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Original Research Article

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

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ABSTRACT

The present research aims to determine the influence of coconut fibers from coconut palms on the physical and mechanical properties of compressed and cement-stabilized earth blocks. The study focused on the density, capillary absorption, compressive strength and flexural strength of the blocks. The first part of this study is devoted to the determination of the characteristics of the soil and those of coconut fibres. Five fiber contents (0, 0.1, 0.2, 0.3 and 0.4%) were used and the soil consists of 70% sand and 30% clay silt. Three cement contents were incorporated (2%; 4% and 8%). Two types of specimens are then manufactured by mixing the fibres with the earth-cement matrix: 14x9.5x29.5 cm^3 blocks for compression and 4x4x16 cm^3 briquettes 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. Overall, the compressive strength decreases with increasing fiber content and increases with cement content. However, the flexural strength increases with the fiber content but within a certain limit: beyond 0.3% fiber, the strength drops.

Keywords: Clay soil – Coconut fibres – Cement – 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 & METHODS

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%

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 SiO2 (81.0%), Al2O3 (8.9%), Fe2O3 (2.8%) and the characterization tests revealed that it was a sandy-clay soil with little plastic and relatively clean.

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

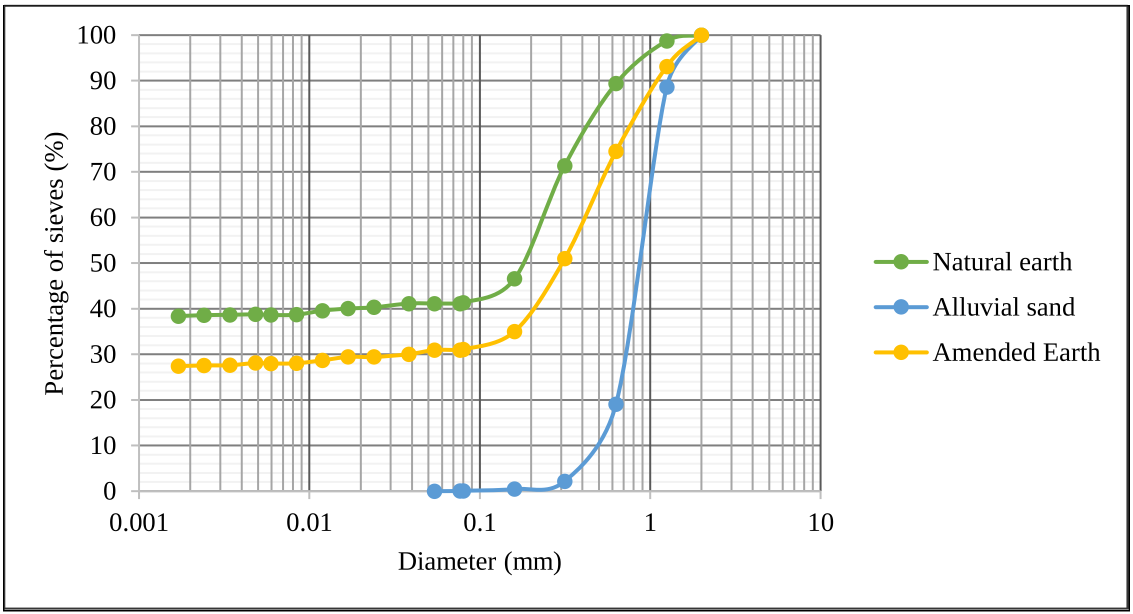

Figure 1: Particle size analyses

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

Figure 2: Extracted fibers

Table 3: Fiber's 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

The cement used is Portland CPJ 45 produced by CIMTOGO, one of Togo's cement plants. The latter and the fibres are measured as a mass percentage of the dry soil. The cement rates used are 2%, 4% and 8%. The fibers content varies from 0 to 0.4% to 0.1% (Table 4).

Table 4: Composition of mixtures

Amended soil (g)	% Fibers	Fibers mass (g)	% Cement	Cement mass (g)	Water body (g)
30000	0%	0	2%	600	2430
30000	0,10%	30			2430
30000	0,20%	60	4%	1200	2430
30000	0,30%	90	8%	2400	2430
30000	0,40%	120			2430

The compression blocks of dimensions 14x9.5x29.5 cm^3 are manufactured using a Terstaram press and the bending blocks using 4x4x16 cm^3 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.

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

Capillarity absorption

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

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

Cb: absorption coefficient;
M0: Dry mass of the block;
M1: 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.

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

Rc: 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 & DISCUSSIONS

Figure 5 shows the density measurement results.

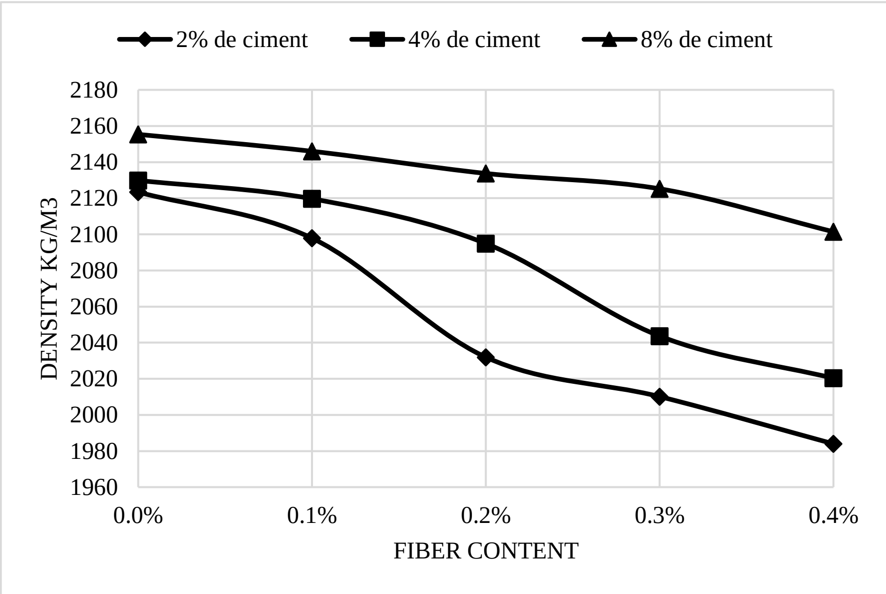

Figure 5: Density

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. However, the density increases with the cement content. Blocks with 8% cement are denser than those containing less. In comparison, these values are higher than those of blocks reinforced with bamboo fibers (1490 -1560 kg/m3) and that of rammed earth (1700 kg/m3), they are close to that of rammed earth (1990 - 2160 Kg/m3) [10], [11].

Figure 6 shows the results of water absorption.

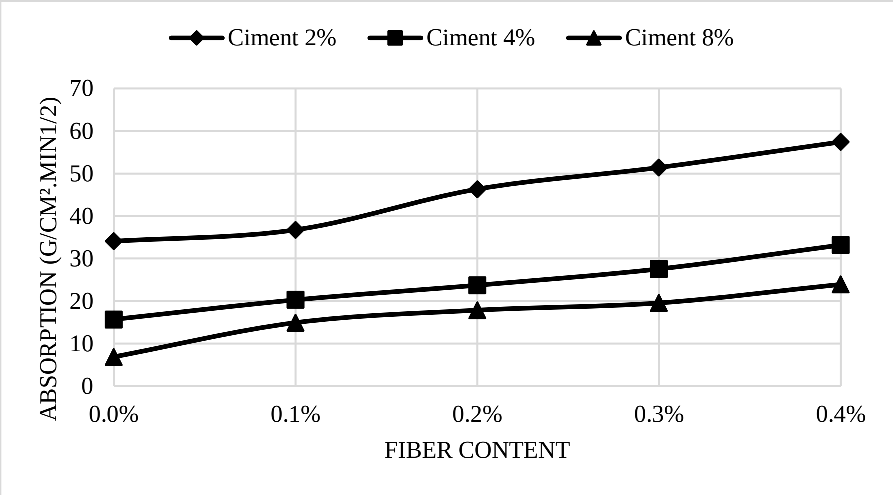

Figure 6: Capillary absorption

Analysis of the curves shows that the capillary absorption of the blocks increases with fiber 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. However, it can be seen that the absorption decreases with the cement content. The cohesion provided by cement has a positive impact on the poral network of the blocks.

The compressive strength measurement results are shown in Figure 7.

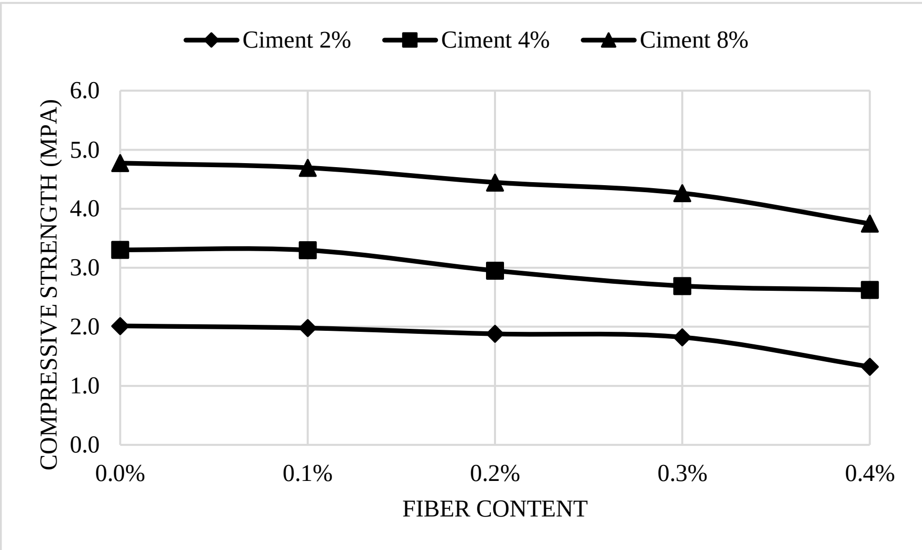

Figure 7: Compressive strength

The results obtained from the compression tests on the blocks show that the strength decreases with increasing fiber content and increases with cement content. The greater the amount of fiber, the less resistant the blocks. This behaviour is explained by the intensification of fiber-fiber contact, which is the consequence of the increase in the percentage of fibres incorporated. This leads to a gradual drop in adhesion and wettability between the fibers and the clay matrix, leading to a weakening of the blocks [12].

The flexural strength results are shown in Figure 8.

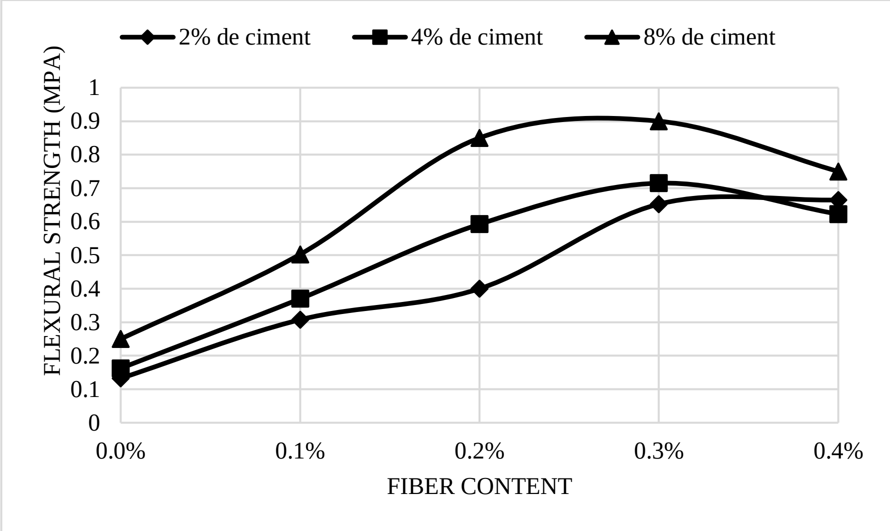

Figure 8: Flexural strength

From the analysis of the results obtained from the bending tests, it can be seen that the strength of the specimens increases with the fiber content. Indeed, there is a spike between 0.2 and 0.3% of fibers for the three curves. This result is explained by the growth of the fibers which allows the specimens to resist fracture through the good tensile strength of the fibers. The observed drop to 0.4% of fibres for the curves is explained by the high presence of fibres 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 and stabilized earth blocks. From the results obtained, it emerges that:

– The capillary absorption of the blocks increases with the fiber content and decreases with cement stabilization, testifying to the effect of the cement on the porous network of the blocks;
– The compressive strength decreases with increasing fiber content and increases with the cement content;
– The flexural strength of the specimens increases with the fiber content, within the observed limits. Outside these limits, resistance falls.

Declaration by Authors

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