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Study of coir reinforced laterite blocks for buildings

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Some index property tests which include natural moisture content, sieve analysis, specific gravity, compaction, Atterberg limits were carried out on the laterite sample for the purpose of identification and classification. Twenty blocks of size 150 mm × 150 mm × 150 mm of coir reinforced laterite were moulded at coir content of 0, 0.063, 0.125, 0.188 and 0.25% by mass of the laterite respectively, and they were cured in the laboratory under atmospheric conditions. These blocks were subjected to compressive strength test at the curing ages of 7, 14, 21 and 28 days respectively. Five blocks were tested for each mix at each curing age, making a total of one hundred blocks. It was found that the 28 days compressive strength of the coir reinforced laterite blocks were 2.11, 2.18, 2.18 and 2.26 N/mm^2 for 0.063, 0.125, 0.188 and 0.25% coir content respectively. The determined strengths of coir reinforced laterite blocks are higher than those for ordinary laterite blocks.

Key words: Buildings, coir, compressive strength, laterite blocks.

INTRODUCTION

The need for locally manufactured building materials has been emphasized in many countries of the world. There is imbalance between the expensive conventional building materials coupled with depletion of traditional building materials. To address this situation, attention has been focused on low-cost alternative building materials (Agbede and Manasseh, 2008).

Often one of the problems encountered in the study of laterite is the basic definition of what is laterite. Many people usually define laterite as a type of red soil used in road construction especially in the tropics. Although laterite physically has element of red colour, the above definition is not a clear and true one in that some soils such as red sandy-clay soil can easily be mistaken as laterite. Laterite may be defined as that class of pedogenics in which the cementing materials are the sesquioxides and constitute not less than 50% of its constituents when the sample is chemically analyzed.

Sesquioxides are those chemical substances with empirical formula M_2O_3 where M=Potassium, K, Rubidium, Rb or Cesium, Cs. At ordinary temperatures and pressure below 100 mm mercury, Potassium peroxide combines with oxygen to give the sesquioxides, K_2O_3.

Study of laterite shows that laterite contains hydrated aluminum and iron oxides and the presence of iron can be noticed by the characteristic colour produced by iron in the soils. The aluminum is generally in the form $Al_2O_3.nH_2O$, which is called Bauxite, an ore of aluminum. The ore appears to be developed when intense and prolonged weathering removes the silicon from the clay minerals and leaves a residue of hydrous aluminum oxides.

Before carrying out chemical analysis for complete definition of laterite, a soil may be suspected to be laterite by observing some of the physical properties. Usually, laterite is reddish brown in colour and gravelly in texture. The reddish colour becomes predominant when wet while the brown colour becomes distinct when dry. Some of the particles stick to the palm of the hand when wet and they

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can easily be dusted off when dried. Also some laboratory index property tests are used to classify laterite. Such tests are the Atterberg limit test, grain size analysis, compaction test etc. The results of these tests are compared with already determined standard results of the index properties.

Soil stabilization and improvement can be achieved by altering the soil properties to conform to the desired characteristics. The objectives of soil stabilization include increase in strength, reducing compressibility, improving stability, decreasing heave due to frost or swelling and increasing or decreasing permeability. Soil stabilization has been extensively used in the construction of roads, airfields, earth dams and embankment. Stabilization includes compaction, pre-consolidation and protection of the surface from erosion and moisture infiltration. Investigation of soil and its groundwater condition will indicate whether soil improvement or stabilization is needed and the technique to be employed. Chemical additives such as Portland cement, hydrated lime, gypsum, alkalis, sodium chloride, calcium chloride, aluminium compounds and industrial waste products have the potentials for soil stabilization. Magafu (2010) reported that lime has proved to permanently increase strengths (compressive, tensile, flexural and shear) of soils, reduce to minimum volumetric expansion of soils and create excellent freeze-thaw resistance (durability). He further added that however, due to cheapness and availability in most developing countries, the most widely used stabilizers are the Portland cement, lime, bitumen and agricultural waste are used to a lesser extent.

Coconuts are agricultural products and edible in at least all the tropical countries including Nigeria. The husks and shells are thrown away as wastes and they pose a lot of environmental waste problems. Within the husks are the strands like fibres called coir, which are removed from the husks by beating, decorticating or defibring (Dutch Plantin). These coconut fibres are strong, tough and extremely resistant to fungal and bacteria decomposition. Fibre length varies from 0.3 to 250 mm but the average length ranges from 100 to 200 mm. Coir cross sections are highly elliptical and non uniform with average diameter of 0.25 mm. It has high degree of crystallinity with spiral angle of micro fibre ranging between 30 and 40° and this imparts greater extensibility compared to other natural fibres. Coir has a high lignin content and thus a low cellulose content, as a result of which it is resilient, strong and highly durable (TIS). In spite of low cellulose content, coir are very closely arranged and this accounts for its better durability compared to other natural fibres.

Chandra et al. (2008) reinforced three types of soil; clay, silt and silty sand with polypropylene fibre of 0.3 mm diameter and found that their uniaxial compressive strengths increased appreciably. This result is synonymous to that of Fatani et al. (1991) who reinforced soils with metallic fibres. Fibres play significant role when soil is subjected to tension forces.

A major advantage of the use of laterite instead of sand in moulding building blocks is the low cost, due to little or no quantity of cement is required to produce blocks with adequate compressive strengths (Aguwa, 2010).

Laterite bricks were made by the Nigerian Building and Road Research Institute (NBRRI) and used for the construction of a bungalow, Madedor (1992). From the study, NBRRI proposed the following specifications as requirements for laterite bricks: bulk density of 1810 kg/m^3, water absorption of 12.5%, compressive strength of 1.65 N/mm^2 and durability of 6.9% with maximum cement content fixed at 5%.

The aim of this study is to investigate the use of coconut fibres in reinforcing laterite blocks in order to improve strength for buildings. Some of the major objectives of this work are; to determine the physical properties of laterite and coir, to mould laterite blocks reinforced with coir at varying percentage of coir content and to determine the compressive strengths of these blocks at 7, 14, 21 and 28 days. The use of laterite blocks in buildings is very common especially in rural areas. With the abundance of laterite and coconut fibres in this country, coir reinforced laterite can be used for various construction works such as load bearing and non-load bearing walls for resisting static loading. This will reduce the cost of construction materials compared to sandcrete blocks which are not economical and also the environmental problem of coir deposition can be reduced by converting these wastes to treasure.

MATERIALS AND METHODS

Laterite

The laterite sample used was collected at a depth of 1.5 m to 2.5 m from an existing borrow pit behind works department of Federal University of Technology Gidan Kwano campus Minna, Nigeria (Latitude 9^o 37¹N and Longitude 6^o 33¹E), using the trial pit method of disturbed sampling.

Coir

The coconut fibre was obtained from coconut farm at Garatu Bida road Minna, Nigeria. They were sun dried properly, removed carefully and cut into smaller pieces, not exceeding 50mm in length to allow for proper mixing with the laterite.

Water

Tap water was used for the mixing and it was properly examined to ensure that it was clean, free from particles and good for drinking as specified in BS 3148 (1980).

Soil index properties

Index property tests on the laterite soil for the purposes of

Plate 1. Coir reinforced laterite blocks under curing.

characterization and classification, which include natural moisture content, particle size distribution, Atterberg limits, specific gravity, linear shrinkage and compaction tests were carried out in accordance with BS 1377 (1990).

Preparation of specimens

The respective quantities of laterite, coir as well as water required for the mix were proportioned and batched by mass. In quality controlled mix such as this, measurement by mass was adopted, (Vazirani and Chandola, 1997). Manual mixing and moulding were used and proper mixing was achieved by turning the mixture from one side to the other for six times (Neville, 2000). Five different mixes were prepared for coir reinforced laterite using coir contents of 0, 0.063, 0.125, 0.188 and 0.25% by mass of laterite respectively. One hundred blocks of coir reinforced laterite mixes of size 150 mm × 150 mm × 150 mm were moulded by filling the mould in three layers and each layer was given 30 blows of compaction using a standard rammer of weight 2.5 kg falling from a height of 30 cm. To ensure even distribution of blows, approximately 150 mm square sheet of plywood was placed on the mixture in the mould and compaction was done on it. The freshly moulded blocks were carefully extruded on a clean and flat surface and were cured under laboratory conditions. The coir reinforced laterite blocks under curing are shown in Plate 1.

Compressive strength test

An electrically operated Seidner compression machine was used for the compressive strength test on the coir reinforced laterite blocks in accordance with BS 1881 Part 116 (1983). The blocks were subjected to compressive strength test at 7, 14, 21 and 28 days age of curing in five replications for each mix and the average compressive strength was calculated. In crushing test, care was taken to ensure that the blocks were properly positioned and aligned with the axis of the thrust of the compression machine to ensure uniform loading on the blocks (Neville, 2000).

RESULTS AND DISCUSSION

Identification of laterite soil

The index properties of the laterite used for the study are summarized in Table 1 while Figure 1 shows the particle size distribution. The laterite was well graded in accordance with BS 882 (1983) and classified to be A-7-6 according to AASHTO (1986) classification based on the geotechnical properties. The laterite is reddish-brown in colour with specific gravity of 2.28 and linear shrinkage of 10. The percentage of the soil passing BS sieve No 200 is 34.32 and the plasticity index is 20.5. An investigation into the geotechnical and engineering properties of sample as well as study of soil maps of Nigeria after Akintola (1982) showed that the sample collected belong to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks.

Figure 2 shows the compaction characteristics for the laterite used in the study and a normal compaction curve for most laterite is depicted, indicating the maximum dry density (MDD) of 1430 kg/m^3 and the optimum moisture content (OMC) of 29.8%.

Compressive strength

The relationship between compressive strength and percentage of coir content is shown in Figure 3. It was observed that the compressive strength of coir reinforced

Table 1. Properties of the Natural Laterite used for the study.

Characteristic	Laterite
Natural moisture content (%)	17.25
Percentage passing BS No 200 sieve (%)	34.32
Liquid limit (%)	50
Plastic limit (%)	18.33
Plasticity Index (%)	31.67
Linear shrinkage	10
AASHTO classification	A-7-6
Maximum dry density (kg/m^3)	1430
Optimum moisture content (%)	29.8
Specific gravity	2.28
Condition of sample	Air-dried
Colour	Reddish-Brown

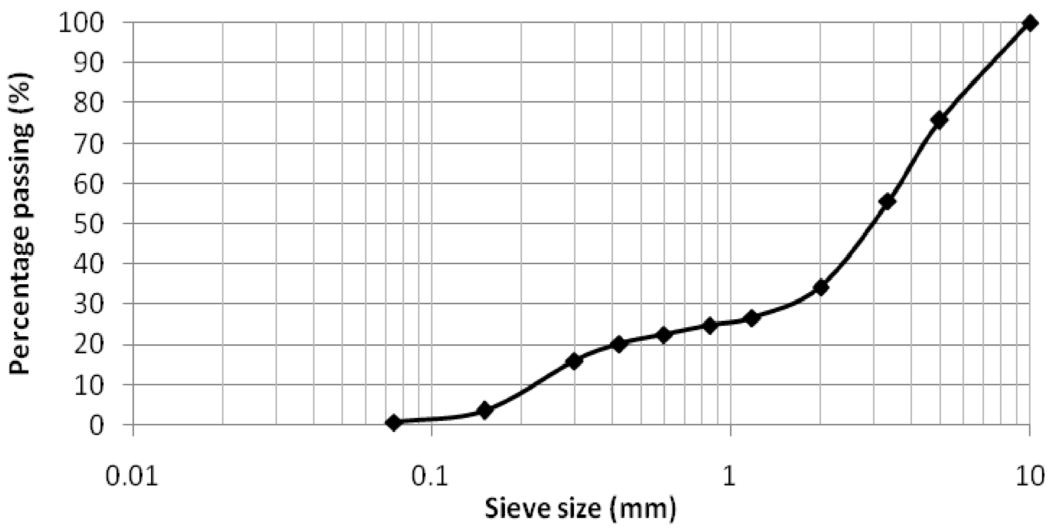

Figure 1. Particle size distribution curve for the Laterite.

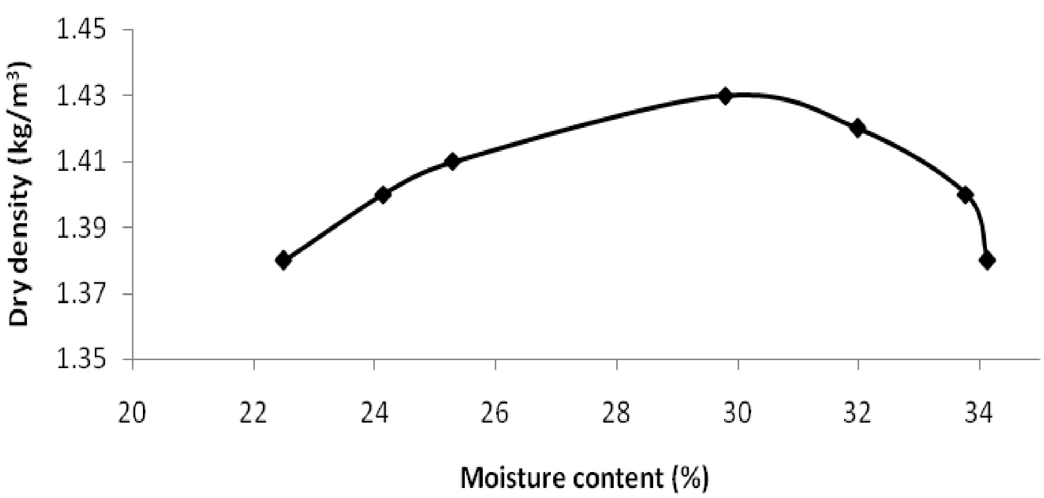

Figure 2. Compaction characteristics for the Laterite.

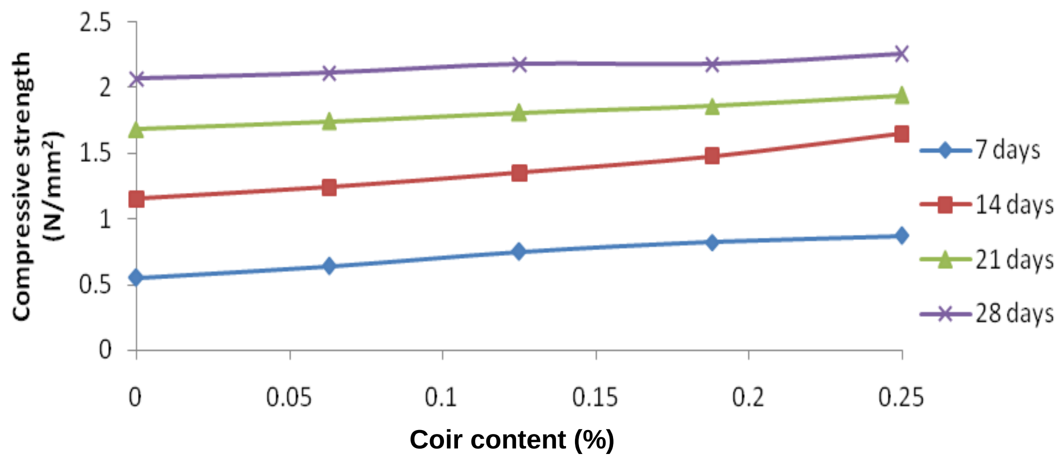

Figure 3. Compressive Strength-Coir content relation for coir reinforced laterite blocks.

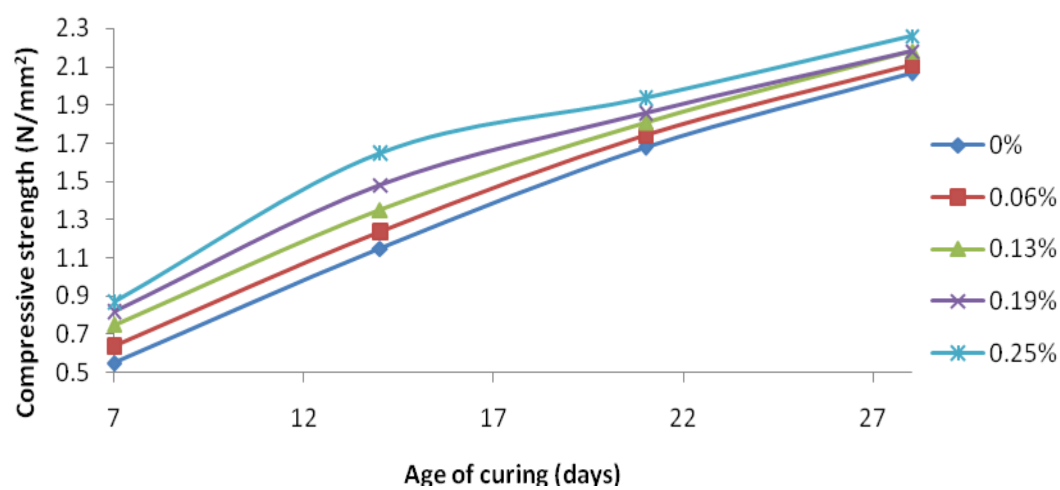

Figure 4. Compressive Strength-Age of curing relation for coir reinforced laterite blocks.

laterite blocks increased with increase in the percentage content of coir for all the curing ages of 7, 14, 21 and 28 days. In accordance with the NIS 87 (2004), the compressive strengths of 2.11, 2.18, 2.18 and 2.26 N/mm^2 for coir content of 0.063, 0.125, 0.188 and 0.25% respectively, are adequate for load bearing and non-load bearing walls. It was also observed that the failure compressive strengths at 28 days curing age did not vary by more than ±0.5 N/mm^2 and this is in agreement with clause 9 of BS 1881-127 (1990). The lowest crushing strength of individual load bearing blocks shall not be less than 2.5 N/mm^2 for machine compaction and 2.0 N/mm^{2}for hand compaction as recommended by NIS 87 (2004). This result is similar to the finding of Alutu and Oghenejobo (2006) who reported that for 7% cement content and13.76 N/mm^{2}compactive pressure, cement stabilized laterite blocks with compressive strength of at least 2.0 N/mm^2 at 28 days could be produced. The compressive strengths increased with increase in coir content within the range of coir content studied.

The coir reinforced laterite blocks consistently showed a definite pyramidal pattern type of failure. The conical shape was found to be the same as that of concrete cubes subjected to compression test (Neville, 2000). This is an indication that buildings constructed with coir reinforced laterite blocks will likely withstand considerable deformation before total failure. This pyramidal pattern of failure conforms to the report by Aguwa and Tsado (2011).

Figure 4 shows the relationship between the compressive strength and age of curing for coir reinforced laterite blocks. An increase in compressive strength is recorded for all the mixes with longer days of curing within the range of curing period tested.

The relationship between mass and age of curing for coir reinforced laterite blocks is shown in Figure 5. The

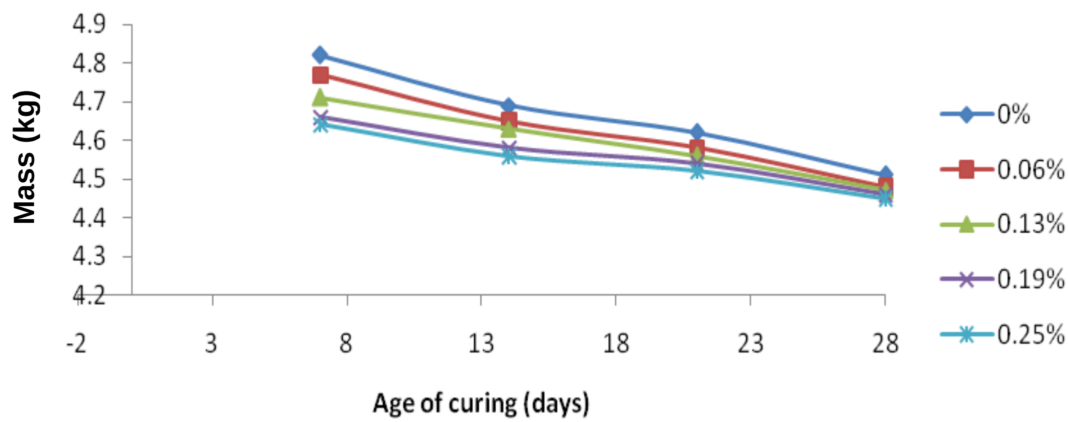

Figure 5. Mass Age of curing relation for coir reinforced laterite blocks.

decrease in mass with longer days of curing could be attributed to continued water absorption by the dry coir. Also gradual shrinkage as a result of water absorption by the coir could lead to loss in weight and increase in bonding.

Conclusion

Coir has the potential to increase the compressive strength of laterite blocks by ten percent (10%) at 28 days curing duration and reduction in mass by two percent (2%). Increase in strength and reduction in mass are two essential qualities of a structural material. Also the use of coir in reinforcing laterite blocks will minimize the environmental problem of waste deposition in addition to reduction in the cost of building blocks.

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