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Engineering Properties of Peat Soils in Peninsular, Malaysia

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Abstract: Aim of this study is to determine physical and mechanical properties of tropical peatland in West Malaysia. To know the proper methods of ground improvement and to know the scale of improvement works, a proper soil investigation requires. A study on peatland in Peninsular, Malaysia was conducted to determine stratigraphy of peat layer, bearing capacity, physical properties, unconfined compressive strength and consolidation properties. Some conventional laboratory and field experiments were done to determine its physical and mechanical properties and to find the soil profile. From experiments it was observed that the depth of the peat was moderate and it had high water, organic and fibre content. The soil was acidic and it had low bearing capacity and had low unconfined compressive strength. Its compressibility was very high and it had high settlement value. These properties should be considered when ground improvement works are undertaken for this type of problematic soil in construction industry.

Key words: Soil profile, bearing capacity, compressibility, settlement

INTRODUCTION

Peat is a mixture of fragmented organic material formed in wetlands under appropriate climatic and topographic conditions and it is derived from vegetation that has been chemically changed and fossilized (Dhowian *et al.*, 1980). Peat is generally found in thick layers in limited areas, has low shear strength and high compressive deformation which often results in difficulties when construction work is undertaken on the deposit.

Study conducted by Islam *et al.* (2008) and Andriesse (1988) revealed that the bearing capacity of peat soil was very low and was apparently influenced by the water table and the presence of subsurface woody debris. Peat poses serious problems in construction industry due to its long-term consolidation settlements even when subjected to a moderate load. Hence, peat is considered as unsuitable for supporting foundations in its natural state. Wong *et al.* (2008) conducted a test on peatland in Peninsular, Malaysia and found that the water holding capacity of this peat was very high and it was found dark brown in colour and the soil was classified H_4 according to Von Post classification system.

According to Jamil *et al.* (1989), where soil with peat depth of <1.0, 1.0-1.5, 1.5-3.0 and >3.0 m is classified as shallow, moderate, deep and very deep peat. Soil fabric, characterized by organic coarse particles, holds a considerable amount of water because the coarse particles are generally very loose and the organic particle itself is hollow and largely full of water. The water content of peat researched in West Malaysia ranges from 200 to 700% and unit weight of peat is typically lower compared to inorganic soils. Previous studies suggested that for peat water content about 500%, the unit weight ranges from 10 to 13 kN m^{-3}. A range of 8.3-11 kN m^{-3} is common for unit weight of fibrous peat in West Malaysia (Huat *et al.*, 2004). The organic content in the range of 50 to 95% and the liquid limit was in the range of 200 to 500% as reported by Huat *et al.* (2004).

Duraisamy *et al.* (2007) reported that tropical fabric causes highest settlement and followed by hemic and sapric when subjected to a load and over the time period. The authors also reported that fibric, hemic and sapric classified as very compressible and they found compression index (Cc) values for tropical peatland from oedometer test for fibric was 1.453 to 3.211, hemic was 1.29 to 2.78 and sapric was 1.15 to 2.44.

Before starting construction works in this problematic soil a proper soil investigation require. Objectives of this study are to:

- Observe the profile of soil in peatland by field investigation and using hand auger
- Estimates bearing capacity of peat layer in terms of N value by using Mackintosh Probe test
- Determine physical properties of disturbed sample of peat soil collected from site by performing various laboratory experiments

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- Determine unconfined compressive strength of undisturbed sample of peat soil by performing Unconfined Compressive Test in laboratory
- Observe compressibility and settlement characteristics of the peat soil sample by doing Oedometer test

MATERIALS AND METHODS

Field investigation: For laboratory investigation, peat soil was sampled from the Klang, Peninsular, West Malaysia. This research was conducted from November, 2007 to February, 2008. Trial pits were excavated to a depth of 1 m below the ground surface to measure ground water table and to obtain both undisturbed and disturbed soil samples below the ground water table. Hand Auger test (Fig. 1) was performed to characterise soil stratigraphy and for sample collection. Mackintosh Probe Test (Fig. 2) was performed to observe bearing capacity.

Laboratory experiment: The physical properties of peat soil which was collected from peat layer was determined by performing moisture content, fibre content, organic content, ash content, bulk density, linear shrinkage, liquid limit, pH, specific gravity test. All these tests were performed as per standard of BS1377: 1990. Unconfined compression test (Fig. 3) was performed according to the BS 1377:1990: Part 7 to determine the unconfined compressive strength. Consolidation properties were determined by using conventional oedometer apparatus (Fig. 4).

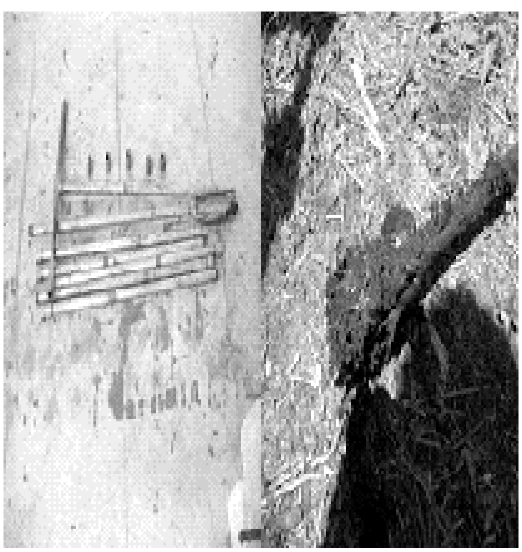

Fig. 1: Hand auger test

Fig. 2: Mackintosh probe test

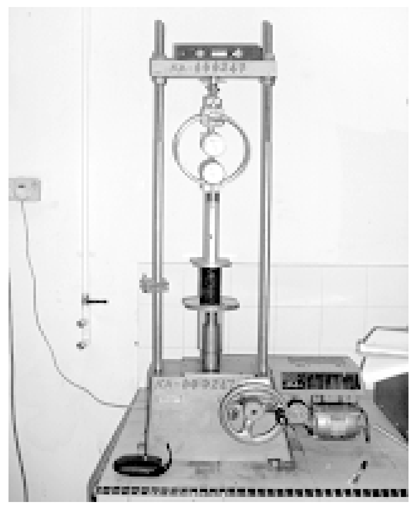

Fig. 3: UCT test

Fig. 4: Oedometer test

RESULTS AND DISCUSSION

Close examination of each trial pit indicated that the ground water table was below 0.3 m from the ground surface. This showed that the peat had a very high water holding capacity. Depth of peat is 1.5 m and according to Jamil *et al.* (1989) classification system it can be classified moderate depth peat. The soil profile of the peatland by visual inspection of soil sample collected using hand auger is shown in Fig. 5.

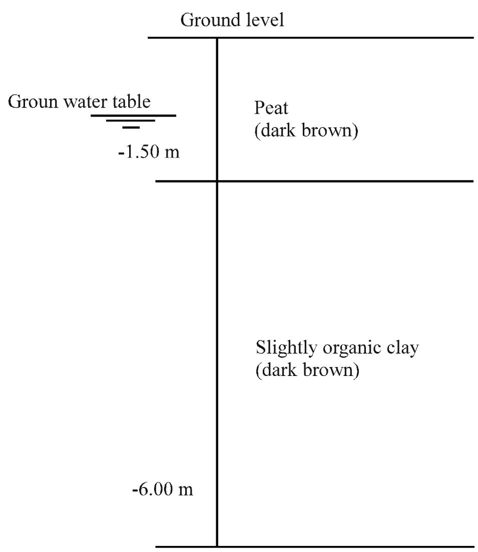

Fig. 5: Soil profile found from field experiment

Visual observation on the peat soil indicated that the soil was dark brown in colour. When the soil was extruded on squeezing (passing between fingers), it was observed that the soil was somewhat pasty with muddy water squeezed out and the plant structure was not easily identified. Based on the visual observation, the soil can be classified as fibrous peat mixed with vegetal fibre, wooden chips inside and roots appear top layer. According to Von Post classification system based on its degree of humification the peat can be classified as H_4 which same as Wong *et al.* (2008) findings.

From the result of Mackintosh Probe test it was found that N value varies from 0 to 2 in peat and organic layer. Then N value gradually increases upto 10 m depth and reaches at 40 after 10 m depth. This means bearing capacity of peat soil is very low which was indicated Islam *et al.* (2008) and Andriesse (1988). Figure 6 shows the mackintosh probe result for three different points.

All the engineering properties such as specific gravity and bulk density of the samples were within the range as reported by Huat *et al.* (2004). Physical properties of the peat soil are shown in Table 1.

From UCT test it was observed that unconfined compressive strength of peat soil was very low. Result showed that it varies from 4.7 to 6.9 kPa. Figure 7 shows the stress vs. strain curve.

From oedometer test it was observed that settlement under 1600 kPa load is reached at 2.5 mm after 3 days. Figure 8 shows time (square root of time in minute) vs.

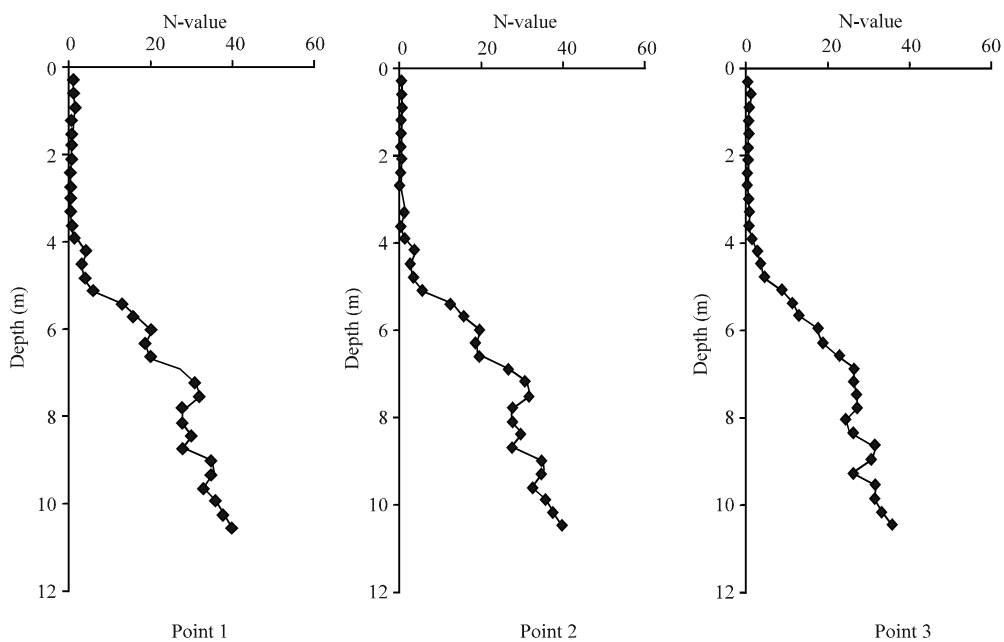

Fig. 6: Result of Mackintosh probe test (N-value vs. depth)

Table 1: Physical properties of peat soil

Index properties	Range	Average
Natural moisture content (%)	414-674	555.000
Specific gravity	0.95-1.34	1.240
Initial void ratio	7.999-9.646	9.329
Fiber content (%)	90.25-90.49	90.390
Organic content (%)	88.61-99.06	96.450
Ash content (%)	0.94-11.39	3.550
Bulk density (kg m^{-3})	1035.66-1040.41	1037.720
Linear shrinkage (%)	29.81-30.14	29.990
pH of peat	-	3.510
pH of ground water	-	4.070
Liquid limit (%)	202.30-220.65	208.390
Classification/von post		H_4

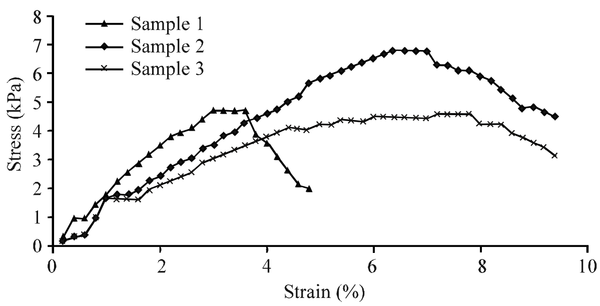

Fig. 7: Stress vs. strain graph

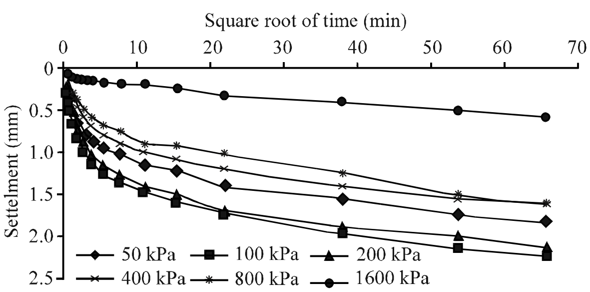

Fig. 8: Time vs. Settlement curve

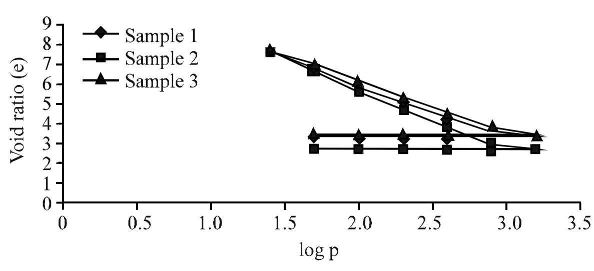

Fig. 9: Void ratio and effective stress (e-logp) curve

Settlement curve for various loading condition. From void ratio and effective stress (e-logp) curve it was found that compression index (Cc) varies from 2.43 to 2.84 and swelling index varies from 0.014 to 0.016. This result is matching results which have been found by Duraisamy *et al*. (2007). Figure 9 shows e-logp graph for three different samples.

CONCLUSION

Based on field investigation and laboratory experimentation on peat soil the following conclusions are made:

- Ground water table is below 0.3 m from top surface and pure peat layer is upto 1.5 m and below peat layer there is a slightly organic clay layer upto 6 m depth
- From Mackintosh Probe it was observed that N value varies from 0 to 2 upto 4 m depth. Then it was increased and after 10 m depth N value exceeds 40 which mean that there is a hard layer after that depth
- One unique characteristics of peat soil is high water content. Moisture content was calculated in this soil was 555.55%. Other significant properties of peat soil its organic content, fibre content, specific gravity, bulk density and pH which were 96.45%, 90.39%, 1.24, 1037.73 kg m^{-3} and 3.51, respectively.
- Unconfined compressive strength of peat soil is very low and from UCT test it was found that the strength varies from 4.7 to 6.9 kPa
- High compressibility is the other property which makes the peat soil difficult to construct any engineering structure over this type of soil. From oedometer test it was observed that under 1600 kPa load the settlement occur upto 2.5 mm after 3 days. Compression index (Cc) varied from 2.43 to 2.84 and swelling index varies from 0.014 to 0.016

Peat soil has unique characteristics and there is a tendency in construction industry to avoid this type of problematic soils. So, proper soil stabilisation method which is economical and consume less time can overcome this type of problem. This experimental data can be used to find out a proper ground improvement method. Now a day's deep mixing method for ground improvement especially by columnar technique in which soil-cement columns are made by using mixing auger and using some admixture, is becoming more popular. Binder can be provided in dry form as peat soil has high water content.

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