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RESEARCH ARTICLE

EXPERIMENTAL STUDY OF ADHESION BETWEEN FRAMEWORK IN RONIER WOOD (BORRASSUSAETHIOPUM) AND LATERITE CONCRETE

Yémalin Daniel Agossou[1], Rémi Boissiere[2], Hubert Frédéric Gbaguidi[1], Abdelouahab Khelil[1] and Edmond C. Adjovi[1]

1. L2EGC /ENSTP, Materials and Structure Team, National University of Sciences Technologies Engineering and Mathematics of Abomey (Benin).
2. Jean Lamour Institute (IJL), UMR CNRS 7198, Nancy, University of Lorraine (France).

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Abstract

In today's world, the environment and the economy, are becoming more and more important, especially in the field of construction. As a result, many researches are beginning to emerge in order to find alternatives to the usual reinforced concrete. In this article, research is focused on constructions using local materials, more specifically on laterite concrete reinforced with plant reinforcement made of rônier wood. The main goal was to study the adhesion between these wooden reinforcements and the laterite concrete in order to submit this structural material to construction stresses. The average value of the adhesion stress obtained is 3.521±0.668 MPa for the reinforcements without serrations and 3.828±0.437 MPa for those with serrations. Rebars with serrations achieved a gain of about 09% to 20% over the surface rebar without serrations. These reinforcements with circular section with or without crenellation and with octagonal section incorporated in the laterite concrete beams considerably increased the resistance of the laterite concrete. This increase is close to 335.86% of the breaking stress for the beams reinforced with two reinforcements of circular section, 386.96% for the beams reinforced with two reinforcements of circular section with crenellation and 353.78% for the beams reinforced with two reinforcements of octagonal section. This study made it possible to show that reinforcements with a circular section with crenellation are better reinforcements in laterite concrete.

Introduction:-

The environment and the economy are becoming more and more important in the world, especially in the field of construction. Therefore, it is important to look for local materials with low environmental and financial impact capable of meeting the needs of builders. The use of concrete as a structural and construction material is one of the most important technological advances of the 21st century. Conceived as a material capable of adapting to the most diverse shapes, thanks to its characteristic solidification property (transition from a fresh state to a hardened state), concrete is a composite consisting invariably of three phases (the matrix cementitious, aggregates and pores) which are only observable at the microstructure scale. Associated with a reinforcement, the concrete is known under the

Corresponding Author:- Yémalin Daniel Agossou
Address:- L2EGC /ENSTP, Materials and Structure Team, National University of Sciences Technologies Engineering and Mathematics of Abomey (Benin).yemdag@yahoo.fr

name of reinforced concrete which must obey certain rules and principles of cohabitation, the main one being adherence.

Generally, reinforced concrete structures are modeled and calculated as if they were made up of a single homogeneous body whose numerical global response can be considered as consistent and acceptable with respect to the real response, (and this) within a given range of use. In principle, the answer depends only on the specific characteristics and behaviors of the materials concerned (concrete with another material, wood in this case). This study on concrete structures reinforced with plant reinforcements is oriented towards the study of potential sources of structural failure, in order to understand and ideally eliminate them, or at least reduce them or control them effectively until a certain safety limit. Among these sources of rupture is the phenomenon of adhesion which allows the transfer of forces between the reinforcements and the concrete in the vicinity.

This complex phenomenon of interaction between the two materials, which develops in the interface, is however not immutable. In fact, it undergoes an increasing degradation when certain thresholds of resistance, specific for each material, are exceeded. Moreover, it is true that this degradation does not mean the total and immediate ruin of the structure. But it locally implies a significant reduction in resistance and consequently a redistribution of forces and internal stresses which will ultimately affect the expected structural response under extreme loads, as well as the service life of the structure.

State of the art

Several wood materials have been the subject of a study on their association with concrete, like steel. One of the limits of this concrete-wood association is the assessment of adhesion, which is a very important parameter whatever the work to be carried out in reinforced concrete. Indeed, the external forces which solicit reinforced concrete structures are generally applied to the concrete and the reinforcements within the reinforced concrete can only participate if there is transmission of the forces from the concrete to the reinforcements. This transmission takes place by the effect of adhesion between the reinforcement and the concrete. For concrete and wood to be able to work simultaneously, their deformations must be identical under the applied stresses. The wood should not slide in the concrete sheath that surrounds it but adhere to it. The quality of adhesion depends on the type and surface condition of the wood, the size of the bar, the position and inclination of the reinforcements during concreting, the strength of the concrete and not to mention the condition of implementation. Several research have been oriented in the study being the subject of the use of plant reinforcement in concrete. The main problem with the use of plant reinforcement in concrete is the adhesion between the two materials.

The authors surveyed agree on the equations and design procedures for steel-reinforced concrete, believing that these rules can be used quite safely for the design of wood-reinforced concrete parts.

Massani , (1977) [1] carried out an extensive study describing the appropriate methods for using Bamboo in construction. It lists the positive aspects of bamboo citing examples of economic, mechanical and environmental properties. The bamboo wood as reinforcement in the concrete, must obey constructive provisions in order to ensure a better performance. The main issue of the use of bamboo as reinforcement in concrete is centered on the waterproofing of the walls through an adequate treatment. This study found that the area of bamboo reinforcement should be 5 times the area of typical steel reinforcement and that even when fine cracks develop on the surface of bamboo, the load bearing capacity of the element is not reduced in flexion.

As for the preparation of the bamboo frames, some recommendations have been made to obtain better performance. Balagaru and Shah, (1985) cited by Ghavami , 1995) [2]concludes that the width of the strips should be between 20 and 25 mm and that the space between them should be at least equal to the width of the reinforcement plus 7.5 mm or the maximum diameter of the aggregates. In addition, he points out that the concave side of the strips should be facing up, so as not to trap air bubbles during pouring, which would affect the concrete-bamboo bond.

Ghavami , (1995) [2] on the other hand experimented with the use of bamboo strips as reinforcements in concrete beams of 12x30x300 (cm^3). The results show that a ratio of a cross-section of the bamboo compared to the cross-section of the beam equivalent to 3%, makes it possible to increase by 400% the load allowed for a beam without reinforcement. However, he points out that the deformations of a bamboo-reinforced beam increase significantly compared to the deformations observed on the steel-reinforced beam.

J. Boucher, (2006) [3] studied the development of a concrete beam reinforced with prefabricated bamboo for the urban habitat of Hanoi. The bamboo stalks used were cut into strips and then treated to make them waterproof. The tensile tests made it possible to estimate the mechanical properties of bamboo as follows $F_e = 150$ MPa ; $E = 8000$ MPa.The concrete used for the manufacture of beams is a high performance self-compacting concrete with the following properties: $F_{c28} = 80$ MPa and $E = 40000$ MPa . The dimensioning led to the reinforcement shown in the figure (Figure 1). The section of bamboo frame is equal to $460\ mm^2$.

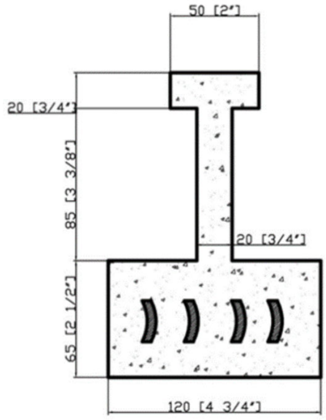

Figure 1:- Geometry of beams reinforced with bamboo [3].

(Sanjeev & Dr. Rajiv, 2016)[4] in their study on the use of bamboo as reinforcement in concrete showed that the load capacity of a beam reinforced with bamboo could reach 3 times that of unreinforced concrete having the same dimensions. Furthermore, the bond strength of the concrete-bamboo treated is between 1.2 and 1.35 MPa.

Obilade&Olutoge , (2014) [5] studied the bending characteristics of beams reinforced with rattan vines in order to determine the contribution of rattan vines to the bending resistance. Based on the beams of dimensions $150\times150\times750\ mm^3$ reinforced with rattan creepers and others with steel, they found that the carrying capacity of the beams reinforced with creepers and steel increased respectively by approximately 20% and 230% compared to the capacity of unreinforced beams. They concluded that rattan vines improve the bending characteristics of concrete.

Mahzuz et al., (2014)[6] evaluated the effectiveness of using Calamus guruba rattan as reinforcement in a beam. From this study, it shows that the rattan bars take about 23.5% of the maximum load that the beam can support.

Palmier reinforced concrete

Bamboo and rattan aren't the only woods that have been associated with concrete in recent years. Indeed, borassusaethiopum has also been used as a substitute for steel. This is how several studies have focused on reinforced concrete with borassus.

AHOUSSINOU and OROUNLA, (2010) [7] tested 4-point bending of rônier reinforced concrete beams grouped into five (5) different categories in order to find the geometric shape of rônier wood reinforcement offering better mechanical performance. They distinguish between beams with crenellated reinforcement in alternating grooves (PACRA), beams with crenellated reinforcement in V notches of dimension 2cmx2cm (PACEV), beams with reinforcement in attached lap (PARA) and beams with lap reinforcement with spikes (PARP). The results of these studies reveal that the PACRA beams resist better than the PACEV beams with an improvement rate of 17.81%.Thisdifference would be due to the type of serration of the reinforcements adopted to improve adhesion.

Kankam and Perry, (1989) [8] , experimentally determined the parameters that influence the concrete-wood adhesion of bamboo. Their studies propose to determine the influence of the treatment of the surface of the bamboo and the resistance of the concrete on the adhesion based on certain variables including the value of the compressive strength of the concrete, the distribution of the knots on the bamboo stems, the drying time of the rods, the improvement of the surface roughness of the rods by sanding, the application of bitumen treatment with and without sand. This study makes it possible to understand that the combined effect of the compressive strength of the concrete, the drying for four weeks and the presence of knots on the rods would make it possible to improve the adhesion. The adhesion value of concrete tobamboo is 1.13 MPa for rods without knots and 2.04 MPa for rods with knots. However, the specimens whose surface has been sandblasted have an adhesion stress of 1.94 MPa compared to the rods that have remained intact with a value of1.65 MPa Finally, covering the rods with a layer of bitumen improves the adhesion stress by 12%, while the same treatment with the addition of grains of sand reduces the adhesion stress by 27%.

Raju et al, (1972) [9] , Foudjet&Fomo , (1995) [10] believe that these results are unsatisfactory when carrying out a comparative study with that of steel-concrete adhesion. To improve its results, they set up a process making use of a containment structure which consists in shaping the rattan or bamboo reinforcements in the form of frames having one side in the compressed zone. Since the length of the rattan rod can reach 150 cm and more, the problem of covering does not arise in the use of this technique of confinement by assuming that the adhesion limit ( ) occurs at the moment of the rupture in tension of $\tau_e$the rattan. Pull-out tests carried out on concrete specimens reinforced with rattan show that the apparent adhesion varies from 2.8 MPa to 5.4 MPa for rattan tensile breaking stresses ranging from 52 to 100 MPa.

Raj, (1991) [11] based on the work of Shui, (1990) [12] suggests that the average adhesion observed between several species of bamboo and concrete is of the order of 0.25 to 0.5 MPa. This range of values is close to that obtained previously for rods without drying and for those having dried for three weeks in the open air.

Ghavami (1995) [2] performs some tearing tests on bamboo stems that have been treated differently. The processing of its results reveals that drying the bamboo for a few weeks, the presence of knots on the stems, sanding, the application of a water-repellent treatment, such as Negrolinmixedwith grains of sand, covering of the rods by a metal mesh as well as an increased resistance to the compression of the concrete are all factors which contribute to improving the adhesion (up to 90%) between the concrete and the bamboo.

Later, Kawai (2000) [13] oriented his research in order to improve the previous results by cutting the reinforcements differently. He made crenellations 30 mm long by 2 mm deep in the longitudinal section of the bamboo strips (Figure 2). Thus, these protrusions have a better grip on the concrete since the results obtained show that the crenellated bamboo reinforcements have an adhesion two to three times greater than that of the bamboo reinforcements without crenellations.

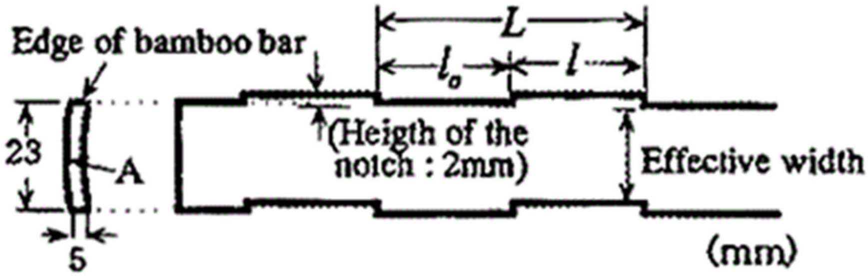

Figure 2:- Crenellated bamboo strip (Kawai , 2000)[13].

Material and Methods:-

The various tests were carried out based on the formulation characteristics of laterite concrete and the mechanical characteristics of rônier wood. The determination of its characteristics is based on the methods exposed by AGOSSOU et al (2021) [14] . The rônier wood used for this study comes from the KPOMASSE plantation as recommended by AGOSSOU et al, (2018) [15] . The estimated compressive strength of the concrete is 22MPa.

Two methods of adhesion measurement were explored in this study.

Pull Out test (SN EN 14488-4)

This test, also called pull-out test, makes it possible to study the cohesion that could exist between the rônier reinforcements and the laterite concrete/ordinary concrete. The experimental principle is to subject a palmyra stem anchored over a length of 10cm in a concrete block to a tensile force until it breaks by tearing the stem out of the concrete block while measuring the force and the corresponding slip. The block diagram is as shown in Figure 3below.

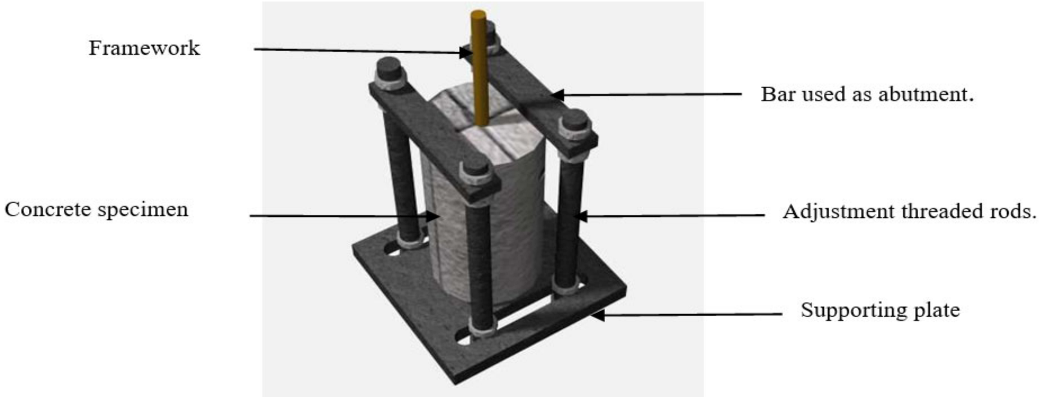

Figure 3:- Pull-out test device.

Configuration of specimens

The pull-out tests carried out in this study are realized instead of carried out with two types of rônier wood reinforcement, the configuration of which is presented in Figure 4**Erreur ! Source du renvoi introuvable.**below. These samples are embedded in cylindrical laterite concrete specimens of the 11×22 cm ^{2} type and the palmyra stems used have a net diameter of 10 mm with a shoulder at one end. These rods are embedded in the concrete (Figure 5) to a height of 10cm. Two categories of rods were tested, these are rods of circular section with or without crenellations.

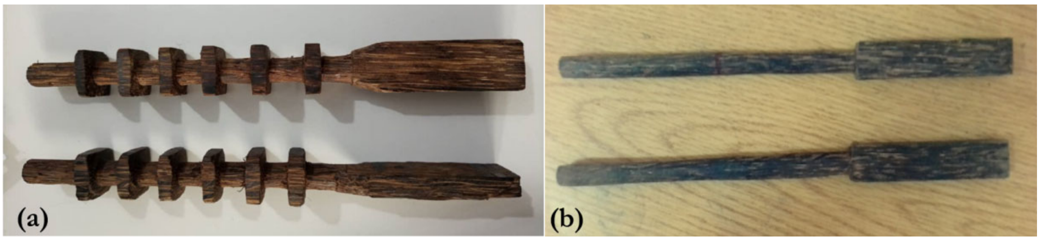

Figure 4:- Configuration of the rods for the Pull-Out Test (a) rod with circular section with serrations, (b) rod with circular section without serrations.

Several series of specimens were made with the two categories of rods. The formulation of laterite concrete is made on the basis of literature data. [16] . The specimens thus obtained are stored in plastic bags (Figure 5) which allows the specimen to retain significant humidity for better grip and curing of the concrete [17] .

Figure 5:- Storage method for test specimens.

The tests are carried out after 28 days of concrete curing to obtain the force-slip curves for each type of concrete.

They are then mounted on the 50kN capacity press in traction according to the very specific protocol. Accuracy comparators of the order of a thousandth have been placed to record the displacements of the rod as the load increases until it breaks. FigureFigure 6shows the system set up to run the tests.

Figure 6:- Data acquisition system (PULL OUT TEST).

The data thus collected thanks to a camcorder are meticulously processed in order to deduce the real displacement of the rod following the application of the load.

The maximum pull-out force is divided by the side surface of the rebar in contact with the concrete to obtain the maximum bond stress:

$$\tau = \frac{F_{max}}{S}$$

Measurement of adhesion by the tensile test by bending

In this part, we present a second approach for measuring the adhesion between the different types of reinforcement and the concrete. This approach consists of placing the rebar to be tested in two concrete blocks of the same dimensions and connected by a joint. The entire system is stressed in four-point bending as shown in Figure 7

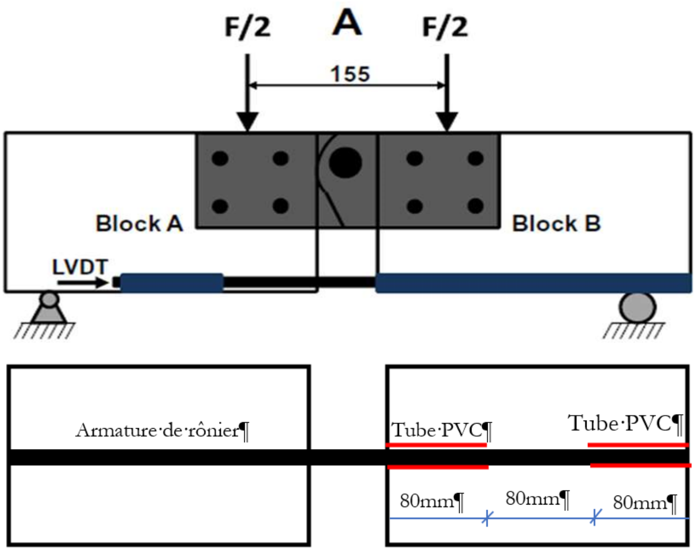

Figure 7:- Schematic diagram for the pull-out tensile test.

Preparation of test samples and conduct of the test

For the manufacture of the test specimens, a wooden prismatic mold was used. The framework is placed in the mold as shown in the photo below.

Figure 8:- Adhesion test device by the tensile bending method.

The reinforcement is anchored in one of the concrete blocks with its entire surface in contact with the concrete. In the second block, the contact surface has been reduced by the use of PVC tubes in which the armature can slide easily during the test. These PVCs were positioned over a distance of 80mm.

After pouring and demolding, the device (hinge) was put in place that could allow rotation during the test as shown in

Figure 9:- Beam sample with the test device allowing rotation.

These different samples were made for each type of reinforcement. We used a bending bench with a maximum capacity of 50 tons equipped with a data acquisition unit. Three sensors are positioned at strategic locations on the test sample to record displacements as the load increases.

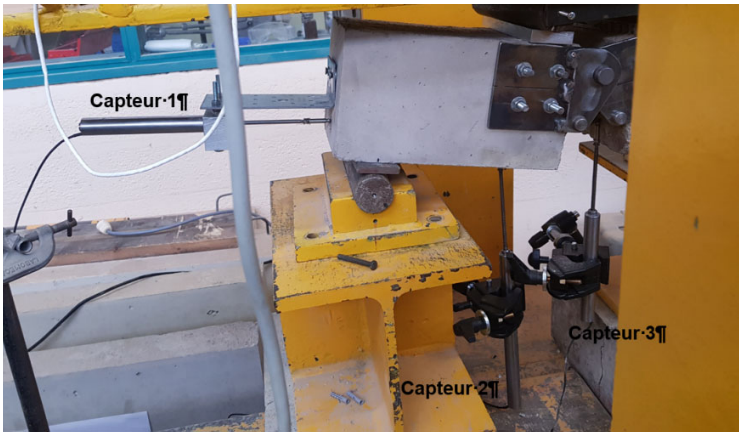

Figure 10:- Arrangement of the displacement sensors during the test.

- Sensor 1 records horizontal movements, i.e., the sliding of the reinforcement in the concrete
- Sensors 2 and 3 record the vertical displacement at each concrete block.

Study in three-point bending of beams reinforced with rônierwood.

Geometry of the rônier wood frames

The geometry of the rônier reinforcements is defined according to the favorable machining conditions and by reference to the circular section of the steel reinforcements. Three types of geometric sections are tested:

1. Type I: Frame with circular section of section 380mm ^{2}
2. Type II: Frame with circular section with crenellations of net section 380mm ^{2}
3. Type III: Armature with octagonal section of section 380mm ^{2}

These different types of frame have been delicately machined from the original square-shaped section slats. Figure Figure 10and Figure 11below summarize the protocol for obtaining these reinforcements starting from the square section .

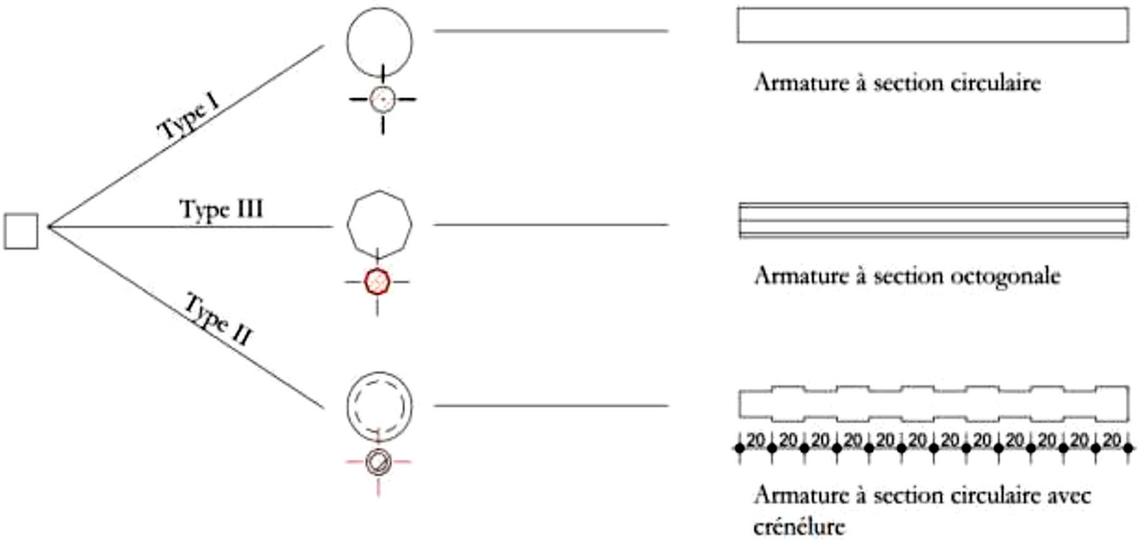

Figure 11:- Typology of rônier frameworks.

Figure 12:- Samples of different types of reinforcement.

Manufacture of laterite concrete beam specimens reinforced with rônier and performance of tests.
The concrete used for the realization of the beams to be tested, results from the formulation suggested on the concrete of laterite and ordinary concrete [16] . To this end, several prismatic wooden molds with internal dimensions of 10cmx15cmx90cm have been designed and produced. After completion of the formwork, the reinforcements are placed at the bottom of the formwork and then cast according to four types with a witness.

1. **Sample Type Unrenforced:** In this category, we have made samples of unreinforced beams. They are witness beams for the analysis of the results.
2. **Type I sample:** In this category, two type I reinforcements are housed in the formwork for the construction of reinforced beams.
3. **Type II sample:** In the third category, two type II reinforcements are housed in the formwork for the construction of reinforced beams
4. **Type III sample:** In this last family of beams, two type III reinforcements are housed in the formwork for the construction of reinforced beams

Figure 13 below shows the principal diagram of each section of beam reinforced with rônierreinforcement.

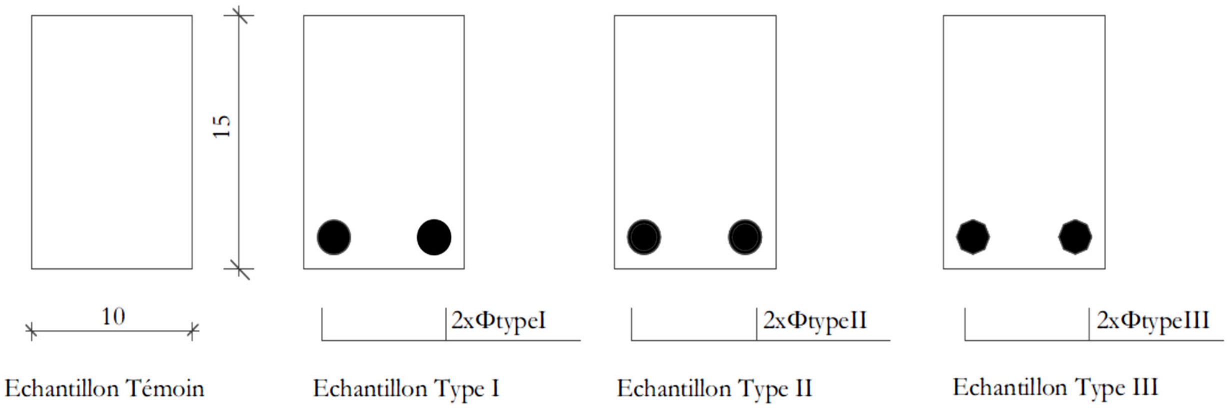

Figure 13:- Configuration of the different beams with the different types of reinforcement.

Each of the specimens is subsequently stressed in three-point bending. It consists in breaking in bending three points each of the prismatic specimens by applying an increasing load of 4kN/s. During the test, the loads are recorded as well as the displacements using a data acquisition system.

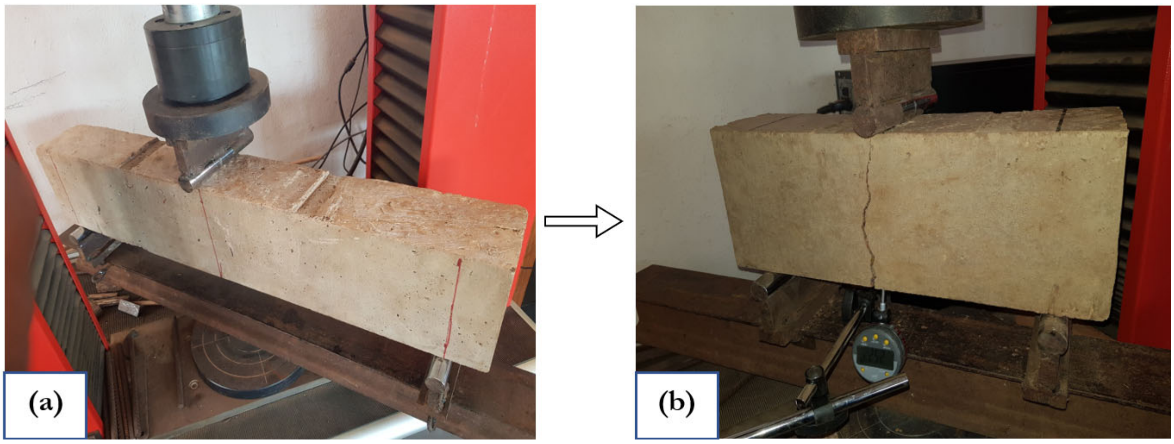

Figure 14:- Upright view: (a) placement of the beam for the test, (b) sample showing the failure mode

Results and Discussion:-

Characteristics of rônier and concrete

The results of the basic preliminary tests on the rônier and the laterite concrete are presented in

Table **1.**

Table 1:- Physical and mechanical characteristics of base materials.

Materials	Physical properties				Mechanical properties		
	H (%)	mv (kg /m^3)	R_v (%)	G_v (%)	E (MPa)	Ϭr_ (MPa)	f_e (MPa)
Ronier (Traction)	15 ±0.35	715 ±69.13	15 ±1.07	16 ±0.79	4456.56 ± 187.36	126.36 ± 18.21	114.94 ± 13.28
Concrete (Compression)	-	2230.02±61.65	-	-	12840.59 ±678	22.89±1.24	12840.59 ±678

Adhesion study

Pull out test (test pull-out)

For each test carried out, the results are processed and then translated into a graph. The results obtained after the various pull-out tests on the smooth reinforcement specimens made it possible to draw the force-slip curves (Figure 15) characterizing the behavior of the lateritic concrete-rônier wood bond. As regards the maximum bond stresses, Table 2summarizes the average values obtained for each type of reinforcement.

Table 2:- Adhesion stress according to the type of reinforcement with laterite concrete.

Identification of specimens	Humidity level (%)	age of concrete	Anchor length (mm)	Diameter (mm)	Contact surface (mm ^{2})	Maximum forces (N)	Maximum stresses (MPa)
AdBL -Acre	14.71±0.54	28 days	100	10/15	3612.83	13.829±1.580	3.828±0.437
AdBL-Alis	12.83±0.44			10	3141.59	11.190±2.097	3.521±0.668

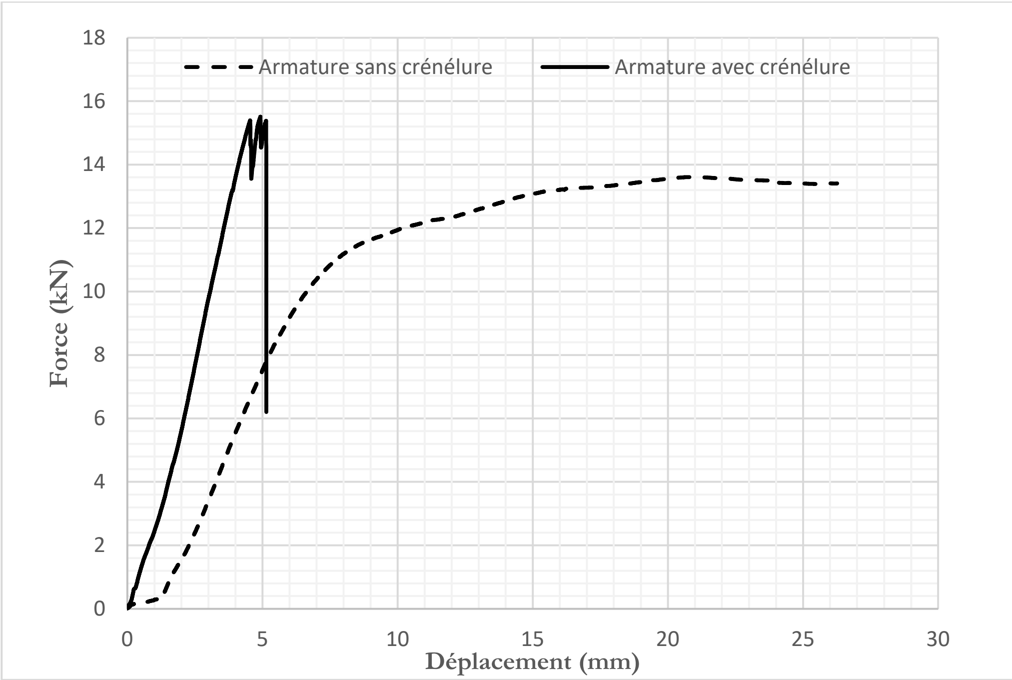

Figure 15:- Displacement force curve of reference samples by type of reinforcement.

Through this graph, we note that the ruin of the specimens with crenellated reinforcement is brutal compared to the specimens without crenellations. This could be explained by the rupture of the extra thicknesses which would nevertheless weaken the reinforcement. However, for reinforcements without serrations, after breaking the connection, prolonged sliding of the reinforcement is observed until the bond breaks completely.

The observation of these curves shows, for an anchorage length of 100 mm of palmier wood with a smooth surface in lateritic concrete, a first quasi-linear deformation zone and a second non-linear displacement zone corresponding to the evolution of sliding without noticeable increase in load. This reflects a loss of adhesion between the two materials. The average value of the adhesion stress obtained is **3.521 ± 0.668MPa.** However, for this same mode of anchoring for crenellated reinforcements, a curve is observed presenting a linear zone followed directly by a zone showing a sudden rupture without plastification. The average value of the adhesion stress obtained is **3.828±0.437 MPa** . This analysis shows that the appearance of serrations on the rônier reinforcement rods leads us to a gain of about **09% to 20%** compared to the surface reinforcement without serrations (list surface).

Bond failure mode analysis

Adhesion bond failure occurred through three modes, namely:

Propagation of longitudinal cracks

This mode of failure is caused by the distribution of internal stresses in the concrete, due to factors such as geometric disparities of the reinforcement. During the test, we observed a microcrack that develops longitudinally along the axis of the reinforcement and as there is a concentration of the tensile forces in the crack front, the concrete has reached its maximum tensile strength and the crack is spreading

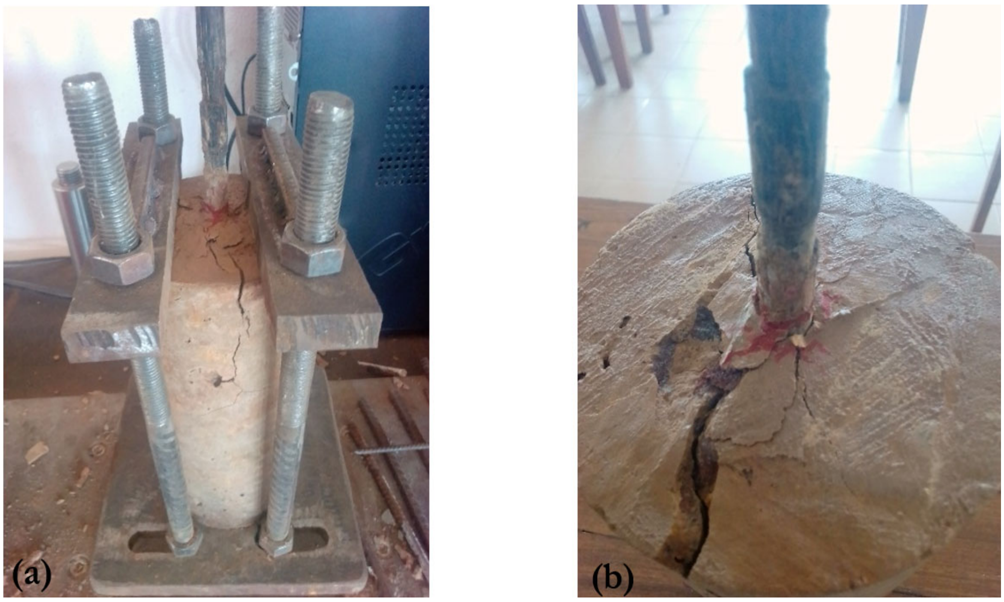

Figure 16:- Propagation of the crack along the wood(a); Final appearance of the crack at bond failure(b)

Yielding or breakage of the reinforcement

This rupture mode has been observed especially for rônier frameworks with crenellations. This rupture justifies a perfect seal between the two materials. Indeed, this rupture is due to the fact that the crenellations created on the surface of the bar prevent the latter from slipping to the point where the tensile force exerted exceeds the elastic limit or the limit of rupture in tension of the wooden reinforcement in leading her to ruin as shown in the Figure 17 (below).

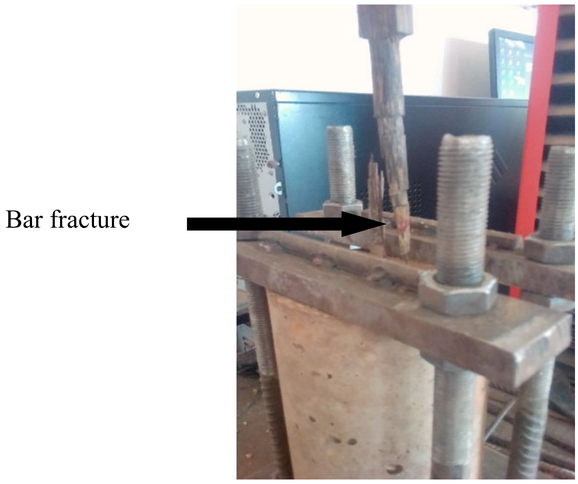

Figure 17:-Failure by reinforcement failure (BL).

Reinforcement shear

This failure mode is observed on some samples when the extraction force is greater than the frictional resistance of the connection. There is then a sliding between the surface of the reinforcement and the concrete surface which envelops it (Figure 18).

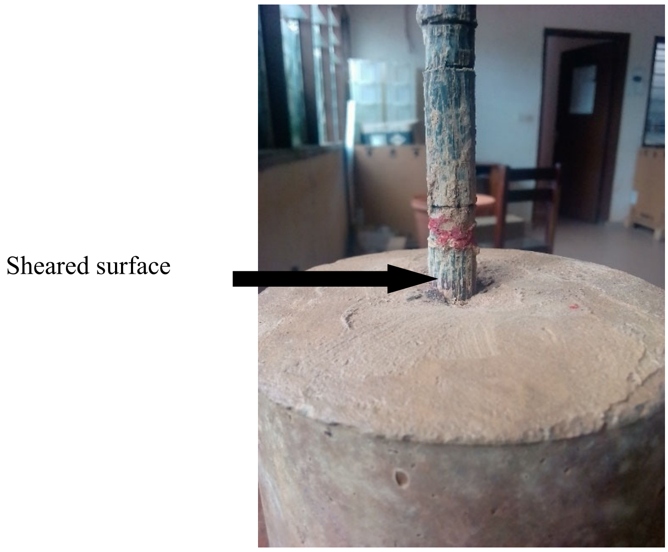

Figure 18:- Slippage of the BL armature.

Influence of wood roughness on anchorage resistance

The beneficial role of the reinforcement roughness is highlighted by the comparison of the pull-out resistance values recorded for the two types of bars used, smooth and crenellated. This comparison is performed for all results by affinity (Figure 19:- Influence of reinforcement roughness on BL

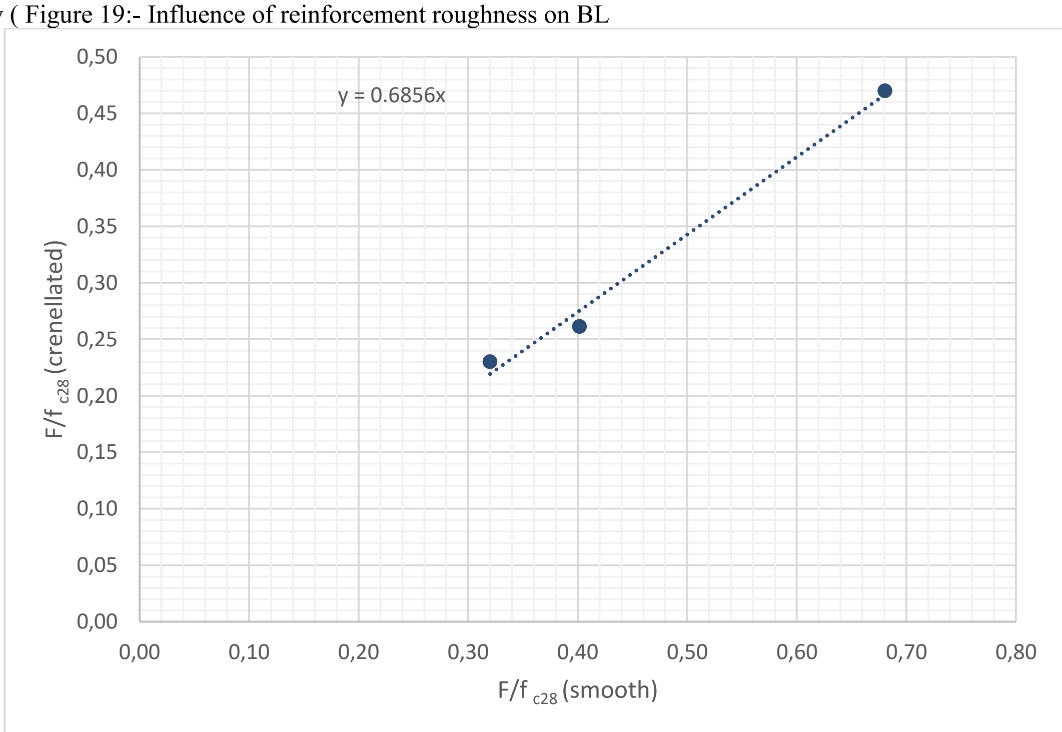

Figure 19:- Influence of reinforcement roughness on BL.

It can be seen, despite the dispersion of the cloud of points, that the shape of the curve is linear and increasing with a coefficient of proportionality which is 0.6856; i.e. $(0.828)^2$ close to the first value. It can thus be seen that the coefficient $\psi_s = 1{,}5$given in the French regulations for the calculation of reinforced concrete constructions, BAEL 91 for HA, for concretes with a resistance limited to 60 MPa, could not therefore be applied to lateritic concretes reinforced with vegetal reinforcements in crenellated rônier [18] . This also shows that lateritic concrete is more sensitive to the absence of reinforcement roughness.

Traction by bending

The test for measuring adhesion in tension by bending is a test which subjects the bar to sliding in the concrete block in which it is embedded following the rotation of its concrete blocks during the application of loads. Figure Figure 20below shows the slippage of the palmar rebar during the test.

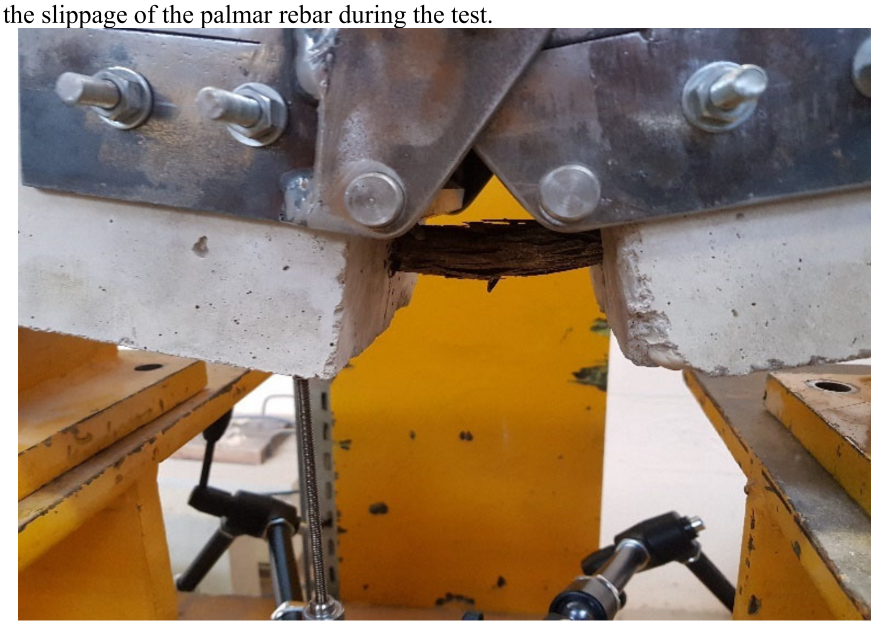

Figure 20:- Bond failure after bending stress by traction.

The results of the different types of reinforcement are presented in Table 3:

Table 3:- Ultimate bond stress between reinforcement and concrete measured in tension by bending.

	Breaking load (kN)	**Adhesion force (N)**	**Displacements (mm)**			**Ultimate Binding Constraint (MPa)**
			Underwire	**Concrete blocks with 100% contact surface**	**Concrete blocks with limitation of contact surface by PVC**	
Type I frame	23.69	16690.682	28	2.14	5.3	**3,321**
Type II frame	9.97	7024.318	0	4.42	13.28	**1,397**
Type III frame	17	11977.273	0	31	21	**2,383**

The results of this test show that the reinforcements with circular section adhere more to the concrete than the two other types of section. This is followed by the octagonal section which offers good adhesion stress. However, the circular section with serrations proved to be more or less failing with an adhesion stress of **1.397MPa**

Simple bending study

The tests carried out on concrete specimens reinforced with rônier to characterize the adhesion and the capacity of the latter to be stressed in bending show us a variability of results (Table 4) according to the type of reinforcement.

Table 4:- Summary of ultimate loads and maximum displacements for different types of beams.

	Unreinforced beam (Witnesses)		**Reinforced beam of circular section (Type I)**		**Reinforced beam of circular section with crenellation (Type II)**		**Reinforced beam with octagonal section (Type III)**	
Test tubes	breaking load	Maximum Movement	breaking load	Maximum Movement	breaking load	Maximum Movement	breaking load	Maximum Movement
1	7,845	1,156	28,793	3,779	31,210	3,834	29.976	7,163
2	9,414	1,249	26,489	4,081	27,643	4,217	27,578	3,366
3	8,865	1,301	23,725	3,854	29,426	3,450	24,700	4,441
Mean	**8,708**	**1,235**	**26,336**	**3.905**	**29,426**	**3,834**	**27,418**	**4,990**
Gap	**0.796**	**0.073**	**2,537**	**0.157**	**1,783**	**0.383**	**2,642**	**1,957**

Figure 21 below translates the behavior in bending of its various studied beams.

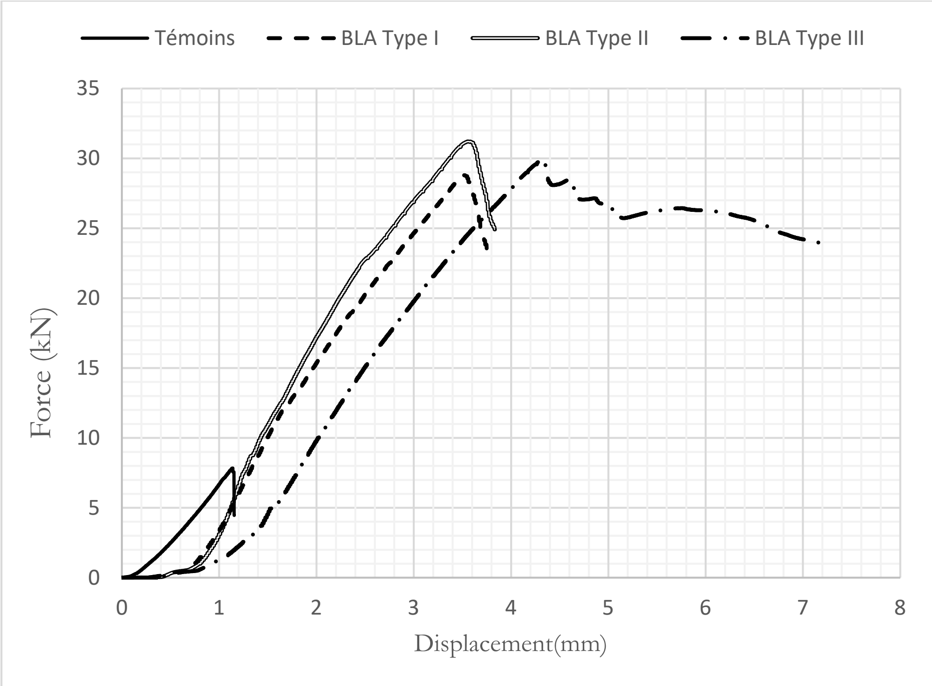

Figure 21:- Force-displacement curve of reinforced laterite concrete beam samples ((BLA) with rônier wood reinforcement.

Based on the experimental data, a processing of the results made it possible to calculate the engineering parameters of the beams reinforced with rônier wood, in particular the ultimate stress and the modulus of elasticity of the composite.

- **Expression of the stress for the homogeneous section**

$$\sigma_{rup}=\frac{3\times F\times a}{b\times h^2}$$

- **Expression of the stress for the reinforced concrete beam of rônier**

$$\sigma_{rup}=\frac{96\times F\times a\times(h\text{-}e)}{\left[64bV^3+64bV'^3+\pi d^3+192nA_S\left(V'\text{-}e\right)^2\right]}$$

- **Expression of the maximum deformation**

The maximum deformation of the beam is y_{max}=y(a)= f

$$f=\frac{Fa^3}{6EI}$$

- **Expression of the deformation modulus**

The modulus of deformation will be determined by:

$E=\frac{a^3}{6\,I}\left(\frac{F}{f}\right)$ et $\Delta E=\frac{a^3}{6\,I}\left(\frac{\Delta F}{\Delta f}\right)$with

I: moment of inertia of the beam$I=\frac{bh^3}{12}$

a : distance between a support and the point of application of the force

$\left(\frac{\Delta F}{\Delta f}\right)$: Variation of the load applied to the variation of the deformation of the beam

Digital Application

$$h = 15\ cmet b = 10\ cm$$
$$a = 40\ cm\ ; d = 2\ cm$$
$$V = 7{,}69\ cmet V' = 7{,}31\ cm$$
$$n = 0.8569\ ; A_S = 7{,}20\ cm^2$$

F=charge de rupture

$$E=0,379259259\left(\frac{\Delta F}{\Delta f}\right)$$

Breaking stresses and deformation moduli are presented for each type of reinforcement in

Table 5

Table 5:- Breaking stress and deformation modulus of the unreinforced beam (Controls).

Test tubes	Breaking load (kN)	Maximum Displacement (mm)	Breaking stress (Mpa)	Young's modulus (Mpa)
Witnesses	8.708±0.796	1.235±0.073	4.644±0.307	2572.204±124.214
Type I	26.336±2.537	3.905±0.157	20.050±1.325	2592.018±218.426
Type II	29.426±1.783	3.834±0.383	22.403±0.905	2936.065±299.980
Type III	27.418±2.642	4.990±1.957	20.873±1.379	2269.941±558.247

Table 5gives the values of the various adhesion breaking stresses of laterite concrete beams dosed with 400 kg of cement per cubic meter reinforced with palmier wood, stressed in tension by bending at 28 days. It should be noted that the breaking stresses of the unreinforced beams are much lower than those of the beams reinforced with rônier. The presence of wooden reinforcement considerably increased the resistance of lateritic concrete. Indeed, at 28 days, we note an increase of **335.86%** in the breaking stress for the beams reinforced with two reinforcements of circular section, **386.96%** for the beams reinforced with two reinforcements of circular section with crenellations and **353.78 %** for beams reinforced with two reinforcements of octagonal section.

Based on these different results obtained, it appears in general that palmyra wood can therefore take the place of tensile reinforcement in a laterite concrete beam. This proves that palmyra adheres well to laterite concrete. This adhesion depends on the geometry of the incorporated rônier wood reinforcements.

Synthesis

This article deals with the experimental study of the adhesion between laterite concrete and various forms of rônier reinforcement. The study of the laterite concrete beam reinforced with rônier wood reinforcement revealed that these reinforcements contributed considerably to the bending strength of the latter at more than 335% compared to unreinforced concrete. The various results show that the reinforcements of circular section with crenellations are more effective than the other sections. However, for adhesion tests by tensile bending, they have been shown to be less effective. It is the same for the pull-out test where these reinforcements show a fragile behavior.

The work of Adewuyi et al., (2015) [19] on reinforced bamboo beams reveals an increase of about 51% for the addition of reinforcement. These results sufficiently show that vegetal frameworks made of rônier wood are better in terms of mechanical performance. Priyadarshi et al., (2016) [20] showed that the use of rattan frames increases performance by around 71%. Blackburn, (2006) [21] despite this increase in bending resistance of concrete reinforced with bamboo has been able to set up constructive systems which have already proven themselves in the field of construction, it is necessary, imperative to see, urgent to deepen the work on the use of the rônier for the same purpose because the performance of the rônier is about 6 times that of bamboo.

Given the difficulties in obtaining rônier frameworks with circular section with or without crenellations, and given the similarity of the mechanical performance of frameworks with circular and octagonal section, we recommend the use of frameworks with octagonal section which moreover are easier to machine than circular-section frames.

Conclusion:-

The general objective of this study is to investigate the adhesion between the rônier reinforcements and the laterite concrete. The results of this experimental study made it possible to understand the influence of the roughness of the surface of rônier wood on its adhesion with laterite concrete. Depending on the type of reinforcement, of the wood-concrete bond, the pull-out tests led to results showing that the absence of serrations on wood sections weakens the bond in order to allow the transmission of forces between concrete and reinforcement as in the case of ordinary reinforced concrete. This is evidenced by the slip curves, graphs of the variation in resistance as a function of the roughness of the reinforcement. However, it appeared that the wood-concrete adhesion bond is clearly sensitive to the effect of the roughness of the palmyra.

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