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Mechanical Caracteristics of Fiber Palmyra

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Tests of traction achieved to the laboratory of institute French of the Advanced Mechanics permitted to determine the elastic modulus, rupture stress and rupture deformation of the fibers extracted from the heartwood and the sapwood.

The knowledge of the mechanical features of these fibers opens a perspective of the survey of their utilization as reinforcement in artificial composite materials.

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MECHANICALCARACTERISTICSOFFIBERPALMYRA

Mechanical Caracteristics of Fiber Palmyra

Ngargueudedjim K. [α], Allarabeye N. [σ], K. Charlet [ρ], J.-F. Destrebecq [ω], R. Moutou Pitti [¥] & J.-L. Robert [§]

Abstract- We are interested in this work to the determination of the mechanical features of the fibre of a male Palmyra (Borassus aethiopum. Mart) aged around 40 years, taken in Houndouma, a village at the southern of Djaména in Chad. The paper presents results of an experimentation achieved on fiber's sapwood and heartwood's fiber. Sapwood and heartwood constitute the part useful of the log of the Palmyra as material of laths and frameworks in the traditional and semi-modern habitat construction in Chad.

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Keywords: palmyra, mechanical characteristic, wood fiber, elastic modulus, rupture stress, cellulose, hemicellulose, lignin.

I. Introduction

Ligno fibers - Natural cellulose are biological structures composed of mainly cellulose microfibrile and an amorphous matrix consisting of lignin and hemicellulose, in relatively small proportion of non-extractable nitrogen, crude protein content, lipids and materials mineral [1] and [2]. The composition of the wood depends on the class of the tree (coniferous or deciduous), species, individuals of the same species and the diameter portion (heartwood, sapwood and heart) of the log of the individual.

Ligno fiber - celluloses wood are used extensively worldwide in the manufacture of paper pulp and dissolving pulp, in the manufacture of composite materials [3] and [4], in industries furniture [2].

The palmyra, wood in the class of palm trees, has a specific morphology. This is a very dense wood fibers (about 100 fibers per cm^2) and compact. Its fibers, brown in color, are very long, very large (area about 1 mm^2) and very rigid (Image.1). Its lignified structures are embedded in the main parenchyma which is also cellulose [5].

In Chad (Image.2), the palmyra is widely used as slats and beams in the construction of habitats, and as fence posts fields. The production of these building elements is hand-crafted without recovery of falls or its residues. Economically, this is a shortfall in earnings, and therefore an obstacle to sustainable development. The use of by-products has become a priority in applied research and key to sustainable development. The objective of this study is to popularize local materials on the one hand to participate in a recovering economy and secondly to gain autonomy by using local products that do not require large investments.

Determining the mechanical characteristics of tensile fibers allow to envisage its use as a reinforcement in the composite artificial. This is why the monotonous tensile tests are carried out on fibers extracted from the heartwood and sapwood of an individual palmyra aged around 40 years.

II. Material and Method

a) Material

The fibers tested are taken from the piece of tree 1.5m above the base. In this part, the heartwood which is very dense in old fibers is clearly distinguishable from the sapwood.

The average density is 124 fibers per cm^2 for the heartwood and 77 fibers per cm^2 for the sapwood (Image.1).

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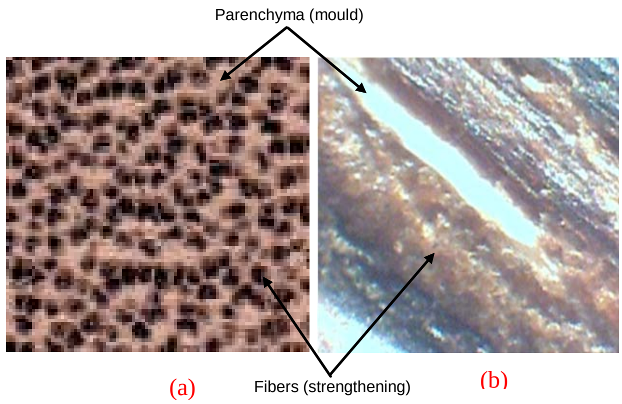

Image 1 : A photograph showing fibers and parenchyma:

(a): cross-sectional view, (b): longitudinal view of fibers [6].

This sample has an average chemical composition is as follows:

- Cellulose: 63.21% in the heartwood and 61.89% in sapwood;
- Hemicellulose: 09.60% in the heartwood and 11.32% in sapwood;
- Lignin: 19.36% in the heartwood and 19.68% in the sapwood.

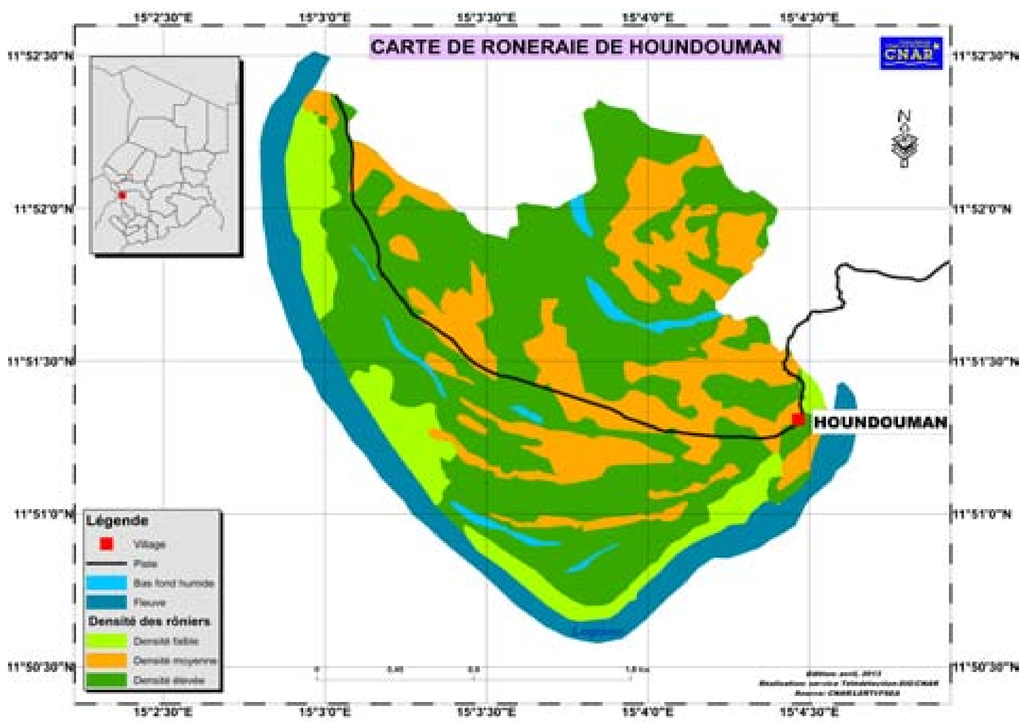

Image 2 : Cartography of palmyra field in Houndouman

a) *Experimental Procedure*

The fibers are manually extracted from the heartwood and sapwood. After drying in the sun for 6 hours, the fibers are manually cleaned for reducing the presence of parenchyma that remained glued on them without. They were not subjected to chemical treatment.

The fiber dimensions were assessed caliper (0.01mm accuracy). Sections, calculated using the method of the circumscribed rectangle (Figure.1) are between 0.48 and 0.96 mm^2 for fibers of sapwood, and 0.46 and 1.03 mm^2 for the heartwood.

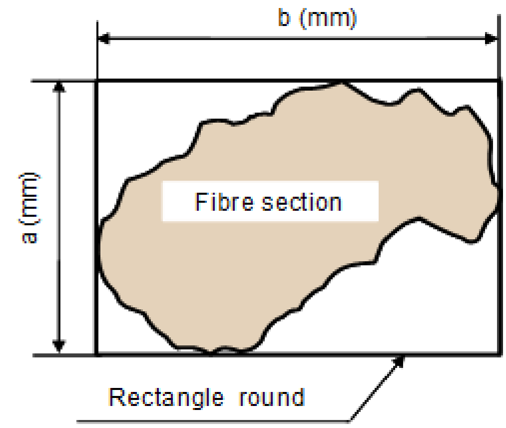

Figure 1 : Determination of the size of a fiber by the method of the circumscribed rectangle

For tensile tests, we used a UTS brand electric machine equipped with a 1.5kN capacity load cell and manual clamping jaws.

The fibers were clamped in the jaws and the test was started at 1 mm / min (as that typically found in the literature when testing plant fibers), up to rupture of the fiber. For each type of fiber, 8 specimens were tested, and those who had broken into the jaws were not taken into account in the calculation of averages.

The stresses are calculated using the formula $\sigma = F/S$, where F is the tensile force in Newton (N) and S the area of the cross section of the fiber in mm^2.

The deformations are calculated from the formula $A(\%) = 100(L - L_0)/L_0$, in which L_0 is the initial lengths and L the lengths after deformation.

The longitudinal elastic modulus of each fiber was obtained by using the linear regression method to the right of the stress - strain curve.

Then the average values of various characteristics were calculated.

III. Results and Discussions

The stress-strain curves are plotted for each of the eight sapwood fibers (Figure.2) and each of the eight heartwood fibers (Figure.3).

The Table.1 and 2 give the values of the calculated mechanical characteristics.

The table.3 presents the average values of the mechanical properties of sapwood and heartwood.

The average values of the mechanical characteristics of Table.3 show that:

- The modulus of elasticity of the fiber of the sapwood (17 GPa) is substantially the same as that of the fiber of the heartwood (16.8 GPa);
- The tensile strength of the fiber of the sapwood (184 MPa) is lower than the fiber heartwood (219 MPa);
- The break strains of the sapwood fiber and the heartwood fiber are substantially the same (a difference of 0.3%).

These differences between the mechanical characteristics are linked to the maturity of the fibers in the wood. Indeed, the fibers of the heartwood are very old, so mature enough to be more resistant than the fibers of the sapwood.

Compared with the fibers of the petiole of the palm doom, the palmyra fibers are very rigid and high-strength than the fibers of the palm petiole doom. However they have low strain at rupture. Note however that this comparison gave to the different aspects. Saw eye, the fiber of Palmyra is a macroscopic cluster of thin fiberboard.

Table 1 : Values of measurements and calculations for each fiber of the sapwood in traction

Sapwood								
N° Fiber	1	2	3	4	5	6	7	8
L_0 (mm)	30	30	31	31	32	30	30	30
S_o (mm²)	0.80	0.58	0.80	0.74	0.96	0.59	0.48	0.58
E (GPa)	16.5	11.8	16.5	16.5	15.7	23.7	20.9	18.6
Rupture stress R_r (MPa)	163	109	118	299	284	157	75	154
Rupture Deformation (mm/mm)	1.2	0.8	0.9	1.8	2.2	0.9	0.4	1.0
RUPT. MORS								

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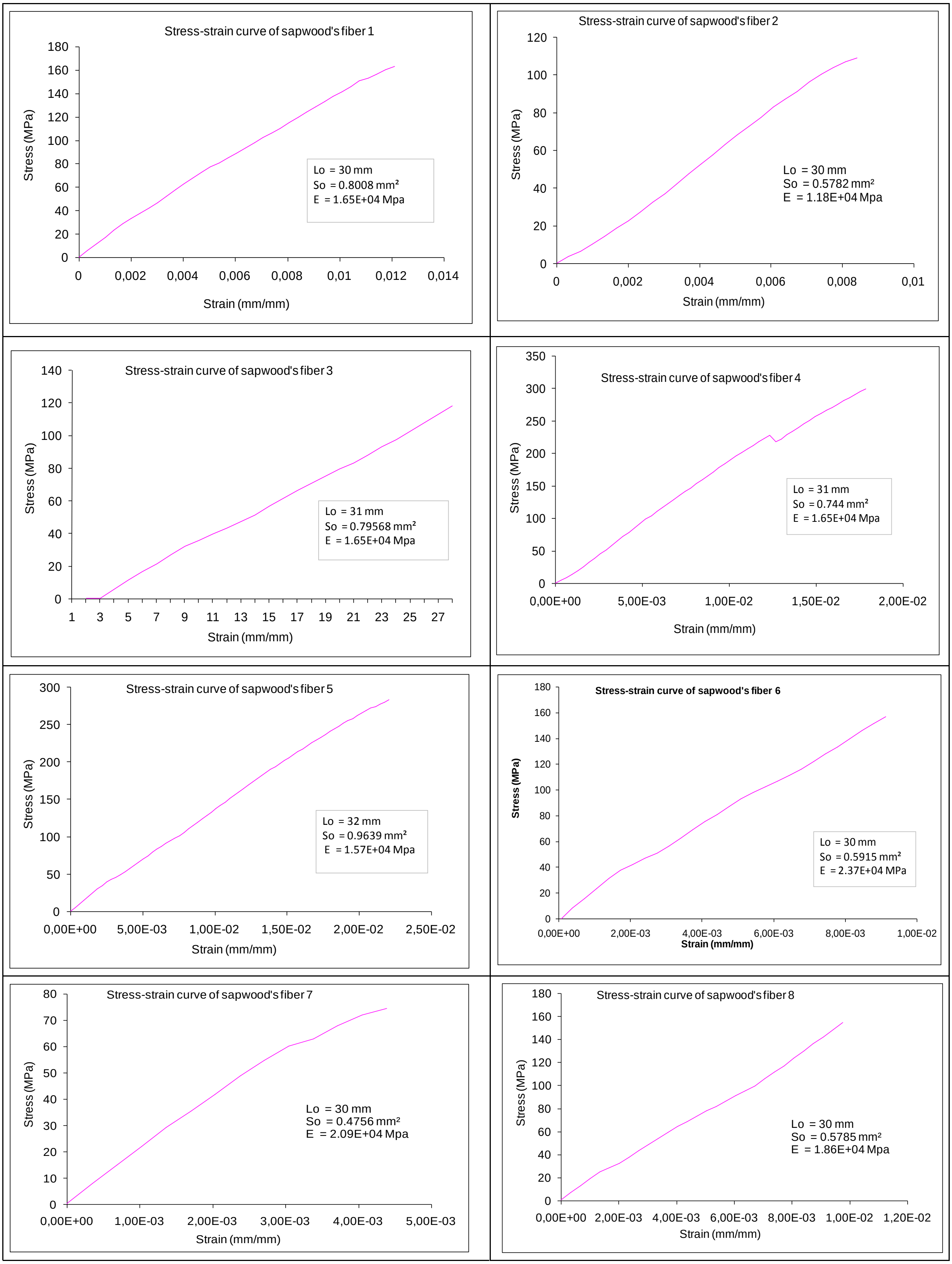

Figure 2 : stress-strain curves of each fiber of the sapwood in traction

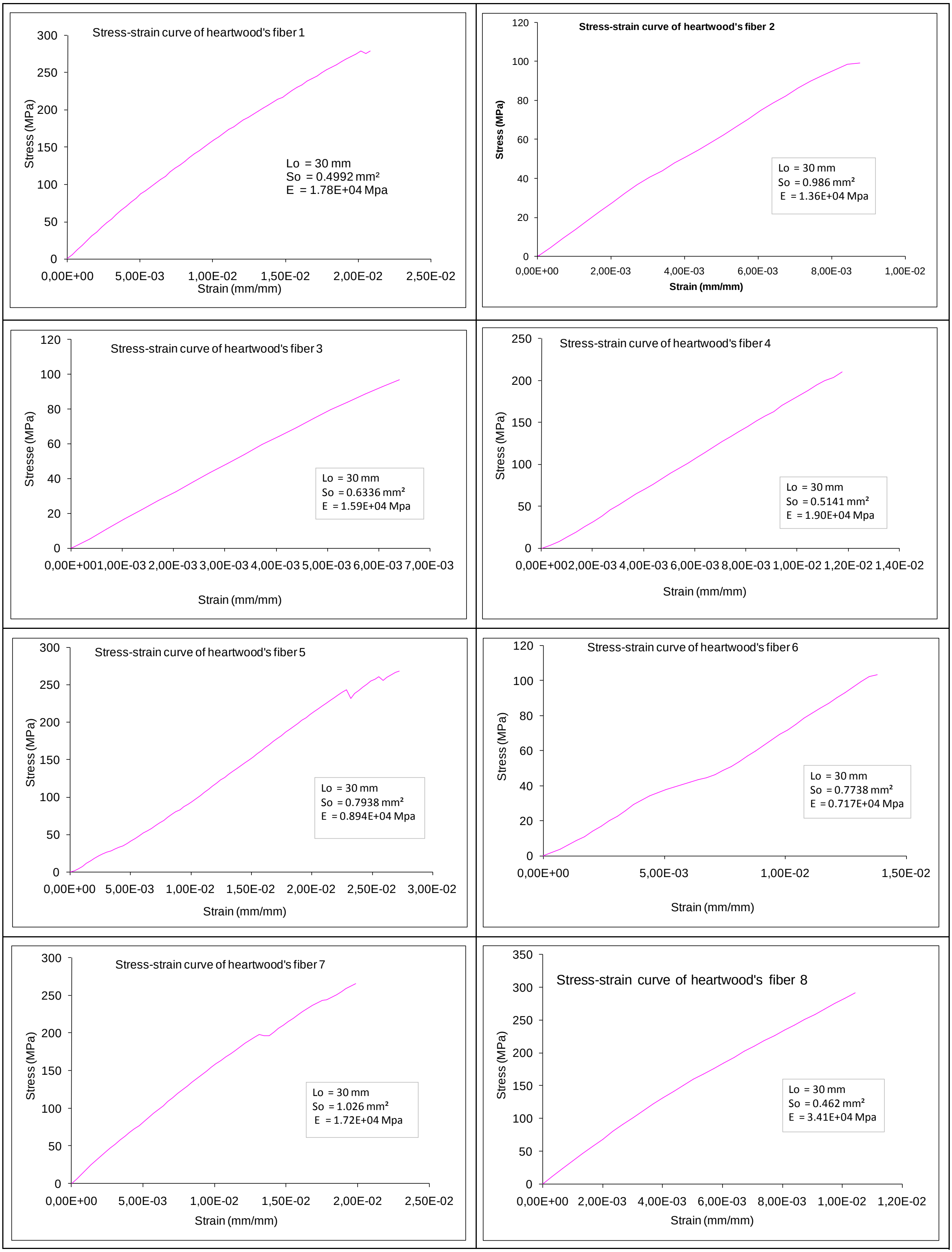

Figure 3 : stress-strain curves of each fiber of the heartwood in traction.

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Table 2 : Values of measurements and calculations for each fiber of the heartwood in traction

Heartwood								
N° Fibre	1	2	3	4	5	6	7	8
L_0 (mm)	30	30	30	30	30	30	30	30
S_0 (mm²)	0.50	0.99	0.63	0.51	0.79	0.77	1.03	0.46
E (GPa)	17.8	13.6	15.9	19.0	8.9	7.2	17.2	34.1
Rupture stress R_r (MPa)	279	99	97	210	268	104	284	291
Rupture deformation A (mm/mm)	2.1	0.9	0.6	1.2	2.7	1.4	2.1	1.0
RUPT. MORS								

Table.3: Mean values of calculated mechanical characteristics in traction.

Average value	**Sapwood**	**Heartwood**
Cross section So (mm²)	0.72 ± 0.15	0.72 ± 0.23
Young's modulus E (GPa)	17.0 ± 3.6	16.8 ± 8.8
Rupture stress R_r (MPa)	184 ± 77	219 ± 8.5
Rupture deformation (mm/mm)	1.3 ± 0.5	1.6 ± 0.7

Table.4: Mechanical characteristics of palm doom fibres [5].

Young's Modulus E (MPa)	**Rupture strength R_r (MPa)**	**Rupture deformation A (%)**
5760 ± 1,35	147,72 ± 34,25	3,19 ± 0,38

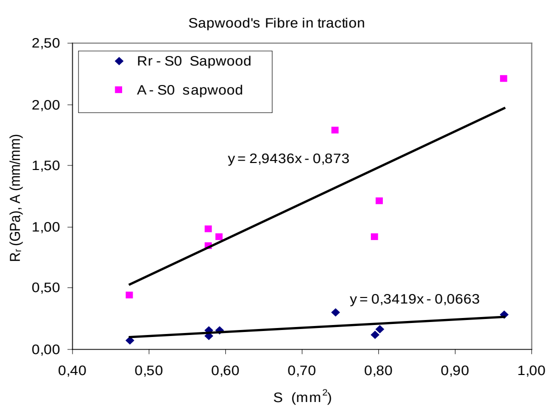

Figure 4 : Evolution curves of rupture strength and rupture deformation of sapwood and heartwood fibers of palmyra according to the cross section

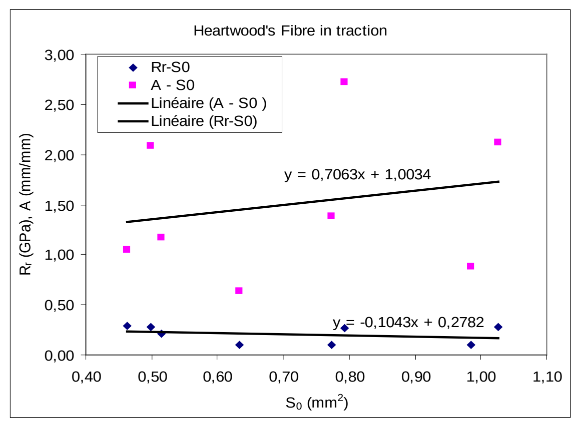

Figure 5 : Evolution curves of rupture strength and rupture deformation of fibers of heartwood palmyra versus the cross section

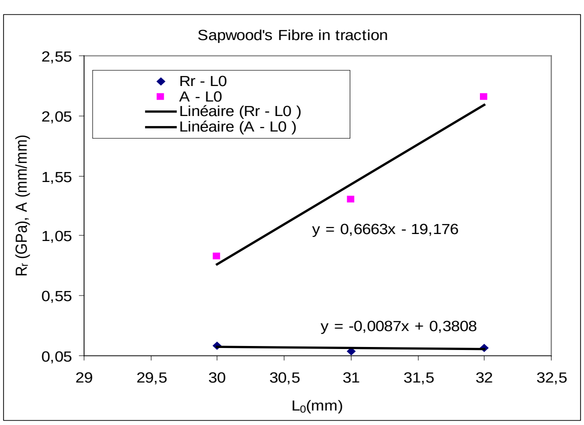

Figure 6 : Evolution curves of rupture strength and rupture deformation of sapwood fibers of palmyra versus the cross section

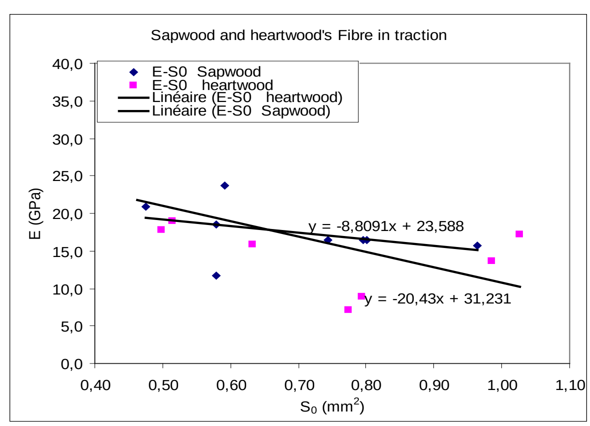

Figure 7 : Evolution curves of elastic modulus of heartwood and sapwood fibers of palmyra versus the cross section

Table.1, Table.2, Figure.4, Figure.5 and Figure.6 show that the percentage of the rupture elongation of the fibers sapwood and heartwood increases by their initial section and initial length. The effect of these two parameters on the tensile strength of a fiber is negligible.

Table.1, Tableau.2, Figure.7 and Figure.8 show that the modulus of longitudinal elasticity of the fibers decreases when their initial section and initial length increase.

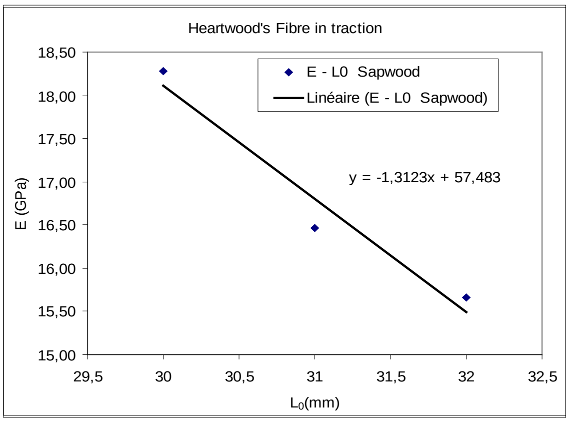

Figure 8 : Evolution curves of elastic modulus of sapwood fibers of palmyra versus the cross section

This behavior of the mechanical characteristics of the fibers is contrary to their intrinsic nature which is independent of their values in relation to the fiber dimensions. CHARLET and al. [7] LILLHOLT and al. [8] and Mott and al. [9] stated in their papers that vegetable fibers are characterized by a very high intraspecific and interspecific variability of their mechanical properties which depend on the species, the organ of origin fiber, the proportion cellulose-hemicellulose -lignin, the degree of polymerization and crystallization of the cellulose, the micro fibril angle (Figure.9) and the structural defects. Indeed, in native fibers, micro fibrils are arranged to describe with the fiber axis a micro fibril angle whose value varies from one plant species to another. The micro fibril angle partly determines the mechanical characteristics of elongation and stiffness of the fiber [8].

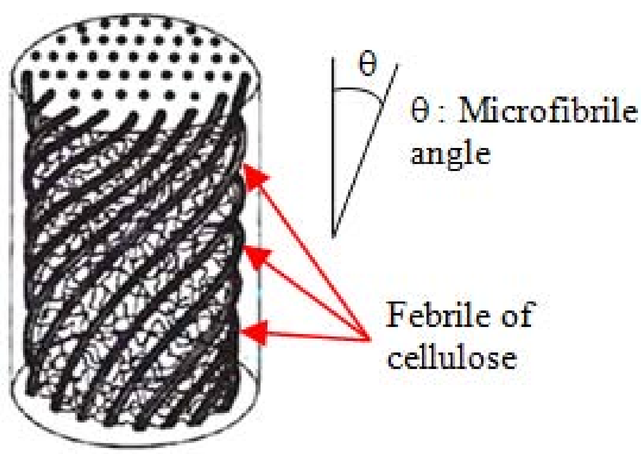

Figure 9 : Model description of the structure of a plant fiber [10]

The random evolution of these characteristics depending on the section and the length can be explained by variability along the fiber section.

In terms of the tensile strength, BOS et al. [11] also noted that its variation is related to the influence of structural defects in the fiber. NILSSON and GUSTAFSSON [12] explained the experimental results (modulus of elasticity) of BALEY [13] proposing a model that considers the dislocations and plastic behavior of hemicellulose as the main parameters governing the strength of the fiber. For them, the non-linearity of the Stress-strain curve (Figure.1 and Figure.2) is mainly dislocation movements.

IV. Conclusion

The study on the mechanical properties of the fiber palmyra shows that:

- The longitudinal elastic modulus (Young's modulus) and the failure strains of heartwood of fibers and fiber sapwood are of the same order of magnitude as those of sapwood;
- The tensile strength of the fiber heartwood is very higher than that of the fiber of sapwood;
- The values of its mechanical properties are strongly dependent on the cross-sectional area (diameter) of the fiber;

This modest contribution to the understanding of the mechanical properties of the fiber palmyra will undertake the study of its use as reinforcement in artificial composite materials.

THANKS

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