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RESEARCH ARTICLE

BORASSUS AETHIOPUM OF BENIN USED AS VEGETABLE REINFORCEMENT IN CONCRETE: CHARACTERIZATION OF THE OVERLAPPING ZONE.

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Borassus aethiopum, overlapping, epoxy glue, metallic plates, *Borassus aethiopum* pieces.

Abstract

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The present article studies the overlapping zone between two reinforcements of *Borassus aethiopum*. To characterize this zone, two types of overlapping were experimented to know, the cover with *Borassus aethiopum* pieces and the one with metallic plates of which the binder is the epoxy glue. It turns out that the maximal length of covering to be realized between two *Borassus aethiopum* reinforcements is 500 mm. This covering length does not depend on substrata which served to achieve the overlapping but rather of the shearing resistance of the glue joint. Furthermore, during the test, *Borassus aethiopum* plates damage after the break of test tubes while the metallic pieces still remain intact. This reveals the advantage of the metallic plates with regard to *Borassus aethiopum* pieces. The behaviour of the interface of both materials is elasto-fragile.

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Introduction:-

Several research works carried out in Benin on the ligno-cellulosic material between the medulla and the bark of *Borassus aethiopum mart* allow to look forward to using it as reinforcement plant in the reinforced concrete. The physical and mechanical characterizations tests reveal that at 12 % of humidity, this ligno-cellulosic material has a basal density of 690kg/m^3 and a bulk density of 890 kg/m^3; that classifies this material in the category of heavy "wood" [1-2]. The tensile breaking strength at 12 % of humidity is 300 MPa; the Young's modulus in four points flexion is 17200 MPa on average with a breaking load of 190 MPa [3].

Other studies carried out on *Borassus* reinforced concrete beams shew that there is hardly any difference between the resistance of *Borassus* reinforced concrete beam with square section of *Borassus* and the one with circular section of *Borassus* [3]. Furthermore, the same studies report that a section of *Borassus* five times bigger than the steel one will bear the same breaking load as the latter. Further studies achieved by the same authors showed that the composite material presents a behaviour similar to that of usual materials; effort-deflection curves registered during the tests present a first zone of linear movement and the second wider zone referring to the plastic domain but which has the particularity to be almost linear; that means the presence of the reinforcements made of *Borassus* increase the bearing capacity of beams and holds place of reinforcements. On this base, studies were achieved on periodic structures of *Borassus* reinforcements [4]. It emerges from it that the best overlapping between two *Borassus* reinforcements is the covering achieved by means of the metal of which the binder is the epoxy glue. However, these works do not specify us the maximal length of overlapping to be achieved to insure the continuity of the stress

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on both sides of the connection zone. That is why the general goal of these research works is to study the overlapping zone between two *Borassus* reinforcements. More exactly, it is a question of determining the maximal length of covering between two *Borassus* reinforcements and to examine the behaviour of this overlapping zone.

Materials and methods:-

▪ ***Borassus aethiopum***

Borassus palm tree (Fig. 1) which served to achieve this study comes from the forest of Pahou-Ahozon. After cutting down, it was cut up, split in laths and conditioned at a moisture content about 12 %. Then it was sawed in armature of section 20x20mm². The kind of *Borassus* cut down is the male.

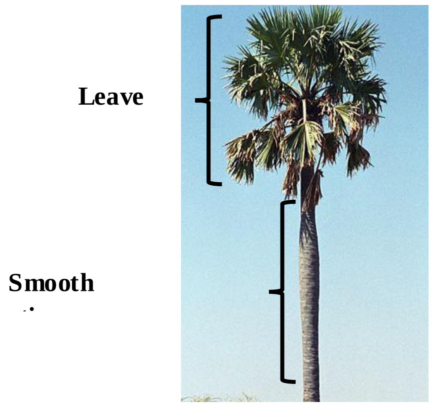

Fig. 1:-Plant of male *Borassus*

▪ **Direct tensile tests on tests tubes of *Borassus* assembled (Standard EN 408 + A1)** [5]

Principle and purpose of the test

This test consists in imposing on a test tube, a state of uniaxial uniform stress, and by measuring the resultant axial deformations to determine the mechanical characteristics expressed in the system of reference bound to the test tube [6].It aims at examining the behaviour of the interface of the assembled *Borassus* reinforcements. The tests are achieved at a moisture content about 12 %.

Assembling and measure

The experimental device used for that purpose is constituted of **(**Fig.2):

- Electromechanic press branded MTS with 20 kN of capacity and 0.5% accuracy;
- Camera branded Pike with 4500 Pixels of precision;
- Lamp of lighting;
- 02 tripods.

During the tests, the test tubes are arranged between the lower and superior bits of the press. The test is piloted in movement of crossbar with a speed of 0.5mm /mn.

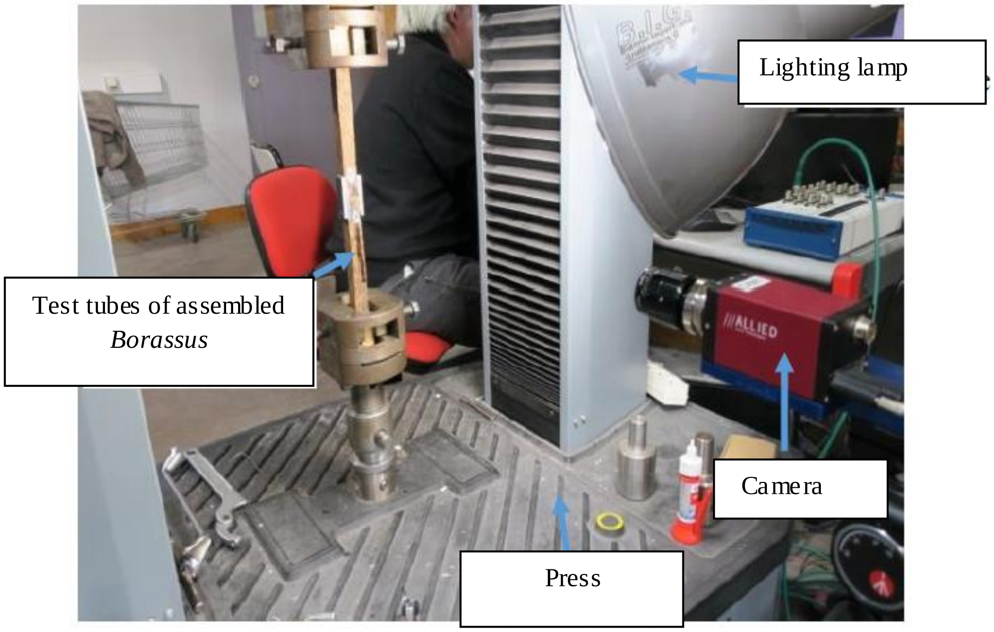

Fig. 2:- Experimental device of direct tensile test

Nature of test tubes

Test tubes are constituted of two *Borassus* reinforcements of 210 mm long with 20 x 20 mm² of section assembled either by means of two metallic profiles, or by means of two pieces of *Borassus* of which the binder is the Sikadure 330 glue. The pieces of *Borassus* have for dimension 80 x 20 x 10 mm^3 and the metallic plates 80 x 20 x 2 mm^3. Table 1 recapitulates the naming of test tubes. In total 12 test tubes were achieved with different lengths of sticking. On every test tube two targets are stuck. The displacement of the axes of these targets is followed by correlation of images during the tests by means of a camera. Fig. 3 illustrates the realized test tubes.

Table 1:- Test tubes list

Designation	Length of sticking	Number
Tests tubes assembled using pieces of *Borassus* (EPR)	50	3
	80	3
Tests tubes assembled using metallic plates (EPM)	50	3
	80	3

a) b)

Fig. 3:- Tests tubes of *Borassus* assembled by means of plates

a) Assembling with pieces of *Borassus* b) Assembling with metallic profiles

Results:-

The results obtained after direct tensile test on test tubes assembled using pieces of *Borassus* (EPR) or metallic plates (EPM), allowed us to draw stress-strain curves characterizing the behaviour of the glue joint. Fig. 4 to 7 present these curves. Concerning the breaking strength, Tables 2 and 3 summarize the obtained values.

The observation of these curves shows for a length of 80 mm of sticking, a first zone of linear strain and the second zone of non-linear strain; whereas for a length of 50 mm of sticking, we observe an elasto-fragile behaviour. According to [7-8], epoxy systems are characterized in the dull state (temperature lower than Tg) in uniaxial traction by a behavior generally fragile and we do not observe threshold of plasticity.

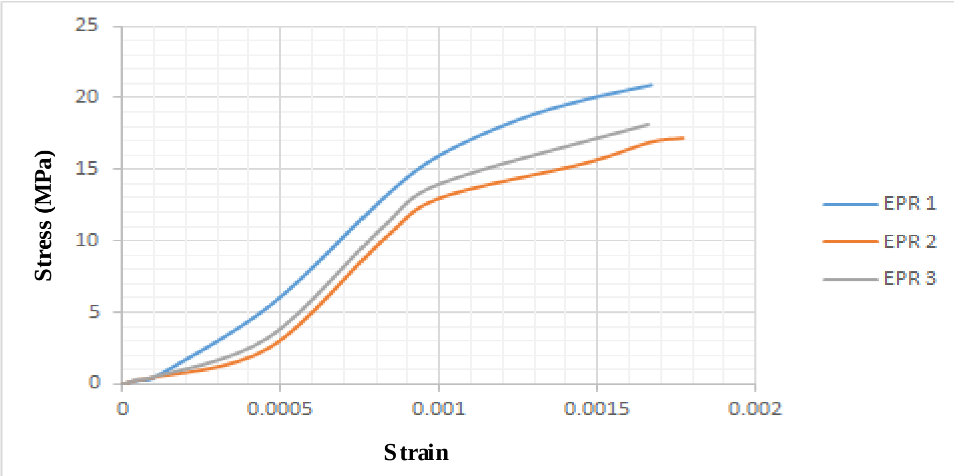

Fig. 4:- EPR test tubes stress-strain curves with 80 mm of sticking length

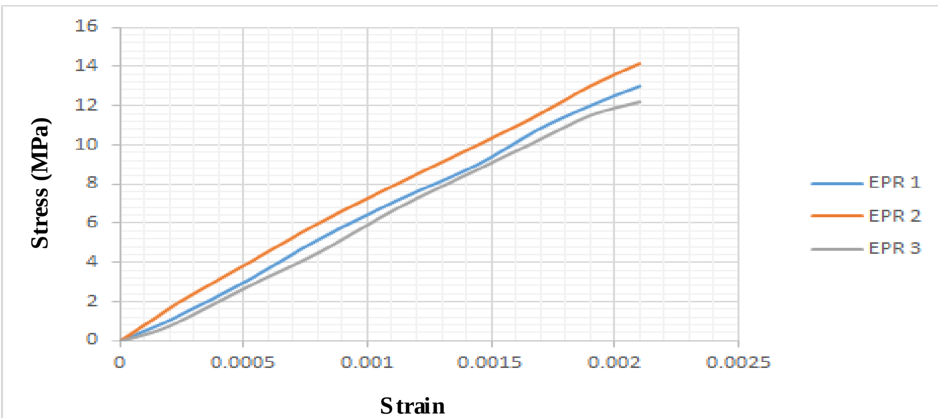

Fig. 5:-EPR test tubes stress-strain curves with 50 mm of sticking length

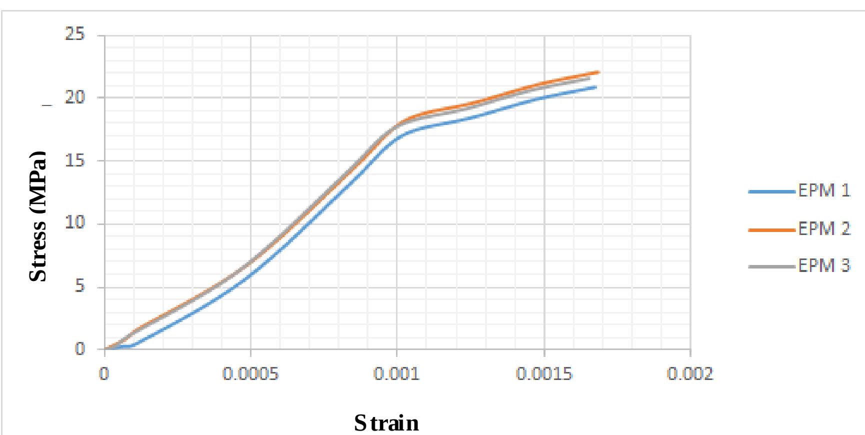

Fig. 6:-EPM test tubes stress-strain curves with 80 mm of sticking length

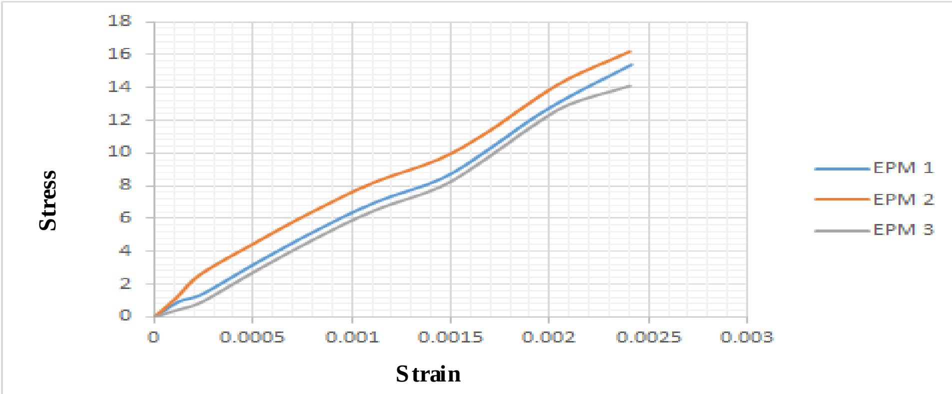

Fig. 7:-EPM test tubes stress-strain curves with 50 mm of sticking length

Table 2:- Breaking strength of test tubes assembled using pieces of *Borassus*

DESIGNATION	RESISTANCE (MPa)	
	Length of joint 80 mm	**Length of joint 50 mm**
EPR1	14.15	20.90
EPR2	12.20	17.20
EPR3	13	18.15
Average	13.12	18.75
Coefficient of variation	0.07	0.1

Table 3:- Breaking strength of test tubes assembled using metallic plates

DESIGNATION	RESISTANCE (MPa)	
	Length of joint 80 mm	**Length of joint 50 mm**
EPM1	13.65	22.5
EPM2	16.20	20.88
EPM3	15.40	23
Average	15.08	22.13
Coefficient of variation	0.07	0.03

These tables allowed to draw the diagrams of the Fig. 8**.** According to these diagrams we can notice that whatever the overlapping (metallic or *Borassus*) type, the breaking stress of test tubes grows with the length of sticking. Moreover, we notice that for the same length of sticking, the breaking stress of test tubes assembled using metallic profiles is greater than the one using pieces of *Borassus*.

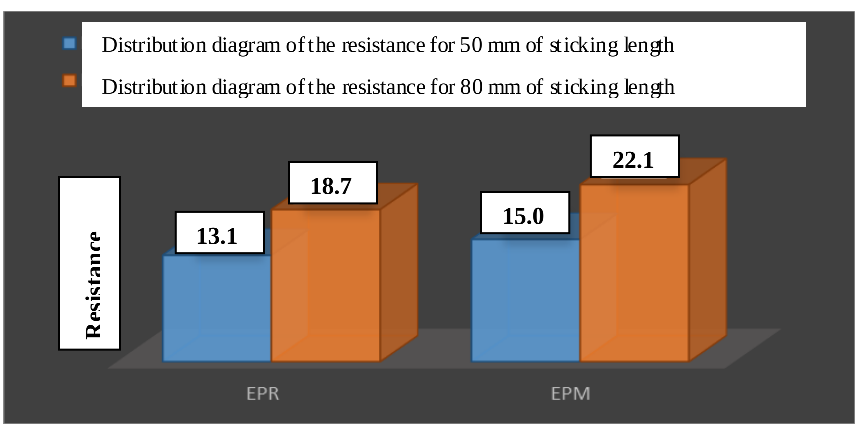

Fig. 8:- Distribution diagram of the resistance according to the sticking length

Discussions:-

From the analysis of these results, it emerges that the resistance of the assemblies depends on substrates which served to realize the covering and highlights the distinction between the resistance of the glue and the one of the stuck joint. Indeed, according to [9-10], at the transition zone between the glue and each of the substrates, interactions and chemical connections are created. This zone, called interphase, has a different composition from the one of the glue or from the substrate and conditions the behavior of the glue joint, in particular its resistance.

- **Optimal length of sticking**

These reports allowed us to determine the optimal length of sticking which can ensure a maximal resistance in the overlapping zone. This length does not depend on the type of covering (Pieces of *Borassus* or metallic profile) but rather of the breaking strain of the *Borassus* reinforcements. To calculate this length, the simplest approach according to [11-12],consists in considering that the joint of glue works only in shearing and that this shearing stress is constant in the overlapping zone.
The calculation procedure of the assembly leads to:

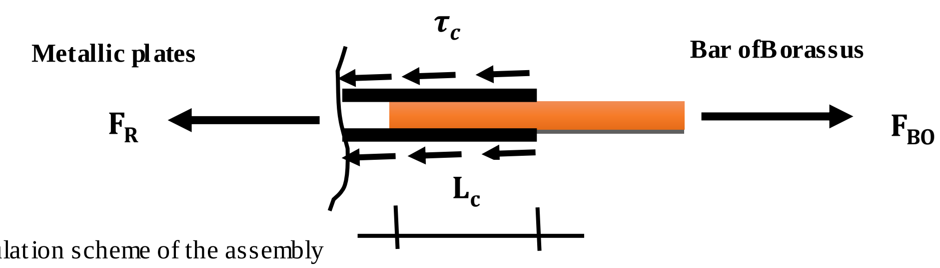

Fig. 9:- Calculation scheme of the assembly

According to this scheme, at balance we obtained:
$F_R = F_{BO}$
Now $F_R = \tau_c * 2 * S_L$ and $F_{BO} = \sigma_{BO} * A_{BO}$ Eq. 1
$\Rightarrow \tau_c * 2 * S_L = \sigma_{BO} * A_{BO}$; $S_L = 20 * L_c$

$$\Rightarrow L_c = \frac{\sigma_{BO} * A_{BO}}{2 * 20 * \tau_c}$$ Eq. 2

With:
$\sigma_{BO} = 150\ MPa$ [13]
$A_{BO} = 20\ x\ 20\ mm^2$
$\tau_c = 6$ MPa [14]
Then

$$L_c = \frac{150 * 400}{2 * 20 * 6}$$

$$L_c = 250 \text{ mm}$$

To ensure a maximal joining in the overlapping zone, it will be necessary to realize the sticking on a total distance of 2*Lc = 500 mm.

- **Types of breaking of test tubes**

Concerning the types of breaking, according to **[8]**, there are different types of breaking of the stuck assemblies according to the place where the crack intervenes (Fig.10):
- The breaking can be confined in one of the two substrates or in the adhesive; that means the cohesion of one of these materials is lower than the adhesion between constituents. We then speak of cohesive breaking.

- The breaking can intervene in the interface and we then speak of adhesive or interfacial breaking. However, sometimes the break is not at the interface strictly speaking, but very close to this one. We speak of breaking in the « interphase » because the closeness of an interface can be synonym of gradient of properties.

- The breaking can also be combined if it is cohesive by place and adhesive in others.

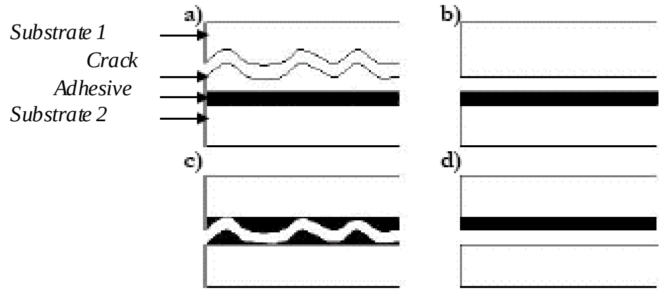

Fig. 10:- Types of breaking of the stuck joints

a) Cohesive breaking in the substrate, (b) and (d) adhesive breaking in the interface (c) cohesive breaking in the adhesive one

In our case, we observed the type (a) that is cohesive breakings in the substrates for the assembly with the pieces of *Borassus* and the types (d) and (c) that means some breakings either in the interface metal - glue, or cohesive in the adhesive for the assembly with metallic profiles. Fig 11 illustrates these types of breaking.

On this Fig. 11, we thus observe that the pieces of *Borassus* damage after the breaking of test tubes while the metallic plates remain still intact. This emphasizes the advantage of metallic profiles with regard to the pieces of *Borassus*.

a) Cohesive breaking in the substrates b) Interfacial breaking

Fig. 11:- Types of breaking of test tubes assemblies by joining organ

Conclusion:-

The general purpose of this study was to study the overlapping zone between two *Borassus* reinforcements. For that, we tested two types of assembly. It is about assemblies with pieces of *Borassus* and those with metallic profiles. The direct tensile tests achieved on these assemblies revealed that the optimal length of overlapping to be realized between two *Borassus* reinforcements is 500 mm. This length of covering does not depend on substrates which served to achieve the assembly but rather the shearing resistance of the glue joint. Moreover, these tests showed that the pieces of *Borassus*damage after the breaking of test tubes while the metallic plates still remain intact. It shows the advantage of the metallic plates with regard to the plates of *Borassus*.

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