Standard Proctor test resulted in 5.294º of internal friction angle (φ) and 0.023 MPa of cohesion (c).

1. Introduction
Indonesia has several major islands such as Sumatra, Kalimantan, Sulawesi, and Papua has considerable peat soil. Characteristics of peat soil generally have poor properties for civilian construction, due to the nature of peat soil which has high moisture content, low compressibility, and low carrying capacity. So that it is a best practice before doing construction work to research the type of land to be built. It starts from researching the physical properties of soil to the mechanical properties of the soil itself.

Almost similar to compost, peat is formed from heaps of dead plant residues, whether or not already rotten [1-6]. The ability of peat soil to hold large amounts of water is since this type of soil has fibers that divide the pore space into macropore and micropore, the smallest part of which is between the peat pore itself [7]. In the physical properties of peat soil, the peat pore numbers generally range from 5 to 15. In fibrous peat soils, the porous figure can be much larger by 25, while granular peat soils have a relatively small pore number and range 2. Peat soil also has a heavy which is very low when compared to mineral soil [8].

In general, the degree of compaction of soil is measured according to relative density (D_r) which can be determined by the void-ratio of the soil in the loosest condition (e_max), void-ratio in the densest state (e_min) and the original void-ratio itself (e). This relative density has a relationship with the internal friction angle (φ), where the denser the soil the greater the internal friction angle. The shear strength of the soil is influenced by the normal stress of the surrounding soil, the arrangement of the grains and cohesion bonds between grains, where these factors form shear barriers that resist the occurrence of collapse or shift in the soil when experiencing pressure loads [9]. The shear strength of peat soil is determined by direct shear test equipment, strain-controlled type.

Compaction is the densification of soil by reduction in air volume, which requires mechanical energy. Compaction testing at the laboratory was approved to find the relationship between water content and weight volume and meet soil requirements to meet the requirements. The weight of the
dry soil volume after compaction depends on the type of soil, the air content, and the effort provided by the compactor. Soil characteristics can be approved from standard laboratory tests called the Proctor compaction test. A compaction test is carried out to reduce the soil pore space.

This study aims to ascertain the index properties, to classify the peat soil classification, to get the optimum water content and maximum dry unit weight by Standard Proctor test, and to analyze the shear strength of peat soil.

2. Method
This activity was carried out in two different places for physical testing and compaction test activities carried out at the Soil Mechanics Laboratory. The experimental method was conducted in the Soil Mechanics Laboratory, 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. Tests carried out using undisturbed soil samples, disturbed soil samples, and soil samples that have been compacted first. Peat soil originates from the Paya Pinang Plantation, Sub-District of Laut Tador, Batubara Regency.

2.1. Sample preparation
Two types of soil samples can be acquired during subsurface exploration, undisturbed and disturbed samples. Thin wall tube was used for obtaining undisturbed soil samples. The thin wall tubes are commonly referred to as Shelby tubes. The undisturbed samples were used for the determination of shearing strength of soil. Hand auger boring was used to obtained disturbed sample. Before starting the research, the soil was divided into several samples for testing for index properties determination, compaction, and direct shear test. 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 [10]. Then 11 samples were utilized for index properties of peat soil. Next, 5 samples were employed for the Standard Proctor test, and afterward 15 samples were used for the Direct shear test based on SNI 3420:2016 [11]. The index properties of peat soil are given in Table 1.

2.2. Testing phase
Index properties testing in the form of physical properties of soil such as water content, specific gravity, void ratio, moist unit weight, and dry unit weight. Peat soil classification needed testing of ash content, organic content, and acidity. Mineral element testing was also carried out to determine the mineral content of peat soil. Mechanical testing in the form of testing compaction test and direct shear test.
3. Results and discussions

3.1. Index properties results
Laboratory test results were shown in Table 1.

| No | Test                   | Result       | Physical properties of normal peat soil |
|----|------------------------|--------------|-----------------------------------------|
| 1  | Water content \((w)\)  | 752.833 %    | 100-1300 %                              |
| 2  | Specific gravity \((G_s)\) | 1.533        | 1.250-1.800                            |
| 3  | Void ratio \((e)\)     | 3.908        | 5-15                                    |
| 4  | Moist unit weight \((\gamma)\) | 0.760 gr/cm³ |                                    |
| 5  | Dry unit weight \((\gamma_d)\) | 0.196 gr/cm³ |                                    |

3.2. Classification of peat soils
Acidity and mineral elements found in native peat soil were presented in Table 2.

| No | Test          | Result       | Classification peat soil |
|----|---------------|--------------|--------------------------|
|    |               |              | Based on ASTM D4427-92 (2002) [8] |
| 1  | Ash content   | 22.424 %     | >15% (high ash peat)      |
| 2  | Organic content | 77.576 %    |                          |
| 3  | pH            | 6            | 5.5-7 (slightly acidic peat) |

3.3. Composition of mineral peat soils
Mineral elements of peat soil were displayed in Table 3.

| Mineral Composition | Result (%) |
|---------------------|------------|
| Silika (SiO₂)       | 10.800     |
| Aluminium (Al₂O₃)   | 0.020      |
| Besi (Fe₂O₃)        | 3.310      |
| Kalsium (CaO)       | 0.520      |
| Magnesium (MgO)     | 0.160      |
| Kalium (K₂O)        | 0.250      |
| Natrium (Na₂O)      | 0.380      |
3.4. Engineering properties of peat soil
The peat soil engineering properties with the direct shear test were shown in Table 4.

| No | Sample          | Dry unit weight (γd) (gr/cm³) | Relative compaction (Rc) (%) | Internal friction angle (φ) (º) | Cohesion (c) (MPa) |
|----|-----------------|-------------------------------|-----------------------------|-------------------------------|-------------------|
| 1  | Disturbed 94 %  | 0.500                         | 94.515                      | 5.294                         | 0.023             |
| 2  | Disturbed 92 %  | 0.511                         | 92.038                      | 4.709                         | 0.022             |
| 3  | Disturbed 90 %  | 0.519                         | 90.507                      | 3.829                         | 0.022             |
| 4  | Disturbed       | 0.215                         | 45.359                      | 1.180                         | 0.016             |
| 5  | Undisturbed     | 0.169                         | 35.655                      | 0.885                         | 0.015             |

\( (\gamma_d) \text{ max } (100\%) \text{ Standard Proctor } = 0.474 \text{ gr/cm}^3 \)

Correlation between the dry unit weight and the relative compaction \( R_c \), the relationship between the internal friction angle and the relative compaction \( R_c \), and the connection between the cohesion and the relative compaction \( R_c \) were shown in Figures 2, 3, 4 respectively.

**Figure 2.** Graph of the effect of the dry unit weight of peat soil on the relative compaction.

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. Graph of the effect of the relative compaction (Rc) on the shear angle in peat soil.

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

Figure 4. Graph of the effect of relative compaction (Rc) on the value of peat soil cohesion.

Figure 4 showed that the cohesion values of peat soil were improved insignificantly by compaction of peat soil. Compaction of peat soils with the Standard Proctor did not influence on the cohesion value because the mineral elements of peat soil was constant.
Figure 5 showed maximum shear strength values that occurred in the type of sample disturbed by 94 %, which was 0.031 MPa at loading 294.300 N.

4. Conclusions
From the research results, it could be concluded that:
1. Peat soil water content Paya Pinang Plantation, sub-district Laut Tador, Batubara Regency had 752.833 % water content and specific gravity (G_s) of 1.533.
2. According to ASTM 4427-92 (2002), the peat soil was classified as high-ash peat with more than 15 % ash.
3. Based on ASTM D4427-92 (2002), the peat soil was classified as slightly acidic peat with a pH between 5.5 and 7.
4. The peat soil had an optimum water content of 37.235 % and 0.474 gr/cm³ maximum dry unit weight.
5. The original undisturbed peat soil sample had 0.885° internal friction angle and cohesion of 0.015 MPa. Standard Proctor test increased the internal friction angle to 5.294° and cohesion to 0.023 MPa.
6. Compaction of peat soils with Standard Proctor affected insignificantly on the cohesion value because there was no change in the mineral elements of peat soil, while the internal friction angle increased more significant than cohesion value because its relative compaction increased too.
7. It can be deduced that compaction according to the Standard Proctor test gave insignificant effect to the shear strength of these peat soil. The peat soil had very low shear strength and compaction effected insignificant to peat soil shear strength. Therefore, it is not feasible to use the peat soil for building construction. Then the replacement of peat soil may be needed.

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