An Experiment to Determine the Prospect of using Cocoa Pod Husk Ash as Stabilizer for Weak Lateritic Soils

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Abstract
A study was conducted to determine the extent to which the engineering and geotechnical properties of a lateritic soil for road construction works can be improved by using cocoa pod husk ash (CPHA) additive.Natural lateritic soil samples were collected from test pits near El wak Sports Stadium, Accra, Ghana and were subjected to Atterberg's limit and particle size distribution tests as well as compaction and California Bearing Ratio (CBR) tests. The soil was then treated with 0.5%, 1.0%, 2.0%, 4.0%, 6.0%, 8.0%, and 10.0% of CPHA and then tested for variations in the engineering properties.From the various tests carried out on the natural soil sample, and when CPHA was added, it was observed that CPHA has a significant negative effect on the maximum dry density and a positive significant effect ($p<0.05$) on the liquid limit. The addition of CPHA to the soil however, did not significantly ($p>0.05$) affect the California Bearing Ratio, optimum moisture content, plastic limit and plasticity index, and therefore the CPHA is regarded as a poor soil stabilizer. Other findings show that CPHA has no pozzolanic properties.
Keywords: Cocoa pod husk ash, stabilizer, lateritic soil, pozzolanic properties

1. Introduction

Stabilization of soil is a practice which is widely used in road construction to improve the engineering properties of natural soils with the aim of increasing its strength by making it less compressible and less permeable and porous, resulting in higher bearing capacity, and decreased volumetric change.

Soil stabilization, which can be achieved by increasing the density of the soil or by adding admixtures and then applying mechanical work to compact it, is a more economic solution for improving the performance of problematic soils, by enhancing their cementation, and reducing their sensitivity to moisture changes (Jackson and Dhir, 1988).

Conventionally, cement, lime and fly ash have been used in stabilizing weak soils in road construction in order to provide a firm base or sub-base for all types of paved areas, to improve foundation conditions, and as a lining for trenches and stacked earthworks (Sherwood, 1993).

Several research works have confirmed the usefulness of fly ash by showing that when added to expansive clay soils it reduces the plasticity index, the amount of the clay size particles, and their swell potential (Kanira and Havanagi, 1999; Nalbantoglu, 2004; Prabakar et al 2004).

It has also been confirmed that when lime is added to some types of clay, such as kaolinite and montmorillonite, it results in an increase in their optimum moisture content, strength and Young's Modulus, California bearing ratio and a decrease in their maximum dry density. Montmorillonite however, experiences a reduction in its plasticity whiles that of kaolinite increases (Bell, 1996).

Cement, lime and fly ash stabilizers are in high demand leading to sharp increases in their prices. In addition large quantities of CO_2 released during their production could worsen global warming.

There are ongoing research studies into the possibility of using other naturally occurring materials such as clays and ashes of agricultural waste products for soil stabilization because of their pozzolanic nature.

Okagbue (2007) assessed the potential of wood ash to stabilize clay soil by determining some engineering properties of clay soil in its natural state as well as when mixed with varying proportions of wood ash. The results showed that the plasticity of clay treated with wood ash was reduced by 35% and California Bearing Ratio and strength increased by up to 50% and 67% respectively. However, the strength of wood ash treated clay deceases after 14 days.

The addition of rice husk ash and lime to clayey soil lowers the dry density and deformability of the soil as well as the liquid limit and plastic limit, but raises the optimum moisture content and California Bearing Ratio (Choobbasti et al., 2010).

Basha, (2005) also observed that 8% cement and 15% rice husk ash added to residual soils reduced the plasticity and the maximum dry density, and increased the optimum moisture content of the soils.

Amu et al. (2011) examined the effect of adding coconut shell and husk ash to weak lateritic soil and found that it improved the maximum dry densities and the shear strengths of the soil and therefore concluded that they could be used for soil stabilization. A similar research on coconut husk ash as additive to weak lateritic soil gave comparable results but was not suitable for lowering the liquid limit (Oluremi et al., 2012).

Owolabi and Dada (2012) have indicated that cocoa pod ash has iron, magnesium, sodium and potassium contents similar to that of cement and that 6 to 8% of the ash could raise the California Bearing Ratio (CBR) and decrease the plasticity index of weak lateritic soil such that it could be used as base course for roads.

It has been observed that Cocoa pod husk, which constitutes about 75% by weight of the fresh Cocoa pods, are allowed to go waste on cocoa farms in Ghana resulting in high disease incidence (Rhule et al., 2005; Ntiamoah and Afranie, 2008; Hagan et al., 2013). Rhule et al., (2005) estimated that if the entire Cocoa pod husks left to rot on farms are collected it could be about 554,400 tonnes. This agricultural product is underutilized.

The aim of this research, therefore, is to find out whether cocoa pod husk ash could be used as an additive in some lateritic soils found in Ghana to improve their plasticity, maximum dry density and the bearing capacity.

2. Materials and Methods

2.1. Extraction and Preparation of Materials

2.1.1. Lateritic soil sample

The lateritic soil sample was obtained from an area near El wak Sports Stadium, Accra, Ghana (5^o 35' 10" N; 0^o 10' 23"E). They were all collected at depths representative of the soil stratum and not less than the 1.2m below the natural ground level. These were kept safe and dry in jute bags and were later air dried in pans to allow partial elimination of natural moisture which may affect analysis. After the drying, lumps in the samples were slightly pulverized with minimal pressure, and then sieved through sieve No. 19mm to obtain the final soil samples for the tests.

2.1.2. Cocoa Pod Husk Ash Samples

Cocoa pod husks were obtained from farms in Twifo Praso (5^o 37' 0" N; 1^o 33' 0"W) in the Twifo/Heman/Lower Denkyira District of the Central Region of Ghana. The husks were spread out on clean paved grounds and air dried to facilitate easy burning. After drying, the pods were burnt in drums into ash. It was then collected into plastic containers after cooling and sieved through a British Standard (BS) sieve 425μm. The ash obtained was preserved in tightly sealed containers to prevent moisture absorption and contamination from other materials.

2.2. Methods

2.2.1. Sieve Analysis

Particle size distribution tests were performed on the soil sample in its natural state using standard sieves in line with British Standard methods BS 1377–1990: Part 2, and the samples trapped in various sieves were weighed and recorded.

2.2.2. Atterberg's limits tests

Using the soil retained on the 425mm sieve the Atterberg's limits tests, comprising liquid limit (LL) and plastic limit (PL), were determined and the plasticity index (PI) was calculated in accordance with BS1377–1990: Part 2.

2.2.3. Compaction tests

Proctor standard compaction tests to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils were in accordance with BS1377–1990: Part 4.

The tests were carried out on the natural soil and then on the soils with different proportions of cocoa pod husk ash (CPHA) additive of 0.5%, 1.0%, 2.0%, 4.0%, 6.0%, 8.0% and 10.0%.

2.2.4. California bearing ratio test

The California Bearing Ratio tests were conducted on soil samples which have been compacted with 2.5kg rammer and soaked for 4 days in water. The tests forces on a plunger at penetration of 2.5mm and 5.0 mm were determined and the California Bearing Ratio (CBR) was calculated as specified in BS1377–1990: Part 4.

2.2.5. Spearman's rank correlation test

Spearman's rank correlation test was carried out using SPSS (version 17) on the different variables which were obtained in the laboratory tests to determine how they associate with each other. The CBR values used for the test relate to the 100% compaction.

2.2.6. Determination of Pozzolanic properties

According Amoanyi (2012) a typical Cocoa pod husk ash consists of the following chemical composition: SiO_2 (8.05%), Al_2O_3 (2.28%), Fe_2O_3 (0.89%), CaO (8.43%), MgO (5.16%), K_2O (37.39%), SO_3 (2.09%), and LOI (32.00%). This major element composition was compared to the chemical requirement for calcined natural pozzolans of the American Society for Testing and Materials (ASTM -C618) shown in Table 4, in order to find out if Cocoa pod husk ash has pozzolanic properties.

3. Results

The figure and tables below show the results of the following tests carried out during the experiments: particle size distribution test, compaction test, California Bearing Ratio and Atterberg's limits tests and Spearman's rank correlation test. In addition the result of analysis of chemical composition of CPHA in comparison with ASTM C618 is also presented.

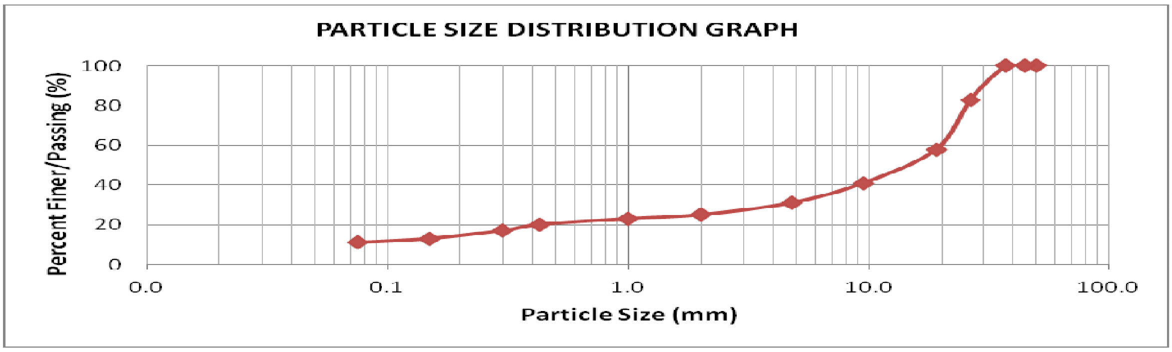

Figure 1. Particles size distribution test results on natural lateritic soil sample

Table 1. A summary of compaction test results on lateritic soil sample.

	MASS OF AIR DRY SAMPLE	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY (kg/m^3)
Natural lateritic soil only	6000g	8.5	2184
Soil plus 0.5% CPHA	6000g	7.1	2317
Soil plus 1% CPHA	6000g	8.2	2264
Soil plus 2% CPHA	6000g	6.5	2256
Soil plus 4% CPHA	6000g	6.6	2171
Soil plus 6% CPHA	6000g	7.4	2227
Soil plus 8% CPHA	6000g	8.4	2143
Soil plus 10% CPHA	6000g	7.2	2135

Table 2. CBR and Atterberg's limits tests results on samples, with and without CPHA additive.

SAMPLE	CBR TEST VALUES AFTER 96 HOURS OF SOAKING				ATTERBERG LIMITS		
	PERCENTAGE COMPACTION						
	100%	98%	95%	93%	PL	LL	PI
Natural soil	90	84	74	60	18	34	16
Soil +0.5% of CPHA	92	81	76	55	18	31	13
Soil + 1% of CPHA	69	61	52	31	22	32	10
Soil + 2% of CPHA	64	60	51	39	21	37	16
Soil + 4% of CPHA	128	108	82	56	19	35	16
Soil + 6% of CPHA	63	63	64	49	20	35	15
Soil + 8% of CPHA	94	91	89	73	22	38	16
Soil + 10% of CPHA	172	148	117	84	21	36	15

Table 3. Spearman's rank correlation test results

		CBR	OMC	MDD	CPHA	LL	PL	PI
CBR	Correlation Coefficient	1.000						
	Sig. (2- tailed)	-						
	N	8						
OMC	Correlation Coefficient	-0.048	1.000					
	Sig. (2- tailed)	0.911	-					
	N	8	8					
MDD	Correlation Coefficient	-0.643	-0.214	1.000				
	Sig. (2- tailed)	0.086	0.610	-				
	N	8	8	8				
CPHA	Correlation Coefficient	0.381	-0.119	-0.714	1.000			
	Sig. (2- tailed)	0.352	0.779	0.047	-			
	N	8	8	8	8			
LL	Correlation Coefficient	0.168	-0.108	-0.671	0.731	1.000		
	Sig. (2- tailed)	0.691	0.799	0.069	0.040	-		
	N	8	8	8	8	8		
PL	Correlation Coefficient	-0.024	0.133	-0.218	0.546	0.537	1.000	
	Sig. (2- tailed)	0.955	0.753	0.604	0.162	0.170	-	
	N	8	8	8	8	8	8	
PI	Correlation Coefficient	0.153	-0.038	-0.524	0.115	0.642	-0.117	1.000
	Sig. (2- tailed)	0.717	0.928	0.183	0.786	0.086	0.783	-
	N	8	8	8	8	8	8	8

Table 4. Results of analysis of chemical composition of CPHA in comparison with ASTM C618. The chemical composition of CPHA is obtained from Amoanyi, (2012).

Chemical requirement	ASTM - C618			Total (%) for CPHA	Remarks
	Class N (%)	Class F (%)	Class C (%)		
SiO_2 + Al_2O_3 + Fe_2O_3 (Minimum %)	70.0	70.0	50.0	11.22	The total for CPHA is far less than the minimum requirement for any of the classes of pozzolans.
SO_3 (Maximum %)	4.0	5.0	5.0	2.09	The total for CPHA falls within all pozzolan classes.
Loss on Ignition (LOI) Max. %	10.0	6.0	6.0	32.0	Total LOI for CPHA far exceeds the requirement for any of the classes of pozzolans.

4. Discussion

The particle size distribution tests results (Fig. 1) show that the lateritic soil which was used for the experiment consists of 59.24% gravels, 24.07% sand and 16.68% fines. It is therefore classified as well graded sandy gravel soil.

The optimum moisture content (OMC) and maximum dry density (MDD) values for the natural lateritic soil sample are 8.5% and 2184kg/m^3 respectively (Table 1). When the cocoa pod husk ash was added to the natural soil at 0.5%, 1.0%, 2.0% and 4.0% the OMC values of 7.1%, 8.2%, 6.5%, and 6.6% and MDD values of 2317kg/m^3,2264kg/m^3,2256kg/m^3, and 2171kg/m^3 respectively were obtained. The variation of OMC with CPHA is inconsistent as it decreased and increased. The same inconsistency was observed in soils with 6.0%, 8.0% and 10.0% of CPHA. The MDD on the contrary increased above that of the natural soil when CPHA of 0.5% to 2.0% was added. CPHA of 4.0% and above did not increase the MDD but rather reduced it below the value for the natural soil. This indicates that to effectively increase the MDD, the CPHA should not be more than 2.0%.

Table 2 shows that the California bearing ratio (CBR) values for the natural soil increased from 60 to

90% progressively as the compaction increases from 93 to 100%. As expected, all the samples showed similar trends of increasing CBR with increasing compaction.

When 0.5% CPHA was added to the natural soil the CBR value at 100% compaction showed a marginal increase from 90% to 92%. However, the CBR value reduced to 69% when 1.0% CPHA was added. It further decreased to 64% with 2.0% CPHA. Conversely when 4.0% CPHA was added to the natural soil the CBR increased to 128% and then dropped to 63% and 94% with 6.0% and 8.0% CPHA respectively. When 10.0% CPHA was used it gave a CBR value of 172%. These findings suggest that CPHA additive did not show any consistent effect on the CBR of the soil.

In order to understand how CPHA associates with CBR, MDD, OMC, PI, PL, and LL the results obtained from the experiments were subjected to some statistical analysis. The results of the statistical analysis shown in Table 3, indicate that addition of CPHA to natural soil has a strong negative correlation (-0.714) with MDD and that the probability that MDD will depend on the quantity of CPHA added is significant ($p=0.047$). This suggests that as the quantity of Cocoa Pod Husk Ash added to the soil increases the Maximum Dry Density of the soil will decrease significantly ($p<0.05$). The addition of CPHA to the soil will also influence the liquid limit (LL) significantly ($p= 0.040$). The strong positive correlation coefficient of 0.731, coupled with the significant probability value, suggests that the amount of CPHA added to the soil when increased would considerably result in a corresponding increase in LL.

A probability of 0.352 recorded for CBR/CPHA dependency as shown in Table 3 indicates that the amount of CPHA added had no significant effect ($p>0.05$) on the California Bearing Ratio and therefore it may not be a good soil stabilizer. Results obtained during the correlation test further shows that CPHA has insignificant ($p>0.05$) effects on plasticity index, optimum moisture content and plastic limit.

The analysis of the chemical constituents of CPHA in reference to classes N, F and C (ASTM C618) as shown in Tables 4 clearly shows that CPHA does not fall in any of the defined classes of pozzolans, indicating that CPHA has no pozzolanic properties. This contradicts some other findings which seem to suggest that CPHA has pozzolanic properties and could increase CBR and lower plasticity index (Owolabi and Dada, 2012).

5. Conclusion

The quantity of CPHA added does not improve the bearing capacity of weak lateritic soils, and its effects on the OMC, PL and PI are also insignificant. It however has significant negative effect on MDD and positive effect on LL. It was therefore concluded that cocoa pod ash additive cannot be used in stabilization of lateritic soil. This is consistent with the fact that CPHA has no pozzolanic properties.

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