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Permeability of Lateritic Soil Treated with Lime and Rice Husk Ash

Musa Alhassan

Civil Engineering Department, Federal University of Technology
Minna, Nigeria
E-mail: <alhassankuta@yahoo.com>

Abstract

A-7-6 lateritic soil was treated at British Standard Light (BSL) compaction energy with up to 8% lime content (by dry weight of the soil) at 2% variations and each was admixed with up to 8% rice husk ash (RHA) at 2% variations. Effects of the ash on the soil-lime mixtures were investigated with respect to unconfined compressive strength (UCS) and coefficient of permeability. The UCS of the specimens increased with increasing RHA content at specified lime contents to their maximum values at 6% RHA. The coefficient of permeability of the cured specimens decreased with increase in the ash content to their minimum values at 6% RHA content and beyond this point, the permeability slightly rises. These results indicate that no more than 6% RHA can be used to increase UCS and reduce permeability of lateritic soil.

Keywords: *Soil-lime mixtures, unconfined compressive strength, coefficient of permeability*

Introduction

The stability of structures founded on soil depends to a large extent on the interaction of the said soil with water. Some soils of the tropics (e.g., black cotton soil), absorb large amount of water during the raining seasons and do not allow easy passage of such water. This consequently results in a large volume increase which drastically reduces during the dry season. This phenomenon has substantial effect on structures founded on such soils. Also, road bases built with soils that are not easily drained are affected by the development of pore water pressures which causes the formation of potholes and, eventually, the total failure of such roads. In an attempt to minimize these effects, such soils are subject to treatments aimed at either disallowing water into them or allowing easy passage (drainage) of water to prevent pore water development.

A lot of laterite gravels and pisoliths which are good for gravel roads occur in tropical countries of the world, including Nigeria (Osinubi and Bajeh 1994). There are instances where a laterite may contain substantial amount of clay minerals such that its strength and durability cannot be guaranteed under load, especially in the presence of moisture. This type of laterite is also common in many tropical regions, including Nigeria, where in most cases sourcing for alternative soil may prove economically unwise. An alternative solution is to improve the available soil to meet the desired properties (Alhassan and Mustapha 2007, Alhassan 2008). Over the times, cement and lime are the two main materials used for stabilizing soils. These materials have rapidly increased in price due to the sharp increase in the cost of energy since 1970s (Neville 2000). This has recently motivated researches (Mustapha 2005; Alhassan, 2005; Oyetola and Abdullahi 2006) aimed at finding possible alternative soil stabilizing materials, especially those that are locally available and less costly.

Numerous researches have been conducted on the permeability of lime-treated soil, while some of the researchers (e.g., Forsberg 1969) reported a decrease of as much as two orders of magnitude in the coefficient of permeability with increasing lime content, others (e.g., Townsend and Klym 1966) reported a substantial increase in the coefficient of permeability of heavy clay soils. These results point to the fact that the effect of lime on permeability of soils, depends on the nature and compositions of the natural soil.

Laterite soils are normally utilized as base for road construction and are generally regarded as good foundation materials because they are virtually non-swelling. However, the use of the material is dependent on the degree of permeability, which determines whether the proposed road foundation is suitable for use (Osinubi 1998). This study offered a good opportunity in investigating the effect of lime-RHA and curing periods on the coefficient of permeability of lime-RHA-treated laterite soil specimens obtained from mixtures of prepared at their maximum dry densities and corresponding optimum moisture contents. The study is also aimed at investigating the effectiveness of reducing lime usage through the use of RHA (an agriculturally available waste product), which also conforms to part of the Millennium Development Goals targets.

Materials Used and Methods of Testing

Soil

The soil samples used were obtained from a borrow pit in Minna (latitude 9^o 37'N and longitude 6^o 33'E) using method of disturbed sampling. A study of the geological and soil maps of Nigeria after Akintola (1982) and Areola (1982), respectively, shows that the samples taken belongs to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks. The index properties of the natural soil are summarized in Table 1.

Lime

Hydrated lime whose magnesium oxide content was less than 5% and is a high calcium lime in accordance with O'Flaherty (1974) was used for the study.

Rice Husk Ash (RHA)

The rice husk used was obtained from local rice millers, burned and ashed in accordance with the methods used by Oyetola and Abdullahi (2006). The oxide composition of the resulting ash conforms with earlier composition presented by Alhassan and Mustapha (2007).

Compaction

Tests involving the moisture density relationship were carried out using air-dried soil samples. Compactive effort utilized throughout the tests was the standard proctor.

This is because the required energy is easily achieved in the field.

Water

Potable water was used to prepare the specimens at the various moisture contents, while distilled water was used as permeant in the permeability tests.

Preparation of Specimens

The soil-lime-RHA mixtures used for permeability test specimens were obtained by first thoroughly mixing dry predetermined quantities of pulverized soil, lime and RHA to obtain a uniform color. The required quantity of water, which is determined from the moisture-density relation for the soil-lime-RHA mixtures, was then added and the mixing continued. After compaction, the specimens and molds were placed in transparent cellophane bags, which were sealed and then cured in a highly humid environment. After the curing period had been attained, the specimens and the molds were removed from the sealed cellophane bags for permeability testing.

Permeability tests

The compaction mold with the specimen in it was used as part of the permeameter in order to eliminate disturbance of the specimens on extrusion from the molds. The falling head test was used for the investigation. In carrying out the permeability tests, the specimens were first saturated in the molds. The saturation process involved placing the permeameter in a small water container. The permeability tests were performed in accordance with Anon.

(1990), and the coefficient of permeability reported are the average of ten tests per specimen performed on three specimens for any given soil-lime-RHA mixtures.

Test Results and Analysis

Identification of soil

The geotechnical index properties of the natural soil are summarized in Table 1, while Fig. 1 shows the particle size distribution of the soil. The overall geotechnical index properties of the soil show that it can be classified under the A-7-6 subgroup of the AASHTO (1986) soil classification system and CH in the Unified Soil Classification System. It is reddish brown, well graded soil with a relatively high plasticity of 20% and clay content of not more than 14%. According to Nigerian General Specification (1997), this type of soil cannot be used directly as road base. It therefore needs to be stabilized.

Table 1. Properties of the natural soil before treatment.

Characteristics	Description
Natural moisture content (%)	10.81
Percent passing B.S Sieve No. 200	61.95
Liquid Limit (%)	45.51
Plastic Limit (%)	25.35
Plasticity Index (%)	20.16
Group Index	19
AASHTO Classification	A-7-6
Maximum Dry Density (Mg/m^3)	1.81
Optimum Moisture Content (%)	15.50
Unconfined Compressive Strength (kN/m^2)	295
Coefficient of Permeability (cm/s)	1.03x10^{-5}
Specific Gravity	2.66
Colour	Reddish-brown

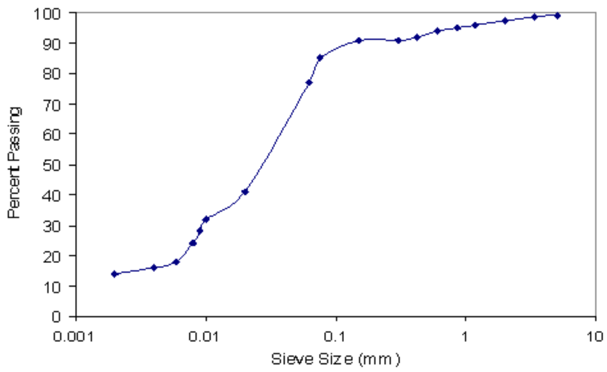

Fig. 1. Particle size distribution of the natural soil.

Compaction Characteristics

The effect of lime content on the maximum dry density (MDD) and optimum moisture content (OMC) of the lateritic soil is shown in Figs. 2 and 3, respectively. The MDD decrease with increase in lime content conforms with the usual trend and is in agreement with earlier findings by Osinubi (1998), Marks and Harliburton (1970) and Ladd *et al.* (1960). This decrease resulted from the flocculation and agglomeration of clay particles, caused by the cation exchange reaction, leading to corresponding decrease in dry density as advanced by Lees *et al.* (1982).

The MDD further decreases with the introduction and subsequent increase of RHA at specified lime contents. This decrease is attributed to the relatively lower specific gravity of the ash.

The increase in OMC with increasing lime content is not in agreement with Ladd *et al.* (1960), Marks and Harliburton (1970) and Osinubi (1998), but conforms with the findings of Ola (1983) and Osula (1991). The reason advanced is that the increased desire for water is somewhat commensurate to the increasing amount of lime as more water is needed for the dissociation of lime into Ca and OH ions to supply more Ca ions for the cation exchange reaction.

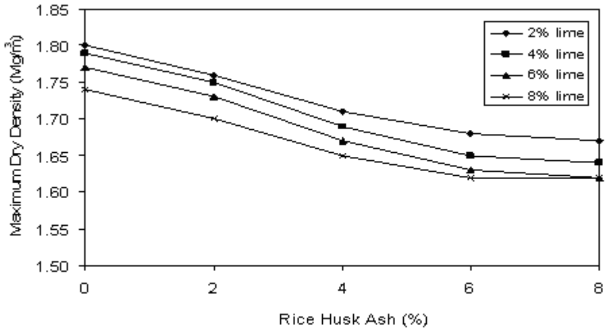

Fig. 2. Variation of MDD with RHA Content.

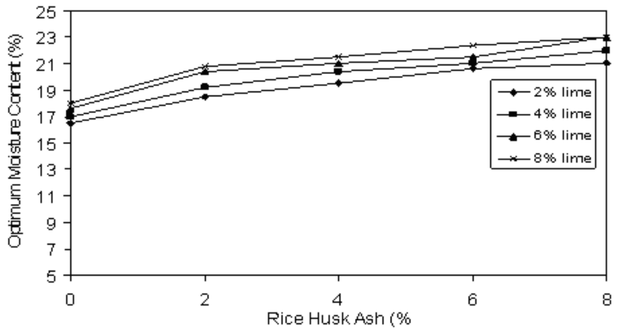

Fig. 3. Variation of OMC with RHA Content.

Compressive Strength

Figures 4, 5 and 6 show the effect of RHA of the soil-lime specimens on the unconfined compressive strength (UCS) for curing periods of 7, 14 and 28 days, respectively. The improvement in strength of lime-treated soil at 0% RHA contents is in agreement with earlier findings by Osinubi (1998). This is attributed to soil-lime reaction, which results in the formation of cementitious compounds that binds soil aggregates (Locat *et al.* 1990; Narasimha Rao and Rajesekaram 1996). This strength improvement also increased with age.

Introduction of RHA at specified lime content further increased the UCS. This increment was rapid between 0 to 4% RHA content but decreased in rate from 6 to 8% RHA content at specified curing period. This could be attributed to the utilization of readily available silica and alumina from RHA by the Calcium from the lime to form cementitious compounds which binds the soil aggregates. The decrease in rate of strength increase after 4% RHA could be attributed to the excess RHA that could not be utilized for the cementation reaction. It was also observed that the UCS increased with curing age at specified lime contents. This is attributed to the pozzolanic reaction between the lime and RHA resulting in the formation of more cementitious compounds.

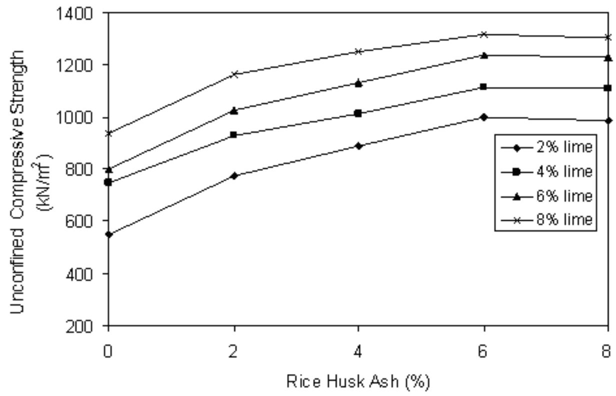

Fig. 4. Variation of 7-day UCS with RHA Content.

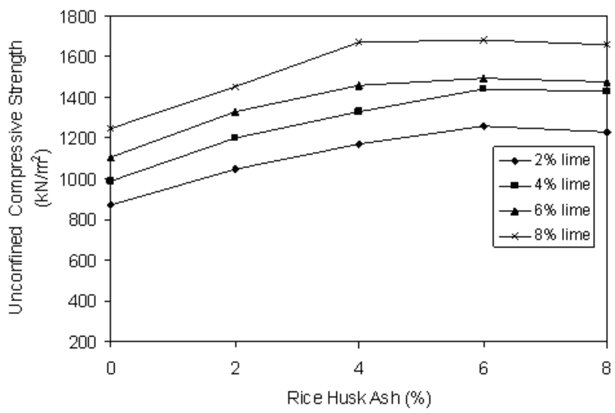

Fig. 5. Variation of 14-day UCS with RHA Content.

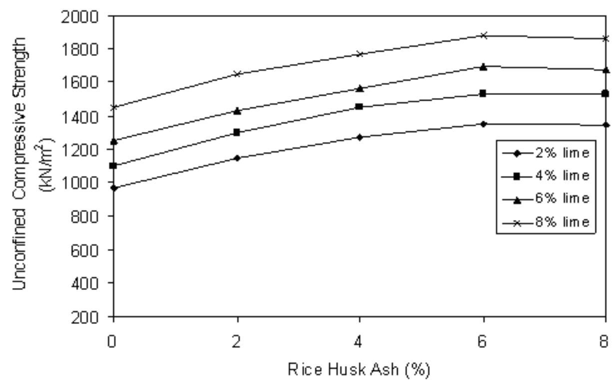

Fig. 6. Variation of 28-day UCS with RHA Content.

Permeability

Figures 7, 8 and 9 show the variation of the coefficient of permeability of soil-lime treated soil with RHA of specimens prepared at the MDD and corresponding OMC for curing periods of 7, 14 and 28 days, respectively.

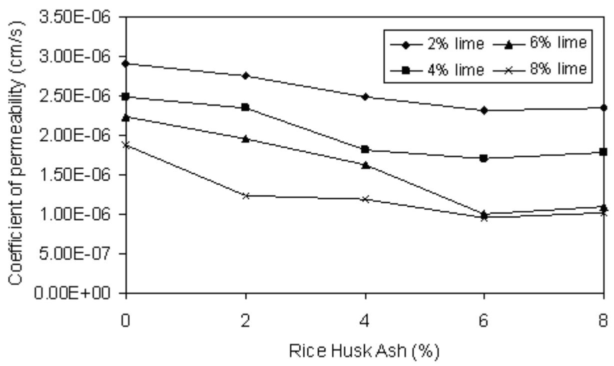

Fig. 7. Variation of 7-day Permeability with RHA Content.

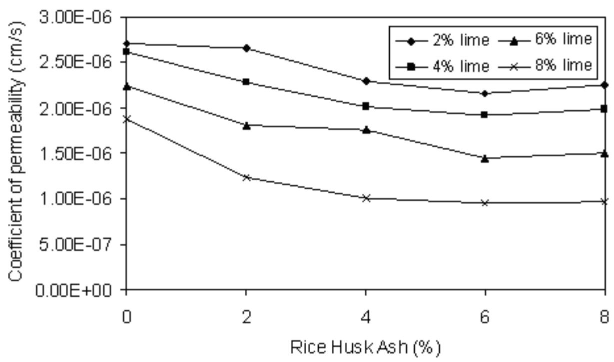

Fig. 8. Variation of 14-day Permeability with RHA Content.

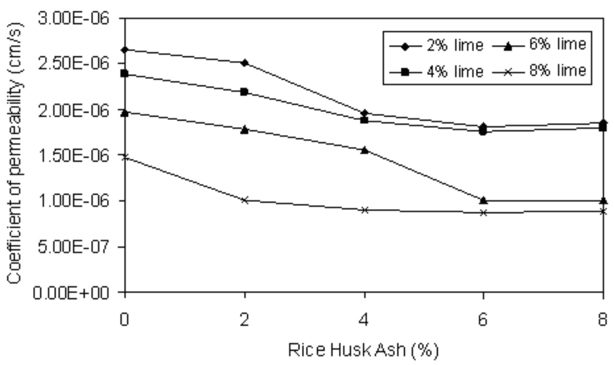

Fig. 9. Variation of 28-day Permeability with RHA Content.

There was generally a decrease in the coefficient of permeability with increase in lime content at 0% RHA content. This is due to the increase in the pH value of the molding water as a result of the partial dissociation of the calcium hydroxide. The calcium ions in turn combined with the reactive silica or alumina, or both, which obstructed flow through the soil voids (Osinubi 1998).

Introduction of RHA further decreases the permeability of the soil-lime specimens. This decrease was rapid at specified lime contents from 0 to 4% RHA after which the decrease reduces in rate. This decrease was as a result of the formation of cementitious compounds by calcium from lime and the readily available silica and/or alumina from both the soil and RHA, which fills the soil voids thereby obstructing the flow of water.

The permeability of the soil-lime-RHA specimens also decreases with the curing period. This is in agreement with the hypothesis that when lime hydrates with age, it reacts with silica and alumina (RHA) and the gel formed grows with the curing period filling the voids in the soil.

Conclusion

This investigation, which revealed the residual lateritic soil, classified as A-7-6 or CH in accordance with AASHTO (1986) and Unified Soil Classification Systems, respectively, shows that the specimens treated with a maximum of 4% lime and 6% RHA for curing period of 7 days yielded UCS value of 1,115kN/m^2. This value is greater than the conventional 1,034.25 kN/m^2 criterion for adequate lime stabilization. This study also shows a reduction in the lime content specified by Osinubi (1998).

The permeability of the cured specimens increased with the curing period. At each of the curing periods, the permeability decreases to corresponding minimum at 6% RHA content at specified lime content. Further increase in RHA shows a minimal rise in the coefficient of permeability. This study shows that percentage from 4 to 6% RHA can be effectively used with about 6% lime to stabilize A-7-6 lateritic soil in order to increase its strength and reduce permeability.

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