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(Research Article)

Study of the effect of water dosage and compaction on the physico-mechanical characteristics of a mixture of earth (Avédji clay soil) and coconut fibers

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Abstract

The objective of this study is to contribute to the popularization of knowledge on the earth construction sector by studying the influence of the variation in the quantity of water and the compaction energy on the physico-mechanical properties of a mixture of earth (Avédji clay soil) and coconut plant fibers.

- To achieve this, we carried out :
- characterization of clay soil and coconut fibers ;
- a pre-formulation to achieve good workability and manageability of the soil-fiber mixture (this made it possible to adopt 80% clay soil and 20% coconut plant fibers) ;
- the formulation and preparation of soil-fiber mixture samples with two compaction modes: vibration and staking and variations in the quantity of water from 16% to 20% in increments of 2% ;
- determination of the mechanical properties of mixtures by compression and tensile tests by bending in the hardened state.

The results obtained show that for a water variation of 16% and 20%, the staked specimens give higher compressive strengths than the vibrated specimens; while at 18% the resistances are approximately the same. In traction, the resistance varies in the same direction as the water variation and the addition of fibers makes it possible to improve this tensile resistance by bending. Furthermore, the best mechanical strengths are obtained in traction, which is about 1.00 MPa, and in compression, which is about 1.544 MPa for a water variation of 20% and for compaction energy by staking precisely at compression.

Keywords: Clay Soil; Coconut Fibers; Water Quantity; Compression; Traction; Compaction Energy.

1. Introduction

After water, cement concrete is the most widely used substance on the planet. But its benefits mask enormous dangers for the planet, human health and culture itself. This material is the basis of modern development with constructions against natural disasters. To deal with this phenomenon, raw earth, an ecological, efficient, almost unlimited raw material with multiple applications, constitutes an alternative; it can be used instead of concrete as a load-bearing construction material, or as a filling material or even as a finishing material [1]. This study therefore does not plan to abandon concrete, but to reserve it for exceptional works and therefore replace it with raw earth mainly in "small" constructions. The basic materials for earth concrete are: clay (the purest clay is kaolin), sand, gravel and water. Thanks to its internal cohesion, clay plays the role of binder, gravel and sand are the internal skeleton, water is the lubricant. Raw earth has been and remains one of the main construction materials used by man for thousands of years. Even today, more than a third of the planet's inhabitants live in earthen buildings [6]. For developing countries, this percentage rises

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to 50% of the rural population and at least 20% of the urban and peri-urban population. The different methods of earth construction come from the traditions, climates and cultures of local populations. The principle underlying each technique is the mixing of earth with a certain quantity of water and sometimes plant fibers. There are a dozen ways of using earth in construction, the most common of which are: cob, adobe, cob, adobe, compressed raw earth brick [2 – 9]. Earth concrete, used alone, has shortcomings in terms of its tensile strength and offers limits due to its great shrinkage (appearance of cracks limiting its tensile strength) and its ability to be too high. creep. It therefore has limitations in its use. And to compensate for these shortcomings, the development of composite products, reinforced with fibers of natural (plant), artificial and synthetic origin in the construction sectors, has offered the possibility of correcting these shortcomings. We therefore incorporate, into the earth concrete matrix, plant fibers fundamentally modifying its intrinsic properties [10 – 14].
The present study is based on the mechanical characterization (compressive and tensile strengths by flexion) of earth concrete reinforced with coconut fibers.

2. Material and methods

The soil used during this study is clayey soil from a construction site in the city of Lomé, the capital of Togo. It is a slightly plastic silt with 31% clay whose characteristics are in table 1. Chemically, it is a hydrated aluminium silicate with a high iron content (iron clay) with a negligible content of iron. Titanium and Barium oxide which can be used as a refractory in the ceramic (earth construction) or cement industry. The fibers (figure 1) are obtained by defibrating coconut husks. These fibers are light and very hygroscopic from the first minute (Table 1). It is reported that the water absorption capacity of coconut fibers is very high. This intrinsic characteristic of the fibers must be strongly considered in the formulations to be proposed. There are therefore two possibilities : either propose pre-wetting the fibers before incorporating them into the earth concrete matrix or incorporate it directly by adjusting the water dosage. Since water absorption is almost immediate, it was opted to incorporate coconut fibers without pre-wetting. The appropriate amount of the wet material is placed in a cylindrical mold and compressed to obtain the cylindrical sample.

Table 1 Clay soil and corn stalks fibers characteristics

Characteristics		Clay soil	Coconut fibers
Apparent density		1.24	0.031
Clay content (%)		31%	-
Sand content (%)		69%	-
Atterberg limits	Liquidity limit	25	-
	Plasticity limit	12.53	-
	Plasticity index	12.47	-
Absorption rate (%)		-	186.80% in one minute

The coconut fiber extraction device is shown in figure 1 as are the extracted fibers.

Figure 1 Coconut, fiber extraction device and coconut fibers

In order to study the effect of the quantity of water on the mechanical characteristics of earth concrete reinforced with coconut fibers, the volume composition of the earth – fiber mixture is set at 80% earth and 20% fibers. after several experimental mixtures based on the workability and workability of the mixtures obtained. Then a volume variation of the water per volume of the soil – coconut fiber mixture is carried out in a range of 16 to 20% in steps of 2%. 16/32 test pieces (measurements of compressive characteristics) and 4*4*16 cm^3 (measurements of tensile flexural characteristics) are made and stored in an enclosure at room temperature. From the seventh day and at 24-hour intervals, the mass of the test tubes is measured. When the mass stabilizes, the test is carried out to measure the compressive and tensile strength by crushing the specimens.

Knowing that compaction has a positive effect on the resistance of the earth concrete matrix, we propose to vary the compaction mode for the same mixtures and to measure the effects on mechanical performance. To produce the specimens subjected to simple compression tests, two compaction methods will be used:

- Compaction on a vibrating table at the rate of two compactions of 30 seconds each, the test piece being filled in two stages and surfaced for the rest. This mode will be practiced on cylindrical test pieces 16*32 cm^3 ;
- Compaction by staking using a 14mm twisted steel rod, the same rod that is used for the Abrams cone subsidence tests. This staking will be carried out at a rate of 56 blows per layer, in reference to the number of blows practiced for the Proctor tests according to standard NF P 94-093, 2014. A total of 112 blows will then be applied per test piece. This mode will be practiced on cylindrical test pieces 16*32 cm^3.

3. Results and discussion

3.1. Mechanical characterization of samples compression

The results of the compression tests on the 16*32 specimens and for the two compaction modes are grouped in table 1.

Table 1 Compression test results for the two compaction modes

Formulation (%T+%F+%E)	Compressive strength (MPa)	
	Vibration	Picketing
100 + 0 + 18	1.213	1.213
80 +20 + 16	0.129	0.275
80 +20 + 18	1.1	1.033
80 +20 + 20	1.351	1.544

Figure 2 shows the variation curves of mechanical compressive strengths as a function of water additions.

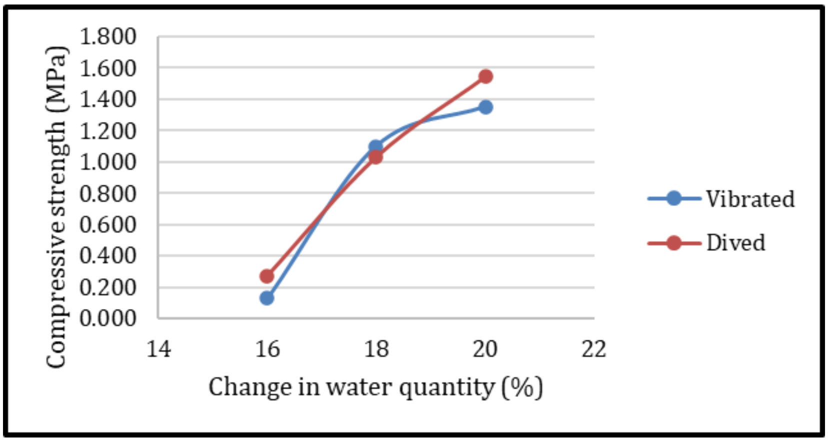

Figure 2 Curves of variation of the mechanical resistance to compression as a function of the rate of water addition

From figure 2, we note an increase in resistance as a function of the addition of water. The trend is towards a general increase in compressive strengths with the addition of water. This increase depends on the rate of water addition. The values obtained show better resistance by adopting staking as a compaction mode, the reduction in voids seems greater for this mode. The maximum value obtained is 1.544 MPa. For an addition of 20% water, we note an increase in resistance of the order of 27.29% compared to the control mixture whose value is 1.213 MPa.

The shape of the curves shows that there are always possibilities of obtaining better compressive strengths beyond the addition of 20% water. Except that it is difficult to meld the test tubes beyond 20% water, the mixture becoming too fluid and sticking to the walls of the test tube (figure 3).

Figure 3 Sticking the mixture in the mixer with more than 20% water.

3.2. Influence of the addition of fibers and water on tensile strength

The results of the tensile tests on the 4*4*16 specimens are recorded in table 2.

Table 2 Tensile test results

Formulation (%T+%F+%E)	Tensile strength (MPa)
100 + 0 + 18	1.213
0 +20 + 16	0.129
80 +20 + 18	1.1
80 +20 + 20	1.351

It should be noted that for these tests, only vibration was applied to the specimens given their thin appearance. Figure 4 shows the evolution of the tensile strengths of the samples as a function of the addition of water.

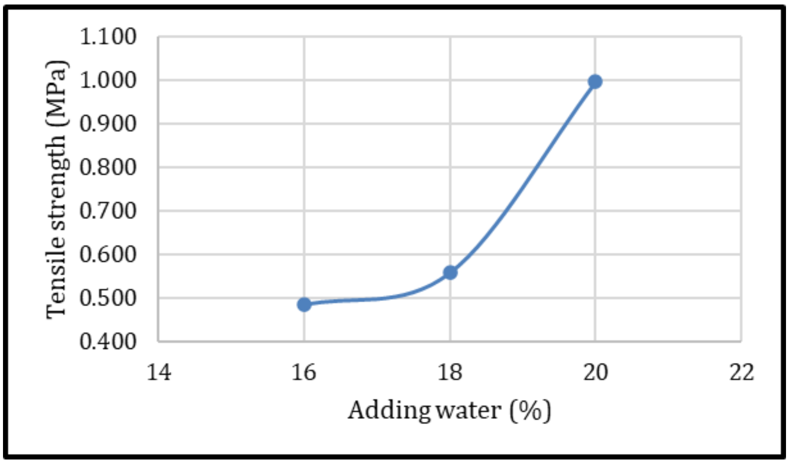

Figure 4 Evolution of the tensile strengths of the samples depending on the addition of water.

From figure 4, we notice a significant increase in tensile strength of 806% compared to the control mixture not containing fibers whose tensile strength is 0.11 MPa. We then note that the addition of fibers to the earth concrete matrix makes it possible to increase the capacity of the latter to resist tensile forces. It should be noted that this impact is possible by looking at the quantity of water to be incorporated (20% water in this case). As observed in the cylindrical specimens, a significant supply of water in the matrix makes the whole thing unwieldy.

4. Conclusion

The objective of this work was both to present the earth materials (Avédji clay soil) and coconut plant fibers and to determine the physico-mechanical behaviour of their mixture for a variation in the quantity of water (16%, 18% and 20%) and compaction energy (staking and vibration).

According to the results obtained, we see that the increase in water leads to an increase in the workability of the mixtures and this up to a certain degree of addition of water. Furthermore, the best mechanical strengths are obtained in traction, which is about 1.00 MPa, and in compression, which is about 1.544 MPa for a water variation of 20% and for compaction energy by staking precisely at compression. Also, the compaction effect and the incorporation of plant fibers greatly improve the mechanical performance (compression and traction) of earth concrete reinforced with plant fibers.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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