Tropical Peat Soil Stabilization using Class F Pond Ash from Coal Fired Power Plant

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***Abstract*—**This paper presents the stabilization potential of Class F pond ash (PA) from a coal fired thermal power station on tropical peat soil. Peat or highly organic soils are well known for their high compressibility, natural moisture content, low shear strength and long-term settlement. This study investigates the effect of different amount (i.e., 5, 10, 15 and 20%) of PA on peat soil, collected from Sarawak, Malaysia, mainly compaction and unconfined compressive strength (UCS) properties. The amounts of PA added to the peat soil sample as percentage of the dry peat soil mass. With the increase in PA content, the maximum dry density (MDD) of peat soil increases, while the optimum moisture content (OMC) decreases. The UCS value of the peat soils increases significantly with the increase of PA content and also with curing periods. This improvement on compressive strength of tropical peat soils indicates that PA has the potential to be used as a stabilizer for tropical peat soil. Also, the use of PA in soil stabilization helps in reducing the pond volume and achieving environment friendly as well as a sustainable development of natural resources.

***Keywords*—**Compaction, Peat soil, Pond ash, Stabilization.

I. INTRODUCTION

PEAT soil is classified as highly organic with organic content more than 75% and represents the extreme form of soft soil [1]. Peat soil originates from the disintegration of plant and organic matters. It has typical characteristics which include; high natural moisture content, high compressibility and water holding capacity, low specific gravity, low bearing capacity and medium to low permeability [2]. It is generally considered that peat soil is not suitable for supporting foundations or loadings in its natural state. Consequently, peat soil is susceptible to instability such as localized sinking and slip failure, and massive and long-term settlement when subject to even moderate load increase.

Unfortunately, Sarawak has the largest peat land area in Malaysia which is about 16,500 km^2 or 13% of the state, of which about 90% of the peat is more than 1 m in depth [3]. Figure 1 and 2 (taken by author) shows the ground settlement in Sibu town, Malaysia, which causes a serious problem. According to Duraisamy et al. [4], ground subsidence on peat land in Sibu town has resulted in negative gradients to drainage. This scenario caused further problem where resulting unhealthy water stagnation in many parts of the town and much of the town is also prone to flooding.

Fig. 1 Housing area on low-lying peat soil ground, Jalan Lai Chee, Sibu.

Fig. 2 Ground settlement caused poor drainage and road system in a commercial lot, Sibu.

The utilization of peat land in Malaysia is currently quite low, although construction on them has become increasingly necessary for economic reasons [5]. With the increasing demand of land for developments, it is difficult to avoid construction on this problematic soil like peat. Therefore, it is mandatory to improve the peat ground for any infrastructure on it. Edil [6] summarize various construction methods that can be applied to peat and organic soils, namely: excavation-displacement and replacement; ground improvement and reinforcement to enhance soil strength and stiffness, such as stage construction and preloading, stone columns, piles, vertical drains; or by reducing driving forces by light-weight fill; and deep stabilization method by using chemical admixture such as cement, lime and fly-ash. Several case histories were reported in the literature where chemical

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stabilization methods were successfully used to treat peat soil. Hebib and Farrell [7] showed that the compressive strength of stabilized Irish peats formed by mixing with cement was greatly improved than that of the original peat. Thus, deep soil stabilization technique is often an economically attractive alternative.

In this study, chemical stabilization method was used. The essential feature of chemical stabilization method is to add stabilized materials into the peat soil, and would result in chemical reaction. The chemical stabilizer will interact with the peat soil, and enhances the physical and engineering properties of the original peat soil.

A number of researchers have studied the stabilization of soft soil by cement [7- 10]; cement-ground granulated blast furnace slag [2, 11] and lime-cement [12]. However, only few studies [13-18] discussed on the stabilization by using recycled waste like fly ash. Although a lot of research has been carried out for peat soil stabilization by using admixtures like cement, lime and fly ash; but a very few literature is available on pond ash (PA) utilization particularly its use as a stabilization material. Also, very little data are available from East Malaysia especially in Sarawak. Thus, Pond Ash, a waste byproduct from the burning of coal in thermal power station, was used in this research. The use of PA as a stabilizer material is not only enhances the strength of natural peat soil but also solve the disposal problem of solid waste. Therefore, this research study concentrates on the stabilization of peat soil samples collected from Sarawak, Malaysia with pond ash (PA).

II. Materials and Method

A. Peat soil sample

In the present study, samples of peat soil for this study were collected from Matang, Sarawak. The soil samples were obtained at depth of 0.3 to 0.6 m below the ground surface. Ground water table was found to be about 0.3 m from the ground surface. The high ground water showed that the peat had a very high water retention capacity and the soil samples are assumed to be fully saturated. Visual observation on the peat soil indicated that the soil was dark brown in color.

B. Pond Ash sample

In this study, PA samples were collected from ash disposal field at Sejingkat Thermal Power Plant, Kuching, Sarawak (Figure 3). The PA samples were obtained about 0.3 m from the ground surface. PA is one type of the solid residues by-products produced from power generating plants. Due to aesthetic as well as hygienic environmental impacts, the interest for the plant by-product as a usable construction material such as landfill material has increased considerably in recent year.

C. Stabilized soil specimen preparation

After sampling, the peat soil samples have been first sun-dried for about 2 weeks. Then the sun-dried sample was grinded and allowed to pass through 1.18 mm sieve size.

Fig. 3 PA sample collection at ash disposal site, Sejingkat Thermal Power Plant, Kuching

In order to investigate the effect of addition of PA on the unconfined compressive strength (UCS), a total of four different dosages of PA were chosen (i.e., 5, 10, 15 and 20%). The mixing of peat-PA sample is performed before the standard Proctor test and unconfined compressive strength test. Remolded peat soil sample and PA sample both passed through 1.18 mm sieve size were mixed together. The mixing time takes at least 10 minutes to make sure the PA is distributed well among the peat soil particles.

III. Experimental Investigation

A. Physical properties test

A series of tests is conducted in order to determine the physical or index properties of the natural or original peat soil and PA sample. Physical properties test includes Atterberg Limit, Loss on Ignition, fiber content, particle size distribution, specific gravity, and pH test.

The natural moisture content of collected peat soil sample has been determined by drying the soil sample in an oven at 105°C for 24 hours as according to ASTM D 2974 [19]. To determine liquid limit, cone penetrometer method has been used as per guidelines based on ASTM D 4318 [20]. While, the plastic limit of the peat soil was not possible to determine as the peat soil is cohesionless. The degree of decomposition of the soil sample was assessed by means of the Von Post scale system. The Loss on Ignition test was conducted according to ASTM D 2974 [19]. The wet soil sample is first oven dried at 105°C for 24 hours, then the oven dried sample placed in a muffle furnace at 450°C for 5 hours. The sample was then cooled at room temperature for LOI calculation. Organic content (OC) is calculated according to an equation proposed by Skempton and Petley [21] as follows:

$$OC\ \% = 100 - C\,(100 - N) \quad (1)$$

where, C is the correction factor (=1.04 for temperature 550°C; Edil [6]) and N is the loss on ignition in percent.

The fiber content of the soil sample is determined from dry weight of fibers retained on ASTM sieve no. 100 over the total oven dried mass sample as according to ASTM D 1997-91 [22]. The specific gravity of the peat soil sample is determined by using pyknometer method based on procedures stated in ASTM D 422 63[23]. Lastly, the pH test was conducted according to procedure mentioned in BS 1377-

1990 [24] where 30 gm dry peat soil sample which is passed through 200 μm sieve was mixed with 75ml of distilled water and stirred for a few minutes before left standing overnight. The pH value of the sample was measured on the second day by a digital pH meter.

The major chemical composition of pond ash (PA), calculated as major oxides, was obtained with the X-Ray Fluorescence Spectrophotometer (Shimadzu 1700). The mineralogical composition of PA was determined with an X-Ray diffraction (XRD) spectrometer (Rigaku, Japan) using a graphite monochromator and Cu-Kα radiation. The samples were scanned on a 2θ ranging from 5 to 80° and the Joint Committee on Powder Diffraction Standards (JCPDS) were used to identify the phases.

B. Engineering properties test

The standard Proctor compaction tests were performed on original peat and as well as peat-PA mixtures to determine the effect of PA on the compaction characteristics as according to ASTM D 698-91[25]. Unconfined Compressive Strength (UCS) test was conducted according to the guidelines provided by ASTM D 2166 [26]. The peat-PA samples were mixed with water at their OMC's which obtained from standard Proctor tests. Then, the peat-PA samples were compacted in three layers in a plastic tube of 38 mm internal diameter and 76 mm height. The mixed samples were kept for approximately 24 hours and then the samples were arranged vertically and submerged in a water tank for curing. A total 60 stabilized peat specimens of different mix design were prepared and cured for 7, 14, 28 and 120 days before tested for UCS. A rate of strain of 1.27 mm/min has been maintained throughout the tests. For the sake of consistent results, a minimum of three samples have been tested.

IV. RESULTS AND DISCUSSION

Table 1 shows different physical properties of the peat soil and PA sample used in this study. From Table 1, it can be observed that peat soil samples fall in the category with degree of humification H4 (Sapric) according to the Von Post scale [27]. The Organic content (OC) of the soil sample tested in this study is more than 75%, that categorized as peat soil as per ASTM D 2607-69 [28]. Table 1 shows that natural moisture or water content of the peat is quite high i.e., around 599% and organic content around 90%. The specific gravity (G_s) value of peat is very low because it contains a lot of fiber i.e., around 79%. According to Den Haan [29], the specific gravity of organic or peat is affected by the organic constituents; e.g., cellulose and lignin which are having lower specific gravity, approximately 1.58 and 1.40, which causes the reduction in specific gravity of peat. Consequently, the specific gravity (G_s) of the peat depends on the organic and fiber constituents. The liquid limit (LL) value is also higher because this sample contains more fiber or organic content and thus it has high water absorption capacity. Peat sample tested in this study are non-plastic. The results also show that peat has lower pH value and acidic. The pH value for fly ash sample is higher than 7 and alkaline.

TABLE I
PHYSICAL PROPERTIES OF PEAT SOIL AND POND ASH (PA)

Physical properties	Peat soil	Pond Ash (PA)
Natural moisture content (w) (%)	598.5	–
Degree of decomposition	H4	–
Fiber content (%)	79.33	–
Loss on Ignition (%)	90.84	4.99
Organic content (%)	90.47	–
Linear shrinkage (%)	5.35	–
Liquid limit (%)	200.2	27.24
Plastic limit (%)	Non plastic	22.47
Specific gravity (G_s)	1.21	2.01
pH	3.75	8.15

TABLE II
CHEMICAL COMPOSITION OF POND ASH (PA)

Major element	Percentage
SiO_2	56.8
Al_2O_3	23.5
Fe_2O_3	7.87
MgO	2.16
CaO	2.41
TiO_2	0.13
SO_3	0.49
P_2O_5	0.31
Alkalis ($Na_2O + K_2O$)	(3.33 + 3.02)
$SiO_2 + Al_2O_3 + Fe_2O_3$	88.17

According to the ASTM D 618-94 [30], the pond ash (PA) sample used in this study; falls in the category of Class F. The mineralogical composition of the pond ash sample was mainly quartz, mullite, hematite and calcite.

The peat soil sample compacted in three layers with 2.5 kg hammer and 25 numbers of blows to each layers of soil. From the specific gravity test, the peat has a specific gravity (G_s) value of 1.21. However, it has a floating behavior on water at the beginning of the peat-PA mixing process was carried out. This is because of tropical peat soil is rich of fiber, deadwood and leaves. In order to find the maximum dry density (MDD)-optimum moisture content (OMC) relation, a graph is plotted based on the results from laboratory tests. From MDD-OMC curves (Figure 4), optimum moisture content was found for each set of peat-PA mixtures. As comparison of results shows that, as the PA content of the mixture is increased, the MDD increases, and OMC decreases. The addition of PA has an influence in increasing physical strength of natural peat soils. These OMC has been used as a control measure of moisture content in preparation of UCS test specimens later on.

Figures 5 and 6 show 28 day compressive strength values for stabilized peat with PA. The stabilized peat specimens showed a significant increment in UCS for all the stabilized peat as compared to the original remoulded peat, which amount 77.6 kPa only. There was a tendency to double the strength for peat and PA mixtures to 153.9 kPa, with addition of 20% of PA.

Figure 7 shows the influence of curing period on the UCS of the stabilized peat soil samples. It is clearly shows that higher strength was obtained from samples that had been cured for 28 days as compared with 7 and 14 days. From the Fig. 7, it can also be noticed that the UCS value of the stabilized peat-PA specimens increased while moisture content of the specimens decreased. It is believed that reduction of moisture content in the stabilized peat-PA specimens as compared to original peat showed that the air void of the original peat was filled up by small particle from PA sample and may be due to a significant amount of pore water was consumed by PA to form the cementing products during the curing-hydration process.

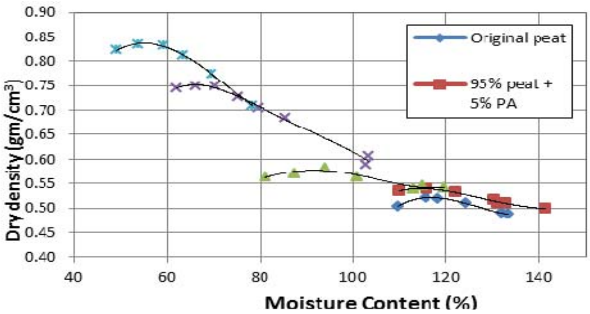

Fig. 4 MDD-OMC curves obtained from standard Proctor tests

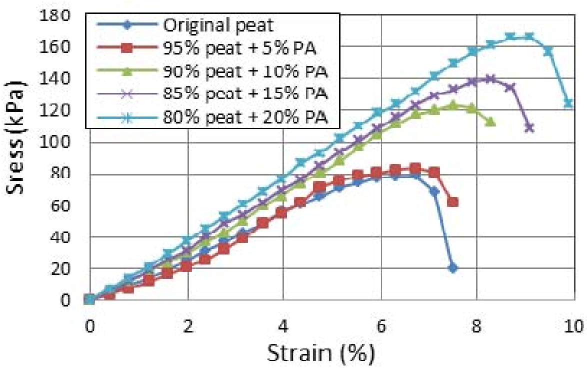

Fig. 5 Stress-strain curves for original peat and as well as a mixture of peat and different amounts of PA that obtained from UCS tests after 28 days

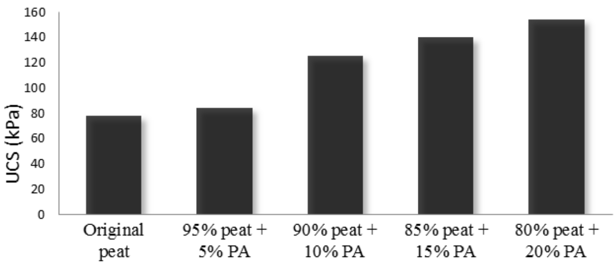

Fig. 6 Comparison between average UCS of original peat and stabilized peat-PA specimens (28 days)

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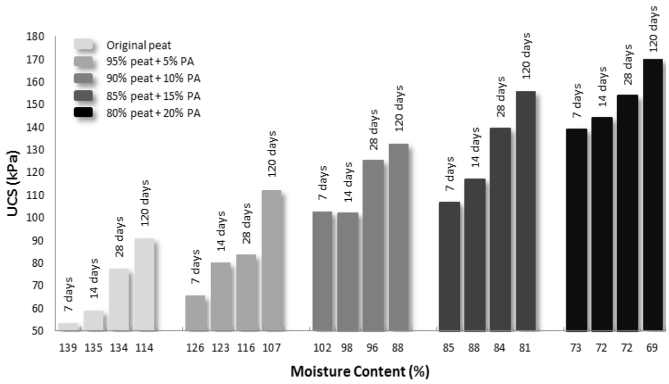

Fig. 7 Comparison between average UCS of original peat and stabilized peat-PA specimens

V. Conclusion

The following conclusion can be drawn from the laboratory investigation conducted in this study.

i. The result of standard Proctor test shows that the MDD for peat-PA sample is found to increase while the OMC is found to decrease with increase in the PA content.

ii. UCS test shows the compressive strength for peat and PA mixed sample increases with the increase of percentage of PA (i.e., 5%, 10%, 15% and 20%) added to the original peat sample and the compressive strength of peat-PA sample increases almost doubled from original peat soil with addition of 20% PA of weight of peat soil.

iii. The UCS value for stabilized peat soils with addition of 20% PA by weight after 28 curing days yielded the highest average compressive strength of 153.9 kPa among the stabilized peat-PA soil samples compare to original tropical peat soil at 77.6 kPa.

iv. The result of UCS test increases significantly with curing period (i.e., 7, 14, 28 and 120 days) for all addition percentage of PA in this study.

From the results of this study it can be concluded that addition of the pond ash (PA) can improve the engineering properties of tropical peat soils. Use of PA not only enhances the strength of natural peat soil, it will also introduce a sustainable development of natural resources by solving the disposal problem of waste byproduct from the thermal power station.

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