World Journal of Engineering and Technology, 2022, 10, 824-842
https://www.scirp.org/journal/wjet
ISSN Online: 2331-4249
ISSN Print: 2331-4222

Elaboration and Characterization of a Plaster Reinforced with Fibers from the Stem of *Cola lepidota* for Industrial Applications

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How to cite this paper: Armand, Z.T.S., Anicet, N.P.M., Merlin, A.Z., Fabien, B.E., Judide, N.Y., Fabien, K. and Ateba, A. (2022) Elaboration and Characterization of a Plaster Reinforced with Fibers from the Stem of *Cola lepidota* for Industrial Applications. *World Journal of Engineering and Technology*, **10**, 824-842.
https://doi.org/10.4236/wjet.2022.104054

Received: August 16, 2022
Accepted: November 1, 2022
Published: November 4, 2022

Abstract

Current environmental and eco-design issues require the use of environmentally friendly materials. These make up a large share of the building materials market. Natural fibers are already used in various types of materials, such as plastics, concrete and lime-based products. They exhibit different attributes like the right combination of mechanical, thermal and acoustic properties, allowing these types of materials to be used for different applications. The main disadvantage associated with plaster is its fragility, especially under mechanical stress. Therefore, it becomes interesting to study different methods that could improve the mechanical properties of plaster. The addition of fibers to the plaster to obtain a composite material is already recognized as a means of improving the behavior of the product, in particular after the rupture of the matrix. The aim of this work was to study the effects of the addition of natural fibers from the stem of *Cola lepidota* (CL), on the physical properties and the mechanical behavior of the composite matrix. This study highlights the effects of fiber size and volume fraction. It has been shown that the mass of composites decreases as the percentage and length of fibers increases. The mechanical properties of composite materials are also discussed. Even at low addition rates, *CL* stem fibers achieved slightly higher values of flexural properties.

Keywords

Cola lepidota, Vegetable Fiber, Plaster, Composite, Retting, Characterization

1. Introduction

Plaster is a white powder produced by calcining gypsum. This material is extremely old, it was discovered by mankind in antiquity. Gypsum is a very abundant rock with crystalline forms. Gypsum has the formula $CaSO_4$, $2H_2O$, and it is called dehydrated calcium sulphate. Due to its availability in the subsoil, its relatively low cost, its high ease of use and its mechanical characteristics suitable for many purposes, plaster is a widely used building material, and its continued use of grow, as does the use of prefabricated gypsum products such as tiles and plates [1] [2]. However, the plaster seems to be permeable and too brittle [3] [4]. It is not suitable for exterior finishing [5] [6], as it is sensitive to humidity [7]. Dimensional variations are also observed depending on climatic conditions [8]. Improving the crack resistance of plaster is an essential problem to which the science of composite materials has naturally responded [9]. The main idea is to introduce a material in the form of fibers into a binder, called a matrix. From an elastic fiber and a fragile matrix, it becomes possible to obtain extremely resistant materials. Fiberglass first appeared in plaster [4]. A number of studies have shown that plaster reinforced with synthetic fibers has better mechanical properties [10] [11], compared to vegetal fibers. However, these reinforcements are expensive, and this considerably weighs down the plates, making them less practical to use on larger sites [10]. In addition, they have a harmful effect on the environment [11]. In view of the disadvantages presented by these types of fibers, scientists have looked for solution to overcome these problems. Vegetable fibers are a potential source of low-cost material from renewable resources, respectful of the environment and less greedy in fossil energy. According to Dalmay *et al.* [12], the mechanical properties of plaster are improved by the use of natural fibres. Several other reinforcements of plant origin can be used to reinforce the plaster [3] [13]-[18].

One of the current trends in the construction industry is to develop "green materials": the use of natural fibers as reinforcement for lime plasters which plays a major role in this transition to renewable materials [19]. In general, the use of natural fibers is attractive for four main reasons: their specific properties, their price, their health benefits and their recyclability [20]. The low density and good specific properties of these fibers is an important asset. In addition, the fibers are renewable and have a CO_2-neutral life cycle, unlike synthetic fibers.

One of the main disadvantages of using natural fibers as reinforcement in construction materials is the weak interaction between the fiber and the matrix. As a result, a large number of studies have focused on chemical (such as silane, alkalization or mercerization, and acetylation) or physical treatments of fibers to increase their surface roughness and improve durability interfacial adhesion while reducing their hydrophilicity [21] [22] [23] [24] [25]. Recently, the use of chemical treatments has become less attractive, as they have proven to be harmful to the environment by involving the use of hazardous reagents. There are modern alternatives to physical and chemical methods of treating plant fibers;

these are biological treatments based on fungi and enzymes. By this approach, the homogeneity, fineness and efficiency of the fibers can be selectively improved by eliminating the hydrophilic phases of pectin and hemicellulose which bind the fiber bundle, with a lower environmental impact than traditional methods [26] [27] [28] [29]. In this study, retting was used. It removes waxy epidermal tissue, adhesive pectin and hemicellulose that bind fiber bundles together.

Previous studies have characterized the stem fiber of *CL* [13] [30]. Those used come from the bark of the stem of the kola tree, genus *CL* present in the humid forest of *ebemewoman* 2, which is a town located in southern Cameroon. The identification of this plant is done thanks to its fruit having a white, edible and sweet aril (**Figure 1**). This aril is called in local language "*imvoe*" or "monkey cola". It belongs to the *Sterculiaceae* family. It is an undergrowth shrub reaching 15 m in height and 25 cm in diameter; bole bumpy, sparsely branched crown; its particularity is its bark: gray-green to brown, its right section shows a whitish slice with brown-yellow lines and exuding a yellowish secretion [13]. This coloration is observed on the raw fibers extracted from the latter. According to Vivian *et al.* [31], it is possible to cultivate the plant and harvest its fruits in the first year.

In the present study, the main objective is to improve the physical and mechanical properties of gypsum by adding *CL* fibers, with a view to industrial applications. This study is divided as follows: the first section is this introduction. It is followed by the part devoted to materials and methods. The third part presents the results and analyses. This article ends with a conclusion.

2. Materials

The raw materials used in this study are plaster and fibers from the stem of *Cola lepidota*. During the study, they were stabilized in a controlled atmosphere (RH = 82% ± 2%) and in temperature (T = 30˚C ± 2˚C).

The plant fiber used to prepare gypsum-based composites was extracted by retting [13]. The average fiber diameter is 158 μm. The organic and mineral contents of the *CL* fibers are 97.68% and 2.32% respectively. This ash content shows that the new fiber could have a good fire resistance capacity [32]. Studies

(a) (b) (c) (d)

Figure 1. *CL*: (a)-plant, (b)-fruit (c)-bark (d)-fibers [13].

have shown that this fiber is thermally stable up to about 230˚C [13]. This value is consistent with those given in the literature for a plant fiber. Therefore, it can be used with a plaster matrix even being subjected to this temperature.

The plaster used in this study is intended for decoration (manufacture of false ceilings and distribution partitions) and is purchased in a FOKOU shop in Ndokoti in Douala. Its flexural strength is 2.3 MPa, its Young's modulus is 79 MPa and its compressive strength is 0.5 MPa. According to Dalmay *et al.* [12] the mechanical resistance in bending of the plaster is 3.2 MPa, this value remains in the same order as ours.

3. Plaster Reinforced *CL* Fiber Elaboration

The specimens are manufactured in accordance with the specifications of Standard EN 13279-2, Plaster binders and plaster renders—Part 2: Test methods. Table 1 shows the environmental parameters for the elaboration of the specimens. Table 2 shows the specimens for the test. These combinations of mixtures make it possible to highlight the effect of the rate and length of the *CL* fibers in the plaster matrix. Figure 2 shows the different compositions of the samples.

The densities of the constituents are provided in the results of this study.

The samples from this study are coded as presented in Table 2 below:

Table 1. Experimental parameters.

Gypsum/water	1
Mixing time (s)	60
Demoulding time (h)	24
Humidity (%)	82
Temperature (˚C)	30

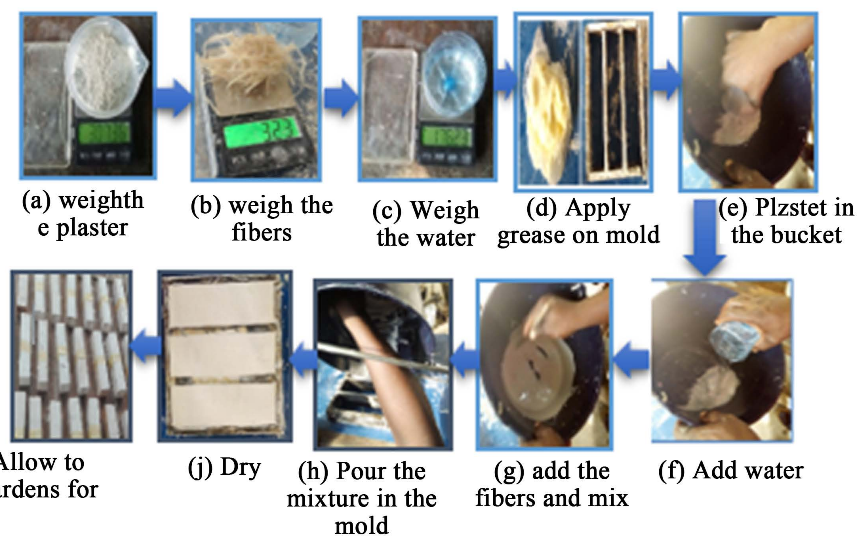

Figure 2. Realization of the composite plaster/*CL*.

Table 2. Designation of specimens.

Sample Codes	Designation
A0	Unreinforced plaster (A0)
A1.5 A2.5 A3.5	Plaster reinforced with a fiber length of 21mm (A) at 1.5%, 2.5% and 3.5% respectively
B1.5 B2.5 B3.5	Reinforced plaster with a fiber length of 51mm (B) at 1.5%, 2.5% and 3.5% respectively
C1.5 C2.5 C3.5	Reinforced plaster with a fiber length of 160mm (C) at 1.5%, 2.5% and 3.5% respectively
D1.5 D2.5 D3.5	Ground fibers (D) of 1.5%, 2.5% and 3.5% respectively

4. Characterization of Composites

4.1. Physical Characterization

4.1.1. Real Density of the Composite

Five specimens are used per length and percentages. The masses (m) of the different test specimens were taken. The volume of each specimen was determined from the dimensions taken and calculated according to formula 1:

$$V = l \cdot w \cdot h \tag{1}$$

where V is the volume (mm^3), l the length (mm), w the width (mm) and h the thickness (mm) of the sample.

The real density (Formula 2) of each composite is determined by taking the average mass of the samples divided by their average volumes.

$$\rho = \frac{m}{V} \tag{2}$$

where ρ (Kg/m^3) is the density, (Kg) the mass and (m^3) the volume of the sample.

4.1.2. Water Absorption of the Composite

The determination of the percentage of water absorption is carried out using five specimens for each type of sample. The protocol complies with British standard EN 317. The samples are dried in the microwave at 30˚C for 12 hours, in order to eliminate any moisture they contain. A sample is taken and its initial mass M_i is noted. It is then placed in distilled water for 24 hours. Finally, we take the samples out of the water, clean it and measure the mass M_f. The following materials were used: distilled water, precision balance (0.01 g), a container, the dried samples, a soft and clean cloth, a stopwatch. The water absorption for each specimen was obtained by the following formula (3):

$$W_A(\%) = \frac{M_f - M_i}{M_i} \times 100 \tag{3}$$

where $W_A(\%)$ is the water absorption percentage, M_f the mass of the wet sample and M_i the mass of the dry sample.

4.2. Mechanical Characterization

4.2.1. Three-Point Bending Test

The objective of the bending test is to determine the bending modulus of elasticity MOE and the breaking stress in bending MOR. The test conditions follow the recommendations of standard EN 1015-11: 2000: Test methods for masonry mortars—part 11: determination of the flexural and compressive strength of hardened mortar. The materials used for the 3-point bending test are: the bending/compression testing machine, the specimens (three specimens for each proportion and fiber length) and a camera. This machine is equipped with a 1/1000th displacement and force sensor. It is located in the services of the Civil Engineering Department of ENSET Douala. The dimensions of the mold for composites are 160 mm × 40 mm × 40 mm. Figure 3 below shows this machine, called M & O universal machine H001B: 1000 kN, Made in Italy.

The three-point bend test was performed on all composites. The MOE and MOR are determined by formulas (4) and (5) below:

$$\text{MOE} = E = \frac{\alpha L^3}{48 I_{Gz}} \tag{4}$$

$$\text{MOR} = \frac{3 F_{\max} L}{2bh^3} \tag{5}$$

where $F_{\max}$ is the maximum load (N); L, the distance between the two supports (mm); E, Young's modulus on bending (MPa); I_{Gz} the quadratic moment of axis z (mm^4); α, is the slope of the line in the domain (N/m); b is the sample width (mm); h, the thickness of the sample (mm).

4.2.2. Compression Test

The purpose of the compression test is to determine the compressive strength of specimens. The EN 1015-11: 2000 standard was used. The 3-point bending test

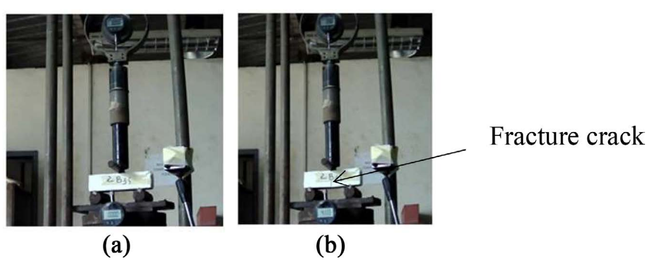

Figure 3. Bending test machine and sequence of the 3-point bending test (a) specimen on device; (b) Cracked specimen (from below) on the device.

machine of the Civil Engineering laboratory of ENSET Douala was used for this purpose. This machine can measure small loads with precision. The test specimens used are of dimensions 40 × 40 × 80 mm. Compressive strength R_C (MPa) is given by formula (6):

$$R_C = \frac{F_C}{A} \tag{6}$$

F_C being the ultimate load in compression and A the cross section of the specimen. $A = 1600\ \text{mm}^2$.

5. Results and Interpretations

5.1. Real Density of the Composite

Figure 4 shows the real density variation of Plaster/*CL* composites.

These results reveal that the unreinforced composite is more compact and denser than all the reinforced composites. The density of composites decreases as the percentage and length of fibers increases. Type D specimens have a density close to that of unreinforced plaster (A0). A classification of the values obtained shows us that the type C specimens (length 150 mm) are the least dense. It can therefore be deduced that samples with short fiber lengths are denser. This density is all the more important as the fiber content is low. The true and apparent fiber densities of *CL* are approximately 1.7266 ± 0.0146 g/cm^3 and 1.205 ± 0.2941 g/cm^3, respectively. Its real density has a value close to that of cotton (1.6 g/cm^3) [33]. Taking into account the standard deviation, the density of *CL* fiber is slightly lower than that of plaster (1.15 g/cm^3). By mixing the two constituents, the volume of the samples is increased while reducing their masses, which could justify the behavior identified. Moreover, when the fiber is long, for the same volume ratio, the constraints related to the arrangement of the fiber bundles within the composite, generate areas of high porosities, thus contributing to

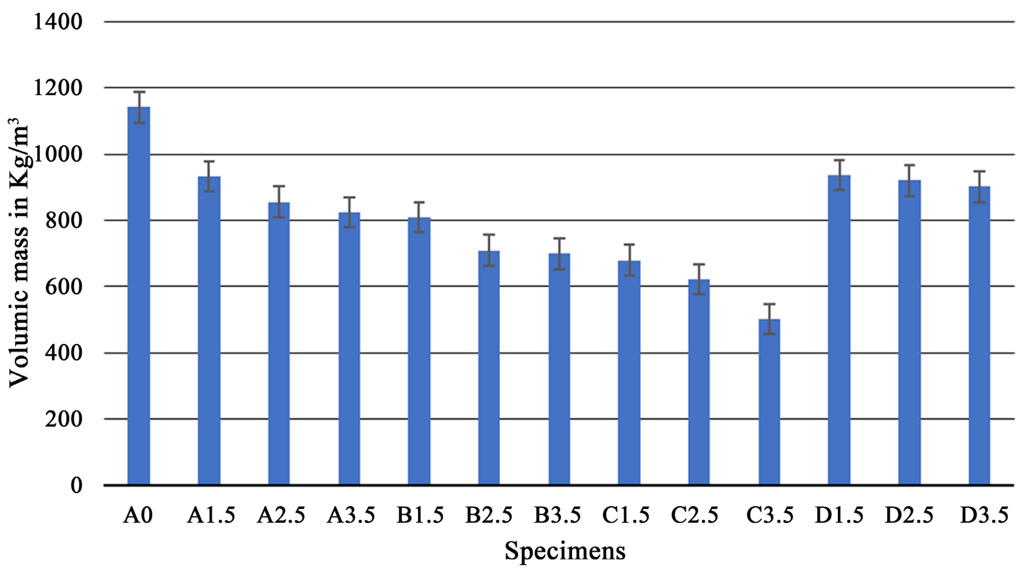

Figure 4. Distribution of the density of the plaster/*CL* composite.

reduce the density of these samples. Conversely, for an identical reinforcement rate, shorter fibers tend to optimize the occupation of spaces within the specimen. There will therefore be an increase in the compactness and therefore the density of the samples. This behavior is similar to that of the plaster/date palm fiber composite [34]. For a plaster/olive fiber composite, this density decreases sharply when the percentage of olive fibers increases from 4% to 12% [35] [36].

The pore size and the dimensional variation capacity of the *CL* fiber can also partly justify the decrease in the density of the composites. Indeed, a statistical analysis of *CL* fiber diameters shows an asymmetric and flattened distribution with a degree of asymmetry (Sk) of 0.58 and a degree of flattening (Ku) of 0.34. The mean fiber diameter measured is 83.81 µm with a coefficient of variation (CV) of 18.61%. Compared to a study conducted on different varieties of flax fibres, this diameter is in the upper range of the values obtained [37]. The intrinsic porosity of *CL* fibers is 13% [13]. This intrinsic porosity is of the order of that of hemp fibers and has a great influence on stress concentrations and entrainment failure within a fiber [30] [38].

5.2. Composite Water Absorption Rate

Figure 5 shows the general variations in the water absorption rate of the plaster/*CL* composite, at different volume fractions and fiber lengths.

Figure 5 shows that the water absorption rate of the unreinforced composite is 59.78%. The water absorption rate of gypsum/*CL* composites increases as the percentage as well as the length of the fibers increase. The maximum and minimum water absorptions belong to specimens C3.5 and A1.5 with values of 130.48% and 17% respectively. The chemical composition of *CL* fibers is presented [13] and compared to those of other lignocellulosic fibers used as reinforcement of eco-composite structures. It is mainly composed of cellulose, hemicellulose and lignin which occupy more than 80% of the constituent fractions. The cellulose content of *CL* fiber is closest to that of kenaf, jute, abaca fibers [39] [40] [41] and higher than that of fibers such as alfa, diss, banana or walnut coco [40] [42] [43], which are annual plants. Its lignin content is similar to that of

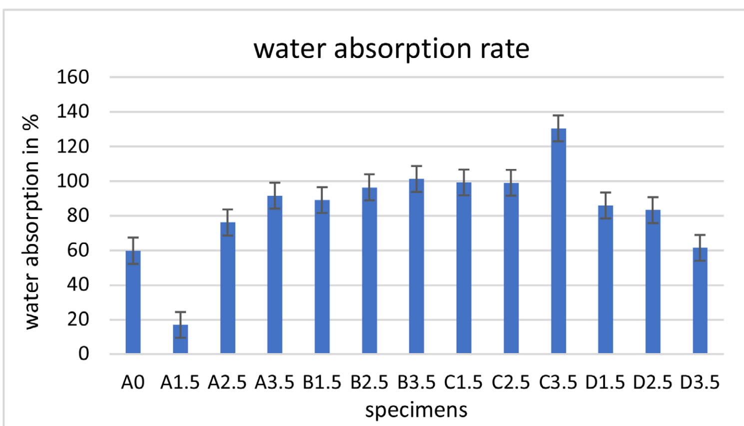

Figure 5. General variation of the water absorption rate of the plaster/*CL* composite.

Rhectophyllum camerunense fiber [44]. Due to its relatively high lignin content, *CL* fiber has a low moisture content (6.47%) [45]. It is therefore predisposed to a good fiber-plaster interaction in the manufacture of composite materials reinforced with *CL* fibers. Products made from this fiber are said to offer a good feeling of comfort as it will absorb less than 7% moisture, very close to that of cotton and linen [46]. It is reported in the literature that a high moisture content compromises the stability of the composite in terms of dimensions, tensile strength, swelling behavior and porosity formation [47]. The O'Connor crystallinity index of *CL* fiber is about 42%. The water absorption capacity of raw *CL* fiber is 172%. This content is closest to that of common natural fibers such as: esparto fiber 158% [46], linen 136% ± 25%, hemp 158% ± 30%, sisal 200%, jute 281% and coconut. 180% [43], which are generally used as reinforcement for composites. This relatively low absorption rate of the *CL* fiber is partly related to its low porosity (**Figure 6** below) [30], which also contributes to good mechanical strength [48]. The water absorption capacity indicates the existence of hydroxyl groups, which attract water molecules from the surrounding medium by hydrogen bonding [49]. These hydroxyl groups are responsible for the presence of hemicellulose molecules in the fiber. This content inspires precautions that should be taken into account before the manufacture of composites with *CL* reinforcements. The low absorption of the plaster/*CL* composites compared to the absorption of the *CL* fiber indicates the impermeability of the matrix, due to its viscosity, thus acting as a barrier to water access to the fibers. Type D samples (crushed fibers) absorb less than other fiber lengths. Indeed, the fact that the fibers are ground, favors obtaining results close to type A fibers (less long). These observations are similar to those in the literature for the plaster/palm fiber composite [50] and the plaster/pineapple fiber [51].

Many studies show that reinforcing plaster with natural fibers increases its mechanical properties and its ability to absorb moisture [44] [52] [53] [54].

5.3. 3-Point Bending Characteristics

Figure 7 is the graph showing the variations of the Young's modulus of the

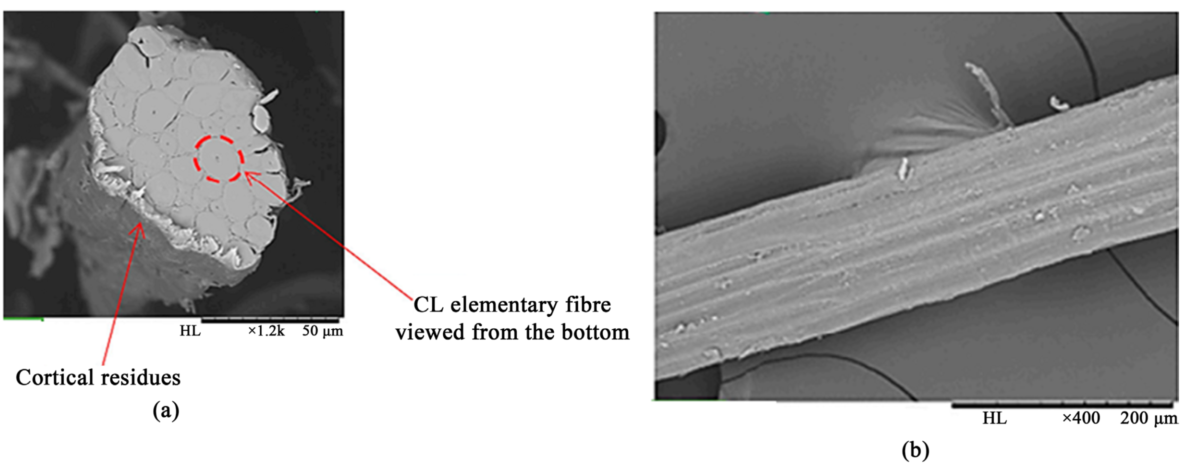

Figure 6. Cross-sectional view (a) and longitudinal view (b) SEM of *CL* fiber bundle [30].

plaster/*CL* composite as a function of the volume ratio and the length of the fibers.

According to the MOE bar chart (**Figure 7**), all specimens reinforced with *CL* fibers provide the better results compared to unreinforced plaster whose modulus of elasticity is 78.11 MPa. The highest value is observed for sample C2.5 with a value of 177.67 MPa. The optimal length of plant fibers is obtained for type C samples (160 mm). The literature confirms these experimental results obtained. Indeed, for a reinforcement of the plaster by a synthetic or vegetable fiber, an increase in the initial properties of the unreinforced plaster is always observed. Thus, in the case of plaster/fiberglass, the modulus of elasticity of reinforced plaster is 880 MPa, *i.e.*, 2 to 3 times higher than that of unreinforced plaster [55]. For the plaster/sisal composite, it is 690 MPa that of the plaster/RC is 500 MPa, plaster/*Ananas cosmosus* (AC) 444.66 MPa and for the plaster/*CL*, 177.67 MPa is determined. The fibers increase the modulus of elasticity of the plaster and make it more ductile and therefore less brittle. But it should be noted that the determination of the percentage of fibers to be added is an overriding factor, since at very low or very high percentages it has no influence [56].

Figure 8 shows the results of mechanical resistance in bending of the Plaster/*CL* composite.

The results in **Figure 8** show that the Plaster/*CL* composite has a flexural strength σ_r = 4.85 MPa for the A1.5 samples against 2.22 MPa for the unreinforced plaster. We can therefore deduce that the presence of fibers in the plaster makes it more resistant, with the exception of samples A2.5, C3.5 and D3.5. The mechanical resistance in bending of the composite of the present study is therefore the best.

In **Table 3** below, the tensile properties of *CL* fibers are compared to those of other plant fibers. In the case of taking into account or not the porosity, the samples are noted *CL*2 or *CL*1 respectively. These elements are integrated in the

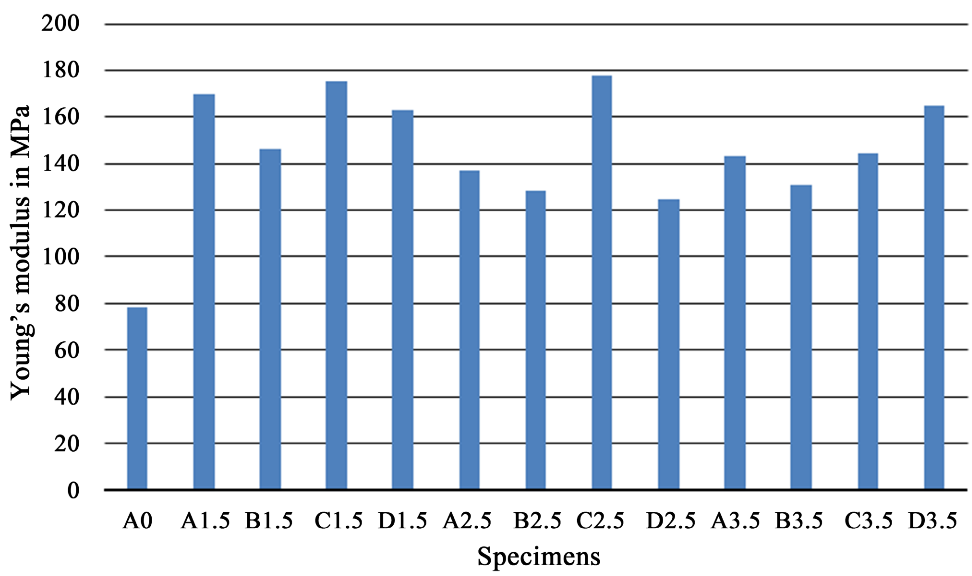

Figure 7. Evolution of the Young's modulus in bending of the plaster/*CL* composite.

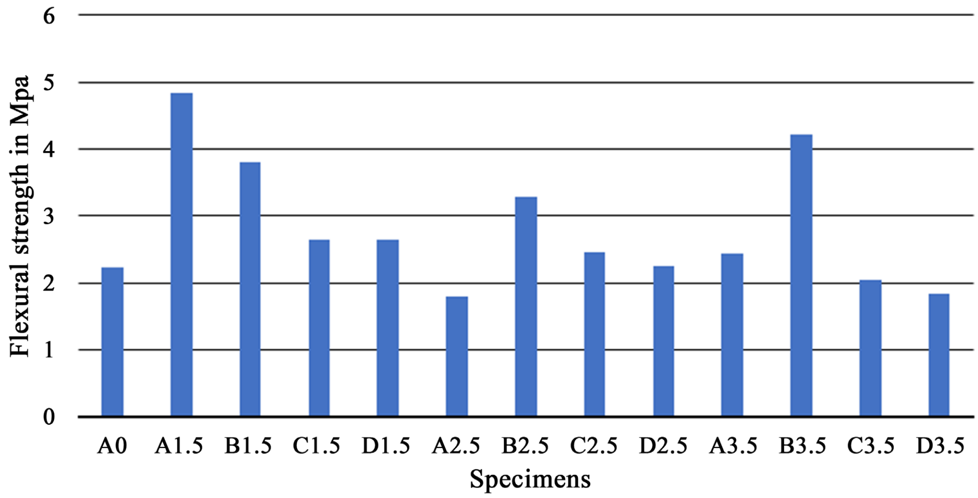

Figure 8. Evolution of the mechanical flexural strength of the plaster/*CL* composite.

Table 3. Comparison of properties of *CL* fibers to others plant fibers.

Fibers	d (μm)	E (GPa)	σ_r (MPa)	ε_r (%)	Specific properties		References
					σ_r/ρ (MPa/g·cm^{-3})	E/ρ (GPa/g·cm^{-3})	
RC	0.947	2.3 - 17	150 - 1738	10.9 - 53	588.3	6.1	[44]
Kenaf	-	41	745 - 930	1.6	620.8 - 775	34	[57]
Banana	10 - 30	12	12 - 30	1.5 - 9	8.8 - 22	8.8	
Bamboo	25 - 40	11 - 32	140 - 800	2.5 - 3.7	127 - 727	10 - 29	[58]
Flax	12 - 600	27.6 - 80	500 - 1500	1.2 - 3.3	333 - 1000	18.4 - 53.3	
Palf	-	71	1020 - 1600	0.8	680 - 1066	47.3	[59]
Sisal	157 - 319.2	4.7 - 20.5	296.6 - 410.4	2.4 - 4	208.8 - 289	33.3 - 14.4	
Hemp	13.7 - 25.8	31 - 65	182 - 1282	1.9 - 3.5	392.6 - 822.2	33.3	[60]
CL1	66.2 - 117.4	18.2 - 60	457.6 - 1440	2.4 - 2.6	280 - 883	11.6 - 36.8	[30]
CL2	66.2 - 117.4	22.2 - 66.89	526 - 1655	2.4 - 2.6	322.7 - 1015	13.6 - 41	

calculation of the section and influence considerably the mechanical characteristics in traction.

When a decrease in flexural strength is observed for large quantities of reinforcing fibers, it means that porosity is created in the material due to an intra and extra-fiber void [61] [62], which reduces the compactness and cohesion of the composite.

Other studies have been conducted on different fibers, such as coconut fibers, Djoudi *et al.* [63] show that the best result is obtained with a volume fraction of 4% while Mathur [64] in a study on the reinforcement of plaster concrete with date palm fibers found that a fraction of 1.5% gives the best results in terms of tensile and flexural strength. Fiber length and optimum fraction in composites are two parameters that differ from fiber to fiber. This difference results from their morphology and chemical composition which are essentially linked to the origin of the organic fiber and the plant itself. In general, the properties of a composite material result from the combination of several factors [4]:

1) fiber length;

2) fiber architecture;

3) fiber orientation;

4) fiber-matrix interface.

5.4. Compression Characteristics

Figure 9 shows the compressive strength of the plaster/CL composite.

From **Figure 9**, unreinforced plaster has a compressive strength of 0.49 MPa. The compressive strength of plaster reinforced with *CL* fibers is superior to unreinforced plaster, but not for all samples. Specimens A2.5, C2.5 have values of 0.96 MPa and 0.78 MPa respectively.

By analogy, mechanical tests carried out on plaster samples reinforced with *Retama monosperma* fibers revealed that fibers with a length of 15 cm and a fraction of 1% gave the best performance in terms of resistance to bending, with an average of 1.12 MPa, as well as the compressive strength which was 11.68 MPa. From these results, it is clearly seen that the flexural strength increases considerably with the dosage and the length of the fibres. A clear improvement for different lengths was observed for a dosage of 1% of fibers of 15 cm in length, after which a loss of the resistance to bending was recorded, due to an excess of fibers and a bad distribution of fibers in the matrix, which increased the porosity of the material and reduced the resistance to bending. Plaster reinforced with a small amount (0.5%) of *Retama monosperma* fibers showed an improvement in the mechanical properties of the composite, this is in agreement with the results of [64] where it is reported that, even in small amounts, the behavior of the plaster changes [4]. The role of the fibers is to limit cracking of the plaster due to the phenomenon of plastic shrinkage.

Table 4 below shows the mechanical characteristics of unreinforced gypsum and gypsum matrix composites reinforced with plant fibers. It appears that the Young's modulus in bending is not sufficiently documented for composites with

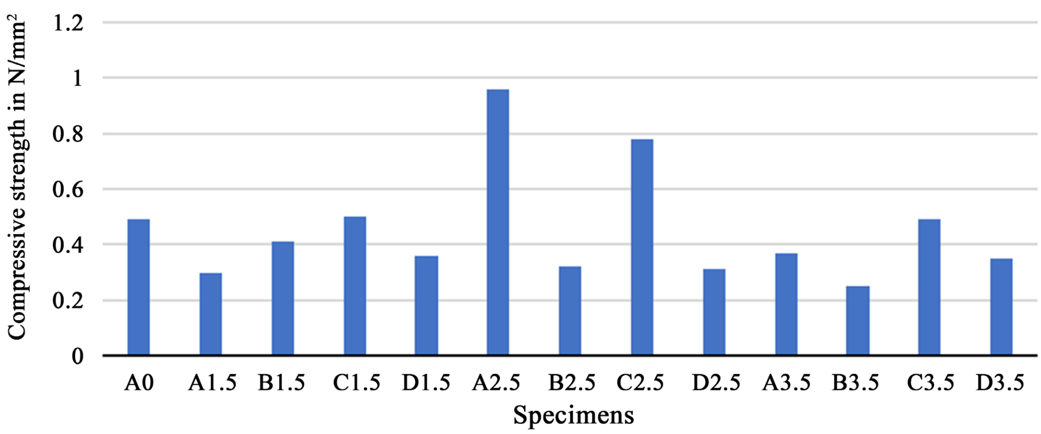

Figure 9. Evolution of the compressive strength of the plaster/CL composite.

Table 4. Mechanical characteristics of unreinforced plaster and plaster matrix composites reinforced with plant fibers.

Plaster reinforcing fiber	MOR (MPa)	MOE (MPa)	Compressive strength (MPa)	Reference
Unreinforced plaster	2.3	78.11	0.49	This study
CL	1.8 - 4.8	120 - 177.67	0.25 - 0.98	
Hemp	2.8 - 3.9	-	-	[12]
Flax	3.6	-	-	
Retama monosperma	1.12	-	5.88 - 11.68	[4]
Sisal	0.38	-	0.39	[66]
Kenaf	0.3	-	0.33	
Abaca	2.46 - 2.95	-	-	[67] [68]
WF	0.73 - 1.39	93 - 538	0.79 - 2.61	[65]
POF	0.5 - 0.88	70 - 355	0.52 - 2.07	

a plaster matrix, reinforced with plant fibers. On the other hand, the mechanical resistance of the composite of the present study is always above the values of the fibers usually used. For compressive strength, CL offers superior mechanical strength to most composites in the literature.

6. Conclusions

In this work, the effect of reinforcement rate and fiber length of *CL* stem on the physical and mechanical properties of gypsum matrix composites was studied. The mechanical adhesion between the *CL* fibers and the plaster is ensured thanks to the rough surface topology of the *CL* fibers. It appears that, except for configuration D, the rate of water absorption increases with the percentage and length of the fibers. The water absorption rate of loaded and unloaded samples ranges from 17% to 130.48% respectively. Sample A1.5 absorbs less than unreinforced plaster. The bulk density for each specimen was determined and the average taken. The density of the reinforced composite varies between 623 Kg/m^3 and 937.273 Kg/m^3, against 1160Kg/m^3 for the unreinforced plaster. Plant fibers therefore tend to reduce the density of the plaster. For the mechanical characterization, did the three-point bending and compression test. The modulus of elasticity in bending increases when the percentage and length of the fibers are high. Variant values are obtained between 124.8 MPa and 177.67 MPa against 78.11 MPa for the plaster alone respectively. The previous trends hold true for flexural fracture toughness. Thus, for unreinforced plaster, it is 4.84 MPa and varies between 1.8 MPa and 4.8 MPa for reinforced plaster. The compressive strength of reinforced plaster is superior to unreinforced plaster, but not for all samples. Specimens A2.5, C2.5 have respectively values of 0.96 MPa and 0.78 MPa respectively against 0.49 MPa for plaster alone.

Overall, it was concluded that reinforcement of gypsum with CL fibers is effective in increasing the physical (lightness and water/moisture absorption) and mechanical (ORM and compressive strength of A2.5 and C2.5 configurations) properties of gypsum. Future work in this area should aim to optimize CL fiber reinforcement, investigate the durability of the reinforcement system, and apply other natural fiber architectures for reinforcement.

Acknowledgments

The team of authors would like to thank the Laboratory of Mechanics (LM), as well as the Innovative Materials Research Group (IMRG) for their collaboration in the realization of this work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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