Preliminary Peat Surveys in Ecoregion Delineation of North Borneo: Engineering Perspective

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ABSTRACT

Peat widely known as a heterogeneous mixture of decomposed plant material with special management concerns that has accumulated in a water-saturated environment in fragile peat strength condition. Peat is soft and easily compressed when load imposed. Water expelled between the fingers and soil material remaining in the hand upon squeezing a saturated sample. Technically, these soils can be described from the engineering perspective as a problematic soil which has a relatively high percentage of decomposed material and the appearance of peat exhibits poor consolidation properties with high compressibility and low shear strength. Peat deposit has variable characters. A preliminary study on peatland in Sabah, Malaysia or well-known as North Borneo was conducted to determine the engineering properties of peat.

This paper is structured to the needs of engineering perspective to establish the engineering properties of North Borneo peat for a deeper understanding in geotechnical perspective. A preliminary peat origin experimental results are presented in this paper and the properties of peat soil data establish to be used in future for geotechnical design and dealing with soil as a construction material.

KEYWORDS: Peat; soft; shear strength; compressibility; Properties

INTRODUCTION

Tropical peat is formed when the organic material does not fully decompose. In their natural state are saturated with high water content that made up of mainly from vegetation, rooting plant materials and storing carbon in dead organic matter. In Malaysia, the total area of peat soil is about 2.6 million hectares or 26,000 km2 and 5 % of that total area account for about 116,965 hectares encompass in Sabah or best known as North Borneo. North Borneo region located in the immense island of Borneo and administered by Malaysia.

There are 116,965 ha of peat soils in Sabah where, the Klias Peninsula and Kinabatangan–Segama Valleys contributed to the areas (Wetlands International – Malaysia, 2010). The Klias Peninsula supported 60,500 ha of peat swamp forest (Fox 1972) and currently remained 5,500 ha

(Phua et al. 2008) and comprising 3,630 ha in Klias Forest Reserve while another 1,870 ha in Binsuluk Forest Reserve. The remainder area converted to the agricultural land and left under grassland after logging activities. Peat soils in the Kinabatangan Valley under "Lower Kinabatangan-Segama Wetlands' Ramsar Site, which includes 17,155 ha peatland (Ramsar 2008). The other area covers 5,000 ha in Kinabatangan Valley between Batu Puteh and Bilit area.

Sabah Peatlands mainly found in a thick water-logged that made up in decaying plant material. With high water table, it becomes suppler although composed of unidentified fibres. Lowland of peat areas in Sabah are often flooded and swampy. Most of the peat land area covered by mud and transferable organic particle transported by water flood.

From the engineering perspective, peat contains of high organic content, often more than 75% and present partially decomposed and disintegrated plant (Kazemian et al., 2011). In natural state, peat consists of water and decomposed plant fragment with virtually no measurable strength (Munro, 2005). Peats are accumulated if the rate of decay is slower than the rate of addition (Bell, 2000). Normally, peat soils considered as soft problematic soil and the peat soil behaviours showed a high scale in the degree of compressibility. Normally, peat soils considered as soft problematic soil and the peat soil behaviours showed a high scale in the degree of compressibility. Tropical fabric causes highest settlement followed by hemic and sapric peat when subjected to a load and over the time period that proved high compressibility factor (Duraisamy et al. 2007).

Study conducted by Adnan and Habib (2015) revealed that, when peat subjected to dynamic loading or determined by traffic loading, the load has reduced the shear strength of peat soil. According to Kazemian et al., (2011) peat soil are geotechnically problematic and cause instability problems such as development of slip failure, local sinking, and massive primary and long term settlement even when load increases moderately. This is showed that the low shear strength and high compressibility in peat itself.

Jamil et al. (1989) described that, peat soil with depth of <1.0 m to >3.0 m are classified as shallow, moderate, deep and very deep peat. Hashim and Islam (2008) in previous study stated that the water content in West Malaysia ranges from 200 to 700%. Huat et al., 2004) suggested that, peat water content about 500%, the unit weight ranges from 10 to 13 KN m-3 and 8.3 – 11 KN m-3 and liquid limit 200% to 500% is commonly recorded for fibrous peat in West Malaysia according to Huat et al., (2004).

MATERIAL AND METHODS

Peat Soil Properties

Peat Location

The study area has a parallelogram shape that is defined by the coordinates at latitude 5.29616940 and Longitude 115.69118810 located in Lumadan, it forms part of the Beaufort District, Sabah. The studied peatland covers an area of 15 ha in the private property in commercial agricultural plantation adjacent to the Klias Forest Reserve (Peat Swamp) and 13 km away from the Beaufort township area. The annual mean rainfall is 3599 mm and the timing of peak month in May and November. The average annual temperature is 27.4 oC. The site consists of a freshly discovered peat soil and covered with typical wet grassland vegetation, palm plantation and agricultural food such as banana, pineapple and sparse patches of three-layered tree structure. Figure 1 show the location of sample point in Lumadan and some distribution of Sabah peat soil.

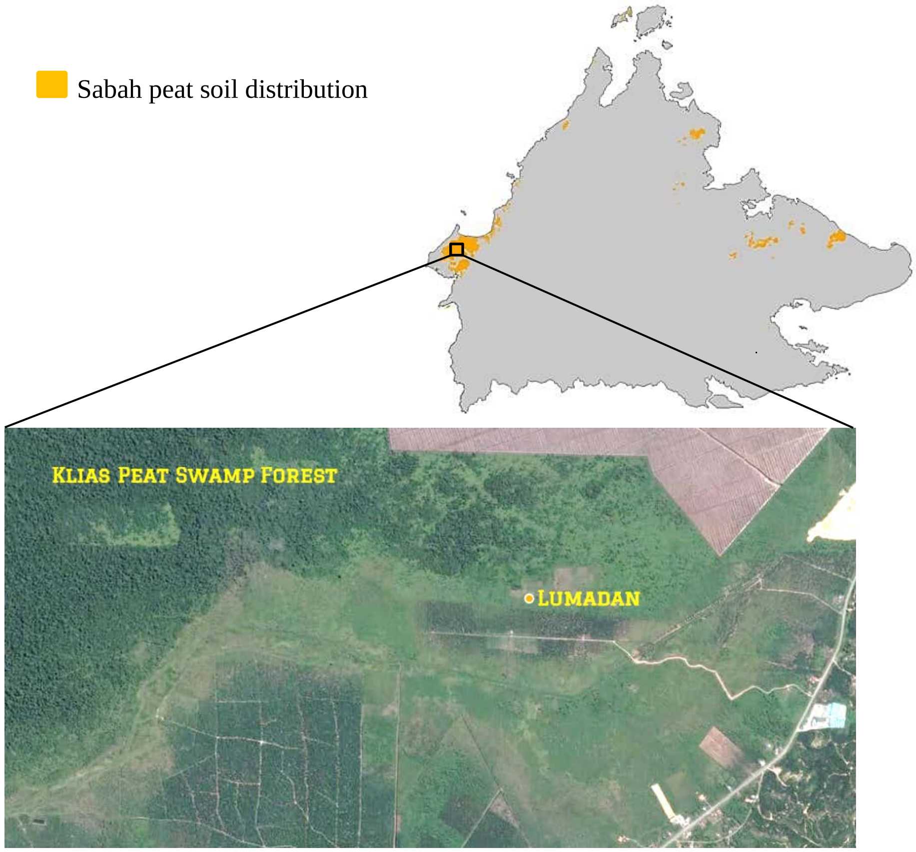

Figure 1: Location of sampling points in Lumadan, Beaufort, Sabah in the agricultural area.

The peat samples were obtained at depth of 0.3 to 0.5 m below the ground surface. Ground water table was found to be about 0.3 m from the ground surface. High water table contributed to the high water content in peat soil and it can be described that the peat samples are assumed to be fully saturated. Sample taken into two points where tagged as Lumadan 1 and Lumadan 2 which the distance only 100 m from each point.

Based on the visual observation, peat indicated that it was dark brown in colour, odour, fibreless, well decomposed and muddy. Figure 2 shows the visual observation of peat soil in field sampling. The degree of decomposition can be classified as H7 where half of peat passes through fingers and water expelled when squeezed. Sample obtained from Lumadan is very soft.

Undisturbed samples of peat soil were taken from Lumadan by using the sampling tube. Sampler size ranges from 50 mm diameter by 100 mm height and 100 mm diameter by 200 mm height. Undisturbed sample preferably used in this study for laboratory testing purposes due to the sample represent the current condition peat sample that eliminated from disturbance of fibre structure and suitable for laboratory testing.

Figure 2: Visual observation of peat soil according to Von Post Scale.

Experimental Investigation

The index properties of peat soil are determined based on test procedures according to the British Standard BS1377: 1990, ‘Methods of test for soils for civil engineering purposes’. Laboratory testing that used in the classification system included water content, loss of ignitions, fibre content, specific gravity and Atterberg limits were performed. Common chemical testing such as peat pH and ground water pH are conducted accordance to determine the acidic or alkaline samples. In-situ undrained shear strength of saturated peat measured in field using Vane Shear Test based on ASTM D2573 ‘Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils’.

RESULTS AND DISCUSSION

Table 1 shows the results of laboratory testing to examine the index properties of Sabah peat soil. Moisture content and liquid limit have significant value, where the moisture content for Lumadan 1 and Lumadan 2 is approximately 491.16 - 985.30% and 448.32 - 887.88% while, liquid limit recorded 266% and 249% respectively. A correlation can be found as it is noted that there is a slight but significant increase in liquid limit with the increase in natural water content as highlighted by Huat (2004). Al-Raziqi et al., (2003) found that the moisture content for West Peninsular Malaysia in their findings was 200% to 700% and Kheong (2011) reportedly 964.50%. The liquid limit value is also higher as the sample that contains fibre within 33% to 66% or organic content and thus it has high water absorption capacity Kolay et al., (2011). Physically, the baseline moisture content characteristics of Lumadan peat soil did not differ significantly. The specific gravity values of the mentioned locations generally range from 1.44 to 1.37 correspondingly for Lumadan 1 and 2 peat soil. Ground water pH showed ranges 4.2 to 4.4, while the peat soil recorded at 4.8 to 4.9. This is show slight differences due to the ground water taken from the drained area of peat where all the substances and decomposed particles converged differ from peat soil, the peat soil pH tested contents were a material that is decaying and miscible with water

These variations of results are due to climate change that are manifested by changes in temperature, precipitation and rainfall which influences the intensity of soil saturation where, the water table formed in a relatively in horizontal plane and may rise to a level that is greater or less than the elevation of the actual water table. It has been observed that the age of decomposition in soil fibre influences the acidic factors of soil. In Lumadan 1 and 2 locations, it can be observed that there are progressive agricultural activities. Natural forest wildfire brutally degraded and influenced the acidic level of the soil. Furthermore, Phua et al., (2008) reported that slash and burn for plantation was the major cause of the fires in 1998. The drainage system is in improper condition, there is no artificial drainage and that situation causes the ground water to be entrapped. This enhances the possibility of ground water retention and naturally making peat soil more acidic. Lumadan, Sabah has the organic content from 53.97% to 55.82% and fibre content from 76.85% to 79.40%. Referred to the ASTM (1990) Standard, peat classification has been classified into three classes based on fibre content where fibrous with intermediate decomposed with more than 33% fibre content are classified as Hemic peat. Lumadan, Sabah has intermediate decomposed peat fibre and classified as hemic peat.

Table 1: Lumadan, Beaufort index properties.

Properties	Lumadan 1	Lumadan 2
Moisture Content (%)	491.16 - 985.30	448.32 - 887.88
Liquid Limit (%)	266	249
Organic Content (%)	55.82	53.97
Von Post Scale	H7	H7
Fibre Content (%)	66	61.61
Specific Gravity	1.44	1.37
Peat soil pH	4.8	4.9
Ground water pH	4.4	4.2
Peat Type	Hemic	Hemic

Figure 3 shows a representative set of shear strength profiles in Lumadan, Beaufort, Sabah peat derived from vane shear tests 17mm X 34mm rectangular shape for two boreholes tagged with Lumadan 1 and Lumadan 2. Peak strengths increase for Lumadan 1 from Suv = 2 kPa at depth 0.1 m to 79 kPa with depth 2.5 m. Lumadan 1 recorded 2 kPa at 0.1 m and at depth 2.5 m the shear strength rapidly increased to 119 kPa. The distance between two boreholes is about 50 m. The sensitivity testing derived from the peat profile indicates sensitivity, $S_t \leq 1$. Michael (2005) stated that the Vane strength (Suv) in peat has been found to decrease with increasing diameter, possibly due to the effect of the fibres. This phenomena has been proved in this case where bigger diameter of Vane blade used at 25mm X 50 mm for borehole number 3 and tagged with Lumadan 3 where the shear strength gradually decreased compared to Lumadan 1 and 2. At depth 2.5 m, Suv for Lumadan 3 at 39 kPa, respectively.

Huat (2004) found that the undrained strength from vane shear test for Peninsular Malaysia of the soils were found to range from 3 kPa -15 kPa at depth 0 – 0.5 m. At the same depth, Lumadan peat has found in line with the ranges at 2 kPa – 12 kPa. However the review, Hanrahan (1994) has acknowledged that the vane shear test as a useful simple method to assess variability with depth, hard and soft layers. Yogeswaran (1995) reported the average field vane shear strength for tropical peat found in Sarawak to be only 10 kPa while the sensitivity ranges from 2 to 11.

Lumadan peat deposits are over 10 m thick with various depth and the average peat depth in Beaufort to be 8 m. According to Sabah – Land Resource Study (1976), the formation of the peat directly attributed to the accumulation of vegetative matter in stagnant, extremely acid and swamp waters. The peat is usually more than 1.2 m (4 ft) in depth and considered to be a very serious limitation to agriculture and it can be observed that, this condition slightly affected and contributed to the instability in prospective of development.

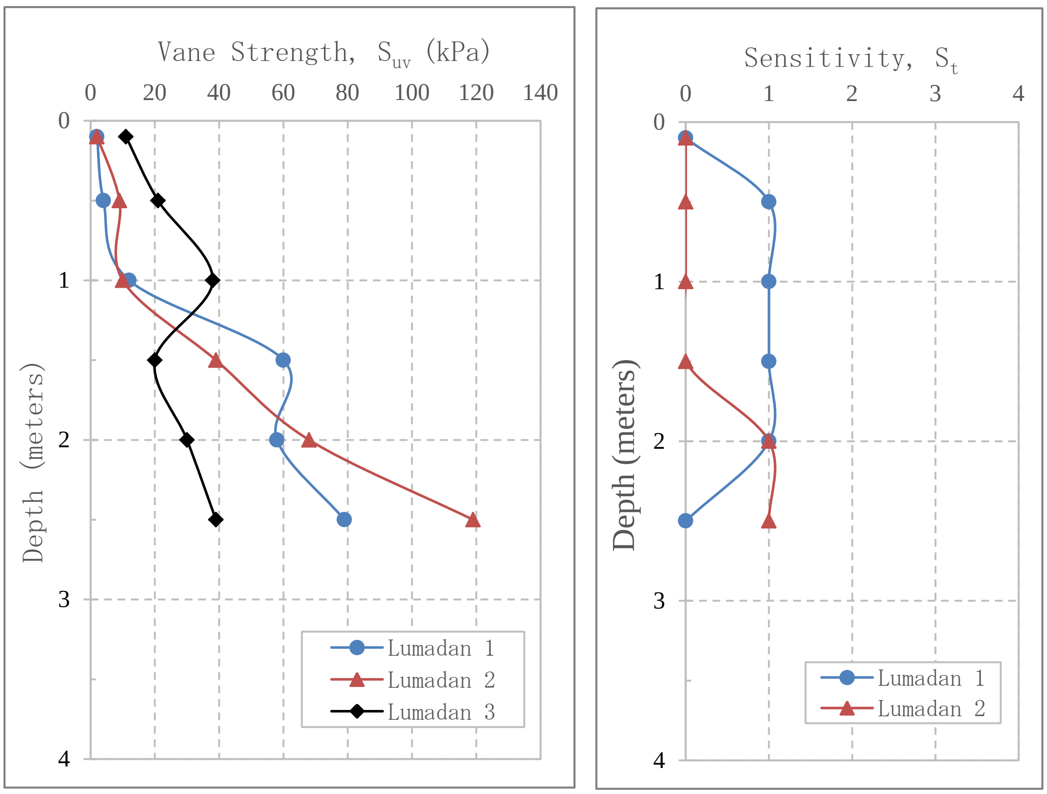

Figure 3: Vane Shear Test Result for Lumadan Peat.

The volume change (cm3) versus logarithmic of time curve response shown in Figure 4 was observed for Lumadan 1 and 2 peat specimens under 100 kPa effective stress and completed in 24 hours consolidation. Lumadan 2 has shown progressively changes in volume. When 100 kPa effective stress is applied to the specimens, a decrease in its volume takes place, when time completed the variations of volume recorded for both samples is about 1531 cm3 and the differences properties in fibre content pertaining to its tendency was identified as the cause of decrease in volume. The variation of the coefficient of consolidation, Cv obtained from Lumadan 1 and 2 is about 1.13 m2/year and 2.98 m2/year.

Classification of peat on the basis of degree of decomposition (Karlson and Hansbo 1981; Jarret 1995) identified as pseudo-fibrous peat with intermediate degree of decomposition. USDA classification of peat (Huat 2004) Lumadan peat has identified as hemic peat which more than 33% of fibre content with H7.

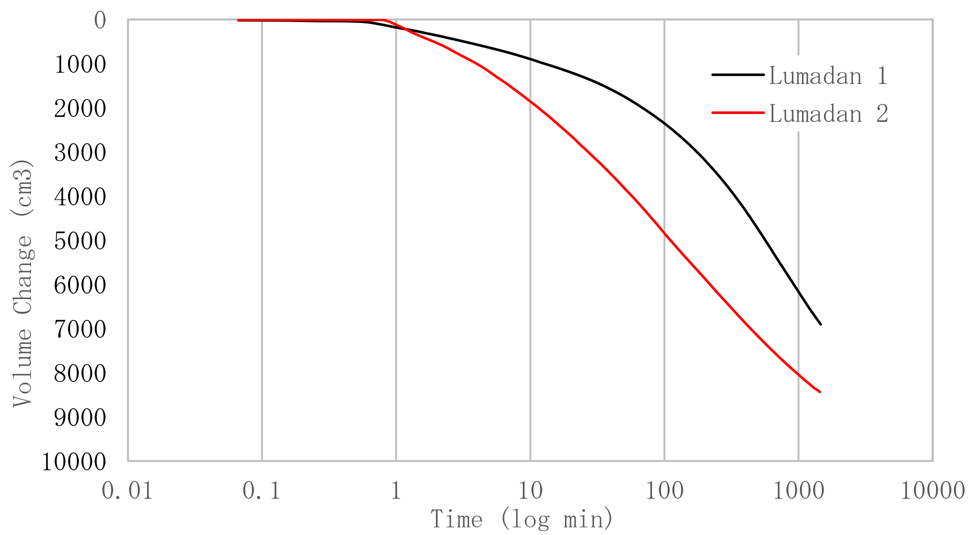

Figure 4: Volume change versus square root of time for a Lumadan Peat specimen under effective stress, σ = 100 kPa.

CONCLUSIONS

(1) The challenge for the coming decade is the creation and maintenance of an artificial structure and infrastructure that is built on peat soil has to be resolved. From observations, peat has a high uncertainty margin. Uncertainties and difficulties in testing of peat soil to determine the strength with very high compressibility, which presents significant challenge in developing peat behaviour in research.

(2) Peat contains high water content hence causing the material to be very sensitive and soft. This is why many researchers described peat as a problematic soil. Lumadan, Beaufort Sabah peat has identified as hemic peat.

(3) These variations of results are due to climate change that are manifested by changes in temperature, precipitation and rainfall which influences the intensity of soil saturation where, the water table formed in a relatively in horizontal plane and may rise to a level that is greater or less than the elevation of the actual water table. This paper has shown a series of laboratory and field testing of Beaufort peat properties for classification purposes.

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