Faculty of Engineering

FEASIBILITY OF MEASURING THE UNDRAINED STRENGTH OF PEAT IN THE DIRECT SHEAR BOX

NUR ALIAA BINTI MOHAMAD

Bachelor of Engineering with Honours
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2017

UNIVERSITI MALAYSIA SARAWAK

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NUR ALIAA BINTI MOHAMAD

This project is submitted in partial fulfilment of

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ABSTRACT

Direct shear test is the most common test to determine the soil shear strength. However, direct shear test can be used only to measure the drained strength of soil. If there is a limited access to the undrained strength testing device for example triaxial test and direct simple shear test, what would be the solution for that. Therefore, this study emphasis on identifying whether conventional direct shear device can be operated to provide reasonable estimates of undrained strength of peat. Due to the simplicity of direct shear testing, the feasibility of this device is tested in estimating the undrained strength of peat using variables of displacement rates.

A comprehensive methodology is performed especially for soil classification test such as Von Post test, moisture content, organic content, fibre content and specific gravity. Then, the main test of this study which are consolidation test and direct shear test is done by varying the t50 multiplier (time to achieve 50% consolidation in conventional oedometer test). T50 value is used to determine the displacement rates of direct shear test. Direct shear test is then carried out as the rate of displacement for that particular t50 multiplier is calculated. Few parameters of shear strength can be obtained from the result of direct shear testing. For example, shear stress, shear strain, volumetric strain and shear strength ratio under variable displacement rates.

From the findings of this study, the smaller the t50 multiplier, the faster the displacement rates. It is possible to measure the undrained strength of peat by performing the direct shear test with fast displacement rates. It is found that the undrained condition happened at 0.1t50 with displacement rates of 9.367 mm/min and shear strength ratio is noted as 0.48 which is falls in between the range of 0.38 - 0.55 for direct simple shear of peat. Such estimates of undrained strength may be useful in engineering practice when access to other shear strength testing device is limited. These findings from the study could also enhance the understanding of shear strength of remoulded peat

ABSTRAK

Ujian geseran langsung adalah ujian yang paling biasa untuk menentukan kekuatan ricih tanah. Walau bagaimanapun, ujian geseran langsung hanya boleh digunakan untuk mengukur kekuatan saliran tanah. Sekiranya terdapat akses terhad kepada peranti uji kekuatan yang tidak dapat dikawal seperti ujian triaxial dan ujian ricih mudah yang langsung, apakah penyelesaiannya. Oleh itu, kajian ini memberi penekanan kepada mengenalpasti sama ada peranti ricih langsung konvensional boleh dikendalikan untuk memberikan anggaran munasabah kekuatan gambut yang tidak dapat dikawal. Oleh kerana kesederhanaan ujian ricih langsung, kebolehlaksanaan peranti ini diuji dalam menganggarkan kekuatan gambut yang tidak dapat dikawal menggunakan pembolehubah kadar anjakan.

Metodologi yang komprehensif dilakukan terutama untuk ujian pengelasan tanah seperti ujian Von Post, kandungan lembapan, kandungan organik, kandungan serat dan graviti spesifik. Kemudian, ujian utama kajian ini yang merupakan ujian penggabungan dan ujian ricih langsung dilakukan dengan memvariasikan pengali t50 (masa untuk mencapai penyatuan 50% dalam ujian oedometer konvensional). Nilai T50 digunakan untuk menentukan kadar anjakan ujian geseran langsung. Ujian ricih langsung kemudian dilakukan kerana kadar anjakan bagi pengganda t50 tertentu dikira. Beberapa parameter kekuatan ricih boleh didapati dari hasil ujian ricih langsung. Sebagai contoh, tegasan ricih, tegasan ricih, nisbah volumetrik dan nisbah ricih di bawah kadar anjakan berubah-ubah.

Dari penemuan kajian ini, semakin kecil pengganda t50, semakin cepat kadar anjakan. Adalah mungkin untuk mengukur kekuatan gambut yang tidak dapat dikawal dengan melakukan ujian geseran langsung dengan kadar anjakan yang cepat. Telah didapati bahawa keadaan tidak teratur berlaku pada 0.1t50 dengan kadar anjakan sebanyak 9.367 mm / min dan nisbah kekuatan ricih dicatat sebagai 0.48 yang jatuh di antara julat 0.38 - 0.55 untuk ricih mudah gambut langsung. Anggapan sedemikian yang tidak dapat dikekalkan mungkin berguna dalam amalan kejuruteraan apabila akses ke peranti pengujian kekuatan ricih lain adalah terhad. Penemuan ini dari kajian juga boleh meningkatkan pemahaman kekuatan ricih gambut semula

CHAPTER 1

INTRODUCTION

1.1 Research Background

Peat or commonly referred as bog is a geomaterial formed by gradual accumulation of partly decomposed or undecomposed organic material derived from plants (Boylan et al., 2008). Geotechnical engineers described peat as having organic content of more than 75 % (Huat, 2004). The accumulation of organic materials over thousands of years under waterlogged condition is often classed as difficult, unconventional and problematic type of soils due to its high water content and low shear strength where it leads to the large settlements observed under relatively low loads, long-term creep settlements and low bearing capacity for structures founded on it (Boylan & Long, 2012).

In Malaysia, peat land is reported around 2.5 million hectares and Sarawak is identified as the biggest reserve of peat land with area of 16,500 km^2 and the peat deposits in 89% of these areas are more than 1m depth (Huat, 2004). The landscape for lowlands peats in Sarawak ranges from basin swamps to valley swamps (Mohamed, Padmanabhan, Mei, & Siong, 2002). According to DID Sarawak (2016), the coastal and riverine area covers about 19% of the state land area including both fresh water peat (1698 million hectares) and mangrove areas (154,000 hectares).

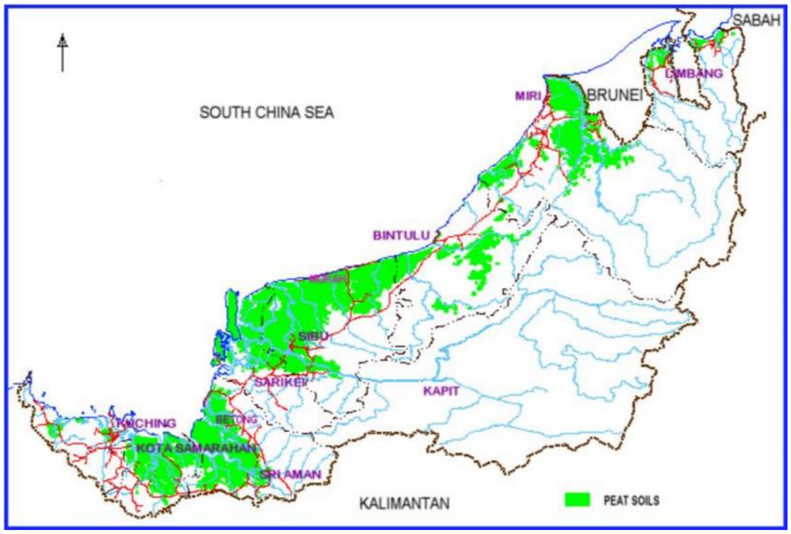

Figure 4.1: Distribution of peat soils in Sarawak (DID Sarawak, 2016).

In Figure 4.1, peat soils are found mostly within the delta and stretching inland along the riverine of the Samarahan-Sadong, Lupar-Saribas, Rajang, Baram and Limbang river system (DID Sarawak, 2016). The virgin lowland peat areas are often flooded and swampy and due to that reason they were left untouched with no development (Kheong, 2012). However, there is an increasing interest in the peat land development. Over the years, government and private sectors started to develop the peat land areas especially for agricultural purposes as there is not much option as the state has large areas of its land mass of peat. Besides, with annually increasing growth of population in urban areas largely covered with peat such as Kota Samarahan, Sibu, Mukah and Bintulu, an intense development are expected to occur. Therefore, it is important to understand the behavior and characteristics of peat soils in order to overcome the engineering challenge of these problematic soils.

According to Kheong (2012), peat materials can be differentiated based on three stages of decomposition namely, sapric (very high stage of decomposition), hemic (moderate stage of decomposition) and fibric (low stage of decomposition). As peat deposits are generally heterogenous with large variations occurring over very small distances, it is a great challenge to identify the geotechnical behavior of peat especially at laboratory-scale level (Zhang & O'Kelly, 2012). This is because peat holds a challenging characteristics such as high organic content, high natural water content, high compressibility and low shear strength (Huat, 2004). Therefore, in order to define the characteristics of peat soils as mentioned earlier and analyse the behavior of peat in terms of shear stress-strain, laboratory tests such as direct shear and consolidated undrained triaxial compression test should be done. Both tests will deduce the apparent cohesion (c') and effective angle of shearing resistance (ϕ') that formed the approximated Mohr-Coulomb failure envelope to determine the angle of internal friction for effective-stress stability analyses.

In this research, undrained direct shear test is perform to determine the shear strength parameters of peat. The peat will initially subjected to vertical compression under a desired effective stress (σ') and be normally consolidated to some degree prior to shearing at a constant shear strain (γ) rate. The results from the test will be analysed through the plotting of shear stress (τ) against shear strain (γ) whereby the shear strength behavior would be a function of the stress history of the peat sample (Boylan & Long, 2012).

1.2 Problem Statement

Failures of dykes, foundation and slopes in peat deposits are common peat soil problems that need a greater attention on understanding the engineering properties of peat (O'Kelly & Zhang, 2013). In Ireland, peat slope failures are not a recent phenomenon as 70 events of peat slope failures are reported and probably a significant number of events are unreported due to remoteness of the area (Boylan et al., 2008). These geohazard triggered the interest of engineers to assess the problem particularly on the shear strength properties of peat and the slope stability analyses (Boylan et al., 2008). On the other hand, peat deposits also give challenge to highway engineering due to the excessive settlements of peat deposits acting as pavement subgrades or foundation for railroad embankments. For these reasons, several studies on peat shear strength were done.

According to prior research, various laboratory tests such as triaxial, direct shear, ring shear, direct simple shear and vane shear test can be applied to measure the drained and undrained shear strength of peat soils. Triaxial test and direct shear test are the most common tests conducted to determine pertinent drained or undrained and effective-stress strength properties of peat (Zhang & O'Kelly, 2012). However, in terms of determining the effective stress strength properties, Zhang and O'Kelly (2012) found that consolidated drained triaxial compression testing was not of particular value since the deviatoric stress continued to increase approximately linearly with axial strain, without reaching a peak value. Thus, the effective angle of shearing resistance was strain-level dependent. Even though Landva et al. (1986) is not recommending direct shear test due to the uncertain stress distribution and mode of specimen deformation, but it gives fundamental ϕ' of the constituents (Zhang & O'Kelly, 2012).

Besides, results of ϕ' obtained from both tests due to the horizontal orientation of fibres also shows a difference (Mesri & Ajlouni, 2007). It is reported that triaxial compression yield a range of 40° to 60° in ϕ' while direct shear indicates ϕ' in the range of 35° to 45°. Since triaxial test is more frequently carried out compared to direct shear test, therefore it is difficult to obtain the dependable data from direct shear peat soil testing. Furthermore, the research on over-consolidated state of peaty soils has not been investigated in details (Hanzawa et al., 1994). Hence, the lack of local region reports and systematic research on the effect of peat fibres through direct shear testing motivate the concerns anticipated on this research. In addition, the local research in relation to peat soil shear strength especially in Sarawak are woefully inadequate to be used in dealing with peat soil problems compared to other nation such as Ireland, Canada and Japan.

Lastly, if there is a limit access to undrained strength testing device such as direct simple shear and triaxial test, what would be the solution to measure the undrained strength of peat. Therefore, in this study, direct shear is performed to determine the undrained shear strength of peat in comparison with direct simple shear data. As direct simple shear device is not as common as direct shear test and triaxial test in determining the shear strength of soil, hence the purpose of this study is to explore whether direct shear test can be used to measure the undrained shear strength of peat.

1.3 Aim and Objectives of Research

The aim of this study is to identify whether conventional direct shear device can be used to provide reasonable estimates of undrained strength. This experimental study are concerns on the peat sample taken from Kampung Endap, Kota Samarahan in which to investigate and analyse the peat undrained shear strength by performing direct shear tests on the remoulded peat sample.

Due to limited data obtained from the prior studies, the research on these peat soil testing is carried out with objectives as follows:

a) To investigate the correct strain rates to be applied during a direct shear test to obtain shear strength, Su.

b) To investigate the possibility of measuring undrained strength of peat in the direct shear box at variable shear displacement rates.

c) To compare direct shear test data with simple shear test data available in the literature.

1.4 Outlines

This thesis is divided into five chapters to presents the works of this research.

Chapter 1: Introduction

Brief explanation on the background of peat soils and overview of laboratory testing to determine the peat shear strength parameters. It also includes the peat failures, problem of peat testing and the objectives of this study.

Chapter 2: Literature review

Briefly discussed the facts about peat such as the composition of organic matter and water by volume, colours and the distribution of peat throughout the world especially in Malaysia. Moreover, their formation, index properties, compressibility and the shear strength of peat soil will also be describe in detail and also stress-strain behavior towards normally consolidated peat soils will be emphasized in depth.

Chapter 3: Methodology

A comprehensive methodology is discussed in detail especially for soil classification test such as Von Post test, moisture content, organic content, fibre content and specific gravity. In addition, the main test of this study which are consolidation test and direct shear test will be describe in detail.

Chapter 4: Results and Discussion

A thorough analysis on the results obtained from all of the tests conducted to clarify the shear strength behavior and classification of Kampung Endap peat samples.

Chapter 5: Conclusion

This experimental study on direct shear testing will conclude the investigation and analysis of the undrained shear strength of local peat by the usage of remoulded peat sample. Recommendation and suggestions for future research in local peat will be included as well.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will briefly discussed the facts about peat such as the composition of organic matter and water by volume, colours and the distribution of peat throughout the world especially in Malaysia. Moreover, their formation, index properties, compressibility and the shear strength of peat soil will also be describe in detail. A thorough reviews of prior research provide a basic understanding to improve the studies on feasibility of measuring undrained strength of peat in direct shear box.

2.2 Facts about peat

Peats are well-defined as organic soil formed by decayed vegetation or partly decomposed plant material accumulated in thousands of years and formed peatlands composed of more than 90% of water by volume (International, 2010). They are dark brown or black in colour forms in bogs and area of high intensity of rainfall make it holds a high portion of water content. Peats are often classified as problematic soil containing 75% or more organic matter and they are acidic soil with low pH levels of 3.5 as well as low nutrient content except when flooded by rivers (International, 2010). Besides, International (2010) also mentioned that water, air, mineral content and organic carbon content are four vital components of peat which are inter-related and dependent on each other.

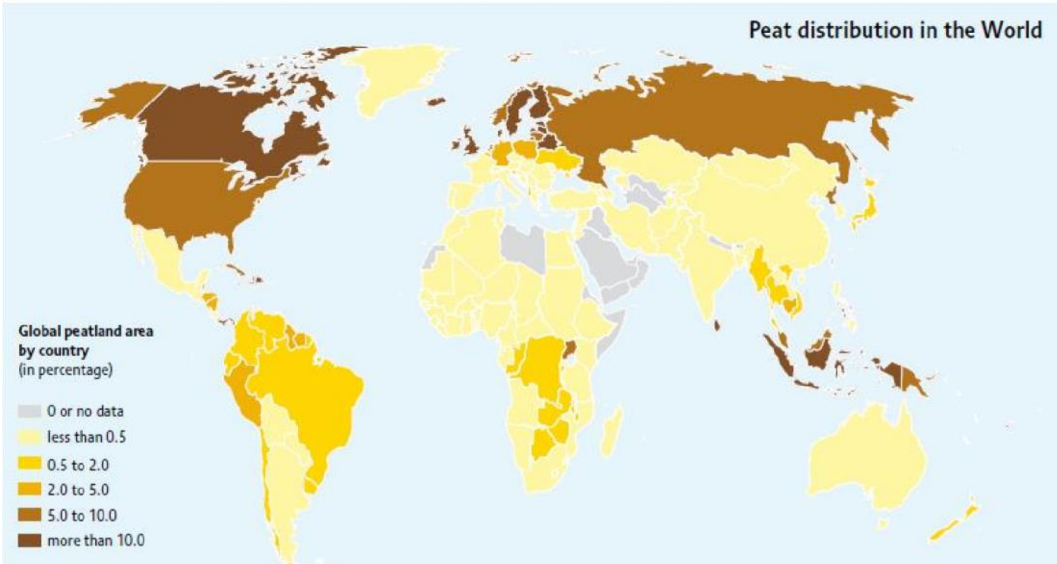

Figure 5.1: Peat Distribution in the World (Trumper et al., 2009)

According to Joosten and Clarke (2002), peatlands area cover 400 million hectares of the global which represents 3% of the total land surface area of the Earth. Figure 5.1 clearly shows that peatlands are more widespread in North America and in Northern Asia and Europe. Over the world, ten percent of peatlands are located in the tropics with 20 million hectares found in Indonesia (Joosten & Clarke, 2002). As presented in Figure 5.2, Malaysia is one of the country with significant number of peatland occurances and it is reported by International (2010) that only 20% of peat soils area in Malaysia are still under forest with a canopy cover of more than 70%. Meanwhile, Table 5.1 illustrates the percentage of area covered by peat in Malaysia in rank order where Sarawak supports the largest area of peat soils by 69.08% of the total peatland area in Malaysia followed by Peninsular Malaysia (642,918 ha; 26.26%) then Sabah (116,965 ha; 4.76%) (International, 2010).

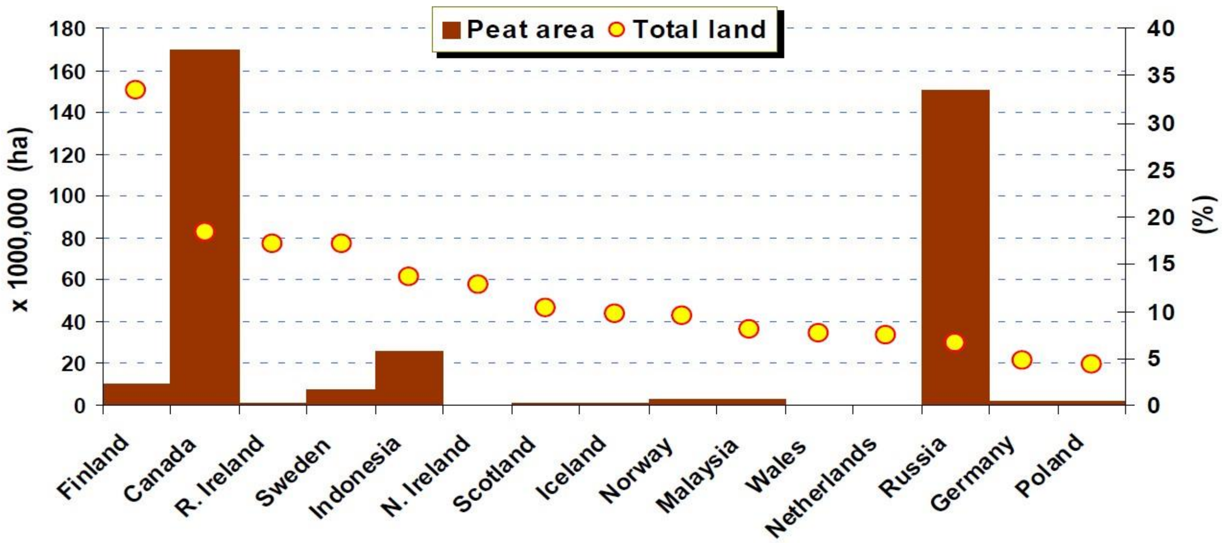

Figure 5.2: Percentage of area covered by peat in different countries in rank order(Behzad Kalantari, 2013)

Table 5.1: The area (ha) of peat soil in Peninsula Malaysia, Sarawak and Sabah. (International, 2010)

REGION	ha	%
SARAWAK	1,697,847	69.08
PENINSULAR MALAYSIA	642,918	26.16
SABAH	116,965	4.76
TOTAL	**2,457,730**	

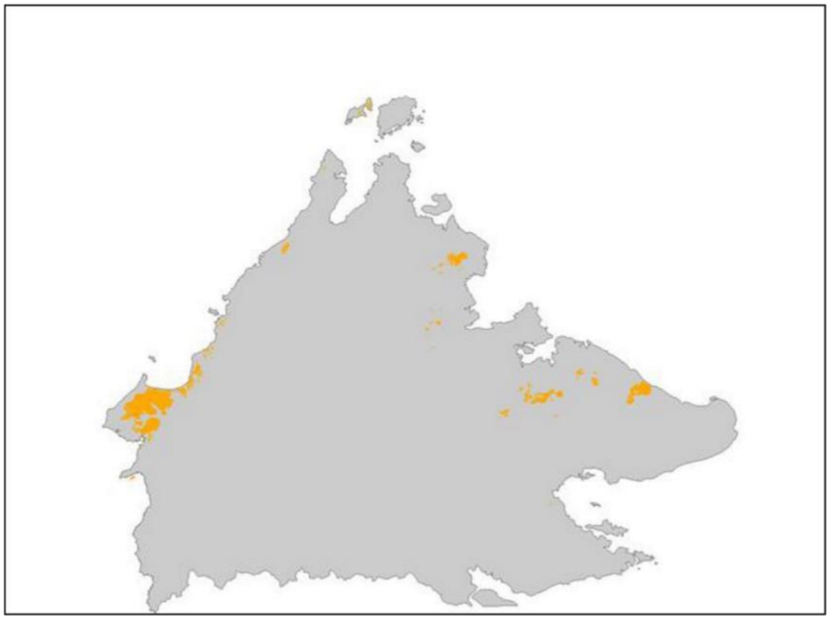

Figure 5.3: Distribution of peat soils in Sabah (International, 2010)

Sabah, the second largest easternmost state in Malaysia encompasses the northern portion of Borneo Island covers an area of about 73,619 km^2 is identified as the least peatland distribution in Malaysia as displayed in Figure 5.3. According to Zainorabidin & Mohamad (2016), as peat is highly flammable with high organic content and fibrous characterises, a large areas of natural peat land were destroyed due to severe fires in 19811982, and subsequently converted for agricultural purposes. Today, only two remaining sites support the largest area of peat soils in Sabah which are in the Klias Peninsula and in the Kinabatangan-Segama Valleys (International, 2010).

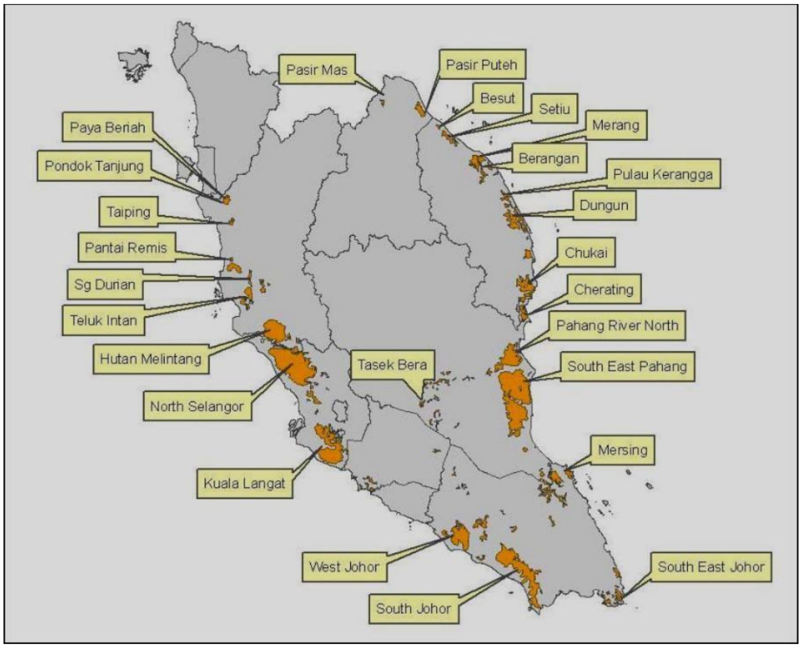

Figure 5.4: Major peat soils distribution in Peninsular Malaysia. (International, 2010)

Meanwhile in Peninsular Malaysia, distribution of peat soils Figure 5.4 can be seen especially in coastal area including Johor, Kelantan, Negeri Sembilan, Pahang, Perak, Selangor and Terengganu. It is reported that Peninsular Malaysia has the largest proportion of peat swamp forest with more than 70% canopy cover restricted to small areas in northern and south-eastern Selangor and also southeastern Pahang that is noted to be the least disturbed peat swamp forest in mainland Asia (Kumaran, 2014). Besides, Pahang state also supports the largest area of good quality peat swamp forest with area of 129,759 ha followed by Terengganu state with area of 51,759 ha (International, 2010).

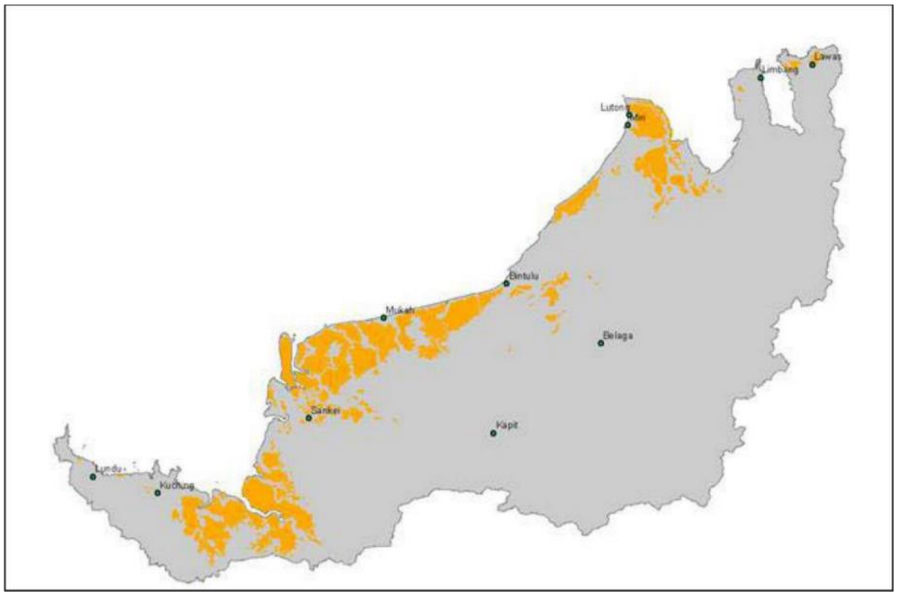

Figure 5.5: Major peat land in Sarawak (International, 2010)

Relatively, Sarawak the largest state in Malaysia supports the largest reserved of peatland area that covers 1,697.847 ha or 13.7% of Sarawak is eventually the largest area of peat swamp forest (DID Sarawak, 2016). However, International (2010) stated that 98.5% of primary forest were lost mainly due to logging. As displayed in Figure 5.5, peat land scattered around the Sarawak land and it seem the clustering of peat coverage is commonly found in Sibu, Sarikei, Mukah, Miri, Bintulu, Limbang, Sri Aman, Betong, Samarahan, and Kuching.

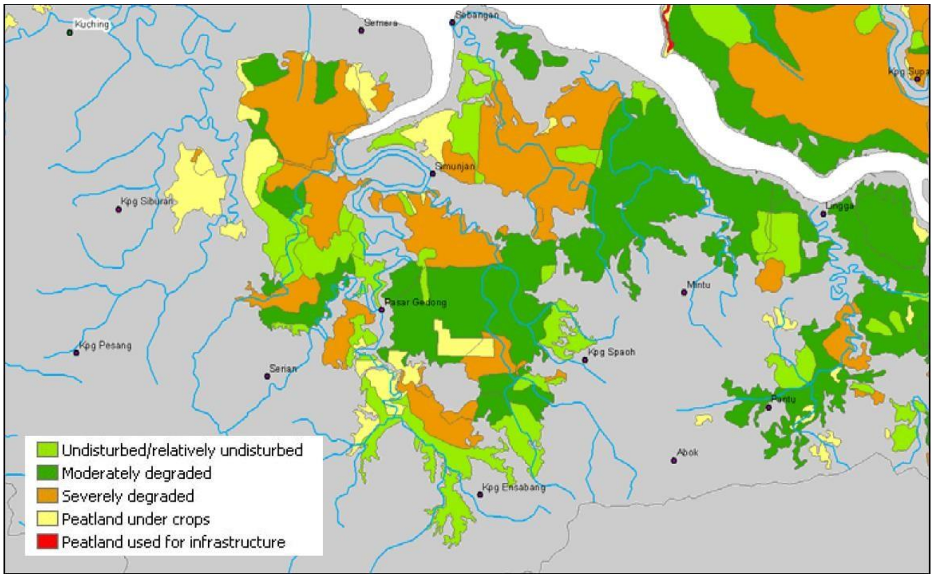

Figure 5.6: Distribution and status of peat swamp forest in Samarahan Division. (International, 2010)

Moreover, a detailed on peat development specifically undisturbed, moderately degraded, severely degraded and usage of peatland for crops and infrastructure as well as peat distribution of peat swamp forest in Samarahan Divison can be seen clearly in Figure 5.6. International (2010) stated that Samarahan has the total area of peatland with area 165,581 ha whereby it is subsequently distributed into severely disturbed of 54,758.72 ha, moderately disturbed of 63,206.64 ha and undisturbed/relatively undisturbed of 32,780.78 ha.

2.3 Formation of Peat Land

Peatland is formed from slow accumulation of vegetation debris in wetlands that takes place over centuries. The formation is dependent on an excess of local plant productivity over the respiratory processes of organisms with few factors that take into considerations such as poorly drained soils, limiting mineral elements, low pH, low temperature and the most common and dominant factors of peat formation in nature is low oxygen concentration (Moore, 1989). Over time, slowly decomposing vegetation debris accumulates under water-saturated condition that frequently associated with low oxygen availability leads to the development of a peat deposit or peat dome that can exceeds 6m in thickness (Association, 2016). Figure 5.7 illustrates the typical processes of peatland formation.

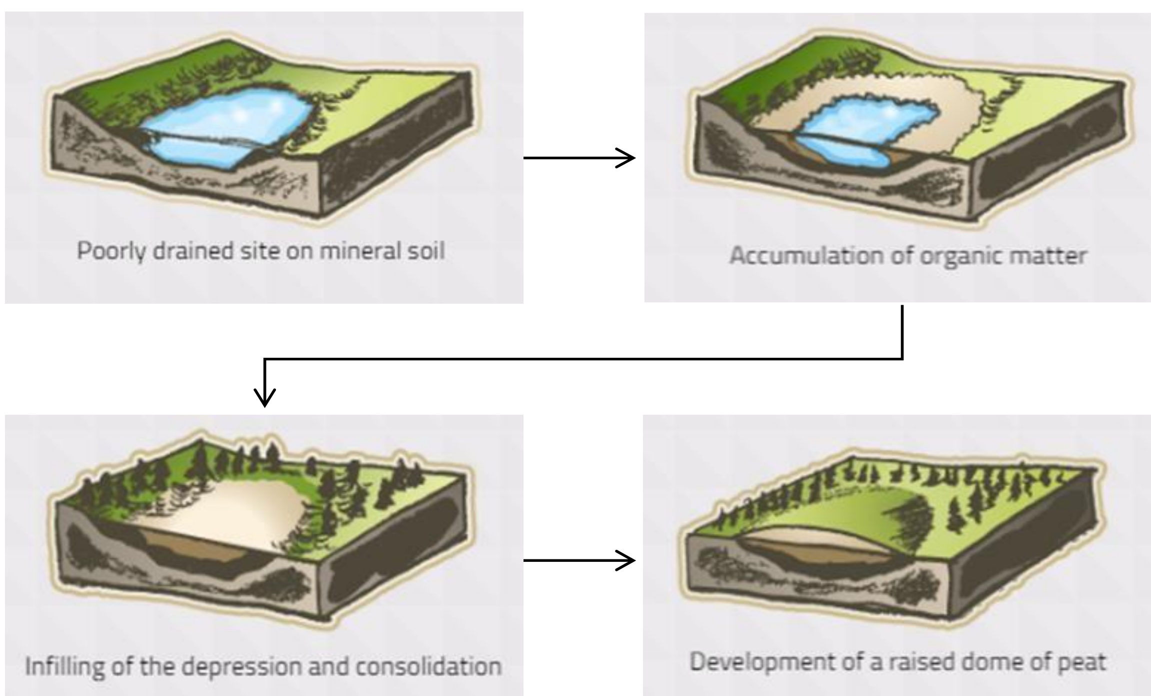

Figure 5.7: Steps in peatland formation (Association, 2016)

In Malaysia, peat lands are commonly developed along the coast and behind accreting mangrove coastlines as individual units on the alluvial plains between rivers flowing to the sea. Generally, peat dome develops between two rivers that possess natural levees in their floodplain stage. Nowadays, many peatlands such as peat areas in Marudi Sarawak are far inland of around 100km from the coastline and it is estimated that the oldest inland peat areas has reached the age of 4000-5000 years (International, 2010). Figure 5.8 shows the highly developed peat dome in the Baram Valley for instance showing the depth and age of peat. Over 4000 years, peat can developed up to 15m.

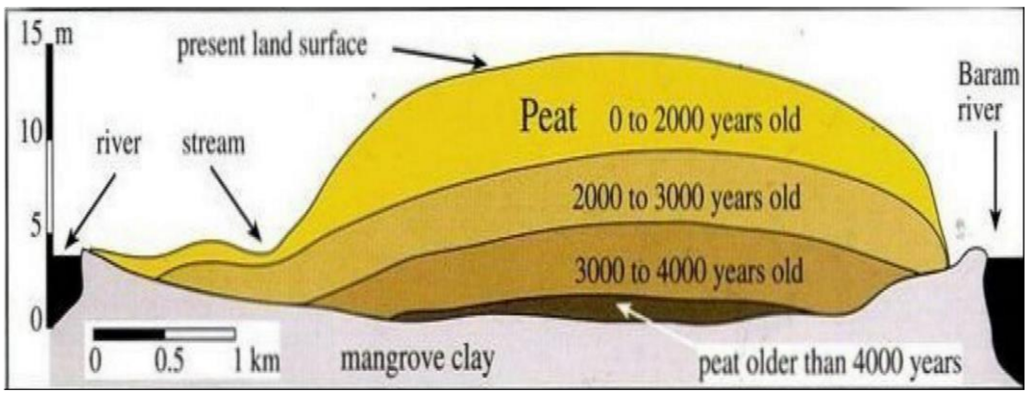

Figure 5.8: Cross-section of highly-developed peat dome in the Baram Valley Sarawak. (International, 2010)

Peat dome formation is largely influence by the flooding events from river water and rainfall and it is believed rainwater creates bulking on the higher part of the peat whereas river water from the river bank permeates to the bottom part of the peat dome (International, 2010). As time passes, the dense peat domes level gradually depletes. Figure 5.9 displayed the extensive flat bog plain in the centre where it may be 10 m higher than the river level.

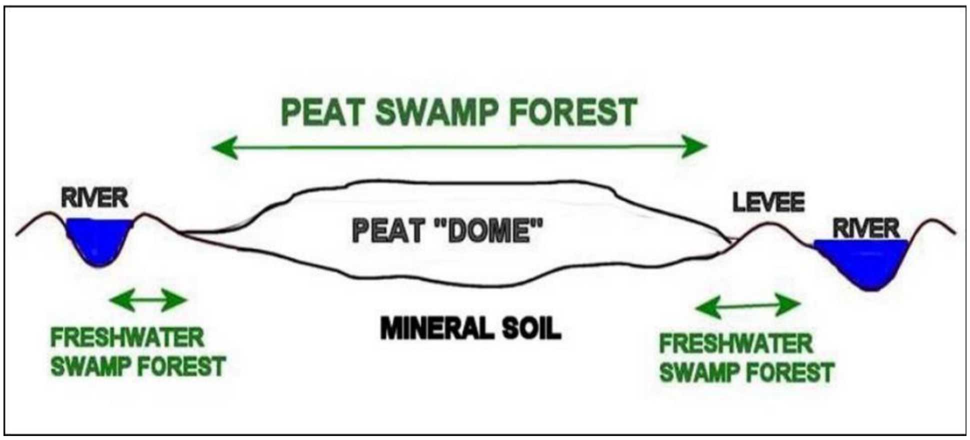

Figure 5.9: Diagramatic representation of a more highly developed inland peat dome. (International, 2010)

2.4 Index Properties of Peat

In order to classify type of soil, (Hobbs, 1986) suggested colour and odour, water content, degree of humification, fibre content, liquid limit and plastic limit and last but not least principal plant component, namely coarse fibre, fine fibre, amorphous granular material and woody material as set of characteristics to be included for a full description of soil. According to Kalantari (2013), there are two methods to classify type of soil which are based on unified soil classification system (USCS) or fibre content as well as their humification of the fibres. Table 5.2 shows the classification of organic soils based on USCS where the soils are divided according their organic content and called as slightly organic, organic and highly organics. Peat are classified as highly organic soil with more than 75% organic content.