Evaluation of Strength Properties on A-7-5 Lateritic Soil Stabilized with River Sand

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ABSTRACT
This work investigated the geotechnical properties of A-7-5 lateritic soil stabilized with river sand. Laboratory and field tests were carried out on the natural and A-7-5 clay stabilized with 20, 40 and 60% river sand by weight. The results, amongst other things revealed a sharp reduction in plasticity index from 19.84% to 15.0% as river sand increase. The in-situ CBR and MDD obtained after 1, 7, 14, 28, 60 and 90 days are 17.6, 27.1, 39.8, 54.8. 71.9, 39.5% and 1.6, 1.89, 1.99, 2.12, 2.13, 2.15 g/cm3 indicating a strong improvement in strength properties of stabilized clay soil. The addition of 60% river sand to A-7-5 clay significantly improves its CBR by 438%. However, sharp reduction in the field CBR values was noticed, when curing period extended beyond 60days, consequent upon exposure of compacted admixture materials to atmospheric conditions and reduction in the specific gravity of the resulting composite matrix.

Keywords: *Geotechnical properties, Lateritic clay soil, River sand, Stabilization, Shear strength.*

1.0 INTRODUCTION

Evaluation of strength properties on lateritic soil stabilized with river sand is a systematic physical process used to identify, assess and possibly improve the engineering behaviour of deficit lateritic soil. Naeini *et al*. (2012) described the benefits of stabilization processes as the reduction of soil plasticity, swelling/shrinkage potentials, increase in soil strength and improved construction materials. The development can further reveal the geotechnical information needed to utilize natural but cheaper construction materials needed in any civil engineering construction Habiba (2017).

Gidigasu (1976) described laterite soil as a popular construction material obtainable in almost all the humid tropical countries of the world. Lateritic soil in its natural state contains a substantial amount of plastic clay minerals and high moisture content. In such a situation, the presence of moisture in the soil materials always affects the bearing capacity, strength and stability of any foundation materials under applied load (Fitsum, 2018).

Lateritic soils have been used extensively as sub-grade and sub-base courses in low trafficked roads in Nigeria and some other countries with abundant deposit. However, most of these lateritic soils have also been observed not to meet the standard specification requirement with respect to its usefulness in some civil engineering structures (Aginam, 2014; Oghenero *et al.*, 2014).

Beach sand soil has the lowest capacity to retain water because of its poor nutrient and little organic matters. They are composed of quartz, feldspar, phosphorus amphiboles and mica formed through weathering of metamorphic rocks and igneous rocks. Sands are and developed from the erosion movement through land masses and weathering of mountains Chiques (2005).

Dredged river sand is commonly used as general construction materials or stabilizing material in conjunction with low performance natural soil and mix together by mechanical processes to improve their engineering properties (Beeghly and Schrock, 2010).

These deficit lateritic soils require stabilization to improve their engineering materials and achieved the desired strength and durability of the compacted composite materials (Mustapha *et al.* 2014; Zumrawi, 2014)

Stabilization of soil are necessary when affordable and likely available stabilizing materials suchlike fly ash, lime, sand, bitumen, cement, rice and husk are within reach Gana and Peter (2018).

The engineering properties of natural soil are investigated to modify their engineering performance in the form of index properties, plasticity index, shear strength or reducing the compressibility, permeability efficiency and increasing the bearing capacity of any deficit soil materials Arora (2011).

The underlying objectives of the study is to underscore the necessity to adopt investigative principles on available construction materials for their strength or weakness potentials and the abundant of cheaper borrow materials.

2.0 MATERIALS AND METHODS

2. 1 Materials

The materials used for this study are pinkish brown clay soil, brownish river sand and clean water. The Natural laterite soil was collected by disturbed sampling method at an average depth of 1.5m after the removal of the top soil from Federal University of Technology (FUT) Gidan Kwano Minna, Niger State, Nigeria. However, river sand was collected by disturbed sampling method at an average depth of 1.5m from Gbarako river adjacent to National Examination Council office along Minna-Bida Road. Clean water was obtained at the premises of Civil Engineering Laboratory, Federal University of Technology, Minna, Niger State.

2.2 Methods

River sand and natural laterite soil samples were air dried for effective control and investigations of all the recommended laboratory tests such as index properties, Atterberg limit, moisture content, specific gravity, CBR and other density tests.
Field density and CBR tests were later conducted using dynamic cone penetration and sand replacement methods to determine compaction characteristics and the potentials of sand admixture in the improvement of weak laterite soil. The laboratory/field test are carried out in accordance with BS1377 (1990) part 4, BS 882 (1992) for the natural laterite and river sand respectively.

The laboratory compaction test on the sample of laterite mixes and composite materials was carry out using British standard heavy (RBSH) energy effort. River sand was added to the natural laterite soil and mixed by weight of the laterite soil at 0, 20, 40 and 60% respectively. The compaction of samples (laterite soil mixes and Composite Mixes) was done by 2.5 kg rammer falling through a height of 30 cm in 3-4 layers, each receiving 15 blows. The compacted sample in the steel mould are trimmed in to identify can and cured for 24 hour in the oven for temperature readings.

The results obtained show the prospect of river sand in improving weak lateritic soils. California bearing ratio (CBR) tests were conducted in accordance with the Nigerian Code of Practice BS 1377 (1990). The in-situ density test was conducted using sand replacement method and dynamic cone penetration test (DCPT) over a period of 1, 7, 14, 28, 60 and 90 days of field compactions.

3.0 RESULTS AND DISCUSSION

Particle size distribution

The grain size distribution curves from Gidan Kwano laterite clay soil and that of river sand from Gbarako are presented in Figures 1 and 2 respectively.

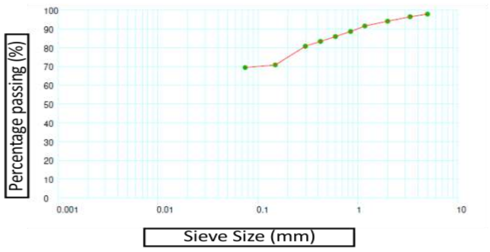

Figure 1: Grading curve for Gidan Kwano lateritic clay

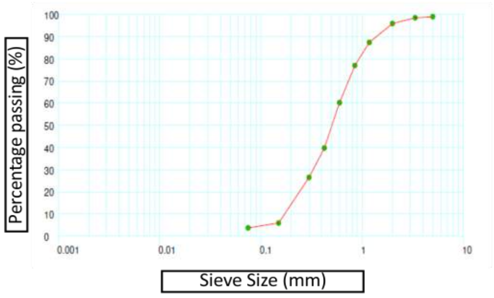

Figure 2: Grading curve for Gbarako river sand

The summary results of all the laboratory tests carried out on the natural laterite soil and river sand are presented in Table 1 and 2 respectively.

Table 1: Geotechnical properties of test clay soil

Property	Values
Natural moisture content (%)	16.69
Description (colour)	Pinkish brown clay
Specific Gravity	2.62
Percentage Passing BS sieve No 200 (%)	69.47
Liquid Limit (%)	50.49
Plastic Limit (%)	30.84
Plasticity Index (%)	19.65

AASHTO Classification	A-7-5
USCS Classification	CH
Maximum Dry Density (g/cm^3)	1.8291
Optimum Moisture Content (%)	17.69
California Bearing Ratio (%)	9.05

Table 2: Geotechnical Properties of test river sand

Property	Values
Natural moisture content (%)	5.64
Description (colour)	Brownish sand
Specific Gravity	2.60
Percentage Passing BS sieve No 200	3.73
Liquid Limit (%)	0
Plastic Limit (%)	0
Plasticity Index (%)	0
AASHTO Classification	A-1-b
USCS Classification	SW

3.0 RESULTS AND DISCUSSION

The index properties of Gidan Kwano laterite clay soil was classified to be an A-7-5 in accordance to American Association for Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS) respectively. The river sand was classified as A-1-b and SW by the AASHTO and USCS. The specific gravity of Gidan Kwano laterite soil and Gbarako river sand was determined as 2.62 and 2.60 respectively.

The laboratory tests revealed the geotechnical properties of Gidan Kwano laterite soil as cohesive in nature with plasticity index of 19.65%. Lateritic soil is not only restricted to the study area as they are widely spread throughout Niger State and Nigeria at large based on the Nigerian General Specification for road and bridges work (1997).

In a similar situation Gbarako river sand materials used for this study to improve the geotechnical properties of the weak lateritic soil. The stability in river sand mostly increases the shear strength parameters, CBR values and angle of internal friction of deficient laterite soil. The addition of Gbarako river sand to Gidan Kwano laterite soil improved the consistency indices of the resultant composite mixes and reduces the plasticity index value from 19.84% - 15.0% respectively. The variation in liquid limit, plastic limit and plasticity index of the laterite clay soil with some percentage of river sand are as presented in Table 3. The summary of laboratory and field densities and CBR data are shown in Table 4, while the variation of this density and BBR data with curing age is shown in Table 5. The variation of MDD and OMC of Gidan Kwano laterite clay soil with river sand are presented in Figures 3 and 4 respectively.

Table 3: Atterberg limit of test clay and sand

	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
0% Sand	50.49	30.84	19.65
20% Sand	44.93	22.01	22.92
40% Sand	39.60	23.92	15.68
60% Sand	35.33	20.33	15.0

Table 4: Summary of Laboratory/Field Densities and CBR Data

Admixture (%)	Lab Density	Field Density (Composite)	Lab CBR
0%sand	1.829	1.516	9.06 @0% sand
60%sand	2.071	1.600	28.38@20% sand
0%sand	1.829	1.650	73.00@40% sand
60%sand	2.071	1.890	88.32@60% sand
0%sand	1.829	1.717	
60%sand	2.071	1.990	
0%sand	1.829	1.770	
60%sand	2.071	2.12	
0%sand	1.829	1.769	
60%sand	2.071	2.13	
0%sand	1.829	1.79	
60%sand	2.071	2.15	
0%sand	1.829	1.516	9.06 @0% sand
60%sand	2.071	1.600	28.38@20% sand
0%sand	1.829	1.650	73.00@40% sand
60%sand	2.071	1.890	88.32@60% sand

Table 5: Summary of Laboratory/Field Densities and CBR Data

Period of Testing	Field CBR	
	0% sand	60%sand
1 Day	13	17.6
7 Days	15.2	27.1
14 Days	16.6	39.8
28 Days	16.6	54.8
60 Days	16.4	71.9
90 Days	16.4	39.5

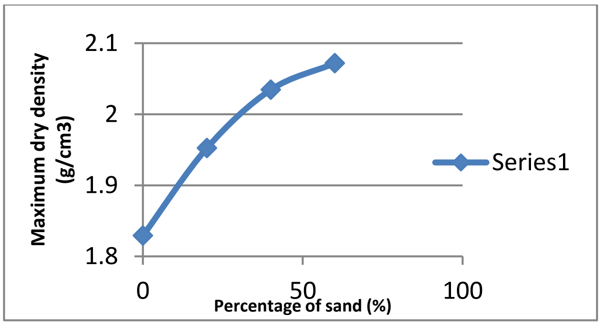

Figure 3: MDD variation with % river sand

In order to find the dry density – moisture content relationship with British heavy compaction test, sand and soil sample passing the 20mm sieve were used for the index tests. The values of MDD for the different soil-sand mixture are shown in Figure 3. The continuous increase of MDD from 1.8291-2.0717 (g/cm^3) has been noted mainly due to increase in the percentage weight of river sand and resulting higher specific weight of the admixture materials. As shown in Figure 4, values of OMC followed a reversed trend from 17% for natural soil up to 12% at 60% sand admixture.

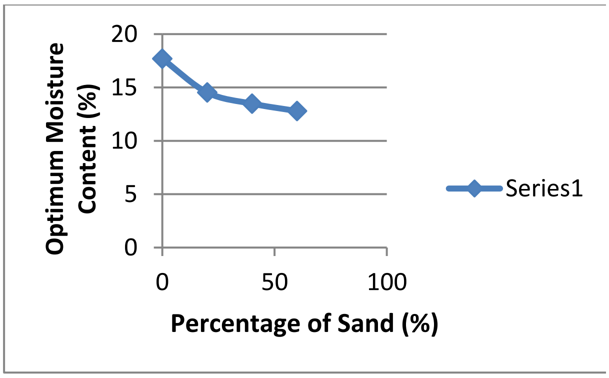

Figure 4: Variation of OMC with % sand

Field in-situ density and CBR

The field study considered the relationship between Dynamic Cone Penetrometer Test slope (DCP) and CBR designed to provide a measure of the in-situ strength of compacted materials using the penetration readings from the field section (A&B) as shown in Figure 5. The values were inserted in to a model derived by Klyen and Van Heerden (1983). The DCP penetration values are converted to CBR calculated values by simply implementing the following equation on the spreadsheet with the aid of an empirical relationship in equation 1 developed by TRL (2008):

$$Log\ (CBR) = 2.46 - 1.2Log(PI) \qquad (1)$$

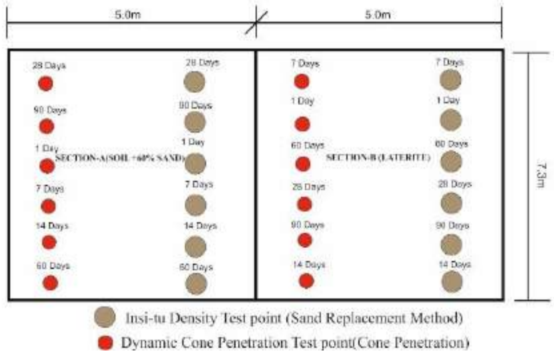

Figure 5: Layout of field test points in section A and B

Field preparation involved stockpiling, mass drying of materials of natural laterite soil and river sand along the proposed field site located on a road leading to Civil Engineering Laboratory, Federal University of Technology, Minna. The width of the test field was divided into two sections (A & B), with each section having a size of 7.5meters width and 5m length. The first section A were covered with composite mixes of A-7-5 lateritic soil, water and river sand. The section B which served as control field area has been covered with only A-7-5 lateritic mixed with water only as shown on Figure 5. Field compaction operation commenced immediately after spreading over the two testing field area by using a 5 tons vibrating hand roller. In-situ CBR and maximum field dry density tests were carried out immediately at 1, 7, 14, 28, 60 and 90 days respectively. The results of the in-situ CBR and density values are recorded as 17.6, 27.1, 39.8, 54.8. 71.9, 39.5% respectively and 1.61, 1.89, 1.99, 2.12, 2.13 and 2.15g/cm^3 respectively as shown in Figures 6 and 7 respectively. However, field section

(A & B) was opened to traffic compaction in order to attain the desired strength over the designed 90 days curing period. The used of river sand as admixture as against other conventional additives in the stabilization method was targeted at improving the geotechnical properties of the weak lateritic soil by using easily sourced/available materials at minimal cost.

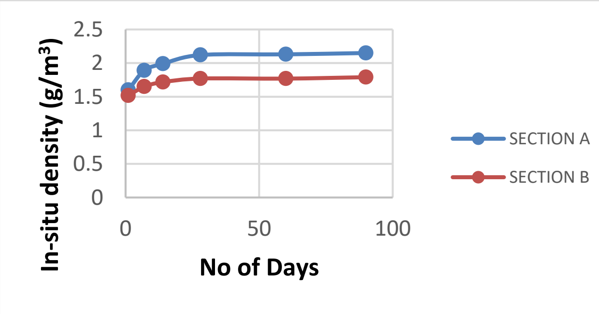

Figure 6: Variation of in-situ density with curing days

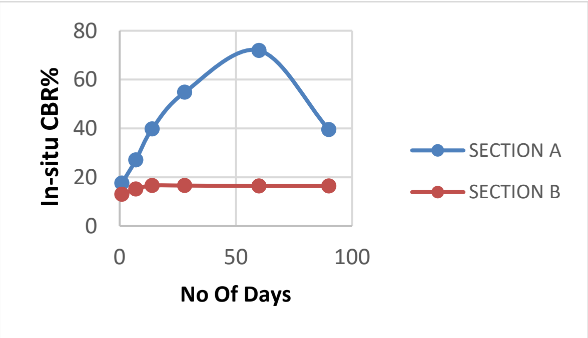

Figure 7: Variation of in-situ CBR with curing days

4.0 CONCLUSIONS

Based on the laboratory and field tests on evaluation of strength properties of weak clay soil stabilized with river sand, the following conclusion were drawn:

1. The index properties tests of the lateritic clay from a section of Gidan Kwano district, a suburb of Minna, is classified as an A-7-5 or CH according AASHTO and Unified Soil Classification Systems respectively.
2. The sand from Gbarako river is classified as well graded A-1-b and SW soil according to AASHTO and Unified Soil Classification Systems respectively.
3. The liquid limits, plastic limits and plasticity indices of Gidan Kwano laterite clay soil reduces with the increased in Gbarako river sand.
4. The OMC of the composite materials reduces from 17.69% at 0% sand to 12.79% at 60% sand, while the MDD s increases from 1.829 (g/cm^3) at 0% sand to 2.071 (g/cm^3) at 60% sand.
5. The strength properties of the weak lateritic soil when river sand was gradually added from 20, 40 and 60%.
6. Introduction of river sand to the weak lateritic soil increased the maximum dry density, compressive strength and the California bearing ratio (CBR) of the resultant composite mixture by the addition of up to 60% former.
7. The field CBR values on compacted stabilized composite increased from 17.6% on day 1 to 71.9% at 60days of curing (438% increment) and further decreases to 39.5% after 90days of curing. However, reduction in the values beyond 60-90days indicated lower specific weight of the admixture materials due to non-application of binder materials.
8. Both in-situ density and CBR values increases as number of field compaction increases indicating loss of admixture materials as a result of exposure of the field materials to atmospheric conditions and traffic flow.

5.0 RECOMMENDATIONS

Based on this research work, the following points are recommended:

1. Construction works involving stabilization of materials should be executed during dry season only.
2. The addition of river sand for stabilization of A-7-5 clay or other weak clay is limited to 60% by weight of the clay material.
3. Appropriate blending by partial replacement of clay soil with river sand for better/improved consistency should be carried out before spreading and compaction of composite materials.

REFERENCES

AASHTO (1986). *Standard Specifications for Transport Materials and Methods of Sampling and Testing*, 14th Edition, American Association of State Highway and Transport Officials (AASHTO), Washington, D.C.

Aginam, C. H., Chidolue, C. A. and Nwakaire, C., (2014). Geotechnical Properties of Lateritic Soils from Northern Zone of Anambra State, Nigeria, *International Journal of Engineering Research and Development*, 10(12): 23-29

Arora, K. R., (2011). Soil mechanics and foundation engineering. *Lomus offset Press, Delhi.*

Beeghly, J. and Schrock, M. (2010). Dredge material stabilization using pozzolanic or sulfo-pozzolanic reaction of Lime by-products to make an engineered structural fill, *International Journal of Soil, Sediment and Water*, 3(1): Art. 6, 1-21.

B.S.1377:1990: British Standard Method of Tests for civil engineering purposes: Part 4. *British Standards Institution*. London, United Kingdom.

B.S.882:1992: Specification of Aggregates from Natural Sources for Concrete. *British Standards Institution*. London, United Kingdom.

Chiques, G.M. (2005). Spectral Characterization of Sandy Beaches in Western Portion of Puerto Rico. *University of Puerto Rico, Department of Geology, Mayaguez Campus.*

Fitsum, M. D., (2018). Recent Literatures Review on Stabilization of Lateritic Soil. International Journal of Scientific Research Engineering & Wolaita Sodo University, Ethiopia. 7(1): Pp.227 – 882.*Technology* (IJSRET); Department of Civil Engineering, Wolaita Sodo University, Ethiopia. 7(1): Pp.227 – 882.

Gana, A. J. and Peter .E. Emem (2018). Bearing Capacity Evaluation of Lateritic Soil Stabilized with Sand for Use as Subgrade, *International Journal of Civil Engineering and Technology*, 9(11), Pp.2620–2629

Gidigasu, M. D., (1976). Laterite Soil Engineering: Pedogenesis and Engineering Principles, *Elsevier Scientific Publisher Company Amsterdam*, Netherlands.

Habiba, A. (2017). A Review on Different Types Soil Stabilization Techniques. International Journal of Transportation Engineering and Technology. Vol. 3, No. 2, 2017, Pp.19-24.

Klyen, E. G. and van Heerden, (1983). Using DCP soundings to optimize pavement rehabilitation, *Report LS/83 Materials Branch, Transvaal Roads Department*, Pretoria, South Africa.

Mustapha, A. M., Jibrin, R., Etsuworo, N. M., and Alhassan, M., (2014). Stabilization of A-6 lateritic unuwadje, S. E., and Jerry, O., (2014). Classification and compaction characteristics of lateritic soils of Warri, Delta State, Nigeria, *Advances in Applied Sciences Research*, 5(3), 451-457.

Mustapha, A. M., Jibrin, R., Etsuworo, N. M., and Alhassan, M., (2014). Stabilization of A-6 lateritic soil using cold reclaimed asphalt pavement. *International Journal of engineering and technology, 4(1*), 4 ISSN: 2049 -3444.

Naeini, S. A., Naderinia, B., and Izadi, E. (2012). Unconfined Compressive Strength of Clayey Soils Stabilized with Waterborne Polymer. *KSCE Journal of Civil Engineering*. 16(6): 943-949.

NRBS (1997). Government of the Federal Republic of Nigeria, *General specifications, Roads and Bridges*, Nigerian Road and Bridges Specification Vol. II.

Oghenero, A. E., Okey, A. T., Brume, O., Okunuwadje, S. E. and Jerry, O., (2014). Classification and Compaction Characteristics of Lateritic Soils of Warri, Delta State, Nigeria, *Advances in Applied Sciences Research*, 5 (3): 451-457.

TRL: 2008 Transport Research Laboratory, DTP Interim Advance Note 73/06: Design Guidance for Road Pavement Foundations using Dynamic Cone Penetrometer.

Zumrawi, M. M. E., (2014). Prediction of In-situ CBR of Subgrade Cohesive Soils from Dynamic Cone Penetrometer and Soil Properties, *International Journal of Engineering and Technology*, 6(5), 438-442.