Characterictics Of Egg Shell Powder Stabilized Lateritic Soil

[1]Oluyemi-Ayibiowu, B. D., [2]Adetukasi, A. O., [1]Fadugba, O. G. and [1]Uduebor, M. A.

[1]Dept. of Civil and Environmental Engineering, The Federal University of Technology, Akure, Nigeria.
[2]Dept. of Civil Engineering, Yaba College of Technology, Yaba, Lagos, Nigeria.
*Corresponding Author Email: olaolufadugba@yahoo.com

Abstract: The process whereby natural chemicals synthetic materials are added to soil to improve the soil properties is known as soil stabilization. A lateritic soil classified as sandy clay (CL) and A-6 (4) according to Unified Soil Classification System (USCS) and AASHTO classification system respectively, was treated with up to 8% eggshell powder to assess its suitability and determine the optimal percentage stabilization. Eggshells are waste of poultries, homes and fast food industries and its components have been discovered to contain calcium compounds as lime and can therefore be used in soil stabilization. Tests were carried out to determine the index properties, compaction characteristics (maximum dry density, MDD and optimum moisture content, OMC), and strength characteristics (California bearing ratio, CBR). Test results show that the Atterberg limits (liquid limit, plastic limit and plasticity index) generally decreased, MDD and OMC increased and decreased respectively with higher eggshell content. Generally, CBR increased from 6.2 % for 0% eggshell powder content up to 37.7 % for 6% content before slightly decreasing at 8% to 31.5% CBR. Based on laboratory test CBR values at 6 % optimal stabilization content was achieved.

[Oluyemi-Ayibiowu, Adetukasi, Fadugba, and Uduebor. **Characterictics Of Egg Shell Powder Stabilized Lateritic Soil.** *Academ Arena* 2019;11(4):16-21]. ISSN 1553-992X (print); ISSN 2158-771X (online). http://www.sciencepub.net/academia. 3. doi:10.7537/marsaaj110419.03.

Keywords: Eggshell Powder; Stabilization; Lime; Poultry Waste;

1. Introduction

For stability of any land-based structure such as earth dams, bridges, roads, building structures, etc., the foundation plays a very critical role and has to be strong enough to support the entire structure. In order for the foundation to be strong, proper knowledge about the geotechnical properties of the soil, factors which affect their behavior and how to alter them to suit the requirements for the engineering structures are highly essential. Some of the soils encountered on site may not be directly suitable for use due to their poor strength characteristics, so, when such occurs, the engineer is left with choice of borrowing a suitable material or improving on the strength of the available one (Oluyemi-Ayibiowu and Owolabi, 2003). Soil stabilization is a process whereby natural, synthetic or chemical materials are added to soil to improve the soil properties (Muthu and Tamilarasan, 2014). It is typically used to modify and improve low-quality materials, which brings about changes in soil properties including decreased rate of subsidence, decreased adhesion coefficient in soils with high cohesion (clay), increased adhesion coefficient in soils with low cohesion (sand), reduced percentage of water absorption and prevention of soil expansion, reduced cost of earth structures (transport), speed up road construction operations, resistance to frost and defrost, improved ductility, reduced rigidity of earth structures, lack of weed growth in the surface of earth structures such as roads and reduced thickness of bearing layer (Muthu and Tamilarasan, 2014).

The two general methods of stabilization are mechanical and additive. In mechanical method of soil stabilization, improvement of soil engineering properties is done by the addition of other soil particles which alters its natural grading (Olarewaju *et al.,* 2011). The additive method of soil stabilization refers to a manufactured commercial product that when added to the soil in the proper quantities will improve the quality of the soil and soil layer. These products are Portland cement, lime, lime-cement-fly ash, bitumen, alone or in combination. According to Olarewaju *et al*., (2011), the use of stabilization agents like cement, lime and bitumen proves expensive and requires an economic replacement and this has led to research into the use of alternative materials to complement the conventional ones. It has been shown that eggshell primarily contains lime, calcium and protein. It has found its use as a source of lime in the agricultural industry, which confirms that lime is present in considerable amounts in eggshell.

Eggshells are waste materials from hatcheries, homes and fast food industries (Phil and Zhihong, 2009; Amu *et al*., 2005) and can be readily collected in plenty. Egg shells are disposal of poultry, homes and fast food industry which has contributed to environmental pollution.

Thus in this research, the possible use of egg shell powder in soil stabilization was studied. This will considerably reduce the cost of earthworks in roadworks if found suitable and it will also reduce the quantity of waste disposal in the environment and provide an economical alternative to soil strength improvement.

The primary aim of this research is to study the effectiveness of egg shells powder for soil stabilization.

A very large area is covered by expansive soils in Nigeria, and due to rapid population growth and industrialization of the country, land is becoming scarce, and to meet the human needs, the cost of rehabilitation and retrofitting of the Civil Engineering structures founded over these soils are increasing day by day. On the other hand, the safe disposal of egg shell powder from poultry, homes and fast food industries has been a challenging issue demanding urgent solution because of the declining effect of these materials on the environment. However, production of cement requires limestone and with the rate at which we are utilizing cement, the day is not so far off when the limestone mines will get depleted. It is a matter of fact that for every 1 kg of cement manufactured, 1 kg of carbon dioxide is released into the atmosphere, which in turn increases the carbon footprint and also poses serious threat to the global warming. Thus there is a need to find an alternative binder, which is environmental friendly, available, economical and suitable.

Soil stabilization is a technique used for improving a soil's strength and involves different methods and additives. The conventional methods have become uneconomical for different additives. Cement which has limestone as a major raw material is preferred due to the cost of imported additives in Nigeria, and because Portland cement normally produce a greater increase in strength than comparable portions of lime (Olanrewaju et al., 2011). In addition, there are some soils that cannot be effectively stabilized with cement alone e.g Black Cotton soil, and thus the use of other available and cheaper materials are being looked into. Eggshell is available as waste all over the country, and thus, its use if found suitable will be helpful in reducing construction costs.

2. Materials And Method

Preliminary tests (natural moisture content, specific gravity, sieve analysis and Atterberg limits) were performed on the soil samples. Eggshell powder used in this research was collected from a fast food restaurant beside Bola International group of schools Alaba layout, FUTA south gate Akure, Ondo State, Nigeria. The eggshell collected were sun- dried and ground into powder to reduce its particle size down to less than 0.425 mm in order to allow for Atterberg limit tests to be performed and other engineering test. It was added to the soil samples in 2, 4, 6 and 8 % by weight of the samples. Atterberg limits and engineering property tests (compaction, California bearing ratio (CBR)) were performed on the samples with varied percentages of eggshell powder. The effects of eggshell powder as stabilizing agent on the samples were thereafter determined. The procedures for the various tests were carried out in accordance with BS 1377 (British Standards institution 1990) and BS 1924 (British Standards institution 1990).

3. Laboratory Test Results And Discussion

3.1. Characteristics of Natural and Stabilized Soil

The summary of the results of the geotechnical properties of the natural soil is presented in Table1. The natural moisture content and specific gravity of the soil were found to be 3.68% and 2.63 respectively. The specific gravity is within the range of 2.6 and 3.4, which was reported by Amadi, (2010) for lateritic soil. Table 2 shows the summary of the particle size distribution of the tested soil. Table 3 shows the results for the Atterberg limit with eggshell powder stabilization. Table 4 and Table 5 show the effect of eggshell powder on stabilized soil for Proctor compaction test and CBR on tested soil respectively.

The particle sizes are 18.18% gravel, 17.53% coarse sand, 17.62% fine sand and 46.67% silt-clay (Table 2). Winterkorn and Chandrasekharen (1951) and Clare and O'Reilly (1960) specified the range of silt and clay contents in lateritic soils to be from 12 % to 82 %. That of this soil sample lies nearly half way within this specified range. For the Atterberg limit test results, LL, PL and PI are 40.2%, 23% and 17% respectively (Table 3). This indicates a soil with medium plasticity. The soil is classified as A-6(4) by the AASHTO system. The MDD and OMC are 1845kg/m^3 and 13.45% respectively. The rating of the soil is poor and cannot be used directly as sub-base and base layers of pavement as a result of the high silt-clay content present, which will cause high swelling and eventual pavement failure if used without any treatment.

On treating the soil with eggshell powder, the liquid limit, plastic limit and plasticity index all progressively decreased with progressive increment in percentage of eggshell content in the lateritic soil. This decrease can be seen for each of liquid limit, plastic limit and plasticity index in Figures 1, 2 and 3, respectively. The figures also show generated linear (model) equations for the variation of each of these parameters with the eggshell in the lateritic soil. The decreases in liquid limit, plastic limit and plasticity index with increases in eggshell powder content is due to the progressive increase in the amount of the silt-size particles in the mixture due to flocculation and agglomeration of clay and the consequent reduction of the amount of clay-size particles in the lateritic soil. These clusters of clay minerals in the soil and clay-size minerals in the eggshell are due to ion exchange at the surface of the soil particles which resulted in more stable silt-sand-like structures, making the mixture more workable (Akinwumi, 2012).

The change in OMC and maximum dry density weight with eggshell content can be seen in Figures 4 and 5, respectively. The maximum dry density of mixtures, expectedly increased with higher eggshell contents, although there was slight stability between 2 and 6% eggshell content while optimum moisture content decreased as the amount of eggshell in the mixture increased from 0 to 6 % before a slight increase for the 8% eggshell content. The increase in maximum dry density with increasing eggshell content is expected because when lateritic soil with specific gravity of 2.63 is mixed with eggshell of 1.09 specific gravity reported by Olarewaju *et al.,* (2011), the tendency is that the mixture tends to increase its dry unit weight.

Figure 6 indicates that the unsoaked CBR value for the soil-eggshell powder mixture progressively increased from 6.2% for the 0% eggshell powder content to 37% for 6% eggshell addition before a decrease to 31% for 8% eggshell powder content.

4. Conclusions And Reccommendation

4.1. Conclusion

The lateritic soil used in this study was classified as A-6 (4) by AASHTO system or CL by UCSC system. The natural soil is a sandy clay with approximately 47 % passing the BS No. 200 sieve, is of medium plasticity, low swelling potential, and CBR.

Test results generally indicate that the addition of eggshell powder reduced the plasticity of lateritic soil and thereby improved its workability and reduced its moisture-holding capacity and swell potential. The maximum dry density of the soil increased with increasing eggshell powder contents while optimum moisture content decreased as the amount of eggshell powder in the mixture increased from 0% to 8%. The uncured strength of the soil increased with increasing eggshell content until after 6% eggshell. Consequently, the optimum eggshell content was determined to be 6%, based on strength criterion. Therefore, at 6% eggshell content with CBR values of approximately 37%, optimal stabilization of the A-6 soil was achieved. The results obtained show that eggshell can be more profitably used as an admixture with a conventional stabilizer such as cement or lime in order to meet the requirement for use as sub-base material.

4.2 Recommendations

In view of the pozzolanic (strength gain with time) property of eggshell, 6% eggshell content optimal stabilization of the A-6 soil is suitable for use as sub-base material for lightly-trafficked (rural) road construction. Further investigation should be conducted to determine the effect of adding eggshell powder on some other lateritic soils within Akure and its environs.

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Table1: Geotechnical Properties of Natural Soil

S/N	SOIL PROPERTIES	VALUES
1	Natural Moisture Content (%)	3.68
2	Specific Gravity	2.63
3	Liquid Limit (%)	40.2
4	Plastic Limit (%)	26.5
5	Plasticity Index (%)	17
6	AASHTO Soil Classification System	A-6
7	Group Index	4
8	Unified Soil Classification System	CL
9	Maximum Dry Unit weight (kg/m^3)	1845
10	Optimum Moisture Content (%)	13.4
11	Unoaked CBR (%)	6.2
12	Colour	Brown

Table 2: summary of particle size distribution of the tested soil

Soil Composition	% Present
Gravel	18.18
Coarse Sand	17.53
Fine Sand	17.62
Silt-clay	46.67

Table 3: Summary of the Atterberg limit test results with Eggshell powder stabilization effects

PERCENTAGE STABILIZATION	LIQUID LIMIT (%),LL	PLASTIC LIMIT (%),PL	PLASTICITY INDEX (%),PI
0	40	23.57	16.43
2	33	25.32	7.68
4	30	24.57	5.43
6	27	23.34	3.65
8	25	20.20	4.80

Table 4: Summary of the compaction characteristics with eggshell powder stabilization effects

S/N	PERCENTAGE STABILIZATION (%)	OPTIMUM MOISTURE CONTENT (%), OMC	MAXIMUM DRY DENSITY (kg/m^3), MDD
1	0	13.6	1845
2	2	12.57	1860
3	4	12.4	1920
4	6	11.7	1910
5	8	12.6	1950

Table 5: Summary of CBR results with eggshell powder stabilization

S/N	PERCENTAGE STABILIZATION	CBR (%)
1	0	6.20
2	2	12.16
3	4	23.25
4	6	37.68
5	8	31.48

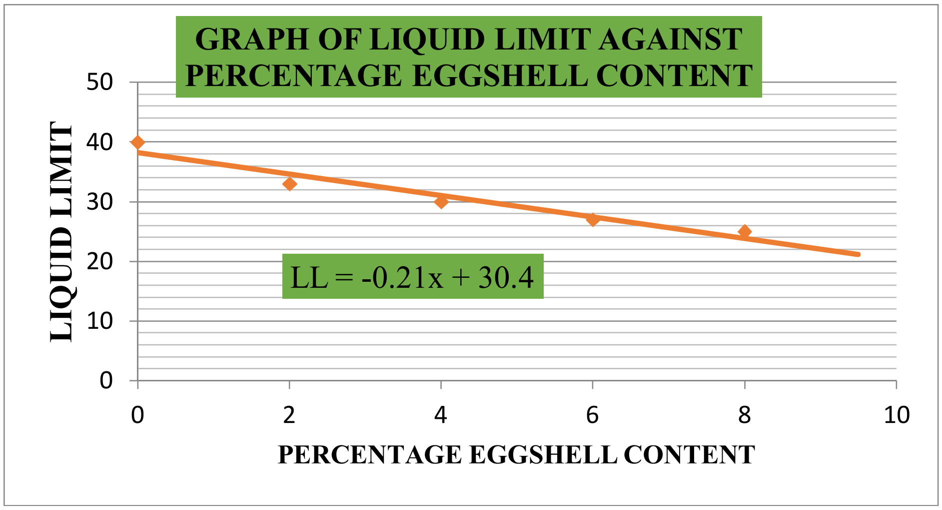

Figure1: Variation of liquid limit with percentage eggshell content

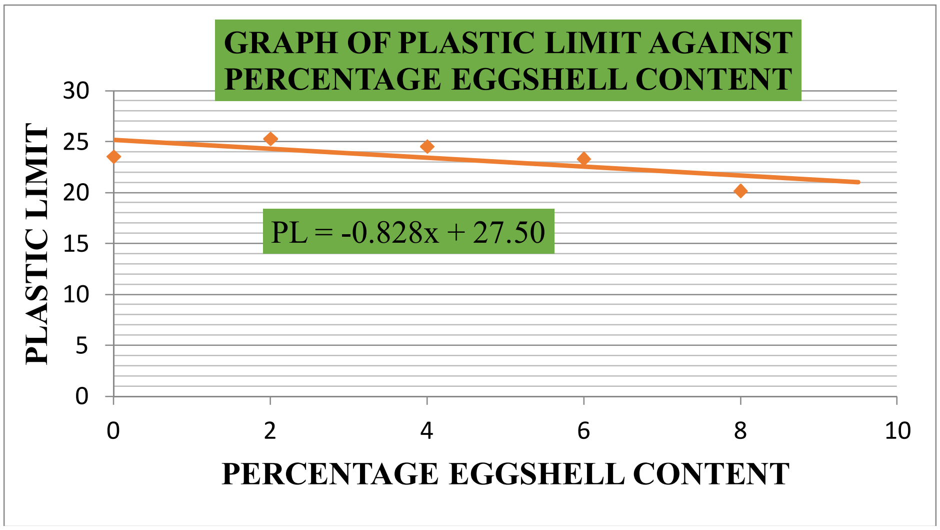

Figure2: Variation of plastic limit with percentage eggshell content

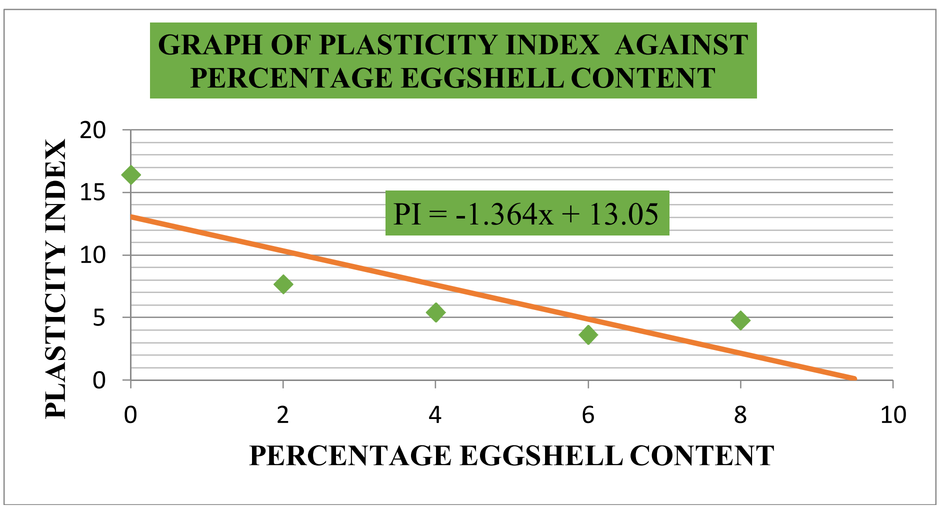

Figure3: Variation of plasticity index with eggshell content

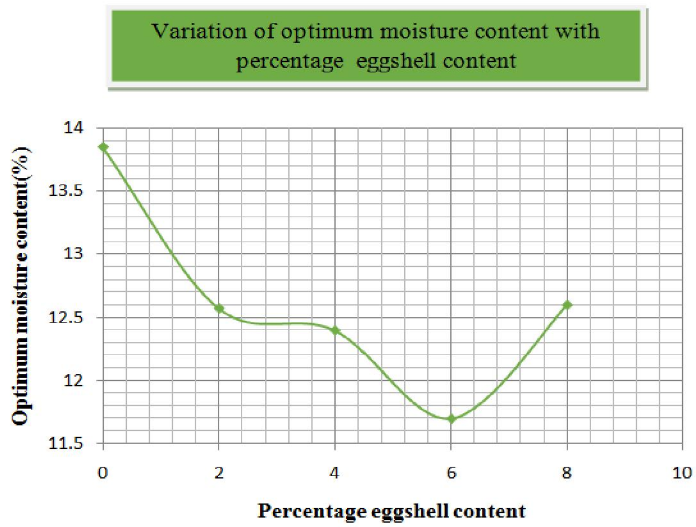

Figure 4: Variation of OMC with percentage eggshell content

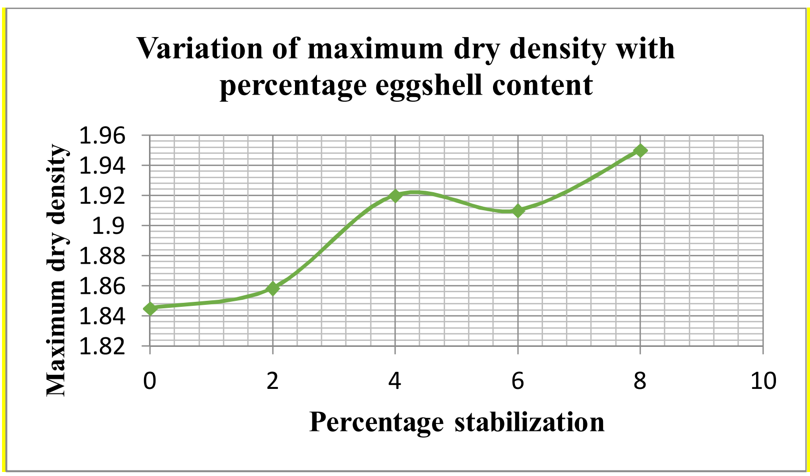

Figure5: Variation of MDD with percentage eggshell content

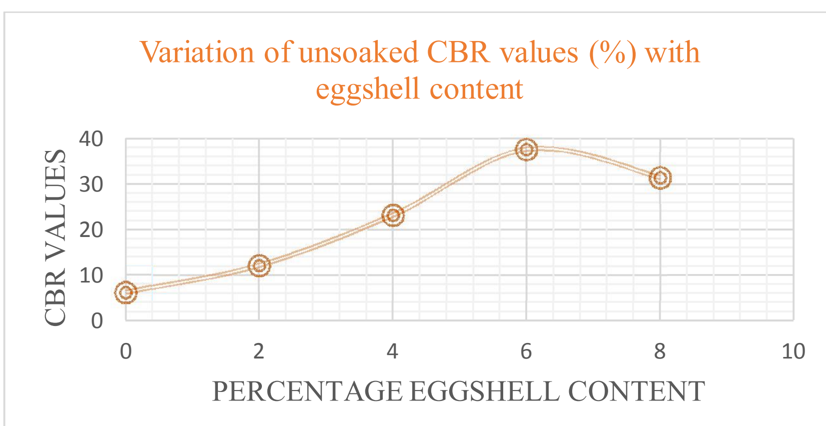

Figure 6: Variation of CBR with percentage eggshell content