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

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Abstract: *Expansive soils tend to be strong in its dry state but when in a wet condition, it tends to lose its strength. The low strength and excessive volume changes of black cotton soil make their use in constructions very difficult. The properties of the black cotton soil may be altered in many ways through mechanical, chemical and other means. Therefore, it becomes very important to investigate the physical and engineering properties associated with the black cotton soil especially as a construction material. The black cotton (expansive) soil was obtained from a borrow pit on the basement complex at Igbo-Ora in Oyo State, South-Western Nigeria. The borrow site lies within the coordinates Longitude 7⁰24'45" and latitude 3⁰18'34". 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 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 basement complex mixed varying degrees of palm kernel shells, for the determination of liquid limit, plastic limit, etc. From the results, shrinkage limit reduced from 2.0cm for 0% substitution to 1.5cm for 30% substitution of palm kernel shell substitution in black cotton soil on basement complex. The percentage shrinkage limit became constant at 30% palm kernel shell substitution which is an indication that the optimum percentage substitution of palm kernel shell in black cotton soil on basement complex is 30%.*

Keywords: *Expansive Soil, Consistency, Basement Complex, Palm Kernel Shell*

Introduction

The idea behind the technique of soil stabilization is that the finer particles of soil are replaced with coarse particles of the waste material so that a composite material is formed having an interlocking ability with better geotechnical properties. Montomoronalite, a clay mineral, is less stable; as a result of this the soil exhibits dramatic nature in an extreme manner from very hard to very soft when saturated. The method of stabilization to be adopted should be chosen in such a way that, the stabilizing material is more economical, easily available, nature friendly 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. The low strength and excessive volume changes of black cotton soil make their use in constructions very difficult. The properties of the black cotton soil may be altered in many ways through mechanical, chemical and other means. Therefore, it becomes very important to investigate the physical and engineering properties associated with the black cotton soil especially as a construction material. The basic property of the soil should be good strength and load bearing capacity so that external loads can be transferred safely and effectively to the layers below without encountering any structural failure. It is therefore important to enhance the desired properties of those soils (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; Okeke, et al. 2020; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).

Background Study

In Nigeria, about 1.5 million tons of palm kernel shells are produced annually; most of which are often dumped as waste products (Nuhu-Koko, 1990). The waste could be converted to construction materials by using it as a stabilizer in soil due to the peculiar problems of swelling and shrinkage. The use of local materials in the construction industry has been advocated by stakeholders in the construction industry to limit costs of construction. There have been several calls for the sourcing and development of alternative stabilizing agents from agro-based and non-conventional local construction materials with a view to harnessing the maximum potential of agricultural waste. 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 admixture for the stabilization of the black cotton soil becomes a necessity to arrest the potential threat (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; Okeke, et al. 2020; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978)..

The Igbo - Ora (basement) complex forms the largest body of biotitic older granite and provides the best examples of the rock - types comprising this group and their mutual relationships, covering a total area of over 207.2 sq. km the complex is elongated being about 48.3 km long and 9.7 km across at its widest point (Jones and Hockey, 1964). Within these confines, however, its configuration is complicated because it comprises a number of smaller bodies of irregular shape. The irregularity is more pronounced on the eastern side of the complex where, there is a greater complexity of rock type and, in particular a higher proportion of early phase rocks. Main phase porphyritic granites occupy a large part of the total area and can be subdivided in the field into three textural variants, each typified by a distinct size and shape of felsparphenocryst .The smallest feldspar-phenocryst, however, forms part of the two coarser porphyritic granites and , although there are bodies of granite typified by the development of this felspar. The two textural variants considered are coarse granite typified by felsparphenocrysts varying in greatest length from 38.1 mm to 63.5 mm and granite in which the largest feldspars are no more than 31.75 mm long (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; Okeke, et al. 2020; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).. The form of the felsparphenocrysts tends to be slightly different in each variety; while the smaller usually attains a more distinct lath shape. The larger - feldspar granite forms most of the complex and gives rise to the more striking topographical features, particularly between Tapa and south of the latitude of Igbo - Ora, while the small - feldspar granite occurs throughout the complex but, in general, tends to be marginal to the large - feldspar granite, particularly on the west side of the main granite body. It is assumed to underlie a wide area on the east side of the main body at about the latitude of Igbo - Ora although outcrops are not numerous (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; Okeke, et al. 2020; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).

Methodology

The black cotton (expansive) soil (Figure 1a) was obtained from a borrow pit on the basement complex at Igbo-Ora in Oyo State, South-Western Nigeria. The borrow site lies within the coordinates Longitude 7º24'45" and latitude 3º18'34". 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 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 basement complex 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).

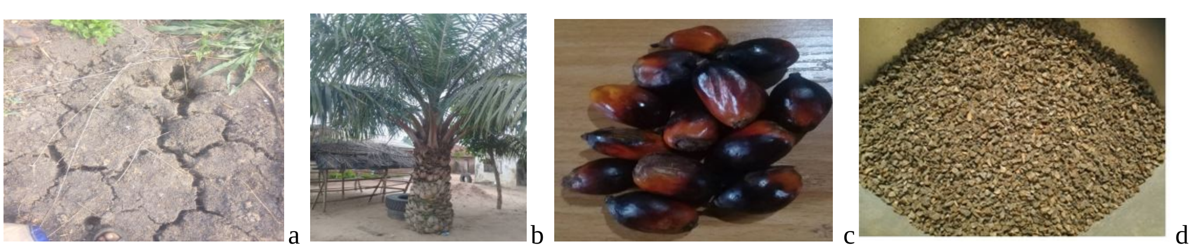

Figure 1: (a) Black Cotton (Expansive) Soil (b) Palm Tree (c) Palm Fruits (d) Palm Kernel Shell

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 basement complex 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 Basement Complex

Liquid Limit Determination

Moisture can no	ORA 1	ORA 2	ORA 3	ORA 4
Percentage moisture content %	45.8	43.8	40.4	37.6
No of blows	16	23	30	46

Plastic Limit Determination

Plastic Limit Determination

Moisture can no	ORA 5	ORA 6
Percentage moisture content %	32.5	30.3

Percentage Shrinkage Limit Determination

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

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

Liquid Limit Determination

Moisture can no	ORA 7	ORA 8	ORA 9	ORA 10
Percentage moisture content %	42.8	41.2	37.4	35.8
No of blows	14	22	40	48

Plastic Limit Determination

Moisture can no	ORA 11	ORA 12
Percentage moisture content %	29.6	28.2

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 Basement Complex

Liquid Limit Determination

Moisture can no	ORA 13	ORA 14	ORA 15	ORA 16
Percentage moisture content %	39.2	38	36.4	35

No of blows	15	21	30	37
Plastic Limit Determination				
Moisture can no			ORA 17	ORA 18
Percentage moisture content %			26.8	24.6
Percentage Shrinkage Limit Determination				
Length of Wet soil (cm)		14.2		
Length of Dry soil (cm)		12.2		

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

Liquid Limit Determination				
Moisture can no	ORA 19	ORA 20	ORA 21	ORA 22
Percentage moisture content %	34.4	33.4	31.4	30.2
No of blows	16	21	30	36
Plastic Limit Determination				
Moisture can no			ORA 23	ORA 24
Percentage moisture content %			23.9	22.3
Percentage Shrinkage Limit Determination				
Length of Wet soil (cm)			14.2	
Length of Dry soil (cm)			12.3	

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

Liquid Limit Determination				
Moisture can no	ORA 25	ORA 26	ORA 27	ORA 28
Percentage moisture content %	33	31.2	29.8	28.2
No of blows	13	22	29	36
Plastic Limit Determination				
Moisture can no			ORA 29	ORA 30

Percentage moisture content %	22.9	21.7
Percentage Shrinkage Limit Determination		
Length of Wet soil (cm)	14.2	
Length of Dry soil (cm)	12.7	

From the results shown in Table 1, the percentage moisture content varies from 45.8 to 37.6% in descending order while the corresponding number of blows varies from 16 to 46. The percentage moisture content for plastic limit determination varies from 32.5 to 30.3% in descending order and shrinkage limit is 2.0cm. In addition to this, from the results shown in Table 3, the percentage moisture content varies from 39.2 to 35% in descending order while the corresponding number of blows varies from 15 to 37. The percentage moisture content for plastic limit determination varies from 26.8 to 24.6% in descending order and shrinkage limit is 2.0cm. Furthermore, from the results shown in Table 4, the percentage moisture content varies from 34.4 to 30.2% in descending order while the corresponding number of blows varies from 16 to 36. The percentage moisture content for plastic limit determination varies from 23.9 to 22.3% in descending order and shrinkage limit is 1.9cm. Finally, from the results shown in Table 5, the percentage moisture content varies from 33 to 28.2% in descending order while the corresponding number of blows varies from 13 to 36. The percentage moisture content for plastic limit determination varies from 22.9 to 21.7% in descending order and shrinkage limit is 1.5cm. Shrinkage limit reduced from 2.0cm for 0% substitution to 1.5cm for 30% substitution of palm kernel shell in black cotton soil on basement complex. 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 basement complex which is an indication of constancy of volume. This shows that the optimum percentage substitution of palm kernel shell in black cotton soil on basement complex 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 and palm kernel substitutions in black cotton soil on both sedimentary formation and basement complex in the work of Olarewaju and Olarewaju (2022) and Olarewaju and Adewunmi (2022). Shrinkage limit in geomecanics is the moisture content below which the soil is non-plastic while 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 and as a result, efforts are still ongoing to determine the consolidation parameters and settlement indices of stabilized black cotton soil on basement complex (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; Okeke, et al. 2020; Omange, 2001; Radhey, 1998); Rahaman ad Ocan, 1978).

Conclusion

Consistency characteristics and behaviors of stabilized black cotton soil on basement complex have been investigated. From the results, the percentage shrinkage limit reduced as the substitution increases and became constant at 30% palm kernel shell substitution in black cotton soil on basement complex similar to the results of Olarewaju and Olarewaju (2022) and Olarewaju and Adewunmi (2022). This shows that the optimum percentage substitution of palm kernel shell in black cotton soil on sedimentary formation as well as basement complex is 30% beyond which no further changes will occur.

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