

Mechanical Enhancement of a Fine-Grained Lateritic Soil blended with Portland cement powder for Use in Construction works.

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, Compaction and triaxial shear tests. The result reveals that cement additive improved the lateritic soil from Liquid limit values of 41.25 at 0% to 44.36 at 8%, but reduces at 10% to 35.67, while RHA increases at increased percentages. The MDD improved with increase in the quantities of all the additive (SSA, cement and RHA) content, while OMC for both cement and RHA reduce from 18.65% at 0% to 11.71 and 18.05 respectively. It reveals cohesion of the soil at 0, 2, 4, 6, 8 and 10% to be 19, 39, 49, 55, 58 and 65 KN/m² respectively, with highest angle of 65⁰ and lowest of 37⁰. This implies that the cohesion of the improved sample was satisfied since the improved angle of internal friction is above the angle that makes soil very plastic which is 28⁰.

Keywords: Geopolymer, Road engineering, Sodium silicate, rice hush ash, Triaxial, Abuja.

Introduction

In recent times, usage of soil in construction road works has become a major crisis to civil engineers [1], specifically geotechnical engineers because most of soils available do not meet some geotechnical engineering properties, on the other hand [2-3], the need for soil enhancement by either stabilization or modification might be needed for obtaining the required results of the properties[4-6]. Lateritic soils are the most common category of soil encountered during any road construction works in Nigeria, and mostly have low bearing capacity and strength [7-9], due to high quantities of clay in its natural state[10-13]. Lateritic soil having high quantity of clay mineral will possess weak strength under load, particularly when it comes in contact with moisture[14-17]. Similarly, lateritic soil with high quantity of plastic clay instigates cracks as well as damage to civil engineering works for example building foundations, road pavement or any correlated civil engineering project works[18-21].

Soil stabilization or enhancement can be categorized into two sets, precisely mechanical and chemical stabilization[22,23]. Mechanical stabilization or improvement process signifies the changes in the physical properties [24] or parameters of the soil particles with the help of either revitalize vibrations [25], compaction or both [26], whereas chemical stabilization is a technique utilized for chemical modification between admixture or cementitious material and the pozzolanic materials (soil minerals) for achieving the best result from improving the principal geotechnical properties of the soil[27-31]. The key problem connected with chemical stabilization, especially cement enhancement or stabilization a major chemical stabilization widely accepted [32], consist of the following; high prize of cement production that trigger high cost of stabilized road construction work [33-35], and high discharge of CO₂ during manufacturing process which in turn responsible for global warming[36-38].

In the technologically advanced nations, the universal and cost-effective materials that are frequently used to partly substitute cement without economic significance are classified into industrial-waste as well as agricultural-waste (agro-waste) materials [37-40], for instances, bag asse

ash, wood ash, groundnut shell ash, iron ore tilling, saw dust ash, bone ash, rice hush ash, and coconut shell ash[41-44].

Literature review publicized that projected quantities of kaolin mineral deposit reserve in Nigeria, is roughly 2 billion metric tons[45,46]. Similarly, metakaolin is the remnant from the burning of kaolin (dehydroxylated kind of kaolin), normally via heating to roughly temperature of 750⁰C [47-49].In view of the fact that kaolin mineral does not have carbonates, thus no amount of CO₂ is discharged during burning or calcination, as such will minimalize the detrimental impact of CO₂released during manufacturing of industrially synthetic soil enhancement agent [50-52].

Table 1: Fundamental and Engineering Properties of the selected lateritic soil before improvement.

PROPERTIES	SOIL SAMPLES (CONTROL)		
	KA	SA	DA
Natural Moisture Content	6.5	7.5	5.4
Specific Gravity	2.5	2.6	2.2
Grain Size Distribution			
Coarse (%)	90.88	93.42	91.87
Fine (%)	09.12	06.58	08.13
Bulk density (KN/m ³)	14.64 – 29.76	12.23 – 22.36	14.63 – 22.76
Consistency Limit (%)			
Liquid Limit	40.45	41.25	37.00
Plastic Limit	17.09	24.59	12.00
Plasticity Index	23.36	16.66	25.00
Compaction Test			
Maximum Dry Density (KN/m ²)	18.65	17.80	15.19
Optimum Moisture Content (%)	9.15	9.89	9.67
California Bearing Ratio (%)	9.88	8.46	7.42
Unconfined compressive strength (N/mm ²)	107.45	105.54	106.95
Triaxial test			
Cohesion (KN/m ²)	19	18	19
Angle of internal friction Θ^0	23	22	23
Soil Classification	A-2-7	A-2-7	A-2-4
Colour	Reddish brown		Brown
Soil Type	Silty or clayey gravel and sand		

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 [53,54]. Rice husk fibre was incinerated into ash in a furnace with temperature of up to 500⁰C 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 [50]. 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 DISCUSSION

3.1 Preliminary Tests results

Results of preliminary tests on the lateritic soil are shown in Table 1. It shows that the soil is classified as A-7-6 according to AASHTO classification system. This implies that it falls below the recommended standard for use for construction work and would therefore require improvement.

3.2 Atterberg limit

Results of Atterberg analysis for Rice Husk Ash (RHA), sodium silicate activator (SSA) and geopolymer are shown in Table 2-4, and graphically represented in Fig 1-3.

The result reveals cement additive improved the lateritic soil from Liquid limit values of 41.25 at 0% to 44.36 at 8%, but reduces at 10% to 35.67, while RHA increases at increased percentages. This implies that rice husk ash (RHA) contains the main chemical constituents of cement which are MgO, Al₂O₃, CaO, SiO₂, etcetera. This implies that RHA is a good pozzolana that can aid the promotion of the cementitious compounds configuration with cement hydration reaction products which is in agreement with Adeyanju et al. [8], Zhu et al. [10] and Xia[11].

Table 2: Effect of RHA on Atterberg limit test.

%	KA			SA			DA		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
0	40.45	17.09	23.36	41.25	24.59	16.66	37.00	12.00	25.00
2	25.30	06.34	18.96	27.23	10.56	16.67	23.89	3.24	20.65
4	28.23	07.32	20.91	31.23	13.24	17.99	27.54	3.67	23.87
6	32.12	08.34	23.78	34.56	14.35	20.21	30.12	4.34	25.78
8	35.23	08.98	26.25	37.05	15.56	21.49	32.76	4.90	27.86
10	37.22	09.08	28.14	38.02	16.53	21.49	33.25	5.62	27.63

Table 3: Effect of SSA on Atterberg limit test

%	KA			SA			DA		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
0	40.45	17.09	23.36	41.25	24.59	16.66	37.00	12.00	25.00
2	20.98	14.05	6.93	20.98	12.56	8.42	19.78	11.05	8.73
4	21.34	12.06	9.28	21.34	11.56	9.78	17.34	10.75	6.59
6	30.67	10.05	20.62	30.67	10.75	19.92	20.67	10.04	10.63
8	31.67	9.06	22.61	31.67	19.45	12.22	21.67	9.54	12.13
10	29.65	8.56	21.09	29.65	17.45	12.20	19.65	8.75	10.90

Table 4: Effect of geopolymer on Atterberg limit test

%	KA			SA			DA		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
0	40.45	17.09	23.36	41.25	24.59	16.66	37.00	12.00	25.00
2	44.67	18.50	26.17	45.67	19.25	26.42	40.67	17.20	23.47
4	49.52	19.50	30.02	50.12	20.45	29.67	42.75	18.50	24.25
6	57.64	31.65	25.99	59.54	32.45	27.09	54.60	30.80	23.80
8	64.80	33.60	31.20	67.50	34.56	32.94	61.50	31.50	30.00
10	71.60	39.50	32.10	73.56	40.56	33.00	69.60	37.60	32.00

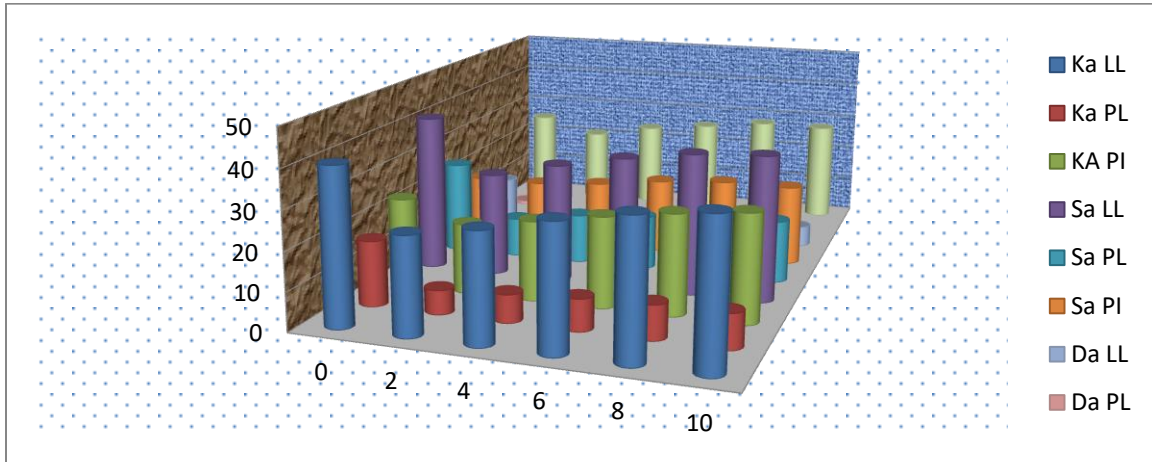


Fig. 1: Impact of RHA on Atterberg limit test.

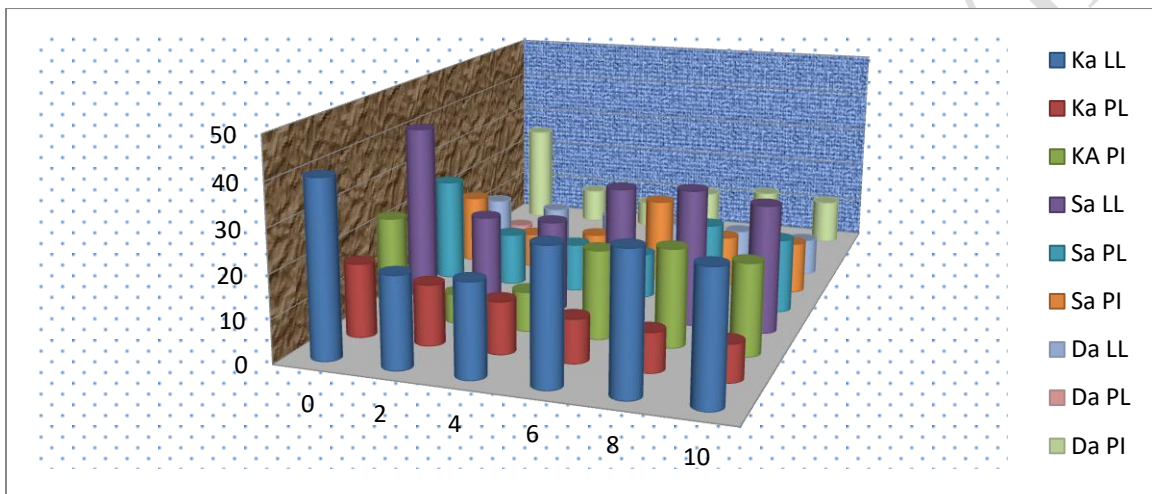


Fig. 2: Impact of SSA on Atterberg limit test.

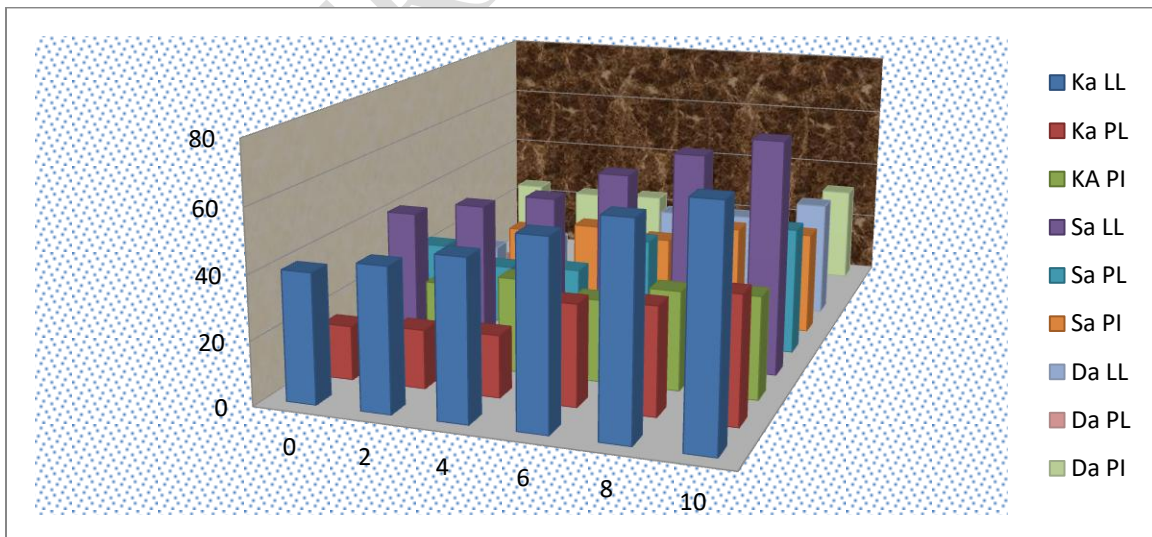


Fig. 3: Impact of geopolymer on Atterberg limit test.

3.3 Effect of compaction

Results of compaction test for Rice Husk Ash (RHA), sodium silicate activator (SSA) and geopolymer are shown in Table 5-7, and graphically demonstrated in Fig 4-6. The figure depicts that adding cement, RHA and KCP increased both the OMC and amount of the MDD correspond to increasing of cement, RHA and KCP percentage. The increase in OMC is probably a consequence of two reasons: (1) the additional water held with the flocculant soil structure resulting from cement interaction, and (2) exceeding water absorption by RHA as a result of its porous properties, as reported in Abdullah [3]. Principally, increase in dry density is an indicator of improvement, though both cement and RHA, instead, increase the dry density gradually. Poon et al. [1] reveals an opinion that the change-up in dry density occurs because of both the particles size and specific gravity of the soil and stabilizer. Increasing dry density indicates that it needs high compactive energy (CE) to attain its MDD, thus making construction more durable and cost effective. Xu et al. [2], Wattex [5] and Agashua et al. [53]. This increase in the dry density can be due to the particle flocculation and agglomeration caused by the slow cation exchange in the soil-stabilizer mixture.

Table 5: Effect of SSA on compaction test

%	KA		SA		DA	
	MDD (mg/m ³)	OMC (%)	MDD (mg/m ³)	OMC (%)	MDD (mg/m ³)	OMC (%)
0	1.342	16.85	1.456	17.75	1.572	18.65
2	1.360	16.90	1.460	18.79	1.580	18.70
4	1.385	17.01	1.465	19.02	1.588	18.75
6	1.400	17.13	1.475	19.30	1.592	18.79
8	1.420	17.30	1.479	19.40	1.598	18.82
10	1.440	17.45	1.483	19.45	1.602	18.86

Table 6: Effect of RHA on compaction test

%	KA		SA		DA	
	MDD (mg/m ³)	OMC (%)	MDD (mg/m ³)	OMC (%)	MDD (mg/m ³)	OMC (%)
0	1.342	16.85	1.456	17.75	1.572	18.65
2	1.520	15.92	1.680	16.34	1.620	16.72
4	1.720	15.60	1.895	15.89	1.870	14.60
6	1.920	14.95	1.980	15.04	2.020	13.95
8	2.150	13.48	2.190	14.02	2.250	12.48
10	2.345	12.11	2.450	12.21	2.465	11.71

Table 7: Effect of geopolymer on compaction test

%	KA		SA		DA	
	MDD (mg/m ³)	OMC (%)	MDD (mg/m ³)	OMC (%)	MDD (mg/m ³)	OMC (%)
0	1.342	16.85	1.456	17.75	1.572	18.65
2	1.760	17.80	1.890	19.80	1.890	19.54
4	1.850	18.01	1.970	20.02	1.970	20.00
6	1.920	19.05	2.250	20.80	2.250	21.20
8	1.980	19.45	2.480	21.40	2.480	21.75
10	2.050	19.80	2.560	21.60	2.560	22.20

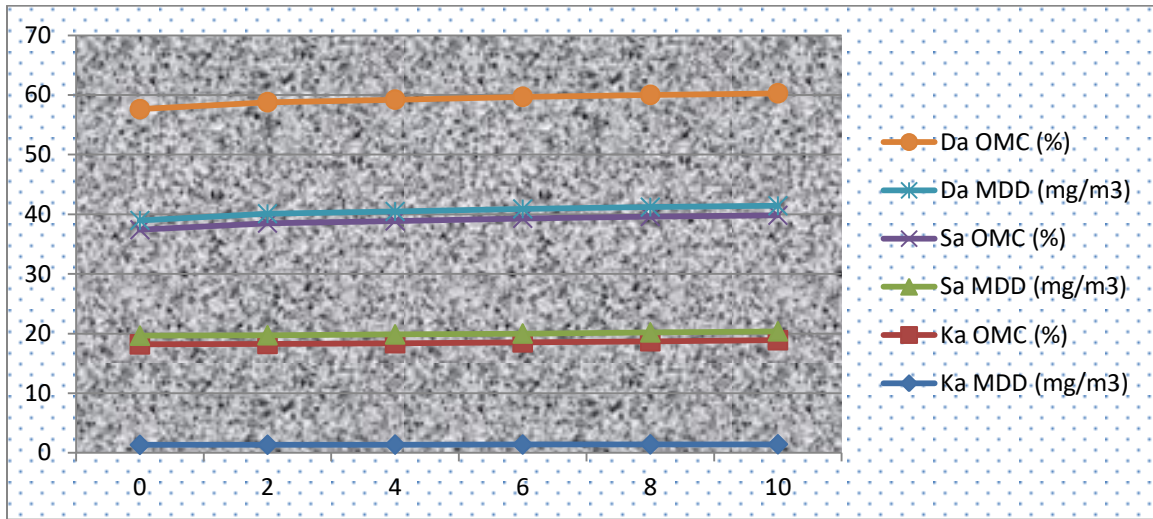


Fig. 4: Impact of SSA on compaction test

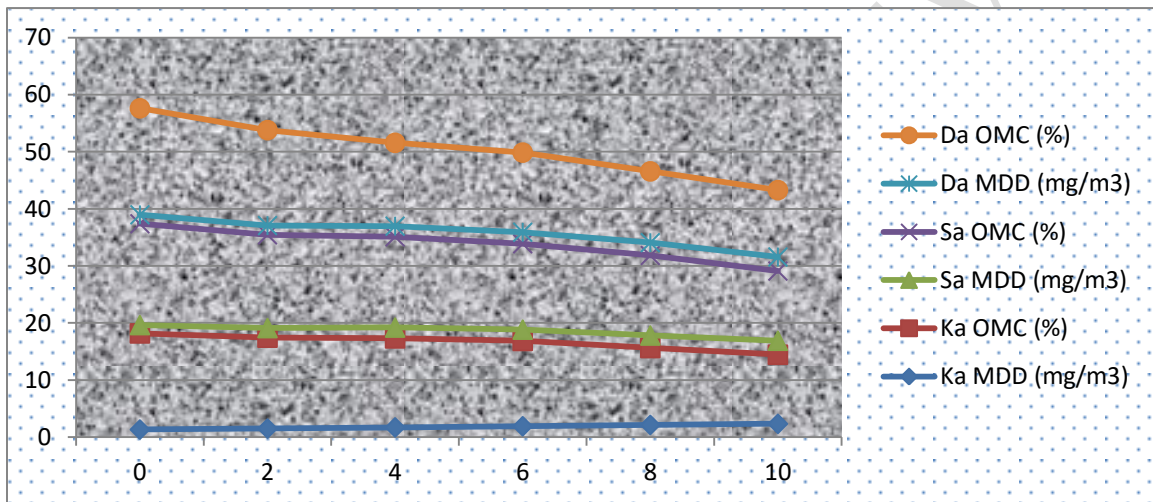


Fig. 5: Impact of RHA on compaction test

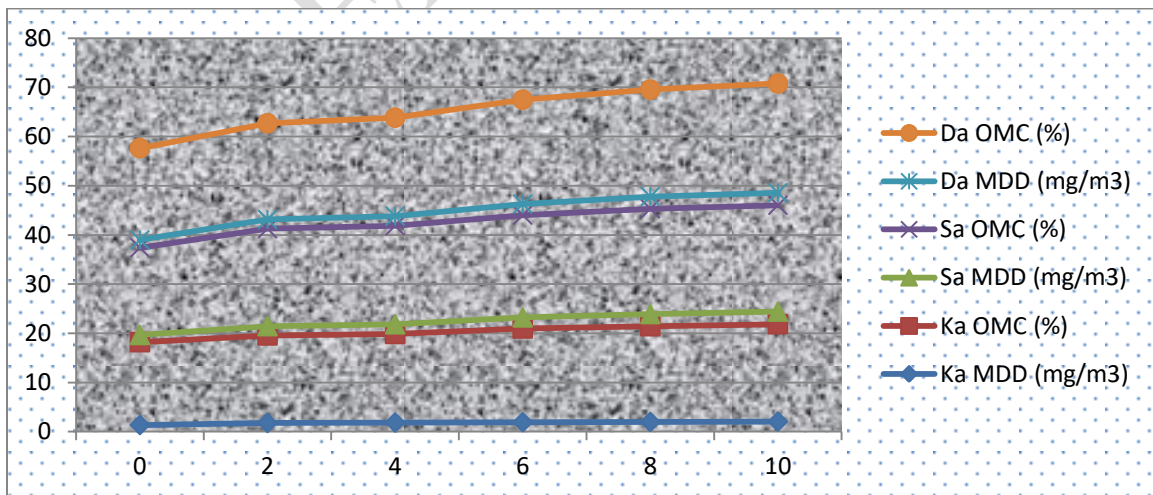


Fig. 6: Impact of geopolymer on compaction test

3.4 Effect of Triaxial test

Results of triaxial test for Rice Husk Ash (RHA), sodium silicate activator (SSA) and geopolymer are shown in Table 8-10, and graphically demonstrated in Fig 7-9. The result shown the impact of various percentages of RHA, SSA and geo polymer on the soil sampling stabilized. The highest cohesion of 19KN/m², 11KN/m² and 65KN/m² was achieved at 10% and frictional angle of 27°, 19° and 57° for RHA, SSA and geo polymer respectively. Likewise site visitation, some laboratory experiment and apparatus utilized for this research is presented in Fig.11-14.

Table 8: Effect of RHA on compaction test.

%	KA		SA		DA	
	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰
0	19	23	18	22	19	23
2	11	26	11	25	11	25
4	10	28	11	28	10	28
6	16	21	16	20	15	20
8	10	29	10	28	10	29
10	19	27	18	26	19	27

Table 9: Effect of SSA on compaction test.

%	KA		SA		DA	
	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰
0	19	23	18	22	19	23
2	8	15	8	15	8	15
4	9	16	9	16	9	16
6	10	18	10	18	10	17
8	10	18	10	18	10	18
10	11	19	11	19	11	18

Table 10: Effect of geopolymer on compaction test

%	KA		SA		DA	
	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰	Cohesion (KN/m ²)	Angle of internal friction (Θ) ⁰
0	19	23	18	22	19	23
2	39	37	37	32	39	37
4	49	40	44	37	49	40
6	52	48	49	41	52	48
8	58	53	56	48	58	53
10	65	57	60	52	65	57

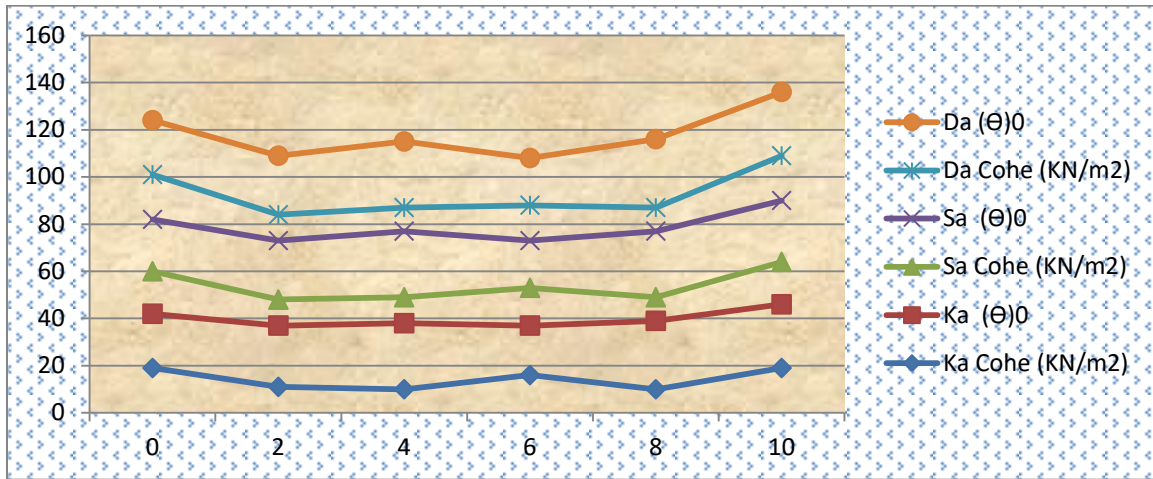


Fig. 7: Impact of RHA on compaction test

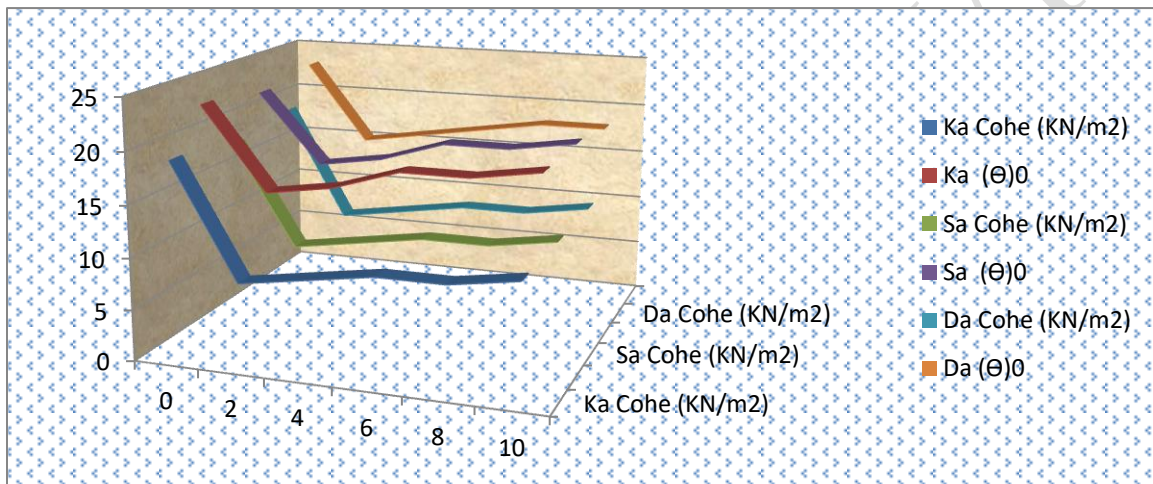


Fig. 8: Impact of SSA on compaction test

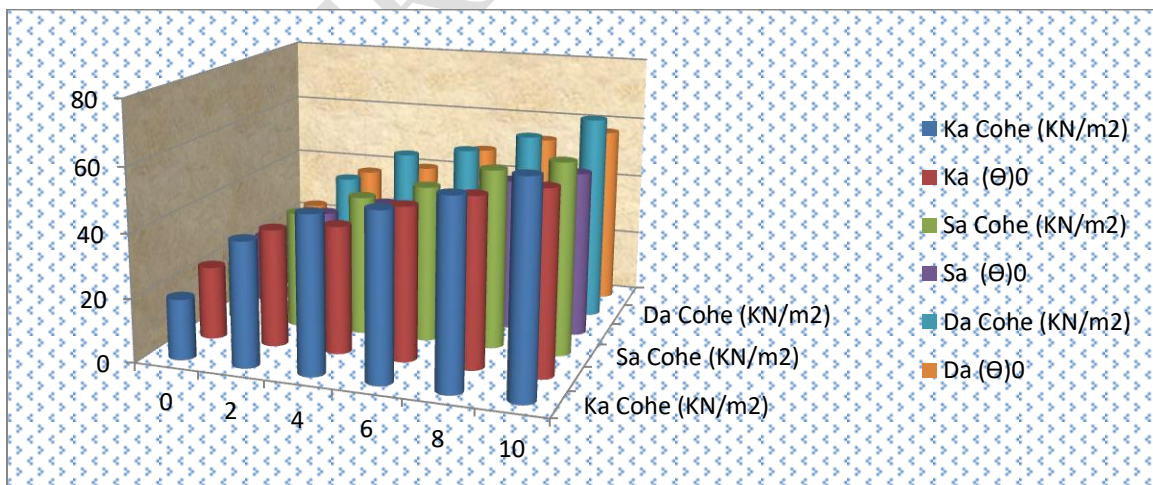


Fig. 10: Triaxial tests result for RHA, sodium silicate and geopolymer mix.



Fig.11: Samples collection at Dabi site where Dantata and Sawoe Construction company is using for Gwagwalada-Kwali road construction.



Fig 12: Samples and rice husk ash at Federal University of Technology Akure Geotechnical lab.



Fig. 12: Specific gravity and Atterberg limit test in progress.



Fig. 13: Atterberg limit test in progress.

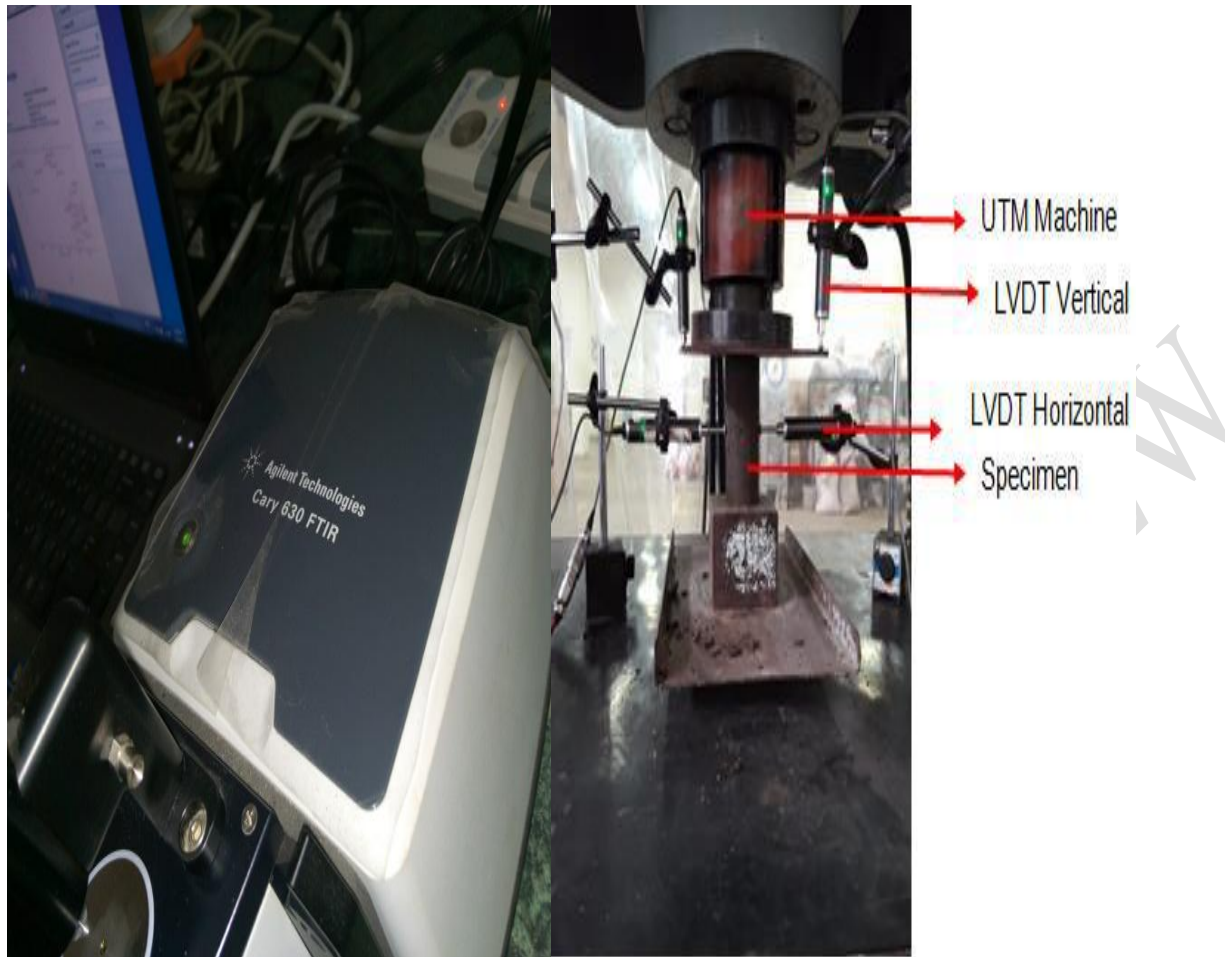


Fig. 14: FITR apparatus and Set up compressive strength.

Conclusions

From the analysis the investigations on KCP-SSA stabilized soils shows that the lateritic soil was classified as A-7-6 soil. Besides, at 6% contents, the investigation showed a general increase in MDD and OMC with increase in RHA and SSA content. Addition of RHA needs a lesser amount of SSA to obtain improved strength as compared to cement-stabilized soils. Also, the highest cohesion of 19KN/m^2 , 11KN/m^2 and 65KN/m^2 was achieved at 10% and frictional angle of 27° , 19° and 57° for RHA, SSA and geopolymer respectively. Hence, rice husk ash and sodium silicate activator are confirmed to be a good admixture in lateritic soil stabilization using 6% as their control.

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