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Valorization of the *Borassus Aethiopum* wood behavior in tensile and bending

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Abstract

Aethiopum is a species of Borassus that is often seen in tropical Africa and has long been used for the construction of beams and poles. The buildings were never bent or damaged as a result of a termite attack. But as it became difficult to use this wood, it was abandoned. This study on wood observes closely its mechanical behavior in flexion and traction. Three-points bending and tensile tries were carried out in the longitudinal direction of the fibers on the samples. Borassus is basically made of intertwined fibers, making it a very elastic material. The packed structure of the fibers gives this wood a good resistance to bending and makes it strong in slab. The high compressive strength makes it possible to use wood as a post. Since wood is a living material, this work presents the range of the Borassus Young's modulus determined by experiments. The slope method used compares the behavior of the material according to two different incentives. Values were established by an Excel spreadsheet. The Young's modulus in tension is 16571 ± 1832 MPa, the modulus of elasticity in flexion is 23565.25 ± 3724 MPa. This article aims to contribute to the valorization of a traditional famous wood because of its natural virtues. In view of these results, we can say that Borassus is resistant to bending bite in traction.

Keywords: *Borassus Aethiopum,* tensile, 3 points bending, elasticity, Young modulus.

Introduction

Wood is a material much older than iron, copper, etc. It is as old as humanity. Since genesis of humanity, vegetation is born. Vegetation is composed of all the trees, small shrubs, and creepers. Tree is an element of vegetation. The main function of vegetation is to protect the soil against solar effects. Another role of vegetation is to the earth a temperature for life. The tree of vegetation feeds human beings (animals and human beings). People, in addition to leaves, fruits, use tree trunk for construction. It is used, exploited and supplied with no technological skills. Wood in a vegetable state is still in a state of strong humidity. Tree itself reacts in the face of many phenomena such as wind. Wood is a ligneous tree, a biological material made up of vegetal material the role of which is to ensure the conduction of raw sap from roots up to the leaves. The vegetal tissues are formed with material that is specialized in cellular division. They are called meristems, and responsible for the growth in length and width of plants. It is also used as mechanical support for the plant. It has characteristics that human being abusively exploits without looking for their values.

It is in this context that we will study the mechanical characteristics of a specimen called Aethiopum (a particular wood). The study of characterization started shyly. *Aethiopum* is a species of the kind known as *Borassus*. It is a monocotyledon plant that germs and the growth of which is similar to that of palm tree or coco tree. Through the bibliographic review, *Borassus Aethiopum* belongs to the large family of palmae. *Borassusaethiopum* is a plant that germs, grows and gets old. It has a cylindrical trunk and smooth called stipe. Like palm trees, *Borassus* produces wine, its leaves are used to make fans, its fruits are edible by people and elephants. For these assets, it is called providence plant[3,9]. The smooth stipe, after desquamation of petioles, unlike palm trees, offers a salutary and exploitable difference. Even though, at 25, palm tree undergoes desquamation, the stipe is not as smooth as the *Borassus*. This is one of the advantages. With coco tree, the family of palm tree, desquamation occurs very soon but varies according to species. The stipe is less smooth than the *Borassus*. The palm tree, the coco tree and the *Borassus* have similar cylindrical stipes, but there is a nuance in them. Only the *rônier* is very smooth and has hard crown where the structure is very packed. In the constructions the stipe of *Borassus* is splitted into boards with burins and they are used as beams and poles in West Africa[2,3,8,9]. These beams and poles remain for a long time without any deterioration or damage. The difficulty of its usage significantly reduces its exploitation.

In this work, in the light of the results from the tests, we will present the structure of this wood, its bending strength, tensile strength and compression strength. We will show a range of module of longitudinal elasticity or of Young for its use as a necessary parameter in the fields of simulation software (Solid Works).

Wood is a living material on the technological qualities of which many factors are based. In order to conduct a good study, the choice of the study zone, the conduct and the operational method should respect standard criteria during the tests.

There are many species of *Borassus* worldwide. On the Asian continent, specifically in India, the studies are carried out on the *Borassus Flabellifer*, the local species. Its stipe is not smooth. Wine is also made from it. Balakrishna and his team used the leave fibers in the construction of composite material in their axis or research of biomaterials that are environmentally friendly[5,4,6]. The natural fibers are prepared and then mixed with the plastic and tested. The purpose is to experimentally and analytically assess the density influence on the fibers. Velmurugan has mixed *Borassus* fibers with glass, a hybrid mixture along with the resin. He notices an improvement in mechanical properties and a drop in the water absorption of the components[3]. Different studies are conducted on the fibers of the fruit. The fibers of the raw fruits are processed, tested with different rates of concentration and used in the strengthening of the composite materials[6,11,12]. The fibers of fruits are extracted, washed with the solution of the caustic soda (NaOH).The fibers of the fruits are used in the strengthening of materials in order to give birth to a new material. These means helped to determine the chemical composition of the fruit and to sort out the impurities. The fibers of the petioles have gone through the same process[14,15]. They are used in mixture with the polyester, leading to improvement in the rate of resistance from 3.16% to 34.76%. The tensile strength is 56.69MPa.TheYoung modulus is about 1052.83 MPa. All these authors have used the fibers of fruits, petioles of the species *Flabelifer* and never the stipe.

In Africa, the studies have long started with the discovery of the tree, the species, its growth and its reparation in the world[9,3]. It is considered as the providence plant, since all the different parts are exploited The leaves are used to make baskets, mats and beds in Senegal, in Benin; Wine is made from the trunk[9,17]. The dominant species in tropical West Africa is *Aethiopum*[8]. Similar species may be found in other places. A providence plant, the fruit of *Borassus Aethiopum* is examined to discover concentrations of various nutritious elements. The study underscores the insufficient exploitation of fruits. The output is high for a concentration of 0.5 mg of pectinase at 35°C and underlines a natural sweetened taste and a bitter aftertaste. The species from the tropical Africa has a smooth trunk or stipe. On the belt, the hard crown of trunk has been exploited in the roofs in West Africa. Works of experimental characterization have been done on this zone of the plant through mechanical tests such as tensile and bending[1,2,13].Samah's team has also determined the elasticity module E (1590 daN/mm^2) and the average constraint of adherence of concrete[13]. The test tubes are shaped and assembled by screws for the tensile test. But the technique they used, the form and the position of the test tube don't correspond to the French standard of wood (NF B 51). Some of their results are similar to those of our DEA works (Modelling of a pale of an aero generator on a local material: determination of mechanical characteristic of palmae), namely the basal volume mass, the longitudinal Young modulus. Gbaguidi's team carried on its works by the determination of thermal diffusion, the specific mass heat. These parameters make it possible to assess the thermal conductivity and effectivity of *Borassus*[7]. In searchof biodegradable material in construction in civil engineering, a comparative study has been completed by the formulation and the characterization. The cement has been taken as matrix to reinforced by *Borassus* fibers and the rice ballots[7]. A study has been also conducted to determine the density effect on variation of fibers on the mechanic properties[10]. It is carried out in different places of the trunk in the longitudinal direction.

Because of its form, the trunk of *Flabellifer* has been not yet dealt with. But as for the *Aethiopum* species, the trunk remains the focal point of many people. This tree is much exploited for various reasons. Wood being a living material, to our knowledge and to our humble opinion, there may be only a range of values of longitudinal elasticity module for these materials. For that there are many methods that help with the determination of this module for a chosen material. We can, among others, mention the destructive method of the test tube and the non-destructive method. The destructive method consists in destroying the test tube. The method of the slope of the characteristic straight or equation of tendency remains true for evaluating the tensile strength, the bending strength of the material.

Since for bite than thirty years or so, the organization department *(Cirad),* has conducted a great deal of researches on the forestry ecosystems in West Africa. Unfortunately, all the species of plants were not taken into account for their valorization[13]. These materials are local materials. In the course of synthesis works on the technological characteristics of reference for main commercial African woods, we can mention Acajou, Bamboo, Teck, Iroco, etc. Based on different forms they are exploited in one way or another. These woods mostly resist very little the champignon attacks, the xylophages(insects and termites) of wood, but are much bite exploited. Wood as the subject of our study presents specificity. It presents a rot proof and hard crown that protects against termites and xylophage. It is about the *rônier* called *Borassus Aethipum*. It offers a hard and exploitable part on which we base our study. The interest of this study is to search and vulgarize this tropical wood. The research will help provide information on this wood and its insertion in the database according to the forestry policy of *CiradForet*[10]. The voluminalmass of *Borassus* may be variable. But by remaining in the crown zone, it exceeds 950 kg/m^3, it is therefore considered as a very heavy wood[13].

Materials and methods

Vegetal material: *Borassus Eathiopum* is the species used in this work. The *Borassus* plant (Figure-1) is a tree discovered in the tropical zone of Africa, in the Southern Asia, in the Islands of the Pacific and the Indian Oceans. It is a component of the kinds of *Borassee*[9]. The African species is *Borassus Eathiopum***.** This tree, adult, measures from 15 to 20 meters. It has, in the early stage, an aspect of a column that is slightly thick and significantly bulging in the middle. When it is as high as an adult the diameter of the stipe reaches 30 to 40 centimeters. The trunk is covered with dried sheath of petioles. The petioles possess thorns on a length of 30 to 40 cm. In young plants the petioles are spread over the whole length of the stipe. The uprooting of sheath of petioles known as desquamation unfolds in cascade from top to bottom, making the stipe to be smooth. The diameter of the trunk varies by the twenty-fifth year. When adult, the leaves are gathered at the summit of the stipe into a bunch. We are interested in the stipe of an adult subject. The stipe has an external hard crown around a spongious part in the circle of cross section (Figure-3). The crown has a very packed structure which makes it much resistant, rot roof, in attackable by insects and mollusks. The crown has remained the focal point of many studies, especially in West Africa. It varies depending on whether it is a female of a male. On a male subject, the thickness of the crown varies between 7 and 10 cm. However, the thickness by a female comprises between 4 and 5 cm before the first bulge[9]. The spongious part is not exploitable and has no mechanical value. We will be interested in the crown of the tree for our study. It is a part of the tree that is very hard and often used in the constructions in the form of boards[1,8,9,13] (Figure-4).

Figure-1: Vegetal material: Stipe of the tree.

Figure-2: Wood saw.

Figure-3 : Cross section of the tree.

Figure-4: Rafters or Slats of the tree.

Figure-3 presents the cross section which shows the hard zone and the spongy zone. The hard zone is the extraction zone and the spongy zone is circumscribed by the circle. Slats or Rafters are extracted from the hard zone. Here, it is about rafters of the trunk from three different areas. Slats are extracted from the crown of the stipe. Slats are traditionally obtained from works where gravers are used as tools. But nowadays, they are processed with the wood saw (Figure-2).

Materials: the tensile test is carried out on the tensile machine of the brand Zwick / Roell (Figure-5). It is a machine that is manufactured in Germany. It has two columns linked by two struts on top and at bottom. The upper strut is mobile. The lower strut is immobile. It carries each a mooring device with two bits. The bits of the machine apply to the head of the test tube a tightening force that is constantly maintained during the test. The tightening force is distributed over each head of the test tube. They carry striated surfaces. The striated surfaces of the bits prevent any slide following the applied direction of the tensile. After that everything is well set on the machine, the machine starts the tensile.

The bank of tiredness INSTRON (Figure-6), of the brand Zwick / Roell also made in Germany is used for the bending test. It has a capacity of 10 kN and a speed equals to 50 mm/100s. It is a machine for test ensuring the movement of the mobile head and allowing measuring the charge exerted with a good precision. The bank is composed of two columns topped by a beam (strut). The beam supports the presser jack of 10 kN. The bending test is completed on a device constituted of two free cylindrical and horizontal supports in rotation of one diameter of 60 mm and distant between axes with a value 1=320 mm and a support with horizontal cylindrical head of the same diameter, in the middle of the bending bank.

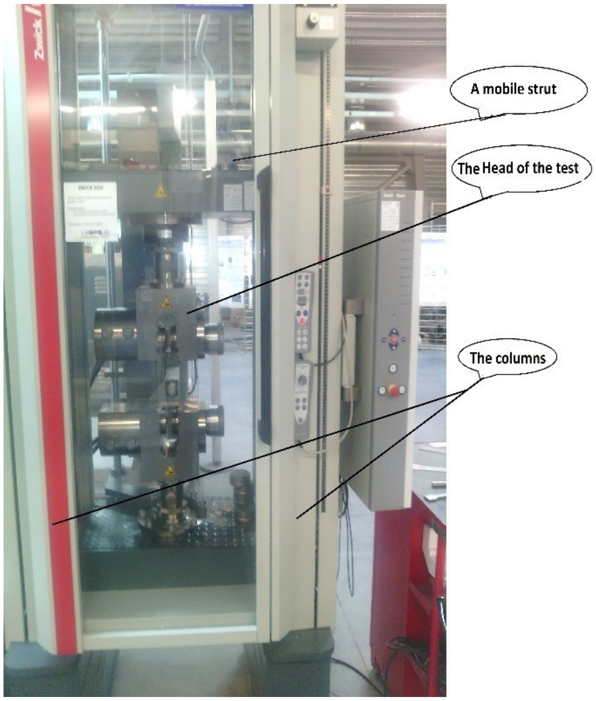


Figure-5: Tensile machine.

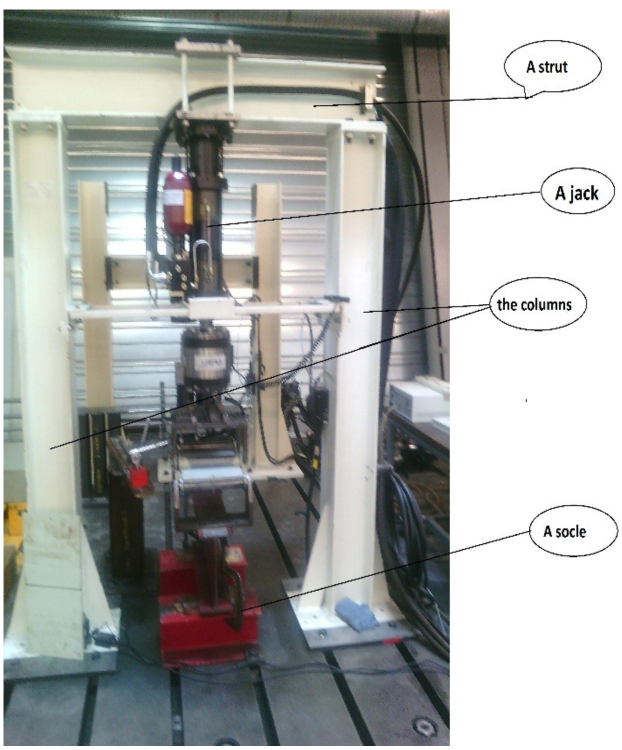


Figure-6: Bending machine.

They are machines (Figures-5 and 6) that provide tests results with a very high precision and a unique easiness of usage. The test speed is not dependent on the applied charge on the test tube. It is comprised between 0.2 and 0.4 mm/s. They belong to the structural laboratory in France.

Methods: We used slats from different areas in southern Togo. The slats are then worked out on wood machines.

The tests remain the necessary stage for acceding to the characteristic sizes of materials, the longitudinal module of elasticity or Young modulus at the limit of elasticity, by going through tenacity or resistance to the tiredness, and this, in variable conditions, for instance the temperature or speed of touches. There are many techniques that may help to determine longitudinal module of elasticity by way of destructive tests or through vibratory method. But, we will only determine the Young modulus by using destructive tests. In order to better know and valorize this wood, the determination of Young modulus is essential. It will be completed in the tests of tensile and bending in 3 points in order to analyze the results. The Young modulus, a constant that establishes proportionality between the charge applied to the material and its resulting deformation. The uniaxes that are quasi-static are carried out. The uniaxial characteristic allows us to directly exploit the results. During the test, the force exerted on the test tube to bring about an extension depends on the section of touch. The extension also depends on the initial length. Reasons why, results gained from the tests are treated to obtain the constraint and the deformation of the test tubes. We conducted three tests of the longitudinal direction of the fibers: tensile and bending. Charges are applied in parallel to the direction of the fibers. The tests are performed on a number of groups of test tubes the curves of which can be found in figure9 &10. The different test tubes have been collected from the same zone (zone where *Borassus* is exploited). Each group is composed of fifteen samples. The tests are performed according to the French standard for wood (NF B 51- 007; NF B51- 008; NF B 51- 018). The slats are worked out on tool-machines (planning machine, universal milling machine) to get the standardized dimensions according to the type of the test. The test tubes are dry. The tests are carried out at a temperature of 18°C.

From the test data, after having treated them, we draw a part of the curves in the elastic zone and the equation in the trend straight (Figure-9 and 10). The slope of the equation of this straight is the Young modulus viewed as the target of the experiment. In order to determine the longitudinal module of elasticity or Young modulus, we will consider the elasticity zone of the different curves. We find it again through the trend curve obtained by the software Excel. With the Excel it is possible to manipulate the digital data (results) gained during the test.

Tensile test: The tensile test is one of the most used tests for mechanical characterization of materials. With this test, when it is uniaxial, we can avoid inverse calculation methods to directly reach a law of uniaxial behavior. It allows determining the longitudinal module of elasticity or Young modulus, the limit of elasticity and the maximal constraint[4]. The test is carried out according to the longitudinal direction of the fibers. The test tube is prismatic and shaped according the French standard FN

B 51-018. Its dimensions are 20 x 20 x 350 mm^3. Once the test tube is available, a slight precharge is applied to make sure everything is correctly set. The test tube, being fixed between bits, is moored to its lower part at the base of the machine and at its upper part at the jack of the tensile. The upward movement corresponds to how the tensile is completed. The speed of the test is 0.2 mm/s. The test tube of the tensile (Figure-7) in line with the French standard FN B 51- 018 is shaped with the extremities of the mooring heads. By the center we have a soul of constant section 4±0.2 x 20±0.1 mm^2 on a length of 90±2 mm. In order to avoid constraint concentration, there is a great curve between the head and the soul. During the test, the recorded data correspond to the relative extension, the constraint and the time of the test. The time should be 1.5 min ± 0.5. The test is completed on dried test tubes.

In view of the variations of the force of tensile in relation to the section of the test tube and the extension of the test tube on the basis of the initial length, we, therefore, rather draw the longitudinal curve σ according to the marked deformation ε (relative extension). It is in fact, intended to report the force to the initial section S_o and the extension Δl to the initial length l_o. We obtain then a conventional curve. The following equations (1 & 2) provide the constraint and the unitary extension.

$$\sigma = \frac{F}{S_0} \quad (1)$$

And

$$\varepsilon = \frac{\Delta l}{l_0} \quad (2)$$

σ: constraint (N/mm^2), F: Tensile stress (N), S_o: initial section (mm^2), ΔI: extension(mm), l_o: initial length(mm), ε: unitary extension.

The data enabled us to draw bend (stress, buckling) of the Figure-7. A bend represents an average of around ten test tubes. Each of the bend presents a linear zone and disturbances. The appearance of the first disturbance is the first dislocation between the fibers in the knit. It corresponds to the elastic resistance or the elastic limit. It occurs between 17 and 35% of the unitary extension. A first series of fibers is uprooted from others. This point of dislocation corresponds to the elastic resistance of the limit of elasticity in the linear zone of the bend from this linear zone, we define the Young modulus (Figure-11 and 12).

Bending test: With the bending test, it is possible to determine the constraint of breakup under a gradually constant charge exerted in perpendicular to the thread of the wood. It may be at three (3) or four (4) points. In our case, it is about a bending with 3 points or supports. The test tube is put on a device with two supports. The distance between the supports on the bank is 320 mm. The pressing charge is applied in the middle of the test tube. The test tubes (Figure-8) have a straight prismatic form at the square section of 20 ± 0.2 mm on side and a parallel length to the thread of the wood of 360 ± 4 mm. The time of the test should be 1.5 mm ± 0.5 according to the French standard FN B 51- 008.

The measure of the elasticity of the wood recommended by the international standards ISO[15] should be applied in the bending tests. In bending, the *Borassus* changes shape and volume under the influence of the applied constraint. The elasticity Young modulus (E) depends on two parameters: the buckling or elongation (ε) and the stress (σ). The stress and the buckling or elongation are determined according to the data of the effort, the displacement and other dimensions of the test tube. Owing to the following equations (4, 5 and 6), we deduct the expressions (3 and 7) that can be used in the draw of the bend stress / buckling:

$$\varepsilon = \frac{6\,de}{L^2} \quad (3)$$

$$\sigma = \frac{M}{\frac{I}{y}}, \quad (4)$$

$$M = \frac{F}{2} \cdot \frac{L}{2} \quad (5)$$

With $y = \frac{e}{2}$

$$\mathbf{I} = \frac{l.e^3}{12} \quad (6)$$

$$\sigma = \frac{F.L}{4.\mathbf{I}} \cdot \frac{e}{2},$$

$$\sigma = \frac{3}{2}\frac{L}{l} \cdot \frac{F}{e^2} \quad (7)$$

F: Bending force (N); M: Bending moment (N.m); I: Quadratic moment of the sample; L: Distance between the two supports; d: Vertical displacement of the sample (m); l: Length (m); e: Thickness (m).

We therefore draw the stress bend / buckling (Figure-9.) in the elastic zone through the method developed above.

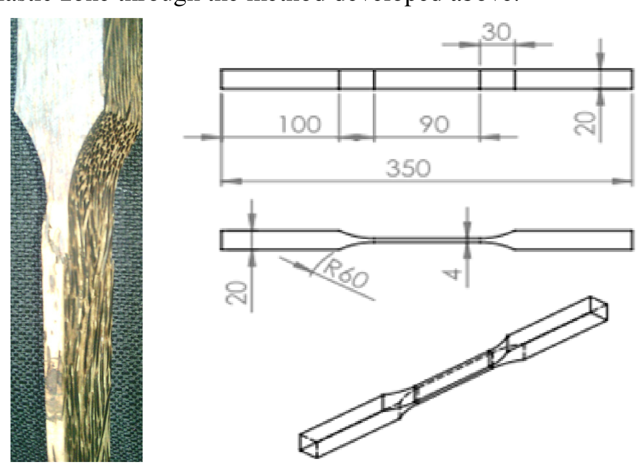


Figure-7: Tensile test tubes.

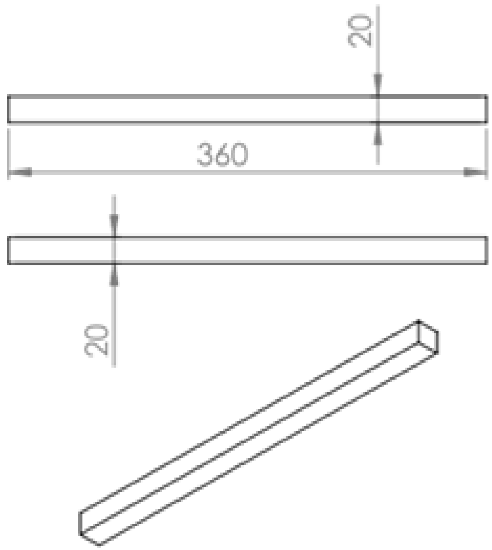


Figure-8: Bending test pieces.

The different bends are the results of 15 samples for the tensile and 15 samples for the bending. We were not rigorous as regards the respect of the position of the samples in the plans. Yet, being an anisotropic material, the position will have an influence on the results. *Borassus* is composed of fibers that are intermingled. They seem not to be continuous.

Results and discussion

The different Figures-9, 10 represent the experimental results of the *Borassus*. It traces back the behavior of this wood subject to these different touches. The wood, in general, is elastic; so is the *Borassus* too. The wood *Borassus* is composed of a matrix (binder) and fibers. Fibers have linear elastic behavior. Without any analysis, we can affirm that the behavior of the matrix will be similar to that of caoutchouc. Yet, the caoutchouc is elastic.

In Tensile (Figure-9), the wood *Borassus* remains elastic up to 0.20%. The fibers are hard like steel. In addition, the first breakups of the fibers are seen. The fibers of *Borassus* are not linear but they are rather intermingled. With the appearance of the breakup, they remain stand together. They break apart hardly. Wood conserves elasticity up to 0.60% of its buckling. The presence of the binders causes the elasticity of the material to rise. The breakup is not straight. The broken fibers are maintained with binders for a moment before breaking up.

In bending (Figure-10), the *Borassus* remains elastic up to 0.60% of its deformation. The elasticity is very high in bending. In bending, the fibers are not cut up, but rather they stick together. They close the cavities of the sap circulations. The breadth of these cavities depends on the considered zone. Where the fiber is not mature (zone where we are), outside 10 cm for males and 6 cm for the females, the cavity becomes more important. The binder, in this case, plays the role of the eraser of shock absorber.

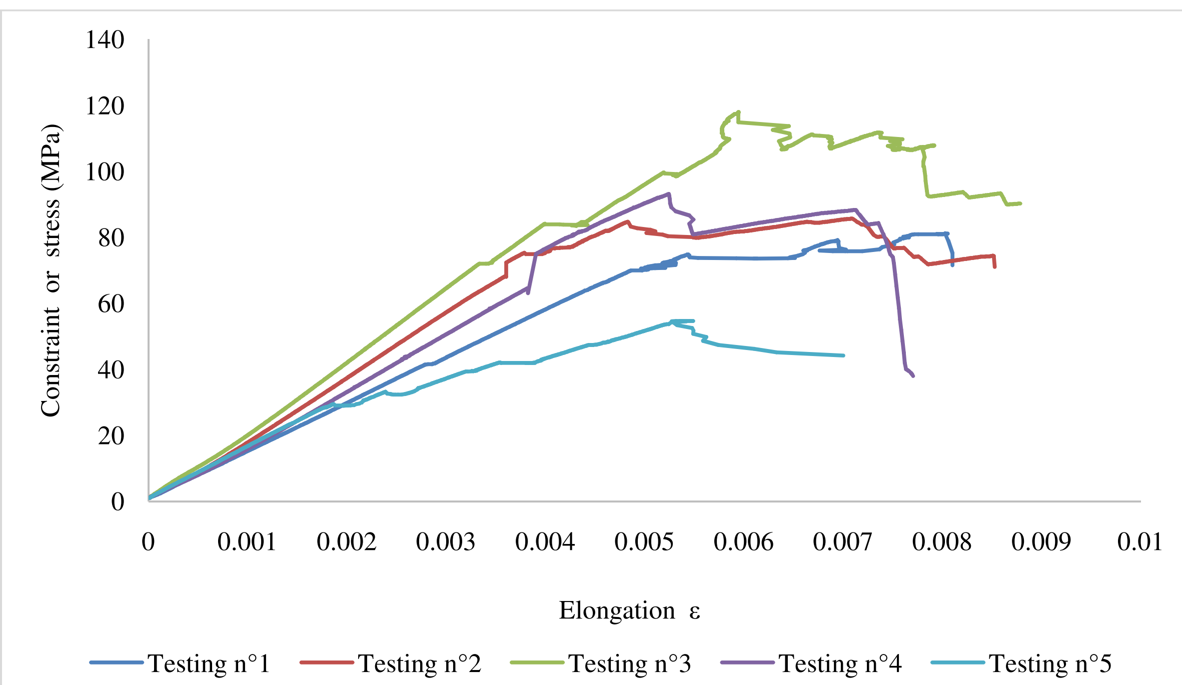


Figure-9: Tensile result.

This elasticity is seen in the three illustrations by the presence of the linearity of the curves before the first buckling. The Figures-11 and 12 show the elastic characteristic of the *Borassus*. In the elastic zone, the slope of the characteristic line is the Young's modulus.

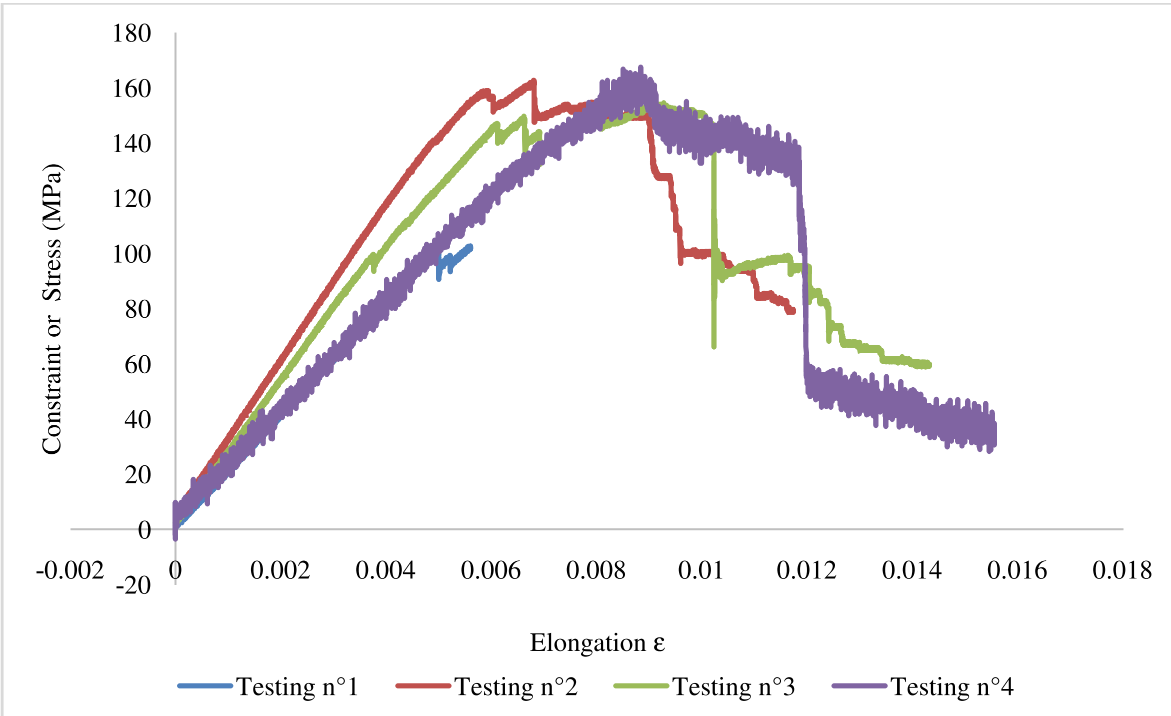
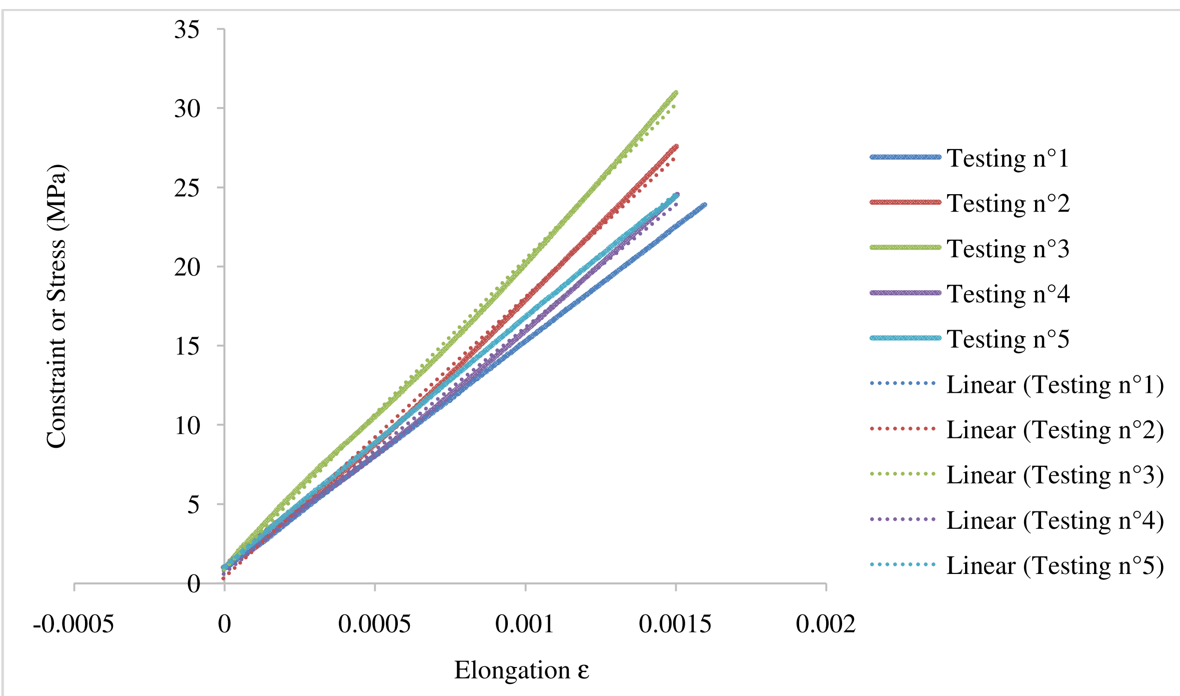
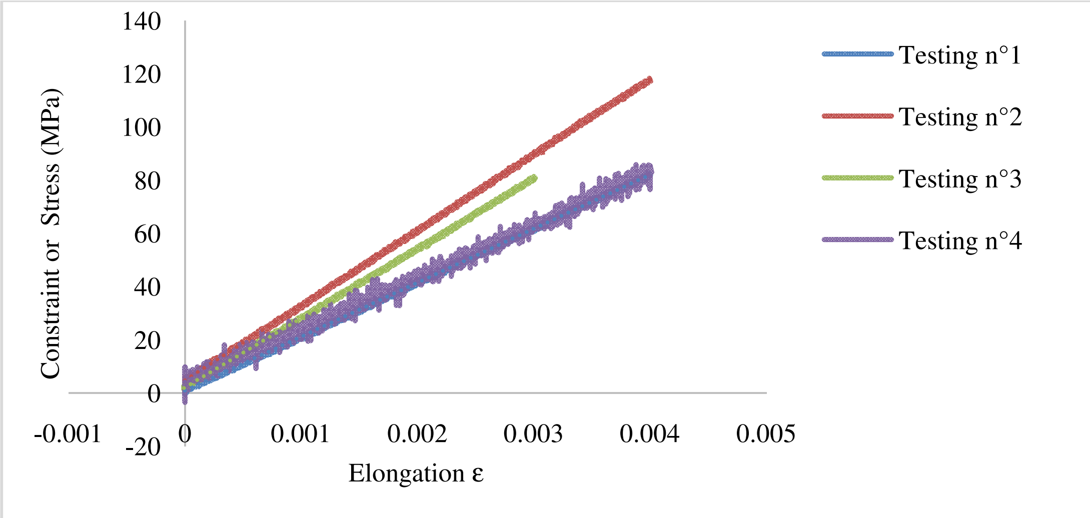


Figure-10: Bending result.



y_1=14420x + 0,8581 R2 = 1, y_2 = 17669x + 0,3924 R^2= 0,9976, y_3 = 19575x + 0,8827 R^2= 0,9988, y_4 = 15504x + 0,6405 R^2= 0,9984, y_5 = 15687x + 1,0684 R^2= 0,9999.

Figure-11: In tensile, Slope of the characteristic straight lines.



$y_1 = 20304x + 0,9497$ $R^2=0,9998$, $y_2 = 28300x + 4,8494$ $R^2=0,9999$, $y_3= 26095x + 2,2135$ $R^2=0,9998$, $y_4= 19562x + 4,3694$ $R^2=0,9982$.

Figure-12 : In bending, Slope of the characteristic straight lines.

Borassus is very smooth both in bending and in tensile. This wood is composed of fibers and matrix and has a structure where there is no order in a long distance between the fibers. The fibers length is not identical. The fibers shape is not the same. Then, during the bending, fibers slide among each other and come together owing to the vacuum inside the binders and fibers. This is possible due to the fact that wood is an amorphous material. The character of the wood is similar to that of amorphous material. The longitudinal module of elasticity E is a crucial parameter of technology for the usages in the structure where the pieces of the wood are frequently asked in static bending following their greatest direction, parallel to the fibers. During the tests many phenomena happened. The drawing of the bend of the test will give an idea about the behavior of the material. Based on the data obtained from the tests, we can draw the stress bend/buckling. We will be interested in the linear zone of the bend. It translates the elasticity of the material. The module of elasticity is the slope of the trend bend obtained[13]. Figure-11 and 12 presents the pace of different bend taken in the elastic zone. The wood is anisotropic and orthotropic material. The range of the Young modulus is comprised between 9 000 and 20 000 MPa as presented by Sciences and technologies of industries and sustainable development. The same literature affirms that the Young modulus of *Bamboo* is 20 000 MPa. We will deal with two tests: tensile and bending.

Tensile test: During the tensiletest, the contraction should happen at the level of the median (in the middle of the test tube). The contraction does not occur in the median plan but rather in a random way. The fibers are not cut up but rather loose from each other on the periphery. The Figure-14 has illustrated the pictures of the state of the test tubes of tensile. The middle of the test tube that should shrink is rather swollen.

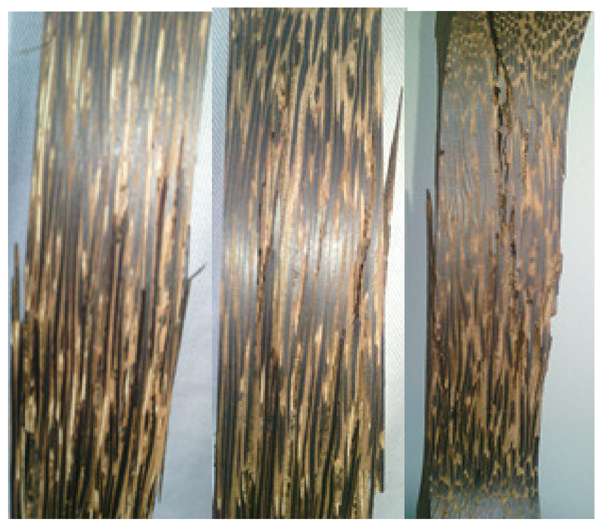


Figure-13 : Test tube after tensile.

Figure-14: Test tube after bending.

Figure-13 and 14 presents the aspect of the test tubes after the different tests (tensile and bending). The resistance of this wood might, on the one hand, be enhanced if the fibers are all continuous and if there is no binder or matrix. The matrix is a weakness for the wood. The fact that the fibers stick together is a very predominant asset in the structure. This fact strengthens the elastic character of the material.

This factor changes the mechanical aspect of the wood. The fibers are intermingled. In the course of the test the fibers don't get withdrawn very quickly enough, which gives to this wood an important elastic state.

With the tensile test the determination of the Young modulus a material is possible. From different bends, the slope of the elastic zone is the elasticity module, as said above. We have different values of the longitudinal module of elasticity or the Young modulus as shown on table 1. It is comprised between 14420 and 19575 MPa and is lower than that of Bamboo (20000 MPa). The Bamboo is also a construction material that presents knots. The maximal value of the Young modulus (19575 MPa) translates the resistant character of the zones close to the bark where the fibers are very tight and where we have fewer binders. The minimal value of the Young modulus (14420 MPa) corresponds to the area where the presence of the binder is important. The average gives a value of 16571±1838 MPa as shown on the Table-1. The resulted gap leads to the assessment of the precision in the samples collections. The gap is wide when the samples are not collected in the same zone.

These values represent the approximate values of the exploitable zone. The value of tests 2 and 3 translate the important presence of fibers; the presence of the matrix or binder is negligible. It is already said above that the density of the fibers translate the rigidity of the wood[1,2,8,13]. The value of the test 1 is only the illustration of the massive presence of the binder. The physiological aspect gives the variation of the resistance on the radial plan. The binder being not rigid, its presence weakens the material. The exploitation of this wood will be based on the consideration of parameters of each zone.

Bending test: The behavior of materials that are, in general, subject to various touches depends on their ability to lose their shape very quickly. This suppleness confers upon it the rheological behavior. The *Borassus*, heterogenic material wood, does not totally provide this flexibility. Not all the fibers undergo the bending in the event of any touch. The observation of the tested test tubes is also a proof that the fibers of the *Borassus* don't break up during the test. They free themselves if possible (Figure-14).

As for the tensile, the different bends of the figure14 represent the illustration of a series of test tubes of the same dimensions and the same mass for the bending. Table 2 gives us as is the case previously the values of the longitudinal elastic module in bending. The range is comprised between 28149 MPa and 19 358 MPa. Study zones should be considered for an effective exploitation of this wood. When the fibers are well mature, they become almost black.

There is a quasi-total absence of the matrix. The registered values in bending are slightly higher than the range supplied by sciences and technologies. Comparing these two results, a conclusion shows up. *Borassus* is more resistant in bending than in tensile. These values are of no surprise since the Bamboo, a wood with great knot, has a module equals 20000 GPa. The works of Gbaguidi in 2010 confirm these results. This value is close to 17 196.86 ± 1145.19 MPa as discovered by a team of Benin[8]. It is close to 15 900 MPa provided byAtcholi[2].

For comparison, the bamboo's elastic module equals 20000 MPa, despite the fact that it presents knots. This value is the one presented in the catalog of Sciences and Technologies. The *Borassus*, on the zone close to the bark, has an elastic module comprised between 25 992 and 28 149 MPa as shown on Table-2. *Borassus* provides a much higher performance than Bamboo.

The dispersion of these results is due to many factors, particularly the zone of collection and the place of the test tube during the test. We earlier explained the issue of the collection zone by talking about a non-conform behavior of the *Borassus* based on the diameter.

Table-1: Longitudinal module of elasticity or Young modulus intensile test.

	Testing n°1	Testing n°2	Testing n°3	Testing n°4	Testing n°5	Average
Module of Young	14420	17669	19575	15504	15687	16571 ± 1832 MPa

Table 2: Longitudinal module of elasticity or Young modulus in bending test (dried-up test tube).

	Testing n°1	Testing n°2	Testing n°3	Testing n°4	Average
Module of Young	20304	28300	26095	19562	*23565.25 ± 3724 MPa*

Conclusion

Borassus, like any other wood, react well in bending. It remains important because of its longitudinal elasticity. This property enables it to be used in the construction. It can be used as beam or rafter. With the ductility aspect of the *Borassus* we can possibly recommend the use of *Borassus* for poles. *Borassus* remains, then, a wood for construction due to its impressive mechanical performances.

The Young modulus is a mechanical parameter necessary for a material. The determination of this parameter can be carried out with the help of some techniques, either destructive or not. The parameter we determined during the present work provides the range of the Young modulus. It lies between 16571 and 23634 MPa. This result is close to that of the Bamboo. These tests are uniaxial. *Borassus* remains a more resistant wood than Bamboo whose Young modulus is 20000 MPa. Borassus wood is more elastic and stronger than Bamboo. His performance in construction proves it and the values found during our mechanical tests qualify him. It is recommendable among the timbers.

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