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Variability of Rice Hush and Kaolin Clay as Locally Available Geopolymer Materials on Cement Stabilized Lateritic Soil

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Abstract: *The strength of a fine-grained lateritic soil from three (3) different localities on Abuja – Lokoja road where road failure happen was treated with rice husk ash (RSA), cement and sodium silicate activator (SSA), with varying percentage examined by means of Atterberg, CBR, and triaxial shear tests. 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%. Lateritic soil treated with 2% stabilizer yielded CBR values of more than 405%, that is for soil treated with 6% sodium silicate, the CBR values increased at least by 14% compared to unimproved soil. Likewise, the outcome of triaxial compressive strength demonstrates that the cohesion of the stabilized sample was low at the highest angle of internal friction which makes soil very plastic. The lowest cohesion of 15 kN/m^2, 11 kN/m^2 and 10 kN/m^2 was achieved at 8% KCP, 4% SSA and 6% RHA at highest frictional angle of 20°, 28° and 28° for KCP, SSA and RHA respectively.*

Keywords:*Geopolymer, construction, sodium silicate, rice hush ash, UCS, Abuja.*

1. INTRODUCTION

Laterite denote a different material to people living in different parts of the world. Most lateritic soils in their natural states have low bearing capacity and low strength due to high content of clay [1-2]. In a scenario or event that lateritic soils have high amount of clay materials its strength as well as stability cannot be guaranteed under load especially in the presence of moisture [3-5]. When lateritic soils contain high plastic clay, soil plasticity is capable of causing cracks, and damage on building foundations, flexible pavement, road ways, or any other civil engineering construction projects [1, 6-9]. The enrichment in the strength and durability of lateritic soil in recent time has become imperative; this has led researchers and scholars toward using stabilizing materials that are locally accessible at a very low cost [10-13]. In geotechnical works, a site is surveyed whether soil conditions meet the design criteria. On the other hand, most commonly, sites designated for earthworks do not meet the minimum standards, for instance those with soft, highly compressible, or expansive soils lacking the desired strength for loading during construction or for their serviceability [14-17]. 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 [18-20].

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. 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 [21-23]. Rice husk fibre was incinerated into ash in a furnace with temperature of up to 500^{o}C 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 [24]. 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.

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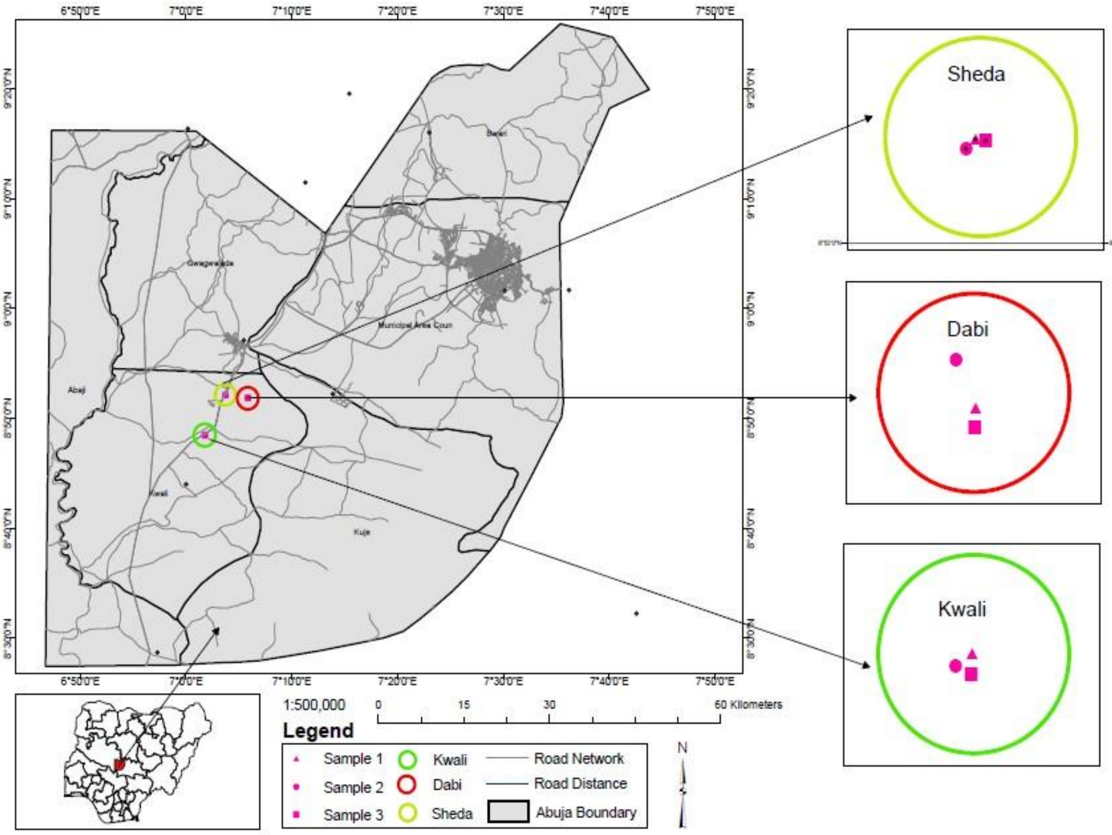

Figure 1: Map of Abuja FCT showing study sites localities within Kwali Local Government

3. RESULTS AND DISCUSSION

3.1 Atterberg limit

Results of Atterberg analysis for Rice Husk Ash (RHA), sodium silicate activator (SSA) and geopolymer are shown in Table 1-6, and graphically represented in Fig 2a&b. The result showed that the ranges of values of liquid limits are: A (40.45 – 42.34%), B (41.25 – 42.23%) and C (37.00 – 38.96%). Ranges of values of plasticity index in percentages are: A (23.36 – 23.53%), B (16.66 – 17.21%) and C (25.00-25.94%). Few of these soil samples did not conform to the requirement that PI should not be more than 12%; Adeyanju et al. [8]. The table also shows that most of the soils fell within A-2-7 and A-2-4 (Silty or clayed gravel and sand) soils according to AASHTO classification system (Table 5 & 6) for use as subgrade materials. Some of the samples met the requirement of BS 1377 specification as subbase and base materials on the basis percentage passing 200mm sieve and plasticity index (PI). Plasticity index (PI) decreases while Liquid limit (LL) increases as cement content increases till 6%. Reduction in liquid limit of lateritic soil treated (OPC) was noticed at 6 % while PI continues decreasing and this is an advantage, because reduction in PI contents indicates an improvement. The finding of the study is similar to that of Saberian [26]. 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.

According to Rezazadeh et al. [33] and Mola [28], liquid limit less than 35% indicates low plasticity, between thirty-five percent (35%) and fifty percent (50%) specifies intermediate plasticity, between fifty percent (50%) and seventy percent (70%) high plasticity, between seventy percent (70%) and ninety percent (90%) very high plasticity and, greater than ninety percent (90%) extremely high plasticity. This illustrates 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 as well as plastic limits of all the samples. These reductions in plasticity indices are pointers of soil improvement. Besides from Table 6, Federal Ministry of Works and Housing, for road works suggested liquid limits of fifty percent (50%) maximum for sub-base and base materials. All the studies soil samples are within this specification, hence making them suitable for sub-grade, sub-base and base materials.

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Table 1: Atterberg limit test for cement rice husk ash (RHA) stabilization

Samples	Percentage stabilization	Liquid limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
A	6% cement + 2% RHA	45.80	28.74	17.06
	6% cement + 4% RHA	46.45	29.85	16.60
	6% cement + 6% RHA	47.07	30.75	16.32
	6% cement + 8% RHA	46.60	30.90	15.70
	6% cement + 10% RHA	45.25	29.95	15.30
B	6% cement + 2% RHA	44.23	33.56	10.67
	6% cement + 4% RHA	45.00	34.60	10.40
	6% cement + 6% RHA	45.90	36.00	9.90
	6% cement + 8% RHA	44.75	35.65	9.10
	6% cement + 10% RHA	44.02	36.05	7.97
C	6% cement + 2% RHA	42.89	23.95	18.94
	6% cement + 4% RHA	43.60	25.95	17.65
	6% cement + 6% RHA	44.05	27.05	17.00
	6% cement + 8% RHA	43.00	26.95	16.05
	6% cement + 10% RHA	42.05	26.75	15.30

Table 2: Atterberg limit test for cement and Kaolin clay powder (KCP) stabilization

Samples	Percentage stabilization	Liquid limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
A	6% cement + 2% KCP	44.65	31.05	13.60
	6% cement + 4% KCP	49.42	38.05	11.37
	6% cement + 6% KCP	53.04	41.95	11.09
	6% cement + 8% KCP	57.00	47.05	9.95
	6% cement + 10% KCP	54.00	44.90	9.10
B	6% cement + 2% KCP	44.05	32.95	11.10
	6% cement + 4% KCP	47.02	38.40	8.62
	6% cement + 6% KCP	51.65	45.05	6.60
	6% cement + 8% KCP	53.75	48.95	4.80
	6% cement + 10% KCP	51.50	47.78	3.72
C	6% cement + 2% KCP	42.00	25.95	16.05
	6% cement + 4% KCP	43.75	27.95	15.80
	6% cement + 6% KCP	44.60	31.90	13.6
	6% cement + 8% KCP	46.50	35.70	10.8
	6% cement + 10% KCP	45.05	37.00	8.05

Table 3: Atterberg limit test for cement and Sodium Silicate Activator (SSA) stabilization

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Samples	Percentage stabilization	Liquid limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
A	6% cement + 2% SSA	43.80	28.30	15.50
	6% cement + 4% SSA	46.82	33.80	15.05
	6% cement + 6% SSA	45.35	31.85	13.05
	6% cement + 8% SSA	45.20	32.75	12.45
	6% cement + 10% SSA	44.05	31.95	12.10
B	6% cement + 2% SSA	44.00	33.95	10.05
	6% cement + 4% SSA	46.75	36.70	10.05
	6% cement + 6% SSA	45.45	36.05	9.40
	6% cement + 8% SSA	45.20	36.05	9.15
	6% cement + 10% SSA	44.75	36.85	7.90
C	6% cement + 2% SSA	41.80	23.85	17.95
	6% cement + 4% SSA	45.50	27.48	18.02
	6% cement + 6% SSA	44.05	26.70	17.35
	6% cement + 8% SSA	43.75	26.85	16.90
	6% cement + 10% SSA	43.05	27.40	15.65

Table 4: Summary of Atterberg limit test for cement and geopolymer (GP) stabilization

Samples	Percentage stabilization	Liquid limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
A	6% cement + 2% GP	44.67	30.05	14.62
	6% cement + 4% GP	49.52	35.45	14.07
	6% cement + 6% GP	54.64	40.05	14.59
	6% cement + 8% GP	61.80	47.95	13.85
	6% cement + 10% GP	59.50	45.78	13.72
B	6% cement + 2% GP	44.75	32.95	11.80
	6% cement + 4% GP	49.62	40.40	9.67
	6% cement + 6% GP	53.65	45.05	9.22
	6% cement + 8% GP	57.75	48.95	8.97
	6% cement + 10% GP	56.50	49.78	6.72
C	6% cement + 2% GP	42.67	25.95	16.72
	6% cement + 4% GP	44.75	28.30	16.45
	6% cement + 6% GP	47.60	31.60	16.00
	6% cement + 8% GP	51.50	35.00	16.00
	6% cement + 10% GP	49.05	37.50	13.55

Table 5: Revised AASHTO system of soil classification

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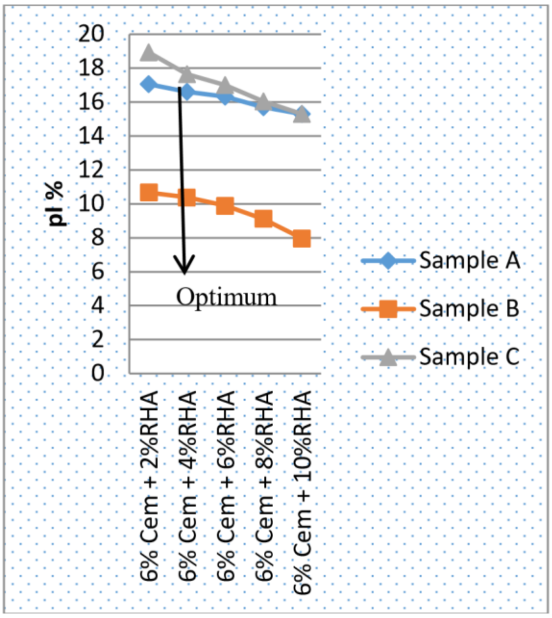
General Classification	General Materials (35% or less passing 0.075 mm)							Silt-clay materials (more than 35% passing 0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis % passing 2.00 mm (No10) 0.425 mm (No40) 0.725 mm (No200)	50max 30max 15max	50max 25max	51min 10max	35max	35max	35max	35max	36min	36min	36min	36min
Characteristics of fraction passing Liquid limit Plastic Index	6max		N.P	40max 10max	41min 10max	40max 11min	41min 11min	40max 10max	41min 10max	40max 11min	40min 11min
Usual types of significant Constituent material	Stone fragment Gravel and sand		Fine Sand	Silty or clayey Gravel and sand				Silty soils		Clayey soils	
General rating	Excellent to Good							Fair to poor			

Table 6: Analysis result versus FMWH and AASHTO system of soil classification

FMWH (1997)	Kwali			Sheda			Dabi		
	Ka_1	Ka_2	Ka_3	Sa_1	Sa_2	Sa_3	Da_1	Da_2	Da_3
LL (< 35%)	40.45 Fail	41.56 Fail	42.34 Fail	41.25 Fail	41.35 Fail	42.23 Fail	37.00 Fail	38.02 Fail	38.96 Fail
PI (<12%)	23.36 Fail	23.53 Fail	23.37 Fail	16.66 Fail	17.05 Fail	17.21 Fail	25.00 Fail	25.35 Fail	25.94 Fail
CBR soaked for subbase (>30%)	10.88 Fail	10.92 Fail	10.96 Fail	10.46 Fail	9.85 Fail	10.54 Fail	10.42 Fail	9.25 Fail	10.51 Fail
AASHO (1990) classification									
LL (Max 40%)	40.45 Fail	41.56 Fail	42.34 Fail	41.25 Fail	41.35 Fail	42.23 Fail	37.00 Pass	38.02 pass	38.96 Pass
PI (Max 10%)	23.36 Fail	23.53 Fail	23.37 Fail	16.66 Fail	17.05 Fail	17.21 Fail	25.00 Fail	25.35 Fail	25.94 Fail
Overall Rating	A-2-4 but not good subbase or base materials.								



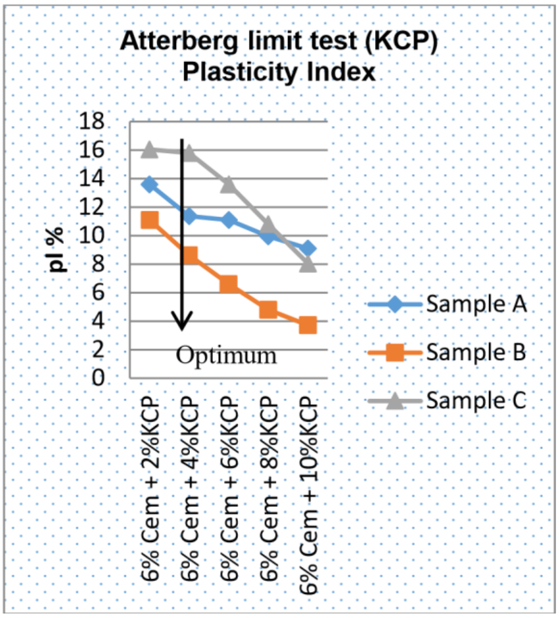


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Figure.2a: Variation of Atterberg at optimum cement with percentages of RHA and KCP

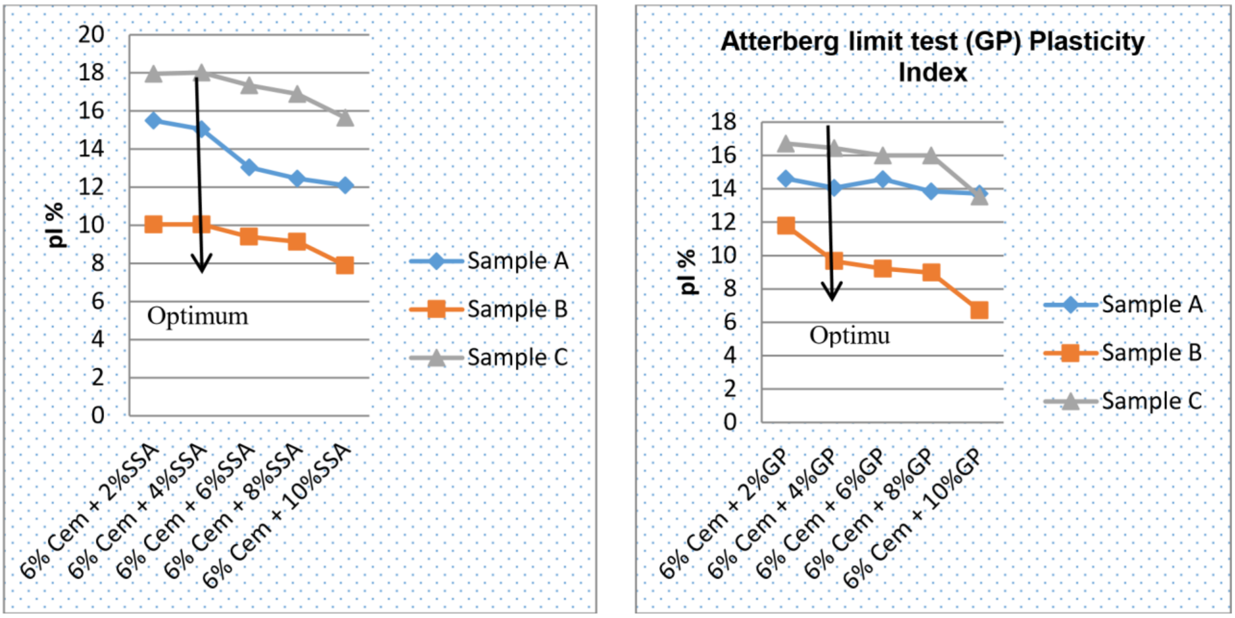

Figure 2b: Variation of Atterberg at optimum cement with percentages of SSA and geopolymer

3.3 Effect of CBR

The results of CBR test presented in Table 7-10 and Figure 3, the CBR values of Ordinary Portland Cement showed an increase in the CBR value of the lateritic soil tested indicating capacity to stabilize the soil. The values increased from 10.88, 16.98 and 9.25% at 0% to 39.09, 32.56 and 31.95% at 6% for samples A, B and C respectively. After 6% CBR values fall for all samples and gave values of: A (29.05), B (28.75) and C (27.25%) at 10%. The finding of the study is similar to that of Chang and Cho [43], Elandaloussi [5] and Kuang [24].

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 indicates that only RHA is not suitable as improver or stabilizer. Combination between RHA as well as 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%, For soil treated with 6% sodium silicate, however, the CBR values increased at least by 14% compared to untreated soil which is in agreement with research work by Sharma [30]. Multiple enhancement of CBR value is reached when lesser of sodium silicate or at most 6% cement content and RHA is mixed. Further, this is a benefit for road construction because is economical. This is in agreement with research works by Ghadakpour et al. [31], Adbulkareen. [32], Rezazadeh [33], Abdullah et al. [34], Tan et al. [36] and Dheyab et al. [37].

Likewise, the observed increase in the CBR was as a result of formation of a crystalline phase of CSH and CAH, which contributes to strength gain [38-40]. Whilst the consequential decrease in the value beyond the 6% kaolin content was as a result of the increase surface area triggered by excess amount of kaolin content, as such making the mixture which necessitates more water for hydration completion [41-43]. According to FMWH, all the peak values recorded at 6% kaolin content for the unsoaked CBR could be acceptable for subbase coarse, if is within the (60-80%) recommendation for adequate sub base material. Whilst for the soaked CBR all the values recorded at 6% kaolin content, within (20-30%) for sub base material, are recommended as adequate sub base material.

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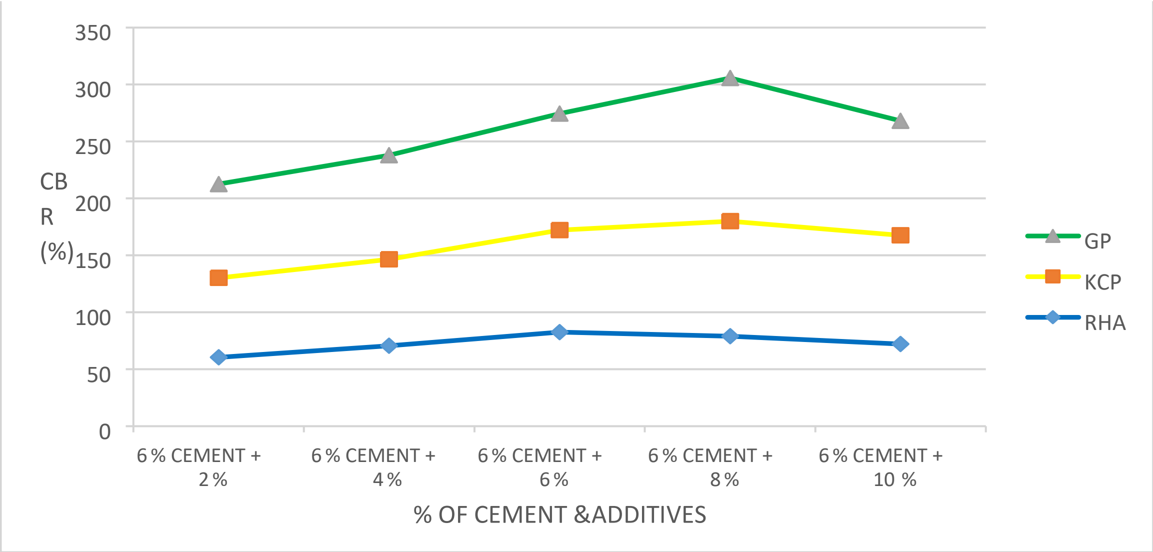

Figure 3: Variations of 6% cement and various proportions of additives

Table 7: Unsoaked CBR with varying percentages of RHA

Samples	**Cement content**	**Unsoaked (%)**
A	6% cement + 2% RHA	60.45
	6% cement + 4%RHA	70.56
	6% cement + 6% RHA	82.60
	6% cement + 8% RHA	79.05
	6% cement + 10% RHA	72.05
B	6% cement + 2% RHA	65.45
	6% cement + 4% RHA	74.45
	6% cement + 6%RHA	87.45
	6% cement + 8% RHA	82.05
	6% cement + 10% RHA	79.50
C	6% cement + 2% RHA	63.89
	6% cement + 4% RHA	72.54
	6% cement + 6% RHA	85.64
	6% cement + 8% RHA	81.45
	6% cement + 10% RHA	78.25

Table 8: Unsoaked CBR with varying percentages of KCP

Samples	**Cement content**	**Unsoaked (%)**
A	6% cement + 2% KCP	69.75
	6% cement + 4% KCP	75.85
	6% cement + 6% KCP	89.50
	6% cement + 8% KCP	100.95
	6% cement + 10% KCP	95.60
	6% cement + 2% KCP	59.25

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B	6% cement + 4% KCP	78.52
	6% cement + 6% KCP	89.25
	6% cement + 8% KCP	97.50
	6% cement + 10% KCP	91.50
C	6% cement + 2% KCP	58.25
	6% cement + 4% KCP	76.50
	6% cement + 6% KCP	85.20
	6% cement + 8% KCP	98.50
	6% cement + 10% KCP	90.70

Table 9: Unsoaked CBR with varying percentages of geopolymer

Samples	**Cement content**	**Unsoaked (%)**
A	6% cement + 2% GP	82.45
	6% cement + 4% GP	91.45
	6% cement + 6% GP	102.45
	6% cement + 8% GP	125.75
	6% cement + 10% GP	100.50
B	6% cement + 2% GP	81.80
	6% cement + 4% GP	89.85
	6% cement + 6% GP	101.25
	6% cement + 8% GP	120.75
	6% cement + 10% GP	105.65
C	6% cement + 2% GP	75.25
	6% cement + 4% GP	87.45
	6% cement + 6% GP	100.05
	6% cement + 8% GP	115.75
	6% cement + 10% GP	104.65

3.4 Effect of Triaxial

Results of triaxial test for ordinary Portland cement (OPC) stabilized lateritic soil are shown in Table 11-13, and graphically demonstrated in Figure 4a&4b. The result shown 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 595.45 kN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 28^0 and Shear stress 175.5 kN/m^2), B (Deviation stress 514.75 kN/m^2, Cohesion 9 kN/m^2, Angle of internal friction 28^0 and Shear stress 168.5 kN/m^2), and C (Deviation stress 530.58 kN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 29^0 and Shear stress 162.0 kN/m^2). While the highest triaxial values for the KCP and GP stabilized soil was A (Deviation stress 608.25KN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 29^0 and Shear stress 175.5 kN/m^2), B (Deviation stress 578.20 kN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 28^0 and Shear stress 173.5 kN/m^2), and C (Deviation stress 556.50Kk/m^2, Cohesion 15 kN/m^2, Angle of internal friction 20^0 and Shear stress 176.5 kN/m^2), as well as (A (Deviation stress 638.05 kN/m^2, Cohesion 10KN/m^2, Angle of internal friction 29^0 and Shear stress 195.5 kN/m^2), B (Deviation stress 628.30 kN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 28^0 and Shear stress 193.5 kN/m^2), and C (Deviation stress 615.40 kN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 29^0 and Shear stress 188.40 kN/m^2), at 8% stabilization respectively, using cement, (59.05, 58.05 and 58.85) N/mm^2 at 6% content. The trends of SSA were at 4% with specified cement value at 6% and the values are: A (Deviation stress 588.40 kN/m^2, Cohesion 10KN/m^2, Angle of internal friction 28^0 and Shear stress 162.2KN/m^2), B (Deviation stress 542.05 kN/m^2, Cohesion 11 kN/m^2, Angle of internal friction 28^0 and

Shear stress 160.8 kN/m^2), and C (Deviation stress 545.40 kN/m^2, Cohesion 10 kN/m^2, Angle of internal friction 28^0 and Shear stress 165.7 kN/m^2). Furthermore, this result reveals that the cohesion of the stabilized sample was low at the highest angle of internal friction which makes soil very plastic. The lowest cohesion of 15 kN/m^2, 11 kN/m^2 and 10 kN/m^2 was achieved at 8% KCP, 4% SSA and 6% RHA at highest frictional angle of 20°, 28° and 28° for KCP, SSA and RHA respectively.

Table 10: Triaxial test for optimum cement and rice husk ash (RHA) stabilization

Samples	**Cement content**	**Deviation stress σ^3 (kN/m^2)**	**Cohesion C kN/m^2**	**Angle of internal friction (Θ)^0**	**Shear stress ꞇ (kN/m^2)**
A	6% cement + 2% RHA	583.50	11	26	161.0
	6% cement + 4%RHA	587.40	15	26	168.3
	6% cement + 6% RHA	595.45	10	28	175.5
	6% cement + 8% RHA	575.05	14	25	145.5
	6% cement + 10% RHA	510.30	19	24	140.2
B	6% cement + 2% RHA	508.45	13	27	159.0
	6% cement + 4% RHA	516.05	12	25	164.2
	6% cement + 6%RHA	514.75	09	28	168.5
	6% cement + 8% RHA	505.20	11	27	145.5
	6% cement + 10% RHA	485.20	18	26	138.5
C	6% cement + 2% RHA	538.45	15	26	164.5
	6% cement + 4% RHA	532.40	14	25	163.5
	6% cement + 6% RHA	530.58	10	29	162.0
	6% cement + 8% RHA	525.62	12	26	158.5
	6% cement + 10% RHA	515.50	19	27	145.2

Table 11: Summary of Triaxial test for optimum cement and kaolin clay powder (KCP) stabilization

Samples	**Cement content**	**Deviation stress σ^3 (kN/m^2)**	**Cohesion C kN/m^2**	**Angle of internal friction (Θ)^0**	**Shear stress ꞇ (kN/m^2)**
	6% cement + 2% KCP	575.50	11	26	160.4
	6% cement + 4% KCP	592.40	12	28	165.3
A-	6% cement + 6% KCP	597.45	16	21	168.7
	6% cement + 8% KCP	608.25	10	29	175.5
	6% cement + 10% KCP	585.50	19	27	160.0

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B	6% cement + 2% KCP	528.45	11	25	159.4
	6% cement + 4% KCP	540.05	11	26	164.8
	6% cement + 6% KCP	564.75	16	20	167.5
	6% cement + 8% KCP	578.20	10	28	173.5
	6% cement + 10% KCP	555.24	18	26	169.0
C	6% cement + 2% KCP	532.45	14	25	169.5
	6% cement + 4% KCP	548.35	15	28	172.6
	6% cement + 6% KCP	556.50	15	20	176.5
	6% cement + 8% KCP	575.40	10	29	178.2
	6% cement + 10% KCP	545.50	19	27	167.0

Table 12: Summary of Triaxial test for optimum cement and Sodium Silicate Activator (SSA) stabilization

Samples	**Cement content**	**Deviation stress σ^3 (kN/m^2)**	**Cohesion C kN/m^2**	**Angle of internal friction $(\Theta)^0$**	**Shear stress ʈ (kN/m^2)**
	6% cement + 2% SSA	562.50	11	26	159.0
	6% cement + 4% SSA	588.40	10	28	162.2
	6% cement + 6% SSA	580.05	16	21	161.5
	6% cement + 8% SSA	494.30	13	26	152.5
	6% cement + 10% SSA	450.20	19	26	147.0
B	6% cement + 2% SSA	518.45	13	25	157.4
	6% cement + 4% SSA	542.05	11	28	160.8
	6% cement + 6% SSA	535.50	16	20	159.5
	6% cement + 8% SSA	485.20	14	26	150.2
	6% cement + 10% SSA	432.30	18	26	147.5
C	6% cement + 2% SSA	525.95	14	25	161.4
	6% cement + 4% SSA	545.40	10	28	165.7
	6% cement + 6% SSA	544.50	15	20	165.5
	6% cement + 8% SSA	475.20	13	26	148.0
	6% cement + 10% SSA	450.50	19	27	146.5

Table 13: Summary of Triaxial test for optimum cement and geopolymer (GP) stabilization

Samples	**Cement content**	**Deviation stress σ^3 (kN/m^2)**	**Cohesion C kN/m^2**	**Angle of internal friction $(\Theta)^0$**	**Shear stress ʈ (kN/m^2)**
A	6% cement + 2% GP	595.50	11	26	180.5
	6% cement + 4% GP	602.40	13	25	185.2
	6% cement + 6% GP	615.45	16	21	188.7
	6% cement + 8% GP	638.05	10	29	195.5
	6% cement + 10% GP	590.00	19	24	185.0
	6% cement + 2% GP	535.45	11	25	179.4

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B	6% cement + 4% GP	550.05	11	26	184.8
	6% cement + 6% GP	584.75	16	20	187.6
	6% cement + 8% GP	628.30	10	28	193.5
	6% cement + 10% GP	585.30	18	26	187.4
C	6% cement + 2% GP	550.34	14	25	179.5
	6% cement + 4% GP	578.05	13	28	182.6
	6% cement + 6% GP	596.60	15	20	186.5
	6% cement + 8% GP	615.40	10	29	188.4
	6% cement + 10% GP	585.50	19	27	185.5

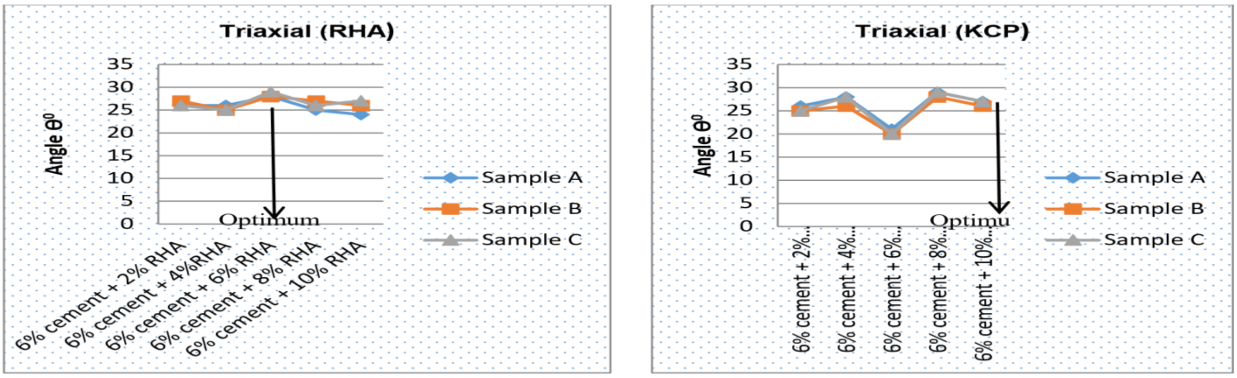

Figure 3a: Variation of Triaxial at optimum cement with percentages of RHA and KCP

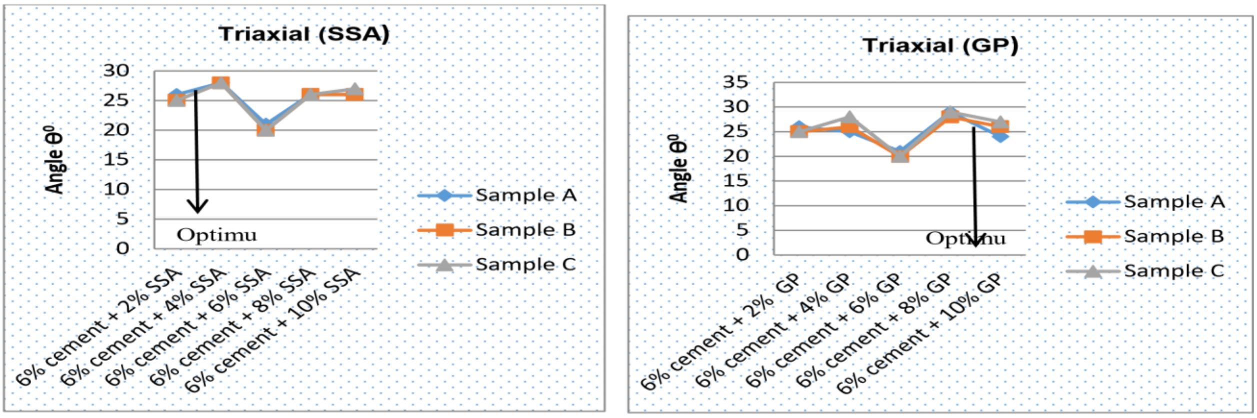

Figure 3b: Variation of Triaxial at optimum cement with percentages of SSA and geopolymer

4. CONCLUSION

From the analysis the lateritic soils were classified to be an A-2-4 soil based on AASHTO classification method. It is also a Silty or clayey gravel and sand according to the same identification system. The addition of sodium silicate changes laterite sample of PI into non-plastic and resulted in a minimum of 11.90 % reduction in PI of lateritic soil which led to the belief that sodium silicate decreases plasticity of soils. The Optimum RHA and cement content was found at 6% for CBR tests for which indicate an improvement in the treated soil compared with the CBR of the natural. The increase in CBR value corresponds to the increase in cement content. Adding RHA, KCP and SSA into cement- treated residual soil, the CBR value increase multiply. In general, 6% of cement and RHA and 8% and 4% KCP and SSA show the optimum amount to improve the properties of soils. Reduction in PI and increase in resistance as well as strength, indicate an improvement. Thus, RHA and kaolin clay can potentially stabilize or enrich the residual soil, either uniquely or mixed with cement. Utilizing is an alternative, it is available to lessen the construction cost, particularly in the sub-urban or rural area of developing nations.

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