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Correlation of Different Peat Soil Index Properties

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Abstract: The present study focuses on the physical properties of Sarawak peat soil and identifies the correlation between the index properties of peat from the present study and various locations in Malaysia. The physical properties of peat from the present study were obtained on site and in the laboratory, including degree of humification, moisture content, organic content, fibre content, specific gravity, liquid limit, linear shrinkage, and pH. The data obtained in this study and other tropical peats in Malaysia were compiled to identify their correlations. The correlation results reveal that with an increase in organic content, there is also an increase in value of moisture content, while the value of specific gravity reduces. Furthermore, as the bulk density of peat increases, the value of organic content reduces. Also, the moisture content, organic content, and fibre content of peat decrease with the increasing value of degree of humification. The correlations between different peat soil index properties have R^2 values ranging from 0.75 to 0.85, showing that the peat soil index properties are consistent with findings from previous studies, in which comparable trends are found. Thus, these correlations are expected to be useful for researchers and engineers to understand the peat soil's preliminary behaviour.

Keywords: Correlation, peat soil, index properties

1. Introduction

Peat is a form of organic soil that exists in swampy and wetlands areas, and it is comprised of a heterogeneous mixture of partially degraded plant remnants preserved by a high-water table [1]. Peatlands are being developed all over the world, including Malaysia, which has 2.4 million hectares of peatland and 1.65 million hectares in Sarawak alone [2]. Due to the massive volume of peatland area in Sarawak, infrastructure development has been through a lot of difficulties. Also, peat's physical and geotechnical properties are extremely difficult to determine as it exhibits high levels of permeability, porosity ratio, compressibility, and consolidation settlement. Zainorabidin & Muhammad [3] classified peat for the entire country of Malaysia as essential knowledge to improve understanding on behaviour of peat soil in tropical conditions. Kolay & Pui [4] focused on identifying peat using various index properties and determined the correlation between various index properties as it is useful for researchers and engineers dealing with peat soil. In addition, the properties of peat vary according to its locality due to several components, such as temperature, humidity, fibre composition, and climate, which may lead to different outcomes when improving the peat soil [5]. Hence, it is necessary to consider these factors in improving the intensity of peat soil since it is a major concern that frequently occurs in construction projects and the development of infrastructure.

In the literature, several researchers have reported the correlation between peat soils' index properties according to their locality. Some researchers evaluated the relationship between numerous physical and geotechnical characteristics

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of peat soils. However, there are limited data on the correlation between the index properties of peat in the entire Malaysia as different localities have varying physical and geotechnical properties. Hence, this study focuses on Sarawak peat soil's physical properties, as well as identifies the correlation between the index properties of peat from the present study and various locations in Malaysia. Thus, the correlations obtained in this study are expected to be useful for researchers and geotechnical engineers to understand the peat soil's preliminary behaviour.

2. Material and Methods

Fig. 1 shows the location of peat soil samples obtained at Kota Samarahan, Sarawak, Malaysia, at the coordinates of 1°26'31.1" N, 110° 28'54.3" E. The sampling area is surrounded by pineapple farm and considered to have less development, potentially due to the existence of peat soil in the area. Peat samples were extracted, and the thickness of the peat layer was established using a peat auger equipment. The peat layer was located at depths of 0.10 to 1.50 m below the ground surface and is considered a potential threat to proposed building or roadway construction projects. The peat samples were then collected in bulk and sealed in two layers of plastic bags to prevent moisture loss from the samples. Next, the Von Post classification test was performed at the site as shown in Fig. 2 by squeezing the peat in hand. Fig. 3 shows the oven dried peat sample after being placed in muffle furnace to determine its organic content and Fig. 4 shows the oven dried peat fibres to obtain the fibre content of peat samples.

Fig. 1 - Location of peat sampling

Fig. 2 - Squeezing of peat

Fig. 3 - Oven dried sample after being placed in muffle furnace

Fig. 4 - Oven dried peat fibres

The index properties for various locations in Malaysia are presented in Table 1. From these data, correlation graphs between the index properties of peat from the present study and various locations in Malaysia were produced to identify which influential relationship parameters are useful in understanding the characteristics of peat in a tropical region.

Table 1 - Index properties of peat in Malaysia

Location	References	Organic Content (%)	Fibre Content (%)	Degree of Humification	Specific Gravity	Moisture content (%)
Sabah Peat	[3]	95.51	79.4	H6	1.28	461.65
	[6]	95.82	76.85	H7	1.25	985.4
	[7]	65.22	70.97	H6	1.34	713.35
Sarawak Peat	[8]	95.96	65.93	H4	1.17	587.15
	[9]	85.67	65	H3	1.45	620.14
		80.79	84.91	H4	1.35	519.98
		85.1	63.45	H3	1.45	620.14
	[10]	78.88	63.45	H5	1.62	473.7
		66.6	61.4	H6	1.64	360.72
	[11]	66.6	61.4	H6	1.64	360.72
		80.85	63.55	H4	1.56	623.76
		85.1	65	H3	1.45	620.14
		42.53	31.98	H7	1.82	605.63
		78.88	63.45	H5	1.62	473.7
		82.4	67.25	H4	1.48	787.04
Peninsular Malaysia Peat	[12]	80.32	40.51	H6	1.33	676.3
	[12]	94.43	36.39	H5	1.24	735.45
	[13]	78.77	40.97	H6	1.34	710.44
	[14]	86.24	-	H5	1.56	546.43
	[15]	83.6	-	H6	1.48	236.31
	[16]	93.93	63.77	-	1.46	-

	[17]	95.44	57.58	-	1.27	784.4
	[18]	98.5	49	-	1.44	659
	[17]	95.72	60.6	-	1.19	964.5
	[19]	96.4	-	H5	1.35	747.37
	[20]	80-96	62	H6	1.38	460
	[13]	76.55	43.65	H5	1.29	898.91
	[21]	97	90	-	1.47	608
	[3]	91.36	55	H6	1.14	472
	[22]	65-95	-	H5	1.38-1.7	-
	[1]	70-80	31-77	-	1.42-1.56	-

3. Results and Discussions

3.1 Physical Properties

Table 2 presents the results of physical properties tests on peat soil samples. On the Von Post scale, the sample of peat soil is categorized as having a degree of humification of H8 (sapric). The peat's natural moisture content was 1118.19%, which was in a range of 200-2207% for East Malaysia peat [5]. Due to its natural water-holding capability, peat has a high natural moisture content, making it incredibly soft and sensitive. As a result, the plastic limit of peat cannot be determined since its plasticity does not provide insight into its characteristics and the calculation of Atterberg limits is complicated by the presence of fibres [2]. The organic content of peat was calculated by measuring its ignition loss at 450°C as a percentage of its oven-dried mass at 105°C, resulting in a value of 75.88%. According to ASTM D 2607-69 [23], the sample can be classified as peat soil as its organic content was greater than 75%. The results demonstrate that the peat sample had a fibre content of 22.19%, revealing that it is sapric peat with greatly degraded components and has the highest organic content and bulk density compared to other types of peat [24]. The specific gravity of peat soil obtained was 1.28, which was in a range of 1.25-2.97 for East Malaysia peat [5]. The liquid limit of peat was 628.13%, which shows that its liquid limit increases with an increase of natural moisture content and organic content. The shrinkage limit was determined to be 13.33%, signifying that when the soil-water mixture is below this value, it is no longer saturated, and its volume does not continue to decrease as it dries [25]. Lastly, the peat sample was identified as acidic because it had a pH value of 4.25. Peat soil in the tropics is often acidic, and pH values less than 4.5 are considered as highly acidic [23].

Table 2 - Physical properties of Kota Samarahan peat soil

Physical Properties and Methods	Values
Degree of Humification, *DoH* Von Post [26]	H8
Natural Moisture Content, *w* (%) BS1377: Part 2 [27]	1118.19
Organic Content, *OC* (%) BS1377: Part 3 [27]	75.88
Fibre Content, *FC* (%) ASTM D1997-91 [28]	22.19
Specific Gravity, G_s BS1377: Part 2 [27]	1.28
Liquid Limit, *LL* (%) BS1377: Part 2 [27]	628.13
Linear Shrinkage, W_s (%) BS1377: Part 2 [27]	13.33
pH BS1377: Part 3 [27]	4.25

3.2 Correlation Between the Index Properties of Peat

This section establishes and presents the correlation between the peat index properties. Fig. 5 illustrates the correlation between peat's organic content and moisture content. The natural moisture contents ranged from 150 to 1100%, with the organic content ranging from 40 to 100%. The organic content of the peat increases with an increase in moisture content. The trend of the relationship matches with the previous correlations on organic content and moisture content reported in the literature [29]. The correlation between organic content and moisture content can be written as Eq. (1), and the correlation shows that the R^2 value is 0.80, which is reasonably good.

$$OC = -8\times10^{-5}w^2 + 0.1406w + 34.605 \quad (1)$$

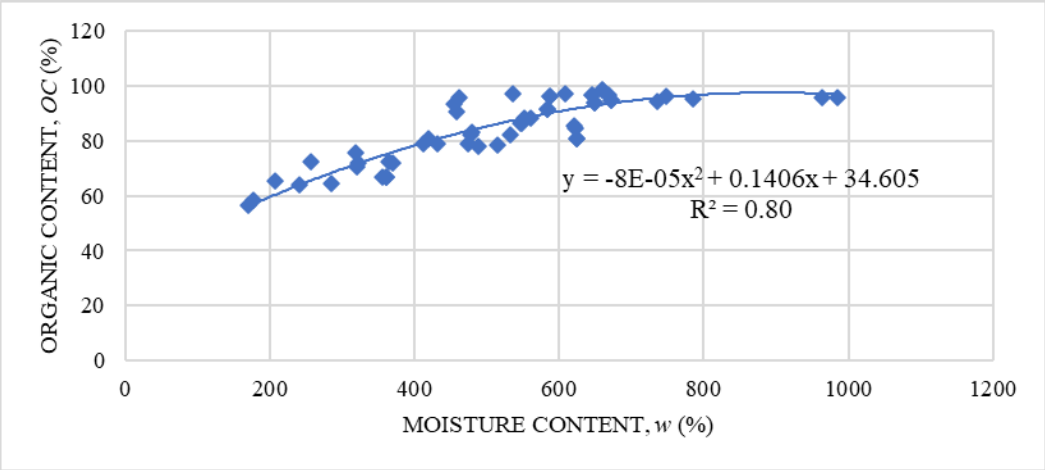

Fig. 5 - Correlation between organic content and moisture content

Fig. 6 presents the correlation between peat's moisture content and its degree of humification, as determined by the Von Post scale. There are no reported correlations in the literature between peat's moisture content and its degree of humification. The result reveals that as the degree of humification increases, the peat's moisture content decreases. According to the Von Post classification, peats categorised in the H1 to H3 range have the highest natural moisture content compared to peat categorised in the H7 to H10 range. According to Moayedi et al. [30], fibrous peat in the H1 to H3 range has a very high water-holding capability, making it the most difficult peat for engineers to work with. The R^2 value of the correlation between peat's moisture content and degree of humification is 0.84, and the correlation can be written as Eq. (2).

$$w = -88.11DoH + 905.3 \quad (2)$$

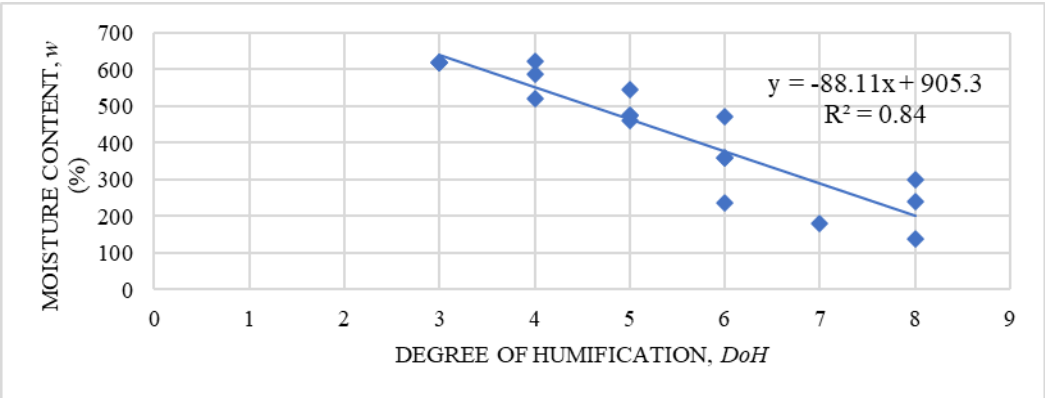

Fig. 6 - Correlation between moisture content and degree of humification

Fig. 7 plots the correlation between peat's organic content and its degree of humification, as determined by the Von Post scale. There are no published studies that show a correlation between peat's organic content and its degree of humification. Organic contents were found in the range of 60-100%, where the highest organic content is peat with H1-H3 degree of humification. The result shows that the organic content decreases as the degree of humification higher. As the organic content increases with an increase in natural moisture content, peats in the H1 to H3 range which have the highest natural moisture content contribute to the decreasing trend in degree of humification [31]. The R^2 value of correlation between peat's organic content and its degree of humification is 0.82, and the correlation can be written as Eq. (3).

$$OC = -0.9392DoH^3 + 18.114DoH^2 - 117.15DoH + 330.02 \quad (3)$$

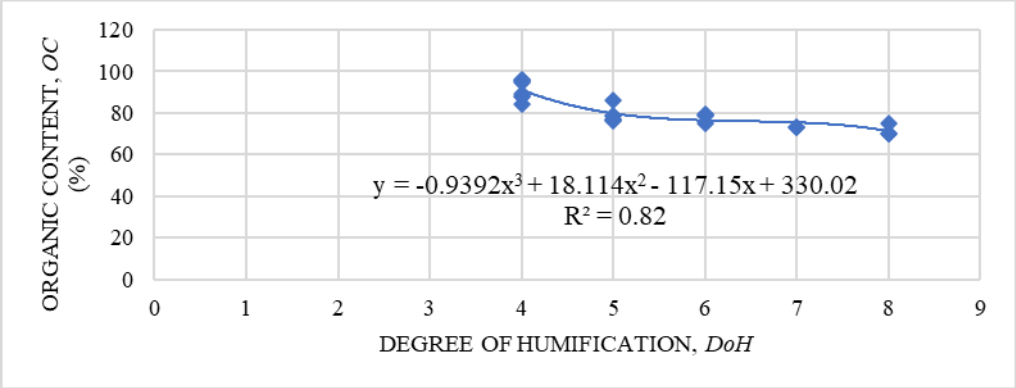

Fig. 7 - Correlation between organic content and degree of humification

Fig. 8 shows the correlation between peat's fibre content and its degree of humification, as determined by the Von Post scale. There are no published correlations between peat's fibre content and its degree of humification. The results reveal that as the degree of humification increases, the fibre content decreases. According to Jarrett [32] and IKRAM [33], fibric peat is mostly undecomposed peat with more than 67% fibre content on the H1 to H3 scale, whereas hemic peat is moderately decomposed peat on the H4 to H6 scale, and sapric peat on the H7 to H10 scale is highly decomposed peat with less than 33% fibre content. The correlation between peat's fibre content and its degree of humification can be written as Eq. (4), and the correlation shows that the R^2 value is 0.85, which is quite good.

$$FC = -12.618DoH + 131.36 \tag{4}$$

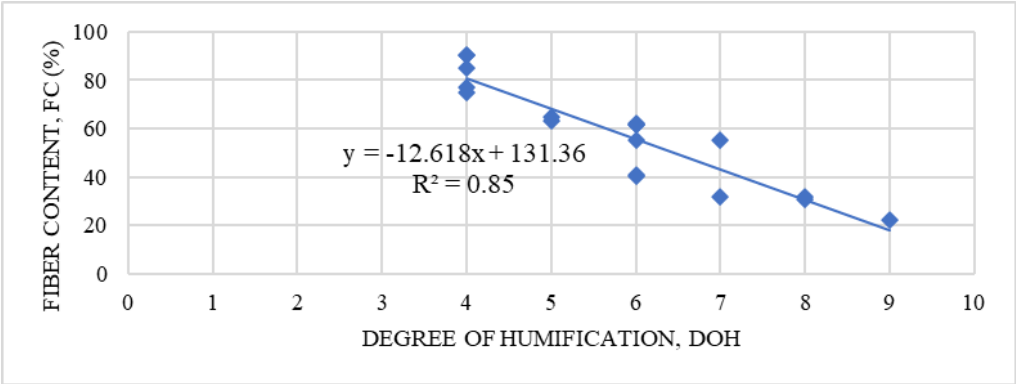

Fig. 8 - Correlation between fibre content and degree of humification

Fig. 9 presents the correlation between peat's specific gravity and its organic content. The peat's specific gravity ranges from 1.1 to 2.0, which is a typical range of specific gravity values for peat in Malaysia. The specific gravity of peat is known to decrease as the organic content of the peat increases. Peat with an organic content of 75% or more has a specific gravity ranging from 1.3 to 1.8 [34]. Huat et al. [35] discovered that a higher specific gravity value indicated a greater degree of decomposition, contributing to the decreasing trend in the organic content. The correlation developed in the present study matches well with similar correlations reported in the literature [36]. The R^2 value of the correlation between peat's specific gravity and its organic content is 0.82, and the equation can be written as Eq. (5).

$$G_s = -0.0001OC^2 + 0.0052OC + 1.7765 \tag{5}$$

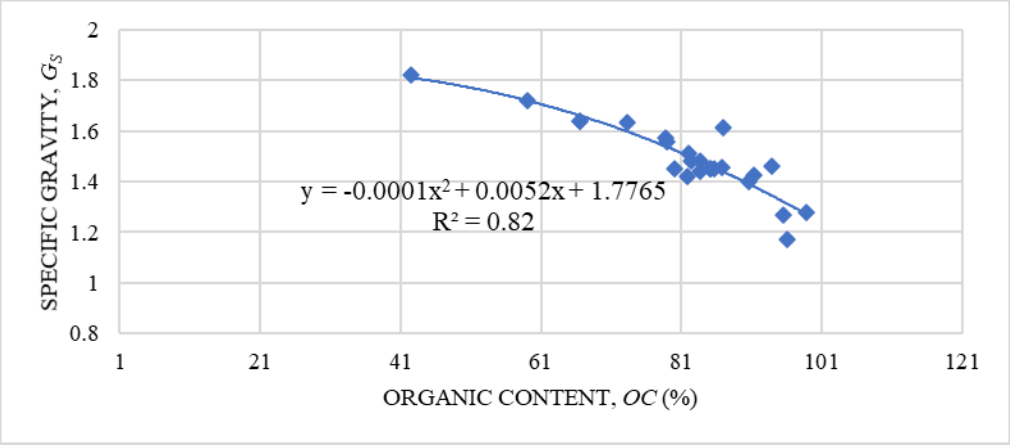

Fig. 9 - Correlation between specific gravity and organic content

Fig. 10 illustrates the correlation between the peat's organic content and bulk density. The result reveals that as peat's organic content decreases, its bulk density increases. The organic content can increase the ability of peat to hold water, but as the compaction increases the bulk density, the water holding capacity is reduced. Thus, low water holding capacity contributes to lower organic content. The developed correlation is consistent with similar correlations reported in the literature [29]. The correlation shows that the R^2 value is 0.75, and the correlation is presented in Eq. (6).

$$OC = -137.08\rho + 199.32 \tag{6}$$

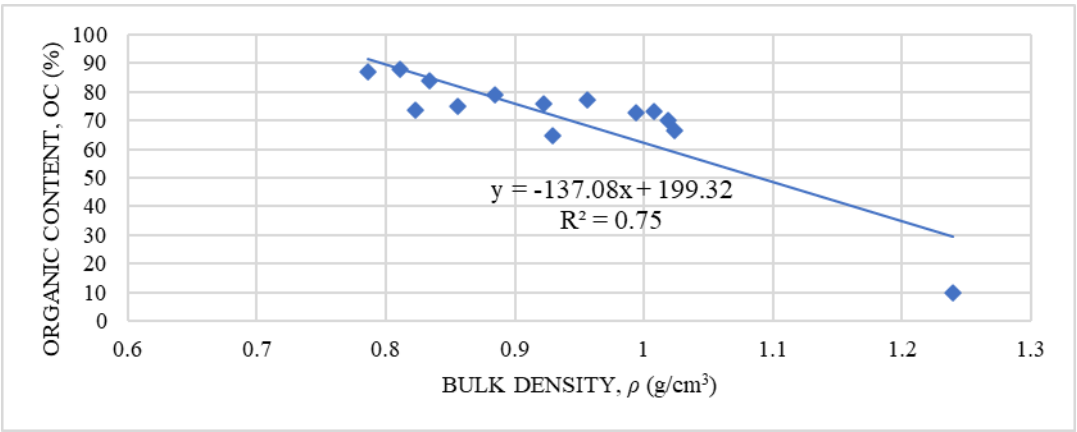

Fig. 10 - Correlation between organic content and bulk density of peat

4. Conclusion

Based on the findings, the following conclusions can be drawn:

- Seven correlations were developed among moisture content (w), organic content (OC), degree of humification (DoH), specific gravity (G_s), and bulk density (ρ) and the newly obtained correlations were compared to previously published correlations.
- As the organic content increases, the value of moisture content also increases, while the value of specific gravity decreases. The R^2 values are 0.80 and 0.82, respectively, as can be observed from the correlations.
- The value of organic content decreases, as the bulk density of peat increases. The R^2 value for the correlation is 0.75, which is a reasonable result.
- Peat's moisture content, organic content, and fibre content decrease with the increasing value of degree of humification. Also, the R^2 values for the correlation are 0.84, 0.82, and 0.85, respectively, which is a decent result.

The correlations between different peat soil index properties have R^2 values ranging from 0.75 to 0.85, showing that the peat soil index properties are consistent with findings from previous studies, in which comparable trends are found.

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