Suitability Of Using Compacted Peat Soil Treated With Palm Oil Fuel Ash (POFA) As Hydraulic Barrier In Municipal Landfill

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***Abstract*—This research work evaluates suitability of using compacted peat soil treated with palm shell ash [POFA] as hydraulic barrier in municipal landfill. The mechanical tests carried out include compaction (standard proctor effort), hydraulic conductivity, volumetric shrinkage and unconfined compressive strength. All tests were carried out in accordance with British Standard (BS1377, 1990; ASTM C618-05 (2005),).Peat soil was mixed with up to 40% POFA using standard proctor compactive effort at the optimum moisture content (OMC), to determine its suitability to be utilized as hydraulic barrier in landfill presented improvement in properties tested. The index properties of the peat soil–POFA content fulfil the basic requirement for a liner. The soil possesses satisfactory quantity of fines along with better plasticity characteristics prerequisite to achieve hydraulic conductivity, while the MDD and OMC decreased and increased respectively with higher POFA content. All mechanical tests carried out showed enhanced properties up 20% POFA, however beyond 20% POFA there was no pleasing result with regards to usage as a liner material. In addition, the use of POFA as additives in soil would help in reducing the environmental challenges caused by the POFA being generated from palm oil production in the mills.**

Keywords—peat soil, palm oil fuel ash, hydraulic conductivity, volumetric shrinkage, unconfined compressive strength

1. INTRODUCTION

Ever since time in memorial, man has fashioned and disposed waste material, solid wastes are the spin-offs of human activities. Due to upsurge in population, change in life style, urbanization and coming on of technology and industrialization, there has been far-reaching change in quantity as well as quality of the solid waste produced. These wastes have become more dangerous to environment and demands careful discarding practices. In the close future, landfilling will remain to be the best choice because incineration is not a worthwhile technique for wide variety of waste and it may lead to air pollution challenge which will leave ash residue that will still require disposal in a landfill [1]. An important part of the landfill is the liner otherwise known as the hydraulic barrier, which has the principal aim of limiting the infiltration of solid waste leachate into ground water or surface water. Compacted natural soils are widely used as hydraulic barrier in waste inhibition system, Daniel and Benson specified that compacted clay liner should have a maximum hydraulic conductivity of $1x10^{-7}$ cm/s [2]. The specified maximum hydraulic conductivity conforms to standard [3]. Other criteria to be considered in the design and construction compacted clay liner are shear strength and volumetric strain of the compacted soil [2] [4]. In this age of sustainable development, scholarly research into the use of waste materials are on the forefront particularly with the positive reuse of most waste materials. Some researchers have carried out vast studies by incorporating waste material into the liner systems such as rice husk ash, groundnut shell ash, bagasse ash, blast furnace slag, cement kiln dust, scrap tires and steel slag [5] [6]. Palm oil fuel ash (POFA) has been produced from a burning process for boiler fuel in palm oil mill. Nigeria has been one of the largest producers of palm oil around the world [7]. Owing to this reason, there is an increase in the quantity of POFA produced and consequently creating huge environmental challenge Peat is a soil that contains a significant amount of organic materials. It is known to deform and fail under a small surcharge load and is characterized by low shear strength, high compressibility and high water content [8]. ASTM D2607-69 defined peat is a soil assumed to have organic matter of more than 75%. Therefore, the likelihood of using peat soil and POFA as a material significantly reduce environmental load pose by POFA. A number of studies have been carried out on the effect of POFA ranging from 5 – 30% on different types of soils to be used for liner purposes [9] [10] [11]. However beyond 30% POFA content no studies have been done to check its effect on these soils. Hence, this present study is aimed at evaluating the suitability of using compacted peat soil treated with palm oil fuel ash as hydraulic barrier in municipal landfill.

2. Materials and Method

2.1 Materials

The peat soil used in this study was obtained from wukari, in wukari local government area of taraba state, northeast, Nigeria.

The additive material used is palm oil fuel ash Palm oil fuel ash (POFA), it was sourced from Baissa, kurmi in wukari local government area of taraba state, northeast, Nigeria. Other equipment and other materials used in this study are of ASTM standard. The POFA percentage for this study were 5%,10%,15%,20%,25%,30%,35% and 40%.

2.2 Methods

2.2.1 Index Properties

Laboratory tests were conducted to determine the index properties of the natural peat soil sample and peat soil – POFA mixture sample in accordance with British Standard (BS1377, 1990).

2.2.2 Mechanical Properties

The mechanical tests carried out include compaction (standard proctor effort), hydraulic conductivity, volumetric shrinkage and unconfined compressive strength. All tests were carried out in accordance with British Standard (BS1377, 1990).

3. Results and Discussion

3.1 Index Properties

The index properties and compaction characteristics of soil and soil – POFA mixture is shown in Table 1. The specific gravity of soil – POFA mixture show a decrease in value which relates to the specific gravity of POFA. The value obtained in this study is in line with values obtained by other studies for supplementary cementing material [10]. The effects of POFA content on the Atterberg limits (liquid limit, plastic limit, and plasticity index) are shown in Table 1. The Atterberg limits for both natural soil and soil – POFA mixture were obtained using the Cassagrande method. The results showed a general across the parameters with addition of palm oil fuel ash. According to Qian [1] the liquid limit and plasticity index of a soil liner should be at least 20% and ≥ 7% respectively because low hydraulic conductivity is attributed to higher liquid limit and plasticity indices. Therefore the soil and soil – POFA mixture meets these criteria. The soil was classified as low plasticity clay CL under the Unified Soil Classification System (USCS). The particle composition of a soil which is determined from the particle size distribution plays a vital role in the hydraulic conductivity of the soil, which is the principal factor to be considered as a hydraulic barrier [12]. Recommendations have been made that a liner material should have fine content of greater or equal to 20 – 30%, therefore this material meets this criteria [13] [14].

Table 1: Index properties of the soil and soil mixed POFA samples used in the study

Properties	Peat Soil	5% POFA	10% POFA	15% POFA	20% POFA	25% POFA	30% POFA	35% POFA	40% POFA	*** Standard
Specific Gravity	2.97	2.71	2.56	2.37	2.21	2.02	1.86	1.64	1.53	-
Liquid limit %	58.90	54.30	52.76	50.80	48.02	45.00	65.60	68.00	63.89	≥ 7
Plastic limit %	35.61	33.19	32.27	31.95	29.85	27.67	49.48	52.96	50.40	-
Plasticity index %	23.29	21.11	20.49	17.33	18.85	23.29	16.12	15.04	13.49	≥ 20
Shrinkage%	10.13	9.60	8.56	7.55	10.91	12.28	14.06	15.94	16.32	
MDD, Mg/m3	2.14	2.08	2.07	1.98	1.78	1.75	1.74	1.68	1.68	-
OMC, %	24.02	23.01	23.85	22.75	17.85	18.00	19.58	21.20	21.90	-

3.2 Compaction Characteristics

The result of POFA on the maximum dry density (MDD) and optimum moisture content (OMC) of peat soil – POFA mixtures are shown in Table 1. The MDD in general decreased with advanced POFA content. This was assigned to the fact that POFA has lower specific gravity when compared with peat soil. On the other hand, the increase in OMC was assigned to the increase in fine content because of the inclusion of POFA with greater surface area that needed more water to react. A comparable pattern was obtained when wastes which have less specific gravity when compared with the soil were used as additive on various types of soils [9] [15].

3.3 Hydraulic Conductivity

The variation in hydraulic conductivity with different percentages POFA content using standard proctor compactive effort is shown in Figure 1. There was a steady decrease and subsequent slim increase in the hydraulic conductivity values obtained. The lowest hydraulic conductivity value of 6.13 x 10^{-3} m/s was obtained at 25% POFA, which did not conforms to the minimum values stated for liner material [16]. The initial decrease in hydraulic conductivity was due to the decrease in pore spaces as the fines from the POFA filled the voids thus reducing water flow. It could also be due to cation exchange reactions between POFA and the soil [17] [18]. On the other hand, the increase in hydraulic conductivity could be due to the existence of excess POFA that would have changed the soil matrix leading to increased flocculation. This was similar to the result obtained when bagasse ash was used as admixture to lateritic soil [19].

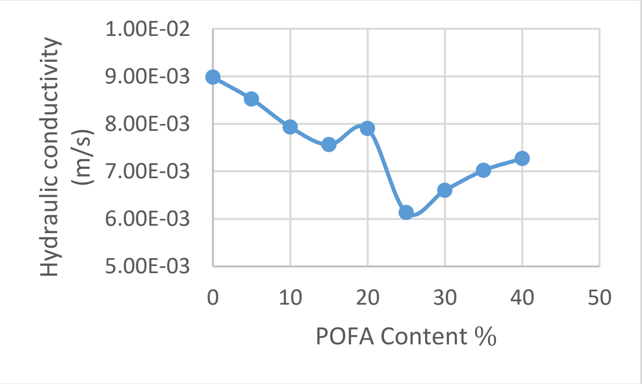

Figure 1: variation in hydraulic conductivity with different percentages POFA content

3.4 Unconfined Compressive Strength (UCS)

Daniel and Wu [16] submitted that the minimum strength of a soil to be used as compacted soil liners should be 200 KN/M^2. The variation of unconfined compressive strength for different percentages of POFA using standard proctor compactive effort is as shown in Figure 2a, 2b and 2c for 30, 60 and 90days curing. There was an initial increase in shear strength values up to 15%, 20% and 25% for 30, 60 and 90days curing and subsequent decrease in shear strength values above 15%, 20% and 25% for 30, 60 and 90days curing. The increase in strength with higher POFA up to 25% for 90days can likely be attributed to the formations of cementitious product such as hydrated calcium silicate gel (C-S-H) and calcium aluminates gel (C-A-H). The pozzolanic reaction and cementitious material hydration that coats and binds the soil particles to produce stronger matrices [20]. However, the increasing percentage of POFA beyond 25% showed decrease in strength. This is because the increasing additive material in a large amount has overcome soil weight thereby lowering the reaction rate at the right side of the graph [11]. From the graph, it can be clear that the clay, 5% and 10% POFA lack adequate strength which may lead to failure of the liner to carry the expected load imposed on it by the waste.

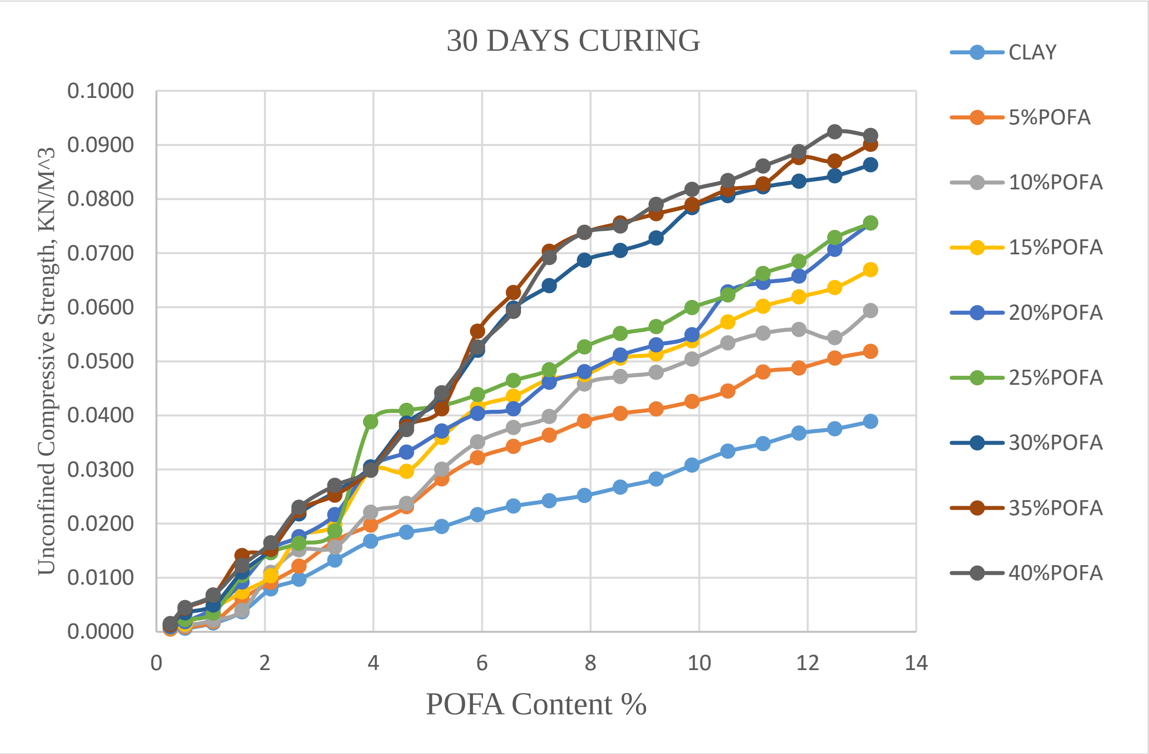

Figure 2a: Variation of UCS for different percentages of POFA

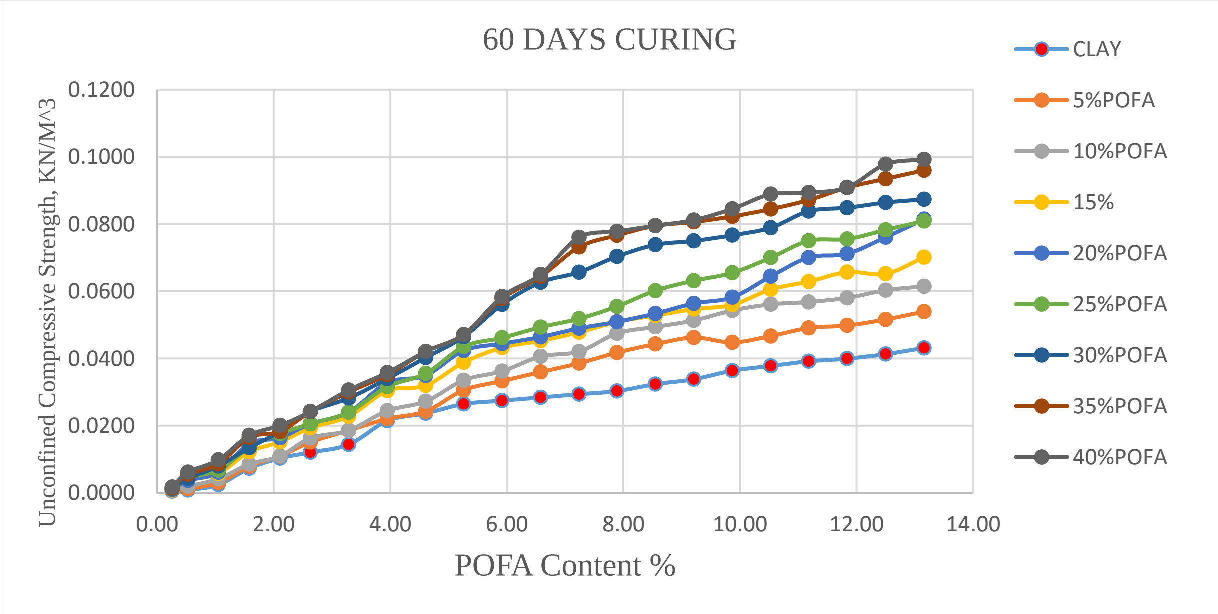

Figure 2b: Variation of UCS for different percentages of POFA

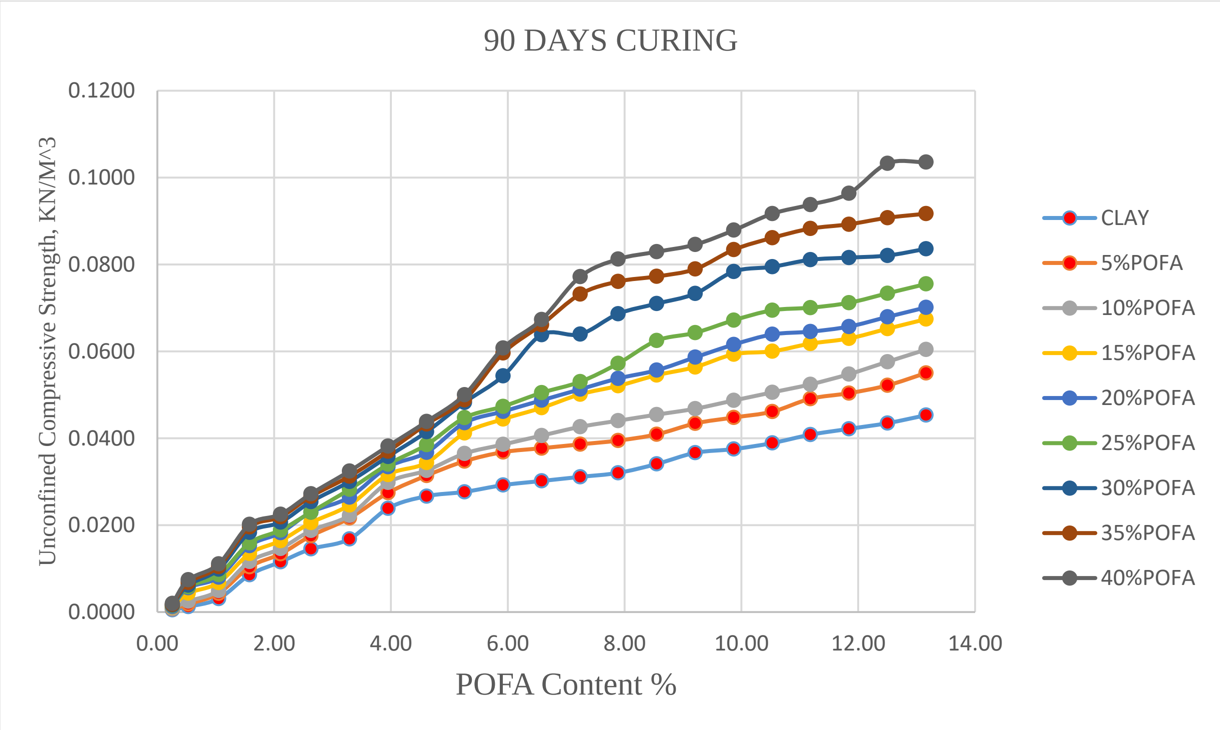

Figure 2c: Variation of UCS for different percentages of POFA

3.5 Volumetric Shrinkage Strain (VSS)

Daniel and Wu [16] proposed that cracking is not probably to occur in soil liners when compacted cylinders of the same soil undergo volumetric shrinkage strain (VSS) of less than 4% upon drying. The variation of volumetric shrinkage strain different percentage POFA using standard proctor compactive is shown in Figure 3. In general, there was a decrease in VSS up to 15% POFA and a successive increase recorded with higher percentage of POFA. The initial decrease might be ascribed as the pozzolanic input of POFA while on the other hand the increase in VSS may occur as a result the higher OMC recorded for conforming POFA content that resulted in more fines to larger surface area present in the soil mixture. The mixture required more water for reaction that led to increased shrinkage during drying. This also could be attributed to physico-chemical reactions (i.e. ion exchange) taking place within the soil POFA mixture [4].

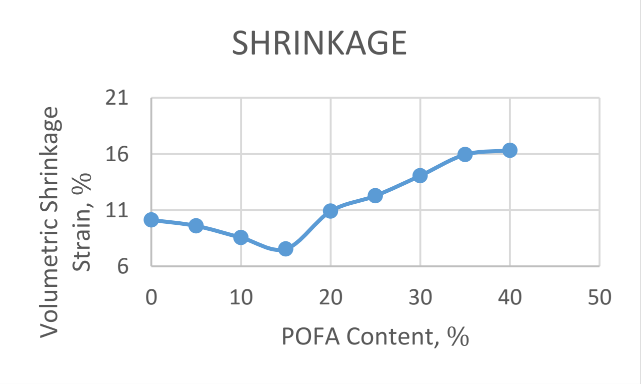

Figure 3: Variation of volumetric shrinkage strain different percentage POFA

4. Conclusions

Peat soil was mixed with up to 40% POFA using standard proctor compactive effort at the optimum moisture content (OMC), to determine its suitability to be utilized as hydraulic barrier in landfill presented improvement in properties tested. The index properties of the peat soil–POFA content fulfil the basic requirement for a liner. The soil possesses satisfactory quantity of fines along with better plasticity characteristics prerequisite to achieve hydraulic conductivity, while the MDD and OMC decreased and increased respectively with higher POFA content. All mechanical tests carried out showed enhanced properties up 20% POFA, however beyond 20% POFA there was no pleasing result with regards to usage as a liner material. In addition, the use of POFA as additives in soil would help in reducing the environmental challenges caused by the POFA being generated from palm oil production.

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To God be all the Glory.

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