INVESTIGATION OF THE STABILIZATION POTENTIALS OF NANOSIZED-WASTE TYRE ASH (NWTA) AS ADMIXTURE WITH LATERITIC SOIL IN NIGERIA

[*1]Onyelowe, K. C., [2]Ekwe, N. P., [3]Okafor, F.O., [4]Onuoha, I. C., [1]Maduabuchi, M. N., and [1]Eze, G. T.

[1.] Department of Civil Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria

[2.] Department of Chemistry, Michael Okpara University of Agriculture, Umudike

[3.] Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria

[4.] Department of Environmental Technology, Federal University of Technology, Owerri, Nigeria

ABSTRACT

The soil improvement potentials of Nanosized Waste Tyre Ash were investigated with a view to studying its effect on the Geotechnical properties of the stabilized lateritic soil. The behaviour of the soil was studied with different proportions of the NWTA i.e. 0% (control), 3%, 6%, 9%, 12% and 15% by conducting the soil properties' tests; soil classification or grading test, specific gravity, compaction test, consistency limits test, unconfined compressive strength (UCS) test, California bearing ration (CBR) test and UV/VIS spectrophotometric characterization was conducted on the ash to determine the absorbance, wavelength and average particle size. The results of the test show that; the soil was classified as A-2-7 soil on AASHTO classification with group index of 0, a Matlab program run on the sample also predicted that the soil is made of silty or clayey gravel and sand and that the general rating as a sub-grade material is 'GOOD". The average particle size of the ash by using the Debye Scherrer method was 11.358 nm, maximum absorbance of 1.120 nm at the wavelength of 650 nm. The MDD decreased from 1.84g/cm^3 of the control experiment to 1.57gm/cm^3, 1.56g/cm^3, and 1.53g/cm^3 at 3%, 6% and 9% proportions of NWTA respectively, and eventually increased to 1.54g/cm^3 and 1.55g/cm^3 at 12% and 15% proportions of NWTA. The OMC also decreased from 13% on natural Olokoro lateritic soil. The plasticity of the sample decreased remarkably from highly plastic sample of 21.85% PI on the control test to 10.65% at 15% proportion of NWTA. The CBR decreased from 14% control test on addition of NWTA to 3% at 3%, 6%, 9%, and 12%. It also increased to 5% at 15% proportion of NWTA. Fortunately, the unconfined compressive strength test yielded good results. It increased from the control test result on all 7, 14 and 28 days curing from 194.26kN/m2, 219.11kN/m^2 and 230.77kN/m^2 to 241.73kN/m^2, 253.03kN/m^2 and 214.54kN/m^2 respectively at 3% proportion of NWTA. Further addition of NWTA reduced the strength except at 28 days curing, which increased to 283.19kN/m^2 at 6%. However, NWTA has proved to be a good admixture in the stabilization of Olokoro lateritic soil and is therefore proposed for use as a subgrade and subbase material for south eastern roads in Nigeria.

Keywords: *Geotechnical Investigation; Nanosized-Waste Tire Ash; UV-VIS Spectrophotometric test; Stabilization; Engineering Soil, South Eastern Nigeria.*

1. INTRODUCTION

Burnt Tyre Ash is a good alternative use for construction of road bases. A natural rubber could be joined with sulphur (using ZnO as catalyst) to prevent chains from sliding off in a process known as vulcanization which led the way to the manufacturing of tyres (Charles, 2009; Ahmad *et al*, 2013; Chang-jun *et al*, 2010; Bao *et al*, 2011; Anitha *et al*, 2014; Anamika *et al*, 2012; Ali *et al*, 2011). The major problem of road engineers in Nigeria is the high incidence and frequencies of road pavement failures. Many research works have been carried out on roads to improve the strength of road bases. Such improvement is known as soil stabilization, which is concentrated on mixing two or more materials and compacting same to improve the strength of the treated soil. In other words, soil stabilization can be defined as the general form for any physical, chemical, and biological method of changing a natural soil to meet an engineering purpose (Kannan, 2010; Kavitha *et al*, 2015; Laila *et al*, 2010; Masaki *et al*, 2006; Osinubi *et al*, 2009). With recent advances in geotechnical engineering, nanomaterials have been in use for the stabilization of weak engineering soils. Nanomaterials are defined as materials with at least one dimension in the size range from approximately 1-999 nanometers (Mercier *et al*, 2002; Chien-I *et al*, 2008; Ershadi *et al*, 2011; Fan *et al*, 2015; Hall *et al*, 2000; Kalpana et al, 2009). Nano particles are objects with all three external dimensions at the nano scale but less than 999 nanometers (Kannan, 2010; Kavitha *et al*, 2015; Laila *et al*, 2010; Masaki

Coresponding Author: konyelowe@mouau.edu.ng, konyelowe@gmail.com.

et al, 2006; Osinubi *et al*, 2009) of which ash from burnt and completely pulverized tire is a typical example. The focus of this research was to achieve a more cost effective way of stabilizing weak lateritic soil making use of locally synthesized nanosized tire ash. The following were the objectives of the research work, (i) to evaluate the effect of the proportions of NWTA on the consistency of stabilized lateritic soil (ii) To evaluate the behaviour of the California Bearing Ratio (CBR) of the stabilized lateritic soil using nanosized tyre ash to meet subgrade and subbase requirements, and (iii) To improve the compressive strength of lateritic soils by studying the stabilization potentials of Nano-tyre Ash as waste.

Nano Technology

According to the National Nanotechnology Initiative (NNI), "nanotechnology" is the control, comprehension, and reformation of material based on the hierarchy of nanometers to develop matter with essentially new uses, new surface area and a new constitution. Considering this, nanotechnology is a novel approach in all sciences. This approach can be applied in geotechnical engineering in two ways: (i) in studying the soil structure in nanometer scale to gain a better understanding of soil nature as well as in studying the performance of soils with different nanostructures, (ii) in conducting soil manipulation at the atomic or molecular scale, which is facilitated by the addition of nanoparticles as an external factor or admixture to soil (Mercier *et al*, 2002; Chien-I *et al*, 2008; Ershadi *et al*, 2011; Fan *et al*, 2015; Hall *et al*, 2000; Kalpana *et al*, 2009).

Nanotechnology is a field of applied science, focused on the design, synthesis, characterization and application of materials and devices on the nanoscale**.** Similar to nanotechnology's success in consumer products and other sectors, nanoscale materials have the potential to improve the environment, both through direct applications of those materials to detect, prevent, and remove pollutants, as well as indirectly by using nanotechnology to design cleaner industrial processes and create environmentally responsible products (Reno *et al*, 2014; Satish *et al*, 2015; Xiao *et al*, 2005). For example, iron nanoparticles can remove contaminants from soil and ground water. Early application of nanotechnology is remediation using nanoscale iron particles. Zero-valent iron nano-particles are deployed in situ to remediate soil and water contaminated with chlorinated compounds and heavy metals. One of the main environmental applications of nanotechnology is in the water sector. As freshwater sources become increasingly scarce due to over-consumption and contamination, scientists have begun to consider seawater as another source of drinking water. The majority of the world's water supply has too much salt for human consumption and desalination is an option but expensive method for removing the salt to create new sources of drinking water. Carbon nanotube membranes have the potential to reduce desalination costs. Similarly, nano-filters could be used to remediate or clean up ground water or surface water contaminated with chemicals and hazardous substances. Finally, nano-sensors could be developed to detect waterborne contaminants (Mercier *et al*, 2002; Chien-I *et al*, 2008; Ershadi *et al*, 2011; Fan *et al*, 2015; Hall *et al*, 2000; Kalpana *et al*, 2009; Kannan, 2010; Kavitha *et al*, 2015; Laila *et al,* 2010; Masaki *et al*, 2006; Osinubi *et al*, 2009).

Types of Nanomaterials.

There are many types of intentionally produced nanomaterials; Carbon based materials, Metal based materials, Dendrimers, Composites, etc.

Carbon-based materials are composed mainly of carbon, most commonly taking the form of hollow spheres, ellipsoids, or tubes. Spherical or ellipsoidal carbon nanomaterials are referred to as fullerenes, while cylindrical ones are called nanotubes. These particles have many potential applications, including improved films and coatings, stronger and lighter materials and application in electronics (Arora, 2008).

Metal-based materials include quantum dots, nano-gold, nano-silver and metal oxides, such as titanium dioxides. A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, and whose size is of the order of a few hundred nanometers. In changing the sizes of quantum dots changes their optical properties (Kannan, 2010; Kavitha *et al*, 2015; Laila *et al*, 2010; Masaki *et al*, 2006; Osinubi *et al*, 2009).

Dendrimers are nanosized polymers built from branch units. The surface of dendrimers has numerous ends, which can be tailored to perform specific chemical functions. These properties could also be useful for catalysis. Also, because three dimensional dendrimers contain inferior cavities into which other molecules could be placed. They may be useful for drug delivery (Kannan, 2010; Kavitha *et al*, 2015; Laila *et al,* 2010; Masaki *et al*, 2006; Osinubi *et al*, 2009).

Composites combine nanoparticles with other nanoparticles or with larger bulk type materials. Nanoparticles such as nanosized clays are already being added to products ranging from auto-parts to packaging materials to enhance mechanical, thermal, barrier, and flame-retardant properties (Kannan, 2010; Kavitha *et al*, 2015; Laila *et al*, 2010; Masaki *et al*, 2006; Osinubi *et al*, 2009; Reno *et al*, 2014; Satish *et al*, 2015; Xiao *et al*, 2005).

Nano Tire Ash in Road Construction

Soil material is constantly changing in its physical and chemical composition. A successful system must be largely independent of such changes and leading the same treatment with the same application rates to the same result. This goal was achieved after several years of development with Nano tire ash. The standard application provides that the soil layer will be treated at a depth of 25cm-30cm with Tire ash. Tyre Ash causes irreversible agglomeration of fine particles in the soil and a partial charge reversal, so that higher densities and a strong reduction of swelling and shrinking capacity of the soil are possible. The recent experience confirms the expectation that Tire Ash can improve the soil permanently (Satish *et al*., 2015).

Sub-grade, Subbase and Base Course Requirments of Engineering Soil

It is very important to note the guiding principles and standards upon which design decisions are made in highway construction. According to **FMW & H specification requirement, pavement design conditions hold as follows; (NGS, 1997)**

(a) Sub Grade

Clauses 6102 and 6122 of the General specification (Roads and Bridges) Vol. II 1997 stipulates that a material will be suitable for use as sub grade if the following requirements are met:-

(i) **Proportion passing BS sieve No 200 Not greater than 35%**
(ii) **Liquid limit (LL)** **Not greater than 80%**
(iii) **Plasticity Index (PI)** **Not greater than 55%**
(iv) **Californian Bearing Ratio (CBR)** **Not greater than 10%**
(v) **Relative compaction** **Not greater than 100%**

(b) Sub Base

Clause 6201 of the General Specification (Roads and Bridges) Vol. II 1997 stipulates that a material will be suitable for use as sub base material if the following requirements are met: -

(i) **Proportion passing BS sieve No 200** **Not greater than 35%**
(ii) **Liquid limit (LL)** **Not greater than 35%**
(iii) **Plasticity Index (PI)** **Not greater than 12%**
(iv) **Californian Bearing Ratio (CBR)** **Not greater than 30%**
(v) **Relative compaction** **Not greater than 100%**

(c) Base Course

Clause 6201 of the General Specification (Roads and Bridges) Vol. II 1997 stipulates that a material will be suitable for use as base course material if the following requirements are met: -

(i) **Proportion passing BS sieve 200** **Not greater than 35%**
(ii) **Liquid limit (LL**) Not greater than 35**%**
(iii) **Plasticity Index (PI)** **Not greater than 12%**
(iv) **CBR (UnSoaked-24 hours)** **Not less than 80%**
(v) **Relative compaction** **Not less than 100%**

And for the Unconfined Compressive Strength of engineering soils to satisfy pavement requirements, they should be; very soft, 0 to 48KN/m^2; soft, 48 to 96KN/m^2; medium, 96 to 192KN/m^2; stiff, 192 to 384KN/m^2; very stiff, 384 to 766KN/m^2; and harder, greater than 766KN/m^2 (Fwa, 2006).

2. MATERIALS AND METHODS

Materials

The disturbed sample was collected from a borrow pit at Olokoro, located at latitude 05°28'36.900''North and

Longitude 07°32'23.170''East from a depth of 2.00 meters at a distance of 5km from Isicourt Junction, Umuahia South, Abia State, Nigeria (www.google.com, 2015). The sample collected was in solid state and reddish brown in color. The soil obtained was air dried in trays for one week after which the soil was crushed. The dried soil was pulverized, using a rubber covered pestle in the tray. Used tyres were obtained from slaughter ground at Mission Hill, a distance of 10km from Umuahia along mission hill/express road and Ohiya mechanic village, Umuahia. The tyres were burnt and the ash was collected, completely pulverized and sieved with 200nm sieve. The UV/VIS Spectrophotometer at 25°C characterization was conducted to determine the maximum absorbance, peak wavelength and the average particle size of the ash and stored for use as an admixture.

Methods

The following tests were carried out according to (BS 1377-2, 1990; BS 5930, 2015; Eurocode 7-2, 1997; NGS, 1997; ASTM D4318-10, 2015; ASTM D698-12, 2013; ASTM D854-14, 2015; ASTM D7262-09; ASTM D1883-99, 2003; ASTM D6913-04, 2009; ASTM D2487-11, 2015; ASTM D2488-09a, 2015; ASTM D3906-03, 2013; ASTM D2166-65, 2015; ASTM D2166/D2166M-13, 2015; ASTM F1185-88, 2015); UV/VIS Spectrophotometer at 25˚C, Sieve Analysis Test, Compaction Test (Standard Proctor Test), California Bearing Ratio Test (CBR), Atterberg or Consistency Limits Test (cassagrande apparatus), Unconfined Compressive Strength(UCS) Test, Specific Gravity Test and results were obtained. Fig. 1 shows the CBR and UCS equipment set up at the Nigerpet Laboratory, Uyo.

3. RESULTS AND DISCUSSION

Table 1 shows the summary of the preliminary investigation conducted on the natural lateritic soil sample

Figure 1: Nigerpet Laboratory Unconfined Compressive Strength and CBR setup

Table 1: Geotechnical Properties of the Lateritic Soil Sample

Property/Unit	Quantity
% Passing BS No. 200 sieve	25.40
Natural Moisture Content, (%)	10
Liquid Limit, (%)	47.00
Plastic Limit, (%)	25.15
Plasticity Index, (%)	21.85
Coefficient of Curvature, $C_c = \frac{{D_{30}}^2}{\mathrm{D_{10} \times D_{60}}}$	0.09
Coefficient of Uniformity, $\mathrm{C_u} = \frac{\mathrm{D_{60}}}{\mathrm{D_{10}}}$	10
Specific Gravity	2.67
AASHTO classification	A-2-7
USCS	GW
Group Index	0
Material	Silty or Clayey Gravel, Sand
Condition/General Subgrade Rating	Good
Optimum Moisture Content, (%)	13
Maximum Dry Density (g/cm^3)	1.84
California bearing ratio, (%)	14
Unconfined Compressive Strength, (KN/m @ 28 days	230.77
Color	Reddish Brown

From Table 1, it can be deduced that the Umuntu Olokoro soil sample has the following properties;

- A plasticity index of 21.85% > 17% and that condition satisfies that Umuntu Olokoro lateritic soil is a highly plastic soil. Also the plasticity index falls between 20 and 35% condition for high swelling potential and between 25 and 41% condition for a high degree of expansion (Gopal and Rao, 2011)
- The soil relative consistency and liquidity index, which are 1.69% > 1 and 0.91% < 1 respectively show that the soil is in a semi-solid or solid state, very stiff and plastic (Gopal and Rao, 2011)
- Is classified as A-2-7 soil on AASHTO soil classification, poorly graded, GP on USCS, the group index of 0 and of silty, clayey gravel and sand material according to (Gopal and Rao, 2011).
- Optimum moisture content of 13% and maximum dry density of 1.84g/cm^3.
- Unconfined Compressive Strength (UCS) of 230.77kN/m^2 which falls between 200 and 400kN/m^2, a condition for soils of very stiff consistency with respect to UCS (Gopal and Rao, 2011).
- Has a California bearing ratio of 14 which makes it good for sub-grade material.

Table 2 shows the chemical oxide compositions and bonding potentials of the nanosized waste tyre ash (NWTA) which satisfies that material bonding is a very important factor in soil stabilization because the soil and added admixture need to form a cohesive bond. Material requirement for cementing materials is that the sum of SiO_2, Al_2O_3, and Fe_2O_3 should not be less than 70%. The result of the analyzed NWTA shown in Table 2 shows that the percentage of SiO_2 + Fe_2O_3 + Al_2O_3 is 78.12% greater than 70% which makes the admixture sample a highly pozzolanic material. This property was of great advantage because it brought about a high degree of interaction and bonding between the studied soil sample and the admixture.

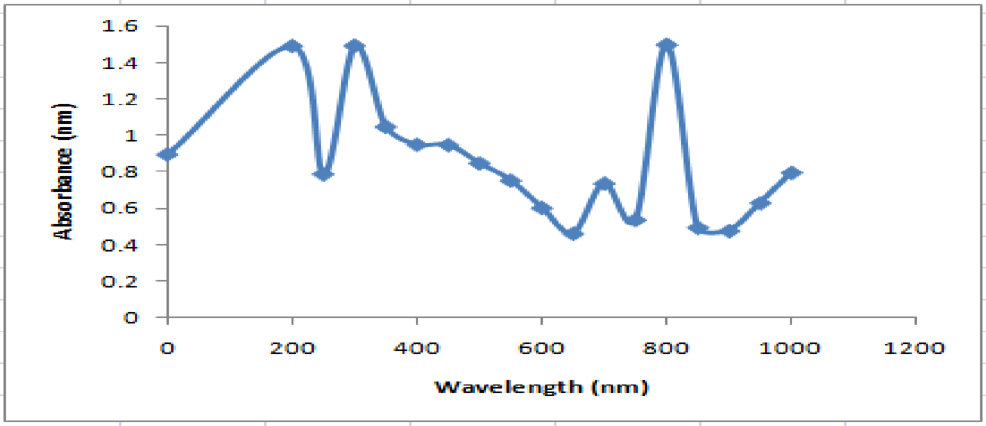
Table 2: Chemical Composition of Nanosized Waste Tyre Ash

Constituents	CaO	MnO	MgO	ZnO	CuO	Fe_2O_2	Al_2O_2	SiO_2	Na_2O	P_2O_5	K_2O
% wt in NWTA	12.57	0.13	0.01	3.21	Trace	2.55	31.12	44.45	4.11	1.81	0.04

Figure 2 shows the Variation of Absorbance against wavelength for the Nanosized Waste Tyre Ash particles using UV/VIS Spectrophotometer at 25^{0}C. From the exercise, it can be deduced that the maximum absorbance was 1.498 nm at a wavelength of 800nm, full width of half maximum of 150m and exposure angle of 65°. The above data gave an average particle size of 11.358 nm by Scherrer expression. The particle absorbance enhances the mechanism whereby size can potentially promote cohesion between admixture and stabilized soil, characterization of the molecular composition of organic matter in soil fundamental pool, lateral distribution of carbon forms in soil microaggregates, characterization of the composition of dissolved organic carbon in the ash during stabilization, etc. The nanopores of the ash material due to nanosization contribute 99% of the surface areas to the mixture homogeneity because it was less kinetically restricted at the temperature when its isotherm constructed during the mixing and stabilization mechanics.

The result obtained from the particle size, distribution indicates that the soil is well graded. From the semi logarithm chart in Figure 3, the value of uniformity coefficient obtained is 10 and that of coefficient of curvature is 0.09 which indicates that the soil is well graded as indicated by the small range which is another method of finding the gradation of particle. The strength and stability of lateritic soils depend on the coefficient of uniformity, the higher the uniformity coefficient, the more stable the soil (Gopal and Rao, 2011).

Wavelength	Absorbance
0	0.897
200	1.491
250	0.789
300	1.493
350	1.049
400	0.951
450	0.949
500	0.849
550	0.754
600	0.604
650	0.463
700	0.738
750	0.538
800	1.498
850	0.496
900	0.478
950	0.631
1000	0.797



Exp details
Re: mouau/chemlab/UV-VIS/sample 1/exp.001
Date Printed: 16:03:2017
Number of Replicate: 3
Max. Absorbance: 1.498 nm at 800 nm wavelenght

Figure 2: Variation of Absorbance against wavelength for the Nanosized Waste Tyre Ash particles using UV/VIS Spectrophotometer at 25^{0}C

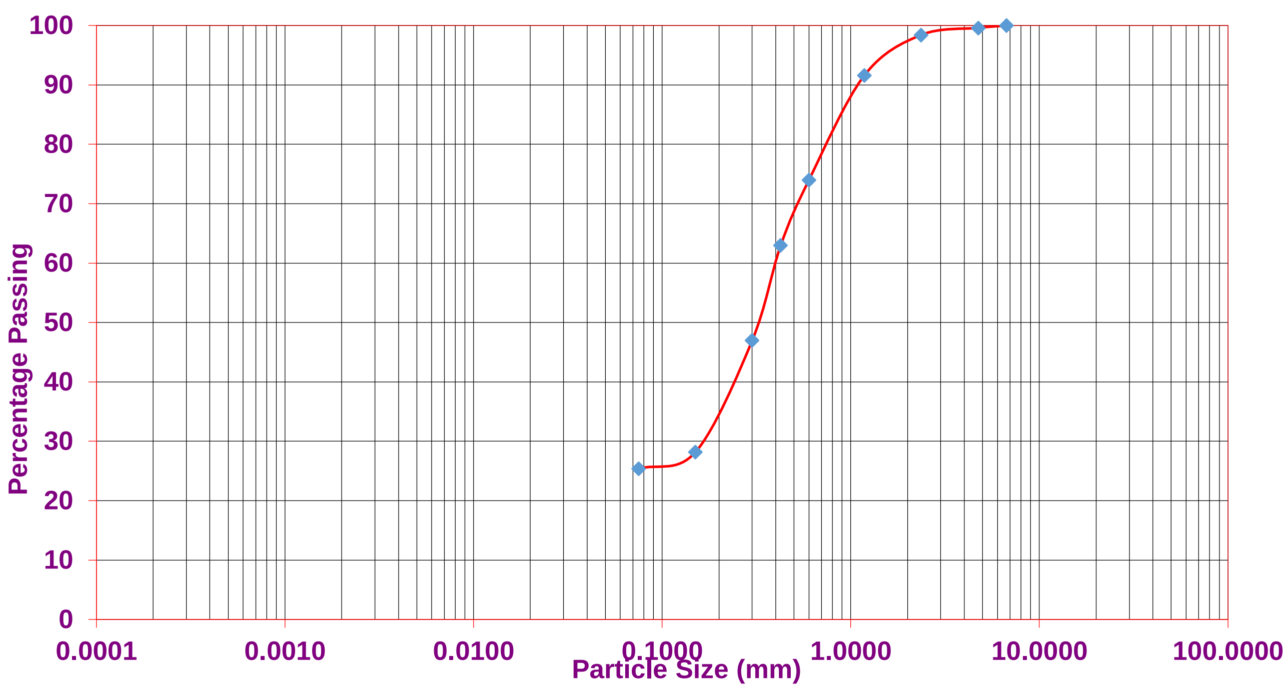


Figure 3: Particle size distribution curve of the lateritic soil

Lateritic Soil Behaviour with Nanosized Waste Tyre Ash on Consistency Limits

The addition of burnt tyre ash to Olokoro laterite was mixed with a certain percentage of water vigorously which made the admixture to have a high effect on the laterite colour. The admixture caused a decrease, thereby reducing the liquid limit and plastic limit. Therefore, the use of 3%, 6%, 9%, 12%

and 15% of the admixture is likely unsuitable for sub-grade material.

The test result generally indicated that the natural soil was progressively losing its plasticity with the increased amount of burnt tyre ash. The consistency test obtained the liquid limit (LL) as 47%, while for the soil/additive mixtures; the LL was 34.0%, 31.0%, 29.2%, 27.8%, and 25.8% for 3, 6, 9, 12 and 15% NWTA content respectively. However, the increase in the PL was large enough to reduce the PI therefore resulting in a steady decrease in PI with burnt ash content from 21.85 at 0% to 14.74, 14.6, 12.2, 9.45, 10.65% for soil admixture containing 3%, 6%, 9%, 12% and 15% NWTA by weight respectively. This is as a result of the hydration of the moisture content of the stabilized mixture thereby reducing the plasticity with an improved consistency.

Table 3: Effect of NWTA on the Consistency of Olokoro Lateritic Soil

Admixtures	0%	3%	6%	9%	12%	15%
LL, (%)	47	34	31	29.2	27.80	25.8
PL, (%)	25.15	19.26	16.40	17	18.35	15.15
PI, (%)	21.85	14.74	14.60	12.2	9.45	10.65

Lateritic Soil Behavior with Nanosized Waste Tyre Ash on Compaction

The results from compaction tests conducted are shown in Table 4. Addition of burnt tyre ash to the natural soil (Olokoro laterite) led to a decrease in the maximum dry density (MDD) and optimum moisture content (OMC) as shown in Table 4. The maximum dry density reduced from 1.84gm/cm^3 which were recorded at the control experiment to 1.57, 1.56 and 1.53gm/cm^3 at 3, 6 and 9% NWTA respectively and a slight increase to 1.54 and 1.55gm/cm^3 at 12 and 15% NWTA respectively. The optimum moisture content reduced from 13% at the control test to 10.92% at 3% NWTA. It hereafter recorded a considerable increase to 12.32% at 12% NWTA and a fall to 12.12% at 15% NWTA. The reduction in the OMC was due to hydration reaction between the nanosized admixtures with an increased reactive surface area while the behaviour of the MDD with added admixture remained below the value recorded at the control experiment. Though the admixture surface rendered more reactive space, it wasn't enough to improve the density of the mixture due to weight reduction at its present nano form.

Table 4: Effect of NWTA on the Compaction of the Lateritic Soil

NWTA Proportion	0%	3%	6%	9%	12%	15%
MDD (g/cm^3)	1.84	1.57	1.56	1.53	1.54	1.55
OMC (%)	13.00	10.92	11.53	12.01	12.32	12.12

Lateritic Soil Behaviour with Nanosized Waste Tyre Ash on UCS

A maximum UCS value of 230.77N/m^2 was obtained on natural Olokoro lateritic soil at 28 days curing. With the addition of NWTA, the highest UCS value obtained was 283.19N/m^2 at 28 days and at 6% NWTA. At 14 days and 7 days, the maximum UCS was recorded at 3% NWTA, which were 253.04kN/m^2 and 241.77kN/m^2, respectively. These decreased at higher proportions of NWTA beyond 3% as shown in Tab. 5. These effects were as a result of the pozzolanic bonding between the soil and the admixture which made the mixture acquire remarkable compressive strength.

Table 5: Effect of NWTA on the Unconfined Compressive Strength of the Lateritic Soil

NWTA Proportion	0%	3%	6%	9%	12%	15%
UCS 7-days kN/m^2	194.26	241.77	226.06	214.54	202.47	192.45
UCS 14-days kN/m^2	219.11	253.04	233.38	230.55	210.49	200.22
UCS 28-days kN/m^2	230.77	214.54	283.19	254.29	243.29	239.07

Lateritic Soil Behavior with Nanosized Waste Tyre Ash on CBR

The California Bearing Ratio (CBR) values of Olokoro lateritic soil untreated with NWTA were 14.00% at optimum moisture content of 13.00%, which satisfies the 10% value specified by the Nigerian general specification, 1997. The CBR values decreased and almost obtained the same values except at 15% increase in the proportion of NWTA. The CBR value obtained decreased with the range 3%, 3%, 3%, 3% and 5% at 3%, 6%, 9%, 12% and 15% admixture respectively which did not satisfy the Nigerian specification for road and bridges (NGS, 1997).

Table 6: Effect of NWTA on CBR of the Lateritic Soil

NWTA Proportion	0%	3%	6%	9%	12%	15%
CBR (%)	14	3	3	3	3	5

Table 7: General Effect of NWTA on the Stabilization of the Soil

Test	0%	3%	6%	9%	12%	15%	**Remarks**
MDD (gm/cm^3	1.84	1.57	1.56	1.53	1.54	1.55	Fair
OMC (%)	13.00	10.92	11.53	12.01	12.32	12.12	Good
LL (%)	47	34	27.8	29.2	31	25.8	
PL (%)	25.15	19.26	18.35	17	16.4	15.15	
PI (%)	21.85	14.74	9.45	12.2	14.6	10.65	Very good
CBR (%)	14	3	3	3	3	5	Poor
UCS 7-days KN/m^2	194.26	241.77	226.06	214.54	202.47	192.45	Very good
UCS 14-days KN/m^2	219.11	253.04	233.38	230.55	210.49	200.22	Very good
UCS 28-days KN/m^2	230.77	214.54	283.19	254.29	243.29	239.07	Very good

4. CONCLUSION

From the laboratory test carried out and the analysis of results, it can be concluded as follows:

1. That the lateritic soil stabilized with the NWTA satisfies the conditions for use as admixture with a plasticity of 10.65% at 15% treatment as a sub-base material.
2. Though the CBR value decreased, but fell within the range useful as sub-grade material i.e. less than 10% CBR.
3. The UCS recorded remarkable improvements with the addition of the NWTA. The highest values were recorded at 3% by weight additive at 7 and 14 days curing time and at 6% by weight additive for 28 days curing time. The highest value of UCS proved very stiff consistency.
4. Finally, NWTA is a good additive for the stabilization of Umuntu Olokoro lateritic soil for use as subgrade and subbase admixture materials.

REFERENCES

Ahmad, K. D., Yaser, K. and Ehsan, T., (2013). Synthesis of nano-alumina powder from impure kaolin and its application for arsenite removal from aqueous solution, J. Environ. Health Sci. Eng., 11(1), 19.

Ali Nazari, Mohammad Hossein Rafieipour and Shadi Riahi, (2011). The effects of CuO nanoparticles on properties of self compacting concrete with GGBFS as binder, Mat. Res., 14(3), 307-316.

Anamika Mubayi, Sanjukta Chatterji, Prashant M. Rai and Geeta Watal, (2012). Evidence based green synthesis of nanoparticles, Adv. Mat. Lett., 3(6), 519- 525.

Anitha, P. and Haresh M. Pandya, (2014). Comprehensive Review of preparation methodologies of nano hydroxyapatite, J. Environ. Nanotechnol., 3(1), 101-121.

ASTM D2166-65 (2015). Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.

ASTM D7262-09 (2015). Standard test methods for laboratory determination of density.

ASTM D1883-99 (2003). Standard test method of CBR.

ASTM D698-12 (2015). Standard test methods for laboratory compaction test for road bases.

ASTM D4318-10 (2015). Standard test methods for laboratory consistency limits test.

ASTM D6913-04 (2009). Standard test methods for Particle Size Distribution (Gradation).

ASTM D854-14 (2015). Standard test methods for specific gravity of soil.

ASTM D2166/D2166M-13 (2015). Standard test method for unconfined compressive strength of cohesive soil.

ASTM D3906-03 (2013). Standard test method for determination of relative Xray diffraction intensities of Faujasite-Type.

ASTM F1185-88 (2015). Standard method of XRD quantitative analysis.

ASTM D7762-11 (2015). Standard practice for design of stabilization for soil and soil-like materials.

ASTM D2487-11 (2015). Standard practice for classification of soils.

ASTM D2488-09a (2015). Standard practice for description and identification of soils and classification.

ASTM C150 (2013). Standard practice for ordinary potland cement specification.

Bao Ying, Zhan Liang, Wang Chunxiao, Wang Yanli, Yang Guangzhi, Yang Junhe, Qiao Wenming and Ling Licheng, (2011). Synthesis of carbon nanofiber/carbon foam composite for catalyst support in gas phase catalytic reactions, New Carbon Mater., 26(5), 341-346.

Chang-jun Liu, Uwe Burghaus, Flemming Besenbacher and Zhong Lin Wang, (2010). Preparation and characterization of nanomaterials for sustainable energy production, ACS Nano., 4(10), 5517-5526.

Chien-I. W., Jiann-Wen, H., Ya-Lan, W, Shaw-Bing, W, Yun-Hwei, S and Mou-Yung, Y., (208). Preparation of TiO2 nanoparticles by supercritical carbon dioxide, Mater. Lett., 62, 1923-1926.

Ershadi, V., Ebadi, T., Rabani, A. R., Ershadi, L. and Soltanian, H., (2011). The effect of nanosilica on cement matrix permeability in oil well to decrease the pollution of receptive environment, Int. J. Environ. Sci. Dev., 2(2), 128-132.

Fan Yang and Yongfeng Li, (2015). Synthesis and application of nanocarbon materials using plasma technology, Int. J. Chem. Eng. Appl., 6(1), 49-52.

Fwa, T.F. (2006). The handbook of highway engineering, Tailor and Francis, New York.

Gangadhera, (2011). Soil mechanics and geotechnical engineering, Kharna Publishers, New Delhi.

Garg, S.K. (2005). Soil mechanics and foundation engineering (Geotechnical engineering), Kharna Publishers, New Delhi

Gopal, R and Rao, A. S. R. (2011). Basic and applied soil mechanics, 2nd Ed., New Age Int'l Publishers, New Delhi.

Hall, B. D., Zanchet, D. and Ugartec, D. (2000). Estimating nanoparticle size from diffraction measurements, J. Appl. Cryst., 33, 1335-1341.

Kalpana Awasthi, Rajesh Kumar, Himanshu Raghubanshi, Seema Awasthi, Ratnesh Pandey, Devinder Singh, Kannan, M. (2010). Preparation and characterization of nano clay-filled polymer blends, Plastics Research Online.

Kavitha, S., Geetha, D. and Ramesh, P. S. (2015). Synthesis and characterizations of silver colloid nanoparticles stabilized by dextran, J. Environ. Nanotechnol., 4(1), 50-55.

Laila Raki, James Beaudoin, Rouhollah Alizadeh, Jon Makar and Taijiro Sato, (2010). Review of cement and concrete nanoscience and nanotechnology, Mater., 3, 918-942.

Masaki Ozawa and Eiji Ōsawa, (2006). Carbon blacks as the source materials for carbon nanotechnology, Carbon Nanotechnol., 6, 127-151.

Nigeria General Specification/Federal Ministry of Works and Housing (1997). Testing for the selection of soil for roads and bridges, Vol. II.

Osinubi, K. J., Bafyau, V. and Eberemu, A. O., (2009). Bagasse ash stabilization of lateritic soil, Springer Link Sciences and Business Media, 271- 280.

Reenu Jacob, Nair, H. G. and Isac, J., (2014). Structural and morphological studies of nano-crystalline ceramic BaSr0.9Fe0.1TiO4, Int. Lett. Chem. Phy. Astr., 41, 100-117.

Satish Bykkam, Mohsen Ahmadipour, Sowmya Narisngam, Venkateswara Rao Kalagadda and Shilpa Chakra Chidurala (2015). Extensive studies on X- Ray diffraction of green synthesized silver nanoparticles, Adv. Nanoparticles, 4(1), 1- 10.

Stulz, R. and Mukerji, K. (1993). *Appropriate Building Materials, Catalogue of Potential Solution*, 3rd edition, SKAT: St. Gallen, Switzerland, Pp. 29.

Xiao, Y., Cai, Z., Wang, Z. L., Lai, B. and Chu, Y. S. (2005). An X-ray nano diffraction technique for structural characterization of individual nanomaterials, J. Synchrotron Rad., 12, 124–128.

Yadav, T.P and Srivastava, O. N., (2009). Synthesis of nano-carbon (nanotubes, nanofibres, graphene) materials, Bull. Mater. Sci., 34(4), 607-614.