Preliminary Study of Stabilization of Peat Soil Using Effective Microorganism

by

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19019

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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(CIVIL)

Approved by,

____
(Miss Niraku Rosmawati Ahmad)

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September 2017

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.

(ZATY AMIRAH BINTI AHMAD RASHIDI)

ABSTRACT

Peat soil is well known as problematic soil because of its poor geotechnical properties such as high water content, low shear strength, high organic matter, low bearing capacity and high compressibility. These properties make the soil as one of the most difficult soils to deal with for peat soil causes excessive settlement under constant load. Due to these geotechnical issues of the peat soil, improvement of the soil is essential in order to enhance its engineering properties so that the soil can act as soil foundation. In this research, Effective Microorganism (EM) is used as the soil stabilizer in order to investigate the optimum mix proportion of EM as the stabilizing agent on peat soil. The objective of this research is to determine the strength effects of 1%, 5%, 10%, 15% and 20% of EM concentration with a constant optimum moisture content which is 43.5%. Basic soil tests such as moisture content, specific gravity, plastic limit, liquid limit and compaction test together with a series of unconfined compression tests were conducted on the peat soil mixtures. The tests were carried out according to BS 1377: 1990. Compacted samples for unconfined compressive tests were prepared at a constant optimum moisture content, at curing periods of 7, 14 and 21 days. Data from the study revealed that the curing period showed a significant influence on the strength of peat soil mixtures. Unconfined compressive strength data showed improvement in strength values ranging from 2.42 to 14.38 times higher than the value for samples tested immediately after the mixture preparation. Data obtained in this study is useful to designers and engineers in implementing the stabilization scheme.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Peat soil is defined as soil containing over 75% organic content. (Kazemian, et. al., 2011). The formation of peat soils happen when the accumulation rate of organic matter is faster than it decays.

Over 415 million hectares of the total earth surface contains peat soil (Adon, et al., 2012). From the records of global chart of total peat deposit around the world, Malaysia is the 9th country with the highest total area of peat soil. The total area of peat soil in Malaysia is about 2.6 million hectares (26,000 km^2) of which about 13 % are in the peninsular Malaysia, over 80 % in Sarawak and about 5 % in Sabah (Zainorabidin et al., 2017)

Generally, peat soil has some common physical characteristics, such as dark brownish coloured, sponginess and a distinguishing organic odor. Besides, peat soil is also well known as a very weak soil that contains high moisture content, high compressibility and low shear strength that deform and fail under a light surcharge load (Kalantari et. al., 2010). Research conducted shows range of strength result ranging from 3–15 kPa values for the shear strength of peat determined using in-situ vane testing and to conclude, it is very weak (Coutinho & Lacerda 1989).

High compressibility of peat soil contributes to settlement which then leads to failure is a very challenging issue that affects the development stability (Adon et al., 2012). There was a case where a housing area in Sibu settled a year after its completion of construction on peat soil. Therefore, all development projects especially building and road constructions require a specific construction method when dealing with peat.

1.2 PROBLEM STATEMENT

In Malaysia, peat soil is widely found and it is one of the major groups of the organic soil. Generally, peat soil is a problematic soil that will be very challenging to all geotechnical engineers. Apart from that, peat soils also creates issue to the construction as it will cause possible shear failure due to its low bearing capacity and excessive settlement due to high water and organic content. Besides, this site is difficult to be accessed due to discomfort of unstable platform (Huat et. al., 2014).

As known, peat soil has a very low bearing capacity. In construction industry, peat soil is a major problem due to its long term consolidation settlement even the load applied is moderate. Huat (2014) also reported that a test being conducted on a peatland in Peninsular, Malaysia revealed that the water holding capacity for peat soil is very high. Hence, peat is very unsuitable material to support any foundations in its natural state.

High compressibility of peat soil causes most engineers to avoid the usage of this soil (Huat et. al., 2014). Apart from that, the rapid development of our country leads to the decreasing of suitable land which leads to construction on peat soil. Having this case, removal of peat soils is a normal practice for civil engineers. As a result, this will lead to an impractical and uneconomic project management as the removal works lead to the increasing cost of the construction and delayed in the duration of project completion.

As an engineer, a lot of issue needs to be taken into consideration for the construction to be well progressed and most importantly is the soil, as it determines the suitability and stability of the soil for construction. The peat soil can either be replaced or treated. When construction has to take place on peat deposit, the peat soil replacement with good quality soil is still a common practice even though most probably this effort will lead to uneconomic design. Therefore, approaches have been developed to address the problems associated with construction over peat soils. One of it is existing peat soil stabilization methods which will be discussed.

1.3 OBJECTIVES

1) To study the optimum content of Effective Microorganism (EM) concentration for a maximum peat shear strength.
2) To study the effect of curing to the strength of peat soil.

1.4 SCOPE OF STUDY

This research study has been carried out using the peat soils sample taken from a palm oil plantation near Bota, Perak, Malaysia. The stabilizer used in this research was Effective Microorganism (EM). The peat soils were stabilized with different dosages of EM (1%, 5%, 10%, 15% and 20% volume per weight (v/w)) added to a constant optimum moisture content, 43.5% which has been obtained from the compaction test as shown in Table 1.1. The curing technique used for the experiment was air curing for 0, 7, 14 and 21 days before the samples were tested for Unconfined Compressive Strength (UCS) Test.

CHAPTER 2

LITERATURE REVIEW

2.1 PEAT SOILS

Southeast Asia contributes over 56% of global tropical peatlands area (Page et al., 1992). Being permanently water logged, peat soils results in the reduction of the decomposition of organic matter from plant litter, which then accumulates as peat. Peat soils refer to purely mass of organic material (Andriesse, 1988). According to Kazemian et al., (2011), mass composition of soil which determines the classification of soil as peat is when soil contains at least 75% of organic matter or conversely, less than 35% mineral content.

Figure 2.1: The distribution of peatland in Southeast Asia. (Page et. al., 1992)

In Malaysia, lowland peat areas are often flooded and swampy. However, as the years passed and development increased, most of the mineral (non-organic) soils were being used up and there will be probability that the peat soil will be unavoidable to be used. In Sarawak, there is less option of suitable land to be used in construction as 80% of the area is being covered with peat soil (Andriesse, 1988).

2.2 PHYSICAL PROPERTIES OF PEAT SOILS

There are four main elements that make up the components of the peat soil (organic soil) system; the organic material, the mineral material, water and air. Andriesse (1988) in his research stated that the variation in the proportions of the components contributes to the difficulties in characterisation of the physical properties of organic soils.

2.2.1 Bulk Density

Since peat soil contains high water table near the soil surface and very high compressibility, the condition of peat soil area is soggy, thus it is easy for any load to settle in the soil. Peat soils are also known as organic soils. Peat soils contains high organic content, the bulk density is also low ranging from 0.09g/cm^3 – 0.12g/cm^3 (Andriesse, 1988). Bulk density is the weight of the soil per unit volume of land area.

2.2.2 Swelling and Shrinking

Most organic soils shrink when dried but swell when re-wetted, unless they are dried to a threshold value beyond which irreversible drying occurs (Andriesse, 1988). Over drainage can cause irreversible drying and shrinkage.

Andriesse (1988) also described peat as similar to coffee grounds, which are very difficult to re-wet. Resistance to re-wetting also related to bulk density where organic soils with high bulk density are comparatively easier to re-wet.

Peatland surfaces may therefore exhibit daily to seasonal vertical movement due to swelling and shrinking. The values of swelling and shrinking range from The vertical movement of the ground surface is accompanied by changes in water storage, but also in the hydraulics, biogeochemistry and thermal properties (Waddington et al., 2010).

2.2.3 Moisture Content

Peat soil is having the characteristic of high wayer holding capacity thus its moisture content is high. Generally, the values range from 90% up to 1000%. (Deboucha et al., 2008).

2.2.4 Porosity

One of the characteristic of peat soil is, it has high porosity. According to Beckwith et al., (2003), unsaturated peat soil's hydraulic conductivity depends on the fraction of the actively porosity and gas. However, in the case of large and complex porosity of peat, there will be a significant alteration in the storage and transmission properties resulting in the properties of unsaturated peat can be inferred from those determined under saturated conditions (Price et al., 2008).

In Malaysia, classification of peat and organic soils is based on the British Standard 5930:1981. Table 2.1 presents the properties of peat soil.

Table 2.1: Engineering Properties of peat soil

Properties	**Value**
Bulk Density	$0.09 g/cm^3 – 0.12 g/cm^3$
Moisture content	90% - 1000%
Porosity	80%-90%
Specific gravity	0.9-1.64
Organic content	95% and above
Shear strength	3 – 15 kPa

2.3 CHEMICAL PROPERTIES OF PEAT SOILS

2.3.1 pH

A study by Mutalib, et al. (2005) stated that the soil acidity (pH) of peat soils (organic soils) in Sarawak was found to be highly connected to the decomposition rate; the higher the pH, the greater the decomposition rate. With pH values ranging from 3.2 to 4.0, peat soils in Sarawak can be classified as very acidic. Variations of the pH range are due to the admixture of the mineral soil or the location of the peat soils (Andriesse, 1988).

2.3.2 Organic Carbon

Determination of organic carbon content in organic soils is important, particularly for calculating the Carbon to Nitrogen (C/N) ratio of the material. The C/N ratio is also an indication of the humification degree of the organic materials. The values of C/N ration revealed to be ranging from 12 – 60 percent (Andriesse, 1988). Organic carbon content has been normally found to be higher at the surface than in the subsoil.

2.3.3 Nitrogen

Most of the nitrogen found in peat soils is in the organic form. According to Andriesse (1988), the Nitrogen levels in the shallow peat of the soil are lower than the Nitrogen levels in the surface layers of deep organic soils.

2.4 PEAT SOIL STABILISATION

Soil stabilization is the process of soil modification by mixing with a stabilising agent in order to reach any desired geotechnical properties of the soil such as compressibility, strength and permeability. According to Sherwood (1993), soil stabilization is a process to improve and stabilize the engineering properties of soil by changing at least one of the soil characteristics. With the use of stabilising agent, a few considerable environmental and economic advantages can be achieved. Looking back at the previous methods of soil stabilization, they cannot provide an economical and environmental friendly solution. In this research project, soils are bonded together using Effective Microorganism (EM) as liquid stabilizer.

2.4.1 Cement & Lime

A number of researchers have studied the stabilization of soft soil by cement, cement-ground granulated blast furnace slag and lime-cement. Since 1960, cement and lime are widely used as a base of stabilizing material and binding agent, and considered as the oldest binding agent. According to Sherwood (1993), cement and lime may be considered as primary stabilizing agent or hydraulic binder because it can be used alone to bring about the stabilizing action required. Besides, lime provides an economical way of soil stabilization and lime modification reacts with the increment in strength resulting by cation exchange capacity. When cement reacts with water in peat, it forms calcium silicate hydrate which then act as glue that bind and hold the soil particles together.

Absorption of organic particles on the surface of cement and solid soil particles occurs during the cement hydrolysis process in the soil. According to Chen and Wang (2006), this would prevent both the formation of cement hydration products, and the hydration between solid soil particles and hydration products. As a result, only minimal increment can be achieved in peat-cement admixture strength as shown in Figure 2.2.

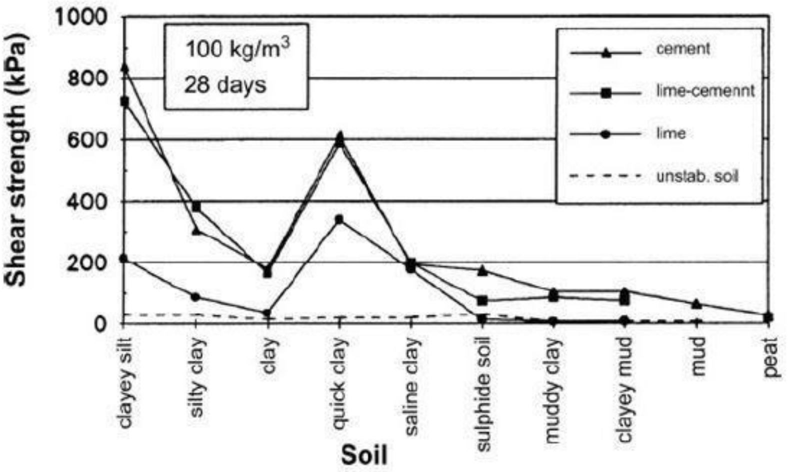

Figure 2.2: Shear strengths of the stabilized soils in 28 days after mixing, and the Shear strengths of the same soils in unstabilized, "undisturbed" condition.

2.4.2 Pond Ash (PA)

According to Kolay et. al., (2011), besides cement and lime, stabilization of peat soil can also be carried out by using recycled waste like pond ash. Pond ash can be obtained in thermal power station. The burning of coal produce a waste by-product known as pond ash. The usage of pond ash as stabilizing agent has strengthen the natural peat soil and also solve issue regarding the disposal of solid waste (Kolay et. al., 2011).

Result obtained by Kolay et. al,. (2011) as shown in Figure 2.3 and Figure 2.4 revealed that there is a significant increment in UCS for all the stabilized peat as compared to the original remoulded peat, which the values of UCS is 77.6 kPa only. There was a double increment in the strength for peat and PA mixtures to 153.9 kPa, with addition of 20% of PA.

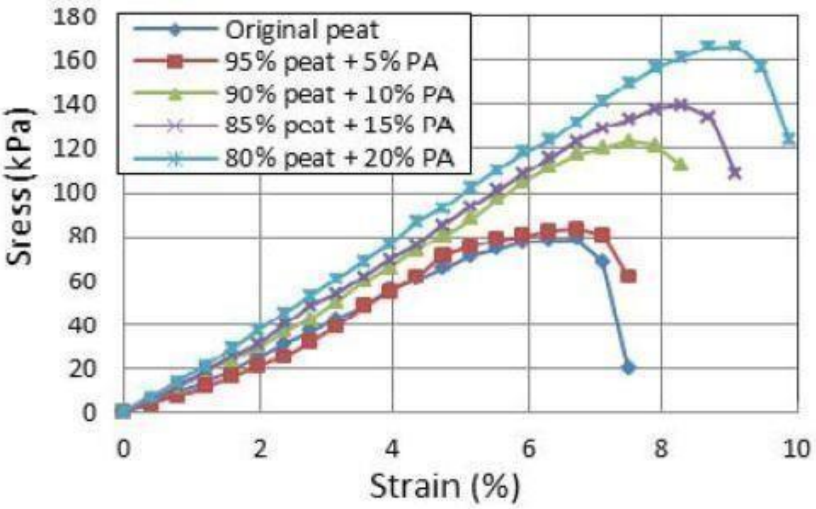

Figure 2.3: Stress-strain curves for original peat and as well as a mixture of peat and different amounts of PA that obtained from UCS tests after 28 days.

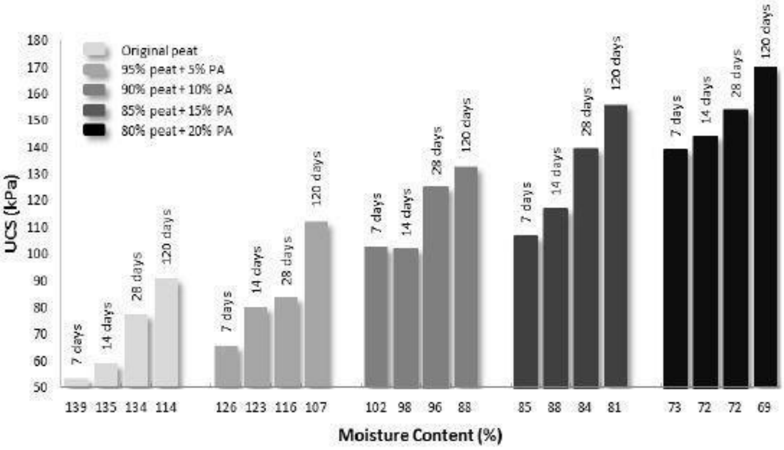

Figure 2.4: Comparison between average UCS of original peat and stabilized Peat PA specimens

2.4.3 Ordinary Portland Cement (OPC) and Polypropylene Fibres

As for soil stabilization, fibres are not new binding agent. Fibres have been used to stabilize clayey soil and based on the study being done by Nagu et al. (2008), UCS values for the stabilised clayey soil with fibres had provided a maximum strength of the peat soil. Based on the research by Kalantari & Huat (2008), in order to find the optimum percentage of fibre contents for the stabilized peat soil that would provide the maximum strength, peat soil samples at their natural moisture contents are being mixed with different percentages of OPC (15%, 25%, 30%) and polypropylene fibres (0.1%, 0.15%, 0.2%) using air curing method for a period of 90 days prior to be tested for their UCS.

According to the results shown in Figure 2.5, the mix design consist of peat, cement and the addition of 0.15% fibers would provide a sufficient result of 100% Unconfined Compression Strength value when compared with the amount of 0.1% and 0.20% fibers after being cured for 90 days.

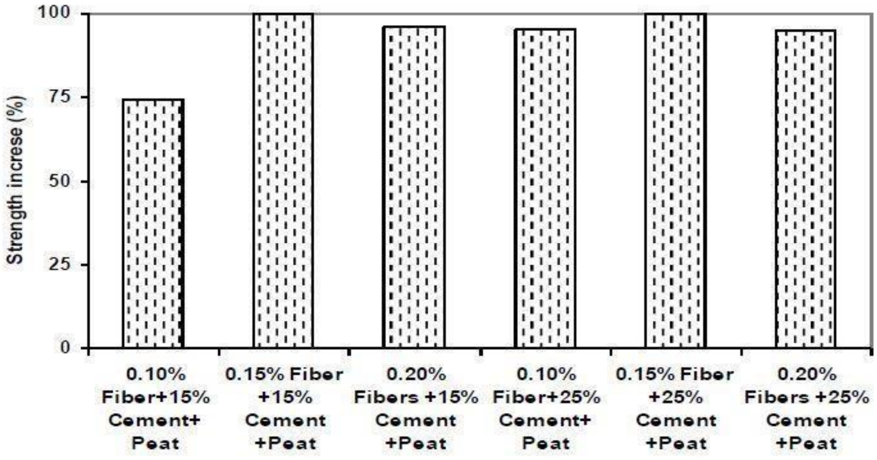

Figure 2.5: Different percentage of fibres and cement mixed with peat soils versus percent strength increase of UCS after 90 days of curing.

2.5 EFFECTIVE MICROORGANISM (EM)

The concept of Effective Microorganisms (EM) was found by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan in the year of 1994. As the research done by Higa (1995), in order to increase the microbial diversity of soils and plants, EM can be added as it consists of mixed cultures of beneficial and naturally-occurring microorganisms that can be applied as inoculants. Research has shown that the inoculation of EM cultures to the soil or plant ecosystem can enhance the soil quality, soil health, growth, yield and quality of crops.

EM is a brown colour liquid concentrate containing a consortium of beneficial microbes and acts as soil conditioner as well as a microbial inoculant. It is produced from cultivation of over 80 strains of beneficial microorganisms, which are collected from the natural environment (Higa, 1995). It was reported that over 90 countries are using this technology successfully today. EM stock solution mainly consists of lactobacillus, photosynthetic bacteria, yeast and ray fungi. EM includes both aerobic and anaerobic species of microorganisms which co-exist in an environment of around 3.5 pH.

Various usage of EM is beneficial to agriculture, animal husbandry, aquaculture, waste water & solid waste management in order to increase the quantity and to improve the quality of products and the treating of certain poluting elements.

According to Szymanki (2003), EM contains specific types of microorganisms including dominating populations of lactic acid bacteria and yeasts, and lesser quantities of photosynthetic microbes, actinomycetes and different sorts of organisms. All of these are mutually compatible with one another and can co-exist in liquid culture.

2.5.1 Usage of Effective Microorganisms (EM) in Industry / Daily Life

2.5.1.1 Construction Industry

Concrete forms major component in the construction industry as it is cheap, easily available and convenient to cast. The only disadvantages of these materials is it is weak in tension thus, it cracks under sustained loading and due to aggressive environmental forces which ultimately reduce the life of the structure which are built using these materials. (Hammes et al., 2003). This process of damage occurs both in the early life of the building structure and also during its life time. Synthetic materials like epoxies are used as a remedy. Unfortunately, they are not compatible, very costly, reduce aesthetic value of the appearance and need regular maintenance.

According to Jonkers et al., (2009) self-healing concrete is a product that will biologically produce limestone to heal cracks that occur on the surface of concrete structures. However, when a concrete structure is damaged and water starts to seep through the cracks that appear in the concrete, the spores of the bacteria germinate on contact with the water and nutrients. Having been activated, the bacteria start to feed on the calcium lactate. As the bacteria feeds oxygen is consumed and the soluble calcium lactate is converted to insoluble limestone. The limestone solidifies on the cracked surface, thereby sealing it up (Day et al., 2003).

2.5.1.2 Agriculture

Studies have shown that, the use of effective microorganisms does not limit in agricultural soil suppress soil-borne pathogens, but also increases the decomposition of organic materials and consequently the availability of mineral nutrients (Singh et al., 2003).

When being brought into the domain of anaerobic biodegradation, the EM rapidly eats up the methanogens and toxic pollutants which are formed as a result of the chemical breakdown process. As a result, anaerobic compost piles that has being mixed with EM produce no harmful or uneasy odours, and decompose very quickly into pure, nutrient-rich composts, which can be specifically implanted once again into the procedure of natural cultivating with surprising outcomes.

Due to the microorganisms’ ability to antioxidize root systems and purify toxic soils, plants grown in EM-rich soil can focus their energy on healthy development, rather than defense, producing fruits and vegetables of the finest taste and quality. Years of tests in soils of all structures around the world have produced indisputable results that confirm EM’s benefit to the healthy growth of all plant species (Higa, 1994).

CHAPTER 3

METHODOLOGY

For analysis purpose requires the determination of the material and several testing in order to obtain data, physical and mechanical tests are being conducted. For physical properties test, moisture content, plastic limit, liquid limit tests and specific gravity test were conducted whereas compaction and Unconfined Compressive Strength (UCS) tests were conducted to study the strength of the peat soils. All of the tests were carried out according to BS 1377: 1990.

3.1 SAMPLING AND PREPARATION OF PEAT SOIL

Sample of peat soil for this study were collected from a palm oil plantation near Bota, Perak. Visual observation on the peat soil indicated that the soil was dark brown in color. The sample was taken at a large area and the soil volumes are determined by the numbers of samples. The sample was kept in the container and brought to Universiti Teknologi Petronas (UTP). Figure 3.1 shows the sampling of peat soil at the site.

Figure 3.1 Peat soil sampling at site

After sampling has been done, the peat soil samples were oven dried for about 24 hours. Then the oven dried samples were grinded and allowed to pass through 1.18 mm sieve size.

3.1.1 PHYSYICAL ANALYSIS OF PEAT SOIL

The physical properties of peat soil were determined by performing moisture content, liquid limit, plastic limit and specific gravity tests. All the tests were performed as per standard of BS1377: 1990. Basic tests on original peat soil alone and on different concentration of EM were conducted in order to access the improvement made on the peat soil samples. Figure 3.2, Figure 3.3, Figure 3.4 and Figure 3.5 present the liquid limit and moisture content tests that were conducted in the laboratoty.

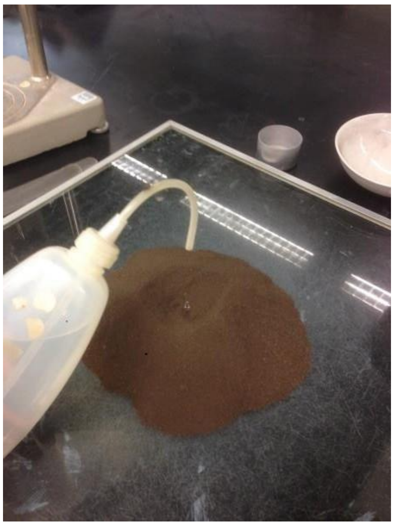

Figure 3.2: Liquid limit test

Figure 3.3: Moisture content test

Figure 3.4: Specific gravity test

Figure 3.5: Plastic Limit test

3.2 OPTIMIZATION OF FACTORS AFFECTING PEAT SOIL STRENGTH.

A total of 3 unstabilized peat specimen (0% EM) considered as controlled test and 40 samples of stabilized peat specimens of different concentration of EM were prepared and cured for 7,14 and 21 days .

3.2.1 Concentration of Effective Microorganism (EM)

Different concentrations of the EM were used in the experiments (1%, 5%, 10%, 15% and 20% (v/w) to obtain the most suitable concentration of stabilizer that will improve the peat soil samples in term of strength and other engineering properties. The EM was mixed with the peat soil samples to get the by-product of the reaction between the admixtures and the peat soil.

Table 3.1: Sample mix design

Sample No.	EM concentration (%)	Mix design
1	0	Peat soil + 43.5% water
2	1	Peat soil + 42.5% water + 1% EM
3	5	Peat soil + 38.5% water + 5% EM
4	10	Peat soil + 33.5% water + 10% EM
5	15	Peat soil + 28.5 % water + 15% EM
6	20	Peat soil + 23.5% water + 20% EM

3.2.2 Optimization of Moisture Content

Modified proctor test was applied to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. The soil was compacted in a mould. The soil was mixed with water and subsequently compacted in three equal layers using an electric hammer that delivers 27 blows to each layer. A total of 16 continuous samples as shown in Figure 3.6 were conducted in order to achieve peat soil optimum moisture content. The OMC obtained from the test was 43.5% which will remain constant to be used for each peat soil samples.

Figure 3.6: 16 samples of peat soil

Figure 3.7: Compaction machine

3.3 TESTING OF STABILSED PEAT SOIL

3.3.1 Unconfined Compressive Strength Test

To prepare a cylindrical sample for UCS test, a standard cylindrical metal case with 38 mm diameter and 76 mm height as shown in Figure 3.8 has been used. The soil samples were easily extracted without disturbing the structure of the soil. The UCS tests for stabilized peat samples were conducted immediately after the mixing and also after the curing period of 7, 14 and 21 days.

Figure 3.8: Standard mould for UCS test

Figure 3.9: A tested samples under UCS machine

3.4 FLOWCHART

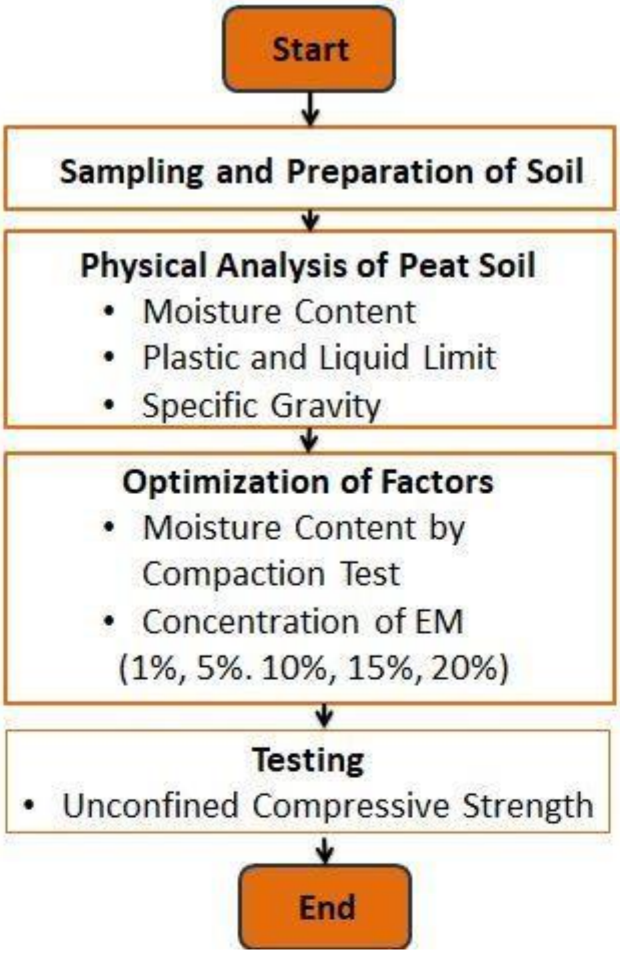

Figure 3.10: Flowchart

3.5 GANTT CHART

Details/ Week	**FYP 1**														**FYP 2**													
	MAY			**JUNE**				**JULY**				**AUGUST**			**SEPT**			**OCT**				**NOV**				**DEC**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
FYP Title selected	🟨																											
FYP title approved		🟨																										
Searching of reading materials			🟨	🟨	🟨																							
Preparation of soil sampling						🟨	🟨																					
Physical Analysis of Peat Soil								🟨	🟨	🟨	🟨	🟨	🟨	🟨														
Preparation of EM															🟨													
Preparation of soil samples (disturbed and undisturbed)															🟨	🟨	🟨	🟨	🟨									
Curing Period of soil samples with EM																	🟨	🟨	🟨	🟨								
Testing of Stabilised Soil Samples																				🟨	🟨	🟨	🟨					
Discussion on Findings																								🟨	🟨			
Concluding and Documentation of Findings																										🟨	🟨	🟨

CHAPTER 4

RESULTS AND DISCUSSIONS

For this study, several laboratory tests have been conducted in order to determine the physical properties and also to evaluate the strength of the stabilized peat soil. The after curing for 0, 7, 14 and 21 days, revealed that the strength of the stabilized peat soil using Effective Microorganism (EM) increased withbhigher percentage (1%, 5%, 10%, 15% and 20% (v/w)) of EM added to the soil but at a certain limit, the EM added is excessed, thus it will lead to the shrinkage of the peat soil whereas for the controlled sample with 0% EM added, the soil will show increment in strength but not as significant as the variety of EM concentration samples.

4.1 PHYSICAL PROPERTIES OF PEAT SOIL

4.1.1 Moisture Content

For the raw peat soil, four samples 30g of peat soil were tested. An average of the four samples was taken for the determination of the moisture content. The moisture content of peat soil is shown in Table 4.1 below. The value for moisture content of peat soil is 149.04%.

Table 4.1: Moisture Content of the soil sample

Container No.		**1**	**2**	**3**	**4**
Mass of wet soil + container (m_2)	g	49.8	48.9	49.2	49.0
Mass of dry soil + container (m_3)	g	32.0	30.8	31.5	30.8
Mass of container (m_1)	g	19.8	18.9	19.2	19.0
Mass of moisture ($m_2 - m_3$)	g	17.8	18.1	17.7	18.2
Mass of dry soil ($m_3 - m_1$)	g	12.2	11.9	12.3	11.8
Moisture Content , W $\frac{(\mathbf{m2 - m3})}{(\boldsymbol{m3 - m1})} \times \mathbf{100\%}$	%	145.90	152.10	143.90	154.24
Average Moisture Content	%	149.04%			

4.1.2 Specific Gravity

Three samples for specific gravity test were being conducted and the average value was taken as shown in Table 4.2. The value for specific gravity of peat soil is 1.13Mg/m^3.

Table 4.2: Specific gravity of the soil sample

Sample no.	**1**	**2**	**3**
Mass of jar + soil + water (m_3)	83.3	83.9	82
Mass of jar + soil (m_2)	46.5	46.4	46.8
Mass of jar + water (m_4)	81.6	81.2	81.5
Mass of jar + cap (m_1)	31.6	31.4	31.9
Mass of soil (m_2-m_1)	14.9	15	14.9
Mass of water in full jar (m_4-m_1)	50	49.8	49.6
Mass of water used (m_3-m_2)	36.8	37.5	35.2
Volume of soil particles (m_4-m_1)	13.2	12.3	14.4
Particle density, ps = (m_2-m_1)/[(m_4-m_1)- (m_3-m_2)]	1.13	1.22	1.03
Average value, ps	**1.13**		

4.1.3 Plastic Limit (PL)

The plastic limit is defined as the moisture content in percent, at which the soil crumbles, when rolled into threads of 3.2mm in diameter. The plastic limit is the lower limit of the plastic stage of soil. It is being used together with the liquid limit to determine the Plasticity Index (PI).

4.1.4 Liquid Limit (LL)

The liquid limit is the moisture content, in percent, at which the transition from plastic to liquid state. The method used to determine the liquid limit is the cone penetrometer test. For this test, three average reading for each samples were taken to determine the fall cone penetration, d.

Table 4.3 shows the data collected for the plastic limit, liquid limit and Plasticity Index for each samples. Data for plastimic limit revealed that addition of EM to peat soil decreased the plastic limit. The reduction of plastic limit is due to hydration of EM between particles of soil. Meanwhile, for liquid limit the pattern shown an increment at initial stage until 10% of EM added and the values decreased as more EM were added.

Table 4.3: The plastic limit and liquid limit of the soil samples

Sample	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index
Peat + 0% EM + 43.5% water	40.73	49.0	8.27
Peat + 1% EM + 42.5% water	45.9	55.0	9.1
Peat + 5% EM + 38.5% water	44.0	72.0	28
Peat + 10% EM + 33.5% water	42.2	116.0	73.8
Peat + 15% EM + 28.5% water	41.7	89.0	47.3
Peat + 20% EM + 23.5% water	41.3	43.0	1.7

4.1.5 Compaction Test

This test covers the determination of the dry density of soil when it is compacted in a specified manner over a rage of moisture content. The range includes the optimum moisture content at which the maximum dry density for this degree of compaction is obtained. In this test, a 2.5kg rammer applied 27 blows from a height of 300mm above the soil for 3 layers.

After 16 samples of different moisture were conducted, the result of compaction as shown in figure 4.1, the optimum moisture content obtained is 43.5% which this moisture content will be used for all the samples for this research.

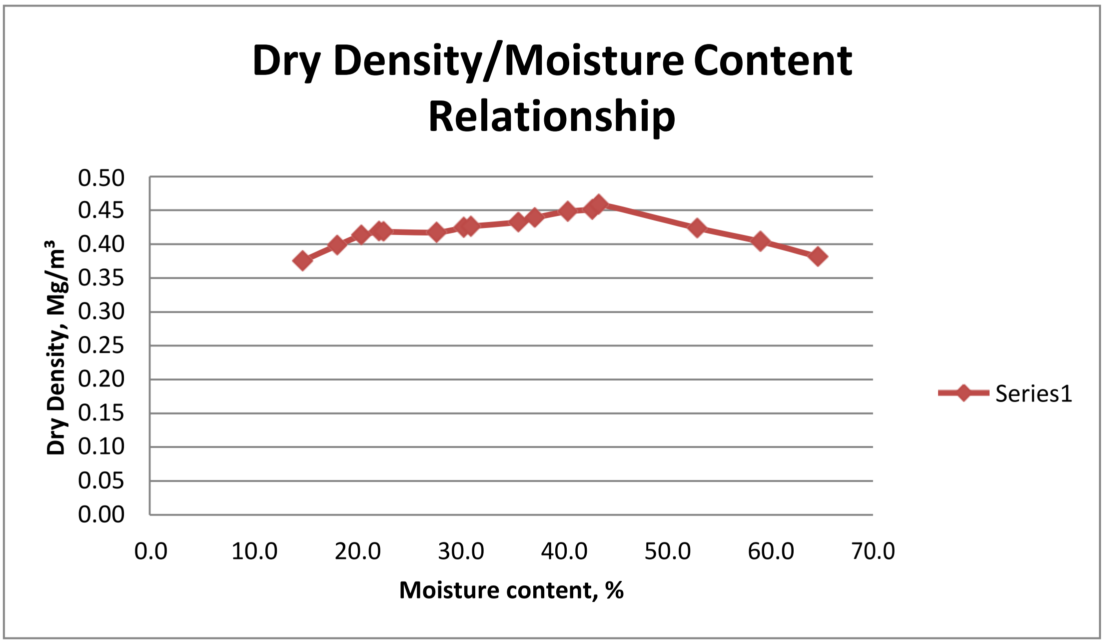

Figure 4.1: Dry density and moisture content relationship of the soil sample

4.2 Testing for Soil Sample

4.2.1 Unconfined Compression Strength (UCS) Test

Figure 4.2 and Figure 4.3 show the relationship between unconfined compressive stress and vertical strain, curing period respectively of controlled peat specimens (0% EM) with an optimum moisture content of 43.5%.

Two specimens were tested for each samples curing time. When being tested immediately, at this state, the unconfined compressive strength of controlled peat was found to be 2.476 kPa. After stabilization of 7,14 and 21 curing days, the strength shows only a slight improvement in unconfined compressive strength when the strength obtained was 6.988 kPa, 9.376 kPa and 17.613 respectively.

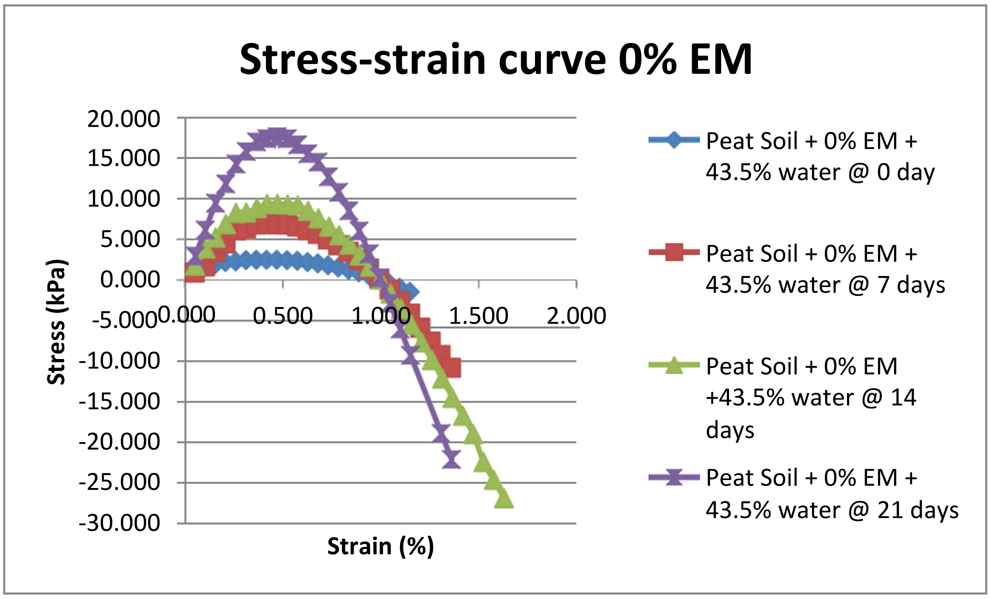

Figure 4.2: Unconfined compressive stress-strain relationship of controlled peat specimen at an optimum moisture content of 43.5%.

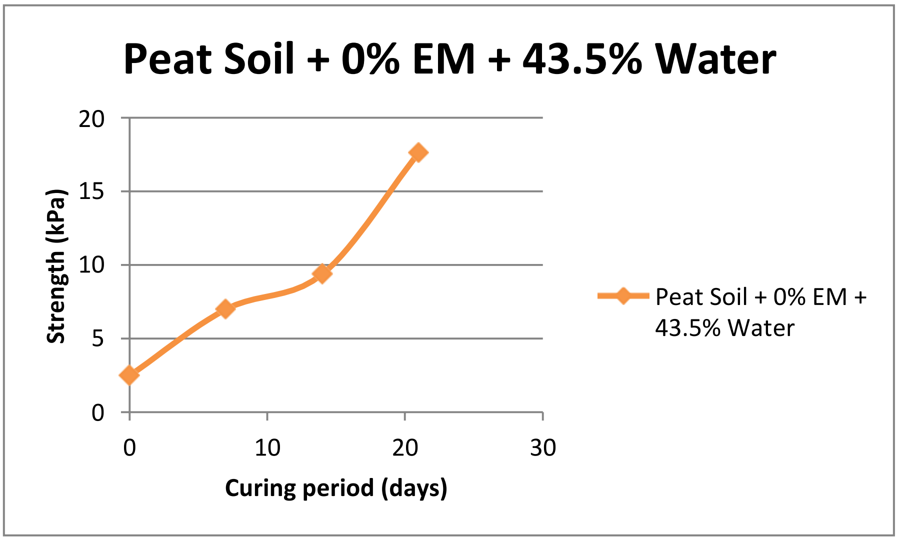

Figure 4.3: Unconfined compressive strength and curing period relationship of controlled peat specimen at an optimum moisture content of 43.5%.

A significant improvement in the strength could be observed when the peat was stabilized with few composition of EM at the same curing period and dosage of moisture content which is 43.5%. Figure 4.4 and Figure 4.5 reveals that the unconfined compressive strength of the stabilized peat reached up to 42.711 kPa which contributes to an increment of 2.5 times of the strength in comparison to the unstabilized peat soil for 21 days.

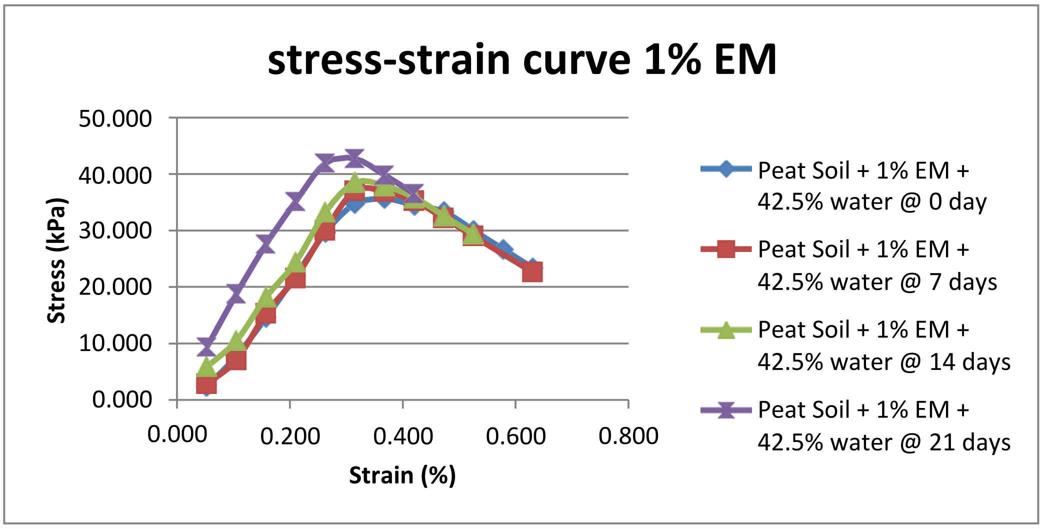

Figure 4.4: Unconfined compressive stress-strain relationship of peat specimen mix with 1% EM at an optimum moisture content of 43.5%.

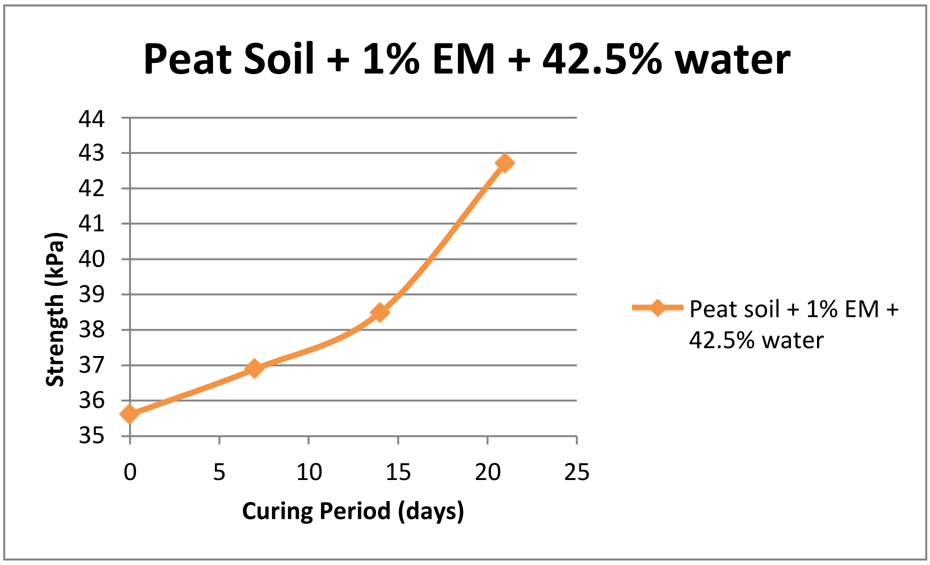

Figure 4.5: Unconfined compressive strength and curing period relationship of peat specimen mix with 1 % EM at an optimum moisture content of 43.5%.

Figure 4.6 and Figure 4.7 show the unconfined compressive stress-strain relationship of stabilized peat specimens with 5% EM and optimum moisture content of 43.5% and curing period respectively. The unconfined compressive strength obtained after 21 days was 36.123 kPa which starts to decrease as compared to the mixing at 1% which gives the strength of 42.711 kPa after 21 days.

In general, all of the stabilized peat specimens showed markedly improvement in unconfined compressive strength when compared to that of controlled peat specimen with 0% EM until it reaches it maximum strength by the optimum moisture content that has been obtained through a compaction test.

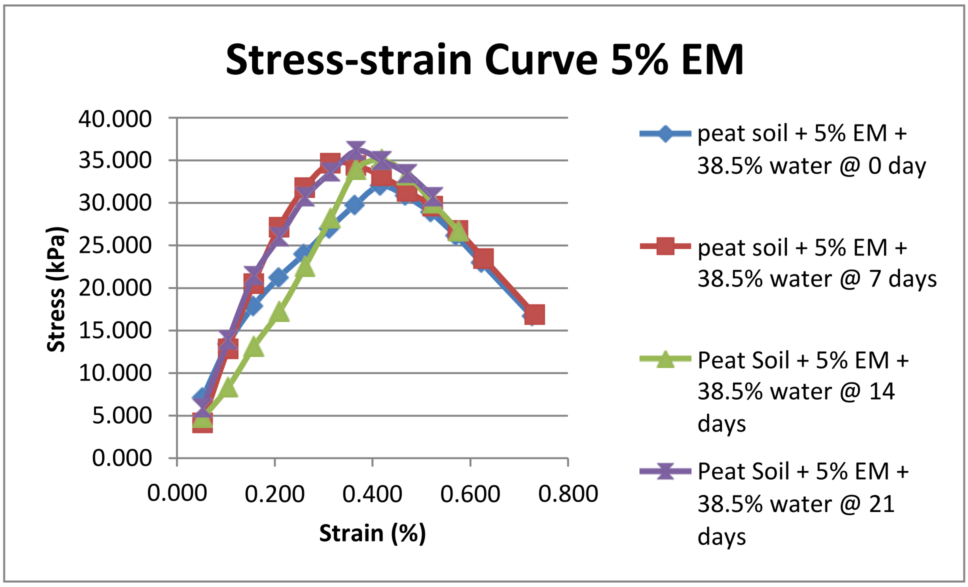

Figure 4.6: Unconfined compressive stress-strain relationship of peat specimen mix with 5% EM at an optimum moisture content of 43.5%.

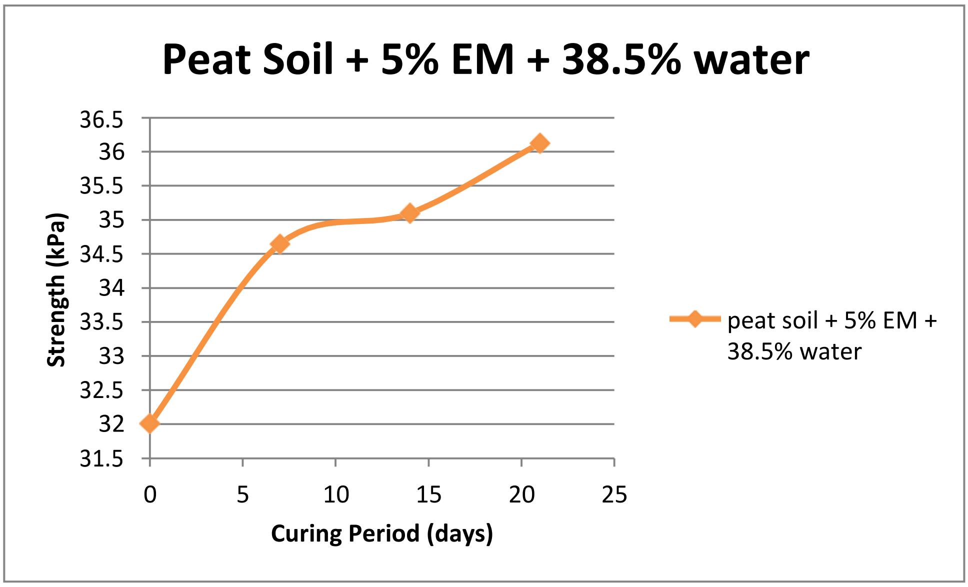

Figure 4.7: Unconfined compressive strength and curing period relationship of peat specimen mix with 5 % EM at an optimum moisture content of 43.5%.

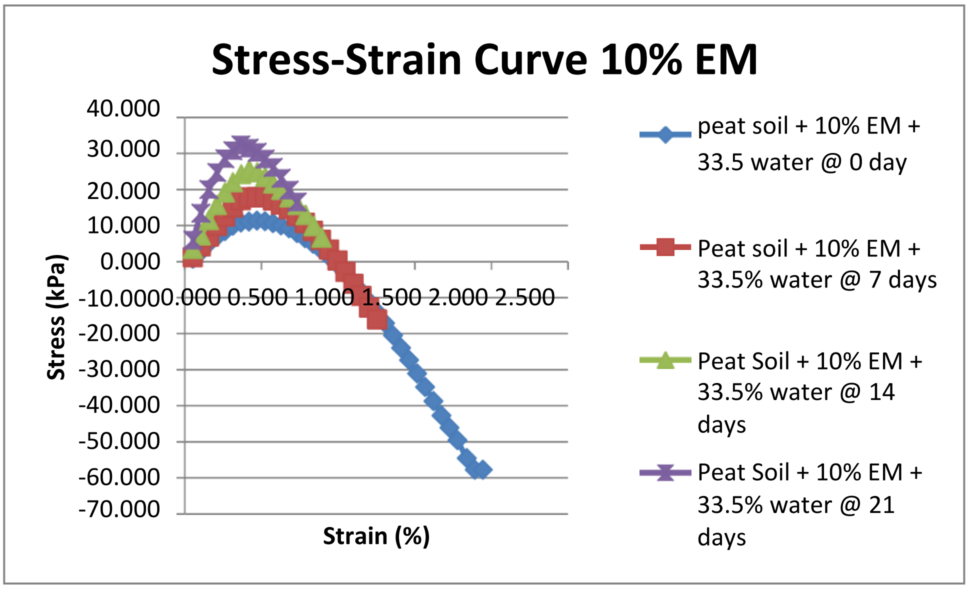

Figure 4.8: Unconfined compressive stress-strain relationship of peat specimen mix with 10% EM at an optimum moisture content of 43.5%.

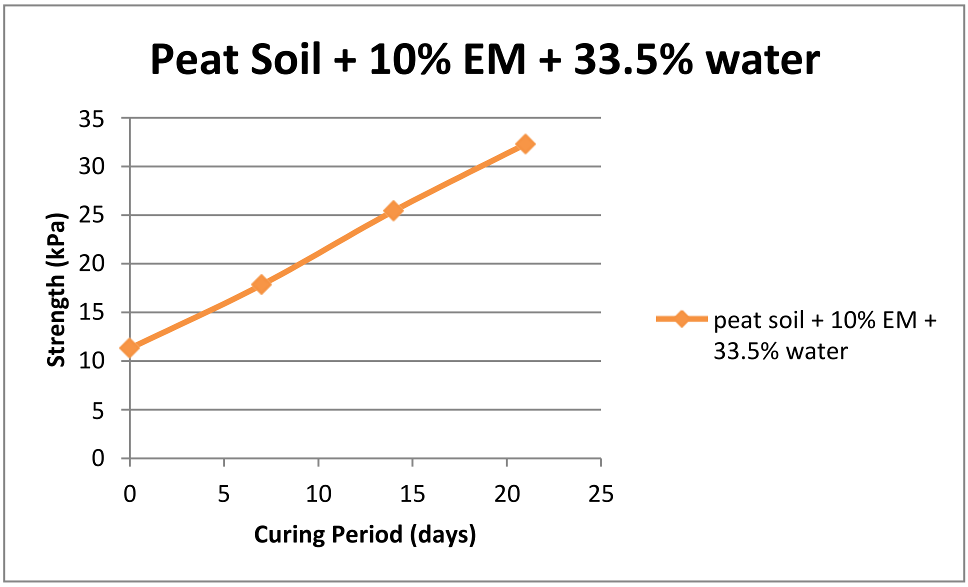

Figure 4.9: Unconfined compressive strength and curing period relationship of peat specimen mix with 10 % EM at an optimum moisture content of 43.5%.

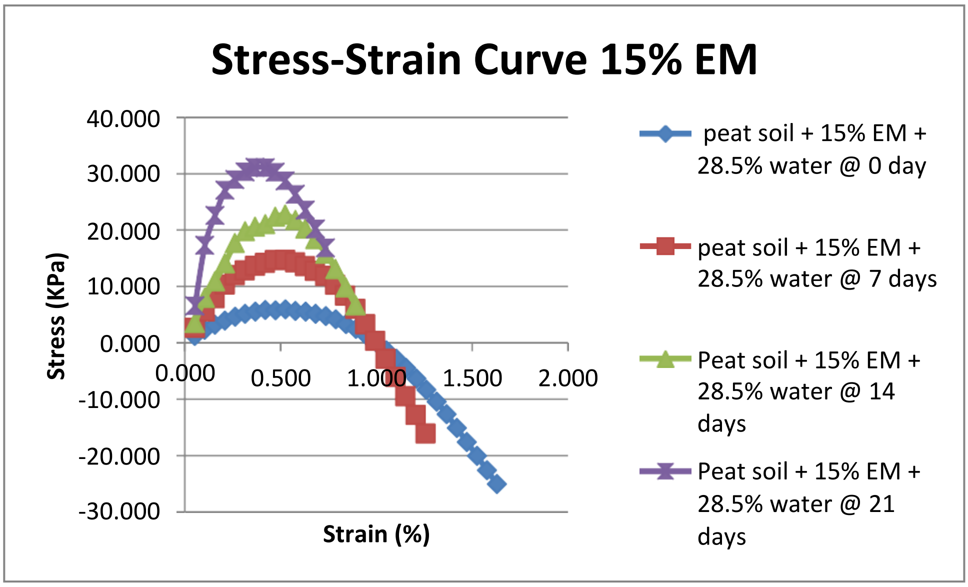

Figure 4.10: Unconfined compressive stress-strain relationship of peat specimen mix with 15% EM at an optimum moisture content of 43.5%.

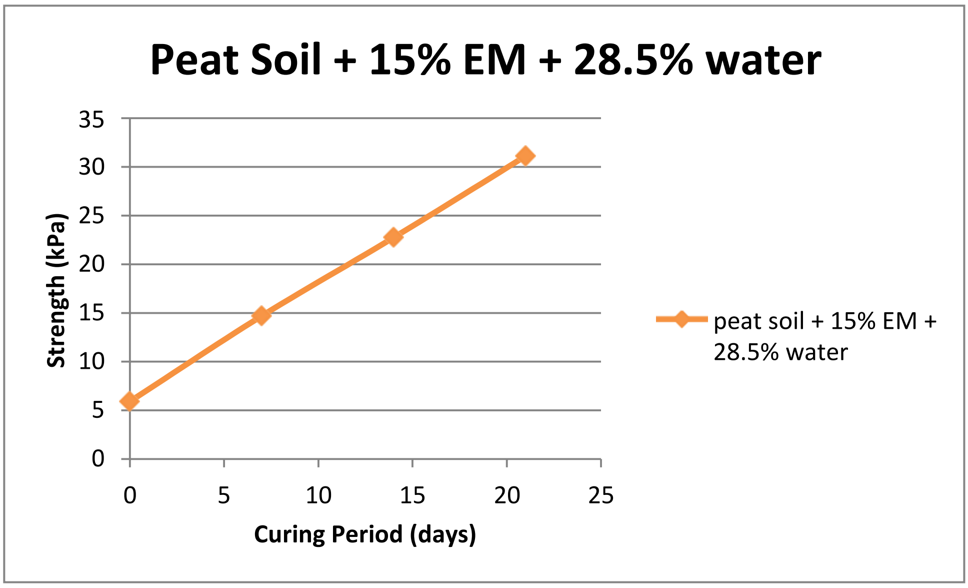

Figure 4.11: Unconfined compressive strength and curing period relationship of peat specimen mix with 15 % EM at an optimum moisture content of 43.5%.

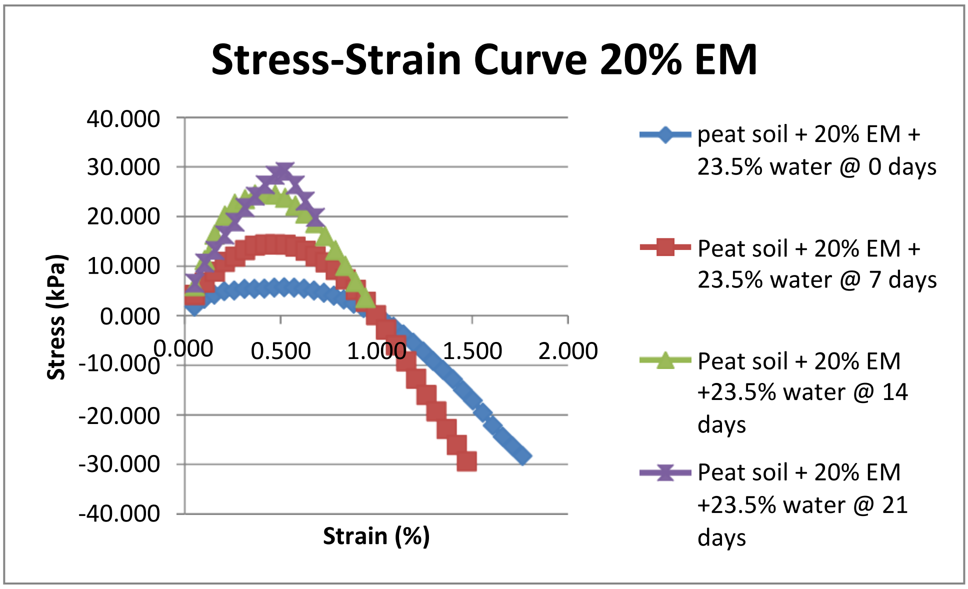

Figure 4.12: Unconfined compressive stress-strain relationship of peat specimen mix with 20% EM at an optimum moisture content of 43.5%.

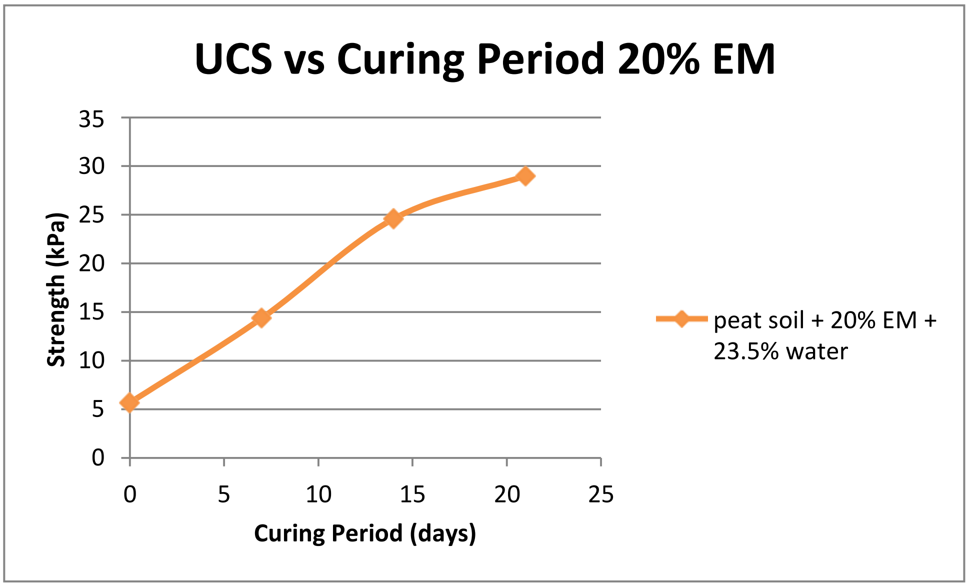

Figure 4.13: Unconfined compressive strength and curing period relationship of peat specimen mix with 20% EM at an optimum moisture content of 43.5%.

The effect of curing time on the strength development of soil mixtures was further demonstrated by a variation analysis of the unconfined compressive strength (UCS) at different curing durations represented in Figure 4.14. It can be observed that the timeline presents a slow rate of increase in strength between the 7th day and 14th day which is followed by a steeper increase that extends to the 28th day. The delay in strength development initially probably represents period for necessary reaction between soil particles and the EM in the mixtures resulting in the formation of bonding.

After 1% of EM added, the rest of the concentration showed decrement in the strength showing that 1% is the optimum concentration for moisture content of 43.5%. This may be due reached of humid acid neutralization in the peat soil (Sing, et al., 2009).

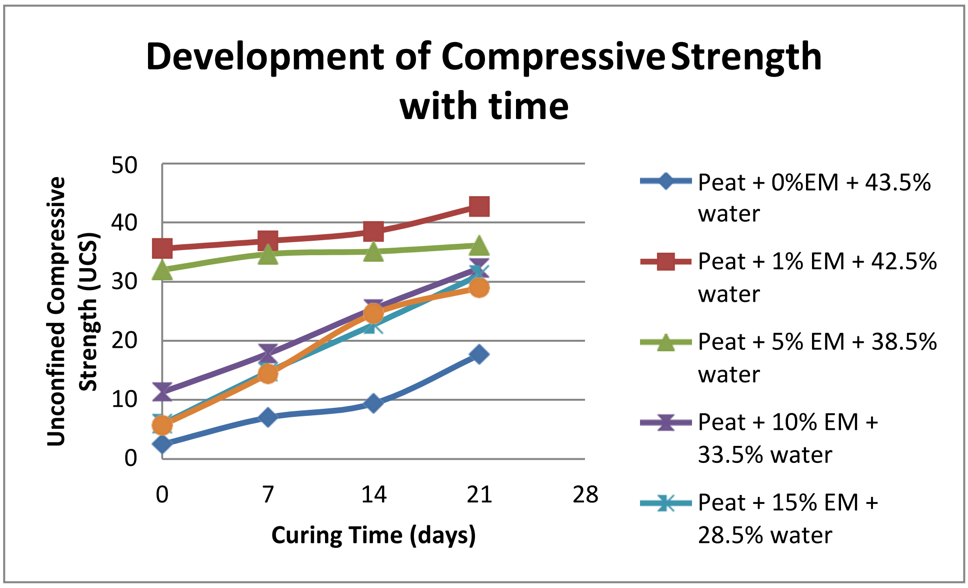

Figure 4.14: Development of compressive strength with time for compacted soil with different admixture percents

The relationship between compressive strength with the percentage of EM added for each curing period is shown in Figure 4.15 to Figure 4.18. Overall performance of the EM concentration added revealed that 1% EM given the highest strength of peat soil.

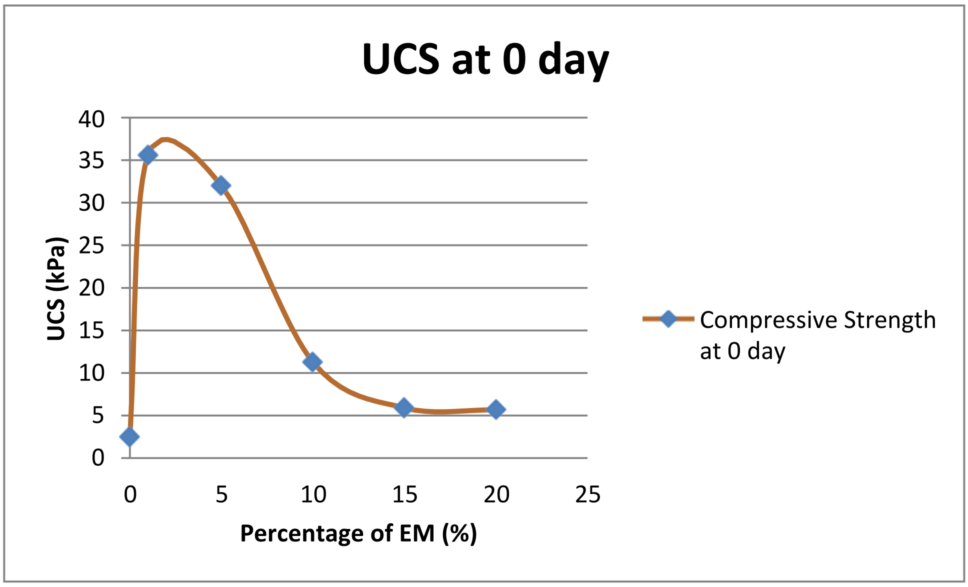

Figure 4.15: Compressive strength of variety percentage of EM at 0 day

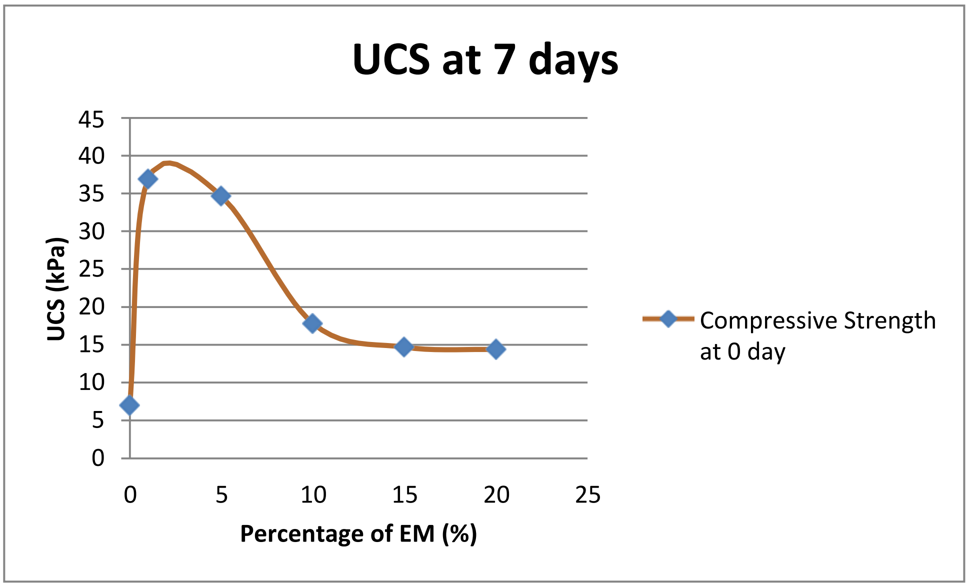

Figure 4.16: Compressive strength of variety percentage of EM at 7 days

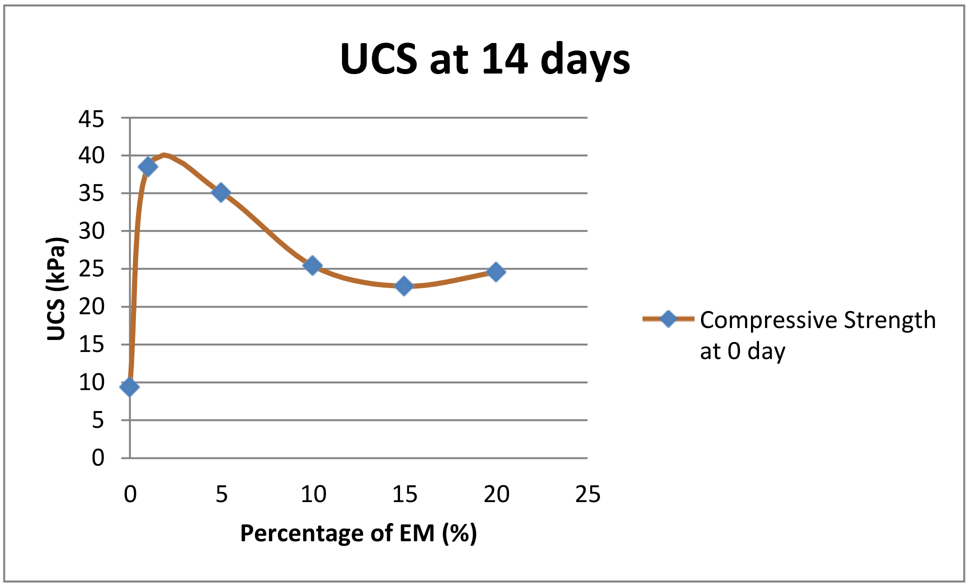

Figure 4.17: Compressive strength of variety percentage of EM at 14 days

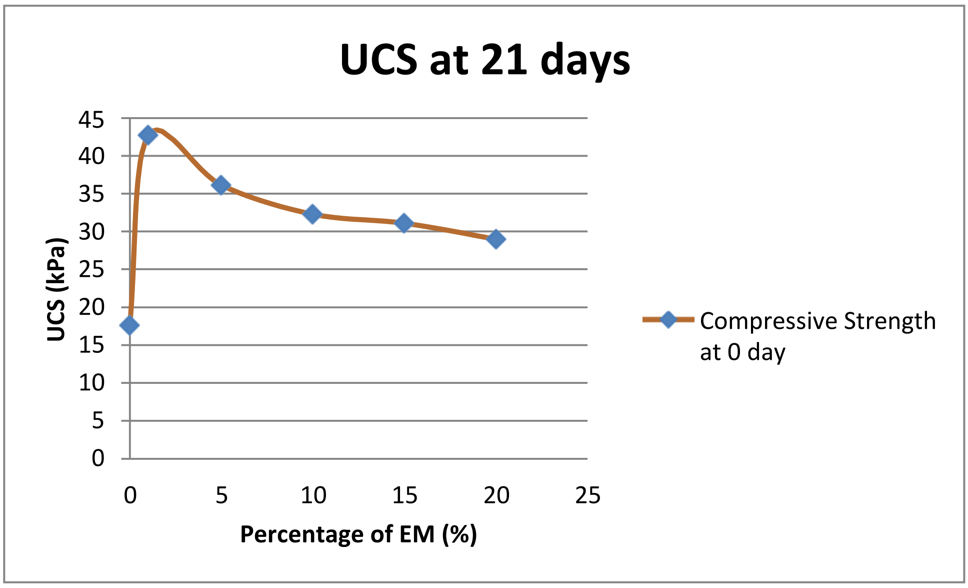

Figure 4.18: Compressive strength of variety percentage of EM at 21 days

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

As a conclusion, peat soil is an organic soil that is in a very weak condition that is not suitable to be used for construction. Thus, the peat soil needs to be stabilized before using it. The addition of EM into peat soil can increase the strength of peat soil sample. The effectiveness of Effective Microorganism (EM) used in each sample is very important since it affects the strength of the peat soil and other desired properties of a strong soil. Stabilization of peat soil needed to be taken into detailed consideration since the properties of peat differ from site to site. Therefore, different type of peat reacts with different type of binder at certain binder dosage to achieve effective stabilization. Basically, the high strength stabilized peat exhibited low permeability and compressibility as a result of its hardening effects.

5.2 RECOMMENDATIONS

As a recommendation, for the peat soil, permeability test and morphology study should be conducted to the raw and stabilized peat soil in order to evaluate how the EM affects the permeability of the peat soil.

Secondly, the curing period should be prolonged such as 90 days or 120 days. This is because air curing method causes the high moisture content of the stabilized peat soil to gradually decrease with time and during the curing process, and as a result, strength values increase as the curing period become longer.

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