EXPERIMENTAL STUDY ON THE BEHAVIOUR OF SHRINKAGE AND COMPACTION BETWEEN PEAT AND MODIFIED PEAT SOIL

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To,

Mom Nadiah Bt. Abdullah, Dad Ismaili Hj. Redzuan, Safarina Bt. Ismaili and Zurina Bt. Ismaili
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ABSTRACT

Peat has a unique properties from other soil due to it’s organic content, which is more than 75%. Beside that, peat is also known as a problematic soil especially in engineering field for development sector and as well as agricultural sector. In Kuching alone, there is 23059 km² of peat area. Therefore, five samples were obtained from Kuching areas with different locations, where there are two sub samples will be obtain from each five location with deference of sampling point. The soil classification process was required to identify the basic physical properties of peat. These can assist to understand the effect of peat behaviour on shrinkage and compaction characteristics. The study on linear shrinkage was performed for each of the modified peat soil for the comparison purposes with the original peat. In this project, peat was modified with 10%, 20% and 40% of sand. The compaction test was conducted for determination of optimum moisture content and dry density between peat and modified peat. The linear shrinkage test and the standard proctor test have close relationship with organic content in the samples. Therefore, the result that obtained from this study elucidate that the decreasing of organic content lead to a decreasing of shrinkage and decreasing of moisture content between peat and modified peat soils.
ABSTRAK

# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>I</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>II</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>III</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>IV</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>VII</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>VIII</td>
</tr>
</tbody>
</table>

## 1.0 INTRODUCTION

1.1 General 1
1.2 Background 1
1.3 Scope of Present Study 3

## 2.0 LITERATURE REVIEW

2.1 General 5
2.2 Formation of Peat 6
2.3 Engineering Application 7
2.4 Characteristics of Peat Soil
  2.4.1 Basic Definition and Terminology 8
  2.4.2 Mineralogy 9
  2.4.3 Structure 9
2.5 Basic Geotechnical Properties and Physical Properties of Peat Soil
  2.5.1 Water Content 10
2.5.2 Soil pH 10
2.5.3 Specific Gravity and Bulk Densities 11
2.5.4 Porosity of Peat 12
2.5.5 Shear Strength of Peat 13
2.5.6 Compression Behaviour of Peat Soil 15
2.5.7 Shrinkage of Peat 17
2.5.8 Loss on Ignition and Organic Content 18

2.6 Summary 19

3.0 TEST PROGRAMME AND METHODOLOGY

3.1 General 21

3.2 Physical Properties of Peat
3.2.1 Moisture Content 21
3.2.2 Soil pH value 23
3.2.3 Ignition Loss and Organic Content 23
3.2.4 Specific Gravity 24
3.2.5 Bulk Density 25
3.2.6 Liquid Limit Test 25
3.2.7 Plastic Limit Test 26

3.3 Determination of Shrinkage and Compaction of Peat Soil
3.3.1 Linear Shrinkage Test 27
3.3.2 Compaction Test 28

4.0 EXPERIMENTAL RESULTS AND DISCUSSION

4.1 General 30

4.2 Experimental Study of Peat Soil on its Physical Properties
4.2.1 Moisture Contents 30
4.2.2 pH Value 31
4.2.3 Liquid Limit Test 31
4.2.4 Plastic Limit Test 32
4.2.5 Specific Gravity 33
4.2.6 Loss on Ignition and Organic Content 33
4.2.7 Bulk Density 34

4.3 The Selection Procedure of the Peat Soil
Among 5 Samples 34

4.4 Experimental Study on the Behaviour of
Shrinkage and Compression Between Peat
and Modified Peat Soil
4.4.1 Linear Shrinkage 37
4.4.2 Compression Test 37

4.5 The Correlation Between Shrinkage
and Compaction 38

5.0 CONCLUSION AND
RECOMMENDATION FOR
FUTURE STUDY
5.1 Conclusion 44
5.2 Recommendation 45

REFERENCES 46
APPENDIX 54
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>Bulk density of tropical peat</td>
<td>12</td>
</tr>
<tr>
<td>3.0</td>
<td>Minimum Mass of Moist Specimen</td>
<td>22</td>
</tr>
<tr>
<td>4.0</td>
<td>Summary of Liquid Limit and Plastic Limit value for 5 samples</td>
<td>33</td>
</tr>
<tr>
<td>4.1</td>
<td>Summary of physical properties value for 5 samples.</td>
<td>35</td>
</tr>
<tr>
<td>4.2</td>
<td>The selected table of peat soil according to well known previous research from few researchers.</td>
<td>36</td>
</tr>
<tr>
<td>4.3</td>
<td>The selected table of peat soil by using three index parameter according to Hobbs (1986).</td>
<td>36</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 2.0: Peat swamp forests in Sarawak 5

Figure 2.1: CU-Triaxial Test 15

Figure 4.0: Correlation between organic content and liquid limit 32

Figure 4.1: Results of Moisture Content obtained from 5 collected samples. 39

Figure 4.2: Results of pH value obtained from 5 collected samples. 39

Figure 4.3: Results of Liquid and Plastic Limit value obtained from 5 collected samples. 40

Figure 4.4: Results of Specific Gravity for 5 samples collected. 40

Figure 4.5: Loss on Ignition & Organic Content. 41

Figure 4.6: Result of Bulk Density for 5 samples collected. 41

Figure 4.7: Results on Linear Shrinkage between peat and modified peat soil. 42

Figure 4.8: Results of Optimum Moisture Content and Dry Density for peat and modified peat soil. 42

Figure 4.9: Relationship Between Organic Content and Optimum Moisture Content. 43
1.0 INTRODUCTION

1.1 General

The main aim of this project is to study the effect of shrinkage and compaction behaviour or characteristics between peat and modified peat soil by performing various experimental studies. Firstly, the soil classification tests were carried out in order to determine some basic physical properties of peat soil. Then, a study on linear shrinkage was performed for each of the modified peat soil for the comparison purposes with the original peat. In this project, peat soils were modified with 10%, 20% and 40% of sand. Next, the compaction test was conducted for determination of optimum moisture content and maximum dry density between peat and modified peat. Finally the correlation between linear shrinkage and compaction test was performed.

1.2 Background

Peat soil is a naturally occurring polyelectrolyte, which is mainly the resultant product of the decayed vegetation over a period of time (Shotyk, 1988). According to Andriesse (1988), peat in strict definition usually refers to the accumulation of a purely 100 % organic material and the distinction between soil and vegetative accumulation is not clear. Over the years, peat has been alternately referred to as organic soils and histosols (Murtedza et al., 2002). Cheng and Jack (1990) also indicated that peat soil has an organic odour, a dark brown to black colour, a spongy consistency and a texture ranging from fibrous to amorphous. Mutalib et al., (1991) reported that it has 3 major components, which are humic acid, lignin and carbohydrates due to its organic in nature. Beside that, peat is very compressible on account of its high water content (Price and Schlotzhauer, 1999). Generally, there are two main types of peat soil, which are highmoor or sphagnum peat that formed from several species of sphagnum or peat moss and the other type is lowmoor peat, it is derived largely from sedges, reeds cattails, pondweeds and other aquatic plants ([WWW]).
Peat soil in Malaysia is known as tropical peat soil (Mutalib et al., 1991). It is cover about 8.2% of the total land area which equivalent about 2.7 million hectar of peatland. Meanwhile, Sarawak as the largest state in Malaysia has the biggest reserves of peatland, which about 1.5 million hectares of peatland, that are relatively underdeveloped (Jamaluddin, 2002). Briefly, peat can be found along the middle and southwestern coast of Peninsular Malaysia and the north western coast of East Malaysia ([WWW]²). Jamaluddin, (2002) quoted that, most of the Malaysian’s peat are initially wetland area located in flood prone areas.

Mutalib et al., (1991) reported that the tropical peat soil has chemically and structurally different from the fibrous peat soil of Europe and Canada. In their nature state, tropical peat soil have generally been recognised as a problem soil with marginal agricultural capability (Jamaluddin, 2002), unless with proper conditioning. The used of this tropical peat soil as a source of fuel for energy is very limited. This is due to their inherent characteristics, which are high leaching, which contributes high colour and Chemical Oxygen Demand (COD) to the effluent and also has a low mechanical strength that courses a poor hydraulic conductivity (Mutalib et al., 1991). Other important characteristics that cause various problems for agricultural use are the presence of submerged and under composed woods, stumps or log which can impede the movement of a farm workers and machinery in the field, the very high ground water table, low bulk density and bearing capacity, very acidic, extremely low level of nutrients and shrinkage and subsidence upon drainage (Jamaluddin, 2002). Consequently, based on these characteristics, peat is considered as a problematic soil.

The multitudes of problems encountered were far too enormous and complicated to be overcome by individual to farm the peat soil land (Jamaluddin, 2002). Therefore, the involvement of government by way of providing financial and technical support, this scenario has changed to one of optimism as evidenced by successes in the cultivation of a number of crops such as oil palm, sago, coconut, pineapple, paddy and mixed horticulture crops (Jamaluddin, 2002). Ambak and Melling (1999) reported that there are approximately 554,775 ha of peat under cultivation in the state of Sarawak.
In engineering aspects, development of the peat area for the construction of road has required the extension of geotechnical principles where there is no consensus on the best methods of analysis. Thus, the development of infrastructures in peat areas are fraught with some engineering problems, where the difficulty in finding the best solution to treat the peat soil. This is due to the low bearing capacity, high compressibility and extremely compressible nature of peat soil itself and may lead to very large settlement, and even under moderate loads (Liang, 1998).

1.3 Scope of Present Study

This present work can be described as an experimental study on the effect of shrinkage and compaction between peat and modified peat soil. The understanding on the behaviour of peat soil due to the shrinkage and compaction is very important in order to determine the capability of the soil for the engineering and development purposes, since peat soil is classified as a problematic soil (Helal Uddin et al., 2003). However, only a small part of this broad study has been focused on this present study. Further, the selective representative sample used are peat and were then mixed with 10%, 20% and 40% of sand which known as modified peat soil as stated below:

- M1: Original peat
- M2: Peat + 10% Sand
- M3: Peat + 20% Sand
- M4: Peat + 40% Sand

The objectives of this project are as follows:

- An identification of physical properties of peat soil and modified peat soil by using soil classification tests.
- Laboratory experiments will be performed to investigate the effect on the shrinkage and compaction behaviour between peat soil and modified peat soil.
Laboratory experiments is to obtain one of the most problematic or soil that given the lowest result from 5 samples at deference locations after undergoes the soil classification test as a representative soil for a commence study on the effect of shrinkage and compaction behaviour of peat soil.

The outlined of the project report are as described below:

Section 1: Presents the introduction, background and scope of the current work conducted in the project.

Section 2: Concerns on a literature review of the characteristics and properties of peat soil and the behaviour with respect to different experimental work conducted by previous researchers.

Section 3: Mainly about the experimental investigation conducted in the present study. In this section, a detailed step-by-step description is provided; the sample preparation for each test; description of main features of the apparatus used and the experimental procedure followed.

Section 4: Presents the results and discussion of the experimental investigation outlined in Section 3.

Section 5: Contains an outlined of the conclusions drawn in the project and the recommendations for further development of the present work for future research.
2.0 LITERATURE REVIEW

2.1 General

Malaysia is moving towards a developed country status by 2020 thus, the pressure on the land use by industry, housing and infrastructure are leading to more frequent utilisation of such marginal grounds (Al-Raziqi et al., 2003). Therefore, the construction need to be carried out almost everywhere and this mean that site where land is categorized as problematic, construction need also to be carried out including construction over peaty soil. Although, it is a great challenge to the engineer to build the infrastructure on peat soil due to it low bearing capacity, which is about 8 kN/m². However, one of the tremendous achievements of construction over peaty soil are the construction of Kuala Lumpur International Airport (KLIA) in Sepang and Projek Lebuh Raya Utara Selatan from Tangkak to Yong Peng (Adnan and Ismail, 2003).

Mutalib et al., (1991) and Government of Sarawak (1990) indicated that Sarawak has the largest peat area in Malaysia with 16,500 km² that makes up 13% of the state, of which about 90% is more than 1m in depth. The Soil Map of Sarawak, on the scale of 1:500,000 shown in Figure 2.0 is based on a classification of Sarawak soil (Jamaluddin, 2002) and subsequent amendments show the extent of the peat. Thus, it is not surprising that peatlands presents a challenge for construction in a state like Sarawak especially due to their location.

Figure 2.0: Peat swamp forests in Sarawak (Jamaluddin, 2002)
2.2 Formation of Peat

The area of peatlands represents some 5% - 8% of the world's land surface, because peat formation is generally closely linked to climate, much of the world's resources lie in the northern temperature zone ([WWW]3). Lam (1989) postulates the possible events leading to the development of peat deposits as a result of sea-level changes. The last global glaciation resulted in rapid denudation and deep incision of the parent rock formation. After the last maximum glaciation (some 18,000 years before present), sea-levels rose rapidly and as a result large amount of sediments were transported and deposited and formed deltas and flood plains. Generally, peat formed in very wet conditions grow considerably faster and less decomposed than that in drier places. This allows climatologists to use peat as an indicator of climate change ([WWW]3). There are 6 types of peatland which are widely recognised as stated below:

- **Blanket mires**: Rain-fed peatlands generally 1 to 3m deep and many found in the United Kingdom. They generally develop in cool climates with small seasonal temperature fluctuations and over 1 m of rainfall and over 160 rain days each year.

- **Raised mires**: Rain-fed, potentially deep peatlands occurring principally in lowland areas across much of Northern Europe, as well as in the former USSR, North America and parts of the southern hemisphere.

- **String mires**: Flat or concave peatlands with a string-like pattern of hummocks (hence the name), found principally in northern Scandinavia but occurring in the western parts of the former USSR and in North America. A few examples exist in northern Britain.

- **Tundra mires**: Peatlands with a shallow peat layer, only about 500 mm thick, dominated by sedges and grasses. They form in permafrost areas, covering around 110,000 to 160,000 km² in Alaska, Canada, and the former USSR.
- **Palsa mires**: A type of peatlands typified by characteristic high mounds, each with a permanently frozen core, with wet depressions between the mounds. These develop where the ground surface is only frozen for part of the year, and are common in the former USSR, Canada and parts of Scandinavia.

- **Peat swamps**: Forested peatlands including both rain- and groundwater-fed types, commonly recorded in tropical regions with high rainfall. This type of peatland covers around 350,000 km², primarily in south-east Asia but also occurring in the Everglades in Florida ([WWW]³).

Liang (1998) also reported that, peat swamps were then initiated in the depressions and basins between the isolated hills and sleeves, and in the deltas. During the initial stage, plants developed on mineral soil and the areas are still under the influence of the rivers with influx of clastic (mineral) sediments during floods. The accumulation of the clastic sediments and plants remains resulted in the formation of clayey peat (topogenous peat). As plant remains accumulated, the ground surface level was elevated and led to the formation of peat which is free of clastic sediments (ombrogenous peat).

### 2.3 Engineering Application

According to Fuchsman (1986), peatland may be drained for several purposes. The drained peat may subsequently be removed for horticultural use (Heikurainen, 1983). Beside that, peat soil can also be use in industrial sector as an ion exchange material to remove metal ion from industrial waste effluent due to its ionic functional groups (Helal Uddin et al., 2003). Compared to commercial ion exchanger, peat is comparatively inexpensive and easily available (Murtedza et al., 2002). Another use of peat soil is as filter media (Helal Uddin et al., 2003). Peat is partially decomposed organic material with a high water holding capacity, large surface area and chemical properties that make it very effective in treating
wastewater (Gustafson et al., 2001). Moreover, its porous nature allows it to adsorb a wide variety of pollutants mainly organic compounds (Poots et al., 1976).

In research conducted in Minnesota, peat filters removed high concentrations of nutrients (nitrogen and phosphorus) and produced a high-quality effluent with less than 30 mg/liter (BOD) biological oxygen demand, a measure of organic material, less than 25 mg/liter (TSS) total suspended solids, and less than 1,000 cfu/100 ml fecal coliform bacteria, an indicator of pathogens and viruses. By using a gravity distribution system, wastewater may pond on top of the peat and compresses it, reducing the flow of wastewater through the filter. With a pressure distribution system, wastewater is applied evenly over the peat surface, allowing rapid infiltration. Filters using pressure distribution are long lasting and provide good treatment of wastewater (Gustafson et al., 2001).

2.4 Characteristics of Peat Soil

2.4.1 Basic Definition and Terminology

Peat is a highly organic material structurally different from mineral soil (Edil et al., 1986), and it is very spongy (Whitlow, 1995). It is one of the most compressible soil in nature (Den Haan et al., 1994) and highly combustible (Whitlow, 1995). Edil (2003) stated that the solid phase of peat and consists of two components, which are organic matter and inorganic earth minerals. As inorganic minerals increase, the material will grade towards and organic soil (Whitlow, 1995). From an engineering point of view, peat pose many problems because of their high compressibility, low shear strength (Al-Raziqi et al., 2003), low bearing capacity (Liang, 1998), void ratio and moisture content and in some cases their acidity (Whitlow, 1995). Liang (1998) indicated that the extremely compressible nature of peat could lead to very large settlements under even moderate loads, it is considered to be the worst foundation material.
2.4.2 **Mineralogy**

Peat, the unconsolidated rock that forms the body of the peat bogs, is one of several biolites, i.e. sedimentary formations developing through biological processes (Lüttig, 1986). Lim (2000) stated that, the solid constituents consist of predominantly of vegetable or animal (Edil, 2003) in various stages of decomposition or preservation (Lim, 2000) with an end product known as humus (Edil, 2003). Lüttig (1986) also explained that the variations in peat arise from the variety of plants whose residues contributes to peat formation, and from the environmental conditions in which humification takes places.

The soil organic matter when extracted can be fractionated into components, primarily those characteristics of plant tissues and those based on humus (Huttunen et al., 1996). The first group (non humic matter) includes fats, waxes, oils, resins, water-soluble polysaccharides, hemicellulose, cellulose and protein (Huttunen et al., 1996). And the second group includes humus fraction (Huttunen et al., 1996) is divided into three different fractions on the basis of their solubility in aqueous acid and base which are humic acid, fulvic acid and humin (Wershaw et al., 1986).

2.4.3 **Structure**

Fox and Edil (1994) indicated that peat fibres have a cellular structure and cannot be considered as rigid solid bodies. Furthermore, Fuchsman (1986) explained that, peat is viewed as a porous compressible solid mass. The dewatering of peat is related to the complex structure of the peat (Edil at al., 1986). Structural details of peat components have been investigated by degradative methods (Fuchsman, 1986). Loxham and Burghardt (1986) reported that the peat actually consists of a collection of individual pores that at a given saturation either contribute to the total flow or not, depending on whether or not they are filled at the capillary suction considered.

Unlike granular soil, peat microstructures are highly irregular and cannot be characterized by a single motif of anyone shape (Fox and Edil, 1994). Microscopically, peat reveal a high degree of structural organization, characterizes
mainly by large channels (macro-pores) and fine channels (micro-pores), some of which are discontinuous (Loxham and Burghardt, 1986). Fuchsman (1986) indicated that peat micropores as the principles sites hydrogen-bonding and absorption of water. The hydrophilicity of peat surface is generally attributed to the availability of organic functional groups capable of hydrogen-bonding such as carboxyls and as well as phenolic and alcoholic hydroxyls. These oxygenated structures are present in humic and fulvic acids and in carbohydrates (Fuchsman, 1986).

2.5 Basic Geotechnical Properties and Physical Properties of Peat Soil

2.5.1 Water Content

The standard drying of soil at 105°C during 24 hours will lead to charring of the organic components in peat, thus producing too large figures for water content (Liang, 1998). Skempton and Petley (1970) and Kabai and Farkas (1988) showed that water content determined by oven drying at 105°C ± 5°C resulted in insignificant decomposition of organic matter in the organic soils. While drying at lower temperatures it may retain a small amount of free water (Liang, 1998). This seems to be an acceptable method for determination of water content of the organic soil (Al-Raziqi et al., 2003). Therefore the temperature of 105°C is recommended (Liang, 1998). Generally, the field moisture is reported to range from 100-1300% on a day weight basis. The high water content is the cause of buoyancy and a high pore volume that results in low bulk density and low bearing capacity (Farrell, 1997).

2.5.2 Soil pH

Usually peat has an acidic reaction caused by presence of carbon dioxide and humic acid resulting from decay (Edil, 2003). Murayama and Zahari (1994) reported that the pH of organic soil in Sarawak was found to be highly correlated to the decomposition rate: the higher the pH, the greater the decomposition rate. Bache
(1979) stated that soils have several mechanisms which serve to buffer pH to varying extends, including hydroxyaluminium ions, CO₂, carbonates and cation exchange reaction. Almost all organic soils in Sarawak are very acidic (Murtedza et al., 2002) and the pH values are between 3.0 to 4.5 (Mutalib et al., 1991). Variations within this range are caused either by admixtures of mineral soil which generally increased the pH or by specific location in the peat swamp (Andriesse, 1988).

Liang (1998) indicated that soil pH usually increases with depth in humid regions where bases are leached down the profile, and can decrease with depth in arid environments where evaporation causes salts to accumulate in the surface horizon. Therefore, ombrogenous peat, which is essentially a pile-up of loose trunks, branches, roots and fruits, is reported to be characterized by a low pH (Yogeswaran, 1995). The pH can be increase due to the reduction in the organic content in the sample and can also be due to the agricultural activity on the peat soil (Adnan and Ismail, 2003), in terms of the methodology for pH determination, a good correlation (R²=0.8) was established between pH measured in KCL and pH measured in water (Murtedza et al., 2002).

2.5.3 Specific Gravity and Bulk Densities

The specific gravity for organic soil is influence by the composition of the organic content like cellulose and lignin (Adnan and Ismail, 2003) and cannot therefore simply been set to somewhere near 2.65-2.75 as for in mineral soils (Al-Raziqi et al., 2003). Den Haan (1997) for example quoted cellulose and lignin will affect the specific gravity because the specific gravity for cellulose around 1.58 and lignin only 1.40 (Adnan and Ismail, 2003). The test to determine the specific gravity of the samples were carried out according to BS 1377 with slight modification of procedures (Adnan and Ismail, 2003). In general, the term of specific gravity is defined as the ratio of the weight of a given volume of material to the weight of an equal volume of water (Liang, 1998). Likewise the bulk densities of the organic soils are lower than those of mineral soil (Al-Raziqi et al., 2003). The bulk density determined for the top 0.30 m is low varying within the range of 100 to 200 kg per cubic meter (Mutalib et al., 1991). Briefly, bulk density depends on the amount of
compaction, the botanical composition of the materials, and their degree of decomposition and the mineral and moisture contents at the time of sampling (Andriesse, 1988). Andriesse (1964) reports that, the mean bulk densities of 0.12 and 0.09 g/cm$^3$ for Sarawak peat. Table 2.0 shows the reported values of bulk density of tropical peat soil in Sarawak.

Table 2.0: Bulk density of tropical peat

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>Bulk density (Mg/m$^3$)</th>
<th>Remarks</th>
</tr>
</thead>
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<tr>
<td>Andriesse, 1964</td>
<td>Sarawak</td>
<td>0.12</td>
<td>0-0.3 m depth</td>
</tr>
<tr>
<td>Andriesse, 1964</td>
<td>Sarawak</td>
<td>0.08-0.09</td>
<td>0.6-1.2 m depth</td>
</tr>
</tbody>
</table>

2.5.4 Porosity of Peat

Soils contain particles of different types and sizes (Liang, 1998). Space between particles can be seen by using polyglycol displacement techniques (Loxham and Burghardt, 1986). Within the pore space, there will be lots of complicated channels, which the water can flow (Loxham and Burghardt, 1986). Therefore, the pore space can be determined as the amount of water that a given volume of soil can hold (Liang, 1998).

Childs and Collis-George (1948) and Millington and Quirk (1961) assumed that the pore space might be divided into many slices taken perpendicular to the overall flow direction. These identical slices are then rejoined randomly and the flow assumed to take place through the connected pores with the diameter given by the smallest of the two (Childs and Collis-George, 1948) and (Millington and Quirk, 1961). Edil (2003) indicated that, the water held at different levels of energy in both pore systems. Therefore, total pore space largely determines the water retention (Andriesse, 1988). According to Liang (1998), porosity is the percentage of the total volume of soil that consists of pore space.

Porosity data for organic soils in Sarawak is equally scarce (Murtedza et al., 2002). The porosity of peat is very high and inversely proportional to degree of