Research Journal of Recent Sciences ISSN 2277-2502
Vol. **14(1),** 17-24, January **(2025)** *Res. J. Recent Sci.*

Influence of coconut fibers on the physical and mechanical properties of stabilized compressed earth blocks

Agbeme Kossivi Eric*, P'KLA Abalo and KOUTO Yaovi Agbeko
Laboratoire de Recherche en Science de l'Ingénieur (LARSI), University of Lomé, BP 1515, Lomé-Togo
kagbemetdi.tdi@hotmail.com

Available online at: www.isca.in, www.isca.me
Received 31st August 2024, revised 30th October 2024, accepted 19th November 2024

Abstract

Clay soil is a raw material commonly used for the manufacture of building materials, thanks to the different improvement techniques used. Binder stabilization or plant fiber reinforcement are among the techniques that are being studied and deepened with the aim of adding value to the properties of this material. The present study reveals the influence of the length and content of coconut fibers from the coconut palm on the physical and mechanical properties of stabilized compressed clay soil (BTCS) blocks. To do this, the clay soil from the Noèpé quarry (Togo) was mixed with the extracted fibers and cut into two length classes (0-6 and 6-10 cm). Three types of soil were used (70% Sand (S), 30% clay silt (CS); 75% S, 25% CS and 80% S and 20% CS). The land was stabilized with cement with a rate varying from 2 to 8% for a step of 2%. The fibers are incorporated into the clay-cement matrix with a mass content of soil varying from 0 to 0.4% for a step of 0.1%. The results obtained show that the density of the blocks decreases with the increase in the content of fibers incorporated for the two length classes and increases slightly with the content of cement. The opposite phenomenon is observed for capillary absorption, which increases with the fibers content and decreases with the increase in the cement content. Overall, the results show that compressive strength decreases with increasing fibers content.

Keywords: Clay soil –coconut fibers – compressed earth blocks – density – capillary absorption–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. As science has evolved, researchers have used several admixtures to improve the physical and mechanical qualities of earthen blocks[1-3]. Other studies have shown that mixing soil with natural fibers reduces shrinkage cracking, improves durability and mechanical properties, and increases thermal inertia[4-6]. Although it has been proven in more recent studies and within certain limits that the addition of date palm fibres or sisal fibres to the soil improves the compressive strength of the blocks[7-8], it can be hypothesized that plant fibres have an influence on the mechanical properties of the 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.Three types of soil called S1, S2 and S3 were then formed, the granular compositions of which are presented in Table-1.

Table-1: Granular soil composition S1, S2 and S3.

Elaborate Clay	Sand (%)	Silt + Clay (%)
EarthS1	70	30
Earth S2	75	25
Earth S3	80	20

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-2 and Table-3 show the extracted fibres and their characteristics respectively.

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 fiber content varies from 0 to 0.4% to 0.1% (Table-4).

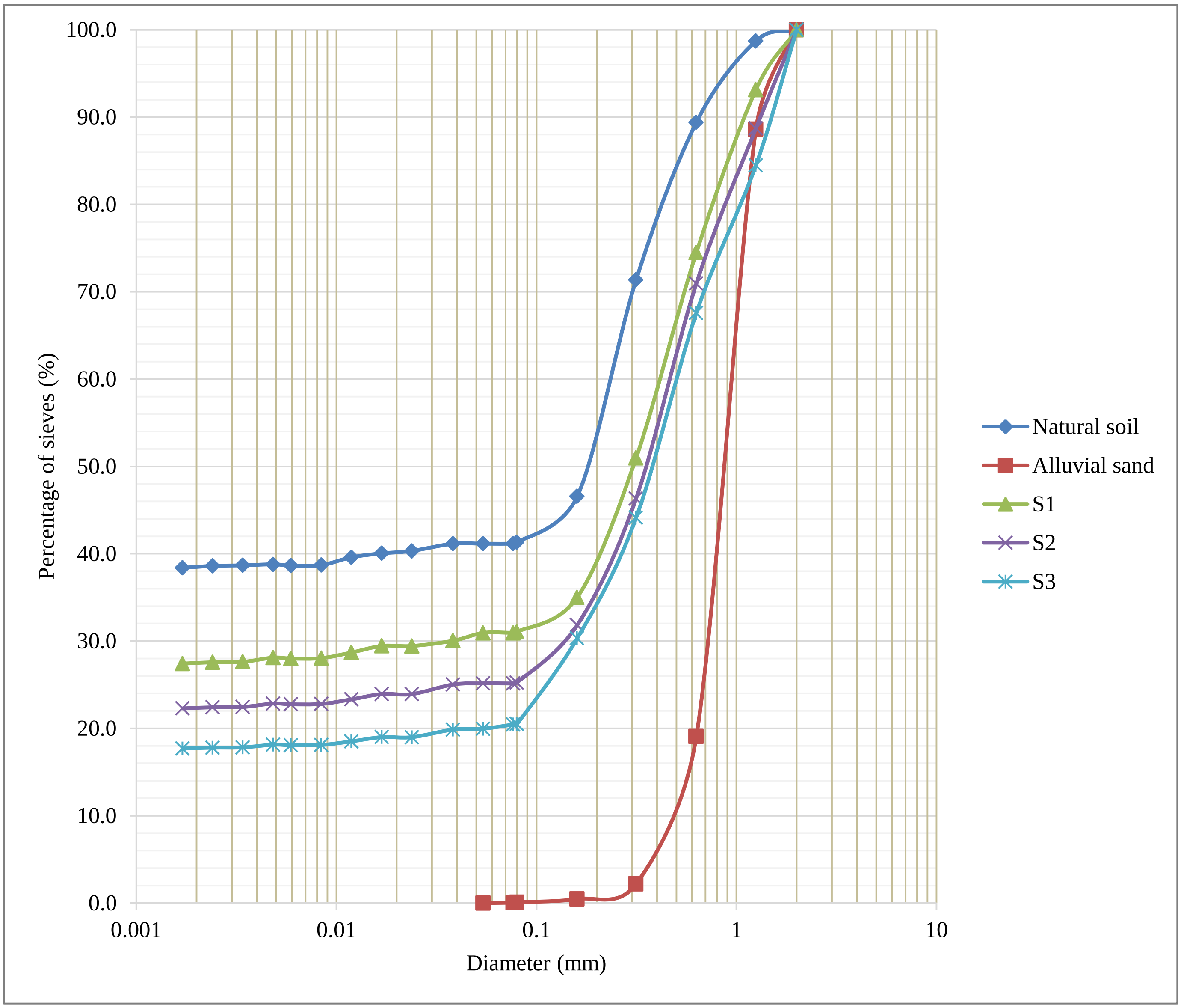


Figure-1: Particle size analyses.

Figure-2: Extracted fibres.

Table-3: Fiber's characteristics.

Features	Value
Maximum Length (cm)	12
Cut-out Length (cm)	[0 – 6[, [6–10]
Density (g/cm3)	1,25
Water Absorption Rate (%)	163
Diameter (mm)	0 – 0,1
Tensile Strength (Mpa)	122 - 133

Table-4: Composition of mixtures.

Earth Weight S1,S2, S3	% Fibers	Fiber mass (g)	% Cem ent	Cement mass (g)	Water body (g)
30000	0%	0	0%	0	2430
30000	0,10%	30	2%	600	2430
30000	0,20%	60	4%	1200	2430
30000	0,30%	90	6%	1800	2430
30000	0,40%	120	8%	2400	2430

The Table-5 indicates the denomination of the samples.

Table-5: indicates the denomination of the samples.

Elaborate Clay	Fiber Length Class	Naming of samples
S1	FC1[0 – 6[,	S1FC1
	FC2[6 – 10]	S1FC2
S2	FC1[0 – 6[,	S2FC1
	FC2[6 – 10]	S2FC2
S3	FC1[0 – 6[,	S3FC1
	FC2[6 – 10]	S3FC2

The compression blocks of dimensions (14x9.5x29.5cm^3) are manufactured using a Terstaram press and the bending blocks using 4x4x16cm^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°C. The blocks are weighed every day and maturity is reached when two successive weightings over a 24-hour interval show a mass loss of less than 0.1% 9.

Figure-3: Blocks 14x9.5x29.5 cm^3.

Figure-4: Briquettes 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: 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.

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

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

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

Inflection: At the failure of the specimen, the bending stress is given by the formula below.

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

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

Results and Discussions

Figure-5 shows the density measurement results.

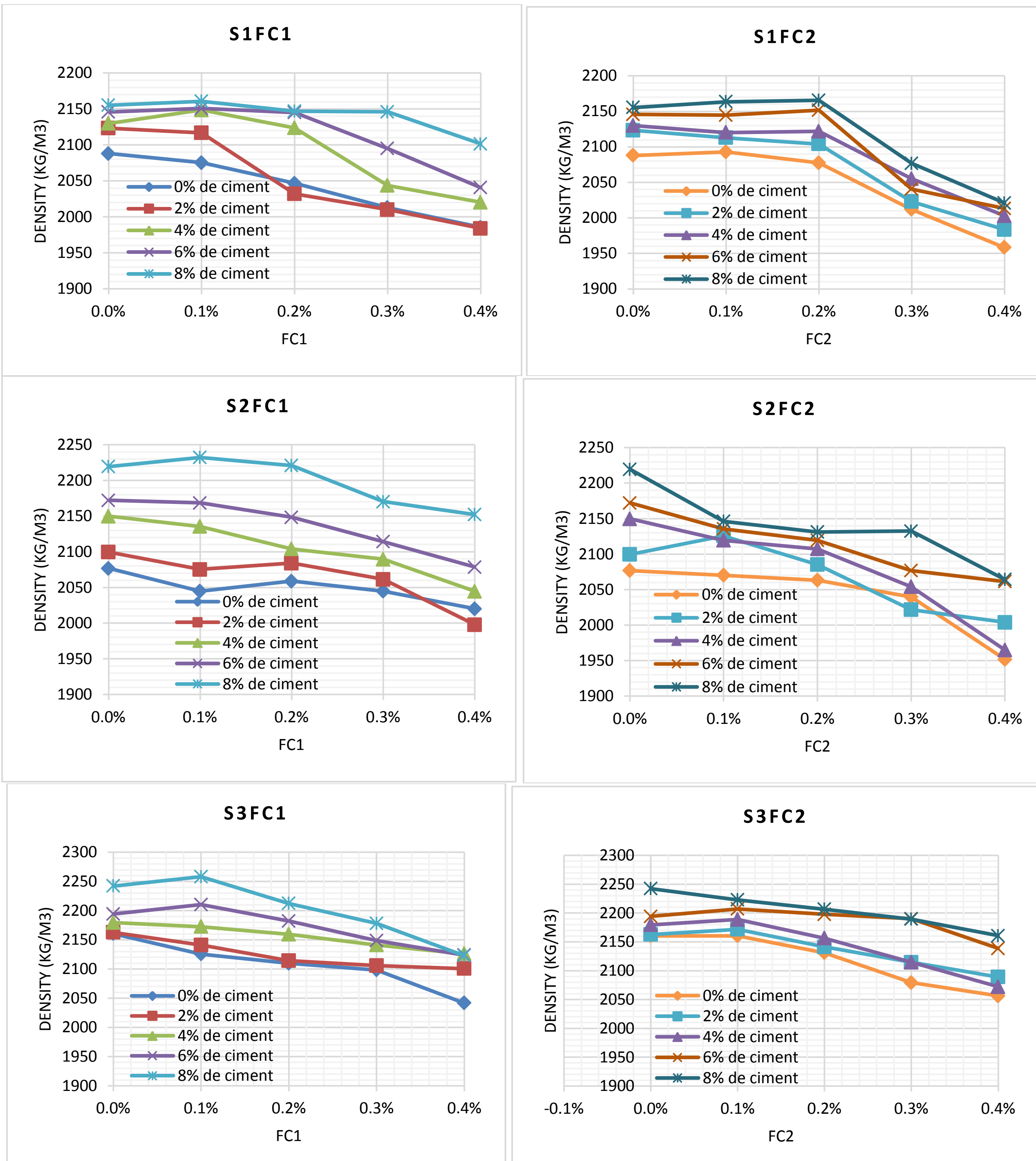


Figure-5: Density.

Analysis of the results shows that the density of the specimens decreases with increasing content of incorporated fiber. This is due to the lightness and low density of the fibres. It reaches a value for the control (0% fiber) and a minimum value at 0.4% fiber. It is also noticeable that the bulk density of the blocks increases with the cement content. In comparison, these values are higher than that of BTC reinforced with bamboo fibers (1490 -1560kg/m^3) and that of clay (1700kg/m3)[18,23]. They are close to that of rammed earth (1990Kg/m^3 - 2160 Kg/m3) and that of terracotta brick (1800-2000kg/m3)[10,11]. Figure-6 shows the results of water absorption.

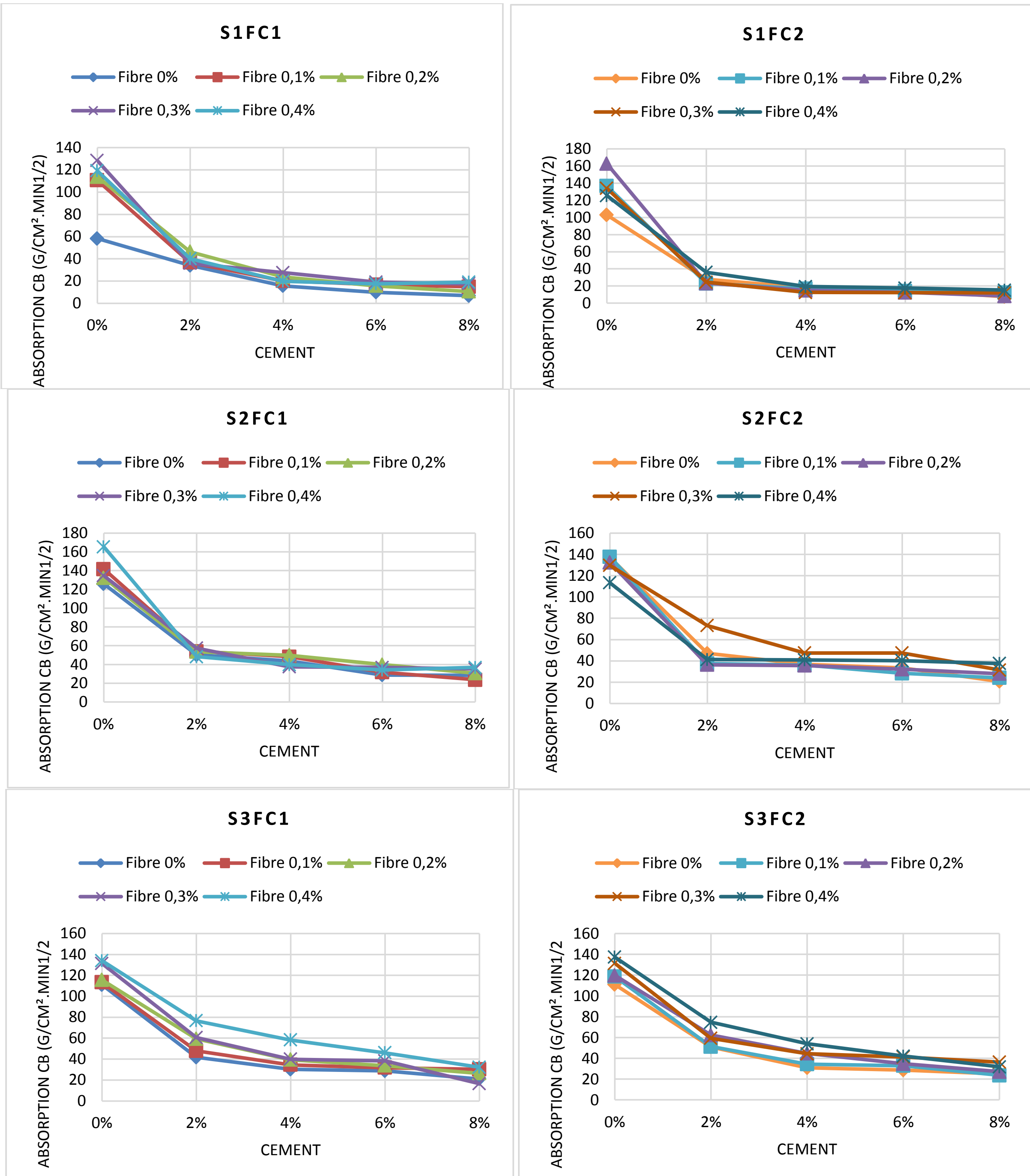
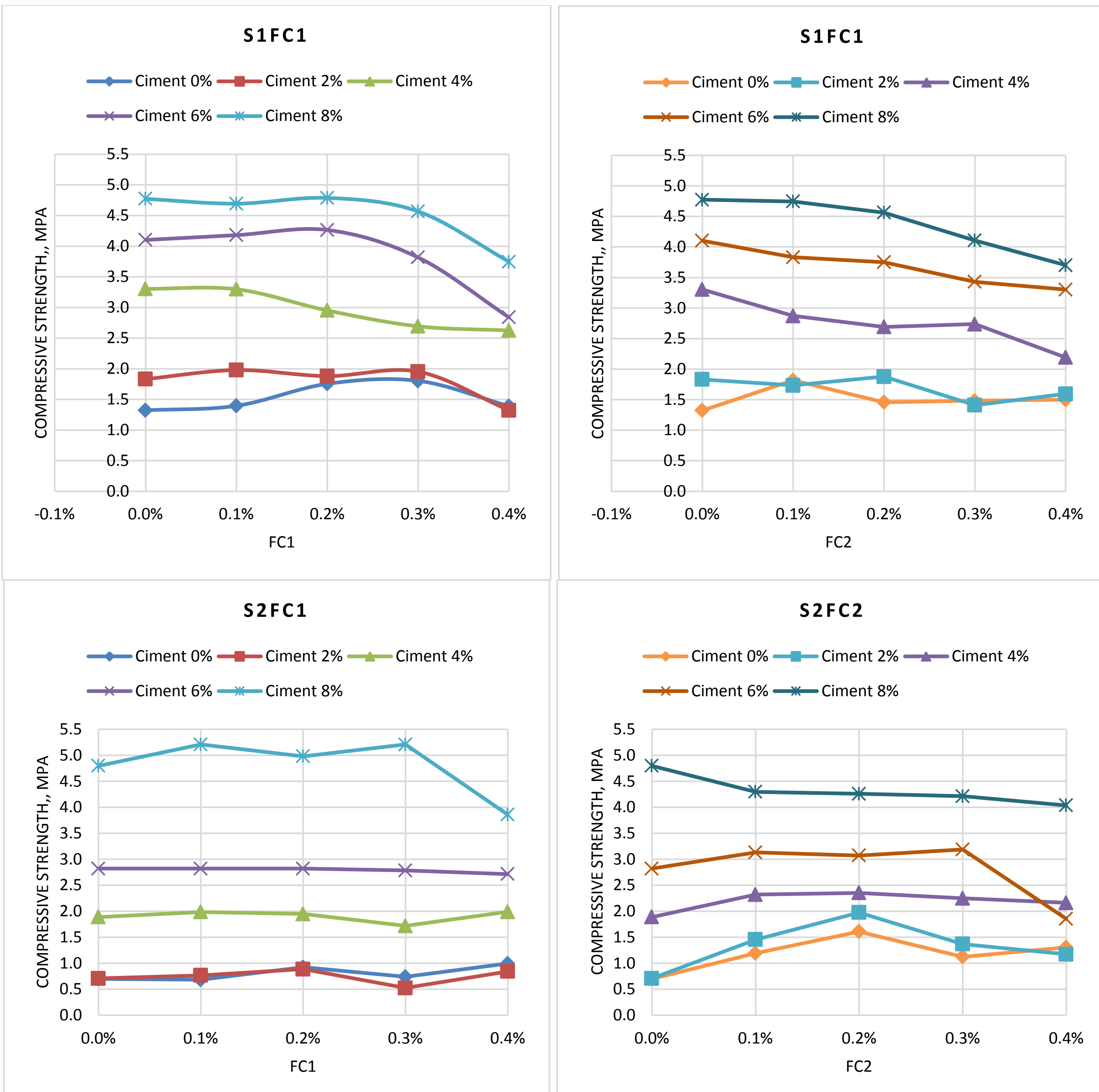


Figure-6: Capillary absorption.

The results show that for the same type of granular soil composition, the absorption coefficient increases with both fiber rate and length. 0% fiber specimens are less absorbent than 0.1 specimens; 0.2; 0.3 or 0.4% fiber. This is explained by increasing porosity with increasing fiber content. The longer fibers lead to an increase in the porosity of the blocks because they would occupy more space in the matrix. The fiber-fiber bond intensifies for this purpose, thus creating more vacuum and promoting absorption[12,13]. These results confirm those of Abessolo[14]. Similarly, it can be seen that absorption decreases considerably with cement content. This is because the blocks become less porous with increasing cement content. The absorption coefficient decreases by 73% from 0% to 2% of cement and from 93% to 8% of cement. These results demonstrate the considerable effect of cement on the absorption and poral network of the blocks. These results are in agreement with those of Taalah[15]. It is also found that, for the same cement and fiber contents, absorption is higher in sandier specimens than in those containing less sand. Indeed, a higher sand content makes the block more porous and therefore more absorbent. The compressive strength measurement results are shown in Figure-7.



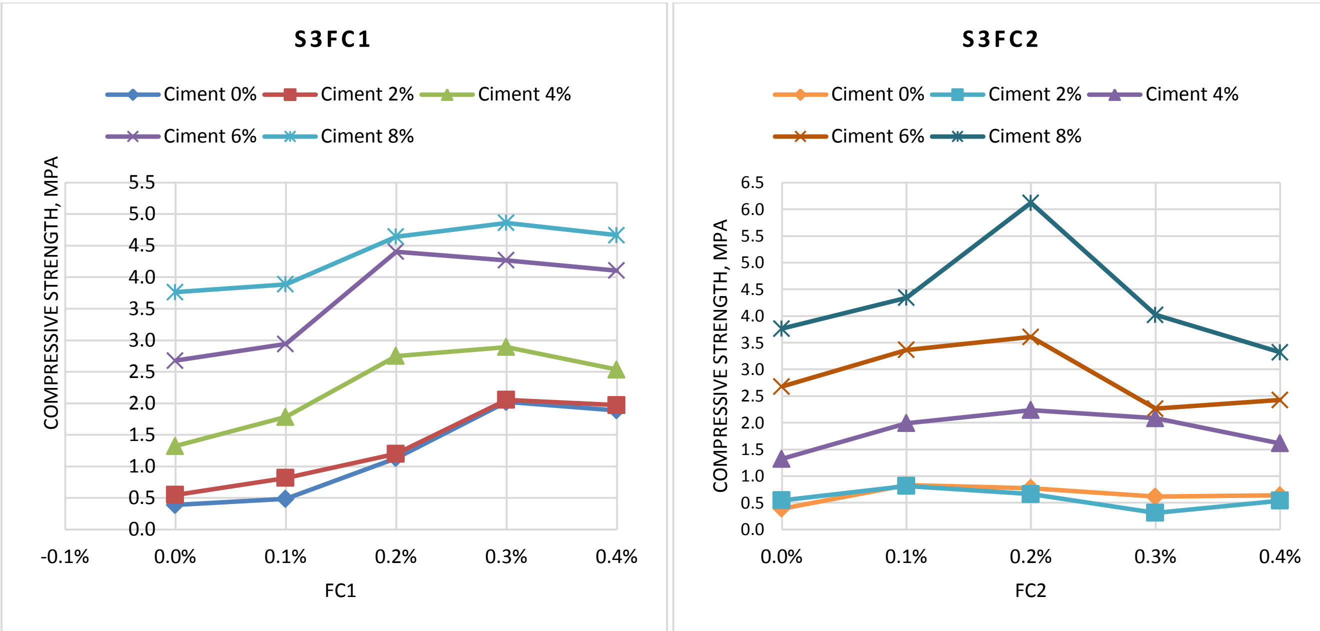


Figure-7: Compressive strength.

The results obtained from the test pieces show in general that the compressive strength decreases with increasing fibre content. This behavior is explained by the intensification of the fiber-fiber link, which is the consequence of the increase in the percentage of fibres incorporated into the blocks. These results confirm those of SEDAN in which the use of hemp in a mortar with a cementations matrix reduces mechanical resistance when the rate of hemp used is high16. However, the compressive strength increases markedly with the cement content. The more the cement content increases, the more resistant the blocks become. The results of the S1 and S2 soils show that the fibers have a negative effect on the compressive strength of the blocks. However, the results of the S3 earth reveal an increase and peak for 0.2 and 0.3% fiber. This result could be explained by the composition of the S3 soil and is similar to the results of D. Abessolo and I. Ntom Nkotto where the strength of the blocks would reach a slight peak and decrease thereafter[17,18]. It is also noticeable that the length of the fibers has a weak effect on the behavior of the specimens in compression.

Conclusion

Ultimately, this research work focused on the study of the influence of coconut fibres on the physico-mechanical behaviour of compressed earth blocks. It focuses on the effect of the content of coconut fibres cut into 0-6 cm and 6-10 cm long classes and also on the effect of the granularity of the soil used on the physical and mechanical behaviour of the said blocks. The results indicate that: i. The density of the blocks decreases with increasing fiber content regardless of the length of the fibers. It is also noticeable that the density of the blocks increases with the cement content; ii. For the same type of granular soil composition, the absorption coefficient increases with both fiber length and incorporation rate. It is also noted that the higher the sand content in the block, the more porous it is and therefore more absorbent. The results also reveal that the capillary absorption of the blocks decreases considerably with cement stabilization; iii. Overall, the compressive strength decreases with increasing fiber content. The greater the amount of fiber, the less resistant the blocks. In the case of blocks made with the S3 soil sample, where the strength increases slightly between 0.2 and 0.3% of fibres and then falls. It is also found that the strength increases with the cement content in the blocks and that the length of the fibres has a small effect on the strength of the compression specimens.

References

1. Anger, R., Fontaine, L., Joffroy, T., & Ruiz, E. (2011). Construire en terre, une autre voie pour loger la planète. *Secteur Privé & Développement, revue bimestrielle de Proparco*, (10), 18-21.

2. Houben H. and Guillaud H. (2006). Treaty construction earth. CRA Terre, Edition Parenthèse, Marseille, France, 2006.355.

3. Houben, H., Rigassi, V., & Garnier, P. (1996). Compressed Earth Blocks. Production Equipment.

4. Rowell, R. M. (2000). Characterization and factors effecting fiber properties. *Natural polymers and agrofibers based composites*.

5. Imen, S., & Belouettar, R. (2011). Comportement mécanique des briques de terre crue renforcées par des fibres de palmier dattier et des fibres de paille. *INVACO2 Séminaire International, Innovation & Valorisation en Génie civil & Matériaux de construction*, (2p-118).

6. Swamy, R. N. (1990). Vegetable fibre reinforced cement composites–a false dream or a potential reality?. In *Vegetable Plants and their Fibres as Building Materials: Proceedings of the Second International RILEM Symposium*, Vol. 10, p. 9780203626818. Routledge, London, UK. DOI.

7. Ngoulou, M., Elenga, R. G., Ahouet, L., Bouyila, S., & Konda, S. (2019). Modeling the drying kinetics of earth bricks stabilized with cassava flour gel and amylopectin. *Geomaterials*, 9(01), 40.

8. Mesbah, A., Morel, J. C., Walker, P., & Ghavami, K. (2004). Development of a direct tensile test for compacted earth blocks reinforced with natural fibers. *Journal of materials in Civil Engineering*, 16(1), 95-98.

9. Moussa, S. H., Nshimiyimana, P., Hema, C., Zoungrana, O., Messan, A., & Courard, L. (2019). Comparative study of thermal comfort induced from masonry made of stabilized compressed earth block vs conventional cementitious material. *Journal of Minerals and Materials Characterization and Engineering*, 7(385-403).

10. Khedari, J., Charoenvai, S., & Hirunlabh, J. (2003). New insulating particleboards from durian peel and coconut coir. *Building and environment*, 38(3), 435-441.

11. Mekhermeche, A. (2012). Contribution à l'étude des propriétés mécaniques et thermiques des briques en terre en vue de leur utilisation dans la restauration des Ksours sahariennes. Doctoral dissertation.

12. Ntenga R. (2012). L'anisotropie élastique de fibres végétales pour le renforcement de matériaux composites.

13. K. V. Maheshwari, A. K. Desai and C. H. Solanki (2011). Performance of fiber reinforced clayey soil, Electron. *J. Geotech. Eng.*, 16, 1067 -1082.

14. Taallah, B., Guettala, A., & Kriker, A. (2014). Effet de la teneur en fibres de palmier dattier et de la contrainte de compactage sur les propriétés des blocs de terre comprimée.

15. Sedan, D. (2007). Study of physicochemical interactions at hemp fiber/cement interfaces: influence on the mechanical properties of the composite. Doctoral dissertation, Limoges.

16. Baley, C. (2005). Fibres naturelles de renfort pour matériaux composites. Ed. Techniques Ingénieur.

17. Abessolo, D., Biwole, AB, Fokwa, D., Koungang, BMG, & Yebga, BN (2020). Effects of bamboo fiber length and content on the physicomechanical and hygroscopic properties of compressed earth blocks (CEB) used in construction. *Afrique Science* , 16(4), 13-22.

18. Risques Naturelles, B. P. (2020). Caractérisation des blocs produits par addition des fibres de coco et des matériaux de construction à base de latérite-ciment. *Afrique Science*, 17(4), 170-184.