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Geotechnical Investigation of Palm Kernel Shell Stabilized Black Cotton Soils on the Basement Complex in South-Western Nigeria.

Olarewaju A. J. and Oloruko-Oba A. A.

Department of Civil Engineering, The Federal Polytechnic, Ilaro, P.M.B 50, Ogun State, Nigeria.
akinola.olarewaju@federalpolyilaro.edu.ng abdulwaheed.oloruko-oba@federalpolyilaro.edu.ng

ABSTRACT

One type of soil where the volume changes as it comes into contact with water is an expansive soil. Due to water intake during the rainy season, it heaves, and during the dry season, it contracts. This phenomenon is a threat to lives and properties. Consequently, it becomes crucial to look at the engineering and physical characteristics of black cotton soil, particularly when using it as a foundation or as a building material. A borrow pit on the basement complex at Igbo-Ora in Oyo State, South-Western Nigeria, provided the black cotton (expansive) soil. The location of the borrow site is located at longitude 14°44'26" and latitude 23°13'41". The black cotton soils were gathered from 0.3 to 1.0 meters below ground. palm kernel shells waste were collected from the palm oil-producing facility, located on the Ilaro-Owode Road , Ilaro, Ogun State, Nigeria. The palm kernel shells were split up and pass through 5 mm sieve. They were then substituted for black cotton soil in increments of 0% to 30% at 10% intervals, with 0% serving as the control experiment. To ensure the compression and expansion properties for 24-hoursoaked samples, 90% consolidation tests were carried out on composite materials consisting of black cotton soil combined with different percentages of palm kernel shells, in accordance with BS 1377 (1990). The findings show that, for all substitutes examined, the compression behavior is linear, or directly proportional to time; nevertheless, for the first 30 seconds, there is no discernible and noteworthy reduction during expansion when removing the load. For every substitute examined, the expansion's rate and size are negligible. This indicates that waste palm kernel shell can be used as a less expensive substitute to costly lime and cement in stabilization. This might be a wise way to apply policy for the advancement of TVET.

Keywords: *Stabilization, Black cotton Soil, Palm Kernel Shells.*

1.0 INTRODUCTION

Black cotton soil is referred to as expansive soils; it is characterized by cracks in dry season and heavens in rainy season for this reason, its geotechnical properties are important to be examined before to authorizing any building over it. The mineralogy of this soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa (Ola, 1983). High percentage of montomorillonite in black cotton soil renders the soil poor for civil engineering project. The shrinking of the soil results in cracks in the soil without any warning. These cracks can sometimes extent to severe limit. Use of soil that contains montomorillonite for civil engineering project may cause severe damage to the construction as a result of change in atmospheric conditions (Mittal, 2001). The semi-arid and dry regions that have black cotton soils are naturally defined by periods of notable parchedness and truncated rain, without any drainage as well as high afternoon temperatures. In this region the climatic condition is such that the annual evaporation exceeds the precipitations. The solution to black cotton soil shrinkage and swelling is soil stabilization, which can be achieved mechanically or chemically. This improves the soil material and gives it the necessary technical properties. According to Rajakumar (2014). Stabilization is necessary to make black cotton soil more resilient and strong. The establishment of a soil material or soil system that will endure under the intended usage conditions for the duration of the civil engineering project is the desired outcome, regardless of the reason for stabilization. Soil stabilization is a common technique used to alter a soil's geotechnical characteristics in order to enhance its engineering qualities and boost its strength, both of which lower the cost of building civil engineering projects. Subgrade material made of black cotton soils is extremely poor and unreliable (Ola, 1983). Palm kernel shells (PKS) are made from the oil palm tree (elaeisguineensis), a native of western Africa and a widely distributed economically useful tree in the tropics. These trees are utilized to produce palm oil in commercial agriculture. Native to West Africa, the African oil palm grows between the Gambia and Angola. The species name refers to the country of origin, while the basic name is taken from the Greek word for oil, elaion (Sulyman, 1990; Ola, 1983). Nuhu-Koko (1990) states that around 1.5 million tons of PKS are produced in Nigeria each year, the majority of which are frequently disposed of as garbage. The expansive soil was stabilized with the use of cement, lime, etc. Due to the unique issues of soil shrinkage and swelling in black cotton soil, agricultural waste has recently been able to be turned into wealth by acting as a stabilizer in the soil. The various governments have been pushing for the usage of local materials in the construction industry since a few years ago in an effort to keep construction costs down. To maximize the potential of agricultural waste in the agricultural sector, there have been multiple requests for the development of non-conventional, agro-based, and alternative to lime and cement for stabilization in construction industries. (Omange, 2001) .

2.0 OBJECTIVES

The objectives of this research is to improve the engineering qualities of the black cotton soil by using palm kernel shells as an additive, an agricultural waste product. This presents another way to look at it: as a chance to employ our numerous young people and turn agricultural wastes into wealth.

3.0 MATERIAL AND METHOD

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 location of the borrow site is in latitude 23°13'41" and longitude 14°44'26". The study's black cotton soil samples were taken from 0.3 to 1.0 meters below ground. The wastes from the palm kernel shells (Figures 1b, c, and d) were removed from the palm oil production facility located along the Ilaro-Owode Road in Ilaro, Ogun State, Nigeria. For black cotton soil (i.e., control, 0%), the amount of water required to achieve the ideal moisture content and maximum dry density was calculated for black cotton soil (i.e control 0%). While, test for consolidation were conducted using this water. The palm kernel shells (Figure 1 d) were broken into pieces passing through 5mm sieve and then substituted for black cotton soil from 0% to 30% at 10% intervals for consolidation and settlement parameters determination while 0% palm kernel shell substitution served as control experiment. 90% consolidation experiments were carried out on composite materials consisting of black cotton soil combined with different amounts of palm kernel shells in accordance with BS 1377 (1990) and other relevant best practices to determine the compression and expansion properties of the samples that were soaked for 24 hours. (Maail et al., 2004; Ola, 1983; Head and Epps (2011); Head (2006); Indrawan et al. (2006); Hincke et al. (2012); Croft et al., 1999; Amu and Salami (2010); Amu et al. (2005); Gopal and Rao (2000); Craig (1987); Modi (2010) Fattah, Y.M. (2012); Sivakugan (1990); Skempton (1944); Terzaghi and Peck (1967); Wallace and Otto (1964); Wroth and Wood (1978).

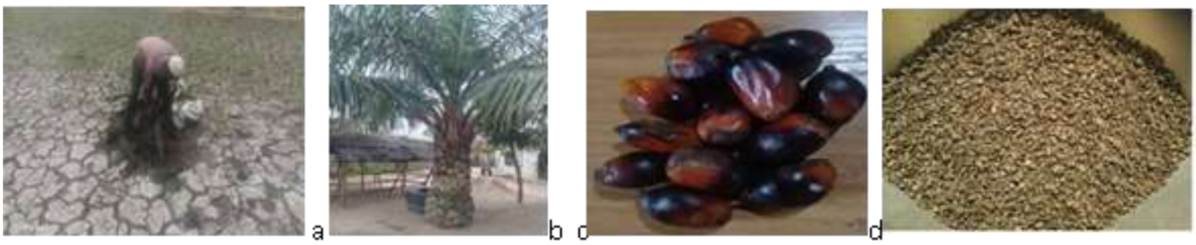

Figure 1: (a) Black Cotton (Expansive) Soil (b) Palm Tree (c) Palm Fruits (d) Palm Kernel Shell

An experimental program that includes specimen preparation, equipment and procedure testing, and a predetermined optimal moisture content. Based on the results of a consolidation test performed on five (5) levels of stabilized black cotton soil with palm kernel shell for 10%, 20% ,30% and natural soil at 0% stabilization.

4.0 RESULTS

The results of consolidation parameters and settlement potentials for the saturated and unsaturated samples of various palm kernel shell substitutions ranging from 0% to 30% at 10% intervals are presented in Tables 1 to10 respectively. Palm kernel shell substitutions of 0% to 10% is considered to be low dosage substitutions while 20% to 30% substitutions are considered to be high dosage substitutions with 0% serving as control experiment for the two considerations.

Table 1: Consolidation parameters for the unsaturated sample (control, 0% palm kernel shell substitution) .

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0.678	0.712	4.761x10^-5
100-200	0	0	0
200-400	0	0	0
400 -800	-0.4546	-2.654	-3.78x10^-9
800 -1600	0.532	3.782	1.31x10^-9
1600-3200	0.3658	4.765	1.23x10^-9

Table 2: Consolidation parameters for the saturated sample (control, 0% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0.0156	0.03	1.1x10^-10
100-200	0.0275	0.052	1.86x10^-10
200-400	0.0306	0.12	2.1x10^-10
400 -800	0.0356	0.27	2.4x10^-10
800 -1600	0.0238	0.36	1.61x10^-10
1600-3200	0.016	0.49	1.08x10^-10

Table 3: Consolidation parameters for the unsaturated sample (10% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0	0	0
100-200	0.4358	0.5649	6.761x10^-11
200-400	0.7643	1.9764	5.875x10^-11
400 -800	0.9543	3,5687	3.018x10^-10
800 -1600	1.7658	4.765	2.317x10^-10
1600-3200	1.9876	6.9801	4.781x10^-10

Table 4: Consolidation parameters for the saturated sample (10% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0.192	0.36	3.13x10^-10
100-200	0.105	0.199	1.71x10^-10
200-400	0.0071	0.027	1.15x10^-11
400 -800	0.0177	0.13	2.88x10^-11
800 -1600	0.039	0.59	6.35x10^-11
1600-3200	0.024	0.73	3.91x10^-11

Table 5: Consolidation parameters for the unsaturated sample (20% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	-0.546	-0.765	-4.198x10^-10
100-200	-0.675	-0.975	-5.987x10^-10

200-400	0.567	0.765	9.145x10^-11
400 -800	0.754	0.865	7.198x10^-11
800 -1600	0.876	1.896	7.156x10^-10
1600-3200	0.654	1.754	9.174x10^-10

Table 6: Consolidation parameters for the saturated sample (20% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0.168	0.32	1.12x10^-10
100-200	0.166	0.316	1.11x10^-10
200-400	0.087	0.33	5.8x10^-11
400 -800	0.050	0.38	3.34x10^-11
800 -1600	0.034	0,52	2.271x10^-11
1600-3200	0.024	0.72	1.6x10^-11

Table 7: Consolidation parameters for the unsaturated sample (30% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0.9751	2.90	5.871x10^-9
100-200	0.9121	3.652	6.231x10^-9
200-400	0.5673	3.975	3.991x10^-9
400 -800	0.5642	5.871	2.891x10^-10
800 -1600	0.3873	7.543	7.165x10^-10
1600-3200	0.1234	8.976	8.134x10^-10

Table 8: Consolidation parameters for the saturated sample (30% palm kernel shell substitution)

PRESSURE (p) (KN/M^2)	VOLUME COMPRESSIBILTY (MV) (M^2/MN)	OEDOMETER SETTLEMENT (MM)	COEFFICIENT OF PERMEABILITY (M/S)
0 -100	0.105	0.198	4.43x10^-11
100-200	0.155	0.295	6.54x10^-11
200-400	0.086	0.327	3.63x10^-11
400 -800	0.057	0.436	2.4x10^-11
800 -1600	0.044	0.67	1.86x10^-11
1600-3200	0.0188	0.57	7.93x10^-12

5.0 DISCUSSION OF FINDINGS

Specific gravity can vary in a composite material, such as black cotton soil that has been blended with variable amounts of palm kernel shell; 1997). As long as the coefficient of volume compressibility remains constant, the coefficient of permeability and the coefficient of consolidation are directly related. The rate at which the coefficient of consolidation increases is directly proportional to an increase in the coefficient of permeability. The rate at which water seeps out of a saturated sample under continuous, steady pressure is determined by measuring the permeability of the soil sample using an odometer. The greater moisture content prior to loading is the cause of the rise in oedometer settlement. (Olarewaju ,2022). The sample heaves (expands) initially before loading, which is the cause of the composite material becoming saturated rather quickly. In comparison to a typical soil sample, the material compresses more quickly when loads are applied. In shorter time, the settling occurs. In addition, the addition of palm kernel shells to black cotton soil tends to cause the soil to lose some of its index qualities, making the soil act more like sand and causing settlement to occur more quickly. Results from settlement observations have shown that the full-scale structure's rate of settlement is typically substantially higher than the values derived from the oedometer test on small specimens, which were used to approximate the settlement values. Rowe has demonstrated that the causes of these disparities are the effects of the clay macro-fabric on drainage behavior. (Craig, 1994; Knappett and Craig, 2012; Chen, 1995)

6.0 CONCLUSION

Several requirements must be met for stabilization in order to create a durable construction using locally accessible soil. This research work will be of great necessity and importance to the geotechnical engineer as it will help to find a way of incorporating agricultural wastes into engineering advantage thereby helping to reduce the nuisance and menace caused by palm kernel shell wastes in the environment and leading to a more stable environment where black cotton soil is predominant. It will also aid in boosting the economy of the nation by reducing the amount of money spent on the disposal and maintenance of palm kernel shell wastes. It will also be an eye opener to the manufacturing engineer prompting them into the manufacturing of palm kernel shell breaking machines; this will lead to more jobs in the sector. More so, in order to solve economic and environmental challenges, this research study is crucial to achieving the best practice in policy implementation of TVET development for the labor force of the future. Although, efforts are still ongoing to determine other relevant geotechnical properties of palm kernel shell stabilized black cotton soil on basement complex.

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. Although black cotton soil has a specific gravity of less than or equal to 2.6, lateritic soils often have a standard specific gravity of 2.60 to 3.40 (Rahardjo et al. 2004; Ola, 1983; Craig, 1994; Knappett and Craig, 2012; Chen, 1995). The low specific gravity of the composite material, which led to a lower unit weight of black cotton soil mixed with palm kernel shell than the soil alone (0%), is a desirable characteristic for its employment in geotechnical applications. Even though the results vary, at the maximum applied pressure under investigation, the coefficient of volume compressibility, or MV, substantially decreases as the percentage of palm kernel shell substitutes increases. The number of voids in a soil sample determines how compressible the black cotton soil is; a higher void ratio indicates a higher possibility for volume changes. The value of the coefficient of volume compressibility, or MV, is also dependent on the stress range that the calculation is made across. This suggests that the compressibility of soil at shallow depths differs from that of soil at greater depths. MV is used in geotechnics to calculate settlement. the coefficient of permeability is a crucial characteristic of soils. Since it indicates the speed at which water percolates through a soil, It influences the rate at which soil consolidates and provides an estimate of the amount of void contained in a particular sample of soil. Despite this, the coefficient of permeability values obtained from the odometer test are typically lower than the in-situ value. This results from the soil becoming compacted, which modifies the macro-fabric of the soil and rearranges the particles. A little odometer specimen does not fairly represent the macro-fabric of black cotton soil, and as a result, its permeability will be less than that of the bulk permeability. Practically loaded soil will experience pore water pressure development. Over time, this pressure will decrease as water escapes the soil, causing volume changes and consolidation settlement. The rate of settlement slows down with time when this procedure takes place. As a result, the soil's permeability, drainage path's length, and compressibility all affect how much settlement happens in a given amount of time. Water will be able to drain from the soil more quickly and settle more quickly in soils with higher permeabilities. Furthermore, as water travels away, energy is transferred from the water to the grain, increasing the effective stress of the soil. The total head gradient and soil permeability determine how quickly water is ejected from the soil, which in turn determines how quickly settlement takes place (Craig, 2004; Bowels, 1981P. N. Modi, (2010):"Soil Mechanics and Foundation Engineering" First edition, Radha Press, Kailsh Nagar, Delhi-110031, pp 399 .

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