PRELIMINARY DESIGN CHART OF CEMENT COLUMN FOR DEEP SOIL MIXING METHOD IN TROPICAL PEAT

(CARTA REKABENTUK AWALAN TIANG SIMEN UNTUK KAEDAH GAULAN TANAH DALAM BAGI TANAH GAMBUT TROPIKA)

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DEDICATION

To my beloved parents Mr and Mrs Duraisamy - Rajamah

ABSTRACT

PRELIMINARY DESIGN CHART OF CEMENT COLUMN FOR DEEP SOIL MIXING METHOD IN TROPICAL PEAT

(Keywords: Cement column, compressibility, organic soil, peat, stabilization)

Peat and organic soils also categorized as soft soil. Application of cement column will leads to some changes in properties of peat. This report presents the effects of cement columns in terms of compressibility and shear strength in tropical peat. This report also discussed the engineering properties of unstabilized and stabilized tropical peat of east and west coast of Peninsular Malaysia. Samples from different locations were collected to distinguish the variants of organic content and fiber content in this study. Tropical peat collected from this location is classified as fibrous peat using Von Post scale. The moisture content and organic content of this peat is ranging from 400 % up to 900 % and 80 % to 90 % respectively. Author also found a good correlation between the engineering properties and the compressibility parameters. A dosage rate of 150 kg/m^3 was used to mixed binders in various ratios. A column with 50 mm in diameter and 150 mm in length is applied into the soil. The compressibility and shear strength of unstabilized and stabilized peat was compared to determine the effectiveness of cement columns. The compressibility of peat was determined using conventional oedometer test and the undrained shear strength, S_u of peat was determined using unconfined compressive strength test. Compressibility indices, C_c and C_α were identified as two crucial parameters to estimate settlements in peat. Based on the results obtained, the mixing of cement column in peat extensively increases the shear strength and significantly reduces the compressibility of peat compare to the unstabilized peat. Thus, preliminary design charts for cement columns were established as a guideline to engineers and academicians.

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ABSTRAK

CARTA REKABENTUK AWALAN TIANG SIMEN UNTUK KAEDAH GAULAN TANAH DALAM BAGI TANAH GAMBUT TROPIKA

(Keywords: Tiang simen, kebolehmampatany, tanah organik, tanah gambut, penstabilan)

Tanah gambut dan organik di kategorikan sebagai tanah lembut. Laporan ini membincangkan kesan penggunaan tiang simen kepada ciri- ciri tanah gambut dan juga ciri-ciri fizikal tanah gambut. Sampel tanah dari tiga kawasan telah diambil untuk membezakan kandungan organik dan kandungan serat. Tanah gambut yang diambil dari pelbagai kawasan dikategorikan sebagai tanah berserat. Kandungan kelembapan dan kandungan organik dalam tanah gambut tersebut dalam lingkungan 400 % hingga 900 % dan 80 % hingga 90 %. Ciri-ciri fizikal telah dapat dikaitkan dengan baik dengan parameter kebolehmampatan. Kadar sukatan sebanyak 150 kg/m^3 *digunakan untuk mengadun pengikat dalam nisbah yang berlainan. Tiang dengan diameter 50 mm dan ketinggian 150 mm dimasukkan ke dalam tanah gambut. Kebolehmampatan dan daya ricih tanah gambut sebelum dan selepas aplikasi tiang simen diambil bagi menentukan kesan tiang simen terhadap ciri- ciri tanah gambut. Ujian yang dilakukan bagi mendapatkan daya ricih ialah ujian daya ricih tak terkurung dan bagi mendapatkan kebolehmampatan tanah gambut ujikaji oedometer digunakan. Parameter* C_c *dan* C_α *adalah dua parameter yang penting dalam menentukan kebolehmampatan tanah gambut. Melalui hasil kajian didapati pengunaan tiang simen meningkatkan daya ricih tanah gambut dan mengurangkan kebolehmampatan tanah gambut. Maka satu carta rekabentuk awalan tiang simen telah dihasilkan sebagai panduan bagi para jurutera dan pensyarah.*

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LIST OF ABBREVIATIONS & SYMBOLS

AOIF	-	Angle of internal friction
ASTM	-	American Standard Testing Machine
Cu	-	Undrained shear strength
CD	-	Curing Day
DR	-	Dosage rate
FC	-	Fiber content
FVS	-	Field vane shear
G_S	-	Specific gravity
LL	-	Liquid limit
MC	-	Moisture content
OC	-	Organic content
OPC	-	Ordinary Portland cement
S	-	Degree of saturation of soil
VPS	-	Von Post Scale
W_{TOT}	-	Wet weight of batch prior to the addition of stabilizer (kg)
ω	-	Moisture content of batch prior to the addition of stabilizer
γ_w	-	Unit weight of water (kg/m^3)

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CHAPTER 1

INTRODUCTION

1.1 Introduction

There are various types of soils that have been classified such as clay, sand and silt. Peat and clay are categorized on soft soil. In Malaysia, two categories of natural soft soil deposits are alluvial & marine clays and peat & organic soil. Peat is the softest soil compared to other soil. Peat is classified to terms of temperate peat and tropical peat. The peat covers in Malaysia are known as tropical peat.

Peat covers in large area in Malaysia. The percentage of peat on certain locations such as Sarawak, Perak, Pahang and Selangor are quite high. It can not be avoided that some construction must be carried on the peat locations due to these factors. The research that has been done is mostly in West Coast of Peninsular Malaysia and Sarawak.

Peat has engineering properties such as highly compressible, low shear strength and has high percentage of ashes. These properties have been classified but some information are still lacking in certain locations in Malaysia especially in East cost of Peninsular Malaysia.

Peat needs lots of concentration during construction. It is whether peat is suitable and strong enough as base for the foundation of the building, and either mass stabilization method and lime cement column methods or removal of peat can save up the cost of the construction. Therefore constructions on peat locations will be avoided if possible and if can not, removal of peat and replacement with other soil will be used, that has high cost. If lime cement column and mass stabilization method is applied, it is one third lower cost than removal and replaces method. It results in less study on how to construct any structure on peat.

There are several methods that are used for construction dealing with peat. Deep soil mixing method is one of it. Some of the civil engineers also designed construction on peat by removing the peat and replaced by other type of soil or called preloading method. By adding stabilizer such to increase the strength of peat is one way that can be done.

Theoretically, any soil can be stabilized with cement. Cement is an example of stabilizers that has the effect to reduce the liquid limit and increase plastic index of peat. Generally, higher amount of cement needed to achieve targeted strength for peat compared to other type of soil. The effect of lime cement stabilizer will give fairly good effect to the peat.

1.2 Problem Statement

Having a peat in the site is a big problem for all construction work. There needs lots of attention on the foundation work. Some of the developer will avoid having their project on a location that has peat. In Malaysia, the construction on peat is unavoidable as there are several cities which now highly developed but located on peat such as the city of Pekan, Pahang.

Research works have been done in some locations in Malaysia and mostly are in west coast of Peninsular Malaysia and Sarawak. Only some information on east coast of Peninsular Malaysia peat has been classified. This little information on peat is found as why the developers in Malaysia are still using high cost methods to construct buildings on peat.

Pekan has big area of peat and there are a lot of constructions that will be held there. There are several methods to construct buildings when dealing with peat type. Some of the contractor will use removal of the peat and replace with stronger type of soil or called preloading method. This method will cost too much money and problems might occur if building is not constructed in proper way. One of the best ways that has been used for more than 30 years in Japan and lately accepted by United States of America (U.S.A) is deep soil mixing, and soil improvement with the use of lime cement column and mass stabilization method.

Mass stabilization is a method that is used to treat soil by improving its engineering properties. Even if successfully treated, the stabilized peat is a new material that has not been investigated previously, thus little is known about mechanism involved in its stabilization. This method is used in this project to investigate the improvement of peat gain and the suitability to tropical environment.

1.3 Objective of the Study

The main objective for this research is to improve the strength of tropical peat. Following are the specific objectives of this research;

i. To classify the peat at Pekan.

ii. To determine the undrained shear strength of unstabilized and stabilized peat mixed with stabilizers in various dosage rates.

iii. To differentiate the effects of dosage rates to the engineering properties of Pekan peat before and after stabilized with peat.

1.4 Scope of Study

To achieve the objective of this research, some limitations have been fixed. The scope of this study are focused on location of the samples taken, the types of soil to be tested, the type of stabilizer to be used, the methods that will be used, dimension of samples, dosage rate, stabilizer ratio, curing time, and humidity for storage.

The location that was chosen is along the highway road from Kuantan to Pekan, Pahang. Samples are taken from three locations that are named as L1, L2 and L3.

Sample on L1 are taken 2 m from the road of Jalan Pekan (km 308, Kuantan - Johor Bahru) with depth of samples are 0.5 m. The sample at L2 are taken 1 m from the road of Jalan Pekan (km 308, Kuantan - Johor Bahru) with the depth of samples are 0.5 m. Sample in L3 are taken 0.5 m in depth at Perkampungan Indera Sempurna in Pekan.

The type of soil used for testing is tropical peat located at selected area in Pekan, Pahang. The classification of peat will be focused on the field test that gives the similar results of properties of peat with the previous research for comparison in chapter 4.

The types of stabilizers used are cement and lime. The type of cement that will be used is ordinary Portland cement type I. Type I cement is the cement type used for general purposes. The type of lime that will be used is common lime.

The methods used to get the parameter and engineering properties of peat is focused on classification of peat, engineering properties of peat, and effects of dosage rates to engineering properties of peat. The field tests that will be done to classify the Tropical Pekan peat are field vane shear test, mackintosh probe, and Von Post Scale test. The engineering properties of peat are done based on preliminary tests such as fiber content, liquid limit, moisture content, organic content, and specific gravity test. The unconfined compressive strength test was carried out to obtain the undrained shear strength in order to be compared with the parameter of unstabilized peat.

Dimension of sample for unconfined compression strength test are 100 mm in height and 50 mm in diameter. The selected dimensions of sample are chosen as it is the best dimensions to be tested and can meet the platen speed on unconfined compressive strength test.

The amount of stabilizers added to the peat was in dosage rate of 150 kg/m^3, 200 kg/m^3, and 250 kg/m^3. The stabilizers selected are on the economic dosage rates that will give good improvements on engineering properties of the peat

The stabilizer used in the unconfined compressive strength test was the optimum content of cement to lime ratio (80:20). There are several stabilizer ratios used such as 50:50, 25:75, 100:0, and 0:100. The optimum content is the most economical ways, has fairly good effects and conventionally used in site.

The percentage for the humidity for storage of peat is set to 100% and in 18 to 22°C temperature. The peat is stored in humidity room to ensure the peat has not experienced any lost on moisture, strength and so on. No load is applied during storage.

The curing days used for sample to cure are 7, 14, and 28 days. During curing of the sample, load applied was 18 kPa as strength of stabilized soil generally increases if a load is applied during curing day.

1.5 Significance of Study

The contribution of this study is the classification of tropical peat in Pekan in the east cost of Peninsular Malaysia. Malaysian peat that has been classified is commonly in west coast of Peninsular Malaysia and Sarawak. In the future, construction on Pekan area can be carried out using the information from this research. The effects of dosage rates that are studied in this research can be used if any construction adopting mass stabilization methods such as lime cement column methods.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review focused on the explanation of peat, its distribution in Malaysia, and previous researches in Malaysia and some well known research about peat in Japan, Ireland and much more. It will also focus on the stabilizers that are used, with the methods that are used such as mass stabilization, lime-cement column, deep soil mixing, and any of the methods that are used in this project.

On the classification purpose, peat that has been classified at west coast of Peninsular Malaysia and other places will be stated. The discussion is on the results from other researchers that show the undrained shear strength, depth of peat distributed in that place and depth of ground water level and characteristics of peat.

On the characterization of engineering properties of peat was focused on the natural moisture content, atterberg limit, specific gravity, content of fibers, and content of organics in the peat.

The effects of various dosage rates to the engineering properties of peat from the addition of peat with stabilizers is discussed on the improved undrained shear strength, moisture content, atterberg limit and improved specific gravity.

The results from other researchers are discussed for comparison in the analysis of results on Chapter 4.

2.2 Peat

Peat is highly organic soft soil with composition of primarily fibrous organic matter. Peat has low strength and high compressibility. The high content of vegetal fibre in peat causes problems and produces inconsistent test results.

Peat is a complex organic composition where chemical, physical and biological processes are continually occurring and changing the soil properties. Peat can be found in coastal areas and even glaciated regions where the water table is near or above the ground surface. They can be either in surface soils and deep deposits. Organic matter from plant and animal decomposed in peat and ended with production of humus.

2.2.1 Peat Distribution

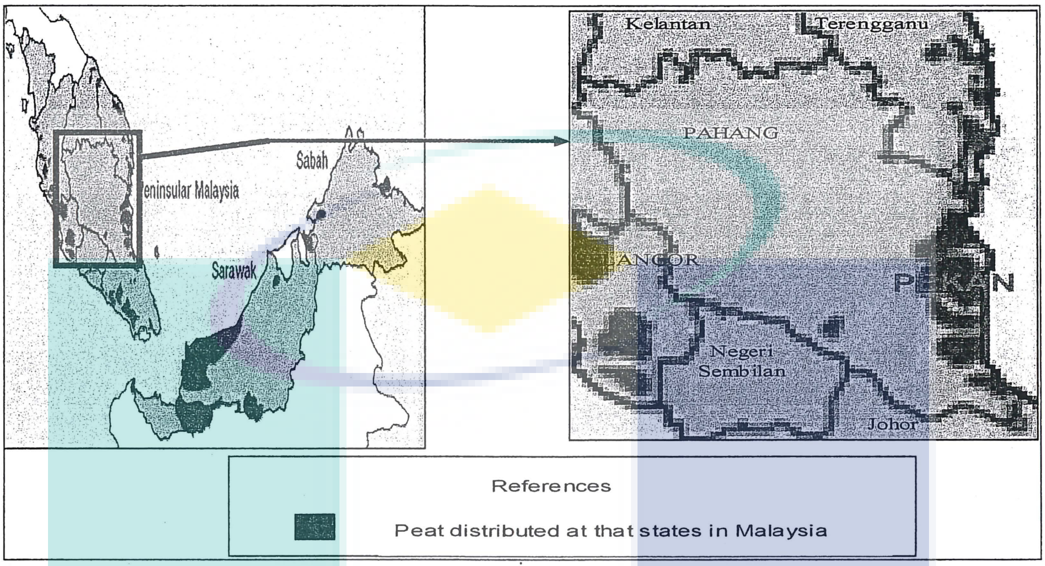

Figure 2.1 : Peat distributed in Malaysia

Figure 2.1 shows the distribution of peat in Malaysia as high. As development in Malaysia is increasing, the development at this type of soil can not be avoided. Meiling et al. (1999) stated that there are about 2.7 million ha of peat in Malaysia. In the soft ground reported by Ting et al. (1988), the thickness of soft soil deposits ranged from 15 m to 30 m for the coastal site and 2 m to 9 m for the inlands areas.

2.2.2 Engineering Characteristic of Peat

Table 2.1 shows the engineering properties of peat in Sarawak with the natural water content, density of soil particles, ignition loss and pH value.

Table 2.1 : Engineering characteristic of peat in Sarawak

Parameter		Value
Natural water content	(%)	630
Density of soil particles	(g/cm^3)	1.60
Ignition loss	(%)	81.4
pH		6.1

Sarawak peat has water content of 630 % which is high with density of soil particles of 1.6 g/cm^3 and ignition loss or organic content of 81.4 % and pH of 6.1.

Table 2.2 shows the engineering characteristic of peat in Ireland with the natural water content, organic content, Von Post Classification and pH value.

Table 2.2 : Engineering characteristic of peat in Ireland

Properties		Raheenmore peat	Ballydermot peat
Natural water content	(%)	630	850 %
Organic Content	(%)	98 – 99	94 – 98
Von Post Classification		H2	H6 – H9
pH		5.3	4.9

Irish peat has similar properties to Sarawak peat where studies of Raheenmore and Ballydermot peat at Ireland. The water content is high and up to 850 % with higher organic content than Sarawak peat that is 94 % to 98 %. The von post classification is H2 for Raheenmore peat and H6 to H9 for Ballydermot peat. Based on Table 2.2, pH of Raheenmore and Ballydermot peat is lower than Sarawak peat where the pH is 5.3 and 4.9.

Table 2.3 shows the engineering characteristic of peat in Japan with the natural water content, density of soil particles, ignition loss and pH value.

Table 2.3 : Engineering characteristic of peat in Japan

Properties		Ebetsu peat	Yubarigawa peat	Enbetsu Peat
Natural water content	(%)	380	719	912
Density of soil particles	(g/cm^3)	1.85	1.60	1.62
Ignition loss	(%)	47	70	95
pH		5.1	4.1	5.0

Three types of Japan peat which was studied are Ebitsu peat, Yubarigawa peat and Enbetsu peat. Ebetsu peat has lower while Yubarigawa and Enbetsu is higher water content compared to Sarawak peat. The density of soil particles is 1.85, 1.60 and 1.62 for Ebetus, Yubarigawa and Enbetsu peat. The ignition loss is 47, 70 and 95% and pH is lower than Sarawak peat that is 5.1, 4.0 and 5.0 respectively.

Peat has high water content which is above 100% water content and in East Malaysia has been found that the range is from 200 to 2207% with organic content of 76 to 98%, liquid limit of 190 to 360% and plastic limit in the range of 100 to 200%.

2.3 Mass Stabilization

Mass stabilization is classified into soil improvement technique. Soil improvement technique is use to improve or to change properties of soil deposits for the purposes of increasing the strength, controlling the settlement and seepage and reducing the liquefaction potential under seismic loading. It is also to improve soil properties such as permeability, durability, and volume stability. A variety of materials such as cement, lime or combinations of it can be added to the soil to change its properties and characteristics. The effectiveness of cement and lime decreases with increasing of water content. The improvement decreases generally with the increasing of plasticity index.

2.4 Type of Stabilizer

The stabilizers that were chosen are cement and lime. The previous research shows the effects of lime and cement to peat and what are the physical and chemical properties of these stabilizers.

Table 2.4 shows the effects of stabilizer to soft soil for different type of soil and different type of stabilizer.

Table 2.4 : Effects of stabilizer to soft soil

Soil	Lime	Lime-cement	Cement
Clayey Silt	*	+	#
Silty Clay	+	#	#
Clay	*	+	+
Clay (Quick)	+	+	#
Clay (Saline)	+	+	+
Clay (Sulphide)	-	+	+
Muddy Clay	*	+	+
Clayey Mud	*	*	+
Mud	-	*	+
Peat	-	*	+

Notes : (- no effect or poor effect) (* fairly good effect) (+ good effect) (# very good effect)

Addition of lime and cement to peat gives fairly good effect to peat while addition of cement only gives better or good results to peat compared to addition of lime cement. The research on the effect of lime and cement to peat will be discussed with reference to a research that has been done on the effects of cement to west coast of Peninsular Malaysia peat by Alwi (2008).

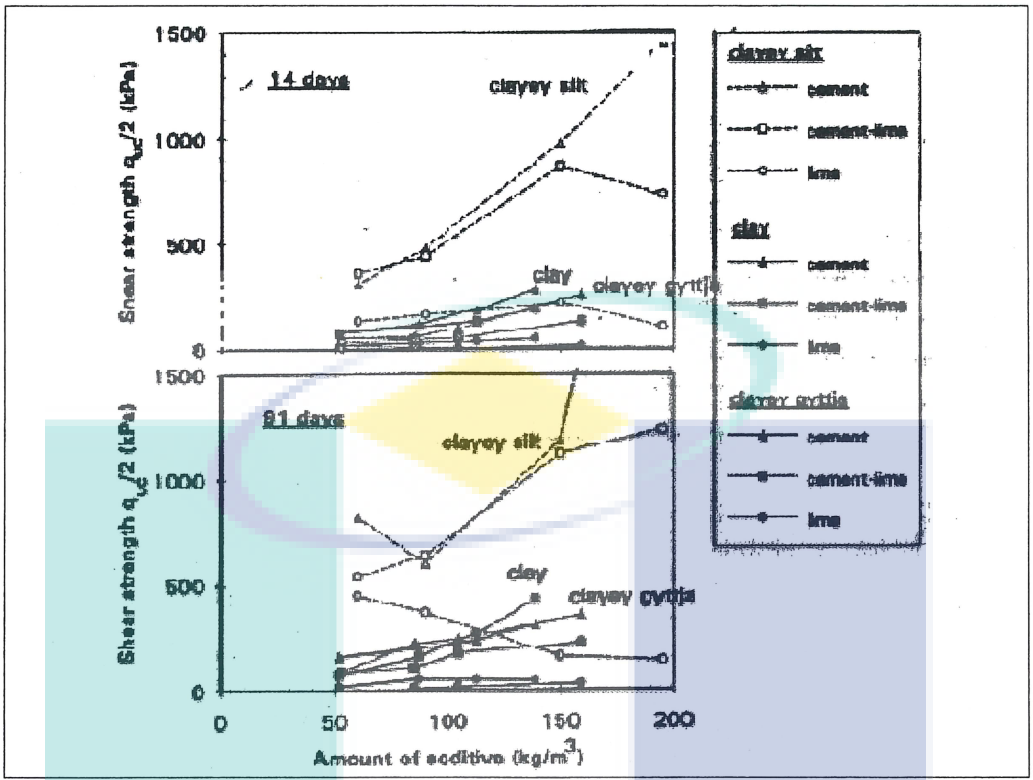

Figure 2.2 : Effects on shear strength of different amounts of additive on the soils stabilized in the laboratory (Ahnberg, 1994)

Figure 2.2 shows the effects of shear strength of different amount of additive on three soils stabilized in the laboratory.

Typical amounts of stabilizer used vary from 70 to 300 kg of stabilizer / m^3 of treated soil, with the optimum amount for a particular soil determined through laboratory testing. Ahnberg's test results agree with theoretical studies of chemical reactions, indicating that the optimal proportion of quicklime would probably be 10 to 25% of the total stabilizer added. Eades and Grim (1966) suggest that for 100 percent lime mixes the optimum lime content for most soils is between 2 and 5% of the dry soil by weight. Where several binder types are used in a laboratory mix design study, the typical ratio being 25:75 lime-cement for a dosage rate of 150 kg/m^3 (Ahnberg et al., 1999).

2.4.1 Cement

Cement is generally the best type of stabilizer to be used with soils because of the relatively high strength as compared to other types of soil admixtures. There are a number of types of cement such as Portland cement, high-alumina cement, natural cement, pozzolanic cement, masonry cement and oxychloride cement.

Portland cement shows an improve to the strength gain for peat. The type of cement that will be used in this research is ordinary Portland cement type I. Type I cement is the cement type used for general purposes. Type I meets all requirements of ASTM C150. The composition of Portland cement is indicated by the following compositions that are lime (CaO) 60 to 67%, silica (SiO_2) 17 to 25%, alumina (Al_2O_3) 3 to 8%, iron oxide (Fe_2O_3) 0.5 to 6%, magnesia (MgO) 0.1 to 4%, sulphur trioxide (SO_3) 1 to 3%, Soda (Na_20) and/or potash (K_2O) 0.5 to 1.3%.

Effects of cement were studied using binder ratio of 80:20 of cement to lime with dosage rate of 150kg/m^3, 200 kg/m^3 and 250kg/m^3.

2.4.2 Lime

The lime used is chemical hydrated lime ($Ca(OH)_2$). The lime types were chosen as it is the most effective and widely used lime types. Lime types were studied using stabilizer ratio of 20:80 of lime to cement with dosage rate of 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3.

Lime is expensive and that is why the optimum content is selected that is the stabilizer ratio of 20:80 of lime to cement as to use only the effective content of stabilizer ratio which will give good results.

2.5 Curing Condition

The curing condition is focused on the curing time that is selected and done before testing of the sample

2.5.1 Curing Time

The curing days used for sample curing are 7, 14, and 28 days. Esrig (1999) stated that most strength gain occurs within the first 28 days after mixing, and strength continues to increase at a slower rate thereafter.

During curing of the sample, load is applied that are 18 kPa as strength of stabilized soil generally increases if a load is applied during curing day.

2.5.2 Curing Temperature

Many variables affect curing temperature. Proper curing temperature for site-specific samples is quite uncertain, resulting in variable laboratory test procedures, typically ranging from 20°C (room temperature) to 75°C. Whatever curing temperature is used, the specimen should be proper spaced and fans or pumps should be used to ensure that all the specimens cure at the same temperature (Sehn, 2001).

2.5.3 Humidity for Storage

The percentage for the humidity for storage of peat is set to 100% and in 18 to 22°C temperature. The peat is stored in humidity to ensure the peat has not experienced any lost on moisture, strength and so on. No load is applied during storage. Den Haan (2000) recommends several methods for controlling the humidity in the curing environment: curing samples is sealed, airtight tubes; curing underwater; or placing samples inside an insulating jacket. Hampton and Edil (1998) found that providing the samples access to water while applying a confining pressure during curing, which may imitate field conditions more accurately, reduces strength.

2.6 Mixing

The mixing is focused on mixing device and mixing time. There are criteria for selecting the mixing device and the duration of mixing time for peat.

2.6.1 Mixing Device

Different soils require different mixing device. Special mixing device is used as to more closely imitate deep mixing techniques in the field as to achieve homogeneity. Typical laboratory-scale mixing device include ordinary kitchen mixers and dough mixers also can be used.

2.6.2 Mixing Time

Specific time should be used to make all the samples are mixed the same way as to analyse the results of the samples. Den Haan (2000) recommends mixing until the soil is visually homogenous. His test results indicate better reproducibility can be achieved in this manner. Most publications, however, designate a particular time set between 2 and 5 minutes and sustained throughout the test series. Poousette et al. (1999) suggested mixing time limited to five minutes for peaty soils, due to the breakdown of fibers during prolong mixing.

2.7 Samples Dimension

Samples are studied to choose the dimensions of the sample, so that the results of can be discussed with the previous research from other researchers.

Typical samples have a diameter of 38mm, and it depend on how easily the soil can be homogenized. Difficult peat mixing and large organic fibers tend to make homogenizing the sample difficult, and larger samples are required in order to minimized the effects of discontinuities. Larger samples reduce scatter in test result (Sehn, 2001). Most laboratory procedures use the height to diameter ratio of two regardless of diameter. Ahnberg (1999) found that as sample diameter increased, Unconfined Compressive Strength decrease. Hampton and Edil (1998) found the opposite.

Table 2.5 shows the platen speed of unconfined compressive strength value refer to specimen diameter value.

Table 2.5 : Platen speed of unconfined compressive strength

Specimen Diameter (mm)	Approximate Platen Speed (mm/min)
38	1.5
50	2
75	3
100	4

Referring to table 2.5, for the specimen or sample on diameter 50 mm, the approximate platen speed that will be used for the unconfined compressive strength test is 2 mm/min.

2.8 Test

All the tests done are focusing on determining the classification and engineering properties of peat.

2.8.1 Classification and Engineering Properties of Peat

The classification of peat is focused on getting the field undrained shear strength, depth of peat and the water table at that location, and to know the symbol and description using Von Post Scale. Its engineering properties are focusing on the fiber content, liquid limit, moisture content, organic content and specific gravity of peat.

Table 2.6 shows USDA classification of peat for the different type of peat with the value of fiber content and the Von Post Scale.

Table 2.6 : USDA classification of peat with Von Post Scale and fiber content

Type of Peat	Fiber Content	Von Post Scale
Fibric Peat	above 66%	H4 or less
Hemic Peat	33 - 66%	H5 or H6
Sapric Peat	Less than 33%	H7

Peat is divided into 3 types based on the content of fiber. When the fiber content of over 66%, the peat is classify as fibric peat and with Von Post Scale of H4 or less. It is Hemic type if the fiber content is between 33 to 66% and sapric peat if the fibric content is less than 33%. Hemic peat has Von Post Scale of H5 to H6 while Sapric peat is H7.

Table 2.7 shows the classification of peat on basis of decomposition on the Von Post scale with the designation of type of peat with the range of Von Post scale value of the group and its description.

Table 2.7 : Classification of peat on basis of decomposition on the Von Post Scale (Karlsson & Hansbo, 1981)

Designation	Group	Description
Fibrous peat	H1 – H4	Low degree of decomposition. Fibrous structure. Easily recognized plant.
Pseudo-fibrous peat	H5 - H7	Intermediate degree of decomposition. Recognizable plant structure.
Amorphous peat	H8 – H10	High degree of decomposition. No visible plant structure. Mushy consistency.

Peat is designed into fibrous with group of H1 to H4. It is describe as to have low degree of decomposition which has fibrous structure and has easily recognized plant. Peat is designed as pseudo-fibrous when group is H5 to H7 where it has intermediate degree of decomposition and has recognizable plant structure. Peat is called amorphous when grouped into H8 to H10 which has high degree of decomposition with no visible plant structure and has mushy consistency.

Table 2.8 shows the Von Post Scale symbol and its description.

Table 2.8 : Von Post Scale symbol and description

Symbol	Description
H1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains easily identifiable. No amourphous material present.
H2	Almost entirely undecomposed peat which, when squeezed, releases clear or yellowish water. Plant remains still easily identifiable. No amourphous material present.
H3	Very slightly decomposed peat which, when squeezed, releases muddy brown water, but from which no peat passes between the fingers. Plant remains still identifiable and no amourphous material present.
H4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat passes between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features.
H5	Moderately decomposed peat which, when squeezed, releases very muddy water with a small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is quite indistinct to recognize certain features. The residue is very pasty.
H6	Moderately highly decomposed peat with a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is very pasty but shows the plant structure more distinctly than before squeezing.
H7	Highly decomposed which contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
H8	Very highly decomposed peat with a large quantity of amorphous material and very indistinct plant structure. When squeezed, about two-third of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material in the hand consists of residue such as roots and fibers that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed it is fairly uniform paste.
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

Peat is called by H_n where n is the number from 1 to 10 with different descriptions of it by referring to Degree of decomposition or also called Von Post Scale. The higher the amount of $_n$, the better the properties of peat will be and the higher decomposition of peat with lower plant structure discerned.

Table 2.9 shows the engineering properties of peat referring to range of organic content.

Table 2.9 : Engineering properties of peat referring to organic content range (ASTM D4427)

Basic Soil Type	Description	Organic Content (%)
Clay or silt or sand	Slightly organic	2 – 20
Organic soil		25 – 75
Peat		Above 75

Organic content of peat must be higher than 75 % as to classify it as peat with reference to ASTM standard. Compared to other soil, peat has higher organic content which shows how problematic it is compared to other organic and soft soil.

Table 2.10 shows engineering properties of peat for different type of peat and its specific gravity value.

Table 2.10 : Engineering properties of peat for specific gravity

Type of Peat	Specific Gravity
Bog peat	1.4 – 1.6
Fen peat	1.8
West Malaysia peat	1.38 – 1.70
Samarahan peat, Sarawak	1.07 – 1.63

Bog peat has specific gravity of 1.4 to 1.6 and fen peat is 1.8. West Malaysia peat has the amount of specific gravity from 1.38 to 1.70. Sarawak peat specific gravity is 1.07 to 1.63. Peat specific gravity value in Malaysia can be from 1.07 and 1.63. Huat (2004) stated that the specific gravity for organic soils is affected by the organic constituents, and cannot be simply set to somewhere near the mineral soils.

For most mineral soils (sand, silt, clay), the specific gravity ranges from 2.60 – 2.80 (Huat, 2004)

2.9 Previous Research

Previous research is done selected to be compared with the results on Chapter 4. The researchers that been selected to be compared with the result on Chapter 4 is Al - Raziqi et al. (2003), Duraisamy et al. (2007), Yulindasari (2006), Wong et al. (2008), and Alwi (2008).

2.9.1 Banting, Kampung Jawa and Dengkil Peat

Table 2.11 shows the previous research of classification of peat and its engineering properties by Al – Raziqi et al. (2003) with the several location of his research and the value for the classification of peat that are field vane shear (FVS) and Von Post Scale (VPS) and the engineering properties of peat with the value of moisture content (MC), organic content (OC), liquid limit (LL), undrained shear strength (Cu) and the angle of internal friction (AOIF).

Table 2.11 : Previous research on classification of peat and its engineering properties (Al – Raziqi et al., 2003)

Location	Location Symbol	Classification of Peat		Engineering Properties of Peat				
		FVS (kPa)	VPS	MC (%)	OC (%)	LL (%)	Cu (kPa)	AOIF (°)
Banting, Selangor	L1	10 – 12	H1	211	85	294	9 – 11	9 – 20
	L2	11	H2	195	79	219	6 – 11	9 – 16
	L3	10	H5	832	84	361	7 – 10	7 – 10
	L4	7 – 9	H6	219	94	316	9 – 12	9 – 12
	L5	4	H8	225	85	166	6 - 11	6 – 11
Kampung Jawa, Selangor	L1	11	H3	214	79	180	10 – 12	6 – 14
	L2	8	H6	225	84	325	12 – 14	7 – 25
	L3	5	H8	618	88	368	7 – 11	8 – 13
	L4	10 – 15	H3	680	85	298	11 – 12	10 – 15
	L5	5 – 10	H5	747	93	352	10 – 12	5 – 10
	L6	9 – 12	H7	720	83	282	7 – 9	9 – 12
Dengkil, Negeri Sembilan	L1	9 – 13	H2	246	98	305	3 – 12	3 – 12
	L2	6 – 10	H5	301	98	335	13 – 15	13 – 15
	L3	3 – 6	H8	786	83	377	12 - 20	12 - 20

Al – Raziqi et al. (2003) selected the three locations as a reference for this study. He carried out the research at several places in West coast of Peninsular Malaysia and the three locations are Banting in Selangor, Kampung Jawa in Selangor and Dengkil in Negeri Sembilan.

Banting peat has undrained shear strength ranging from 4 to 12 kPa with the Von Post Scale of H1 to H8. The natural moisture content is 195 to 832% with organic content of 79 to 94%. The cohesion value is 6 to 12 kPa with angle of fiction is 6^{o} to 20^{o}.

Sample from Kampung Jawa have undrained shear strength from field vane shear strength approximately 5 kPa to 15 kPa. The Von Post Scale is ranging from H3 to H8, with moisture content of 200 to 750%. The organic content value is 79 to 93%. The liquid limit is 180 to 370 %. The cohesion value is 7 to 14 kPa and the angle of friction is 5^{o} to 25^{o}.

Dengkil locations have undrained shear strength of 3 to 13 kPa from the field vane shear strength with the Von Post Scale is H2 to H8 and natural moisture content of 240 to 790%. The organic content is 83 to 98% and the liquid limit is 300 to 380 %. The cohesion and angle of internal friction is both 3° to 20°.

2.9.2 Pontian Peat

Table 2.12 shows the previous research of classification of peat and its engineering properties by Yulindasari (2006) for Pontian peat and the value for the classification of peat that are field vane shear (FVS) and pH and the engineering properties of peat with the value of moisture content (MC), organic content (OC), fiber content (FC), and specific gravity (G_s).

Table 2.12 : Previous research on classification of peat and its engineering properties (Yulindasari, 2006)

Location	Classification of Peat		Engineering Properties of Peat			
	FVS (kPa)	pH	MC (%)	OC (%)	FC (%)	G_s
Kampung Baru, Pontian, West Johor south coast of Peninsular Malaysia	10.1	3.24	608	97	90	1.468

Yulindasari (2006) research on Pontian peat where the peat location is at Kampung baru, Pontian, that is in West Johor of south coast Peninsular Malaysia. Pontian peat from her research are having undrained shear strength from field vane shear test is 10.1 kPa with pH of peat is 3.24 that shows high acidic peat type. The moisture content of peat is 608% with organic content is 97% and fiber content is 90%. The specific gravity of Pontian peat is 1.468.

2.9.3 Sungai Buaya Peat

Table 2.13 shows the previous research of classification of peat and its engineering properties by Duraisamy et al. (2007) for Sungai Buaya peat in Banting and the value for the classification of peat that are the peat type and Von Post Scale (VPS) and the engineering properties of peat with the value of moisture content (MC), organic content (OC), liquid limit (LL), fiber content (FC), and specific gravity (G_s).

Table 2.13 : Previous research of classification of peat and its engineering properties (Duraisamy et al., 2007)

Location	Classification of Peat		Engineering Properties of Peat				
	Peat type	VPS	MC (%)	OC (%)	LL (%)	G_s	FC (%)
Sungai Buaya, Banting	Hemic	H6	241	75	275	1.53	58
	Fibric	H5	286	77	310	1.51	68
	Fibric	H4	350	88	398	1.42	77

Duraisamy et al. (2007) selected peat at Sungai Buaya, Banting focusing on different type of the peat. The types of peat in the research are hemic and fibric, where the Von Post Scale is H4 to H6. The moisture content is in range of 240 to 350% with 75 to 90% organic content and liquid limit of 275 to 400%. The fiber content of the selected locations are 58 to 77% which shows the peat has high and some got low fiber content. The specific gravity range is 1.4 to 1.55.

2.9.4 Klang Peat

Table 2.14 shows the previous research of classification of peat and its engineering properties by Wong et al. (2008) for Klang peat and the value for the classification of peat that are the peat type and pH and the engineering properties of peat with the value of moisture content (MC), organic content (OC), ash content (AC), specific gravity (G_s), and fiber content (FC).

Table 2.14 : Previous research on classification of peat and its engineering properties (Wong et al., 2008)

Location	Classification of Peat		Engineering Properties of Peat				
	Peat type	pH	MC (%)	OC (%)	AC (%)	G_S	FC (%)
Sri Nadi Village, Klang Selangor, West coast of Peninsular Malaysia	Fibrous	3.51	668	96	4	1.40	90

Wong et al. (2008) selected Klang peat as his research where the Klang peat type is Fibrous peat. The pH of Klang peat is 3.51 with moisture content, organic content, ash content and fiber content are 668%, 96%, 4%, and 90% respectively. The specific gravity of Klang peat is 1.40.

2.9.5 Banting Peat

Table 2.15 shows the previous research of classification of peat and its engineering properties by Alwi (2008) for Banting peat and the value for the classification of peat that are the peat type and Von Post Scale (VPS) and the engineering properties of peat with the value of moisture content (MC), organic content (OC), liquid limit (LL), fiber content (FC), and specific gravity (G_s)

Table 2.15 : Previous research on classification of peat and its engineering properties (Alwi, 2008)

Classification of peat		Engineering properties of peat				
VPS	pH	MC (%)	OC (%)	LL (%)	G_S	FC (%)
H4	4.6	700 - 850	98.46	173.75	1.343	84.99

Alwi (2008) research is on tropical peat in Malaysia. The pH of tropical peat is 4.6 with Von Post Scale of H4. The moisture content, organic content, liquid limit and fiber content are 700 to 850%, 98.46%, 173.75% and 84.99% respectively. The specific gravity of tropical peat is 1.40.

2.10 Effects of Dosage Rates

Effects of dosage rates is measured from the effects of addition of stabilizer to peat from the value of undrained shear strength, moisture content, atterberg limit and specific gravity. The effects is positive if the undrained shear strength and specific gravity value is increase and moisture content and liquid limit is decrease and negative for the opposed results. Laboratory work is emphasized on unconfined compressive strength test that focus in determining the undrained shear strength of the peat.

2.10.1 Unconfined Compressive Strength Test

Unconfined compressive strength is done to find the undrained shear strength, discussed on the principle of the test and the modes of failure with results from previous research.

i) Principle test

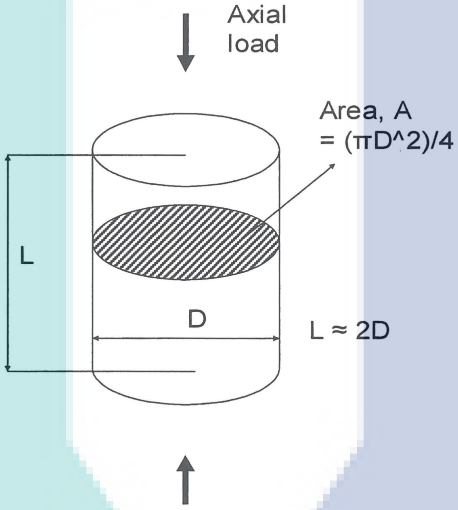

Figure 2.3 : Principle of unconfined compression test

Figure 2.3 shows the diagram of principal of unconfined compressive strength test.

ii) Modes of failure

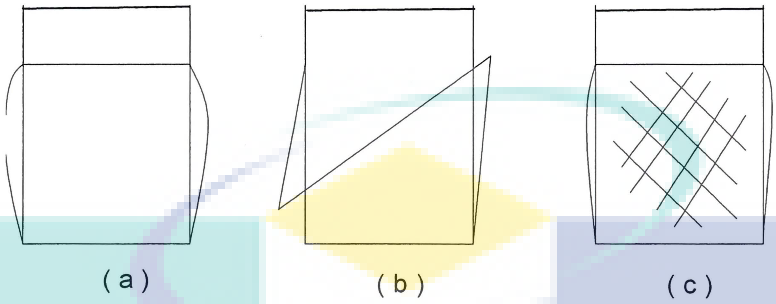

Figure 2.4 : Models of failure in compressions specimens : (a) Plastic failure (barrelling), (b) Brittle failure (shear plane), (c) Intermediate type

Figure 2.4 shows the models of failure in compressions specimens where the types are plastic failure, brittle failure, and intermediate failure.

iii) Results from previous research

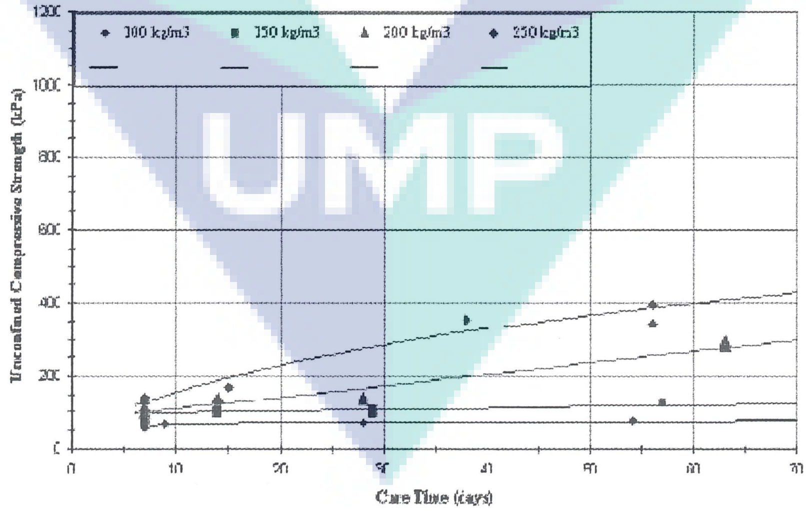

Figure 2.5 : Effect of dose rate for L:C

Figure 2.5 shows the effects of dosage rates graph. From the graph, with high dosage rates, the strength gained will increase. With the increment of cure time, the strength gain will also increase but at a slower rate on the days after 28 days.

Table 2.16 shows the effects of stabilizer to the unconfined compressive strength of peat referred to the curing day and mixed design for screened peat and also added with stabilizer that is ordinary Portland cement (OPC).

Table 2.16 : Effects stabilizer to the unconfined compressive strength of peat

Mix Design	Unconfined compressive strength (kPa)			
	0 Days	7 Days	28 days	56 days
OPC – A	-	11.13	16.19	24.67
OPC – B	-	29.60	33.65	45.39
OPC – C	-	48.27	49.34	52.43
Screened peat	6.902	-	-	-

Note : (OPC – ordinary Portland cement)

The screened peat that is similar meaning to unstabilized peat with no addition of stabilizer results are unconfined compressive strength with 6.902 kPa. The addition of stabilizer to peat increased the undrained shear strength value that shows for all OPC – A, OPC – B and OPC – C, shows an increment value from 7 to 56 days. The undrained shear strength is really high at the 7 days curing and increased at slower rate on the 28 days and 56 days.

CHAPTER 3

METHODOLOGY

3.1 Introduction

To improve the engineering and physical properties of peat will need the methods of soil improvement that are lime cement column and mass stabilization method. With the used of different proportions of dosage rates of stabilizers mixed to peat will make variables results to be analyzed. The strength gained from the peat analyzed from this study will easier the calculation of amount of the binders needed to be mixed to stabilized with peat and as well as for the lime cement column method that will be used in construction work.

The division of work is separate into field work, preliminary laboratory work, and final laboratory work.

3.2 Flow Work Diagram

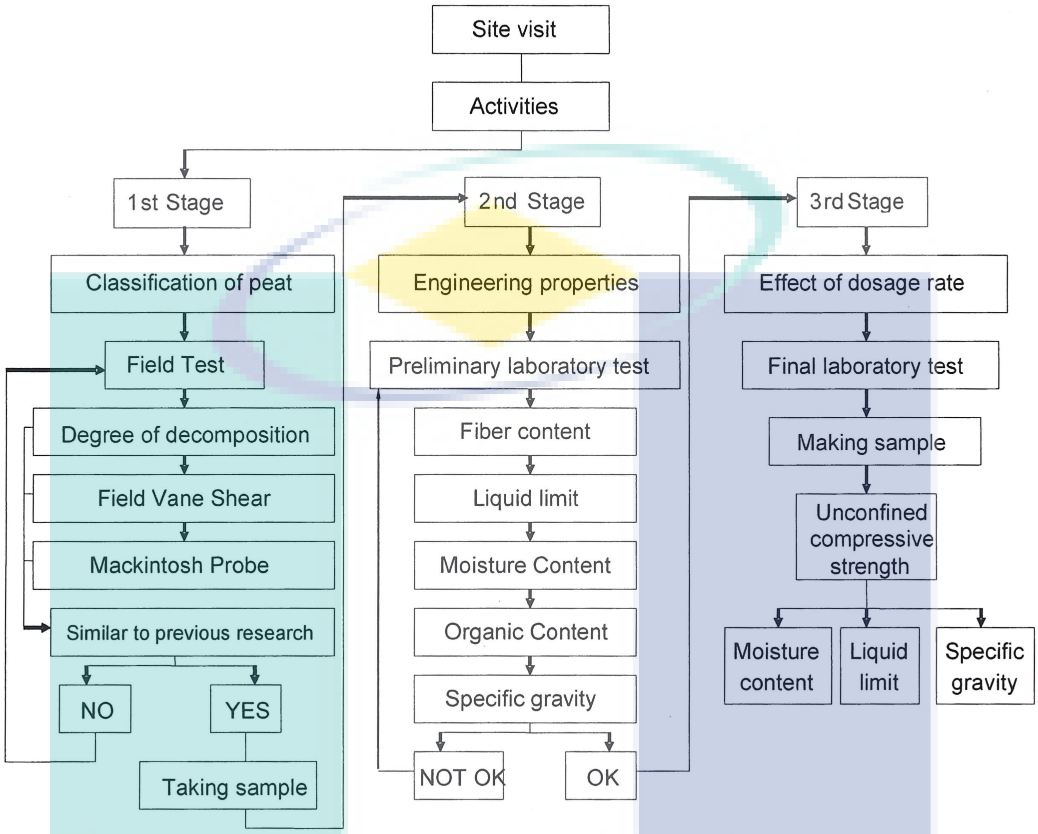

Figure 3.1 : Research methodology flow chart

Figure 3.1 shows the flow chart of research methodology. The first stage of work is the classification of peat and the method that is used is the field work test. The tests that were done are degree of decomposition, field vane shear, and mackintosh probe test. Second stage is followed by determination of engineering properties of peat by preliminary laboratory test. The preliminary laboratory tests that were done are fiber content, liquid limit, moisture content, organic content and specific gravity. The third stage of is to differentiate the effects of addition of stabilizer to peat before and after stabilization. The tests that were used are unconfined compressive strength and other tests are moisture content, liquid limit, and specific gravity.

3.3 Classification of Peat and Site Selection

The classification and site selection for the peat location is done from field test which are Mackintosh probe, Field vane shear and Degree of decomposition Test. Some locations are selected from the data from Mineral and Geoscience Department of Pahang where the place is located from the maps given. The first survey done is to locate the peat location at Pahang from the map and do survey by going to the selected locations to make sure that there are peat distributed there. It is easier as peat is known by the black colour and easier to be found in Pekan Pahang as Pahang is one of the states in Malaysia that have high peat distribution. Three locations is selected in consideration of having similar properties of undrained shear strength, and degree of decomposition from the previous research.

The field works that were done are degree of decomposition, field vane shear test and mackintosh probe test.

The preliminary test for the determining of engineering properties of peat is done with preliminary laboratory test that are fiber content, liquid limit, moisture content, organic content, and specific gravity test.

The final laboratory test is done as to find the effects of dosage rates of stabilizers mixed to peat with the engineering properties of peat and in this final test, only selected test is done that are unconfined compressive strength, moisture content, specific gravity and atterberg limit with liquid limit test.

3.3.1 Degree of Decomposition

Von post scale for assessing peat degree of decomposition is represented by symbol H1 until H10. To perform the test, the sample of peat or organic soil is squeeze in the hand. The color and form of fluid that is extruded between the fingers is observed together with the pressed residue remaining in the hand after squeezing.

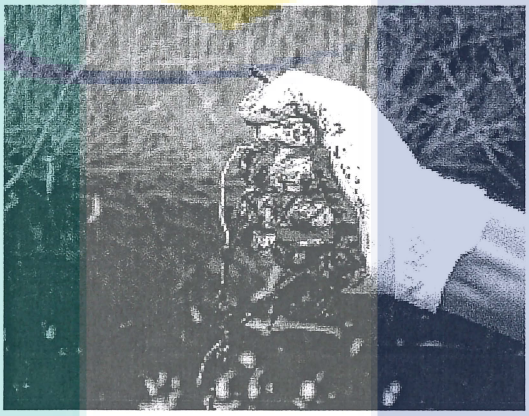

Figure 3.2 : Von Post Scale identification

Figure 3.2 shows the Von Post Scale identification through the color of the water dissipates out when the soil is squeezed. Thus it gives early prediction on the degree of decomposition of peat.

3.3.2 Field Vane Shear

The required vane was connected to the inspection vane instrument. When coupling and uncoupling the vanes and rods, always use both spanners to avoid straining the spring which could ruin the accuracy of this calibrated instrument.

The plastic cover was removed. The vane was pushed into the ground to a depth of about 70 - 80 mm with as little sideways movement as possible. Twisting is avoided during penetration of the inspection vane. The pointer needle was ensured set to zero reading.

The body was turned clockwise with a constant speed equivalent to one complete revolution in a minute. Failure and maximum shear was obtained in the clay at the vane when the pointer needle is not increasing anymore (stays on the same reading) or the pointer even falls back.

The body was hold firmly and allows it to return to zero position. Spring back of the body is not allowed. The reading was note on the graduated scale. Touching or in any way disturb the position of the pointer needle until the reading is taken is avoided. The reading wrote down together with the position of hole and depth.

Figure 3.3 : Field vane shear test

Figure 3.3 shows the field vane shear test done to get the undrained shear strength of natural peat.

3.3.3 Mackintosh Probe

The steel of size 1200 mm is marked for 300 mm long on each part. After the machine is set up, the 1200 mm diameter steel rod pointers of 25 mm diameter and 60 ° cone using a hammer of 5 kg weight is drove into the soil in vertical direction.

The blow is counted of hammer penetrated reach the marked of 300 mm, the blow is stop when encountered the resistance exceeding 400 blows / 300 mm.

400 blows is reached means that the probe is reaching the hard soil. That shows that the test should be stop. Graph of depth versus number of blows is then plotted.

Depth of peat is classified when the blows from 0 – 10 blows and the depth of soft soil is determined before 400 blows is reach.

3.4 Engineering Properties of Peat

Engineering properties is of peat categorization is done with preliminary laboratory test done to the peat. In this research, the categorization of peat is done with test of fiber content to find to content of the fiber in it, liquid limit as to find the atterberg limit, moisture content of unstabilized peat, organic content of peat that is to find the content of organic and specific gravity of peat.

3.4.1 Fiber Content (ASTM D 1997)

Test method for laboratory determination of fiber content of peat samples by dry mass. The fiber content is determined from dry weight of fiber retained on #100 sieve (>0.15mm) as a percentage of oven dried mass.

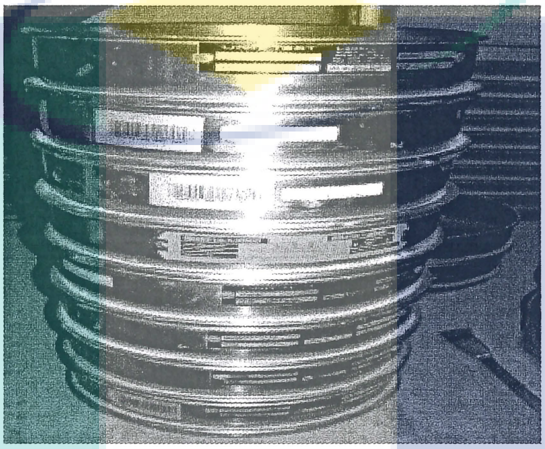

Figure 3.4 : Fiber content test

Figure 3.4 shows the sieve that is used to determine the fiber content of peat.

3.4.2 Liquid Limit (ASTM D 4318)

In order to estimate the plasticity of the soils, the liquid limit and plastic limit values were determined. The Atterberg limits device was used to determine the liquid limit.

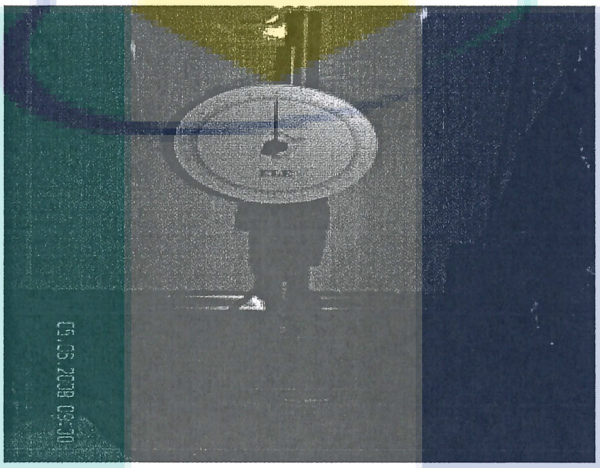

Figure 3.5 : Liquid limit test

Figure 3.5 shows the liquid limit apparatus to determine the liquid limit of peat.

3.4.3 Moisture Content (ASTM D 2216)

Soil specimens were weighed as received then oven-dried at 105° C for 24 hours, and weighed again. The difference in weight is assumed to be the weight of the water driven off during drying. The difference in weight is divided by the weight of the dry soil, giving the water content on a dry weight basis. To expedite the testing program, moistures were often determined using the microwave drying method as described by Hagerty et al. (1990).

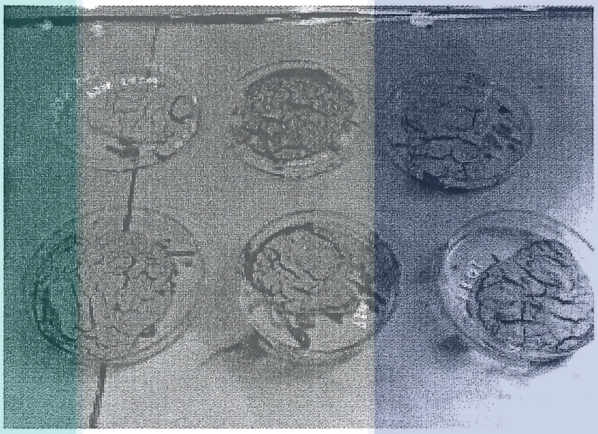

Figure 3.6 : Moisture content test

Figure 3.6 shows the moisture content plate and peat that had been oven dried to test the moisture content of peat.

3.4.4 Organic Content (ASTM D 2974)

The organic contents of these soils were determined by first oven drying a sample at 105°C for 24 hours and recording the moisture content. The sample was then placed in a muffle furnace, heated to 440°C, and when constant mass was achieved, the sample was weighed. Weight loss due to ignition divided by initial dry weight produces the ash content. The organic content is calculated as one minus the ash content.

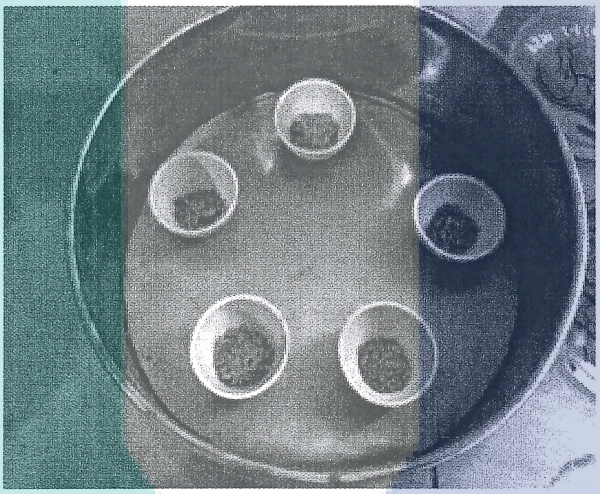

Figure 3.7 : Organic content test

Figure 3.7 shows the crucible that is put into furnace for organic content determination.

3.4.5 Specific Gravity (ASTM D 854)

Values of the specific gravity of the soil solids were determined by first weighing a 150 ml flask empty (W_F) and then full of water (W_{FW}). A known weight of air-dried soil (W_S) was placed in the flask, which was then filled to the 150 ml mark and weighed again (W_{FWS}). The weight of water displaced by the soil can be calculated as $W_W = W_S + W_{FW} - W_{FWS}$. Specific Gravity can then be calculated as $G_s = W_S / W_W$.

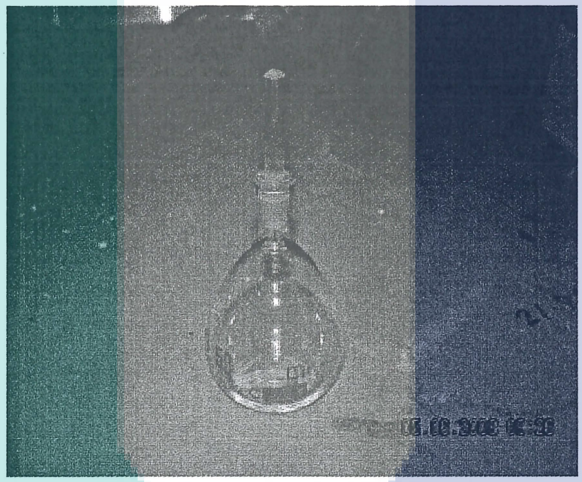

Figure 3.8 : Specific gravity test

Figure 3.8 shows the density bottle that was used to determine the specific gravity of peat.

3.5 Effects of Dosage Rates of Stabilizers to the Engineering Properties of Peat

The effects of dosage rates to the engineering properties of peat is done with the final laboratory test with the peat mixed with stabilizers in 150, 200 or 250 kg/m^3 dosage rates where stabilizers is in ratio of 80:20 of cement to lime. The test that are done are Unconfined compressive strength as to find the undrained shear strength of stabilized peat, moisture content with moisture content test, atterberg limit with liquid limit test and specific gravity with specific gravity test.

3.5.1 Unconfined Compressive Strength

From the measured Specific Gravity (Gs) of the soil, the dry mass of the soil (Ps) can be obtained by using formula.

$$Gs = Ps / Pw$$

Where;

Pw = Density of water

Ps = Dry mass of the soil

From the obtained Ps, the mass of the soil can be known to be weighed to be fit 1 mould, where the volume is already known which is 1963.49 mm^3.

$$Ps = Mass / Volume$$

The value of the mass of the soil is needed to calculate the relative mass of the stabilizer needed which is in percentage of weight to the soil.

After the mass of the stabilizer needed is known, peat and the stabilizer are mixed in drum mixer until homogeneous mixture is gotten.

The mixture is then put in the mould where it is place layer by layer into the mould. The mixture is tampered for 25 blows by using hammer to avoid any void in the mixture.

PVC is put on top of the mixture in the mould where the shape is cut according to the area of the mould's surface and a plastic is put on the bottom of the mould where it is make with lots of small hole to substitute it with the porous stone.

The loading of 18 kPa is then placed slowly on the PVC. The purpose of this loading is to let it be in its original state as it is taken from a depth below the surface of the peat taken.

Finally, the mould is cured for 7 days and UCS test will be done after the curing day ended. The UCS test will be conducted again after 14 days and 28 days curing day is achieved.

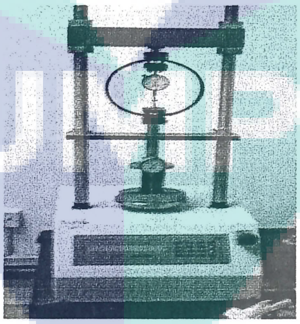

Figure 3.9 : Unconfined compressive strength test

Figure 3.9 shows the unconfined compressive strength tools that was used to determine undrained shear strength of peat

3.6 Designation

Designation is done so that the samples can be easily identified. Designation is done for sample and location designation.

3.6.1 Location Designation

Table 3.1 : Location designation

Sample Location	Depth of Sample Taken (m)	Symbol
Along Kuantan-Pekan Road (km 308 Kuantan – Pekan)	0.5	Location 1 (L1)
Along Kuantan-Pekan Road (km 308 Kuantan – Pekan)	0.5	Location 2 (L2)
Taman Inderapura Sempurna	0.5	Location 3 (L3)

3.6.2 Sample Designation

The sample is named on,

<Location>.<Curing Day>.<Dosage Rate>.<Test Number>

Example : L1.7.150.1

L1 = Location One

7 = 7 days curing day (0 refer to no curing is done)

150 = 150kg/m^3 dosage rate (0 refer to unstabilized)

1 = Test trial number one

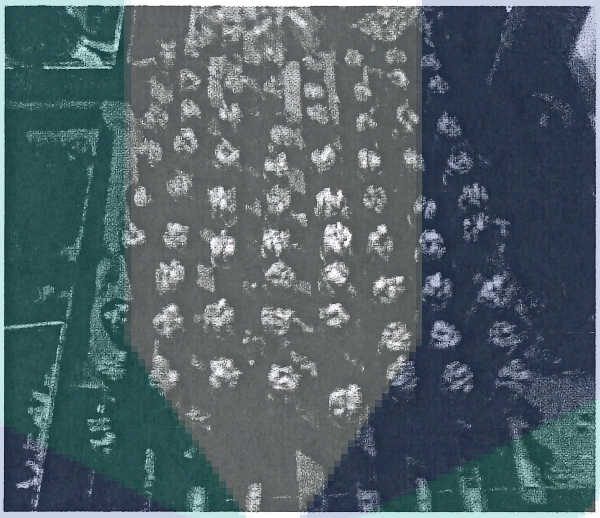

Figure 3.10 : Samples

Figure 3.10 shows the samples that were done test for the final laboratory test using unconfined compressive strength test.

Table 3.2 shows the sample designation for the peat samples that is done for the final laboratory test.

Table 3.2 : Sample designation

Curing Days	Dosage Rates kg/m³	Sample Trial no	L1 Symbol	L2 Symbol	L3 Symbol
0	0	1	L1.0.0.1	L2.0.0.1	L3.0.0.1
		2	L1.0.0.2	L2.0.0.2	L3.0.0.2
		3	L1.0.0.3	L2.0.0.3	L3.0.0.3
7	150	1	L1.7.150.1	L2.7.150.1	L3.7.150.1
		2	L1.7.150.2	L2.7.150.2	L3.7.150.2
		3	L1.7.150.3	L2.7.150.3	L3.7.150.3
	200	1	L1.7.200.1	L2.7.200.1	L3.7.200.1
		2	L1.7.200.2	L2.7.200.2	L3.7.200.2
		3	L1.7.200.3	L2.7.200.3	L3.7.200.3
	250	1	L1.7.250.1	L2.7.250.1	L3.7.250.1
		2	L1.7.250.2	L2.7.250.2	L3.7.250.2
		3	L1.7.250.3	L2.7.250.3	L3.7.250.3
14	150	1	L1.14.150.1	L2.14.150.1	L3.14.150.1
		2	L1.14.150.2	L2.14.150.2	L3.14.150.2
		3	L1.14.150.3	L2.14.150.3	L3.14.150.3
	200	1	L1.14.200.1	L2.14.200.1	L3.14.200.1
		2	L1.14.200.2	L2.14.200.2	L3.14.200.2
		3	L1.14.200.3	L2.14.200.3	L3.14.200.3
	250	1	L1.14.250.1	L2.14.250.1	L3.14.250.1
		2	L1.14.250.2	L2.14.250.2	L3.14.250.2
		3	L1.14.250.3	L2.14.250.3	L3.14.250.3
28	150	1	L1.28.150.1	L2.28.150.1	L3.28.150.1
		2	L1.28.150.2	L2.28.150.2	L3.28.150.2
		3	L1.28.150.3	L2.28.150.3	L3.28.150.3
	200	1	L1.28.200.1	L2.28.200.1	L3.28.200.1
		2	L1.28.200.2	L2.28.200.2	L3.28.200.2
		3	L1.28.200.3	L2.28.200.3	L3.28.200.3
	250	1	L1.28.250.1	L2.28.250.1	L3.28.250.1
		2	L1.28.250.2	L2.28.250.2	L3.28.250.2
		3	L1.28.250.3	L2.28.250.3	L3.28.250.3

The sample will be tested with different dosage rates of 150 kg/m³, 200 kg/m³, and 250 kg/m³ with proportion of cement to line tested with unconfined compression test is 80:20 and cured for 7, 14, and 28 days with loading of 18 kPa. The sample is tested on unconfined compressive strength test for 3 times as to reduce uncertainties and the value will be counted as taking the average value if there is no sample that failed in the test, if failed only average for the samples left and will merely be count for two nearest value if there is big difference between the three value of samples tested.

3.7 Amount of Cement and Lime Added to Peat

Amount of cement and lime added to peat is done by using a formula that considering the amount of peat to be treated, ratio of lime and cement added to peat and dosage rates of stabilizer to be mixed with peat with some properties of peat to be used that are moisture content of peat, specific gravity of peat and unit weight of water.

3.7.1 Formula to Calculate Amount of Stabilizers

Determine the amount of lime and cement to add to the nearest g, based on kg stabilizer per cubic meter of soil to be treated,

$$\text{Amount of cement (g)} = 1000\, W_{TOT} \frac{\left(1 + \frac{\omega G_s}{S}\right)}{G_S\, \gamma_w\, (\omega + 1)} \text{DR. Proportion of cement}$$

$$\text{Amount of lime (g)} = 1000\, W_{TOT} \frac{\left(1 + \frac{\omega G_s}{S}\right)}{G_S\, \gamma_w\, (\omega + 1)} \text{DR. Proportion of lime}$$

Where ;

W_{TOT}	:	Wet weight of batch prior to the addition of stabilizer (kg)
ω	:	Moisture content of batch prior to the addition of stabilizer
GS	:	Specific gravity of the soil solids
S	:	Degree of saturation of the soil, which is often assumed to be 1.0 for soft clays below the water table
γ_w	:	Unit weight of water (kg/m^3)
DR	:	Dose rate in kg of stabilizer / m^3 of soil to be treated
Proportion of Cement	:	Weight of cement / weight of cement and lime
Proportion of Lime	:	Weight of lime / weight of cement and lime

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Introduction

The results are analyzed based on the classification of peat, engineering properties of peat, and effects of various dosage rates mixed to peat. These results will be discussed by cross referring the results from other researchers.

On the classification of peat, analysis of results is on the undrained shear strength from field vane shear test, depth of peat distributed in those places and depth of water at the location from mackintosh probe test and characteristics of peat from von post degree of decomposition test.

On the characterization of engineering properties of peat, the properties of peat is focused on the getting the natural moisture content from moisture content test, atterberg limit from liquid limit test, specific gravity from specific gravity test, content of fibers from fiber content test, and content of organics from organic content test.

The effects of dosage rate to the engineering properties of peat from the addition of peat with stabilizers is discussed on the improved undrained shear strength and moisture content results from unconfined compressive strength test, atterberg limit from liquid limit test and improved gravity from specific gravity test.

4.2 Classification of Peat

Classification of peat is done by referring to some basic test that shows the characteristics of peat. The field vane shear test is done to determine the field undrained shear strength value of peat. Mackintosh probe test is done to find the depth of peat distributed at the location, the height of water level, the depth of soft soil and the depth of hard soil found. Degree of decomposition is done to classify the peat to its properties from Von Post Scale.

4.2.1 Field Vane Shear

Diameter of Vane, Ø = 12.7 mm
Height of Vane, H = 1.0 m (L1)
0.8 m (L2)
Distance of point location = 1 m

Table 4.1 shows the undrained shear strength result from the field vane shear test at L1, L2, and L3.

Table 4.1 : Undrained shear strength result from field vane shear test

Location	C_u Readings (kPa)
L1	5 – 8
L2	5 – 9
L3	7 – 10

Table 4.1 shows that in every location with different vane used gives different result yet the value was in range of 5 to 10 kPa. From the literature review on Table 2.11, the range of the Pekan peat was almost the same with Kampung Jawa at Klang, Malaysia.

4.2.2 Mackintosh Probe

Table 4.2 shows the result of classification of peat using mackintosh probe for 0 – 10 blows, 400 blows and the water level.

Table 4.2 : Results of mackintosh probe

Location	Mackintosh Probe		
	0 – 10 Blows	400 Blows	Water Level
L1	1.5 m	13.8 m	1.2 m
L3	1.8 m	13.2 m	0.3 m

The peat depth was referred to the penetration height when the blow is 0 to 10 blows and the results shows the depth was 2.1 m at L1 and 2.8 m at L3. 400 blows which means that the penetration had met the hard soil is at 14.4 m at L1 and 13.8 m at L3. The water level of L1 is at 1 m and at L3 is at 0.3 m.

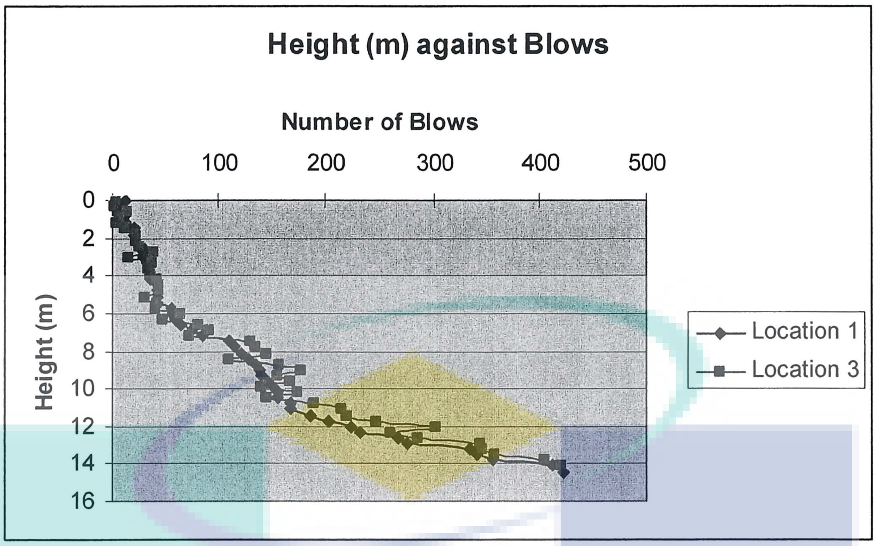

Figure 4.1 : Graph of mackintosh probe result

Figure 4.1 summaries the explanation of Table 4.2 where we can see clearly that the peat depth was not higher than 2 m from the surface. The depth of soft soil was 13.2 m and 13.8 m for L3 and L1 respectively.

4.2.3 Degree of Decomposition

Table 4.3 shows the table of degree of decomposition on Von Post Scale.

Table 4.3 : Table of degree of decomposition (Von Post Scale)

Location	Degree of Decomposition
L1	H1
L2	H2
L3	H2

From the Von Post Scale on Table 2.8, L1 was completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains easily identifiable. No amorphous material present.

L2 and L3 was almost entirely undecomposed peat which, when squeezed, releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.

L1 was on H1 scale where L2 and L3 are on H2 scale. From Table 2.6, the Pekan peat results show that Pekan peat is either fibric or hemic peat that has fiber content higher than 33%. Pekan peat was classified as fibrous peat for all the location tested with degree of decomposition test. The Pekan peat had similar degree of decomposition to L1 for Banting peat as it also had degree of decomposition of H1, L3 of Banting peat, L5 of Kampung Jawa peat and L1 and L2 of Dengkil peat referring to Table 2.11.

4.3 Engineering Properties of Peat

Preliminary laboratory work done for categorization of engineering properties of peat to be analyzed are focused on fiber content, liquid limit, moisture content, organic content and specific gravity.

4.3.1 Fiber Content

Table 4.4 shows the fiber content result of unstablized peat for L1, L2, and L3.

Table 4.4 : Fiber Content of Unstabilized Peat

Location	Fiber Content (%)
L1	89.24
L2	91.4
L3	92.47

Table 4.4 shows Pekan peat fiber content was from 89% to 93%. In reference to literature review on Table 2.6, the percentage of fiber for Pekan peat shows that Pekan peat was classified on Fibric peat type and must have the Von Post Scale of H4 or less. Refer to Table 4.3, L1, L2and L3 agreed with the statements.

Referring to Table 2.11, Pekan peat was similar to Banting peat. Pontian peat and Klang peat referring to Table 2.12 and 2.14 is higher than 89% and above. The fiber content of Pekan peat was higher than Sungai Buaya peat in west coast of Penisular Malaysia studied by Duraisamy et al. (2007) with fiber content lower than 80%.

4.3.2 Liquid Limit

Table 4.5 shows the liquid limit result of unstabilized peat for L1, L2, and L3.

Table 4.5 : Liquid limit of unstabilized peat

Location	Moisture Content (%)
L1	304.80
L2	227.86
L3	236.62

Table 4.5 shows the result of liquid limit for Pekan peat that was in range of 220 to 305%. From Table 2.11, the liquid limit for Pekan peat that was the east coast of Peninsular Malaysia was similar to L1, and L2 for Banting peat, L1 and L4 for Kampung Jawa peat, and L1 for Dengkil peat.

The liquid limit studied by Duraisamy et al. (2007) on Table 2.13 is comparable to the liquid limit of Pekan peat where it was in range of 200 to 400%. Liquid limit of Pekan peat is lower than locations on west coast of Peninsular Malaysia studied by him.

4.3.3 Moisture Content

Table 4.6 shows the moisture content result of unstabilized peat for L1, L2, and L3.

Table 4.6 : Moisture content of unstabilized peat

Location	Moisture Content (%)
L1	1039.88
L2	442.07
L3	705.75

The moisture content for Pekan peat was in range of 440 to 1040%. The moisture content ranged of 200 to 800% from Table 2.11, 2.12, 2.13, 2.14 and 2.15 shows that Pekan peat had higher moisture content than west and south coast of Peninsular Malaysia peat.

4.3.4 Organic Content

Table 4.7 shows the organic content result of unstabilized peat for L1, L2, and L3.

Table 4.7 : Organic content of unstabilized peat

Location	Organic Content (%)
L1	79.80
L2	92.70
L3	87.20

Soil that has organic content above 75% is considered as peat from Table 2.9 is classified as peat. Refer to graph 4.6, all the organic content is higher than 79.80% at L1 and other location was higher than at L1.

Yulindasari (2006) reported the Pontian peat is having high organic content of 97% on Table 2.12 and really high if compared to Pekan peat. Organic content of Pekan peat was almost alike with west coast of Peninsular Malaysia peat in Table 2.13 reported by Duraisamy et al. (2007). Klang peat has high organic content referring to Table 2.14 if compared to Pekan peat. All results show that the type of soil is peat as the organic content is above 75%.

4.3.5 Specific Gravity

Table 4.8 shows the specific gravity result of unstabilized peat for L1, L2, and L3.

Table 4.8 : Specific gravity of unstabilized peat

Location	Specific Gravity
L1	1.78
L2	1.43
L3	1.41

From Table 2.10, the bog peat has specific gravity value of 1.4 to 1.6, for fen peat is 1.8. At west coast of Peninsular Malaysia, the range is from 1.38 to 1.7. Pekan peat had higher value compared with west coast of Peninsular Malaysia peat with specific gravity which is in range of 1.4 to 1.8 referred to Table 4.8.

4.4 Effects of Dosage Rate to Engineering Properties of Peat

The effects of dosage rate are focused on amount of stabilizer to be mixed with peat and the result of undrained shear strength and the shear stress value.

4.4.1 Amount of Stabilizer Added

$$\text{Amount of cement (g)} = 1000\ W_{TOT} \frac{\left(1+\frac{\omega G_S}{S}\right)}{G_S\,\gamma_w\,(\omega+1)} \cdot \text{DR. Proportion of cement/lime}$$

Where ;

W_{TOT}	:	Wet weight of batch prior to the addition of stabilizer (kg)
ω	:	Moisture content of batch prior to the addition of stabilizer
GS	:	Specific gravity of the soil solids
S	:	Degree of saturation of the soil, which is often assumed to be 1.0 for soft clays below the water table
γ_w	:	Unit weight of water (kg/m^3)
DR	:	Dose rate in kg of stabilizer / m^3 of soil to be treated
Proportion of Cement	:	Weight of cement / weight of cement and lime
Proportion of Lime	:	Weight of lime / weight of cement and lime

Table 4.9 shows the data for amount of stabilizer calculation.

Table 4.9 : Data for amount of stabilizer calculation

Location	ω (%)	G_s	W_{TOT}
L1	1039.88	1.78	5 kg
L2	442.07	1.43	
L3	705.75	1.41	

Table 4.10 shows the amount of stabilizer to be mixed with Pekan peat for L1, L2, and L3 with its curing day and dosage rate added.

Table 4.10 : Amount of stabilizer to be mixed with peat

Location	Dosage Rate (kg/m^3)	Amount of Cement (g)	Amount of Lime (g)
L1	150	600	150
	200	800	200
	250	1000	250
L2	150	600	150
	200	800	200
	250	1000	250
L3	150	600	150
	200	800	200
	250	1000	250

4.4.2 Unconfined Compressive Strength Result

Table 4.11 shows the average undrained sheat strength result of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added.

Table 4.11 : Average undrained shear strength result

Curing Day	Dosage Rate (kg/m^3)	L1 (kPa)	L2 (kPa)	L3 (kPa)
0 days	Unstabilized	2.98	5.50	3.18
7 days	150	4.64	10.27	5.20
	200	9.62	16.00	10.13
	250	23.81	30.47	27.33
14 days	150	11.68	18.91	13.18
	200	14.97	24.56	17.13
	250	28.00	34.63	32.71
28 days	150	27.50	49.10	29.53
	200	41.37	52.30	42.97
	250	48.20	56.67	49.80

4.4.3 Effects of Dosage Rate to Curing Day of Peat

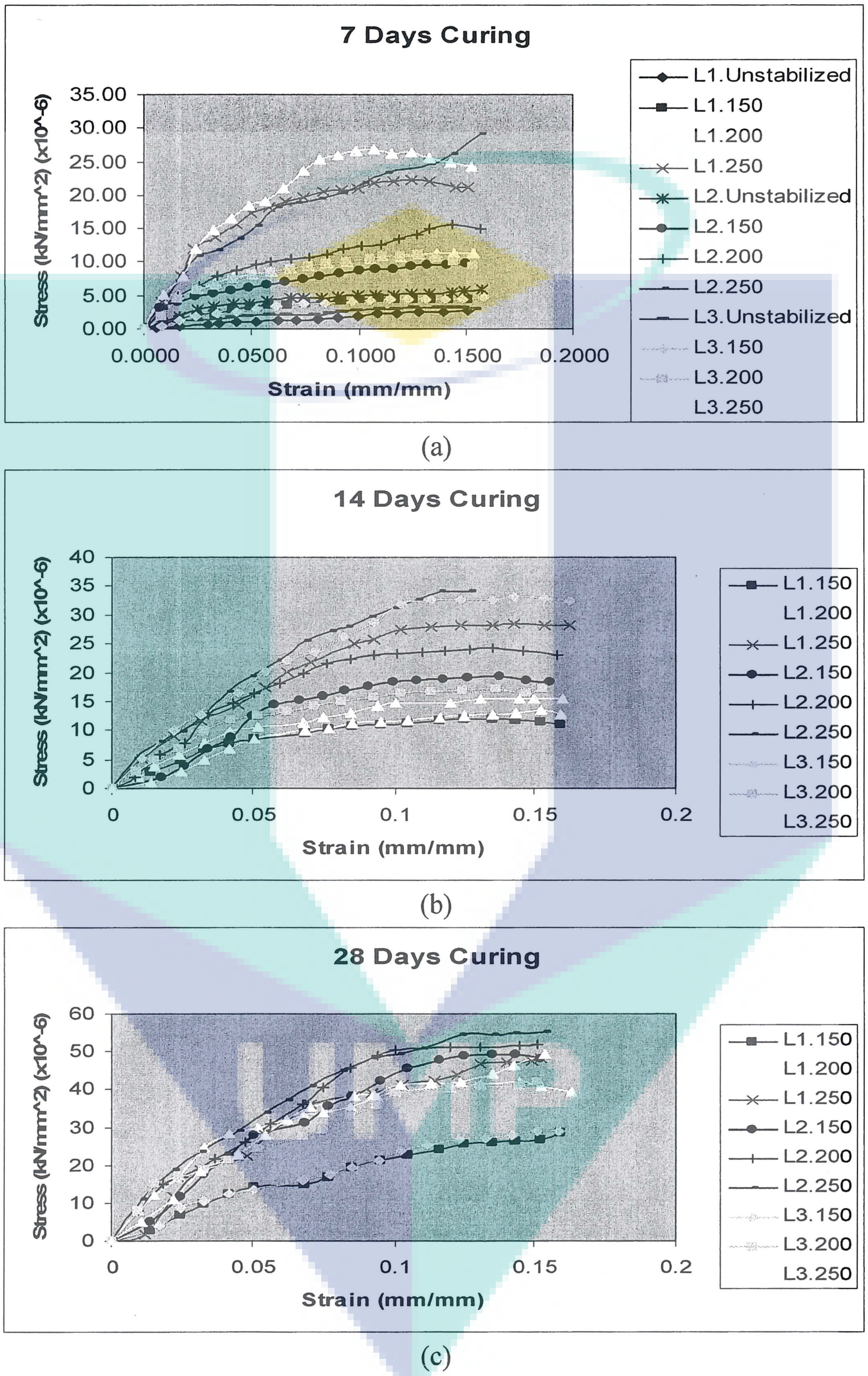

Figure 4.2 : UCS result of dosage rates for (a) 7 days, (b) 14 days and (c) 28 days curing

Figure 4.2 illustrate the pattern of curing day which shows almost similar results that are the highest the value for stress over strain for both curing day is at L2 with the highest dosage rate that is 250 kg/m^3during the 28 curing days.

This statement agreed with the literature review on Figure 2.5 where the higher the dosage rate is, the higher the unconfined compression value.

4.4.4 Effects to Undrained Shear Strength

Undrained shear strength (C_u) is equal to half of Shear Stress (q_u)

$$C_u = ½ \times q_u$$

Table 4.12 shows the undrained shear strength result of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added.

Table 4.12 : Undrained shear strength results

Dosage Rate	Curing Days	L1	L2	L3
0	Unstabilized	1.49	2.75	1.59
150	7 days	2.32	5.14	2.60
	14days	5.84	9.46	6.59
	28 days	13.75	24.55	14.77
200	7 days	4.81	8.00	5.07
	14days	7.49	12.28	8.57
	28 days	20.69	26.15	21.49
250	7 days	11.91	15.24	13.67
	14days	14.00	17.32	16.35
	28 days	24.10	28.34	24.90

Table 4.12 shows results of unconfined compression strength peat on stabilized and unstabilized peat. The highest increment of peat is on L2 cured for 28 days and mixed with stabilizers in dosage rate of 250 kg/m^3.

From Table 2.16 on literature review chapter that shows the effects of addition of 100% cement ratio to peat shows a higher results compared to the research that is done. The value of undrained shear strength from Alwi (2008) results was high that is nearly 34 and 49 kPa. From literature review on point 2.4.1 states that cement is generally the best stabilizers to be used. Table 2.4 shows the effects of peat stabilized with cement only give a good effects and peat stabilized with cement and lime give a fairly effects. The results of effects of cement and lime to peat compared with the research from Alwi (2008) that use fully cement as stabilizer supports and strengthen this statements where if peat is stabilized with fully cement, the undrained shear strength value will be higher.

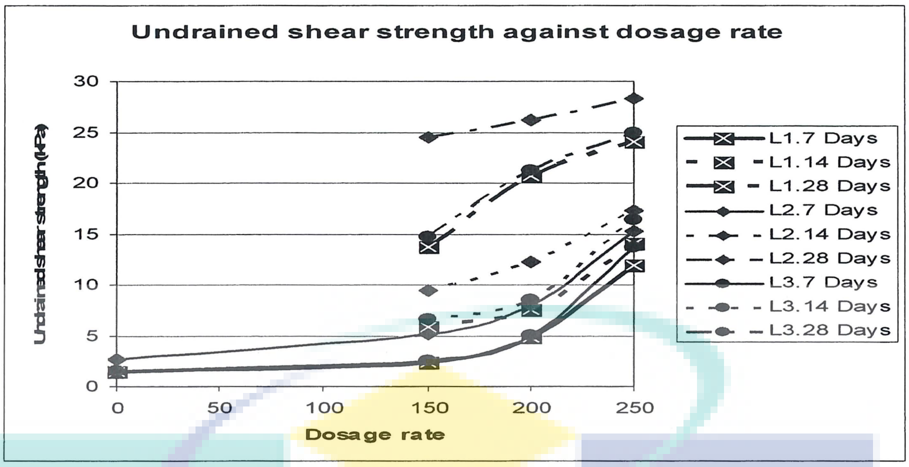

Figure 4.3 : Stabilized undrained shear strength graph

Table 4.12 and Figure 4.3 explained the effects of dosage rates to the undrained shear strength of peat after stabilized with 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3, dosage rate of 80:20 of cement to lime in ratio added to peat. L2 with the dosage rate of 250 kg/m^3, and curing days on the 28 days shows the highest value of undrained shear strength compared to other locations and dosage rate mixed to peat.

Properties of pekan peat at L2 were having the lowest moisture content value, and highest organic content if compared to the other two locations. Having the lowest moisture content summarized why L2 was having the highest undrained shear strength which shows that L2 has higher shear strength than the two locations.

All the three locations shows highest result on 28 curing day compared to other curing days. The dosage rates effects shows a drastic increase for all dosage rates added to peat if compared to unstabilized peat. 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 dosage rates show a drastic increase for all the locations. For example, for L3 on 28 curing days, the value of undrained shear strength on 150, 200 and 250 kg/m^{3}dosage rate is 15 kPa, 20 kPa, and 25 kPa respectively. The increment of dosage rates used to peat shown a drastic increase to the undrained shear strength value.

4.4.5 Effect to Moisture Content

Table 4.13 shows the moisture content result of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added.

Table 4.13 : Moisture content results

Dosage Rate	Curing Days	L1	L2	L3
0	Unstabilized	86.52	76.65	82.01
150	7 days	74.27	66.93	71.34
	14days	72.14	68.13	68.41
	28 days	70.85	64.23	65.34
200	7 days	69.90	64.33	67.47
	14days	66.03	61.05	65.64
	28 days	64.53	58.82	61.67
250	7 days	66.49	60.39	63.04
	14days	62.19	56.50	61.50
	28 days	58.36	53.18	56.53

Table 4.13 shows the results of Pekan peat at L2 shows a highest decrease of moisture content if compared to other locations followed by L3 and L1 at 28 curing days with dosage rate of 80:20 cement to lime added is 250 kg/m^3.

All locations show a decrease of moisture content during the duration of curing day and if the value of dosage rate is high, the higher the decreasing of moisture content of the locations will be.

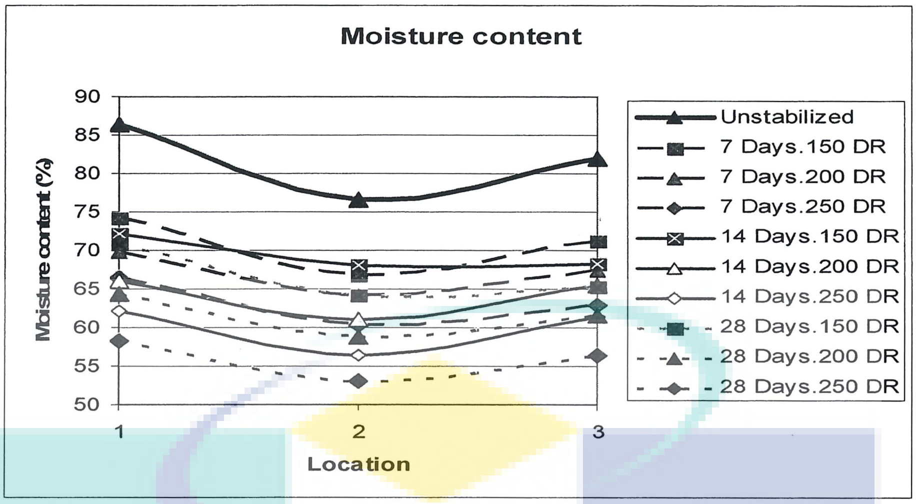

Figure 4.4 : Stabilized moisture content graph

The Figure 4.4 enlightened the effects of dosage rate has reduced the moisture content of peat of the locations cured for 28 days mixed to various dosage rates. L2, with highest dosage rate of 250 kg/m^3 shows extreme changing of decreasing of moisture content from 78% to a value of 53%. The reducing of moisture content shows positive results which support the statement for Figure 4.3 which enlightens the peat having lower natural moisture content gave the highest undrained shear strength value. On Figure 4.4, L2 that had lowest natural moisture content shows a value of undrained shear strength is the highest.

4.4.6 Effect to Liquid Limit

Table 4.14 shows the liquid limit results of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added.

Table 4.14 : Liquid limit results

Dosage Rate	Curing Days	L1	L2	L3
0	Unstabilized	305	228	236
150	7 days	100	86	98
	14days	85	78	86
	28 days	75	74	72
200	7 days	98	84	96
	14days	78	75	82
	28 days	74	70	72
250	7 days	92	82	88
	14days	82	72	80
	28 days	70	62	86

Table 4.14 shows the results of Pekan peat at L2 shows a highest decrease of liquid limit if compared to other locations followed by L3 and L1 at 28 curing days with dosage rate of 80:20 cement to lime added is 250 kg/m^3.

All locations show a decrease of liquid limit during the duration of curing day and if the value of dosage rate was high, the higher the decreasing of liquid limit of the locations will be.

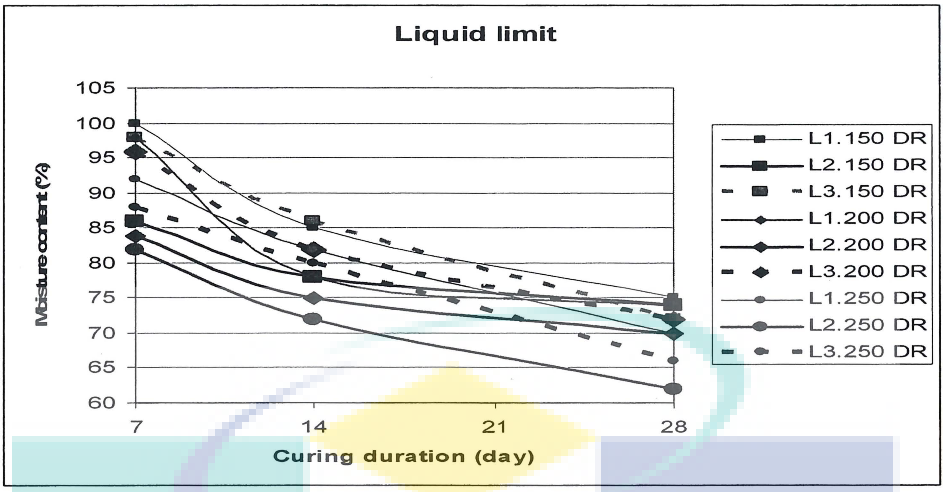

Figure 4.5 : Stabilized liquid limit graph

Figure 4.5 clarified the results of liquid limit from the various peat location tested with various dosage rates. L2 with addition of 250 kg/m^3 dosage rates on the 28 curing day shows the highest decrease of liquid limit value if compared to other locations. Liquid limit is mentioned in percentage of moisture content value which is once again support the statements of Figure 4.3 and 4.4 which was the lowest the value of natural moisture content, the lower the value of stabilized peat will be.

From Table 2.13, that is the research studied by Duraisamy et al. (2007) on Sungai Buaya in west coast of Peninsular Malaysia the natural moisture content of 241% that is the lowest also shows the lower value of liquid limit that is 275% and the highest value of natural moisture content of 350% shows the highest value of liquid limit that is 398%. Banting peat also shows similar results on Table 2.11, a research done by Al – Raziqi et al. (2003). Banting peat that had lower natural moisture content had a lower liquid limit.

This statement maintained the results of peat having lower liquid limit when having lower natural moisture content and strengthen the statement of why Pekan peat at L2 shows an increase in undrained shear strength and decrease of moisture content and liquid limit.

4.4.7 Effects to Specific Gravity

Table 4.15 shows the specific gravity result of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added.

Table 4.15 : Specific gravity results

Dosage Rate	Curing Day	L1	L2	L3
0	Unstabilized	1.78	1.43	1.41
150	7 days	1.96	1.82	1.83
	14days	2.14	1.92	1.93
	28 days	2.39	2.23	2.27
200	7 days	1.99	1.90	1.94
	14days	2.23	1.98	2.04
	28 days	2.41	2.28	2.38
250	7 days	2.03	1.96	1.99
	14days	2.29	2.12	2.22
	28 days	2.47	2.32	2.44

Table 4.15 shows the results of Pekan peat at L1 shows a highest value of specific gravity if compared to other locations followed by L3 and L2 at 28 curing days with dosage rate of 80:20 cement to lime added is 250 kg/m^3.

All locations show an increasing of specific during the duration of curing day and if the value of dosage rate is high, the higher the increasing of moisture content of the locations will be.

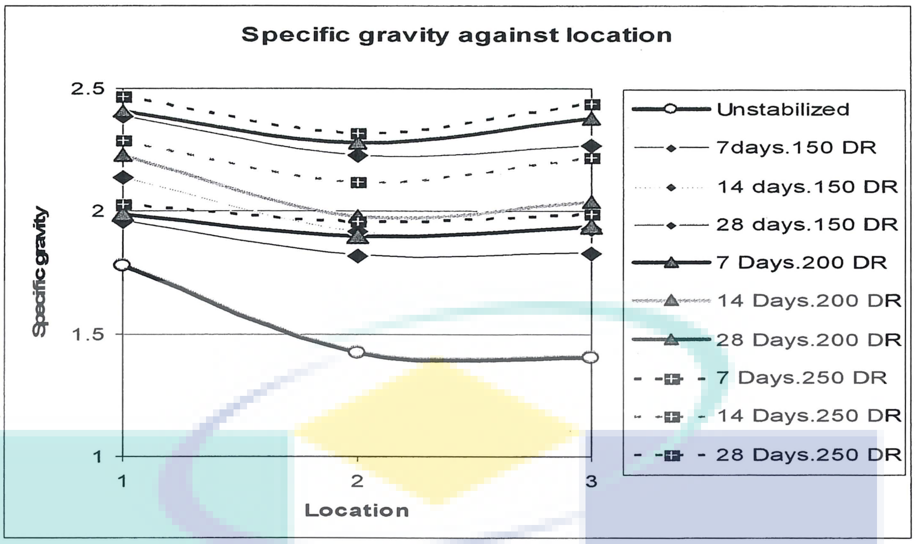

Figure 4.6 : Specific gravity graph

Figure 4.6 shows the graph of specific gravity against location.

The highest value of stabilized specific gravity of peat is on L1 that is stabilized with 250 kg/m^3 dosage rate cured for 28 days. The increment of stabilized peat is high if compared to unstabilized peat which shows that the effects of stabilizer to specific gravity of peat are the increment of the specific gravity.

Huat (2004) summarized the specific gravity of mineral soils ranging from 2.60 to 2.80. The improvement value of stabilized peat shows that the addition of stabilizers increased the specific gravity which shows the properties of peat on specific gravity is nearly reaching the mineral soils properties.

4.5 Statistical Analysis

Table 4.16 shows the overall result of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added with its engineering properties of undrained shear strength (Cu), moisture content (MC), specific gravity (Gs) and liquid limit (LL).

Table 4.16 : Summary on results of peat

DR (kg/m^3)	Curing Day	L1				L2				L3			
		Cu (kPa)	MC (%)	Gs	LL (%)	Cu (kPa)	MC (%)	Gs	LL (%)	Cu (kPa)	MC (%)	Gs	LL (%)
150	7 Days	2.32	74.27	1.96	100	5.14	66.93	1.82	86	2.60	71.34	1.83	98
	14 Days	5.84	72.14	1.99	85	9.46	68.13	1.90	78	6.59	68.41	1.94	86
	28 Days	13.75	70.85	2.03	75	24.55	64.23	1.96	74	14.77	65.34	1.99	72
200	7 Days	4.81	69.90	2.14	98	8.00	64.33	1.92	84	5.07	67.47	1.93	96
	14 Days	7.49	66.03	2.23	78	12.28	61.05	1.98	75	8.57	65.64	2.04	82
	28 Days	20.69	64.53	2.29	74	26.15	58.82	2.12	70	21.49	61.67	2.22	72
250	7 Days	11.91	66.49	2.39	92	15.24	60.39	2.23	82	13.67	63.04	2.27	88
	14 Days	14.00	62.19	2.41	82	17.32	56.50	2.28	72	16.35	61.50	2.38	80
	28 Days	24.10	58.36	2.47	70	28.34	53.18	2.32	62	24.90	56.53	2.44	66

Table 4.17 shows the calculation on percentage performance of Pekan peat for L1, L2, and L3 with its curing day and dosage rate added with its engineering properties of undrained shear strength (Cu), moisture content (MC), specific gravity (Gs) and liquid limit (LL).

Table 4.17 : Calculation on percentage of Pekan peat performance

DR (kg/m^3)	CD	L1				L2				L3			
		Cu (kPa)	MC (%)	Gs	LL (%)	Cu (kPa)	MC (%)	Gs	LL (%)	Cu (kPa)	MC (%)	Gs	LL (%)
0	28 Days	1.49	1039	1.78	304	2.75	442	1.43	227	1.59	705	1.41	236
150		13.75	70.85	2.03	75	24.55	64.23	1.96	74	14.77	65.34	1.99	72
200		20.69	64.53	2.29	74	26.15	58.82	2.12	70	21.49	61.67	2.22	72
250		24.10	58.36	2.47	70	28.34	53.18	2.32	62	24.90	56.53	2.44	66
% 150		822	- 93.2	14	- 75	792	- 85	37	-67	829	- 90.7	41	- 69
% 200		1288	- 93.9	28.6	- 76	850	- 87	48	-69	1251	- 91.3	57	- 69
% 250		1516	- 94.4	38.8	- 77	931	- 88	62	-73	1466	- 92	73	- 72

L1 shows a higher performance compared to the other location in increasing of undrained shear strength, and specific gravity that are 1516% and 38.8% on 250 kg/m^3respectively and decreasing in moisture content and liquid limit that is 94.4% and 77% respectively in both curing day and dosage rates.

Due to this performance, L1 is selected to be analyzed using t-test due to its stabilization using dosage rates of 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3.

4.5.1 t-test

t-test result shows a significance result when the t-test that is calculated is lower than t-test that is obtained from standard table. The t-test analysis is done on the effects of dosage rate to the undrained shear strength, moisture content, liquid limit, and specific gravity of Pekan peat.

i) Undrained shear strength

Table 4.18 shows the t-test calculation on effects of dosage rate to undrained shear strength of Pekan peat.

Table 4.18 : t-test calculation on undrained shear strength

Dosage Rate	Before Stabilized	After Stabilized	t-test Calculated	t-test Table
150 kg/m^3	1.49	13.75		
200 kg/m^3	1.49	20.69		
250 kg/m^3	1.49	24.10	0.0136	2.353

Analysis of t-test for the effects on undrained shear strength of peat using 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 stabilizers shows that the t-test calculated, 0.0136 is lower value than value from table that is 2.353. Due to this result, the analysis shows a significance result.

Due to the significance analysis, the addition of stabilizers with dosage rates of 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 shows effects to the undrained shear strength of peat.

ii) Moisture content

Table 4.19 shows the t-test calculation on effects of dosage rate to moisture content of Pekan peat.

Table 4.19 : t-test calculation on moisture content

Dosage Rate	Before Stabilized	After Stabilized	t-test Calculated	t-test Table
150 kg/m^3	1039	70.85		
200 kg/m^3	1039	64.53		
250 kg/m^3	1039	58.36	$6.85x10^{-6}$	2.353

Analysis of t-test for the effects on moisture content of peat using 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 stabilizers shows that the t-test calculated, $6.85x10^{-6}$ is lower value than value from table that is 2.353. Due to this result, the analysis shows a significance result.

Due to the significance analysis, the addition of stabilizers with dosage rates of 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 shows effects to the moisture content of peat.

iii) Liquid limit

Table 4.20 shows the t-test calculation on effects of dosage rate to liquid limit of Pekan peat.

Table 4.20 : t-test calculation on liquid limit

Dosage Rate	Before Stabilized	After Stabilized	t-test Calculated	t-test Table
150 kg/m^3	304	75		
200 kg/m^3	304	74		
250 kg/m^3	304	70	2.19×10^{-5}	2.353

Analysis of t-test for the effects on liquid limit of peat using 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 stabilizers shows that the t-test calculated, 2.19×10^{-5} is lower value than value from table that is 2.353. Due to this result, the analysis shows a significance result.

Due to the significance analysis, the addition of stabilizers with dosage rates of 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 shows effects to the liquid limit of peat.

iv) Specific gravity

Table 4.21 shows the t-test calculation effects of dosage rate on specific gravity of Pekan peat.

Table 4.21 : t-test calculation on specific gravity

Dosage Rate	Before Stabilized	After Stabilized	t-test Calculated	t-test Table
150 kg/m^3	1.78	2.03		
200 kg/m^3	1.78	2.29		
250 kg/m^3	1.78	2.47	0.0316	2.353

Analysis of t-test for the effects on specific gravity of peat using 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 stabilizers shows that the t-test calculated, 0.0316 is lower value than value from table that is 2.353. Due to this result, the analysis shows a significance result.

Due to the significance analysis, the addition of stabilizers with dosage rates of 150 kg/m^3, 200 kg/m^3 and 250 kg/m^3 shows effects to the liquid limit of peat.

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

The classification of Pekan peat in L1 and L3 is H1 which is completely undecomposed peat whereas the peat in L2 is classified as H2 which is almost entirely undecomposed peat in reference to Table 2.8. Karlsson & Hansbo (1981) classify the peat ranging from H1 to H4 into fibrous peat. All the three locations are in the range of H1 to H4 which means that Pekan peat is fibrous peat type. Pekan peat is also classified into fibric peat as the fiber content is above 66 % from the USDA classification on Table 2.6.

The natural moisture content of peat is high and in the range of 440 to 1040%. After stabilized and cured for 7, 14 and 28 days, the moisture content of peat was decreased and lowers than the unstabilized peat. It shows that with the addition of stabilizer, the moisture content of the peat could be reduced drastically.

The undrained shear strength of stabilized peat after stabilized and cured for 28 days with dosage rate from 150 kg/m^3 to 250 kg/m^3 is in the range of 13 to 30 kPa which shows that the stabilized peat has gain strength with high value of undrained shear strength compared to unstabilized peat that is in the range of 1.4 to 2.8 for the three locations. The strength gain is not really high if compared with other type of soils.

Table 5.1 : Summary of data

	Al-Raziqi (2003)	Yulindasari (2006)	Duraisamy (2007)	Wong (2008)	Alwi (2008)	Authors (2008)
Location	Dengkil, Kg. Baru, Banting	Pontian	Sungai Buaya	Klang	Banting	Pekan
Von Post Scale	H2 - H8	-	H4 – H6	-	H4	H1 – H5
Peat type	-	-	Hemic & Fibric	Fibric	-	Fibric
Moisture content (%)	240 – 790	608	240 – 350	668	700 – 850	400 – 1100
Liquid limit (%)	300 - 380		270 – 400	-	173.75	200 – 310
Fiber content (%)	-	90.118	58 – 77	90	84.99	89 – 93
Organic content (%)	-	97.091	75 - 88	96	98.46	79 – 93
Specific gravity	-	1.468	1.4 – 1.55	1.40	1.343	1.4 – 1.8
Field vane shear (kPa)	3 – 13	10.1	-	-	-	5 – 10
Cohesion (kPa)	12 – 20	-	-	-	-	1.49 – 2.75

5.2 Recommendations

Housing development should use mass stabilization soil treatment for the soil work rather than preloading method. For high building, it is suggested to use piling with no need of soil removal but with treated peat using mass stabilization method. This method is highly recommended to use for highway and road construction and for light weight structure.

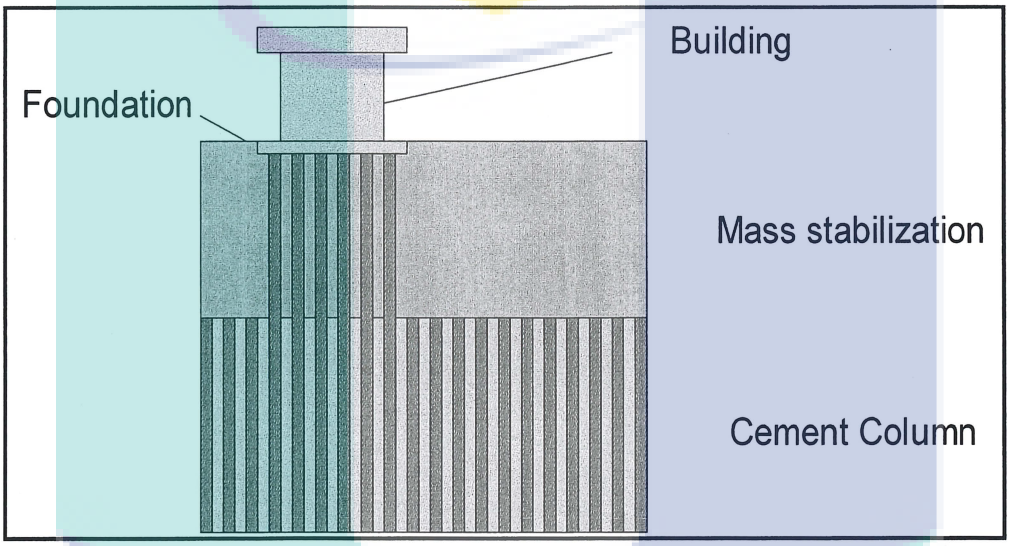

Figure 5.1 : The recommended method of construction on peat

The recommended method to construct any building is the combination of mass stabilization method and cement column method where both of these methods are approved suitable to be done in peat soil. Combination of this method can be done so that more cost effective method is done to reduce the cost in construction. (Al-Tabba, 1999) conclude that mass stabilization is the cost effective method to be done on peat and is more effective than preloading method.

REFERENCES

ASTM 1995. *Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*, Practice No. D4318-93, 1995 Book of ASTM Standards, 04.08,Philadelphia, PA.

ASTM 1995. *Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock*, Practice No. D2216-92, 1995 Book of ASTM Standards, 04.08, Philadelphia, PA.

ASTM 1995. *Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*, Practice No. D2974-87, 1995 Book of ASTM Standards, 04.08, Philadelphia, PA.

ASTM 1995. *Standard Test Method for Specific Gravity of Soils*, Practice No. D854-92, 1995 Book of ASTM Standards, 04.08, Philadelphia, PA.

Al-Raziqi, A. A., Huat, B. B. K. & H. A. Munzir. 2003. Potential usage of hyperbolic method for prediction of organic soil settlement. In *Proceeding of 2nd International Conference on Advances in Soft Soil Engineering and Technology.* Putrajaya, Malaysia. P. 439 – 445.

Alwi A. (2008). *Ground Improvement on Malaysia Peat Soils Using Stabilised peat-Column Techniques*. PhD thesis. University of Malaya.

Ahnberg, H. and Holm, G., 1999. *Stabilisation of some Swedish organic soils with different types of binder. Dry mix methods for Deep Soil Stabilisation.* Brendenberg, Holm, and Broms, eds. Balkema, Rotterdam. 101-108.

Ahnberg, H., Holm, G., Holmqvist, L., and Ljungcrantz, C., 1994. The use of different additives in deep stabilization of soft soils. *International Conference on Soil Mechanics and Foundation Eng.*, 13(3): 1191-1194.

Den Haan, E. J., 2000. *Laboratory Preparation of Test Samples of Soil Stabilized by Cement-Type Materials*. Eurosoilstab Design Guide Chp. 6 Report no. 393220/6.

Eades, J. L., and Grim, R.E. 1966. *A Quick Test to Determine Lime Requirements for Lime Stabilization.* Highway Research Record 139, HRB, NRC Washington, D.C.

Duraisamy Y., Huat B. B. K. and Azlan A. Aziz. (2007). Engineering Properties and Compressibility Behavior of Tropical Peat Soil. *American Journal of Applied Sciences.* 768-773.

Hampton, M. B., and Edil, T.B., 1998. *Strength Gain of Organic Ground With Cement-Type Binders.* Soil Improvement for Big Digs pp 135-148.

Hagerty, D. J., Ullrich, C. R., and Denton, M.M., Microwave Drying of Soils. *Geotechnical Testing Journal, GTJODJ,* Vol. 13, No. 2, June 1990, pp. 138-141.

Hernandez-Martinez, F. G. and Al-Tabbaa, A. (2005) *Mechanical properties of stabilised peat based on laboratory testing* In: The The Sixteenth International Conference on Soil Mechanics and Geotechnical Engineering (16ICSMGE) v.3, 12-16 September 2005, Osaka, Japan.

Huat B. B. K. (2004). *Organic and Peat Soils Engineering.* University Putra Malaysia Press.

Melling, L., K. Ambak, J. Osman & Ahnad Husni. 1999. Water Management for the Sustainable Utilization of Peat Soils for Agriculture. In *Proceeding of the International Conference & Workshop on Tropical Peat Swamps.* Penang, Malaysia.

Pousette, K., Macsik, J., Jacobsson, A., Andersson, R., and Lahtinen, P., 1999. *Peat soil samples stabilised in the laboratory – Experiences from manufacturing and testing. Dry mix methods for Deep Soil Stabilisation.* Brendenberg, Holm, and Broms, eds. Balkema, Rotterdam. 85-92.

Wong L. S., Hashim R., Ali F. (2008). *Compression Rates of Untreated and Stabilized Peat Soils. Electronic Journal of Geotechnical Engineering.* Volume 13.

Yulindasari (2006). *Compressibility Characteristics of Fibrous Peat Soil.* University Teknologi Malaysia. Master thesis.

APPENDIX A

Overall Result of Preliminary Work

Table A1 : Table of results from preliminary work

No.	Test	Result at Location		
		1	2	3
1.	Moisture content (%)	1039.88	442.07	705.75
2.	Liquid limit (%)	304.8	227.86	236.62
3.	Fiber content (%)	89.24	91.4	92.47
4.	Organic content (%)	79.80	92.70	87.20
5.	Specific gravity	1.78	1.43	1.41
6.	Undrained shear strength (kPa)	1.49	2.75	1.59

APPENDIX B

Raw Data of Moisture Content

Table B1 : The raw data of moisture content

Curing Day	Dosage Rate (kg/m^3)	Moisture Content value (%)								
		Location 1			Location 1			Location 1		
		1	2	3	1	2	3	1	2	3
		Average			Average			Average		
7	0	86.95	86.09	Fail	77.23	76.30	76.43	82.35	81.34	82.53
			86.52			76.65			82.01	
	150	74.27	75.17	73.38	66.20	65.90	68.67	70.24	72.15	71.64
			74.27			66.93			71.34	
	200	69.68	69.82	70.21	64.36	63.78	64.85	65.43	64.32	66.67
			69.90			64.33			67.47	
	250	65.91	67.71	65.86	60.47	59.32	61.39	60.52	59.21	63.38
			66.49			60.39			63.04	
14	150	74.05	72.21	70.15	68.21	67.84	68.34	70.97	73.85	Fail
			72.14			68.13			68.41	
	200	66.93	64.23	67.25	60.63	61.47	Fail	60.75	58.43	59.73
			66.03			61.05			65.64	
	250	62.79	64.35	61.60	56.73	57.21	55.57	55.57	57.58	55.35
			62.19			56.50			61.50	
28	150	72.25	69.45	Fail	65.13	66.9	60.66	65.12	68.76	65.14
			70.85			64.23			66.34	
	200	63.17	66.74	63.68	56.61	59.57	60.28	63.12	63.59	61.3
			64.53			58.82			62.67	
	250	57.64	58.85	58.59	52.91	54.86	51.77	57.82	55.45	56.62
			58.36			53.18			56.53	

APPENDIX C

Raw Data of Undrained Shear Strength

Table C1 : The raw data of undrained shear strength

Curing Duration (days)	Dosage rate (kg/m^3)	Undrained shear strength value (kPa)								
		Location 1			Location 2			Location 3		
		1	2	3	1	2	3	1	2	3
		Average			Average			Average		
7	0	2.91	3.05	Fail	5.28	5.21	6.01	3.10	3.10	3.30
		2.98			5.50			3.18		
	150	5.27	4.35	4.31	10.10	10.40	10.30	5.60	4.80	5.20
		4.64			10.27			5.20		
	200	8.92	11.50	8.41	16.00	15.80	16.20	10.10	10.60	9.70
		9.62			16.00			10.13		
	250	22.32	22.30	26.80	29.20	32.00	30.20	27.00	27.00	28.00
		23.81			30.47			27.33		
14	150	10.60	12.07	12.39	18.93	18.49	19.31	12.97	13.38	Fail
		11.68			18.91			13.18		
	200	13.91	15.49	15.5	24.22	24.9	Fail	17.10	17.04	17.25
		14.97			24.56			17.13		
	250	26.50	29.00	28.50	33.90	35.20	34.80	32.68	32.29	33.17
		28.00			34.63			32.71		
28	150	29.00	26.00	Fail	48.20	48.90	50.20	30.10	29.50	29.00
		27.50			49.10			29.53		
	200	41.20	41.90	41.00	52.00	52.90	53.50	43.00	43.10	42.80
		41.37			52.30			42.97		
	250	48.00	48.70	47.90	56.00	56.00	58.00	49.90	50.00	49.50
		48.20			56.67			49.80		

APPENDIX D

Raw Data of Field Vane Shear Test

Table D1 : Raw data of field vane shear test

Point	Reading	S_u Readings (kPa)		
		Location 1	Location 2	Location 3
1	1	6	7	7
	2	6	5	7
	3	7	9	8
2	1	5	8	9
	2	6	8	8
	3	8	6	8
3	1	8	5	8
	2	5	7	7
	3	7	8	7
4	1	8	6	7
	2	8	8	7
	3	7	6	9
5	1	6	7	8
	2	8	9	10
	3	5	8	8