STABILIZATION OF MAKURDI SHALE USING LIME-GROUNDNUT SHELL ASH

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Abstract – *This research was carried out in other to investigate the effect of Lime (L) and Groundnut shell ash (GSA) on some geotechnical properties of Makurdi shale. In this research work, soil classification tests, Compaction test, California bearing ratio test (CBR), unconfined compressive strength test (UCS) and durability test were carried out on the natural shale as well as shale treated with combined range of 2 – 10 % lime and 4 – 20 % groundnut shell ash. Strength improvement was observed with the use of lime – groundnut shell ash combination more than when they were applied in single as the CBR value increase from 8 % to a maximum value of 67 % for the natural shale and shale treated with 10 % L, 20 % GSA respectively. 7 – day, 14 – day and 28 – day UCS increase from 286.42 kN/m², 463.25 kN/m² and 340.16 kN/m² respectively for the natural shale to a maximum value of 933.73 kN/m², 1018.62 kN/m², 1030.74 kN/m² at the respective day for the shale treated with 10 % L, 4 % GSA respectively and the durability value increase from 8.0 % to 43.4 % for the natural shale and shale treated with 4 % L, 16 % GSA respectively. Response of Makurdi shale to treatment clearly shows that, shale can be stabilized with lime + Groundnut shale ash for Civil engineering work.*

Key Words: **Ground nut shell ash, California bearing ratio test, unconfined compressive strength test, foundation.**

1.INTRODUCTION

1.1 Background of Study

Civil engineering structures have foundations on which they rest. These soils that support the foundation transmit load from the super structure through the sub-structure to the underlying soil. It is obvious then that, the stability of any civil Engineering structures depends solely on the stability of the underlying soil. However, in some cases, where expansive soils are encountered, they do not usually meet those requirements and this is basically as a result of the characteristic excessive swelling and shrinkage and consequently causing failure to structures on them. The soils usually absorbed water during the raining season and swells. In the dry season, it loses water resulting to drying and contraction. When this behavior continues, it leads to the formation of cracks on buildings and roads (Warren, 1995).

Makurdi town, the Headquarter of Benue State is extensively deposited with shale (Agbede and Smart, 2008). The shale deposit like any other expansive soil has caused extensive failure of buildings and roads constructed on and or with them. These defects are prominent on buildings in University of Agriculture, Makurdi, Wadata etc. in form of cracks ranging from fraction of millimeters to about 10 mm (plates i-iv). Thereby reducing the lifespan of these structures and posing threat to lives and properties using them.

1.2 Aim and Objectives

The study is aimed at investigating the potential of Groundnut shell ash (GSA)-lime in improving the engineering properties of shale. The specific objectives include;

1 To determine the change in swelling and shrinkage property of shale treated with GSA and lime admixture.
2 To evaluate the changes in strength properties (unconfined compression strength and California bearing ratio) of the stabilized soil.

1.3 Justification of the Study

This study is an attempt at improving the physical and strength characteristics of Makurdi shale with lime-groundnut shell ash for the purpose of flexible pavement construction.

The present of shale in Makurdi especially University of Agriculture Makurdi has caused a lot of damages, hazards and threats to most commercial, residential and official buildings in Makurdi.

Several researchers have worked on the stabilization of Makurdi shale among most notably are (Agbede and Smart 2007, Nongu 2010, Agbede and Joel 2011, Iorliam, et al 2012). However, records on treating Makurdi shale with lime + GSA are scarce. This has necessitated the research on stabilization of Makurdi shale with lime-GSA admixture. The research when completed will complement the work done by other researchers and promote the use of cheap and locally available waste like GSA in stabilization of problematic soils.

1.4 Location of the Study

Makurdi town, the study area is the Headquarter of Benue State in Nigeria. The town lies between latitude 7^0 and 8^0 N as well as longitude 8^0 and 9^0 E. it has a total area of 25 km^2 and an average relief of 120 m (Agbede and Smart, 2007).

1.5 Climate of the Study Area

Makurdi is situated in the savannah vegetation belt. The climate is tropical and alternating and distinct wet and dry season. The wet season usually starts around April and ends October. The maximum and minimum temperature of 35 ^{0}C and 21 ^{0}C respectively. The rainfall is both convention and tropical, it has a heavy form of high intensity between 508 to 1016 mm during rainy season and 0 to 254 mm in the dry season (Agbede and Smart, 2007).

1.7 Scope of the Study

This work is limited to shale obtained from University of Agriculture Makurdi, Benue State Nigeria. The soil sample was treated with various percentages of 2 %, 4 %, 6 %, 8 %, 10 %, lime and 4 %, 8 %, 12 %, 16 %, 20 % of groundnut shale ash admixture. The tests to be performed on the natural shale samples treated with lime-GSA includes: natural moisture content, durability test, specific gravity test, particle size analysis, hydrometer test, swelling test, compaction test, Attergberg limit test, California bearing ratio, unconfined compressive strength, X-ray fluorescence.

2.7.0 Chemical Properties of Groundnut Shell Ash

According to Elinwa and Awari (2001) the comparison of the chemical properties of groundnut shell ash and other related materials is as shown in Table 2.0 below.

Table 2.0: Comparison of Chemical Properties of Groundnut Shell Ash and other Related Materials

Constituents	**GHA % by weight**	**Rice husk ash % by weight**	**Bagasse ash % by weight**	**Ordinary Portland cement weight**	**ASTMC618 Limits**
SiO_2	54.03	93.10	73.00	20.70	Max of 70 %
Al_2O_3	39.81	0.40	6.70	5.75	
Fl_2O_3	4.34	0.20	6.30	2.50	
CaO	1.70	0.40	2.80	64.00	-
MgO	0.004	0.10	3.20	1.00	-
Na_2O	0.85	2.30	1.10	0.20	Max of 1.5 %
K_2O	0.17	-	2.40	0.60	-
P_2O_5	0.44	-	2.09	0.15	-
MnO	0.10	-	0.26	0.05	-
SO_3	0.09	2.80		2.75	Maximum Of 5 %

Source: Elinwa and Awari (2001).

2.1.0 ORIGIN, CLASSIFICATION AND CHARACTERISTCS OF SHALE

Shale, consolidated clay is derived from the weathering and degradation of igneous and sedimentary rocks. It is a variable material that exhibits behavior ranging from – consolidated clay to that of a hard, durable cemented rock.

In general, Shales are highly consolidated clay, silts and sands or a mixture of all the three fractions of soil derived from the weathering of rocks, their particles get deposit in seas or rivers beds in layers, which are subjected to high overburden pressure which tends to eject water from the particles coming very close to each other. Shale is primarily produced by changes which occur in sediment between deposition and prettification under conditions of heat and pressure on the surface and the upper crust. (De Graft Johnson and others.1973)

2.2 Problems Associated with Shale

Problematic soils such as expansive soils are normally encountered in foundation engineering designs for highways, embankments, retaining walls, backfills etc. Expansive soils are normally found in semi – arid regions of tropical and temperate climate zones and are abundant, where the annual evaporation exceeds the precipitation and can be found anywhere in the world (Chen, 1975; Warren and Kirby, 2004).

Expansive soils are also referred to as "black cotton soil" in some parts of the world. They are so named because of their suitability for growing cotton. Black cotton soils have varying colors' ranging from light grey to dark grey and black. The mineralogy of this soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. Deposits of black cotton soil in the field show a general pattern of cracks during the dry season of the year. Cracks measuring 70 mm wide and over 1 m deep have been observed and may extend up to 3 m or more in case of high deposits (Adeniji, 1991).

The mineral content of shale influences its geotechnical properties. Underwood (1967) stated that clay fraction containing high percentages of illite and montmorillonite generally has lower strength, higher swelling potential and other undesirable properties than do shale with clay fractions consisting predominantly of kaolinite, chlorite or only low percentages of illite, montmorillonite, or other mixed layer minerals.

RESULTS AND DISCUSSION

4.1 Index Properties of Makurdi Shale

The index properties of natural Makurdi shale are as summarized in Tale 4.1. The soil was found to be an A – 7 – 6 soil by the AASHTP classification system, CH by the Unifined Soil Classification System, USCS (ASTM, 1992) and medium swell potential soil according to the NBRRI (1983). The test results showed that the natural soil was not suitable for use as sub-base or base course materials and even requires a modified layer above it as a sub-grade soil. The Oxide Composition of Groundnut Shale Ash, GSA and Makurdi shale obtained from chemical analysis is as shown in Table 4.1 below. The results showed that SiO_2 (30.80 %) and Eu_2O_3 (0.05 %) as the least component, while Shale has SiO_2 (48.00 %) as major constituents followed by Al_2O_3 (16.80%) and with Z_nO (0.03 %) as the least constituent.

Table 4.1: Index Properties of Makurdi Shale

Properties	Quantity
Percentage passing BS Sieve No.	87
200%	30.43
Natural moisture content (%)	46.90
Liquid Limit (%)	31.0
Plastic Limit (%)	14.68
Plasticity Index (%)	12.10
Linear Shrinkage (%)	30
Free Swell (%)	2.42
Specific gravity	A – 7 – 6
AASHTO Classification	CH
USCS Classification	1.49
Maximum Dry Density (Mg/m³)	23.50
Optimum Moisture Content (%)	53.52
Unconfined Compressive	2
Strength (KN/m²)	
California Bearing Ratio, after	
(after 24hrs soaking)	

i.
ii. **Table 4.2:** Chemical Composition of Makurdi Shale and GSA

Chemical Composition	Concentration (% by weight)	
	Makurdi Shale	GSA
SiO_2	48.00	30.80
P_2O_5	-	4.45
SO_3	0.65	2.76
K_2O	6.67	25.20
CaO	3.24	17.70
TiO_2	1.90	1.57
V_2O_5	0.092	0.082
Cr_2O_3	0.039	-
MnO	0.099	0.765
Fe_2O_3	11.62	7.57
CuO	0.039	0.11
ZnO	0.03	0.16
BaO	0.40	0.76
Eu_2O_3	0.19	0.05
Re_2O_7	0.09	-
Al_2O_3	25.24	-
MgO	1.16	-
Na_2O	2.57	-
LOI	-	25.00

4.2 Effect of Lime – Groundnut Shale Ash (GSA) on Atterberg's Limits of Makurdi Shale.

The addition of both GSA and lime to Makurdi shale improved its consistency properties, as the Plasticity Index reduced from 30.8 % for untreated Makurdi shale to 19.85 % at 4 % Lime plus 12 % GSA. This can be shown on table 4.3

LIME CONTENT (%)	0	2	4	6	8	10
0 % LL SHA PL PI SL	64.1 33.3 30.8 0.98	45.1 28.35 16.75	50.1 21.65 21.65 0.16	47.1 27.75 19.35 0.17	44.1 23.2 20.9 0.12	40.5 22.1 18.4 0.10
4 % LL SHA PL PI SL	45.8 22.25 23.55 0.86	53.3 23.4 29.9 0.29	45.1 29.5 15.6 0.96	44.05 23.98 20.07 0.09	44.26 25.65 18.61 0.25	54.2 27.1 27.1 0.96

8 % SHA LL PL PI SL	46.2 22.85 23.35 0.84	50.0 26.55 23.45 0.23	40.6 28.3 12.3 0.13	48.05 28.3 19.75 0.10	44.86 28.15 16.71 0.19	54.2 27.1 27.1 0.96
12 % SHA LL PL PI SL	46.35 22.9 23.45 1.24	53.2 28.8 24.6 0.12	51.0 28.7 22.3 0.17	52.51 28.70 23.81 0.08	50.4 27.1 23.3 0.13	53.2 29.35 23.85 0.86
16 % SHA LL PL PI SL	43.8 23.5 20.0 1.30	54.0 30.7 23.3 0.13	52.5 30.15 22.35 0.14	55.98 28.0 27.98 0.29	50.4 29.6 23.3 0.12	45.9 23.6 22.3 0.14
20 % SHA LL PL PI SL	50.0 28.7 21.3 0.12	52.5 32.15 19.85 0.12	45.86 20.72 25.15 0.29	45.86 20.72 25.15 0.29	50.4 29.6 23.3 0.102	45.9 20.04 25.86 0.09

Table 4.3: Variation of Plasticity Index (%) with L - GSA combination.

4.3 Effect of Lime – Groundnut Shell Ash (GSA) on Compaction Characteristics of Makurdi Shale.

LIME CONTENTN (%)	0	2	4	6	8	10
0 % GSA OMC MDD	14.5 1.80	14.56 1688	15.04 1.706	15.34 1.1.796	15.61 1.806	15.51 1.788
4 % GSA OMC MDD	14.54 1.803	14.66 1.671	15.06 1.566	15.12 1.601	15.14 1.582	15.30 1.560
8 % GSA OMC NDD	14.68 1.1.80	15.13 1.746	15.21 1.731	15.24 1.707	15.25 1.670	15.52 1.652
12 % GSA OMC MDD	15.34 1.766	15.41 1.788	15.86 1.719	16.34 1.694	19.45 1.660	19.23 1.650
16 % GSA OMC MDD	15.60 1.758	15.43 1.622	16.02 1.617	17.55 1.575	18.34 1.568	18.55 1.520

20 % OMC	13.52	15.32	15.34	17.45	19.30	20.44
GSA MDD	1.673	1.554	1.551	1.542	1.523	1.510

Table 4.4: Compaction characteristics of L- GSA on Makurdi shale.

The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of Makurdi Shale are as shown in Table 4.4 and fig. 4.1.1 and 4.1.2 The Maximum Dry Density (BS light) compaction of Makurdi shale was substantially reduced from 1.75 Mg/m³ at 0% L – GSA content to 1.510 Mg/m³ at % 10 L – 20 % GSA contents. But the optimum moisture content increased with the addition of L - GSA content. The decrease in density according to Ola (1977) is as a result of the flocculated and agglomerated clay particles occupying larger spaces leading to a corresponding decrease in dry density. The increase OMC with increasing L - GSA content is as a result of the extra water required for the pozzolanic reactions.

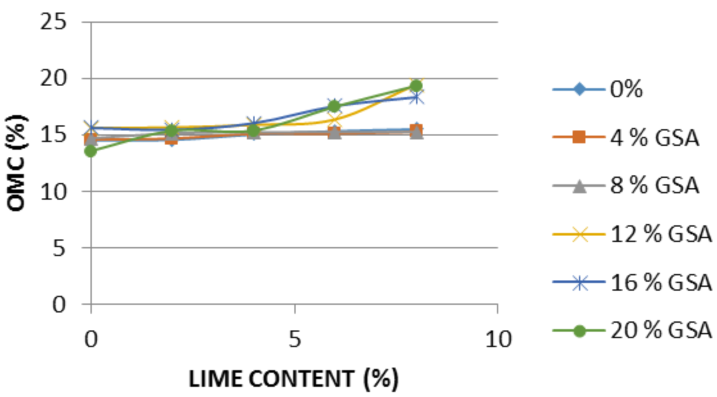

Fig. 4.1.1: Variation of Optimum Moisture Content (%) with L - GSA combination.

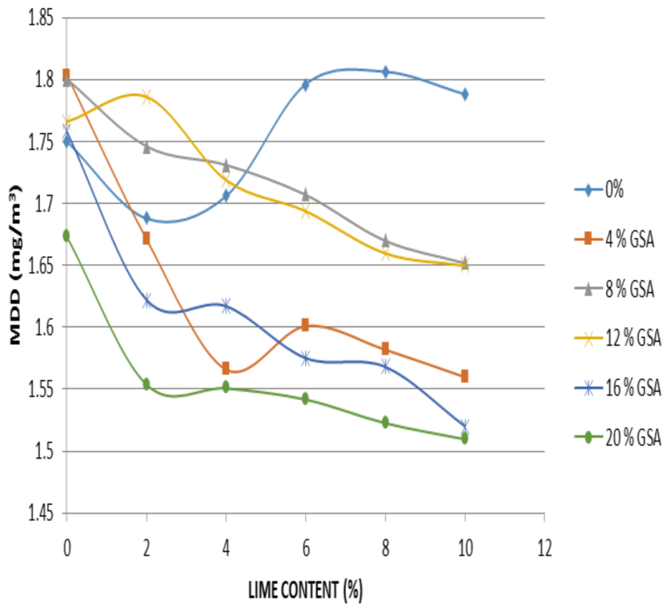

Fig. 4.1.2: Variation of Maximum Dry Density (Mg/m³) with L - GSA combination.

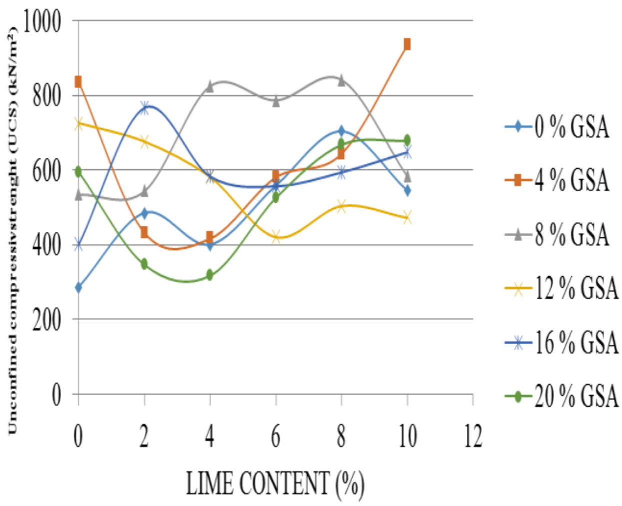

Fig. 4.1.3: Variation of Unconfined Compressive Strength (UCS) (KN/m²) of treated Makurdi Shale with L - GSA content. (7 DAYS UCS)

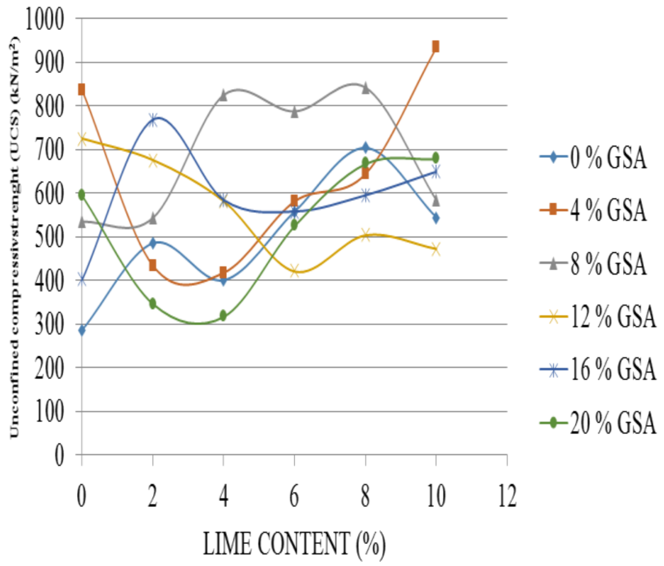

Fig. 4.1.4(14-Days UCS): Variation of Unconfined Compressive Strength (UCS) (KN/m²) of treated Makurdi Shale with L - GSA content.

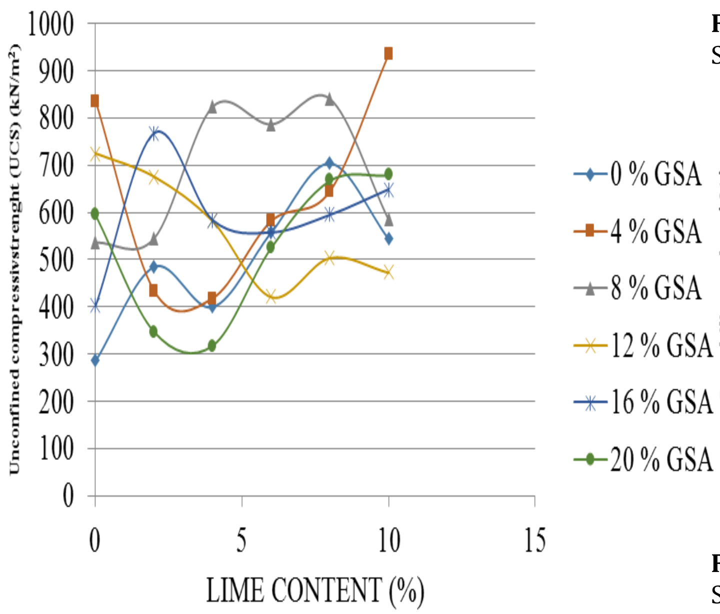

Fig. 4.1.5 (28 days UCS): Variation of Unconfined Compressive Strength (UCS) (KN/m²) of treated Makurdi Shale with L - GSA content.

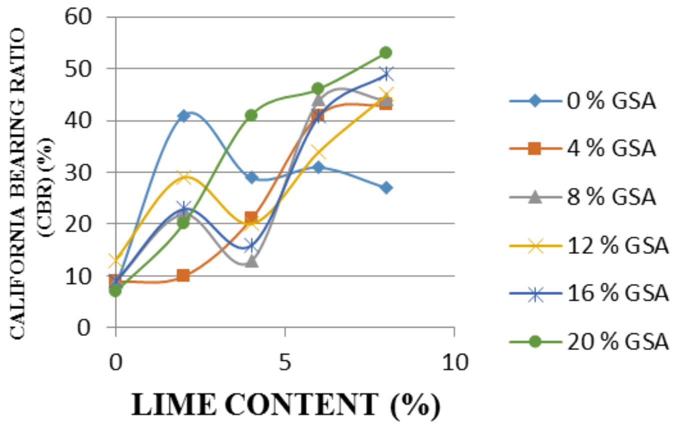

Fig. 4.1.6: Variation of California Bearing Ratio (CBR) (%) of treated Makurdi Shale with L - GSA content.

The same trend was also observed with the durability test as shown in figure 4.7, exhibiting an increase from 8.0 % for untreated Makurdi shale to 67% at a combination of 10% Lime + 20% GSA. The increase in durability showed that L - GSA combinations has a long time strength improvement capacity.

Fig. 4.1.7: Variation of Durability (%) of treated Makurdi Shale with L - GSA content.

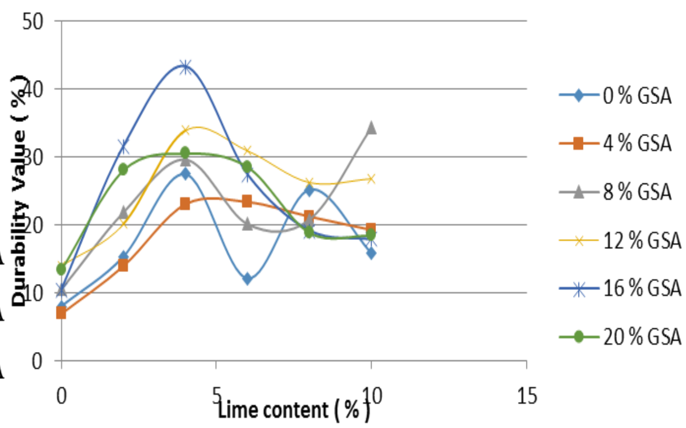

Fig. 4.1.7: Variation of Durability (%) of treated Makurdi Shale with L - GSA content.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Makurdi shale is silty clay and can be classified as an A – 7 – 6 soil by AASHTO system and CH by the Unified Soil Classification System. The results showed the ineffectiveness of stabilizing Makurdi shale with only Groundnut Shale Ash or Lime. However, results showed that the use of Groundnut Shale Ash as a modifier and Lime as a stabilizing agent improved the engineering properties of Makurdi shale.

The use of a combination of 10 % Lime plus 20% GSA with a CBR of 67 % to treat Makurdi shale for use as sub-base material. Using the plant mix method if economic analysis of alternatives on site or if possible, adequate manual compactive efforts if applied could justified its use.

5.2 Recommendation

It is recommended that, for stabilization of University of Agriculture Makurdi shale, an optimum of 4 – 10 % lime content be used with 20 % GSA combination. These combinations show an improvement in the engineering properties of the shale as seen in the summary work.

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