



Impact of Compaction Time Lag on Strength Characteristics of Cement Stabilized Lateritic Soils

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Abstract

In the tropics and sub tropics, the common material for road construction is laterite, which is residual in nature. Most laterite requires some forms of stabilization before they can be effectively used in road construction to improve their bearing capacity. However, due to machine or machine parts breakdown, negligence of workers and company policy, the stabilized laterite might not be compacted immediately. Three laterite samples were collected from three different trial pits. The samples were subjected to laboratory tests; Grain Size Analysis, Natural Moisture Contents, Atterberg Limit Tests (liquid limit and plastic limit), Specific Gravity, British Proctor Compaction test, California Bearing Ratio (CBR) and Unconfined Compressive Strength test. Deduction from laboratory tests revealed that samples A, B and C were A – 2 – 6 (0), A – 2 – 6 (0) and A – 7 – 6 (0) respectively. The A and B soils were stabilized with 3%, 4% and 6% cement of dry mass of soil sample while sample C soil was stabilized with 6%, 8% and 10% cement of dry mass of soil sample. The stabilized samples were delayed for 1, 2 and 3 hours before compaction. The CBR soaked result showed a strength reduction between 4.16% and 12.1% for an hour delay for samples A and B and 4.3% to 21.4% for sample C. CBR (unsoaked) for soil sample C has a least drop of 2.5%, 5.5% and 12.6% for 1, 2 and 3 hours delay period respectively, while samples A and B had maximum decrease of 6.49%, 13.74% and 23.86% for similar delay periods. The unconfined compressive strength showed that the highest strength decrease for samples A and B ranges between 14.9% and 38.7%, while that of sample C was 38.63% for 3 hours delay period. Delay in compaction reduced the strength of different samples of stabilized lateritic soils.

Keywords: stabilized, lateritic soil, California bearing ratio, compaction delay, moisture content.

Introduction

Stabilization simply implies a process of improving or maintaining the geotechnical properties of soil materials and making it more stable. Soil stabilization has been used in the building of roads and bridges, earth dams and embankments for erosion control (Nwaiwu *et al.*, 2022). Soils in their natural form may not possess the sufficient bearing capacity for base and sub base course materials for highway construction (Little and Nair, 2009). Laterite soil, the most common of all tropical soils in Nigeria are mostly used earth materials for highway construction (Hagos, 2017). Lateritic soils are defined as highly weathered natural materials with a high concentration of hydrated oxides of iron or aluminium due to the residual accumulation or absolute enrichment caused by the solution, movement, and chemical precipitation of aluminium, iron and manganite (Oluyemi – Ayibiowu, 2019). The strength and durability properties of natural soils can be improved by both mechanical and chemical means of stabilization (Ayanlola and Oladele,

2006). The goals of stabilization are therefore; to improve the soil strength, bearing capacity and durability of a soil under adverse moisture and stress condition, and to improve the volume stability of a soil mass (Komolafe and Osinubi, 2019). Strength and durability of soils can be improved by mechanical means using compaction without the addition of any foreign matter. The amount of cement for stabilizing lateritic soils normally ranges between 1 – 8% (Okonkwo, 2009). Lateritic soils have been shown to be stabilizable with any of the additives with the improved soil produced being used as sub – base and base course of road. The strength of a stabilized soil is dependent on many variables such as soil type and properties, additive content, type of additive, curing time and method, water content, unit weight and time elapsed between mixing and compaction (Olaobaju, 2003). Portland cement have been used to appreciably improve the properties of soils (Berthelot *et al.*, 2005; Gadzama, 2009). Bello (2011) reported that compaction delay influences the measured value of CBR and UCS



of yellow soil. Gadzama (2009) also established that 4% cement can be recommended as an optimal content to stabilize soil from parts of Northern Nigerian. During construction, unprecedented conditions such as machine or machine parts breakdown, negligence of workers, insufficient workers and company policy usually occur which may lead to delay in compaction of the treated soil after mixing operation and placing had taken place, hence this study investigated the effects of delay in compaction on strength of cement stabilization of lateritic soils from different sources.

Materials and Methods

Sample Collection

Three samples were taken at three different locations. The depth of the trial – pits were 1.2m. No variation was observed in the soil profile with depth at each location. Soil identification and description was carried out by visual observation and physical feeling. Laboratory tests carried out on the laterite soils include: sieve analysis, Atterberg limits (liquid and plastic limits), Moisture content, British proctor compaction, California bearing ratio and unconfined compressive strength. All tests were carried out in accordance with BS 1377 (1991)

Laboratory Tests

Sieve Analysis

The apparatus used to carry out the test include set of sieves, weighing balance, mechanical sieve shaker, wash bottle, measuring can, porcelain dish and mortar and pestle. A representative sample of 200g was placed on sieve No 0.8mm and the system was shaken for 15minutes. The sieves were removed and carefully weighed with its contents. The weight of material passing (g) and percent passing were estimated from;

Weight of material passing =

weight of dry sample –

Weight retained on the sieve 1

$\% \text{ Weight retained} = \frac{\text{Weight retained}}{\text{total dry weight of sample}} \times$

100% 2

$\% \text{ Weight passing} = 100\% -$

percent retained 3

cumulative % Weight retained =

$\frac{\text{Cumulative weight}}{\text{total dry weight sample}} \times 100\%$ 4

Liquid Limit Test

A sample weighing 20g was taken from the material passing through 425mm BS test sieve.

The sample was mixed with drinkable water to a consistency of a thick paste and allowed to stand in an airtight container for 24hours to allow the water to permeate throughout the soil mass. A portion of the mixed soil was placed in the cup of liquid limit apparatus and level, after which the grooving tools was used to divide the sample along the diameter through the center of the hinge. The crank was turned at the rate of two revolutions per second, the cup was lifted and dropped until the two part of the soil came into contact at the bottom of the groove along a distance of 13mm. the number of blows at which this occurred was recorded. A little extra of the soil mixture was added to the cup and mixed with the soil in the cup. The operation was repeated until two consecutive runs gave the same number of blows for closure. A quantity of soil from the sample that flowed together was removed with spatula and placed in container and the moisture content determined.

Plastic Limit Test

A sample weighing 20g was taken from the material passing through 425mm BS test sieve. The sample was mixed with water to make a malleable but not sticky ball. This is rolled between the palms of the hand until it begins to dry and crack. Half of this sample is rolled further to a a length of 5cm and thickness of 6mm. the treated formed during this process was rolled between the tip of the finger of one hand and the surface of the glass plate. The thread was rolled to about 3mm in five to ten complete (forward and backward) movement of the hand. The soil was formed into a thread and rolled out again. The procedure was repeated until the thread sheared both longitudinally and transversely when it had been rolled to about 3mm diameter. The portion of crumbled soil thread was gathered together and transferred immediately to the container for moisture determination

California Bearing Ratio Test (CBR) (Unsoaked)

This test established a standard grading of crushed rock compacted under specified condition as a standard for measurement of bearing capacity of any soil. In this test, a calculated bulk mass of soil (from compaction test) was tested as well as water content. This sample was then filled to the mould in five layers by a 4.5kg rammer. The weight of the soil plus mould was measured and the dry density was calculated. The sample was tested

for strength in the mould by the application on a bearing surface at the ratio 0.5:2.00mm/min. load reading were taken at 0.5mm, 1.0m penetration. CBR was calculated from the equation

$$CBR = \frac{\text{measured load} \times 100\% \text{ for the Top and bottom}}{\text{Standard load}} \times 5$$

The procedure was repeated for 4.5% and 6% cement of dry mass of soil for samples A and B while 6%, 8% and 10% of dry mass of soil was used to stabilize sample C

California Bearing Ratio Test (CBR) (Soaked)

In this test, the calculated dry mass of samples was taken and mixed with water to the optimum moisture content (OMC) of the soil as predetermined by compaction test. The sample was then filled to the mould and rammed. The soil with a surcharge of 2.5kg was now soaked for 24 hours. The soaked sample was tested for strength in the mould with the surcharge load still in place by application on a bearing surface at the rate of 1.00mm/mm. CBR was calculated from the equation 4. The procedure was repeated for samples A and B with 3%, 4.5% and 6% cement (stabilized) and for sample C, 6%, 8% and 10% cement content

Unconfined Compressive Strength Test (UCS)

The UCS test is a special type of unconsolidated undrained test commonly used for clay specimens. The sample was taken as calculated from the dynamic compaction and water was added appropriately. This was thoroughly mixed and placed into the BS mould and compacted in three layers applying 27 blows of 2.5kg rammer drop from 300mm height in each layer. The top of the mould is scraped off to remove excess soil after compaction. The compacted soil is removed from the mould with the aid of hydraulic jack. This is then taken to the UCS machine for test. The procedure was repeated for 3%, 4.5% and 6% for samples A and B, 6%, 8% and 10% for C.

RESULTS AND DISCUSSION

Soil Description

The three soil samples A, B and C were identified by hand feeling to be reddish brown gravelly clay

Sieve Analysis

The result of the sieve analysis for the three soil samples are presented in Table 1. The percentage of particles that passes sieve No.

200 for the three samples were greater than 35%. These values are higher and requires that the soil should be stabilized before it could be used as base and sub-base courses in highway applications (Olaniyan *et al*, 2017).

Table 1: Sieve Analysis Result Showing % Passing

Sieve Size or No.	A	B	C
0.8mm	96.18	97.85	98.28
5.6mm	91.72	93.73	94.97
4.0mm	83.57	87.69	90.13
2.0mm	68.00	71.75	77.35
710µm	51.60	49.07	59.16
500µm	43.72	39.84	15.71
355µm	38.68	31.68	45.21
250µm	34.04	25.23	40.04
63µm	27.71	16.17	32.77
<63µm	20.36	4.96	23.77
PAN	0.11	0.02	0.00

Engineering Properties of Unstabilized Soil

The results of moisture content, Atterberg limits, specific gravity, plasticity index, optimum moisture content, maximum dry density, sieve analysis, AASHTO classification, CBR (%) both soaked and unsoaked and UCS (qu) (P/A) kpa tests carried out on the samples are shown in Table 2. The plasticity index (PI) of sample C almost double that of samples A and B, while there is negligible difference between the PI of sample A and B, Ditto for Liquid limit (LL). The specific gravity is however too close as it ranges between 2.48 and 2.50. The three representative soil samples have virtually similar physical properties. The various engineering properties of soil samples A and B are very close. The difference in their maximum dry density (MDD) being 0.03kg/dm³ and that of optimum moisture content (OMC) being 1.78%. Meanwhile sample C has its OMC and MDD being appreciably far from the other two their unconfined compressive strength (UCS) range between 51.88 and 55.37 for the three samples. The California bearing ratio result shows that samples A and B are much stronger and structurally desirable than sample C. Therefore, the classification of the lateritic soil samples based on the Atterberg limits and sieve analysis results according to AASHTO (1986) system of classification groups samples A and B as A- 2 – 6 (0) and sample C as A – 7 – 6 (0).

Table 2: Engineering Properties of Natural Soil Samples

		A	B	C
Natural Moisture (%)		12.34	11.60	12.49
Liquid Limits(LL) %		36.00	36.70	71.75
Plastic Limits (PL)%		18.88	18.91	35.98
Plastic Index (PI)%		17.12	17.09	35.97
Optimum Moisture Content (%)		9.98	8.20	16.50
Maximum Dry Density (kg/dm ³)		2.05	2.02	1.78
Specific Gravity		2.50	2.48	2.50
% Passing Sieve No. 200		20.36	4.96	23.77
AASHTO Classification	A - 2 - 6 (0)	A - 2 - 6 (0)	A - 7 - 6 (0)	
CBR Soaked (%)		9.40	10.22	6.12
CBR Unsoaked (%)		8.57	8.11	4.72
UCS (qu)(P/A) kpa		53.44	55.37	51.88

Effect of compaction Time Lag on Stabilized Soil Samples

The results of the California Bearing Ratio (CBR) tests (unsoaked) on the stabilized soil samples A, B and C for 0 – 3 hours' delay periods are presented in Figures 1a, 1a and 1c. The CBR (unsoaked) of the stabilized A – 2 – 6 (0) soils have maximum decrease of 6.99%, 13.14% and 23.86% for similar delay periods while that of sample C minimally decreased in value by 2.5%, 5.5% and 12.6% for 1,2 and 3 hours' delay periods respectively. The CBR (soaked) of the stabilized samples A and B (A – 2 - 6 (0)) soils as presented in Figures 2a, 2b and 2c showed decrease by a minimum of 4.16% and a maximum of 12.1% in value for an hour delay period. And that of Sample C (A – 7 – 6 (0)) soil showed decrease by a least of 4.3% and highest of 21.4% for the same delay period. There was initial increase in strength between 1 and 2 hours while decrease was recorded between 2 and 4 hours. With the curve shape, higher hour of delay may result in further decrease in strength. At 0 hour, increase in strength with increase in the percentage of cement was observed. The unconfined compressive strength (UCS) values obtained after varying the compaction delay periods, as presented in Figures 3a, 3b and 3c, reveals a notable drop in strength. For samples A and B A – 2 – 6 (0) soils, the worst strength drop was 69.20%, while the minimum reduction for A – 7 – 6 (0) soil was 38.63% for three-hour delay period. The observed decrease in strength could be as a result of the fact that in the presence of water cement hydration commences immediately which

results in hardening of the stabilized soil. As a result of delay in compaction this process is disrupted by compaction at a later time thus weakening the soil (Okonkwo, 2009).

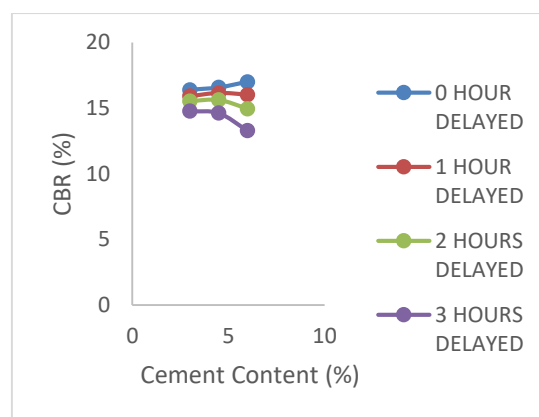


Figure 1a: CBR (Unsoaked) of Stabilized Soil Sample A

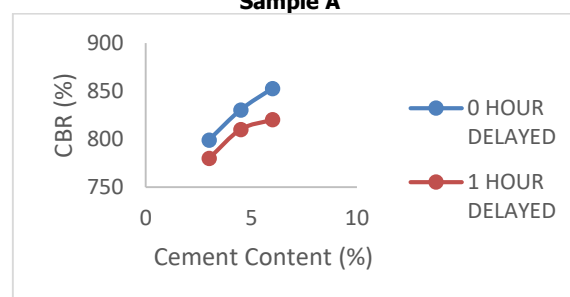


Figure 1b: CBR (soaked) of Stabilized Soil Sample A

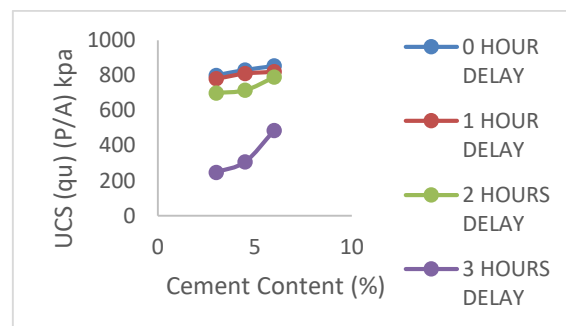


Figure 1c: UCS of Stabilized Soil Sample A

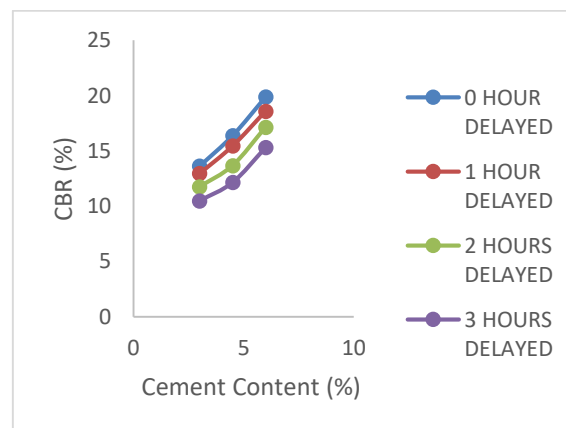


Figure 2a: CBR (Unsoaked) of Stabilized Soil Sample B

Fig. 2b: CBR (Soaked) of Stabilized Soil Sample B

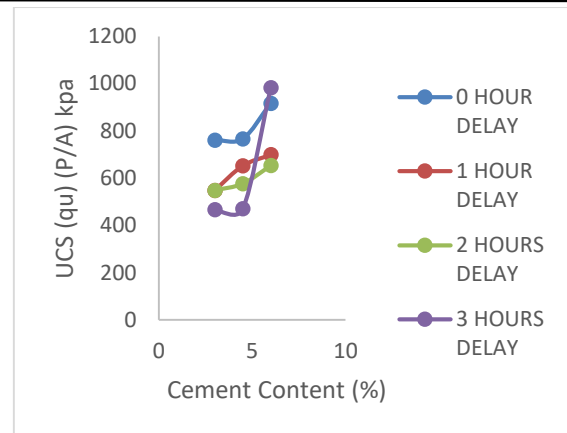
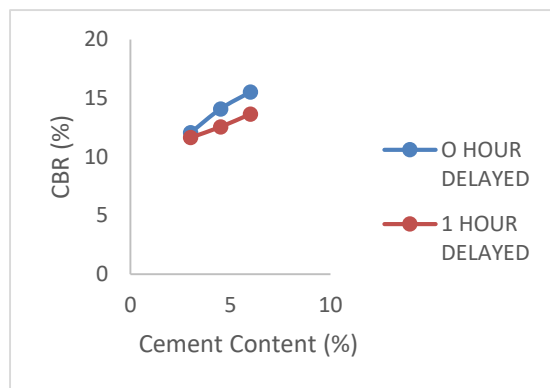


Figure 3c: UCS of Stabilized Soil Sample C

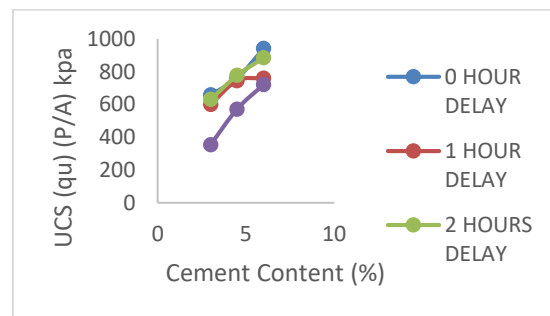


Figure 2c: UCS of Stabilized Soil Sample B

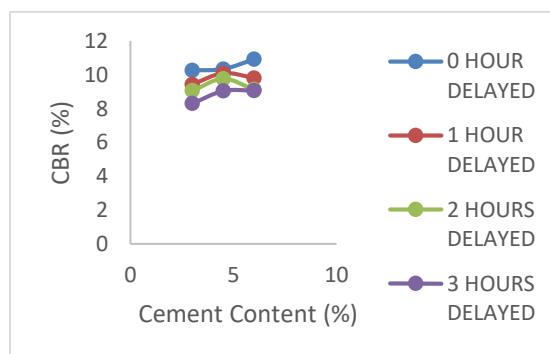


Figure 3a: CBR (Unsoaked) of Stabilized Soil Sample C

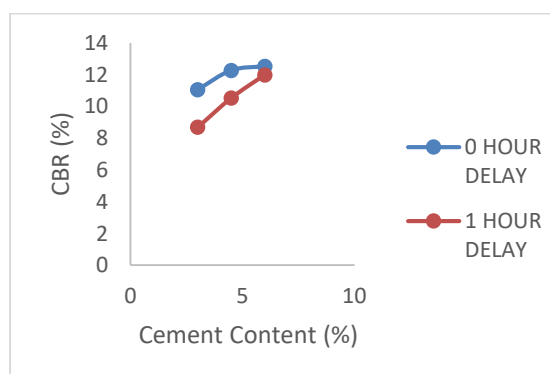


Figure 3b: CBR (soaked) of Stabilized Soil Sample C

Conclusions

It has been shown experimentally that cement stabilized lateritic soil can gain more compressive strength as up to 77% of its original strength; increase in its bearing capacity can be as much as 100% but in soaked condition, about 60%. The compressive strength of the cement stabilized laterite can drop by a maximum of 23.7% if delayed beyond 3 hours and the bearing capacity of the mixture can also reduce for as much as 23.9% for the same time delay

Recommendations

Based on the preceding laboratory work, the following recommendations are made to maximize benefits from road lateritic earthworks:

- soil cement mixture should be compacted as soon as the desired mixture is accomplished.
- in case of some inevitable delay owing to construction intricacies, it is advisable not to stabilize the soil until the laying and compaction materials are readily available.
- delay should hence be minimized to less than one hour to avoid greater loss of soil strength.
- higher mixing percentage of cement should be chosen to achieve meaningful increase in strength of the stabilized soil

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