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A Systematic Literature Review on Basic Properties of Peat Soils in Malaysia

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ABSTRACT

Peat soils have low engineering properties compared to other soft soils with high permeability, high moisture content and high fibre content. It also has low pH, specific gravity, bulk density, bearing capacity, shear strength, and relatively low plasticity. The basic properties of soil are properties that facilitate soil identification and classification for engineering purposes. The purpose of this study is to determine the basic properties of untreated peat soils by conducting a systematic literature review. Peat has three classes namely fibric, hemic, and sapric according to the degree of decomposition and also can be categorized based on fibre content. From the systematic review conducted, Malaysia has all three classes of peat. The basic properties of peat in Malaysia have high water content, high organic content, high fibre content, ash content less than 25%, low pH, low specific gravity, a liquid limit between 136.11 to 309%, and the plastic limit is non-plastic. The plastic limit is difficult to obtain because of the fibre content. Based on the basic properties of peat soil, it can be used as a guide to plan and build structures from the occurrence of failures on buildings to be built below or on the ground surface.

1. Introduction

Peat has been described as one of Malaysia's major groups of soil. The peat deposit area is around 3.0 million hectares or 8% of Malaysia's total area [1]. In several countries, peat soils have been named and classed in different ways. Some as bogs, moors, muskeg, mire, tropical swamp forests as well as fens. These names assist in defining the peat through its variations caused by climate influence and the composition of the plant substance that make up the peat. Peats from Malaysia are categorized as tropical peats.

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Peat is also seen as problematic soils, primarily due to their inferior engineering properties relative to other soft soils. Peat is brownish-black in colour, generated by decomposing organic matter that has gathered over thousands of years in an oxygen-deprived environment and under waterlogged conditions. They encourage its creation. Peat is defined strictly as a soil that contains at least 65 percent organic content [2]. The peat soil has further subdivided into three zonal based on fibre content range and type: Fibric (greater than 66%), Hemic (between 33 to 66%), and sapric (less than 33%) [3]. The geotechnical properties are for the identification and classification of soil for engineering purposes. Properties of peat soil is low pH, bulk density, bearing capacity, and shear strength; and peat also has high permeability, porosity, compressibility, and settlement consolidation; and relatively low plasticity [4]. Thus, the objective of this study is to determine the basic properties of untreated peat soils.

2. Classification and Basic Properties of Peat

As a whole, the category basis for peat soil is based upon physical, chemical, and physico-chemical residential properties such as structure, organic content, mineral material, moisture content, pH, colour, and also the decomposition level. Based on the ASTM (American Society for Testing and Material) as shown in Table 1, the peat category was diminished to three (3) courses based upon fibre content, ash content, and soil level of acidity. In category of fibre content, peat is segmented right into three groups or classes which are fibric, hemic as well as sapric. The classifications of soils in ASTM are according to their ash material as well as organic content. In this classification, soil can be categorized as peat if its organic content is greater than 75% as well as its ash content was less than 25% [5].

Table 1
The classification of peat in ASTM according to fibre content and ash content

Classification of peat according to ASTM Standard	
Fibre Content (ASTM D1997)	Fibric: Peat with more than 67% fibres
	Hemic: Peat with between 33% and 67% fibres
	Sapric: Peat with less than 33% fibres
Ash Content (ASTM D2974)	Low ash: Peat with less than 5% ash
	Medium ash: Peat with between 5% and 15% ash
	High ash: Peat with greater than 15% ash

The other classification of soil based on Von Post test. The Von Post is a classification system to verify the degree of humification or decomposition of peat soil depend on water and peat soil that comes out through the fingers when the sample is squeezed by hand. Von Post is also a widely used classification system. The system classification consists of ten degrees of humification scaled from H1 to H10, representing the state of decomposition of the remaining organic plant. The degree of humification can be determined based on observations of water and soil coming out from between the fingers when squeezing soil samples in hand [2,5,6].

In Malaysia, MSCS (Malaysian Soil Classification System) also had been presented to identify organic soil and also peat. The MSCS is established based upon British Standard (BS 5930: 1981) as well as enhanced by Public Work Malaysia and Jarret (1995) to make this system a lot more specific to the Malaysian environment. MSCS utilized the degree of decomposition or humidification as an additional criterion to identify the state of degeneration of organic soil after organic material and also shown in Table 2. Another factor that considered in MSCS is the percentage of fibre content. The fibre content has three classes used in the classification of peat soils in Malaysia. This category is

fibric peat (greater than 66% fibre), hemic (around 33 to 66% fibre) as well as sapric (not more than 33% fibre) [7,8].

Table 2
Malaysia Soil Classification Systems for Peat soil [7]

Soil Group	Organic Content	Degree of Humidification	Subgroup Name	Field Identification
Peat	More than 75%	H1 – H3	Fibric or Fibrous Peat	Dark brown to black in colour. Material has low density so seems light. Majority of mass is organic so if fibrous the whole mass will be recognized plant remains. More likely to smell strongly if highly humidified
		H4 – H6	Hemic or Moderately Decomposed Peat	
		H7 – H10	Sapric or Amorphous Peat	

The basic properties of peat soils such as moisture content, ash content, organic content, fibre content, particle size distribution analysis, consistency limits, specific gravity, permeability, and pH values were carried out in the laboratory. The moisture content is an essential and also very fickle properties. The amount of moisture content of peat varies relies on origin, decomposition level as well as chemical composition. Peat naturally contains a high-water content because of its water holding ability. According to Huat et al., (2011) emphasize that the moisture content in peat soils around 200 to 2000%, where peat soils are rather different from clay and silts.

The value of organic content of peats around 35 and 79%, without any obvious trend in this worth's from one area to the next. Perhaps the lack of a trend is due to the affected of various factors like historical farming activities, the depth of the water table, the intensity of rainfall, and possibly other localities characteristics on the organic content of peat deposits in a specific place. The organic content contributes to water movement and also boosts soil water retention, leading to higher water content in peat soils [9].

Fibre content of peat soil has divided into three classes. The first class is fibrous. Fibrous is the least decomposed and its fibre content is very high compared to another which exceeds 67%. The second class is hemic and also is in intermediate decomposition. The last class is sapric, the most decomposed which is has a fibre content of less than 33% [6].

Liquid limit and plastic limit properties show greater ranges of 190 to 550% and 100 to 297%, respectively. The Atterberg limit is hard to obtain or determine due of the existence of the fibres [3].

The specific gravity of peat is considerably affected by its make-up as well as a portion of the inorganic component. It relates to the decomposition level of the peat as well as the mineral content. Greater specific gravity shows a higher degree of decomposition and also greater mineral content. Peat with an organic content more than or equal to 75%, the specific gravity remains in the variety from 1.3 to 1.8 with approximately 1.5 [5].

Permeability in peat soil plays a crucial role because as it influences the rate of consolidation and rises in the shear strength of the soil. The peat's permeability depends on void ratio, mineral content, decomposition level, chemistry, and gas presence. The permeability coefficient around 10-5 to 10-8 m/s has been obtained from past research [5]. The hydraulic conductivity of peat is often affected by density and decomposition level, but these factors often change over time, resulting in a shift in hydraulic conductivity. The peat's hydraulic conductivity can be as high as sand in its natural condition, which is around 10-5 to 10-4 m/s [5].

The soil pH value indicates the soil's acidity or alkalinity. The peat soils have actually been considered problematic soils. Usually, the soil in their natural state are not ideal for the cultivation of

a lot of crops because of the high level of acidity, range of pH is from pH 3.0 to pH 4.0 [10]. The pH of peat soil is between 3.7-5.2, with an average pH of 4.5 (acidic)[11].

3. Methodology

The method for conducting the systematic review is called PRISMA, which included resources, criteria for eligibility and exclusion, review procedures (identification, screening, eligibility), and abstraction and analysis of data. The PRISMA Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was utilized as a guide for conducting this systematic review of the literature which focused on journals or articles related to keywords. This method allows various search of terms related to the basic properties of peat soil. This methodology was used to monitor the properties of peat soils (see Figure 1).

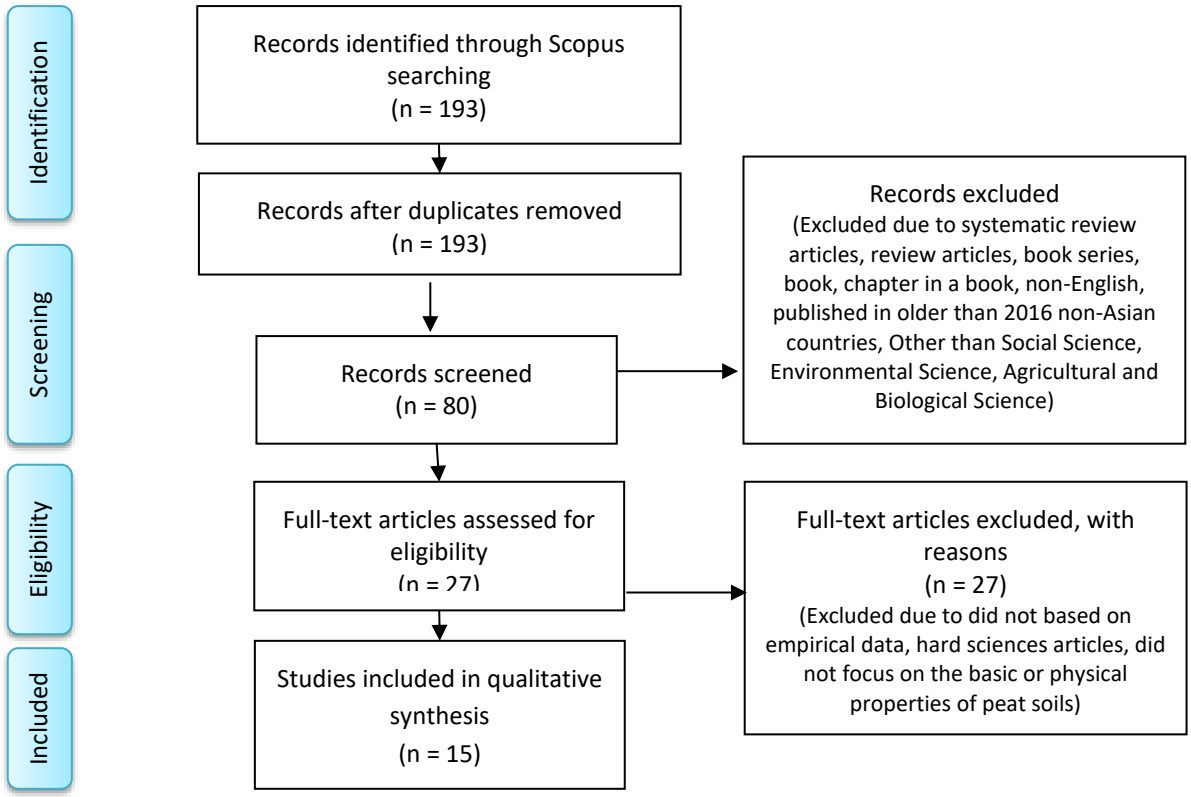

Fig. 1. A flow chart detailing the application of PRISMA

3.1 Identification

A systematic review of applications and methodologies for the basic properties of peat soil in the field of geotechnical engineering was conducted using the Scopus database. The most recent published papers were found based on several searching keywords such as peat soil, basic, properties, and testing.

3.2 Screening

A few inclusions and exclusion criteria were set. The first consideration chosen is the type of literature for which only research journals are selected. This means paper reviews, books, book

series, book chapters, and conference proceedings are all excluded. Second, to prevent confusion and difficulties in translation, the search efforts excluded non-English publications and concentrated exclusively on English-language articles. Next, the publication date of the paper was considered; only papers published within the last six years (between 2016 and 2021) were included to see the expansion of research and related publications. Lastly, only the articles related to peat soil properties were selected based on an objective focusing on peat soil properties.

3.3 Data abstraction and analysis

The remaining assessed from 27 journals were assessed and analysed. Efforts were concentrated on the basic properties of peat The data were extracted by reading the abstracts and then concentrating on the entire articles (in-depth) to identify acceptable topics and sub-topics. The final analysis will be included in the systematic review discussion.

4. Results and Discussion

The identification of articles was accomplished by searching electronic databases with the defined search terms (see Figure 1). A total of 193 articles were discovered. The records had been screened to meet at a total of 80 articles. There are 27 articles that have been evaluated for eligibility through abstract and full-text review. However, 12 articles were removed for various reasons. Therefore, a total of 15 studies were evaluated as part of the qualitative synthesis. Table 3 and Table 4 summarizes the findings of 15 articles.

Table 3
Basic properties of peat in Malaysia

Location	Authors	Moisture Content	Degree Of Decomposition	Organic Content	Specific Gravity	Fibre Content
Parit	Johari *et al.,* [12]	640.09%	H5	83.01%	1.36	61.42%
Nipah,	Azhar *et al.,* [13]	545%	H5	-	1.49	66.56%
Johor	Wahab *et al.,* [14]	502.59%	-	-	-	-
Pontian,	Kamaruidzaman *et al.,*	533%	-	92.69%	1.66	48%
Johor	[15]					
	Yacob & Som [16]	230.80%	H3	90%	0.6	-
	Dehghanbanadaki *et al.,*	495%	H3	91%	1.38	80%
	[17]					
Selangor	Daud *et al.,* [18]	443.75%	H3	92.68%	1.19	40.58%
	Jais *et al.,* [19]	599.20%	-	84.15%	1.38	46.46%
West	Wahab *et al.,* [14]	476.85%	-	-	-	-
Malaysia	Zambri & Ghazaly [20]	327.14%	-	-	-	-
Sabah	Zainorabidin &	713.35%	H6	65.22%	1.34	70.97%
	Mohamad [21]					
	Sapar *et al.,* [22]	673.99%	H6 - H7	99.42%	1.22	67.03%
	Sapar *et al.,* [22]	630.32%	H6	56.63%	1.57	61.28%
Sarawak	Mahmood *et al.,* [6]	2193 -	-	56.1 -	1.14 -1.16	-
		2683%		58.33%		
	Afip & Jusoff [23]	1136.68%	H7	91.78%	1.33	5.70%
	Kifli *et al.,* [24]	964.52 -	H4 - H5	96.22 -	1.16 - 1.20	43.45 -
		1096.59%		96.35%		48.23%
	Mario *et al.,* [25]	808.10%	H6	-	1.13	-

Table 4
Basic properties of peat in Malaysia

Location	References	Ash Content	Liquid Limit	Ph Value	Plastic Limit	Permeability	Peat Class
Parit	Johari *et al.,* [12]	-	322%	-	-	-	Hemic
Nipah,	Azhar *et al.,* [13]	-	360%	-	-	-	Hemic
Johor	Wahab *et al.,* [14]	-	182.53%	-	-	-	-
Pontian,	Kamaruidzaman *et al.,* [15]	7.31%	189%	3.23	-	-	Hemic
Johor	Yacob & Som [16]	5.34%	-	4.15	-	-	-
	Dehghanbanadaki *et al.,* [17]		260%	4.1	Non-Plastic	0.89 m/day	Fibric / Fibrous
Selangor	Daud *et al.,* [18]	7.32%	-	3.5	-	-	-
	Jais *et al.,* [19]	-	-	3.02	-	-	Hemic
West Malaysia	Wahab *et al.,* [14]	136.11%	-	-	-	-	-
	Zambri & Ghazaly [20]	-	-	-	-	-	-
Sabah	Zainorabidin & Mohamad [21]	-	256.13%	4.6	-	-	Hemic
	Sapar *et al.,* [22]	-	171%	3	-	-	Hemic
Sarawak	Mahmood *et al.,* [6]	-	-	-	-	-	-
	Afip & Jusoff [23]	-	-	3.57	-	-	Sapric
	Kifli *et al.,* [24]	3.65 - 3.78%	305 - 390%	3.59 - 3.69	-	-	Hemic

4.1 Degree of Decomposition/ Humification

The degree of decomposition uses von post-test method to determine the scale of peat soil. Where the scale of humification has H1 to H10. According to this review, most researcher get degree of decomposition is H3 to H7. From this degree of decomposition can be categorised peat class. In Malaysia, they have three class for peat soil which is fibric, hemic and sapric but most the researcher get peat class is hemic. The peat class also can be categorised based on fibre content.

4.2 Moisture Content

Peat soils have a high moisture content. Based on this review, moisture content for peat soil in West Malaysia range between 230.89 to 640.09%, and East Malaysia is 630.32 to 2683%. According to Bujang (2004), moisture content for West and East Malaysia is 200 to 700% and 200 to 2207%. Therefore, the moisture content in Malaysia for this review range between 230.89 to 2683%. In Sarawak, the moisture content is 2193 to 2683% is higher from range East Malaysia [6]. The moisture content of peat soil is influenced by fibre content and organic content. Where the ability of peat soils to hold or absorb more water when the fibre content and organic content is high. Therefore, the moisture content of peat soil also higher [12,24,26]. Besides, the main factor that contributes to the characterization of peat with low bearing capacity and bulk density is the high moisture content [20].

4.3 Organic Content

Organic content is essentially plant waste and vegetative things whose accumulation rate is quicker than its decomposition rate [22]. Organic content for peat soil in Malaysia is range 56.1 to 99.42%. Based on Malaysia Soil Classification Systems for peat soil, organic content for peat soil is more than 75% [7]. Organic content for West Malaysia is range between 65 to 97% and East Malaysia is range between 50 to 95% [8].

4.4 Fibre Content

The fibre plays an essential role in peat masses due it is related to the shear strength and compressibility of soil parameters [22]. The standard that is always used is ASTM to determine fibre content. Based on ASTM D 1997, it can identify the type of peat class, which is fibric, hemic and sapric. According to Afip and Jusoff [23], obtain a fibre content of 5.67%, classifying it as sapric. Based on Sapar *et al.,* [22], Zainorabidin and Mohamad [21], and Dehghanbanadaki *et al.,* [17] obtains the fibre content to be between 67.03 to 80%, which is classed as fibric.

These findings are based on the ASTM standard, which classifies peat as fibric if it contains greater than 67% fibre, hemic if it contains between 33% and 67% fibre, and sapric if it has less than 33% fibre. Additionally, the fibres found in peat can be used to evaluate the degree of decomposition of the peat, whether it is slightly, moderately, or highly decomposed [24].

4.5 Ash Content

Ash content is a measurement value made by the oven drying method. ASTM D2974 standard is used to determine the ash content for peat soils. According to researcher Kifli et al., 2017 gets 3.65 to 3.78%, where the ash content is low ash. Another researcher gets 5.34 to 7.32%, where the ash content is medium ash [15,16,18].

These findings are based on the ASTM standard, which classifies peat as low ash if it contains less than 5% ash and as medium ash if it contains between 5% and 15% ash. It can be concluded, the higher the ash content of peat, the more inorganic components it contains [24].

4.6 Specific Gravity

Specific gravity (G_s) is to determine the density of the soil solids. The specific gravity of soil also is mainly controlled by soil mineralogy [22]. Specific gravity values for peat soil in Malaysia get around 1.13 to 1.49 but according to Yacob and Som [16] get less than 1.0 which is 0.6. Based on Bujang (2004), the specific gravity values of peat in West Malaysia and East Malaysia are range from 1.38 to 1.70 and 1.07 to 1.63. Peat's specific gravity is impacted by its organic contents, which by their nature have a lower specific gravity, resulting in a drop in the specific gravity of peat soils as a whole [24]. Besides, lower fibre content values result in higher specific gravity values [26].

4.7 Liquid Limit

The liquid limit of peat soils gets ranges between 136.11 to 309% but according to Zainorabidin and Wijeyesekera [3], the liquid limit properties show a range around 190 to 550%. Liquid limit for West Malaysia ranges between 190 to 360% and for East Malaysia range between 210 to 550% [8,27]. The fibre content of peat can also affect its liquid limit because of the peat's high water absorption ability [24]. Besides, the behaviour of the liquid limit appears to be influenced by the moisture content of peat soil [21]. The higher the fibre content, the higher moisture content, the higher the liquid limit [21,24].

4.8 Plastic Limit

Plastic limit of peat soil is non- plastic. Non-plastic soil is peat soil that has very little or no clay component. Generally, a lower clay content in peat soil would make the plastic limit test more

difficult to accomplish [25]. According to Zainorabidin and Wijeyesekera [3] plastic limit properties show range between 100 to 297% but the presence of fibre content makes it difficult to get the plastic limit.

4.9 pH Value

The pH of the soil is a chemical property that shows its acidity or alkalinity. The acidity of peat is influenced by the type of rock and plant, the supply of oxygen, and humic acid concentration [22]. From this review obtain pH value for peat soil is 3 to 4.15. The organic content of peat has an effect on the pH of peat. Where the higher the organic content of peat, the lower the peat pH values [24].

4.10 Permeability

Permeability for peat soil gets 0.89 m/day by Dehghanbanadaki *et al.,* [17]. The permeability of peat is influenced by the void ratio, mineral content, decomposition level, chemistry, and the existence of gas. In a natural state, peat's hydraulic conductivity or permeability, which ranges from 10^{-5} to 10^{-4} m/s, can be as high as sand [5]**.**

4. Conclusions

In conclusion, this study delves into the comprehensive understanding of peat soils in Malaysia, highlighting their classification, basic properties, and the challenges they pose in the field of geotechnical engineering. The vast peat deposits covering 8% of Malaysia's total area have been categorized as tropical peats, presenting unique challenges due to their inferior engineering properties compared to other soft soils. The classification of peat soils, based on ASTM standards, reveals distinctions in fibre content, ash content, and acidity levels. Additionally, the Von Post test and the Malaysian Soil Classification System provide further insights into the degree of humification and the state of decomposition of organic material in peat soils.

This systematic review conducted through the PRISMA method highlighted the basic properties of peat soils in Malaysia in order to gain a better understanding of the characteristics of peat. Malaysia has all three classes of peat namely fibric, hemic and sapric. The classes of peat can be determined according to the degree of decomposition or based on the fibres present in the peat soil. Based on this study, it can be concluded that the properties of peat soil are:

i. The degree of decomposition for peat soil is H3 to H7.
ii. Moisture content range between 230.89 to 2683%, organic content around 56.1 to 99.42% and fibre content ranges 5.67 to 80%. Moisture content is influenced by fibre content and organic content.
iii. Ash content ranges 3.65 to 7.23% and specific gravity is around 0.69 to 1.39. The specific gravity influenced by organic content and ash content represents inorganic content in peat soil.
iv. Liquid limit for peat ranges between 136.11 to 309% and plastic limit is non- plastic. The plastic limits can difficult to get due to the existence of fibre content.
v. The pH value around 3 to 4.15 and permeability is 0.89 m/day.

As Malaysia continues to undergo development, the findings of this study underscore the importance of considering and managing peat soils effectively. Future research and engineering practices should focus on innovative solutions to mitigate the engineering challenges associated with peat soils, ensuring sustainable development and environmental preservation.

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