PERMEABILITY OF CEMENT-RICE HUSK ASH TREATED LATERITIC SOIL

By

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% cement 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-cement mixtures were investigated with respect to Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and coefficient of permeability. The MDD of the soil-cement specimens decreased with increasing RHA content at specified cement contents to their minimum values at 6% RHA. The OMC of the specimens increased with increasing percentages of the ash. The coefficient of permeability of the cured specimens decreased with increase in the ash content to their minimum values at 4% RHA content and beyond this point, there was no further significant reduction in the permeability. These results indicate that not more than 4% RHA can be used with cement to reduce the permeability of lateritic soils.

KEYWORDS: ***Soil-cement mixtures, coefficient of permeability***

INTRODUCTION

The stability of structures founded on soil, to a large extent depends on the interaction of the latter (soil) with water. Some soils of the tropics (e.g. black cotton soil), absorb large amount of water in the raining seasons and do not allow easy passage of such water. This consequently, results to a large volume increase which drastically reduces in the dry season. This phenomenon has drastic effect on structures founded on such soils. Also, road bases built with soil that are not easily drained, result in the development of pore water pressures which cause the formation of potholes and eventually total failure of such roads. In an attempt to minimize these effects, such soils are subjected 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 that it's strength and durability cannot be guaranteed under load, especially in the presence of moisture. This type of laterite are also common in many tropical regions including Nigeria where in most cases sourcing for alternative soil may prove economically unwise but rather to improve the available soil to meet the desire properties (Alhassan and Mustapha 2007). Over 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.

Laterite soils are normally utilized as base for road construction and are generally regarded as good foundation material 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 cement-RHA and curing periods on the coefficient of permeability of cement-RHA treated laterite soil specimens obtained from mixtures prepared at their maximum dry densities and corresponding optimum moisture contents. The study is also aimed at investigating the effectiveness of reducing cement usage through the use of RHA (an agriculturally available waste product), which also conforms to part of the Millennium Development Goals targets. Earlier work by Alhassan and Mustapha (2007), have shown that RHA used with cement can be effective in stabilizing soils, but their work was not extended to permeability of such soils.

MATERIALS USED AND METHODS OF TESTING

Soil

The soil samples used were obtained from a borrow pit in Minna (latitude 9° 37'N and longitude 6° 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.

Cement

Ordinary Portland Cement (OPC) 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 soil samples air-dried. Compactive effort utilized throughout the tests was the standard proctor. This is because this energy is easily achieved in the field.

Water

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

Preparation of Specimens

The soil-cement-RHA mixtures used for permeability specimens was obtained by first thoroughly mixing predetermined quantities of pulverized soil, cement and RHA to obtain a uniform color. The required quantity of water which is determined from the moisture-density relation for soil-cement-RHA mixtures, was then added and the mix 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 BS 1377 (1990), and the coefficient of permeability reported are the average of ten tests per specimen performed on three specimens for any given soil-cement-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 shows that it can be classified under the A-7-6 subgroup of the AASHTO (1986) soil classification system and CL 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 can not be directly used as road base. It therefore need be stabilized.

Table 1. Properties of the Natural soil before treatment

Characteristics	Description
Natural moisture content (%)	22.27
Percent passing B.S Sieve No. 200	77.01
Liquid Limit (%)	49.50
Plastic Limit (%)	24.40
Plasticity Index (%)	25.106
Group Index	20
AASHTO Classification	A-7-6
Maximum Dry Density (Mg/m^3)	1.482
Optimum Moisture Content (%)	18.40
Unconfined Compressive Strength (kN/m^2)	295
Coefficient of Permeability (cm/s)	$1.03x10^{-5}$
Specific Gravity	2.69
Colour	Reddish-brown

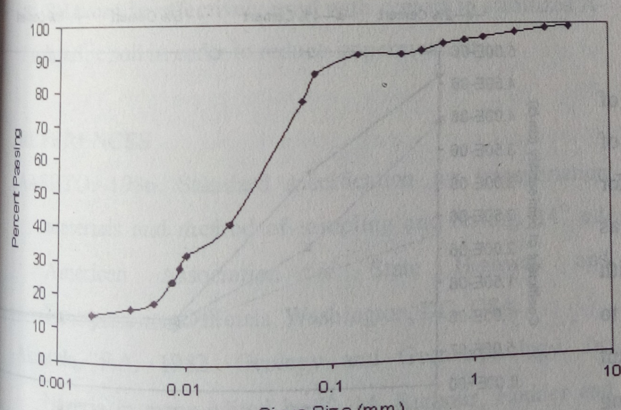

Fig. 1. Particle size distribution of the natural soil

Compaction Characteristics

The effect of cement 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 and OMC both increase with increase in cement content. This trend is in agreement with earlier findings by Alhassan and Mustapha (2007). The increase in MDD with cement content is attributed to the relative higher specific gravity of cement (3.15) to that of the soil (2.69). The increase in OMC with increase in cement content is as a result of water needed for the hydration of cement.

At specific cement contents, the results indicates a decrease in the MDD with increasing RHA contents, to their minimum at 6% RHA, after which there was a slight increase to 8% RHA. The initial decrease in the MDD can be attributed to the replacement of soil/cement with RHA which have lower specific gravity of 2.25 (Ola, 1975 and Osinubi and Katte, 1997). It may also be attributed, as explained by Ola (1977) and Osula (1991), to the coating of the soil/cement by the RHA which result to large particles with lager voids and hence less density. The increase in density from minimum at 6% RHA content to 8% ash content could be due to molecular rearrangement of "transitional compounds" which have higher densities at 8% RHA content (Osinubi, 1998).

The variation of OMC with increase in RHA for each of the various cement contents has relatively the same trend. There was increase in OMC with increase RHA for each of the cement contents. This trend is in line with (Ola, 1975), (Gidigasu, 1976) and (Osinubi, 1999). The increase in OMC was due to the addition of combined cement and RHA, which decreased the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This implies that, apart from the water needed for hydration of cement to take place, more water is needed to compact the soil-cement-RHA mixtures.

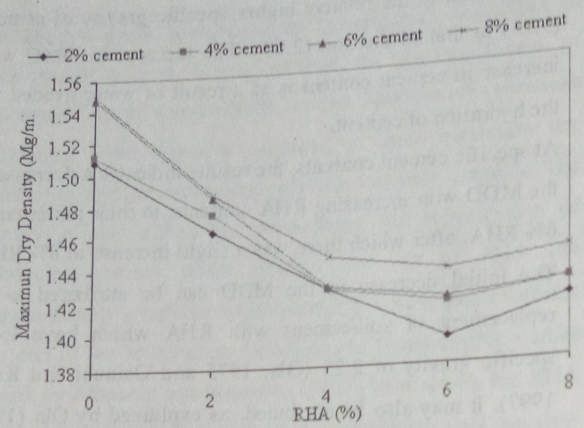

Fig. 2. Variation of MDD with RHA content

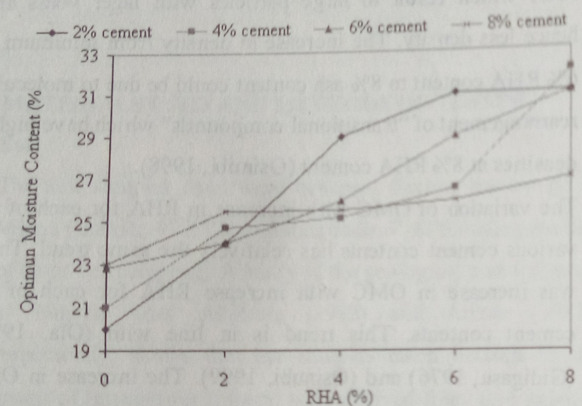

Fig. 3. Variation of OMC with RHA content

Permeability

Figs. 4, 5 and 6 show the variation of the coefficient of permeability of soil-cement treated soil with RHA of specimens prepared at the MDD and corresponding OMC for 7, 14 and 28 days curing periods respectively. There was generally a decrease in the coefficient of permeability with increase in cement content at 0% RHA content. This is due to the formation of cementitious compounds from the cement reactions, which fills the soil voids and therefore obstructing the flow of water in the soil.

Introduction of RHA further causes decrease in the permeability of the soil-cement specimens at specified cement contents from 0 to 4% RHA after which there was no further significant decrease in the permeability from 6 to 8% RHA contents. This further decrease (from 0 to 4% RHA contents) was as a result of the formation of secondary cementitious compounds by the products of the cement hydration and the readily available silica and/or alumina from the RHA, which further fills the soil voids thereby further obstructing the flo[w] of water.

The permeability of the soil-cement-RHA specimens [...] decrease with curing period. This is in agreement with [...] hypothesis that when cement hydrate with age, the avai[...] products of the hydration react with readily avai[...] and alumina (RHA) to further form secondary cementi[...] compounds which grow with curing period filling the voi[...] the soil.

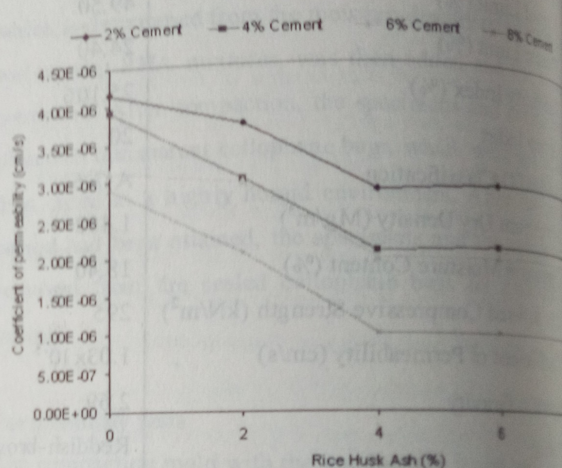

Fig. 4. Variation of 7 days Permeability with RHA Con[...]

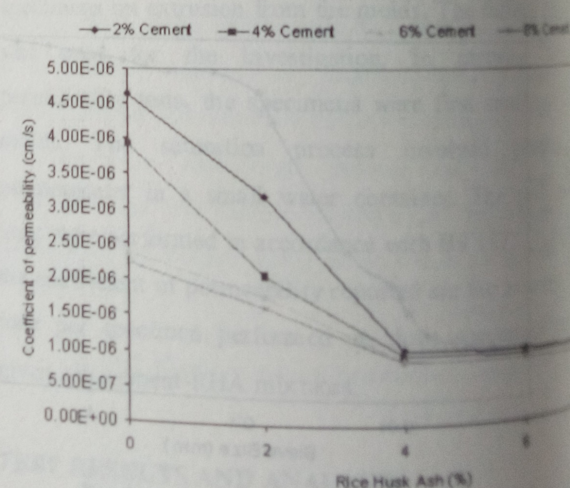

Fig. 5. Variation of 14 days Permeability with RHA C[...]

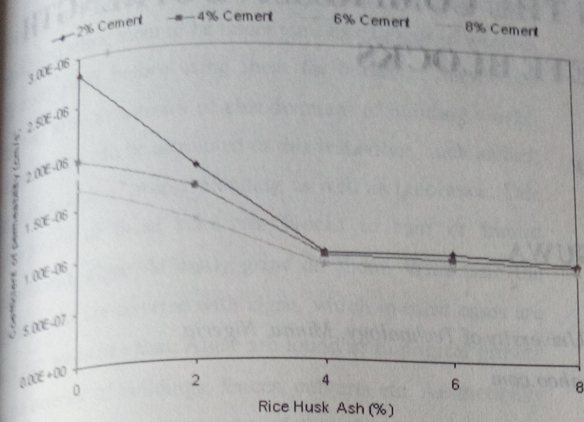

*Fig. 6. Variation of 28 days **Permeability with RHA Content***

CONCLUSION

The investigation revealed the residual lateritic soil to be classified as A-7-6 or CH in accordance with AASHTO (1986) and Unified Soil Classification Systems.

The permeabilities of the cured specimens increased with curing period. At each of the curing period, the permeability decreases to their minimum at 4% RHA content at specified cement content. Further increase in RHA shows a minimal effect on the coefficient of permeability. This shows that up to 4% RHA can be effectively used with cement to stabilized A-7-6 lateritic soil in order to reduce its permeability.

REFERENCES

AASHTO. 1986. Standard specification for transportation materials and method of sampling and testing. 14th ed. American Association of State Highway and Transportation Officials, Washington, DC, USA.

Akintola, F.A. 1982. Geology and Geomorphology. *In:* Nigeria in maps edited by K. M. Barbour, Hodder and Stoughton, London., UK.

Alhassan, M. 2005. Effect of Bagasse Ash on Lime Modified Laterite. Seminar presented in the Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria.

Alhassan, M.; and Mustapha, A.M. 2007. Effect of rice husk ash on cement stabilized laterite. Leonardo Electronic J. Practice and Technol., 6(11), Romania, 47-58.

Areola, O. 1982. Soils. *In:* Nigeria in maps edited by K.M. Barbour, Hodder and Stoughton, London., UK.

Gidigasu, M. D. (1976), Laterite Soil Engineering: Pedogenesis and Engineering Principles, Elsevier scientific publication company, Amsterdam.

Mustapha, A.M. 2005. Effect of Bagasse Ash on Cement Stabilized Laterite. Seminar presented in the Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria.

Neville, A.M. 2000. Properties of Concrete, 4th ed. Pearson Education Asia Ltd, Kuala Lumpur, Malaysia.

Nigerian General Specification. 1997. General Specification for Bridge and Roads Work. Federal Ministry of Works, Lagos, Nigeria.

Ola, S.A. (1975). Stabilization of Nigeria lateritic soils with cement, bitumen and lime, Proceeding of 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering. Durban, South Africa.

Ola, S.A. (1977). The potentials of lime stabilization of lateritic soils, Eng'g. Geol. J. 11. Pp. 305-317.

Osinubi, K.J. 1998. Permeability of lime-treated lateritic soil. J. Transport. Engrg., 124: 465-9.

Osinubi, K.J.; and Bajeh, I., 1994. Bituminous stabilization of laterite. Spectrum J. 1(2): 104-12.

Osula, D.O.A. 1991. Lime modification of problem laterite, J. Engrg. Geol. 30: 141-149.

Oyetola, E. B.; and Abdullahi, M. 2006. The use of rice husk ash in low-cost sandcrete block production. Leonardo Electronic J. Practice and Technol. 5(8): 58-70.