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# The Innovation Breakthrough in Digital and Disruptive Era

# Laboratory Testing-Based Characterization of Peat in Palangkaraya, Central Kalimantan

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**Abstract.** Peat is a unique type of soil because it has a very high organic matter content. One of the locations in Indonesia that has the most peat distribution is Palangkaraya City, Central Kalimantan. It is important to understand the characteristics of peat, especially in engineering applications. The characteristics of peat can be known based on laboratory testing, but in practice many tests are not carried out in accordance with the characteristics of the peat. In this paper, laboratory tests will be carried out based on the characteristics of the peat, with a focus on testing the physical and mechanical properties of the soil. Based on the results of the tests conducted, it can be concluded that the Palangkaraya peat is a fibrous hemic peat. The Palangkaraya peat has a water content of 639.5%, ash content of 3.25%, organic content of 96.75%, fiber content of 53.32%, pH of 3.2, content weight of 0.983 gr/cm<sup>3</sup>, specific gravity of 1.48, cohesion value of 0.138, and inner shear angle of 16.26°. The characteristics of this peat can provide an overview for researchers or the local government to make the best use of peatlands. Further research is needed to find out other aspects outside the engineering field to determine the characteristics of peat in Palangkaraya City, Central Kalimantan.

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## 1 Introduction

Peat soil is an organic soil formed from the process of decay or decomposition of plants and accumulated for thousands of years in water-saturated soil conditions [1]. This decomposition causes peat soil to contain a lot of organic material, which causes peat soil to have disadvantageous characteristics in the implementation of infrastructure development [2]. The distribution of peat soils in the world reaches 423 million hectares [3]–[7], where Indonesia is the country with the most peat soil in Southeast Asia, which is 13.43 million hectares [8], [9]. Kalimantan Island has a peatland distribution of 4.78 million hectares or 35.59% of the total area in Indonesia. In general, the distribution of peat is found in the lowlands of Central Kalimantan, with an area of 2.55 million hectares [10].

Infrastructure development must consider the type of subgrade that will be used. In locations where peat soils are dominant, soil improvement or reinforcement must be carried out because peat has significant differences with other types of soil. In determining the type of soil improvement or reinforcement to be carried out, it is necessary to analyse the characteristics of the soil.

Therefore, to determine the characteristics of peat soil, laboratory tests will be conducted to determine the physical and mechanical properties of the peat. The tests must be carried out in accordance with the characteristics of peat which has a high-water content [11], has irreversible dry properties [12], low pH [13], low bearing capacity [14] and others. This is done to get a full picture of the peat under study, because it should be underlined that many tests related to peat soil are carried out inaccurately due to the lack of knowledge of researchers related to the characteristics of peat.

This case study will be conducted on peat from Palangkaraya City, Central Kalimantan. The laboratory tests carried out consisted of testing physical properties in the form of moisture content, specific gravity, weight, ash content, organic content, fiber content, fiber size, and mechanical properties in the form of determining cohesion and inner shear angle in direct shear testing.

## 2 Literature Review

### 2.1 Definition of Peat

Peat is organic material that is not completely decomposed because it exists in anaerobic conditions (airtight). The decomposition process occurs very slowly and makes organic material accumulate over a thousand years so that a layer of peat is formed. Peat is generally found in waterlogged areas such as swamps, basins between rivers, and coastal areas. These organic materials then form a layer on top of the mineral soil at the bottom of the basin. Subsequent plants grow and then die on top of the formed layer, gradually forming new layers of peat.

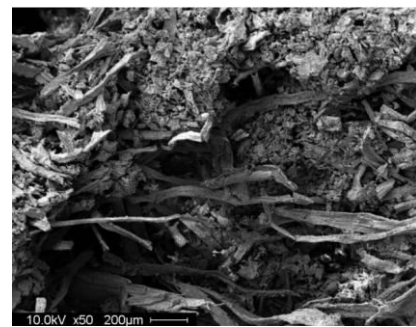
### 2.2 Types of Peat

The rate of peat soil formation is very slow and differs from place to place, which is influenced by many factors, especially the local environment, including the source and balance of water, mineral content in the water, climate, vegetation cover, and management after drainage [15], [16]. Peat can be differentiated in several conditions, such as fiber content, peat thickness, or peat composition.

Based on its composition, peat is divided into two, there are fibrous peat and amorphous granular peat [17].

#### 2.2.1 Fibrous Peat

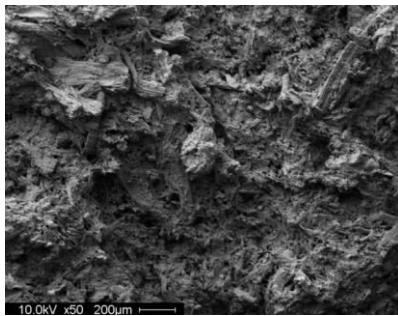
Fibrous peat refers to peat soil with a fiber content exceeding 20%. It is commonly located in tropical regions like Indonesia, where the fiber content can reach as high as 50%. This peat soil primarily consists of woody plant or tree biomass with abundant cellulose and lignin, resulting in visibly larger fibers within the soil. The fibrous peat is shown in **Fig. 1** below.



**Fig. 1** SEM Magnified Fibrous Peat x200 Magnification. Source: De Guzman and Alfaro (2018)

#### 2.2.2 Amorphous Granular Peat

Amorphous granular peat refers to peat soil with a fiber content less than 20%. It shares similarities in behavior and characteristics with clay. This type of peat soil is commonly found in subtropical regions and mainly comprises grasses, low bushes, or aquatic plants with lower levels of lignin and cellulose, resulting in smaller fibers within the soil. Moreover, this type of peat soil has a faster regeneration time compared to fibrous peat soil. The amorphous granular peat is shown in **Fig. 2** below.



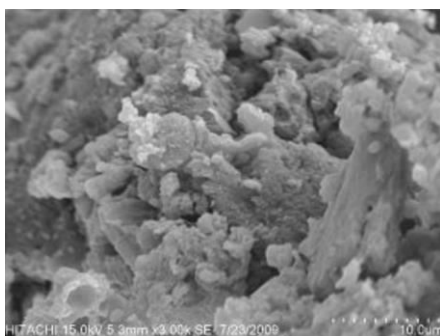
**Fig. 2** SEM Magnified Amorphous Granular Peat x200 Magnification.

Source: De Guzman and Alfaro (2018)

Peat has different rates of decomposition, so there are peats that are mature because they have been decomposed and peats that have not been decomposed. Based on its decomposition of fiber content, peat is divided into three, there are sapric, hemic, and fibric [18].

### 2.2.3 Sapric Peat

Sapric peat, also known as mature peat, is found in the deepest position within the peatland floor, typically located 3 meters below the soil surface. This type of peat has a high content of humus, which is a well-decomposed organic material. Moreover, sapric peat exhibits excellent mineral protecting capabilities, likely due to its advanced stage of decomposition [19]. It is dark brown to black in color and relatively finer in structure, so when squeezed by hand the fiber content left on the hand is less than 15%. The sapric peat is shown in **Fig. 3** below.



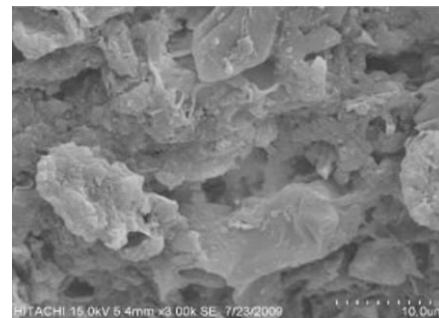
**Fig. 3** SEM of Sapric Peat

Source: Kezemian, et al. (2011)

### 2.2.4 Hemic Peat

Hemic peat, also referred to as partially mature peat, is characterized by being semi-decomposed, allowing some of its original parent material to still be recognizable. The color of hemic peat is brown. In terms of structure, it falls between sapric peat and fibric peat. It is coarser in texture compared to sapric peat, but finer compared to fibric peat, so when squeezed the fiber material left in the hand is in the range of 15-75%. This intermediate level of decomposition gives hemic peat its distinct

characteristics. The hemic peat is shown in **Fig. 4** below.

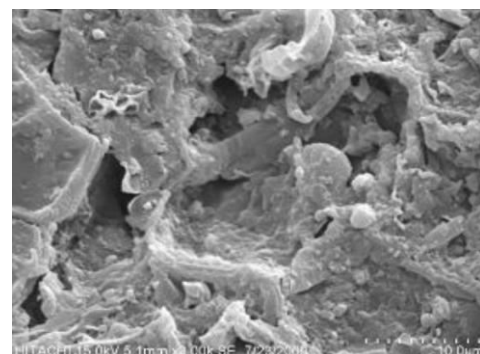


**Fig. 4** SEM of Hemic Peat

Source: Kezemian, et al. (2011)

### 2.2.5 Fibric Peat

Fibric peat is the least decomposed type of peat, with over two-thirds of its content consisting of recognizable plant fibers. It has a coarse-grained texture. In temperate climates, fibric peat is primarily derived from sphagnum mosses and the fine root systems of shrubs. Due to its relatively low degree of decomposition, fibric peat retains much of its original plant material. The fibric peat has a brown color, and its structure is predominantly composed of coarse fibers. When the peat is squeezed, more than 75% of the fiber material remains in the hand, indicating a significant presence of recognizable plant fibers. This high fiber content is a reflecting its relatively low degree of decomposition compared to other types of peat. The fibric peat is shown in **Fig. 5** below.



**Fig. 5** SEM of Fibric Peat

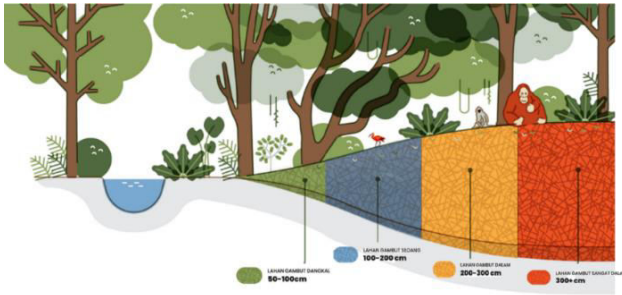
Source: Kezemian, et al. (2011)

### 2.2.6 Peat Thickness

Based on the thickness of the soil layer, peat can be categorized into four main types [9]:

1. Shallow peat soil: This type of peat has a thickness ranging from 0.5 meters to 1 meter.
2. Medium peat soil: Peat in this category has a thickness ranging from 1 meter to 2 meters.
3. Deep peat soil: This type of peat has a thickness ranging from 2 meters to 3 meters.
4. Very deep peat soil: Peat in this category has a thickness exceeding 3 meters.

The classification of peat soil based on its thickness is shown in **Fig. 6** below.



**Fig. 6** Classification of Peat Soil based on Layer Thickness  
 Source: *Pantau Gambut* (2022)

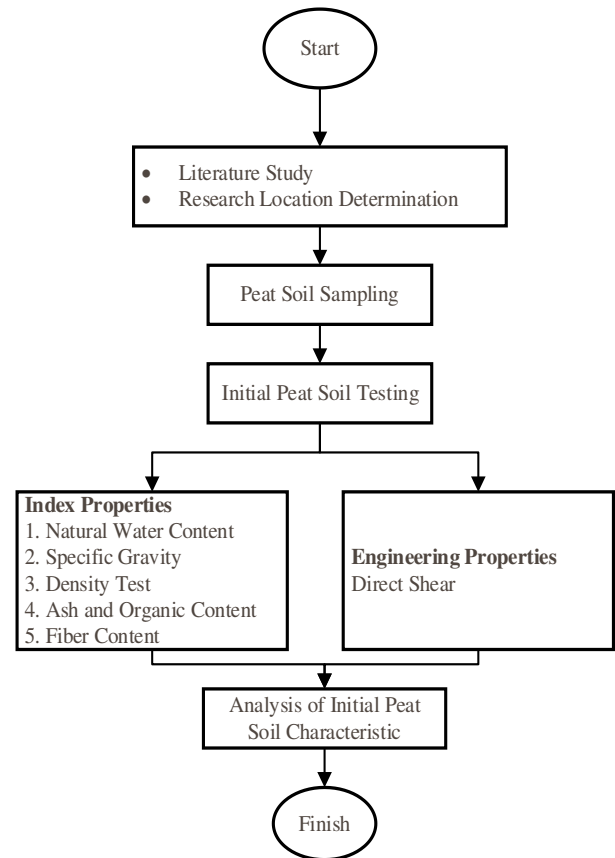
**2.3 Peat Testing**

In the testing of peat, two main categories of characteristics are evaluated: index properties and engineering properties. Index properties help identify the type and condition of the soil, while engineering properties provide information on the soil's strength, compressibility, expansive tendencies, and permeability.

Laboratory soil testing is performed in a controlled laboratory environment to determine soil properties and attributes that cannot be ascertained through field testing. The soil samples used for laboratory testing can be either undisturbed samples (UDS), which maintain their natural structure, or disturbed samples (DS) obtained through the disruption of the soil's original composition.

**3 Methodology**

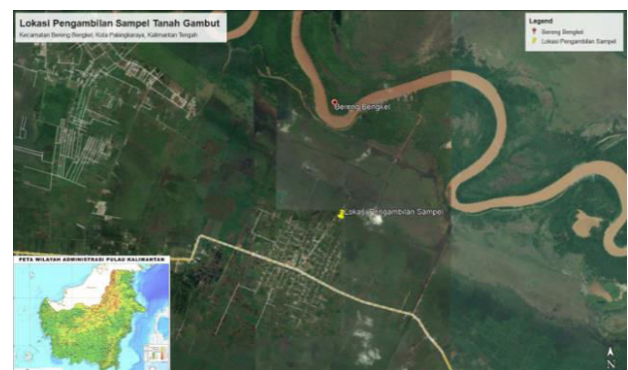
This research aims to obtain the characteristic of Peat in Palangkaraya City, Central Kalimantan. The stages that will be carried out in this research are as follow in **Fig. 7**.



**Fig. 7** Methodology Research

**3.1 Peat Sampling**

Peat sampling will be done in Palangkaraya City, Central Kalimantan, in exact location is Bereng Bengkel Subdistrict as shown in **Fig. 8**. The samples collected will consist of undisturbed samples (UDS) and disturbed samples (DS).



**Fig. 8** Peat Sampling in Palangkaraya

### 3.2 Laboratory Testing

The Laboratory testing will be carried out in accordance with applicable regulations and peat characteristic. The types of the test will be carried out are as follow.

1. Soil Physical Properties Testing (Index Properties)
  - a) Moisture Content and Weight
  - b) Specific gravity
  - c) Organic and Fibre Content
  - d) Ash Content
  - e) Fibre Size
  - f) Acidity
  - g) Pore number and Density
2. Testing of Soil Mechanical Properties (Engineering Properties)
  - a) Direct Shear Test

## 4 Analysis and Discussion

### 4.1 Index Properties

#### 4.1.1 Moisture content

Water content or soil moisture content is measured with standard methods ASTM D2974-00 that uses drying temperature of  $110 \pm 5^\circ\text{C}$ .

$$\text{Moisture Content, \%} = ((A - B) \times 100) / A$$

A = mass of the as-received test specimen, g,

B = mass of the oven-dried specimen, g.



**Fig. 9** Water or Moisture Content Testing

#### 4.1.2 Specific Gravity

The implementation of soil specific gravity is based on SNI 1964:2008 and Peat Testing Manual 1979 where the water used is replaced by using kerosene.

$$GS_{(Tx)} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \times k$$

$W_1$  = Weight of pycnometer

$W_2$  = Weight of pycnometer + dry soil sample

$W_3$  = Weight of pycnometer + soil sample + kerosene

$W_4$  = Weight of pycnometer + kerosene



**Fig. 10** Specific Gravity Testing

#### 4.1.3 Ash and Organic Content

The ash content of peat or organic soil samples is determined by burning in a furnace at  $440^\circ\text{C}/750^\circ\text{C}$  after testing the moisture content.

$$\text{Ash Content (\%)} = \frac{C \times 100}{B}$$

C = ash, g,

B = oven-dried test specimen, g



**Fig. 11** Ash Content Testing

Organic content is determined by subtracting 100% from the percentage of ash content.

$$\text{Organic Matter (\%)} = 100 - D$$

D = ash content, %.

#### 4.1.4 Fiber Size Analyses

Fiber size testing was conducted based on the Peat Soil Testing Manual 1979. The test was conducted using a No.8 and No.20 sieve. Peat soil fiber size requirements are as follows.

- a. Retained on sieve No.8 = coarse fiber
- b. Retained on sieve No.20 = medium fiber
- c. Passed sieve No.20 = fine fiber



**Fig. 12** Fiber Size Testing

#### 4.1.5 Acidity

The acidity of peat soil is tested by looking at its pH value. The pH value of peat soil tends to be low, making it acidic, which is highly corrosive to concrete and steel. Before conducting the pH test, it is necessary to ensure that the device is calibrated.



**Fig. 13** Acidity Testing

#### 4.1.6 Density

The pore number and density of the peat soil were tested based on the ratio between the weight of the soil and the volume of the soil. The pore number value of peat soil is very large, ranging from 5 - 15, while the density of peat soil tends to be low, ranging from 0.9 - 1.25 gr/cm<sup>3</sup>.



**Fig. 14** Density Testing

## 4.2 Engineering Properties

To obtain the engineering properties of peat, direct shear testing is required. The aim of conducting a direct shear test is to ascertain the shear strength of a soil. This is achieved by subjecting the soil to shear along a created horizontal plane of weakness at a constant rate. To obtain accurate results, a minimum of three subtests are performed, wherein the sample is consolidated using three different weights and then sheared at a consistent rate. The peak shear stress and residual shear stress observed in each subtest are carefully recorded and plotted on a graph. By analyzing this data, the cohesion and friction angle of the soil can be determined.



**Fig. 15** Direct Shear Testing

## 4.3 Test Result

Based on the laboratory tests previously described on peat in Palangkaraya City, Central Kalimantan, the following results were obtained is shown in **Table 1**.

**Table 1.** Laboratory Test Result

No.	Kind of Test	Units	Value
<b>Index Properties</b>			
1	Specific Gravity (Gs)	-	1.48
2	Moisture Content (w <sub>c</sub> )	%	639.35
3	Density (γ)	gr/cm <sup>3</sup>	0.98
4	Dry Density (γ <sub>d</sub> )	gr/cm <sup>3</sup>	0.13
5	Pore Number (e)	-	10.12
6	Acidity (pH)	-	3.2
7	Organic Content (Oc)	%	96.75
8	Ash Content (Ac)	%	3.25
9	Fiber Content (Fc)	%	53.23
	- Crude Fiber Content	%	56.61
	- Medium Fiber Content	%	26.62

	- Fine Fiber Content	%	16.77
<b>Engineering Properties</b>			
10	Direct Shear		
	Shear Angle ( $\emptyset$ )	$^{\circ}$	16.26
	Cohesion (c)	kg/cm <sup>2</sup>	0.138

#### 4.1.4 Peat Characteristic

The peat soil in Palangkaraya City is classified as fibrous peat because it has a fiber content of >20%, which is 53.23%, according to MacFarlane (1965) [20], [21] This peat soil is a very soft soil with a very low load-bearing capacity and a very large compression value [22].

Based on ASTM D4427-84, the peat soil from Palangkaraya City is also included in the fibric peat soil with a fiber content of less than 67%, which is 53.23% with a predominance of coarse fiber of 56.61%. This peat soil has a low ash content (low ash peat) with an ash content below 5% at 3.25%.

Peat soils in Palangkaraya City are highly acidic with a pH value of less than 4.5, at pH 3.2, indicating that the peat soil has a very high organic content. The density of peat soil is 0.98 gr/cm<sup>3</sup>, the dry density value is 0.13 gr/cm<sup>3</sup>, with a medium water storage capacity of 639.35%. This shows that the largest component of the peat soil is water.

The size distribution of the fibers in the peat soil will greatly affect the value of the shear angle of the soil. The laboratory test results show that this peat soil has a shear angle of 16.26° with a cohesion value of 0.138 kg/cm<sup>2</sup> or 13.53 kPa.

## 5 Conclusion

This study was conducted to investigate the characteristics of peat from Palangkaraya City, Central Kalimantan based on laboratory testing. Based on the amount and size of fibers, Palangkaraya peat is classified as fibrous peat which has medium water storage and is dominated by coarse fiber and low ash content. The peat is highly acidic which proves it contains a lot of organic material. The coarse fibers in Palangkaraya peat determine the inner shear angle and cohesion values of this peat soil. The Palangkaraya peat is a very soft soil with low load bearing capacity.

## Acknowledgments

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