E-ISSN: 1116 – 2716 P-ISSN: 3026-8214
MPRI-JAAE | INTERNATIONAL JOURNAL OF APPLIED & ADVANCED ENGINEERING RES.
VOL. 05 NO. 5 - JULY, 2024

USE OF TERMITE MOUND SOIL AS ADDITIVE TO IMPROVE THE GEOTECHNICAL PROPERTIES OF LATERITIC SOIL IN VUNOKLANG, ADAMAWA STATE-NIGERIA

SANUSI SULEIMAN; MAGAJI SULEIMAN UMAR; & HAMAJODA JIBIRILLA

Department of Civil Engineering Technology, Adamawa State Polytechnic, Yola, Nigeria.
Corresponding Author: babasayyida78@gmail.com

Abstract

This research was carried out to investigate the properties of termite mound soil; as an additive for stabilization of soil strength in construction industry. Three termite mound soils were sampled through a vertical section from top at intervals of 0-0.6 m, 0.6-1.2 m and 1.2-1.8 m; and mixed with the two soil types separately; termite mound + clayey soil and termite mound + lateritic soil. Twenty different compaction tests were conducted on the soil samples mixtures at 5% intervals ranging from 0%-100%. Compressive strengths were determined from the optimum moisture content values obtained from compaction test using triaxial machine model HM -5020. The tests were carried out according to the American Public Health Association (APHA) and the data were analyzed using descriptive statistics and one-way ANOVA. The results of geotechnical analyses showed that the termite mound soils were sandy clay loam whereas the lateritic soils were sandy loam. The termite mound soil samples recorded higher maximum dry densities and compressive strengths compared to the lateritic and clay soil samples. Increasing the ratio of termite mound soil in the mixture indicated increase in maximum dry density but little effect on the optimum moisture content for both the lateritic and clay soil samples. In term

Keywords:
Geotechnical Properties, Termite Mound, Additive, Lateritic Soil, Clay Soil, Mixture, Sandy Clay Loam, Sandy Loam.

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

of compressive strength and maximum dry density, using termite mound soil as an additive proved more effective in lateritic soils than in clay soil. At the same termite mound soil ratio, the compressive strength of the lateritic soil was almost twice that of the clay soil. Hence, termite mound soil can be recommended as an additive for improving the quality of lateritic soil.

Introduction

One of the major challenges in developing countries such as Nigeria is infrastructural development. This often translates into lack of access road in the rural areas and high cost of transportation. High cost of transportation on the other hand had multiplier effect on the cost of food and any other material produced in rural areas. Consequent to the present economic recession in this country, it became a challenge on engineers and all stakeholders in road construction to look for locals and devise means of improving the quality of the lateritic soils commonly used for local roads. This challenge has informed the use of lateritic soils which are naturally occurring materials often rejected by traditional specifications for use in the upper layers of road pavements (Minjinyawa, et. al, 2007). Lateritic soils occur extensively in the tropical zones of the world, including Nigeria.

The performance of lateritic soils has often been better than expected on the basis of traditional specifications (Adam, et. al, 2001). It can be successfully put into used under specific conditions. It can be used as alternative materials to replace asphalt and cement partially or wholly for construction purposes (Okoli, et. al, 2002). Lateritic soil as a construction material often contains some amount of clay minerals that affect its strength and stability. It also has some undesirable properties such as loss of strength when saturated with water, erosion due to wind or driving rain and poor dimensional stability (Adeoye, et. al, 2019). These can be eliminated or reduced significantly by stabilizing the soil with additives (Abe, et. al, 2014).

As ecosystem engineers, termites built mounds; in so doing enhance the content of organic carbon, clay and nutrients (King, 2006). They decompose and redistribute organic matter, improve soil stability and its physical and chemical properties (Manuwa, 2009), and improve its water absorbing and storing capacity (Olowofoyeku, et. al, 2016). A termite mound is very strong especially in the dry season. Its structure changes with climatic condition; it is very dry during dry season and wet or sticky during rainy season (Anusha, et. 2010), Geotechnical properties such as particle size distribution, optimum moisture content (OMC), maximum dry density (MDD, and ultimate compressive strength (UCS) are important in engineering construction. Inadequacy of quantity of termite mound making it not be enough for meaningful usage suggest it to be used as additive for other local materials that are available in large quantities (Momah, et. al, 2018). Hence, this research is aimed at investigating the effect of termite mound additive on soil

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

geotechnical properties. This should involve both index and engineering characteristics of the soil.

Materials and methods

Sample site location

The study area is located in Vunoklang, Girei L.G.A., Adamawa State; which is situated on the northern bank of River Benue. The underlying rocks are sandstones on which weathered lateritic and termite mound soils are encountered. The sampled lateritic soils which served as control were about 100 m away from the termite mounds. Three termite mounds on a uniform slope were selected to evaluate their chemical and geotechnical properties in relation to the surrounding soils. Three lateritic soils adjacent to the mounds; three in each location were sampled to serve as controls for this research.

Soil sampling

Termite mound and adjacent lateritic soils were selected for characterization and sampling. A soil profile pit was dug and soil samples (both disturbed and undisturbed) were collected from each genetic horizon. After carefully scrapping the surface, three representative soil samples were taken from each termite mound. The termite mound soils were sampled from top at 0-0.6 m, 0.6-1.2 m and 1.2-1.8 m intervals through a vertical section.

Geotechnical analyses

Geotechnical analyses were carried out on the samples collected from the termite mounds and lateritic soils following BS 1377 laboratory procedures. The disturbed soil samples were air dried and ground gently for evaluation of index, engineering and chemical properties such as particle size distribution, optimum moisture content, maximum dry density, compressive strength and unconfined compressive strength while the undisturbed soil cores were used determined the bulk density.

Optimum moisture content (%)

To determine the gravimetric moisture content, soil samples were taken with soil auger at various depths and intervals; weighed, oven dried at 105°C for 24 h and weighed again. Optimum moisture content was determined using the formula:

OMC = [(Weight of moist soil) – (Weight of dry soil)]/ (Weight of dry soil) X 100 --------- (1)
OMC = Optimum moisture content (%)

Maximum dry density (kg m^{-3})

Maximum dry density was determined using the optimum moisture content by the Proctor model ASTM D 698-78 (Standard, 2018). The experiment was repeated 5 times

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

and then dry the density of soil was calculated. The dry density the corresponded with the optimum moisture content is the maximum dry density.

Bulk density (kg m^{-3})

Gravimetric method was used to determine **b**ulk density of the soil samples. The empty samples box was weighed and then weighed with the soil samples. It was then placed in an oven at a temperature of 105°C for 24 hours and allowed to cool in a desiccator. The bulk density was determined using the formula:

Bulk density of soil (kg m^{-3}) = Mass of over dry soil (kg)/ Volume of core (m^3) ---------- (2)

Particle size of soil

The particle sizes of the soil samples were determined using hydrometer analyses. 100 grammes of air-dried finely powered soil was put in a 500mL of conical flask and 15 mL of 0.5 N sodium oxalate (Na_2SiO_3) was added. 200 mL of distilled water was added to the mixture and shake for 20 min. The content was transferred to one litre capacity measuring cylinder to make it up to one litre by adding enough water. The suspension was thoroughly stirred and the time was noted.

Hydrometer was dipped into the suspension after 5 minutes to give direct reading of the percentage of Clay plus Silt. Reading after 5 h of sedimentation gives the percentage of Clay directly. Percentage of sand was determined by deducting the percentage of Clay + Silt from 100 % and percentage of silt was determined by subtracting the hydrometer reading from clay + silt. Hydrometer readings are given in g/L (APHA, 2005).

Sample preparation and compressive strength test

Two lebelled metal bays were used; one each for 6 kg of clayey soil and lateritic soil and kept. 6 kg of the respective air dried sample was mixed with 5% of water in a metal bay and their weight of the respective sample was recorded. 12 kg of termite mound soil was also kept in a labelled metal bay and mixed with 5% of water and all records taken. Twenty one termite mound and clay soil samples were mixed in the percent ratio of 5:95; 10:90; 15:85; 20:80; 25:75; 30:70; 35:65; 40:60; 45:55; 50:50; 55:45; 60:40; 65:35; 65:35; 70:30; 75:25; 80:20; 85:15; 90:10; 95:5; 100:0. In the same manner, termite mound and laterite soil of the ratios as presented in the same as termite mound and clayey soil (OMC) from the compaction test was used to compacted soil for determination of the compressive test. Triaxial testing machine model HM-5020 was then used to determine the failure loads of the soil samples.

Data analysis

Chemical and geotechnical properties of soil samples were determined in accordance with the American Public Health Association Standards (APHA, 2005). Descriptive

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

statistics was used in analyzing the data. Duncan`s multiple range test was used to compare the means of each parameter. The statistical inference was made at 0.05 (5%) level of significance.

CS = Failure X PRC/ Area **KN mm^{-2} ---------- (3)**

where,
CS = Compressive strength. KN mm-2;
PRC = providing ring constant, is given as 0.025;
A = area of sample = $\pi d^2/2$;
(*d* = 38 mm)

UCS = *CS*/2 , KN mm^{-2} ----------(4)
where,
UCS = Unconfined compressive strength, KN mm^{-2}.

Results and discussion
The results of particle size distribution and geotechnical properties of the soil samples are presented in Table 1.

Table 1. The particle size distribution and engineering particle properties of the soil samples

Parameters	Termite mound height, cm			Lateritic Soil Depth (cm)			Clay soil
	0-0.6	0.6-1.2	1.2-1.8	0-0.6	0.6-1.2	1.2-1.8	
Sand, %	69.2±4.1a	68.5±3.7a	68.3±3.8a	81.8±4.3b	81.6±4.1b	82.5±3.6b	
Silt, %	14.1±1.2a	14.4±1.1a	14.9±1.1a	10.9±1.4b	11.2±1.2b	10.8±1.2b	
Clay, %	16.7±3.2a	17.1±3.1a	16.8±3.1a	7.3±3.6b	7.2±3.3b	6.7±3.1b	
Textural class	SCL	SCL	SCL	SL	SL	SL	
BD, g cm^{-3}	1.48±0.1a			1.53±0.1b			1.28±0.1c
OMC, %	19.5±0.2a			18.7±0.3b			23.3±0.1c
MDD, g cm^{-3}	1.85±0.2a			1.42±0.3b			1.03±0.02c
CS, kPa	6.34×10^{-4}			4.22×10^{-4}			$1.18\times x10^{-4}$
UCS, kPa	3.17×10^{-4}			2.11×10^{-4}			0.59×10^{-4}

Optimum moisture content (OMC) and maximum dry densities (MDD) of the soil samples were determined by compaction test. Table 2 shows the of compaction test for the mixed ratio of termite mound and clayey soil and also that of the mixed ratio of termite mound and laterite soil.
Fig. 1 and 2 shows the results of compressive test results for Dial gauge reading, compressive strength (CS) and unconfined compressive strength (UCS) for the mixed

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

ratio of termite mound and clayey soil and also for dial gauge reading, compressive and unconfined compressive strength for the mixed ratio of termite mound and lateritic soils.

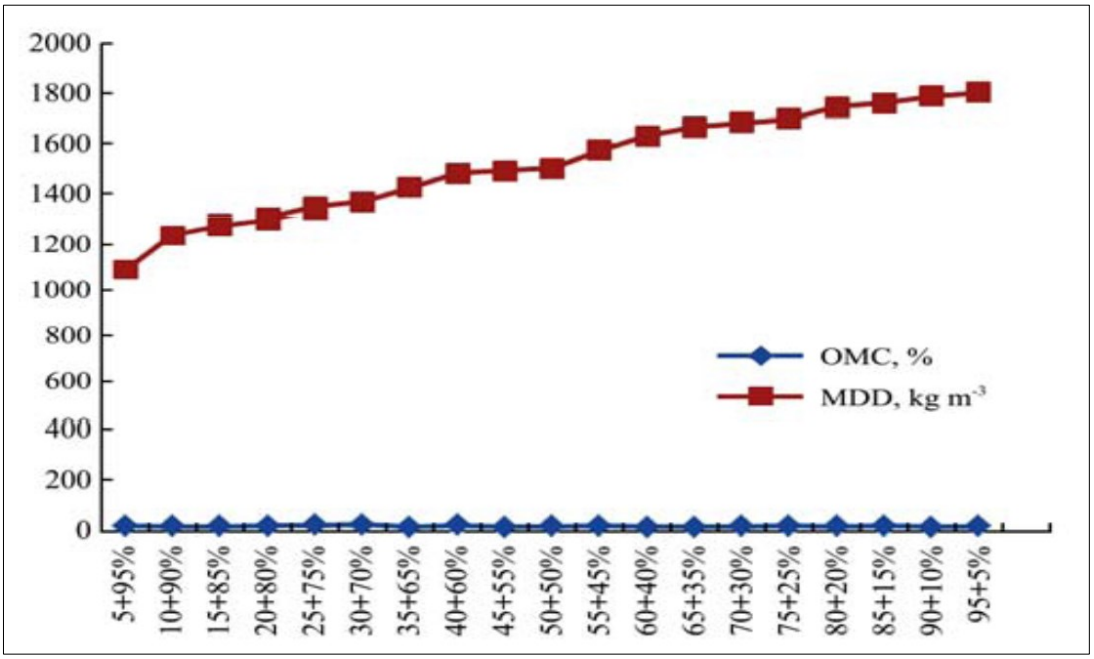

Fig. 1.Graph shows the mixed ratios of termite mound and clay soil

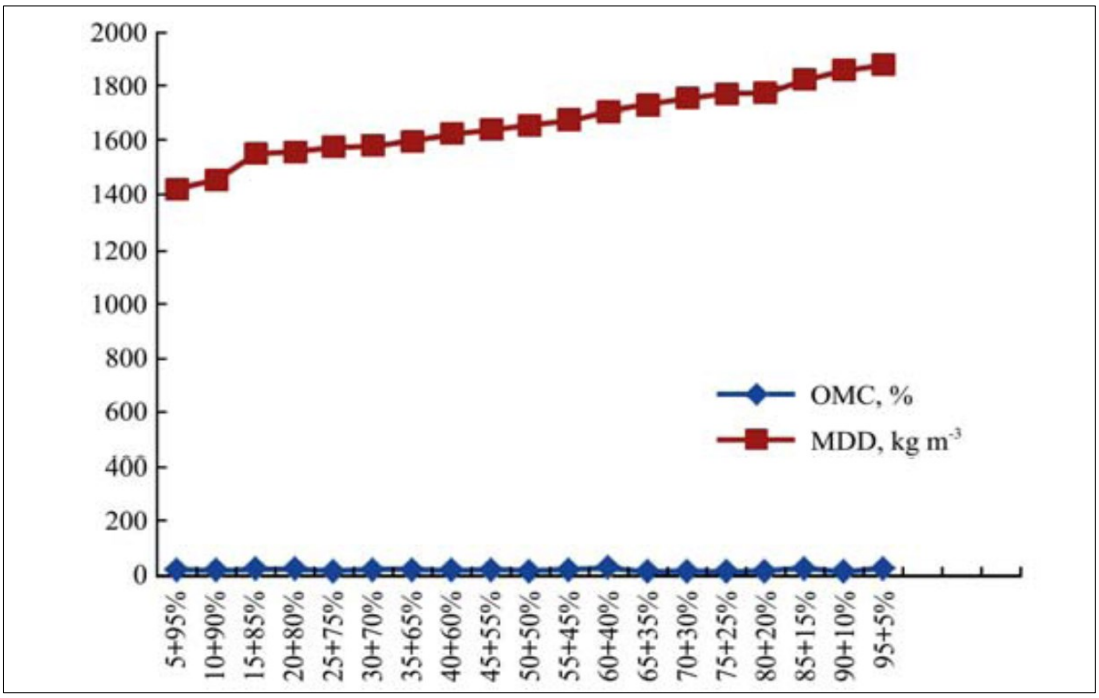

Fig. 2. Graph shows the mixed ratios of termite mound and lateritic soil

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

Values are means of four replicates (n=4) in all treatment results, they were presented as means values of each determination ± standard error means (SEM) Means indicated by the same letter did not differ (P≥0.05) as assessed by Duncan's multiple range test (horizontal comparisons only)

Key:
SCL = Sandy Clay Loam
SL = Sandy Loam

Table 2 Comparisons between the mixed ratios of termite mound + clayey soil and termite mound + lateritic soil on (MDD), (CS) and (UCS)

Parameters	Termite mound and Clayey soil		Termite mound and Lateritic soil	
	MIN. VALUE	MAX. VALUE	MIN. VALUE	MAX. VALUE
OMC, %	13.09	24.12	12.65	27.57
MDD, kg m^{-3}	1092	1855	1425	1890
CS, KN mm^{-2}	1.48×10^{-4}	6.78×10^{-4}	3.22×10^{-4}	1.12×10^{-3}
UCS, KN mm^{-2}	7.20×10^{-5}	3.45×10^{-4}	1.60×10^{-4}	5.41×10^{-4}

Particle size distribution

From Table 1, the textural classifications of the termite mound soils were sandy clay loam while the lateritic soils were sandy loam. In all the soil samples, there was no significant difference (p≥0.05) within the soil profiles.

Geotechnical properties of the soil samples

The lateritic soil sample has the highest value of bulk density 1.54 g cm^{-3} (1540 kg m^{-3}) followed by the termite mound soil sample with 1.46 g cm^{-3} (1460 kg m^{-3}). The clay soil sample has the least value of 1.34 g cm^{-3} (1340 kg m^{-3}). The clay soil sample has the highest values of optimum moisture content of 21.1%; followed by the termite mound soil sample with 19.2% and lateritic soil samples with the least value of 18.5%. The termite mound soil sample has the highest values in terms of maximum dry density and compressive strength, followed by lateritic soil sample and least values was clay soil sample (Table 1). The optimum moisture content of a soil at the time of compaction significantly affects the dry density which in turns affects the strength of the soil samples. The optimum moisture content serves as a guide for the preparation and mixing of the block units. Moisture contents affect strength development and durability of the material and have a significant influence on the long term performance of stabilized soil material especially on bonding with mortars at the time of construction. The compressive strength is the most universally accepted criterion or determining the quality of material for construction.

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

Optimum moisture content and maximum dry density

From Fig. 1, the minimum value of optimum moisture content value for the termite mound and clayey soils was 13.00%; which occurred at mixed ratio of 40% and 60%, while the maximum value was 24.00%; which occurred at mixed ratio of 30% and 70%. Likewise, the maximum dry density minimum value was 1087 kg m^{-3}; which occurred at mixed ratio of 5% and 95%, while the maximum value was 1848 kg m^{-3}; which occurred at mixed ratio of 100% and 0%. These indicate that with increase in the termite mound soil content in the mixed ratio, the maximum dry density increases without significant effect on the optimum moisture content. From Fig. 2, the minimum value of optimum moisture content in the termite mound and laterite soil samples was 12.50%; which occurred at mixed ratio of 75% and 25%, while the maximum value was 27.50%; which occurred at mixed ratio of 60% and 40%. Likewise, the maximum dry density minimum value was 1420 kg m^{-3}; which occurred at mixed ratio of 5% and 95%, while the maximum value was 1885 kg m^{-3}; which occurred at mixed ratio of 100% and 0%.

The optimum moisture contents for both mixed ratios were not affected by the inherent properties of the mixtures; similarly, the trend indicated that with increase in the content of termite mound, maximum dry density increased. It was observed that the trend exhibit time and environment dependant. Also the maximum dry densities for both the mixed ratios were dependent upon the inherent property of termite mound only. Mijinyawa et al., (2007) and Yohanna et al., (2003) opined that maximum dry density is directly proportional to termite mound soil content and inversely proportional to clayey and lateritic soil contents. Fig. 1 showed the different values for both minimum and maximum for MDD recorded between the mixed ratios and they were not significant ($P \geq 0.05$). The maximum dry density values for both mixed ratios were below the minimum specified value of 2000 kg m^{-3} (2.0 g cm^{-3}) for road construction in Nigeria (Briges, 2007). But the maximum dry density of the lateritic and termite mound soil started from 85%-95% mixed ratios (1825-1880 kg m^{-3}) have values greater than 1810 kg m^{-3} recommended for building construction in Nigeria (Madedor, 1992; Oshodi, 2004). Therefore, termite mound soils can be used as additive in building construction.

Compressive strength and unconfined compressive strength

The compressive strength for the termite mound and clayey soil mixture ranging from 1.43×10^{-4} to 6.71×10^{-4}) KN mm^{-2}, the results of the ration of termite mound 5% mixed with 95% clayey soil gave1.43×10-4 KN mm^{-2} as the minimum compressive strength at which the soil failed in stress; while maximum compressive strength occurred at 95% termite mound soil mixed with 5% of clayey soil. In the same vein, the unconfined compressive strength ranging between (7.15×10^{-5} and 3.36×10^{-4}) KN mm^{-2} and formed the same pattern with the compressive strength. For the termite mound and lateritic soil mixed ratio, the compressive strength ranging between (3.09×10^{-4} and 1.07×10^{-3}) KN mm^{-2}, the results of

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

termite mound 5% mixed with 95% clayey soil gave 3.09×10^{-4} KN mm^{-2} as the minimum compressive strength at which the soil failed in stress, while maximum compressive strength was 1.07×10^{-3} KN mm^{-2} and it is occurred at 100% termite mound mixed with 0% of clayey soil. Similarly, unconfined compressive strength ranging between (1.55×10-4 and 5.35×10^{-4}) KN mm^{-2} and formed the same pattern with the compressive strength. The compressive strength of termite mound only is higher than the values of the termite mound mixture. The relationship between compressive strength of clay and laterite soils at the same termite ration is presented in Figure 3.

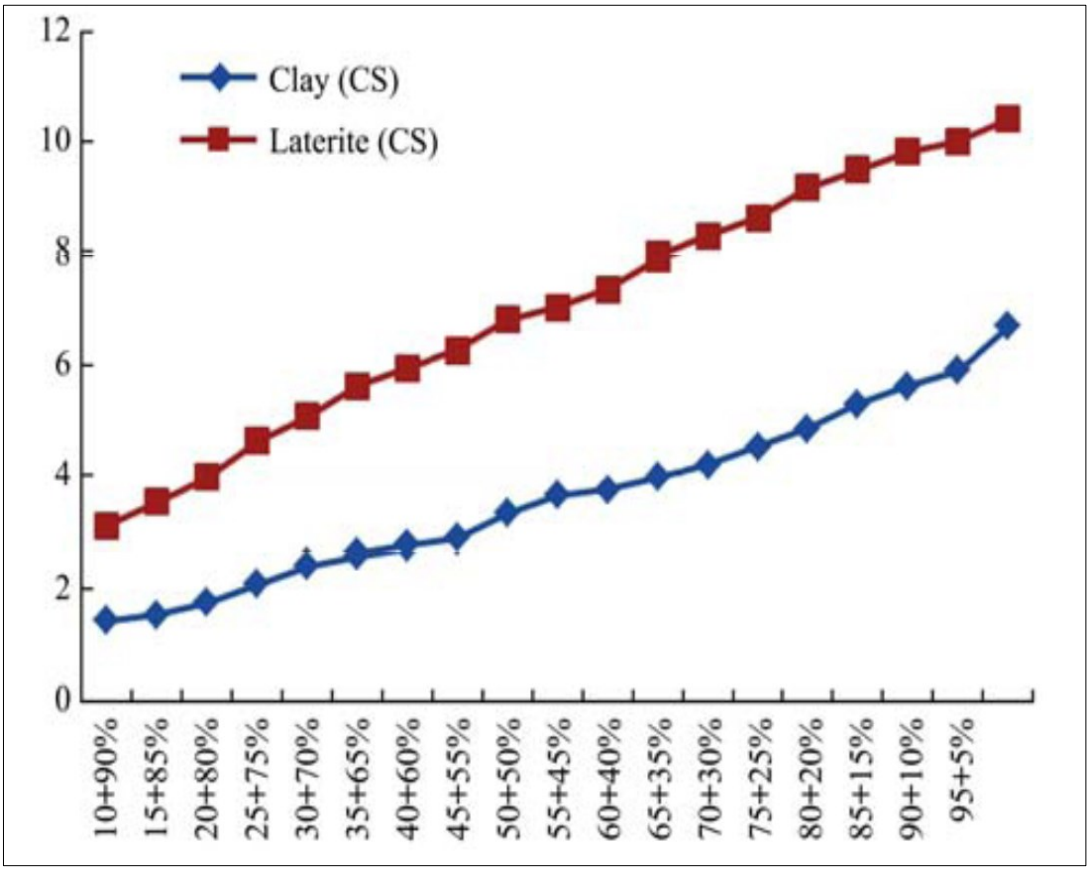

Fig. 3. The relationship between compressive strength of clay and lateritic soils at given termite mound ratios

From Table 2, the values of compressive strength of the termite mound and lateritic soil almost doubled that of termite mound and clayey soil. This may be due to allotropic nature of clay soil, impurity in the clayey soil, difference in composition of clay and lateritic soil and difference in moisture content. Despite all these, different values of for both minimum and maximum for compressive strength and unconfined compressive strength recorded between the mixed ratios and they were not significant different ($P \geq 0.05$).

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]

Conclusions

It can be concluded from the results of this research that:

1. The textural class for the termite mound soil was sandy clay loam whereas that of the lateritic soil was sandy loam.
2. The termite mound soil samples recorded the highest maximum dry density and compressive strength compared to the lateritic and clay soil samples.
3. Increase in the content of termite mound soil ratio in the mix results in significant increase in maximum dry density for both the lateritic and clay soil samples but has little effect on their moisture content.
4. Using termite mound soil as an additive proves to increase the strength of the soil samples.
5. In term of compressive strength and maximum dry density, using termite mound soil as an additive signify much more effective in the lateritic soil than in clay soil in term of compressive strength and maximum dry density.
6. The compressive strength of the lateritic soil was almost twice that of the clay soil at the same mix ratio with termite mound soil.

References

Abe O. E, and Oladapo S. A. 2014. Investigation of the Index Properties of Lateritic Soil Reworked By Termite for Road Construction. International Journal of Engineering Research and Technology (IJERT). 3(4): 1032-1034.

Adam, E. A., and Agib, A. R. A. . 2001. Compressed Stabilized Earth Block Manufactured in Sudan, France, Paris: Graph print for United Nation Education, Scientific and Cultural Organization American Public Health Association (APHA). 2005. Standard Methods for the Examination of Water and Wastewater, 16th and 17th Eds. Washington, DC; American Water Works Association, Water Control Federation.

Adeoye A. S., Ajayi C. A., Okoroafor D. G., (2019) Geotechnical Properties of Termite-Reworked Lateritic Soil from Ibadan, Southwestern Nigeria, International Journal of Engineering Science Invention, Volume 8 Issue 03 Series. IV PP 65-72.

American Public Health Association Standards (APHA, 2005). Standard Methods for the Examination of Water, Wastewater and Soil (21st edition). Washington DC.

American Standards for Test Methods, 2018. Standard Test Methods for Compaction of Soil (ASTM D 698-78). Washington DC.

Anusha R., ArveeSujil J. and Sreedevi C., (2010), "Chemical and Geotechnical Properties of Termite Mounds and Surrounding Soils", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), pp 86-90.

Briges, T. ed. 2007. *Nigeria Highway Code.* Concept Publisher, Lagos, Nigeria.

British Standards Institution (1377). 1998. Methods of test for Soils for civil engineering purposes, England.

King, T. 2006. The value of ant-hill in grassland Bristish wildlife. Journal of Soil Ecology, 17(B): 392–397.

Manuwa, S. I. 2009. Physico-chemical and dynamic properties of termite mound soil relevant in sustainable food production. In 9th African Crop Science, Conference Proceedings, 365-369. Cape Town, South Africa.

Minjinyawa, Y., E. B. Lucas, and F. O. Adegunioye. 2007. Termite mound clay as material for grain silos construction. Agricultural Engineering International, CIGR E-Journal: 43–51.

Madedor, A. O. 1992. The impact of building materials research on low cost housing development in Nigeria. *Engineering Focus*, 4(2): 37–41.

Momah, M., Odokuma-Alonge, O., Andre-Obayanju, O. and Okieimen, F.E. (2018). Geotechnical properties of termite mound soil from Ika area of Delta state, nigeria, Nigerian Research Journal of Engineering and Environmental Sciences 3(1) pp. 428-435.

Okoli, O. G., and Zubairu, I. K. 2002. Preliminary study of properties of compressed building blocks stabilized with Rice Husk Ash. In Proceedings of the Millennium Conference Building in the 21st Century, ed A. T. Lawal, 64–74. Zaria: Building of Department, Ahmadu Bello University.

Olowofoyeku, A., Ofuyatan, O., Bamgboye, G. and Ayobami, B. (2016). Assessment of the geotechnical properties of termite reworked soils. APRN Journal of Engineering and Applied Sciences, 11(17), pp. 10327-10331.

Oshodi, O. R. 2004. Techniques of producing and dry stacking interlocking blocks. In *Nigerian Building and Road Research Institute (N.B.R.R.I) Workshop on Local Building Materials*, 234–238. Ota, Ogun State, Nigeria, 19-20 July.

Yohanna, J. K., U. Fulani, E. D. Azagaku, and A. D. Anda. 2003. Prosect of using anthill materials for the control of seepage in earthdam. *Proceeding of the Nigerian Institution of Agricultural Engineering*, 135–143. 5-6 August.

EDITOR-IN-CHIEF
Prof. Saeid Eslamian [IRAN]