Contribution to the Determination of the Elasticity Modules of a Material (*Borassus Aethiopum*) based on an Experimental Method: Effort (Force)/Elongation or Moment/Degree ratio

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Abstract— *The mechanical characterization of a material involves the determination of longitudinal elastic modulus, the transverse modulus and the fish coefficient. To Obtaining these data is subject to experimentation. To obtain these data, there is need to experimentation. Several conditions contribute to the realization to the carrying out of the tests.To achieve this, there are methods which make it possible to better know the materials in general and especially the building materials by working on very small samples. Machinery, sample deposits and working conditions are obstacles to research. A civil engineering CBR press enabled us, during the three-point bending test, to determine the modulus of longitudinal elasticity by increasing the press force and elongation. Based on the example of bending, the transverse module is obtained by the torsion test based on the torsion moment and the torsion angle.*

The method is based on consideration of the Bending Effort/Elongation ratio or Moment/Torsion angle ratio. The experimental material is an object with its own morphology, the wandering wood. The difficulty of the work is related to the accuracy of all components of the sample.This method complements previous methods and puts into practice the indispensable dimensions of the strength of the materials.It shows the purpose pursued by an engineer in these experiments.

Keywords*— *Engineer, Characterizations, Essential quantities, Simple Technique, Rônier.

I. INTRODUCTION

One of the ways to know a material and its solicitation behavior is the characterization. It can be done in several fields: physics, mechanics, acoustics,... and in several ways. But for each domain, the characterization follows rules and principles: it is based on laws. It depends on the information sought. The main characterization techniques are mechanical tests, non-destructive tests and physico-chemical analyzes. In the case of mechanical and rheological characterization, machines or apparatus such as a mechanical phenomena analyzer, a rheometer, a bending machine are indicated for destructive or non-destructive tests based on the vibratory method in which the specimen is not destroyed.

Depending on the method of testing (destructive or not), methods such as the vibratory method, the ultrasonic method adopted on "Stress grading" are also used. Vibratory tests led to the determination of the longitudinal elastic modulus (MOE). Authors (Jehl et al, 2011, Viguier et al, 2015, JG van de Kuilen, 2002) have revealed the importance of the vibratory method. A similar method is the ultra sonic method of analyzing the speed of sound propagation in the sample. Another method based on the diffusion of X-rays. The aim is to measure the flux of ray that passes through the material over a period of time.These methods are performed on specified equipments or machines having sensors or detectors reading dimensional extensions. The principle must meet standards. In these standards, the experimental conditions**,** the number, the shape and the dimensions of the sample are to be respected.The characterization work must be carried out on the most suitable apparatus and machines [1]. The technique of the shapes of the materials must dictatethe shape of the samples. Experience data are to be considered. Unfortunately, these parameters differ according to the materials and objects to be manufactured. The damage during these characterization works is related to the testing machines and the popularity of samples. That is why we say the problem of the popularity of the samples remains.

Experimental material is limited. The probability of finding the same sample with the same characteristics is low. This is similar to archeology studies. It is very rare to be able to carry out physic-mechanical characterizations on old materials found in excavations or on works in restoration. However, the validation of results now a day's requires, from the statistical point of view, a considerable number of samples. The same samples are therefore rare to be identified because we cannot have the same morphology for samples taken from a tree or a portion of a tree. The elastic properties are characteristic of solid items, wood included. Elasticity means that the deformations are temporary. The body resumes its original dimensions when the force is removed [2]. When an elastic material exhibits at the same time a linear relationshipbetween the stress and the deformation, it is called linearly elastic. This is the case for wood [3] [4] [5].In our case, characterization of the material rônier wood, an analysis of the mechanical behavior is the work sought. But the literature gives little information about morphology [3] [6] and virtues. The sap is used as local wine, the fruit is edible and the leaves are used to make fans, baskets, mats [7] [8]. Know about the particular wood that is the rônier. The rônier is a building material of tropical Africa. It consists of fibers [9].

Due to its difficult work, it is abandoned. The rônier already has its structure and cannot undergo any formulation of the constituents. The material is made according to the morphology and the metallurgy. Difficulties are other techniques; there are no working tools, twig-shaped fibers act as nails. However, the mechanical, electrical and thermal values are unknown. With mechanization, his work can be possible and less tedious. The interest of this work is to provide a simple technique for obtaining data without sophisticated machines.

II. EXPERIMENT

2.1 Presentation of the material

Our article is focused on the rônier of the scientific name *Borassus Aethiopum*. The rônier belongs to the family of Borassoïdeae, of the palm category. The rônier is a slow-growing plant, up to 18 to 20 m tall. At this size, the plant can be between 40 and 50 years old. He is from tropical Sahelian Africa. The trunk has a greyish color and a cylindrical shape imbued at times. It is formed of fibers, surmounted by palms in spread tuft. These leaves are similar to large fans. The trunk of the rônier is considered as a false trunk so called stipe [3] [10] [11]. It is very hard on the bark but spongy in the heart of the plant. The life of the plant is influenced by the soil, climate and living conditions. The influences of man, the bush fire, the presence of man act on its growth. The rônier presents two subjects: male subject bearing fruit and a female subject carrying fruit. The male has male inflorescences of about 1 m 80.The female subject, flowering, bears flowers that will become fruit. The fruits have a pale yellow color and are edible [7]. The trunk remains the essential part of our study. It is rot-resistant and highly resistant to xylophages, mollusks and termites [10].

In our study, a female subject was used. It may be 30 years old. This treated subject lived in a humid climate environment.The trunk is large, 0.66 m in diameter. The trunk of the plant is felled. Slices are taken. Work is carried out on the slices to extract specimen samples. The size of the samples follows standard NF B 51 008. It is presented in figure 1. The dimensions of the specimens have a prismatic shape of square section of 20 ± 0.2 mm side and a length of 360 ± 2 mm [12].It is cut into the length of wood grain.

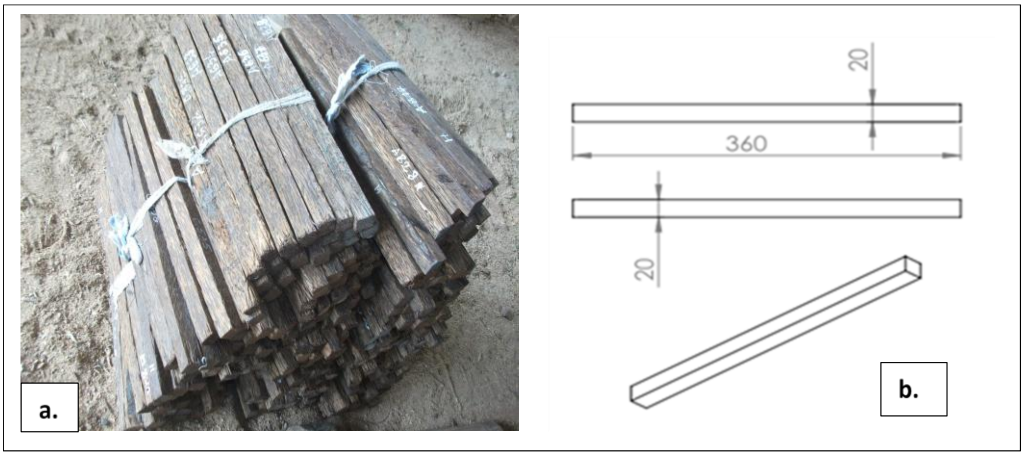

FIGURE 1: Shape of the samples
a. Samples put in piles b. Sizing of samples

Practical working machines are used. This is a CBR press, civil engineering and Tecquipment. The CBR press (fig. 2) is a compaction press. We attach to the press a device we have designed. The following figures show the CBR press and the Tecquipment (fig. 3).

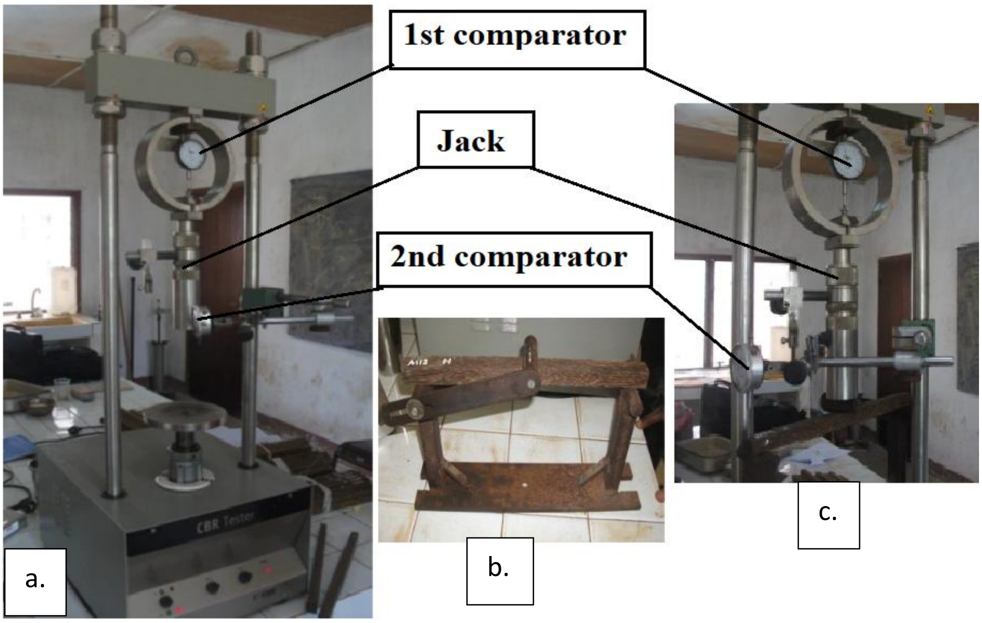

FIGURE 2: Experimental equipment
a. CBR civil engineering press; b. Testing device; c. Test Phase Device Sample

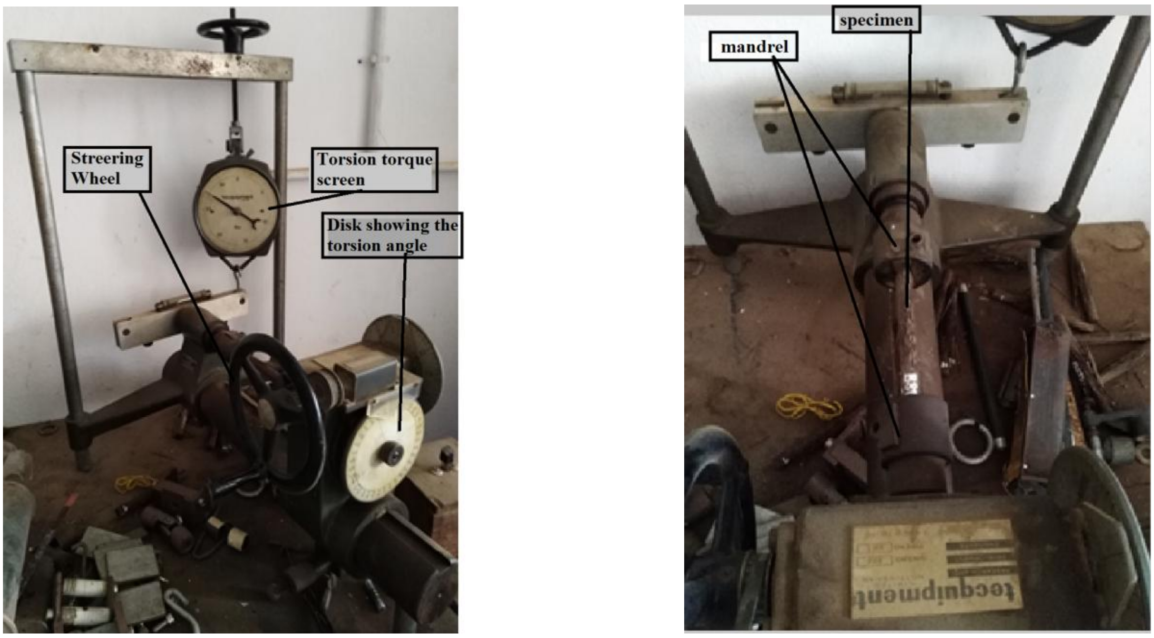

FIGURE 3: Torsion Device – Tecquipment

The CBR press is a press powered by electric current. It is equipped with a position switch that allows the machine to start. The approach speed is constant and is 1.27mm / min. The race is 120 mm. The pressing capacity is 50 kN. The load is applied by a motorized mechanical jack. The indicated speed is obtained by means of a reduction gearbox coupled to an electric motor of power 0.30 kW.

Tecquipment is an old test machine. It is a bench mounted machine. It is composed of two parts (I) and (II). Part (I) is intended for the torque reaction and a torquemeasurement system. This part has a dial capable of displaying torque. It also protects a torsion shaft supported by the bearings. The shaft carries a mandrel in which the test piece is mounted. Part (II) is the driving part where the mechanical force is applied to a crank. Through the reduction system, the rotation of the crank is transformed to some degree of deformation applied to the specimen. A decoder is used toread the number of rotation corresponding to the angle of torsion. It also carries a mandrel in which the specimen is mounted or tightened.

2.2 Description of the methodology

In this article, we present a technique developed for two different tests made of different devices. This is the bending test and the torsion test.

A civil CBR press is used in the bending test. The test carried out is the three-point bending. A civil engineering CBR press is used instead of a fatigue bench or a universal test machine. In performing the RDM tests, the engineer exploits some particular data that are integrated in the algorithm of the machine. These data enable longitudinal and transverse elongation to be obtained by means of sensors for tensile tests. Our technique is developed on a press on which we can obtain the pressing force and stroke of the box spring or apron. The sample is puton the test device that we designed. It rests on two cylindrical supports 320 mm apart. The press base (cylinder) goes down to press the test tube in the middle. The test begins when the comparator needle deviates. It ends when the test tube breaks.There is no deformation or elongation recorder on our press. Readings are made directly on the dial at selected time intervals. Every thirty (30) seconds, we read the position of the hands of the two comparators. From the experimental data (Force-Distortion distance), we plot the bending curve of the specimen in the elastic domain. The drawn curve follows the trend line whose equation is written next to it. The slope of this line is the ratio of the variation of these two sizes (Force-Distortion distance). However, as part of the characterization of the rônier, an experimental methodology was set up. It is the solution to our machine or work equipment problem. But if we do not have a modern universal machine with sensors, what should we do?

The values are recorded by the operator on the dial of the comparators. During the test, the value is read on the dial of a comparator. From an abacus accompanying the press allows to have the real value of the pressing force. A second comparator is placed 10 mm away from the outside and not toward the middle. It gives the value of the displacement. From these two data, a curve of the experiment is drawn. We deduce a ratio called stiffness K [13] in flexion (see relation 1).

$$K = \frac{\Delta F}{\Delta l} \tag{1}$$

ΔF: value of the force (N) and Δl: Distortion distance or elongation (mm).

The ratio K will be used in the search for longitudinal elastic modulus E (see relation 2).

$$E = \frac{1}{4b} \cdot \left(\frac{l}{h}\right)^3 . \boldsymbol{K} \tag{2}$$

l, b and h are the dimensions of the specimen or test piece (l: the length, b: the width and h: the height or thickness of the test piece).

For a torsion test, a similar method is used. It allows us to determine the shear module G (relations 3 and 4).

$$G = \frac{M_t}{\theta . I_0} \tag{3}$$

There for $\theta = \alpha / L$

L: length of the specimen.

From where

$$G = \frac{M_t}{\alpha} \cdot \frac{L}{I_0} \tag{4}$$

Here is a ratio of the torsion moment between torsion angle. We can write $\frac{M_t}{\alpha}$. By designating C this ratio, we can write C = f (α), that is to say that the moment is a function of the variation of the angle. The machine used is equipped with a crank of length **d**. When turning the crank, we vary the angle and read the force deployed **F**. The moment is the product (**F.d**). The angle of torsion is gradually changed. At each interval of 1 degree, the value of the corresponding force is read. An illustration is made of these obtained data. The relationship between moment and angle is given by equation 4.

For both methods, the linear part of the curves will be considered. It looks like a straight linewith a slope or guideline. The material is supposed to be elastic. With Excel spreadsheet, we find the equation of the line and therefore the slope. Said value makes it possible to find the longitudinal and transverse modules.

III. RESULTS AND DISCUSSIONS

From the experimental data collected, different curves are drawn. The experiments are conducted until the sample is broken. Forcevalues correspond to elongations. A curve has a linear zone and a curvilinear zone. The linear zone reflects the elastic aspect of the material. The nonlinear or curvilinear zone is the illustration of the permanent deformation of the material. This deformation occurred as soon as the first constituents of the material were destroyed. In this article, we are interested in the linear part of the curve. The Excel spreadsheet gives us the corresponding line. The slope of the line is the ratio revealed by the engineer. From two examples, we present the technique that constitutes our contribution.

3.1 First evidence : Bending test

Forty-four (44) specimens were tested for the same type of trunk test. Here is the bending test result which is the illustrative curve of three samples tested. We record the effort in ordered and the arrow in abscissa. We obtain the complete curve illustrating the test from the beginning to the break. The curve thus obtained is similar to the curve having a linear part and a nonlinear part. The linear zone is the quasi linear zone that we will consider. The curve of the test is the illustration of all the information of the test. During the test, the breaking of the first fibers or the first deteriorations causes the change of the curve shape. So as soon as the curve is no longer linear, we have entered another phase. In this case, the material remains elastic up to 4.5 mm for a force corresponding to 900 N. Using our method, we draw the straightline and then calculate the longitudinal elastic modulus (MOE). The maximum deflection varies between 9 and 11.1 mm for an effort of between 922 and 1334 N.However, the determination of the MOE requires sophisticated machines and more indicated [1]. And if the sophisticated machine fails, it is necessary to consider techniques to prove the feasibility of the model. These curves are almost identical to those obtained on sophisticated machines. Despite the precautions taken, some distortions are observable on the curves. We attribute them to manufacturing errors related to cutting and handling conditions during the test. But the rônier is a material that does not break abruptly because of intertwined fibers. It is very elastic. One of these advantages is the absence of nodes.

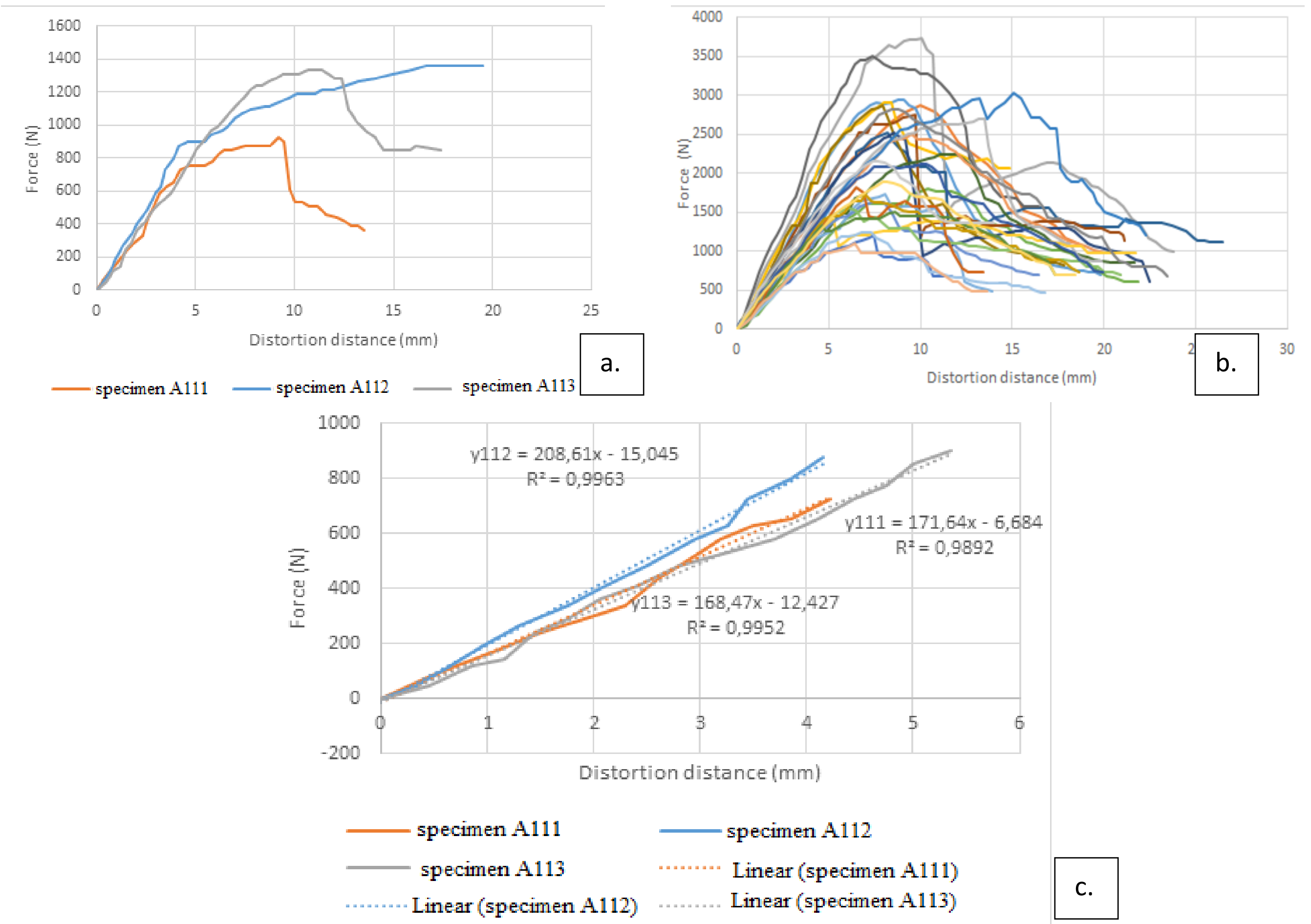

FIGURE 4: Presentation of the bending test result
a. Complete curve b. Curves grouping c. Linear portion of the curve

TABLE 1
RESULT OF EIGHT SLATS FROM THE TRUNK - MOE CALCULATION BASED ON K

N° slats	Code	Dimensions (mm)				Mass	ρ	Rigidity		MOE	Force
		e	h	e/h	L	m (g)	(g/cm^3)	K	R²	(N/mm^2)	(N)
L1	A111	20,7	21,0	0,986	360	143,55	0,92	177,64	0,98	10 808	922,3
	A112	23,2	20,2	1,149	360	165,85	0,98	208,61	1,00	12 724	1359,2
	A113	22,2	18,0	1,233	360	139,82	0,97	168,47	1,00	15 177	1334,9
	A114	20,3	23,0	1,133	360	158,16	0,94	207,48	0,97	9 798	1674,7
	A115	21	23,3	1,11	360	156,53	0,89	330,27	0,99	14 502	1626,2
	A116	19,5	22,5	1,154	360	144,12	0,91	272,06	0,99	14 287	1165
L2	A211	19,6	20	0,98	360	135,78	0,96	157,26	0,99	11 698	728,1
	A212	17,9	21,4	0,836	360	142,03	1,03	196,83	1,00	13 087	1043,6
	A213	20,8	19	0,913	360	140,4	0,99	180,05	1,00	14 720	946,6
	A214	20	19,29	0,965	360	136,25	0,98	192,73	1,00	15 659	1067,9
L3	A311	19,5	20,3	0,961	360	142,4	1,00	243,63	0,99	17 420	1019,4
	A312	20,6	20,6	1	360	150,28	0,98	180,14	0,99	11 668	1286,4
	A313	20,4	20,35	0,998	360	145	0,97	163,58	1,00	11 098	655,2
	A314	19,7	20	1,015	360	144,45	1,02	169,08	0,99	12 514	1165
L4	A411	22	21,6	1,019	360	148,57	0,87	166,84	0,99	8 777	995,1
	A412	22,8	20,7	1,101	360	154,77	0,91	203,78	0,99	11 753	1262,1
	A413	22,5	17,5	1,286	360	138,37	0,98	148,9	1,00	14 403	970,8
	A414	20	22	1,1	360	147,53	0,93	256,03	0,99	14 023	1189,3
	A415	20,5	21,6	1,054	360	147,56	0,93	204,35	0,98	11 537	1553,3
	A416	21	17,67	0,841	360	115,84	0,87	135,32	0,98	13 623	1140,7
L5	A511	18,9	17,4	1,086	360	116,1	0,98	109,34	0,99	12 809	1067,9
	A512	19,7	19,1	1,031	360	133,1	0,98	175,62	1,00	14 923	1432
	A513	19,9	20	0,995	360	141,6	0,99	127,07	1,00	9 310	752,4
	A514	18,6	20,3	1,091	360	138,59	1,02	168,74	1,00	12 649	558,2
	A515	17,8	19,8	1,112	360	130,13	1,03	143,32	0,98	12 099	315,5
	A516	20	20	1	360	140,42	0,98	155,21	0,99	11 315	703,8
L6	A611	20	20	1	360	122,65	0,85	162,16	1,00	11 821	1092,2
	A612	19,9	20	0,995	360	135,62	0,95	172,28	1,00	12 622	1213,5
	A613	20	19,1	1,047	360	129,48	0,94	171,43	1,00	14 348	1140,7
	A614	19,7	19,5	0,99	360	131,9	0,95	171,87	0,99	13 724	776,6
	A615	19,9	20	1,005	360	136,24	0,95	129,31	0,99	9 474	898
	A616	20	19,5	0,975	360	147,61	1,05	147,84	0,99	11 628	849,5
L7	A711	18	18,5	0,973	360	125,25	1,04	138,4	0,99	14 164	970,8
	A712	20	20	1	360	146,15	1,01	163,76	1,00	11 938	1456,3
	A713	18,4	20	0,92	360	138,93	1,05	155,28	1,00	12 304	1286,4
	A714	18,4	17,4	0,946	360	133,64	1,16	111,09	1,00	13 368	679
	A715	20,4	19,3	0,946	360	135,31	0,95	104,71	0,98	8 328	970,8
	A716	20	19,9	0,995	360	133,13	0,93	180,91	0,99	13 388	970,6
L8	A811	19,7	20,6	0,956	360	134,94	0,92	204,35	1,00	13 841	1699
	A812	20	20	1	360	144,26	1,00	174,34	0,99	12 709	1601,9
	A813	20	20	1	360	124,77	0,87	140,93	1,00	10 274	1577,6
	A814	20	19,4	0,97	360	140,63	1,01	142,17	1,00	11 356	266,9
	A815	20	20	1	360	149,62	1,04	238,77	0,99	17 406	1092,2
	A816	19,5	20	1,026	360	143,23	1,02	150,29	0,99	11 237	825,2
Average							**0,97**	**169,48**	**0,99**	**12 649**	**1 036**
Standard Deviation							**0,06**	**43,21**	**0,01**	**2 011**	**335**

Through the graph c. of figure 4, we see the pace of the various curves with deviations of the order of a thousand. The curves express the true or real behavior of the material. The dashed line represents the ideal curve. In this step, in order to validate our technique or method, we considered using the linear part of the experimental traced curve so as to correlate the obtained results with those obtained analytically. We use the slope value in the calculation of the longitudinal elastic modulus. The values of the lines are obtained with an accuracy of 0.021 for the coefficient of determination (R^2 = 0.9892). The error is therefore minimal. We note a similarity between the curve of the actual behavior and that of the ideal. Wecould have worked with a machine having elongation readers or sensors, we will not have largedifferencein measurements therefore in the layout. We start from this information mainly from the slope of the plotted curves to calculate the longitudinal elastic modulus (MOE). Density and MOE are classifying parameters of a material [1]. In the following table, we will see the MOE calculated on the basis of K (slope of the straight line) with the very significant coefficient of determination (R^2> 0.95). Table 1 shows the result of about forty-four samples tested at one level. This result is level 1(level very close to the bark). We have defined three levels. The trunk is divided into eight slats. The following table gives the wood (Rônier) density, the MOE and the force corresponding to a start of deformation.

At the end of the result, the MOE is 12649 daN/mm^2 with a standard deviation of 2010. This value is close to that of wood in general. The MOE of wood in general is between 10000 and 20000 daN/mm^2 according to the literature. The density is 0.97 g / cm^3 corresponding to that of wood in general. This density makes it possible to classify it among the heavy woods. The Rônier is a good quality wood.

3.2 Second evidence: Torsion test

This is the curve of a torsional sample. We record the moment in ordinate and the angle of torsion in abscissa. We see the complete curve and the linear area considered. The material remains elastic up to 8 degrees for a torsion moment equivalent to 337500 N mm.

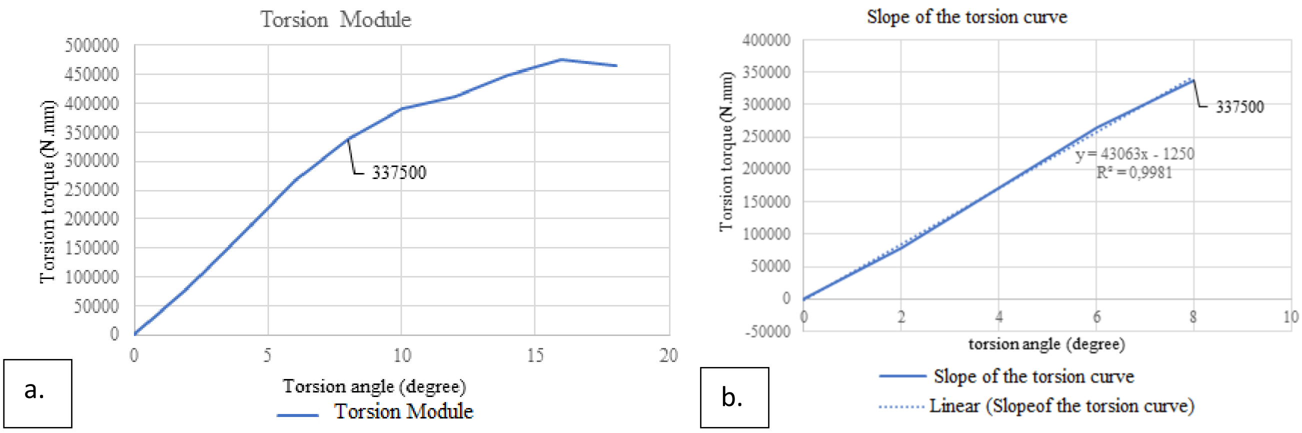

FIGURE 5: Presentation of the torsion test result
a. Complete curve b. Linear portion of the curve

We use the value of slopes in the calculation of the transverse modulus of elasticity. The value of the line is obtained with an accuracy of 0.002 (R^2 = 0.998). The error is therefore minimal.

This technique is based on the algorithm of the mechanical machines that record the data as if we are using a universal test machine. Thus through a fatigue machine or test bench, we performed almost the same bending curves. The errors are similar.

IV. CONCLUSION

Better knowledge of a material and its behavior in the face of the various demands require the deployment of an appropriate test machine and the important deposit to assess the quality of the result statistically. The absence of an adequate machine is solved by the development of a simple technique based on the ratio Stress / Elongation or Moment / Angle of torsion ratio. This experience constitutes the solution to the lack of machine. This technique will allow the learner to get to work. The combination of these two tests provides information about longitudinal and transverse modules with unexpected accuracy.

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