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The Borassus Aethiopum Mart Wood Frame In The Concrete of Laterite Nodules: Appreciation of The Rate of Adhesion

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ABSTRACT

This work deals with '' the borassus wood frame in the concrete of laterite nodules: appreciation of the adhesion rate ''. The material characterization tests (lagoon sand from Dêkoungbé, lateritic nodules from Avlamè to Zogbodomey) made it possible to formulate laterite nodules concrete according to Dreux-Gorisse. Three types of beams of the concrete of dimensions 16x16x64cm3 armed with borassus reinforcements (24x24mm²) or not, made up, were tested by four-point flexion at 7, 14, 21 and 28 days until the adhesion failure. Also, cubic specimens made of 16cm reinforced concrete at the center of borassus of section 24x24mm² made, were tested with direct traction at 28 days until the adhesion failure. The results obtained show that the borassus adheres well to the said concrete. The presence of borassus reinforcements considerably increased the resistance of the said concrete. Borassus can therefore take the place of tensile reinforcement in this concrete.

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Nomenclature

Denomination	*Signification*	*Units*
σ_{rup}	*Contraintes de rupture*	*(MPa)*
τ_{rup}	*Contraintes de rupture par cisaillement*	*(MPa)*
M_{max}	*Moment fléchissant maximal*	*kN.m*
h	*Hauteur de poutre*	*m*
I	*Moment d'inertie*	m^4
F	*Charge de rupture*	*kN*
F_{max}	*Charge de rupture maximale*	*kN*
a	*Coté (section transversale de la poutre)*	*m*
v	*Position de l'axe neutre par rapport à la fibre supérieure*	*m*
v'	*Position de l'axe neutre par rapport à la fibre inférieure*	*m*
e	*Position de l'axe de l'armature par rapport à la fibre inférieure de la poutre*	*m*
n	*Rapport des modules d'Young*	-
A_s	*Section transversale de la poutre*	m^2
S	*Section de rupture*	m^2
E	*Module d'Young*	*MPa*
HA	*Haute Adhérence*	-

Introduction

The populations of the under developed African countries and in particular Benin, are currently facing the high cost of buildings (housing or housing, basic socio-community infrastructure and sanitation). In order to significantly reduce this cost, quality and low-cost buildings must be promoted and multiplied extensively, taking into account demographics, to enable every citizen to feel at ease and to provide themselves with this vital need easily. One of the ways to solve this problem is to promote quality local composite materials in the field of construction of such housing and socio-community infrastructure. This promotion basically involves the research and scientific study of these local composite materials that must meet the standards in terms of adhesion, resistance and behavior.

Several research studies have been the subject of a study of the mechanical behavior on the one hand, of borassus wood substituted for steel as reinforcement in ordinary concrete made from gravel and sand and on the other hand, nodule lateritic substituted for gravel as an aggregate in reinforced lateritic steel nodule concrete.

Indeed, the borassus is a wood that is resistant to termites. It can maintain its integrity in use for several centuries [1]. In Southern Benin (Porto-Novo, Ouidah, Abomey and Savè), the borassus aethiopum mart is available [2].

Borassus aethiopum is common in Senegal, Guinea Conakry, Guinea Bissau, Mali, Côte d'Ivoire, Burkina Faso and Niger [1]. The various characterization tests carried out on the borassus aethiopum mart of Beninese origin are satisfactory and make it possible to envisage the use of the borassus wood as reinforcement in ordinary concrete reinforced in place of the steel [3]. Also, the thermal, physical and even mechanical characteristics of the species of wood studied and the durability of the material in the traditional constructions from the Borassus allow to consider its use as reinforcement in the concrete. [4]

In addition, the lateritic nodules are aggregates extracted from laterites which "derive from the alteration of various materials: crystalline eruptive rocks, sediments, detritic deposits, volcanic ash etc." (Maignien R., 1964) [5]. These lateritic soils are common between the tropics of cancer and Tropic of Capricorn, in South America, in the heart of Africa and also in India and some parts of Asia. They represent one-third of the land masses and feed a large part of humanity (Legros J. P., 2013) [6]. Also, it has been proved that laterite gravels can be a cheap source of aggregates for the manufacture of structural concretes [7]. Concrete laterite nodules have good strength to compression (90% compared to that of crushed gravel concrete). Their compression behavior gives stress-strain diagrams that are about 85% to 95% of those of crushed gravel concrete [8].

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We have therefore decided to study the behavior of a new composite material by combining lateritic nodule concrete and borassus wood (Borassus Aethiopum Mart). Hence our subject entitled '' the Borassus Aethiopum Mart wood frame in the concrete of lateritic nodules: appreciation of the adhesion rate ''.

Experimental

Materials and methods

At the beginning of this study, we proceeded to the supply of the materials (sand and lateritic nodules chosen) allowing us to realize the lateritic nodule concrete. This is the lagoon sand of Dêkoungbé and the lateritic nodules of the Avlamè deposit at Zogbodomey. The different samples of these said aggregates were taken. Based on NF EN 933 and NF EN 1097 standards, we have by means of laboratory tests (particle size analysis, bulk density, pre-dried real density, cleanliness test, sand equivalent) [9-11] realized at LERGC (Laboratory of Testing and Research in Civil Engineering of Civil Engineering Department of the Polytechnic School of Abomey - Calavi) identified and characterized these aggregates. From the results of characterization tests obtained, the concrete based on lateritic nodules was formulated with the method of DREUX - GORISSE [11]. As a result, lateritic nodules concrete was realized and the suitability tests such as the Abrams cone slump test (NF EN 12350-2) and the simple compression test (NF EN 12390- 3) were made in accordance with the relevant standards [12-13] for the manufacture of our test pieces.
In addition, we milled the borassus wood so as to obtain the reinforcement sections to be incorporated into the concrete of laterite nodules to produce the concrete composite material of laterite nodules-wooden frames which were later tested in the laboratory for the appreciation of the adhesion rate.
The materials retained and used for making the specimens and samples of the composite material are as follows:
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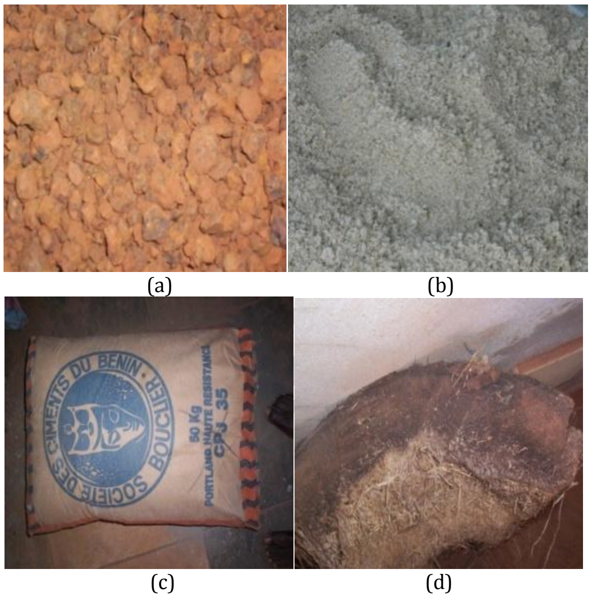


Figure 1: (a) Lateritic nodules from Avlamè quarry in Zogbodomey, (b) Lagoon sand of Dèkoungbé, (c) cement CPJ 35, (d) Cup of borassus wood

In order to fully appreciate the "wood-concrete adhesion of lateritic nodules", we realized two types of samples (specimens):
- 16cm x 16cm x 64cm beam samples according to standard NF P 18 - 401 [11], on which we carried out the 4-point bending tensile test.
- Samples for direct tensile test

Samples for 4 point flexural tensile tests

For this purpose, several metal prismatic molds of dimensions 16cm x 16cm x 64cm were designed and made as shown in Fig. 2.

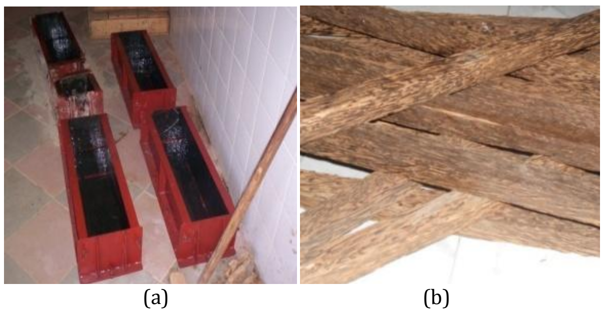
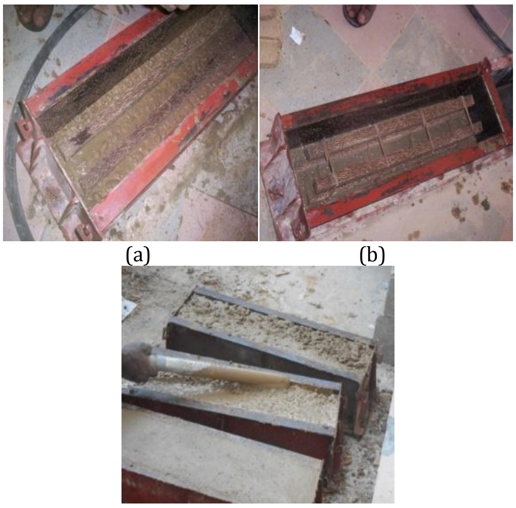


Figure 2: (a) Metal prismatic molds, (b) Borassus reinforcements (section 24x24mm^2)

Here, three types of samples have been distinguished:
- 1st type of sample: Concrete beams of unreinforced lateritic nodules.
- 2nd type of sample: Beams reinforced with two (2) borassus frames (section 24x24mm^2) placed at the bottom.
- 3rd type of sample: Beams made reinforced with four (4) borassus frames sewn with HA6 steels.



(a) (b)

(c)

Figure 3: (a) Making beams reinforced with two (2) Borassus frames placed at the bottom, (b) Making beams with four (4) borassus frames sewn with HA6 steels, (c) Making armed beams

From Fig. 3, it should be noted that the borassus reinforcements used in these beams have a smooth contact surface and have a square section of 24mm x 24mm with a moisture content of 12%. A 2.5 cm coating was adopted for making the beams.

Samples for direct tensile tests

Here a cubic concrete specimens of laterite nodules was made of 16cm of edge and reinforced with borassus wood ($24x24mm^2$) in the central part (Fig 4).

Figure 4: Concrete cube specimen of 16cm lateritic nodules of ridge and reinforced in the central part

Traction tests

The tests were carried out at the National Center for Testing and Research in Public Works (CNERTP) located in Cotonou.

4-point flexural tensile tests on beams

The tests on the beams were made at 7; 14; 21; 28 days. In each group of samples we made and tried three (3) test pieces. The 4-point bending test was carried out according to standard NF P 18-401 [11].

The equipment (Fig. 5) used consists of a press and a 4-point bending device designed for this purpose. The test specimen was centered on the test press. The test piece was gradually loaded up to breaking. The maximum breaking load was recorded during each test.

Figure 5: Execution of the 4-point bending test

Expression of the results of the 4-point bending test

The bending tests were carried out on prismatic test specimens with a square base of 16 cm side and length 64 cm made for this purpose. The average breaking loads were obtained during these tests and recorded. The strength (breaking stress) is expressed in MPa and has the following formula:

$$\sigma_{rup} = \frac{M_{max}.h}{I} \quad (1)$$ [14]

With M_{max} the maximum moment, I the moment of inertia and h the height of the beam.

Thus, we have:

- Unreinforced beams

$$\sigma_{rup} = \frac{M_{max}.y}{I} = \frac{3F.a^2}{a^4} = \frac{3F}{a^2} \quad (2)$$

- Beams reinforced with two (2) borassus frames placed at the bottom

$$\sigma_{rup} = \frac{F.\frac{a}{2}.(a-e)}{\frac{a.v^3}{3} + \frac{a.v'^3}{3} + I_{borassus} + nA_s(v'-e)^2} \quad (3)$$

- Beams reinforced with four (4) borassus frames sewn with HA6 steels

$$\sigma_{rup} = \frac{F.\frac{a}{2}.(a-e)}{2\left(\frac{a.v^3}{3} + I_{borassus} + nA_s(v-e)^2\right)} \quad (4)$$

Direct tensile tests

The tests on the cubic specimens were carried out at 28 days. In each group of samples we made and tried three (3) test pieces.

This is to determine the strength that will allow to break the adhesion between concrete and wood incorporated in the center. For this purpose a device has been designed. It makes it possible to immobilize the mass of cubic concrete and to pull on the incorporated wood until we reach the breaking.

The equipment (Fig. 6) used consists of a press and the direct pull device designed for this purpose and composed of two elements.

The test specimen was centered on the test press. The test piece was gradually loaded up to breaking. The maximum breaking load was recorded during each test.

Figure 6: Conduct of the direct tensile test

Expression of the results of the direct tensile test

The tests were carried out on cubic specimens of edge 16 cm made for this purpose. The average breaking loads were obtained during these tests and recorded. The strength (breaking stress) is expressed in MPa and has the following formula:

$$\tau_{rup} = \frac{F_{max}}{S} \quad (5)$$

With S the breaking section and F_{max} the maximum effort developed to break the adhesion.

Results and Discussion

Synthesis of tensile breaking loads by 4-point bending according to ages are shown in Table 1, and summary table of breaking loads by direct tensile at 28 days is listed in Table 2.

Table 1: Synthesis of tensile breaking loads by 4-point bending according to ages

Types of beams	Average breaking loads(kN)			
	at 7 days	at 14 days	at 21 days	at 28 days
Unreinforced beams	9.33	11.33	12.26	12.60
Beams reinforced with two (2) borassus frames placed at the bottom	30.67	41.67	45.00	49.33
Beams reinforced with four (4) borassus frames sewn with HA6 steels	38.67	47.33	52.00	53.33

Table 2: Summary table of breaking loads by direct tensile at 28 days

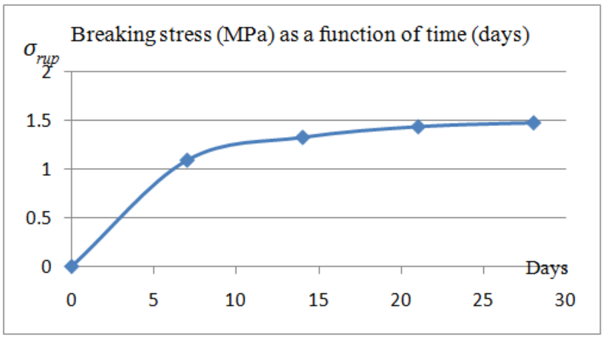
Type of test pieces	Breaking load (KN)
Concrete cubic test pieces reinforced in the borassus central section 24mm x 24mm	50.67

Table 3 above gives the values of the various adhesion breaking constraints of concrete beams of laterite nodules dosed at 350 Kg / m3, reinforced or not, tested in flexural tensile strength at 7; 14; 21 and 28 days.

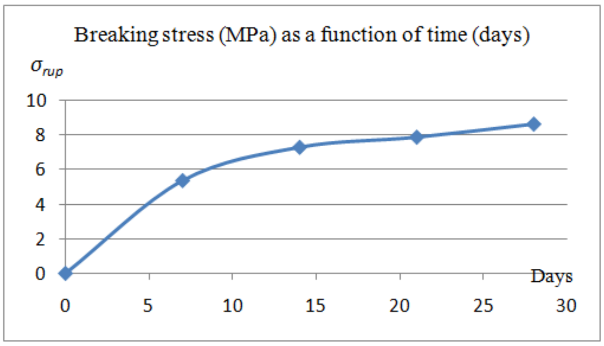
Table 3: Table of the breaking stresses of the beams

Types of beams	Breaking stress(MPa)			
	at 7 days	at 14 days	at 21 days	at 28 days
Unreinforced beams	1.09	1.33	1.44	1.48
Beams reinforced with two (2) borassus frames placed at the bottom	5.39	7.32	7.91	8.67
Beams reinforcedwith four (4) borassus frames sewn with HA6 steels	6.62	8.11	8.91	9.13

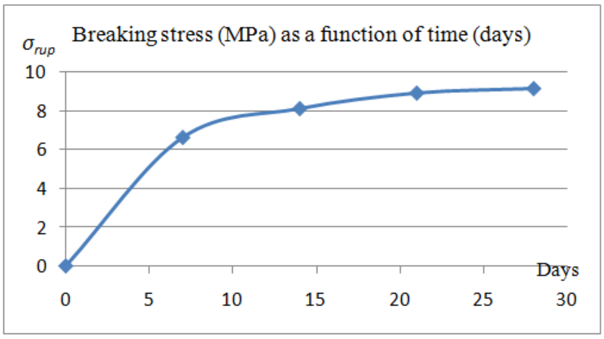
Note: $E_{borassus}$=17196.86 MPa[3], $E_{concrete}$= 17392.00MPa[8], $n=E_{borassus} / E_{concrete}$= 0,99.



(a)



(b)



(c)

Figure 7: Different curves of the breaking stresses of the beams, (a) Unreinforced beams, (b) Beams reinforced with two (2) borassus frames placed at the bottom, (c) Beams reinforced with four (4) borassus frames sewn with HA6 steels

Figures 7 and 8 show that the breaking stress at different ages of the unreinforced beams are much lower than the breaking stress at different ages of the two (02) other types of reinforced Borassus beams. An improvement of 7,192 MPa in the strength of the beam was noted, an increase percentage of 486.93% compared to the strength of the unreinforced beam. This reveals that the presence of wood reinforcements has considerably increased the strength of lateritic nodules concrete. The presence of unsewn tensile reinforcement greatly enhanced the stress of the composite material. The presence of HA6 stretched rigid reinforcements further improved this stress. Indeed, it went from 8.669MPa to 9.133MPa; a percentage increase of 5.35%. It appears then that the wood can therefore take the place of stretched tensile reinforcement in a concrete beam of laterite nodules. This proves that borassus adheres well to concrete made with lateritic nodules.

During the crushing of the beams (tensile bending), we found that the breaking of the unreinforced beams was abrupt. on the contrary that of the reinforced beams of Borassus was progressive with apparent cracking.

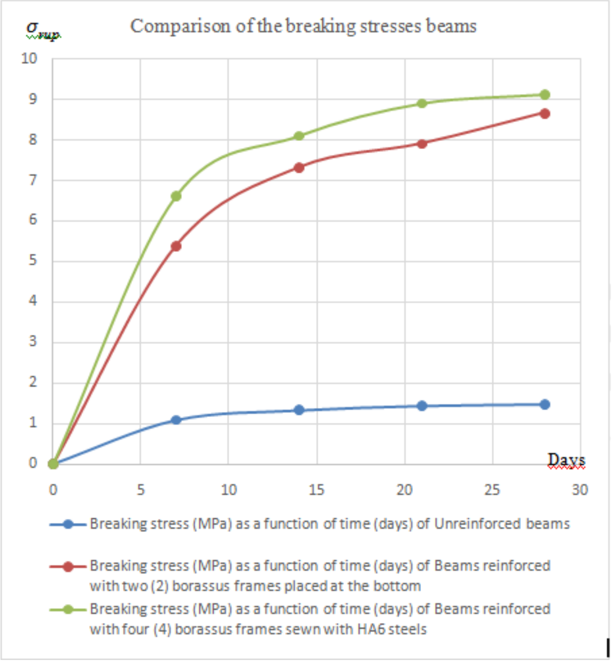


Figure 8: Superposition of the breaking stress curves of the beams

Direct tensile tests

The application of equations (5) allows us to draw up the Table 4 below.

Table 4: 28 day direct tensile adhesion breaking

Type of test pieces	Adhesion breaking stress (MPa)
Concrete cubic test pieces reinforced in the borassus central section 24mm x 24mm	3.299

Table 4 gives the average value of the adhesion breaking stress cubic concrete test specimens of 350 Kg / m3 laterite nodules reinforced with borassus in the center, tested in direct traction at 28 days.

This table shows us that the breaking stresses of 28 days adhesion of the test pieces are high of the order of 3,299MPa. This high value shows that the borassus adhered well to the concrete of lateritic nodules.

We can note from the results of the 4-point bending tests on the beams that the breaking stress of the Borassus reinforced beams increases sharply compared to unreinforced beams. This highlights the adhesion between Borassus wood and concrete laterite nodules. The values of the 28-day direct tensile strength tensile stress also confirm this.

Conclusions

Today, the problems of development and reduction of the cost of housing in Africa and particularly in Benin are new and are crucial problems that must be addressed by finding adequate and reliable solutions. It is therefore important to study quality local composites at a lower cost that can withstand the load concerning the supporting structure of these buildings. It is with this in mind that we have focused our research on borassus-concrete composite of laterite nodules. At the end of our study which focused on '' the Borassus Aethiopum Mart wood frame in the concrete of laterite nodules: appreciation of the adhesion rate '', we can globally conclude that the lateritic nodules concrete has a good adhesion with the reinforcement borassus wood. It can therefore be envisaged for the future, the study of the conditions of durability of this adhesion in the future. Then, the design methods of low load bearing housing based on quality local materials at lower cost will envisaged in the interest of the African populations and of Benin in particular.

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