International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Stabilization of Omu-Aran Lateritic Clay Soil with Cement-Milled Eggshell Waste

Adewara Sunday O.; Gana A.J; Abolusoro S.A. & Obayanju T.O
Department of Economics, Landmark University Omu-Aran, Kwara State
Department of Civil Engineering Landmark University, Omu-Aran, Kwara State
Department of Agriculture, Landmark University Omu-Aran, Kwara State
Email: phildeb0123@gmail.com; oladewara02@gmail.com

ABSTRACT
Clayey soils with high content of clay particles cannot be used for either construction due to their weakness. In order to overcome the identified weakness several techniques have been tried to make the soil suitable for construction. The study used combination of cement and egg shell powder to analyze the properties of clayey soil. Components of Eggshell are magnesium, carbonate, protein and calcium. This research work was carries out in investigate the properties of an Omu- Aran lateritic clay soil stabilized with eggshell powder. A varying percentage of 0, 2, 4, 6 and 8% of eggshell powder, cement and eggshell powder (ratio 1:1) and cement were added to the lateritic clay soil in order to stabilize it. Various laboratory tests which include the basic geotechnical test (such as particle size distribution, density specific gravity, natural moisture content and Atterberg limit) and strength test (i.e. CBR and U C S) were carried out on the sample. The results of the laboratory test showed that there was a significant improvement in the properties of the stabilized specimen. The results also showed that for this study, when cement is mixed with eggshell it was the most effective out of the three varying binder forms that were used.
Keywords: Stabilization, Omu-Aran Lateritic clay soil, Cement-Milled Eggshell Waste.

INTRODUCTION
The presence of a poor soil around the foundation of any engineering structure of highway pavement may lead to damage or failure of the entire structure or highway pavement. One of the features of expensive soil such as clay is that it normally swell up whenever it is mixed with water. Due to this, it is not suitable generally for pavement that are high as well as foundation. Hence, it is important to consider the soil factors and components prior to the commencement of any construction work. If we eventually come across a poor soil, a possible solution should then considered. The options may include leaving the poor soil for a new site, excavation to deep foundation level (for structures), removal of the poor soil and subsequent replacement with a more suitable one, redesigning the structure for the poor condition or treating the poor soil to improve its properties, otherwise known as stabilization. In situations where another site is not available, improvement of the soil by the addition of chemical materials (additive) to the soil to improve soil physical quantities, such as strength, texture, workability and plasticity would be the most probable solution. Some of the materials that can be used as an additive to improve the soil properties are lime, Portland cement, asphalt (bitumen), fly ash, etc. Agricultural Solid wastes and Industrial wastes can also be used for stabilization of expensive soil. Agricultural solid wastes include: Rice Husk Ash (RHA), Groundnut Shell Ash, Olive Cake Residue, and Coconut Husk Ash, While industrial waste includes: iron slag, wood ash, plastic wastes and iron filings. In a bid to improve the engineering properties of soil to make it suitable for road construction, several researches on soil stabilization have been carried out (Ola, 1977; Oloruntola *et al.*, 2008; Okafor and Okonkwo, 2009; Okunade, 2010; Amu *et al.*, 2011). Soil stabilization is any treatment applied to a soil to improve its strength and

reduce its vulnerability to water, if the treated soil is able to withstand the stresses imposed on it by traffic under all weather conditions without deformation, then it is generally regarded as stable.

Calcium rich eggshell is a poultry waste with chemical composition nearly same with the limestone (Amu *et al.*, 2005). Besides, its chemical composition almost similar to that of ordinary Portland cements (Uma Shankur & Balajl, 2014). However, as limestone is a natural mineral resource, quarrying and further uses of limestone may lead to problems related to environment. Apart from that, lime production involves energy intensive process and consumes water. Therefore, identifying analogues material from waste and using the same I soil stabilization could be wise idea. Stabilization is aimed at improving the engineering properties of soil, which may involve increasing the soil density, increase in cohesion, frictional resistance and reduction of plasticity index.

Material

Soil

The soil (lacteritic clay) used in this study was collected from Ora Ayoka permanent site opposite Federal government girl's college , along Omu-Aran Irepodun local government area of Kwara State , Nigeria, using the trial pit method in which a 1.4m by 1.4m by 1.4m pit was dug and samples taken . The samples collected was classified as disturbed and conveyed to the laboratory in an air tight polyethylene bag to prevent moisture loss. The basic physiochemical properties of the soil were determine first The Atterberg limits which was measured as per Bs 1377:1990. Also, the specific gravity test was conducted as per Bs 1377: 1990. The grain size distribution was done with the aid of the mechanical sieve analyzer and the standard protector compaction test.

Milled Eggshell Waste

Chicken eggshell is a waste material from domestic sources such as poultries, hatcheries, home and fast food restaurants. The eggshell for the purpose of this study was collected from Landmark University farms. Eggshells were spread on the ground and air dried for 2 days to facilitate easy milling .After air drying the eggshells, they were manually broken and milled into powdery from which was collected in polythene bags ,The eggshell was sieved through BS sieved 75pm. The sieved was used in order to achieve a uniform powdery form since chemical reaction takes place faster and more effectively with larger surface areas.

Cement

Ordinary Portland cement (OPC) GRADE 42.5 was purchased from a retailer in Omu-Aran town.

Preparation of Stabilized Soil Mix

Three modes of stabilizing materials were used on the lateritic clay soil samples; they include;

(1) Cement

(2) Cement and milled eggshell waste (added in ratio 1:1)
(3) Milled eggshell waste

The stabilizing material was added to the lateritic clay soil specimens in percentage of 0, 2, 4, 6, and 8% by weight of the soil. These quantities fall in the range of those used in previous studies (Olarewaju *et al*, 2011).

Experimental Programme

Various test methods have been adopted in research and practice to assess the efficiency of using cement-milled eggshell waste as soil stabilizer. These assessment tests were carried out on triplicate samples for each mix and they include the following.

Moisture Content Determination

The oven-drying method is the definitive procedure used in standard laboratory practice. The moisture content of the lateritic clay soil sample was determined according to BS1377:1990 Part 2:3 and it was carried out in the Geotechnical Laboratory of Landmark University.

Atterberg Limit Test

The Atterberg limit is a basic measure of the nature of a fine grained soil, depending on the moisture content of the soil. It was determined on the lateritic clay sample and stabilized lateritic clay samples according to BS1377:1990 Part 2:4 & 2:5 and it was carried out in the Geotechnical Laboratory of Landmark University.

Density

Density is expressed in terms of mass density and it was determined on the lateritic clay sample in accordance to BS 1377:1990 Part 2:7 which was carried out in the Geotechnical Laboratory of Landmark University. The bulk density of a soil is the mass per unit volume of the soil deposit including any water it contains. The dry density is the mass of dry soil contained in a unit volume. Both are expressed in Mg/m^{3}, which is numerically the same as g/cm^{3}.

Specific Gravity

This is a property of the mineral material forming soil grains; it was determined on the lateritic clay sample in accordance to BS1377:1990 Part 2:8 and carried out in the Geotechnical Laboratory of Landmark University.

Sieve Analysis (Particle Size Distribution)

This was done on the lateritic clay sample in accordance to BS1377:1990 Part 2:9 and was carried out in the Geotechnical Laboratory of Landmark University.

Unconfined Compressive Strength Test

Unconfined compression test was determined on the lateritic clay samples and stabilized lateritic clay samples according to BS1377:1990 Part 7:7 using the tri-axial machine in the Geotechnical Laboratory of Landmark University.

COMPACTION

Compaction is the process of packing soil particles more closely together by rolling or other mechanical means, thus increasing the dry density of the soil. It was determined on the lateritic clay samples and stabilized lateritic clay samples according to BS1377:1990 Part 4:3 using a cylindrical metal mould, a metal rammer and a weighing balance. The compaction test was conducted in the Geotechnical Laboratory of Landmark University.

CALIFORNIA BEARING RATIO (CBR)

CBR (expressed as a percentage) was determined on the lateritic clay samples and stabilized lateritic clay samples according to BS1377:1990 Part 4:7 using the CBR machine in the Geotechnical Laboratory of Landmark University.

RESULTS AND DISCUSSIONS

CLASSIFICATION TESTS

The results of the classification tests which include the natural moisture content, specific gravity, density, particle size distribution and Atterberg limits test are presented and discussed below.

Natural Moisture Content

The results of the tests to determine the natural moisture content of the soil sample is presents in the Table 4.1. The test was done in four trials and the average natural moisture content of the soil was calculated as 10%.

Table 1 Natural Moisture Content.

Weight of can (g)	Weight of wet sample + can (g)	Weight of dry sample + can (g)	Moisture Content (%)
13.5	28	26.5	12
13.5	32.5	31	9
13.5	29	27.7	9
13.5	30.5	29	10
			10

Specific Gravity

The results of the specific gravity which describes hoe heavy the soil sample is compared to water is presented in Table 4.2. The test which was done in triplicate showed that the average specific gravity was 2.36.

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Table 2 Specific gravity of laterite soil before stabilization.

Trials	1	2	3
Weight of empty Pycnometer. (M_1)	16.0g	16.0g	16.0g
Weight of Pycnometer + Soil sample (M_2)	32.0g	35.0g	30.0g
Weight of Pycnometer + Soil sample + Water (M_3)	76.5g	78.0g	76.0g
Weight of Pycnometer + Water only. (M_4)	67.5g	67.5g	67.5g
Specific Gravity =	2.29	2.24	2.55
Average	2.36		

$$\frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Density

The results of the ratio of the mass to the volume of the soil otherwise referred to as density is presented in Table 4.3. The test was done in triplicate and the average bulk density of the lateritic clay soil sample was calculated as 1,130.52kg/m^3

Table 3 Bulk density

Trials	1	2	3
Weight of empty mould (kg)	4.338	5.046	4.949
Weight of mould + soil (kg)	5.402	6.146	6.007
Weight of soil (kg)	1.064	1.100	1.058
Volume of mould (m^3)	0.00095	0.00095	0.00095
Bulk density (kg/m^3)	1,120.00	1,157.89	1,113.68
Average	1,130.52kg/m^3		

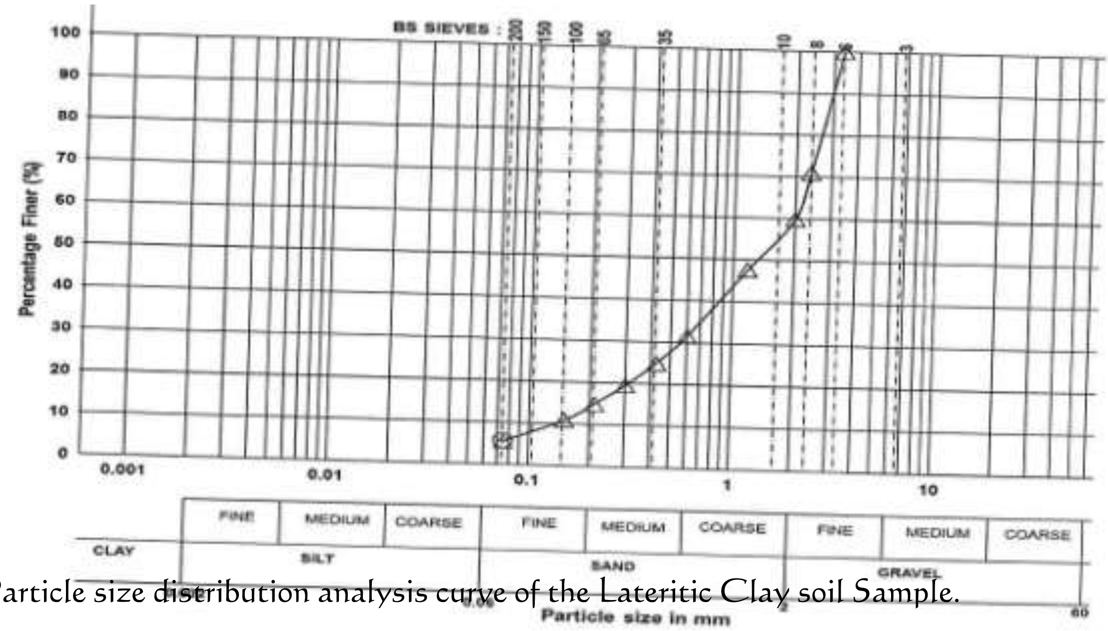
PARTICLE SIZE DISTRIBUTION

All soils are made up of particles of various sizes, it is convenient to classify them in terms of these characteristics. This is done by the observation of the particle-size distribution of a given weight of soil. This would show what percentage (by mass) of each size is present in the material. The resulting distribution is presented in Table 4.4 and plotted on the chart in Figure 4.1.

Table 4 Particle Size Distribution Result of the Lateritic Clay Soil Sample

Sieve No (mm)	Percentage Passing
4.75	100.00
2.36	70.90
2	59.70
1.18	47.55
0.6	31.50
0.5	24.90
0.425	19.45
0.212	14.90
0.150	10.80
0.075	5.5
Pan	0.00

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com



Particle size distribution analysis curve of the Lateritic Clay soil Sample.

Atterberg's Limit Test

The result of the Atterberg limit test on the lateritic clay soil sample soil sample showed that the liquid limit was 40, the plastic limit was 25.6 and the plasticity index was 14.4. From the particle size distribution curve in Figure 4.1,5.5% of the soil passed through sieve No. 200. The soil sample could therefore be classified as an A-2-6 soil according to the American Association of Highway Transportation Officials (AASHTO) and as a SC (Clayey sand) soil according to the Unified Soil Classification System (USCS).

Results of Atterberg's Limits Tests on Stabilized Soil Samples

The result of the atterberg limit tests carried out on the stabilized soil samples to access the efficiency of the stabilizing binder used is presented in this section. Three forms of stabilizing binders which include cement, mixture of cement and eggshell powder and eggshell powder were used to stabilize the lateritic clay soil. The results are below:

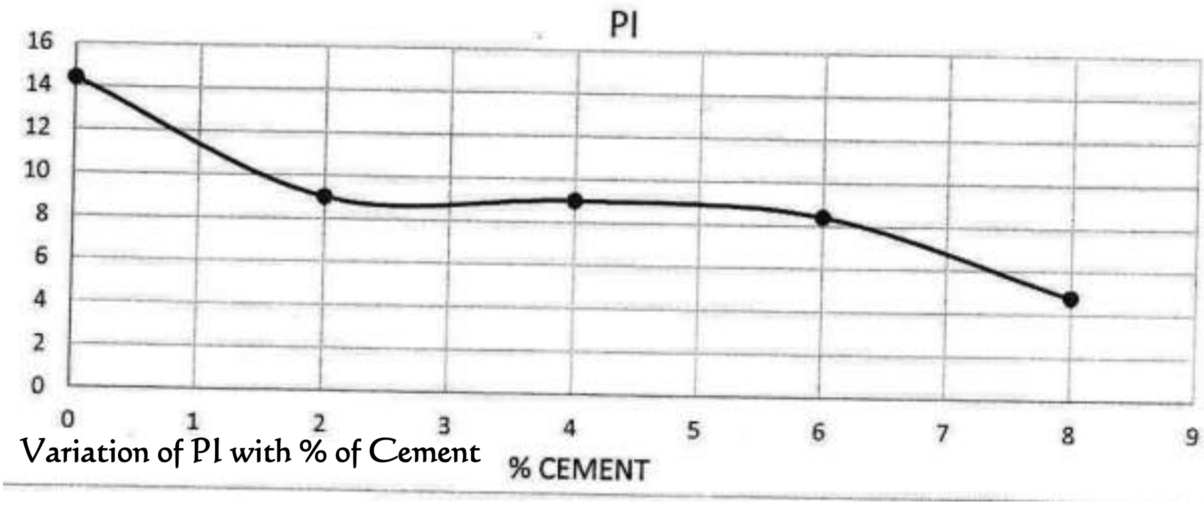
Atterberg limits test on lateritic clay sample stabilized with cement only.

The moisture content of a soil sample is necessary in accessing the suitability of the sample as a highway material. The results of the Atterberg limit on the cement stabilized soil sample is shown in Table 4.5 and plotted in figures 4.2-4.4.

Table 5 Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of cement stabilized

% CEMENT	LL	PL	PI
0	40	25.6	14.4
2	33	24	9
4	32	23	9
6	30.5	22.1	8.4
8	26	21.2	4.8

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com



Variation of PI with % of Cement

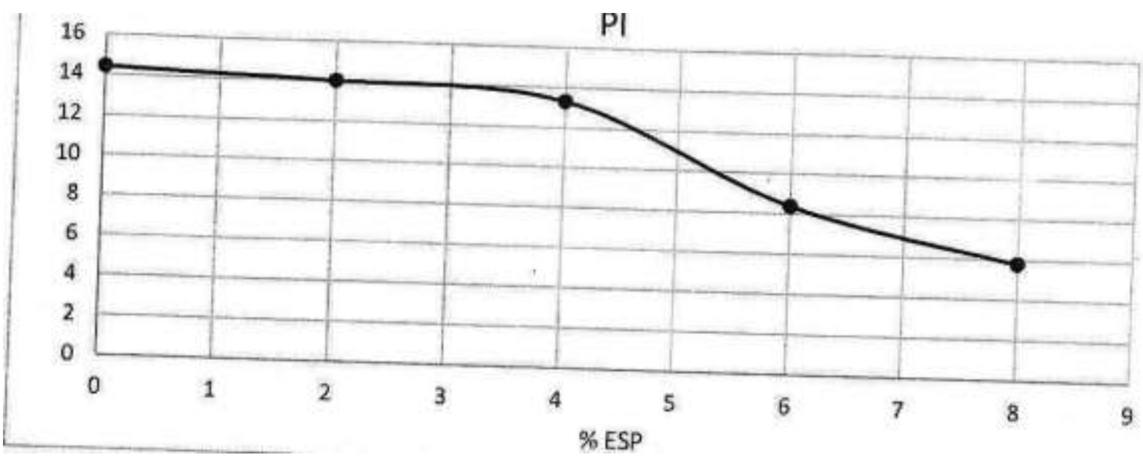
From the results displayed in Figures 4.2 –4.4. It showed that all the Atterberg limits and index including the liquid limit (LL), plastic limit (PL) decrease with an increase in cement added to the soil samples. This decrease may be due to flocculation and agglomeration arising from cation exchange reactions where Ca^+ in the additives reactives reacted with ions of lower valence in the clay structure.

Atterberg limits test on latertic clay sample stabilized with eggshell powder only.

The results of the Atterberg limit on the eggshell powder (ESP) stabilized soil sample is shown in Table 4.6 and plotted in Figures 4.5-4.7.

Table 6 Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of eggshell stabilized soil samples.

%ESP	LL	PL	PI
0	40	25.6	14.4
2	39	25	14
4	36	22.7	13.3
6	35	26.6	8.4
8	32	26.2	5.8



Variation of PI with % of ESP.

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

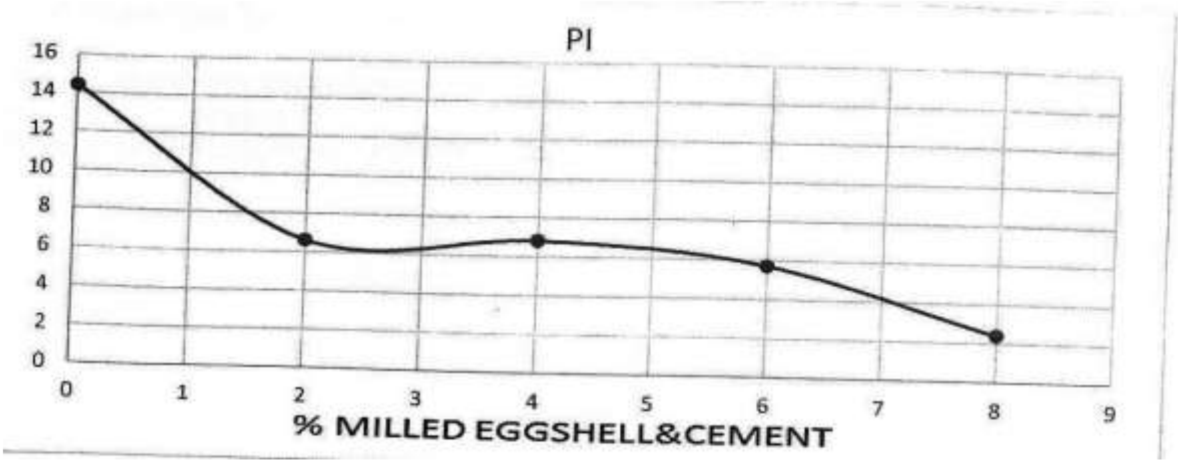
From the results displayed in Figures 4.5-4.7. it showed that liquid limit and the plasticity index decreses with an increase in eggshell powder (ESP) added to the soil samples. The plastic limit however increased with the 6 and 8% ESP addition to the soil. This increase may be due to the plastic nature of the eggshell.

Atterberg limits test on laterite clay sample stabilized with eggshell powder and cement

The results of the Atterberg limit on the soil sample stabilize with cement and eggshell powder in a ratio 1:1 is shown in Table 4.7 and plotted in Figures 4.8-4.10.

Table 7 Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of eggshell and cement stabilized soil samples.

%CEMENT % ESP	LL	PL	PI
0	40	25.6	14.4
2	30	23.4	6.6
4	30	23.2	6.8
6	20	14.3	5.7
8	17	14.6	2.4



Variation of PI with % of Cement & ESP.

From the results displayed in Figures 4.8-4.10. It showed that all the Atterberg limits and Index including the liquid limit (LL), plastic limit (PL) and plasticity index (PI) decrese with an increase in the mixture of eggshell powder and cement added to the soil samples. The decrease in the atterberg limit was more pronounced than when only cement was added to the soil sample. This decrease may be due to flocculation and agglomeration arising from cation exchange reactions where Ca^+ in the additives reacted with ions of lower valence in the modified soils met the requirements of the Nigerian General Specifications of not more than 33% passing sieve No. 200, maximum plasticity (PI) index of 30% and liquid limit (LL) of a maximum of 50% for a subgrade material in road construction.

Results of Compaction test on Stabilized Soil Samples

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

The results of the compaction tests carried out on the stabilized soil samples to access the efficiency of the stabilizing binder used is presented in this section. The three forms of stabilizing binders which include cement, Mixture of cement and eggshell powder and eggshell powder were also used to stabilize the laterite clay soil. The results are below:

Compaction Test Results on Cement Stabilized Soil

The compaction test was used to determine the effect of cement stabilizer on maximum dry density (MDD) and optimum moistur content (OMC) of the lateritic clay soil. The maximum dry density and optimum content of soil mized with varying proportions of cement are reported in Table 4.8 and Figures 4.11 and 4.12.

Table 8. Compaction test results on Cement stabilized soil.

% CEMENT	MDD	OMC
0	1750	17
2	1680	19
4	1600	21.9
6	1600	29
8	1250	32

The results displayed in Figures 4.11 and 4.12 showed that MDD decreased while OMC increased with an increase in percentage cement added to the soil samples. Similar behavior was observed by other researchers (Hossain *et al.*, 2007; Manasseh and Olufemi, 2008). The following reasons could explain this behavior: (1) the stabilizing binder causes aggregation of the particles to occupy larger spaces and hence alters the effective grading of the soils, (2) the specific gravity of cement generally is lower than the specific gravity of soils tested, (3) the pozzolanic reaction between the soil and the stabilizing for the increase in OMC.

Compaction Test Results on Eggshell Powder Stabilized Soil

The compaction test was used to determine the effect of eggshell powder as a stabilizing binder on the maximum dry density (MDD) and optimum moisture content (OMC) of the lateritic clay soil. The maximum dry density and optimum moisture content of soil mized with varying proportions of eggshell powder are reported in Table 4.9 and Figure 4.12 and 4.14.

Table 9 Compaction for Egg Shell Powder

% ESP	MDD	OMC
0	1750	17
2	1690	21
4	1430	25
6	1300	27
8	1280	31

The results displayed in figures 4.13 and 4.14 showed that MDD decreased while OMC increased with an increase in percentage of eggshell powder added to the soil samples.

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

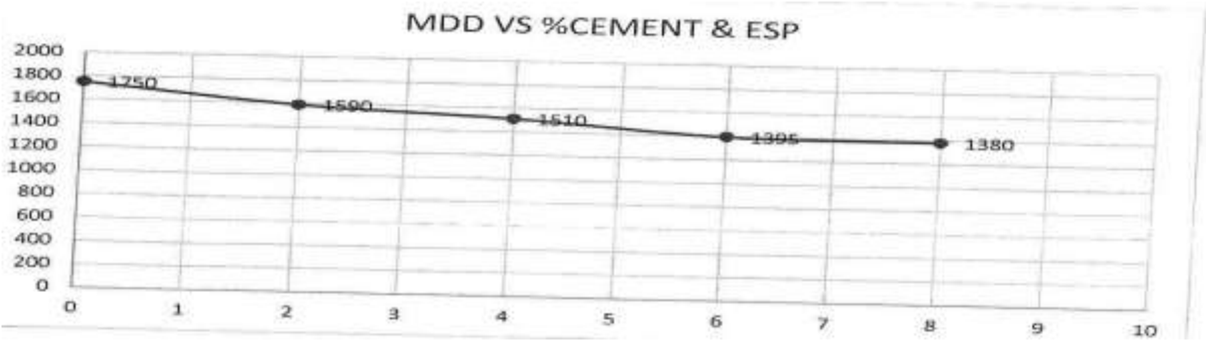
Similar behavior was observed by other researchers (Hossain *et al.*, 2007; Manasseh and Olufemi 2008). The following reasons could explain this behavior: (1) the stabilizing binder causes aggregation of the particles to occupy larger spaces and hence alters the effective grading of the soils, (2) the specific gravity of eggshell powder generally is lower than the specific gravity of soils tested, (3) the pozzolanic reaction between the soil and the stabilizing binder is responsible for the increase in OMC.

Compaction Test Results on Cement and Eggshell Powder Stabilized Soil.

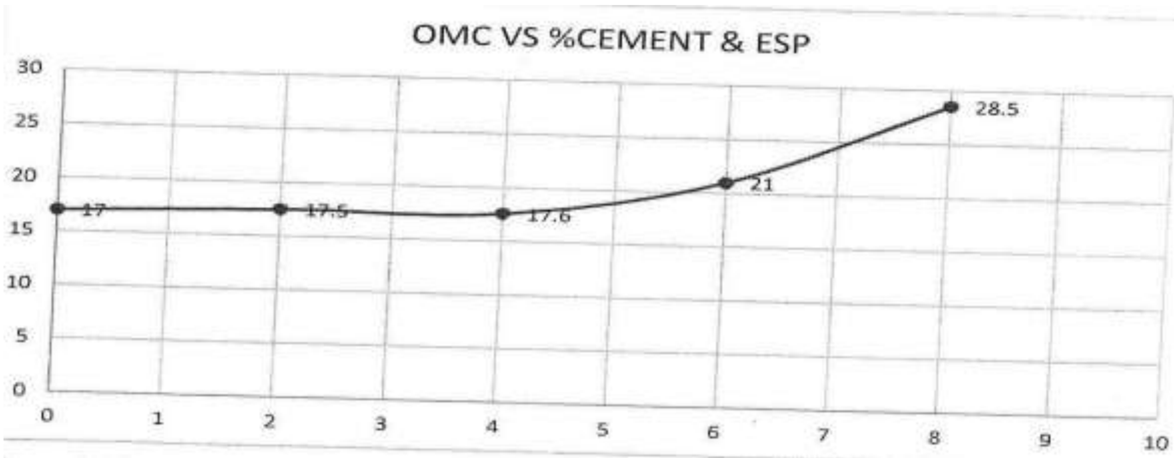
The compaction test was used to determine the effect of the mixture of cement and eggshell powder as a stabilizing binder on the maximum dry density (MDD) and optimum moisture content (OMC) of the lateritic clay soil. The maximum dry density and optimum moisture content of soil mixed with varying proportions of the mixture of cement and eggshell powder are reported in Table 4.10 and Figures 4.15 and 4.16.

Table 10 Compaction for Cement & ESP.

% CEMENT & ESP	MDD	OMC
0	1750	17
2	1590	17.5
4	1510	17.6
6	1395	21
8	1380	28.5



Variation of MDD with Varying % of Cement & ESP



Variation of OMC with Varying % of Cement & ESP

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

The results displayed in Figures 4.15 and 4.16 showed that MDD decreased while OMC increased with an increase in percentage of cement and eggshell powder added to the soil samples. Similar behavior was observed by other researchers (Hossain *et al.,* 2007; Manasseh and Olufemi 2008). The following reasons could explain this behavior: (1) the stabilizing binder causes aggregation of the particles to occupy larger spaces and hence alters the effective grading of the soils, (2) the specific gravity of the cement and eggshell powder mixture generally is lower than the specific gravity of soils tested, (3) the pozzolanic reaction between the soil and the stabilizing binder is responsible for the increase in OMC.

Results of Unconfined Compressive Strength Test (UCS) on Stabilized Soil Samples.

The results of the unconfined compressive strength (UCS) test carried out on the stabilized soil samples to access the efficiency of the stabilizing binder used is presented in this section. The three forms of stabilizing binders which include cement, mixture of cement and eggshell powder and eggshell powder were also used to stabilize the lateritic clay soil. The results are below:

Unconfined Compressive Strength Test Results on Cement Stabilized Soil

The unconfined compressive strength (UCS) test was used to determine the effect of cement stabilizer on the strength of the lateritic clay soil. The UCS values of soil mixed with varying proportions of cement are reported in Table 4.11 and Figures 4.17.

Table 11. UCS for Cement

%CEMENT	UCS(kn/m^2)
0	89.1
2	121.1
4	149.6
6	159.3
8	167.4

Variation of UCS values with varying % of Cement.

The results in Figure 4.17 showed that adding cement from 0% to 8% increased the UCS value of soil from 89.1 Kn/m^2 (UCS of natural soil) to 167.4kN/m^2. The results were in the same range as those reported by Muthukumar and Tamilarasan (2014). From chemical viewpoint with geotechnical considerations, when the cement was mixed with lateritic clay soil, reactions occur via two distinct processes (i) ion exchanged reactions known as modification and (ii) soil-cement pozzolanic reactions known as stabilization. These mechanisms are responsible for the improvement in the UCS of soil-cement mixtures.

Unconfined compressive strength Test Results on Eggshell Powder Stabilized Soil

The unconfined compressive strength (UCS) test was used to determine the effect of eggshell powder on the strength of the lateritic clay soil. The UCS values of soil mixed with varying proportions of eggshell powder are reported in Table 4.12 and Figures 4.18.

Table 12 UCS for Eggshell Powder

%ESP	UCS(kN/m²)
0	89.1
2	101.7
4	107.8
6	114.8
8	130

Variation of UCS values with varying % of ESP.

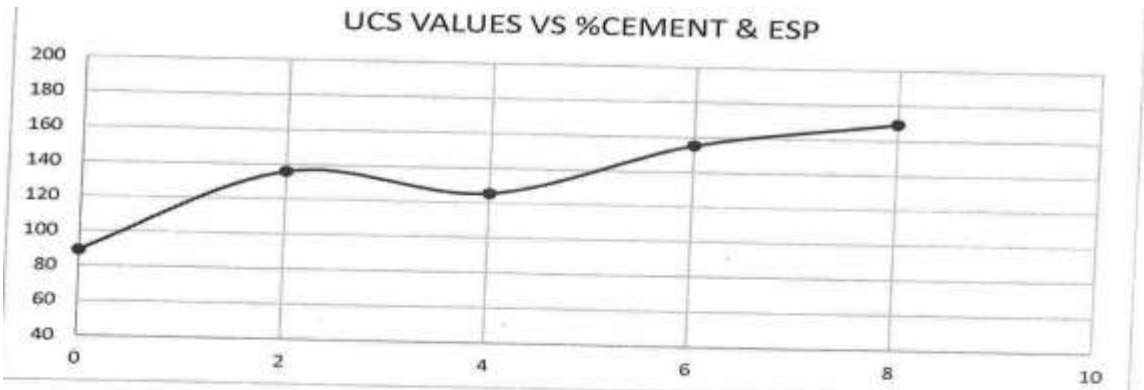
The results in Figure 4.18 showed that adding eggshell powder from 0% to 8% increased the UCS value of soil from 89.1kN/m² (UCS of natural soil) to 130 kN/m² . the results were in the same range as those reported by Muthukumar and Tamilarasan (2014). From chemical viewpoint with geotechnical considerations, when the eggshell powder was mixed with lateritic clay soil, reactions occur via two distinct processes (i) ion exchange reactions known as modification and (ii) slower soil-eggsehll powder pozzolanic reactions known as stabilization. These mechanisms are responsible for the slight improvement in the UCS of soil-eggshell powder mixtures.

Unconfined compressive strength Test Results on Cement and Eggshell Powder Stabilized Soil

The unconfined compressive strength (UCS) test was used to determine the effect of the mixture of cement and eggshell powder on the strength of the lateritic clay soil. The UCS values of soil mixed with varying proportions of the mixture of cement and eggshell powder are reported in Table 4.13 and Figures 4.19.

Table 13 UCS for Cement & ESP.

%CEMENT & ESP	UCS
0	89.1
2	135.9
4	125.5
6	155.1
8	169.1



International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Variation of UCS values with varying % of Cement & ESP

The results in Figure 4.19 showed that adding the mixture of cement and eggshell powder from 0% to 8% increased the UCS value of soil from 89.1kN/m^2 (UCS of natural soil) to 169.1 kN/m^2. The results were in the same range as those reported by Muthukumar and Tamilarasan (2014). The UCS value (169.1 kN/m^2) of the 8% mixture of cement and eggshell powder added to the lateritic clay was the highest of all the stabilizing binder used in this study. This value falls short of 1710 kN/m^2 specified by TRRL (1977) for base materials stabilization using ordinary Portland cement. And this value also fails to meet the requirement of 687-1373 kN/m^2 for sub-base as specified by Ingles and Metcalf (1972). However, the 8% mixture of cement and eggshell powder added to the lateritic clay may be suitable for use as a subgrade material.

Results of California Bearing Ratio (CBR) on Stabilized Soil Samples

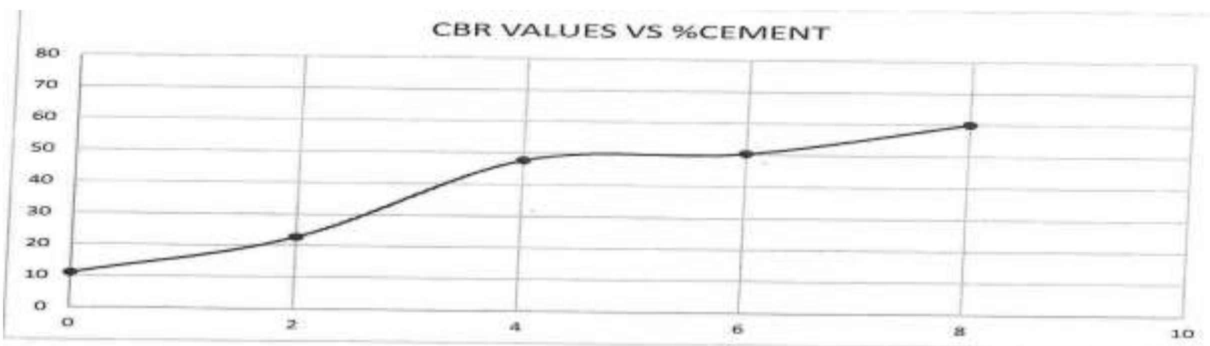
The California Bearing Ratio (CBR) test is a relatively simple test that is commonly used to obtain an indication of strength of a subgrade soils, subbase and the base course materials for use in road and airfield pavement design (Liu and Evett, 2003). The results of the Unsoaked Califoenia Bearing Ratio (CBR) tests carried out at the MDD and OMC on the stabilized soil samples to access the efficiency of the stabilizing binder used is presented in this section. The three forms of stabilizing binders which include cement, mixture of cement and eggshell powder and eggshell powder were also used to stabilize the lateritic clay soil. The results are below:

California Bearing Ratio Test Results on Cement Stabilized Soil

The California Bearing Ratio (CBR) test was used to determine the effect of cement stabilizer on the strength of the compacted latertitic clay soil. The CBR values of soil mixed with varying proportions of cement are reported in Table 4.14 and Figures 4.20

Table 14 CBR for Cement

%CEMENT	CBR (%)
0	10.9
2	22.7
4	47.6
6	50.3
8	60



International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Figure 4.20. Variation of CBR values with varying % of Cement

The results in Figure 4.20 showed that adding cement from 0% to 8% increased the CBR value of soil from 10.9% (CBR of natural soil) to 60%. The increase in the CBR value could be attributed to the cementitious nature of the binder.

California Bearing Ratio Test Results on Eggshell Powder Stabilized Soil

The California Bearing Ratio (CBR) test was used to determine the effect of eggshell powder on the strength of the lateritic clay soil. The UCS values of soil mixed with varying proportions of eggshell powder are reported in Table 4.15 and Figures 4.21.

Table 15 CBR for Egg Shell Powder.

% ESP	CBR(%)
0	10.9
2	22.5
4	33
6	43.3
8	58.9

Variation of CBR values with varying % of ESP

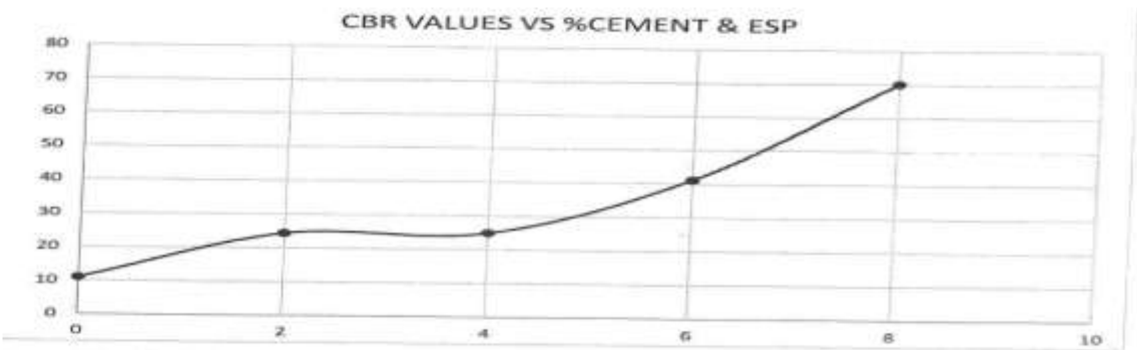
The results in Figure 4.21 showed that adding eggshell powder from 0% to 8% increased the CBR value of soil from 10.9% (CBR of natural soil) to 58.9%. The increase in the CBR value could be attributed to the cementitious nature of the binder.

California Bearing Ratio Test Results on Cement and Eggshell Powder Stabilized Soil

The California Bearing Ratio (CBR) test was used to determine the effect of the mixture of cement and eggshell powder on the strength of the lateritic clay soil. The CBR values of soil mixed with varying proportion of the mixture of cement and eggshell powder are reported in Table 4.16 and Figures 4.22.

Table 16 CBR for Cement & ESP.

%CEMENT & ESP	CBR (%)
0	10.9
2	24.4
4	24.9
6	41.1
8	70.1



International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Variation of CBR values with Varying % of Cement & ESP

The results in Figure 4.22 showed that adding the mixture of cement and eggshell powder from 0% to 8% increased the CBR value of soil from 10.9% (CBR of natural soil) to 70.1%. This CBR value was the highest of all the stabilizing binder used in this study. This value falls short of 80% minimum (unsoaked) for road base materials specified by Federal Ministry of Works and Housing (FMW&H, 1997). Although soaked CBR was not performed in this study (To determine the soaked CBR value, soil sample needs to be soaked in water for at least 4days prior to the test. Thus to complete soaked CBR test it requires at least 5days which is time consuming and a tedious process), the values of the soaked CBR of the mixture of cement and eggshell powder may meet the 30% minimum (soaked) for sub-base materials and 10% minimum (soaked) for subgrade soil. However an increase in the percentage of the mixture of cement and eggshell powder could have increased the CBR value to the minimum required value for unsoaked.

Results of Microstructural Analysis on stabilized Soil Samples

Microstructural analyses (using the Scanning Electron Microscope [SEM]) were performed on the lateritic clay, the eggshell powder and the lateritic clay soil stabilized with 8% eggshell powder. Figures 4.23-4.25 showed the SEM images of the samples that were analyzed. Figure 4.23a and b showed the micrograph of the lateritic clay at different magnifications. The latertic clay sample consists of closely knitted fabrics (agglomerate) as shown in Figure 4.23a. At a higher magnification, Figure 4.23b showed that the soil samples contain some pores. However, the micrograph of the lateritic clay soil stabilized with 8% eggshell powder displayed in Figure 4.25 indicated that the soil particles were bonded more closely than the natural lateritic clay sample and the pore spaces filled. This microstructural characteristic also explains an increase in the mechanical (strength) properties of the stabilized samples.

CONCLUSION

The study was conducted to stabilize clayey soil using various stabilizing binders which include cement, and eggshell powder. A series of laboratory tests that included basic geotechnical tests on the collected clayey soil sample, compaction and strength tests were performed on the sample mixtures to evaluate the effectiveness of the stabilization process. Based on the laboratory tests, the following conclusions were drawn:

- The clayey soil sample collected was an A-2-6 soil according to the American Association of Highly Transportation Officials (AASHTO) and as a SC (Clayey send) soil according to the Unified Soil Classification System (USCS). The clayey soil natural moisture content was 10% and specific gravity of 2.36 and a bulk density of 1,130.52kg/m^3 . Atterberg limits were 40% and 25.6% respectively for the liquid limit and plastic limit.

- The Plasticity of the stabilized samples decreased with increase in the stabilizer content a decrease in soil plasticity gives an indication of a more stable with marked increased workability.
- The compaction test showed that increase in the quantity of the stabilizing binder decrease the maximum dry density of the soil and increase the optimum moisture content of the soil.
- The strength of the stabilized soils gotten from the UCS and CBR values of the varying amount of stabilizing binder on the soil showed that the strength of the samples were increased with an increase in the amount of stabilizing added.
- The mixture of eggshell powder and cement was more effective in stabilizing the soil sample tham cement alone or eggshell powder alone in this research work.

RECOMMENDATION

As a result of the outcome of this study, it is recommended that proper attention must be given to our highways by looking for innovative methods to improve the properties. More laboratory test should be performed to determine the feasibility and durability in the use of cement and eggshell powder as a soil stabilizer. Afterwards the soil stabilizer can be tested on the field so that it can be used for large scale highway construction.

CONTRIBUTION TO KNOWLEDGE

This research work had established the extent to which agricultural wastes like milled egg shell can be used alongside cement for the stabilization of clay soil. An improvement in the index and strength properties of soil by addition of ESP will help to find an application for waste materials to improve the properties of soil and can be used as a better stabilizing agent. Furthermore it will also give other researchers a vague indication on the exploration and utilization of several other waste in civil engineering, and in turn improving the environments.

REFERENCES

Ahmad, M., Lee, S.S., Yang J.E., Ro, H.M., Lee, Y.H., & Ok, Y.S. (2012). Effect of soil dilution and amendments (mussel shell, cow bone, and biochar) on Pb availability and phytotoxicity in military shooting range soil, Ecotoxicology and Environmental Safety, 79, 225-231.

Alsawaiha, M. (2012). Insturmental Characterization of Clay by FTIR, XRF, BET and, TPD-NH3, In International Confernce on Agriculture, Chemical and Environment Sciences (ICACES2012), Dubai Oct (pp.6-7).

Amu, O.O., Fajobi, A. B., & Oke, B.O. (2005). Effect of eggshell powder on the stabilizing potential of lime on an expansive clay soil. Applied Science, 5, 1474-1478.

Amu, O.O., Ogunniyi, S.A., & Oladeji, O.O. (2011). Geotechnical properties of lateritic soil stabilized with sugarcane straw ash. American hournal of Scientific and Industrial Research, 2(2), 323-331.

Bakhtayar, R., Brovelli, A., barry, D.A., Robinson, C., & Li, L. (2013). Transport of variable-density solute plumes in beach aquifers in response to oceanic forcing Advances in Water Resources, 53, 208-224.

Barazash, A., Saba, H., Gharib, M., & Rad, M. Y. (2012). Laboratory Investigation of the Effect of Eggshell powder on Plasticity Index in Clay and Expansive Soils. European Journal of Experimental Biology, 2(6), 2378-2384

Daengrok, W., Garnjanagoochorn, W., & Mine, Y. (2002) Fermented pork sausage fortified with commercial or hen eggshell calcium lacate. Meat science, 62(2), 199-204.

Gajera, D.S.K. (2015). A review of utilization of egg shell waste in concrete and soil stabilization. Medical Science, 67-69.

Gowsika, D., Sarankokila, S., & Sarguman, K. (2014). Experimental investigation of egg shell powder as partial replacement with cement in concrete. Interntional Journal of Engineering Trends and Technology, 14(2), 64-68.

Grim, R.E. (1962). Clay mineralogy. Science, 135(3507), 890-898.

Hossain, K.M.A., Lachemi, M. and Easa, S. (2007). Stabilized soils for construction application incorporating natural rsources of Papua New Guinea, Resources, Conservation and Recycling, 51, 711-731.

Ing, D.S., & Choo, C.S. (2014). Eggshell Powder: Potential Filler in Concrete.

Ingles, O.G. and Matcalf, J.B. (1972). Soil Stabilization Principles and practices, Butterworths, Sydney.

Lee, S.S., Lim, J. E., El-Azeem, S.A.A., Choi, B.,Oh, S.E., Moon, D.H., & Ok, Y.S. (2013). Heavy metal immobilization in soil near abandoned mines using eggshell waste and rapessed residue, Environmental Science and Pollution Research, 20(3), 1719-1726.

Liu, C. and Evett, J. (2003). Soils and Foundation, 6th ed. USA: Prentice Hall.