INVESTIGATION ON THE MECHANICAL PERFORMANCE OF SILICA FUME AND OPC STABILISED PEAT

by

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Dissertation submitted in partial fulfillment of the requirement for the

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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BACHELOR OF ENGINEERING (Hons)

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Approved by,

(Ir Dr Muslich Hartadi Sutanto)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2021

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

YUVERAAJ VEERA SINGHAM

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ABSTARCT

Peat geotechnical properties such as low shear strength, high organic matter, low bearing capacity and high compressibility make it been regarded as difficult soil. Peat soil is considered by geotechnical engineers as an unfavourable soil for construction. It has covered approximately twenty-three (23) million hectares in South-East Asia with about three (3) million hectares or 8% of the total area in Malaysia. Peat soil has been regarded as problematic soil that poses significant threat to roads and building foundations stability due to its unique characteristics of high compressibility, low shear strength and consolidation settlements even when subjected to a moderate load. Construction on peat soil has proven to be a challenging task to civil engineers because of its characteristics. Geotechnical risks and costs frequently accompanied to be higher when doing construction on soft soil likes peat. The aim of this study is to use Ordinary Portland Cement and silica fume to stabilise the peat soil from Teluk Intan, Perak. Unconfined Compressive Strength (UCS) test and California Bearing Ratio (CBR) test. Having analysed the laboratory test results, it was noticed that the Unconfined Compressive Strength of peat, 15% OPC and 15% silica fume was the highest (333.50 kPa) compared to other mixtures of additives. At the same time, California Bearing Ratio of peat 15% OPC and 15% silica fume was the highest (24.80% for without curing and 26.29% with 7 days curing) as well.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

1.1.1 Peat Soil

Peat grounds have two very fundamental interrelated problems as far as their engineering response to load bearing behaviours are concerned [10]. First, they have high water content, low bearing capacity, relatively low plasticity, and high compressibility. Second, for almost any kind of civil engineering construction projects such as bridge, building, road and etc they experience significant settlements upon loading. In general, organic soils, and peat especially, are considered unstable. Current data shows that organic soils cover 436.2 million hectares worldwide, of which 35.8 million hectares (8.2%) are in tropical and subtropical regions. The world's gross tropical peatland area is approximately 30 million hectares, two thirds of which are in Southeast Asia [11]. In the absence of a complete oxidative atmosphere, peat forms through the deposition of partially or fully decomposed plant biomass that has been fossilised over a long period of time. The peat structure consists mostly of the pores that are open and connected, dead-ended, or isolated that eventually increases its water retention capacity substantially [1]. Peat soil is classified as very soft soil with low shear strength, high organic matter, low bearing capacity and high compressibility in an unconsolidated condition. These features cause unnecessary settling, which is very difficult for geotechnical engineers and the overall construction sector. Because of this difficult nature of peat soil, constructing work on it has been a rather difficult job for geotechnical and civil engineers, and therefore the engineers considered peat soil as the worst foundation for supporting the structures constructed on it because of its undesirable nature and behaviour. Hence, peat is considered as unsuitable for supporting foundations in its natural state. All soils with more than 75 percentage organic content are known as peat and soils with an organic content below 75 percentage are classified as organic soils [2]. As shown in Figure 1, peat is in brownish-black colour due to plant and mineral decay.

Figure 1.1: Peat Soil [3]

Malaysia is ranked 9th among world countries with the highest peat soil. Out of 32,975,800 hectares land in Malaysia, peat covers about 2,457,730 hectares. Which means approximately 8% of Malaysia's total land is covered by peat [1]. Sarawak contains greater peat land as compared to Peninsular Malaysia and Sabah while Sabah has the least covered peat soil [4]. Table 1 shows the summary of peatland distribution in different states of Malaysia.

Table 1.1: Peatland Distribution in Malaysia [4]

Region	**Total Area of ""peat"" (ha)**	**Percentage (%)**
Sarawak	1,697,847	69.08
Peninsular Malaysia	642,918	26.16
Sabah	116,965	4.76
Total	**2,457,730**	**100**

Figure 1.2: Peatland Distribution in Malaysia [5]

1.1.2 Peat Stabilization

Many research are taking place to figure out the best way to stabilise and improve peat soil. The techniques are primarily focused on peat soil modification and stabilisation. The primary objective of peat soil stabilisation and modification is to maximize its capacity to perform well by increasing its strength and avoiding excessive settlement when the soil is fully exposed to structural loads [6]. There are a few types of soil stabilizations which are currently in practice. For example, mechanical stabilization and chemical stabilization.

Ordinary Portland Cement (OPC) is one of the commonly found materials used for stabilizing soils. However, the material has rapidly increased in price due to the sharp increase in energy cost. In addition to that, organic matter in peat contains humic acid and various organic acids such as fulvic and humin that tend to delay the hardening of the OPC and severely reduce the obtained strength and durability of the formed mineral structure. Thus, Stabilization of peat using an OPC as sole binder is not recommended due to the high affinity of acid and organic matter in peat with calcium. However, Pozzolans can be added to OPC stabilized peat to enhance the secondary pozzolanic reaction in the stabilized soil, where both of the OPC and pozzolan react with water in the soil under certain condition and forming higher strength binder that bind the soil particles. Previously, it is noted that their reactivity is dependent on the lime to silica ratio (CaO: SiO2). The higher the ratio, the more hydraulic the material.

Silica Fume (SF) is known as a proven pozzolanic material with a pozzolanic activity of approximately 120–200% that of OPC. SF is a product resulting in reduction of high purity quartz with coal in an electric arc furnace in the manufacture of manganeese or ferrosilicon alloy. Condensed SF is essentially silicon-dioxide (SiO2) in non-crystalline form.

In order to greatly improve mechanical properties, silica fume has been considered the most efficient pozzolanic admixture. By minimising permeability and refining pore structure, applying silica fume to concrete improves the longevity of the latter, contributing to a decrease in the diffusion of harmful ions and the content of calcium hydroxide and leading to a greater resistance to sulphate attack. The silica fume is a very reactive pozzolanic material, due to its extreme fineness and very high amorphous silicon dioxide content. It releases calcium hydroxide as the Ordinary Portland Cement in concrete starts to chemically react. Besides, Silica fume reacts with this calcium hydroxide to form additional binder material known as calcium silicate hydrate, which is quite similar to the calcium silicate hydrate formed from Ordinary Portland Cement [7]. The physical properties of silica fume is shown in figure 2 below.

Property	**Value**
Particle size (typical)	<1 μm
Bulk density	
(as-produced)	130–430 kg/m^3
(slurry)	1320–1440 kg/m^3
(densified)	480–720 kg/m^3
Specific gravity	2.22
Surface area (BET)	13,000–30,000 m^2/kg

Figure 1.2: Physical properties of silica fume [8]

1.2 PROBLEM STATEMENT

Although planning major construction projects in peat deposits is commonly avoided, with the rapid industrialization and population growth, it has become necessary to construct infrastructures facilities on peatland [9][10]. Hence, a thorough understanding of peat soil's engineering properties it very essential. Different methods have been used to improve the peat soil, but the typical techniques used by engineers to cope with this problematic soil are either to extract the peat deposits and substitute those soils with strengthened soils or to drive the piles (end bearing) towards the more stable soil layers beneath through the peat layer [11]. However, this method is not an economical choice. Currently, there are several alternatives on the methods of construction on peat are available.

The promising alternative would be stabilizing the peat soil itself by using appropriate stabiliser, which can minimize the need for costly borrowing materials and expedite construction. Although OPC is commonly used for stabilizing soils, due to the high affinity of acid and organic matter in peat for calcium, stabilising peat with an OPC as the sole binder is not recommended. Pozzolans, on the other hand, can be applied to OPC stabilised peat to boost the secondary pozzolanic reaction in the stabilised soil, in which both OPC and pozzolan react with water in the soil under some conditions, creating a stronger binder that binds the particles together. Therefore, stabilization using Ordinary Cement Portland (OPC) and Silica Fume will be an economical method to overcome the problem of peat soil.

1.3 OBJECTIVES:

1. To investigate the index properties of peat soil
2. To assess the Unconfined Compressive Strength (UCS) of OPC-Silica Fume stabilised peat.
3. To assess the California Bearing Ratio (CBR) of OPC-Silica Fume stabilised peat.

1.4 SCOPE OF STUDY

To achieve the objectives of this study a few experiments needed to be carried out. peat soils samples will be taken from Teluk Intan, Perak. The stabilisation of peat soil will be tested using admixture such as Ordinary Portland Cement (OPC) and Silica Fume. The scope of study included the determination of Unconfirmed Compressive Strength (UCS) by carrying out Unconfined Compression Test (UCT), determination of soil compaction by carrying out Proctor Compaction Test and determination of bearing capacity by carrying out California Bearing Ratio (CBR). All these tests will be carried out by using two types of sample which are undisturbed peat sample and peat which is mixed with Ordinary Portland Cement (OPC) and Silica Fume in different percentage. The scope of study also includes the investigation of physical characterises of peat soil examining the unconfined compressive strength of OPC-silica fume stabilised peat and access the CBR value of OPC-silica fume stabilised peat.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL PROPERTIES OF PEAT SOIL

Peat soil has physical, chemical, and engineering properties like almost any other soil. Peat soil has been characterised as a type of soil with a broad range of physical characteristics, which includes specific gravity, water content, texture, colour and density. [6]. Those physical properties should be included in a full description of the peat soil. They are driven by the key components of the formation, such as mineral content, organic content, moisture content and air content. However, the overall physical properties of the peat soil can differ if one of these components changes. This difference in the characteristics of the peat soil is due to changes in temperature, water level, ageing, and the amount of inorganic soil deposited during the peat soil formation. The degree of decomposition determines both the particle sizes and the composition of the peat and the porosity of peat soil. [12]. This means that with an increase in decomposition, the size of the particles of organic matter will decrease.

The chemical properties of peat are influenced by the chemical composition, the environment in which they have been deposited, and the degree of decomposition of the peat components. Chemical composition, carbon exchange capability (CEC) and acidity are the chemical characteristics of peat soil. As its content heavily depends on temperature and degree of decomposition, the compositions of the peat varies with locations [12].

Table 2.1: peat classes according to ASTM [27]

Fibre content	fibric:	> 67 % fibres
	hemic:	33–67 % fibres
	sapric:	< 33 % fibres
Ash content	low ash:	< 5 % ash
	medium ash:	5–15 % ash
	high ash:	> 15 % ash
Acidity	highly acidic:	pH < 4.5
	moderately acidic:	pH 4.5–5.5
	slightly acidic:	pH > 5.5 and < 7
	basic:	pH ≥ 7

2.2 SOIL STABILISATION

Soil stabilization is a very common process for almost all the civil engineering projects. Whenever there is an unsuitable construction are encountered the typical solution for the engineers are redesign the structure according to the site suitability, remove the unsuitable soil and replace it with stronger soil which suits the construction [13]. Modern technology, however, drives engineers to enhance the engineering properties of the soils at the site. This process is referred to as soil stabilisation. All kinds of soil stabilisation can usually be classified into two groups; Mechanical stabilisation and chemical stabilisation. During mechanical stabilisation, the grading of the soil is modified by mixing it with other soil types of different grades. By doing so, a compacted soil mass can be obtained [14]. Chemical stabilisation, on the other hand, is correlated with changing soil properties by applying chemically active materials. The material properties involved in the mixture and the result after mixing are very important to understand in soil stabilisation. In addition, after stabilisation, it is necessary to find out how the material will work. At the very same time it is important to determine the effect of the operation on nearby buildings and surrounding environments. Therefore, decisions should be made regarding the choice of materials and the required doses. In addition to the selection of materials and doses, there are many other factors controlling the effectiveness of this procedure, such as mixing and spreading, roller selection, compaction layer thickness, compaction effort, activity sequence, curing, environmental and climatic conditions, etc [14].

2.3 ORDINARY PORTLAND CEMENT (OPC)

Ordinary Portland Cement (OPC) is a mechanical additive which could be used for soil improvement or soil stabilisation (to enhance soil quality). The amount of cement used will dictate whether modification or stabilization has occurred. The strength gained by cement stabilisation can benefit almost all soil types. However, when used with well graded fines that have enough fines to create a floating aggregate matrix, the best outcomes have occurred [15]. Ordinary Portland Cement (OPC) is described as an adhesive material capable of uniting a compact whole with a fragment or mass of solid matter. Ordinary Portland cement (OPC) clinker is produced in an inclined rotary kiln with a surface area of approximately 300 m2/kg, a specific gravity of 3,15 and a bulk density of 1350 kg/m3 by calcinating a mixture of finely ground limestone and clay at a maximum temperature of 1450 °C. After cooling, the fine aggregate is grounded with 2 percent to 5 percent gypsum to control the setting rate when adding water. [16] .

Name of Components	Oxide	Abbreviation
Tricalcium Silicate	$3CaO\ SiO_2$	C_3S
Dicalcium Silicate	$2CaO\ SiO_2$	C_2S
Tricalcium Aluminate	$3CaO\ Al_2O_3$	C_3A
TetracalciumAluminate ferrite	$4CaSO_4.\ Al_2O_3.\ Fe2O3$	C_4AF
Calcium Sulphate	$CaSO_42H_2O$ or CaSO4	Gypsum
Chemical Compositions		**Content (%)**
SiO_2		20.5
Al_2O_3		6.5
Fe_2O_3		3.2
CaO		62.5
MgO		0.95
SO_3		<0.01
Na_2O		<0.01
K_2O		<0.01

Figure 2.2: Chemical compositions and main components of Ordinary Portland Cement [16]

Cement type	Use
I	General purpose cement, when there are no extenuating conditions (Standard or ordinary Portland cement)
II	Aids in providing moderate resistance to sulphate attack
III	When high-early strength is required
IV	When a low heat of hydration is desired (in massive structures)
V	When high sulphate resistance is required
IA	A type I cement containing an integral air-entraining agent
IIA	A type II cement containing an integral air-entraining agent
IIIA	A type III cement containing an integral air-entraining agent

Figure 2.2: Ordinary Portland Cement and their uses [16]

Figure 2.3: Ordinary Portland Cement [17]

2.4 SILICA FUME

Silica fume (SF) is a by-product of the silicon and ferrosilicon industry. SiO2 vapours are created by the reduction of high-purity quartz to silicon at temperatures up to 2000 ◦C, which oxidises and condenses into small particles consisting of non-crystalline silica in the low-temperature region [8]. By-products of the manufacturing of silicon metal and the ferrosilicon alloys have silicon contents of 75 percent or more contains 85 to 95 percent non crystalline silica. The by-product of ferrosilicon alloy processing has a much lower silica content of 50 percent silicon and it is less pozzolanic. Therefore, the silica fume's SiO2 content is linked to the type of alloy produced [8]. The particles of Silica Fume are really small and form a greyish black powder with more than 95 percent of the particles thinner than 1 mm and a specific area of approximately 20,000 cm2/g. Table 2.2 shows the physical properties of Silica Fume.

Besides, the silica fume consists of very small spherical particles and has a very high content of amorphous silicon dioxide. There are also small quantities of iron, magnesium, and alkali oxides present [17]. Table 2.3 shows the chemical properties of silica fume.

Table 2.2: Physical Properties of Silica Fume [17]

Property	Guneyisi et al. (2012)	Mardani-Aghabaglou et al. (2014)	Haruehansapong et al. (2014)	Lilkov et al. (2014)
Particle size (μm)	<1	–	0.1	<1
Specific gravity	2.20	2.10	–	–
Specific surface area (cm^2/g)	21,080	18,000	20,000	18,600

Table 2 3: Chemical Properties of Silica Fume [17]

Composition (%)	Guneyisi et al. (2012)	Mardani-Aghabaglou et al. (2014)	Haruehansapong et al. (2014)	Lilkov et al. (2014)
SiO_2	90.36	87.29	88.3	89.50
Al_2O_3	0.71	0.47	1.17	1.13
Fe_2O_3	1.31	0.63	4.76	2.31
CaO	0.45	0.81	0.48	0.98
MgO	–	4.47	2.14	1.55
K_2O	1.52	1.28	–	0.60
Na_2O	0.45	1.25	–	0.42
SO_3	0.41	0.22	1.05	0.40
LOI	3.11	2.70	2.1	2.40

There are several benefits of using silica fume as an admixture. The benefits of using silica fume are [8]:

- Superior resistance to chemical attack from chlorides, acids, nitrates, and sulphates, etc.
- High tensile, flexural strength, and modulus of elasticity
- Enhanced durability
- Increased toughness

Figure 2.5: Silica Fume

2.5 COMPACTION

Soil compaction is the process where the solid particles are more closely packed together thus increasing the soil's dry unit weight. Compaction tests are conducted in the laboratory to obtain the moisture relationship for a given compaction effort on a particular type of soil. [16]. ASTM D 698 and AASHTO T180 D describe the procedures for obtaining the moisture density relation for finer soils such as silty or clayey soils using compaction or modified compaction tests. In a laboratory test, the density of the compacted soil is measured in terms of the dry unit weight of the soil. The weight of the dry unit of soil is a calculation of the quantity of soil volume presented by a solid material unit. The higher the volume of solid materials, the stronger and more durable the soil would be. The design specifications typically indicate the suitable density (maximum density) and the water content. On the other hand, maximum moisture content (OMC) results in the highest water content density. [6].

2.6 UNCONFINED COMPRESSIVE STRENGTH (UCS)

The compressive strength test evaluates the adequacy of the soil to be treated and the suitability of different mixtures is evaluated. In the unconfined compression test, a cylindrical specimen of cohesive soil is subjected to progressively increasing axial compression before failure happens. The only force applied to the specimen is the axial force. The test is typically performed on specimens with a diameter of 38 mm, but may also be performed on specimens with a diameter of up to 100 mm. (B.S 1990) [16]. It is suitable only for saturated, non-fissured cohesive soils. Unconfined compressive strength test is described by ASTM 2166, and is widely used for a quick, economical mean of obtaining the approximate shear strength of a cohesive soil.

2.7 CALIFORNIA BEARING RATIO (CBR)

The ratio (calculated as a percentage) of the force needed to cause a 1935 mm 2 cross-sectional area circular piston to penetrate the soil at a continuous rate of 1 mm/min from the surface to the force required for equal penetration into a sample soil or rock. At penetrations between 2.5 mm and 5.0 mm, the ratio is calculated, and the higher value is used (BS 1990). The intensity of the underlying subgrade is one of the most significant criteria to assess in any pavement design since it is this that is to be covered from damage by constructing a pavement and it has the major effect on the structural design. [16].

2.8 PEAT SOIL STABILIZATION BASED ON PAST RESEARCHERS

Kaolin, has been used as a pozzolanic additive by Wong et al. to improve the strength and reduce the permeability of “peat”. Besides kaolin, they also incorporate Portland composite cement, calcium chloride, and silica sand to strengthen “peat”. It has been concluded that using 90% PCC, 10% K (4% CC) in binder Composition, 300 kg m-3 binder dosage, and 596 kg m-3 silica sand dosage an unconfined compressive strength of 485 kPa has been achieved [18]. In Egypt, Abdel-Salam tried two locally available admixtures to enhance the properties of “peat” soil [19]. The first one comprises of 20% clayey diatomite, 27% calcium carbonate, 12% lime, and 41% water which increased the strength of “peat” soil from zero to 170 kPa. While the other one consists of 25% cement, 33% calcium carbonate, 14% lime, and 28% water, which boosts up the strength from zero to 4000 kPa. Kaolinite has also used by Haut et al. along with sodium silicate and ordinary Portland cement. The maximum strength gained by using kaolinite 30% was 85 kPa [11]. A tremendous increase in the strength of stabilized “peat” has been achieved by Farah Izzati Norazam et al. using a new polymer named Envirotic [20]. After 21 days of drying, 573.89 kPa strength has been gained by adding 40% Envirotic by weight of “peat”. Another polymer, Geopolymer Flexible Activator has been incorporated along with fly ash by Mohamed Jais et al. to strengthen the mechanical properties of “peat” soil [21]. The maximum strength gained was 64 kPa by adding 15% fly ash and 40% GeoFlexA. The overall maximum strength of “pea”” soil has been achieved by Behzad Kalantari and BK Haut which is about 590 kPa by incorporating 50% cement by weight of “peat” soil [22]. Samir Hebib and Eric R. Farrell achieved the maximum strength of 1080 kPa by using blast furnace slag (85%) & gypsum (15%) [23]. Table 2.4 below shows the summarized version of the past research on “peat” soil stabilisation.

Table 2.4: Past Research Results

No	**Research Title/ Reference**	**Authors**	**Stabilizer Used (%)**	**Max. Strength Achieved**	**Region/ Country**
1	Stabilization of “peat” Soil Using Locally Admixture [19]	Ashraf E. Abdel-Salam	20% clayey diatomite / 25% Cement (27% calcium carbonate, 12% lime, & 41% water)	170 kPa Using 20% Diatomite & 4000 kPa Using 25% Cement (45 Days)	Cairo / Egypt
2	Improved strength and reduced permeability of stabilized “pea””: Focus on application of kaolin	Leong Sing Wong, Roslan Hashim, & Faisal Ali	90% PCC, 10% Kaolin (4% CC) (300 kg m-3 binder dosage, and 596 kg m-3 silica sand dosage)	485 kPa	Selangor / Malaysia

	as a pozzolanic additive [18]				
3	Effect of Cement-Sodium Silicate Grout and Kaolinite on Undrained Shear Strength of Reinforced “peat” [11]	Bujang B.K. Huat, Sina Kazemian & Wong Lit Kuang	1. Na2SiO3 (0,1, 2.5, 5.0) 2. OPC (0,40,50) 3. Kaolinite (0, 30, 40)%	1. 80 kPa (2.5 %) 2. 90 kPa (5.0 %) 3. 85 kPa (30 %)	Selangor (Kampung Jawa Klang)/ Malaysia
4	Stabilization of “peat” soil by Using Envirotic [20]	Putri Nur Farah, Ismail Bakar, Alvin John, & Herman Shah	Envirotec Polymer in liquid Form (15, 30, 45)%	573.89 kPa using 40% Envirotec (21 Days)	Selangor (Jenjarom Dengkil) / Malaysia
5	“Peat” Modification on Integrating Geopolymer & Fly Ash [21]	Mohamed Jais, N Abdullah, Md Ali, & M A Johor	GeoFlex A (40%) + Fly Ash (5, 10, 15, 20) %	64 kPa on 15% fly Ash and 40% GeoFlexA (28 Days)	Selangor (Kampung Johan Setia) / Malaysia

6	Load-Bearing Capacity Improvement for “peat” Soil [22]	Behzad Kalantari & Bujang BK Huat	Cement (50%)	590 kPa	Selangor (Kampung, Jawa) / Malaysia
7	Some experiences on the stabilization of Irish peats [23]	Samir Hebib and Eric R. Farrell	Blast furnace slag (85%) & gypsum (15%)	1080 kPa	Daingean / Ireland

CHAPTER 3

METHODOLOGY

3.1 PROJECT FLOW CHART

To achieve the aims of this experiments conducted, the methodology explains the chosen experimental methods or techniques. Based on the flow chart below the experimental study will be performed.

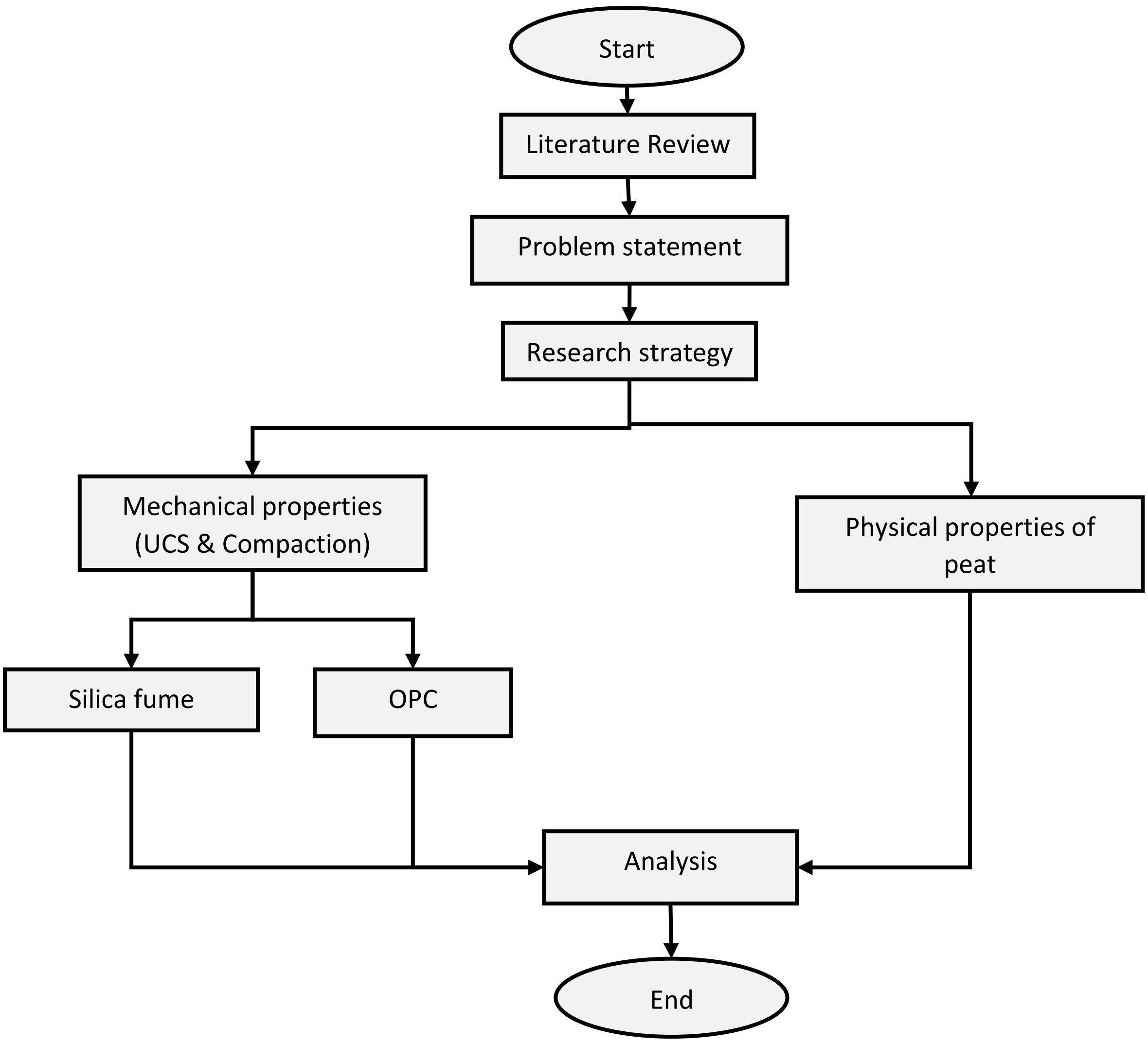

Figure 3.1: Project Flow Chart

3.2 MATERIALS

In this experiment OPC-Silica Fume stabilized peat will be used. Table 3.1 shows the materials that is going to be used in this study consists of the following components:

Table 3.1: Materials Used for the Experiment

Materials	Description
Water	• Enhances the workability of the mix • Activates the hydrophilic elements of the concrete mix
Ordinary Portland Cement	• Essential binding element to any concrete mix
Peat	• Surface organic layer of a soil that consists of partially decomposed organic matter
Silica Fume	• A very reactive pozzolan • Used to partially replace cement

3.3 SAMPLE COLLECTION

In this study, the peat soil were collected from a oil palm plantation area in Teluk Intan, Perak. Before carrying out each experiment the soil will be kept in the oven prior to 24 hours before the experiment. The remaining soil were kept in a plastic container. The supplier provided the Ordinary Portland Cement (OPC) and Silica Fume which later on were used for stabilisation. Both these additives were kept in a plastic container.

Figure 3.2: Location of Peat Sample Collection

3.4 INDEX PROPERTIES OF PEAT SOIL

The experiments were carried out in order to analyze the peat soils and determine their index properties. The experimental for each of the peat soil index properties are defined below.

3.4.1 Von Post Humification Test

The von Post scale is a very easy method to use. It involves squeezing a handful of moist soil (modest enough just to cover with one hand's fingertips) until as much as possible has extruded through the fingers. The colour and viscosity of the exudate, as well as the proportion and condition of the remaining fibre, are all noted. A score is assigned according to the table below.

Table 3.2: Von Post Humification scale [24]

<table>
<tr><th>Degree of Humification</th><th>Decomposition</th><th>Plant Structure</th><th>Content of amorphous material</th><th>Material extruded on squeezing (passing between fingers)</th><th>Nature of residue</th></tr>
<tr><td>H1</td><td>None</td><td>Easily identified</td><td>None</td><td>Clear, colourless water</td><td>-</td></tr>
<tr><td>H2</td><td>Insignificant</td><td>Easily identified</td><td>None</td><td>Yellowish water</td><td>-</td></tr>
<tr><td>H3</td><td>Very slight</td><td>Still identifiable</td><td>Slight</td><td>Brown, muddy water; no peat</td><td>No pasty</td></tr>
<tr><td>H4</td><td>Slight</td><td>Not easily identified</td><td>Some</td><td>Dark brown, muddy water; no peat</td><td>Somewhat pasty</td></tr>
<tr><td>H5</td><td>Moderate</td><td>Recognizable, but vague</td><td>Considerable</td><td>Muddy water and some peat</td><td>Strongly pasty</td></tr>
<tr><td>H6</td><td>Moderately strong</td><td>Indistinct (more distinct after squeezing)</td><td>Considerable</td><td>About one third of peat squeezed out; water dark brown</td><td rowspan="3">Fibres and roots more resistant to decomposition</td></tr>
<tr><td>H7</td><td>Strong</td><td>Faintly recognizable</td><td>High</td><td>About one half of peat squeezed out; any water very dark brown</td></tr>
<tr><td>H8</td><td>Very strong</td><td>Very indistinct</td><td>High</td><td>About two thirds of peat squeezed out also some pasty water</td></tr>
<tr><td>H9</td><td>Nearly complete</td><td>Almost unrecognizable</td><td>-</td><td>Nearly all the peat squeezed out as a fairly uniform paste</td><td>-</td></tr>
<tr><td>H10</td><td>Complete</td><td>No discernible</td><td>-</td><td>All the peat passes between the fingers; no free water visible</td><td>-</td></tr>
</table>

Figure 3.3: Von Post Humification Test Conducted on Site

3.4.2 Oven-Drying Method

It is a method where the sample is dried for a 24 hours' time at constant temperature. The moisture content of the sample will be determined by weighing the sample before keeping it in the oven and also after taking it out from the oven. The moisture content of the sample can be obtained by using the formula below:

Moisture Content (%) = (W2 – W3 / W3 – W1) x 100

Where: W1 = weight of the container

W2 = weight of the container + sample

W3 = dried weight of the container + sample after 24 hours

3.4.3 Cone Penetrometer Method

By using this method, the liquid limit (LL) of the peat soil can be determined. The water content of the soil at which it transitions from liquid to plastic and stops flowing like a liquid is known as the liquid limit. Approximately 300g of undisturbed peat soil has been oven dried for 24 hours. Then it was sieved passed through 425 µm. The soil was later thoroughly mixed by distilled water to form a uniform paste. Once it mixed it was transferred to a brass cup. We made sure that no air is entrapped in the cup. The soil is flattened at the top of the cup and the cup is positioned under the cone. Next, the cone is steadily lowered until it only touches the soil in the cup's surface. The very first reading on the graduated scale is marked as the initial reading. The timer is then started, and the cone is released by pressing the push button. For 5 seconds, the cone was allowed to penetrate the soil. The reading on the graduated scale is reported as the final reading after 5 seconds. The difference between the initial and final readings of the scale can be used to determine the depth to which the cone has penetrated the soil specimen. The test was repeated with the exact procedure at least three times with different water contents. Each trial's precise moisture content is calculated, and a graph of water content vs. cone penetration is generated. The water content value corresponding to 20 mm of cone penetration is now interpreted from this graph, and that value is considered as the soil's liquid limit.

Figure 3.4: Cone Penetrometer

3.4.4 Organic Content

The aim of this test is to assess the organic content of soils. The organic content is the ratio of the mass of organic matter in a given weight of the soil to the mass of dry soil solids, expressed as a percentage. Many of the physical, chemical, and biological properties of soils are influenced by organic matter. Organic matter affects soil structure, compressive strength, and shear strength, among other properties. It also has an effect on water retention capability, nutrient contributions, biological activity, and water and air infiltration rates[25]. During this test, the soil specimen was left in the furnace at 440°C for 24 overnight. The next day, allow it to cool at room temperature and the organic content was determined after weighing the sample.

3.4.5 Specific Gravity

A given material's specific gravity is expressed as the ratio of the weight of a given volume of the material to the weight of an equal volume of distilled water. Soil specific gravity is an important element in measuring the weight-volume relationship. Specific gravity is measured in this test using a small pycnometer, which is used for soils with particles finer than 2mm. After collecting the soil sample, it was dried in the oven at temperatures ranging from 105ºC to 115ºC for 24 hours. First the empty dry pycnometer will be weighed (Wp). 125g of soil were sieved using sieve No.10 and the soil was placed in the pycnometer. The weigh is recorded (Wps). Then, the pycnometer was filled with distilled water until the neck of the pycnometer and weight is recorded (Wb). After 24 hours, the pycnometer was emptied, cleaned, and refilled with distilled water only. The weight pycnometer and distilled water were noted. The specific gravity of the soil was calculated by using the formula below:

Specific Gravity (Gs) = Wp/ [Wp + (Wps – Wb)]

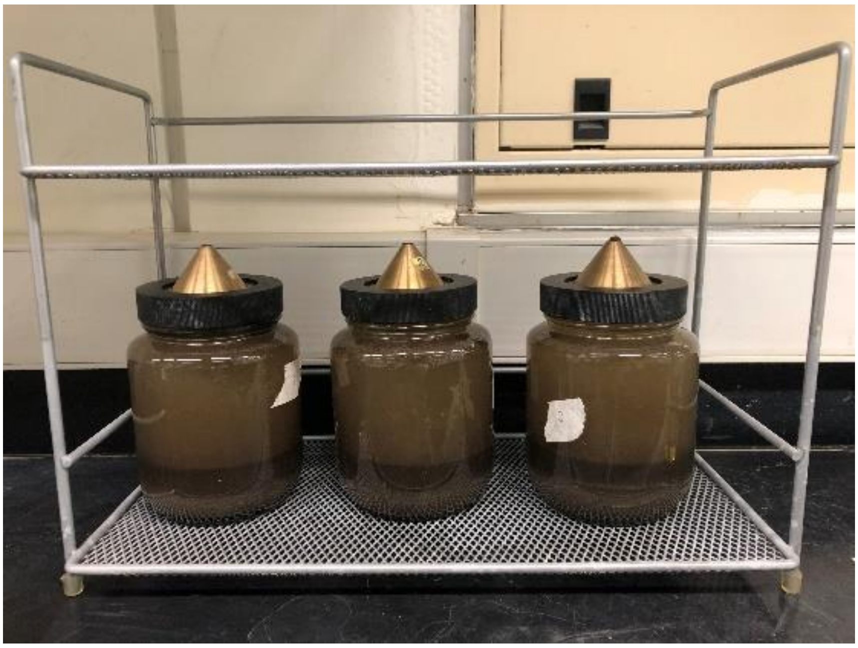

Figure 3.5: Pycnometer

3.4.6 Standard Proctor Compaction

This experiment was performed to evaluate the optimum moisture content at which peat soil will become denser and reach its maximal dry density. A standard proctor compaction test consists of compacting soil with a known moisture content into a cylindrical mold with standard height of 12cm and 10cm diameter measurements. The peat soil is compacted into three equal layers in the mold, with each getting 27 blows from a standard weighted 2.5kg hammer at a 30cm height. This step was performed for different moisture contents, and the dry densities for each are calculated. A compaction curve is created by plotting the relationship of dry density to moisture content on a graph.

Figure 3.6: Standard Proctor Compaction Machine

3.5 EXPERIMENTAL WORKS

3.5.1 Air Curing for Peat Stabilization

Air curing is a process in which the peat-cement combination is exposed to the atmosphere for curing, with no external water interfering into the stabilized samples. Air curing is a method of curing that involves combining peat with cement (OPC) and silica fume and exposing the combination to air without adding any water. Since the natural water content of the peat was very high, this air curing technique was used[26]. The specimens were prepared in a mould, removed after compaction, covered in a thin plastic sheet, and stored in the air at room temperature throughout the curing time.

3.5.2 Unconfined Compression Strength (UCS)

This test was carried out to determine the “unconfined compressive strength (UCS) of OPC-Silica fume stabilised peat sample. The peat was mixed with a few different percentages of Ordinary Portland Cement (OPC) and Silica Fume. The test will be carried out on 7th day and 14th day. The samples were air cured at normal room temperature. The tests were conducted on undisturbed sample and OPC-Silica fume stabilised peat as well. The purpose of conducting this test on undisturbed sample is to compare the test results with the stabilised ones. The sample size for the experiment will be 38mm in diameter and 76 in height.

Procedure:

1. Put the soil samples in a sampling tube and remove the sampling tube once it is filled with soil.
2. Measure the diameter and length of the sample with vernier callipers.
3. Place the sample on the compression machine.
4. An axial strain at the rate of 2% will be applied.
5. Record the dial gauge reading.
6. Stop the experiment once the failure has started to occur.

Figure 3.7: Unconfined Compression Strength (UCS) Test

3.5.3 California bearing ratio (CBR)

This test is carried out to assess the capability of soil to support the load.

Procedure:

1. Weigh 4kg of soil. Add additives if they are any.
2. Add water to the mixture and mix thoroughly until the maximum moisture content is reached.
3. The standard mould of CBR is prepared and spacer disc is placed over the base plate at the bottom of mould and a filter paper is placed over the spacer disc
4. Add the soil to the compaction mould. Total of five layers will be added. Each layer was compacted using CBR Compaction Machine with 56 evenly distributed blows.
5. After compaction with 5 layers of soil in a CBR mould, the excess soil and base plate are removed. The mould is then inverted and clamped to baseplate.
6. weights of 2.5kg is placed on top of the soil and the mould is then placed on the CBR testing machine.
7. Place the mould under the penetration piston of the compressing machine and place 4kg of weight on top of the mould.
8. Then the compressing machine will start to apply load with a constant penetration rate (1.25mm per minute).

9. Record the value on the compressing machine.

Figure 3.8: California bearing ratio (CBR) Testing Machine

Figure 3.9: California bearing ratio (CBR) Testing Compaction Machine

3.6 GANTT CHART

Table 3.3: Gantt Chart for FYP 1

NO	DETAIL/ WEEK	1	2	3	4	5	6	7	8	9	10	11	12
1	Selection of FYP Title	■											
2	Literature Research		■	■	■	■							
3	Study on Properties of Peat Soil Stabilization			■	■								
4	Study about OPC and Silica Fume				■	■							
5	Preparation and Submission of Extended Proposal				■	■	■						
6	Proposal Defense							▲					
7	Study on UCS test and Compaction								■	■	■		
8	Preparation and submission of draft interim report									■	■	■	
9	Submission of Interim report												▲

LEGENDS:
▲ : MILESTONE
■ : PROGRESS

Table 3.4: Gantt Chart for FYP 2

NO	DETAIL/ WEEK	1	2	3	4	5	6	7	8	9	10	11	12
1	Literature study	■	■	■	■	■	■	■	■				
2	Data collection from research paper		■	■	■								
3	Carry out lab activities			■	■	■	■						
4	Preparation of Progress Report				■	■							
5	Submission of Progress Report					▲							
6	Prepare result and discussion						■	■	■	■	■		
7	Submission of final report and technical paper											▲	
8	Submission of Project Dissertation												▲

LEGENDS: ▲ : MILESTONE ■ : PROGRESS

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Index Properties of Peat Soil

The results of the experiment are discussed below, along with descriptions and discussions of the findings.

Table 4.1: Index Properties of Peat Soil

1	Depth of Sample (m)	-	m	1.3 – 1.7
2	Von Post/Classification	Landva & Pheeney (1980)	-	H_3
3	Moisture Content (%)	ASTM D2974-87	%	224.18
4	Optimum moisture content (%)		%	31.1
5	Specific gravity (*Gs*)		kg/m^3	1.68
6	Dry Density (g/cm^3)	Den Haan (1997)*	g/cm^3	1.13
7	Organic content (%)	ASTM D2974-87	%	80.86
8	Fibre Content (%)	ASTM D1997-91	%	80.4
9	Ash Content (%)	ASTM D2974-87	%	19.13
10	Liquid Limit (%)	ASTM D4318-00	%	64.4

The results of index properties of peat soil from Teluk Intan are presented in Table 4.1. The sample was taken from a depth of 1.3m to 1.7m below the ground. It has been observed that this peat sample falls in H_3 (fabric) category under Von Post Humification test. The moisture content of this peat soil is 224.18%. It means the water content of the peat soil is about 224.18% of the overall weight of the peat soil. As a result, it indicates that peat soil has a very high natural high holding ability because the soil structure is characterized by organic coarse particles (fibres), which means that they can hold a significant amount of water because the soil fibres are very loose and hollow. The specific gravity obtained from the research is 1.68 $kg/m^{3.}$ It shows that the peat soil is denser than water as it has specific gravity value greater than 1 kg/m^3. Apart from that, from this study we can know that the organic content of the soil is 80.86% while the fibre content of the soil is 80.4% which means it is a natural peat soil. It also shows that the peat soil used for this study is very high in organic matter. Besides, the liquid limit of the soil is 64.4%. It means that the moisture content at 64.4% is where the peat soil passes from liquid state to plastic state.

4.2 Optimum Moisture Content

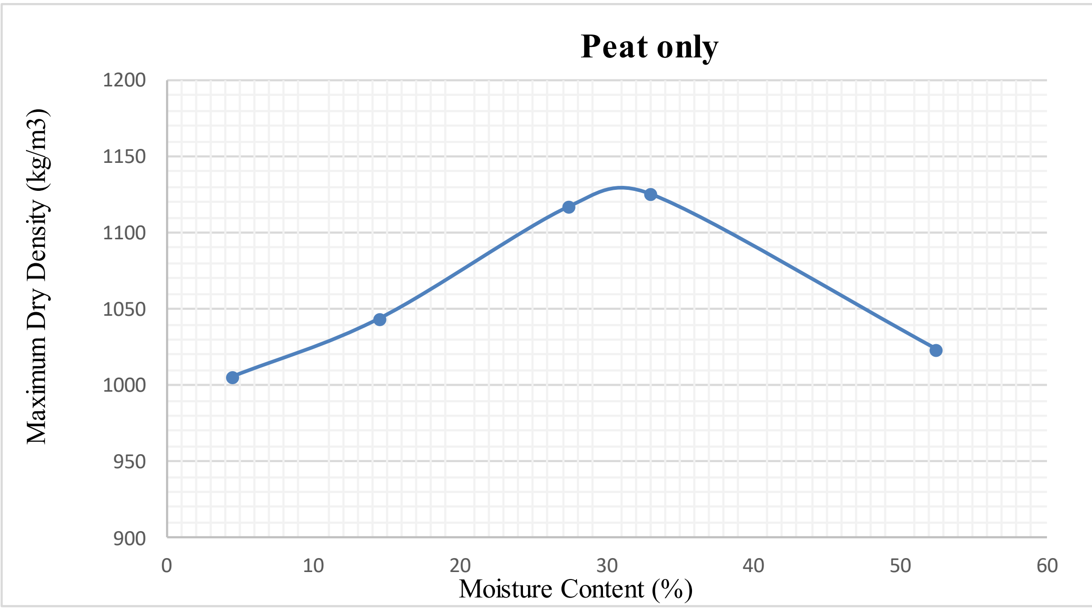

Figure 4.1: Maximum Dry Density vs Moisture Content

Figure 4.2 shows the optimum water content obtained for the peat soil. This optimum moisture content was used to determine peat soil strength throughout experiment. According to this data, the optimum moisture content for peat soil is 31.1%, as shown in Figure 4.1. If the specimen were compacted at a moisture content higher than the optimal moisture content, it would contribute to a weaker soil structure. However, if the specimen was compacted at a moisture content lower than the optimal, it would usually result in a flocculated structure.

Table 4.2: Summary of Optimum Moisture Content and Maximum Dry Density

SAMPLE	OMC (%)	MDD (kg/m3)
Peat only	31.1	1130
Peat + 10% SF	37.88%	1198.26
Peat + 15% SF	34.63%	1233.56
Peat + 20% SF	35.50%	1299.8
Peat + 15% OPC	26.5	1260.1
Peat + 15% SF + 15% OPC	28.22	1370.15

The table 4.2 above shows the summary of Optimum Moisture Content and Maximum Dry Density obtained from various type of samples. The figure 4.3, figure 4.4 figure 4.5 figure 4.6 and figure 4.7 shows the graph on how the Optimum Moisture Content is obtained.

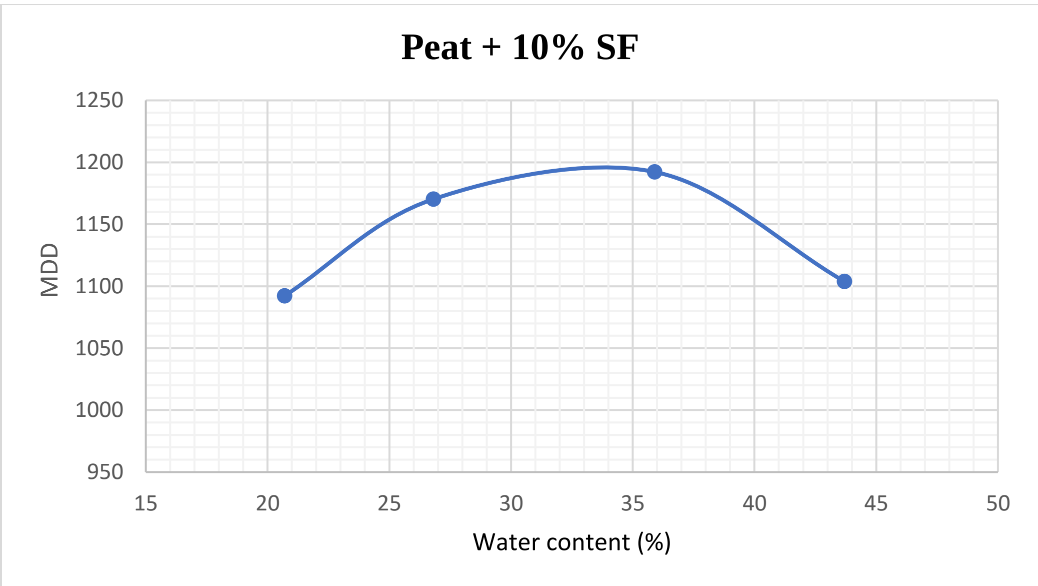

Figure 4.2: Maximum Dry Density vs Water Content (Peat + 10% SF)

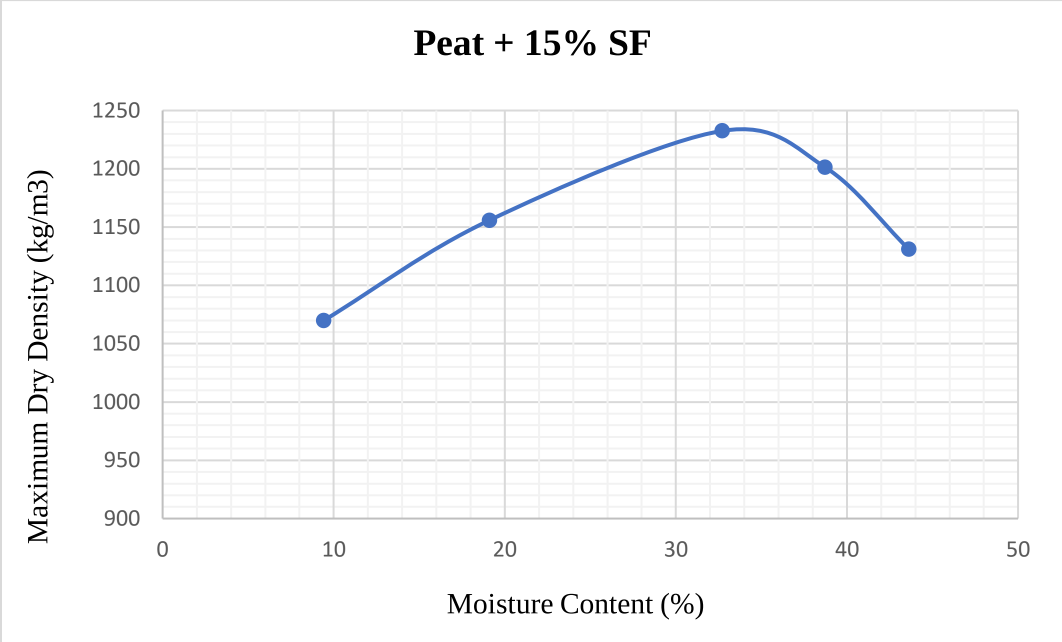

Figure 4.3: Maximum Dry Density vs Water Content (Peat + 15% SF)

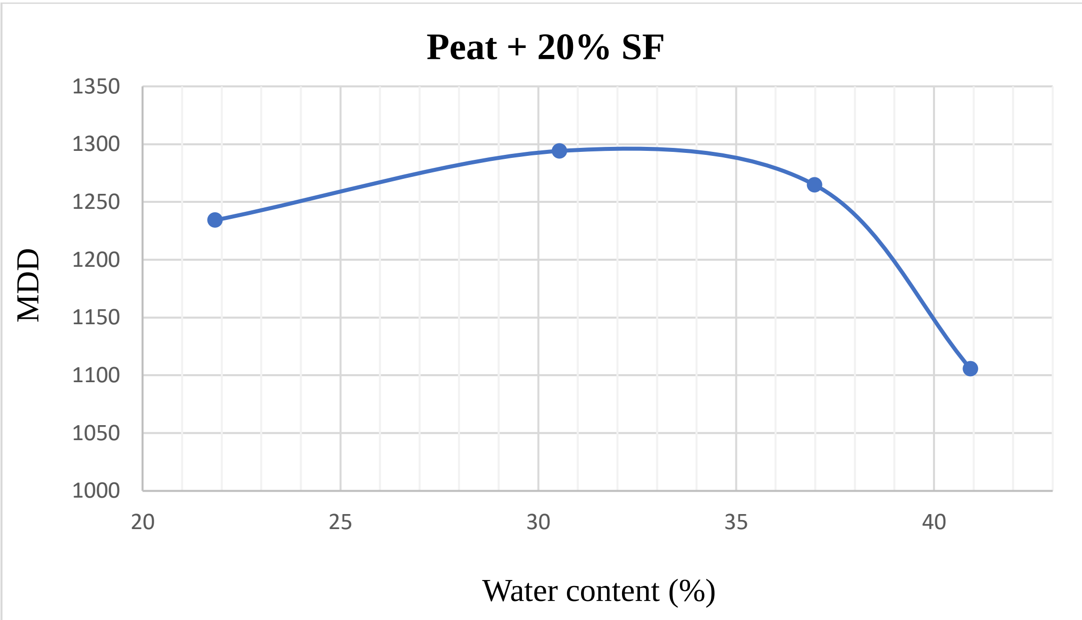

Figure 4.4: Maximum Dry Density vs Water Content (Peat + 20% SF)

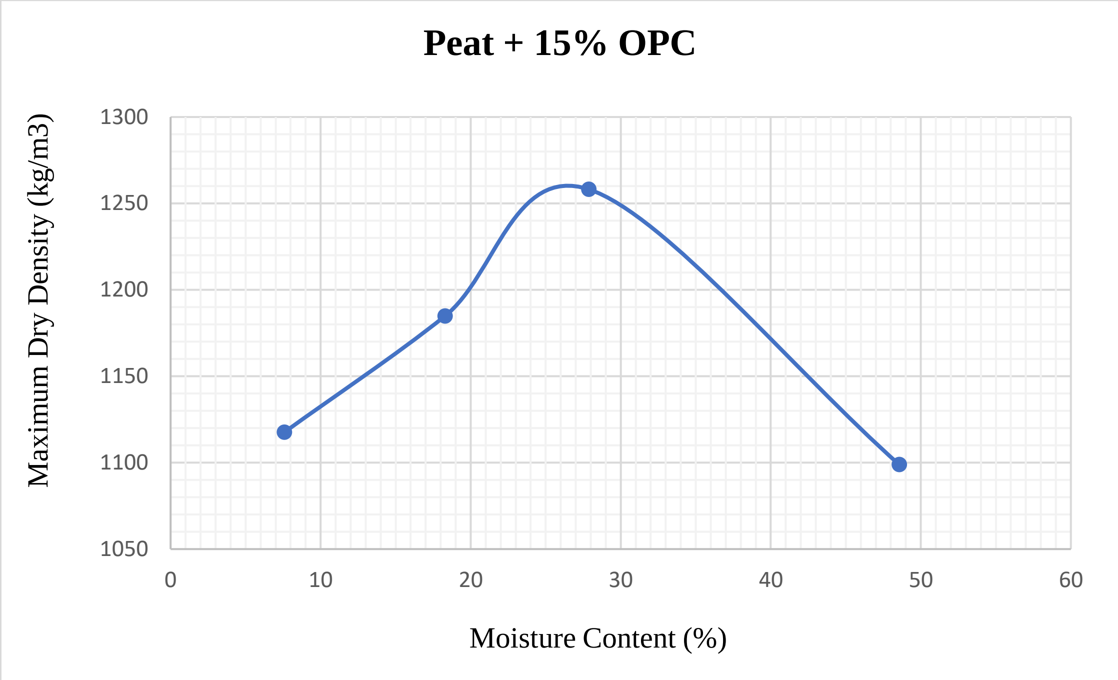

Figure 4.5: Maximum Dry Density vs Water Content (Peat + 15% OPC)

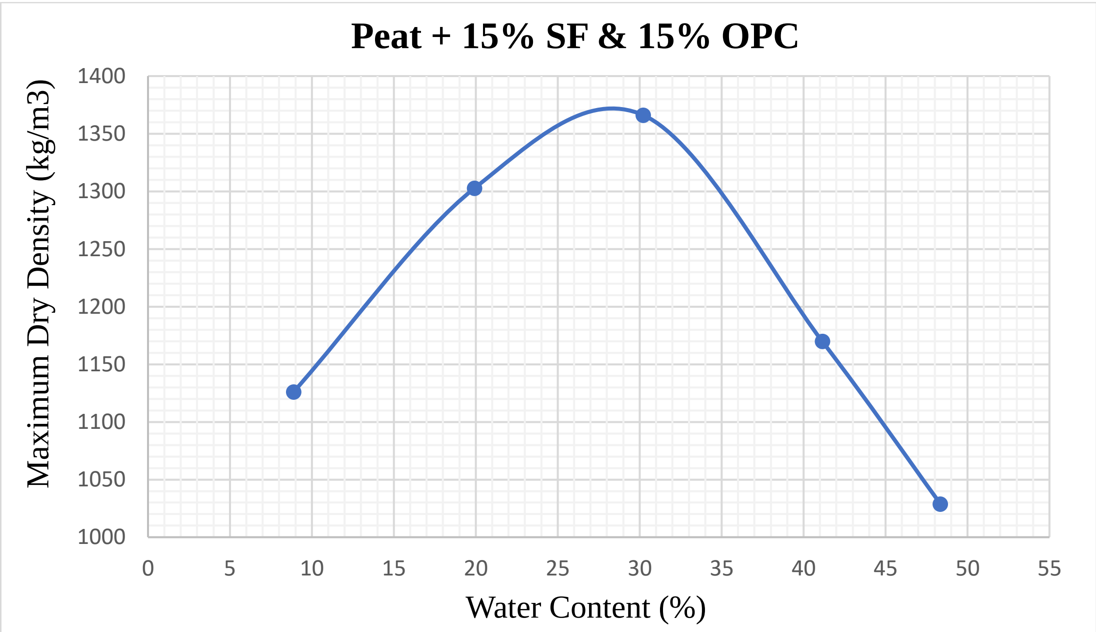

Figure 4.6: Maximum Dry Density vs Water Content (Peat + 15% SF % 15% OPC)

4.3 Unconfined Compression Test

The primary aim of this project is to evaluate the unconfined compressive strength of peat stabilized with OPC-Silica Fume. The unconfined compression test (UCT) is a crucial method for determining the durability of stabilized peat soil. Each cylindrical sample of peat soil was subjected to a constantly rising axial load before failure occurred in this test. Every sample measured 38mm in diameter and 76mm in length. The strength has been recorded after carrying out unconfined compression tests on peat soil, 10%,15% and 20% of peat and silica fume mixture. This peat and silica fume mixed samples were air cured for 7 days. Besides, the 15% of silica fume and peat mixture were cured for 28 days as well. There were 15% OPC and peat mixture also which were cured for 28 days. And lastly, there were a mixture of peat, 15% silica fume and 15% OPC which were cured for 28 days. The figures below show the results obtained from the Unconfined Compression Test.

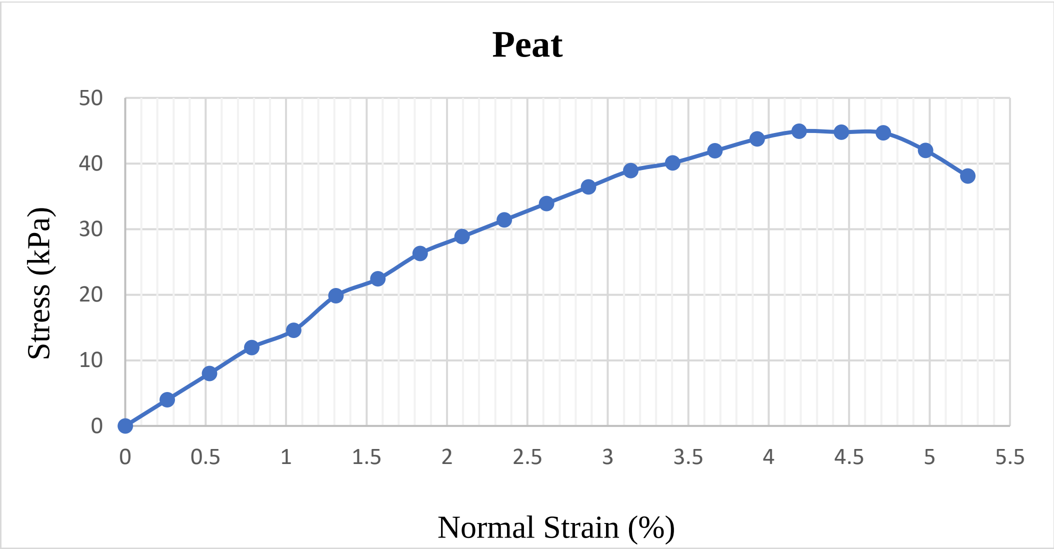

Figure 4.7: UCS of Peat

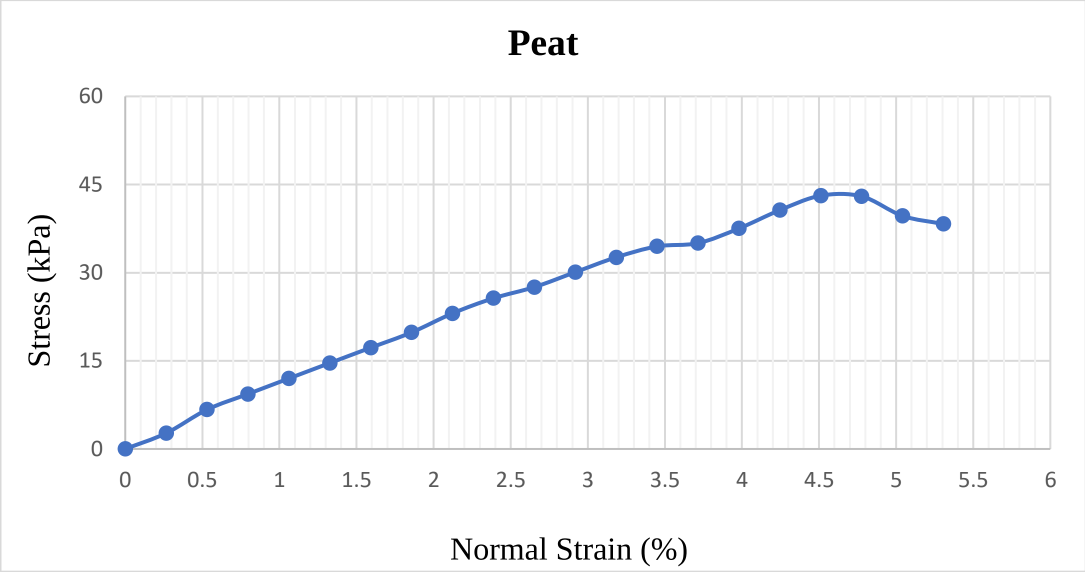

Figure 4.8: UCS of Peat

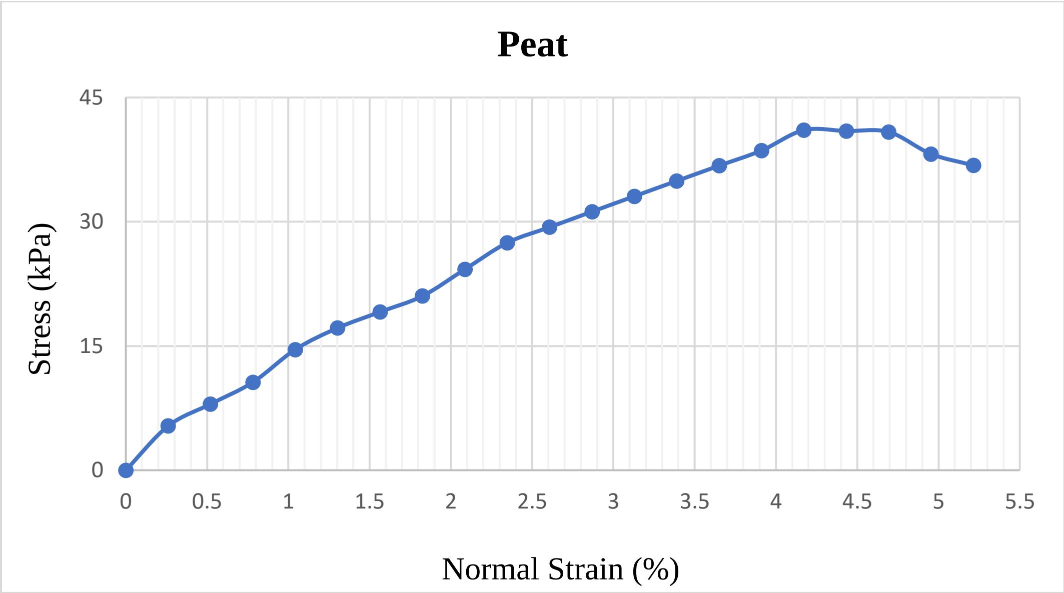

Figure 4.9: UCS of Peat

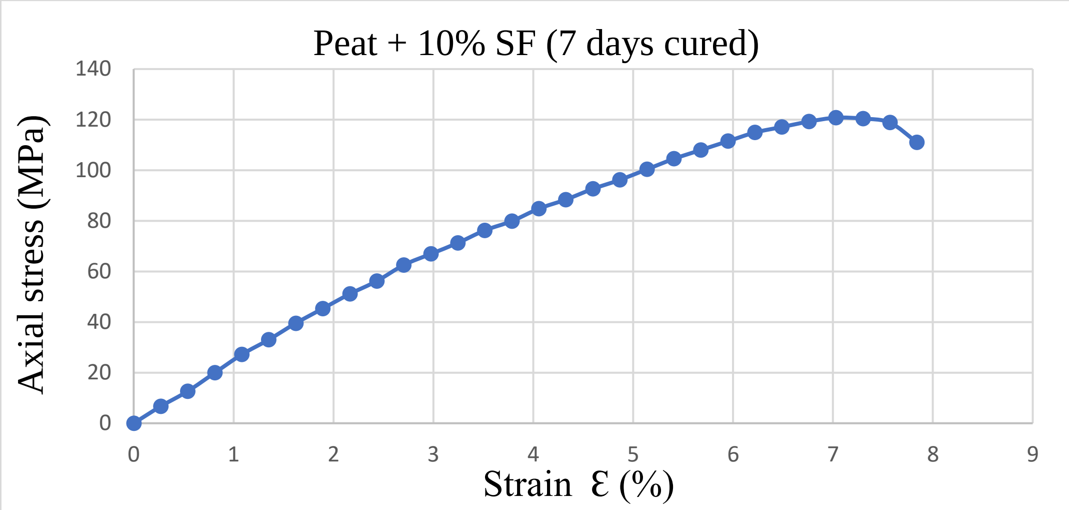

Figure 4.10: UCS of Peat + 10% SF (7 days curing)

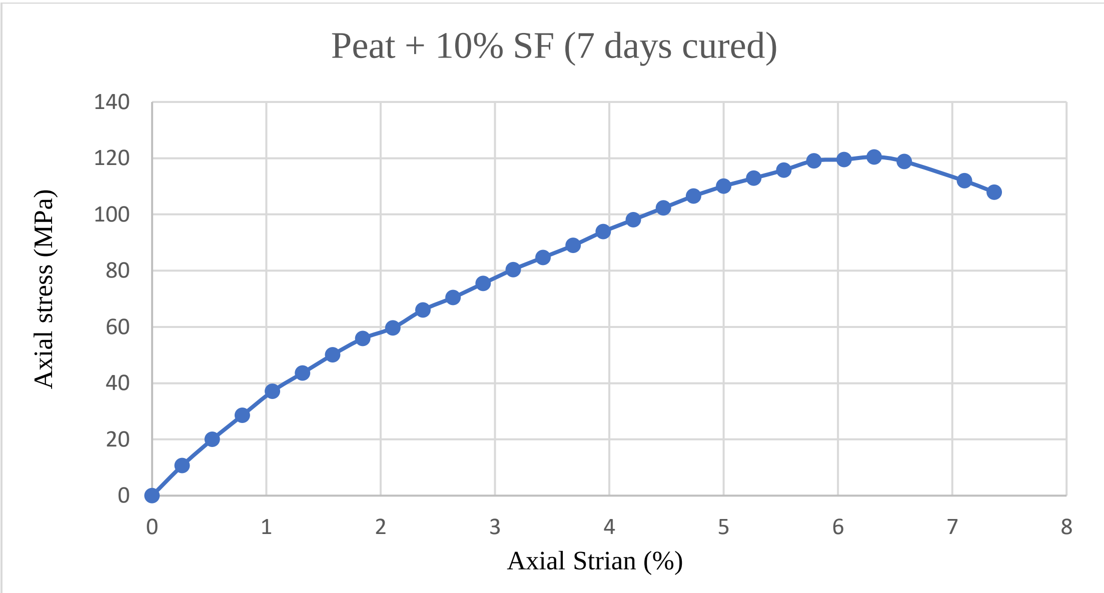

Figure 4.11: UCS of Peat + 10% SF (7 days curing)

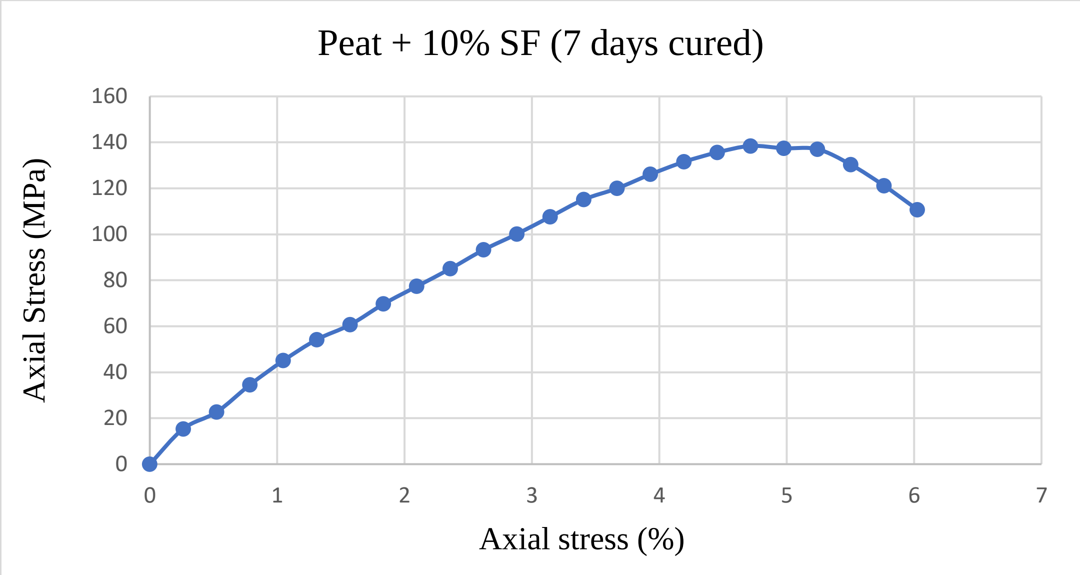

Figure 4.12: UCS of Peat + 10% SF (7 days curing)

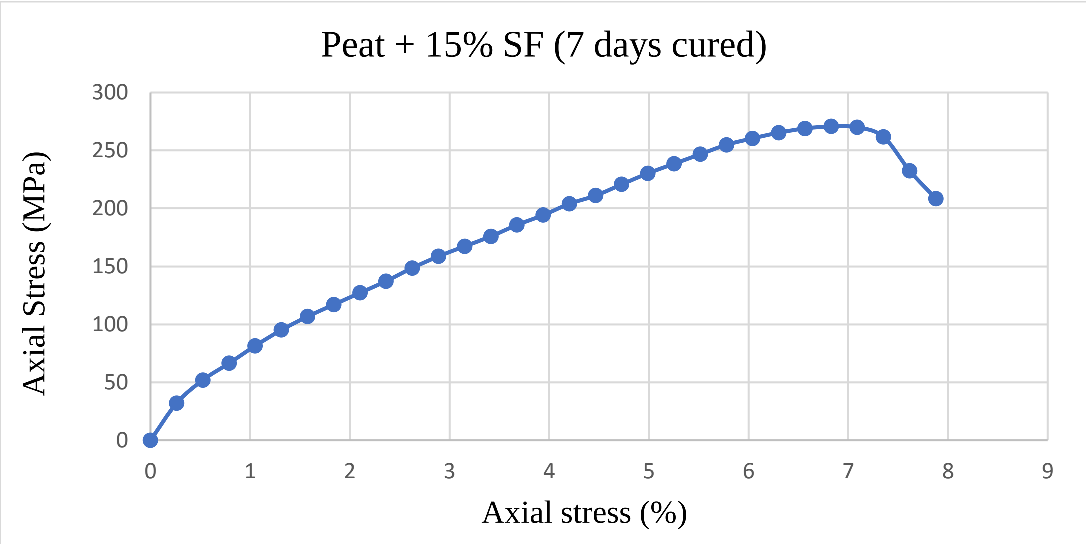

Figure 4.13: UCS of Peat + 15% SF (7 days curing)

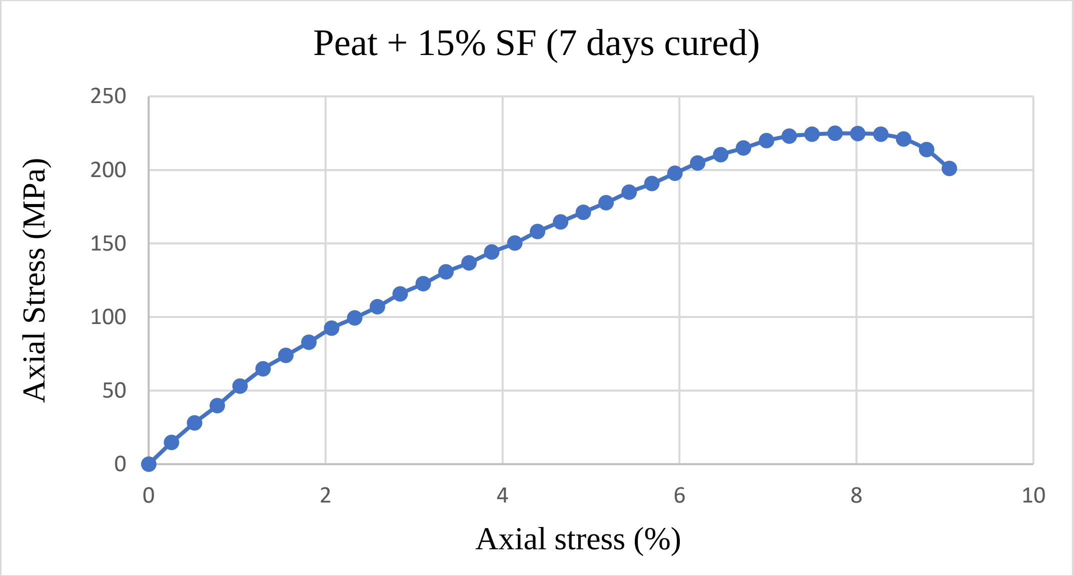

Figure 4.13: UCS of Peat + 15% SF (7 days curing)

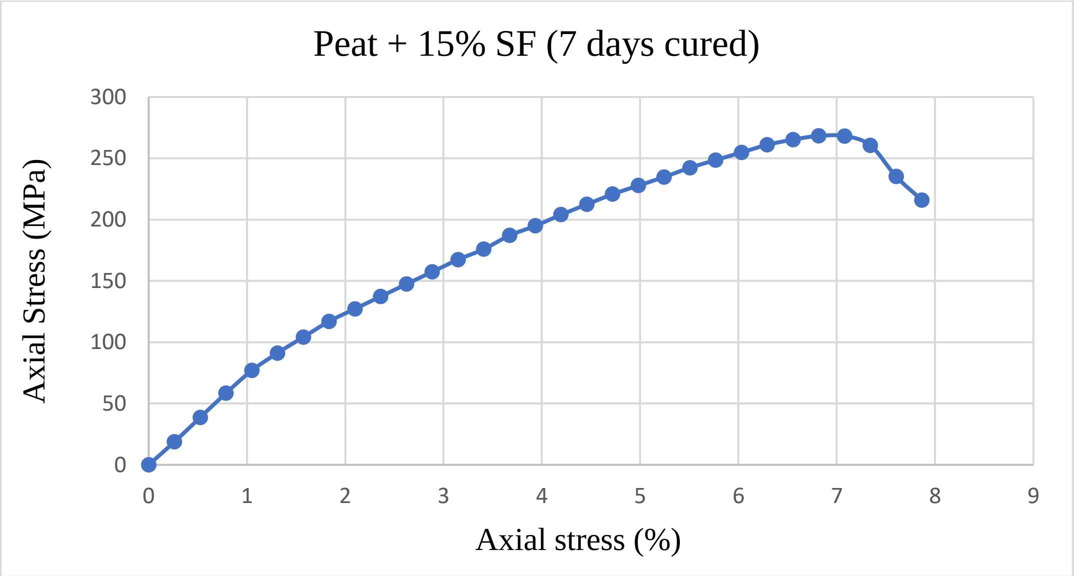

Figure 4.14: UCS of Peat + 15% SF (7 days curing)

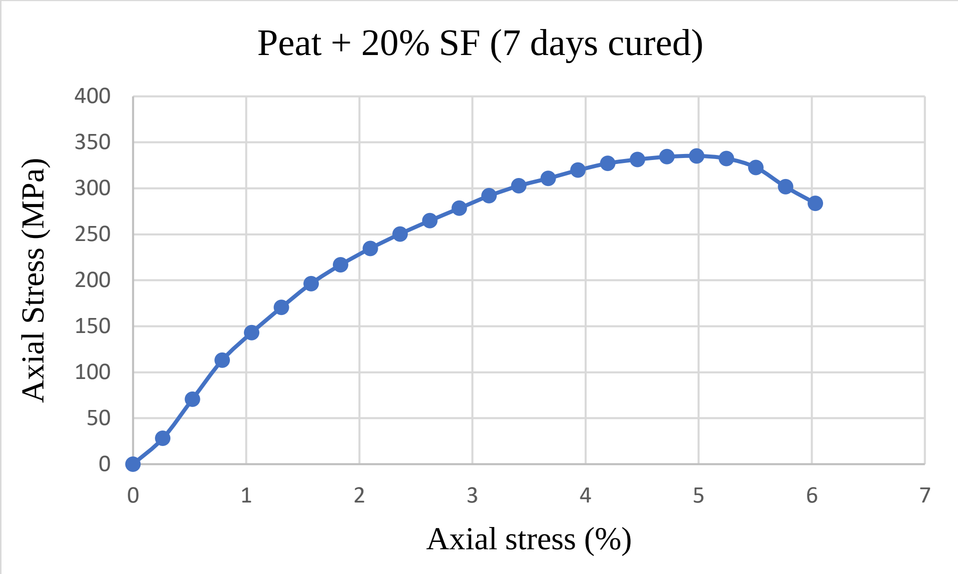

Figure 4.15: UCS of Peat + 20% SF (7 days curing)

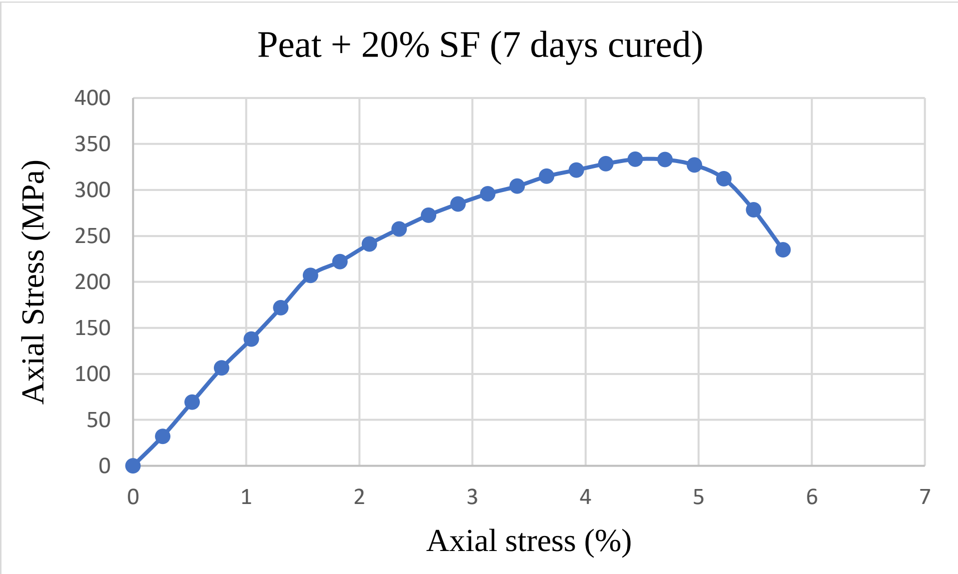

Figure 4.16: UCS of Peat + 20% SF (7 days curing)

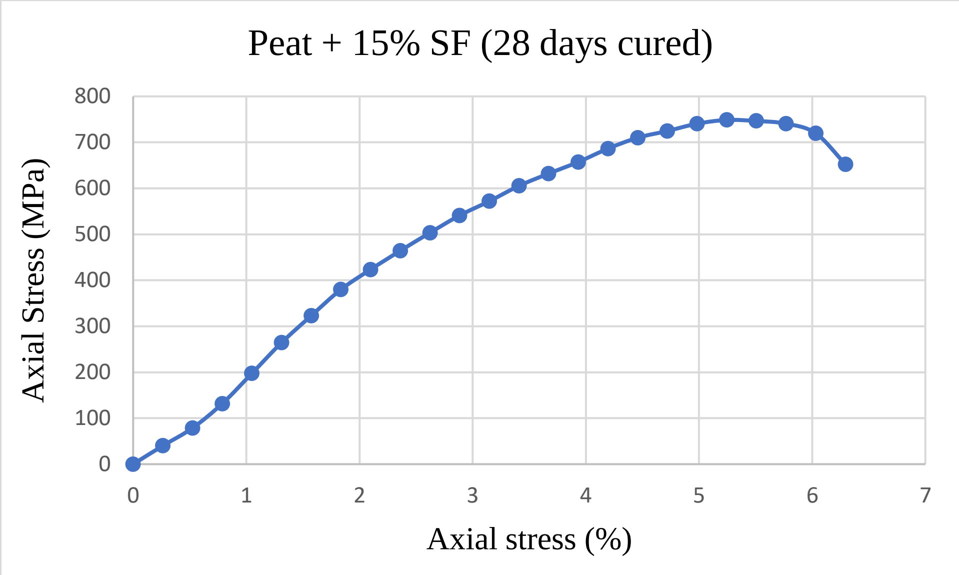

Figure 4.15: UCS of Peat + 15% SF (28 days curing)

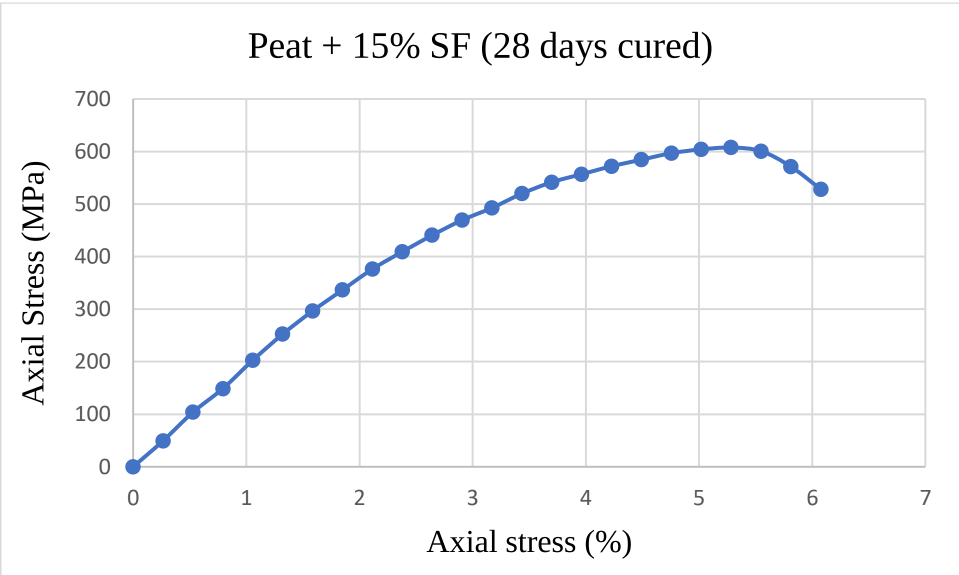

Figure 4.16: UCS of Peat + 15% SF (28 days curing)

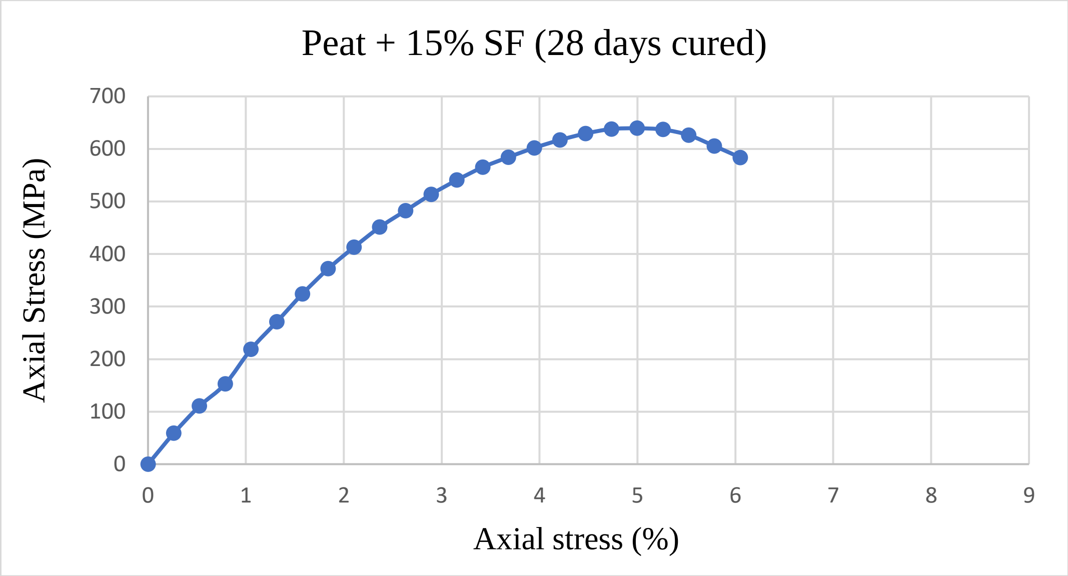

Figure 4.17: UCS of Peat + 15% SF (28 days curing)

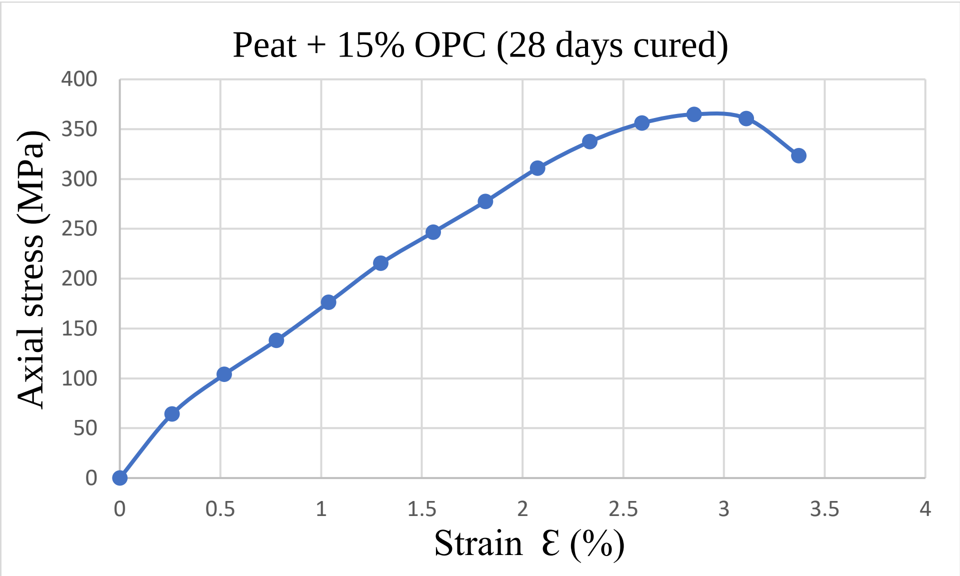

Figure 4.18: UCS of Peat + 15% OPC (28 days curing)

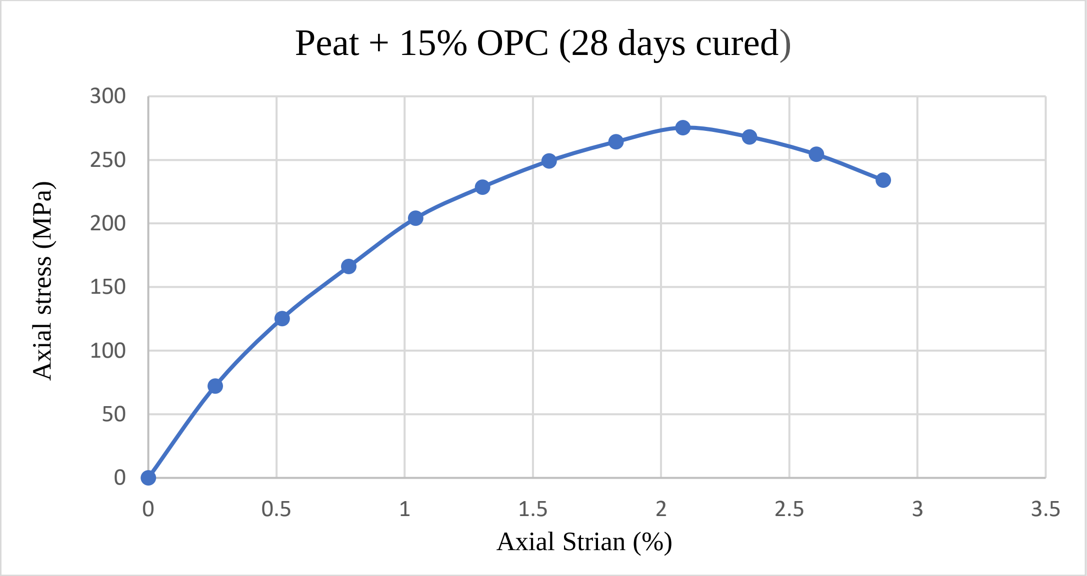

Figure 4.19: UCS of Peat + 15% OPC (28 days curing)

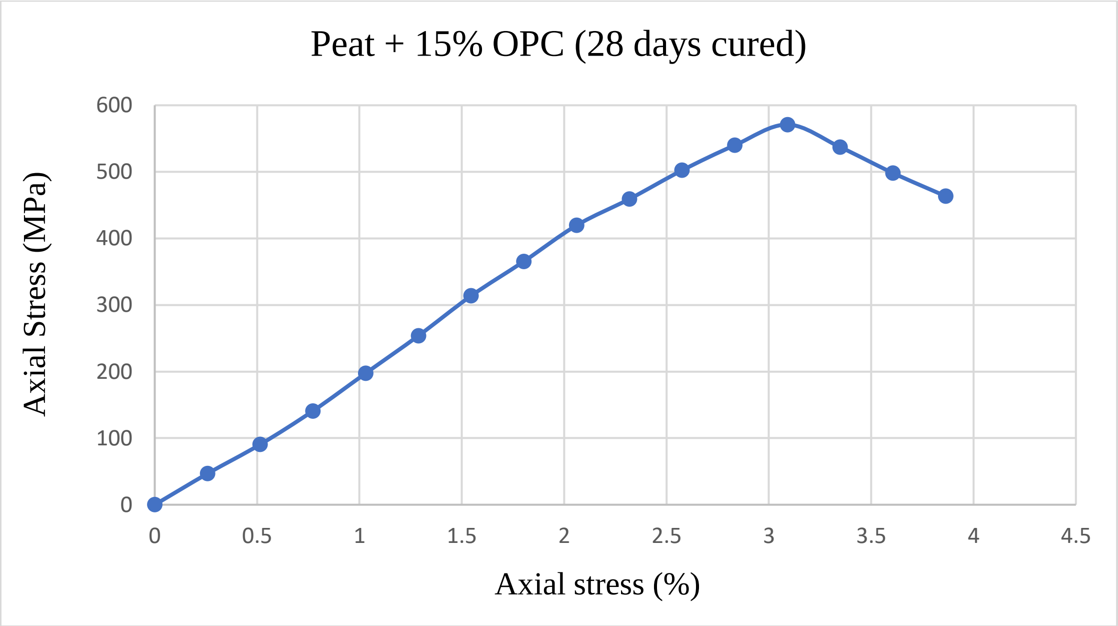

Figure 4.20: UCS of Peat + 15% OPC (28 days curing)

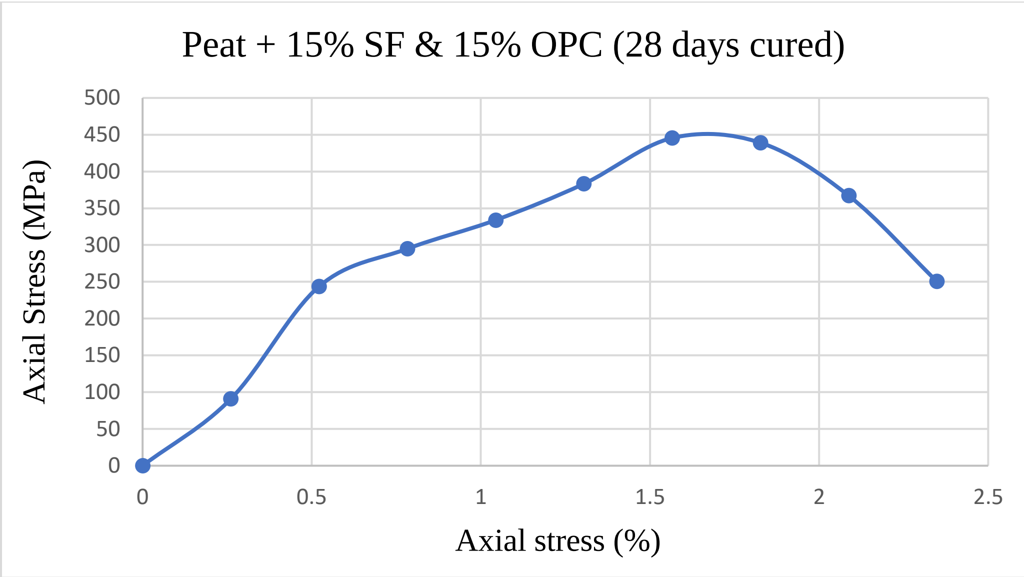

Figure 4.21: UCS of Peat + 15% SF + 15% OPC (28 days curing)

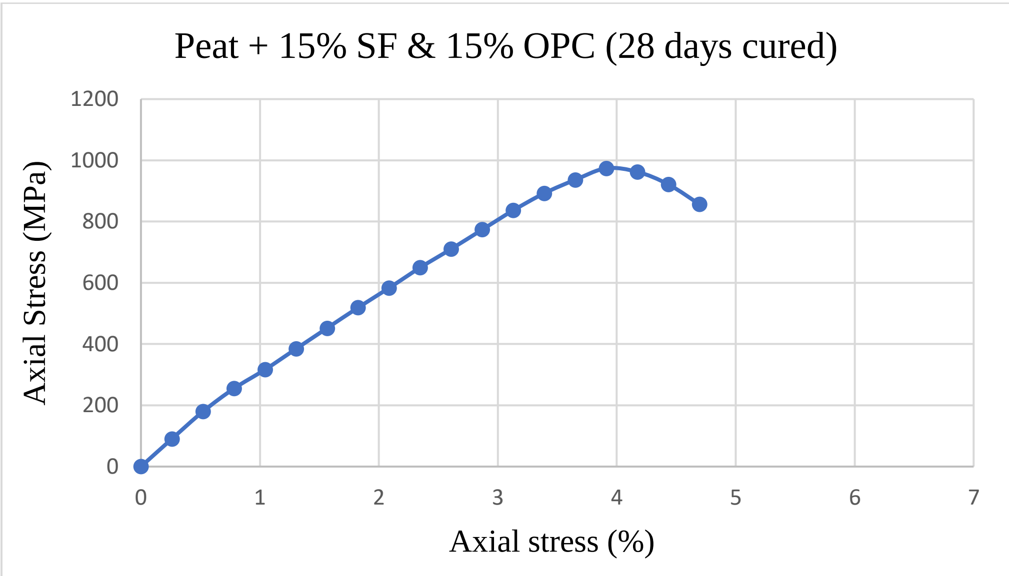

Figure 4.22: UCS of Peat + 15% SF + 15% OPC (28 days curing)

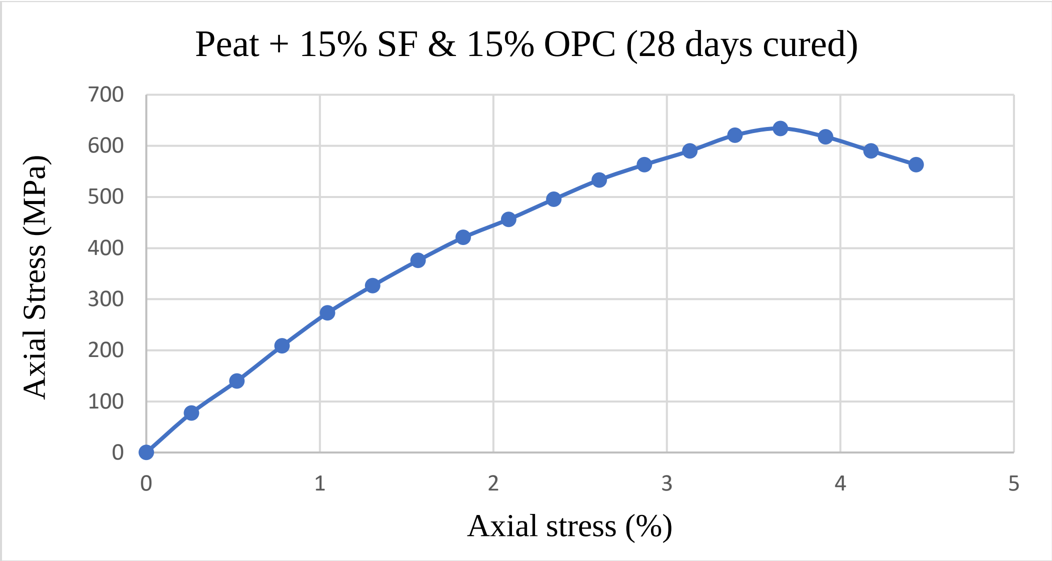

Figure 4.23: UCS of Peat + 15% SF + 15% OPC (28 days curing)

Table 4.3: Summary and Average of UCS

Sample	Curing days	kPa	Average
Peat	-	21.87	
Peat	-	18.761	
Peat	-	20.531	20.39
Peat and 10% Silica Fume	7	60.379	
Peat and 10% Silica Fume	7	60.215	
Peat and 10% Silica Fume	7	69.218	63.27
Peat and 15% Silica Fume	7	135.37	
Peat and 15% Silica Fume	7	112.401	
Peat and 15% Silica Fume	7	134.135	127.30
Peat and 20% Silica Fume	7	167.631	
Peat and 20% Silica Fume	7	166.668	167.15
Peat and 15% Silica Fume	28	374.305	

Peat and 15% Silica Fume	28	303.76	
Peat and 15% Silica Fume	28	319.625	332.56
Peat and 15% OPC	28	182.446	
Peat and 15% OPC	28	137.671	
Peat and 15% OPC	28	245.486	188.53
Peat + 15% OPC and 15% Silica Fume	28	222.758	
Peat + 15% OPC and 15% Silica Fume	28	317.048	
Peat + 15% OPC and 15% Silica Fume	28	460.684	333.50

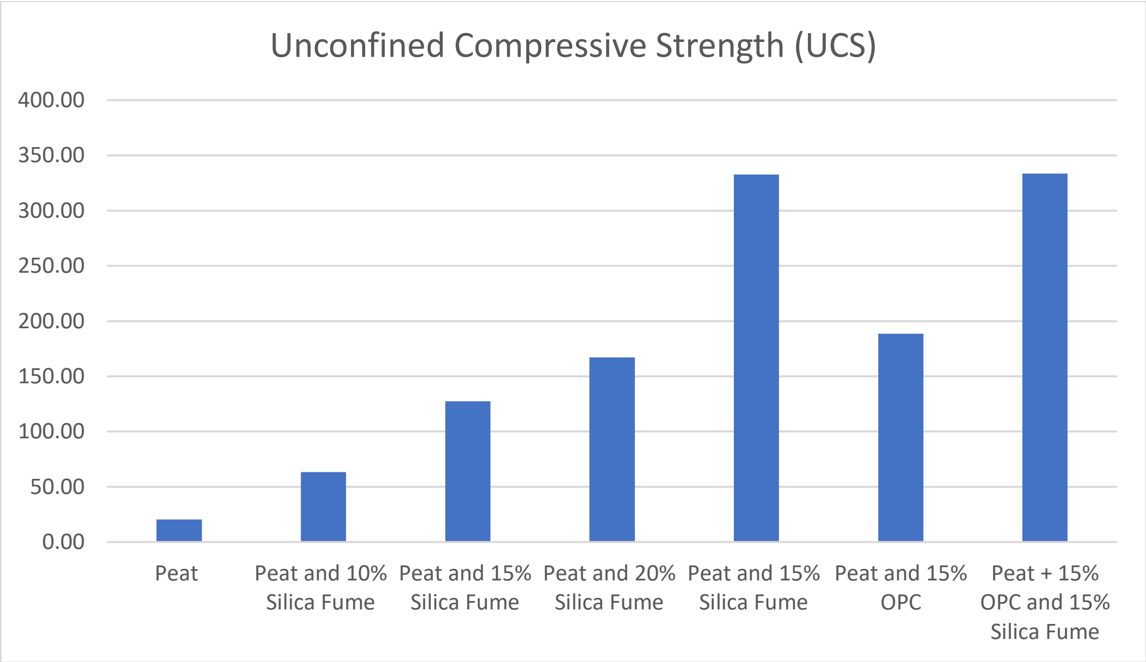

Figure 4.24: Summary of UCS with Different Mixtures of Soil

Table 4.3 and Figure 4.24 shows the summarized results from the UCS test conducted. From the summary above it shows peat mixture with 15% silica fume and peat mixture with 15% OPC and 15% silica fume have the highest compressive strength with an average of 332.56 kPa and 333.50 kPa respectively. Whereas the average UCS value of peat soil only is 20.39 kPa. Therefore, the mixture of OPC and silica fume with peat soil have increased the compressive strength of peat soil by 93.88%. It shows that one of the main scopes of this study to stabilise peat with Ordinary Portland Cement and silica fume has been achieved. From this UCS test it can be concluded that addition of OPC and silica fume to the peat soil increases the shear stress.

4.4 California Bearing Ratio (CBR) Test

This test has been conducted for peat soil only, 10%, 15% and 20% of silica fume, 15% OPC and mixture of 15% silica fume and 15% OPC. Two types of CBR test were conducted which was soaked and unsoaked. The unsoaked samples were left for curing for 7 days except peat sample which was not left for curing. Meanwhile the soaked samples were soaked in water for 4 days. During soaking a surcharge load of approximately 4.5kg were placed on the sample.

	sample	CBR Value%
Unsoaked	Peat	3.1
	Peat + 10% SF	6.74
	Peat + 10% SF (7 days cured)	11.67
	Peat + 15% SF	9.55
	Peat + 15% SF (7 days cured)	16.74
	Peat + 20% SF	10.5
	Peat + 20% SF (7 days cured)	17.05
	Peat + 15% OPC	4.35
	Peat + 15% OPC (7 days cured)	11.97

	Peat + 15% SF + 15% OPC	24.8
	Peat + 15% SF + 15% OPC (7 days cured)	26.29
Soaked	Peat	1.1
	Peat + 10% SF	2.9
	Peat + 10% SF (7 days cured)	3.35
	Peat + 15% SF	5.5
	Peat + 15% SF (7 days cured)	7.77
	Peat + 20% SF	6.67
	Peat + 20% SF	8.53
	Peat + 15% OPC	3.9
	Peat + 15% OPC (7 days cured)	6.26
	Peat + 15% SF + 15% OPC	8.7
	Peat + 15% SF + 15% OPC (7 days cured)	9.78

Table 4.4: CBR Result

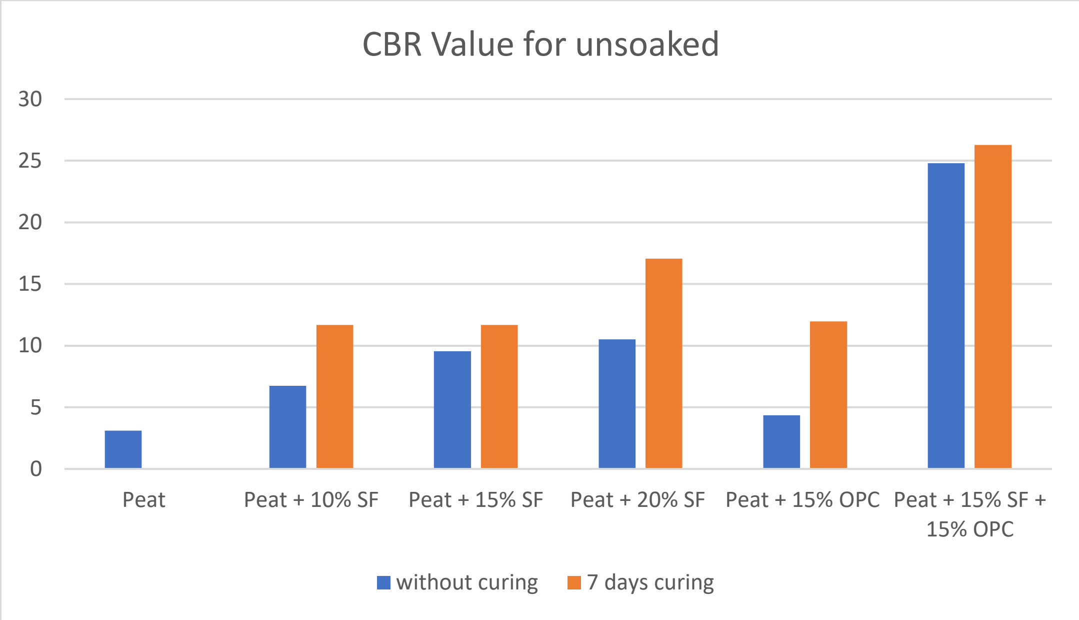

Figure 4.25: Comparison of unsoaked CBR test

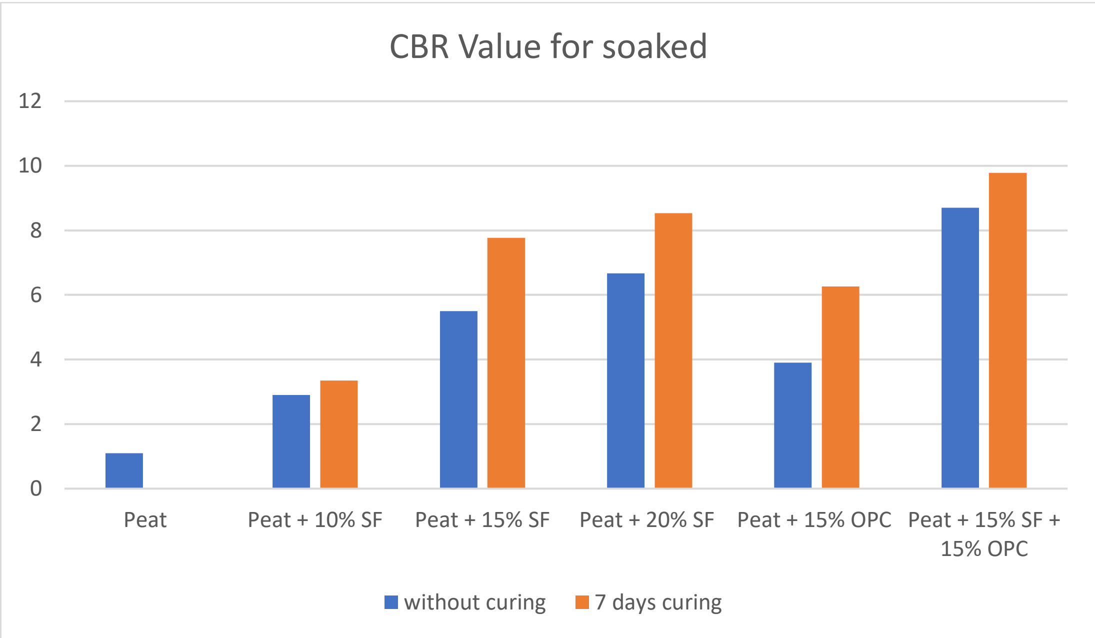

Figure 4.26: Comparison for soaked CBR test

The results obtained from CBR test are summarised and presented in the table 4.4, figure 4.25 and figure 4.26. It is noticed from the result the mixture of peat, 15% silica fume and 15% OPC has the highest CBR value for both soaked and unsoaked. For the unsoaked mixture sample the CBR value has increased by 87.5% compared to only peat CBR (without curing) and increased by 88.21% for curing. This study also shows that the additives used for this experiment plays an important role to stabilise the peat soil as the CBR value for all peat mixture has increased compared to only peat. From the graph represented in figure 4.25 and figure 4.26 it is obvious that curing helps the soil to stabilise better because all the values have increased by a specific amount after curing for 7 days.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The use of silica fume and ordinary portland cement (OPC) chemical stabilizer to stabilize peal soil from Teluk Intan, Perak has been discussed and examined in this research study. The study focused was to evaluate and compare the undisturbed peat samples, peat-silica fume sample, peat-OPC sample and peat, silica fume and OPC sample based on soil properties and their application to achieve maximum strength.

Peat soil samples obtained from Teluk Intan, Perak site have a high organic content of 80.86 percent on average and a low ash content of 19.13 percent. This means that peat soil does have unique geotechnical properties that distinguish it from inorganic soils such as clay and sand, which are primarily composed of inorganic soil particles.

The main objective of the research was to assess the unconfined compressive strength of OPC-Silica Fume stabilised peat and to assess the CBR value of OPC-Silica Fume stabilised peat. To achieve these objectives few experiments were carried out by using various amount of OPC and silica fume. The amount used was 10%,15% and 20% silica fume; 15% of OPC; and lastly combination of 15% silica fume and 15% OPC with peat soil. The samples were cured for 7 days or 28 days. Furthermore, the air curing technique was used for the curing process, which keeps the sample in the air and away from water intrusions throughout the curing phase.

It can be concluded that the addition of these additives made the peat soil gain strength. The results which have been presented in the form of graph and table shows with the use of additives the peat soil has gained a significant amount of strength. For example, the mixture of peat, OPC and silica fume has increased the strength of peat by 93.88% during unconfined compressive test. And during CBR test the same mixtures increased the value by 87.5%.

5.2 Recommendation

For the future research work, other additives can be used to stabilise the peat soil. The current research was using fibric type peat soil. For the future research sapric or hemic type of peat from other locations in Malaysia can be used. Errors might occur when the reading is wrongly recorded, or the data is interpreted incorrectly. Therefore, all the data and readings must be noted down carefully when conducting laboratory activities. Besides, morphological tests can be carried out on the samples so that the observation on the samples can be made more clearly. Apart from that, the studies should also be carried out at the actual site to make it easier for the industrial usage purpose. Conducting the research at the actual site would also give more exposure about the peat soil to the researcher.

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