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CHARACTERIZATION OF CONCRETE REINFORCED WITH BORASSUS AETHIOPUM MART SUBMITTED TO PRESTRESSING BY PRETENSIONING: BEHAVIOURAL SIMULATION

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ABSTRACT: The present work is taken into account for the study of the possibility of substituting steel reinforcements by reinforcements of Borassus Aethiopum Mart. Specifically, the purpose of our study was the use of Borassus in the field of prestressing. Several tests have been carried out for this purpose. The characterization tests of the materials carried out at the beginning of this study on the constituents of the concrete made it possible to adopt a concrete formulation by the DREUX-GORISSE method. This allowed us to make six test pieces; Three with steel reinforcements and three others in frame of Borassus. After their preservation for 28 days, they were subjected to flexion tests four points. Thus the loads and the arrows induced were recorded for the different types of concretes. In addition, we performed the direct traction test. This test allowed us to define the elastic zone of our framework of Borassus. A simulation of the flexion test four points on the Borassus reinforced concrete subjected to prestressing by pre-tensioning was then made. This taking into account the elastic zone of our framework and the physical and mechanical characteristics of the reinforced concrete of Borassus. The overall flexural behavior of four points of prestressed beams by numerical simulation and those of reinforced concrete of steel reinforcements were analyzed. The results obtained allow us to conclude that the elastic stress of Borassus reinforced concrete subjected to prestressing is superior to that of reinforced steel.

KEYWORDS: Borassus Aethiopum Mart, tests, prestressing, simulation, elastic stress.

1 INTRODUCTION

With the Millennium Development Goal n° 7 (MDG 7) " To ensure a sustainable environment" the world has set itself the goal to halve the proportion of people suffering from hunger and to significantly improve housing conditions of at least 100 million hovel dwellers around the world. Face to socio-economic problems in rural areas, many people are demanding for a real promotion of natural resources. The reflections of the great institutions and researchers on this subject have led to the valorization of local building materials as a solution. Indeed, the promotion of so-called "local" building materials can be interesting in sub-Sahelian countries, especially in the countryside. These local materials have the advantage of responding validly to the question of architectural heritage; during these last decades, researches have shown the possibility of substitution of steel by reinforcements of Borassus Aethiopum Mart [1], [6]. Borassus AETHIOPUM, one of these local materials, commonly called rônier in French is a plant species encountered in Sahelian Africa in general and in Benin in particular. Some authors recognize it as a fibrous tree that grows in the temporarily flooded slums of Sahelian Sudanian zones of Africa [3]; others show that the rônier constitutes in Africa one of the best woods in the Sahelo-Sudanese zone [4]. This possibility of substitution by binding with the numerous advantages of this material has led researchers to know the typology of the Borassus plant species, to become acquainted with its endogenous use as timber, to study its physical, mechanical and chemical characteristics. Later, other conclusive studies were carried out in the direction of comparison of reinforced concrete of steel to that reinforced with Borassus under various stresses. Apart from conventional reinforced concrete in civil engineering, today we have prestressed concrete, an invention of Eugène Freyssinet in 1928. This concrete is a known technology, unambiguous and commonly used technology for large crossing structures. It is also widely used for precast floor joits and many other types of structures. But, in the idea of substituting steel by Borassus reinforcements, could we subject them to prestressing in order to have concrete reinforced with Borassus Aethiopum Mart submitted to prestressing by pre-tensioning?

This paper presents the results of the work on the characterization of Borassus Aethiopum Mart reinforced concrete subjected to prestressing pre-tensioning by behavioural simulation by using the Ansys Inc. software.

2 METHODOLOGY

The main object of the literature search was to make a bibliographic synthesis which led us to make an inventory of the previous works carried out, to have their results; this allowed us to realize the existence of a bibliographic gap with regard to the objective of our study which is the identification of the connection which will give a maximum resistance in the lapping zone. So we went, for the start of the study, in the forest gallery of Pahou-Ahozon in the South of Benin where we proceeded to the felling, sawing up and putting into planks of a foot of male Borassus Aethiopum Mart. After these stages, the planks were dried at the society ATC du Bois in Allada at a moisture content of 12%. Further to it, we proceeded to the machining of the latter into standardized specimens in the wood workshop of the Coulibaly Technical High School in Cotonou. In a parallel to the previous activities, identification tests have achieved on the samples of lagoon sand, of rounded gravel of Mono and of SCB Bouclier CPJ 35 ciment that will be used in the formulation of concrete reinforced with Borassus Aethiopum Mart. The Laboratory of Materials and Structures (LAMS) of the Véréchaguine A. K High School of Civil Engineering served as a framework for the achievement of various mechanical tests on samples and specimens.

3 RESULTS AND DISCUSSIONS

3.1 PHYSICAL CHARACTERISTICS OF MATERIALS

On the materials used in the mixing of the concrete of study (lagoon sand, Mono rounded gravel and CPJ cement), physical characterization tests such as grain size analysis by sieving, specific gravity, bulk specific density and sand equivalent were made. Some tests of grain size analysis of the lagoon sand, of specific gravity, of bulk specific density and of sand equivalent, gave us the results recorded in the following table:

Table 1. Summary of materials characteristics

	Lagoon sand	Rounded gravel from Mono	Cement
Granular class	0.08/5	5/15	-
Coefficient of Finess FM	2.55	-	-
Uniformity Coefficient of Cu	3.255	.538	-
Curvature Coefficient of Cc	1.23	1.06	-
Specific density (g/cm³)	1.42	2.05	-
Bulk specific density (g/cm³)	1.5	1.62	3,10
Density « SSS »	2	-	1,00
Percentage of absorption	0.33	1.60	-
E.S	89.47	-	-
E.S.V	94.74	-	-

From the various results obtained, we formulated the concrete to be used for the molding of the beams.

3.2 MECHANICAL CHARACTERISTICS OF FORMULATED CONCRETE

The formulation of the concrete was made according to Dreux-Gorisse's method [5] where we wish to make a plastic concrete for the realization of beams with a maximum size Dmax = 31.50 mm for aggregates. The desired resistance is σ'n = 300 bar. Aggregates are of current quality, rounded with a normal vibration of SCB of the true class at 490 bars.

The slump in the desired cone is 5 cm.

The different tests were carried out in the Laboratory of Materials and Structures (LAMS) of the V.A.K. High School of Civil Engineering (ESGC-VAK). Among these tests, we have:

- **Abrams cone slump test carried out on fresh concrete (NF EN 12350-2)**

This test was carried out every time we poured the concrete for the construction of the beams.

After each concrete mixing, we measured the workability of our concrete by making the Abrams cone slump test.

Fig. 1. Subsidence test in progress

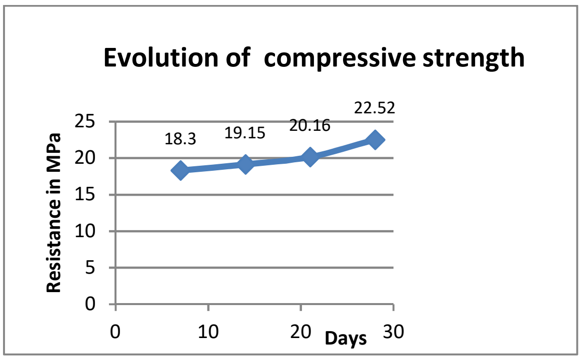
This allowed us to note a medium subsidence of the Abrams cone obtained from 5cm allowing us to conclude that our concrete is firm and well-vibrated.

- **Compression test on hardened concrete (NF P 18 – 406)**

The assessment of the strength of our concrete was made by carrying out compression tests on cylindrical specimens with a diameter of 16 cm and a height of 32 cm according to the standard NF EN 12390-3.

Fig. 2. Start of compression test on hydraulic press

The tests were performed after 7, 14, 21 and 28 days on two (2) different samples. The evolution of the compressive strength of our test pieces is shown in the figure below:



The breaking stress of the concrete used for the construction of the beams is : fc_{28} = 22.52 MPa

- **Four-point bending test (NF P 98- 302)**

Four (04) points bending tests were performed on three rônier beams and three steel beams.

Fig. 3. Beginning and end of the four-point bending test

The results obtained during this test, in particular the values of the breaking forces, the maximum sags and the Young's modulus of the different types of beams are recorded in the table below:

Table 2. Values of breaking forces, maximum sags and Young's modulus

Designation	Breaking force (daN)			Average of the breaking force (daN)	Maximun sags (mm)	Young's modulus (MPa)
Beam reinforced with Borassus	1005,75	1061,25	1087,5	1052,00±10	0,47	690,75
Beam reinforced with Steel	1172,25	1185	1140,45	1166,00±13,33	0,44	817,01

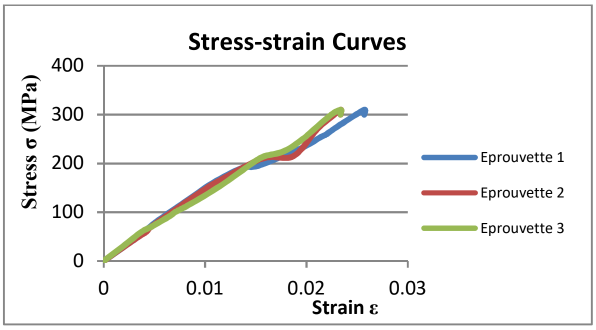
- **Direct tensile test (ASTM D1037)**

Direct tensile tests were carried out on three rônier test pieces.

Fig. 4. Placement of the test specimen; beginning and end of the direct tensile test

The results of these tests allow us to draw the stress-strain curve of Borassus Aethiopum Mart in Traction. We note on the series of tests that the three curves allow us to identify only the elastic domain.

These different tests also give us information about the type of breaking observed at the test tubes of Borassus Aethiopum Mart; it is an elasto-fragile breaking.



The treatment done on the results obtained is summarized in the table below.

Table 3. Values of elastic stresses, breaking stresses and strains in the elasticity

Designation	Elastic stresses (MPa)	Breaking stresses (MPa)	Deformations in the elasticity
Specimen 1	190	310	0.0135
Specimen 2	210	310	0.0156
Specimen 3	205	310	0.0149
AVERAGE	200±10	310	0.0148

4 Behavioural Simulation In Flexion Four (04) Points Of The Armed Beams Of Borassus Subjected To Prestressing By Pretensioning

Using the ANSYS Inc. software, we simulated the test of pretensioning by pretensioning to know the elasticity and breaking stress, in four (04) points bending, of a beam.reinforced with Borassus Aethiopum Mart subjected to prestressing by pretensioning.

4.1 Physical and mechanical characteristics of materials

In order to facilitate the task of writing the program and inserting the data of each material, we present here the summary of the physical and mechanical characteristics of these materials.

Table 4. Characteristics of the material " Concrete "

	Young's Modulus E (MPa)	Poisson's ratio ν	Shear modulus G
Value	30000	0.2	12712

Table 5. Material's characteristics " Steel "

	Young's Modulus E (MPa)	Poisson's ratio ν	Shear modulus G
Value	200000	0.3	76923

Table 6. Characteristics of the material " Borassus Aethiopum Mart "

Young's Modulus E (MPa)	17196
Density at 12% moisture	0.89±0.003
Maximum elastic stress in parallel traction to fibers at H = 12% (MPa)	200±10
Breaking stress in parallel traction to fibers at H = 12% (MPa)	310
Poisson's ratio ν	0,2
Shear stress perpendicular to fibers (MPa)	13.59±1.02
Shear stress parallel to fiber (MPa)	0.88±0.22
Young's modulus in shear (MPa)	13.59

4.2 BASIC DATA AND ASSUMPTIONS FOR THE SIMULATION

In order to facilitate the writing of the program, the following data are essential:

Dimension of the test piece: 15cm x 15cm ; Length of the test piece: 91cm ; Section of Borassus bar: 2cm x 2cm

Length of Borassus bar: 101cm ; Tensile force Nmax = 80 kN ; The tensile stress: σ = 200 MPa

Prestressing force N = 80 kN ; Offset (cm): e1 = 0; e2 = 0; e3 = 0 because it is a self-stressing.

Later on, we have, in the idea to get much closer to the reality of performing the four-points bending test, issued a number of assumptions listed below:

- Perfect adhesion between the Borassus bar and the concrete;
- The supports used are cylindrical;
- The square sections are likened to circular sections.

4.3 WRITING OF PROGRAM

It is a question of observing the behaviour of a beam of 91cm long and of section 15x15cm2, subjected to a pre-tensioning.

The simulation performed is done according to the following stages:

Definition of the study and the geometry

Definition of loading and boundary conditions;

Application of properties of materials (introduction of characteristics);

Treatment of the model: It is recommended that this processing must be done before creating the mesh;

Creation of the mesh: The mesh begins with the evaluation of the geometry;

The resolution of the system;

The preparation of the report and the observation of the results can finally be done.

4.4 MECHANICAL CHARACTERISTICS OF THE FORMULATED CONCRETE

- **Geometry, loading and mesh of the Borassus Aethiopum Mart reinforced beam**

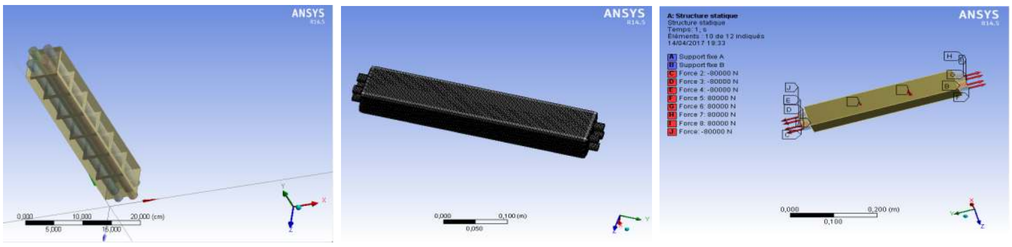


Fig. 5. Beam reinforced with Borassus Aethiopum Mart

Before the calculations started, we had made sure that the stages were verified. The figure above shows that all the stages have been verified successfully.

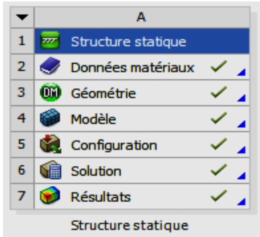


Fig. 6. Verification of different stages

- **Stresses, strains and displacements**

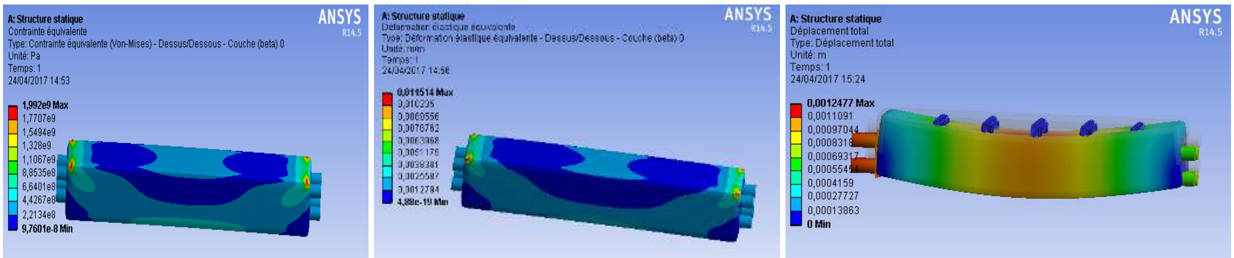


Fig. 7. Stresses, strains and displacements recorded in the beam reinforced with Borassus Aethiopum Mart subjected to prestressing

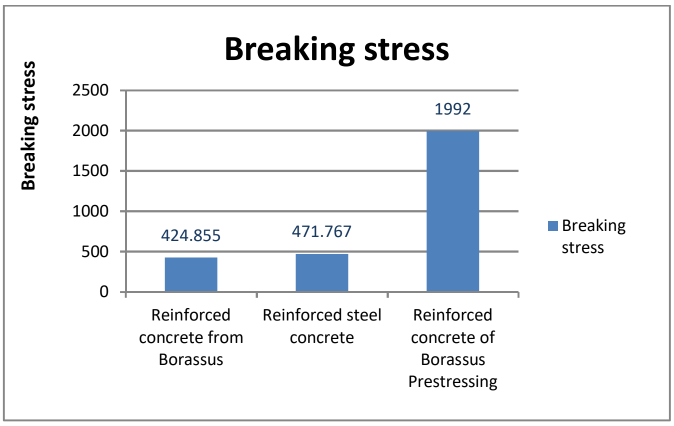
Considering the results obtained on ANSYS, we note that the diffusion of stresses and deformations is more important at the edges of the beams. This is explained by the fact of the application of tension in the reinforcements which in turn induces a compression in the concrete. As for displacements, we noticed with ease that the adhesion between the bars of rônier and the concrete is almost non-existent; which is not the case between the steel transverse reinforcement and the concrete.

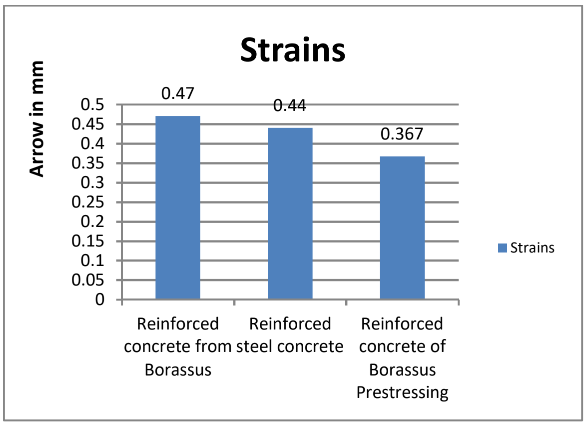
4.5 Interpretation and analysis of results with other tests done

From the results obtained, it can be concluded that the tensioning of the Borassus reinforcement has a considerable influence on the breaking strength of the beam in four (04) points bending; therefore of the breaking stress.

Further, this tensioning of the Borassus reinforcements avoids the observation of a big arrow during the achievement of the simulation test even though we observe a non-adhesion between the concrete and the Borassus. These interpretations led us to conclude that concrete reinforced with Borassus Aethiopum Mart subjected to pretensioning by pretensioning offers better characteristics than a single-steel reinforced concrete.

It would be interesting to test the laboratory for confirmation of results.





5 CONCLUSION

The purpose of the study presented was to compare the values of the elastic and breaking stresses at four (04) points bending of concrete beam reinforced with Borassus subjected to prestressing by pretensioning with those of concrete beam reinforced with steel. This aim is achieved by first making a physical and mechanical characterization in the laboratory of the various materials used in the manufacture of our beam reinforced with Borassus Aethiopum Mart armature and finally the determination of the elasticity and breaking stress of our different types of beam.

The bibliographical synthesis has highlighted the utility of Borassus wood as reinforcement in concrete; which allowed us to characterize this Borassus reinforcement in other aspects: prestressing.

Modeling and behavioural simulation with ANSYS software Inc. showed.

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