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Soil Properties of Residual Soil mixed with Agricultural Waste Ashes

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ABSTRACT
Agricultural waste ashes have been investigated worldwide by researchers for their ability to be used as an additive in soil stabilization process. To improve the stability of problematic soil, thus ensuring their long term performance especially in foundation purposes is usually a challenge. This paper describes the effect of palm oil fuel ash (POFA) and rice husk ash (RHA) combined with ordinary Portland cement (OPC) as additives to improve the strength properties of residual soil. Results show an improvement in physical and strength properties of stabilized soils for both additives compared to the original residual soil. The optimum condition for both additives is 10% for each mixture with fix 10% OPC.

Keywords: *Palm oil fuel ash; Residual soil; Rice husk ash; Stabilization; Strength.*

1 INTRODUCTION

Construction of any structures on weak or soft soil is difficult without any soil improvement due to their poor shear strength and high compressibility. Several studies on ground improvement techniques using agricultural waste and ashes to stabilize soil indicate that the soil properties such as shear strength and permeability characteristics can be improved (Bayshakhi et al, 2017, Nik Daud et al, 2016a; Nik Daud et al, 2016b).

Subgrade layer is important in road construction. It is the in-situ material upon which the pavement structure is placed. Subgrade layer provides an adequate support and stability to the road pavement. However, there are many types of defects which occur in road pavement such as crack, corrugation and ruts, due to the construction of a road on problematic soil. Previously, traditional soil stabilization using lime or cement is well established. However, despite the fact that this type of stabilization is very famous and has been successful in the past, there is the need to look for other solutions or alternative technologies which are more environmental friendly and economical.

Nowadays, the used of lime or cement are gradually being replaced by industrial or agricultural waste by-product which proved sustainable and provides cost-effective methods to improve the engineering properties of low load bearing or problematic soils. So it is shown that soils stabilized with industrial waste materials have been extensively tested and do not have any adverse environmental impact and consequences. Consequently, in order to reduce the cost of construction of stabilized road subgrade, the use of natural waste such as rice husk ash (RHA) and palm oil fuel ash (POFA) as an alternative additive would be the best solution, towards reducing the environmental hazards caused by cement (Aparna, 2014).

Rice husks are the shells produced during de-husking operation of paddy, which varies from 20% (Mehta, 1986) to 23% (Della et al. 2002) by the weight of paddy. The husk is a waste material and is disposed of either by dumping or burning in the boiler for processing paddy. According to Nair (2006), this ash known as RHA contains silica as a major constituent whose quality (percent of amorphous and unburnt carbon) is influenced by the type of burning process. The RHA is pozzolanic in nature because of its high amorphous silica content (Mehta, 1986). However, RHA cannot be used individually for the soil stabilization due to lack of cementitious properties (Ali et al. 1992). Therefore, it is used along with a binder, for example; cement, lime, lime sludge, and calcium chloride for the stabilization of soil (Ali et al. 1992; Muntohar and Hantoro, 2000; Basha et al. 2005; Sharma et al. 2008; Brooks, 2009).

Palm oil fuel ash (POFA) is one of the most abundantly produced waste materials in tropical regions which has a strong potential to treat physicochemical characteristics of soft soils due to its amorphous nature and high silica content. POFA is widely produced by the oil palm industry through the burning of empty fruit bunches, fiber and palm oil shells as fuel to generate electricity and the waste, collected as ash, becomes POFA. Hypothetically, the large amount of amorphous silica in POFA potentially contributes to the pozzolanic reaction during hydration, which results in the cementitious compound called calcium aluminate hydrates and calcium silicate hydrates. These compounds are responsible for improving the engineering characteristics of soils that increase over time as the pozzolanic reaction develops. However, rice husk ash

(RHA) and palm oil fuel ash (POFA), can only be used as a partial replacement for the more expensive additive Ordinary Portland Cement (OPC) because it has inadequate cementation property.

Therefore, this study focusses on the effect of residual soil stabilization using agriculture waste ash (RHA and POFA), using ordinary Portland cement (OPC) as the binding agent. The specific areas of interest include;

a) To determine the physical and compaction properties of residual soil mixed additives.
b) To investigate and analyse the mechanical properties of residual soil mixed additives.

2 METHODOLOGY

Soil samples were collected within the Universiti Putra Malaysia, Serdang Selangor, Malaysia (GPS: 2°59'19.1"N 101°43'46.8"E). The location is shown in Figure 1.

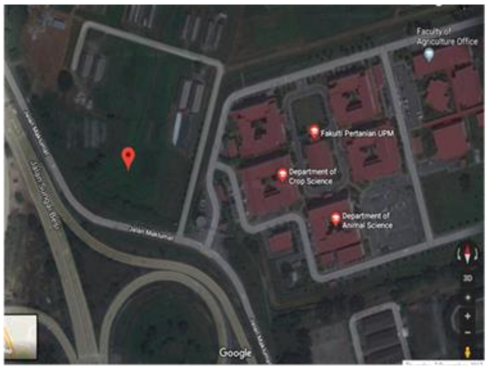

Figure 1: Location of residual soil samples collected for this study

From observation, the soil sample is categorized as residual soil type. Residual soil is a soil which has been formed in situ by decomposition of parent material, which has not been transported to any significant distance.

2.1 ADDITIVES

The rice husk ash (RHA) sample (Figure 2) was collected from Kilang Bernas Seri Tiram Jaya which is located in Tanjung Karang, Selangor, Malaysia.

Figure 2: Rice husk ash (RHA) samples used for this study

Open burning is the process used to form RHA because based on the field observation, RHA is characterized by black color. Meanwhile for this sample, burning was under controlled temperature below 800 °C.

Palm oil fuel ash (POFA) sample (Figure 3) was collected from Tenaga Sulpom Sdn Bhd Lot 3115, Batu 34 Jalan Banting, Dengkil Selangor, Malaysia. The factory used the incineration process for the oil palm waste which resulted in fly ash and bottom ash as their by-product. The fly ash samples were used in this study.

Figure 3: Palm oil fuel ash (POFA) samples used for this study

As an extra additive, Ordinary Portland Cement (OPC) was used as a binding agent in a small amount and combined with soil-RHA and soil-POFA sample respectively.

The soil sample was air dried and sieved through 4.75mm sieve aperture in preparation for the test. The soil basic property and soil mechanical property tests were carried out according to BS 1377: 1990. On the other hand, the POFA and RHA samples were kept in sealed plastic bag to protect it from outside moisture content and was subsequently oven dried at 110^{o}C to remove extra moisture. The batch of each sample with and without additive was prepared by adding 5, 10 and 15% of additives.

For each mixture, the compaction tests using standard proctor compaction technique were carried out to determine its maximum dry density and optimum moisture content. The amount of additives as percent of dry soil by weight was mixed thoroughly to produce a homogenous additive-soil mixture. Since there is no standardized protocol for testing additive-soil mixtures, there is a report that compaction of samples should be done two hours after blending to simulate field compaction delay (Acosta et al., 2003). Then, the optimum condition of each soil mixed additive was used to test the strength behaviour.

3 RESULTS AND DISCUSSION

3.1 BASIC PROPERTIES

Basic properties of residual soil sample used in this study are shown in Table 1.

TABLE 1: BASIC PROPERTIES OF RESIDUAL SOIL USED IN THIS STUDY

Parameter	Unit	Value
Initial moisture content, *wc*	%	128
Specific Gravity, G_s	-	2.52
Liquid Limit, *LL*	%	68.7
Plastic Limit, *PL*	%	56.6
Plasticity Index, *PI*	%	12.1
Percent passing BS No. 200 sieve	%	5
Coeff. of Curvature, *Cc*	-	2.5
Coeff. of Uniformity, *Cu*	-	4.44
pH	-	5

The initial moisture content of the soil is about 128% which is very high for normal residual soil due to the rainy season. Meanwhile, the specific gravity is 2.52 which fall in the range of 2.52-2.66, for clay inorganic type of soil. Thus, it can be summarised that the initial moisture content will increase due to the clay content present in it. The percentage of liquid limit, plastic limit, and plasticity index is 68.7%, 56.62% and 12.08%, respectively. According to plasticity chart of Unified System, it indicates that the soil fall in high in silt (MH) or organic (OH) type of soil. The percent of particle which passed through no. 200 sieve is 5% and the Cc and Cu values are 2.5% and 4.44%, respectively. It indicates that the soil is well graded soil, and the Cc fall in the range of 1 to 3. The pH value of about 5, show that the soil sample is moderately acidic.

3.2 COMPACTION CHARACTERISTICS

The characteristics of compaction for residual soil with and without additives were presented in this section. Figure 4, 5 and 6 showed the behaviour of compaction varied by additive with 5, 10 and 15% content; ordinary Portland cement (OPC), palm oil fuel ash (POFA) and rice husk ash (RHA), respectively.

For OPC additive, the sample mixed with 10% showed the optimum condition of the mixture of all samples (Figure 4). The maximum dry density and optimum moisture content for the optimum condition of residual soil mixed 10% OPC is 1.51 Mg/m^3 and 23%, respectively.

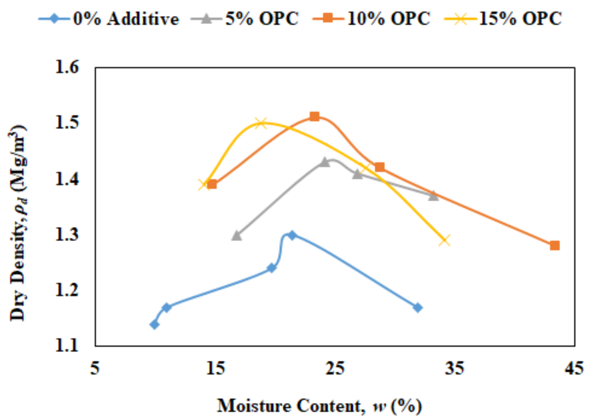

Figure 4: Compaction characteristics of OPC varied by percentage

Figure 5 shows the maximum dry density and optimum moisture content for the optimum condition of residual soil mixed 10% POFA is 1.54 Mg/m^3 and 16.9%, respectively.

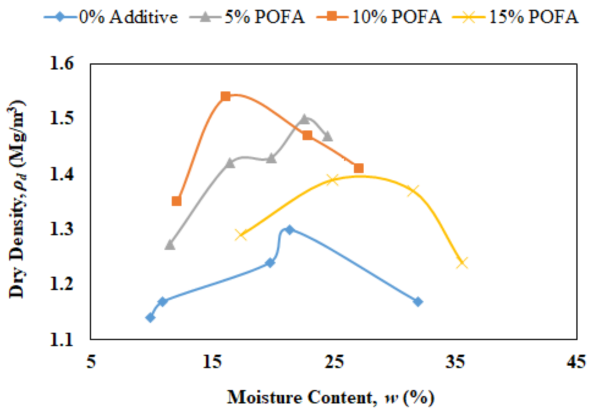

Figure 5: Compaction characteristics of POFA varied by percentage

Figure 6 shows the maximum dry density and optimum moisture content for the optimum condition of residual soil mixed 10% RHA is 1.5 Mg/m^3 and 21%, respectively.

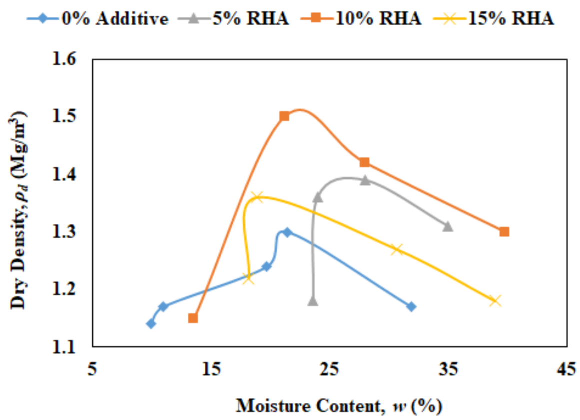

Figure 6: Compaction characteristics of RHA varied by percentage

Table 2 shows the detailed values of maximum dry density and optimum moisture content for each mixture of different additives. According to the results, in general, the values of maximum dry density for each additive-soil mixture showing an increment pattern if it is compared to the original soil. However, in contrast, the values of optimum moisture content showing a decrement pattern in additive-soil mixture.

TABLE 2: COMPACTION PROPERTIES OF RESIDUAL SOIL WITH AND WITHOUT ADDITIVES

Parameter	0% additive	POFA (%)			RHA (%)			OPC (%)		
		5	10	15	5	10	15	5	10	15
MDD (Mg/m^3)	1.3	1.5	1.54	1.39	1.39	1.5	1.36	1.43	1.51	1.5
OMC (%)	21.42	22.56	16.19	17.35	28.02	21.19	18.82	24.11	23.32	18.8

*MDD – Maximum Dry Density; OMC – Optimum Moisture Content

3.3 STRENGTH PROPERTIES

The strength behavior of residual soil with and without additives at their optimum condition are discussed in this section. The direct shear box test was used to determine the shear strength properties of the samples.

TABLE 3: SHEAR STRENGTH PARAMETERS OF SAMPLES WITH AND WITHOUT ADDITIVES

Parameters	Original Soil	Soil + 10% POFA + 10% OPC	Soil + 10% RHA + 10% OPC
Cohesion, *c* (kN/m^2)	5	13	9
Internal friction angle, ϕ (°)	29	35	32

The values of both shear strength parameters show an increment once mixed with additives.

4 CONCLUSION

This investigation has been successful and shows that both waste materials are suitable for soil stabilization. The optimum condition for both additives is 10% content and the amount of ordinary Portland cement for each mixture is fixed by 10%. The addition of rice husk ash (RHA) and palm oil fuel ash (POFA) with 10% ordinary Portland cement (OPC) indicated an improvement in physical properties and strength properties of residual soil. The RHA and POFA can alter the engineering properties of residual soil.

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