ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY & ENVIRONMENT
AZOJETE, September 2019. Vol. 15(3) 733-749
Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria.
Print ISSN: 1596-2490, Electronic ISSN: 2545-5818
www.azojete.com.ng

ORIGINAL RESEARCH ARTICLE

REVIEW OF AGRICULTURAL WASTE UTILIZATION AS IMPROVEMENT ADDITIVES FOR RESIDUAL TROPICAL SOILS

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ARTICLE INFORMATION

Submitted 22 November, 2018
Revised 7 March, 2019
Accepted 10 March, 2019

Keywords:
Agricultural waste
Soil improvement
rice husk ash
Palm oil fuel ash
Corn cob ash

ABSTRACT
The development of a nation partially depends on sustainable materials obtained from agricultural products. Increased agricultural products could increase the amount of waste generated yearly. This paper presents a review on the use of agricultural waste with pozzolanic properties (rice husk ash, Locust bean waste ash, Palm oil fuel ash, Banana leaf ash, Bagasse ash, Coconut shell ash, Bamboo leaf ash, Corn cob ash, Cassava peel ash and Palm kernel shell ash) in various geotechnical engineering applications. Interestingly, these wastes were subjected to various laboratory tests such as (particle size distribution, Compaction, Atterberg, unconfined compressive strength (UCS) and California bearing ratio (CBR)) to assess their effectiveness in soil improvement. In all these, the percentages of the materials required for soil improvement were discussed. The reports from various researchers have shown that agricultural waste having pozzolanic properties improves the engineering properties of soil. For instance, palm oil fuel ash (POFA) is mostly used as an admixture in concrete as reported elsewhere. Few studies have been carried out on the use of banana leaf ash and palm oil fuel ash as soil improvement materials. It is recommended that further researches should focus on the possibility of using other agricultural waste from Cocoyam, Yam peel, maize trunk, Cashew and Guava that have limited reporting researches for use as soil improvement materials.

1.0 Introduction

Several studies have shown the importance of agricultural waste products as an alternative to conventional material for soil improvement (Olonode, 2010; Oluremi et al., 2012; Ako and Yusuf, 2016, Ishola et al., 2019). The residues generated from the growing and processing of raw agricultural materials such as fruits, vegetables, meat, poultry, dairy products, and crops are regarded as agricultural wastes. The report of Obi et al. (2016) sheds light on the waste obtained from the food processing industry especially that of maize where it was indicated that 20% is good for canning and remaining 80% counted as waste. The significant increase in agricultural wastes globally was due to intensifying farming systems, high demand in the food industry and increase in housing areas that lead to the clearance of plantation area (Daud et al., 2016). The increases in global population lead to a high rate of agricultural products which in turn increases the waste produce yearly (Agamu, 2009). Interestingly, wastes from agricultural product like locust bean, Rice husk, Palm oil, Banana Tree, Sugarcane, Bamboo Tree and palm kernel have widely been used to improve the geotechnical properties of tropical soils (lateritic and black cotton soils) among others that are deficient for engineering application in their natural form (Bello et al., 2015; Sadiq et al., 2015). A report shows that about 998 million tonnes of agricultural waste are generated every year (Agamu, 2009). These rates prompted researchers to focus more on how the materials can be converted for use as a material for soil improvement in construction.

Lateritic soils are generally used in many developing countries like Nigeria for the construction of sub-base and base courses in both flexible and rigid pavements. In most of these regions, the dominant soil material available is lateritic soil. Additionally, it is readily available and found in abundance and are cost-effective (Alhassan and Mustapha, 2015). Naturally, lateritic soil has a low bearing capacity and low strength due to high clay content. It has been reported that lateritic soil with large clay materials would not have guaranteed strength and stability under loading in the presence of moisture (Bello et al., 2015). Typical laterite soils are generally rich in iron and aluminum formed in tropical areas. Most laterites are rusty-red because of the presence of iron oxides (Osinubi et al., 2009). They are formed by intensive and long-lasting 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. The initial products of weathering are essentially kaolinite rocks called saprolites (Nnochiri and Aderinlewo, 2016). Researchers have worked extensively on the geotechnical and engineering properties of lateritic soils in all geopolitical zones of Nigeria and other part of the country (Adewoye et al., 2004; Agbede and Osuolale, 2005; Bello, 2007; Bello et al., 2007; Bello and Adegoke, 2010; Owoseni et al., 2014 and Lekha, 2015).

Black cotton soil is tropical black clay having a colour characteristic of dark grey to black with high clay content and usually expansive in nature and contains over 50 % of montmorillonite which is the principal clay mineral (Rajakumar and Meenambal, 2015). These soils dominated semi–arid regions of tropical/ temperate zones and mostly found anywhere in the world, especially where the annual evaporation exceeds the precipitation (Rajakumar and Meenambal, 2015). Tropical black clays possess shrink-swell characteristics and cause damages (settlement) to structural pavement resting on such soils. However, this happened as a result of variation in moisture content that is not evenly distributed (Osinubi et al., 2010; Akinmade, 2016). Generally, deposits of black cotton soil in the field show a general pattern of cracks during the dry season of the year. The Cracks measured about 70 mm wide and over 1m deep have been observed and may extend up to 3m or more in case of high deposits (Rajakumar and Meenambal, 2015). Black cotton soil usually loses its strength properties to the wet and dry characteristic which have effect in its hardness. The presence of montmorillonite and illite in the black cotton soil has made it exhibit very low bearing capacity, low permeability, and high volume change. However, In their natural state, these properties make them unsuitable for construction of embankment, highway, building or any other load bearing structure (Das, 1998). These types of soil group form found in the North Eastern part of Nigeria and exhibit large volume changes with respect to the variation of seasonal moisture content (Eberemu et al., 2012). They usually pose challenges to civil engineering works because of their swelling and shrinkage characteristics and call for a need to improve such soils prior to their applications for load bearing structures.

In order to make deficient soils suitable for use as a construction material, it presents properties needed to be improved. Such soils required the laboratory test such as permeability, unconfined compressive strength, and California bearing ratio, to assess their suitability for various engineering applications such as embankment, concrete and road construction (George and Oriola, 2010; Ochepo, 2014; Eberemu, 2013; Eberemu 2015; George et al., 2013; Sadiq et al., 2015; Amu et al., 2011; Bello et al., 2015). Generally, the improvement of deficient soils could either be by modification or stabilization or both. In the modification process, a modifier such as cement and lime are added to soil to change (improve) its index and friction properties. While Soil stabilization enhanced the strength and durability characteristic of the soil. However, they become totally suitable for construction beyond their original classification.

Over time, cement and lime have been the two main materials used for stabilizing soils. Neville (2000) reported that the cost of these materials has rapidly increased due to the sharp increase in the cost of energy since the 1970s. Current trend in research works of geotechnical engineering and construction materials has focused more on the search for cheap and locally available materials such as agricultural wastes (Rice husk ash(RHA), Locust bean ash (LBA), Palm oil fuel ash (POFA), Banana leaf ash (BLA), Sugar cane bagasse ash (SCBA), Bamboo leaves ash (BLA), Cassava peel ash (CPA), Corn cob ash (CCA) and palm kernel shell ash (PSA)) as stabilizing agents for the purpose of full or partially replacement of traditional stabilizers. Agricultural waste has become a focus of researchers, because of the enhanced pozzolanic capabilities of such waste when oxidized by burning. Thus, this review work evaluated the possibility of utilizing agricultural wastes in the improvement of residual tropical soils as suggested by several authors and pointed at the agricultural products that have limited reports in the literature.

2.0 Literature Review

2.1 Saw Dust Ash

Sawdust ash is obtained as a by- product of burning of sawdust from a timber shed. The sawdust is first air-dried and burnt under atmospheric condition within a temperature range of 550 – 650°C measured with a thermocouple. The ash obtained from the sawdust is allowed to pass through the No. 200 sieve (75 µm aperture) to meet the requirement of ASTM C618-78 (2013)

Thompson (2012) evaluated the effects of saw dust ash (SDA) on the geotechnical properties of soil obtained from two locations (A and B) in Southwestern Nigeria. Laboratory test was carried out on the two samples and samples mixed with up to 10% SDA content with respect to consistency limits, specific gravity, compaction, California bearing ratio, unconfined compressive strength and shear strength. The results show that saw dust ash has improved the geotechnical properties of the soil samples: maximum dry density increased from 1403 to1456 Kg/m^3 and 1730 to 1785 kg/m^3, optimum moisture content increased from 23.6 to 28.2% and 26.2 to 29.2%, unconfined compressive strength increased from 101.4 to 142.14 and 211.11 to 154.97, shear strength increased from 50.92 to 71.07 kN/m^2 and 77.49 to 105.99 kN/m^2 for samples A and B, respectively. Based on the laboratory test results, he concluded that saw dust ash is therefore found to be an effective stabilizer for lateritic soils.

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Yohanna et al. (2016) performed a reliability assessment of black cotton soil stabilized with sawdust ash admixtures for use in road construction. Treatment with up to 8% sawdust ash significantly improved the index properties, compaction and strength characteristics of the natural black cotton soil studied. Reliability estimates of strength characteristics (California bearing ratio, CBR and unconfined compressive strength, UCS) results with variable factors produced safety index values that are less than 1.0 and unacceptable. The results recorded indicate that black cotton soil compacted with reducing British standard light (RBSL) energy cannot be used as a road pavement material, but for low load bearing structures such as road shoulders and pedestrian walkways. However, saw dust ash (SDA) can be beneficially used as an admixture in road construction when a higher compactive effort is used.

Mannir et al. (2016) studied the effect of sawdust ash mixtures on compacted black cotton soil as road construction material. The result shows that the liquid limit, plastic limit, and linear shrinkage decreased, while the plasticity index increased with SDA content. Also, optimum moisture content (OMC) increased to a maximum value of 30% while maximum dry density decreased to a minimum value of 0.86Mg/m3 at 10% SDA content. Peak unsoaked California bearing ratio (CBR) value of 4% was recorded at 2% SDA content. On the other hand, peak 7 days unconfined compressive strength (UCS) value of 90kN/m^2 was recorded at 8% SDA content. The results recorded indicate that black cotton soil compacted with RBSL energy cannot be used as a road pavement material, but for low load bearing structures such as road shoulders.

Oluremi et al. (2007) evaluated the plasticity characteristics and cation-exchange capacity (CEC) of lateritic soil treated with up to 10% of iron ore tailing (IOT) and waste wood ash (WWA) using laboratory tests and regression analysis. Their results showed an initial increase in the cation-exchange capacity up to 8% IOT content and 2% WWA content. However, the plasticity characteristics (liquid limit and plastic limit) initially increased with higher IOT content and then decreased up to 2% WWA content and thereafter increased up to 10% WWA content. The plasticity index decreased up to 8% for IOT and 6% for WWA and thereafter increased with additional IOT and WWA contents, respectively. The regression analysis showed a close relationship between the experimental values and the predicted values for both IOT and WWA treated lateritic soil. The conclusion was made on the treated soil that an optimal blend of 8% IOT and 6% WWA contents with lateritic soil improved the consistency indices for use as a subgrade material in lightly trafficked roads.

2.2 Rice Husk Ash

Rice husk is an agricultural waste obtained from milling of rice/ rice mill factories and contains pozzolanic material (Yoobanpot and Jamsawang, 2014). Rice mill factories create a waste product called raw husk which is used as heating fuel in rice mill processing and produces the RHA as a byproduct from the burnt raw husk. In a year, about 10 tons of rice husk is usually produced globally (Bello et al., 2014). Oyetola and Abdullahi (2006) reported that in Nigeria, about 2.0 million tons of rice is produced annually, especially in Niger State where about 96,600 tons of rice grains are produced, however, this rate of production shows that high quantities of rice are being consumed, which in turn increase the quantity of rice husk produce annually. Generally, Rice husk ash has been reported to be a pozzolanic material with about 67-70 % (silica), 4.9 % (aluminum) and 0.95% (iron oxides) (Oyetola and Abdullahi, 2006).

Bello et al. (2014) investigated the influence of four compactive efforts namely Reduced British Standard Light (RBSL), British Standard Light (BSL), West African Standard (WAS) and British Standard Heavy (BSH) on the engineering properties of lateritic soil stabilized with rice husk ash (RHA) derived from Osun State University main campus, Osogbo, Osun State, Southwestern Nigeria. The results of laboratory tests conducted showed a reduction in maximum dry density (MDD) values for RBSL, BSL, WAS, BSH compaction energies, when natural soil was treated with 6%, 8%, 10% and 12% RHA respectively, however, increase in optimum moisture content (OMC) was recorded for RBSL, BSL, WAS, BSH at 4 %, 6 % and 8 % RHA respectively. They reported an improvement in California bearing ratio (CBR) of soaked samples from 2.5, 8 and 11% for BSL, WAS and BSH to 10, 18 and 30% at 4 -8% RHA content. Finally, the BSL that yielded CBR value of 10% at 6% RHA treatment of soil was recommended for use as subgrade of lightly trafficked roads and BSH that yielded CBR value of 30% at 4 % RHA stabilization of soil was being recommended for subbase construction (Bello et al., 2014).

Yoobanpot and Jamsawang (2014) investigated the compressive strength characteristics of soft soil improvement using RHA as a partial replacement of cement at various curing times of 3, 7, 14 and 28 days. In their results, 30% of RHA produced the soil strength of 424, 722, 915 and 1,126 kPa at 3, 7, 14 and 28 days curing respectively. They concluded that the increase in strength of the stabilized soil was relative to the formation of major reaction products such as calcium silicate hydrate.

Choobbasti et al. (2010) conducted a laboratory test to determine the influence of adding RHA on the amount and quickness of soil and lime reaction. They reported that the combination of soil with 4% lime gives the maximum amount of cohesion and internal friction angle parameters which is similar to the situation of using 3% and 5% RHA. However, the addition of RHA to the combination of soil with 4% lime caused an increase in the dilation parameter but shows a decreasing rate in the combination of soil with 6% lime. The addition of lime and RHA to the soil causes a decrease in the deformability of soil samples and gives more brittle materials. Moreover, this action causes an increase in shear strength. The maximum shear strength of soil with lime combination occurs at 5% RHA for 28 days of soil samples.

Chao-Lung et al. (2011) carried out a laboratory test to investigate the effect of marble dust on the strength and durability of an expansive soil stabilized with an optimum percentage of rice husk ash (RHA). Their report showed that the optimum percentage of RHA used was 10% based on unconfined compressive strength (UCS) tests. However, compaction tests, UCS tests, soaked CBR tests, swelling pressure tests, and durability tests were conducted on these samples after 7 days of curing. Finally, the result of UCS and soaked CBR of RHA stabilized expansive soil showed an increase of up to 20% addition of marble dust.

2.3 Locust Bean waste ash (LBWA)

The locust bean waste is a material obtained from locust bean fibrous after the husk has been removed. Locust bean tree is common in the environment, especially in Nigeria. The tree grows to about 15 m in height with dark, evergreen, pinnate leaves. An estimated value of about 200,000 tons of locust bean seeds is reported gathered each year in Nigeria (Osinubi et al., 2016). This comprises of husk, powder, and the seed which is commonly used to produce local seasoning for food. However, the husk is known to be waste among the three components which when burnt in an open place, produces ash called Locust bean waste ash (LBWA).

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Nwadiogbu and Salahudeen (2014) reported that LBWA is a pozzolanic material that is capable of reacting with lime in the presence of water at ordinary temperature to produce a cementitious compound.

Samaila and Srividhya (2015) reported the results of laboratory tests conducted to evaluate the characteristics of two weak soils (sample 1 and sample 2) stabilized with up to 8% and 6% LBWA content respectively. The preliminary test produced results for the two soil samples and showed that sample 1 and sample 2 that classified as CL and CH soil respectively have 75% and 100% free swell index, 43.6% and 53.2% liquid limits; 19.6% and 18.12% plasticity index; 72% and 68% fine content. They reported the results of other properties such as maximum dry densities, optimum moisture contents and unconfined compressive strength (UCS) for the two soil samples (sample 1 and 2) and are given as (1.74 g/cm^3 and 1.67 g/cm^3), (17.5% and 18%) and (1.5 kg/cm^2 and 2.1 kg/cm^2) respectively for the two soil samples. However, result of the stabilized samples showed that the UCS improved by 45% when soil sample 1 was treated with 8% LBWA, while the improvement of 102% was obtained when soil sample 2 was treated with 6% LBWA content for the same 7 days curing. Their report indicated that the properties of weak soils improved when stabilized with LBWA.

Nwadiogbu and Salahudeen (2014) carried out a laboratory test on the lateritic soil to evaluate the potential of lime on modified lateritic soil using locust bean waste ash as an admixture. The lateritic soil used was treated with up to 4% lime content and 8% LBWA content by weight of the dry soil sample In the sieve analysis performed, an increase in the particle sizes was observed with an increase in lime/LBWA content. However, an improvement in the atterberg limits was also observed as the maximum dry density (MDD) for British Standard Light (BSL) compaction increased to a peak value at 4% LBWA for all lime contents, while the West African Standard (WAS) compaction, have the MDD trend that followed continuous decrease. As per British Standard Heavy (BSH) compaction, no consistent trend was observed. Their report showed that corresponding optimum moisture content (OMC) values for all the three compactive efforts generally increased steadily. Generally, cohesion decreased while the corresponding angles of internal friction increased with increase in lime/LBWA content.

Adama et al. (2013) evaluated the effect of locust bean pod ash on the compaction characteristics of weak subgrade soils. Their studies made use of soils obtained from old borrow pits along Minna-Kataeregi-Bida road in Northern Nigeria and analyzed for the main index properties and compaction. The experimental results revealed that locust bean pod ash reduced the maximum dry density from 1.68-1.62, 1.33-1.304 and 1.62-1.50 g/cm^3 respectively for all the lateritic soil samples obtained while it increased the optimum moisture content from 10.4 -11.5, 18.0 -19.5 and 12.03-18.50% respectively thus, improving the compaction properties. Considering compaction characteristics and economy, 6-10 % weight of stabilizer to the soils was considered as the required optimum values for satisfactory accomplishment of the stabilization of the weak soil as road sub-base.

Akinmade et al. (2016) conducted a study on the evaluation of strength characteristics of tropical black clay treated with locust bean waste ash up to 15 % of LBWA to assess its soil improvement potential. The natural and treated soil samples used for the study were subjected to index and compaction test using three energy levels (British Standard light, BSL, West African Standard, WAS or 'Intermediate' and British Standard heavy, BSH), shear strength (unconfined compressive strength, UCS), California bearing ratio, CBR and durability tests. It was reported that maximum dry density (MDD) and optimum moisture content (OMC) decreased and increased, respectively. However, regardless of the compactive effort and curing period, strength and durability properties increased with higher LBWA content.In checking for durability results, it was observed that optimal 12.5% LBWA treatment of black cotton soil obtained from BSL energy level cannot satisfy criteria for its use in road construction.

Namadi and Yamusa (2013) carried out a laboratory test to investigate the influence of locust bean waste ash (LBWA) on cation exchange and plasticity characteristics of ordinary Portland cement (OPC) modified lateritic soil. In the preliminary tests carried out on the natural soil and soil-cement mixtures up to 4% OPC admixed with 8% LBWA content by weight of the dry soil showed an improvement in the plasticity characteristics of the soil, reflected in the decrease in liquid limit, increase in plastic limit and decrease in plasticity index with increase a cement and LBWA content .Following the results obtained, they concluded that modification with cement and LBWA blend significantly improved the plasticity characteristics through cation exchange of the lateritic soil.

2.4 Palm Oil Fuel Ash (POFA)

Palm oil fuel ash (POFA) is a product of palm oil residue obtained from palm oil mills, when burnt into ashes it contained a large amount of silica in its chemical composition, which may be used as a cement replacement like rice-husk ash and sawdust (Ikpong and Okpala 1992; Elinwa and Mahmood 2002; Tangchirapat et al., 2009). However, the use of POFA as a pozzolanic material to replace conventional stabilizing materials (cement, lime etc) is known to few researchers and POFA not more than 10% by weight of a binder has been recommended by Tay (1990). POFA exhibited some pozzolanic properties and could be used as a partial replacement for cement (Safiuddin et al., 2011; Tangchirapat et al., 2009).

Pourakbar et al. (2015) investigated the possible uses of Palm oil fuel ash (POFA) on clayey soil. The laboratory tests (Proctor compaction, Atterberg limit and unconfined compression strength) were carried out on stabilized and unstabilized soil and results obtained were then compared with samples treated with cement. Scanning electron microscopy with X-ray microanalysis was conducted on untreated and treated soil to show their strength properties. From their findings it was revealed that POFA/cement mixture treatments result significantly reduce the soil plasticity index (PI), decrease the optimum moisture content and increased the maximum dry density across selected binder dosages. However, using POFA alone to stabilize clayey soil resulted in a slight increase in the UCS of the specimens until the 28 days of curing, whereas combining POFA with cement results in a sharp increase in the UCS of the samples in the same curing time.

Tangchirapat et al. (2009) conducted a research study on utilizing palm oil fuel ash (POFA) as a pozzolanic material for replacing Portland cement. The POFA was grounded to replace cement 40% by weight of the binder and the effects of POFA fineness on the set times, compressive strength, and expansion of mortars exposed to a 5% $MgSO_4$ solution was investigated. It was found that the use of POFA to replace Portland cement caused an increase in water demand and setting time. Up to 10% replacement of Portland cement with POFA increased the compressive strength of the mortar. However, the ground POFA was a good pozzolanic material and can be used to increase both the compressive strength and the sulfate resistance of mortar.

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2.5 Banana Leaf Ash (BLA)

Banana is known as a plant that produces fruit and possesses the largest herbaceous flowering plant that consists of fruit, flower, and leaves. Banana is produced in 135 countries and among the highest producer in the year 2017 were indian and china, which approximated to about 38 % of the total world population (FAOSTAT, 2017). This rate showed the wide application and high consumption level of banana in the country, especially in Nigeria. Banana leaf is large, flexible, and waterproof and often used as ecologically friendly disposable food containers or as "plates" in South Asia and several Southeast Asian countries.

Emeka and Aderinlewo (2016) investigated the geotechnical properties of lateritic soil stabilized with banana leaf ash. They carried out preliminary soil tests (natural moisture content, specific gravity, and Atterberg limit) on the natural soil sample collected from the Federal University of Technology, Akure (FUTA), Nigeria and Engineering tests such as compaction, California bearing ratio, and unconfined compressive strength tests were also performed on the lateritic soil at their natural and stabilized states up to 10% banana leaf ash content by weight of the dry soil. Result of the strength tests showed that the banana leaf ash enhanced the strength of the lateritic soil. The unsoaked CBR and unconfined compressive strength values improved at 4% banana leaf ash. However, they concluded that banana leaf ash satisfactorily acted as cheap stabilizing agents for subgrade purposes.

2.6 Bagasse Ash (BA)

Bagasse is the fibrous residue obtained from sugar cane after the extraction of sugar juice at sugar cane mills (Osinubi and Stephen, 2005). Bagasse ash is the residue obtained from the incineration of bagasse in sugar producing factories. The ash has been reported to be a good pozzolanic material (Osinubi and Alhassan, 2008., Osinubi and Mustapha 2008) with possession of silica and alumina contents of up to 77. 29% and 10.95% respectively for ash obtained from bagasse burnt at 700°C temperature.

Osinubi et al. (2009) investigated the geotechnical properties of the deficient lateritic soil up to 12% bagasse ash by dry weight of the soil sample. Soil samples were subjected to particle size analysis, compaction, unconfined compressive strength (UCS), California bearing ratio (CBR) and durability tests. The energy level employed for compactions test was British Standard Light (BSL) producing results that showed changes in moisture-density relationships resulting in lower maximum dry densities (MDD), higher optimum moisture contents (OMC), reduction in fine fractions with higher bagasse ash content in the soil – stabilizer mixtures. Results of UCS and CBR values were given as 836 kN/m^2 and 16%, respectively at 2% bagasse ash treatment of lateritic soil. They concluded that since these values were below 1,700 kN/m^2 and 80% for UCS and CBR, respectively, recommended for adequate cement stabilization. It implies that bagasse ash cannot be used as a 'standalone' stabilizer but should be employed in admixture stabilization.

Salahudeen and Ochepo (2015) carried out laboratory tests on lateritic soil to evaluate the effect of bagasse ash (BA) on the California bearing ratio of lateritic soil. The tests were performed on natural and bagasse ash treated soil. In the study, treated specimens were prepared by mixing the soil with bagasse ash in steps of 0, 2, 4, 6 and 8% by dry weight of soil. Results of their investigation showed that the specific gravity of the soil samples decreased from 2.61 for the natural soil to 2.48 at 8% bagasse ash content. However, by dry weight of the soil sample the liquid and plastic limits increased from 36.32 to 38.0 and 21.30%, to 21.54 % respectively at 2% bagasse ash content. The maximum dry density (MDD) of the soil increased from 1.48 Mg/m3 for the natural soil to a peak value of 1.49 Mg/m^3 at 8% bagasse ash content with the corresponding increase in optimum moisture content (OMC) from 18.5% for the natural soil to 19.0% at 4% bagasse ash content. Result obtained for unsoaked California bearing ratio for the lateritic soil treated with 4% BA content and above met the minimum CBR value of 30% specified by (BS 1990) for material suitable for use as base course material when determined at MDD and OMC. However, the highest CBR value of 62% recorded at 8% BA content failed to meet the 80% CBR value recommended by the Nigerian general specification (1997) for cement stabilization. Bagasse ash improved the CBR value of lateritic soil when compacted at optimum moisture content.

Ochepo et al. (2015) evaluated the effect of bagasse ash on the California bearing ratio of contaminated lateritic soil. In their study, the treated specimen was mixed with bagasse ash up to 8% by dry weight of the soil sample and contaminated with used oil up to 6% by dry weight of the soil sample. Result of investigations showed that the specific gravity of the soil sample decreased from 2.61 for the natural lateritic soil to 2.48 at 8% bagasse ash content and a similar trend was reported for 6% oil / 0% bagasse ash and 6% oil/8% as decreased to 2.16 and 2.11 respectively. Other test results such as liquid limit and plastic limit increased from 36.32 and 21.30 % respectively to peak values of 38.0% and 21.54 % at 2% bagasse ash content for all oil contents. The MDD of the soil increased from 1.48 Mg/m^3 to 1.49 Mg/m^3 at 8% bagasse ash content for all oil contents. OMC values increased from 18.5% for the natural soil to 19.0% at 2% bagasse ash content. Result of unsoaked CBR obtained at 4% BA content and above met the minimum CBR value of 30% specified by BS 1990 for materials suitable for use as base course material when determined at MDD and OMC. However, higher CBR value of 62% recorded at 8% BA content failed to meet 80% CBR value recommended by the Nigeria general specification (1997) for cement stabilization. Oil contamination caused reduction in the strength andCBR value of lateritic soil.

2.7 Coconut Shell Husk Ash (CSHA)

Coconut shell husk can be regarded as an agricultural waste that is widely available in larger quantities in tropical countries of the world (Obi et al., 2016) and it is used in Nigeria and some other part of the country as a source of fuel for the boilers (Obi et al., 2016). Onyelowe (2016) studied the effect of coconut shell husk ash (CSHA) and palm kernel shell husk ash (PKSHA) on the axial load and compaction behavior of pozzolan stabilized lateritic soil. The admixtures (CSHA and PKSHA) used in the study, were applied in proportions by weight of soil sample as 0, 2, 4, 6, 8 and 10 %. Results showed that the two admixtures increased optimum moisture content and decrease the maximum dry density of soil. The triaxial test examination conducted on the stabilized soil showed that the value of unit weight and dry unit weight decreased at addition of different percentages of CSHA and PKSHA but that of PKSHA reduced drastically than that of CSHA. However, the unconfined compression strength (UCS) increased with respect to the curing days and also increased at different percentages of CSHA and PKSHA. Natural UCS value was given to be 6.43 kN/m^2, 8.65 kN/m^2 and 14.80 kN/m2 for 0, 7 and 14 days respectively and later improved to 10.79 kN/m2, 31.82 kN/m^2 and 40.00 kN/m^2 respectively when stabilized with up to 10% CSHA content. However, 11.38 kN/m^2, 33.43 kN/m2 and 41.64

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kN/m^2 was recorded for an improvement at 10% PKSHA for 0, 7 and 14 days respectively. With the improvement of the strength properties of the weak soil studied by using CSHA and PKSHA, he then recommended for use as admixtures for the improvement of the geotechnical properties of weak engineering soil.

2.8 Bamboo Leaf Ash (BLA)

Bamboo grows abundantly in most of tropical countries and found naturally as a composite material. The possession of cellulose fibers embedded in a lignin matrix makes bamboo considered a composite material (Amu and Babajide, 2011). Some researchers has identified various species of bamboo to be 1,200 globally (Wang and Shen, 1987). Bamboo chips were used to record history in ancient China and have been used as a building material over the history of mankind (Amu and Babajide, 2011). It has also been used widely for household products and extended to industrial applications due to advances in processing technology and increased market demand. Massive plantations of bamboo provide an increasingly important source of raw material for the pulp and paper industry in China (Hammett et al., 2001).

Amu and Adetuberu (2010) conducted a research study on the characteristics of lateritic soil stabilized with bamboo leaf ash (BLA) in highway construction. Preliminary and geotechnical property tests (compaction, California bearing ratio (CBR), and triaxial) were performed on the three soil samples at step concentration of 0, 2, 4, 6, 8 and 10% bamboo leaf ash (BLA) by dry weight of soil sample. The results showed that the addition of BLA improved the strengths of the samples. However, reduction in optimum moisture contents was recorded for the three soil samples (A, B and C) classified as A-2-7(2), A-2-4(1) and A-2-5(3) soil respectively at 8, 4 and 6% BLA, respectively, while MDD increased for the samples (A, B and C) at 8, 2 and 4% BLA respectively. The unsoaked CBR values and shear strength values increased for sample A and B, and it was concluded that bamboo leaf ash had a good potential for stabilizing lateritic soils in highway construction.

Umoh and Adesola (2015) investigated the characteristics of bamboo leaf ash blended cement paste and mortar. In their test results, the physical properties of pastes were determined and compared with the requirements stipulated by relevant standards. An increase in compressive strength was recorded for the mortar cubes with an increase in curing age. They reported that the mix with 15% bamboo leaf ash favourably satisfied the standard mix at 28 days. Therefore, it was recommended that 15% BLA could replace cement for adequate production of masonry mortar.

2.9 Corn Cob Ash (CCA)

Corn cob is an agricultural waste product obtained from maize or corn. Zhang et al. (2013) reported that an estimated weight of about 160- 180 kg corncobs generated from every 1 ton of corn produced. However, most of the corncobs generated worldwide are discarded as waste (Zhang et al., 2010). The disposal of this enormous waste constituted pollution to the environment. Thus, many researchers have considered recycling it for various applications.

Akinwumi and Aidomojie (2015) investigated the effect of corncob ash (CCA) on the geotechnical properties of lateritic soil stabilized with Portland cement. Preliminary tests (specific gravity, consistency limits, compaction, California bearing ratio (CBR) and permeability) were carried out on natural soil and stabilized soil with up to 12 % corn cob ash. Results obtained from the test showed that the addition of CCA to the lateritic soil reduced its plasticity, swell potential and permeability; and increased its strength. It improved the geotechnical properties of the soil for pavement layer material application.

Raheem et al. (2010) investigated the effects of plasticizer on the properties of corn cob ash (CCA) cement concrete. Their study was aimed at the workability and compressive strength of CCA cement where the end results showed an improvement in the workability of corn cob ash cement concrete. The CCA cement concrete incorporated with accelerator achieved greater strength at early ages, plasticizer achieved very high strength at both young and old ages; and water retards the strength at old age. Olafusi and Olutoge (2012) made a study to determine the strength properties of corn cob ash concrete, enhancement of the reduction of corn cob wastes and reduction in the cost of concrete. They carried out various tests on concrete cubes of size 150 × 150 × 150 mm^3 and concrete cylinders of size 100 x 200mm with different percentages by volume of CCA to Portland cement and their physical and mechanical properties were determined. Result of mechanical properties tests on the compressive strength showed that 10% of the CCA in replacement for cement was quite satisfactory with no compromise in compressive strength requirements for concrete mix ratios 1:2:4 at 7days. In addition, the test results also showed that the use of CCA as a partial replacement for cement in concrete, particularly in plain concrete works and non-load bearing structures will enhance the waste to wealth initiative. Hence, CCA could be used as a partial replacement for cement in high strength concrete.

2.10 Cassava Peel Ash (CPA)

Cassava Peels is an agricultural waste obtained from cassava processing, either for domestic consumption or industrial uses and constituted up to 20-35% of the weight of tuber, especially in the case of hand peeling. In Nigeria, about 6.8 million tonnes of cassava peel are produced yearly which estimated to be 20% of the total population (Bello et al., 2015). The disposal of cassava peels indiscriminately constitutes a nuisance to the environment due to improper management and lack of appropriate technology to recycle them.

Olatokunbo et al. (2018) investigated the effect of cassava peel ash as a replacement for cement at 5, 10, 15, 20 and 25%. The cassava peel used was calcinated at 700oC temperature to obtain ash and test results showed that addition of 10 and 15% CPA gave stable compressive strength. The improvement reported was attributed to the cassava peel ash that contained all the main chemical constituents of cement in lower percentage compared with OPC which showed that it can serve as a suitable replacement if the right percentage is used.its durability and sulphuric acid resistance improved considerably at 10% replacement of cement with cassava peel ash.

Bello et al. (2015) carried out studies to assess the impact of Cassava Peels Ash (CPA) on the stabilization of lateritic soil deposit found within Osogbo local government area in Osun State, Nigeria. The preliminary and geotechnical property tests (compaction, California bearing ratio (CBR), and Unconfined Compression Test) were performed on three samples, L1, L2, and L3 classified as CL, SC and CL soil respectively for identification and classification purposes. The natural soil used was improved at step concentrations of 2, 4, 6, 8 and 10% Cassava Peels Ash (CPA) by dry weight of soil. Results obtained showed that addition of CPA improved the strengths of the samples as optimum moisture contents (OMC) reduced to 14.58, 18.40 and

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16.0% at 6, 4 and 6% CPA for samples L1, L2 and L3 respectively while maximum dry density (MDD) increased to 1470, 1410 and 1440 kg/m^3 at 10, 4 and 2% CPA for samples L1, L2, and L3 respectively. The unsoaked CBR values increased for the three soil samples at 8 and 10% CPA content and the shear strengths of samples (L1, L2, and L3) also increased up to 10 % CPA content. The studies concluded that the CPA has a good potential for stabilizing lateritic soil.

2.11 Palm Kernel Shell Husk Ash(PKSHA)

Onyelowe (2016) evaluated the effect of coconut shell husk ash (CSHA) and palm kernel shell husk ash (PKSHA) on the axial load and compaction behaviour of pozzolan stabilized lateritic soil. In his study, he made use of lateritic soil collected from Oboro in Delta state, coconut shell husk ash and palm kernel shell husk ash were applied in step concentration by dry weight of soil sample as 2, 4, 6, 8 and 10% respectively. An increase in optimum moisture content and a decrease in maximum dry density were recorded for the addition of the varied proportions of CSHA and PKSHA. However, the triaxial test results showed that the value of unit weight and dry unit weight of the test decreased at different percentages of CSHA and PKSHA while UCS results also show improvement for treated soil at 10 % CSHA and PKSHA.

3.0 Conclusion

This study showed the resurgence of interest in the use of alternative naturally occurring materials to the conventional additives (cement, bitumen and lime) for soil development. Agricultural wastes such as (Rice husk ash, Locust bean waste ash, Palm oil fuel ash, Banana leaf ash, Bagasse ash, Coconut shell ash, Bamboo leave ash, Corn cob ash, Cassava peel ash, and Palm kernel shell husk ash) have been found useful in concrete, geotechnics and Highway engineering applications. Engineering properties such as Atterberg, Strength, durability, and gradation to soil particles could be modified and improved upon by simple use of these materials as additives. However, there is little information regarding the use of banana leave ash and palm oil fuel ash as soil improvement materials. Furthermore, further study is required for the use of Palm oil fuel ash to understand its property and potential as a soil improvement material. In addition, waste sourced from Cocoyam, Yam, maize trunk, Cashew, and Guava have limited reports and is recommended to check for their properties and use as hydraulic conductivity material in stabilizing problematic soil.

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