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SARAWAK HEMIC PEAT CONSOLIDATION SETTLEMENT AND SHEAR STRENGTH BEHAVIOUR

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SUMMARY

Peat layer in Sarawak alone represents 13 percent or about 1.66 million hectares of Sarawak's total land area. They are mostly in low-lying areas; with in some areas, peat exceeding 10 m in depth. During past few decades, the demands of urbanisation resulted in the expansion of land development into swamp and deep peat areas. Thus, proper understanding, management and construction practices should be emphasized on peat to overcome consequential occurrence of ground subsidence problems. The objectives of this study are to investigate the consolidation settlement parameters and shear strength behaviour of hemic peat in Sarawak. The samples were taken from Matang, Batu Kawa, and Kota Samarahan, Sarawak. The initial characteristic tests consist of the degree of humidification, loss on ignition, Atterberg limit, particle density; moisture content and pH value. The results recorded high moisture content and organic content for Sarawak hemic peat. The value of Compression Index, C_c, determined from the oedometer test for hemic peat is in the range of 1.13 to 3.20 and compression ratio, $Cc/1+e_o$ is classified as very compressible (> 0.20) for all three locations; Matang, Batu Kawa and Kota Samarahan,. From the direct shear box test, the cohesion, c′ values are in the range of 8.0-18.0 kPa and angle of internal friction φ′ in the range of 24^o- 37^o.

***Keywords**: Sarawak hemic peat, peat consolidation, degree of humidification, loss of ignition.*

INTRODUCTION

Peat is defined as highly organic soil with the heterogeneous mixture of partially decomposed plant remains, with some contents of sand, silt and clay under damp and anaerobic condition at low temperature. The content of organic remains in peat is sufficiently fresh and undisturbed to permit identification of plant remains whose structure ranges from more or less decomposed plant remains to a fine amorphic mass. Approximately 1.7 million ha (13%) of the total land area of the Malaysian state of Sarawak State's total land area, are covered with tropical peat land (refer Figure 1) and about 90 percent is classified as deep peat with depth of more than 1.5 meter (Melling, *et al.*, 2002). The depth of peat layer increases from the coast towards the inlands. According to Huat et al., (1997), field investigation conducted in Western Sarawak has proven that there are three significant layers differentiated by its level of humidification based on the Von Post classification system, where each layer overlays the subsequent layer. The top thin layer of 0.5 m to 1.5 m thick is recognized as sapric (H7-H10) peat with fiber content of less than 33 percent. The second layer of peat, overlain by sapric peat, is recognized as hemic peat (H4-H6) with fiber content ranging from 33 to 66 percent. The near beneath of peat soil layer, overlain by hemic peat, is recognized as fibric peat (H1-H3) with fiber content of greater than 66 percent. A layer of grey mangrove clay may be seen under the fibric layers. The content of peat differs from location to location such as origin fiber, temperature and humidity (Huat *et al.,* 2009).

Peat has poor engineering properties, such as high compressibility and low in shear strength, due to high void ratios which results in higher values of compression index, Cc and secondary compression, $C\alpha$, when compared with other soil types. A study by Mesri *et al.* (1997) showed that the secondary compression is prominent in peat deposits because it exists at a high void ratio, which exhibit high values of Cc and displays a high ratio of $C\alpha/Cc$. Table 1 presents the summary of the natural moisture content with the relevant $C\alpha/Cc$ values for different peat deposits (Mesri *et al*., 1997). Landva (1980) reported the in-situ vane shear tests on peat with void ratio of 6.1 – 11.5 displayed shear strength levels ranging from 5-35 kPa. However, Lea and Brawner, (1963) observed that the low strength will increase when fibers, and the particles of the peat come together under compression. Such a considerable gain in strength is attributed to the exceptionally high values of the effective angle of shearing resistance ϕ', which has been observed in various laboratory testings on peat (Karunawardena, 2007). This paper presents the findings on geotechnical characteristics, consolidation settlement parameters and shear strength of hemic peat. The tests have been performed in Geotechnical Laboratory, UNIMAS and all the experimental investigations were performed in accordance to BS 1377: Part 2 (1990) unless stated otherwise.

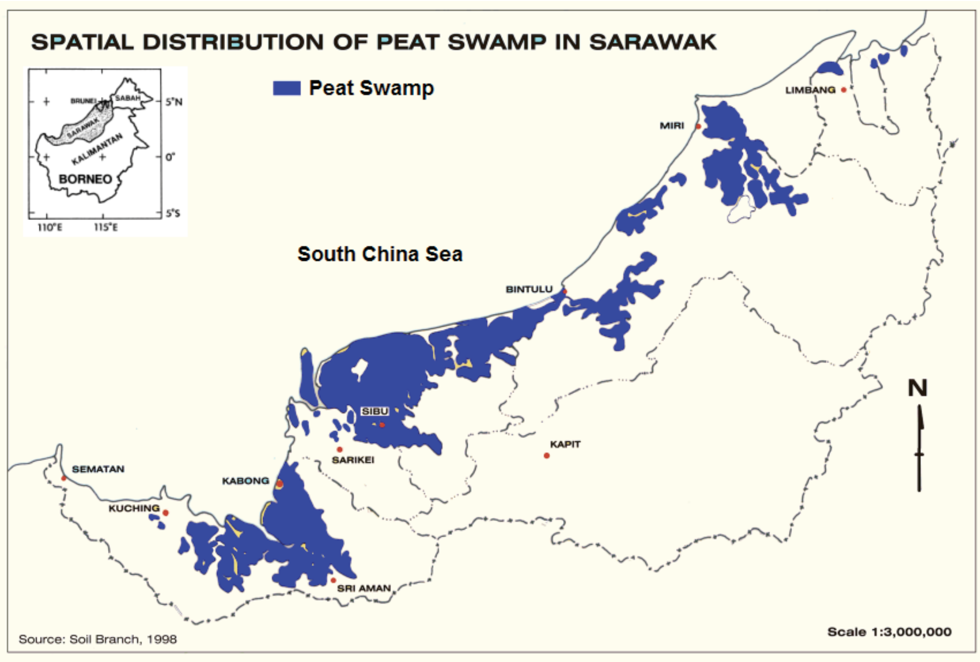

Figure 1 Sarawak peat swamp distribution (Melling et al, 2002)

Table 1 Summary of natural moisture content and Cα/Cc for peat deposits (Mesri *et al*,. 1997)

Peat	Natural Moisture Content	Cα/Cc	Reference
Fibrous peat	850	0.060-0.100	Hanrahan (1954)
Peat	520	0.061-0.078	Lewis (1956)
Armorphous and fibrous peat	500 -1500	0.035-0.083	Lea and Brawner (1963)
Canadian muskeg	200-600	0.090-0.100	Adam (1965)
Amorphous to fibrous peat	705	0.073-0.091	Keene and Zawodniak (1968)
Peat	400-700	0.075-0.085	Weber (1969)
Fibrous peat	605-1290	0.052-0.072	Samson and LaRochell (1972)
Fibrous peat	613-886	0.060-0.085	Berry and Vickers (1975)
Amorphous to fibrous peat	600	0.042-0.083	Edil and Dhowian (1981)
Fibrous peat	660-1590	0.060	Lefebvre et al. (1984)
Dutch peat	370	0.060	Den Haan (1994)
Fibrous peat	610-850	0.052	Karunawardena (2007)

PROPERTIES OF SARAWAK HEMIC PEAT

Table 2 presents the geotechnical properties of Sarawak hemic peat taken from three different locations; Matang, Batu Kawa and Kota Samarahan by using the UNIMAS peat sampler. The samples (Figure 2) were categorized into the hemic group, ranging from H4 to H5 assessed through to the Von Post classification system on a 10-point scale. The description suited the classification made as the samples were slightly decomposed and a very small amount of granular peat with muddy dark water escaped between the fingers upon squeezing. Organic content in Sarawak hemic peat is best determined by performing loss on ignition test. From the test, it can be seen that the organic content for Sarawak hemic peat is very high, which varies from 89% to 95%. Higher percentage of organic matter produced relatively high moisture content in Sarawak hemic peat. Based on the published work, it has been proven reasonable that the voids between organic particles have a high capacity of entrapping moisture content, which resulted in high moisture content of peat. It is clearly shown that, the organic content does affect the moisture content of Sarawak hemic peat. Batu Kawa and Matang samples have shown relatively high organic content, which also resulted in high moisture content records. The pH value for Sarawak peat falls in the range of 3 to 4, to which are classified as acidic and reduced of organic content.

Figure 2 Sarawak hemic peat – Kota Samarahan sample

Table 2 Geotechnical properties of Sarawak hemic peat

Properties	**Matang**	**Batu Kawa**	**Kota Samarahan**
Von Post Classification	H4 - H5	H5	H4
Moisture Content (w_N) (%)	594 - 856	607 - 926	426 - 817
Liquid Limit, LL (%)	234 - 245	252 - 261	192 - 200
Organic Content, OC (%)	95	95	89
Fiber Content, FC (%)	45.6	50.3	23.2
Specific Gravity (G_s)	1.08 - 1.35	1.11 - 1.34	1.25 - 1.67
pH Value	3.2 – 3.8	3.3 - 3.9	3.4 – 4.3
Initial Void Ratio, e_o	2.720-3.104	2.830	3.318

Table 3 Compression parameters of Sarawak hemic peat

Location	**Compression Index**	**Compression Ratio**	**Coefficient of Secondary Compression**	**Law of Compressibility**
	Cc	**Cr=Cc/(1+e_o)**	**Cα**	**Cα/Cc**
Matang	3.185	0.790	0.1110	0.035
Batu Kawa	1.130	0.295	0.0395	0.035
Kota Samarahan	1.220	0.282	0.0427	0.035

TEST RESULTS AND DISCUSSION ON SARAWAK HEMIC PEAT

Consolidation Settlement Parameters of Sarawak Hemic Peat

In this section the results of consolidation parameters using the Oedometer test are presented. The study focused on two consolidation parameters, which are Compression Index, Cc and Coefficient of Secondary Compression, Cα. About sixteen (16) oedometer tests with different loading schedules in the range of 10-100 kPa have been performed. The load ranges were chosen to replicate the most common cases in the construction practice. All procedures of the Oedometer test were in accordance to BS 1377: Part 5: 1990. The compression index, Cc values obtained for hemic peat were in the range of 1.13 to 3.20, which were smaller than published work for Cc values of peat reported as 5 to 10 in previous study. This may be due to the samples collected from this tropical region which possesses high compressibility when subjected to higher loading over the time period (Huat, 2007).

The coefficient of secondary compression, Cα, value were determined from the correlation of Cα = 0.035Cc developed by Mesri *et al.* (1997). The Cα value calculated is in the range of 0.0395 to 0.111 for Sarawak hemic peat. According to Mesri (1973), soil with Cα values of more than 0.064 is classified as soil with extremely high compressibility.

The compression ratio, Cr = Cc/1+e_o, for the Sawarak hemic peat is classified as very compressible with greater than 0.20 for all three locations; Matang, Batu Kawa and Kota Samarahan based on the study by O'Loughlin and Lehane (2003). The study presented that the compression ratio of peat ranges from 0.01 to 0.05 is categorized as very slightly compressible; 0.05 to 0.10 is moderately compressible, and between 0.20 to 0.35 is very compressible.

Table 3 tabulated the value for Law of Compressibility; Cα/Cc is 0.035 of Sarawak hemic peat. The value obtained corresponds well with the range, Cα/Cc = 0.020 to 0.100, as reported by Mesri and Castro (1987) for a wide range of soils including sands, inorganic and organic clays and peat. Also, the finding is in agreement with

Duraisamy et al. (2007), where the samples of peat were taken from the West Coast of Peninsular Malaysia. However, further laboratory testing especially involving long-term oedometer test and field investigation of peat throughout Sarawak are still required in order to perform comprehensive parametric studies on Sarawak peat.

Shear Strength of Sarawak Hemic Peat

The shear strengths of Sarawak hemic peat were determined in the laboratory using the shear box. The samples taken from Matang, Batu Kawa and Kota Samarahan are placed in a shear box which has two stacked rings to hold the sample. A confining stress is applied vertically to the sample, and the upper ring is pulled laterally until the sample fails. The load applied and the strain induced is recorded to determine a stress–strain curve for each confining stress. The results from the shear box tests obtained are tabulated in Table 4 and showed that the Sarawak hemic peat has very low cohesion, c′ ranging from 8.0 kPa to 18.0 kPa. The hemic peat exhibits a high angle of internal friction ϕ ′, which ranges from 24° to 37° and these findings have an agreement with Kazemian *et al.,* (2011). The high internal angle of friction is attributed to the existence of fibre content in peat, which acts as a reinforcement, thus modify the strength of the peat.

Table 4 Shear box test results of Sarawak hemic peat

Location	Cohesion c′ (kPa)	Angle of internal friction, ϕ′(deg)
Matang 1	17.0	25
	12.0	27
	8.0	30
Matang 2	18.0	25
	16.0	24
	10.0	28
Batu Kawa	12.0	32
	8.0	34
	8.0	37
Kota Samarahan	14.0	33
	12.0	36
	13.0	30

CONCLUSIONS

This paper briefly described the geotechnical characteristics, consolidation settlement parameters and shear strength of hemic peat. Based on the results, the following conclusions were obtained:

- The results from the laboratory show high moisture content and organic content of Sarawak hemic peat.
- The value of Compression Index, Cc for hemic peat is in the range of 1.13 to 3.20 and compression ratio, $Cc/1+e_o$ is classified as very compressible (> 0.20).
- The value for Law of Compressibility, Cα/Cc is 0.035 for Sarawak hemic peat, which is lower from the values reported by Mesri and Castro (1987) but in agreement with Duraisamy et al. (2007).
- The cohesion, c′ values are in the range of 8.0-18.0 kPa and angle of internal friction φ′ in the range of 24°-37° determined from direct shear box test.

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