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Evaluation of the Strength Characteristic of Soft Clay Soil Stabilized with Rice Husk Ash and Fly Ash Blend

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ABSTRACT:

This study presents evaluation of strength characteristic of soft clay soil stabilized with rice husk ash and fly ash blend. The index properties, compaction characteristics, unconfined compressive strength (UCS) and CBR of the soft clay soil stabilized with 2:4, 4:6, 6:8, 8:10 and 10:12% rice husk ash and fly ash blend were explored. British Standard light, British Standard Heavy and West Africa Standard compactive efforts were used. From the results, the clay sample is classified as A-7-5 or SC soil type. The results showed a decrease in Liquid and Plastic limits with increase rice husk ash and fly ash. It further shows 62-76% increment in Maximum Dry Density (MDD) of the stabilized soil with progressive increment in compactive effort. The CBR and UCS of the clay were improved by 356% and 106% respectively with the optimal values obtained at 2:4% Rice husk ash and Fly ash addition. The study has established the potential of using rice husk ash and fly ash to stabilize a class of soft clay soil for construction purposes.

Keywords: *Compaction characteristics, Fly ash, Shear strength, Soft clay, Stabilization, Rice husk ash.*

1 INTRODUCTION

Soft clay lacks enough strength to withstand the load from a structure, therefore, the strength has to be increased to make the soil suitable for structural applications (Arun *et al.*, 2019). Soft clays are said to be soils which have large fraction of fine particles such as silts, clay soils having high moisture contents, peat foundation and loose sand deposits near or under the water table (Kamon and Bergado, 1992). Several methods such as prefabricated vertical drains, geotextile reinforcing, cement and lime stabilization have been successfully implemented to improve such soils which would increase the properties of these soft clays (Amir and Indra, 2007). Soft clays are characterized with high compressibility, low bearing capacity, low strength and low permeability (Otoko, 2014).

Rice Husks (or rice hulls) are the hard protective outer shell of rice grains. It shields the rice during growing season. Rice Husk Ash (RHA) is gotten from the burning of rice hulls and can be used in Portland cement production, as good thermal insulating materials, sealing fine cracks in structures and as fuel (Mehta, 1986). Alhassan and Alhaji, (2017) concluded from a research review that the use of agricultural waste (Rice Husk Ash) has great potentials in improving the geotechnical properties of deficient soil. Akinleye *et al.* (2015) carried out a research on the use of Rice Husk Ash as a stabilizing agent on lateritic clay soils. The research concluded that on the addition of rice husk ash, the index properties of the soil increased which qualifies it as a good stabilizing agent for subgrade in road construction and back filling in retaining walls but the mix should not exceed 10% of Rice Husk Ash. Chayakrit *et al.* (2016) examined the viability of using Fly Ash (FA) and Calcium Carbide Residue (CCR) based geopolymer as a sustainable binder to improve strength of soft marine clay. The strength of the stabilized soil was found to be strongly dependent upon Fly Ash (FA) and Sodium Hydroxide (NaOH) concentration. The optimal ingredient providing the highest strength was found to be dependent on water content. Zhen *et al.* (2016) studied the feasibility of Fly Ash (FA) based geopolymer on loess stabilization.

Polymers are either organic materials such as carbon based or inorganic polymers such as silicon based. Fly ash is an example of geopolymers. Geopolymers are inorganic materials that form long range covalently bonded non-crystalline networks. Commercially produced geopolymers are used for fire and heat resistant coatings and adhesives,

medicinal applications, binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation and new cement for concrete. Slag based, rock based, fly ash based and Ferrosilicate based are examples of geopolymers (Moser, 2013). Fly ash is one of the by products from the combustion of coal in coal fired power plants. In industrial context, it is said to be the ash produced during the combustion of coal. The two types of fly ash are class C and Class F. Class F fly ash is produced by burning antharacite or bituminous coal which usually has less than 20% Calcium Oxide (CaO). It has pozzolanic properties only. Class C is produced from burning lignite. It has both pozzolanic and cementitious properties and contains more than 20% Calcium Oxide (CaO). Alkaline and Sulphate (SO_4) are usually higher in class C. The distinctive different between Class F and Class C fly ash is the amount of Calcium (Ca), Silicon (Si), Aluminium (Al), and Iron(Fe) content. Geopolymers can possess good mechanical properties when synthesised at certain conditions. Low permeability, high compressive strength, high durability and low shrinkage can be achieved using geopolymer binders (Xu and Deventer, 2000)
Soil stabilization is a process whereby soils are modified to improve its properties. Stabilization increases shear strength of the soil, It controls the swelling and shrinkage properties of soil which improves the load bearing capacity of a subgrade. Soil stabilization is used in roadways construction, parking areas, site development projects, airports and many other construction conditions where subsoil are not suitable for construction. Wide range (ranging from expansive clays to granular materials) of subsoil are improved using stabilization. Lime, Portland cement, Bitumen, Lime-kiln dust, Cement kiln dust are used as additives to improve soils (Firoozi and Baghini, 2017).

Geotechnical Engineers are faced with the problem of deficient soils such as soft clay, hence the need for soil improvement. Soil improvement can be achieved either by modification, stabilization or both. Modification is improvement of soil by addition of a modifier such as cement or lime to improve its index properties, while stabilization on the other hand is the treatment of soil to enable improvement of their strength and durability such that it is suitable for construction (Kennedy, 2012).

2. METHODOLOGY

2.1 Soft clay soil

The soil sample used in this research was obtained in Birgi and Lapai-Gwari villages in the suburbs of Minna, Niger State. The sample was collected at a depth of 1.00m - 2.00m using undisturbed sampling (remoulded). The soil sample was subjected to laboratory testing. The sample was tested again with the addition of Rice Husk Ash and Fly Ash in varying percentages.

2.2 Rice husk ash

The rice husk sample used in this research work was obtained from Bida, Niger State. Rice Husk Ash was produced by burning rice husk in an enclose incinerator in an open field for two hours.

2.3 Fly ash

The fly ash for this research is processed in powder form from a major supplier in Lokoja, Kogi State. It is a form of geopolymer available for construction purposes.

2.4 Test Method

The sample for testing was prepared as per the requirement of the tests. The pulverized soil sample was first sieved through the required sieve for a particular test. The required quantum soil was weighed out for the test. The material to be added to the soil was also sieved through the 425μm sieve, for the particular test and then the required quantum was weighed out on the weight basis as per the percentage to be added to the soil for test. The various proportions 2:4, 4:6, 6:8, 8:10and 10:12% of rice husk ash and fly ash blend . The soil and the material were then mixed together in dry conditions thoroughly before testing. The mixed sample was then used for performing the various tests. The laboratory analysis was carried out in accordance with British Standard methods 1377-2: 1990 of test for soil; While BS 1377: 1990 was used for the natural soil sample, BS 1994: 1990 was used for the stabilized soil samples.

2.5 Particle size

This test was carried out to determine the particle size distribution of the soil sample in accordance with BS 1377-2:1990. A representative sample of mass 600g was used for this test. This test was carried out using set of sieves. The sieves were cleaned and arranged orderly from sieve No. 4 at the top and sieve No. 200 at the bottom just before the collection pan. Dry weight of the sample was recorded before pouring it into the sieve assemblage. The mechanical shaker was turned on for 10 minutes. Thereafter, weight retained in each sieve and the collection pan was obtained.

2.6 Consistency Limits (Liquid Limit and Plastic Limit)

Consistency limit test is used to determine the clay content in the soil sample in term of Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI). Soil sample passing through 425µm sieve, weighing 200g was mixed with clean water to form a homogenous paste which was used for the determination of Liquid Limit (LL). The homogenous paste was placed in the Casangrade's apparatus, a groove was made in the paste and the number of blows made to close up the groove was obtained. Also, Plastic Limit (PL) was obtained using soil sample passing through 425µm sieve, weighing 200g mixed with clean water to form a homogenous paste. The paste was moulded into a ball shape before rolling in on a glass plate. Rolling of the sample on the glass plate continues until the thread cracks at approximately 3mm diameter is achieved. The plastic limit was determined by placing the 3mm diameter sample in oven at 105^{0}C for 24 hours to determine the moisture content.

$$PI = LL - PL \qquad (1)$$

2.7 Compaction Test

Compaction test was done in accordance with BS 1377: 1990. The soil sample was air dried and thoroughly pulverized so that it passes through BS sieve No. 4 (4.75mm). Test specimens were obtained by mixing reasonable quantity of dry soil with 2:4, 4:6, 6:8, 8:10 and 10:12% of both rice husk ash and fly ash respectively. The optimum moisture content (OMC) and maximum dry density (MDD) for the natural soil and mixture of the stabilized soil were obtained using the three energy levels adopted in this study.

2.8 California Bearing Ratio Test

This is a penetration test used to assess the strength of the soil for construction purposes. The test was carried out using the optimum moisture content obtained from the compaction test. It was compacted with 62 blows, 5 layers and at a drop height of 450mm with a 4.5kg rammer.
This was conducted according to the BS 1377 (1990) standard.

3. RESULTS AND DISCUSSION

3.1 Index properties

Results of particle size analysis and index properties of the natural soil are presented in Tables 1 and 2 respectively. The natural soil has 60.0% of silt – clay material passing through sieve No. 200. It has a Liquid Limit (LL) of 42% Plastic Limit (PL) of 26.10% and Plasticity index of 15.9% therefore, this soil is classified as A-7-5 according to AASHTO classification system and as Sandy Clay (SC) according to Unified Soil Classification System USCS.

Table 1: Particle size distribution result

Sieve	Percent by Weight		
Designation	Mass. Retained	% Retained	% PASSING
5.00	10.80	3.60	96.40
3.35	11.10	3.70	92.70
2.36	12.00	4.00	88.70
2.00	7.30	2.43	86.27
1.180	22.80	7.60	78.67
0.850	8.80	2.93	75.73
0.600	15.80	5.27	70.47
0.425	10.40	3.47	67.00
0.300	8.90	2.97	64.03
0.150	10.80	3.60	60.43
0.075	1.30	0.43	60.00

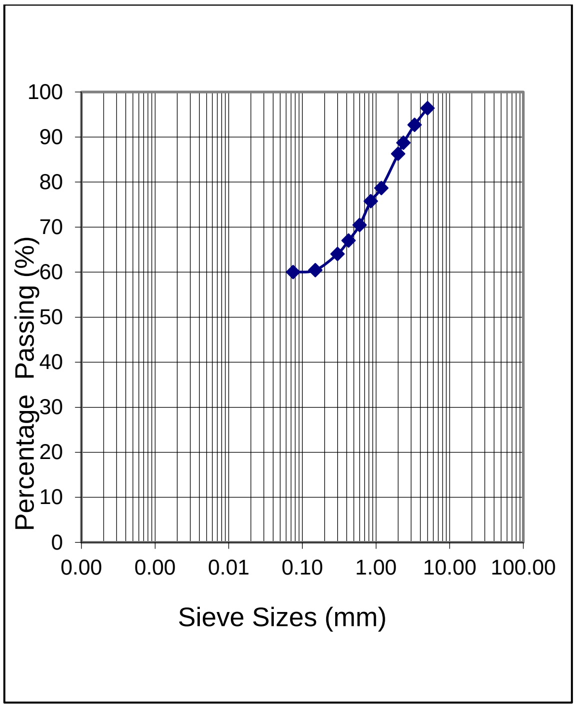


Figure1: Particle size distribution of soft clay soil

Table 2: Index properties of soil

Property	**Value**
Percentage passing BS sieve No. 200	60.00%
Liquid Limit	42.00%
Plastic Limit	26.10%
Plasticity Index	15.90%
AASHTO Classification	A-7-5
USCS classification	SC
Specific Gravity	2.65
Colour	Brownish

3.2 Compaction Characteristics

Maximum Dry Density

Figure 2 shows how the maximum dry density changes with the addition of rice husk ash and fly ash for British light, British Heavy and West Africa Standard compaction. It can be observed that the MDD value for British Light compaction reduced from 1.900g/cm³ for the natural soil to 1.850 g/cm³, then decreased to 1.740 g/cm³ and 1.49 g/cm before the value increased to 2.02 g/cm³ and 1.83 g/cm³ for proportion of (8:10) % and (10:12) % of rice husk ash and fly ash content respectively. British Heavy compaction and West African Standard Compaction shows an initial decline of the MDD value at (4:6) % addition of rice husk ash and fly ash. The MDD then progressively increased from 1.850 g/cm³ - 2.010 g/cm³ at (2:4) % of rice husk ash and fly ash respectively. Unlike British Light, the MDD increased slightly from 1.900 g/cm³ - 2.020 g/cm³ at (8:10) %. These results indicate that the values of MDD increases with increasing energy level. British standard heavy gave the best performance of 2.010 g/cm³ at (2:4) % addition of rice husk ash and fly ash. This implies that the higher the MDD values the higher the strength attained by the soil specimen.

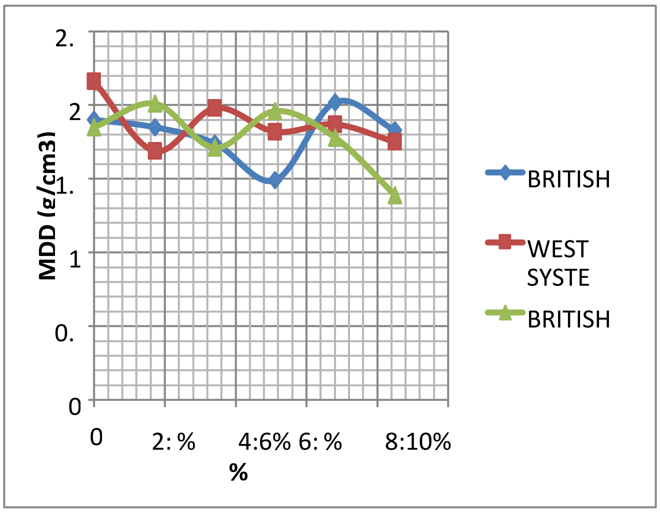


Figure 2: MDD variation with %RHA and %FA

Optimum Moisture Content

The optimum water content (OMC) of natural soil and specimens containing various percentages of rice husk ash and fly ash are presented in Figure 3. The result shows that upon addition of rice husk ash and fly ash for British Standard Heavy and West African System energy level, the OMC value initially increased from 15.20% and 10.20% for natural soil to 18.10% and 15.4% respectively. Thereafter, the values reduce to a minimum of 13.5% and 13.1% at 4:6% of rice husk ash and fly ash. British Standard Light effort experienced reduction in OMC of the natural soil which is 17.20% to a minimum value of 20.90% at 8:10% of rice husk ash and fly ash. This result indicates that a MDD of 1.710 g/cm³ can easily be attained at 13.50% OMC for pavement subgrade.

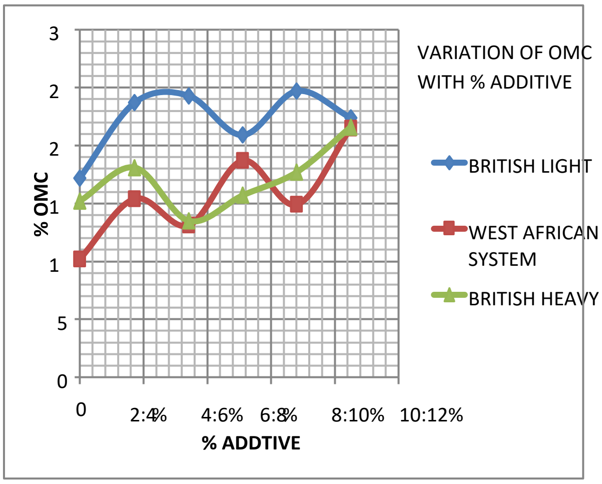
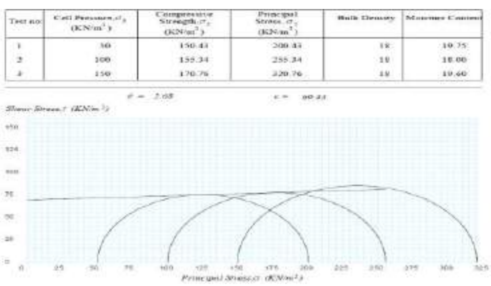


Figure 3: Variation of OMC with % rice husk ash and fly ash addition

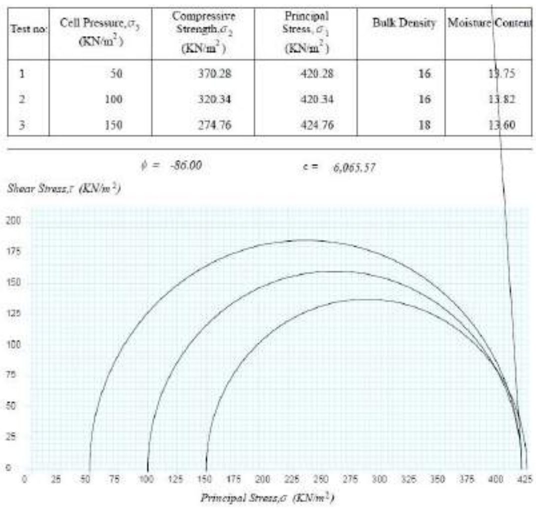
3.3 Shear Strength

The unconfined compressive shear strength results of the natural soft clay soil and specimens containing various percentages of rice husk ash and fly ash are presented in Figure 4. The result indicates that upon the addition of rice husk ash and fly ash for British Standard Heavy energy level, the UCS value initially increased from 320.76 kN/m^2 to 424.76 kN/m^2 which is the optimal value at (2:4) %. Thereafter, the value decreased to 308.11 kN/m^2 at (4:6) % replacement of rice husk ash and fly ash. Other energy level such as the British Standard Light and West African Standard all decreased according to the increment in the level of replacement of rice husk ash and fly ash.



Test no:	Cell Pressure, σ_3 (KN/m^2)	Compressive Strength, σ_2 (KN/m^2)	Principal Stress, σ_1 (KN/m^2)	Bulk Density	Moisture Content
1	50	150.43	200.43	18	19.75
2	100	155.34	255.34	19	18.00
3	150	170.76	320.76	19	19.60

Figure 4: UCS for British Standard Heavy at (0) % RHA and FA



Test no:	Cell Pressure, σ_3 (KN/m^2)	Compressive Strength, σ_2 (KN/m^2)	Principal Stress, σ_1 (KN/m^2)	Bulk Density	Moisture Content
1	50	370.28	420.28	16	13.75
2	100	320.34	420.34	16	13.82
3	150	274.76	424.76	18	13.60

Figure 5: UCS for British Standard Heavy at (2:4) % RHA and FA

3.4 California Bearing Ratio

The C.B.R values from the test result as shown in Figure 6 depicts that for the three compactive efforts like the British Heavy standard, British Light standard and West African standard the C.B.R values increased with the percentage addition of RHA and FA. The California bearing ratio of the soil specimen was optimally increased by 356% (from 33 kN/m^2 to 117.6 kN/m^2) at 2:4% mix proportion. This gives an optimal value as 117.6 kN/m^2, when the British Heavy Standard compaction method was used at 2:4% addition of Rice husk ash and Fly ash.

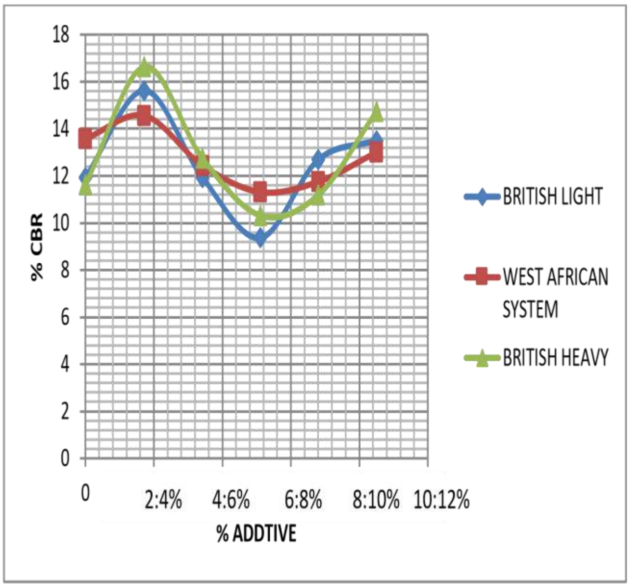


Figure 6: C.B.R value with %RHA and %FA

4. CONCLUSION

The conclusions drawn from the study were;

1. The test soil is classified as A-7-5 and SC according to AASHTO and Unified Soil Classification System respectively.
2. The Liquid Limit and Plasticity Index reduces with increasing percentage of rice husk ash and fly ash while the Plasticity Limit slightly increased with increment in rice husk ash and fly ash at 6:8, 8:10 and 10:12% respectively.
3. The Maximum Dry Density (MDD) shows an average increment with increasing compactive effort.
4. The unconfined compressive strength result of the soil was improved by 204% upon at 2:4% addition of rice husk ash and fly ash for British standard heavy compactive effort.
5. The results also indicate that the optimum performance of rice husk ash and fly ash blend with A-7-5 soil at 2:4% is suitable for subgrade pavement construction using the British Standard Heavy compactive effort.
6. The California bearing ratio of the soil specimen was optimally increased by 356% (from 33 kN/m^2 to 117.6 kN/m^2) at 2:4% mix proportion.
7. The study has established the potential of using rice husk ash and fly ash to stabilize a class of soft clay soil for construction purposes.

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