Recent Literatures Review on Stabilization of Lateritic Soil

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ABSTRACT

Laterite is a soil and rock type rich in iron and aluminium and occur mostly in tropical and sub-tropical regions with hot, humid climatic conditions. Laterite contain a substantial amount of clay minerals hence its strength and stability cannot be guaranteed under load especially in the presences of moisture. Stabilization using stabilizing agents improve the engineering properties and make it suitable for construction. This paper aims to present a review on the effects of various stabilizing agents used for stabilization of Lateritic soil

Keywords - Lateritic soil, Stabilization

I. INTRODUCTION

Laterite is a soil and rock type rich in iron and aluminium, and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. They develop by intensive and prolonged weathering of the underlying parent rock. Tropical weathering (laterization) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. [1]

The formation of lateritic soil involves physico-chemical breakdown of primary minerals and the release of constituent elements (SiO2, Al2O3, Fe2O3, CaO, MgO, K2O, Na2O, etc), which appear in simple ionic forms; leaching (laterization) under appropriate conditions, of combined silica and bases and the relative accumulation or enrichment of oxides and hydroxides of Sesquioxides (Fe2O3, Al2O3, and TiO2); and partial or complete dehydration (sometimes involving hardening) of the Sesquioxide rich materials and secondary minerals. [2]

Laterites occur mostly in tropical and sub-tropical regions with hot, humid climatic conditions. It has been suggested that a minimum annual temperature of around 250C is needed for their formation, and in seasonal situations there should be a coincidence of the warm and wet periods. If there is high rainfall during the cold seasons, laterite does not develop freely. The minimum rain fall required for the formation of laterites is generally at least 750mm.The higher rain fall above this value, the greater the leaching effect, which removes the silica, reducing the Silica/Sesquioxide ratio and increase the degree of laterization. [3]

Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains a large amount of clay materials its stability and strength and stability cannot be guaranteed under load in presence of moisture. lateritic soil consists of high plastic clay, the plasticity of the soil may result to cracks and damage on pavement, roadways, building foundations or any civil engineering construction projects. [4], [5]

Soil stabilization is the alteration of the properties of an existing soil either by blending (mixing) two or more materials and improving particle size distribution or by the use of stabilizing additives to meet the specified engineering property. Quite often soils are stabilized for road construction to Improve the strength (stability and bearing capacity) for subgrade, subbase, base, and low-cost road surfaces; Improve the volume stability- undesirable properties such as swelling, shrinkage, high plasticity characteristics, and difficulty in compaction, etc, caused by change in moisture ; and Improve durability – increase the resistance to erosion, weathering or traffic, improve high permeability, poor workability, dust nuisance, frost susceptibility, etc. When selecting a stabilizing agent, these factors must be considered: types of soil to be stabilized, purpose for which the stabilized layer will be used, the desired quality of the stabilized soil, required strength and durability of the stabilized layer and Cost and environmental conditions. [6]

Soil stabilization can be accomplished by several methods, all these methods fall into two broad categories namely mechanical and chemical stabilization. Mechanical Stabilization is a physical process that involves altering the physical nature of native soil particles by either induced vibrations or compaction or by incorporating other physical properties such as barriers and nailing. Chemical Stabilization involves initiating chemical reactions between stabilizers (cementitious material) and soil minerals (pozzolanic materials) to achieve the desired effect of improving the chief properties of a soil that are of interest to engineers namely volume stability, strength, compressibility, permeability and durability.[7]

II. LITERATURES REVIEW

Recent research works conducted on stabilization of lateritic soil using different stabilizing agents were referred and their summary was listed below:

O. S Aderinola and E. S. Nnochiri [8] studied stabilizing lateritic soil using Terrasil solution. Geotechnical tests such as compaction Test and California Bearing Ratio Test were performed on both the natural soil samples and the stabilized lateritic soil samples which were stabilized by adding terrasil solution in percentages ranging from 0% to 16% at 2% interval. The result indicated that between 0% and 12% terrasil solution, the MDD values and the unsoaked CBR values increased while the OMC values generally reduced. They concluded that the terrasil solution serves as a cheap and effective stabilizing agent for poor soil.

A.A. Amadi and A. Okeiyi [9] undertaken a laboratory study to evaluate and compare the stabilization effectiveness of different percentages (0, 2.5, 5, 7.5,10%) of quick and hydrated lime when applied separately to locally available lateritic soil. Performance evaluation experiments included: Atterberg limits, compaction, unconfined compression tests, California bearing ratio (CBR), swelling potential using CBR instrument and hydraulic conductivity. The soil mixtures used for unconfined compressive strength (UCS), CBR, swelling potential and hydraulic conductivity tests were compacted at optimum moisture content using the British standard light compactive effort and cured for 28 days. It was found that treatment with lime on plasticity characteristics resulted in a reduction of plasticity index (PI) of soil mixtures while the quicklime caused the soil to have lower plasticity. The addition of either quick or hydrated lime resulted in a decrease in the maximum dry unit weight and a slight increase in the optimum moisture content while hydrated lime treated specimens exhibited higher dry unit weight than that achieved with quick lime addition. There is generally an increase in strength with lime content regardless of the type and higher UCS especially at higher dosages (7.5 and 10%) was produced when soil sample was treated with quicklime. Results of CBR test for the stabilized soil show that the addition of either the quicklime or hydrated lime significantly improved the bearing strength (CBR) of the soil while quicklime-stabilized soil have superior load bearing capacity. Finally, the two types of lime are effective in reducing swelling potential and quicklime treated specimens reached slightly lower swelling values than the hydrated lime while no appreciable distinction in hydraulic conductivity values of specimens treated with the two types of lime was observed. They concluded that quicklime is adjudged to have exhibited somewhat superior engineering properties and therefore creates a more effective stabilization alternative for the soil.

E. S. Nnochiri and O.O. Aderinlewo [5] investigated the geotechnical properties of lateritic soil stabilized with banana leaves ash. Engineering tests such as compaction, California bearing ratio and unconfined compressive strength tests were carried out on the lateritic soil at their natural states and at when the banana leaves ashes were added to the soil at varying proportions of 0, 2, 4, 6, 8 and 10% by weight of soil. The result of the strength tests showed that the banana leaves ash enhanced the strength of the lateritic soil. The unsoaked CBR value of the soil at its natural state was 10.42 % and it got to optimum value of 28.10% by addition of 4% banana leaves ash by weight of soil. The un-confined compressive strength improved from 209.18 kN/m2 at natural state to 233.77 kN/m2 at 4% banana leaves ashes. They concluded that the banana leaves ash satisfactorily act as cheap stabilizing agents for subgrade purposes.

E. S. Nnochiri and O.O. Aderinlewo [10] assessed the geotechnical properties of lateritic soil stabilized with the oil palm fronds ashes (OPFA). These properties are then com-pared with those of the same soil stabilized with cement to determine how well the ashes perform since cement is considered to be the best stabilizer. The natural soil sample was classified according to AASHTO soil classification system as an A-7-5 soil which is a poor soil. Hence, the need for stabilization. Thereafter, strength tests such as California bearing ratio (CBR), unconfined compressive strength (UCS) and compaction tests were performed on the soil to which the ashes and cement were added in percent-ages of 2, 4, 6, 8 and 10 by weight of the lateritic soil. The compaction test showed that the highest maximum dry densities (MDD) were recorded in the case of the oil palm frond ash (OPFA) and cement at 4% (MDD = 2.02kg/m3) and 6% (MDD = 2.40kg/m3) respectively. The highest CBR values obtained were 32.6% and 87.32% at 4% OPFA content and 6% cement content respectively. The unconfined compressive strengths (UCS) of the soil were highest at 4% OPFA content (234.86kN/m2) and 6% cement content (588.32kN/m2). These represent the optimum values for the OPFA and OPC to be used as stabilizers in the lateritic soil.

S. Haldankar, et al. [11] evaluated the geotechnical proper-ties of eggshell powder(ESP) stabilized clay with a view to determine its suitability as a substitute for conventional lime stabilized clay. The eggshell powder is mixed in different proportions with lateritic clayey soil and a series of laboratory tests were conducted on samples containing various percentages of eggshell powder, i.e., 0%,4%, 8%, 12% and 16% by weight of the dry soil and various percentages of lime, i.e., 1%,2%, 3%, 4% and 5% by weight of the dry soil . ESP has improved the soil properties considerably. Liquid limit and plastic limit decreased on addition of Lime and ESP when compared with normal clay. Maximum dry density increased with addition of Lime and ESP whereas the OMC showed a decreasing trend. Un-confined compressive strength of the soil also improved on addition of ESP when compared with normal clay.

The study to determine the lime effect on vertical deformation of road base physical model of laterite Halmahera soil was conducted by S. Zubair and D. Herry [12]. The samples of laterite soil were obtained from Halmahera Is-land, North Maluku Province, Indonesia. Soil characteristics were obtained from laboratory testing, according to American Standard for Testing and Materials (ASTM), consists of physical, mechanical, minerals, and chemical. The base layer of physical model testing with the dimension; 2m of length, 2m of width, and 1.5m of height. The addition of lime with variations of 3, 5, 7, and 10%, based on maximum dry density of standard Proctor test results and cured for 28 days. The model of lime treated laterite Halmahera soil with 0,1m thickness placed on subgrade layer with 1,5m thick-ness. Furthermore, the physical model was given static vertical loading. Some dial gauge is placed on the lime treated soil surface with distance interval 20cm, to read the vertical deformation that occurs during loading. The experimental data was analyzed and validated with numerical analysis using finite element method. The results showed that the vertical deformation reduced significantly on 10% lime content (three times less than untreated soil), and qualify for maximum deflection (standard requirement L/240) on 7-10% lime content.

O.Ayeni [13] evaluated the potential of limestone ash for the improvement of some geotechnical properties of Laterite soils for construction purposes. The geotechnical properties of the soil were determined both in the natural state and after stabilization with 2%, 4%, 6%, 8% and 10% of limestone ash waste at a normal curing of 6 hours. Accelerated curing at 40°C, 60°C and 80°C for 24 hours was carried out for compressive strength tests for 4% and 6% respectively due to similarities in the values of both the CBR and compressive strength. The dry density and plasticity index decreased while liquid limit, plastic limit, compressive strength and CBR increased with increasing percentages of limestone ash. Maximum strength was achieved at 6% proportion of limestone ash for CBR and compressive strength respectively. The results of this re-search indicate that limestone ash is comparatively suitable for the chemical stabilization of Laterite soils as lime is, as reported by other researchers.

O. D. Afolayan [14] evaluated the effect of Cement and Lime on selected engineering properties of lateritic soils. In order to study this effect, fresh laterite was obtained and tested for its index and geotechnical properties. Afterwards, the soil sample was altered with additives proportions which includes 0%, 2.5%, 5%, 7.5%, and 10% of both cement and lime replacement by dry weight. On examination laterite, it was discovered that the laterite can be classified as good. After carrying out the engineering properties on the sample, it was observed that the maximum dry density reduced with increase in the lime content and for cement content at 2.5 and 10% but increases at 5-7.5%. Also, the optimum moisture content increased for increasing lime content and fluctuates for increasing cement content. However, an increase in the California Bearing Ratio (CBR) was noticed for increase in cement but a low effect for lime addition. He concluded that lime and cement modifies the chemical property of the tested soil with cement the most suitable.

G. L. Dumessa and R. K. Verma [15]assessed the effects of cement on the behavior of compacted lateritic soil to examine the benefits of cement stabilized lateritic over selective borrow material both in the quality and saving cost. The basic index and engineering properties of lateritic soil were determined following the ASTM procedure and classified as A-7-5 and inorganic silt according to the AASHTO classification system and Unified Soil Classification System, respectively. The soil samples were subsequently stabilized with 3%, 5%, 7%, and 9% cement. Results showed that stabilization of the lateritic soils with cement increased the Maximum Dry Density, California Bearing Ratio, and Un-confined Compressive Strength while there was a reduction in Optimum Moisture Content as cement up to 7%. The effect of curing time indicated marginal on the compaction characteristics and CBR, whereas it revealed substantial effects in unconfined compressive strength tests results. There-fore, They concluded that Lateritic soils stabilized with 5% cement proved better quality than the selective borrow material taken from the existing nearby areas and its economic benefits over selective borrow material by 26.95%. Thus, the stabilization of lateritic with cement is effective in the constructions of stable and durable sub-grade and sub-base course layer.

E. S. Nnochiri and O. M. Ogundipe [16] assessed the geotechnical properties of lateritic soil stabilized with Ground-nut Husk Ash. Engineering property tests such as California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and compaction tests were performed on both the natural soil sample and the stabilized lateritic soil, which was stabilized by adding Ground -nut Husk Ash, GHA, in percentages of 2, 4, 6, 8 and 10 by weight of the soil. The results showed that the addition of GHA enhanced the strength of the soil sample. The Maximum Dry Density (MDD) reduced from 1960 kg/m3 to 1760 kg/m3 at 10% GHA by weight of soil. The Optimum Moisture Content (OMC) increased from 12.70% to 14.95%, also at 10% GHA by weight of soil. The unsoaked CBR values increased from 24.42% to 72.88% finally, the UCS values increased from 510.25 kN/m2 to 1186.46 kN/m2, for both CBR and UCS, the values were at 10% GHA by weight of soil. They concluded that GHA performs satisfactorily as a cheap stabilizing agent for stabilizing lateritic soil especially for subgrade and sub base purposes in road construction.

K. C. Onyelowe et al [17] investigated the use of Nanostructured Clay additive in lateritic soil stabilization and their effect at different percentages on the natural soil. The preliminary tests on the soil showed it was an A-2-7 soil, according to AASHTO classification. The soil sample was also observed to be silty clayey sand and the general rating as a sub-grade material was 'GOOD'. The consistency limits result shows that the value of the LL for the natural soil is 47% and 25.15% was recorded for the plastic limit (PL) and finally the PI was 21.85% i.e. highly plastic soil. Further, the effect of the addition of NC in the proportions of 3%, 6%, 9%, 12% and 15% by weight of the stabilized lateritic soil was investigated. The consistency limits results showed that the addition of variable proportions of NC considerably improved the plasticity of the stabilized soil which gave 13.8%; a medium plastic material at 15% NC addition, compared to the preliminary result of 0% by weight additive which gave 21.85%; a highly plastic material. The strength properties' test showed significant improvements with the addition of NC; CBR test result recorded 29% at 15% by weight proportion of NC which satisfies the material condition for use as sub-base material and the UCS test results similarly improved consistently and recorded a maximum UCS of 340.18kN/m2 at 15% by weight proportion of NC addition which satisfies "very stiff" material consistency for use as sub-base material. With the foregoing, the addition of various proportions of NC to the stabilized lateritic soil has presented to be a Geotechnical solution to the varied environmental failures on the road pavements. They concluded that NC satisfies all the material conditions for use as a sub-base material for the stabilization and improvement of the strength characteristics of lateritic soils.

E.S. Nnochiri et al [18] assessed the geotechnical characteristics of lateritic soil and sawdust ash lime (SDAL) mixtures. Preliminary tests were carried out on the natural soil sample for identification and classification purposes. The sawdust was mixed with lime for stabilization in the ratio 2:1. This mixture was thereafter added to the lateritic soil in varying proportions of 2, 4, 6, 8 and 10% by weight of soil. Addition of SDAL increased values of Optimum Moisture Content (OMC) from 17.0% at 0% SDAL to 26.5% at 10% SDAL by weight of soil, also, values of Maximum Dry Density (MDD) decreased from 2040 kg/m3 at 0% SDAL to 1415 kg/m3 at 10% SDAL. Values of Unconfined Compressive Strength (UCS) increased from 38.58 kN/m2 at 0% SDAL to highest value of 129.63 kN/m2 at 6% SDAL. The values of liquid limits and plasticity index of the soil were effectively reduced with the addition of the SDAL, from 54.0% at 0% SDAL to 49.0% at 10% SDAL and from 13.7% at 0% SDAL to 12.5% at 10% SDAL respectively. It was therefore concluded that the sawdust ash lime (SDAL) mixture can serve as a cheap soil stabilizing agent for poor lateritic soil.

K. C Onyelowe [19] studied the effect of Coconut shell husk ash (CSHA) and palm kernel shell husk ash (PKSHA) on the grading and consistency of lateritic soil stabilized with pozzolan. Results of the grading analysis have shown that the natural soil was classified as A-7-6 soil according to the AASHTO classification system and CH-inorganic sandy fat clay according to USCS. The consistency result of the natural soil showed that the soil is highly plastic with a plasticity index of 54.4% > 17. The admixtures were used in the pro-portions of 2%, 4%, 6%, 8% and 10% and their proportional effect on the grading of the pozzolan stabilized soil showed that the uniformity and curvature of the soil improved with increased admixtures. CSHA recorded a better improvement with the uniformity of the soil while PKSHA recorded better improvement with the curvature of the soil. The consistency limits results showed that the plasticity of the stabilized soil decreased with increase in percentage of ad-mixtures making the mixture less plastic. Finally, He concluded that CSHA and PKSHA are good admixtures in the stabilization of weak and highly plastic engineering soil and are recommended for use.

J. James et al.[20] investigated the performance of ordinary Portland cement (OPC) stabilized soil blocks amended with sugarcane bagasse ash (SBA). Locally available soil was tested for its properties and characterized as clay of medium plasticity. This soil was stabilized using 4% and 10% OPC for manufacture of blocks of size 19 cm × 9 cm × 9 cm. The blocks were admixed with 4%, 6%, and 8% SBA by weight of dry soil during casting, with plain OPC stabilized blocks acting as control. All blocks were cast to one target density and water content followed by moist curing for a period of 28 days. They were then subjected to compressive strength, water absorption, and efflorescence tests in accordance with Bureau of Indian standards (BIS) specifications. The results of the tests indicated that OPC stabilization resulted in blocks that met the specifications of BIS. Addition of SBA increased the compressive strength of the blocks and slightly increased the water absorption but still met the standard requirement of BIS code. They concluded that addition of SBA to OPC in stabilized block manufacture was capable of producing stabilized blocks at reduced OPC content that met the minimum required standards.

E.S Nnochiri [21] assessed the effects of periwinkle shell ash (PSA) on lime-stabilized A-7-5 lateritic soil. The soil sample was mixed with lime at percentages of 2, 4, 6, 8 and 10 and subjected to atterberg limit tests to get the optimum amount of lime, which was 10% because the least value of plasticity index was recorded at this state. PSA was added to the lime-treated soil sample at varying proportions of 2, 4, 6, 8 and 10%. The mixes were subjected to compaction, California bearing ratio (CBR), atterberg limits and unconfined compressive strength (UCS) tests, in so doing, the values of the CBR and UCS increased considerably. They concluded that the PSA performs satisfactorily as a cheap complement for lime in soil stabilization.

The stabilization potentials of Nanostructured Waste Paper Ash (NWPA) and the CBR optimization were investigated on the treated lateritic soil by K.C. Onyelowe [22]. The soil was classified as an A-2-7 soil according to AASHTO classification method. From the stabilization procedure, it has been found that the admixture improved the strength characteristics of the stabilized lateritic soil for use as base material in pavement construction. With the laboratory results, a nonlinear regression relationship was formulated through the multiple regression algorithms for the California bearing ratio (R) as a dependent variable with optimum water content (w), maximum dry density (D), and percent-age by weight additive of NWPA (SA) as the independent variables. The nonlinear relationship was linearized to enable the optimization operation with Simplex Linear Programming (Optimization) to be conducted. This iteration procedure was conducted and the results showed that the CBR (R) was optimized at Rmax=219.16% with x1= 48.103, x2=4.833, x3=13.45, and x4= 0.948 in the stabilization of lateritic soils with NWPA as an admixture applied in the percentages of 0, 3, 6, 9, 12, and 15%.

Y.T. Todingrara, et al.[23] conducted Laboratory and field testing programs to evaluate lime-cement treated laterite soil for application in the evaluation procedures of pavement structures. The laboratory program consisted of performing unconfined compression test on lime-cement treated laterite soil. The field testing program included conducting in-situ tests of Light Weight Deflectometer (LWD), and field CBR. Based on the performance of the treated laterite soil observed in the study they suggested that the treated laterite soil with lime and cement content of 12% and 5%, respectively, can be employed as a pavement foundation layer to bear the vehicle loads.

A laboratory investigation was conducted to examine the performance of TerraZyme on different soil types by, S.A.M..N Yusoff et al [24]. Laterite and kaolin were treated with 2% and 5% TerraZyme to determine changes in the soils' geotechnical properties. The obtained results were analysed and investigated in terms of compaction, Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR). The changes in geotechnical properties of the stabilized and unstabilized soils were monitored after curing periods of 0, 7, 15, 21 and 30 days. Changes in compaction properties, UCS and CBR were observed. It was found that laterite with 5% TerraZyme gave a higher maximum dry density (MDD) and decreased the optimum moisture con-tent (OMC). For kaolin, a different TerraZyme percentage did not show any effect on both MDD and OMC. For strength properties, it was found that 2% TerraZyme showed the greatest change in UCS over a 30-day curing period. The CBR value of stabilized kaolin with 2% TerraZyme gave a higher CBR value than the kaolin treated with 5% TerraZyme. It was also found that laterite treated with TerraZyme gave a higher CBR value. Lastly, it can be concluded that TerraZyme is not suitable for stabilizing kaolin; TerraZyme requires a cohesive soil to achieve a better performance.

V. Sharma and S.G. Upadhyay [25] studied the effect of Calcium Chloride CaCl2 on Laterite Soil. This study comprises the experiment results like UCS, CBR on laterite soil by using four percentage (0.5,1.0,1.5,2.5%) of chemical. It is observed that by using the chemical stabilizer the property of soil is improved. The CBR value increased. The use of chemical concentration at 1.5% gives the effective stabilization result and therefore it is used as stabilization of soil.

Segun N.E and Oluyemisi E.H [26] assessed the effects of Coconut Shell Ash (CSA) on lime-stabilized lateritic soil. Preliminary tests were carried out on the natural soil sample for identification and classification purposes, also, engineering property tests such as California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and Compaction were carried out on the natural soil sample. Lime being the main stabilizing material was thoroughly mixed with the natural soil sample in proportions of 2, 4, 6, 8 and 10%. The optimum lime requirement for stabilization was 6% lime content because the least value of plasticity index was recorded at this level. This value was adopted as the standard and control, thereafter, CSA was mixed with the lime-stabilized soil in proportions of 2, 4, 6, 8 and 10%. By the addition of CSA to the lime-stabilized soil, CBR increased from 53.6% at 0% CSA to 66.4% at 6% CSA. UCS increased from 345kN/m2 at 0% CSA to highest value of 442kN/m2 at 4% CSA by weight of soil. Values of Optimum Moisture Content (OMC) increased from 21.44% at 0% CSA to 26.10% at 10% CSA. Maximum Dry Density (MDD) decreased from 1342Kg/m3at 0% CSA to 1255Kg/m3 at 10% CSA. It was therefore concluded that Coconut Shell Ash (CSA) is an effective complement for lime stabilization in lateritic soil.

A. W. Otunyo and C. C. Chukuigwe [27] investigated the impact of palm bunch ash (PBA) on the stabilization of poor lateritic soil. The palm bunch ash in percentages by weight (0%, 20%, 25% and 30%) was added to the lateritic soil. The 0% PBA acted as the control. The following parameters of the (lateritic soil+ palm bunch ash) were tested in the laboratory: Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR) and un-confined compression strength (UCS). The values of the MDD, OMC, CBR and UCS increased as the PBA con-tent in the lateritic soil was increased up to between 25% PBA, thereafter the values started to decrease. The UCS of the (lateritic soil + palm bunch ash) specimen cured for 14 days were also found to higher than that of 28 days curing period at 20% PBA content. The UCS values for 14 days be-came higher than that at 28 days at 25% PBA content. The PBA can be used as a lateritic soil stabilizer between (20-25%) PBA content.

G. M. Ayininuola & S. P. Abidoye [28] examined effect of stabilizing lateritic soil with combination of bitumen emulsion and cement. Soil samples were obtained from borrow pits located in Kwali Area Council in Abuja. Three percent-ages of additives were considered: 4%, 6% and 8%. The bitumen emulsion and cement contents were combined in percentages: 100:0, 75:25, 50:50, 25:75 and 0:100 to form five additives. The stabilized soils and unstabilized soils (control) geotechnical properties such as Unconfined Compressive Strength (UCS) test and California Bearing Ration (CBR) test were determined. The UCS and CBR for soil samples A and B were 0.46 MPa and 19.6%, 0.95 MPa and 22.6%, respectively. The CBR of soil A at 4% additives of mix proportions 100%/0%, 75%/25%, 50%/50%, 25%/75% and 0%/100% were 49.1%, 68.8%, 140.5%, 172.1% and 218.5%, respectively. The corresponding values for UCS were 0.64, 0.66, 1.21, 1.27 and 1.33. While for 8% additives the CBR for soil B were 78.4%, 88.4%, 180.5%, 224.2%, 288.1% and UCS were 0.48, 0.68, 1.50, 2.16 and 2.45, respectively. It was observed that both the UCS and CBR values increased as the cement component increased for both soil samples. Stabilizing laterite with mixture of bitumen emulsion and cement improved the strength of the soil.

The Effects of wood saw dust ash admixed with treated sisal fibre on the geotechnical properties of, A-7-6(10) classification for AASHTO (1986) and CL according to unified soil classification system USCS, lateritic soil was investigated by J.E. Sani et al [29].The soil was treated with both wood saw dust ash (WSDA) and treated sisal fiber, in stepped concentration of 0,2,4,6, and 8% for WSDA and 0, 0.25, 0.5, 0.75 and 1% treated sisal fibre by dry weight of soil using Standard proctor. The Sisal Fibre was treated with Sodium Borohydride (NaBH4) (1% wt/vol) for 60 minutes at room temperature to remove the cellulose content present in the Fibre. Statistical analysis was carried out on the obtained results using XLSTART 2017 software and analysis of variance with the Microsoft Excel Analysis Tool Pak Software Pack-age. The liquid limit (LL) of the soil was found to be 48% while the plastic limit(PL) is 21.27%. The maximum dry density (MDD) however, decreases generally from a value of 1.85 Mg/m3 to 1.68Mg/m3 at 0.25% sisal fiber content/0% WSDA. It has its least value of 1.57Mg/m3 at 1% sisal fiber and 8% WSDA. The OMC increased from 18 % of the natural soil to 23.7% at 0.75% sisal fiber / 6% WSDA content. There was a general increase in the value of UCS of the soil sisal fibre mixture with WSDA content from 100 kN/m2 of the natural soil to 696 kN/m2 at 0.75 % sisal fibre content / 6% WSDA.

K. Chethan [30] Studied the Effect of Industrial Textile Effluent Interaction with both Laterite Soil and Expansive Soil. Atterberg limit, free swelling, compaction values, optimum moisture content(OMC), and maximum dry density(MDD) and also Unconfined Compressive Strength (UCS) for both expensive soil and laterite soil evaluated by mixing various percentage (0%, 20%, 40%, 60%, 80% and 100%) of textile effluents with a time period of zero to fifteen days. The Liquid limit and plastic limit values of expensive soil decreased and Increased in laterite soil treated with various percentages of textile effluent. The optimum moisture con-tent of expensive soil increase with treating the different percentages of textile effluent whereas decreases in laterite soil. There is a slight reduction in MDD for expensive soil and slightly increases for laterite soil addition with various percentages of textile effluent. The UCS of the both soils in-creases with treated with different concentration textile effluent with respective curing period. The UCS of the laterite soil gradually increases with textile effluent with respective curing period. For lesser curing periods more quantity of textile effluent is required to achieve the same strength. The stability of soils mass is increased due to the addition of textile effluent. Finally, He concluded that textile effluent is more effective for laterite soil.

J.Menon and M. S. Ravikumar [31] evaluated the strength of locally available laterite soil stabilized using Polyethylene Terephthalate(PET) Bottle fibers and Polypropylene(PP) Sack fibers which can be applied in the manufacture of com-pressed stabilized earth blocks (CSEB). The experimental analysis was conducted at four percentages of fiber content i.e. 0%, 0.10%, 0.15% and 0.2%. Based on the test results they suggested that 0.15% PP(sack) fiber is the most suitable stabilizer for laterite soil which is to be used for making com-pressed stabilized earth blocks.

A laboratory assessment of a lateritic soil stabilized with milled eggshell, cement and mixture of both in ratio 1:1 for potential use as a highway construction material were carried out by O.E. Oluwatuyi et al [32]. The stabilizing binders were added to the soil at varying percentages of 0, 2, 4, 6, and 8% by weight of the soil and afterwards subjected to various laboratory tests to determine its ameliorating effect. The test results showed that both unsoaked and soaked California bearing ratio (CBR) values increased with higher stabilizing binder content. The unconfined compressive strength (UCS) values just like the CBR values also increased with higher stabilizing binder content. The 8% milled eggshell and cement stabilized samples recorded peak UCS value of 760.7 kN/m2, unsoaked CBR value of 87% and soaked CBR value of 45%. This peak UCS value met the condition by Nigerian General Specifications for highways of 750–1500 kN/m2 for use as subbase material for light trafficked highways. The durability of some stabilized soil samples was satisfactory, the percentage resistance to loss in strength was not below the recommended maxi-mum of 80%. An 8% by soil weight of milled eggshell and cement mixture in ratio 1:1 stabilized lateritic soil could be used as a potential subbase material for high-way construction.

G. M. Ayininuola and O. A. Adekitan [33] studied the compaction behaviour of two lateritic soils stabilized with a blend of Portland cement (PC) and Calcined kaolinite clay (CKC) combined in CKC:PC ratios of 0:1, 1:3, 1:1, 3:1 and 1:0 with total binder percentages of 0 (control), 2.5, 5, 7.5 and 10 of the weight of soils. Two lateritic soils samples were adopted and classified as A-1-a and A-2-6 based on AASH-TO system. corresponding fineness modulus were 2.18 and 4.33 with cation exchange capacities (CECs) of 1.678 meq/100 gms and 1.738 meq/100 gms respectively. The results showed that, as the CKC:PC mixes varies, compaction behaviour of the stabilized A-2-6 soil was widely varied whereas it was minimally varied for the stabilized A-1-a soil. The differences in the particle sizes (fineness modulus) and CEC are adduced as factors responsible for these differences in compaction behaviour. However, the CECs of the soils is about the same. Thus, the differences in compaction performance could only be attributed to differences in the particles sizes of the soils. Statistical evaluation of differences in the results using ANOVA confirms that the differences for the A-2-6 soil are significant whereas that of the A-1-a soil are not.

E. S. Nnochiri and O.M. Ogundipe [34] Studied the effects of coconut shell ash (CSA) on lime stabilized lateritic soil for road construction. The optimal percentage of lime CSA combination was achieved at a 4% lime + 4% CSA because the highest value of Unsoaked CBR was recorded at this stage. The results in terms of the California Bearing Ratio and Unconfined compressive strength, indicate that the 4% lime + 4% CSA Combination is higher than the 8% lime stabilization. Coconut Shell Ash(CSA) can therefore serve as a cheap compliment for lime in soil stabilization.

The geotechnical properties of lateritic soil stabilized with beach sand were determined by Q. Memudu et al [35].The beach sand was added in percentages of 0(control), 2.5, 5, 7.5, 10, 12.5 and 15% by weight of the soil. Results of the CBR (soaked) test showed an increase in value from 4.53% for the control to 5.96% at 15% beach sand addition while the CBR (unsoaked) showed an increase in value from 3.46% for the control to 34.85% at 15% beach sand addition.

An experimental study on the effects of Palm Kernel Shell Ash (PKSA) on CBR and UCS parameters of cement-modified lateritic soil samples were carried out by A.O. Olutaiwo and J. O Adetunji [36]. PKSA was used to stabilize plain and also cement-modified soil samples at 2%,4%,6%,8%,10% and 12% by dry weight of the soil. The results showed significant increase in the strength parameters of the soil modified with PKSA and cement, by 51%, 391%, and 32% for MDD, CBR and UCS respectively. They concluded that a PKSA alone is not a suitable stabilizing agent for lateritic soils but when mixed with 3% OPC, significant results can be obtained in terms of strength.

K. Onyelowe et al [37] studied the effect of the Green Crude oil (GCO) on the strength properties of lateritic soil. The soil was treated with varying percentages of crude oil; 0, 2, 4, and 6% by weight of the soil. The results obtained showed that the GCO improved the strength properties of the treated soil.

E.E. Ndububa [38] Stabilized lateritic bricks as alternative to mud housing. The laterites had particle components of 22.0% clay, 16.8% silt and 61.2% sand. They were stabilized with cement, lime and bitumen respectively and tested for compressive strength, water absorption capacity, linear Shrinkage and permeability. The stabilizers were introduced to the laterite in ratios of 3%, 5% and 7% respectively before testing. They were cured for 7, 14, 28 and 42 days respectively. After 28 days of curing, cement stabilized laterites (CSL) possessed compressive strengths of 1.98N/mm2, 2.83N/mm2 and 3.48N/mm2 respectively. Zero stabilized laterite (ZSL) had a maximum value of 1.27 N/mm2 after 42 days. The water absorption capacities were 6.65%, 5.23% and 4.88%. Lime stabilized laterite (LSL) had compressive strengths of 0.84N/mm2, 0.94N/mm2 and 1.02N/mm2 and water absorption capacities of 10.3%, 9.48% and 9.14%. ZSL had 16.41% value. Compressive strength for bitumen stabilized laterite (BSL) were 0.92N/mm2, 1.03 and 1.11N/mm2 with water absorption capacities of 3.13%, 1.73% and 1.49%. Further results showed that 7% CSL had a permeability of 4.47 x 10-9 m/s at 20oC and 7% LSL had a permeability of 7.30 x 10-9m/s. Generally the bricks experienced less linear shrinkage with increase of percentage of stabilizers, however CSL had least shrinkage of 0.47% while BSL had highest of 1.33%. The results showed that stabilized laterites produced superior performance than ZSL. Cement was the best characteristic performer except in water absorption where BSL absorbed least water.

The effect of eggshell powder or ash on the strength properties of cement-stabilization on Olokoro lateritic soil was studied by M.N. Maduabuchi and F.O. Obikara [39]. The eggshell was mixed with the cement-stabilized soil in the proportions of 3%, 6%, 9%, 12% and 15% and the geotechnical behavior of the soil was carefully observed. The results of the study showed that the strength properties of the A-6 soil, according to its AASHTO classification, improved with the addition of eggshell ash.

III. CONCLUSION

From the review of literatures on the stabilization of lateritic soil, the following conclusions are drawn: (i)stabilization of lateritic soil using Terrasil solution, quick and hydrated lime, banana leaves ash, oil palm fronds ashes, eggshell powder, limestone ash, cement, lime-cement mix, Ground-nut Husk Ash, Nanostructured Clay additive, Nanostructured Waste Paper Ash, Coconut shell husk ash (CSHA), palm kernel shell husk ash (PKSHA),saw dust ash-lime mix, sugarcane baggase ash-cement mix, Terrazyme, Industrial textile effluent, beach sand, cement- calcinated kaolinite clay, coconut shell ash-lime mixture, palm bunch ash, bitumen emulsion–cement mix, wood saw dust and Sodium Borohydride treated sisal fiber, Green crude oil, polypropylene sack fibers, milled egg shell-cement mix and periwinkle shell ash- lime mix improves some of the geotechnical properties of Lateritic soil, (ii)the effects of stabilizing agents on index properties, compaction properties, unconfined compressive strength and California bearing ratio properties of lateritic soil discussed on majority of the literatures, (iii)most researchers have not studied the effects of stabilizing agents on consolidation properties and shear strength of lateritic soil, (iv)results of field studies are also found to be negligible in literatures and (v)the response of the stabilized soil subjected to cyclic loading is limited in literatures.

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