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Formulation of Compressed Earth Blocks Stabilized With Lime and Hibiscus Sabdariffa Fibres Showcasing Good Thermal and Mechanical Properties

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ABSTRACT
In search of sustainable materials adapted to the economic and climatic context in Africa, particularly in sub-Saharan Africa, our investigation focused on the formulation of compressed lateritic earth blocks providing good mechanical and thermal properties. After conducting a series of geotechnical tests on the matrix and physical tests on the selected inputs, formulas were proposed according to three criteria: compaction energy (3 strokes or 6 strokes), stabilization with 7% hydrated lime and reinforcement of the matrix stabilised with lime with 1.4% Hibiscus Sabdariffa fibres. The tests carried out on the formulated blocks concerned compressive strength, resistance to three-point bending, thermal conductivity and Young's dynamic modulus based on the speed of ultrasonic waves. The results showed that the variation in compaction energy has no significant effect on the properties of the proposed materials. Furthermore, bricks that are lime stabilised only or lime stabilised and reinforced with Hibiscus Sabdariffa fibres have a much higher compressive strength than CraTerre recommended. As for thermal properties, compressed earth blocks lime stabilized and fibre-reinforced have a lower thermal conductivity than other building materials commonly used in masonry such as cut laterite stone, baked earth, concrete.

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Introduction

Africa is the second most densely populated continent after Asia, with an annual urbanization rate of around 4% and an urban population living in slums estimated at around 50% according to the 2013 census of UN-Habitat [1]. This rapid urban growth is leading to a housing deficit that the continent needs to address through a comprehensive construction program in order to contain needs. Indeed, according to UN-Habitat, 80% of the buildings that will be inhabited in 2050 are not yet built. In addition, Africa needs close to 4 million dwellings per year, of which more than 60% are needed to house urban dwellers [2-3]. To meet these needs, the continent needs to develop regulations that ensure effective planning that will enable cities to cope with the growth of informal settlements and provide decent, sustainable housing adapted to the economic and climatic contexts.

In its quest for modernity, the African building has unfortunately been cut off from the centuries-old bioclimatic tradition, i. e. from a set of skills that have enabled dwellings to cope with sometimes extreme climates. Today, most of the materials used for construction on the continent are often low thermal performance and require a high energy consumption that Africa does not have. Moreover, the building sector alone contributes up to 18.4% of total greenhouse gas (GHG) emissions [4]. This high negative environmental impact combined with the scarcity of energy sources has motivated the search for materials that are less energy-consuming, more environmentally friendly and guarantee acceptable thermal comfort in homes.

The use of geo-materials such as cut laterite stone, compressed earth blocks, natural fibres in the construction of modern housing is a solution to be explored in Sub-Saharan Africa and particularly in Burkina Faso given the great availability of basic raw materials (laterite, fibres, limestone, etc...) for the manufacture of these construction elements which are predisposed to guarantee interesting thermo-physical and mechanical properties. This will have a significant positive social impact, especially since 2/3 of Burkina Faso's surface area is covered with laterite and several quarries are in operation [5-6]. The country also has limestone quarries for the manufacture of lime and natural fibres such as *Hibiscus Sabdariffa* and kenaf, which are unfortunately not valorized.

The objective of this research is to develop a BTC formula based on laterite, stabilized with lime and reinforced with Hibiscus Sabdariffa fibres to ensure both good mechanical strength and good thermal resilience. The aim is to guarantee the construction of sustainable housing with good thermal comfort using local materials.

Experimental

State of the art on BTC-Selection of materials - Stabilization techniques: Thermo-mechanical properties

Among many techniques of raw earth construction (adobe, "pisé", "torchis", straw earth, "bauge"...), that of the BTC, which consists in compacting the stabilized earth with the aid of various materials according to the evolution of science, is the most recent technique and which has known a great industrialization. The development of mechanical,

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manual or hydraulic presses in the 1950s made it possible to obtain consistent blocks, solid, hollow or honeycombed, of regular shapes (rectangular, circular, square...), more dense and having a better resistance to compression and to water, which allowed their use as masonry elements in modern constructions[7-8]. One may wonder if compared to other earthen building materials, BTCs offer more benefits such as economical, architectural benefits, thermal comfort.

The most used stabilizer for the production of BTCs is cement, despite the fact that its production requires a lot of resources and emits more CO2 (5% of world production). However, stabilization with cement is not well adapted to clay soils such as laterite. Indeed, the choice of the amendment of a material will depend on the texture of the soil and its content in fine elements [9]. Research by [10-12] has shown that soil with more sand and less clay is more suitable for cement stabilization, while soil with higher clay content is more suitable for lime stabilization. Usually lateritic soils contain a significant amount of clay [5], hence the choice of lime as a stabilizer in this study.

Previous studies have shown that optimization of the lime content is necessary to obtain better mechanical characteristics of the lime stabilized BTCs. Indeed, the results of research conducted by Millogo et al. [8] showed the influence of lime content on mechanical strength. The maximum value of the compressive strength is reached at about 10% by mass content of lime and from 12% onwards this value decreases.

The other parameter that influences the improvement of mechanical properties is time because of the pozzolanic properties of lime. Indeed, studies conducted by Oti et al. [13] on clays stabilized with hydraulic lime and slaked lime have shown that the compressive strength of stabilized lime specimens increases over time. Samples stabilized with slaked lime show a progressive increase in compressive strength measured at 7, 28, 56 and 90 days of age; with a maximum value of 7.4 MPa at 90 days of age. Progress is of lesser importance for specimens stabilized with hydraulic lime with a maximum value of 5.5 MPa at 90 days of age.

The incorporation of vegetal materials (straw, stem, plant fibre...) to reinforce the matrix of earth bricks is a practical monitoring. The addition of vegetable fibres is particularly recommended in view of their high tensile strength and low stiffness. In fact, studies conducted by Millogo et al. [8] on Cannabinus hibiscus fibres (kénaf) have shown that they have a tensile strength twice as high as steel with twice the rigidity of steel. Adding fibres to the BTC matrix also limits the spread of cracks. Studies have shown that the addition of fibres improves the flexural strength of blocks [14] and compressive strength if the length of the fibres is about 3 cm for a fibre weight percentage of about 0.4% [15]. However, this incorporation decreases Young's modulus.

These observations highlight the question of optimal fibre content for good physical, thermal, mechanical performances. Indeed, to formulate fibre concrete, it emerged from author toguyeni's unpublished experiments that beyond 3.5% and for fibre lengths between 4 and 5 cm, the fibres preferentially absorbed the mortar and found themselves in ball, thus preventing to have a homogeneous concrete paste. To have a homogeneous concrete paste it was necessary to reduce the percentage of fibres to 0.5% and give the fibres a length between 0.5cm and 1.2 cm.

In addition, recent studies conducted by Babatoundé Laibi [16], on the hygro-thermo-mechanical behavior of BTC fibre with Kenaf fibres with mass rates of 0.5%, 1% and 1.5% and between 0.5 and 3cm in length, found that the most compression-resistant (3 to 10%) cement-stabilized and containing fibres BTCs were obtained with 0.5% fibre of 3cm in length. These results alone justify the fact that the authors have in perspective the search for optimal performances according to the length of the fibres and their mass rate.

Other difficulties are also observed: the problem of adhesion of fibres to the matrix, the increase in water absorption which favors the development of molds and adversely affects the mechanical resistance, deterioration or mineralization of certain fibres [17-19].

Earth material in its natural state does not really possess the thermal potential that one wants to give it when it is used in construction [20]. However, when it is mixed with other materials such as binders, fibres ..., these additions contribute to the improvement of its mechanical and thermal performances. Several researchers were therefore interested in improving the thermal properties of blocks by adding vegetable fibres. Khedari et al. [21] found that the thermal conductivity of bricks based on compressed lateritic clay stabilized by coconut fibres decreases with increasing fibre content. This reduction has reached a significant rate of about 50% compared to the thermal conductivity of unreinforced bricks. Millogo et al. [8] also confirmed this decrease in the thermal conductivity of compressed blocks by adding Hibiscus Cannabinus fibres. These authors have shown that conductivity decreases with increasing levels and length of Hibiscus Cannabinus fibres.

Properties of composites used

Numerous laboratory tests have made it possible to determine the physical and mechanical properties of composites used to make BTCs. The properties of these materials are summarized in the following paragraphs.

Laterite

The laterite sampling quarry used in this study is located approximately 4.5 kilometres north of Kamboinsé (Burkina Faso). Physical and mechanical tests such as particle size analysis, Atterberg limits, specific weight, normal Proctor test were carried out on samples taken in accordance with the standards (respectively NF P 94-056 [22] - NF P94-057 [23] - NF P 94-051[24] - NF P 94 093 [25]).

These tests show that the laterite used has a liquidity limit of 47.2%, a plasticity limit of 25.1%, a plasticity index of 22.2 (Table 1) and a granulometric distribution (Figure 1) in accordance with the requirements recommended by CRATerre and H. Guillaudet et al. [26, 9] for the manufacture of compressed bricks. The clay and silt content of 46% is higher than 40%; this justifies the choice of lime stabilization [8].

The density of the laterite at the normal Proctor optimum is 1.8 for an optimum water content of 17.6% (Figure 2). This value will be used to determine the amount of mixing water during the formulation of the BTCs.

Lime

The lime used is produced in Burkina Faso by COVEMI in a limestone quarry located in the Orodara region

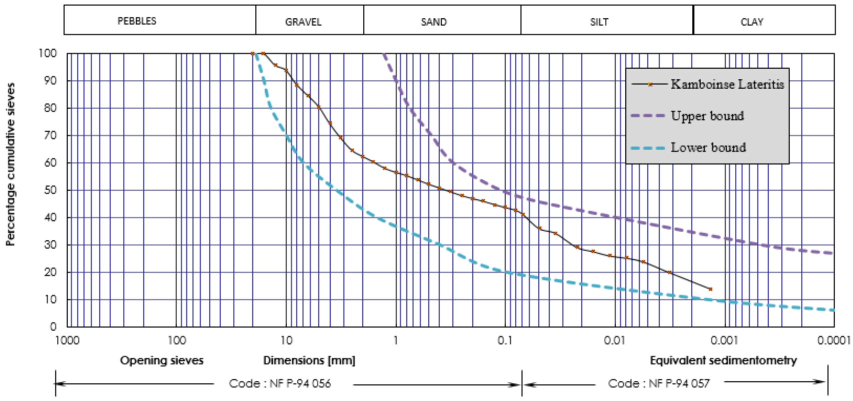

Figure 1: Granulometric curve of laterite and granular spindle of CRATerre for BTC

(southwestern Burkina Faso). It was extinguished and stored underwater for seven (07) days.

Table 1: Physical properties of the laterite used

Tests carried out	Results obtained	
Granulometric analysis	Sand (%)	33
	Limon (%)	29
	Clay (%)	17
	Gravel (%)	21
Methylene blue	Laterite	1.45
Atterberg limits	Liquidity limit (%)	47.20
	Plasticity limit (%)	25.10
	Plasticity index	22.20
Specific Gravity	γs (g/cm3)	2.64

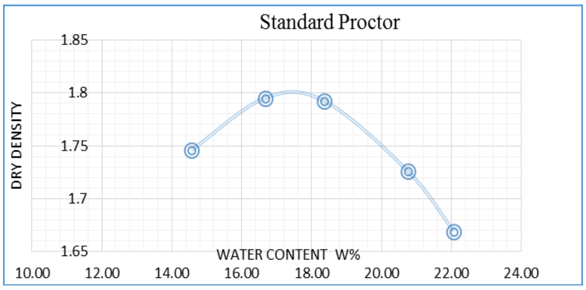

Figure 2: Curve of the laterite standard Proctor test

Hibiscus Sabdariffa fibres

The fibres used come from the envelope or cortex of Hibiscus Sabdariffa commonly called "Bissap" in Africa. After getting the plant's cortex, we make sure to remove first the epidermis and attached pieces of wood because rich in lignin and hemicelluloses, they are more sensitive to the alkaline medium (mineralization) [18].

The fibres were the subject of a characterization conducted by the author Toguyeni in 2010 during a study trip to the LOMC, University of Le Havre (France). They can reach up to 3 m in length with a diameter ranging from 40 to 380 µm, a density of about 0.86 g/cm3 and a water absorption coefficient of up to 3.25.


Figure 3: Hibiscus Sabdariffa fibres (David TOGUYENI, April 2010)

BTC Confection

A sieve pre-treatment of the laterite for BTC production using a 5 mm mesh sieve was required due to the presence of coarse particles in the quarry sample. The sieved passing particles are spread thinly in the open air for seven (07) days to ensure natural drying.-

The Hibiscus Sabdariffa fibres are then cut at a length of 1 cm in wet state to facilitate the cutting operation and prevent the impeller of the mixer from becoming entangled by very long fibres. They are then dried in an oven at 105 °C for 3 days. Three (3) BTC formulas were proposed for which the weight percentages of mixtures are summarized in Table 2. It is a BTC formula with unstabilized laterite as reference, a lime stabilized BTC formula and a Hibiscus Fibre and Lime stabilized BTC formula.

A suitable mixing in a "Terstaram" type mixer was carried out for 5 minutes according to this order of material introduction: laterite - lime - fibres. The mixing water is added gradually until the mortar is brought to the optimum water content of the laterite, previously determined using the standard Proctor test. The production of the BTCs was carried out in accordance with Craterre's specifications [27, 28]. For each formula, BTCs of dimensions 14 x 14 x 9.5 cm^3 and 29.5 x 14 x 9.5 cm^3 with two different compaction energies (3 and 6 press strokes) were produced using a TERSTARAM manual press with a maximum theoretical load of 15,000 kg. A press stroke corresponds to about 15 bars according to the press specifications.

Table 2: Types of composites of the different formulas of the prepared BTCs

BTC formula	Symbol	Laterite %	Lime %	Fibre %	Water %
Unsterilized laterite compressed with 3 press strokes	L/3	82.4	-	-	17.6
Unstabilize d laterite compressed with 6 press strokes	L/6	82.4	-	-	17.6
Laterite + Lime compressed with 3 press strokes	$(L+C_7)/)3$	75.4	7	-	17.6
Laterite + Lime compressed with 6 press strokes	$(L+C_7))/6$	75.4	7	-	17.6

Laterite + Lime + Fibres compressed with 3 press strokes	$(L+C_7+F_{1.4})/3$	74	7	1.4	17.6
Laterite + Lime + Fibres compressed with 6 press strokes	$(L+C_7+F_{1.4})/6$	74	7	1.4	17.6

The produced BTCs are then stored in a well-insulated solar radiation room under a polyester blanket for seven (07) days in order to ensure a wet cure, the bricks being in contact with air whose relative humidity varies between 90% and 100%. The cure is prolonged after exposure in the room for 28 or 45 days, depending on the program of thermo-mechanical tests.

Characterization methods

In the absence of standards setting the number of samples to test in order to validate experimental results [29], we decided to determine each property from testing three (03) samples of each formula at 28 days then 45 days. Besides some recent studies such as Babatoundé's [16] and O. Izemmourena's [30], used the same number of samples.

Mechanical characterization method

Compressive strength and three-point flexural strength are the two mechanical characteristics of BTCs that were determined in this study. Thus, for each formula:

The compression test (Figure 4) was carried out on three (03) blocks of size 14x14x9.5cm³ from each formula at 28 days and then at 45 days, in accordance with standard [31]. The compressive strength is calculated by formula 1, with S being the section receiving the compressive load and F the breaking force.

$$Rc = 10\frac{F}{S}\ ; \qquad (1)$$

The three-point bending test was carried out on three (03) specimens of size 29.5x14x9.5cm³ (length l = 29.5 cm, base B = 14 cm and height H = 9.5 cm). Three-point bending strength is determined by formula 2:

$$Rf = \frac{3.F.L}{2.B.H^2} \qquad (2)$$

Figure 4: Compression testing device

Figure 5: Three-point bending test device

Thermomechanical characterization method

The thermal conductivity, ultrasonic velocity and dynamic Young's modulus are the properties determined in this study:

- Thermal conductivity is measured by a device called KD2 PRO (Figure 6). For our study we used the two needle sensors device which is adapted to materials as BTC. Measurements were made also on three (03) 14x14x10 cm³ sized samples for each formula at 28 days and 45 days.

Figure 6: Device for measuring thermal conductivity (KD2 PRO)

- The velocity of ultrasonic wave propagation through the materials blocks is measured using Pundit Plus. Once the device is turned on, the propagation rate in meters per second (m/s) and the time of propagation in microseconds (μs) can be read.
- The Young dynamic module is calculated by formula 3:

$$Ed = \rho V^2 \frac{(1+\nu)(1-2\nu)}{g(1-\nu)}\ ; \qquad (3)$$

With ρ= dry density of the specimens, g= acceleration of gravity ($10 m/s^2$) and υ = Poisson coefficient (taken equal to 0.3).

We would like to note that to determine Ultrasonic velocities (V) and dynamic Young's modulus (E), measuments were conducted at the same time on three (03) blocks of size 14x14x10 cm³ from each formula at 28 days and then at 45 days.

Results and Discussion

Mechanical Characterization

Compressive strength

Compressive strength results for the blocks at 28 days and 45 days of age are summarized in Figures 7 and 8 (table 3, cf.annex).

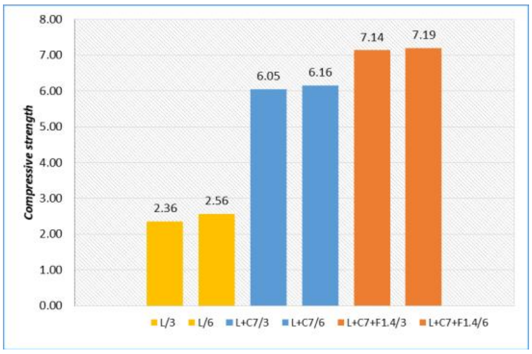

Figure 7: Compressive strength on the 28th day

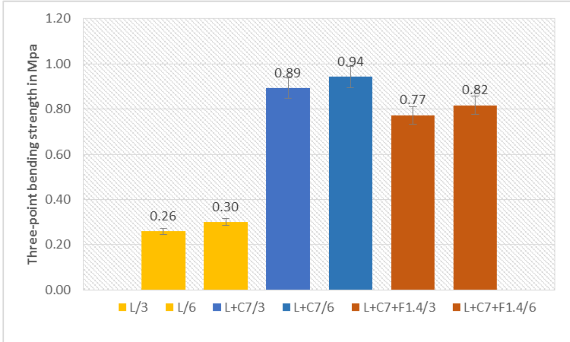

Figure 9: Three-point bending strength on the 28th day

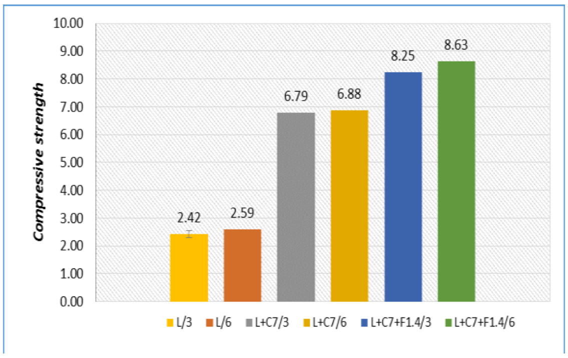

Figure 8: Compressive strength on the 45th day

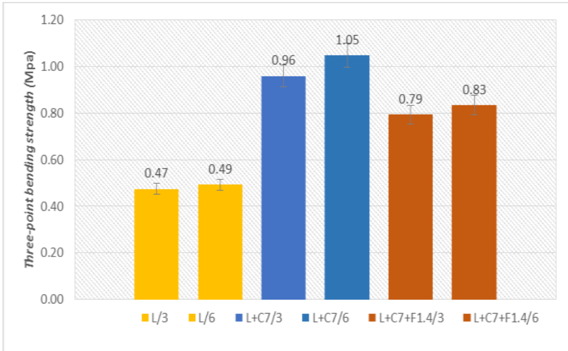

Figure 10: Three-point bending strength on the45th day

The 28th day compressive strength of the 3 strokes compacted reference blocks (unstabilized laterite) is in the order of 2.36 MPa. The change in compaction energy (from 3 press strokes to 6 press strokes) does not bring a significant change in compressive strength (8.4%). This could be explained by the fact that the water content of the samples (mixed water) is constant (Optimum Proctor). The variation in resistance with age of the blocks is also low (1-2.5%).

Stabilization at 7% of the lime (LC_7) allowed an increase in compressive strength of about 150% at 28 days of age and 180% at 45 days of age. This increase in resistance over time is confirmed in previous studies [13, 10] and may be explained by the activation of the pozzolanic properties of laterite with lime.

The change in compaction energy also has no significant effect on compressive strength. The slight increase in strength could be explained by the reduction in block porosity due to a reorganization of grain layout.

Stabilization at 7% lime and 1.4% fibres (LC7F1.4) yielded the highest compressive strengths ([7.14 -7.19] MPa at 28 days and [8.25 - 8.63] MPa at 45 days of age depending on the compaction energy). The addition of fibres therefore contributes to the increase in compressive strength, while the contribution of compaction energy is still small. This increase in compressive strength with the addition of fibres is also evidenced by the work of Oti et al. [13], P. Sherwood [15], Millogo et al. [8].

Flexural strength

Figures 9 and 10 (Table 4 in annex) present the results of bending at 28 and 45 days of age for the three formulas according to the variation in compaction energy.

Whatever the formula, flexural strength is between 9 and 15% of compressive strength. The highest bending strength is achieved with lime stabilized blocks (0.89-1.05MPa); about twice that of unstabilized blocks (0.26-0.49 MPa).

The introduction of fibres into the matrix causes flexural strength to drop by 12% at 28 days of age and by 20% at 45 days of age compared to stabilized lime blocks. The reduction in bending strength was also observed in the thesis work of Zoma [32]. Actually, the presence of lime contributes to increase the pH of the matrix, thus favouring the degradation of plant fibres in the presence and consequently negatively affecting the reactions of taking [18, 19]. However, compared to the flexural strength of unstabilized blocks, there is always a very significant gain (of the order of 100%) with the addition of fibres. Millogo et al. [8] also observed this improvement in flexural strength by studying lateritic soil stabilized by Hibiscus Cannabinus (kenaf) fibres. This improvement could be explained by the high flexural strength of Hibiscus Sabdariffa fibres and maybe their length.

Thermo-mechanical Characterization

Thermal conductivity of BTC

For all formulas, the values of thermal conductivity range from 0.54 to 1.0 W/m. K (table 5 in annex, Figures 11 and 12). There is a slight increase in conductivity by increasing the compaction energy and a slight drop in conductivity over time (less than 1%). This could be explained by the reduction in porosity due to the increase in compaction energy on the one hand and to the departure of water over time, leaving space for air which has a conductivity thirty times lower than that of water[26].

The highest conductivity value is obtained with lime stabilized blocks (0.86-1.00 W/m. K)

The introduction of fibres into the matrix causes the conductivity to drop by 20% (0.76-0.80 W/m. K) compared to that of lime stabilized blocks. These results are close to those obtained by Millogo et al. [8] with Hibiscus Cannabinus stabilized fibre blocks.

The thermal conductivity of Lime Stabilized BTC with fibre-reinforced lime is better than that of other building materials commonly used in masonry such as carved laterite block, baked earth, concrete, etc [9].

Figure 11: Thermal conductivities at 28 days

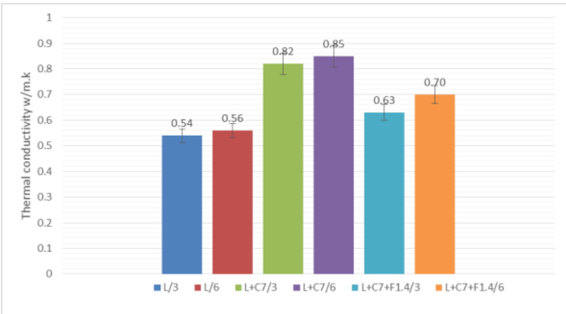

Figure 12: Thermal conductivities at 45 days

Ultrasonic velocity and Young's module

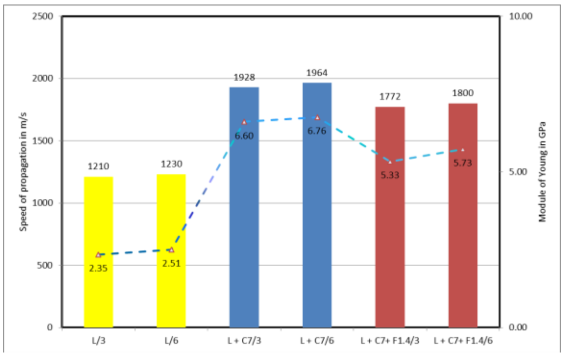

Figure 13: Wave propagation speed at 28 days

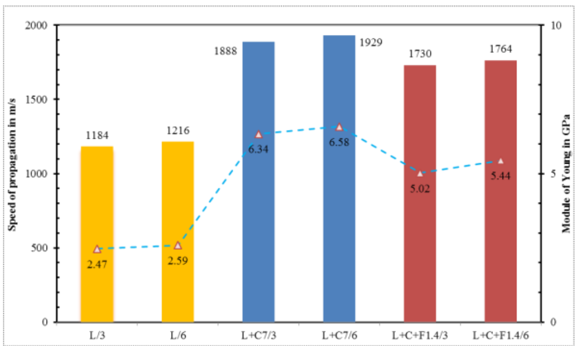

Figure 14: Wave propagation speed at 45th day

Figures 13 and 14 (Table 6 in annex), show the ultrasonic velocities and dynamic Young's modulus calculated by formula (3) respectively at 28 days and 45 days of age for blocks of different formulas.

For many materials the smaller the Young's module, the more insulating the material is. The representation of the ultrasonic velocity and the dynamic Young's module on the same graph makes it possible to appreciate the insulating character because the latter is proportional to the square of the velocity. In these figures, the lowest velocity is obtained with unstabilized laterite samples (1210-1230 m/s) and the highest with lime stabilized samples (1928-1964m/s). This shows that the most insulating material is unstabilized laterite. On the other hand, stabilization with lime and fibres (1772-1980m/s) improves the insulating power compared to stabilization with lime alone.

This is due to the considerable reduction in air-filled pores due to the introduction of fine elements during lime stabilization. The reduction in fibres input into the matrix may be due to the thermal conductivity of the matrix compared to other materials in the mixture. This explains why the formulas L+C7+F1, 4 and L+C7 are less porous composites compared to unstabilized laterite because lime is composed of fines, the addition of 7% of lime considerably reduces the number of air-filled pores whose conductivity is relatively low.

Finally we note that with the duration of cure, the wave propagation rate decreases slightly. This is due to the water flow from the pores, leaving space for air which is more insulating.

Conclusions

The aim of this study was to develop a BTC formula with good mechanical strength and low thermal conductivity based on the stabilization of laterite with lime and reinforcement of the matrix by *Hibiscus Sabdariffa* fibres.

With a stabilization at 7% of lime and a reinforcement with *Hibiscus Sabdariffa* fibres of 1.4% (% by weight), the stabilized BTCs have compressive strengths at 28 days of about four times greater than unstabilized blocks. A gain of 1 to 2 MPa is also obtained compared to the compressive strength of only lime stabilized blocks. These values are nearly twice as high as the CraTerre [18] recommended for use in masonry. However, the introduction of fibres causes the flexural strength to drop, compared to that of BTC stabilized with lime alone. The bending strength values obtained are about one-tenth of the compressive strength. The change in compaction energy does not have a significant effect on the strength of the material due to the non-variable mixing water quantity (Optimum Proctor).

The study also showed that the thermal conductivity of stabilized blocks with addition of fibres is lower than that of lime-stabilized blocks alone. This 20% reduction in conductivity could be explained by the good insulation properties of *Hibiscus Sabdariffa* fibres and the presence of microspores filled with air.

As a perspective for this study, it is necessary to consider:

- A variation of the BTC components to determine an optimal formula that would give both the best thermal and mechanical properties;
- A wider variation in compaction energy (number of strokes) at different water contents
- Study the other thermo-physical parameters that are used to evaluate the thermal comfort of a building.

- The influence of fibres length on the thermophysical and mechanical properties of Lime Stabilized Fibres BTC.

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Annexes

Table 3: Compressive strengths (Rc)

Composition	Energy (number of strokes)	RC [MPa] at 28 days	Total tested samples	RC [MPa] at 45 days	Total tested samples
L	3	2.36±0.06	3	2.42±0.04	3
	6	2.56±0.04	3	2.59±0.09	3
L+C_7	3	6.05±0.32	3	6.79±0.43	3
	6	6.16±0.31	3	6.88±0.47	3
L+C_7+$F_{1.4}$	3	7.14±0.3	3	8.24±0.28	3
	6	7.19±0.12	3	8.64±0.2	3

Table 4: flexural strengths (Rf)

Composition	Energy (number of strokes)	Rf [MPa] at 28 days	Total tested samples	Rf [MPa] at 45 days	Total tested samples
L	3	0.26±0.01	3	0.47±0.02	3
	6	0.3±0.03	3	0.5±0.02	3
L+C_7	3	0.89±0.09	3	0.96±0.05	3
	6	0.95±0.14	3	1.05±0.01	3
L+C_7+$F_{1.4}$	3	0.77±0.01	3	0.8±0.01	3
	6	0.82±0.03	3	0.83±0.03	3

Table 5: Thermal conductivities (K)

Composition	Energy (number of strokes)	K [w/m.k] at 28 days	Total tested samples	K [w/m.k] at 45 days	Total tested samples
L	3	0.56±0.07	3	0.84±0.16	3
	6	0.61±0.06	3	0.86±0.06	3
$L+C_7$	3	1±0.06	3	0.81±0.09	3
	6	0.86±0.03	3	0.82±0.14	3
$L+C_7+F_{1.4}$	3	0.8±0.01	3	0.63±0.02	3
	6	0.76±0.07	3	0.7±0.1	3

Table 6: Ultrasonic velocities (V) and dynamic Young's modulus (E) measured

Composition	Energy (number of strokes)	E [GPa] at 28 days	V [m/s] at 28 days	Total tested samples	E [GPa] at 45 days	V [m/s] at 45 days	Total tested samples
L	3	2.35±0.09	1190.37±21.28	3	2.45±0.06	1183.66±12.31	3
	6	2.51±0.14	1229.99±32.7	3	2.59±0.17	1215.67±39.5	3
$L+C_7$	3	6.61±0.2	1928.2±27.59	3	6.34±0.3	1887.99±50.69	3
	6	6.76±0.24	1964.06±35.07	3	6.59±0.41	1929.45±60.26	3
$L+C_7+F_{1.4}$	3	5.34±0.17	1771.89±19.83	3	5.04±0.6	1730.4±79.45	3
	6	5.73±0.37	1799.99±55.19	3	5.45±0.46	1763.9±75.08	3