<https://doi.org/10.36293/sfj.2019.0013>

INFLUENCE OF XL-TERRASOIL NANO-CHEMICAL ON GEOTECHNICAL PROPERTIES OF WEAK LATERITE

Olaniyan O.S*, Ajileye V.O, Adewusi, M.O and Anifowose, O.I

Department of Civil Engineering,
Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Nigeria.

Abstract

Laterite is an important materials used in road construction. There exists a research gap on effect of XL-Terrasol on geotechnical properties of weak laterite. The geotechnical properties of weak laterites stabilized with Nano chemicals (XL -Terrasol) were determined in this study. Lateritic soil samples A and B were collected from two different burrow at ($8^{\circ}08'N$, $4^{\circ}15'E$) and ($8^{\circ}25'N$, $4^{\circ}3'E$) and their geotechnical properties at natural state were determined. XL - Terrasol were measured in weight to stabilize the laterites at 5, 10, 15, and 20 %, respectively. The geotechnical properties (Sieve Analysis, Liquid Limit (LL), Plastic Limit (PL), Plastic Index (PI) Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and California Bearing Ratio (CBR), sieve analysis of stabilized and unstabilized soil samples were determined. The CBR, MDD, PI and percentage passing sieve number 200 of sample A and B were (2%, 1700kg/m³, 45.6%, 50.1%) and (3%, 1840kg/m³, 30.6%, 46.1%), respectively. Using AASHTO classification system, the soils falls into A-5 - A-7 soils. The LL, PI, MDD and OMC for XL-Terrasol stabilized samples A ranged (36 -52%), (8 -32%), (1.73 - 2.34g/cm³) and (7.20 - 10.8%). The corresponding values for sample B were (36 - 58%), (15-34%), (1.8 - 2.63g/cm³), (10.5 - 14.0%). The average CBR (soaked and unsoaked) for stabilized samples varied from (5 - 6%); (13-17%) and (4 - 8%); (20 - 25%), respectively. The Optimum percentage of Nano Chemicals that gave the highest Compressive Strength was 15%. Nano Chemicals (XL-Terrasol) enhanced the geotechnical properties of weak lateritic soil.

Keywords: Laterite, Nano Chemicals, Geotechnical properties, XL-Terrasol

*Corresponding author email: osolaniyan@lautech.edu.ng;
ajileyevictoroluwaseun@gmail.com

Introduction

Lateritic soils are the most common construction materials due to their relative abundance, usually used for land filling and other purposes. Swelling and expansive lateritic soil can lead to road failures and other engineering application (Abu-Farsakh

et al, 2004; Al-Mukhtar *et al.*, 2010; Amadi *et al.*, 2012). Lateritic soils are located in the tropical environment characterized with an intense chemical weathering and leaching of soluble minerals (Oke and Amadi, 2008). Road accidents of are products of bad road

which emanated from usage of unsuitable constructional materials especially laterite as base and sub-base layers (Hussain and Apdagyei, 2012). The strength of lateritic soil in transmitting the axle-load to the sub-grade determine its usage as base course or sub base layers (Butalia *et al.*, 2003). The good constructional material must be efficiently durable in response to the load applied on it without failure. Geotechnical parameters such as specific gravity, shear strength, swelling potential, attterberg limits, bearing capacity and petrographic properties depend on mineralogical composition of materials (Al-Tabbaa and Evans, 2005; Christopher, 2005; Akinmade, 2008).

XL-Terrasol is water soluble, heat stable, waterproof and easy to apply nano-chemical. It disallows capillary rise from top and reduces water permeability of soil bases. It also controls expansivity and free swell in lateritic soil. XL-Terrasol nano-chemical offers a technology platform which can do away with the major causes of failure of roads. XL- Terrasol nano-chemical due to nano-level molecular hydrophobation of soil particle reduces the moisture susceptibility of the very expansive soil such as lateritic soil. The expansion of soil is eliminated and become impermeable to water penetration. It is economical and improves strength of soil. XL-Terrasol nano-chemical reacts with lateritic soil, making the soil waterproofed hence provide flexibility to construct roads at a reduced cost. The application of nano-chemicals such as XL-Terrasol can modify soil index properties. The nano-chemical improves workability and load bearing properties of soil when used to stabilize the soil (Zydex, 2013).

The specific objectives of the study are to: evaluate the geotechnical properties of the lateritic soil at natural state, determine the geotechnical properties of XL-Terrasol

stabilized soil, and determination of concentration of Nano-chemical that produces the maximum strength.

Materials and Methods

Lateritic soil samples were collected from Gbagada and Egbeda areas of Lagos State, sample A (8°08'N, 4°15'E) and sample B (8°25'N, 4°3'E). XL-Terrasol, available in concentrated liquid form was measured in weight of total weight of soil 5, 10, 15 and 20%, respectively. The percentages of XL-Terrasol used was in accordance with chemical stabilization trend from Literature (Ooi *et al.*, 2004; Nosu, 2005; Ysui, 2005; Zhang and Tao, 2006; Maaitah, 2012). The OMC of the natural soil was determined for effective chemical stabilization. The chemical was mixed with water in specified proportion before mixing with the soil. Figure 1 shows the composition and characterization procedures of XL-Terrasol. Its chemical specification is presented in Table 1.

Experimental Investigation

Laboratory Test

The geotechnical properties of the lateritic soil in this study were determined through the following tests: Sieve Analysis, Atterberg limit (Liquid Limit, Plastic Limit), Compaction Test and California Bearing Ratio (CBR) Test.

Atterberg Limit Test

The experiments were done in accordance with the provision of BS 1377 (No 40; BS sieve (0.425). The apparatus used include Liquid-limit device with grooving tool, moisture cans, plastic limit plate, and weighing balance sensitive to 0.01g for mass determination, and sieve pan (BS No. 35).

120g of soil sample were air dried and placed upon the glass plate. Spatula was used to mix soil thoroughly with the Nanochemical (XL-Terrasoil) as additive at 5, 10, 15 and 20%, respectively until the mass acquires the consistency of a thick

paste. The cup was half filled with the wet soil and the top was symmetrically leveled with the spatula. The soils were allowed to dry by returning it to the sample on the plate and spreading out thinly. After sufficient time, the sample was mixed

Figure 1: Composition and characterization procedures of XL-Terrasoil (Zydex, 2013)

Table 1: Technical Specifications of XL-Terrasoil

Property	Description
Appearance	Pale yellow liquid
Solid content	68±2%
Viscosity at 25°C	20-100cps
Specific gravity	1.01
Solubility	Forms water clear solution
Flash Point	Flammable 12°C
XL-Terrasoil	1 kg : 400 liters of water

Zydex (2013)

together again. The cup was lifted and dropped until the two grooved parts of the soil touched. The number of blows at which this occurs was recorded. Small portion of the sample was put into moisture can for moisture content determination. The moisture content correspond to each number of blows was read off as liquid limit

To determine the plastic limit test for lateritic soil sample; about 15g of soil sample was sieved through a No. 36 B.S sieve. The soil was well mixed on the glass plate and sufficient nano-chemical (XL-Terrasoil) as additive at 5, 10, 15 and 20% respectively was added to make it plastic enough to be shaped into a small ball. The ball was rolled into a thread between the hand and glass plate. The diameter crumbled thread decreases until it breaks. The moisture content of broken soil materials was determined as the plastic limit.

To determine the plastic limit test for lateritic soil sample; about 15 g of soil sample was sieved through a No. 36 B.S

sieve. The soil was well mixed on the glass plate and sufficient nano-chemical (XL-Terrasol) as additive at 5, 10, 15 and 20% respectively was added to make it plastic enough to be shaped into a small ball. The ball was rolled into a thread between the hand and glass plate. The diameter crumbled thread decreases until it breaks. The moisture content of broken soil materials was determined as the plastic limit.

Sieve Analysis Test

The natural soil samples were crushed respectively and 100 g of each sample were measured. The weights of each sieve and bottom pan were measured. Thereafter, the soil was placed in an array of sieves in decreasing order from top to bottom in the electric shaker and shaken for 15 min. The sieves were then weighed independently along with the soil retained. The percentage retained in each sieve was determined, after which the distribution curves were plotted.

Compaction Test

The apparatus used were: BS mould, displaced disk, base plate, a rammer, weighing balance, scraper, moisture cylinder, and head pan. An air dried sample of the soil was pre-treated and passed through 20 mm BS sieve and the particles passing were collected for the compaction. The empty weight of the mould was taken using a balance readable to 1 g and recorded. A quantity of the collected soil was weighed and with a measured volume of water mixed with nano-chemical (XL-Terrasol) as additive at varying percentages as above. The soil mixing was done manually using a scoop and trowel and five layers of the soil were introduced into the mould whose base plate was already covered with filter paper to prevent adherence.

The quantity of the soil for each layer was such that five of it filled the mould. Then, 62 blows of 4.5 kg metal rammer were applied for each layer. After compacting the five layers, the collar was disengaged and excess soil was removed with a straight edge. The mould and compacted soil were weighed to determine the wet bulk density. A sample of the soil was collected at top and bottom of mould for moisture content determination. This procedure was repeated to determine maximum dry density and optimum moisture content. A compaction curve was obtained by plotting dry density against moisture content for each of the sample.

California Bearing Ratio (CBR) (Soaked and Unsoaked) Test

The apparatus used are: CBR equipment consisting of 152 mm diameter $\times$ 178 mm height, CBR compaction mould with collar and spacer disk 151 mm diameter $\times$ 61.4 mm height, compaction rammer, expansion measuring apparatus with dial gauge reading to 0.01 mm, and compression machine equipped with CBR penetration piston. The experiment was done in accordance with the provision of BS 1377. The desired amount of water was added, mixed with nano-chemical (XL-Terrasol) as additive at 5, 10, 15 and 20%, respectively. The moulds were then assembled and compaction of the specimen was done. Five (5) test specimens each were compacted over a range of moisture content to establish the optimum water content and maximum dry density.

After the specimen has been compacted, the collar was removed from the mould and the compacted soil was carefully trimmed even, with the top of the cylinder by means of the straight edge. The perforated base plate and spacer disc were then removed, and the weight of the mould and compacted soil was

recorded. A disc of coarse filter paper was placed on the perforated base plate, the mould and compacted soil inverted and the perforated base plate was clamped to the mould with the compacted soil in contact with the filter paper. The mould was placed in the loading frame of the CBR machine and the plunger was adjusted appropriately by lowering to within 1.5 mm of the mould. The surcharge rings were placed, the machine switch on and both the penetration and load gauge readings noted and recorded. The mould is inverted and the loadings and penetrations are again noted also for the bottom just as for the top side. Portions of the sample from (top and bottom) part of the mould were taken for moisture content determination.

Results and Discussion

The Atterberg limit results are presented in Table 2. The PI decreases as the percentage of XL-Terrasol increases up to 10%, after which the PI start to increase. This could be due to changes in the micro structure of soil grains as the percentages of nano-chemical increase. The compaction result for the stabilized soil is given in Table 3. The

Maximum dry density (MDD) for Sample A and B ranged 1.73 – 2.34g/cm³, respectively. The decrease in density according to Whitlow (1995) and Osinubi (2006) is due to the flocculated and agglomerated clay particles occupying few spaces which lead to a decrease in dry density. It was observed that between 0-10% inclusions of XL-Terrasol solution to lateritic soil sample, there was an increase in the value of MDD for sample A. The trend decreases with sample B which may be due to varying particle sizes. Percentage passing sieve no 200 is higher in Sample A than Sample B. Generally, the MDD decreases due to the increase in the percentage of XL-Terrasol in lateritic sample.

Furthermore, the OMC increases from 7.20-10.8 % and from 10.5-14.0 % for XL-Terrasol stabilized samples. The increase in the trend of OMC agrees with findings of Osinubi (2006); Bunga (2012) and Akinmade (2008). This is due to the fact that the various cations and clay minerals demands more water for hydration of the particles. Increase in OMC with higher stabilizer content and decrease in MDD of the soil permit compression to be easily attained with wet soil. Thus, the soil may not be dried prior to compaction in the field.

Table 2: Atterberg Test

XL-Terrasol content (%)	Sample A			Sample B		
	LL	PL	PI	LL	PL	PI
0	52	20	32	56	22	34
5	49	23	26	58	27	31
10	38	25	13	56	41	15
15	38	26	12	52	29	23
20	36	28	8	36	19	17
Mean	42.6	24.4	18.2	51.6	27.6	24
Standard Deviation (SD)	3.2	4.4	3.7	4.4	2.4	3.2

LL, Liquid Limit; PL, Plastic Limit; PI, Plastic Index

Table 3: Compaction results for stabilized soil

XL-Terrasol solution (%)	Sample A		Sample B	
	OMD (%)	MDD (g/cm ³)	OMD (%)	MDD (g/cm ³)
0	7.20	2.15	10.5	2.58
5	9.0	2.26	11.0	2.12
10	10.2	2.34	11.9	1.8
15	10.6	1.73	6.5	2.63
20	10.8	1.90	14.0	2.06
Mean	9.56	2.08	10.78	2.24
Standard Deviation (SD)	1.54	0.26	0.53	0.58

The strength characteristics of the stabilized soil (CBR soaked and unsoaked) is presented in Table 4. The CBR is used to quantify the behavioral feature of the soil to defy distortion of applied load. The CBR test was carried out for 0, 5, 10, 15 and 20% of nano-chemical (XL-Terrasol) as chemical stabilizer as presented by AASHTO compaction energy for both soaked and unsoaked samples with a compactive volume of 2305 cm³ and 4.5 kg rammer.

The CBR (soaked and unsoaked) values obtained gradually increases between 5-15% of inclusion of XL-Terrasol most especially for Sample B. The maximum value of CBR was obtained at 15% nano-chemical (XL-Terrasol) addition. It was observed that the California Bearing Ratio (CBR) values ranged from 5-6 % and 13-17 % for both soaked samples A and B. The CBR (Unsoaked) varies from 4-6 % and 20-25 % for sample A and B, respectively. This indicates an increment in CBR values with

increase in Nanochemical. It can be concluded that the additive inclusion between 5-15% could increase significantly the CBR for sandy clayey lateritic soil sample. Also, XL-Terrasol stabilized samples have CBR value of 25% which is lesser than 30% of Federal Ministry of Works (FMW) specification. This implies that the stabilized sample B could be suitable for subgrade in road construction. Stabilized sample A can also be useful for a fill material in any Civil Engineering construction.

Conclusion

The present study has shown that the inclusion of XL-Terrasol reduced liquid limit for both soil samples, with the maximum dry density for sample A and B achieved at 10 and 15%, respectively. However, the CBR value for sample B increased considerably with the addition of XL-Terrasol; to attain the optimum CBR at 15% addition of chemicals to the lateritic soil.

Table 4: Statistical results of California Bearing Ratio (CBR) Test

XL-Terrasol (%)	Sample A (%)		Sample B	
	Unsoaked CBR	Soaked CBR	Unsoaked CBR	Soaked CBR
0	4	6	20	13
5	4	5	23	9
10	6	6	17	13
15	6	6	25	17
20	3	6	15	5
Mean	4.6	5.8	20	11.4
Standard Deviation (SD)	0.7	0.4	0.1	1.3

Thus, the stabilized laterite soil B satisfies the requirements for “sub-base type 2” and sub-grade as stated by the Federal Ministry of Works standard specification for roads and bridges (FMW, 1997). Further study is required on the micro structure of the stabilized soil samples to understand the mechanism of XL-Terrasol laterite stabilization.

Acknowledgement

The authors acknowledge the academic and technical staff of Civil Engineering Department, LAUTECH, Ogbomoso, Nigeria for creating enabling environments for research.

References

Abu-Farsakh, M., Alshibli, K., Nazaal, M. and Seyman, E. 2004. Assessment of *in situ* test technology for construction control of base courses and embankments. Technical Report no 389, Louisiana Transportation Research Center.

Al-Mukhtar, M., Lasledj, A. and Alcover J.F. 2010. Behavior and mineralogy changes in lime-treated expansive soil at 20° C. *Applied Clay Science* 50: 2-18

Al-Tabbaa, A. and Evans, W.C. 2005. Stabilization-solidification treatment and remediation: Part I: Binders and

technologies-basic principal. *Proceedings of the International Conference on Stabilization/Solidification Treatment and Remediation Cambridge, UK: Balkema*. pp. 367-385.

Akinmade, O.B. Unpublished. The effects of locust bean waste ash on the geotechnical properties of Black cotton soil. Unpublished M.Sc. Thesis, Department of Civil Engineering, Ahmadu Bello University, Zaria.

Amadi, A.N., Eze, C.J., Igwe, C.O., Okunlola, I.A. and Okoye, N. O. 2012. Architect's and geologist's view on the causes of building failures in Nigeria. *Modern Applied Science* 6(6): 31-38.

Bunga, E. 2012. Stabilization effect of emulsified Asphalt on erosion rate of sandy clay loam. *International Journal of Civil and Environmental Engineering* 6: 54-61.

Butalia, T.S., Huang, J., Kim, D.G. and Croft F. 2003. Effect of moisture content and pore water pressure buildup on resilient modulus of cohesive soils in Ohio. Resilient modulus testing for pavement components, ASTM International, West Conshohocken, PA.

Christopher M. G. 2005. Stabilization of soft clay subgrades in Virginia Phase I

laboratory study”. Master’s thesis, Virginia Polytechnic Institute and State University.

Hussain, M.S. and Apdagyei, A.K. 2010. Evaluation of the lightweight deflectometer for In-situ determination of pavement layer moduli. Virginia Transportation Research Council. http://www.virginiadot.org/vtrc/main/online_reports/pdf/10-r6.pdf 147

Maitaah, O.N. 2012. Soil stabilization by chemical agent. *Geotechnical and Geological Engineering* 30: 1345-1356.

Nozu, M. 2005. Regional Report: Asia. *Proceeding of the International conference on deep mixing-best practice and recent advances*. Stockholm.

Oke, S.A. and Amadi, A.N. 2008. An assessment of the geotechnical properties of the subsoil of parts of Federal University of Technology, Minna, GidanKwano campus, for foundation design and construction. *Journal of Science, Education and Technology* 1(2): 87-102.

Oklahoma Department of Transportation. 2009. *Soil modification mix design procedure*.

Ooi, P.S.K., Archilla, A.R. and Sandefur, K.G. 2004. Resilient modulus models for cohesive soils. *Transportation Research Record* 1874: 115-124.

Osinubi, K.J. 2006. Influence of comparative efforts on lime-slag treated tropical black soil. *Journal of materials in Civil Engineering* 2: 175-181.

Whitlow, R. 1995. Basic Soil Mechanism. 3rd ed. Addison Wesley Longman Limited, Edinburg.

Yasui, S., Yokozawa, K., Yasuoka, N. and Kondo, H. 2005. Recent technical trends in Dry Mixing (DJM) in Japan. Stockholm: *Proceeding of the International conference on deep mixing-best Practice and recent advances*.

Zhang, Z. and Tao, M. 2006. Durability of cement stabilized low plastic soils, Transportation research board, *Annual meeting, CD-ROM publication, Transportation Research Board, National Research council, Washington D.C.*

Zydex. 2013. Zydex Industries, Nanochemicals. www.zydexindustries.com