

Geotechnical Properties of Malaysian Organic Soils (Case Study: Batu Pahat, Johor)

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Abstract: Subsurface exploration is required before any development project in order to gain an understanding of the characteristics of the material that one will encounter. The type of the tests and exploration are normally specified based on the design requirement in accordance to respective code of practice. In general, the physical properties and strength of the material are important in civil engineering applications. However, the chemical contents and organic contents are only specified sometimes when necessary despite the fact that the physical and strength of the material are closely related to its chemical properties and organic contents. In most construction works, the top soil and peat soil which are highly organic will be removed prior to carrying out construction work which resulted in exposing the bottom layer of soil. Hence, the aim of this study is to determine the geotechnical properties of the organic soils at the interface layer of peat soil and inorganic soil which normally exposed after removing top soil and peat soil at the surface. The physical & chemical properties, strength and organic contents of the soils are determined in accordance to the BS1377:1990 and BS ISO 13320:2009. Three locations which are identified to be rich in organic soils namely Parit Nipah, Parit Sidek and Batu Puteh of Batu Pahat, were chosen in this case study. These locations are found to be difference geographically. The soil samples were collected using a peat auger at Parit Nipah and Batu Puteh while undisturbed tube sampler was used at Parit Sidek because the soil is too stiff to be sampled using peat auger. The findings of this study showed that the physical properties of the soil are strongly correlated with its organic content. However, the chemical properties and strength of the soil is found to be site dependent and poorly correlated to its organic content.

Keywords: organic soil, peat, physical properties, chemical properties, strength

1. Introduction

Generally, organic soil is found in three different environments, namely fluvial, fluvial-terrestrial and terrestrial. However, most of the times the boundaries between these three environments are difficult to be differentiate [1]. Moreover, organic soil is normally classified differently with its genesis, formation and contents in which the classification systems can be divided into two groups which are non-genetic/descriptive classification and genetic/descriptive classification, broadly. Despite the differences in each classification systems, the main objective of each classification system is to provide relevant information for different field of study such as agriculture and construction.

The early exploration of works-site investigation is carried out to provide designer with the most suitable parameter for design. The physical, chemical and strength of the materials are necessary for the designer to foresee and predict the potential challenges of proposed works and also the most suitable construction methods to

mitigate the risk. Traditionally, the top soil and peat soil with high organic contents are normally removed from the site in which exposing the bottom layer of soil. Based on the exploration works at Pontian, Johor carried out by Minerals and Geoscience Department, Malaysia, a layer of organic clay is normally found at the interface of peat and marine clay [2]. Extensive works had been carried out on peat soil at this region by researchers [3, 4] on its mechanical and engineering properties. However, very few works are found on the exploration of the interface layer that potentially exposed after excavation of top and peat soil. The interface layer is defined in this study as the layer of soil in which the traces of organic substances are mixed with the inorganic soil at the deeper layer.

Batu Pahat, as currently the second largest township in Johor after Johor Bahru is experiencing rapid development since last decade. Hundreds hectare of peat or organic land which were previously agricultural land are being developed as housing and commercial lands. Hence, it is important for engineers to understand the soil behaviour especially its geotechnical properties.

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2. Materials & Experimental Programme

Organic soil samples were retrieved from three different locations, namely Parit Nipah, Parit Sidek and Batu Puteh of Batu Pahat District, Johor- southern of peninsular Malaysia. The locations of the sampling site are shown in Fig. 1. These three locations are private owned palm oil trees estate with an almost flat profile. The Parit Nipah is situated far inland of Batu Pahat district while Parit Sidek and Batu Puteh are nearer to the coastal area. Geologic map of Peninsular Malaysia [5] as illustrates in Fig. 2 shows that the selected locations consist of peat, humid clay, silt, marine clay and marine silt.

Preliminary exploration works are required to determine the types and thickness of each layer soil. Peat auger, one type of gouge auger, as shown in Fig. 3, is used to sample soft organic soil at different thickness of Parit Nipah and Batu Puteh. This type of sampler is suitable to take soft soil samples below the groundwater level because the containing section of the sampler is sealed off by a plate or fin during extraction [6]. Whereas, the organic soil at Parit Sidek was sampled using sample tube of 38mm (internal diameter) x 230mm (tube length). The top soil with vegetation roots was manually eliminated by using hand auger or hoe and the sample tubes was manually pushed into the desire depth and extracted by using hand auger and sampling equipment as shown in Fig. 4. The sampling tubes were immediately sealed with end caps to prevent loss of moisture. In-situ vane shear test was carried out adjacent to the sampling point with the Geonor H60 hand held vane tester.

All the soil samples were kept in double layer zipped plastic bags and stored in an air-conditioned room before test to prevent and minimize the possibility of sweating and oxidation of soil. The list of the laboratory tests, in-situ tests and its reference standards are listed in Table 1. In general, the tests are categorized into three major group namely physical properties: moisture content, liquid limit, plastic limit, specific gravity, and particle size distribution; chemical properties: organic content (Loss of ignition (LOI), pH, and bulk chemical composition through X-ray fluorescence (XRF); and strength: unconfined compressive strength & in-situ vane shear test.

Based on the field exploration, the soil at the Parit Nipah and Batu Puteh can be broadly divided into four layers, which are top soil, peat soil, organic soil (interface layer between peat soil and inorganic soil) and inorganic soil (alluvium). The photographic records of the preliminary exploration works were shown in Fig. 5 and Fig. 6, respectively. The soil layers were distinguished visually at site based on its difference in colour and material structure. The top soil and peat soil are further characterized using Von Post classification system [7] in order to differentiate the soil with its humification level. The preliminary exploration works at Parit Sidek area was carried out using hoe and Edelman auger because the soil is too stiff by using peat auger. Based on the informal interview with the owner, the Parit Sidek area which is

originally peat deposit about 15 years ago have gradually transformed into organic soil after the dewatering project carried out by the Drainage and Irrigation Department (DID), Malaysia. The early exploration found that the soil condition up to 1.5m from top layer remains quite similar except that the soil is found to be stickier below ground water level.

3. Results and Discussion

The main scope of this study is focused on the interface layer which was found to be below the groundwater level after the initial exploration works. The interface layer is specified by neglecting the layer that rich in non-humidified matter, such as leaves and roots. The results of the laboratory tests and in-situ tests are summarized in Table 2 and Table 3, which subdivided based on its location, namely Parit Nipah, Parit Parit Sidek and Batu Puteh of Batu Pahat, Johor.

From the results of test, it is shown that the moisture content of organic soil from Parit Nipah and Batu Puteh are higher than its liquid limit. The results correlated well with the findings that the samples were soft and unable to stand without lateral support. The organic soil samples at Parit Sidek area reported to fall in the range of one liquid limit and it is relatively stiff when compared to the Parit Nipah and Batu Puteh. The soil at this area is able to stand at its own weight and tested using unconfined compressive test frame as shown in Fig. 6.

In terms of its plasticity, it is clearly shown in Fig 8 that most of the soils in these areas fall under A-line which behaved as silt with high to very high plasticity except the soil at 0.74 to 1.0m of Batu Puteh which falls in the region of clay with high plasticity. The results of analysis agreed well with the findings of particle size distribution in which the soil at this region are generally in silt sized.

Table 3 shows that the chemical contents of the organic soil in these areas are aluminosilicate which deficit in alkali and alkaline earth elements. Moreover, it is also rich in sulfur element. Hence, it can be explained that even though the organic contents of the soil are relatively low compared to peat soil, the pH of the soil are acidic due to its chemical compositions.

In addition, the carbon contents as determined by energy dispersive analyser which attached to Scanning Electron Microscope had complimented the limitation of wavelength X-ray fluorescence in determining the lighter elements namely carbon. The carbon contents are found to be correlated well with the loss on ignition data in which higher carbon content s are found in soil with high loss on ignition. However, this method is unable to differentiate the types of carbon whether it is elemental C, inorganic C or organic C.

The organic soils at these areas are found to be weak and site dependent. High water content and low overburden pressure are believed to be the main causes of its low strength, which is common for quaternary deposit at this region.

4. Conclusion

In general, strength of the organic soil at the studied areas is relatively weak (less than 20kPa) and is unable to support the self weight of an adult of average 70kg. Hence, it is of great importance for soil stabilization works if the top soil and peat soil will be removed for any potential development works. In addition, the organic soils which are found to be deficit in alkaline elements and high sulphur contents possess potential ill effect for reinforced concrete which may result in steel corrosion or carbonation in concrete.

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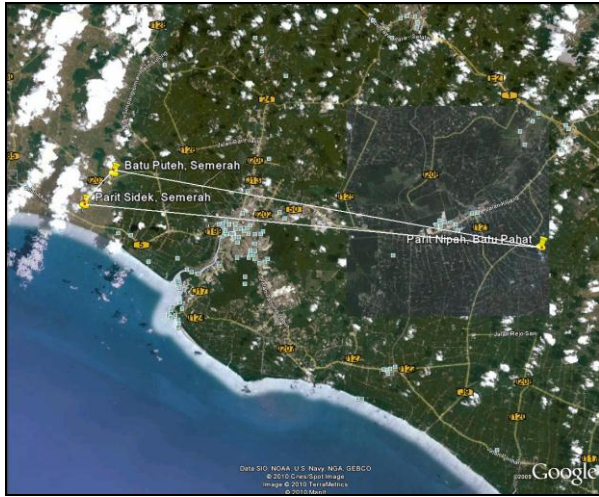


Fig. 1 GPS locality of sampling site

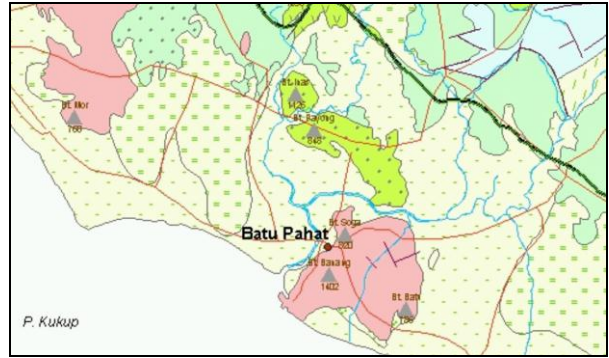


Fig. 2 Geological map of sampling site

Table 1 List of laboratory tests and its reference standards

Laboratory & In-situ Tests		
No.	Details	Reference Standard
1	Determination of moisture content - Oven drying method (at 50°C)	BS 1377: Part 2: 1990 (subsection 3.2)
2	Determination of liquid limit - Cone penetrometer method	BS 1377: Part 2: 1990 (subsection 4.3)
3	Determination of plastic limit	BS 1377: Part 2: 1990 (subsection 5.3)
4	Determination of particle density (specific gravity) -Small pycnometer method	BS 1377: Part 2: 1990 (subsection 8.3)
5	Determination of particle size distribution -Laser diffraction method	BS ISO 13320: 2009
6	Determination of organic content -Mass loss on ignition at 440°C	BS 1377: Part 3: 1990 (subsection 4)
7	Electrometric method of pH determination	BS 1377: Part 3: 1990 (subsection 9.5)
8	Bulk chemical composition - XRF - EDX	Technical guide of : Bruker JEOL
9	Determination of unconfined compressive strength -Load frame method	BS 1377: Part 7: 1990 (subsection 7.2)
10	Determination of in-situ vane shear -Geonor H60 hand held vane tester	Instruction manual of Geonor H60



Fig. 3 Peat auger with sampled organic soil



Fig. 4 Soil sampling using sample tube



Fig. 5 Photographic record of subsurface layer at Parit Nipah, Batu Pahat

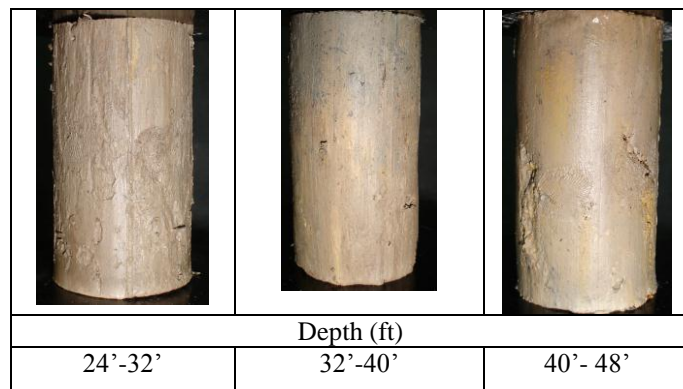


Fig. 6 Photographic record of subsurface layer at Parit Sidek, Batu Pahat



Fig. 7 Photographic record of subsurface layer at Batu Puteh, Batu Pahat

Table 2 Physical and chemical properties of organic soil

Location	Parit Nipah-P3		Parit Sidek			Batu Puteh-P2	
Depth (m)	1.66 – 2	2 – 2.5	0.6 – 0.8	0.8 – 1	1 – 1.2	0.74 – 1	1 – 1.5
Properties	Value						
Physical Description	Peaty soil	Marine soil	Organic soil	Organic soil	Organic soil	Peaty soil	Peaty soil
Soil Colour [8]	Grey 1 5/N	Grey 1 5/N	Grey 1 4/10Y	GREY 1 4/10Y	Grey 1 4/10Y	Grey 1 4/10Y	Grey 1 4/10Y
Moisture content (%)	125.87	94.83	83.64	90.00	86.89	119.13	103.68
Liquid limit, LL (%)	89.66	61.09	97.41	81.12	91.33	75.25	106.13
Plastic limit, PL (%)	39.58	32.03	48.86	38.75	41.72	32.44	48.94
Plasticity index, PI (%)	50.08	29.06	48.55	42.37	49.61	42.81	57.19
Specific gravity	2.41	2.53	2.51	2.52	2.52	2.41	2.37
Particle Size Distribution							
Clay fraction (%)	27.22	25.97	26.22	29.07	28.66	6.61	9.24
Silt fraction (%)	72.78	74.03	73.78	70.93	71.34	84.26	82.56
D ₁₀ (µm)	0.82	0.86	0.88	0.79	0.80	3.02	2.16
D ₃₀ (µm)	2.27	2.42	2.39	2.08	2.12	12.01	8.13
D ₆₀ (µm)	6.64	7.45	7.25	5.99	6.00	31.98	25.99
UC ¹⁾	2.93	3.08	3.03	2.88	2.83	2.66	3.20
C _c ²⁾	0.95	0.91	0.90	0.91	0.94	1.49	1.18
Loss of ignition (%)	15.82	10.69	9.09	7.50	8.20	7.29	14.21
Soil classification [9]	MVo	MHo	MEo	MEo	MEo	MVo	MEo
pH (at 25°C)	2.86	3.19	2.87	3.4	3.18	4.73	2.47
Vane shear (kPa)	14 (at 2.3m)		0 (at 0.7m)	10 (at 0.9m)	8 (at 1.1m)	4 (at 0.9m)	1 (at 1.3m)
Unconfined compressive strength (kPa)	- (Samples are too soft to be tested)		18.22	11.05	15.89	- (Samples are too soft to be tested)	
Remarks	- Soil layers at 0 – 1.66 m were excluded due to existence of decaying woods, - Water table was recorded at 0.33 m from surface		- Soil layers at 0 – 0.6 m were excluded due to existence of non-decaying woods - Water table was recorded at 0.75 m from surface			- Soil layers at 0 – 0.74 m were excluded due to existence of non-decaying woods - Water table was recorded at 0.6 m from surface	

$$1) UC = \frac{D_{60}}{D_{30}} ; \quad 2) C_c = \frac{D_{30}^2}{D_{10}D_{60}}$$

Table 3 Bulk chemical composition of organic soil

Location		Parit Nipah-P3		Parit Sidek			Batu Puteh-P2	
Depth (m)		1.66 – 2	2 – 2.5	0.6 – 0.8	0.8 – 1	1 – 1.2	0.74 – 1	1 – 1.5
Formula	Source	Concentration (% w/w)						
SiO ₂	XRF	57.8	63.1	62.5	61.5	61.5	71.7	65.4
Al ₂ O ₃	XRF	25.8	25.4	27.7	26.4	26.1	21.8	20.2
SO ₃	XRF	6.51	3.01	0.66	1.58	1.63	0.92	6.53
Fe ₂ O ₃	XRF	5.07	3.71	4.77	6.26	6.52	1.21	3.37
K ₂ O	XRF	1.94	1.89	2.04	1.96	1.96	1.72	1.71
MgO	XRF	1.53	1.62	1.05	1.13	1.13	1.19	1.25
TiO ₂	XRF	0.68	0.67	0.74	0.68	0.69	0.66	0.62
Na ₂ O	XRF	0.26	0.26	0.25	0.25	0.25	0.39	0.45
CaO	XRF	0.21	0.18	-	-	-	0.16	0.24
Total of alkali and alkaline earth elements		3.94	3.95	3.34	3.34	3.34	3.46	3.65
C	EDX	46.60	-	13.87	12.45	31.61	16.11	43.12

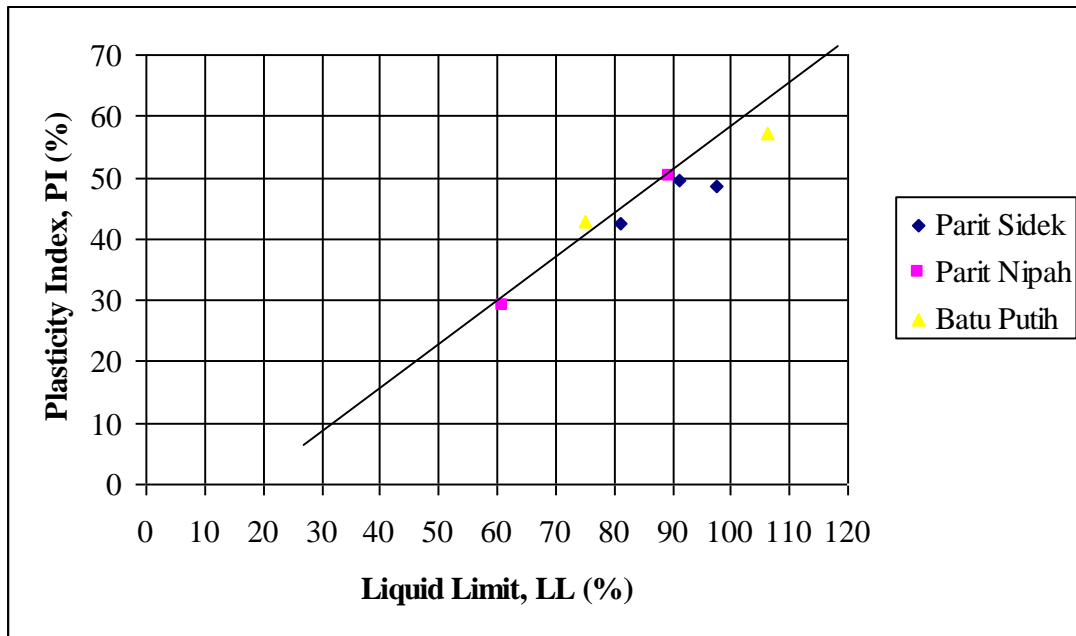


Fig 8 Plasticity chart