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**Research Article**

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# Influence of Coconut Fibers on the Physical and Mechanical Properties of Compressed Earth Blocks

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**Abstract:** The present research aims to determine the influence of coconut fibers from the coconut palm on the physical and mechanical properties of compressed earth blocks. The study focused on density, capillary absorption, compressive strength and flexural tensile strength. The first part of this study is devoted to the determination of the characteristics of the soil and those of coconut fibers. Five fibers contents (0, 0.1, 0.2, 0.3 and 0.4%) were used and the soil consists of 70% sand and 30% clay silt. Two types of specimens are then manufactured by mixing the fibres with the earth: blocks with dimensions 14x9.5x29.5 cm3 for compression and briquettes 4x4x16 cm3 for bending. The latter are stored away from the sun until maturity. From his studies, it appears that the density of the blocks decreases with increasing fiber content and the opposite is observed with capillary absorption. The compressive strength increases with the fibers content up to 0.3% and decreases thereafter. Similarly, the fibers improve the flexural tensile strength of the specimens, within a certain limit: beyond 0.2%, the strength drops.

**Keywords:** Clay soil, Coconut fibers, Blocks, Tensile strength, Compressive strength

## Introduction

Earth has always been a very accessible building material. It's simple and economical use has many advantages that make it particularly interesting for obtaining ecological, aesthetic and comfortable housing. It is a material that has been used for thousands of years in many places around the world. Today, it is still in use in many countries. Over the course of scientific development, researchers have used several admixtures to improve the physical and mechanical qualities of earthen blocks [1], [2], [3]. Other studies have shown that mixing soil with natural fibers reduces shrinkage cracking, improves durability and mechanical properties, and increases thermal inertia [4], [5], [6]. While it has been proven, in more recent studies and within certain limits, that the addition of date palm fibers or sisal fibers to the soil improves the compressive strength of the blocks [7], [8], [9]. It can be hypothesized that plant fibres have an influence on the mechanical properties of earth blocks. In Togo, there is a strong presence of coconut palm (Cocos nucifera) throughout the country. The latter is grown for its drupe (coconut). After eating its fruit, the residues (coconut husks) are usually piled up in wild dumps or burned for the cooking fire or used for derisory purposes. In an approach of recycling and valorization of local natural resources, the fibers of the coconut husks were extracted and used to reinforce earth blocks, with the aim of studying their influence on the physical and mechanical properties of these blocks.

## Materials and Methods

The soil used comes from the Noèpé clay deposit, a quarry located northwest of Lomé, the capital of Togo. The chemical identification test revealed that it was mainly Alumina Silicate $SiO_2$ (81.0%), $Al_2O_3$ (8.9%), $Fe_2O_3$ (2.8%) and the characterization tests revealed that it was a sandy-clay soil with little plastic and relatively clean.

**Table 1:** Characteristics of natural clay soil

| | |
|---|---|
| **Sand content** | 58,99 |
| **Silt content** | 2,62 |
| **Clay content** | 38,39 |
| **Absolute density** | 2.65 |
| **Bulk density** | 1.24 |
| **Liquidity Limit** | 60.29 |
| **Plasticity limit** | 20.13 |
| **Plasticity index** | 39.98 |
| **Methylene Blue Value** | 1,56 |
| **Organic matter content** | 0,27% |
| **Natural water content** | 11% |

As the natural soil was too clayey, it was amended by adding alluvial sand, the characteristics of which are given in Table 2. Figure 1 shows the particle size analysis of the soil in its natural state, that of the alluvial sand and the soil obtained after amendment.

**Table 2:** Characteristics of alluvial sand

| **Actual Density (Kg/m$^3$)** | **Bulk density (Kg/m$^3$)** | **Sand equivalent (%)** | **Fineness module** |
|---|---|---|---|
| 2570 | 1440 | 96 | 2,72 |

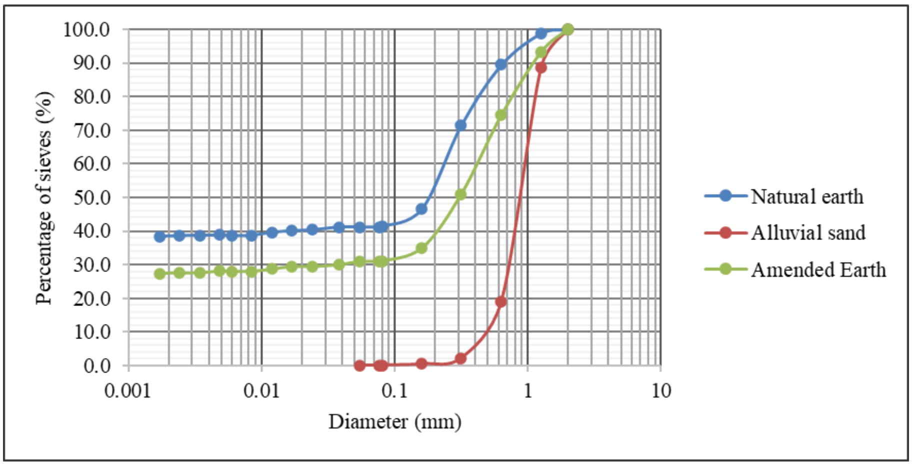


***Figure 1:** Particle size analyses*

Figure 2 and Table 3 below show the extracted fibres and their characteristics, respectively.

***Figure 2**: Extracted fibers*

**Table 3:** Fibers characteristics

| Characteristics | Valeur |
|---|---|
| **Maximum length (cm)** | 12 |
| **Cut-out length (cm)** | 0 - 6 |
| **Density (g/cm3)** | 1,25 |
| **Water absorption rate (%)** | 163 |
| **Diameter (mm)** | 0 – 0,1 |
| **Tensile strength (Mpa)** | 122 - 133 |

Fibres are measured as a mass percentage of dry soil with dosages varying from 0 to 0.1% to 0.4% pitches (Table 4).

**Table 4:** Composition of mixtures

| Almond earth (g) | % Fibers | Fibers mass (g) | Water body (g) |
|---|---|---|---|
| 30000 | 0% | 0 | 2430 |
| 30000 | 0,10% | 30 | 2430 |
| 30000 | 0,20% | 60 | 2430 |
| 30000 | 0,30% | 90 | 2430 |
| 30000 | 0,40% | 120 | 2430 |

The compression blocks of dimensions (14x9.5x29.5 cm3) are manufactured using a Terstaram press and the bending blocks using 4x4x16 cm3 moulds. The latter are kept in a dry laboratory protected from the sun. The daily storage temperature over the curing period is 28 to 29°. The blocks are weighed every day and maturity is reached when two successive weighings over a 24-hour interval show a mass loss of less than 0.1% [9].

***Figure 3:*** *Blocks 14x9.5x29.5 cm3*

***Figure 4:*** *Test specimens 4x4x16 cm*$^3$

The characterization tests performed on the blocks are density, measurement of capillary absorption, compressive strength and flexural tensile strength.

**Density**

The test consists of weighing each sample of each formulation and determining the bulk density. M: mass of the specimen and v its volume.

$$\rho = \frac{M}{v} \qquad (1)$$

**Capillarity absorption**

Capillary absorption is measured by the absorption coefficient (Cb), given by the following formula.

$$C_b = \frac{100(M_1 - M_0)}{s\sqrt{t}} \qquad (2)$$

$C_b$: absorption coefficient;

$M_0$: Dry mass of the block;

$M_1$: mass of the block after the test;

t: duration of the test;

S: surface of the submerged face.

**Compressive strength**

The nominal strength in simple compression is determined according to the XP P 13-901 standard. It is given by the following formula.

$$R_c = 10\frac{F}{s} \qquad (3)$$

$R_c$: compressive strength;
F: Breaking load of the specimen;
S: Average surface area of the faces of the specimen.

**Tensile strength**

At the failure of the specimen, the tensile strength is given by the formula below.

$$R_f = \frac{3}{2}\left(\frac{L.F}{b.h^2}\right) \qquad (4)$$

F: breaking force,
L: the length,
l: the width,
h: thickness.

**Results And Discussions**

Figure 5 shows the density measurement results.

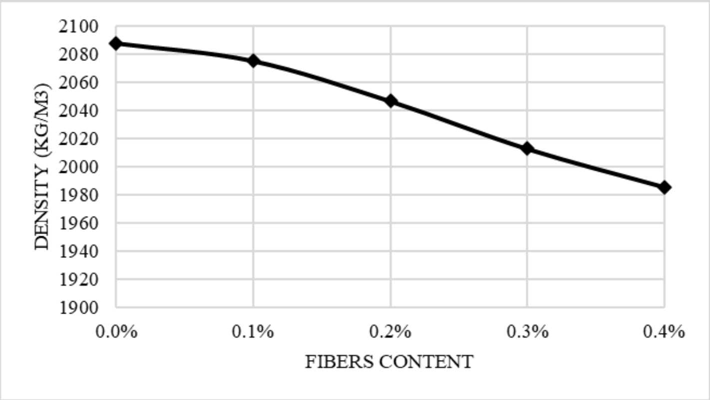


***Figure 5:*** *Density*

Analysis of the results reveals that block density decreases with increasing embedded fiber content. This is due to the lightness and low density of the fibres. In comparison, earth blocks reinforced with coconut fiber are denser than blocks reinforced with bamboo fibers (1490 -1560 kg/m3) and beaten earth (1700 kg/m3). The values obtained are close to those of rammed earth (1990 - 2160 Kg/m3) [10], [11].

Figure 6 shows the results of water absorption.

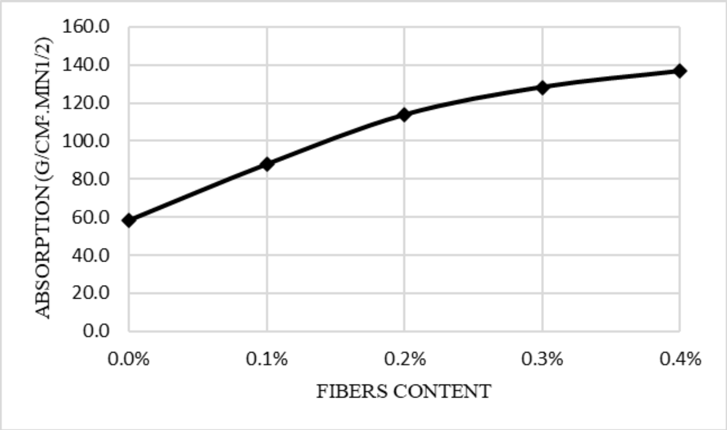


***Figure 6:*** *Capillary absorption*

Analysis of the curve shows that the capillary absorption of the blocks increases with fibers content. The fibers lead to an increase in the porosity of the blocks because they occupy more and more space in the matrix. The fiber-fiber contact intensifies for this purpose, creating more vacuum and promoting absorption.
The compressive strength measurement results are shown in Figure 7.

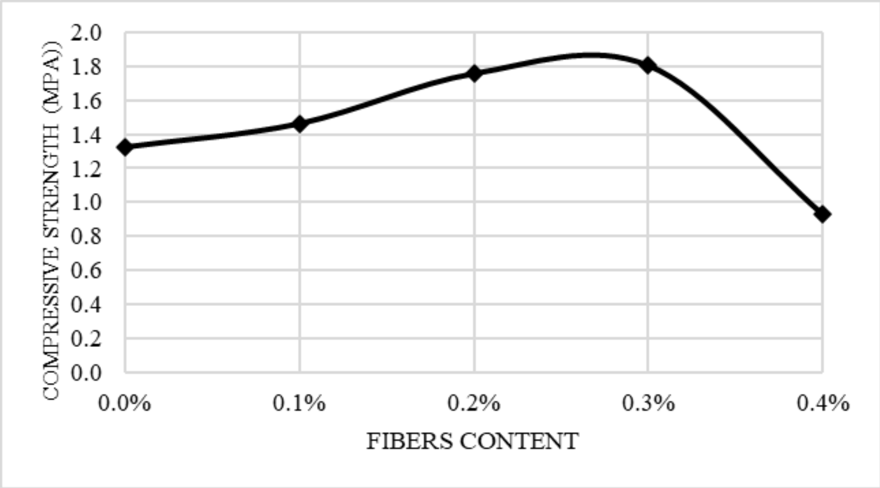


***Figure 7:*** *Compressive strength*

The results obtained from the compression tests on the blocks show that the resistance is increasing by 0 to 0.3% and then falls. The observed increase in strength is due to the good wettability and perfect adhesion between the fibers and the clay matrix. The subsequent drop is the consequence of the intensification of fiber-fiber contact due to a relatively high fibers content. This leads to a drop in adhesion and wettability between the fibers and the clay matrix, leading to the weakening of the blocks [12].
The flexural strength results are shown in Figure 8.

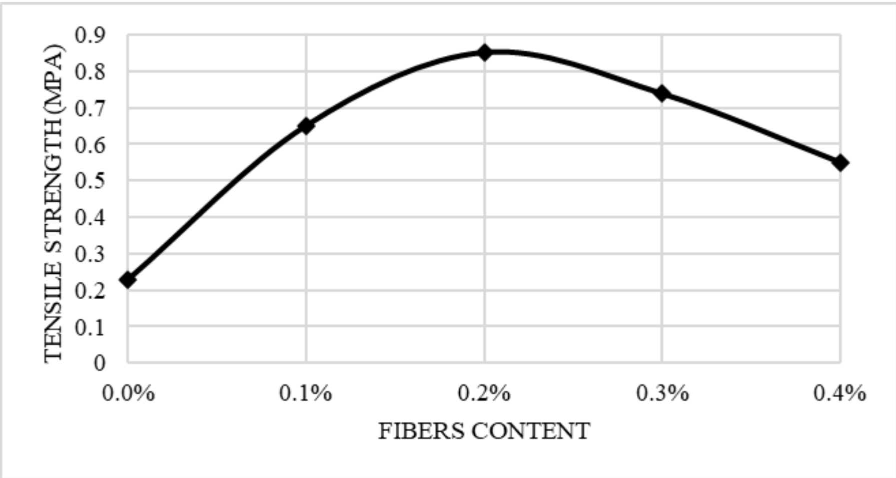


***Figure 8:*** *Tensile strength*

From the analysis of the results obtained from the bending tests, it can be seen that the strength of the specimens increases from 0 to 0.2% and then gradually decreases to 0.4%. The spike observed at 0.2% fibers is explained by the fact that this value is the optimal one allowing good adhesion within the composite, thus allowing it to resist fracture through the good tensile strength of the fibers. The subsequent drop is explained by the high presence of fibers in the clay matrix. Indeed, a high presence of fibers in the composite leads to a decrease in wettability between the matrix and the fibers and an increase in contact between the plant matter creating nodules in places that result in areas of mechanical weakness.

**Conclusion**

The objective of this work is to study the influence of coconut fibers on the physical and mechanical behavior of compressed earth blocks. From the results obtained, it emerges that:

- The density of the blocks decreases with increasing fiber content and the opposite is observed with capillary absorption;
- The compressive strength increases with the fiber content up to 0.3% and decreases thereafter;
- The fibers improve the tensile strength of the specimens, within a certain limit: beyond 0.2%, the strength drops.

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