Research Paper Agriculture

Natural Fibre Induced Properties on Stabilized Earth Bricks

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ABSTRACT

The development of a new, low-cost building material that is composed of non-fired, compressed stabilized earth brick incorporating oil palm kernel fibre was investigated in this study. The main aim of this research was to evaluate the strength properties of stabilized earth bricks reinforced with palm kernel fibre, which include the compressive strength and abrasion loss of matter. The mix proportion of the control bricks was 76.9% sand, 23% fines and 8% cement. The palm kernel fibre contents ranged from 1% to 5% by weight. The experimental design was completely randomized with 3 replications. The research result showed that the addition of the palm kernel fibres significantly improved the compressive strength of the bricks (P<0.05) and the maximum compressive strength determined in this study for bricks was with 4% fibre content. Finally, the abrasion loss of matter of the bricks was decreased significantly (P<0.05) with the increase in the fibre content of the bricks.

Keywords : Palm kernel fibre, reinforcement, earth bricks, compressive strength, abrasion loss

INTRODUCTION

The provision of adequate housing for both man and livestock has become a challenge around the world, especially in developing countries. This is as a result of the ever increasing population, low gross national product (GNP) and the general lack of purchasing power [1]. Adequate housing is constrained by the high-cost of building materials. The progressive deterioration of buildings necessitates the development of alternative building materials from locally available raw materials for low-cost housing. These raw materials must be abundantly available and renewable in nature.

Earth bricks are very cost effective, energy efficient (excellent thermal properties and low energy input required for production), environmentally friendly and safe [2]. These qualities are particularly relevant and important with the ever growing need for increased awareness to reduce energy consumption worldwide [3]. 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 the lower 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 brick 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 [4]. The application of natural fibres has been widely used in cement composites and earth bricks as construction materials for many years in developing countries due to the availability and low cost of fibres (e.g. [5], [6], [7]. Oil palm production is a major agricultural industry in Nigeria and therefore quantities of palm waste, such as palm kernel fibre, are left in plantations where palm oil is produced. The abundance of oil palm kernel fibre has created crucial environmental issues, such as fouling and attraction of pests. This can be reduced by its utilization in earth brick production.

The compressive strength of a brick is perhaps one of its most important engineering properties. It was established from the literature that the durability of earth bricks increases with increase in its strength [12 and 13]. Indeed a stronger brick which has been well cured is usually more resistant to deleterious environmental agents. Thus, this research investigated the strength characteristics of compressed earth bricks that are reinforced with palm kernel fibres.

METHODOLOGY

Materials

The main materials that were used in the experiment are soil, stabilizer, and fibre. The research was conducted at the Department of Agricultural and Bioresources Engineering, University of Nigeria Nsukka. Soil samples (predominantly sandy) were taken at the 90 cm depth of soil profile to avoid a mix with soil organic matter. The samples were air-dried under roofed shed. The moisture content of all samples was 16.6%, as tested according to BS 1377 [8]. The particle size analysis carried out 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 for soil classification. The soil was found suitable for earth brick production because it has sufficient proportions of coarse fraction (sand) for the skeletal frame and body of the brick, as well as an adequate proportion of fines (silt and clay) for binding of the soil particles. The stabilizer used in this research was the ordinary

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Portland cement manufactured by Dangote cement company, Nigeria. The physical and chemical compositions are listed in Tables 1 and 2, respectively.

Palm kernel fibres were obtained from a privately owned oil palm processing mill in Anambra State, Nigeria. The fibres were sun dried for two weeks prior to usage as additive to the mixture of sand and cement at 5 levels of weight fractions (1 %, 2%, 3%, 4% and 5%) to produce stable and improved laterite bricks.

Experimental Design

- The soil type was kept fixed, with approximate composition: gravel (0%), sand (76.9%), fines (23%). Keeping the soil type the same for all specimens helped increase reliability in the tests.
- The stabilizer type and amounts was kept constant (8%). The stabilizer type used was Ordinary Portland Cement (OPC) supplied from Dangote Cement Company. OPC was selected as the main stabilizer because it is widely available.
- Fibre content was varied (from 1% to 5%)
- Compaction pressure was maintained at 2 MPa, It is common to compress stabilized earth bricks at compaction pressures between 2 MPa and 8 MPa although values higher than 4 MPa are rarely used in practice. [10].
- Normal curing conditions were applied to all the bricks produced. Primary curing spanned a period of 7 days, followed by secondary curing for 28 days.

Preparation of Brick Specimens

The experiments demanded a large number of specimens prepared to a high degree of accuracy, reliability and consistency. Extra care was taken at all stages of the brick production process: soil preparation, mixing, compression, and curing of the samples. Apart from the mix-proportioning stage that distinguished the brick types by amount of fibre reinforcement, the rest of the procedures remained the same. The procedures involved in the production of the required number of brick specimens are presented below. The description is based on the four main stages of Compressed Stabilized Earth Bricks (CSEB) production namely:

Soil preparation → Mixing → Molding → Curing

Mixing of soil with stabilizers (OPC), palm kernel fibre and water, was done in four stages. The objective during the mixing stage was to ensure a good distribution of the stabilizer, fibre and water throughout the mix. Consistent proportioning of the mix was done to obtain required 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. The bags were sealed to avoid contamination from foreign materials. 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 procedures repeated. The water added to the mix was meant to be sufficient for hydration of the stabilizer. After uniform mix was achieved, an optimum water content test was done for each mix. Any mix that passed the test was immediately put in the mould.

Compression of the damp mix was done using a locally manufactured press shown in Plate 1. 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 bricks were compressed to the same height using the locally fabricated press.

Plate 1: Locally Fabricated Press

The compaction exercise was done at three stages namely: mould filling, molding, and demolding. Mould filling was done after first cleaning the mould. This was repeated after every four to six bricks 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 bricks was produced. Three bricks were produced for each specific mix type. After the bricks were made, demolding and handling followed, (done with great care as the bricks were still weak). The bricks were then carefully labeled. This was done to identify each brick by date of manufacture, serial number and stabilizer content.

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

Bricks Strength Test Procedures

The bulk properties identified as likely to influence strength of earth bricks are Compressive strength and Abrasion loss of matter [11], [2]. The 7, 14, 21 and 28-day compressive strength test on brick samples was carried out by imposing the bricks to loading compression until breakage to examine the variation of strengths, allowing the researchers to categorise the bricks by their strength level. Compressive strength was calculated by dividing the maximum load by the load area of the specimen. The compressive strength was determined using the Denison crushing machine (Plate 2), which has the capacity to deliver a maximum load of 1960 kN.

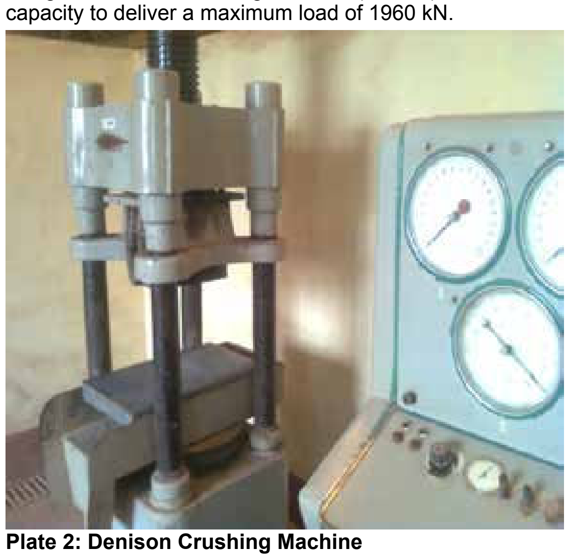

Plate 2: Denison Crushing Machine

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The abrasion loss of matter represented the weight loss percentage of a CSEB samples subjected to friction. After 28 days curing, a CSEB specimen was first weighed and the initial weight M_O was recorded. The specimen was held in a fixed position and abraded by rubbing one side back and forth with a metallic brush. Each back and forth operation was a cycle. After 50 cycle's operation, the specimen weight M_F was recorded. The abrasion loss of matter M_{abr} was calculated using the following relationship:

$$M_{abr} = \frac{M_O - M_F}{M_O} \times 100 \quad [1]$$

RESULTS AND DISCUSSIONS

Compressive Strength The compressive strength of a material determines the load-carrying capacity of that material before breakage. The mean values of compressive strength of the brick samples under different fibre contents are shown in Table 3. The plot of these values against the fibre content is shown in Figures 1– 4.

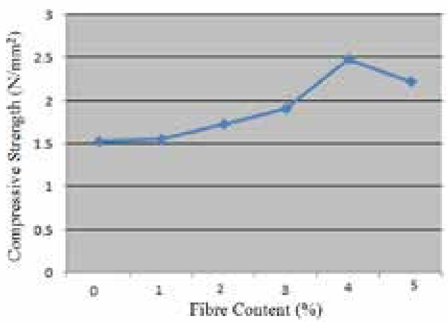

Figure 1. Relationship between Fibre Content and 7-day Compressive Strength

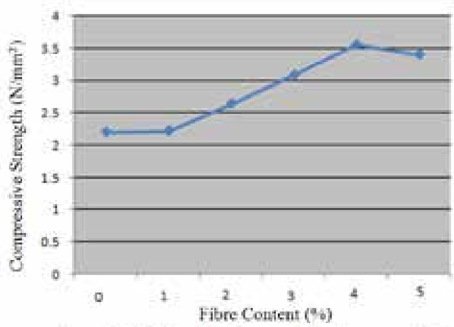

Figure 2. Relationship between Fibre Content and 14-day Compressive Strength

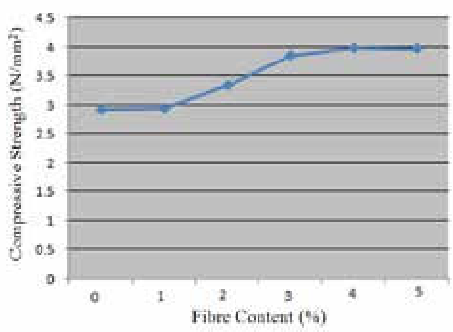

Figure 3. Relationship between Fibre Content and 21-day Compressive Strength

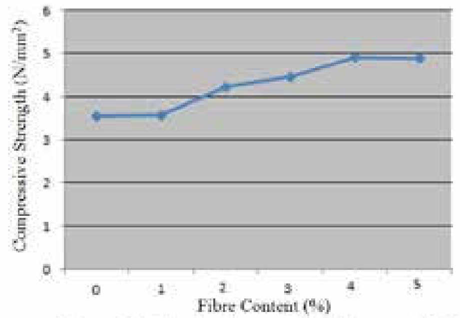

Figure 4. Relationship between Fibre Content and 28-day Compressive Strength

The compressive strength of bricks samples after 7 days of cure ranged between 1.56 N/mm² and 2.48 N/mm², while at 14-day of cure, it ranged between 2.22 N/mm² and 3.55 N/mm². The 21-day value ranged between 2.94 N/mm² and 3.98 N/mm², while that of the 28-day compressive strength ranged between 3.57 N/mm² and 4.92 N/mm². The average values of compressive strength for the control after 7, 14, 21 and 28days of curing period were 1.53 N/mm², 2.20 N/mm², 2.92 N/mm², and 3.55 N/mm² respectively. The lowest correspond to the sample with 1% fibre content while the higher one corresponds to 4% % fibre content.

The experimental values obtained here however, compare well with most current CSEB standards. Some recommended minimum values are: 1.2 N/mm²[11], 1.4 N/mm² [13] and 2.8 N/mm² [14] The value of 1.2 N/mm² is now more widely used [10]. The lowest compressive strength (CP) value obtained in samples with 1% fibre content is about 23% higher than the recommended 1.2 N/mm² while samples with 4% fibre content about 75% higher in CP than the recommended standard. Both values correspond to bricks stabilized with 8% OPC. The bricks made with OPC contents less than 8% may be significantly lower than the 1.2 N/mm² standards.

The compressive strength values in CSEBs increased with increase in the fibre content. Although there was no significant difference in compressive strength between the control and 1% fibre reinforcement (P□0.05) at the different curing days; the compressive strength of 1% fibre reinforcement was higher than that of the control. There were significant differences between the compressive strength of the control specimen (0% fibre) and the other levels of fibre reinforcement.(2%, 3%, 4%, 5%) (P□0.05). Also there was no significant difference between the 4% and 5% fibre reinforcement for both the 21-day and 28-day compressive strength. Thus, it can be concluded that the optimum palm kernel fibre percentage that can successfully increase the maximum compressive strength of CSEBs is 4% of the fibre content. In this case, an increase in the compressive strength occurs because the fibres can withstand stresses [15] and successfully reinforce and hold the soil.

The decrease in the compressive strength of the CSEBs with 5% fibre contents occurred because the space occupied by the fibres acted like voids in the soil. Such a void space could be attributed to the high volume fraction of the fibres, and the non-uniform fibre distribution tended to make fibres ball or clump together. When the fibres are not evenly distributed and orientated in the soil, they can clump together with less soil material in between to hold them together, creating more voids and making the CSEBs weak. The insignificant increase of the compressive strength with the 1% fibre content occurred because there were not enough fibre materials to hold the soil matrix together.

Abrasion Loss of Matter

The effect of varying the fibre content on the 28-day abrasion loss of matter was investigated experimentally. Figure 5 is a plot of water absorption against fibre content of CSEBs.

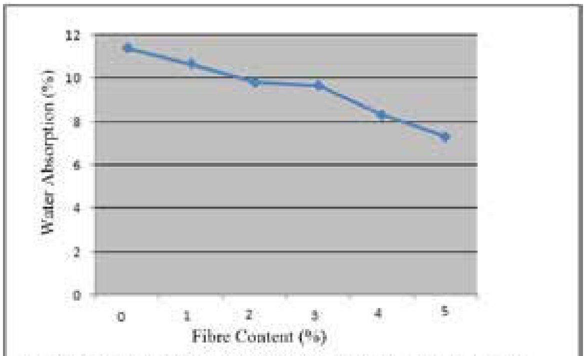

Figure 5. Relationship between water absorption and Fibre Content

Table 4 shows a summary of the plotted values in figure 5.The abrasion loss of matter during the 28days of bricks cure for the different fibre contents ranged from 7.3% to 10.69%. The value of absorption for the control was 11.41%. The lowest values of abrasion loss correspond to 5% fibre content while the higher values correspond to 1% fibre content. There was no significant difference in samples abrasions loss at different fibre content. It can be seen that the abrasion loss of matter reduced with an increase in the fibre content. This may be attributed to the fact that the Palm Kernel Fibre (PKF) protected the soil matrix against frictional forces. The non significant decrease in the abrasion loss of matter with 1%, 2%, and 3% fibre content may be attributed to the fact that there was not enough fibre to protect the soil matrix from frictional forces.

CONCLUSION

The following conclusions can be drawn from the findings of this research;

- The addition of palm kernel fibres at 2%, 3% and 4% significantly increased the compressive strength of earth bricks. During mixing, it was observed that the palm kernel fibres at these levels and lower were well-distributed in the bricks. The addition of more fibre (≥ 5%) was found to reduce the strength of bricks.
- Addition of palm kernel fibre reduced the abrasion loss of matter of the compressed stabilized earth bricks.

The properties of the compressed stabilized earth bricks may be improved by the addition adequate percentage (2%-4%) of palm kernel fibres.

REFERENCES

[1] Arumala, J. and Gondal, T. (2007). “Compressed earth building blocks for affordable housing” The construction and building research conference. Royal Institution of Chartered Surveyors. Georgia Tech, Atlanta USA. | [2] Rigassi, V. (1995). “Compressed Earth Bricks: Manual of Production”. Vol. 1. CRATerre-EAG. Vilefontaine Cedex, France. | [3] Adam E.A and Agib A.A.G (2001). “Compressed stabilized earth bricks manufacture in Sudan”, United Nations Educational, Scientific and Cultural Organization. | [4] Li, V.C. (2002). Large volume, high-performance applications of fibres in civil Engineering. Journal of Applied Polymer Science, 83(3), 660-686. | [5] Nilsson, L.H. (1975). Reinforcement of concrete with sisal and other vegetable fibres. Swedish Council for Building Research, Document DIY, Stockholm, Sweden | [6] Aziz, M.A, Paramasivam, P and Lee, S.L. (1984). “Concrete reinforced with natural fibres”. Concrete Technology and Design, Volume 2, New Reinforced Concretes. Surrey University Press. London, pp 106-140. | [7] Coutts, R.S.P. and Ni, Y. (1995). Autoclaved bamboo pulp fibre reinforced cement. Cement Concrete Composites, 17, 99–106. | [8] British Standards Institution. (1990). BS 1377: Part 4: 1990 Methods of Testing Soils for Civil Engineering Purpose. BSI, London. | [9] Portland Cement Association (1956). “Soil-Cement Laboratory Handbook”. Portland Cement Association Skokie, Ill | [10] Houben, H and Guillaud, H. (1994). “Earth Construction: A Comprehensive Guide”. CRATerre-EAG. Intermediate Technology Publications. London, England. | [11] Lunt, M.G. (1980). “Stabilized Soil blocks for Building”. Overseas Building Note No. 184. Building Research Establishment. February 1980. Garston, England. | [12] Stultz, R. and Mukerji, K. (1998), “Appropriate Building Materials”. ITDG Publications | [13] Fitzmaurice, R. (1958). “Manual on Stabilized Soil Construction for Housing”. Technical Assistance Programme. United Nations. New York, USA. | [14] ILO (1987). “Small-scale manufacture of stabilized soil blocks”. Technological Memorandum No 12, International Labour Office, Geneva. | [15] Binici, H., Aksogan, O. and Shah, T. (2005). “Investigation of fibre reinforced mud blocks as a building material”. Construction and Building Materials, 19, 313–318.