THE SUITABILITY OF POFA (PALM OIL FUEL ASH) TREATED CLAY SOIL FOR LINER MATERIAL IN SANITARY LANDFILL

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Abstract
Liner is the most important part of waste containment systems such as landfills. It serves as a hydraulic barrier to control or restrict the migration of contaminant/leachate from the landfill into the environment. Many liner systems have been developed and used such as compacted clay liners are widely used because of its cost effectiveness low permeability, large attenuation capacity and resistance to damage and puncture. The target from this project is to reduce the permeability of compacted POFA treated clay liner until k value at least 1 x 10^{-7} cm/s (Daniel and Benson, 1990; Daniel 1993; Mohamed and Antia, 1998). The main purpose of this study is to determine the potential use of POFA as soil stabilizer for liner landfill construction. The laboratory tests were conducted on the clay soil properties, permeability, linear shrinkage, unconfined compression test for origin soil, direct shear test for admixture sample. The test results will compare with those recommended by researchers for evaluation suitability. The engineering properties of clayey soils may need to be improved to make them suitable for liner construction. Stabilized mixture of POFA-clay improve the shear strength as well as permeability, the permeability were reduced until 4.222 x 10^{-10} m/s. 14 and 16 percent of POFA through sieve 300 µm and 425 µm are suitable to used as admixture to sample with the shrinkage limit ≤ 4%. Only soil admixture with 14% of POFA (300µm) has the strength of 225 kPa. Thus, the soil with 14% of POFA is suitable for liner material of sanitary landfill.

Key words: *Clay soil, POFA, Compaction, Permeability, Direct Shear Test, Shrinkage Limit*

1.0 INTRODUCTION

The main long term emissions from landfills are leachate and gas. While the gas phase can be controlled to a high degree and environmental effects are limited, leachate control is much more difficult.

Leachate is the medium by which soluble materials inside a landfill may subsequently be transported into the environment. In order to avoid uncontrolled release into the environment, landfills are lined and the leachate is collected and treated. The main problem is that of designing and building liners which retain leachate at the landfill base and avoid leachate production through elimination of water infiltration from outside. To control this problem, sanitary landfill have utilized several types of liner materials such as compacted natural clay (soil) liner, bentonite clay, asphalt, geomembrane, geocomposites clay liner. The main purpose of using these materials is to prevent the migration of polluted leachate into the surrounding area.

Soil stabilization always involves certain mechanical treatment of the natural soil or remixing the natural soil with admixtures followed by compaction of the mixture (M.A. Ansary, 2003). Some researchers Nagaraj (1964), Broms and Boman (1979), El-Rawi & Awad (1981), Locat (1990), Tuncer & Basma (1991), Nicholson *et. al* (1994) and Rao *et. al*(2001) have used different additives such as cement, lime, fly ash and bitumen. The objective of these admixtures is to provide artificial cementation thus increasing the strength and reducing deformability. The use of lime has increased as the stabilizing material, in the past 30 years, for naturally occur fine-grained clay soils (Hamid Nikraz, 2003).

This study is focus on POFA, which was used as stabilization minerals to be mixed with the disturbed sample of clay. A further reaction can happen between clay minerals and POFA and depends on the amount of POFA added and reactivity of the clay. The stabilization was to decrease the permeability of the soil. The laboratory testing was carried in order to study the effect of inclusion of POFA on the engineering behavior of clay soil in reducing its permeability.

The main objectives of this project are to find out the Suitability of POFA Treated Clay Soil for Liner Material in Sanitary Landfill. The target from this project is to reduce the hydraulic conductivity of compacted POFA treated clay liner until k value at least 1 x 10^{-7} cm/s (Daniel and Benson, 1990; Daniel 1993; Mohamed and Antia, 1998).

2.0 STATEMENT OF PROBLEM

There are two general problems regarding landfills; leachate and methane gas. Leachate is harmful and can contaminate soil and ground water system underneath the landfill sites. To control this problem, sanitary (secured) landfills have utilized several types materials such as compacted natural clay (soil) liner, bentonite clay, asphalt, geomembrane and geosynthetic clay liner. The main purpose of using these materials is to prevent the migration of polluted leachate into the surrounding area. (Wan Zuhairi et.al, 2004).

The material placed in a waste disposal site (landfill) is very mixed in composition and suffers from organic decomposition and psycho-chemical breakdown after deposition. Liquids are usually present in wastes and rainwater enters during land filling process. This water promotes biological activity and acts as a transport mechanism for contaminants that dissolve in the water. If the polluted water (leachate) is allowed to enter the underlying groundwater, contaminations result. Carbon dioxide, methane and hydrogen sulphide are also produced during the decomposition process. (Sarsby R, (2000)

The installed liners must have sufficiently low permeability to all constituent transmission through the lining system does not pose a threat to human health or the environment. (Hendry and Paul, 1994)

By recycling of POFA it is on a way helping our country in solving the problem of excessive emission of palm oil waste.

3.0 OBJECTIVES

The objectives of this study are:

a) To analyse the physical-chemical characteristic of POFA-clay mixture.
b) To determine the optimum percentage of POFA-clay mixture that produce the greatest strength.
c) To compare the result on the permeability and shrinkage limit with the previous result.

4.0 SCOPE OF STUDY

The scope of this study is to focus on the permeability, strength and shrinkage limit of clay soil when mixed with POFA. All clay-POFA samples are prepared by using 425 μm and 300 μm size of POFA. Analyses according to standard specification for construct sanitary liner; Soil specification (Daniel, 1993), Permeability (Daniel 1993a; Mohamed et al 1998), Compressive strength (Daniel & Wu 1993) and shrinkage limit (Daniel & WU 1993; Tay et al. 2001).

4.1 MATERIAL

The soil used for this study was marine clay soil. The soil was obtained from RECESS is located in KUiTTHO's campus in Parit Raja, Batu Pahat, Johor, Malaysia. The undisturbed soil sample was taken from the site by using thin wall samplers for UCS test.

The additive material used in this research is palm-oil fuel ash or (POFA). POFA is farm ashes produced from the remains of the palm oil bunch burned in a furnace. According to Awal and Husin (1997), POFA is a waste material obtained by burning of palm oil husk and shell as fuel in palm oil mill boilers. POFA has pozzalanic characteristics, which enables it to be a stabilizer. As the fineness of the fuel ash increases, the pozzolanic activity also increases (Meyers et al. 1976).

In this study, the supply of POFA will be from the palm oil factory in Felda Semenchu, Kota Tinggi, in state of Johore. POFA was crushed in L.A Abrasion machine with full cycle to produce finer dust. The POFA were sieved through 425μm and 300μm passing sieve to removed foreign material. Before sieve, the POFA should stay at air dry to make easier to sieve. The through 425μm passing sieved of POFA were tested for specific gravity to make comparison to previous research. The POFA percentages for this study were 8 %, 10 %, 12 %, 14 %, 16%, 18% and 20%.

4.2 METHOD

The chemical and physical test such as pH test, Atterberg limit, moisture content, particle size distribution and specific gravity of soil were performed according to British Standard (BS 1377:1990). The pH test to identify the pH value of soil with and without additives. The particle size determination of the soil was carried out by CILAS 1180 machine.

Compaction of the soils is the process that brings about an increase in soil density, with a consequent reduction of air-voids volume but with no change in the volume of water. This test were conducted using standard proctor test (BS 1377 : Part 4 : 1990 : 3.3), using 2.5kg rammer with 27 blows per layer is used. The purpose doing this testing is to get optimum moisture content and maximum dry density for clay soil and every mixing sample with their percentage 95% from their maximum dry density (based on JKR standard) to make the sample for direct shear test. The optimum moisture content is used for permeability test.

The permeability of a soil is a measure of its capacity to allow the flow of a fluid through it using (BS 1377: Part2:1990). The optimum moisture content from compaction test was used as percent of water content. Processes soils were compacted with standard within the mould. Then the moulds were placed in a sink, while the air bleed valve was opened so that the water could back up through the specimen. This procedure was applied to ensure saturation of the samples and to eliminate entrapped air. **Figure 1** show the falling head apparatus.

Figure 1: Laboratory falling-head test equipment.

The linear shrinkage is found by determining the change in length of a bar sample of soil when it dries out. This method is based BS 1377: Part 2: 1990: 6.5. The soil passed through 425µm was prepared. The changes of dimension were measure before and after 24 hour in oven.

Clay soil strength were determined using unconfined compression test. The strength of admixture soil sample with percentage of POFA were determined using direct shear. Test in accordance the BS 1377: Part 2 procedures. The test was formed on square specimens having dimension 60mm x 60mm x 20mm. The samples were tested in direct shear machine and will be compressed with three different loads that 1.25kg, 2.50kg, and 3.75kg. All the data that collected is analyze using ELE International analysis. The parameter that obtained from the analysis is cohesion (C) and angle of shear resistance (Ø) value. **Figure 2** show the direct shear test.

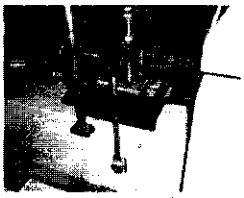

Figure 2: Laboratory direct shear test equipment.

5.0 RESULT AND DISCUSSION

5.1 Index Properties Soil

The clay with no admixture of POFA was tested to examined its physical properties. These are shown in **Table 1.**

Physical properties	Test result
Natural moisture content (%)	48
Liquid Limit (LL) (%)	67.0
Plastic Limit (PL) (%)	27.0
Plasticity Index (%)	40.0
Optimum moisture content (%)	16.5
Sand particles (%)	4.26
Silt particles (%)	94.41
Clay particles (%)	1.33
Specific gravity	2.69

Table 1: Physical characteristic of clay sample (0% POFA)

In the British System, the soil can be grouped under CH-MH (inorganic clays and silts of high plasticity. Physical properties influence the permeability performance of liner . The acceptance criteria for the soil material for landfill liner should meet the following (DOE 1995; CIRIA 1996; Murray 1992; NRA 1992); permeability of 1 x 10-9 m/s; minimum clay content of 10%, liquid Limit greater than 90 and plasticity index not greater than 65.

5.2 Specific Gravity of POFA

The specific gravity for the POFA used is 2.29. From the previous researcher, it shows that the range of the specific gravity of POFA in 2.22-2.64.

Researcher	Specific gravity
Bukit Lawang (Salihuddin, 1991)	2.64
Banting (Salihuddin,1991)	2.40
Bukit Lawang (A.S.M. Abdul Awal & M. Warid Hussein,1997)	2.22
Wan Aishah Wan Hashim (2006)	2.40

Table 2: Specific gravity from previous researcher

5.3 pH TEST

The soil has a pH of 3.69. The pH affects the effectiveness of POFA stabilization. The POFA stabilization was more effective with a high pH (alkali condition) as it gave strength. The pH of the soil changed after the addition with various percentage of POFA. The pH value in Figure 3 increased gradually. **Figure 3** show that pH value became higher with higher percentage of POFA. The 300 µm passing sieved POFA have higher pH than 300 µm passing sieved. **Appendix A** show the data of pH in every percentage applied.

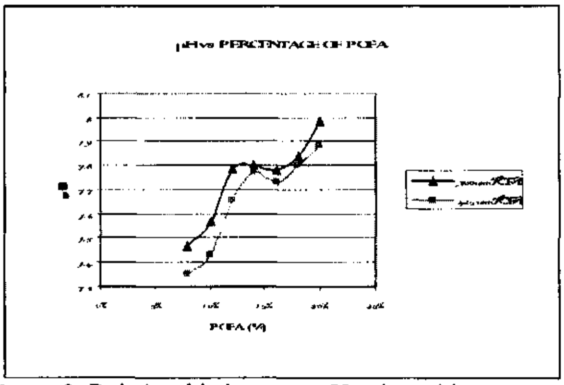

Figure 3: Relationship between pH value with percentage of POFA.

5.4 COMPACTION TEST

Figure 4(a) and 4(b) shows the compaction soil curve. From the graph, the optimum moisture content and maximum dry density of the soil are 16.5% and 1600 kg/m^3, but decreased with percentage of POFA content. The maximum dry density and optimum moisture content of admixture sample soil is in the range (1800 – 1900) kg/m^3 and (24 – 27) %. Relatively, higher moisture content will decrease the dry density of soil. Optimum moisture content will made lubrication on soil and improve workability of soil.

Appendix B shows the maximum dry density and the optimum moisture content of admixture sample.

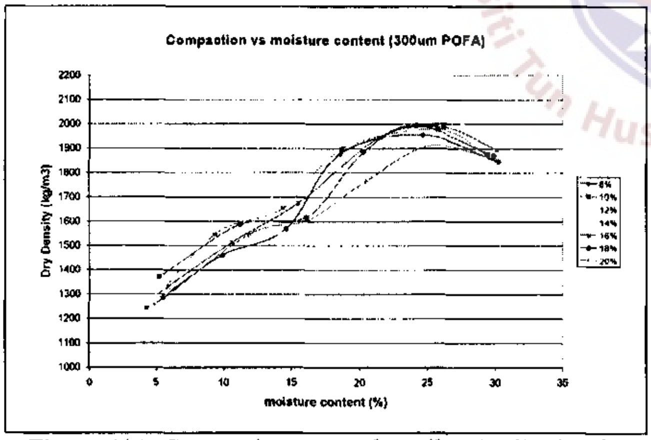

Figure 4(a): Compaction curves for soil and soil + % of POFA (300µm)

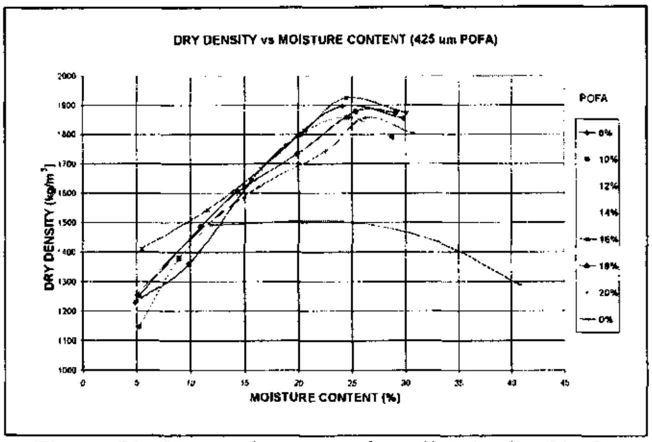

Figure (b): Compaction curves for soil and soil + % of POFA (425µm)

5.5 PERMEABILITY

The permeability was determined by using a falling head permeameter. The soil compacted at its optimum moisture content. Soils compacted at wet of optimum water content tend to have lower conductivity. **Appendix C** shows the permeability of soil and mixing with POFA. **Figure 5** shows that the POFA (300µm) posses low permeability. The highest value of permeability is 5.232 x 10^{-10} m/s occurred at soil POFA mixture with 12% POFA content through 425 µm passing sieve might be caused of its lower dry density where the void ratio is high. It is easier for water to move through bigger spaces. While the lowest value of permeability is 4.222 x 10^{-10}occurred 20% POFA content through 300 µm passing sieve caused of its higher dry density where the void ratio is low. Thus, soils with large voids are more permeable than those whose voids are small. The permeability is the key parameter for most soil liners and covers, thus grate attention generally focused on ensuring that low hydraulic conductivity is achieved.

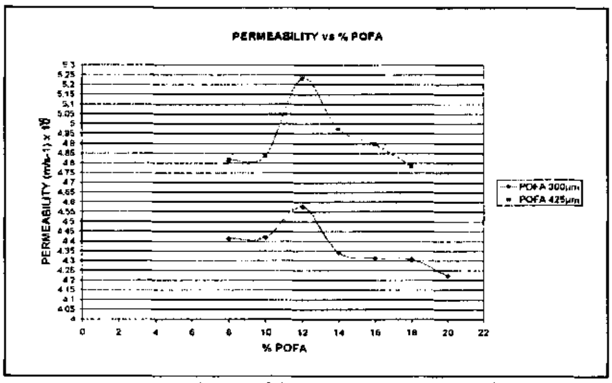

Figure 5: Relationship between permeability and percentage of POFA

5.6 DIRECT SHEAR TEST.

The shear strenght using unconfined compression test of origin sample is 6.88 kN/m^2. The shear strength of origin soil were low because the high moisture content and organic content Direct shear test are for disturbed sample were addition with different percent of POFA. This test was done because the easy preparation compare to Unconfined Compression.

The **Figure 6.1a and Figure 6.2b** shows the higher value of POFA passing sieve 300µm compare sieve size 425 µm with increasing of loading.

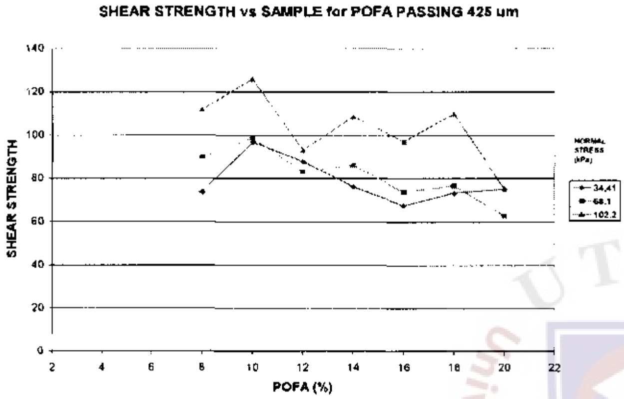

Figure 6a: The result of maximum shear strength between different percentage POFA. (425µm)

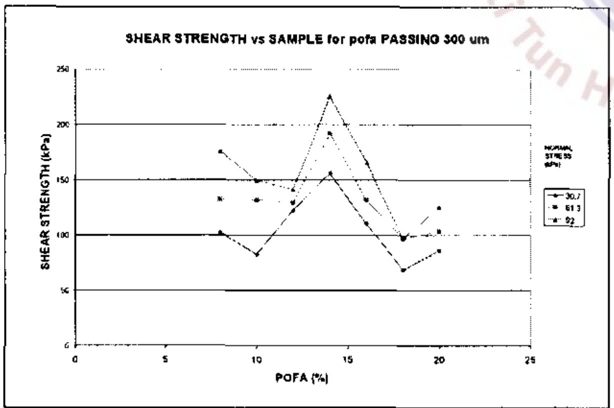

Figure 6b: The result of maximum shear strength between different percentage POFA. (300µm)

From **Figure 6c**, POFA passing 300µm have the highest shear strength is on the percentage 14% POFA with 225.23 kPa, while particles passing 425µm, on the percentage 10% POFA with 125.94 kPa. Appendix D show result that obtained from direct shear test.

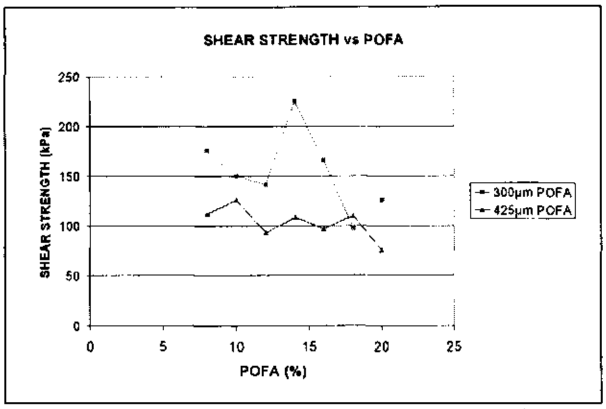

Figure 6c: *Relationship maximum shear strength between percentage of POFA*

5.7 SHRINKAGE LIMIT

Literature review suggest the shrinkage limit of soil when compacted are below than 4%. (Daniel and wu 1993: Tay et al. 2001). From the result, the soil without admixture and 8%, 10% 12%, 18%, 20% soil-POFA were not in shrinkage limit. From analysis, the shrinkage limits for soil admixture with 14% and 16% POFA are suitable for sanitary liner.

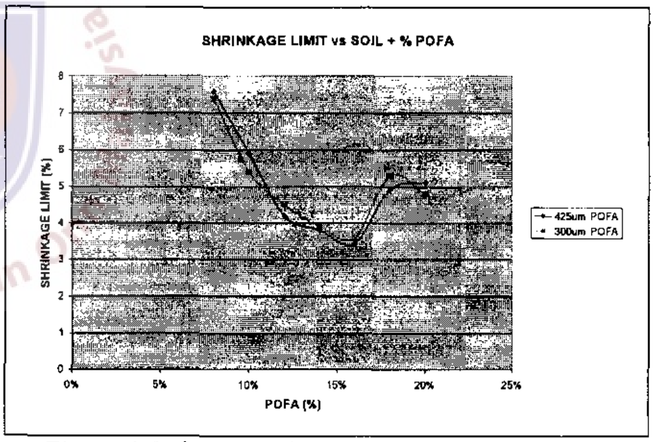

Figure 7: Relationship between shrinkage limit with percentage of POFA

6.0 CONCLUSION

From the result, the objective is achieved. The suitability of POFA treated soil for liner material is 14% POFA through 300µm sieving. The summary of result are in .The result from this research gives much benefit to all of us especially for sanitary landfill construction which facing with the problem to control leachate. As a conclusion, POFA, the available local material is having the ability as an additive material in soil stabilization.

7.0 RECOMMENDATION

Further research on POFA-clay mixture should be done in improving three aspect, permeability, shear strength and shrinkage limit. Modeling using software on the seep/W would show the seepage through the compacted POFA-clay liner.

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