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Effect of Groundnut Shell Ash on Laterite Soils Stabilized with Lime for Civil Structures

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Abstract: This study considered the practicality of groundnut shell ash (GSA) on laterite stabilized with lime for civil structures. Three site locations of lateritic soil named specimen I, II and III were assembled from Ifewara, Atakunmosa West Local Government Area, Ilesa East Local Government Area, and Ilesa West Local Government, all situated in Osun State, Nigeria. Preliminary tests were wrapped up on the soil specimens in their characteristic states and when stabilized with optimum lime. Compaction, California Bearing Ratio (CBR) and undrained triaxial shear strength tests were performed when fluctuating paces of 2 %, 4 %, 6 %, and 8 % of GSA were included to the soil specimens at optimum lime. The Atterberg limits tests showed a critical decrease in plasticity index for all the soil specimens when stabilized with lime. Compaction test showed a lessening in the maximum dry density from 1732 kg/m^3 to 1651 kg/m^3 for specimen I, 1874 kg/m^3 to 1621 kg/m^3 for specimen II and 1683 kg/m^3 to 1655 kg/m^3 for specimen III on stabilizing with lime, presentation of GSA to stabilized lime-soil decreases the maximum dry density for all the soil specimen with specimen I diminished to 1642 kg/m^3, 1595 kg/m^3, 1611 kg/m^3 and 1611 kg/m^3 at 2 %, 4 %, 6 % and 8 % GSA substances individually. Addition of GSA substances enhanced the engineering properties of laterite stabilized with lime as the unsoaked CBR values expanded for all the soil specimens. At optimum lime measurements, addition of 4 % GSA expanded the shear strength to 110.74 kN/m^2 and 127.53 kN/m^2 for specimens I and II individually while at 6 % GSA addition, the shear strength of specimen III was peak 118.24 kN/m^2. The expansion in shear strength further affirms the improvement prior shown in the geotechnical properties of lateritic soil with the addition of groundnut shell ash. addition of 2 % GSA content extended the triaxial shear strength from 60.43kN/m^2 to 188.36kN/m^2 for specimen I, and at 4% GSA content, both soil specimens II and III expanded from 19.19kN/m^2 to 201.48kN/m^2 and 30.62kN/m^2 to 111.65kN/m^2 separately. Conclusively, GSA improved the durability and strength of lateritic soils stabilized with lime for civil structures.

Keywords: Laterite, stabilization, optimum lime, groundnut shell ash, civil structures

1. Introduction

The utilization of subsoil investigations is turning out to be more significant these days, considering the current spate of falling of civil structures. Civil structures like buildings, culverts, dams and roads throughout the years had been confronted with the issue of negligible lingering soil across non-industrial nations like Nigeria [1]. Soil properties are the main issue which should be recollected prior to executing a structure. For any civil structures, the underneath

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subsoils for the foundation are the most crucial and should be strong to withstand the heap of the entire design [2]. In their study, Adeyemo & Omosuyi [3] researched that subsoil configuration, being a regular structural designing framework, requires the appropriate assurance of profundity to subsurface bedrock, its geotechnical uprightness just as an assessment of its physical properties.

Subgrade soil that does not meet the plan parameter had in the past stabilized with lime, Ordinary Portland cement, and asphaltic materials [4]. However, these materials have quickly reached out in cost because of a sharp expansion in the expense of energy since 1970s [5]. This so-far has kept on preventing the developing, underdeveloped and poor nations of the world from giving moderately standard constructions to inhabitants that constitute the higher percentage of their population [6]. In a proposition to diminish the expense of sourcing for alternative soils and the utilization of standard stabilizers, this beneficial journey had prompted the revelation of materials that can fill in as a substitution for lime in in civil structures foundation.

Several appraisals have been made on soil stabilization utilizing notable materials found by researchers to be suitable as a soil stabilizer. Abdulla et al. [7] showed the sufficiency of augmentation of calcium chloride to soil treatment. Talal & Gabriel [8], utilized calcium oxide as a change strategy in earth soils to restrict its improvement tightening properties. Saeid et al. [9] utilized coal consuming outcomes in roller compacted strong, street and stopping regions. Amu et al. [10] explored the sugarcane straw ash impacts on lime settled lateritic soil for structural works and reasoned that the expansion of sugarcane straw ash improved the Geotechnical contemplations of the lime stabilized lateritic soil tests for structural works.

This work was as such dependent on the effect of groundnut shell ash (GSA) as a stabilizing agent of laterite soils stabilized with lime for civil structures. Though [11] researched the properties of groundnut shell ash on lime stabilized structural lateritic soil for highway structural works where the outcome showed that GSA improved the toughness and strength of lime stabilized lateritic soil for highway structural works.

Groundnut shell is an agrarian waste acquired from treatment of groundnut. In Nigeria, around 7% of world groundnut is produced which makes Nigeria the third most maker of groundnut on earth [12]. Around 2,699,000 metric tons proportions of groundnut were made in around 2,783,000 hectares of land in Nigeria in year 2002. Out of a few million tons of groundnut finished on the planet reliably, groundnut shell makes around 25% of the full-scale mass made and is used basically in steers and poultry feed. Groundnut shell has unfathomable potential for business use. It is utilized as a fuel, filler in cows feed, hard particleboard, plug substitute, activated carbon, and so on. The groundnut shell is huge as domesticated animals feed, particularly in dry season in the semi-arid region.

1.1 Foundation Failure

Foundation is the main component of a structure where the development begins. Over the long haul, foundation can weaken, settle, or sink into the ground because of a variety of issues; sub-soil moisture development, inconsistent settlement of sub-soil, inconsistent settlement of workmanship, horizontal development of sub-soil, lateral pressure on the divider, air activity, weathering of sub-soil because of tree and bushes. Nevertheless, one significant reason for failure lies in the subgrade part. A subgrade is comprised of local soil that has been compacted to withstand the heaps above it [13].

It is a layer needed in numerous civil structural projects. Subgrade layer which serves in as the foundation bedrock, is of key importance in the foundation construction. How strong, firm, and drenched this layer is will control the overall general structural foundation execution [14]. The main limit of subgrade soils is to offer assistance to structural foundations. Under significant super structures, subgrade soils may wind and add to inconvenience in the structural foundation [15]. At the point when the subgrade material is not sufficient to help the vital super structures, at that point extra work ought to be done to make the subgrade material suitable for the construction [16].

After expulsion of topsoil and other natural materials and accepting that the soil is solid, the subgrade might be stabilized by compaction alone. However, numerous soils contain laterite and are classed as flimsy due to the critical shrinkage and expansion that happen with moisture removal and moisture interruption, individually [17]. At the point when the moisture interruption is high, such soils are powerless and untrustworthy. To battle such impacts, such a subgrade ought to be stabilized before construction by mixing in lime, Ordinary Portland concrete, or different added substances, trailed by exhaustive compaction [18].

1.2 Laterite

Laterite (lateritic soil) is one of the significant gatherings of the tropical and subtropical soils of the world, the laterite soils possess an interesting spot, concerning both their broad event and peculiar properties. Lateritic soils structure a gathering including a wide variety of red, earthy colored, and yellow fine-grained lingering soils of light surface just as nodular rock and solidified soils [19]. Lateritic soils vary from a free material to a monstrous stone, they are described by the presence of iron and aluminum oxides or hydroxides, especially those of iron, which give the tones to the soils. For construction purposes, the term laterite is bound to the coarse grained vermicular solid material, including massive laterite. Larrahondo et al. [20] alluded the term lateritic soils as materials with lower convergences of oxides. Laterites are shaped from the filtering of parent sedimentary rocks (sandstones, muds, limestones);

transformative rocks (schists, gneisses, migmatites); molten rocks (stones, basalts, gabbros, peridotites); and mineralized proto-metals which leaves the more insoluble particles, prevalently iron and aluminum.

Laterite soils as indicated by [21] are shaped in hot, wet tropical areas with a yearly precipitation between 750 mm to 3000 mm (as a rule in region with a huge dry season) on a wide range of kinds of rocks with high iron substance. Laterite as described by [22] is found essentially, yet not solely, as a remaining enduring item on mostly or entirely disintegrated basalts and other fundamental to moderate molten rocks. Nigeria is among the nations favored with tremendous deposits of laterite, which is residua in nature, and one of the least expensive material for civil constructions [23]. In any case, not all deposits of laterite are reasonable for use as base and subbase material in their common state. Treatment with added substances is typically needed before such laterite can accomplish the ideal properties.

Lateritic soil containing a critical extent of clay may expand when moisture is present and recoil when the moisture present is practically nothing. Cracks may develop because of the shrinkage which may prompt a decrease of a portion of the mechanical properties of the laterite [24]. In territories where lateritic soil of this sort is available, attempting to get appropriate alternative soil may not be practical. Thus, stabilization of the laterite to meet the necessary strength is unavoidable [25]. Notwithstanding, Oluyinka & Olubunmi [26] and Adeyemi & Ilesanmi [27] detailed that lateritic soil in its compacted state has not furnished the necessary toughness expected with the life expectancy of the civil structures as clear from the different disappointments saw on most construction projects the nation over. Subsequently, there is a need to improve the geotechnical attributes of lateritic soil in Nigeria, particularly for its utilization as a base course material in civil structures.

1.3 Groundnut Shell Ash

Groundnut shell is an agricultural waste obtained from milling of groundnut. The ash obtained by burning the groundnut shells is named groundnut shell ash (GSA). The burnt ash would be passed through a BS sieve (75 microns), portion passing through the sieve would have the required degree of fineness of 0.063mm and below while the residue would be thrown away [28]. When compared with the composition of ordinary Portland cement, the percentage of CaO in ordinary Portland cement was higher than that of the Groundnut Shell ash. These compounds are known to have cement properties that would be beneficiary to the concrete [29].

Previous studies had proven that GSA is a viable supplement in soil stabilization, in the investigation to determine the potentials of groundnut shell ash for stabilization of Ekiti state soil, Nigeria, [30], portrayed that stabilization of soil with GSA content brought about improvement in both the coarse particles of the soil through cementation and mechanical strength. Krishna & Beebi [31], in soil stabilization by groundnut shell ash and waste fiber material, affirmed that the groundnut shell ash and polypropylene fiber reinforced soil can be considered to be good ground improvement technique specially in engineering projects on weak soils where it can act as a substitute to deep/raft foundations, reducing the cost as well as energy. Sujatha et al. [32] concluded in their research, influence of groundnut shell ash on strength and durability properties of clay, that, the use of groundnut shell ash can be used as a viable economic alternative in construction of roads and for stabilizing soil acting as bearing medium. According to [33], stabilization of black cotton soil using groundnut shell ash, the optimum usage of groundnut shell ash added to the soil is 6%, and concluded that groundnut shell ash can be utilized and useful as soil stabilizing material.

1.4 Soil Stabilization

Stabilization is the alteration of foundation soils to the desired characteristics or the improvement of a less stable soil in both strength and durability. Many soils are subject to differential expansion and shrinkage when they undergo changes in moisture content [34]. It is therefore usually necessary to stabilize them to reduce the volume changes and strengthen them to the point where they can carry the imposed loadings even when they are saturated.

Earlier, soil improvement has been in the qualitative sense only, but more recently it has also become associated with quantitative values of strength and durability which are related to performance [25]. These quantitative values include compressive strength, shearing strength, load bearing quality, adsorption softening and reduction in strength and so on. Several studies have been made on soil stabilization using different stabilizing agents. [35] showed the effectiveness of addition of calcium chloride to soil treatment. [36] used calcium oxide as a stabilization technique clay soils in order to inhibit its expansion contraction properties. [37] used coal combustion by-products in roller compacted concrete, roadway and parking lots. Table 1 records the most reasonable treatment for different soil types to stabilize these soils for various objectives [38].

2. Material and Methods

The materials utilized in this investigation are, lateritic soil, hydrated lime, groundnut shell ash, and portable water. The lateritic soil utilized was gathered from three distinct areas termed (specimen I, II, III). The global positioning of the locations of specimen are; specimen I, 7° 28' 0" N, 4° 40' 59" E, Ifewara, Atakunmosa West Local Government Area, specimen II, 7°37'40.4" N, 4°44.497' E, Ilesa, Ilesa East Local Government Area, and specimen III, 7° 37' 40.40" N 4° 44' 29.80" E, Ilesa West Local Government, all situated in Osun State, South-Western Nigeria. Hydrated lime was utilized for the stabilization, this was acquired by obtaining in 25kg-sacks from a standard chemical store. The groundnut shell was gotten from nearby ranchers. It was washed and liberated from any earth or contaminant. The shell was then dried outdoors for 72 hours. The ash was acquired by burning the shells outdoor under normal temperature in a steel compartment. Consumable water was gotten from faucet water accessible in the research centre.

Table 1 - Stabilization methods most suitable for specific applications [38]

Purpose		Soil Type	Method*
Subgrade stabilization	Improve load carrying and stress distribution characteristics	Clays of high PI	SA, SC, MB, C, CMS, LMS, SL
	Reduce frost susceptibility	Fine granular	CMS, SA, SC, LF
		Clay of low PI	CMS, SC, SL, LMS
	Waterproofing and improved runoff	Clays of low PI	CMS, SA, LMS, SL
	Control of Shrinkage and swell	Clays of low PI	CMS, SC, C, LMS, SL
		Clays of high PI	SL
	Reduce resiliency	Clays of high PI	Fine Granular
		Plastic silts or clays	Coarse granular
Base course stabilization	Improvements of substandard materials	Fine granular	Clays of low PI
		Clay of low PI	SC, SL
	Improved load carrying and stress distribution characteristics	Coarse granular	SA, SC, MB, LF
		Fine granular	SC, SA, LF, MB
	Reduction of pumping	Fine granular	SC, SA, LF, MB, membrane
Dust palliative	Improvement in dust palliative	Fine granular	CMS, SA, Oil or bituminous surface spray, APSB
		Plastic soils	CMS, SL, LMS, APSB, DCA 70

*****APSB – Asphalt Penetration Surface Binder; C – Compaction; CMS – Cement Modified Soil; DCA 70 – Polyvinylacetate emulsion; LF – Lime Fly ash; LMS – Lime modified soil; MB – Mechanical Blending; SA – Soil-Asphalt; SC – Soil Cement; SL – Soil-Lime

2.1 Preparation of Soil Sample

The materials were satisfactorily checked for suitability, and put away in cool dry region in open air. The laterite specimens were spread in the sun to dry for about fourteen days preceding tests to dispense all dampness. To guarantee total vanishing, the specimens were turned over as often as possible. The hydrated lime was kept safe to forestall any contact with moisture and whatever other outside variables that can influence its property. The groundnut shell ash was also contained in packs to shield it from moisture and any external influence that can affect its property.

2.2 Test and Method

The research was done utilizing the standard hardware in the Civil Engineering laboratory workshop at the Federal University, Oye Ekiti, Ekiti state, Nigeria. The techniques and procedures for different test utilized in this research project were done as per both standard codes of the British Standard International codes, [39] and American Society for Testing and Materials, [40] separately.

Preliminary tests including natural moisture contents, specific gravity, particle size analysis and Atterberg's limit were completed on the un-stabilized and stabilized soil samples to determine the index properties and the soil type. The standard test technique for liquid limit, plastic limit, and plasticity index of soils was finished following procedures by [41]. The test was completed on the natural soil without the option of the addictive (lime and GSA) to discover as far as possible, liquid limit, plastic limit and plasticity index of the natural soil samples, this empowered the simplicity of watching the impact of the addictive on the natural soil when included and tested. The addition of the lime and GSA contents were as per the following; (i) lime dosage (4%, 5%, 6% and 10% by soil weight), and (ii) groundnut shell ash in the shifting rates of 2%, 4%, 6% and 8% GSA were added to the determined optimum lime proportion. The strength index test and compaction test were done according to the standard of [42] while the CBR was finished utilizing [43] standard.

3. Results and Discussion

3.1 Preliminary and Index Results

The rundown of aftereffects of preliminary and index properties tests for soil specimens I, II, and III are shown in Table 2. It can be observed in the Table 2 that soil specimens I, II and III are delegated as A-7-6, A-7-5, and A-7-5 separately. Natural moisture content of the selected soil specimens I, II and III are 8.60 %, 11.45 % and 15.88 %

individually which showed that soil specimen II has the least characteristic natural moisture content and specimen III with the most elevated natural moisture content. Shi & Marschner, [44], expressed that the natural moisture of a soil relies to a great extent upon void proportion and specific gravity, which is to a great extent influenced by the climatic condition such as temperature, intensity and term of precipitation in the region. The specific gravity of a soil specimen is a proportion of the weight of the aggregate to the weight of an equivalent volume of water. The specific gravity of specimens I, II and III are 2.34, 2.38 and 2.94 respectively.

The soil samples were additionally arranged by their liquid limit and plasticity index. All the soil specimens I, II and III have their liquid limit more prominent than 41% and plasticity index higher than 11%. As per the AASHTO [45] characterization, soils having a place with this class are viewed as not acceptable subgrade material. The weak quality of the specimens is further shown by their high plasticity indices, which will necessitate soil stabilization.

Table 2 - Summary of properties of soil samples

Property	Specimen I (Ifewara)	Specimen II (Ilesa East)	Specimen III (Ilesa West)
Percentage passing BS No 200 sieve	3.9%	5.2%	4.0%
Natural moisture content, %	8.60	11.45	15.88
Specific Gravity	2.34	2.38	2.94
AASHTO Classification	A-7-6	A-7-5	A-7-5
Liquid Limit, %	75.66	66.99	72.40
Plastic Limit, %	27.50	33.77	30.83
Plasticity Index, %	48.16	33.22	41.57
Maximum Dry Density, kg/m^3	1732	1874	1683
Optimum Moisture Content, %	23.53	29.70	27.41
California Bearing Ratio, %	4.00	3.00	5.00
Triaxial Shear Strength, kN/m^2	74.21	68.19	65.77

3.2 Lime Stabilization

The Atterberg limits of the soil specimens on addition of changing rates of lime to decide the optimum lime measurements dependent on decrease in plasticity index are given in Table 3.

Table 3 - Atterberg limits for lime stabilization

Specimen	Lime Stabilization (%)	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plasticity Index (PI) (%)
I	0	75.66	27.50	48.16
	4	61.38	32.33	29.05
	5	61.20	30.14	31.06
	6	59.34	24.58	34.76
II	0	66.99	33.77	33.22
	4	56.67	29.01	27.66
	5	54.45	25.03	29.42
	6	50.99	21.02	29.97
III	0	72.40	30.83	41.57
	4	64.98	35.88	29.10
	5	62.98	42.33	20.65
	6	62.52	46.90	15.62

Fig. 1 to Fig. 3 indicated the variety of Atterberg's limits with lime dosage for soil specimens I, II, and III separately. Addition of lime at 4 %, the results indicated a critical decrease in liquid limit from 75.66 % to 61.38 %, expansion in plastic limit from 27.35 % to 32.33 % and diminished plasticity index from 48.16 % to 29.05 % on addition of 4 % lime demonstrating a general improvement in the plasticity index of the soil specimen I. At 4 % lime dosage, soil-specimen II liquid limit decreased from 66.99 % to 56.67 %, plastic limit decreased from 33.77 % to 29.01 % and plasticity index decreased from 33.22 % to 27.66 %. Addition of 4 % lime demonstrated a general improvement in the plasticity index of the soil specimens I and II. In view of the outcomes on Table 3, lime dose of 4 %, 4% and 6 % were chosen as the optimum dose for stabilizing soil-specimens I, II and III individually.

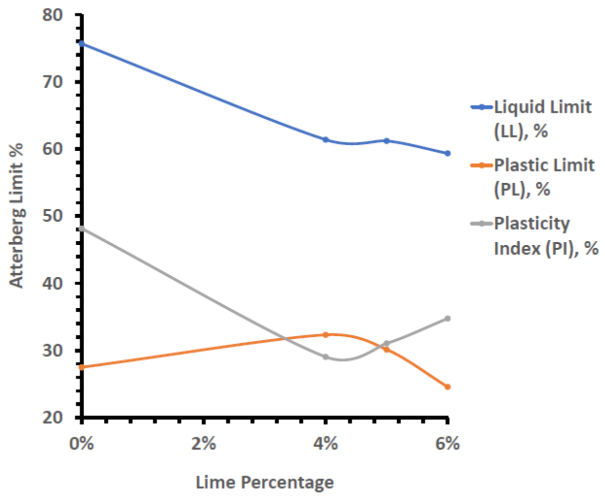

Fig. 1 - Variation of Atterberg limits with varying lime percentages for specimen I

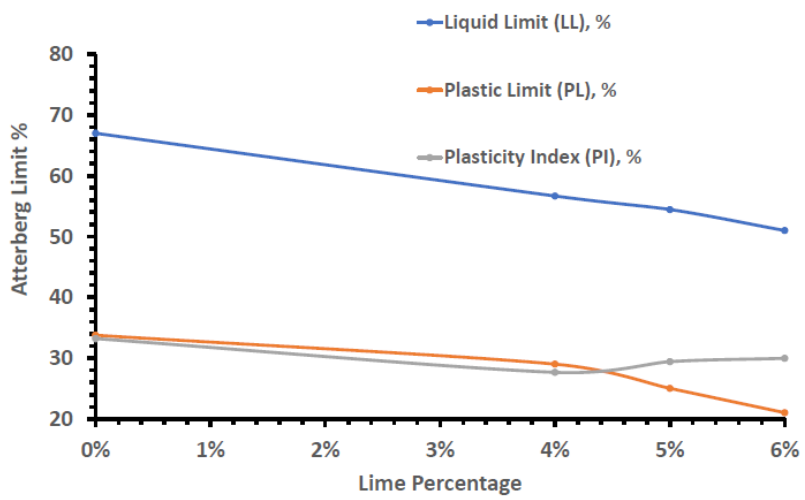

Fig. 2 - Variation of Atterberg limits with varying lime percentages for specimen II

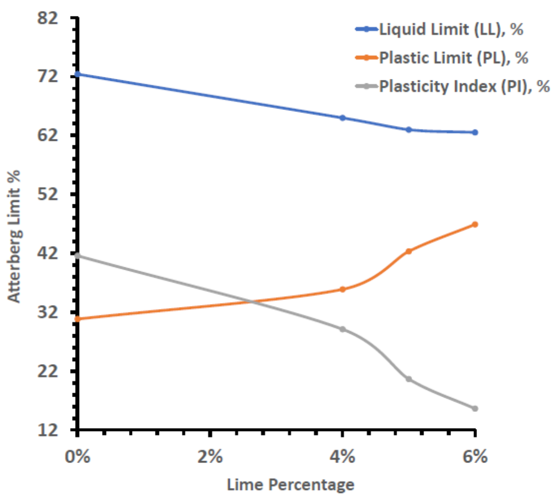

Fig. 3 - Variation of Atterberg limits with varying lime percentages for specimen III

3.3 Compaction Test

The compaction test was done to decide the optimum moisture content (OMC) and the maximum dry density (MDD) of the three soil samples at their natural state, when stabilized with optimum lime doses and when groundnut shell ash was added. The outcome shows that the natural soil samples had an OMC of 25.53 %, 29.70 %, 27.41 % and an MDD of 1732 kg/m^3, 1874 kg/m^3, 1683 kg/m^3 for specimens I, II and III separately. At 4% lime stabilization, OMC for specimen I diminished to 25.01 % and MDD diminished to 1651 kg/m^3, OMC for specimen II diminished to 22.33 % and MDD diminished to 1621 kg/m^3, OMC for specimen III diminished to 26.99 % and MDD diminished to 1655 kg/m^3. Shi & Marschner, [44], expressed that for good soil, the lower the OMC, the better its workability and an increment in dry density is a pointer of progress. The decline in OMC for specimen I might have been because of cation trade response that caused the flocculation of clay molecule [46].

The diminishing in the MDD could be credited to the substitution of the soil by the lime particles which has lower specific gravity contrasted with that of the soil [47]. It might likewise be ascribed to covering of the soil by the ash content which result to enormous particles with bigger voids and consequently less density [48] and [49]. For soil specimen I, addition of 2 % GSA and 4% lime to the soil brought about a diminishing in the MDD to 1642 kg/m^3 and increment in OMC to 25.68 %, the addition of 4 % GSA and 4 % lime diminished the MDD to 1595 kg/m^3 and expanded the OMC to 25.03 %. An increment in GSA to 8 % and 4 % lime increased the MDD to 1621 kg/m^3 and expanded the OMC of 31.44 %. For specimen II, addition of 2% GSA at optimum 4 % lime to the soil brought about an increase in both MDD to 1627 kg/m^3 and OMC to 26.70. For specimen III, addition of 2% GSA and 6% lime to the soil brought about a diminishing in both the MDD to 1612 kg/m^3 and OMC to 25.66 %.

The expansion in the OMC affirms the pozzolanic conduct of GSA with an expanding interest for water to respond and form aggregate particles in the soil. Table 4 shows the consequence of MDD and OMC of the variety in blend level of GSA at optimum lime measurements and Fig. 4 and Fig. 5 showed the variety of OMC and MDD with expanding GSA content.

Table 4 - Compaction test on lime stabilized samples and varying groundnut shell ash

Specimen	Percentage Stabilization (% GSA)	Optimum moisture Content (%)	Maximum Dry Density (kg/m^3)
I	0	25.01	1651 ± 135.45
	2	25.68	1642 ± 198.23
	4	25.03	1595 ± 200.61
	6	24.52	1611 ± 166.03
	8	31.44	1621 ± 133.05
II	0	22.33	1621 ± 411.43
	2	26.70	1627 ± 409.86
	4	25.05	1650 ± 399.45
	6	25.75	1611 ± 409.82
	8	30.52	1541 ± 422.63
III	0	26.99	1655 ± 186.97
	2	25.66	1612 ± 309.34
	4	26.01	1634 ± 278.65
	6	23.51	1638 ± 266.69
	8	32.50	1525 ± 213.24

The effects of addition of varying quantities of GSA dosage at the optimum lime on OMC are illustrated in Fig. 4. The correlation coefficients obtained for % GSA dosage and OMC were 0.6417, 0.8209 and 0.4172 individually for soil specimens I, II and III respectively. These results indicated a very strong positive correlation for specimens I and II and a moderate positive correlation for specimen III. The relationship between the GSA dosage and MDD as showed in Fig. 5 indicated that, there is a strong positive correlation of 0.6322, 0.6763 and 0.7196 respectively for the soil specimens I, II and III.

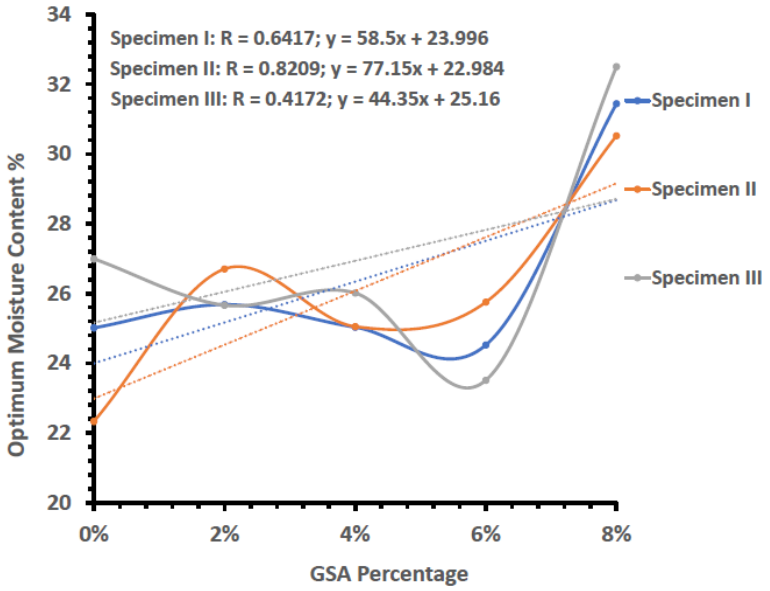

Fig. 4 - Variation of optimum moisture content with increasing GSA at optimum lime

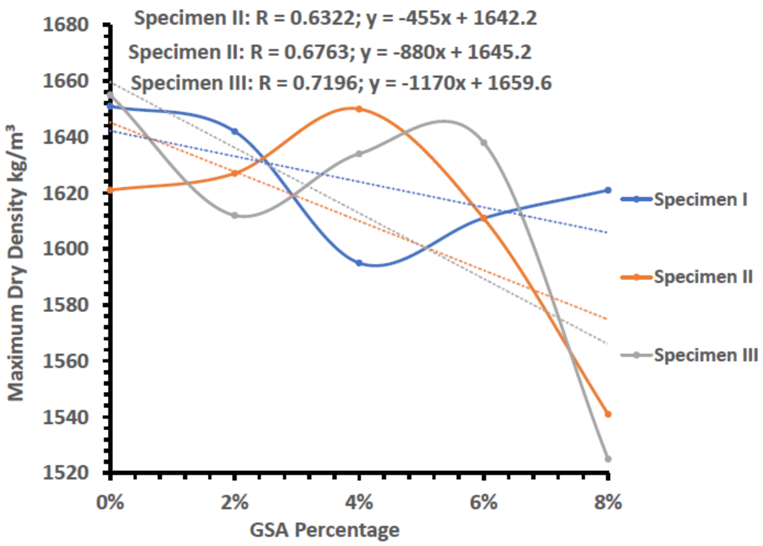

Fig. 5 - Variation of maximum dry density with increasing GSA at optimum lime

3.4 California Bearing Ratio

In highway structural works, it is significance to assess the quality of subgrade, subbase, and base coarse materials after the compaction. California Bearing Ratio (CBR) is an in-situ test ordinarily used to gauge the strength of soil layer by looking at the penetration resistance of the soil to that of a standard material. The CBR test which were directed at OMC of the soil, soil-lime or soil lime-GSA as determined from the compaction test. The California bearing proportion (CBR) esteems of the stabilized soils is a significant parameter in measuring the appropriateness of the stabilized soils. Thus, it invigorates a sign of the strength and bearing capacity of the soil; which will help the engineers in recommending or dismissing the appropriateness of the soil for base or sub-base material.

The unsoaked CBR esteems for the natural soil were seen as 4 % for specimen I, 3 % specimen II and 5 % specimen III. The reduction in the CBR estimations of the soil on addition of lime can be ascribed to the high-water content used during compaction. Additionally, the stabilization of soil with lime necessitates that the blend be permitted to remedy for a couple of days before compacting. During curing, it is seen that the blend loses moisture and henceforth increments in strength. The increase in strength of stabilized soil with increasing curing days proposes that the blend be permitted to cure so as to evaluate the genuine strength of the soil [50]. The addition of 2 %, 4 %, 6% and 8 % GSA however expanded the unsoaked CBR esteems to 9%, 7 %, 7 %, and 6 % for soil-lime specimen I; 5 %, 5 %, 4 % and 5 % for soil-lime specimen II; 6 %, 10 % 6 %, and 6 % for soil-lime specimen III. This shows that GSA can build the strength properties of soil particularly with lime present to improve the response between the soil and the supplements.

The connection between GSA dosage at optimum cement and the unsoaked CBR is displayed in Fig. 6. The low CBR values observed are in the scope of qualities for soil suitable for subgrades. There exists a very strong positive correlation of 0.6708 and 0.6063 obtained respectively for the specimen I and II, and a moderate positive correlation of 0.3811 for specimen III.

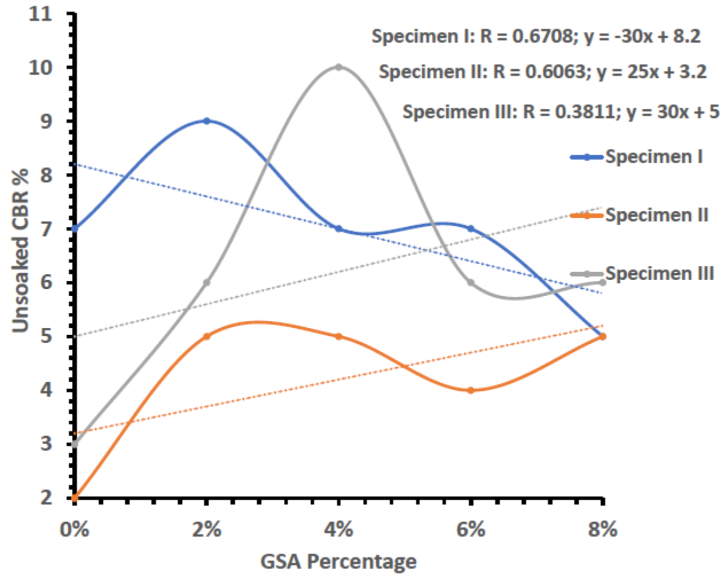

Fig. 6 - Variation of Unsoaked CBR values at optimum lime

3.5 Undrained Triaxial Shear Strength Test

The triaxial test is one of the most dependable techniques accessible for the assurance of shear parameters, an expansion in the shear strength of a soil demonstrates an improvement in the strength of the soil and furthermore an improvement in construction functionality [51]. The synopsis of the outcomes for the triaxial test on unstabilized and lime stabilized specimens are shown in Table 5. The test was performed from soil samples got from the remolded soil with the OMC obtained from the compaction test. Cell pressure of 20 kN/m^2, 40 kN/m^2 and 80 kN/m^2 were applied. The shear strength of the soil samples is 74.21 kN/m^2, 68.19 kN/m^2 and 65.77 kN/m^2 respectively for unstabilized specimens I, II and III respectively. The addition of 4 % GSA at optimum lime expanded the shear strength to 110.74 kN/m^2 and 127.53 kN/m^2 for specimens I and II individually while at 6 % GSA addition, the shear strength of specimen III was peak 118.24 kN/m^2. The expansion in shear strength further affirms the improvement prior shown in the geotechnical properties of lateritic soil with the addition of groundnut shell ash.

Table 5 - Variation of Shear strength with GSA addition at optimum lime

Specimen	Percentage (% GSA)	Cohesion, Friction C (kN/m^2)	Angle of Internal Friction (ϕ)	Average Deviator Stress (σ_1-σ_3) (kN/m^2)	Shear stress = C+(σ_1-σ_3) tanϕ (kN/m^2)
I	0	35.56	21.94	116.67	82.55
	2	18.28	26.81	161.62	99.95
	4	19.47	30.79	151.28	109.62
	6	18.55	26.92	181.55	110.74
II	0	72.70	27.86	180.17	167.93
	2	99.62	17.20	135.56	141.58
	4	65.37	21.68	156.39	127.53
	6	35.79	33.01	130.38	120.49
III	0	28.96	24.40	190.72	115.47
	2	45.77	16.49	220.03	110.90
	4	32.81	12.04	221.75	80.09
	6	23.19	27.49	182.70	118.24

The effects of addition of varying quantities of GSA dosage on shear stress variations of the soil specimens are shown in Fig. 7. The correlation coefficients obtained were 0.1054, 0.1118 and 0.3787 respectively for soil-specimens I, II and III. These results indicated a very weak positive correlation for specimens I and II, and a moderate positive correlation for specimen III.

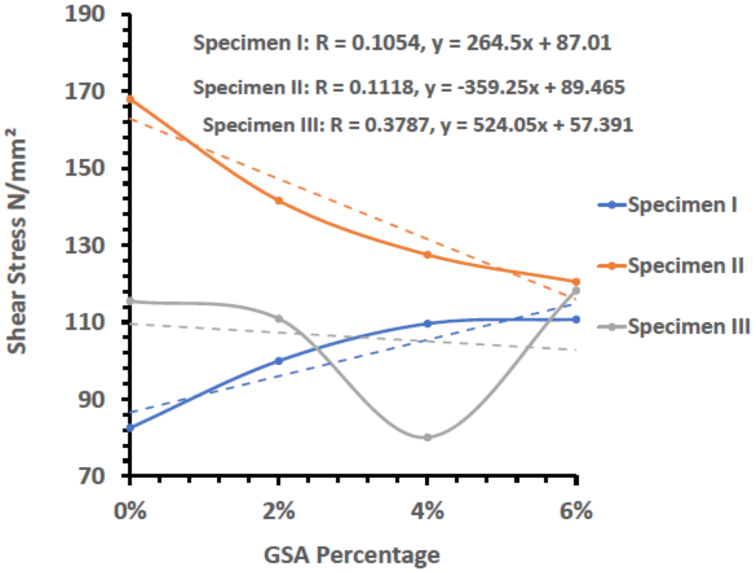

Fig. 7 - Shear stress variations at optimum lime

4. Conclusion

This study researched the effect of groundnut shell ash on laterite soils stabilized with lime for civil structures. The outcomes preliminary tests demonstrated that specimen II has low plasticity index while specimens I and III have intermediate plasticity index, thus soils in that scope of plastic fall inside the inorganic slits and clay groupings. The plasticity index of the soil specimen diminished as the GSA stabilizers were added, indicating an improvement in the consistency of the soil specimens.

The compaction test revealed that the addition of GSA on lime stabilized soils increased the optimum moisture content and decreased in maximum dry density. The maximum dry density of soil specimens I, II and III diminished significantly on addition of lime and groundnut shell ash with the most elevated worth acquired at 4 % lime and 2 % GSA for specimen I, 0 % lime and 2 % GSA for specimen II and 6 % lime and 2 % GSA for specimen III. The optimum moisture content expanded extensively for the specimens I and III but lessens at addition of GSA content for specimen II until 6 % GSA.

The CBR esteems for the unstabilized soil specimens I, II and III are correspondingly 4 %, 2 % and 2 % for unsoaked samples. The addition of GSA expanded the CBR esteems for the lime stabilized specimens I, II and III. The CBR esteems for the lime stabilized soil specimens I and II just expanded imperceptibly and lower than 10 %.

The shear strength test results showed an increase in shear strength in all the soil specimens with the addition of GSA contents up to 6 %.

Conclusively, addition of GSA contents improved the geotechnical properties of soil in that it helps in shaping colloidal particles and decrease in the inclination of the soil to expand when wet, the optimum percentage of GSA contents addition to soil stabilized lime is at 4 %.

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