Consistency Characteristics and Behaviors of Palm Kernel Shell Stabilized Black Cotton Soil on Sedimentary Formation of Part of South-Western Nigeria

[1] Akinola Johnson OLAREWAJU and Adeniyi Francis ADEWUNMI

Civil Engineering Department, Faculty of Engineering,
Federal University, Oye, Ekiti State, Nigeria.

E-mail: [1] akinolajolarewaju@gmail.com

Abstract: *The disposal of waste materials is a big problem in the developing country like Nigeria. As a result of lack of land required for disposal technique. The substitution of these waste materials in the form of stabilizing agent in the soil stabilization is a modern approach by which waste materials can be of advantage in civil engineering projects. The idea behind the technique of soil stabilization is that the finer particles of soil are replaced with coarser particles of the waste material so that a composite material is formed having an interlocking ability with better geotechnical properties. The black cotton (expansive) soil was obtained from a borrow pit on the* sedimentary formation *at Idogo in Ogun State, South-Western Nigeria. The borrow site lies within the coordinates 6º 50' 6" N and 2º 58' 42" E. The black cotton soils used in the study were collected from depths between 0.3-1.0m below ground level. The palm kernel shell wastes were taken from palm oil producing plant along Ilaro-Owode Road, Ilaro, Ogun State, Nigeria. The quantity of water which was used to obtain optimum moisture content and maximum dry density for black cotton soil (i. e. control, 0%) was determined. This water was then used to run consistency tests. The palm kernel shells were broken into pieces passing through 5mm sieve and then substituted for black cotton soil from 0% to 30% at 10% intervals while 0% palm kernel shell substitution served as control experiment. In line with BS 1377 (1990) and other relevant codes, consistency tests were conducted on the composite materials of black cotton on sedimentary formation mixed varying degrees of palm kernel shells for the determination of liquid limit, plastic limit, etc. The observed or measured parameters reduce as the palm kernel shell substitutions increases. It is evidently clear from the results that the percentage shrinkage limit became constant at 30% palm kernel shell substitution in black cotton soil on sedimentary formation which is an indication of constancy of volume.*

Keywords: *Expansive Soil, Consistency, Sedimentary Formation, Palm Kernel Shell.*

Introduction

Palm kernel shells are derived from the oil palm tree, an economically valuable tree, which is native to western Africa and widespread throughout the tropics Omange (2001). These trees are used in commercial agriculture in the production of palm oil. The African oil palm is native to West Africa, occurring between Gambia and Angola. The basic name is derived from the Greek word for oil, elaion, while the species name has referred to its country of origin. In Nigeria, about 1.5 million tons of PKS are produced annually; most of which are often dumped as waste products (Nuhu-Koko, 1990). The waste could be converted to wealth by using it as a stabilizer in black cotton soil due to the peculiar problems of swelling and shrinkage of the soil. Since few years ago, the use of local materials in the construction industry has been campaigned to limit costs of construction. There have been several calls for the sourcing and development of alternative to the conventional stabilizing agents and non-conventional local construction materials in view to harness the maximum potential of agricultural waste in agricultural sector. As a result of the hazardous and threat to safety on super structures constructed on black cotton soil, due to its poor characteristics and the economic cost of transporting suitable sub-grade material for the construction work, the addition of palm kernel shell as an agent for the stabilization of the black cotton soil becomes a necessity to arrest the potential threat. The disposal of waste materials is a big problem in the developing country like Nigeria. As a result of lack of land required for disposal technique. The substitution of these waste materials in the form of stabilizing agent in the soil stabilization is a modern approach by which waste materials can be of advantage in civil engineering projects. The idea behind the technique of soil stabilization is that the finer particles of soil are replaced with coarser particles of the waste material so that a composite material is formed having an interlocking ability with better geotechnical properties BS1377, 1990; Chen, 1975; Craig, 1987; Jones and Hockey, 1964; Joseph, 1981; Kotresh and Sharanakumar, 2019; Madurwar, et al.. 2013; Nelson and.Miller, 1992; Nuhu-Koko, 1990; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).

Background Study

The black cotton soil most especially on sedimentary formation is a highly plastic clayey soil having a swelling and shrinkage nature and is proved to be very problematic for construction. The soils contain clay mineral which causes the swelling and shrinkage nature in the soil, due to water bond between the particles of the soil. The method of stabilization is chosen in such a way that, the stabilizing material is more economical and easy to process with black cotton soil (Kotresh and Sharanakumar (2019). Although black cotton soils tend to be strong in its dry state, when in a wet condition, it tends to lose its strength out rightly. The low strength and excessive volume changes of black cotton soil make their use in constructions very difficult. Black cotton soil is clay-rich soil that mainly contains lime, iron, carbonate, magnesium, and a small amount of organic matter along with nitrogen, phosphorous, etc. in small quantities. It has a low bearing capacity, high moisture-absorbing power, low shear strength and high plasticity value. Thus, it needs an additional technique for its stability in advance before one could start any project work over it. In the case of sedimentary formation in question where black cotton soil is found (Jones and Hockey, 1964), Ilaro formation is a typical example of a sedimentary formation which includes both marine and continental deposits. Idogo black cotton soil belongs to Ilaro sedimentary formation. At the time of the deposition of the basal beds, the Eocene shore lay only a short distance to the north of the existing outcrop of the formation and, with the regression of the sea southwards, the marine environment soon gave place to eatuarine and deltaic conditions .Thus within the formation there is a transition from marine to continental sedimentation from south to north and from the lower beds to the higher. Over most of the outcrop, the formation is continental in character and lateral changes in thickness and lithology are rapid and confusing .The type locality of the arenaceous and predominantly continental facies is the Akisinde - Ifo junction area (BS1377, 1990; Chen, 1975; Craig, 1987; Jones and Hockey, 1964; Joseph, 1981; Kotresh and Sharanakumar, 2019; Madurwar, et al.. 2013; Nelson and.Miller, 1992; Nuhu-Koko, 1990; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).

Methodology

The black cotton (expansive) soil (Figure 1a) was obtained from a borrow pit on the sedimentary formation at Idogo in Ogun State, South-Western Nigeria. The borrow site lies within the coordinates 6º 50' 6" N and 2º 58' 42" E. The black cotton soils used in the study were collected from depths between 0.3-1.0m below ground level. The palm kernel shell wastes were taken from palm oil producing plant (Figure 1d) along Ilaro-Owode Road, Ilaro, Ogun State, Nigeria. The quantity of water which was used to obtain optimum moisture content and maximum dry density for black cotton soil (i. e. control, 0%) was determined. This water was then used to run consistency tests. The palm kernel shells were broken into pieces (Figure 1d) passing through 5mm sieve and then substituted for black cotton soil from 0% to 30% at 10% intervals while 0% palm kernel shell substitution served as control experiment. In line with BS 1377 (1990) and other relevant codes, consistency tests were conducted on the composite materials of black cotton on sedimentary formation mixed varying degrees of palm kernel shell for the determination of liquid limit, plastic limit, etc (Joseph, 1981; Ola, (1983); Craig, 1987; BS 1377, 1990; Olarewaju and Tella, 2022; Olarewaju and Oloruko-Oba, 2022; Olarewaju and Falola, 2022).

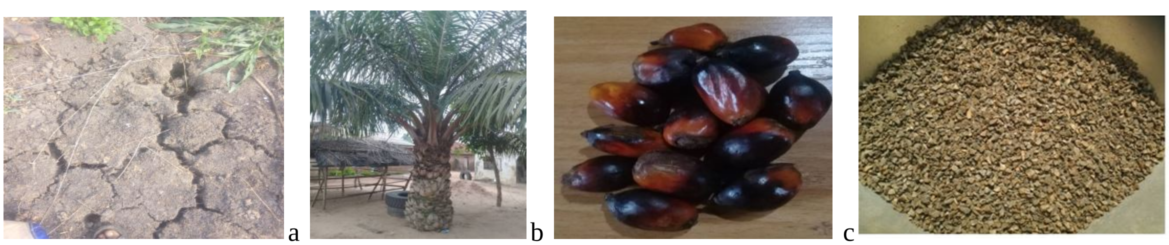

Figure 1: (a) Black Cotton (Expansive) Soil (b) Palm Tree (c) Palm Fruits (d) Palm Kernel Shell

Results and Discussion

The results of consistency tests (liquid limit, plastic limit, shrinkage limit, etc. for various substitutions of palm kernel shell in black cotton soil on sedimentary formation from 0% to 30% substitution with 0% serving as control experiment are presented in tabular forms in Tables 1 to 5 respectively. Less emphasis is laid on 5% palm kernel shell substitution.

Table 1: Results of Consistency Test on 0% Replacement of Palm Kernel Shell in Black Cotton Soil (Control) on Sedimentary Formation

Liquid Limit Determination				
Moisture can no	IDO 1	IDO 2	IDO 3	IDO 4

Percentage moisture content %	45	42.8	39	35.6
No of blows	13	20	32	43

Plastic Limit Determination

Plastic Limit Determination

Moisture can no	IDO 5	IDO 6
Percentage moisture content %	29.8	27.4

Percentage Shrinkage Limit Determination

Length of Wet soil (cm)	14.2
Length of Dry soil (cm)	12.5

Table 2: Results of Consistency Test on 5% Replacement of Palm Kernel Shell in Black Cotton Soil on Sedimentary Formation

Liquid Limit Determination

Moisture can no	IDO 7	IDO 8	IDO 9	IDO 10
Percentage moisture content %	42.4	40.4	37.4	33.8
No of blows	13	21	33	47

Plastic Limit Determination

Moisture can no	IDO 11	IDO 12
Percentage moisture content %	27.2	25.4

Percentage Shrinkage Limit Determination

Length of Wet soil (cm)	14.2
Length of Dry soil (cm)	12.2

Table 3: Results of Consistency Test on 10% Replacement of Palm Kernel Shell in Black Cotton Soil on Sedimentary Formation

Liquid Limit Determination

Moisture can no	IDO 13	IDO 14	IDO 15	IDO 16
Percentage moisture content %	39.6	38	36.4	35.2
No of blows	11	22	33	42

Plastic Limit Determination		
Moisture can no	IDO 17	IDO 18
Percentage moisture content %	26.7	24.1

Percentage Shrinkage Limit Determination	
Length of Wet soil (cm)	14.2
Length of Dry soil (cm)	12.3

Table 4: Results of Consistency Test on 20% Replacement of Palm Kernel Shell in Black Cotton Soil on Sedimentary Formation

Liquid Limit Determination				
Moisture can no	IDO 19	IDO 20	IDO 21	IDO 22
Percentage moisture content %	35.6	33.8	31.8	30.4
No of blows	13	23	34	42

Plastic Limit Determination		
Moisture can no	IDO 23	IDO 24
Percentage moisture content %	24.6	23

Percentage Shrinkage Limit Determination	
Length of Wet soil (cm)	14.2
Length of Dry soil (cm)	12.5

Table 5: Results of Consistency Test on 30% Replacement of Palm Kernel Shell in Black Cotton Soil on Sedimentary Formation

Liquid Limit Determination				
Moisture can no	IDO 25	IDO 26	IDO 27	IDO 28
Percentage moisture content %	33.2	32	31	30.2
No of blows	12	22	31	38

Plastic Limit Determination		
Moisture can no	IDO 29	IDO 30
Percentage moisture content %	22.9	20.1

Percentage Shrinkage Limit Determination	
Length of Wet soil (cm)	14.2
Length of Dry soil (cm)	13.2

From the results shown in Table 1, the percentage moisture content varies from 45 to 35.6% in descending order while the corresponding number of blows varies from 13 to 43. The percentage moisture content for plastic limit determination varies from 29.8 to 27.4% in descending order and shrinkage limit is 1.7cm. In addition to this, from the results shown in Table 3, the percentage moisture content varies from 39.6 to 35.2% in descending order while the corresponding number of blows varies from 11 to 42. The percentage moisture content for plastic limit determination varies from 26.7 to 24.1% in descending order and shrinkage limit is 1.9cm. Furthermore, from the results shown in Table 4, the percentage moisture content varies from 35.6 to 30.4% in descending order while the corresponding number of blows varies from 13 to 42. The percentage moisture content for plastic limit determination varies from 24.6 to 23% in descending order and shrinkage limit is 1.7cm. Finally, from the results shown in Table 5, the percentage moisture content varies from 33.2 to 30.2% in descending order while the corresponding number of blows varies from 12 to 38. The percentage moisture content for plastic limit determination varies from 22.9 to 20.1% in descending order and shrinkage limit is 1.0cm. It is evidently clear from the results that the percentage shrinkage limit became constant at 30% palm kernel shell substitution in black cotton soil on sedimentary formation which is an indication of constancy of volume. This is an indication that the optimum percentage substitution of palm kernel shell in black cotton soil on sedimentary formation is 30%. Although observed or measured parameters reduces as the palm kernel shell substitutions increases, these results, in terms of reduction, are similar to that of eggshell powder substitutions in black cotton soil on basement complex in the work of Olarewaju and Olarewaju (2022). In geo-mechanics/soil mechanics, cohesion limit is that moisture content at which soil crumbs, just stick together while sticky limit is that moisture content at which soil just stick to a metal surface such as a spatula blade. In addition to this, a shrinkage limit is the moisture content below which the soil is non-plastic. Furthermore, liquid limit is that moisture content below which the soil behaves as a plastic material, at this moisture content, the soil in on the verge of becoming a viscous fluid. The liquid limit is sometime used to estimate settlement in consolidation problems BS1377, 1990; Chen, 1975; Craig, 1987; Jones and Hockey, 1964; Joseph, 1981; Kotresh and Sharanakumar, 2019; Madurwar, et al.. 2013; Nelson and.Miller, 1992; Nuhu-Koko, 1990; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).

Conclusion

Consistency characteristics and behaviors of stabilized black cotton soil on sedimentary formation have been investigated. From the results, it is evidently clear from the results that the percentage shrinkage limit became constant at 30% palm kernel shell substitution in black cotton soil on sedimentary formation which is an indication of constancy of volume similar to that of Olarewaju and Olarewaju (2022). This is an indication that the optimum percentage substitution of palm kernel shell in black cotton soil on sedimentary formation is 30% beyond which no further changes will occur.

Acknowledgement

The author acknowledges the contributions of OLOEOKO-OBA Abdulwaheed, BAMISAYE Ayodele, OGUNJIMI Wale, ADEBESIN Ayodeji, and FALOLA Ebenezer as well as Aro, M. O. for technical assistance in the Geotechnical and Material Laboratories of the Federal Polytechnic Ilaro, Ogun State, Nigeria. Special thanks to Teejay O. Allinson Nigeria Enterprises, Ikate, Surulere, Lagos with palm kernel oil factory located at Olorunsomo, Sabo, Ilaro, Ogun State, Nigeria.

References

BS1377, (1990): Methods of Testing Soil for Civil Engineering Purposes. British Standards Institute, London

Chen.F.H (1975): Foundations on Expansive Soils, Elsevier Scientific Pub. Co. Amsterdam.

Craig, R. F (1987): "Soil Mechanics", Spon Press, Philadephia USA 4th edition.

Jones, H. A. and Hockey, R. D. (1964): The Geology of Part South-Western Nigeria, Ministry ofMines and Power, Geological Survey of Nigeria, Bulletin No. 31,

Joseph E. Bowles, (1981): Engineering Properties of Soil and Their Measurement, 2nd edition, International Student Edition, McGraw-Hill, Inc., London.

Kotresh, M.Y. and Sharanakumar (2019) Strengthening of black cotton soil using egg shell powder and coconut shell powder .

Madurwar, K.V. Dahale, P. P. and Burile, A.N. (2013):Comparative Study of Black Cotton Soil Stabilization with RBI Grade 81 and Sodium Silicate International Journal of Innovative Research in Science, Engineering and Technology.

Nelson, D and D.J.Miller, D. J. (1992): Expansive Soils: Problems and Practices in Foundation and Engineering. New York: John Wiley, 259.

Nuhu-Koko M. K. (1990): The use of Palm kernel shells as aggregates for concrete, Paper presented at 21st Annual Conference of Materials Testing, Control and Research, Federal Ministry of Works, Lagos, Nigeria,

Okeke, O.C. Iwuoha, P.O. Eberendu, C.J., Omoko, E.N. Amadi, C.C. and Nwachukwu, H.G.O. (2020): Consolidation Characteristics of Expansive Soils from Parts of Anambra Basin, Southeastern Nigeria.

Olarewaju, A. J. and Bamisaye, A. S..(2022): Pressure Load Characteristics of Unsaturated Eggshell Powder Stabilized Black Cotton Soil on Basement Complex of Part of South-Western Nigeria, International Journal of Advanced Geotechnic and Impact Engineering (IJAGIE), ISSN (Online): 2545-5559, July, pp 33 – 40

Olarewaju, A. J. and Olarewaju, O. S. (2022): Consistency Behaviors of Eggshell PowdervStabilized Black Cotton Soil on Sedimentary Formation of Part of South-Western Nigeria, International Journal of Advanced Geotechnic and Impact Engineering (IJAGIE), ISSN (Online): 2545-5559, July, pp 48 – 54.

Olarewaju, A. J. and Oloruko-Oba, A. A. (2022): "Compression and Expansion Characteristics of Palm Kernel Shell Stabilized Black Cotton Soil on Basement Complex of Part of South-Western Nigeria", International Journal of Advanced Geotechnic and Impact Engineering (IJAGIE), ISSN (Online): 2545-5559, July, pp 15 – 23

Olarewaju, A. J. and Falola, E. O. (2022): "Pressure Load Characteristics of Unsaturated Palm Kernel Shell Stabilized Black Cotton Soil on Basement Complex of Part of South-Western Nigeria", International Journal of Advanced Geotechnic and Impact Engineering (IJAGIE), ISSN (Online): 2545-5559, July, pp 7 - 14

Omange, G.N . (2001): Palm Kernel Shells as Road Building Materials, Technical Transactions of the Nigerian Society of Engineers.

Radhey, S.S. (1998) Mechanical Bahaviour of Unsaturated Highly Expansive Clays.

Rahaman. M.A, Ocan. O (1978): On relationships in the Precambrian Migmatite-gneisses of Nigeria. Niger J. Min Geology 15:23 32