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RESEARCH ARTICLE

MECHANICAL CHARACTERIZATION OF RONIER WOOD FOR ITS USE IN THE DESIGN OF WINDMILL BLADES.

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Abstract

Wind energy and the materials that support the production of this energy remain a challenge. The work carried out aims to verify the possibility of using *Borassus Aethiopum* wood in the wind turbine industry. This study of this wood closely observes the resistance to weather, insects and its mechanical behavior in bending and its resistance in water and in the face of solar radiation. Immersion, three-point bending tests were carried out in the longitudinal direction of the fibers on the samples. *Borassus* is essentially composed of intertwined fibers, making it a very elastic material. Since wood is a material that does not withstand water, this book presents the behavior of *Borassus* in the face of water and the effects of sun radiation. Experimental surveys have evaluated the duration of absorption of this wood, as well as the simple bending test. Curves have been established by the Excel spreadsheet.

The analysis of the different results showed that *Borassus Aethiopum* wood has a compact structure of fibers, has good flexural strength and makes it resistant to the weather. *Borassus* wood may be well suited for wind turbine blades, but for wind turbines of nominal power not exceeding 7.097 kW.

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Introduction:-

The depletion of conventional energy resources and the fight against greenhouse gases are the main causes of renewed interest in renewable energies in recent years. Among the many clean or green energy sources, there is wind energy [1].

The aerogenerator transforms the kinetic energy of the wind into mechanical energy. It is then converted into electrical energy by an electromagnetic generator coupled to the wind turbine [2]. This transformation uses a wind turbine whose essential element is the blade. The electric power supplied by an aerogenerator at its output depends essentially on the surface swept by the rotating blades. Thus, obtaining a high electrical power requires blades of large sizes [3].

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The development of wind energy is closely linked to the evolution of wind turbine construction techniques and their performance, particularly the design of wind turbine blades [4]. Wind turbine blades are critical elements. They are subject to vibration, stability and resistance problems during the operation of the wind turbine.

The materials used for wind turbine blades have evolved. Materials such as metals, ceramics, polymers and composites used today can be cited. The criteria for choosing a material for the construction of a wind blade are the main functions of the construction (stresses, temperatures, conditions of use), property of the material (resistance, conductivity, etc.) and the cost price. Wood in general is a lightweight, easy-to-work material that is resistant to fatigue but sensitive to erosion and has low resistance to deformation [5]. The wood is usually reserved for small sized blades.

In the modern industry of wind turbine blades, 95% of the materials used are based on composite materials [6]. Fiber-based composite materials solve the problem of various blade stresses [7], [8].

The purpose of this article is to study the feasibility of using Borassus Aethiopum Mart.) In the design and construction of wind turbine blades, resistant to strong gusts of wind, shocks and weather conditions. difficult, at a controlled cost and respectful of the environment. The results obtained will lead to conclusions that can be exploited by the wind industry.

The choice of a responsive material for the wind turbine remains a serious subject. Normally the choice of a material for the wind turbine is not a problem. But Borassus Aethiopum remains a particular wood that can meet the mechanical characteristics desired for the realization of the blades. Aethiopum is a species of the genus known as Borassus. He is known as the rônier. It is a monocotyledonous plant with seeds and whose growth is similar to that of the palm or coconut palm. The study of characterization began timidly [9].

Through the bibliographic review, Borassus Aethiopum belongs to the large family of palmae [10]. Borassus aethiopum is a plant that germinates, grows and ages. It has a cylindrical trunk and smooth but considered a false trunk called stipe [11]. Like palms, Borassus produces wine, its leaves are used for the manufacture of fans. Its fruits are edible for humans and elephants. For these assets, it is called the plant of providence [11]. The smooth foot, after the peeling of the petioles, unlike the palms, offers a salutary and exploitable difference. With coconut palms, the family of palms, desquamation occurs very early (around five years) but varies according to the species. The stipe of the coconut palm and the palm is less smooth than the Borassus. Borassus Aethiopum has a singularity in its germination and growth [12]. It has a tough, rot-proof crown that protects against termites and xylophagus. It offers a difficult and exploitable part on which we base our study. The interest of this study is exposed the behavior of this tropical wood. The research will help confirm this among the lumber. In the constructions, the section of Borassus is divided into planks with chisels and is used as beams and poles in West Africa. These beams and poles stay a long time, without any deterioration or damage. However, the difficulty of its use considerably reduces its exploitation.

In this work, in the light of the test results, we will present the behavior of this wood facing the water for twenty days, its resistance to bending at three points. But by approaching its exploitation in a wind environment (realization of blades), the behavior will differ. The blades have a recessed (locked) end. The possibility of flexion is greater. The method of conduct and the operational method must meet the standard criteria during the tests.

Material and methods:-

Materials :

Our working materials are the plant material (wood), water and the flexural test bench.

Plant Material :

Wood is an old building material as humanity. The man uses the tree trunk without necessarily knowing the technological competence. The wood comes from the tree. The tree is often subject to the action of wind forces; in short, the tree is flexed. The destructive agent is water.

Borassus Eathiopum is the species of wood used in this work. The Borassus plant (Figure 1) is a tree found in the tropical zone of Africa, Southeast Asia, the Pacific Islands and the Indian Ocean It is a component of the Borassee types [11]. The African species is Borassus Eathiopum. An adult subject can measure 15 to 20 meters [11] in height. On the ground and at the roots, the species has the appearance of a slightly thick column with a stipe diameter of

between 300 and 400 millimeters. The trunk is often covered with a dried sheath of petioles that fall when the tree becomes mature [11]. The drop of the petioles known as peeling is cascading up and down, making the stipe smooth. There is a male *Borassus* and a female.

In our case, we are interested in an adult subject. The basic reason is that the stipe has a harder and wider outer crown. This crown has a very compact structure that makes it much more resistant, rot-proof, unassailable by insects and molluscs. The crown has remained at the center of many studies, particularly in West Africa. After the crown, there is the spongy central part. It is not exploitable and has no mechanical value. It is made of fibers. The following views expose the stipe or trunk, the power saw, slices or slats and chopsticks.



Figure-1: Plant material: standing tree standing



Figure 2: Section of the stipe



Figure -3: Chain saw



Figure-4: Stipe slices to produce herring bone



Figure-5: Test rods extracted from slats

Figure 2 shows the cross section showing the hard zone and the spongy zone. The hard zone is the extraction zone and the spongy zone is delimited by the circle and is located towards the center of the circle. The slats or rafters are extracted from the hard zone. Figure 4 shows slices of the stipe. They will be worked to produce rafters. Here, it is trunk rafters from three different areas. The slats are extracted from the crown of the stipe by means of the chain saw (Fig. 3) for cutting or machining wood. Chopsticks are extracted from rafters. From the chopsticks taken from the hard zone, small samples are cut. We see them deposited in experimental tanks in the following figure (Fig. 6).

Water :

Two types of water are used. This is seawater and rainwater. Rainwater has a pH (Hydrogen potential) almost equal to 7. We consider rainwater as neutral. We consider salt water to have a pH different from 7, so able to react either as an acid or a base.

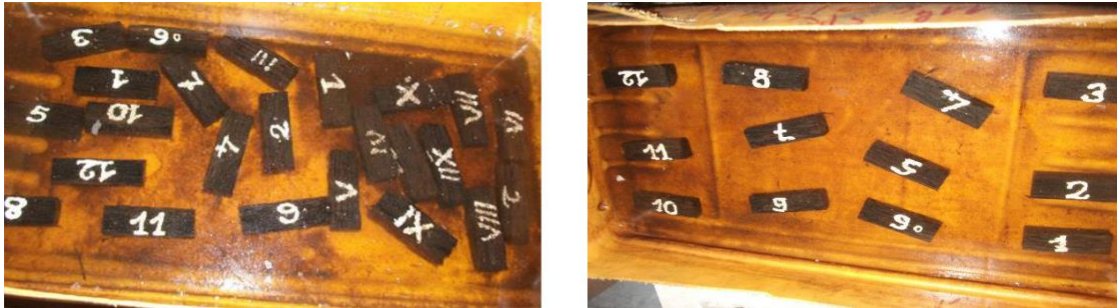


Figure 6:-Water containers with test specimens for immersion tests.

The test machine : it is a press CBR (fig.7) motorized civil engineering brand CONTROLS. The press has a capacity of 50 kN, a power of 0.30 kW and is equipped with two columns, a mechanical cylinder and a comparator for reading the pressure force (pressure force). It was modified by providing, for our three-point bending tests, a second distortion reading comparator and a bending device used to support the test pieces. The device consists of two vertical supports at a distance of 320 mm and another adjustable cylindrical head support.



Figure 7:-CBR Press

Bending device



Figure-8: CBR press with bending device



Figure 9: Shapes of specimens

Methods:-

Our samples or test pieces (Fig. 9) of tests are taken from slats of Togo. The method of obtaining the slats is a little described during the presentation of the plant material. The slats are then worked on woodworking machines. This material will be used in many environments such as water, sun and wind. He will be on a wind turbine.

To demonstrate the physical strength of Borassus in nature, several tests can be made including drying laths under the sun (conditioned drying), abandonment in the wild under the wind, the sun and rain (natural drying). The method consists in evaluating the action of the sun or the water on this wood under these conditions of drying. For this, we put the test pieces of this wood in water for several days. We consider distilled water and sea water. This immersion time remains a maximum condition of use; which is not possible because it will never rain for twenty days. The specimens are put in the tanks containing water. All specimens are completely immersed in water. They rest at the bottom of the water. The duration of the examination is about twenty days. We will measure the mass of all specimens before immersion. And we do daily readings during the experiment.

The most important element in a wind machine is the blade. The study of the blade leads to the knowledge of the complete profile whose cross section corresponds to that of figure 10 [14].

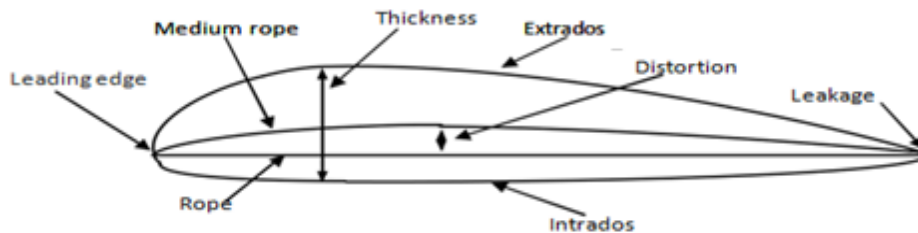


Figure-10: Profile of a blade

The section of the profile is not regular nevertheless it is assumed that all the samples taken in this section will be solicited almost completely in the same way. The blade will be constantly subjected to the action of the wind. The action of the wind is not concentrated in the middle. It is evenly distributed over the length of the blade. Depending on the length, the blade is bent. In the transverse direction (width direction), the blade can be twisted (combination of flexions). But in this article, the simple bending (Fig. 11) in the longitudinal direction will be exposed and then the data will be transformed into those of the bending of an embedded beam (Fig.12).

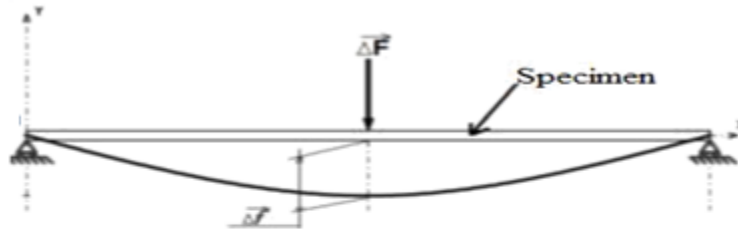


Figure 11: Simple bending

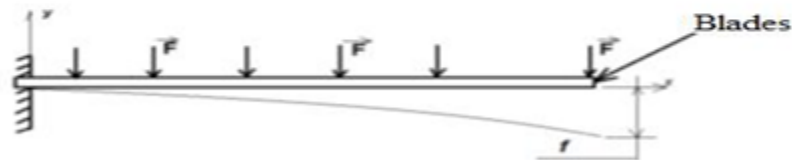


Figure 12: Bending a recessed beam

To access the characteristic quantities of this wood, tests or tests remain the necessary stage. Many techniques determine the longitudinal modulus of elasticity (MOE) by means of destructive tests or by the vibratory method. To have this flexural modulus, the destruction test is adopted because of the machine we have. The test pieces are subjected to three-point bending tests (single bending). They were made in the exploitation zone (hard zone). The tests are carried out according to the French standard for wood (NF B51-009). The laths are worked on machine tools (cutting or cutting machine) to obtain the standardized dimensions of the chopsticks. Chopsticks are cut into small test tubes. The tests are carried out at a temperature of 25 ° C. The specimens are made in the longitudinal direction (fiber direction).

In bending, the elasticity of a material depends on two parameters: the unit elongation (ϵ) and the stress (σ) or the resistance to the various stresses. The following exercise is specific to the bending stresses with three supports. By exerting a force on the specimen, it breaks at a maximum load with a given maximum deflection. The load exerted is concentrated in the middle of the specimen. The test data are the pressing force and the deflection before breaking. After a conversion following the abacus of the press we find the corresponding effort. During the test, we record the maximum force and the corresponding distortion. The Force-distortion ratio refers to the bending stiffness (in N / mm):

$$K = \frac{\Delta F}{\Delta f} \quad (1)$$

With ΔF the variation of the applied force (N) ; Δf the variation of the corresponding distortion (mm).

For three-point bending, the maximum deflection is given by :

$$f_{max} = -\frac{FL^3}{48EI} \quad (2)$$

F being the bending force (N); L length of the specimen (mm); E flexural modulus of elasticity (N/mm²); I: Quadratic moment (mm⁴); f_{max}: distortion (mm).

In operation on a wind system like blades, the solicitation is no longer the same. For the blades have one end embedded (blocked) and the other free. Figure 12 actually shows us the facts in part. The load is evenly distributed along the specimen. The following illustrations tell us the reality. The distortion for this case depends on where one is located since the embedding. The maximum arrow in this case, for the whole length (L) is given by:

$$f_L = -\frac{FL^4}{8EI} \quad (3)$$

With F: bending force (N); L: length of the specimen (mm); E: flexural modulus of elasticity (N/mm²); I: Quadratic moment (mm⁴); f_L: distortion (mm).

For a built-in load such as that free at one end, the module E and the moment of inertia I remain unchanged. We assume that the load is evenly distributed for a free load. In writing the arrows report, we will have:

$$\frac{-FL^4/8EI}{-FL^3/48EI} \quad (4)$$

$$\frac{f_L}{f_{maxi}} = 6L \quad (5)$$

The ratio depends on the length of the specimen. Figure 14 is the result of the samples tested. We were not rigorous in respect of the position of the samples in the plans. The width of the blade did not interest us in this calculation of bending. The force F acting on the blade is estimated by the ratio between the power P and the speed v of the wind, that is to say:

$$F = \frac{P}{v} \quad (6)$$

With F: Wind force (N); P: Wind power (W) and v: wind speed (m / s).

The power of the wind is expressed by the formula:

$$P = \frac{1}{2}\rho S v^3 \quad (7)$$

With P: Wind power (W); ρ: density (kg/m³); S: Area swept by the blade (m²) and v: wind speed (m/s).

From this relation we can draw the length L of the blade by relation (8) which is the following:

$$L = \sqrt{\frac{8P}{\pi\rho v^3}} \quad (8)$$

Results and discussions:

The results are presented in the form of figures. Naturally when the wood is dried, deformations appear: withdrawals, curvatures or wave deformations. Faced with the sun, Borassus showed no deformation in the form of shrinkage or curvature. It is not attacked either by rodent insects (borers) or wood molluscs.

We plot the curve of the relative values of absorbed water during the experimental period. Figure 13 is the behavior of Borassus with water. During the first fifteen (15) days, the test tubes absorbed a quantity of water. After the 16th days, the Borassus becomes rot-proof. After more than twenty days, the water is infinitely penetrated the pores. There are not enough pores. In addition, the fibers are very tight. At the 20th day, the pores are saturated. But these fibers do not even have holes where water can lodge [12]. The type of water did not have a significant reaction on Borassus. The amount of water absorbed does not reach half the mass of the sample. The blades of a wind turbine will not be immobile, moreover there will never be rain for twenty days for us to reach this experimental regime. The rainwater that will wet the blades will be almost completely rejected during the rotational movements of the blades. The blades will keep their condition even after several days of rain.

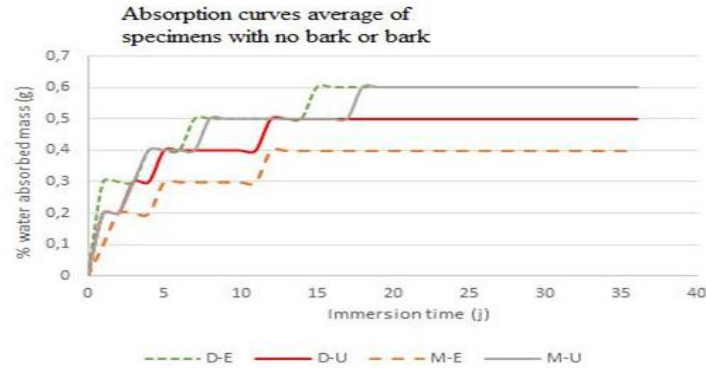


Figure 13:-Behavioral curves of Borassus pieces in water

D-E: Experiment made with distilled water for specimen with Bark,

D-U: Experimentation with distilled water for completely machined test specimen,

M-E: Experiment made with seawater for test tube with Bark,

M-U: Experiment made with seawater for completely machined specimen.

Wood, in general, is elastic. It is the same for the Borassus. Borassus is composed for the most part of firmly bound fibers through a matrix (binder). The Borassus fibers are not linear but they are rather pell-mell. The experiment area does not have enough binder but fiber. The mathematical formula (law 5) informs us on the maximum arrow to reach for a free request. She is high. For the same consideration, a blade whose one end is embedded, the reaction is not the same. The blade, which has dimensions similar to those of the specimens, may bend up to $13,496.9 \pm 4221.5$ mm for this short length (approximately 360 mm) against a maximum deflection of 6 mm for a three-point bend. The crushing of the specimen in the case of a recessed blade will not be fast. The breakage is very weak. The calculation of the report has demonstrated it above (6L). The angle of deflection is about 1.52° . He remains very weak.



Figure 14:-Form of the sample tested after flexion

Borassus is a plant that does not present any nodes. But it is the nodes that constitute the shadows for flexion. The presence and the density of the fibers are assets for a good resistance in bending. Another advantage is the fact that you do not have to protect it against the attacks of the bugs.

In fact, the blade would not be subjected to a force of the wind supposed higher. Table 1 gives us the power, the force as a function of the wind speed with considerations of blade length. On the living matter that is the stipe, we can have a length of 5 m.

Table 1:-Calculation of the power and the force of the wind for a length of 3 and 3.5 m

Vitesse V (m/s)	Longueur L = 3 m		Longueur L = 3,5 m	
	Puissance P(W)	Force F(N)	Puissance P(W)	Force F(N)
1	4,33	4,33	5,89	5,89
1,5	14,61	9,74	19,88	13,25
2	34,62	17,31	47,12	23,56
2,5	67,61	27,05	92,03	36,81
3	116,84	38,95	159,03	53,01
3,5	185,53	53,01	252,53	72,15
4	276,95	69,24	376,96	94,24
4,5	394,33	87,63	536,72	119,27
5	540,91	108,18	736,24	147,25
5,5	719,96	130,90	979,94	178,17
6	934,70	155,78	1 272,23	212,04
6,5	1 188,39	182,83	1 617,53	248,85
7	1 484,27	212,04	2 020,25	288,61
7,5	1 825,59	243,41	2 484,82	331,31
8	2 215,58	276,95	3 015,66	376,96
8,5	2 657,51	312,65	3 617,17	425,55
9	3 154,61	350,51	4 293,78	477,09

A wind turbine starts with a speed between 3.5 and 4 m/s to reach a nominal speed of 12 m/s.

For a length of 3 m, in our context (Table 1) where we consider a speed of 9 m/s, the results show us the availability of realization of a power of 3154.6 Watts with a force of 350,5 N. When we vary the length 0.5 m, the power becomes 4293.7 watts and the force becomes 477.09 N, an increase of 1139.2 Watts in power and 126.5 N in force.

Table 2:-Calculation of wind power and strength for a length of 4 and 4.5 m

Vitesse V (m/s)	Longueur L = 4 m		Longueur L = 4,5 m	
	Puissance P(W)	Force F(N)	Puissance P(W)	Force F(N)
1	7,69	7,69	9,74	9,74
1,5	25,96	17,31	32,86	21,91
2	61,54	30,77	77,89	38,95
2,5	120,20	40,08	152,13	60,85
3	207,71	69,24	262,88	87,63
3,5	329,84	94,24	417,45	119,27
4	492,35	123,09	623,13	155,78
4,5	701,03	155,78	887,23	197,16
5	961,63	192,33	1 217,06	243,41
5,5	1 279,92	232,71	1 619,90	294,53
6	1 661,69	276,95	2 103,07	350,51
6,5	2 112,69	325,03	2 673,87	411,37
7	2 638,70	376,96	3 339,60	477,09
7,5	3 245,48	432,73	4 107,57	547,68
8	3 938,82	492,35	4 985,06	623,13

8,5	4 724,46	555,82	5 979,40	703,46
9	5 608,20	623,13	7 097,87	788,65

For a length of 4 m, in our context (Table 2) where we consider a speed of 9 m/s, the results show us the availability of realization of a power of 5608. Watts with a force of 623.1 N. When we vary the length 0.5 m, the power becomes 7097.8 Watts and the force becomes 788.6 N, an increase of 1489.7 Watts in power and 165.6 N in force. The longer the blade becomes, the more power the machine produces and the wind becomes stronger.

The different values found for the wind force are much lower than those used during the three-point bending test. The action of influence on the blade at these different lengths is minor. A blade made with Borassus will be without fear but preferably for small wind turbines.

Conclusion:-

This article aims to contribute to the valorization of a traditional wood known for its natural virtues. Borassus is very resistant to flexion. It remains rot-proof and inert in the weather. Borassus's reaction to the water, the sun and the mechanical demands reassures us that it will be hard to rework for the future. This property allows it to be used in construction. Borassus, like any other wood, reacts well in flexion. It remains important because of its longitudinal elasticity. We are reassured that Borassus can be well indicated for a wind turbine blade without any fear.

The different results show that the magnitude of the wind force depends on the length of the blade. This material can be validly used for the realization of the blades of the wind turbines of nominal power not exceeding 7,097 kW.

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