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Improving the Soil Properties by Adding Rice Husk Ash (RHA) and Ordinary Portland Cement (OPC): An Experimental Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The stabilization capability of rice husk ash (RHA) and Ordinary Portland cement (OPC) was scrutinized using laboratory scrutiny. Three soils (Soil A, B, and C) were improved with various percentages (via weight of dry soil) at 0, 2, 4, 6, 8, and 10% for all stabilizing agents and compacted via BSL (British Standard light) energy. Their impacts were assessed on the strength physiognomies such as UCS (unconfined compressive strength), OMC (optimum moisture content), California bearing ratio (CBR), and MDD (maximum dry density tests based on ASTM (American Standard Testing Materials) codes. The result reveals the optimum values for three lateritic samples, A, B, and C, illustrated a reduction in plasticity for rice husk ash (RSA) stabilizer from 17.32%, 12.67%, and 19.07% (at 6% cement) to 16.32%, 9.90% and 17.00% (at 6% cement and 6% RHA) respectively. Likewise, the optimum Triaxial test result for RHA at 6% with a specified cement content of 6% are A (Deviation stress 595.45KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 280, and Shear stress 175.5KN/m^2), B (Deviation stress 514.75KN/m^2, Cohesion 9KN/m^2, Angle of internal friction 280 and Shear stress 168.5KN/m^2), and C (Deviation stress 530.58KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 290 and Shear stress 162.0KN/m^2.

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1. INTRODUCTION

Laterites contribute to the general economy of the areas where they are found, their scope is very extensive and comprises of mining research such as (iron, aluminum as well as manganese) deposits, civil engineering and agronomic [1,2,3]. There is no need to emphasize the significance of laterites for various construction purposes [4,5]. In geotechnical works, a site is surveyed whether soil conditions meet the design criteria. Nevertheless, most frequently, sites designated for earthworks do not reach the minimum criterions [6,7,8], such as those with soft, highly compressible, or expansive soils lacking the desired strength for loading during construction or for their serviceability [9,10,11]. For this reason, such soils are enhanced through soil stabilization, wherein the mechanical properties of the soil are improved by applying materials that have cementitious properties or are considered to be binder materials [12,13,14]. Stabilization is necessary when soils at site are loose or highly compressible; when the soils have unsuitable consistency indices and are too highly permeable or any other undesirable property making them unsuitable for use in construction project [15,16,17]. Rapid rate of industrialization and expansion leads to high demand on quantity of cement for infrastructure works [18]. The manufacturing of cement, quite it's most vital material for concrete, cement signifies a sustainability subject that should be dealt with; which in turn known to be a substantial contributor towards the greenhouse gas emissions (GHGE) signifying about 5% of global CO_2 discharge [19,20,21]. The cement company needs intense energy, third (3^{rd}) largest consumer of energy after the power as well as steel sector [22,23]. An alternative to stabilizing soil is by introducing geopolymer materials and activators, a readily available proximate raw material, that release just 1 t of carbon-dioxide of energy into the climatic condition save energy beside create green environment [24]. Besides, is a product of the alkali activation of aluminosilicate materials present in industrial waste materials such as furnace slag, slag furnace, granulated blast-furnace slag, fly ash, kaolin clay and red mud.

2. MATERIALS AND METHODS

Soil sample used in this paper was collected from three different lateritic soil borrow pit along Abuja – lokoja road in the Federal capital territory of Nigeria. It was collected at a depth below than 150mm using the disturbed sampling approach and afterward air-dried [25,26]. The both cement and sodium silicate activator was purchased from the local market while rice husk was collected from a rice mill located at kwali, FCT Nigeria [6]. Rice husk fibre was incinerated into ash in a furnace with temperature of up to 500^0C for more than six (6) hours after which it was allowed to cool and absolutely grounded. Then it was sieved via 75mm sieve as prescribe BS 12 [21,5]. Similarly, Preliminary tests on the collected three lateritic soil sampling were done in the laboratory of the Department of Civil Engineering, Federal University of Technology, Akure, Ondo State, Nigeria.

3. RESULTS AND DISCUSSIONS

A. Atterberg Test

The effect of RHA, KCP, SSA and GP stabilized soils on the liquid limit (LL) and plasticity index (PI) on the different soils are showed in Table 1 and Fig. 1. In this context, the optimum values for three lateritic sample A, B and C illustrated reduction in plasticity for rice husk ash (RSA) stabilizer from 17.32%, 12.67% and 19.07% (at 6% cement) to 16.32%, 9.90% and 17.00% (at 6% cement and 6% RHA) respectively. In the same way, optimum of both kaolin clay powder (KCP) and geopolymer (GP) stabilizer was at 6% cement and 8% additives, meanwhile the values also experience reduction from 17.32%, 12.67% and 19.07% (at 6% cement) to 9.95%, 4.80% and 10.8% (KCP) as well as 13.85%, 8.97% and 16.00% (GP) for samples A, B and C respectively. Also sodium silicate activator (SSA) revealed decreasing trends and Optimum at 6% cement and 4% SSA, with values of 15.05%, 10.05% and 18.02% for sample A, B and C respectively. Reduce in the PI indicate an improvement.

According to Adeyanju et al. [6] and Igibah et al. [3], liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity and greater than 90% extremely high plasticity. This shows that samples A, B, and C, have intermediate plasticity. The addition of Portland cement in 2, 4, 6, 8 and 10% to the samples caused changes in the liquid limits and plastic limits of all the samples, the plasticity indices of samples A, B and C decreased from

23.36 to 7.89, 16.66 to 7.78 and 25.00 to 12.78 respectively. These reductions in plasticity indices are indicators of soil improvement.

B. Effect on the compressive strength (CBR)

Table 2 and Fig. 2 showed tremendous improvement in the CBR with increase in the RHA, KCP, SSA and GP content at specified cement contents.

The peak values of 6% cement and RHA is 6%, with values of 82.60%, 87.45% and 85.64% for samples A, B and C respectively. For both KCP and GP the optimum was 6% cement content plus 8% KCP or GP contents. The KCP optimum values are A (100.95%), B (97.50%) and C (98.50%), Whereas GP values are 125.75%, 120.75% and 115.75% for all the samples (A, B and C). Meanwhile it was observed that CBR of the soil-cement-SSA content increases upon adding sodium silicate activator content up to 4% SSA content before the value experiences reduction at much higher SSA content. But, the RHA-treated residual soils decrease the CBR value from 6% upwards. This, again, alludes that RHA alone is not suitable as stabilizer. Combination between RHA and cement yields a significant enhancing of strength. This result confirms that 6% cement– 8% KCP mixtures, and 6% cement–8% -GP mixtures attain the maximum CBR value, respectively, 100% and 125.75%

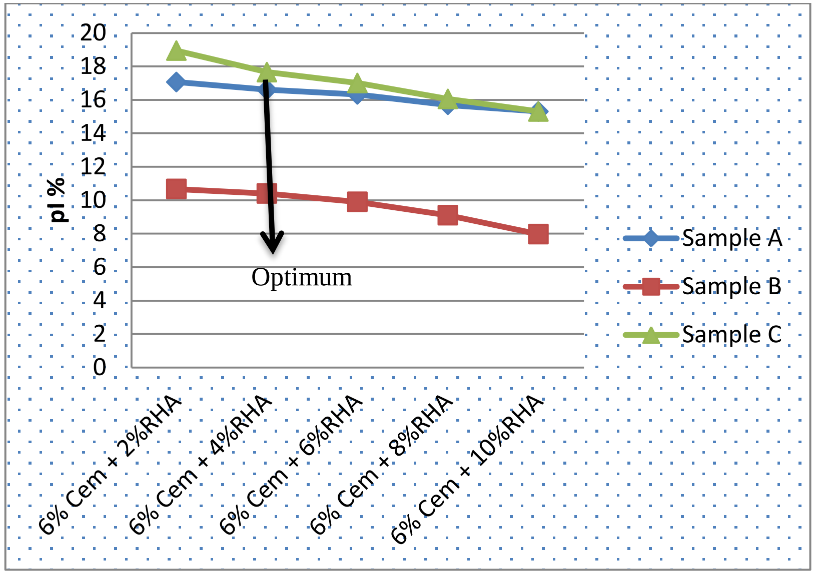
C. Effect on Triaxial

Results of triaxial test for Rice Husk Ash (RHA), sodium silicate activator (SSA) and geopolymerare shown in Table 3 and Fig. 3. The result showed the impact of various percentages of RHA, SSA and geopolymer on the soil sampling stabilized. The results showed that the optimum Triaxial test result for RHA at 6% with specified cement content of 6% are: A (Deviation stress 595.45KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 28^0 and Shear stress 175.5KN/m^2), B (Deviation stress 514.75KN/m^2, Cohesion 9KN/m^2, Angle of internal friction 28^0 and Shear stress 168.5KN/m^2), and C (Deviation stress 530.58KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 29^0 and Shear stress 162.0KN/m^2).

While the highest triaxial values for the KCP and GP stabilized soil was A (Deviation stress 608.25KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 29^0 and Shear stress 175.5KN/m^2), B (Deviation stress 578.20KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 28^0 and Shear stress 173.5KN/m^2), and C (Deviation stress 556.50KN/m^2, Cohesion 15KN/m^2, Angle of internal friction 20^0 and Shear stress 176.5KN/m^2), as well as (A (Deviation stress 638.05KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 29^0 and Shear stress 195.5KN/m^2), B (Deviation stress 628.30KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 28^0 and Shear stress 193.5KN/m^2), and C (Deviation stress 615.40KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 29^0 and Shear stress 188.40KN/m^2), at 8% stabilization respectively, using cement, (59.05, 58.05 and 58.85) N/mm² at 6% content. The trends of SSA was at 4% with specified cement value at 6% and the values are: A (Deviation stress 588.40KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 28^0 and Shear stress 162.2KN/m^2), B (Deviation stress 542.05KN/m^2, Cohesion 11KN/m^2, Angle of internal friction 28^0 and Shear stress 160.8KN/m^2), and C (Deviation stress 545.40KN/m^2, Cohesion 10KN/m^2, Angle of internal friction 28^0 and Shear stress 165.7KN/m^2).

Table 1. Atterberg limit test for RHA, Kaolin clay powder and geopolymer mix

Percentages	**Plasticity Index**								
	RHA (%)			**Kaolin (%)**			**Geopolymer mix (%)**		
	Ka	***Sa***	***Da***	***Ka***	***Sa***	***Da***	***Ka***	***Sa***	***Da***
6% cement +2% Additives	17.06	10.67	18.94	13.60	11.10	16.05	14.62	11.80	16.72
6% cement +4% Additives	16.60	10.40	17.65	11.37	8.62	15.80	14.07	9.67	16.45
6% cement +6% Additives	16.32	9.90	17.00	11.09	6.60	13.6	14.59	9.22	16.00
6% cement +8% Additives	15.70	9.10	16.05	9.95	4.80	10.8	13.85	8.97	16.00
6% cement +10% Additives	15.30	7.97	15.30	9.10	3.72	8.05	13.72	6.72	13.55



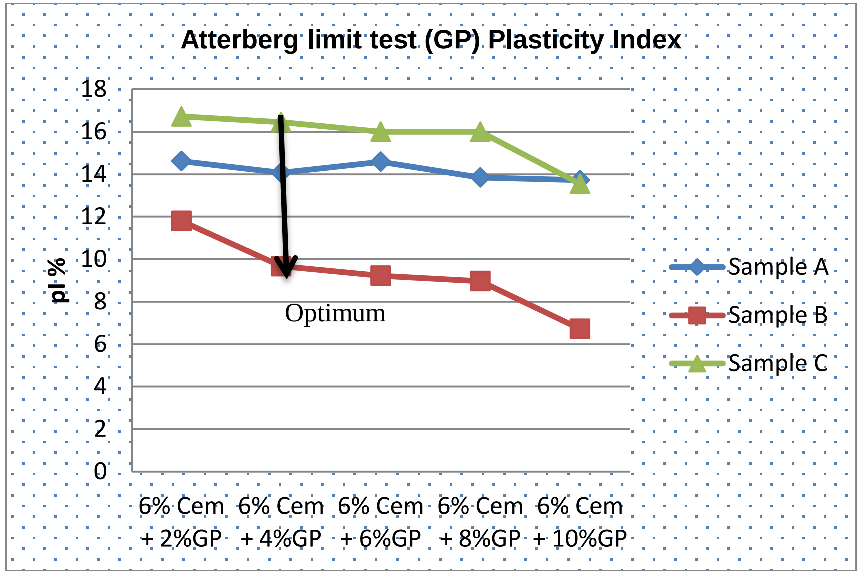


Fig. 1. Variation of Atterberg at optimum cement with percentages of geopolymer

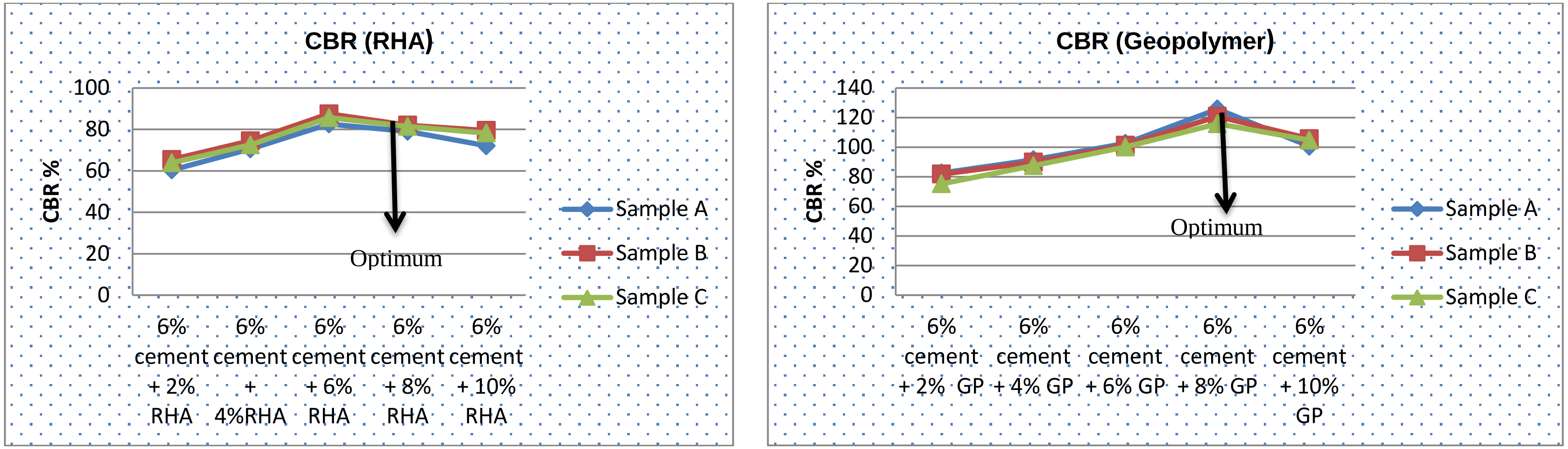


Fig. 2. Variation of CBR at optimum cement with percentages of Rice husk ash and geopolymer

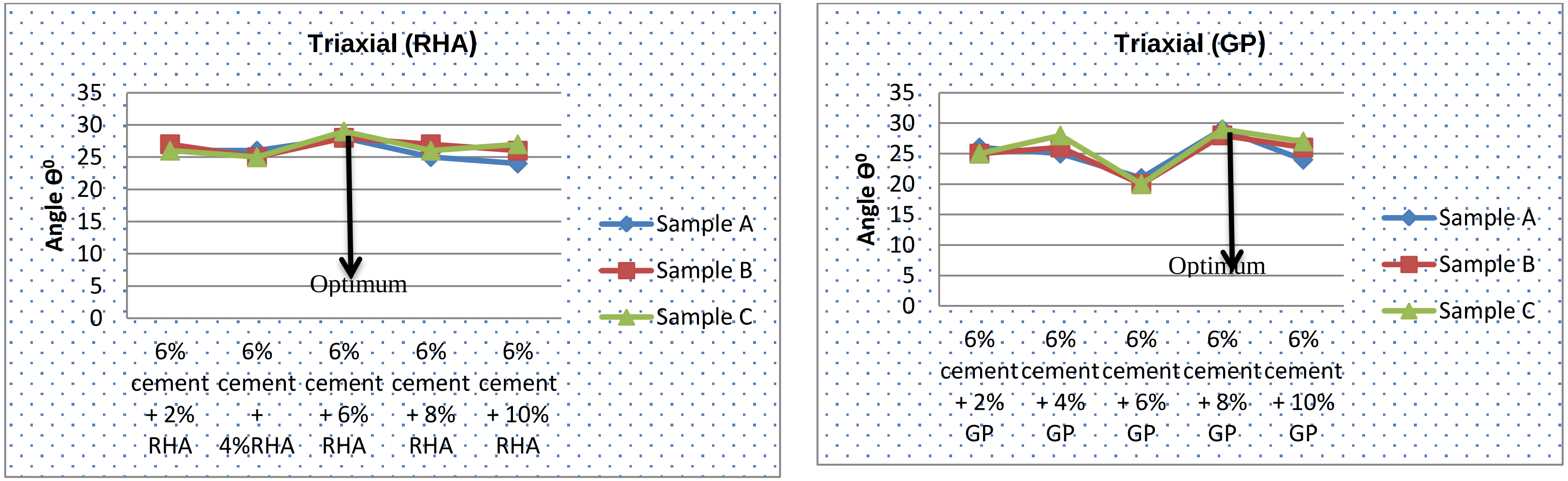


Fig. 3. Variation of Triaxial at optimum cement with percentages of Rice husk ash and geopolymer

Fig. 4. Field visit, material collection and laboratory test

Table 2. CBR for RHA, Kaolin clay powder and geopolymer mix

Percentages	CBR values								
	RHA (%)			Kaolin (%)			Geopolymer mix (%)		
	Ka	*Sa*	*Da*	*Ka*	*Sa*	*Da*	*Ka*	*Sa*	*Da*
6% cement +0% Additives	10.88	9.85	9.25	10.88	9.85	9.25	10.88	9.85	9.25
6% cement +2% Additives	60.45	65.45	63.89	60.45	65.45	63.89	60.45	65.45	63.89
6% cement +4% Additives	70.56	74.45	72.54	70.56	74.45	72.54	70.56	74.45	72.54
6% cement +6% Additives	82.60	87.45	85.64	82.60	87.45	85.64	82.60	87.45	85.64
6% cement +8% Additives	90.05	93.50	91.45	90.05	93.50	91.45	90.05	93.50	91.45
6% cement +10% Additives	98.65	100.25	98.90	98.65	100.25	98.90	98.65	100.25	98.90

Table 3. Triaxial for RHA, Kaolin clay and geopolymer mix

%	Angle of internal friction $(\Theta)^0$								
	RHA			Kaolin			Geopolymer mix		
	Ka	*Sa*	*Da*	*Ka*	*Sa*	*Da*	*Ka*	*Sa*	*Da*
6% cement +0% Additives	19	23	18	107.45	105.54	106.95	107.45	105.54	106.95
6% cement +2% Additives	11	26	11	320.26	300.12	300.46	399.54	387.44	398.42
6% cement +4% Additives	10	28	11	365.65	342.25	345.45	445.20	435.80	442.40
6% cement +6% Additives	16	21	16	370.45	359.25	369.35	460.32	440.42	458.72
6% cement +8% Additives	10	29	10	445.35	426.95	435.35	560.98	550.78	556.75
6% cement +10% Additives	19	27	18	540.05	519.65	520.75	678.35	658.45	675.35

Furthermore, Fig. 4 shows author visit to study location for collection of materials and Atterberg test in progress in the laboratory.

4. CONCLUSIONS

The investigations on KCP-SSA stabilized soils revealed that the lateritic soils were A-7-6 soil and the addition of RHA and silicate at 6% contents above, the OMC is increased abruptly. It also revealed that geopolymer material used will effectively improve cement stabilized lateritic soil at cement 6% plus, RHA 6%, KCP 8%, SSA 4% and GP 8%. The Optimum RHA and cement content was found at 6% for CBR and Triaxial tests for which indicate an improvement in the treated soil compared with the CBR of the natural The UCS values were at their peak at 6% RHA. Thus, KCP, OPC, RHA and sodium silicate activator are confirmed to be a good admixture in lateritic soil stabilization using 6% as their control.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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