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Application of Portable Soil Strength Probe on Bengkalis' Peat

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Abstract. Peat shear strength measurement in the laboratory is very challenging because undisturbed sampling of very soft peat is very difficult to get. Traditional in-situ test such as standard penetration test (SPT) and cone penetration test (CPT) on peat also have problems i.e. they are very heavy and the measurement is not sensitive on very soft peat. This study described the application of portable soil strength probe on peat. The tool can measure penetration resistance in term of stress and torsion in newton meter. Peat samplings and physical laboratory tests were also conducted. The location of the study is Bengkalis Regency, Riau Province. The result revealed that peat (up to 6-meter depth) at the location is mainly sapric, low ash content with water content more 1000%. Penetration resistance is predominantly 400 kPa. While shear test depicts that peat is mainly frictional with friction angle mainly between 17-21 degrees and very low cohesion i.e. 0.8-3kPa. This study revealed that fibre content correlate moderately with penetration resistance and shear strength. this preliminary work suggested that soil strength probe may be useful for peat characterization.

1. Introduction

Peat is partially decomposed vegetation and organic materials which are usually accumulated in a basin or shallow lake. Peat can be also developed in the former river bed. According to American Standard and Testing Material (ASTM), based on its degree of decomposition stage peat can be classified as *fibric* (young), *hemic* (intermediate) and *sapric* (old). Fibric can be identified by its fibre content (FC) which is larger than 67%, hemic between 33-67% and *sapric* less than 33%. While according to the ash content (AC), peat can be classified as low (<5%), medium (5-15%) and high (15-25%) [1].

Determination of peat mechanical properties i.e. penetration resistance/shear strength in the laboratory is a very challenging task. Taking undisturbed sampling of peat, for laboratory testing, at depth shallower than 1 meter may be done using block sampling technique. However, for particularly below 1 m depth, is cumbersome because it is very soft and the water content is high. Thus in-situ soil test is preferred. However, traditional soil investigation tools such as standard penetration test (SPT) and cone penetration test (CPT) are too heavy thus not practical in very soft peat. They are also relatively expensive in term of cost. In term of measurement of soil strength, both of them are they are not sensitive enough in very soft peat. Based on the author's knowledge of soil investigation in Riau province SPT usually penetrate on its own weight before it is hammered. SPT value on peat usually



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range in a very narrow value of from 0-2. While penetration resistance value from mechanical CPT on peat usually less than 1000 kPa. It should be noted the accuracy of mechanical CPT measurement is 100kPa and 500kPa for 6000 kPa and 25000 kPa manometer respectively.

This study describes the application of a **portable and cost-effective** soil investigation tools i.e. soil strength probe or *Dosoukyoudokensabou* (*Doken*), patented by Sasaki [2], to determine penetration resistance and shear strength component of peat. To the best Author's knowledge this is the first study of the tools on peatland in Indonesia. Laboratory tests were also performed to determine peat physical properties.

2. Methodology

2.1. Location

The location of this study is in Bengkalis Island, Riau Province, -Indonesia. Bengkalis is an island which located at eastern coastal of Sumatra Island i.e. $1^{\circ}30'0''$ N and $102^{\circ}15'0''$ E. Figure 1a shows the location of the study regionally. Bengkalis Island was chosen because it is a peat island [3] and Authors' previous studies [4]. Based on the geological map, the lithology of the location is classified as alluvial composed of clay, silt, clean gravel, vegetation raft and peat swap. Aquifer can be classified as moderate to low transmissivity, depth to water table varies and well generally yield less than 5 litre/sec [5]. Figure 1b shows the point of location of the study i.e. $1^{\circ}29'39''$ N, $102^{\circ}23'40''$ E.



Figure 1. Location of study

2.2. Equipment

The main equipment used in this study are soil strength probe, peat sampler and laboratory apparatus. More information about the equipment is described in the following sub section.

2.2.1. Soil strength probe or *Dosoukyoudokensabou*. It is a very portable tools because for a 5 m depth test, the whole apparatus weight only 4.5kg. It consists of doken penetration cone 15mm diameter with a tip angle of 60° , calibrated spring to measure force, 10mm diameter rod, torque wrench, vane cone and handle (Figure 2a). There are two measurements that can be done i.e. penetration resistance profile (interval 10 or 20cm) using doken penetration cone and estimation of shear strength (cohesion and angle of friction) at certain depth using vane cone. The smallest doken penetration load is 2.5N which is equivalent of about 14kPa, more sensitive than mechanical CPT. For shear strength measurement at certain depth, a vertical load (less than maximum doken penetration resistance) is held at a certain value then the rod is rotated until the torque measurement does not increase anymore (Figure 2b). The vertical load (at the same depth and hole) then is increased then torque is measured again. The process is repeated at increased vertical load as necessary. A plot of vertical load and shear stress, similar to laboratory direct shear test, can be drawn to determine cohesion (y-intercept) and angle of friction i.e. slope of regression line [6]. The apparatus has been used in recent years for

various soil investigation purposes such as assessment of surface slope stability, river embankment and embankment [7, 8].



Figure 2. Soil strength probe parts (a) Vane cone shear test (b)

Equations used in the calculation are

$$q_{dk} = \frac{Q_{dk}/1000}{A} \quad (1)$$

$$Q_{dk} = W + (m^0 + n \times m^1) \times g \quad (2)$$

where:

- q_{dk} = Doken penetration resistance
- Q_{dk} = Total vertical force (N)
- A = cone area ($1,76 \times 10^{-4} \text{ m}^2$)
- W = Vertical force reading (N)
- m^0 = weight of cone and 450mm rod (kg)
- n = number of 500mm rod
- m^1 = weight of 500 mm rod (kg)
- g = gravity acceleration $9,81 \text{ m/s}^2$

Empirical formulas then may be used to calculate vertical stress and shear stress.

$$\sigma = 2,4 \times 10^2 \times W_{vc} \quad (3)$$

$$W_{vc} = W_N + (m^0 + n \times m^1) \times g \quad (4)$$

$$\tau = 1,5 \times 10^4 \times T_{vc} \quad (5)$$

$$T_{vc} = T_N - T_0 \quad (6)$$

where:

- W_{vc} = Applied vertical force on vane cone (N)
- T_{vc} = Net applied torque (N.m)
- W_N = Vertical load (N)
- T_N = Maximum torque with load W_N (N.m)
- T_0 = Maximum torque without vertical load (N.m)

Shear strength of soil, s , can be calculated as

$$s = c + \sigma \tan \phi \quad (7)$$

where σ =effective stress. For frictional material shear strength can be approximated as $\sigma \tan \phi$

2.2.2. Peat Auger. “Eijkelkamp” Russian type peat sampler was used in this study (Figure 2). It comprises of consists of peat sampler, extension rods and rotating handle. The peat sampler consists of hooked blade (fin) and half cylindrical tube (gouge) that has sharp edge to cut soil or peat. At first the

gouge is open and when the rod handle is rotated, it close and cover the cut soil sample. Sample length is 50cm.



Figure 3. Peat auger Russian type.

2.2.3. Laboratory apparatus. Laboratory apparatus used in this study are pocket and laboratory scale to weight sample in the field, oven to measure water content, furnace to measure ash content.

2.3. Procedure

The locations of peat sampling and soil strength probe were chosen close to each other (about 1m). Once the sample is taken to the surface (interval 50 cm), the peat is observed visually. A small sample is taken from the peat sampler using plastic ring (known volume), weigh it using pocket scale, thus the moist weight can be measured which later oven in the laboratory to get the moist unit weight and water content. The leftover sample is put in the labelled plastic bag for other laboratory test e.g. specific gravity, ash content, fibre content. After peat sampling is finished, soil strength probe test was conducted.

3. Results

Peat boring was conducted to about 6-meter depth, which mineral soil i.e. clay was encountered. Based on visual observation the peat at the site is predominantly sapric (Figure 3) and very soft. Table 2 shows laboratory test results on the peat physical properties. Water content (w) is mainly more 1000%. Specific gravity (G_s) range from 0.87-1.65 while dry unit weights (γ_{dry}) lie between 0.75-0.91 kN/m³. Void ratio (e_o) range between 8.94-16.87, indicating very porous media. The majority of ash content values are less than 7% indicating relatively high organic content, thus can be classified as low ash content. This results in in line with visual observation.



Figure 4. Peat sample.

Result from soil strength probe test in term of penetration is presented in Figure 4. The penetration resistances range from 221-1201 kPa while the majority of them is at value of 400 kPa (Figure 5). kPa. Those values are within the typical value of CPT on peat. The 1201 kPa penetration resistance at 3m depth may be due to the present of wood chunk. It was hypothesized that peat penetration resistance from higher to lower are those of fibrous, hemic and sapric respectively. Unfortunately, there is no clear distinct difference in penetration resistance between sapric and hemic in this study (there is only

one data of hemic peat in this study i.e. at 4m depth). Further study and more data are required to validate the hypotheses.

Figure 6 illustrates normal and shear stress relationship at depth 2m from the vane cone test which show reasonable trend i.e. higher normal stress tend to increase shear stress. Table 2 shows result from vane cone test at various depth. The table shows peat has low cohesion, c , value (0-3kPa) and friction angle, ϕ , between $17-21^\circ$. This observation is in accordance to previous literature [8,9]. This suggest that peat is a frictional material rather than cohesive one [10].

Table 1. Laboratory Results

Depth (m)	Water content w (%)	Wet unit weight γ (kN/m ³)	Dry unit weight γ_{dry} (kN/m ³)	Gs	Void ratio e_o	Ash content (%)	Fibre content (%)	Note
1	1465	11.67	0.75	1.16	14.28	3.23	9.13	Sapric
2	1245.7	11.70	0.87	1.15	11.92	1.41	7.92	Sapric
3	1378.1	13.40	0.91	1.65	16.87	1.33	20.60	Sapric
4	1392.8	12.80	0.86	0.87	8.94	1,37	42.72	Hemic
5	1335.3	12.12	0.84	1.20	12.96	3.12	31.22	Sapric
6	997.4	10.36	0.94	1.58	15.41	6.41	17.70	Sapric

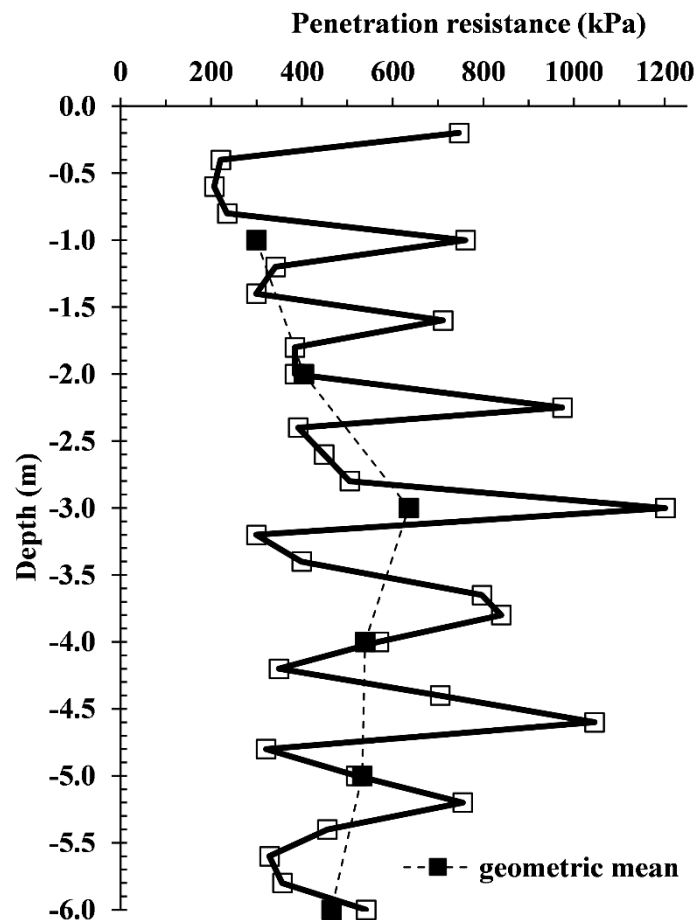


Figure 5. Penetration resistance

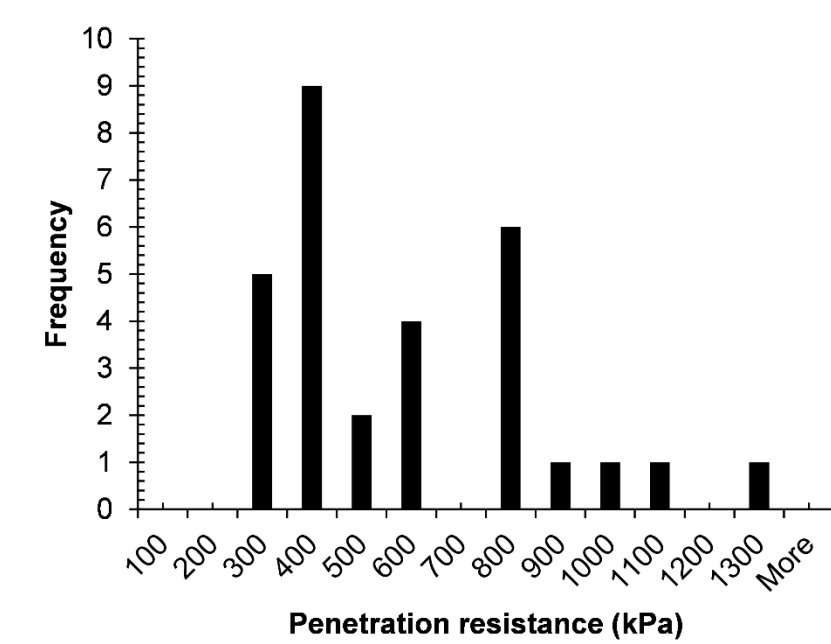


Figure 6. Distribution of penetration resistance

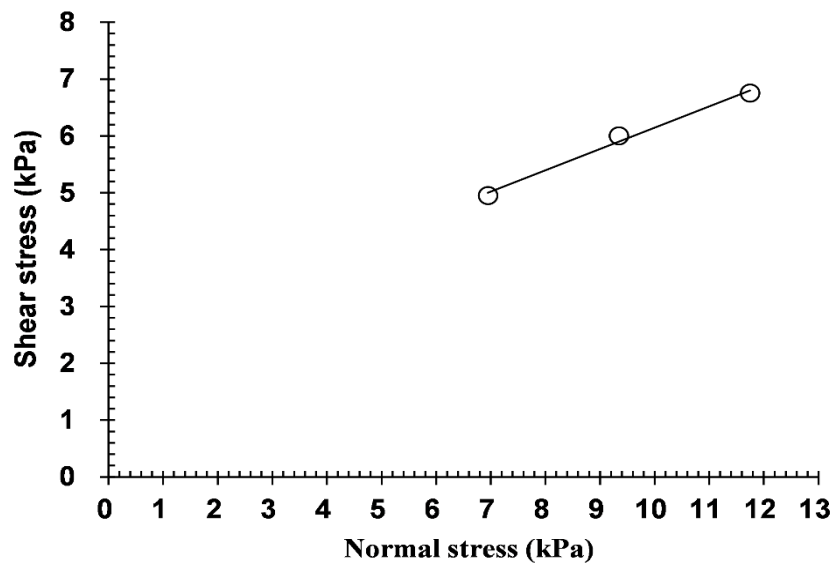


Figure 7. Example normal stress vs shear stress at 2m depth

Table 2. Shear stress component and shear strength

Depth (m)	c (kPa)	ϕ (degree)	s^* (kPa)	Note
2	2.4	20.6	1.43	*frictional material
4	0	17.4	3.26	$s \approx \sigma'_v \tan \phi$
5	0.9	18.1	4.16	
6	3.4	17.4	4.16	

It was hypothesized also that fibre content affect penetration resistance and shear strength [11]. Figure 7(a) shows that fibre content has moderate correlation [12] to geometric mean penetration resistance (one-meter interval) with coefficient of correlation $r=\sqrt{R^2}=0.63$. Likewise, a moderate correlation was also found between fibre content and frictional shear strength but with lower r value i.e. 0.51 (Figure 7b). These trends should be further investigated in the future.

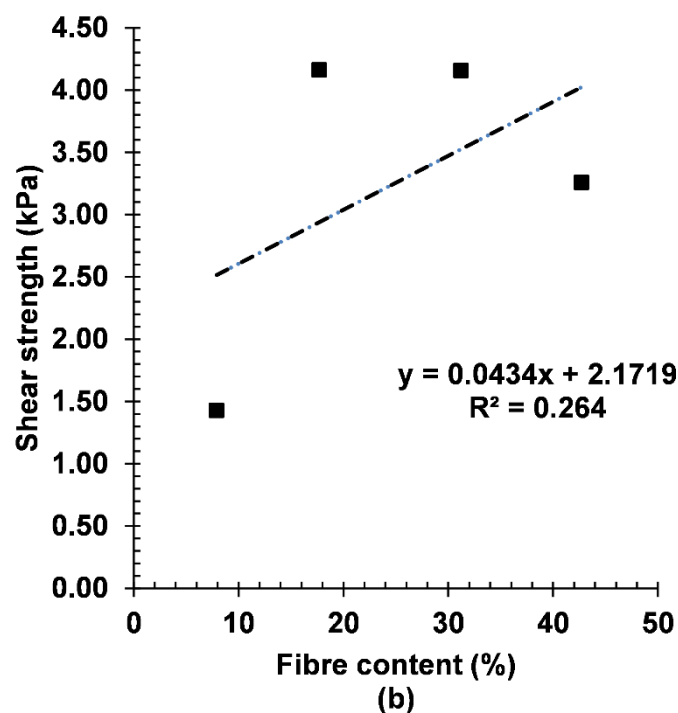
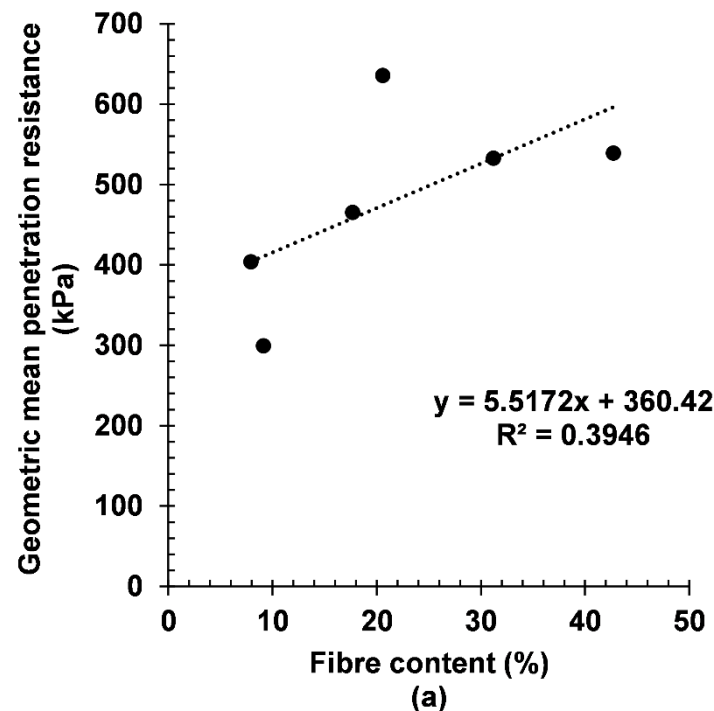


Figure 8. Effect of fibre content to penetration resistance(a) and shear strength (b)

4. Conclusions

Preliminary work of the application of soil strength probe to measure penetration resistance and shear strength component of Bengkalis' peat was conducted. Laboratory test shows that the peat can be classified as sapric and low ash content. The penetration resistances range from about 200-1200 with a predominant value of 400 kPa. This study reveals that peat on the site is mainly frictional material with a friction angle between 17-21 degrees. Fibre content correlates moderately with geometric penetration resistance and shear strength. This study suggests that soil strength probe could be useful for peat characterization. Further study and more data may give useful correlation between physical and mechanical properties of peat from soil strength probe.

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