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ASSESSMENT OF THE EFFECTS OF STONE-DUST ON SOIL STABILIZATION.

ELEKE C. N. NWOLUM C. F.

Abstract

The essence of this study is to expose the way Stone dust aids in Soil stabilization for construction purposes, thereby increasing its strength, load bearing capacity and overall performance of the soil. Due to the large deposit of Laterite found in the sub-soil and subgrade when the topsoil is excavated, Laterite is the load bearing soil for most land construction in our locality (Eastern Nigeria) and its high ability to swell and contrast during wet and dry season respectively, tend to cause differential settlement and other structural failures. Sieve analysis and California Bearing Ratio (CBR) test was done on Stone dust, Laterite and Stone dust + Laterite to their different grading and load bearing capacity. Result showed that a ratio of 40:60 of Laterite to Stone dust has a stronger load bearing capacity when compared to either only stone dust or Laterite. The strength, engineering quality of soil increases with addition of Stone dust when compared to plain soil. Which effectively means it should be used as a soil stabilizer for construction purposes so as to recycle its wastage at Stone Quarries.

Keywords: Soil Stabilization, Laterite, Stone dust, Sieve analysis, California Bearing Ratio (CBR).

Introduction

Stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for intended purpose. In the simplest sense, stabilization includes compaction, pre-consolidation, drainage and many other suitable processes. Improvements include increasing the weight bearing capabilities, tensile strength, and overall performance of in-situ sub-soils, sands, reducing the permeability and compressibility of the soil, increasing the soil's shear strength and also increasing the overall performance of waste materials in order to strengthen road surfaces.

Soils stabilization could either be done by the following method; mechanical method, cement method, lime method, bitumen method of soil stabilization. The main use of soil stabilization is the improve the natural soil for the construction of highways and airfields, for controlling the grading of soils and aggregates in the construction of sub-bases and bases of highways, airfields, foundation and other engineering constructions.

Objectives Of The Study

The objectives of this research are as follows:-

1. To assess if stone dust is an adequate material for soil stabilization.

2. To compare the functionability and adequacy of stone dust to other materials for soil stabilization.

3. To determine the strength of a soil stabilized with stone dust.

Materials and Methods

In order to assess the effect of stone dust on soil stabilization two (2) tests were carried out via: - grain size distribution ie sieve analysis and California bearing radio (CBR) test.

The samples used are laterite and stone dust. The laterite was gotten from Amochi borrow pit, Oko and the stone dusts sample gotten from Nkwelle borrow pit Oyi local government area, all in Anambra State, Nigeria.

Theory Of Experiment For Sieve Analysis

Sieving is the most direct method for determining particle sizes but here are practical lower limits to sieve openings that can be used for soil. This lower limits is approximately at the smallest size attributed at sand particles (75u or 0.015mm) sieving is a screening process in which coarse fractions of soil are separated by means of series of graded mesh.

As per provisions of is 460 – 1972 (revised) soils having particles of size larger than seventy five micron (75u) are termed as coarse grained soils. Thus sand, gravel, cobble and boulder do fall within the definition of coarsed grained soils, since the size range of different types of these soils are as follows:

Boulder = more than 300mm

Cobble = 80mm to 300mm

Gravel = 4.7 to 80mm

Sand = 0.075 to 4.75mm

75u are classified as silt and clay. Hence they are called fine grained soils.

Crushed stones contain varying percentages of different sizes of coarse particles (9.5mm to 75u) and a certain percentage of fines.

In order to determine the percentage of various sizes, the crushed stones (stone dust) is sieved through a set of sieves having different sizes each placed successively below the larger sized sieve.

After the stone dust is successfully sieved through, the percentage (%) passing is determined and grain size distribution curve is plotted. From the grain size distribution curve, fill becomes flexible to read of different sizes of soil particles such as percentage composition of boulders, gravel and sand.

The value of coefficient of curvature (Cc) and the value of uniformity coefficient (Cc) can also be evaluated by using their appropriate equations.

Coefficient of curvature (Cc) = (D 〖30〗^2)/(D10 X D60)

Uniformity coefficient (Cu) = D60/(D10)

When the given coarse soil contains less than five (50) percent of fines, it is analyzed by dry sieving, but when it contains fines exceeding five (5) percent, it is analyzed by wet sieving. The grain size distribution curve gives an idea regarding the gradation of the soil. Thus the test makes it possible to identify a well graded or poor graded soil.

In mechanical stabilization of soils, the primary principle is to mix a few selected soils in such a proportion that a desired grain size distribution is obtained for the design soil mix.

Hence, for proportioning, the selected stone dust its grain size distribution is required which is been done in this test. This applies to both stone dust and laterite.

First test

Title of experiment: sieve analysis for stone dusts.

Aims and objectives: To determine the grain size distribution analysis on stone dust by sieve analysis.

Apparatus used:

1. Mechanical shaker
2. Weighing balance
3. Power supply
4. A set of 1.5 sieves (9.5mm , 4.7mm ,2.36mm, 1.18mm, 600un, 300un, 150ung, 75un and receiver)
5. Stop watch
6. Hand trowel
7. Oven machine
8. Empty pan

Procedures Adopted

1. The sample was oven dried and allowed to attain room temperature.
2. An empty pan was weight and its mass recorded in grain. Then sample was weighed inside the pan and its mass was also noted in grams.
3. The sample is sieves were cleaned and their individual masses were noted.
4. The sieves were placed successively, the larger on the smaller on the mechanical shaker.
5. The sample was poured into the first sieve (9.5mm) and it was covered and screw knobs were lightened.
6. At exactly fifteen (15) minutes the stop watch was stopped and the sieves were weighed with the same retained on then.
7. The mass at the various samples on the sieves were added together and its value was approximately equal to the mass of the original sample.

This test was repeated using another stone dust sample with a more coarse particle

Second test

Title of experiment: sieve analysis for laterite

Aims and objectives: To determine the grain size analysis for lateritic soil by sieve analysis

Apparatus used:

1. Empty pan
2. Oven
3. Hand trowel
4. Stop watch
5. Power supply
6. Mechanical shaker
7. Weighing balance

8. A set of 1.5 sieve (9.5mm, 4.7mm, 2.36mm, 1.18mm, 600un, 300un, 150ung, 75un and receiver (pan)

Procedure Adopted

1. The sample was oven-dried and kept to attain room temperature
2. The empty pan was weighed and its mass in grams was noted and the sample was weighed with the pan.
3. The sieves were cleaned and their masses weighed and noted.
4. The sieves were placed on the mechanical shaker, the larger size sieve placed on the smaller successively.
5. The soil sample was poured on the first sieve and the machine was powered for fifteen minutes
6. The sieves were taken out and weighed and their masses were noted in grams.
7. Individual masses of the soil sample retained on the sieves were added together and compared with the original mass of the sample before sieving.

2.3.0 PRECAUTIONS TAKEN FOR SIEVE ANALYSIS

1. The sieves were relatively fixed to the mechanical shaker and covered before powering the machine.
2. After weighing the sample with pan, care was taken not to allow the sample to pour or shorten in mass before putting it in the sieves.
3. We ensure that the time stopped at exactly fifteen minutes
4. We ensured that the sieves were cleaned before putting the soil samples.
5. While drying the soil in the oven, we ensured that the temperature of the oven did not exceed 105oc since higher temperature may cause some permanent changes in the seventy five micron (75u) particles.
6. 6.The measurements of samples on the weighing balance were done in a vacuum to avoid air interference

Theory Of Experiment For C.B.R

The CBR can be defined as the rate of the force per unit area required to generate a soil mass with a standard circular plunger of 50mm diameter at the rate of 1.25mm/min to that required for the corresponding penetration of a standard material.

The California bearing ration test is conducted for evaluating the suitability of the sub grade and the material used in sub-base and base of a flexible pavement.

The plunger in the CBR test penetrates the specimen in the mould at the rate of 1.25 mm per minute. The load required for a penetration of 2.5mm and 5.0mm are determined. The penetration load is expressed as a percentage of the standard loads at the respective penetration level of 2.5 mm or 5.0 mm

CBR value = (penetration load)/(standard load) X 100

The CBR value is determined corresponding to both penetration levels. The greater of these values is used for the design of the pavement.

Third test

Title of experiment: California bearing ratio.

Aims and objectives: to determine the CBR value for stone dust sample.

Apparatus

1. A cylindrical CBR mould having internal diameter (150mm) and height (175mm)

2. A detachable extension collar of fifty millimeter (50mm) height (required to compact the soil sample into the mould.

3. A detachable perforated plate of 10mm thickness and 235mm diameter, having a small, threaded stem at the centers.

4. A cylindrical penetration plunger (piston), 50mm in diameter having a minimum height of 100mm. A plate of 70mm diameter is fixed at its upper end.

5. Two to three annular weights, each of 25N (2.5kg), 147mm in diameter with a central hole.

6. Penetration dial gauge with fixing screws with least count of 0.01 (100 divisions reading 1mm).

7. Cylindrical spacer disc (with a detachable handle) having

148mm diameter and 47.7m height, with a central threaded hole to be used for screwing the handle, for enabling insertion and removal of the disc into or from the mould.

8. Metal rammer having weight (2.5kg) with a drop of 310mm for light compaction.

9. Hydraulic jack type loading machine having a capacity of 50kn (500kg) with accessories like proving ring, dial guage to measure applied load etc.

10. Miscellaneous items: mixing bowl, straight edge, drying oven.

Test Procedures: (preparation of remolded soil specimen)

Dynamic compaction

1. About two thousand five hundred grams of stone dust sample was put in a tray, water was added to increase its water content to optimum water contents. The sample was mixed thoroughly with hands to obtain a uniform paste.
2. The extension collar was fixed at its upper end, and the fixed to base plate fixed to the bottom.
3. The space disc was inserted over the base with the central hold of the disc at the lower face.
4. The soil sample was poured into the mould, compacted in three (30 equal layers, each layer was given twenty seven blows by the 2.5kg rammer with a drop of 310mm.
5. The extension collar was removed and the excess compacted soil was removed and the excess compacted soil was trimmed carefully with a straight edge of the top of the mould.
6. The base plate was loosened and removed with the space disc.
7. The mould was weighed with compacted soil in it.
8. The mould with the specimen was place on the lower plate of the loading machine with the top face exposed.
9. The penetrating plunger was seated at the center of the specimen to establish full contact between the plunger and the specimen. The seating load should be about forty Newton (40N).

10. The dial gauge load was set to zero and the displacement gauge set to zero.
11. The load was applied on the plunger and the penetration rate was kept as 1.25mm / minute.
12. The corresponding penetrations were recorded and the value of the maximum load noted.
13. At the end of the test, the plunger was raised and the load removed from the loading machine.

Fourth test

Title of experiment: California bearing ration (CBR)

Aims and objectives: to determine the CBR value for the lateritic soil sample

Apparatus used:

1. A cylindrical CBR mould having internal diameter (150mm) and height (175).

2. A detachable extension collar of fifty millimeter (50mm) height.

3. A detachable perforated base plate of 10mm – thickness and 235 diameters, having a smaller threaded stem at the centre.

4. A cylindrical penetration plunger (piston) 50mm in diameter having a minimum height of 100mm- A plate of 70mm diameter is fixed at its upper end.

5. Penetration dial gauge with fixing screws with least count of 0.01mm (100 divisions reading 1mm) .

6. Cylindrical spacer disc (with a detachable handle) having 148mm diameter and 47.7m height, with a central threaded hold to be used for screwing the handle, for handling insertion and removal of the disc into or from the mould.

7. Metal rammer having weight 2.5kg with a drop of 310mm for light compaction.

8. Hydraulic jack type loading machine having a capacity of 50kN (5000kg) with accessories like proving ring, dial gauge to measure applied load etc.

Other tools are: mixing bowl, straight edge, and oven

. Test Procedures

1. Two thousand five hundred grams (2500g) of laterite was put in a tray, water was added to increase its water content to optimum water contents. The sample was mixed thoroughly with hands to obtain a uniform paste.
2. The extension collar was fixed at its upper end, and the fixed to base plate fixed to the bottom.
3. The soil sample was poured into the mould, compacted in three equal layers, each layer was given twenty seven blows by the 2.5kg rammer with a drop of 310mm

4. The extension collar was removed and the excess compacted soil was removed and the excess compacted soil was trimmed carefully with a straight edge.
5. The base plate was loosened and removed.
6. The mould with the sample was placed on the lower plate of the loading machine with the top face exposed.
7. The penetrating plunger was seated at the center of the specimen to establish full contact between the plunger and the specimen. The seating load should be about forty Newton (40N).
8. The dial guage load was set to zero and the displacement guage set to zero.
9. The load was applied on the plunger and the penetration rate was kept as 1.25mm / minute.
10. The corresponding penetrations (a standard material. 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5mm) were recorded and the value of the maximum load noted.
11. At the end of the test, the plunger was raised and the load removed

Fifth test

Title of experiment: California bearing ratio

To determine the CBR for the composition of stone dust and lateritic soil in ratio of 60/40 percetage by mass.

APPARATUS USED:

1. A cylindrical CBR mould

2. A detachable extension collar of fifty millimeter

3. A detachable perforated base plate of 10mm – thickness and 235 diameters, having a smaller threaded stem at the centre.

4. A cylindrical penetration plunger (piston) 50mm in diameter having a minimum height of 100mm. A plate of 70mm diameter is fixed at its upper end.

5. Penetration dial gauge with fixing screws with least count of 0.01mm (100 divisions reading 1mm).

6. Cylindrical spacer disc (with a detachable handle) having 148mm diameter and 47.7m height, with a central threaded hold to be used for screwing the handle, for handling insertion and removal of the disc into or from the mould.

7. Metal rammer having weight 2.5kg with a drop of 310mm for light compaction.

8. Hydraulic jack type loading machine having a capacity of 50kN (5000kg) with accessories like proving ring, dial gauge to measure applied load etc.

Other tools are: mixing bowl, straight edge, and oven.

TEST PROCEDURES

1. Two thousand five hundred grams (2500g) of both laterite soil stone dust was mixed thoroughly in the ratio of 40: 60 percentage by mass in a tray and water was added to obtain an optimum water contents.
2. The extension collar was fixed at its upper end, and the fixed to base plate fixed to the bottom.
3. The soil sample was poured into the mould, compacted in three equal layers, each layer was given twenty seven blows by the 2.5kg rammer.
4. The extension collar was removed and the excess compacted soil was removed and the excess compacted soil was trimmed carefully with a straight edge.
5. The base plate was loosened and removed.
6. The mould with the sample was placed on the lower plate of the loading machine with the top face exposed.
7. The penetrating plunger was seated at the center of the sample to establish full contact between the plunger and the specimen. The seating load should be about forty Newton (40N).
8. The dial gauge load was set to zero and the displacement gauge set to zero.

9. The load was applied on the plunger and the penetration rate was kept as 1.25mm / minute.
10. The corresponding penetrations (0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, and 5.0, 7.5, 10.0 and 12.5 mm) were recorded and the value of the maximum load noted.
11. At the end of the test, the plunger was raised and the load removed from the loading machine.

3.5.0 PRECAUTIONS TAKEN DURING C.B.R TEST TO AVOID ERRORS:

1. The dial gauges were set to zero mark in the beginning of the test.
2. Care was taken to ensure that each layer received equal number of blows.
3. We ensured that the penetrating plunger was centralized on the specimen.
4. We also ensure that the sample obtained a uniform mixture when mixing with water.

Results

The results of the physical properties of laterite and stone dust are presented. The sample is sieved through a set of sieves. The material retained on different sieves was determined. The percentage weight retained on any sieve is given as:

$$Pn = V = \frac{Mn}{m} X\ 100$$

Where:

Mn = mass of soil retained on sieve "n"

M = total mass of the sample

The cumulative percentage of the material retained on the sieve

$$Cu = P_1 + P_2 + P_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots + P_u$$

Where:

$P_1 + P_2 + P_3$.............................. are the percentage weight retained on the sieves

Cu = cumulative percentage weight retained. The tables and graphs presented below are the results of particle size distribution of laterite and stone dust.

SIEVE ANALYSIS FOR STONE DUST

B.S SIEVE NO	MASS OF SIEVE (g)	MASS OF SIEVE + SAMPLE RETAINED	MASS OF SOIL RETAINED (g)	M S R
9.5mm	297.9	310.1	12.2	0

4.75mm	334.0	909.4	575.4	29.25	29.87	70.13
2.36mm	335.9	429.0	93.1	4.73	34.60	65.4
1.18mm	556.0	268.4	287.6	14.62	49.22	50.78
600um	268.4	445.0	176.6	8.98	58.20	41.8
300um	276.5	613.3	336.8	17.12	75.32	24.68
150um	263.1	560.0	296.0	15.09	90.41	9.59
75um	250.8	352.4	101.6	5.20	95.61	4.39
Pan	271.3	358.0	86.7	4.39	100.00	0.00
			1966.9	**100.00**		

Mass of stone dust sample used is 2000g

TABLE 1.0

For uniformity of soil, Cu = uniformity coefficient

$Cu = = \frac{D60}{D10} = = \frac{2.35}{0.15} = 15.7$

Where D_{60} = particle size such that 60% of the soil is finer than this size

D_{10} = particle size such that 10% of the soil is finer than this size and also known as the effective size. For gradation of the particle, coefficient of curvature is used for the determination;

$C_C : = \frac{(D30)^2}{D60 \; X \; D10} = \frac{(0.60)^2}{2.35 \; X \; 0.15} = \frac{0.360}{0.3525} = 1.0$

RESULTS OF PARTICLE SIZE DISTRIBUTION FOR LATERITE

B.S SIEVE NO	MASS OF SIEVE (g)	MASS OF SIEVE + SAMPLE RETAINED	MASS OF SOIL RETAINED (g)	M S R
9.5mm	298.09	399.2	101.1	4
4.75mm	340.50	540.1	199.6	7
2.36mm	403.9	714.3	310.4	1
1.18mm	38.02	730.9	350.7	1
600um	241.0	1644.7	1403.7	5
300um	326.7	430.0	103.3	2
150um	316.9	317.4	0.500	0

75um	214.9	222.6	7.700	0.31	95.89	4.11
Panum	215.0	325.6	110.6	4.11	100.00	0.00
			2587.7	**100.00**		

Mass of lateritic soil sample used is 2600g

TABLE 2.0

Cu = uniformity coefficient

$$Cu = = \frac{D60}{D10} = = \frac{1.20}{0.6} = 2$$

$$C_{C:} = \frac{(D30)^2}{D60\ X\ D10} = \frac{(0.9)^2}{1.20\ X\ 0.6} = \frac{0.81}{0.72} = 1.1$$

1.2.2 DISCUSSION OF RESULT OBTAINED

From the table and calculation, it is found out that the particle size distribution of stone dust is WELL-GRADED because the uniformity coefficient (Cu =15.7) is great than 4 and also the coefficient of curvature (Cc) falls between 1 and 3 which also indicates that the stone dust is WELL-GRADED.

For the lateritic soil, the particle size distribution, using the uniformity coefficient as a measure indicate that it is POORLY- GRADED because its uniformity coefficient, Cu is 2, and which also classifies it as a POORLY-GRADED SOIL.

Also, the curves for both samples of soil shows that, the lump curve of the laterite soil makes it a GAP-GRADED soil meaning that some of the intermediate particle size are missing, while the that S- curve of the stone dust represents a soil which contains, the particle of sizes in proportions. Such a soil is called WELL-GRADED SOIL.

1.3 CALIFORNIA BEARING RATIO RSULTS FROM BOTH SAMPLES.

(Laterite and stone dust) least count (Lc) penetration dial gauge = 0.01mm proving ring constant (PRC) = 1 divn = 11.76N.

TABLE 3

S/NO	Penetration in mm	
	Divns	[2] X Lc [mm]

				Ang for laterite		
[1]	[2]	[3]	[4]mm	[5]mm	[6]	[7]
1	0	0	0	0	0	0
2	50	0.5	1.5	1.0	17.64	11.76
3	100	1.0	3.5	3.0	29.40	35.28
4	150	1.5	3.0	4.0	35.28	47.04
5	200	2.0	3.7	4.5	43.512	52.92
6	250	2.5	4.0	5.5	47.04	64.68
7	400	4.0	7.0	11.5	82.32	135.24
8	500	5.0	10.2	16.0	119.952	188.16
9	750	7.5	20.0	35.0	235.2	411.6
10	1050	10.5	30.4	75.0	357.504	882
11	1250	12.5	40.2	106.3	472.752	1250.088

FOR LATERITE

Load corresponding to 2.5mm penetration,

$P_1 = 47.04N$

Load corresponding to 5mm penetration; =

$P_2 = 119.952N$

i. CBR at 2.5mm = $\frac{P1}{13700}$ X 100%

$\frac{47.04}{13700}$ X 100

= 0.34%

ii. CBR at 5mm = $\frac{P2}{20550}$ X 100%

$\frac{119.952}{20550}$ X 100

0.58%

FOR CBR OF STONE DUST / LATERITE COMPOSITION

Load corresponding to 2.5mm penetration,

$P_1 = 64.68N$

Load corresponding to 5.0mm penetration,

$P_2 = 188.16N$

i. CBR at 2.5mm

$\frac{64.68}{13700}$ X 100

= 0.47%

ii. CBR at 5.0mm

$\frac{188.16}{20550}$ X 100

= 0.92

From the above table;

Discussion Of Result Obtained

The C.B.R values are usually calculated for penetration of 2.5mm and 5mm. generally the C.B.R value at 2.5mm will be greater than at 5mm and in such case, the former [2.5mm] shall be taken as C.B.R for design purpose. If C.B.R for 5mm exceeds that for 2.5mm, the test should be repeated. If identical results follow, the C.B.R corresponding to 5mm penetration should be taken for design.

Therefore, from the above calculation, the C.B.R to be taken for design is that of 5mm penetration because it is higher than that of 2.5mm as such, since the value at 5mm penetration is 0.92% = 92.

Therefore, if the stone dust is to be used for stabilization of soil for pavement design for subgrades with C.B.R values of 15% and above the sub-base should have a standard thickness of 150, a value determined as the minimum practical for spreading and compaction. For subgrade with CBR values in excess of 30% and a low water table or hard rock subgrades, the sub-base may be omitted.

Conclusion And Recommendations

The conclusion is based on the test carried out on soil selected for the study. The following conclusion can be made from this research work:

- The waste product removed from stone crusher which can be used as soil stabilizer.
- The appropriate use of stone dust gives the stability and also gives strength to soil.
- It is observed that value increases significantly after of 1.0% stone dust content.
- In earth soils, stone dust can be used as a soil stabilizer which enhanced the engineering properties of the soil.
- As the strength of soil increases with an addition of stone dust, the quality, strength of soil will be more as compare to plain soil.

Recommendations

Based on the outcome of this research work, we therefore give the following recommendations;

a. Stone dust should be used effectively as a stabilization material for various civil engineering constructions.
b. Engineering monitoring committee responsible for monitoring pavement

construction specifically should ensure that less quality materials must not be used as stabilization materials, in order to achieve acceptable standard.

c. The disposal of stone dust as waste materials should be stopped because of its importance in the field of engineering.

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