International Journal of Physical Research, 10 (1) (2022) 33-38

SPC

International Journal of Physical Research

Website: www.sciencepubco.com/index.php/IJPR

Research paper

Investigation of properties of soils stabilised with groundnut waste

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Abstract

Improvement of soil strength has gained a wider and increasing acceptance in civil engineering applications. This study therefore investigated the effects of coarse content of groundnut shell ash on the properties of selected lateritic soils. To achieve the aim of the study, soil samples were collected from two identified active borrow pits. The following geotechnical tests were conducted on the soil samples in their natural state, using standard procedures: natural moisture content, specific gravity, grain size analysis, Atterberg limits, compaction and California bearing ratio. Subsequently, the soils were treated with coarse content (part retained on 425 µm BS sieve) of groundnut shell ash at 2 %, 4 % and 6 % proportions by weight of dry soil. Results showed that the degree of laterisation is high in the two soil samples, having specific gravity values of 2.84 and 2.72 respectively. Results of Atterberg limit tests and grain size analysis showed that the soils belong to A-2-7 using AASHTO classification system. 6 % groundnut shell ash gave the lowest plasticity index for first sample, while 2 % ground-nut shell ash gave the lowest plasticity index for second sample. Also, 2 % groundnut shell ash gave the lowest optimum moisture content for first sample, while 6 % groundnut shell ash gave the lowest optimum moisture content for the second sample. Similarly, 2 % groundnut shell ash gave the highest maximum dry density for first sample, while 4 % groundnut shell ash gave the highest maximum dry density for second sample The California bearing ratio reached a maximum value of 4 % at 6 % groundnut shell ash, for first sample; it increased to 14 % at 2 % groundnut shell ash, for second soil sample. The study concluded that lateritic soils can be modified with coarse component of groundnut shell ash.

Keywords: *Ash; Groundnut; Shell; Soil Properties; Soil Strength.*

1. Introduction

The importance of soils in civil engineering construction and applications cannot be over emphasized. For soils to be considered suitable for civil engineering work, the engineer seeks to ensure the suitability of the soil – reduction or elimination of expansive characteristic, high bearing capacity or strength. In the absence of soils with the required engineering qualities, engineers and researchers consider it useful and economical to consider the improvement of soils with the application of economical and easily available materials.

As a means of improving the geotechnical properties of lateritic soils, researchers have, over the years and variously, used lime and cement as stabilizing agents. It has been variously reported (Ola, 1983; Balogun, 1990; Osinubi, 1995; Osinubi, 1999) that appreciable improvements in the geotechnical properties of lateritic soils were observed when treated with lime and cement. Although the properties of the lime- and cement-stabilized soils were significantly improved, the implementation cost as a stabilizer is quite expensive. It is the cost implication that has aroused the thinking of researchers and engineers to focus more on the use of potentially cost effective materials that are locally available to improve the properties of deficient soils (Osinubi, 1998; Osinubi, 1999).

It is commonly accepted today in soil improvement work to examine the effects of local materials considered to be wastes or residues which actually do not connote worthless substances as they may be economically viable for construction purposes (Osinubi, 1998). One of the local materials been considered is the ash obtained from the combustion of groundnut shell, that is, groundnut shell ash (GSA). GSA is obtained from groundnut shell, which is an agricultural waste. It exhibits high shear strength, which is highly beneficial for its use as a geotechnical material with a good permeability and variation in water content which does not seriously affect its desirable properties (Sridharan et al, 2006).

The treatment of lateritic soil with GSA could be a viable way of reducing agricultural waste in the environment. GSA is a material that possesses pozzolanic as well as coarser contents in it, while other materials like fly ash possesses only pozzolanic property and no coarser soil particles.

According to Onyelowe (2012), GSA is considered as one of the well accepted as well as cost effective ground improvement agents for the stabilization of weak soil deposits. Tiza and Iorver (2016) reviewed some literature on the effects of agricultural solid wastes on stabilization of expansive clay. Various researches have investigated the effects of GSA on soils for civil engineering applications.

Sridharan et al (2006), conducted studies on the effect of GSA on the geotechnical properties of soil used in highway construction and concluded that the California bearing ratio (CBR) value steadily increased with increase in percentage of GSA and the improvement in CBR value could be as a result of the significant improvement in angle of shearing resistance.
Oriola and Moses (2010) studied GSA stabilization of black cotton soil. From the observations of the 7, 14 and 28 days unconfined compressive strength (UCS) of cured specimens, they found that GSA showed progressive strength development with longer curing periods.
George and Karibo (2014) stabilized Nigerian deltaic clay (chikoko) using GSA. They found that this soil, in its natural state, is characterized by low undrained shear strength, high Atterberg limits and natural water contents. It was observed that addition of GSA to the soil led to an increase in its UCS and CBR, with optimum at 3 % and 5 % GSA respectively.
Adetoro and Dada (2015) studied the potentials of GSA for stabilization of soil in Ekiti state, Nigeria. The soil sample was treated with GSA in 2 % to 10 % by weight of soil. Though the authors observed an improvement in soil properties, they recommended that GSA should be combined with other additive like cement for the formation of secondary cementitious compounds, which will be produced from the cement hydration.
Gajera and Thanki (2015) also did stabilization analysis of black cotton soil by using GSA. They observed that 10 % GSA content reduced the swelling potential and increased the strength of the soil.
Krisha and Shekun (2015) studied soil stabilization with the use of GSA and Waste Fibber Material (WFM) - polypropylene fibre. The soil was first stabilized with GSA at varying proportions of 3 %, 6 % and 9 %; and also with 0.05 %, 0.1 % and 0.15 % polypropylene fibre. It was observed that soil cohesion, angle of internal friction and UCS increased with increase in GSA content. The UCS also increased with increase in polypropylene fibre. The authors concluded that GSA and polypropylene fibre reinforcement can be considered as a good ground improvement technique.
Iorver et al (2016) investigated the effects of lime and GSA on some geotechnical properties of Makurdi shale. After conducting preliminary and strength tests on natural shale as well as shale treated with combined range of 2 – 10 % lime and 4 – 20 % GSA, the authors observed that there was an improvement in soil strength with the use of lime – GSA combination more than when the stabilizers were applied singly. They concluded that shale can be stabilized with lime + GSA for civil engineering applications.
Rashmi et al (2016) investigated the effects of GSA on expansive soil. They found that addition of GSA led to the soil improvement with reduction in plasticity index, increase in dry density (which translates to improvement in the bearing capacity of clayey soil).
Sadeeq et al (2017) investigated the effects of GSA on selected lateritic soil from Shika, Zaria. They treated the soil with GSA blend in stepped concentration of 3 %, 6 %, and 9 % by dry weight of soil. They reported improvement in the soil at 3 % GSA treatment. The authors concluded that the lateritic soil can be modified with GSA for road construction works.
Abdu et al (2017) studied the compaction behaviour of lateritic soils stabilized with blends of GSA and Metakaolin (MK). The soil was stabilized with increment of 2-10 % GSA and 5-25 % MK by weight of the dry soil. They observed that, with increase in GSA and MK contents in the mix proportions, there was a decrease in plasticity index, liquid limit, plastic limit, and water absorption; an increase in maximum dry density (MDD) and CBR. Karthika and Muthukumar (2018) investigated the use of GSA as a stabilizing agent for black cotton soil. They observed that an optimum value of 6 % GSA yielded the best improvement in the properties and strength of the soil.
Venkatraman et al (2018) studied the effect of GSA on index properties of clay soil. They used various proportions (5 %, 10 %, and 15 %) of GSA to stabilize locally available highly compressible clay soil. They concluded that addition of GSA led to improvement in the properties and load-bearing capacity of the soil. Ramesh et al (2019) used GSA to stabilize black cotton soil of Anantapur district region. They reported that, with the addition of 2 % GSA, significant improvement was observed in liquid limit, plastic limit, UCS, compaction, permeability and CBR of the soil.
Ajala et al (2020) studied the effects of GSA on strength characteristics of soil. The authors treated the selected soil samples with GSA content passing 450 µm British Standard (BS) sieve size. The proportions of GSA used were 2 %, 4 % and 6 % by weight of dry soil. They observed that addition of GSA led to an improvement in the properties and strength of the soils. Optimum value of GSA was obtained at 2 % and 4 % for each of the tested samples, respectively. They concluded that GSA could be used to significantly improve he strength of lateritic soil.
There have been several cases of failure in road pavement and foundation of civil engineering structures. Among other reasons, this situation is attributable to non-usage of soils with adequate engineering strength. The improvement of the engineering strength of soil has therefore become necessary. Available literature shows that previous attempts at stabilizing soils with GSA have either employed the whole content (both fine and coarse) of GSA or only its fine content. This study therefore undertook to investigate the effects of the coarse component of GSA on selected lateritic soils.
The aim of the study was to study the effects of GSA on the properties and strength of lateritic soils. The specific objectives were to: (i) characterize selected soil samples; (ii) determine the geotechnical properties of the soils stabilized with GSA; and (iii) evaluate the effect of GSA on the selected soil samples.

2. Materials and methods

2.1. Materials and equipment

The main materials used for this study were lateritic soil samples and groundnut shells. The soil samples were obtained from two existing borrow pits, one located beside Ipetu market, Ipetumodu, Ife North Local Government Area, Osun state; and the other located along Ede road, Moro, Osun state. The groundnut shells were obtained in bulk from waste disposed at Akinola Market, a local market in Ipetumodu Osun state; Shaki – in the Northern part of Oyo State, Southwest Nigeria; and in Obafemi Awolowo University.
The following equipment and apparatus were used for the laboratory analyses: set of British Standard sieves; Mechanical sieve shaker; Chemical weighing balance; Sensitive balance. Drying oven; CBR machine; Cassagrande apparatus for Atterberg limit test; Standard Proctor mould for compaction.

2.2. Soil sampling and preparation

The method of soil sampling adopted was disturbed sampling. Soil samples were collected at a depth of about 0.5-1.0 m. The samples were collected inside polythene bags and immediately taken to the Geotechnical Laboratory in the Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, for laboratory analyses.

2.3. Preparation of groundnut shell ash

The obtained groundnut shells were thoroughly washed with clean water to free it of any dirt or contaminant. They were then air-dried for about 72 hours. The groundnut shell ash (GSA) was then produced by burning the clean dry groundnut shells in the furnace at the Department of Materials Science and Engineering, Obafemi Awolowo University Ile-Ife, Nigeria. The quantity retained on 425 µm BS sieve was taken, stored in a tight polythene bag, to avoid any form of hydration, and kept for subsequent treatment of the earlier prepared soil samples.

2.4. Geotechnical tests on soil samples

The following geotechnical tests were conducted on soil samples in their natural state: natural moisture content determination, particle size analysis, specific gravity, Atterberg limits, compaction, and California bearing ratio (CBR). All the tests were conducted following standard procedures as outline in BS 1377 (1990).

2.5. Preparation and remoulding of soils with GSA

New soil samples were prepared by adding the GSA to the natural soil samples in varying proportions: 2 %, 4 % and 6 % GSA, by weight of the soils.

2.6. Determination and evaluation of properties of treated soil samples

The soils treated with the varying proportions of GSA were subsequently subjected to laboratory tests to determine, and thus evaluate the effects of GSA on the properties of the soils.

3. Results and discussion

3.1. Properties of soil samples in their natural state

Table 1 presents the results of tests on the soils in their natural state. As for the natural moisture content values, the void ratio of the soils is the predominant factor that affects the moisture content. The higher the void ratio of a soil, the higher its moisture content, which means that the lower the moisture content the better the soil (Jackson and Ravindra, 2002). The results (see Table 1) therefore shows that sample B (with higher moisture content) has a higher void ratio than sample A.

Table 1: Result of Geotechnical Tests on Soil Samples in Their Natural State

Property	Sample A	Sample B
Natural moisture content (%)	15.26	27.99
Specific gravity	2.84	2.72
Liquid limit (%)	51.66	54.07
Plastic limit (%)	37.6	17.69
Plasticity index (%)	14.06	36.38
Percentage passing sieve No. 200 (fines content)	0.14	0.56
Percentage passing sieve No. 40	12.98	30.26
AASHTO Classification	A-2-7	A-2-7
Optimum moisture content (%)	29.34	18.15
Maximum dry density (kg/m^3)	1430.4	1355.5
California Bearing Ratio (%)	6	2

According to Lamber and Whiteman (1971), the specific gravity of most lateritic soil falls within the range of 2.65 - 2.85. The specific gravity of the solids making up a given soil sample is useful mainly for deriving other needed properties of the soil (Gidigasu, 1971). The high specific gravity values for lateritic soils are generally associated with the gravel fraction in which the iron oxides tend to be concentrated. The specific gravity values (see Table 1) of the soil samples gave an indication that the degree of laterization is quite high in the soils.

A soil is said to be clayey if fine fractions (fractions passing sieve number 40) have a plasticity index greater than or equal to 11 (Das, 2006). Results of particle size analysis (Table 1) show that the two soil samples are clayey, since they have plasticity index values greater than 11 %. Also, Wahab (1997) indicated that any lateritic soil having a liquid limit in excess of 30 % and plasticity index above 12 should be rated poor for use under bituminous surfacing. However, Federal Ministry of Works and Housing (1997) specified a maximum liquid limit of 40 % and a maximum plasticity index of 10 % for a highway subgrade material. The results of Atterberg limits tests and sieve analysis (see Table 1) also resulted in classification (according to AASHTO system) of the soil samples. The two soils belong to A-2-7 class.

Federal Ministry of Works and Housing (1997) states that lateritic soils with CBR values of 15 % could only be used as fill material. The results of the engineering tests (compaction and CBR) as shown in Table 1 therefore indicate that the two soil samples, in their natural state, are only good as fill materials.

3.2. Effect of GSA on the properties of soil

Figs 1 to 3 present the variations of Atterberg limits (liquid limit - LL, plastic limit – PL, and plasticity index - PI) values with varying compositions of GSA.

For Sample A, the highest value of LL (51.87 %) was obtained at 0 % GSA content (see Fig. 1); that is, GSA does not seem to increase the LL of the soil. However, GSA led to an increase in the PL, with the optimum value (61.15 %) at 2 % GSA content (Fig. 2). Also, after the initial increase at 2 % GSA content, the value of PI generally reduced with the addition of GSA to the soil (see Fig. 3).

For Sample B, the values of LL fluctuated with the addition of varying proportions of GSA, with the highest value obtained at 6 % GSA (see Fig. 1). The same scenario repeated itself for PL, with the highest value obtained at 6 % GSA content (see Fig. 2). However, the lowest value of PI (9.04 %) was obtained at 2 % GSA content (see Fig. 3), just as it was the case for sample A). Since a reduction in plasticity index of soils gives an indication of improvement in its quality, it is obvious that 2 % GSA content improves the properties of the soils, in terms of the Atterberg limits.

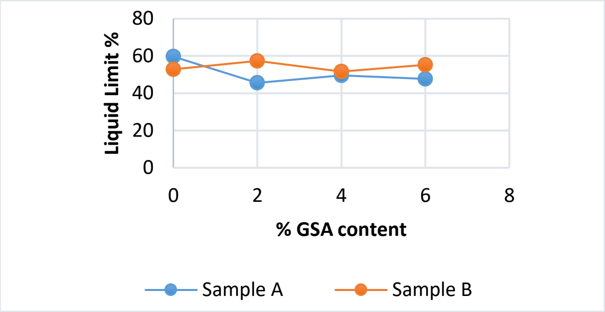

Fig. 1: Variation of Liquid Limit with GSA.

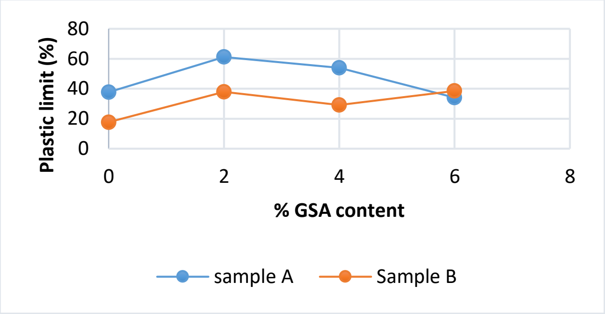

Fig. 2: Variation of Plastic Limit with GSA.

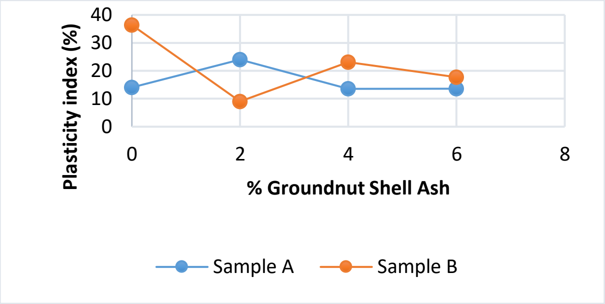

Fig. 3: Variation of Plasticity Index with GSA.

Figs 4 and 5 show the variation of OMC and MDD with GSA, respectively. As observed, the minimum value of OMC (indicating improvement in soil engineering properties) was obtained at 2 % GSA content, for sample A; and at 6 % GSA content, for sample B. Also, the highest values of MDD (indicating improvement in soil engineering properties) were observed at 2 % GSA content, for sample A; and 4 % GSA content, for sample B. It is therefore obvious that, on a general note, 2 % to 6 % GSA content yields improvement in the compaction characteristics of the soil samples.

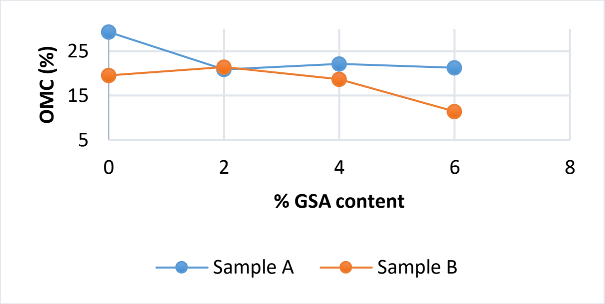

Fig. 4: Variation of OMC with GSA.

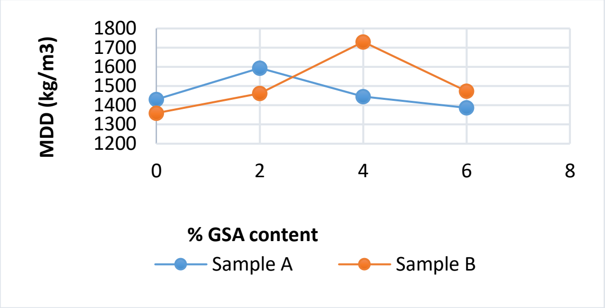

Fig. 5: Variation of MDD with GSA.

Fig. 6 presents the variation of CBR with varying GSA compositions with the soil. At 4 % GSA content, Sample A attained a maximum CBR of 4 %, while Sample B attained a maximum CBR of 15 %. It is seen that the addition of GSA improved the CBR values of the soils at 4 % optimum value for both samples, with significant improvement or increase noticed in Sample B. The implication it that the stabilisation of these soils with GSA is advantageous only up to 4 % content of the stabiliser.

For both samples, the increment in the CBR value from 0 % up to 4 % GSA content could be attributed to gradual formation of cementitious compound between the GSA and Calcium Hydroxide ($Ca(OH)_2$) present in the soil. For sample A, the gradual decrease in the CBR value after 4 % GSA content could be due to excess GSA that were not mobilised in the reaction, which consequently occupied spaces within the soil sample. Since an increase in CBR is an indication of soil improvement (Craig, 2004), it could be said that addition of GSA to the soils led to their improvement, with 4 % optimum GSA content. The improvement could be attributed to the pozzolanic reaction that improved the strength in properties.

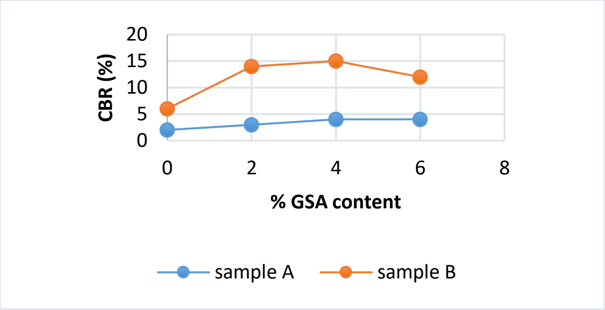

Fig. 6: Variation of CBR with GSA.

4. Conclusion

The effects of coarse content of groundnut shell ash on properties and strength of selected lateritic soils had been studied. In their natural state, the soils were found to belong to A-2-7; they possess high plasticity; hence, they are expansive with high cohesiveness. It was found that addition of GSA generally improved the quality of the soils by reducing the plasticity index and OMC; and increasing the MDD and CBR at some optimum values of GSA. It is concluded that GSA retained on 425 µm BS sieve could be used to improve the properties and strength of lateritic soils.

Acknowledgement

The authors wish to acknowledge and thank Mr. T. Y. Olasupo (of the Geotechnical Engineering Laboratory, Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife) and all technical staff of the Materials Laboratory, Department of Materials Science and Engineering, Obafemi Awolowo University, Ile-Ife. Their efforts and assistance during the different laboratory works are highly appreciated.

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