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Effects of Natural Fiber Reinforcement on Water Absorption of Compressed Stabilized Earth Blocks

Engineering

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ABSTRACT

This paper discusses the influence of fiber reinforcement on water absorption of compressed stabilized earth blocks for its suitability in block production. The mix proportion of the control blocks was 76.9% sand, 23% fines and 8% cement. Meanwhile, the palm kernel fiber contents ranged from 1% to 5% by weight. The experimental design was completely randomized with 3 replications. The findings of this study show that water absorption increased with fiber content. Water absorption values for the different fiber contents ranged between 5.68% and 12.53%. The value of absorption for the control was 5.65%. The lower values correspond to 1% fiber content while the higher values correspond to 5% fiber content. There was no significant difference between the control and both 1% and 2% fiber content (P<0.05). Also soil sample from Enugu State was found to be suitable for earth block production without modification.

1. Introduction

Cheap building materials are necessary for the development of low cost housing. In particular, cement stabilized earth blocks are attractive building material because they are inexpensive to manufacture. Earth construction is very cost effective, energy efficient (excellent thermal properties and low energy input required for production), environmentally friendly and safe (Rigassi, 1995). These qualities are particularly relevant and important with the ever growing need for increased awareness to reduce energy consumption worldwide (Adam and Agidi 2001). But traditional earth construction techniques such as wattle and daub, cob and adobe need continuous maintenance in order to keep them in good condition. Their major limitations include: water penetration, erosion of walls at level by splashing of water from ground surfaces, attack by termites and pests and high maintenance requirements etc.

These limitations and the need for sustainable low-cost buildings to house man and livestock justify the need for more research on the strength and durability properties of earth block before it can be considered as an efficient construction material. The concept of using natural fibres is not new in the construction industry, as the utilisation of fibres in materials and construction can be traced back to many centuries ago. During the Egyptian times, straws or horsehairs were added to mud bricks, while straw mats were used as reinforcements in early Chinese and Japanese housing construction (Li, 2002). The application of natural fibres has been widely used in cement composites and earth blocks as construction materials for many years in developing countries due to the availability and low cost of fibres (e.g. Nilsson, 1975; Aziz *et al.*, 1984; Coutts and Ni, 1995) Oil palm production is a major agricultural industry in Nigeria. Large quantities of palm waste, such as palm kernel fiber, are left in plantations where palm oil is produced. The abundance of oil palm kernel fiber has created crucial environmental issues, such as fouling and attraction of pests. This can be reduced by its utilization in earth block production.

The objective of this paper was to present the influence of fiber reinforcement on water absorption of compressed stabilized earth blocks. The study will also evaluate soil samples from two locations in southeastern Nigeria to determine their suitability for earth block production.

2.0 Materials And Methodology

2.1 Materials

The main materials that were used in the experiment are soil, stabilizer, and fiber. They are discussed in the sections below.

Soils

Laterite is a surface formation which is enriched in iron and aluminum and develops by intensive and long lasting weathering of the underlying parent rock in tropical areas. In this research, two representative lateritic soil samples were collected from two locations in southeastern Nigeria to test for their suitability for CSEB production. These locations are:

Enugu State:

- Soil sample from behind the department of Agricultural and Bioresources Engineering, University of Nigeria Nsukka. The soil was taken at a depth of 0.9144 meters to avoid organic matter. The soil from this location was designated Soil Type 1.

Anambra State:

- Soil sample from a privately owned farm in Adazi-Nnukwu in Anaocha Local Government Area of Anambra State. The soil was collected from a depth of1.219 meters depth to get rid of organic materials. The soil from this location was designated Soil Type 2.

Stabilizer

The stabilizer used in this research was the ordinary Portland cement manufactured by Dangote cement factory, Nigeria. The physical and chemical compositions are listed in Table 1 and Table 2, respectively.

Table 1. Physical Properties of Ordinary Portland Cement (Portland Cement Association, 1956)

Physical Properties	Unit	Value
Specific gravity		3.15
Specific surface (Blaine)	cm^2/g	3180
Initial setting time	Minute	170
Final setting time	Minute	450
Compressive strength 7 days	MPa	27.8
28 days	MPa	36.8

Table 2. Chemical Composition of Cement (Portland Cement Association, 1956)

Oxide	SiO2	Al2O3	Fe2O3	CaO	MgO	SO3
(%)	20.40	6.00	2.9	64.2	2.0	1.9

The fibres

The palm kernel fibres were obtained from a privately owned oil palm processing mill in Anambra State, Nigeria. They were sun dried for two week prior to usage. In this research, the fibres were used as additives, whereby they were added at a weight fraction of 1-5% to produce stable and improved laterite bricks.

Preparation of Block Specimens

The experiments demanded a large number of specimens prepared to a high degree of accuracy, reliability and consistency. Extra care had to be taken at all stages of the block production process: soil preparation, mixing, compression, and curing of the samples. Apart from the mix-proportioning stage that distinguished the block types by amount of fiber reinforcement, the rest of the procedures remained the same. The descriptions of the processes involved in the production of the required number of block specimens are presented below. The description is based on the four main stages of CSEB production:

Soil preparation Soil preparation → Mixing → Molding → Curing

Soil Preparation
This stage started with the excavation of soil. The soil was collected at a depth of 3 feet to avoid organic matter. After, the soil was moved into the laboratory were the specimens were to be manufactured.

Mixing
Mixing of soil with stabilizer (OPC), palm kernel fiber and water, was done in four stages. The key objective during the mixing stage was to ensure a good distribution of the stabilizer, fiber and water throughout the mix. Consistent proportioning out, dry mixing and wet mixing were required to obtain proper samples. The proportioning out of soil and stabilizer was done by weight, not by volume. A weighing scale capable of weighing up to 10 kg to an accuracy of 0.05 grams was used each time.

All materials were weighed inside a plastic bag which was then sealed and clearly marked. The bags were carefully labeled to show the exact weight and type of material. By sealing the bags, contamination of the weighed out material were avoided. In all cases, dry mixing was done first before wet mixing with water. All mixing (wet and dry) was done manually using a shovel. Dry mixing was done for about three to four minutes. After this, water was then uniformly added to the dry soil and stabilizer mix and the process repeated. The water added to the mix was meant to be sufficient for hydration of the stabilizer. After uniform coloration was achieved, an optimum water content test was done for each mix. Any mix that passed the test was immediately put in the mould.

Molding
Compression of the damp mix was done using a locally manufactured press. Before the compression using the local press, a sample was compacted at a pressure of 2MPa in the laboratory. The height at which the pressure was achieved was marked on the mould. The rest of the blocks were compressed to the same height using the locally fabricated press. The compression procedures were done in three stages: mould filling, molding, and demolding. Mould filling was done after first cleaning the mould. This was repeated after every four to six blocks were made. On filling the mould, the mould cover was turned into position to cover the mix. The press was used to deliver the required force. The procedures were repeated till the required number of blocks was produced. Three blocks were produced for each specific mix type. After the blocks were made, demolding and handling followed, (done with great care as the blocks were still weak). The blocks were then carefully labeled. This was done to identify each block by date of manufacture, serial number and stabilizer content.

Curing
Curing of the blocks was done under room temperature and humidity. Primary curing periods was seven days. During this period, the blocks were covered with plastic bags to prevent water loss from the blocks. This period was followed by secondary curing periods of 28 days.

Test Procedure
The Water Absorption Test is basic in nature but may be the most useful in assessing the durability of CSEBs. After 28 days curing, CSEBs were totally immersed in water tank for 24 hours They were then taken out, wiped with a cloth, and weighed. The weight of each specimen was recorded. This was the wet weight.The specimen was then stored in the oven to dry up for 48 hours. Temperature in the oven was 40°C during this period of time. After drying, the specimen was weighed once again and the weight was once again recorded. This was the dry weight. If MH is the wet weight and MS the dry weight, the block water absorption WA was given by the following relationship:

$$W_A = \frac{M_H - M_S}{M_S} \times 100 \quad (1)$$

3.0 Results And Discussion
Soil Suitability
The results of the various tests conducted to determine the suitability of the two soil types for CSEB production are presented below:

Particle Size Distribution
The particle size distribution curve for Soil Type 1 is shown in Figure 1. The test results for the soil shows that the soil type is predominantly sandy. The proportions of the main soil fractions present (Gravel, 0%; Sand, 76.9%; Fines (Silt and Clay), 23%) fall within the recommended ranges. The soil is suitable for CSEB production because it has sufficient proportions of coarse fraction (sand) for the skeletal frame and body of the block, as well as an adequate proportion of fines (silt and clay) for binding of the soil particles.

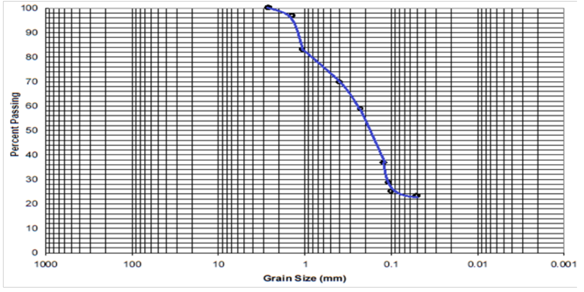

Figure 1. Particle Size Distribution Chart for Soil Type 1

The particle size distribution curve for Soil Types 2 is shown in Figure 2. The test results for the soil show that the soil type is sandy. The proportions of the main soil fractions present does not fall within the recommended ranges (Gravel, 2%, Sand, 96%; Fines (Silt and Clay), 2%). As a result of this, the soil may not be suitable for CSEB production because there is insufficient quantity of fines which serve as binding materials in the CSEB. For this soil to be suitable for CSEB production, the soil has to be modified by the addition of clay.

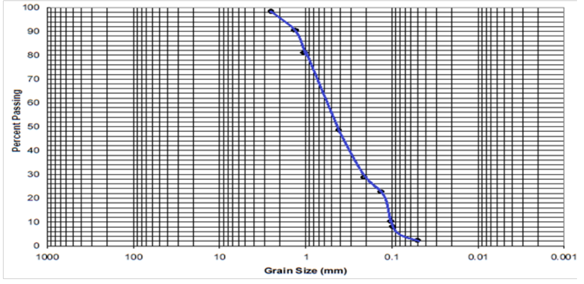

Figure 2. Particle Size Distribution Chart for Soil Type 2

Sedimentation Test
The results of the sedimentation test confirm the presence of sufficient quantities of coarse soil fraction in both soil types. This result shows a convergence with the particle size distribution test. According to the results, the amount of coarse soil fraction was about 78% and fines fraction about 22% for Soil Type 1. While the amount of coarse and fine soil fractions were 92% and 8% respectively for Soil Type 2. The sedimentation test was however, quite slow (over 48 hours) and of medium accuracy. The values of silt and clay can be slightly distorted due to swelling and expansion in water. It was also found difficult to

differentiate the silt from the clay as both appeared to be well intertwined.

Atterberg's Limits Test

The liquid limits for the two soil types are shown in Table 3. Liquid limits for Soil Type 1 and Soil Type 2 are 22% and 26% respectively. Also the plastic index for the two soil types is 11% and 22% respectively. According to Houben and Guillaud (1994), the liquid limit for a soil suitable for CSEB production is between 20 - 42% while the plasticity index should fall within 10% and 25%. From this literature source, it can be seen that the two soils are suitable for compressed stabilized earth block production based on Atterbeg's limits.

The summary of the results for the various tests conducted to determine the suitability of local soils for CSEB production is shown in Table 3.

Table 3. Summary of Soil Suitability Test Results

S/N	Test	Unit	Siol type 1	Soil type 2	Recom-mended Value
1	Particle size distribution gravel sand silt and clay	 % % %	 0 76.9 23	 2 96 2	 <40 25-80 18-55
2	Sedimentation (jar) gravel and sand silt and clay	 % %	 78 22	 92 8	 - -
3	Atterbeg's limits Liquid limits Plastic limits Plastic index	 % % %	 26.0 15.0 11.0	 22.0 0 22.0	 20 – 42 - 10 – 25

Effect of Fiber Reinforcement on Water Absorption

Absorption measures the unit's total capacity to absorb moisture. Figure 5 shows the effect of percentage content of palm kernel fiber on the 28-day water absorption of CSEBs after the blocks were immersed in the water for 24 hours.

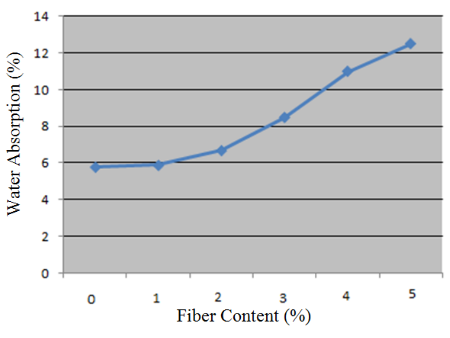

Figure 3. Relationship between Fiber Content and Water Absorption

The water absorption values for the different fiber contents ranged between 5.68% and 12.53%. The value of absorption for the control was 5.65%. The lower values correspond to 1% fiber content while the higher values correspond to 5% fiber content. There was no significant difference between the control and both 1% and 2% fiber content ($P<0.05$). CraTerre (1989) requirements set the material water absorption in the 10-20% range. The gathered data show that all the processed CSEBs were either in the 10-20% water absorption range or below. All the CSEBs therefore met the minimum requirements for their use in house construction with respect to this parameter.

It can be seen that the water absorption increased with an increase in the fiber content. The higher water absorption capacity of fiber reinforced CSEBs may be attributed to the amount of water absorbed by the cellulose fibers, which is influenced by void volume and the amount of cellulose material present, and both of these parameters affect density. The packing of the fibers and the matrix becomes less efficient as the fiber content is increased, and causes the void volume to increase, followed by a decrease in density and an increase in water absorption (Coutts and Ni, 1995). In other words, this result is compatible with the density theory, which predicts that samples of higher density are less likely to absorb water, and vice versa. The result also shows the same trend as the observation previously conducted by Ghavami et al., (1999) which indicates that the fibers absorb water and expand during mixing and drying of soil. The swelling of the fibers pushes the soil away, at least at the micro-level. At the end of the drying process, the fibers lose the moisture and shrink back almost to their original dimensions, leaving very fine voids around them.

4.0 CONCLUSION

This study was based on evaluating local soils to determine their suitability for making compressed earth blocks for use in affordable residential and animal buildings. The local soil constituent proportions were compared to recommended guideline proportions and one of the soils was found to be suitable for use while the other will need a little modification for it to be suitable. Blocks with palm kernel fibers have a slightly higher water permeability or absorption than fiberless blocks. In more specific terms, the fibers are believed to be responsible for the absorption of more water and increase block permeability to water. The density of the fiber reinforced blocks decreases with the increase in fiber content. This may be due to the fibers displacing heavier constituent materials, such as cement and soil, from the CSEBs.

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