A Study on Factors Affecting Strength of Solidified Peat through XRD and FESEM Analysis

J A Rahman[1], A M A Napia[1], M A A Nazri[1], R M S R Mohamed[1*], A S Al-Geethi[1]

[1]Faculty of Civil Engineering and Environment, Universiti Tun Hussein Onn, Johor

Email: *maya@uthm.edu.my*

Abstract. Peat is soft soil that often causes multiple problems to construction. Peat has low shear strength and high deformation characteristics. Thus, peat soil needs to be stabilized or treated. Study on peat stabilization has been conducted for decades with various admixtures and mixing formulations. This project intends to provide an overview of the solidification of peat soil and the factors that affecting the strength of solidified peat soil. Three types of peats which are fabric, hemic and sapric were used in this study to understand the differences on the effect. The understanding of the factors affecting strength of solidified peat in this study is limited to XRD and FESEM analysis only. Peat samples were collected at Pontian, Johor and Parit Raja, Johor. Peat soil was solidified using fly ash, bottom ash and Portland cement with two mixing formulation following literature review. The solidified peat were cured for 7 days, 14 day 6 days. All samples were tested using Unconfined Compressive Strength Test (UCS), X-ray diffraction (XRD) and Field Emission Scanning Electron Microscope (FESEM). The compressive strength test of solidified peat had shown consistently increase of sheer strength, q_u for Mixing 1 while decrease of its compressive strength value for Mixing 2. All samples were tested and compared for each curing days. Through XRD, it is found that all solidified peat are dominated with pargasite and richterite. The highest q_u is Fabric Mixing 1(FM1) with the value of 105.94 kPa. This sample were proven contain pargasite. Samples with high q_u were observed to be having fly ash and bottom ash bound together with the help of pargasite. Sample with decreasing strength showed less amount of pargasite in it. In can be concluded that XRD and FESEM findings are in line with UCS values.

Keywords: organic soil, peat treatment, OPC, fly ash, bottom ash

1. Introduction

Peat soil contains high organic and natural water substance up to more than 70 % and 400 %, respectively. It frames in the waterlogged zone, where lack of oxygen anticipates characteristic microorganisms from breaking down the dead plant material [1]. It classified as soft soils in geotechnics term. Therefore, to improve its geotechnical properties, the peat soil need to be solidified first. Peat soil solidification is referring to the stabilization of the soil that is expected to be strengthened for development above ground. The use of waste material such as ashes for stabilization of peat soil is being studied by many researcher [2, 3].

Study in peat solidification area has been conducted for years. The ability of these admixtures to increase the peat strength has been proven by [4-6]. However, the actual factors that affect to the strength gained are not yet discuss in detail. This study aim to compare the strength value of solidified peat with X-Ray Diffraction (XRD) and Field Emission Scanning Electron Microscope (FESEM) findings with Unconfined Compressive Strength (UCS) values.

XRD is a good tool to identify mineralogy of a solid state material [7]. Basically, peat consist of more than 75 % carbon whereas, content of mineral in original peat is normally low. However, the binder used to solidify peat soil is rich with mineral especially quartz, kaolinite, etc. The interaction between humic acid in peat and chemicals in binders might form new crystal or mineral. When ordinary Portland cement (OPC) react with water, hydration process will takes place. The calcium, aluminium and sulphur from binder will combine

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with water to form ettringite. Ettringite is in crystal form and can be detected using XRD. Ettringite is believe to be element that bind particles thus strengthen its physical properties [8]. The presence of ettringite can be observed by using field emission scanning electron microscope (FESEM).

FESEM work with a narrow scanning beam of electrons and it is bombarded on the surface of the specimen. Secondary electrons are provided from each crash spot on the specimen. A detector catches the secondary electrons and makes an electronic signal producing a video scan image that can be seen on a monitor or as a digital image that can be saved and processed further [9].

Kolay *et al*. [10] study on stabilization of tropical peat soil with different stabilizing agents which are OPC, quick lime (QL) and fly ash. The sample of peat was stabilized with different agents and amount of agents used. The formulations are 20 % OPC, 20 % fly ash, 6 % QL and a mixture of 6 % QL with 20 % fly ash. It was then cured for 28 days following British Standard (BS 1377) before tested with SEM. A significant changes as new mineralogical phases was observed when cured under water with different stabilizers.

A combination of XRD and FESEM analysis is expected to give a new perspective in peat solidification study. The knowledge can be used to utilize the mixing formulation on future solidified peat soil research.

2. Sample Preparation and Mixing Process

Three types of peat soil was used in this study. Fabric peat, with fiber content more than 66 % was obtained from Parit Raja, Johor while more decomposed peat, hemic and sapric were obtained from Pontian, Johor. Samples were all kept in bin with few plastic bags covered on it to prevent moisture loss. All peats were tested its physico-chemical and engineering properties before mixing process take place.

Peat samples was segregate from fiber larger than 20 mm to ensure the UCS sample can be formed nicely and homogenous in UCS mold. The peat was solidify using fly ash (FA), bottom ash (BA) and OPC with proportion in Table 1. Two mixing were used in this study. Mixing 1 is for q_u value consistently increase it strength after 56 days of curing. Mixing 2 is designed to replicate the sample with q_u decrease after 28 days of curing. All admixtures were mixed using home mixer for about 5 minutes and scrap off before continue mixed it again until a homogenous mixture was gained.

Triplicate sample for UCS test were prepared for each curing days with total of 72 UCS samples were formed. Each samples were tested with UCS followed with FESEM and XRD for every curing days.

Table 1. Mixed design for solidified peat [6]

	Fabric Peat	Hemic Peat	Sapric Peat
Mixing 1	OPC with equal amount of dry peat 25% FA Addition of BA to give the coarse particle of 23-34% of the total mixtures		
Mixing 2	w/b = 1 50% OPC 25% BA 25% FA	w/b = 3 50% OPC 50% BA	w/b = 3 50% OPC 50% BA

3. Results and Discussions

3.1 Physical and Chemical Characteristic

The raw materials are categorize into two which are physical and chemical properties as shown in Table 2. The fiber content test is important in grouping the type of peat soil. In this study, three types of peat which are fibric, hemic and sapric were used. All peat types are acidic with low pH while all binders are found alkaline. The reaction between these materials expected to give some neutralization effect thus water and salt are formed. The water formed will then use by OPC to perform hydration process. Basically, all peat contain high water content. This make peat easily compressible and not rigid. The LOI indicates that all soil samples are peat where carbon content in the samples are more than 75 %. The binders and filler are classify as non-organic as its carbon content are very low.

Table 2. Physico-chemical Properties of Raw Materials

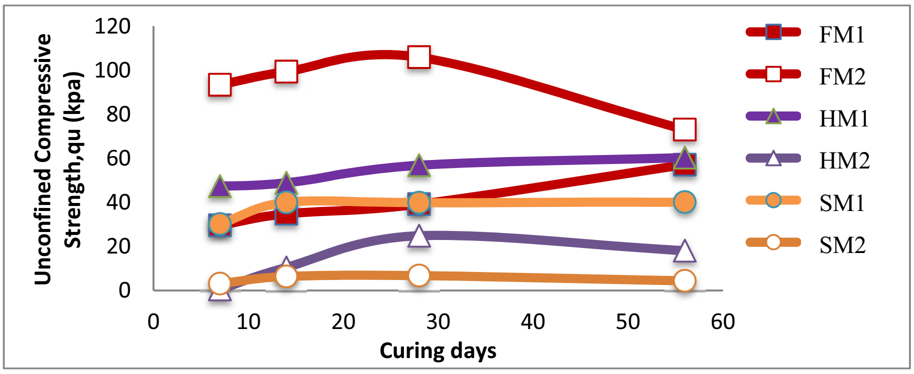
Physical Characteristics	Peat			Cement	Fly Ash	Bottom Ash
	Sapric	Hemic	Fabric			
Moisture Content, w (%)	759.72 ± 11.4	651.00 ± 7.9	171.90 ± 3.5	Free from moist		
Fiber Content (%)	14.62 ± 0.67	56.48 ± 1.24	68.80 ± 1.55	NR	NR	NR
Specific Gravity	1.58 ± 0.13	1.63 ± 0.81	1.47 ± 0.17	2.41 ± 0.21	2.67 ± 1.31	3.03 ± 0.05
LOI (%)	81.45 ± 3.42	89.97 ± 1.08	96.40 ± 4.33	0.33 ± 0.05	0.48± 0.03	0.46 ± 0.03
pH	3.18 ± 0.21	3.10 ± 0.07	3.36 ± 0.08	10.4 ± 0.42	9.7 ± 0.23	8.6 ± 0.61

N=3; NR = Not related

3.2 *Unconfined Compressive Strength*

Figure 1 provides an overview of the UCS test over curing days of solidified peat. The solidified peat was cured at 7, 14, 28 and 56 days before testing. It can be seen that all Mixing 1 samples are steadily increase of compressive strength until 56 days of curing period. Meanwhile different outcomes are recorded from Mixing 2 samples where the compressive strength decrease at 56 days of curing period.

Almost similar pattern are recorded for HM2 and SM2. The mixing formulation for both samples contain no fly ash. This proves previous theory by Yeo et al. [11] that fly ash can act as neutralizer or pozzolan that helps in strengthening effect for longer period. As the peat was control to be around 300 % of moisture content before mix, water can be said does not giving significant effect to the different in strength achieved by different mixing formulation. The different in pattern for Mixing 1 and Mixing 2 most probably due to the formation of ettringite in solidified peat. Certain amount of alkaline binder might lessen the formation of ettringite.



FM1 = Fabric mixing 1; FM2= Fabric mixing 2; HM1 = Hemic mixing 1; HM2= Hemic mixing 2; SM1 = Sapric mixing 1; SM2= Sapric mixing 2

Figure 1. Unconfined Compressive Strength - Curing Days

3.3 *XRD Analysis on Solidified Peat*

The result of an XRD measurement is in diffractogram which is showing the phase concentration (peak height) and phase present (peak positions). Figure 2 shows XRD results for Fibric Mixing 2 (FM2) which having highest q_u (Figure 1). Pargasite is recorded as the most influence mineral present in the mixture. According to concrete study [12], the strengthening effect in treated soil is mostly come from ettringite. Ettringite is a hydration product when water react with Silica, Aluminium and Calcium. Referring to Loucks [13], Pargasite is a complex mineral with formula $NaCa_2(Mg_4Al)(Si_6Al_2)O_{22}(OH)_2$. It exist in a form of crystal from transparent to translucent in colour. Richterite, Dellaventuraite, Potassicpargasite, Magnesiohastingsite and Motassic-chloropargasite are all pargasite associates and species [14]. It common function are retained water. Thus, the present of pargasite in solidified peat is suspected to be acted as ettringite in concrete.

Unlike finding from FM2 day 28, FM2 day 56 recorded different in mineralogy as can be seen in Figure 3. FM2 was chosen as it showing decrease in strength after day 56. Selenium antimony chloride is recorded to be highest peak in this sample. Selenium antimony chloride is not part of pargasite species. In facts, none of the detected minerals are from pargasite associate. This strengthen the theory that pargasite is the reason of strength gained in solidified peat.

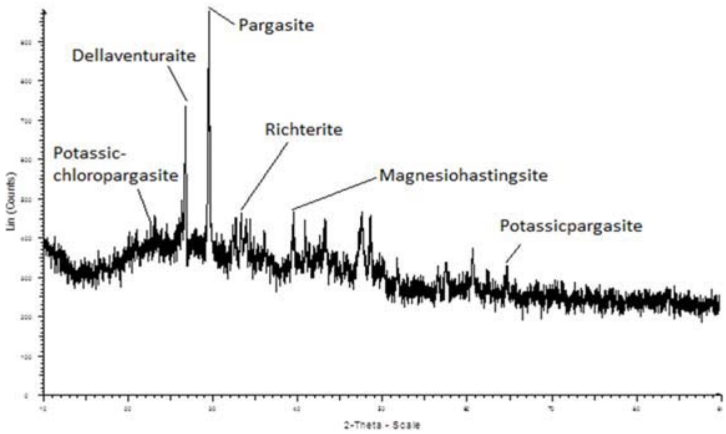


Figure 2. XRD result of FM2 day 28

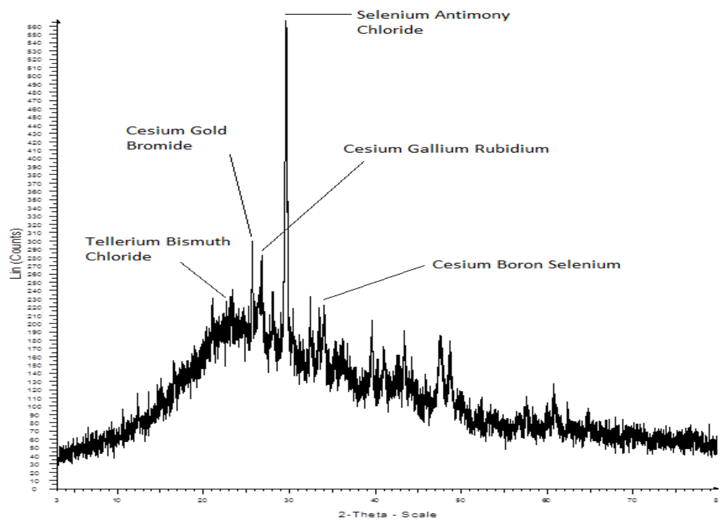


Figure 3. XRD result of FM2 day 56

3.4 FESEM Image on Solidified Peat

The FESEM analysis had shown microstructure of the solidified peat sample. From the FESEM images in Figure 4 it can be observed that fly ash had a spherical and smaller particles compare to bottom ash. Meanwhile the bottom ash had irregular shape and complicated shape. The differences between fly ash and bottom ash appearance in stabilized peat is observe from the FESEM images. The diameters of the pore that can be seen from the microstructure of day 7 until day 56 become decreases. Ettringite shape object can be detected at sample FM2 D7, 14 and 28. However, the ettringite could not be found in FM2 day 56 sample. The bonding between the particles become closer as the effect of this ettringite and then improves the strength of the solidified peat. It can be proved by compressive strength value of FM2.

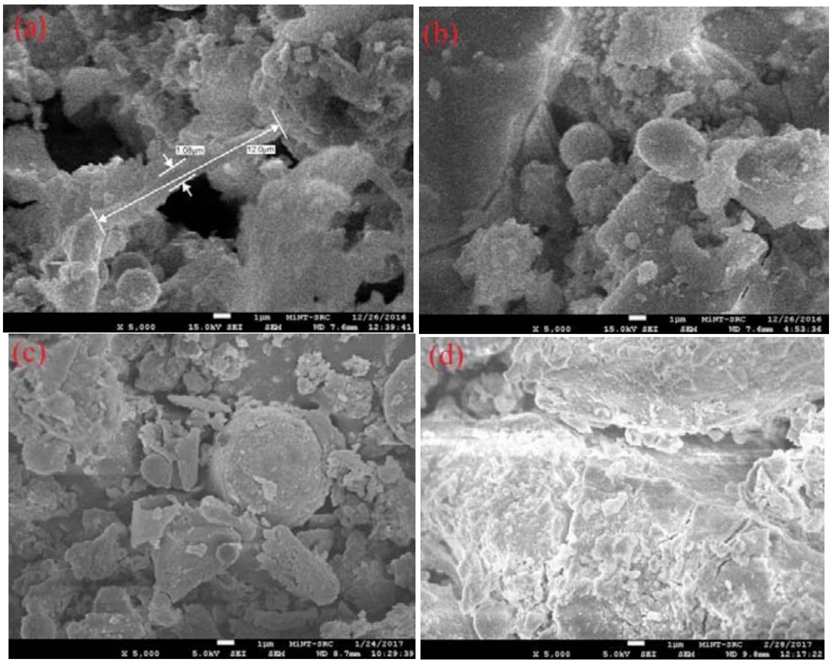


Figure 4. FESEM result for FM2. a) day 7 b)day 14 c)day 28 d)day 56

4. Conclusions

Moisture content of peat soil in this study that collected from Pontian, Johor is in range between 172-760%. Thus, from the moisture content test can be concluded that moisture content of the peat soil is directly proportional to the depth of the soil.

Fiber content in peat soil depending on the moisture content where the higher fiber content in peat soil, the lower moisture content in it. This is because, the organic matters in peat soil absorb the water from the soil.

The pH value for the peat soil used in this study is acidic which is in range between 3.10-3.36. Pargasite is suspected to be attringite in solidified peat. The presence of pargasite was detected at all increasing strength sample and non for decreasing strength samples.

From the FESEM image of solidified peat had help in demonstrate the microstructure and bonding of the peat, cement, fly ash and bottom ash. The size of pores that can be seen in enlarged by FESEM that occurred are representing the strength of bonding between peat, cement, fly ash and bottom ash. Thus, can be proved by the UCS test of the solidified peat where the solidified peat that had large pores had low compressive strength value.

It can be concluded from the compressive strength value show the solidified peat without fly ash had the lowest compressive value. Thus in this study had proved that binder which is fly ash, affect the strength of the solidified peat.

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