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MICROSTRUCTURE OF SOLIDIFIED PEAT AT DIFFERENT DECOMPOSITION LEVELS

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SUMMARY

Peat is well known for their inherent high moisture content, porosity and compressibility. This soil type requires pre-treatment, such as solidification, to improve the engineering properties before loads from infrastructure above ground can be applied. There are three decomposition levels for the peat soil, namely fabric, hemic and sapric peat. In the present study, the soil samples were treated using ordinary Portland cement and coal ashes etrieved from the coal power plant. The peat soil was mixed with bottom ash and fly ash using four formulations. The microstructure of the soil was observed before and after solidification by using a Field Emission Spectroscopy Electron Microscope (FESEM). The analysis of FESEM showed needle -like objects known as ettringite which effectively enveloped the treated soil matrix in a progressive manner. The amount of ettringite was increased with the increasing of curing period, resulting in greater coverage of the voids in the soil. The ettringite, which are C-S-H and C-A-H, bound the soil particles and coal ashes, and consequently improves the soil strength and stiffness. However, the amount of ettringite presence in the mixed samples was found parellel with the Unconfined Compressive Stress (UCS) value recorded. The formation of ettringite depends on the proportion of cement and coal ashes, as well as the decomposition level of the organic matter in the soil. The decomposition level of the peat soil affects the environment for solidification and the physical presence of solid matter in the soil for binding with the admixtures (e.g. remaining organic debris). In general, mixtures with high UCS value produced more extensive ettringite development. Prolonged curing was also found to further improve the ettringite formation, leading to more significant strength and stiffness improvement.

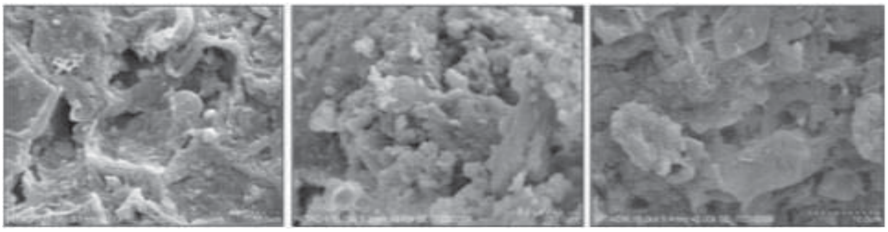
Keywords: *decomposition level of peat, solidified peat, FESEM, ettringite, microstructure.*

INTRODUCTION

Peat is known with its challenging properties among geotechnical engineer. Hundreds hectare of peat which were previously agricultural land are being developed as housing and commercial lands (Ling *et al.*, 2014). Mass stabilization is one of the techniques to improve the initial strength of peat before any construction above ground can be built up. Several binders and fillers were studied for centuries and proven the workability of mass stabilization theory (Kalantari 2010 and Kolay *et al.*, 2011). Peat is derived from decomposed plant materials. Its physical characteristics very much depended on the plant origin and the humification degree. The less decomposed peat, known as fibric peat has larger particles and have lots of void in between it. These made fibric peat is able to retain more water compared to the moderately decomposed peat (hemic peat) and most decomposed peat (sapric peat). The difference in decomposition level also affect to the strength improvement after solidification. The organic content in peat make is shows significant different in most peat study. Studies by Axelsson *et al.* (2002) and Alwi (2007) shows that fibric peat can be improve its strength from 12kPa to 300 kPa. Although the additives and technique used in peat solidification study differ among the researchers, they concluded that sapric peat is the most difficult to be solidified. The strongest solidified sapric peat recorded so far was 37.5 kPa where Ordinary Portland Cement (OPC), sand and Ground Granulated Blast Furnace Slag were used as additives in the study (Wong *et al*., 2009).

The microstructure of peat has been studied by Huat *et al*. (2011) as shown in Figure 1. The cellulose normally can be seen in fibric peat. The particle size is decreasing in increasing peat's decomposition levels. In most studies, the microscopic images shown a tighter particles in solidified peat compared to the loosely arrange particles for fresh peat. Table 1 compares SEM images of other researchers finding before and after solidification at D28. Different techniques and mixing portions were use in the respective studies. SEM images are suggested to be discussed along with its chemical precipitation using Electron Disperse X-Ray (EDX), X-Ray Diffraction (XRD) or X-Ray Fluorescence (XRF) (Ismail *et al*., 2014).

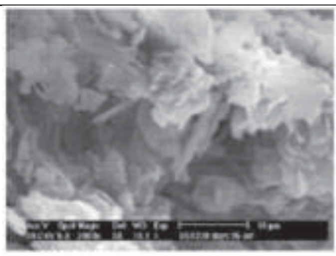
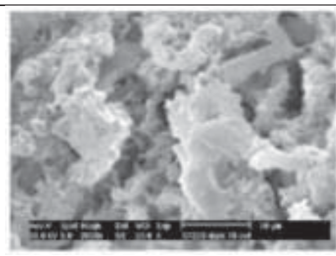
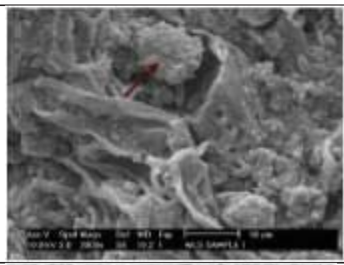
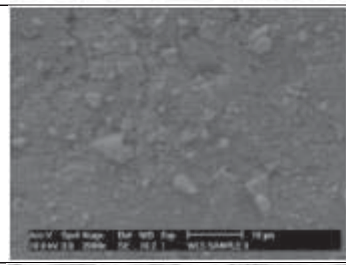
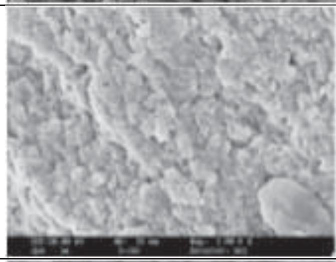
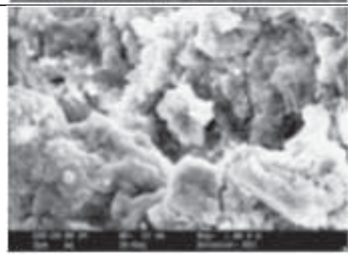
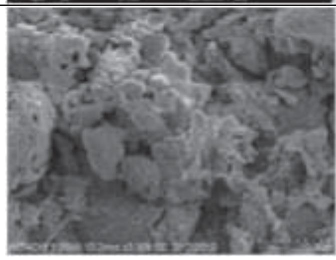
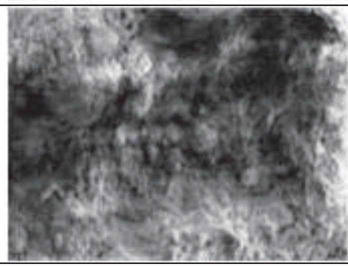
In soil improvement study, cement has been widely used to improve the strength of soils. Horpibulsuk (2012) explained hydration process which produced ettringite (C-S-H and C-A-H gel); object that bind the soil particles thus improve the soil strength. Etrringite can be observed as needle-like-object in microscopic images. In the present study, the soil samples were treated using ordinary Portland cement and coal ashes. The microstructure of the raw material and solidified peat will be the focus of this paper.



(a) (b) (c)

Figure 1 SEM images of peats: (a) fibrous, (b) sapric and (c) hemic (Huat *et al.*, 2011)

Table 1 SEM images and q_u of solidified peat at D28 with different mixing portion and techniques

Reference	Mixing portion & techniques	Before solidification	After solidification
Islam and Hashim (2010)	100% cement, $CaCl_2$ (4 % of binder) and 25% of sand by volume of soil in-situ peat column q_u of solidified peat = 3000 kPa		
Wong *et al.* (2013)	90% Portland Composite Cement: 10% Kaolin (4% Calcium Carbonate) Curing in water q_u of solidified peat =574 kPa		
Leong and Eriktius (2014)	38% municipal solid waste fly ash by dry weight Curing 28 days q_u of solidified peat = 100 kPa		
Moayedi *et al.* (2014)	CaO 6% Electrokinetic treatment q_u of solidified peat = 64 kPa		

METHODS

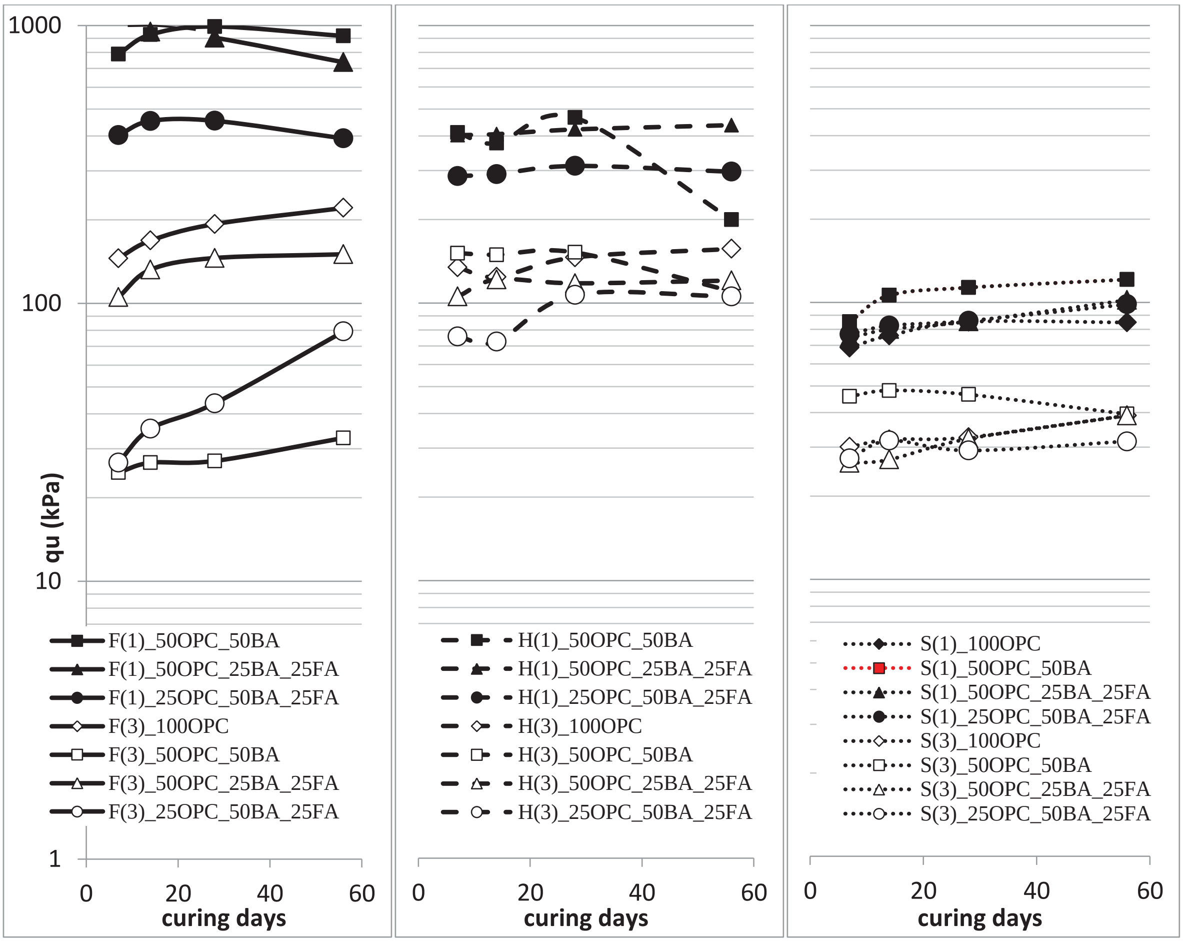
Sample Preparation

Peat samples were obtained from Kg Medan Sari, Pontian, Johor, Malaysia. Samples were kept in container, covered with few layer of plastic bags and seal. The samples were placed in a controlled room with temperature of 25 ^oC to maintain the moisture. Additives used in this study were obtained from Tanjung Bin Power

Plant at Pontian, Johor. The coal ashes; bottom ash (BA) and fly ash (FA) were oven dried at 50 °C to make sure it moist free before mixing process is done. All peat types were mixed using 4 formulation; 100% OPC, 50%OPC + 50%BA; 50%OPC + 25%BA + 25%FA and 25%OPC + 50%BA + 25%FA with two water/binder ratio; 1 and 3. All mixed samples were cured and undergo unconfined compressive stress (UCS) test and imaging test at day 7, 14, 28 and 56.

RESULTS AND DISCUSSION

The UCS test was carried out at four curing days for all mixed samples. Figure 2 shows that there are two patterns of peat solidification for all types of peat. The first pattern shows that the strength of solidified peat increase with increasing of curing days. The second pattern shows decrease of strength after curing 28 and 56 days.

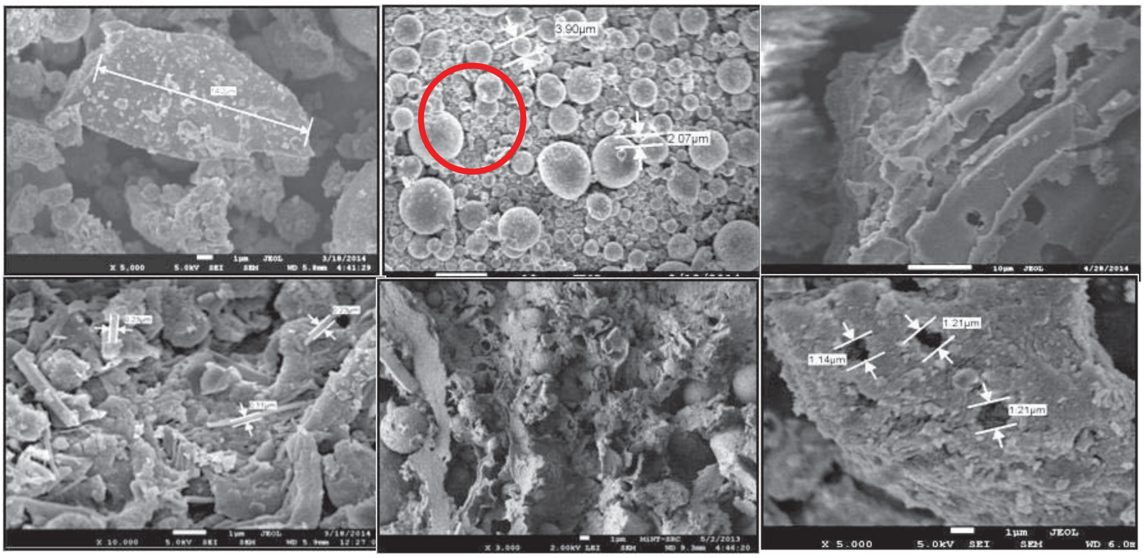


a) Fabric peat **b)** Hemic peat **c)** Sapric peat

Figure 2 q_u versus curing days

MICROSCOPIC IMAGE

The microscope imaging was done on all samples before and after solidification. The physical shape, morphological view and size of particles in a sample could be obtained from this method. Figure 3 shows the variety of shapes and sizes of peat, binders and filler. The main components in the respective materials were also labelled in the figure. Physically, the FA, ettringite, humic acid and cement paste were found filling the porous spaces in peat. The variety of sizes of FA and ettringite, fit nicely to these porous spaces**.**



a) Calcium carbonat in OPC
b) Fly ash
c) Humic acid
d) Ettringite (CSH and CAH gel)
e) Void due to arrangement of fiber
f) Void in BA

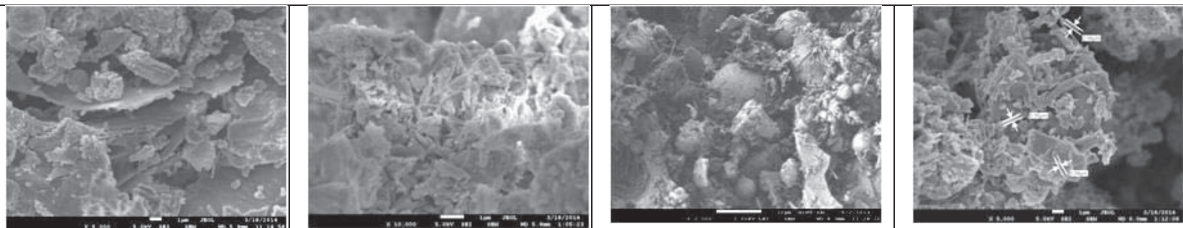
Figure 3 Particles and its sizes in the peat-binder-filler mixture

As discussed in earlier section, there are two patterns recorded for peat solidification. The first pattern (A) shows increasing q_u is parallel with curing days. The second pattern (B) shows that q_u increase at D7 and D14 followed by decrease it q_u on D28 or D56. The differences in the FESEM images of these two samples are compared. Mixture of H(1)50OPC_25BA_25FA (Figure 4) is selected to represent pattern A while mixture of H(1)_100OPC (Figure 5) is selected for pattern B. The patterns are summarized in Table 2.

Table 2 Summary of patterns in solidified peat

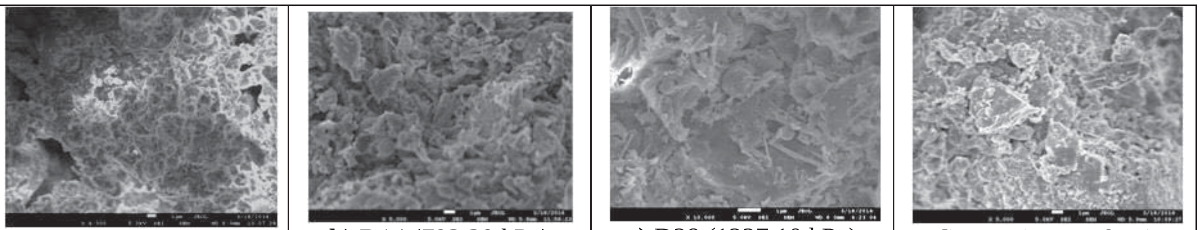
Pattern	Description	Sample
A	q_u increase in parallel with curing days	Mixture of H(1)50OPC_25BA_25FA
B	q_u increase at D7 and D14 followed by decrease q_u on D28 or D56	Mixture of H(3)_50OPC_50BA

The images of solidified peat with improving strength show that the hydration products growing from the cement grains connecting the fly ash particles and peat - cement clusters together. Some of the surfaces of fly ash particles were coated with hydration products. At D7, the ettringite was not obvious if compared to D14. It shows that the formation of ettringite increases over time. Image of D28 shows that amount of ettringite increase rapidly and can be captured easily. The ettringite is present in large quantity. Different phenomenons captured at D56 where the ettringite seem to be connected with one another thus interlock with the soil particles. The thickness of the ettringite was also found increasing with the increase of curing days.



a) D7 (737.38 kPa) **b)** D14 (792.20 kPa) **c)** D28 (903.65 kPa) **d)** D56 (949.76 kPa)

Figure 4 Sample labelled as H(1)50OPC_25BA_25FA



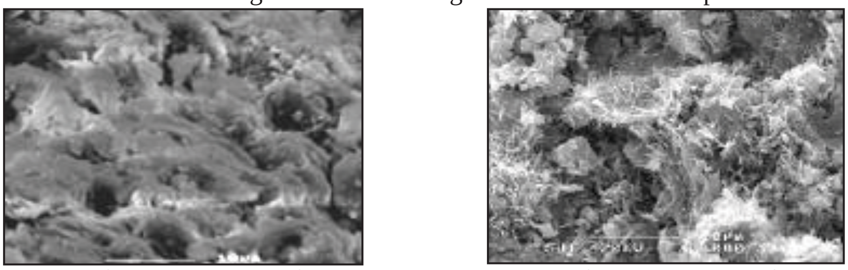
a) D7 (764.00 kPa) | **b)** D14 (793.30 kPa) | **c)** D28 (1227.10 kPa) | **d)** D56 (199.80 kPa)

Figure 5 Sample labelled as H(3)_50OPC_50BA

H (1)_100OPC was found decreasing in strength on D56. The FA, an element of OPC can be easily captured in D7 and D14 samples. Ettringite was also observed at D7 and D14 samples. At D28, ettringite was found fixated to the sample. The ettringite amount has lessened and merely found at D56. The sample was rather uniform. The FA also merely found in D56 sample.

The humic acid may be re-activated after the hydration process has ended, or maybe accumulated due to the decomposition of the peat (microbial activity) was back to active. Theoretically, microorganisms still active in cement mixture (Ismail *et al.*, 1993 and Cwalina, 2008). The same findings were found to all samples that experiencing decrease in strength at D28 and D56.

The findings by Horpibulsuk *et al.* (2012) were similar with current work findings. Horpibulsuk *et al.* (2012), found that after 4 hours of curing (Figure 6(a)), the soil clusters and the pores were covered and filled by the cement gel (hydrated cement). Over time (Figure 6(b)), the hydration products in the pores were clearly observed and the soil–cement clusters tend to be larger because of the growth of cementitious products over time.



a) 4 hours of curing (3000x magnification) b) 7 days of curing(3000x magnification)

Figure 6 SEM photos of 10 % OPC at different curing time (Horpibulsuk, 2012)

CONCLUSION

Ettringite can be said a dominant factor that increase the peat strength. The amount and size of the ettringite increase with the increase of UCS value and vice versa. The loss of the ettringite could be caused by re-activation of microbe in the non-optimum mixture of solidified peat. Study on the effect and impact of optimum mixture may open a new dimension in peat solidification.

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