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Strength of Peat Treated with Peat Ash

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ABSTRACT: For construction on peaty ground, shallow peat layer is normally replaced by stiffer soil. The replaced peat may be burned into peat ash to reduce the volume. In this study, the potential of peat ash in improving the shear strength of peat was investigated using unconfined compression tests. It is found that peat ash has insignificant effect to the 7 days strength of peat. Peat ash increases the strength of peat by about 50% at Day 14. At Day 28 and 56, the effect of peat ash to strength of peat is comparable to the effect of cement, whereas the effect of cement is about 10% larger than that of peat ash. It is found that effect of peat ash in strengthening the peat become less significant with the present of cement.

KEYWORDS: Peat, Peat ash, Cement, Unconfined compressive strength

1. INTRODUCTION

Peat, which is high in organic content and water content, normally has low bearing capacity and high in compressibility. For construction on a shallow peat layer, the peat layer is normally replaced by a stiff soil. The peat is dumped to a dump site. The dumped peat eventually will decompose and greenhouse gas shall be emitted. It would be a better solution if the dumped peat could be burned into ash under a control process. The volume of dumped peat will be reduced significant by burning it into peat ash. The peat ash may pose commercial value if it is useful in improving the strength of peat.

Researches about the usage of peat ash for engineering purposes are rare. Huttunen and Kujala (2001) stated that peat ash is suitable to be used as filler material in pavement construction and landfill cover structures. Juvankoski et al. (2001) reported that cement stabilized peat ash has adequate compressive strength and stiffness for road construction. Heikkinen (1986) reported that peat ash has influence on the compressive strength of concrete. Besides, peat ash had been used by Mousavi and Wong (2015) to replace portion of cement used in treating clay. However, the effects of peat ash on the strength of peat remain unknown. In revealing the potential of peat in improving strength of peat, a study has been conducted to investigate the effect of peat ash to unconfined compressive strength of peat.

2. EXPERIMENTAL PROGRAM, MATERIAL AND TEST PROCEDURES

2.1 Experimental Program

Four series of unconfined compression tests were carried out to investigate the effect of peat ash to unconfined compressive strength of peat. Series A consists of peat only subjected to curing time of 7, 14, 28 and 56 days. This served as control to evaluate the effect of peat ash to unconfined compressive strength of peat. Test Series B determines the effect of cement to unconfined compressive strength of peat subjected to curing time of 7, 14, 28 and 56 days. Test Series B could be used to evaluate the effectiveness of cement in improving the strength of peat. Ordinary Portland Cement was used in this series of test. Test Series C is used to investigate the effect of peat ash to unconfined compressive strength of peat. Comparing with Test Series B, effectiveness of peat ash in improving the strength of peat shall be assessed. Test Series D could be used to evaluate the interaction between cement and peat ash in improving strength of peat. The details of the test plan are summarized in Table 1.

2.2 Material

Peat used in this study was collected during widening of Kuala Baram By Pass Road, Miri, Sarawak, Malaysia. The peat is dark brown in color and can be classified as H7 of the Von Post scale. It is an amorphous peat. The peat has moisture content ranged from 289 to 324%, organic content of 93 to 97%. Peat ash is produced by first drying the peat under sunlight for 12 hours before drying in oven at 110°C. The oven-dried peat is then burned in ash in a furnace at 440°C. X-ray fluorescence (XRF) test was conducted to obtain the chemical composition of the peat ash as shown in Table 2. The peat ash consists of 16% of silica, 5% of aluminum oxide and 15% of iron oxide. The peat ash also consists of 11% of calcium oxide. Ordinary Portland Cement (OPC) of Grade 42.5 was used in this study. The cement has particle density of 2950 kg/m^3 and specific gravity of 3.14 as reported by Nagaratnam et al. (2016). Chemical composition of OPC obtained from Nagaratnam et al. (2016) is shown in Table 2.

Table 1 Test Plan

Test Series	Cement (%)	Peat Ash (%)	Curing Time (Day)
A	0	0	7,14,28,56
B	20	0	7,14,28,56
C	0	20	7,14,28,56
D	20	20	7,14,28,56

Table 2 Chemical Composition of Ordinary Portland Cement and Peat Ash

Oxides	Cement[1] (%)	Peat Ash (%)
SiO_2	20.0	15.79
Al_2O_3	5.2	5.33
Fe_2O_3	3.3	15.04
CaO	63.2	10.67
MgO	0.8	1.60
K_2O	-	1.44
Na_2O	-	0.15
SO_3	2.4	4.89

Note:-
[1]Chemical composition for cement is obtained from Nagaratnam et al. (2016)

2.3 Sample Preparation

For Test Series B, the peat was mixed with 20% of cement in a mixer for 2 minutes. The percentage of cement was measured based on the dry weight of the peat. The dry weight was estimated based on the moisture content of the peat. After mixing the peat and cement thoroughly, the peat was compacted in three layers in a mold. Each layer was compacted for 10 to 15 times. After the compaction, the sample was extruded from the mold and cured. Same specimen preparation procedures were adopted for peat mixed with peat ash as well as peat mixed with peat ash and cement.

2.4 Test Procedures

Unconfined compression test apparatus was used to obtain unconfined compressive strength of peat. Figure 1 shows an unconfined compression test for peat mixed with peat ash. Each specimen was compressed at a rate of approximately 6 mm per minute. The test was stopped when the axial strain reached 30%. The maximum compressive stress is taken as unconfined compressive strength of peat.

Figure 1 Unconfined Compression Test for Peat Mixed with Peat Ash

3. RESULTS AND DISCUSSIONS

In this section, the effect of peat ash to unconfined compressive stress of peat at different curing time are described and discussed.

3.1 Effect of Curing Time to Unconfined Compressive Stress of Peat

Figure 2 shows the variation of unconfined compressive stress with axial strain for peat subjected to curing time of 7, 14, 28 and 56 days. At Day 7, the unconfined compressive stress increase with axial strain in a reducing rate and reaches a steady state with maximum compressive stress of 6.8kPa. As expected, variation of compressive stress with axial strain are similar for peat specimens cured up to 56 days, indicating no significant cementation is occurred. This also shows the consistency of the results using manually operated unconfined compression test apparatus.

3.2 Effect of Peat Ash to Unconfined Compressive Stress of Peat at Day 7

Figure 3 shows unconfined compressive stress for untreated and treated peat cured for 7 days. The unconfined compressive strength for untreated peat is 6.8kPa at Day 7. Variation of unconfined compression stresses with axial strain for peat mixed with peat ash is similar to that for untreated peat. Unconfined compressive strength for peat mixed with peat ash is 7.8kPa, which is close to the unconfined compressive strength of untreated peat. These imply that peat ash has insignificant effect to compressive stress of peat at Day 7. Calcium oxide in the peat ash may react with water to form calcium hydroxide. The calcium hydroxide may increase the pH of peat water but not contributing to strength increment. For axial strain up to 30%, the compressive stresses for peat treated with cement are about double of the compressive stress for untreated peat. The stiffer response indicates that stiffness of peat treated with cement is more than two times of the stiffness for untreated peat. Unconfined compressive strength for peat treated with cement is 12.8kPa. It is about 88% larger than the unconfined compressive strength for untreated peat. For peat treated with cement and peat ash, the stress increases in a slower rate as compared with that for peat mixed with cement. By adding additional 20% of peat ash, it reduced the stiffness of peat. The peat ash may act as weak filler and reduce the effectiveness of cement in improving the stiffness of the peat. The unconfined compressive strength of 13.3kPa for peat treated with cement and peat ash is only marginally (about 4%) larger than that for peat treated with cement.

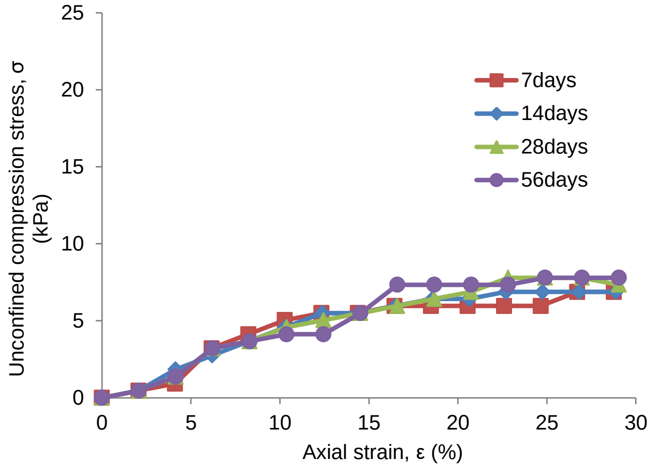

Figure 2 Unconfined Compressive Stress for Peat at Different Curing Time

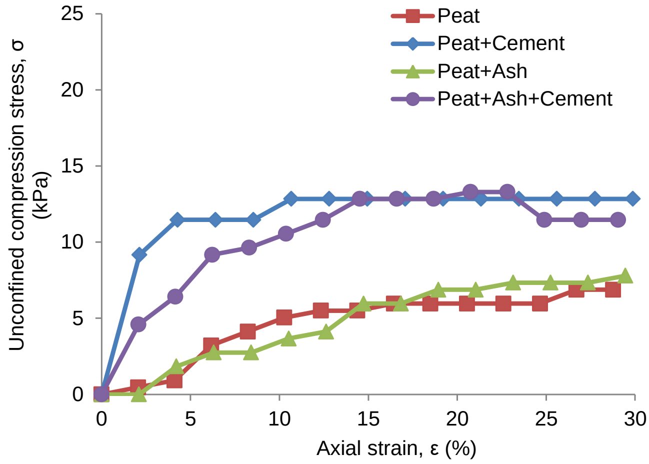

Figure 3 Unconfined Compressive Stress for Untreated and Treated Peat at Day 7

3.3 Effect of Peat Ash to Unconfined Compressive Stress of Peat at Day 14

Figure 4 shows the unconfined compression stress for untreated and treated peat at Day 14. Unconfined compressive strength for untreated peat is 6.8kPa. Unconfined compressive stresses for peat treated with peat ash are slightly higher than those for untreated peat for axial strain up to 10%. For axial strain larger than 10%, the unconfined compressive stress is about 50% larger than that for untreated peat. Unconfined compressive strength for peat treated with peat ash is 10.5kPa. Peat ash improves the unconfined compressive strength of peat by 54% at the end of 14 days. The improvement may be attributed to the pozzolanic reactions between alumina, silica or iron oxide with calcium hydroxide. The pozzolanic reactions shall produce calcium aluminate silicate hydrate or calcium silicate hydrate (Janz and Johansson, 2002) which may bind the organic matter and result in strength increment. Besides, the precipitated calcium humate might also contribute to the increment of strength. According to Bonomaluwa and Palutnicowa (1987) as cited by Chen and Wang (2006), humic acid may react with calcium hydroxide to form insoluble calcium humate. Besides, ion calcium may bridge the humic particles (Swift, 1996). Unconfined compressive stress for peat treated with cement shows a stiffer response as compared to untreated peat as well as peat treated with peat ash. The unconfined compressive stresses for peat treated with cement are more than double of the unconfined compressive stresses for untreated peat. Unconfined compressive strength for peat treated with cement is 16.9kPa. Compressive stress of peat treated with peat ash and cement is close to that for peat treated with cement. The response at axial strain less than 10% is softer as compared to that for peat treated with cement only. The 14 days unconfined compressive strength for peat treated with cement and peat ash is 17.9kPa, which is about 6% higher than the unconfined compressive strength for peat treated with cement. It appears that adding peat ash to peat improves the compressive strength of peat significantly. However, effect of peat ash in strengthening the peat become insignificant with the present of cement.

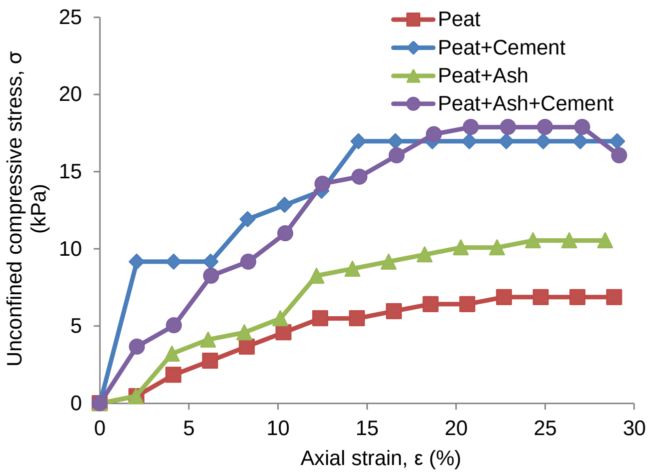

Figure 4 Unconfined Compressive Stress for Untreated and Treated Peat at Day 14

At the end of 14 days of curing time, it was observed that there was white mold in the specimen for peat treated with peat ash as shown in Figure 1. The white mold was also observed in the specimen for peat treated with peat ash and cement. The white mold was started to form after 10 days of curing. White mold was not observed on the surface of specimens for both untreated peat and peat treated with cement. It appears that the present of peat ash in peat creating a favorable environment for the activity of microorganisms. It is unclear if the white mold might link to the increase in strength.

3.4 Effect of Peat Ash to Unconfined Compressive Stress of Peat at Day 28

Figure 5 illustrates unconfined compressive stress for untreated and treated peat at Day 28. Unconfined compressive strength for untreated peat is 7.8 kPa. Unconfined compressive stresses for peat treated with peat ash are about double of those for untreated peat. The compressive stresses are slightly lower than the compressive stresses for peat treated with cement. The rate of increment of compressive stresses for peat treated with peat ash is lower than that for peat treated with cement. In other words, the stiffness of peat treated with peat ash is lower than stiffness of peat with cement.

The 28 days unconfined compressive strength are 15.6 kPa and 17.4 kPa respectively for peat treated for peat treated with peat ash and peat treated with cement. The compressive strength for peat treated with peat ash and peat treated with cement is 200% and 223% respectively of the compressive strength of untreated peat. This implies that the cementitious effect due to the present of peat ash and cement is significant, though the effect for peat ash is lower than cement. The unconfined compressive strength for peat treated with cement is about 12% larger than compressive strength for peat treated with peat ash. The unconfined compressive strength for peat treated with peat ash and cement is 18.7kPa. There is about 8% increase in strength as compared to compressive strength of peat treated with cement. In other words, peat ash does not increase the compressive strength of peat significantly with the present of cement.

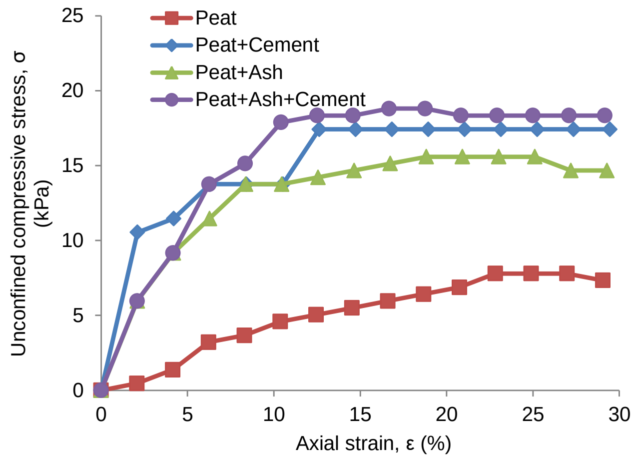

Figure 5 Unconfined Compressive Stress for Untreated and Treated Peat at Day 28

3.5 Effect of Peat Ash to Unconfined Compressive Stress of Peat at Day 56

Figure 6 shows unconfined compressive stress for untreated and treated peat after curing for 56 days. The 56 days unconfined compressive strength for untreated peat is 7.8kPa. The compressive stresses for peat treated with peat ash are comparable to those for peat treated with cement as well as peat treated with peat ash and cement. Unconfined compressive strength is 18.3 kPa, 20.2 kPa and 23.0 kPa respectively for peat treated with peat ash, cement as well as peat ash and cement.

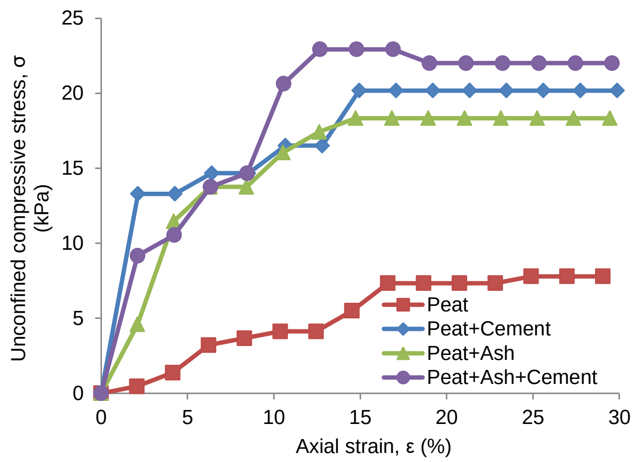

Figure 6 Unconfined Compressive Stress for Untreated and Treated Peat at Day 56

The increase in compressive strength is 235%, 259% and 295% respectively for peat treated with peat ash, cement as well as peat ash and cement. Compressive strength for peat treated with cement is only 10% larger than compressive strength for peat treated with peat ash. Peat ash may be used to replace the cement in treating peat. The dumped peat at site may be burned to peat ash and used to improve the compressive strength of peat. Compressive strength for peat treated with peat ash and cement is 14% larger than the compressive strength for peat treated with cement. In other words, by adding 20% of peat ash to peat with the present of cement does not improve the compressive strength significantly.

3.6 Effect of Peat Ash to Undrained Shear Strength of Peat with Different Curing Period

Figure 7 shows undrained shear strength for untreated and treated peat at different curing time. Half of the unconfined compressive strength of peat is taken as undrained shear strength. Undrained shear strength for untreated peat is 3.4kPa at Day 7 and Day 14. The undrained shear strength increases slightly to 3.9kPa at Day 28 and Day 56.

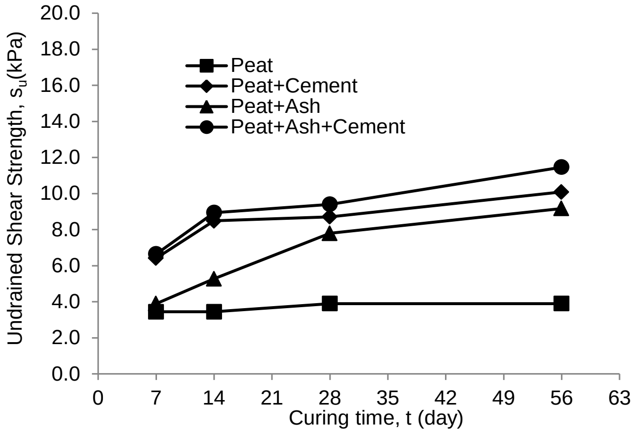

Figure 7 Undrained Shear Strength of Peat Treated with Peat Ash and Cement

For peat treated with cement, the undrained shear strength at Day 7 is 6.4kPa, which is 88% larger that the shear strength for untreated peat. At Day 14, the undrained shear strength for peat treated with cement increases to 8.5kPa. It is 150% larger than the shear strength of untreated peat. At Day 28, the undrained shear strength is 8.7kPa. The shear strength increases to 10.1kPa at Day 56. It increases the shear strength of untreated peat by 159%. The shear strength for peat treated with cement increases significantly from Day 7 to Day 14. It increases marginally from Day 14 to Day 28. From Day 28 to Day 56, the shear strength increase by 16%. Hydration of cement occurs rapidly, 60% of the cement hydrated after 7 days and 90% of the cemented hydrated after 90 days (Janz and Johansson,2002). In this study, it is observed that about 63% of Day 56 strength achieved at Day 7. From Day 14 to Day 56, there is about 20% increase in strength, this may due to slow hydration rate and no significant amount of pozzolanic material to react with calcium hydroxide.

Undrained shear strength for peat treated with peat ash is 3.9kPa at Day 7. At Day 7, the shear strength of peat treated with peat ash is only marginally larger than the strength for untreated peat. The shear strength of peat treated with peat ash increases linearly with curing time until Day 28. The rate becomes lower after Day 28. The shear strength for peat treated with peat ash are 5.3kPa, 7.8kPa and 9.2kPa respectively at 14, 28 and 56 days. Peat ash increases the shear strength of peat by 56%, 100% and 136% respectively at 14, 28 and 56 days. At Day 28 and Day 56, the shear strength of peat treated with peat ash is about 10% smaller than the shear strength of peat treated with cement.

For peat treated with peat ash and cement, the undrained shear strength is 6.6kPa at Day 7. The undrained shear strength increases to 8.9kPa at Day 14. The shear strength at Day 7 and 14 is only marginally larger than that for peat treated with cement. From Day 7 to Day 14, the shear strength increases by 35%. At Day 28, the shear strength is 9.4kPa. There is an increment of 5% in shear strength from Day 14 to Day 28. It is only 8% larger than the shear strength of peat treated with cement. The shear strength is 11.5kPa at Day 56. It is about 14% larger than the shear strength of peat treated with cement. Since the reaction is mainly due to pozzolanic reaction as described previously, this might imply that the reaction has negligible contribution to the strength of peat up to 14 days. The reaction might contribute 8 and 14% respectively at Day 28 and 56. It might imply that the precipitation of calcium humate while using peat ash to treat the peat may contribute to the shear strength significantly and result in only 10% lower in shear strength as compared with peat treated with cement at Day 28 and 56.

4. CONCLUSIONS

A study has been conducted to study the effects of peat ash to the strength of peat. Peat ash has insignificant effect to the 7 days strength of peat. Peat ash reduces the stiffness of peat treated with cement after curing for 7 days. Peat ash increases the strength of peat by about 50% at Day 14. At Day 28 and 56, the effect of peat ash to strength of peat is comparable to the effects of cement, whereas the effect of cement is about 10% larger than that of peat ash. It is found that effect of peat ash in strengthening the peat become less significant with the present of cement.

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