PHYSICAL, GEOTECHNICAL AND MORPHOLOGICAL CHARACTERISTICS OF PEAT SOILS FROM SARAWAK

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ABSTRACT

In Malaysia, Sarawak has the largest area of peat-land in the country, covering approximately 1.66 million hectares. With the rapid industrialisation and population growth, construction is scheduled almost all over the place including the area of peat-land. As peat or highly organic soil is a major problem in infrastructure development of the tropical and coastal regions, we should initially discern the physical and geotechnical properties of these soils. The current study describes the physical and geotechnical properties of tropical peat soils from Matang, Sarawak. Different physical properties e.g. organic content (OC), liquid limit (LL), fiber content (FC), and specific gravity (G_s) and geotechnical properties e.g. compaction, and Unconfined Compressive Strength (UCS) test have been conducted on remoulded peat soil samples. The results show that peat has very high moisture content and organic content; low specific gravity, dry unit weight and UCS value. Also, Scanning Electron Microscope (SEM) images were taken for some peat soil samples in order to study their microstructures.

Keywords: *Geotechnical Properties, Physical Properties, SEM, Tropical Peat Soil*

1.0 INTRODUCTION

The state of Sarawak is crossed by deep rivers and contains extensive freshwater wetlands and salty mangrove peat swamps or soils. These peat soils have been identified as one of the major groups of soil found here and it has the largest peat land area in Malaysia which is about 16,500 km^2, of which about 90% of the peat is more than 1 m in depth [1], which contributes difficulties in construction industries. High rain fall intensity of 120 inches per year makes peat soils become extremely soft and wet. Figure 1 shows the distribution of peat land in Sarawak [2].

Peat soil is a major problem in the infrastructure development of the coastal areas in Sarawak and generally considered as problematic soil in any construction project, because of its high compressibility and very low shear strength [3]. With the rapid industrialisation and population growth, it has become a necessary to have infrastructure facilities in peat-land as well. Before endorsing any types of construction on it, we should determine the physical and geotechnical properties of these soils.

Several researchers have studied on the soft or peat soil stabilisation and their physical properties [4-12]. Few researchers have discussed on the morphological investigation of clay and peat soils [13-17]. However, most of these studies concentrate on the stabilisation and very few studies are available on physical or geotechnical properties of original peat or soft soil from East Malaysia especially from Sarawak. Hence, the present study concentrates on determining the physical, geotechnical and morphological characteristics of peat soil samples from Matang, Sarawak, Malaysia, for better understanding of the behavior of these peat soils.

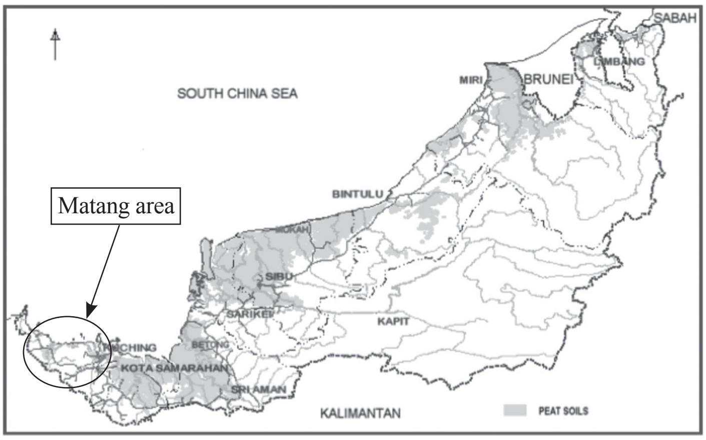

Figure 1: Peat soil distribution map in Sarawak, Malaysia [2]

2.0 TEST MATERIALS AND METHODOLOGY

Different types of peat soils were collected from six different locations (e.g., L_1 to L_6) in Matang area (from 0.40 to 0.80 m depth) designated as M_1 to M_6, respectively. The locations of sampling are shown in Table 1, as global coordinate. First the peat soil was sundried, grinded and passed through specific sieve and used for various physical and engineering properties test.

Table 1: Global coordinate or position of peat soil samples collected

Sample Location	Designation	Position
Taman Malihah-1	M_1	N 01˚ 33.986'; E 110˚ 15.464'
Taman Malihah-2	M_2	N 01˚ 33.997'; E 110˚ 15.415'
Kopodim-1	M_3	N 01˚ 34.782'; E 110˚ 16.396'
Kopodim-2	M_4	N 01˚ 34.914'; E 110˚ 16.400'
SMK Matang-1	M_5	N 01˚ 34.030'; E 110˚ 15.326'
SMK Matang-2	M_6	N 01˚ 35.730'; E 110˚ 16.440'

2.1 Physical Properties

The natural moisture content of peat soil samples has been determined as per BS 1377: Part 2: 1990 [18]. The Loss on Ignition has been determined as a percentage of oven-dried mass as per ASTM D 2974 [19]. The moist sample is first dried in the oven at a temperature of 105°C for 24 hours then the oven dried sample was kept in a muffle furnace at temperature of 550°C for 4 to 5 hours. The sample was then cooled at room temperature and the change in weight is calculated as Loss on Ignition. Organic content (H) is calculated according to an equation proposed by Skempton and Petley [20] as follows:

$$H\ \% = 100 - C\ (100 - N) \qquad (1)$$

Where, *C* is the correction factor (=1.04 for temperature 550°C; Edil [21]) and *N* is the loss on ignition in percent. The degree of decomposition is generally assessed by means of the Von Post scale. There are 10 degrees of humification (H_1 to H_{10}) in the Von Post system [22]. The specific gravity (G_s) of the highly organic or peat soil is determined based on procedure stated in BS 1377: Part 2: 1990 [18]. In this test, Gs is determined by using small pyknometer and the average Gs is obtained from the results of three tests. The fiber content (FC) is determined from dry weight of fibers retained on ASTM sieve no. 100 (>0.15 mm opening size) as a percentage of oven dried mass [23]. In this study, cone penetrometer method has been used to determine the liquid limit (LL) of peat soil sample. The LL and pH test have been conducted as per guidelines based on BS 1377: Part 2: 1990 [18].

2.2 Engineering Properties

Standard Proctor test has been conducted as per BS 1377-1990: Part 4 [18] to determine the maximum dry density (MDD) (γd) and the optimum moisture content (OMC) of the peat soil sample. To determine the undrained shear strength of the original remolded peat soil, the UCS test has been conducted according to the guidelines provided by ASTM D 2166 [24]. The size of the mould used in this study was 38 mm in diameter and 76 mm in height. A rate of strain of 1.27 mm/min has been maintained throughout the tests. For the sake of consistent results, a minimum of 3 samples have been tested. The prepared specimens were kept for 1 hour at room temperature in open space and then tested.

2.3 Microstructure Analysis

The SEM micrographs of only M_1, M_3 and M_6 peat soil samples (with the highest, medium and lowest fiber/organic content, respectively) have been conducted to study the morphology of the samples. SEM can produce high resolution three dimensional image of specimen surface. SEM consists of an electron gun (V-shaped tungsten filament) which emits electron beam thermionically when heated to a certain temperature and because of the application of high negative voltage this electron beam is directed towards anode (electron gun acts as cathode). The electron beam is refined by a system of electromagnetic lenses before it strikes the specimen. The specimen is inserted in a 'specimen stage' which is located in the direction of impinging electrons. These beaming electrons after striking the specimen surface produce secondary electrons which are then collected by a 'secondary electron detector' to generate a variety of signals. These signals are processed and converted into a series of pixels which can be viewed on a cathode ray tube or monitor (Bozzola and Russell [25]). The oven dried peat soil samples used in this tests which were coated with gold before taking SEM images. The SEM test was conducted by using the instrument JEOL, Japan, with model no. JSM-6701F. The micrographs were taken at a magnification of 1000 for all three samples.

3.0 RESULTS AND DISCUSSION

3.1 Physical Properties

The results of different physical properties of the peat soil samples are presented in Table 2. From Table 2, it is found that the moisture content of the peat soil is very high, this may attributed to the fact that, peat soils have high fiber content which is able to absorbed water. Huat [3] stated that the natural water content of West Malaysian peat varies from 200 to 700% and East Malaysian peat varies from 200 to 2207%. Our value also falls within the ranges. From the laboratory test, it has been observed that the sample M_1 to M_5 falls in the category with degree of humification H_4 to H_6 (Hemic) and sample M_6 can be categorized as H_7 to H_{10} (Sarpic); according to the Von Post scale. If the percentage of organic content (OC) in soil is more than 75% then the soil can be categorised as peat soil as per ASTM D 2607 69 [26]. In this study sample M_4 and Sample M_6 contain less than 75% OC and can be categorised as highly organic soil. The remaining soil samples can be categorised as peat. The result shows that M_1 soil sample has higher fiber content (FC) than others soil samples and the sample M_6 has lowest fiber content (FC).

Den Haan [27] studied that, the specific gravity in organic or peat soils is affected by the organic constituents; e.g., cellulose and lignin which are having lower specific gravity, approximately 1.58 and 1.40, which causes the reduction in specific gravity of peat soils. Huat [3] also reported that for tropical peat soil, G_s ranges from 1.07 to 1.7. In the present study, specific gravity (G_s) for the peat soil samples tested also falls within the ranges except for sample M6. The Gs value for sample M6 is higher as compared to the other samples tested. This may be attributed to the fact that sample M_6 is highly decomposed and has lowest fiber content (FC).

The LL value is higher for M_1 sample because M_1 sample contains more fiber which results in high water absorption capacity compared to the other samples. It is also found that all samples collected from Matang are non-plastic. The result also shows that sample M_2 has lower pH value than other peat soil samples and sample M_6 has the highest value. As a result, M_2 sample is more acidic due to the higher organic content.

Table 2: Physical properties for different peat soil samples

Property	Sample					
	M_1	M_2	M_3	M_4	M_5	M_6
Natural moisture content, (%)	620.14	473.70	360.72	787.04	623.76	605.63
Degree of decomposition	H_3	H_5	H_6	H_4	H_4	H_7
Loss on Ignition, (N) (%)	85.67	79.70	67.88	83.08	81.59	44.74
Organic content, (H) (%)	85.10	78.88	66.60	82.40	80.85	42.53
Specific gravity, (Gs)	1.45	1.62	1.64	1.48	1.56	1.82
Fiber content (FC) (%)	65.00	63.45	61.40	64.25	63.55	31.98
Liquid Limit (LL) (%)	78.00	79.00	73.00	75.00	77.00	69.00
pH value	4.05	4.64	5.15	4.25	4.33	6.18

3.2 Engineering Properties

3.2.1 Standard Proctor Test

Standard Proctor test were carried out for peat soil samples and the results are presented in Figure 2 and Table 3. From Figure 2, it can be noticed that for the soil sample M_6 has MDD of 0.88 gm/cm^3 and the value of OMC is 54.95%. It can also be observed that this soil sample has the maximum dry density and minimum moisture content as compared to the other samples tested in this study. This may be attributed to the fact that sample M_6 has lower fiber content (FC) and as a result, it has lower water absorption capacity compared to the remaining peat soil samples.

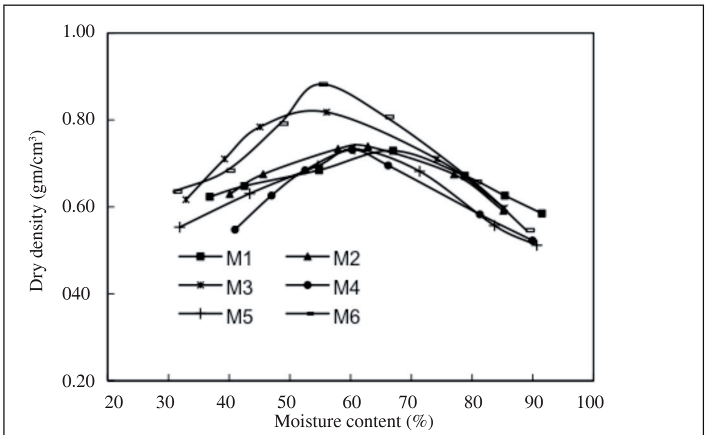

Figure 2: Standard Proctor test for different peat soil samples

The maximum dry density of the peat sample tested in this study varies from 0.72 to 0.88 gm/cm^3. Our result falls within the range as reported by Huat [3]. The bulk densities of peat are in the range of 0.8 to 1.2 gm/cm^3 whereas the dry densities are 0.1 to 1.4 gm/cm^3.

3.2.2 Unconfined Compressive Strength Test

The UCS tests have been conducted for all soil samples compacted at its MDD and OMC of the soil and the results are presented in Table 3. In this study UCS value for original remoulded peat soil sample varies from 14.23 to 21.62 kPa. Behzad and Huat [28] also mentioned in their study that the UCS value for remoulded peat is 22 kPa.

It can be noticed that considerably higher compressive strength has been obtained from M_6 samples, it may be attributed to the fact that the sample M_6 has lower fiber content (FC) (i.e., 31.98%) which results lower water holding capacity and higher compressive strength. Also M_1 sample has lower UCS strength value it may be to the fact that, the M_1 sample has higher fiber content (FC) and organic content (OC).

Table 3: Geotechnical properties for different peat soil samples

Property	Sample					
	M_1	M_2	M_3	M_4	M_5	M_6
Optimum moisture content (OMC) (%)	65.36	62.84	56.10	60.25	60.64	54.95
Maximum dry density (MDD) gm/ cm^{-3}	0.72	0.74	0.83	0.73	0.73	0.88
Unconfined compressive strength (UCS) (kPa)	14.23	17.25	19.15	18.00	14.85	21.62

3.3 Scanning Electron Microscope (sem)

Scanning electron micrographs of peat soil samples M_1, M_3 and M_6 are shown in Figures 3, 4 and 5, respectively. Figure 3 shows that M_1 soils are composed of fibers, woody and porous in nature compared with M_3 and M_6 samples. Figure 4 shows that M_3 sample is more compact than M_1 sample. From Figure 5 (sample M_6), it can be observed that the particles are plate/sheet-like clay type structure. It may be attributed to the fact that, the more fibrous/organic content a soil is/has, the more porous space it has.

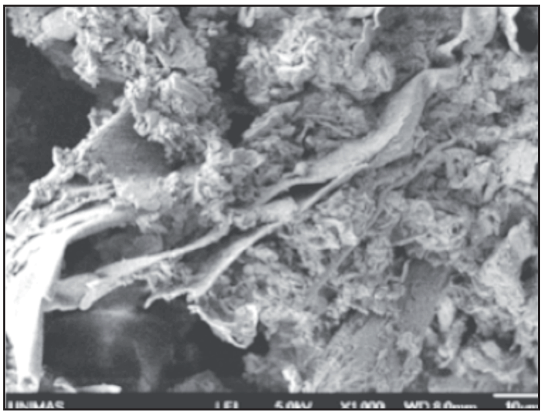

Figure 3: SEM micrograph of the peat soil sample M_1

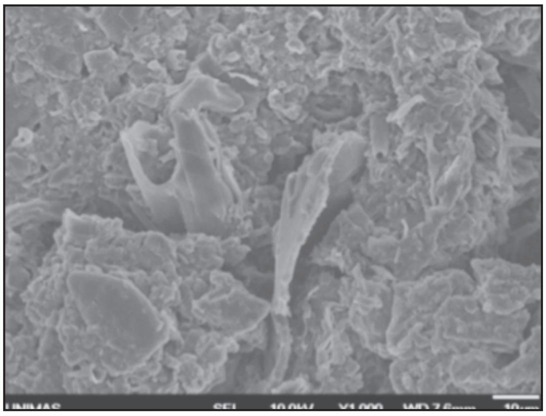

Figure 4: SEM micrograph of the peat soil sample M_3

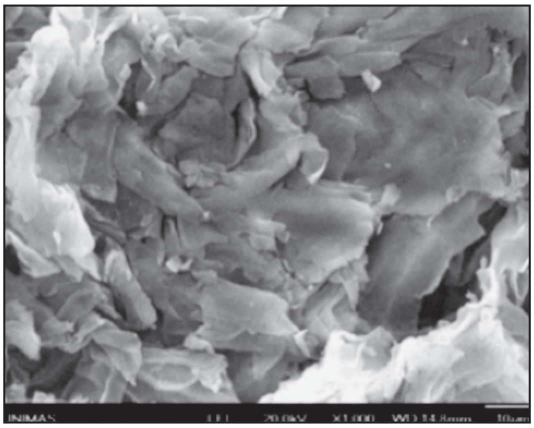

Figure 5: SEM micrograph of the peat soil sample M_6

4.0 CONCLUSIONS

The present paper investigates the physical, geotechnical and morphological properties of different types of peat soil samples from Matang, Sarawak, Malaysia. From the laboratory tests results, the following conclusions can be drawn:

i. The ranges of the natural moisture content, G_s, and pH for peat soil samples are between 360 to 787%, 1.45 to 1.82 and 4.05 to 6.18, respectively.
ii. The result shows that, FC, OC and *N* are within the ranges, 31 to 65%, 42 to 85% and 44 to 85%, respectively and according to the Von Post scale the sample M_1 to M_5 is Hemic and the sample M_6 is falls in the category of Sarpic.
iii. The standard Proctor test result shows that MDD and OMC ranges approximately between 0.72 to 0.88 gm/cm^{-3} and 55 to 65%, respectively.
iv. The result of UCS test shows that, the strength for different peat soil samples is between 14.23 to 21.62 kPa.
v. SEM result shows that the peat soil sample M_1 contains more fibers, woody and porous as compared with the samples M_3 and M_6. From sample M_6, it can be observed that the particles/fibers are so packed, plate or sheet-like and strongly bonded.

From the available data and to be established data bank on the region's peat soil compiled by the Construction on Soft Soil (CoSS) Group of UNIMAS, it is hope that the local geotechnical engineers can easily understand the behavior of physical and geotechnical properties as well as morphological characteristics of Sarawakian peat soils.

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