Effect of Bagasse Ash on Some Engineering Properties of Lateritic Soil

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ABSTRACT

This study was carried out to evaluate the effect of bagasse ash (BA) on the California bearing ratio of lateritic soil. Laboratory tests were performed on natural and bagasse ash treated soil samples in accordance with BS 1377 (1990) and BS 1924 (1990), respectively. Treated specimens were prepared by mixing the soil with bagasse ash in steps of 0, 2, 4, 6 and 8 % by weight of dry soil. The preliminary investigation carried out on the natural lateritic soil shows that it falls under silt-clay material of Group A-6 using AASHTO classification and inorganic clay material CL according to Unified Soil Classification System (USCS). The specific gravity of the soil samples decreased from 2.61 for the natural soil to 2.48 at 8% bagasse ash content. The liquid and plastic limits increased from 36.32 and 21.30%, respectively, to 38.00 and 21.54% both at 2% bagasse ash content. The maximum dry density (MDD) of the soil increased from 1.48 Mg/m^3 for the natural soil to a peak value of 1.49 Mg/m^3 at 8% bagasse ash content. The Optimum Moisture Content (OMC) increased from 18.5% for the natural soil to 19.0% at 2 and 4% bagasse ash content and then decreased. The unsoaked California bearing ratio values from 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, 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 and maximum dry density.

KEYWORDS: Bagasse ash, Lateritic soil, Maximum dry density, California bearing ratio (CBR).

INTRODUCTION

Laterite is a clayey soil rich in iron and aluminium oxides, and is formed by weathering of igneous rocks in moist warm climates (Agbenla, 2010). It is composed mainly of iron and aluminium compounds and poor in humus and essential plant nutrients such as phosphorus, nitrogen and potassium, but may contain large amounts of quartz and kaolin (Alexander and Cady, 1962). Lateritic soils are products of intensive weathering that occurs under tropical and sub-tropical climatic conditions resulting in the accumulation of hydrated iron and aluminium oxides (Alexander and Cady, 1962; Gidigasu, 1972). Lateritic soils are mostly found as leached soils in the humid tropic climatic zone, where they were first studied. Lateritic soils are formed under weathering systems known as laterization, the most important characteristic of which is the decomposition of ferro-alumino silicate minerals and the permanent deposition of sesquioxides (Al_2O_3 and Fe_2O_3) within the soil profile to form the material known to engineers and builders as laterite (Gidigasu, 1972).

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The term "laterization" describes the processes that produce laterite soils (Gidigasu and Dogbey, 1980). Construction Industry Research and Information Association (CIRIA, 1988) proposed the following definition for lateritic soils, which states that: laterite in all its forms is a highly weathered natural material formed by the concentration of the hydrated oxides of iron and aluminium. This concentration may be by residual accumulation or by solution, movement and chemical precipitation (Ijimdiya, 2013).

Lateritic soils have been successfully used for the construction of roads, highways, aircraft runways, embankments and earth dams in various parts of the tropics. The degree of success in the use of these soils as a construction material depends on their characteristics and the specific purpose for which they are being used. A number of geotechnical studies on both stabilized and unstabilized lateritic soils for specific applications to road and building construction have been conducted (Osinubi, 1998; Osinubi and Katte, 1997).

Sugar cane is one of the major crops grown in over 110 countries, and its total production is over 150 million tons per annum. After the extraction of the sugar juice from sugarcane, about 40%-45% fibrous residue is left. This is reused in the same sugar cane industry as fuel in boilers for heat generation leaving behind 8%-10% ash as waste, known as sugar cane bagasse ash (SCBA). The resulting bagasse ash is deposited in stockpiles in waste landfill dumps and represents environmental problems to the society. When bagasse is left in the open, it ferments and decays; this brings about the need for safe disposal of the pollutant, which when inhaled in large doses can result in respiratory disease known as *bagassiosis* (Misari et al, 1998).

Results of various studies conducted on the properties of bagasse ash show that the ash possesses pozzolanic properties. There is a growing demand for fine amorphous silica materials in the construction industry today, hence it is economical for industrial waste materials such as bagasse to be recycled and converted into useful materials which can be used as additives to improve the engineering properties of deficient soil and make it suitable as a construction material.

According to Misari et al. (1998), the estimated land under sugar cane cultivation in Nigeria is between 25,000 and 30,000 hectares. However, land available for sugar cane cultivation is up to 147,000 hectares. Also, sugar cane yield in Nigeria was estimated at 80 tons per hectare, which leaves the amount of sugar cane produced today at between 2 million tons and 2.4 million tons per annum (Misari et al., 1998). According to Ogbonyomi (1998), the estimated average amount of bagasse from sugar cane is 30% by weight and the ash content from bagasse is 2.48%, which leaves the amount of bagasse produced in Nigeria annually to lie between 600,000 tons and 720,000 tons, while the amount of bagasse ash lies between 14,880 tons and 17,856 tons. While some of the bagasse is burnt to generate steam at the sugar factories, there is still substantial quantities of waste bagasse which create disposal challenges.

Bagasse is also used to make disposable food containers, replacing materials such as styrofoam which are increasingly regarded as environmentally unacceptable. It can also be used in a variety of applications such as flame retardants, insecticides and bio-fertilizers, insulators and ceramic glaze (NPCS, 2012). It has also shown to be suitable in geo-environmental applications for the treatment of lateritic soil in the construction of compacted clay liners for landfills (Eberemu, 2008). Ogbe (2006) recommended, after testing the effects of bagasse ash and curing period on the permeability of laterite compacted soils using standard proctor energy, that materials of this kind can be used for low-cost roads with light traffic.

MATERIALS AND METHODS

Materials

Soil: The soil used in this study is a natural reddish brown laterite which was collected from a borrow pit in Shika village, Zaria Local Government Area, Kaduna

State in the Northern part of Nigeria (latitude 11^o 15$^'$ N and longitude 7^o 45$^'$ E). Disturbed samples were collected at 1.5 m depth from the natural earth surface to avoid organic matter influence.

Bagasse Ash: The bagasse was obtained locally from a sugar cane processing plant situated in Gaskiya, Zaria Local Government Area in Kaduna State. The sugar cane waste (bagasse) was collected, air-dried and burnt under atmospheric conditions. The residue obtained was collected in sacks and transported to the soil laboratory of the Department of Civil Engineering, Ahmadu Bello University (ABU), Zaria. The ash was passed through B.S. sieve No. 200 (0.075mm) to meet the requirements of BS 1924 (1990) and ASTM (618-78). The chemical composition of the bagasse ash (BA) was determined at the Center for Energy Research and Training (CERT), ABU, Zaria using the method of Energy Dispersive X-Ray Fluorescence.

Methods

Index Properties: Laboratory tests were performed to determine the index properties of the natural soil and bagasse ash treated lateritic soil in accordance with BS 1377 (1990) and BS 1924 (1990), respectively.

Compaction: Compaction tests were performed on the natural soil and the bagasse ash treated soils at 0, 2, 4, 6 and 8 % BA treatment by dry weight of soil, using the British Standard light (BSL) energy.

California Bearing Ratio Test

The strength characteristic test carried out in this study is the California bearing ratio (CBR) test. It was carried out in accordance with the Nigerian General Specification (1997) which specified that specimen be cured in the dry for six days and then soaked for 24 hours before testing.

Table 1. Properties of the natural lateritic soil

Properties	Quantity
Percentage passing BS sieve no. 200	70.85
Liquid limit (LL) (%)	36.32
Plastic limit (PL) (%)	21.30
Plasticity index (PI) (%)	15.02
Linear shrinkage (LS) (%)	3.60
AASHTO classification	A-6
USCS	CL
Group index	107.74
Specific gravity	2.61
Natural moisture content (%)	15.8
Colour	Reddish brown
Optimum moisture content (OMC) (%)	18.50
Maximum dry density (MDD) (kg/m³)	1.48
Dominant clay mineral	Kaolinite

RESULTS AND DISCUSSION

Properties of Materials

The index properties of the natural soil show that it is an A-6 soil according to AASHTO classification system (AASHTO, 1986), and low plasticity clay (CL) using the Unified Soil Classification System, USCS (ASTM, 1992). The soil has a liquid limit value of 36.32%, plastic limit of 21.30%, plasticity index of 15.02%, linear shrinkage of 3.60% and specific gravity of 2.61 with 70.85% of the soil particles passing the BS No. 200 sieve (0.075 mm apertures). The predominant clay mineral is kaolinite. The properties of the natural soil are summarized in Table 1, while its particle size distribution curve is shown in Figure 1. The specific gravity of the bagasse ash used in this study is 2.34 and its oxide composition is given in Table 2.

Table 2. Oxide percentage of bagasse ash

Oxide	Composition
SiO_2	57.95
Al_2O_3	8.23
FeO_3	3.96
CaO	4.52
MgO	4.47
K_2O	2.41
LOI*	5.0

** Loss on Ignition.*

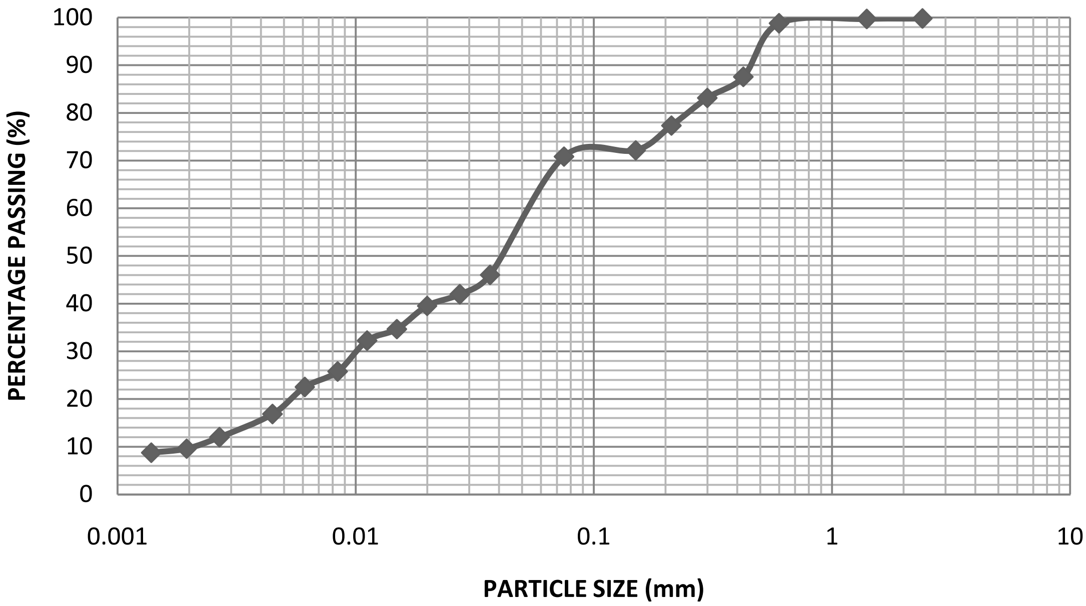

Figure (1): Particle size distribution curve for the natural lateritic soil

Effect of Bagasse Ash on the Specific Gravity of Lateritic Soil

The specific gravity of solid particles is the ratio of the mass of a given volume of solids to the mass of an equal volume of water. Specific gravity is an important parameter used for the determination of the void ratio and particle size of any soil particle (Arora, 2011). The value of the specific gravity of the soil-bagasse ash mixes decreased steadily from a value of 2.61 for the untreated lateritic soil to 2.48 at 8% bagasse ash content. This decrease in specific gravity is due to the lower specific gravity value of bagasse ash (2.34) compared to that of the soil.

Effect of Bagasse Ash on Atterberg Limits of Lateritic Soil

The variation of Atterberg limits of lateritic soil with bagasse ash content is shown in Figure 3. The introduction of bagasse ash into the soil first caused an increase in the Atterberg limits to a peak value at 2% bagasse ash treatment and thereafter decreased. The increase can be attributed to the pozzolanic activity of bagasse which required more water for hydration to be completed. The subsequent decrease can be associated with the agglomeration and flocculation of the clay particles as a result of ions' exchange at the surface of the clay particles. This observed trend is in agreement with those of Salahudeen and Akiije (2014) and Ramzi et al. (2001). Venkaramuthyalu et al. (2012) and Ramzi et al. (2001) reported that the reduction in plasticity index with chemical treatment could be attributed to the depressed double layer thickness due to cation exchange by potassium, calcium and ferric ions.

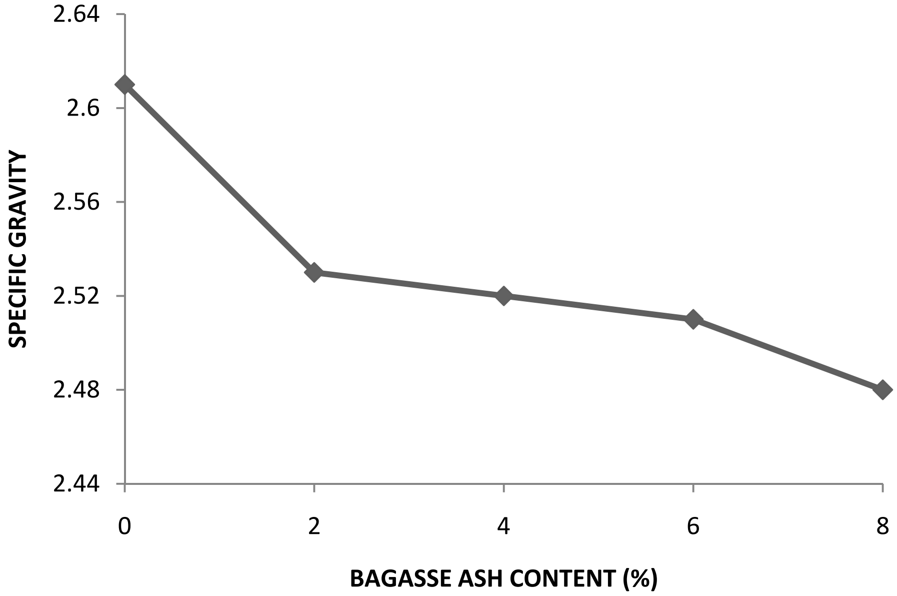

Figure (2): Variation of specific gravity of lateritic soil with bagasse ash content

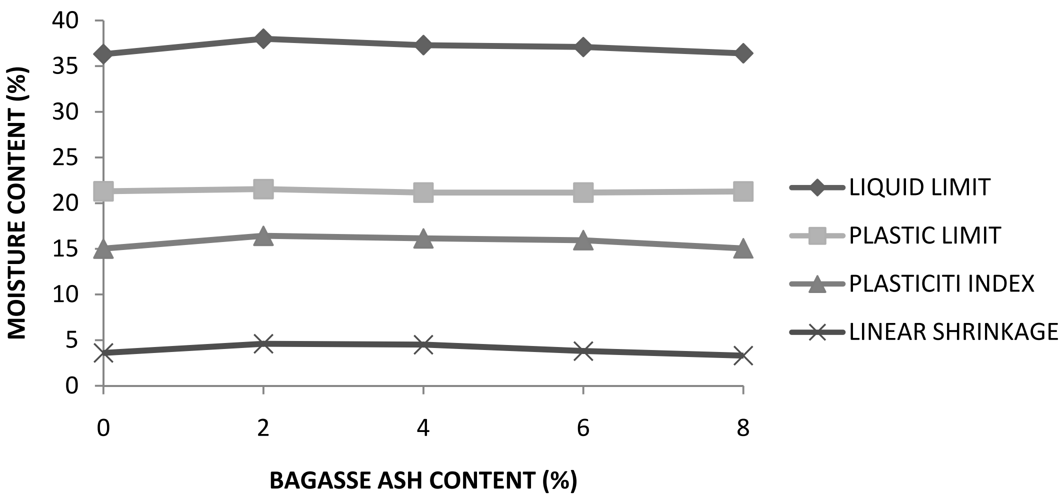

Figure (3): Variation of Atterberg limits of lateritic soil with bagasse ash content

Compaction Characteristics

The variations of maximum dry density (MDD) and optimum moisture content (OMC) of lateritic soil with bagasse ash (BA) content are shown in Figure 4. The MDD increased continuously with higher BA content. This increase in MDD could be due to BA occupying the voids within the soil matrix as well as the flocculation and agglomeration of the clay particles due to exchange of ions (Osinubi, 2000; Oriola and Moses, 2010; Salahudeen et al., 2014). The trend is in agreement with the findings reported by Lees et al. (1982), Ola (1991), Iorliam et al. (2012), Salahudeen and Akiije (2014) and Salahudeen et al. (2014).

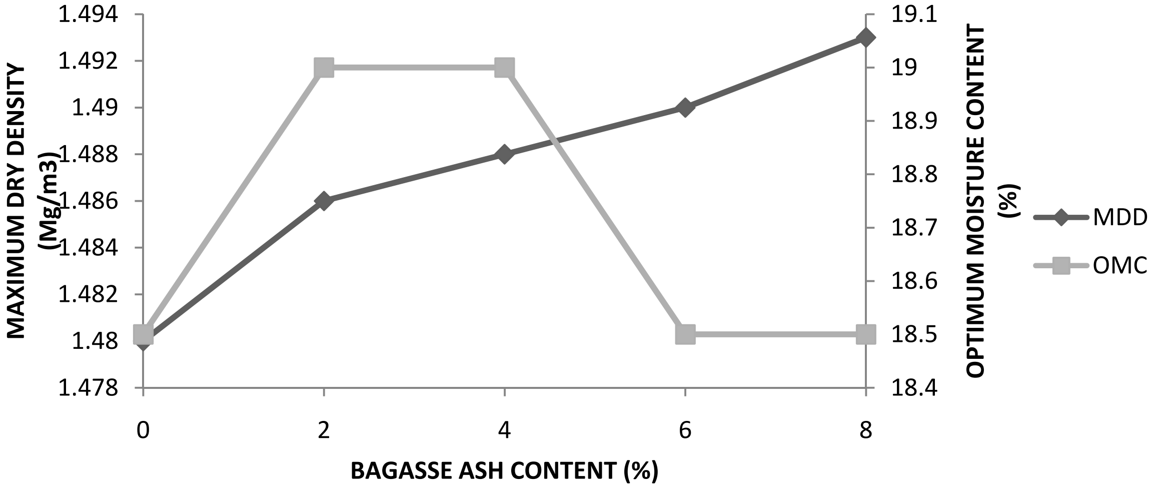

Figure (4): Variations of maximum dry density and optimum moisture content of lateritic soil with bagasse ash content

The OMC increased to a peak value at 2% and 4% BA contents and thereafter decreased with higher BA content. This trend is in conformity with results reported by Ola (1978), Gidigasu (1976) and Osinubi (1999). An explanation for this trend was the increased demand for water commensurate with the higher amount of admixture required for its hydration reaction and dissociation needed for cation exchange reaction. The subsequent decrease in OMC with increase in BA content might be due to cation exchange reaction that caused the flocculation of clay fractions of the soil.

California Bearing Ratio (CBR)

The variations of the unsoaked and soaked CBR values with bagasse ash (BA) content are given in Figure 5. A general increase in CBR values with BA content was observed. This increase could be due to the presence of adequate amounts of calcium required for the formation of calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH), which are the major compounds responsible for strength gain (Salahudeen and Akiije, 2014). For the soil–BA mixtures with 4 %BA content and above, the unsoaked CBR 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, the highest unsoaked 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.

The soaked CBR value (24 hours of soaking) of 20% observed at 8% BA content also met the value recommended by Gidigasu and Dogbey (1980), who stated that a minimum CBR value of 20%-30% is required for sub-bases when compacted at OMC.

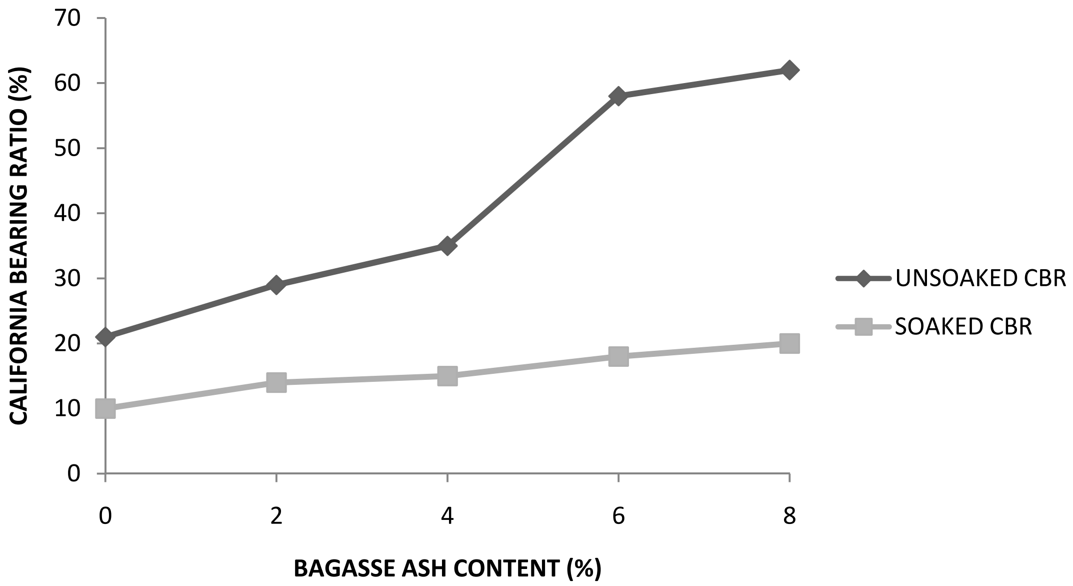

Figure (5): Variations of California bearing ratio of lateritic soil with bagasse ash content

CONCLUSIONS

From the results of the study, the following conclusions can be drawn.

- The lateritic soil is classified as A-6 using the AASHTO classification system and CL using the USCS. This makes it geotechnically a problematic soil.
- Some of the properties of the natural soil improved with the addition of bagasse ash. The specific gravity decreased steadily which indicates a decrease in voids and hence higher densities. However, the consistency limits test did not show any significant improvement on the natural soil. The plasticity index increased with the increase in bagasse ash content. None of the values of plasticity indices met the 12 % plasticity index specified by clause 6201 of the Nigerian General Specifications (1997) for sub-base materials.
- The maximum dry density (MDD) of the soil increased with bagasse ash content and appreciable changes were observed in the optimum moisture content (OMC).
- The unsoaked California bearing ratio for soil mixtures with BA content of 4% 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, the highest unsoaked 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.
- The soaked CBR value (24 hours of soaking) of 20% observed at 8% BA content also met the value recommended by Gidigasu and Dogbey (1980), who stated that minimum CBR value of 20%-30% is required for sub-bases when compacted at OMC.
- Bagasse ash improved the CBR value of lateritic soil when compacted at optimum moisture content and maximum dry density.
- The highest CBR value of 62% recorded at 8% BA content is an indication of considerable bearing capacity of building foundations, most especially raft foundations on weak soils.

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