CONSISTENCY BEHAVIOUR OF SLAG STABILIZED BLACK COTTON SOIL ON SEDIMENTARY FORMATION.

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Abstract

This research study is determined to know the consistency behavior of black cotton soil modified with slag, with the aim of discovering a cheaper and effective replacement for soil stabilizers in civil engineering. Getting rid of nonbiodegradable waste seems to be a big challenge in the developing country like Nigeria. As a result of nonavailability of land required for disposal technique. The substitution of nonbiodegradable waste materials as a stabilizing agent in soil stabilization is a modern approach by which waste materials can be of great advantage in civil engineering projects. The black cotton soils used in this study was collected from a borrow pit on the sedimentary formation in Idogo at Yawa South Local Government, Ogun State, South-Western Nigeria. The borrow site can be located within the coordinates 8 ^{0}30' 43" N and 9 ^{0}48' 52" E. The slag wastes were taken from Universal Steel at Ikeja industrial layout Lagos State, Nigeria. The slag was mechanically pulverized into pieces and passed through 20um BS Test sieve after which it was substituted for black cotton soil in the percentage range of 0% to 30% at 10% intervals with 0% black cotton soil substitution serving as control experiment. In line with BS 1377 (1990) and other relevant civil engineering codes, consistency tests were conducted on the composite materials of the expansive soil mixed with varying degrees of slag, to determine the Atterberg limit test of the soil. It can be observed from the results that the percentage shrinkage limit became constant at 30% slag substitution in black cotton soil on sedimentary formation which is an indication of constancy of volume.

Keywords: Black cotton Soil, Consistency, Composite materials, Stabilization, slag.

Introduction

Slags are by product of the metallurgical industry. Metallurgical slags play a great role in the extraction and refining of metals. They are formed when a flux material is included or is added in the charge which reacts with misfit minerals during extraction or smelting, or with the products of the oxidation of unimportant solute elements during refining of slag. A low melting complex oxide melt are produced by the fluxing, the slag is easily separated due to fact that it is immiscible with the metal phase (David, 2007). They vary in chemical composition and properties e.g., Iron blast furnace slag are hydraulic, iron L.D (Linz -Danowitz) slag are not, while nickel and copper slag have only pozzolanic properties they need to react with lime before becoming hydraulic. (Sewedo ,2009).

The important idea behind the technique of soil stabilization is that most of 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 is a Special type of clay mineral which exhibit a volume change due to expansive soil dramatic nature in an extreme manner from very hard to very soft when saturated. (Olarewaju and Saheed ,2022)

The method of stabilization to be used should be chosen in such a way that, the stabilizing materials are easily available, nature friendly, more economical and easier to process with black cotton soil (Kotresh and Sharanakumar, 2019). Black cotton soils are always strong in its dry state, in its wet condition, it loses its strength. The low strength and excessive volume changes of black cotton soil makes the soil always difficult for constructions. The characteristic of the black cotton soil can be improved upon through mechanical, chemical and other means. Furthermore, it becomes paramount important to investigate the behavior and engineering properties associated with the black cotton soil especially as a construction material. Good strength and load bearing capacity should be the basic property of construction soil so that external loads can be transferred safely and effectively to the layers below without encountering any structural failure. It is therefore important to improve the desired properties of these soils (Chen, 1975; Craig, 1987; Jones and Hockey, 1964; Joseph, 1981; Kotresh and Sharanakumar, 2019; Madurwar, et al. 2013; Nuhu-Koko, 1990; Okeke, et al. 2020; Nelson and Miller, 1992; Omange, 2001; Radhey, 1998; Rahaman and Ocan, 1978).

Literature Review

Shrinking and swelling excessively are tendency of black cotton soil. It is hard material like stone, it often shrinks and has very high bearing capacity when it is dry. But when the soil is comes in contact with water, it expands, becomes very soft and loses its bearing capacity. It increases in volume to the extent of 20% to 30% of its original size This significant process of swelling and shrinking results in the differential settlement of foundation which may result cracks in building and failure in flexible pavement. (Hassan ,2021).

According to Shilpa and Mohammed (2019) lack of stable soil for development of constructions is very common. In view of this, constructure of buildings on unsuitable soils is unavoidable and making a suitable soil before constructions a challenging issue for Geotechnical and structural engineers.

Aliyu, et. al., (2020) reported that Black cotton soils commonly exhibit high compressibility leading to shrinkage problems during dry periods. Rice husk ash mixed with black cotton soils were used for this study. The black cotton soils were substituted with the additives in percentages at 0%,6%,8%,10% and 12% by dry weight of the soils. The laboratory test results show that both the free swell and linear shrinkage increases with increase in (RHA) to a peak of 12%. Conclusion from the study shows that up to 12% of rice husk ash could be used to stabilize the black cotton soil to achieve a satisfactory performance. It recommended that rice husk ash could be used as a partial replace cement in stabilization of black cotton soils.

Methodology

The black cotton soil (Figure 1a) used for this investigation 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 8^0 13' 43" N and 9^0 48' 52" E. The black cotton soils that were used in the study were collected from depths between 0.3-1.0m below ground surface. The slag wastes were taken from Universal Steel at Ikeja industrial layout Lagos State, Nigeria. (Figure 1b). The quantity of water which was used to obtained maximum dry density for the control experiment (i.e., 0%) was then used to run the consistency tests. The slag was pulverized into pieces (Figure 1b) passing through 20um BS Test sieve and then substituted for black cotton soil at a percentage range of 0% to 30% at 10% intervals with 0% slag substitution served as control experiment. In line with BS 1377 (1990) and other relevant civil engineering codes. Consistency tests were conducted on the composite materials of black cotton on sedimentary formation mixed with varying degrees of slag for the determination of liquid limit, plastic limit and shrinkage limit. (Joseph, 1981; Ola, (1983); Olarewaju and Tella, 2022; Olarewaju and Oloruko-Oba, 2022; Olarewaju and Falola, 2022; BS 1377, 1990).


a

b

Figure 1: (a) Black Cotton (Expansive) Soil and (b) Slag

Results and Discussion

From the results shown below in Table 1, the percentage moisture content varies from 27.16 to 20.21% in descending order while the corresponding number of blows varies from 15 to 45. The percentage moisture content for plastic limit determination varies from 19.8 to 17.41% in descending order and shrinkage limit is 1.9 cm. Table 2, the percentage moisture content varies from 24.01 to 17.69% in descending order while the corresponding number of blows varies from 14 to 46. The percentage moisture content for plastic limit determination varies from 14.98 to 12.43% in descending order and shrinkage limit is 1.8 cm. In addition to this, from the results shown in Table 3, the percentage moisture content varies from 21.91 to 15.33% in descending order while the corresponding number of blows varies from 15 to 47. The percentage moisture content for plastic limit determination varies from 12.52 to 10.63% in descending order and shrinkage limit is 1.7cm. Finally, from the results shown in Table 4, the percentage moisture content varies from 18.13 to 16.63% in descending order while the corresponding number of blows varies from 14 to 48. The percentage moisture content for plastic limit determination varies from 11.62 to 9.2% in descending order and shrinkage limit is 1.7cm. It is evidently clear from the results that the percentage shrinkage limit became constant at 30% slag 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 slag in black cotton soil on sedimentary formation is 30%. Although observed or measured parameters reduces as the slag 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 or soil mechanics, cohesion limit can be simply explained as the water content at which soil crumbs and start just sticking together while sticky limit is the water content at which soil just stick to a metal surface such as a spatula blade. In addition to this, a shrinkage limit is the water content below which the soil start acting as a non-plastic materiel; Moreso, liquid limit is that water content below which the soil starts behaves as a plastic material, at this water content, the soil is on the verge of becoming a viscous fluid. The liquid limit can be used to estimate settlement in consolidation problems.

The Results of consistency test (liquid limit, plastic limit and shrinkage limit) for black cotton soil that was mixed with slag in varying percentage of 0% to 30% with 0% serving as control experiment, are presented in table 1 to 4 respectively.

Table 1: Results of Consistency Test on 0% Replacement of slag in black cotton Soil (Control) on Sedimentary Formation.

Liquid Limit Determination

0% Replacement.

Table 1a

Moisture can no	IDO 1	IDO 2	IDO 3	IDO 4
Weight of can (W1) g	9	9.2	9.1	9
Weight of can + wet soil (W2) g	33.56	30.16	24.91	21.22
Weight of can + dry soil (W3) g	26.89	24.87	21.41	18.75
Weight of water (W2 -W3) g	6.67	5.29	3.5	2.47
Weight of dry soil (W2-W1) g	24.56	20.96	15.81	12.22
Percentage moisture content %	27.16	25.24	22.14	20.21
No of blows.	15	23	35	45

Plastic Limit Determination

0% Replacement.

Table 1b

Moisture can no	IDO 5	IDO 6
Weight of can (W1) g	9	9.2
Weight of can + wet soil (W2) g	25.67	23.56
Weight of can + dry soil (W3) g	22.37	21.06
Weight of water (W2 -W3) g	3.3	2.5
Weight of dry soil (W2-W1) g	16.67	14.36
Percentage moisture content %	19.80	17.41

Percentage Shrinkage Limit Determination

0% Replacement.

Table 1c

Length of wet soil (cm)	14.2
Length of dry soil (cm)	12.3

Table 2: Results of Consistency Test on 10% Replacement of Slag in black cotton Soil on Sedimentary Formation.

Liquid Limit Determination

10% Slag Replacement.

Table 2a

Moisture can no	IDO 37	IDO 38	IDO 39	IDO 40
Weight of can (W1) g	9	9.2	9.1	9
Weight of can + wet soil (W2) g	31.53	29.5	26.47	24.38
Weight of can + dry soil (W3) g	26.12	25.2	23.02	21.66
Weight of water (W2 -W3) g	5.41	4.3	3.45	2.72
Weight of dry soil (W2-W1) g	22.53	20.3	17.37	15.38
Percentage moisture content %	24.01	21.18	19.86	17.69
No of blows.	14	24	39	46

Plastic Limit Determination

10% Slag Replacement.

Table 2b

Moisture can no	IDO 41	IDO 42
Weight of can (W1) g	9	9.2

Weight of can + wet soil (W2) g	23.02	21.27
Weight of can + dry soil (W3) g	20.92	19.77
Weight of water (W2 -W3) g	2.1	1.5
Weight of dry soil (W2-W1) g	14.02	12.07
Percentage moisture content %	14.98	12.43

Percentage Shrinkage Limit Determination

10% Slag Replacement.

Table 2c

Length of wet soil (cm)	14.2
Length of dry soil (cm)	12.4

Table 3: Results of Consistency Test on 20% Replacement of Slag in black cotton soil on Sedimentary Formation.

Liquid Limit Determination

20% Slag Replacement.

Table 3a

Moisture can no	IDO 43	IDO 44	IDO 45	IDO 46
Weight of can (W1) g	9	9.2	9.1	9
Weight of can + wet soil (W2) g	29.63	26.75	24.55	22.7
Weight of can + dry soil (W3) g	25.11	23.3	21.83	20.6
Weight of water (W2 -W3) g	4.52	3.45	2.72	2.1
Weight of dry soil (W2-W1) g	20.63	17.55	15.45	13.7
Percentage moisture content %	21.91	19.66	17.61	15.33
No of blows.	15	27	35	47

Plastic Limit Determination

20% Slag Replacement.

Table 3b

Moisture can no	IDO 47	IDO 48
Weight of can (W1) g	9	9.2
Weight of can + wet soil (W2) g	21.46	19.55
Weight of can + dry soil (W3) g	19.9	18.45
Weight of water (W2 -W3) g	1.56	1.1
Weight of dry soil (W2-W1) g	12.46	10.35
Percentage moisture content %	12.52	10.63

Percentage Shrinkage Limit Determination

20% Slag Replacement.

Table 3c

Length of wet soil (cm)	14.2
Length of dry soil (cm)	12.5

Table 4: Results of Consistency Test on 30% Replacement of Slag in black cotton soil on Sedimentary Formation.

Liquid Limit Determination

30% Slag Replacement.

Table 4a

Moisture can no	IDO 49	IDO 50	IDO 51	IDO 52
Weight of can (W1) g	9	9.2	9.1	9
Weight of can + wet soil (W2) g	26.15	23.69	21.58	18.68
Weight of can + dry soil (W3) g	23.04	21.28	19.78	17.48
Weight of water (W2 -W3) g	3.11	2.41	1.8	1.2
Weight of dry soil (W2-W1) g	17.15	14.49	12.48	9.68
Percentage moisture content %	18.13	16.63	14.42	12.40
No of blows.	14	26	37	48

Plastic Limit Determination

30% Slag Replacement.

Table 4b

Moisture can no	IDO 53	IDO 54
Weight of can (W1) g	9	9.2
Weight of can + wet soil (W2) g	18.47	15.72
Weight of can + dry soil (W3) g	17.37	15.12
Weight of water (W2 -W3) g	1.1	0.6
Weight of dry soil (W2-W1) g	9.47	6.52
Percentage moisture content %	11.62	9.20

Percentage Shrinkage Limit Determination

30% Slag Replacement.

Table 4c

Length of wet soil (cm)	14.2
Length of dry soil (cm)	12.5

Analysis of Results

Table 5

Atterberg Limit parameters.	0%	10%	20%	30%

Liquid Limit (%)	25.2	22.1	19.9	16.5
Plastic Limit (%)	18.61	13.71	11.58	10.41
Shrinkage Limit (%)	13.38	12.68	11.97	11.97

Conclusion and Recommendation

Consistency properties and behaviors of black cotton on sedimentary formation soil stabilized with slag was studied. Based on the results obtained it is evidently clear 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 slag in black cotton soil on sedimentary formation is 30% beyond which no further changes will occur. 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 waste in the environment and leading to a more stable environment where black cotton soil is predominant. Based on the results obtained and observations from the tests conducted, I will like to recommend further research work on other non -biodegradable wastes to be considered as soil stabilizing agents. Research work on utilization of dumped waste in other aspect of Civil Engineering Construction should be given adequate encouragement

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