On the development of measurement procedure of particle density for peat material

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Abstract. Value of particle density of tropical peat materials commonly is considered to be 1.4 g/cm\textsuperscript{3}. This value was based on the measurement using a pycnometer. However, this value would not be correct for tropical peat that has coarse material that could plug the narrow opening of the pycnometer. Hence, the use of pycnometer to measure particle density of tropical peat material has a possibility to get false values because the coarse material will inhibit the measurement process. Therefore, we are proposing the use of a three phases meter to measure particle density of tropical peat materials. The particle density value obtained by using three phases meter was around 1.8 g/cm\textsuperscript{3}. The value was higher than pycnometer result due to the three phases meter could ensure the measurement of all size tropical peat material.

1. Introduction

Peat soil of Indonesia has an area of 16.03 million ha which spreads in three islands, that are Sumatera, Kalimantan and Papua [1]. Peat soil is potential to be developed as productive agricultural land. The use of peatland’s increasing because of its large potential area, some successful reclamation and socio-economic pressure caused by food needs [2]. Therefore, a true and comprehensive understanding on the characteristics of Indonesian peatland is very important to determine the most appropriate management.

Correct measurement of characteristic from the physical properties of peat soil is a must to use as base for management. One of the physical properties of soil that should be carefully determined is particle density. The particle density is used in the calculation of the soil total pore space (TPS) that is the key parameter in interpreting the water retention of a soil. The component of tropical peat material is quite diverse in particle size composition, so it is possible that the particle density value would have wide variety. The measurement of particle density actually is not easy and simple, therefore in several researchs the value is generally used as reference without direct measurement. When a tropical peat assessment should be carried out with the use of particle density value, in general it will use value of 1.4 g/cm\textsuperscript{3}. This value is the result of measurements using a pycnometer on tropical peat samples [3]. However a critical question still should be addressed to this value, because the measurement using a pycnometer has a high possibility to get an error due to the following reasons. The particle of tropical
peat is actually not homogenous in size and not necessarily fine as of European (temperate) peat. As the consequency there will be part of the tropical peat samples that will not be included on the measurement because of its larger size than the size of the opening of the pycnometer tip. In addition, the coarse particle has high possibility to plug the opening. Therefore, the reference value still has to be studied further.

This need is amplified by the fact that even for European peat that is fine and homogenous in particles results of has the particle density values from the pycnometer method still varied, about 1.26-1.80 g/cm³. By the theory, the variations is indeed very possible because the material component of peat across the European lands has also some variations. Then the value of 1.4 g/cm³ is even still too low for the temperate peat so the value needs further study. The development of other method is needed to upgrade the value of particle density more significantly. One of the method is using three phases meter. Therefore, the aimed of this study was to measure the particle density of tropical peat soil using three phases meter.

2. Materials and Methods
The research was conducted at the Laboratory of Physical Land Resources Development and Laboratory of Soil Science and Water Conservation. Both laboratories are belong to Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University.

2.1 Materials
Materials used in this study were undisturbed samples of peat soil in ring samplers. The equipments used were three phases meter, sandbox, pressure plate apparatus, oven 105°C and scale.

2.2 Samplings
The peat soil samples in ring samplers (100 cm³) were taken in triplicate from either 0-10 cm depth or 0-20 cm depth. The locations of sampling were four locations in Riau Province, as presented in table 1.

| Location           | Depth of peat (m) | Decomposition stage   | Depth of soil sampling (cm) |
|--------------------|------------------|-----------------------|-----------------------------|
| Rupat              | > 3              | hemic-sapric          | 0-10                        |
| Siak               | > 3              | hemic-sapric          | 0-10                        |
| S. Gasip area      | > 3              | hemic-sapric          | 0-10                        |
| Selat panjang      | > 3              | hemic-sapric          | 0-20                        |

2.3 Measurements and Calculations
Measurement in this research consists of : 1) measurement of water retention, 2) calculation of solid volume using three phases meter, 3) calculation of particle density values. Measurements of water retention are carried out at pF 1, pF 2.54 and pF 4.2. The calculation of solid volume is obtained from the measurement results using a three phases meter. The three phases meter measurements are carried out for the samples after used for the water retention measurement at pF 1, pF 2.54 and pF 4.2 to get the air volume, then the water volume and solid volume can be calculated. From the results of (1) and (2) the particle density value can be calculated using the formula:

$$PD = \frac{W_s}{V_s}$$

Which:
PD : particle density, in g/cm³
W_s : solid weight of soil, in g
V_s : solid volume of soil, in cm³
3. Results & Discussions

3.1 Characteristics of the peat samples

The characteristics of tropical peat samples used in this study are presented in Table 2. Based on Table 1, all samples are categorized to have decomposition stage of hemic to sapric. Therefore, if only based on decomposition stage than all the samples are supposed to have similar characteristics. However, Table 2 shows that there are still some degrees of variation. The Selat Panjang samples show the highest bulk density and porosity of the Selat Panjang peat can be attributed to the deeper sampling (0-20 cm). The bulk density and porosity of soils to some extend have a correlation with the particle density. The S. Gasip area samples show the highest porosity and lowest bulk density have a correlation with the highest particle density. The other significant differences that is shown in Table 2, is in the water retention of peat soil with values below 10%. Characteristics of water retension and hidrourlic conductivity of peat materials depending on the origin of peat component and decomposition materials [4]. The difference in peat component might result in differences in particle density values.

Table 2. Bulk density, porosity, water content, water availability and ash content of the peat sample

| Code        | Depth (cm) | Bulk density (g/cm³) | Porosity (%) | Water content (% v/v) at pF | Available water (%) | Ash content (%) |
|-------------|------------|----------------------|--------------|-----------------------------|---------------------|-----------------|
| Rupat 1     | 0-10       | 0.12                 | 94.55        | 47.24                       | 43.83               | 35.52           | 8.07            | 1.15  |
| Rupat 2     | 0-10       | 0.16                 | 91.67        | 53.99                       | 50.15               | 42.91           | 7.24            | 8.71  |
| Average     | 0.14       | 93.11                | 50.62        | 46.99                       | 39.22               | 7.66            | 4.93            |
| Siak 1      | 0-10       | 0.17                 | 91.19        | 57.70                       | 49.22               | 44.03           | 5.19            | 5.30  |
| Siak 2      | 0-10       | 0.15                 | 92.27        | 66.66                       | 54.41               | 47.03           | 7.38            | 9.01  |
| Average     | 0.16       | 91.73                | 62.18        | 51.82                       | 45.53               | 6.29            | 7.16            |
| S. Gasip area 1 | 0-10    | 0.09                 | 95.96        | 44.69                       | 35.30               | 32.32           | 2.99            | 3.77  |
| S. Gasip area 2 | 0-10   | 0.15                 | 92.98        | 49.09                       | 36.72               | 33.51           | 3.21            | 3.31  |
| S. Gasip area 3 | 0-10  | 0.14                 | 94.09        | 55.05                       | 44.70               | 41.26           | 3.44            | 6.56  |
| Average     | 0.13       | 94.34                | 49.61        | 38.91                       | 35.70               | 3.21            | 4.55            |
| Selat panjang 1 | 0-20   | 0.17                 | 91.83        | 65.80                       | 51.62               | 48.65           | 2.97            | 3.15  |
| Selat panjang 2 | 0-20  | 0.18                 | 90.33        | 79.33                       | 64.59               | 61.12           | 3.48            | 2.05  |
| Selat panjang 3 | 0-20  | 0.18                 | 90.17        | 75.33                       | 60.56               | 58.21           | 2.35            | 2.02  |
| Selat panjang 4 | 0-20  | 0.17                 | 91.24        | 64.70                       | 53.11               | 51.07           | 2.04            | 1.97  |
| Average     | 0.18       | 90.89                | 71.29        | 57.47                       | 54.76               | 2.71            | 2.30            |

1-location 1, 2- location 2, 3- location 3, 4- location 4

3.2 Particle density value from three phases meter method

Values of particle density obtained by the method used in this study are presented in Table 3. The Rupat and S. Gasip area of the particle density more varied than others. The cause of the local differences are not clear yet.

Table 3. Particle density value from three phases meter

| Code       | Rupat 1 | Siak 1 | S. Gasip area 1 | Selat panjang 1 | Rupat 2 | Siak 2 | S. Gasip area 2 | Selat panjang 2 | Rupat 3 | Siak 3 | S. Gasip area 3 | Selat panjang 3 | Rupat 4 | Siak 4 | S. Gasip area 4 | Selat panjang 4 |
|------------|---------|--------|----------------|-----------------|---------|--------|----------------|----------------|---------|--------|----------------|----------------|---------|--------|----------------|----------------|
| Particle density (g/cm³) | 2.30    | 2.03   | 1.91           | 1.90            | 2.18    | 2.09   | 2.25           | 2.07            | 2.07    | 1.83   | 1.82           | 1.88           | 1.83    | 1.82   | 1.88           | 1.88           |
| Average    | 2.17    | 1.905  | 2.17           | 1.90            |

1-location 1, 2- location 2, 3- location 3, 4- location 4
The tropical peat of particle density by three phases meter in this study was found higher than 1.4 g/cm³. Based on table 4., the particle density values of peat in the European lands actually were also tend to be more than 1.4 g/cm³ (ranges around 1.26-1.80 g/cm³). The European peat data were obtained by a pycnometer measurement. Regardsles the fine and homogenous in particle, the particle density shown in table 4., are higher than 1.4 g/cm³ and varied. Therefore the range of particle density found in this study that is 1.82-2.30 g/cm³ is quite acceptable. Moreover, using a three phases meter there should no measurement problem especially in regard to coarse particle, so it can represent the whole characteristic of tropical peat which has coarse particles. In addition, the use of three phases meter is also much easier and simpler in the measurement process.

Table 4. Some specific density values of peats reported in literature

| Author       | Particle density (gr/cm³) | Kind of peat/location       |
|--------------|---------------------------|-----------------------------|
| [5]          | 1.26 – 1.80               | “peat” in general           |
| [6]          | 1.4 – 1.7                 | non-silted bogs, Byelorussia|
| [7]          | 1.4 – 1.6                 | Ash perc. 10-30%, U.S.S.R.  |
| [8]          | 1.47                      | Average Dutch high moor peat|
| [9]          | 1.49 – 1.59               | High-moor peat, North Germany|
| [10]         | 1.5 – 1.6                 | “pure peats”, U.S.A.        |

4. Conclussion
The particle density value of 1.4 g/cm³ which is currently used as a reference is considered to be low. It is supported by the data on the tropical and subtropical values which are vary above 1.4 g/cm³. The tropical peat in Riau Province had a particle density value greater than 1.8 g/cm³ by using a three phases meter. We suggest to compare the particle density measurement by using a pycnometer and three phases meter from the same soil samples.

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