American Journal of Materials Science and Engineering, 2016, Vol. 4, No. 1, 13-19
Available online at http://pubs.sciepub.com/ajmse/4/1/3
©Science and Education Publishing
DOI:10.12691/ajmse-4-1-3

Use of Vegetable Fibers as Reinforcement in the Structure of Compressed Ground Bricks: Influence of Sawdust on the Rheological Properties of Compressed Clay Brick

S. Ouattara[1,*], M. O. Boffoue[1], A. A. Assande[1], K. C. Kouadio[1], C. H. Kouakou[1], E. Emeruwa[1], Pasres[2]

[1]Laboratory of Geomaterials and building Technology (LGTB), DEPARTMENT of Earth sciences and Mining Resources, Felix Houphouet Boigny University, Abidjan, 22 po box 582 Abidjan 22, Ivory Coast
[2]Strategic Support Program to Scientific research (financing agency of the study)
*Corresponding author: ouatsoul@gmail.com

Abstract The present study aims at understanding the rheological behavior of Compressed Ground Bricks (CGB). It thus uses as raw materials the clay and the sawdust which are an industrial waste with the multiple consequences on the environment. The composites elaborate clay-sawdust of wood are bricks intended to be used like fill material of the walls. Their mechanical properties were studied in order to place at the disposal of the users, of competitive materials; but a particular stress was laid on their behavior at the rupture. Thus, the study shows that the CGB containing clay only have flexural strength and compressive strength respectively of 1.3 MPa and 2.6 MPA. When one adds the sawdust to it, these resistances grow to reach optimal values, before decreasing. For the flexural strength, optimal resistance is of 1.4 MPa, for a content of sawdust of 20%. For the compressive strength, the optimum is reached to sawdust 15% with a resistance of 4.4 MPa. The study of the relations stress-strain shows that the curve of the CGB without sawdust has only one pace rectilinear before the rupture (elastic range); these bricks thus have a fragile behavior. The addition of the sawdust to clay confers on the CGB a quasi ductile behavior characterized by curves which present initially a rectilinear part (elastic range), followed by a curvilinear part (plastic range). One can also note that the addition of the sawdust cause a drop in the dry density of bricks.

Keywords: *compressed ground bricks, clay, sawdust, compressive strength, flexural strength, stress-strain*

Cite This Article: S. Ouattara, M. O. Boffoue, A. A. Assande, K. C. Kouadio, C. H. Kouakou, E. Emeruwa, and Pasres, “Use of Vegetable Fibers as Reinforcement in the Structure of Compressed Ground Bricks: Influence of Sawdust on the Rheological Properties of Compressed Clay Brick.” *American Journal of Materials Science and Engineering,* vol. 4, no. 1 (2016): 13-19. doi: 10.12691/ajmse-4-1-3.

1. Introduction

The Ground Bricks (GB) are materials containing ground and/or of industrial binders. The technique of their working by compression was adopted in order to give to bricks mechanical characteristics improved compared to the other techniques of working which preceded it (moulding, casting, adobe etc). The Compressed Ground Brick (CGB) thus was introduced and remains today one of materials the most used in the field of building materials made wcontaining ground. However, the CGB, in their great majority, are heavy and the methods of formulation of the mixtures of the raw materials are not always well controlled by the producers whose great majority is artisanal in Africa. Consequently, the CGB did not have great success in the sub-Saharan countries, contrary to the European countries.

This article treats rheological behavior of GB. It should be noted that rheology is the study of the mechanical behavior of the bodies. One studies in experiments the reaction of one body to the action of a stress field by applying a force of ascending value to him and by measuring the produced total deflection. The deformation of the body is measured by its elongation e or its contracting r:

If L0 is the initial length and L1 the final length:

$$e = (\mathbf{L_1} - \mathbf{L_0}) / \mathbf{L_0}. \quad (1)$$

According to the got results, one distinguishes three fundamental rheological models (Figure 1).

- Elastic bodies

The deformation is reversible and proportional to the intensity of the constraint. Time does not intervene in the deformation. the curve is an oblique straight lines (Figure 1A).

- Plastic bodies

The deformation occurs only starting from one certain threshold of constraint. When this threshold is reached, the deformation occurs without it being possible to increase the value of the constraint. The deformation preserves the value reached when the constraint ceases. The curve is horizontal (Figure 1B).

- Viscous bodies

The value of the deformation depends on the period of validity of the constraint. For a no worthless given constraint, the deformation is done at constant speed. After suppression of the constraint, the system preserves its final state (Figure 1C).

- Viscous bodies

The real bodies are never perfectly elastic, plastic or viscous. Moreover, their behavior can change during the deformation. In the general case, they combine the properties of the three fundamental types. It is the case of the rocks which are elastic for a low constraint and become plastic when the constraint becomes stronger. The passage of the elastic behavior to the plastic behavior is accompanied by a hardening: the body undergoes irreversible modifications in its structure. The deformation of material can remain ductile but increase in the course of time, although the value of the constraint remains constant\; it is creep (Figure 1D). In other cases, it appears a rupture, the material becomes fragile (Figure 1E).

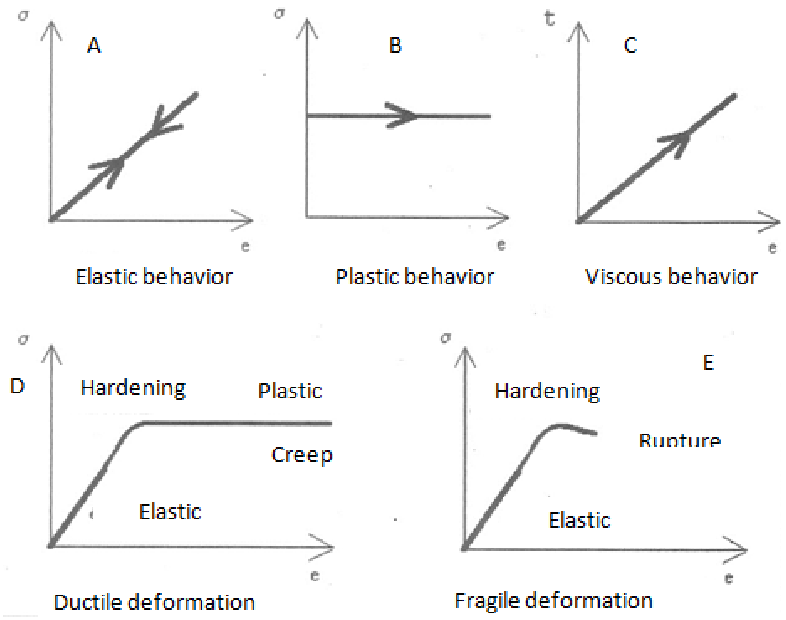

Figure 1. Different rheologic behaviour of the bodies

2. Material and methods

2.1. Raw Material Used

The raw materials used in this study are the clay and the sawdust. This clay is plastic and primarily made up of kaolinite and illite like argillaceous minerals, with which is associated quartz Kouakou (2005) [1].

The sawdust is not the object of particular preparation. It is used such as it is produced in the sawmills (Figure 2). The sawdust is that of the wood of framire (generic name) still called Terminalia ivorensis (scientific name).

Before its use, it is removed from all the massive pieces of wood as of all the impurities which it contains. It is used in the form of mixture of powder, granules and short fibers. Piece of wood with the sawdust, framiré has a density in a dry state which varies between 450 and 600 kg/m^3.

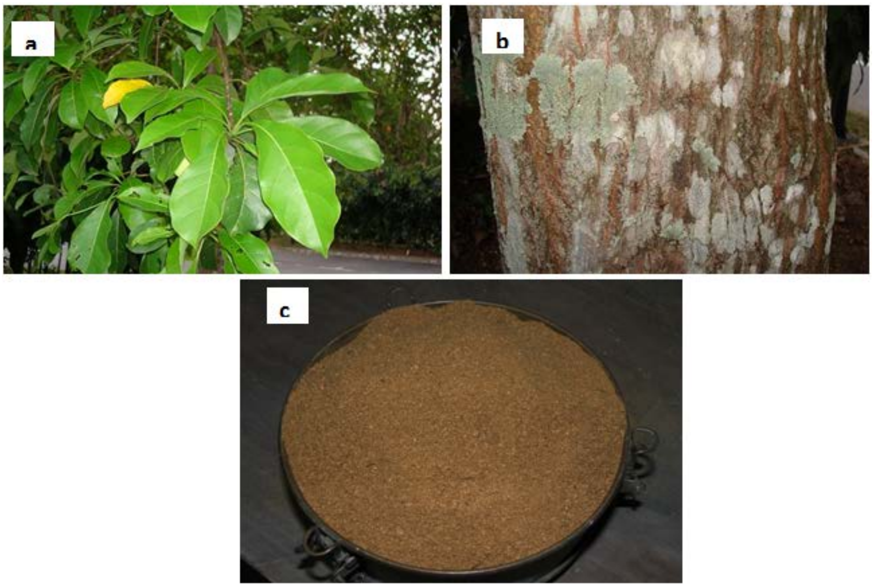

Figure 2. Photographs showing: (a) sheets of framire, (b) a wood trunk of framire and (c) sawdust of framire

It is used without preliminary processing and will be of use as reinforcement to the mineral matrix.

Samples are realized from the mixture of raw materials (clay + sawdust) to which we add some water for the kneading. Raw materials are dry mixing so as to obtain a homogeneous mixture. The plan of samples elaboration is presented below (Figure 3).

After the mixture of raw materials, the spoiling and the kneading according to the rule book, the necessary dough volume to fill well the mold has been determined. This volume is closely linked to the size of the press mold. The chosen volume is the one for which the elaborate bricks present the best Ouattara (2013) [3] compression resistances**.** For this study, a volume of 5530 cm3 is introduced into the mold to be compacted. The compaction was made by means of a mechanical TERSTARAM crank press.

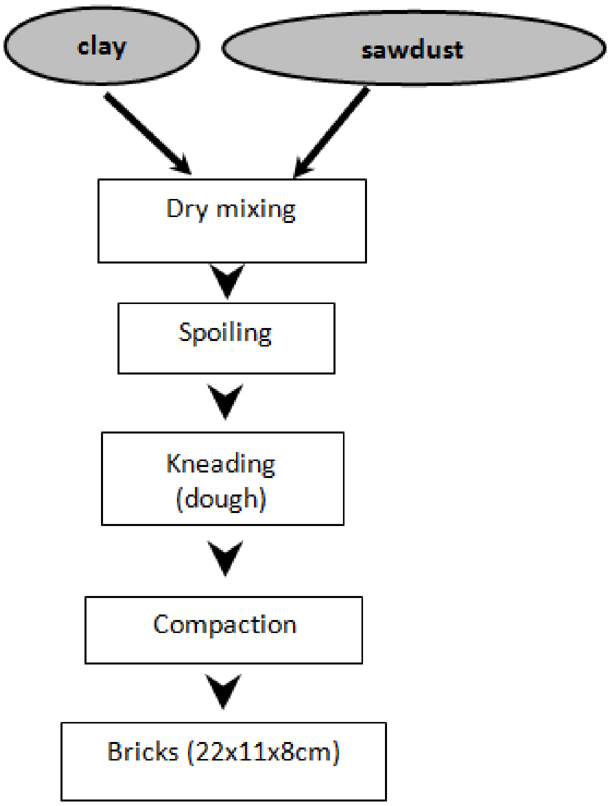

Figure 3. Plan of the procedure of bricks elaboration (Modified according to Kouadio, 2010) [2])

2.3. Characterization Methods of CGB

2.3.1. Test of Dry Density

To determine the apparent dry density of bricks, the samples are placed at the drying oven with 60°C until constant mass. Stoving is done with 60°C to avoid the combustion of the sawdust (organic matter) which is there. Dimensions are then measured using a slide caliper. From these dimensions (length, width and thickness), the volume of the samples is calculated. The dry density is then calculated thanks to the following formula:

$$\gamma_d = \frac{M}{V} \quad (2)$$

With γ_d, the dry density (kg/m^3), M, mass in kg and V, volume in m^3.

2.3.2. Tests of Mechanical Characterization of Bricks

The mechanical properties of wood clay-sawdust bricks depend mainly on the volume of fibers, the matrix and the type of binder.

To consider comparatively these mechanical properties, we study the behavior of bricks using the flexural strength (three points flexural) and of the compressive strength.

The tests of flexural strength and compressive strength were carried out on bricks after the duration of drying.

2.3.2.1. Flexural Strength Test

The three points flexural tests were carried out on parallelepipedic test-tubes of dimensions 22x11x8 mm^3. These tests were carried out using an apparatus of the type EZ 20 Lloyd Instrument of mark AMETEK. The precision of reading is of 0.1 kN and the speed of load is of 2 kN/s.

The test-tube rests on two simple, distant supports of L, and F charges it is applied to the center of the sample, symmetrical compared to the medium of the span (Figure 4). The composites of section b x h, being supposed homogeneous, the flexural strength σ_f applied to the section of prismatic brick will be determined by the formula:

$$\sigma_f = \frac{3}{2}\frac{Fl}{bh^2} \quad (3)$$

Where F is the reading in Newton (N), l is the length (mm) between both supports, b is the width (mm), h is the thickness (mm) and σ_f is the flexural strength (MPa).

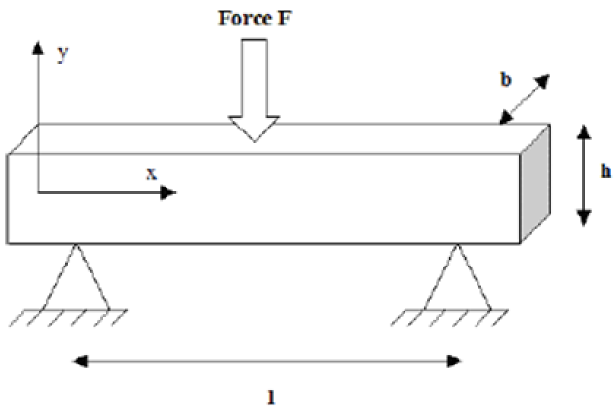

Figure 4. Plan of the assembly of the 3 points flexion

The flexural behavior is the most important characteristic for a fiber concrete because this composite material generally undergoes this kind of loading in its applications. One adds fibers in the matrix of the concrete to improve ductility and to allow a control of the mechanism of cracking.

2.3.2.2. Compressive Strength Test

The compressive strengths were given thanks to a hydraulic press of 500 T type BEVAC T.

One ensures the correct contact of the higher plate of the press on the upper surface of the test-tube, then the load is applied. The maximum loading supported by the test-tube is measured, which makes it possible to calculate the compressive strength by the formula:

$$\sigma = \frac{F}{Ll} \quad (4)$$

Where F is in Newton (N); L and l are respectively the length and the width in mm and σ the resistance in MPa.

The compressive strengths were given on the blocks after 28 days of drying. The value of resistance obtained is an average calculated on 5 bricks.

3. Results

3.1. Dry Density of Bricks

The results of the variation of the dry density of the CGB according to the content of sawdust are presented on Figure 5 hereafter. The dry density decreases with the increase in the content of sawdust. It passes from 2115 to 1220.2 kg/m3, for contents of sawdust going from 0% (brick of reference) to 25%; what corresponds to a lightening of 42.31%, particularly useful in work of lightening of the structure of the building.

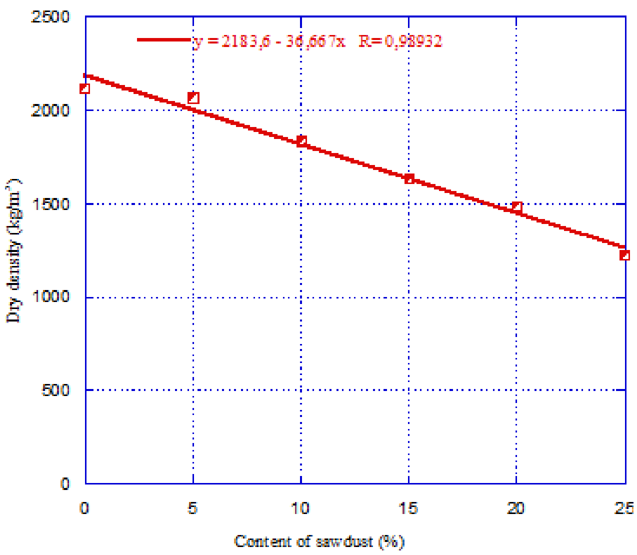

Figure 5. Variation of the density of the composites clay-sawdust of wood

Moreover, the results show that it is possible to establish a relation of proportionality between the density and the content of sawdust. The curve obtained is of decreasing rectilinear pace. It has as an equation: y = -36,7x + 2183.6, with a coefficient of correlation of 0.99. It would be then possible, starting from this formula, to determine the content of sawdust for a given density of bricks.

3.2. Influence of the Sawdust on the Flexural Strength of Bricks

Figure 6 has the results of the flexural strength simple of wood clay-sawdust bricks. This figure presents a light increase in the flexural strength between 0 and 20% of sawdust. Beyond 20%, it falls.

Indeed, the wood particles being coated by clay, during the deflection test, one attends the birth of forces of shearing with the interface of clay (purple) and wood fiber (in yellow) on Figure 7. In the argillaceous mass which wraps wood fiber, forces at the divergent something to lean on (blue arrows) while on the level of fiber itself, these internal efforts converge (black arrows) to enable him to bend before breaking. Wood having naturally a raised flexural strength, the increase in its content in the composite involves an increase in the flexural strength. Beyond 20%, the wood particles are not well any more coated by the clay which becomes insufficient in material from where the fall of the flexural strength. The sawdust thus influences the flexural strength of bricks.

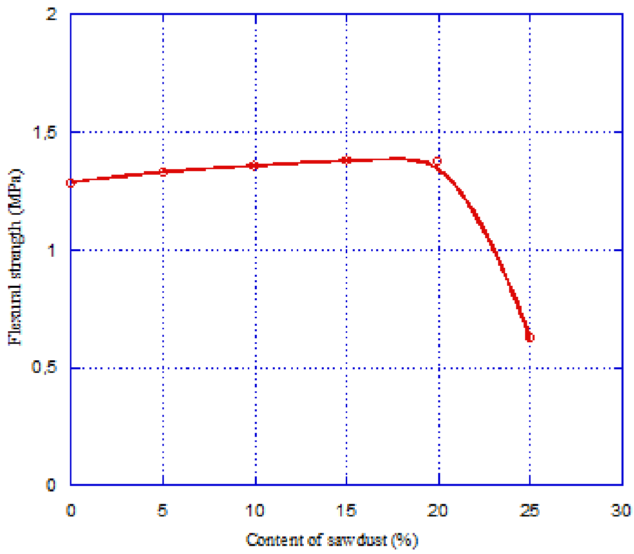

Figure 6. Flexural strength of the composites clay-sawdust of wood

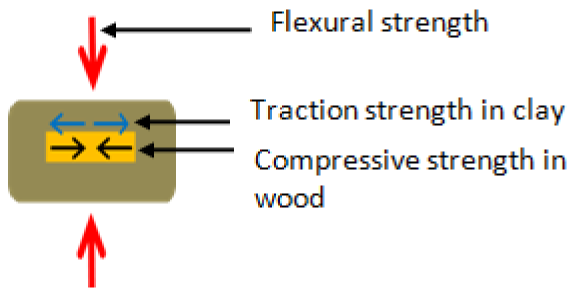

Figure 7. Diagram showing the various forces being exerted in brick during the flexural test

3.3. Influence of the Sawdust on the Compressive Strength of Bricks

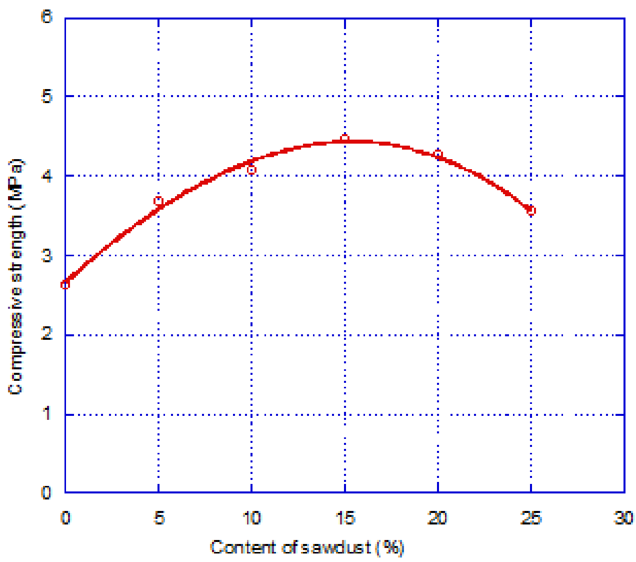

Figure 8. Variation of the compressive strength of wood clay-sawdust bricks

The results of the compressive strength of the composites according to the content of sawdust are presented on Figure 8. One notes a strong increase in the compressive strength until the content of sawdust 15% (4.5 MPa) then beyond this content, the compressive strength decrease. Resistance believes because the sawdust reinforces the structure of compressed clay bricks. Resistance believes because the sawdust reinforces the structure of compressed clay bricks. Indeed, in the composite, clay plays the part of binder and the sawdust, that of reinforcement. It slows down the propagation of the cracks in the argillaceous mass. More the rate of reinforcement will grow and that the quantity of clay will be sufficient to ensure a good coating of the wood particles, more the compressive strength will be large (Figure 9a). In the same way, the presence of the sawdust prevents the accelerated propagation of the cracks in material. It is what justifies the increase in the compressive strength of bricks between 0 and 15% of sawdust.

Beyond sawdust 15%, the quantity of sawdust is excessive, then creating many zones of weakness which weaken material (Figure 9b). This embrittlement is due to the formation of tufts by tangle of the fiber particles and a lack of real connection between the clay and the sawdust. The increase in the content of sawdust then involves the fall of the withdrawal of drying and the fall of the density of the composites, from where the fall of the compressive strength.

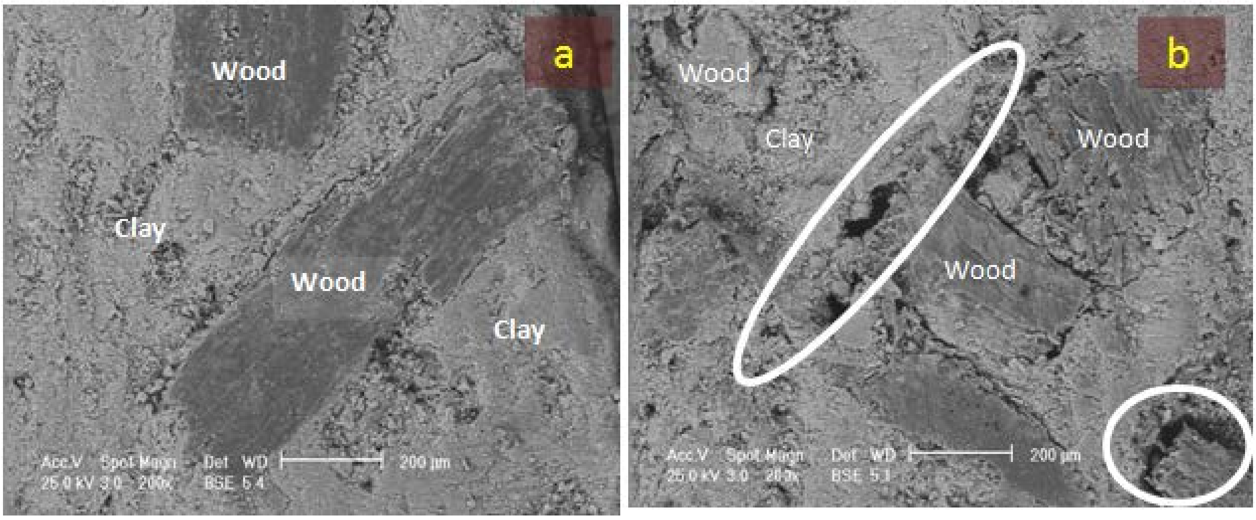

Figure 9. Microphotographies showing the distribution of the sawdust in the clay matrix with: a, dense structure (sawdust content between 5 and 15%); b, porous structure (sawdust content higher than 15%)

3.4. Study of the Relation Stress-Strain of Bricks

Kouakou [1] showed that the blocks of clay stabilized with Portland cement fall under the large family of materials with behavior in general elastoplastic with a quasi fragile rupture. Would the compressed clay brick, reinforced with the sawdust fit in this category of material? It appears necessary to us then to study the influence of the sawdust on the behavior with the rupture of this composite. Thus, the results got following the study of the relation stress-strain are presented on Figure 10 below. This study indicates that the addition of vegetable particles to the argillaceous matrix modifies the behavior of bricks by making them pass from bricks to fragile deformation (practically elastic behavior) to bricks to semi-ductile deformation (plastic behavior marked good). The curves can be subdivided in two distinct parts or fields before the rupture.

At sawdust 0% (brick of reference), the behavior results in a straight line, characterizing the elastic range of material (part 1).

At sawdust 10%, after the elastic range, one notes the appearance of a second phase of deformation where the curve curves. It is characteristic of a plastic behavior: it is thus the plastic range (part 2).

When the content of sawdust increases, this part 2 curves more (15 to 25%), thus materializing the semi-ductile deformation of materials.

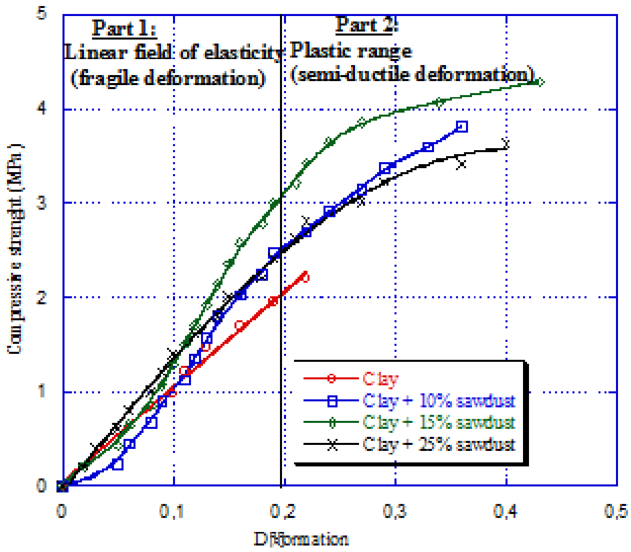

Figure 10. Variation of the stress-strain curves of the composites clay-sawdust of wood

In the elastic range, an examination much more detailed indicates than the extent of the elastic range drops with the increase in the content of sawdust. This fall of the plastic range of bricks (between 0 and 25% of sawdust) shows that the forces are propagated (in the form of cracks) initially in the argillaceous matrix, then they are then deadened by fibers. Part 2, where the ductile deformation appears only for bricks with sawdust, confirms this analysis. However, the progressive change of the pace of stress-strain curve between the two fields most probably translates a damage of the matrix which progresses until a maximum force, marking the rupture. Clay is thus used as binder between the particles of wood and it ensures the cohesion of bricks. This is in conformity with work of Kouadio [2] on the clay-sand mixtures. He showed that between 15 and 20% of sand, clay makes it possible to have the best mechanical resistances. On the other hand, the role of the sawdust mainly consists in limiting the progression of macrofissure (Rossi and Al, 1987) [4]. The incorporation of the sawdust in the argillaceous matrix thus allows the appearance of the two fields in the diagram stress-strain, thus characterizing the ductility of the composites. This result is also interesting insofar as it translates the fact that the propagation velocity of the cracks in the composites clay-sawdust of wood is slowed down by the wood particles.

4. Discussion

On the mechanical level, the results show that the sawdust influences little the flexural strength of bricks between 0 and 20% because of fact that it is presented in the form of short fibers and contains particles whose form is connected with grains. This result is in accordance with those several authors who showed that the length of wood fiber influenced the flexural strength of elaborate materials (Dardare, 1975 [5]; Andonian and Al, 1979 [6]; Gopalaratman and Shah, 1985 [7]). For these authors, the composites reinforced with long fibers develop flexural strengths raised compared to those reinforced with short fibers. The length of wood fibers would be then a paramount element in the inflection of such materials. Indeed, in the composites with wood fibers, those come to replace the rigid traditional aggregates which are sands, gravels etc. the wood fibers having thus low resistance, they constitute the "weak points" of material. Thus, in the case of such composites, the constraints walk on through the paste. Resistance in traction of wood fibers thus controls the flexural strength of the composites clay-sawdust of wood. The materials containing of long fibers give greater flexural strengths compared to those containing of short fibers as in our case. However, it is also shown that for composites reinforced with long fibers, their flexural strength is higher than their compressive strength. This is partly related to the length of fibers. It is besides what develop Coutts and Nor (1995) [8] like Blankenhorn and Al (1999) [9] in their respective studies on cementing composites reinforced with short fibers and long fibers for the first and on composites containing of recycled paper fibers, of leafy trees as well as coniferous tree for the seconds. In our case, beyond 20%, the sawdust becomes harmful with the composite because of its too great quantity because it contributes to weaken the structure of material.

The results of the compressive strength are function of the state of the zones of contact between the wood particles and the clay particles (zone of connection matrix-fiber). According to the content of sawdust, adhesion (cohesion) interparticle exchange, thus causing a variation of the compressive strength. It increases resistance up to 15% and by decreases beyond this content. This result is confirmed by the studies of Khenfer and Morlier (2000) [10] which showed that the interfacial connection, in the case of cements reinforced by fibers, could be affected by several parameters among which, the morphology of fiber and compaction. Of the same Ledhem and al. (1996) [11] obtained similar results at the time of their study on the effect of addition of shavings to the cement mixture + clay. Moreover, studies of Savatona and Al (2000) [12] as those of Agarwall (1995) [13] showed that there exists an optimal content, for materials having of the vegetable fibers, beyond which the compressive strengths and the flexural strength drop. These conclusions are identical to our results.

The fall of the dry density is due to the low density of wood (500 kg/m^3) compared to clay (2610 kg/m^3). These results are similar to those of certain authors concerning the concretes of wood (Benmalek and al., 2000 [14]; Bederina, 2007 [15]).

5. Conclusion

This study shows that the sawdust influences indeed the rheological behavior of the CGB. The incorporation of the sawdust in the argillaceous matrix up to 15% makes it possible to reduce the composites. The studies show a light increase in the flexural strength, but the compressive strength strongly increases with the increase in the content of sawdust. It passes by an optimum located at sawdust 15% before falling. The study of the diagram stress-strain shows a change of the mechanical behavior of the composites. Indeed, one passes from a material to fragile behavior to a material to semi-ductile behavior when one adds the sawdust. To finish, this study shows the possibility of developing the sawdust through its incorporation in the argillaceous matrix and solves at the same time an environmental problem by its recycling. However, it would be interesting, to have optimal performances of the composites, to use 10 to sawdust 15%.

References

[1] Kouakou C. H. (2005). Valorisation des argiles de Côte d'Ivoire : étude de la stabilisation à froid de l'argile de Dabou avec un liant hydraulique (le ciment Portland). Thèse de Doctorat des Sciences de la Terre, option Géomatériaux, Université de Cocody, Abidjan 196 p.

[2] Kouadio K. C. (2010). Élaboration et caractérisation de blocs d'argile stabilisée au ciment (Cimarg) : influence de l'apport de dégraissant sur les caractéristiques physiques et mécaniques des blocs. Thèse de Doctorat des Sciences de la Terre option Géomatériaux, Université de Cocody, Abidjan, 151 p.

[3] Ouattara S. (2013). Recherche de briques légères : conception et caractérisation de briques crues à base d'argile et de sciure de bois, stabilisées au ciment Portland. Thèse de Doctorat unique des Sciences de la Terre, option Géomatériaux, Université Félix Houphouët Boigny, Abidjan 150 p.

[4] Rossi P., Acker A. and Maller Y. (1987). Effect of steel fibers at two different stages: the material and the structure. Material and Structure, vol. 20, pp 436-439.

[5] Dardare J. (1975). Contribution à l'étude du comportement mécanique des bétons renforcés de fibres de polypropylène. Fiber reinforced cement and concrete, RILEM, symposium 1975, Edited by A. NEVILLE, Lancaster, Construction Press, pp 227-235.

[6] Andonian R., Mai Y. W. and Cotterll B. (1979). Strength and fracture properties of cellulose fiber reinforced cement composites. Journal of Cement Composites, vol. 1, n° 3, pp. 151-158.

[7] Gopalaratman V. S. and Shah S. P (1985). “Softening Response of plain concrete in Direct Tension.” ACI Journal, May-June 1985, Vol. 82, N° 3, pp 310-323.

[8] Coutts R. S. P. and Ni Y. (1995). Autoclaved bamboo pulped fibre reinforced cement. Cement and Concrete Composites, vol. 17, pp 99-106.

[9] Blankenhorn P. R., Silsbee M. R., Blankenhorn B. D. and Dicola M. (1999). Temperature and moisture effect on selected properties of wood fiber-cement composites. Cement and Concrete Research, vol. 29, pp 737-741.

[10] Khenfer M. and Morlier P. (2000). Caractérisation et microstructure de ciments renforcés de fibres de cellulose. Bulletin des Laboratoires des Ponts et Chaussées, vol. 224, n° 4236, pp 49-58.

[11] Ledhem A., Al-Rim K. et Queneudec M. (1996). Étude des paramètres de fabrication d’un composite argile-ciment-bois. Materials and Structures, vol. 29, pp 514-518.

[12] Savastano J. H., Warden P. G. et Coutts R. S. P. (2000). Brazilian waste fibres as reinforcement for cement-based composites. Cement, Concrete Composites Journal, vol. 22, pp 379-384.

[13] Agarwall L. K., (1995). Bagasse-reinforced cement composites. Cement and Concrete Composites, vol. 17, pp. 107-112.

[14] Benmalek M. L., Houari H., Bali A. et Queneudec M. (2000). Comportement d’un composite fine minérale - ciment - bois élaboré à l’aide de déchets industriels solides, Sciences & Technologie n°13 juin (2000), pp 65-72.

[15] Bederina M. (2007). Caractérisation mécanique et physique des bétons de sable à base de déchets de bois. Thèse de Doctorat, École Nationale polytechnique, Alger, Algérie, 166 p.