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Elaboration of a Cement Matrix Composite, Improved with the Pozzolan of Rice Husk Ash, Reinforced with Sugar Cane Bagasse Fibers

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ABSTRACT

In this work it's developed a multifunctional eco-material based on short fibers of sugar cane with a cement matrix improved with the rice husk pozzolana. The properties of the sand were analyzed by particle size, fineness modulus and sand equivalence tests. The rice husk pozzolan was obtained by calcination at 600 ° C, the temperature at which the fire loss becomes constant, until calcination of the ash, which was determined by Thermogravimetric Analysis. The characterization of the ash was determined by the X-ray Diffraction and Fluorexence X tests to obtain its mineralogical constituents, in particular the silica content of 98.78%, in preponderance which had characterized its pozzolanicity. The pozzolanic activity of 0.71 was in the active range of 0.67 to 1. The composite material was tested for maneuverability with a water / cement ratio E = 0.7. Substitution of the sand by sugarcane fibers, up to a rate of 5%, had improved the behavior in compression, in bending, which were tested by the 3-point bending test, combining good mechanical properties in flexion of 4.82 MPa, ductile and very light for its use to reduce the weight of the structures and fight against global warming, due to the quantity of cement less, source of production of significant quantities of polluting CO_2.

Keywords: eco-material; matrix; maneuverability; fibers, mechanical; compression; resistance.

1. INTRODUCTION

The building sector has been proven as a vector of environmental pollution, through the consumption of natural resources (rocks, wood, water, etc.) and energy (construction process, transport, heating, lighting, etc.) during all phases of its evolution: construction, use, rehabilitation and destruction. Philippe. Deshayes (2012) showed that, the building represented around 40% of CO_2 emissions from developed countries, 37% of energy consumption and 40% of the waste produced. Also faced with an exhaustion of fossil resources having non-renewable petro-sourced constituents, the researchers were interested in the valorization of renewable vegetable or natural materials. Bio-composite materials, reinforced of animal or vegetable origin, thus meet ecological and economic challenges. Solid waste management is one of the main concerns worldwide due to the increasing quantities of industrial waste and by-products. Therefore, for a few years, scientific interest has being turned to tropical fibers, such as sisal, alpha and jute fibers. A very few researches where performed on sugarcane bagasse reinforcements. To cater for the concern of valorization of the waste of the sugar cane, the husks of rice husk and also the reduction of greenhouse gases and for the civil engineer, the lightening of the structures, a solution was on the one hand, to study the possibility of using ecological materials produced from these wastes, respecting scientific standards, of very low weight. In Benin, SUCOBE, a factory that transforms sugar cane into industrial products (sugar, ethanol, etc.), produces a large amount of sugar cane waste, an industrial residue, eliminated by burning. The husks of the rice are also wastes from husking of rice from industries located in Zangnalando in central Benin. The originality of the study was to develop a material with a cementitious matrix, improved with an artificial pozzolan rich in amorphous silica and reinforced by short bagasse fibers from sugar cane, randomly arranged which gives a property of anisotropy to this material.

2. MATERIALS, EQUIPMENT AND METHODS

Materials

In this study, several materials are used for the confection of composites including:

- sugarcane bagasse fibers;
- rice husk;
- sand;
- water;
- cement.

2.1.1 Bagasse fibers from sugar cane:

According to the literature, the bagasse of sugar cane is a residue generated largely by agro-industries for the production of sugar or ethanol. Sandra. Luz, Adilson. Roberto. Goncalves, and al, (2007) showed that this residue, obtained after extraction of the sugar cane juice, is mainly made up of fibers usable for composite reinforcements. Davina. Michel, (2013) proved that this crude residue consists of 50-60% in the dry base of useful fibers. The main production plant in Benin is the Complant Sugar Factory of Benin (SUCOBE). Today, in the SUCOBE factory, the residues are used partly as fuel for boilers, and the rest eliminated by uncontrolled burning. In the context of the present study, preliminary treatments are carried out, consisting in separating the organic matter and the marrow, from the fibers of the bagasse itself, after immersion in water. The fibers, after this treatment are dried in the open air for seven days. They are stoved at 105 ° C in the laboratory for 24 hours.

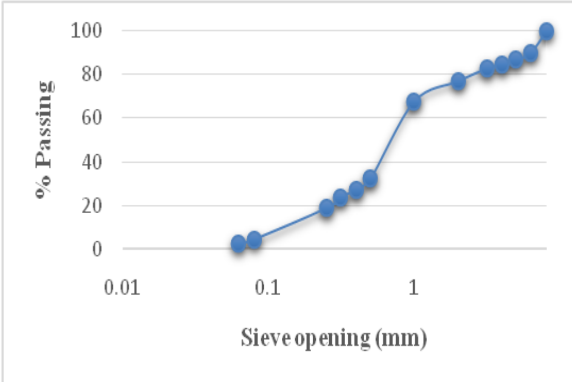

Figure 1: Sugarcane bagasse
Figure 2 : Particle distribution of sugarcane bagasse fibers

The size distribution of crushed sugarcane bagasse fibers, is shown in Figure 2. This curve is similar to that obtained from Mohamed. El-Sayed and Taher. El-Samni, (2006), on the granulometry of the bagasse of sugarcane.

For made-up composites, we are interested in the granular class of [2 ;2,5 ;5].

2.1.2 Rice husk Ash / Artificial Pozzolan

Anissa. Benredouane, Larbi. Kacimi, and al (2014) worked on artificial pozzolans and claimed that they are minerals from factories, thermal power stations and even from the calcination of agricultural by-products rich in reactive silica and alumina.

An artificial rice husk pozzolana was obtained by calcining the husks of rice, at various temperatures ranging from 400 ° C and 850 ° C. The optimal calcination temperature is given to us from the stabilization temperature of the mass of the ash. Figure 3 gives the loss on ignition as a function of variation in the calcination temperature. A 'm' mass of 10 g was taken for analysis.

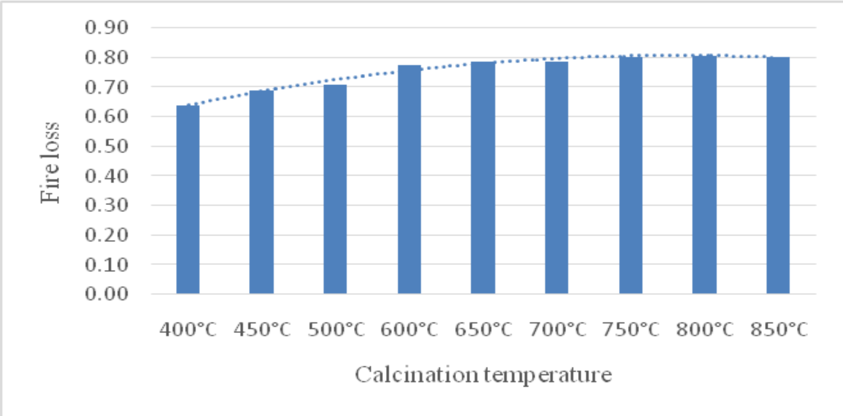

Figure 3. Variation of loss on ignition as a function of temperature.

The heating speed of the oven was adjusted to 5 ° C / min to obtain a calcined and homogeneous ash, according to the protocol, for 5 hours of time. The temperature was then kept constant for 2 hours. The calcination temperature was that from which the loss on ignition became constant. As shown in Figure 3, the target calcination temperature for one of this rice husk reactive pozzolana was 600 ° C. Lavie Arsène and Mango-Itulamya (2018) in; Jesse. Kigozi, Moses Kiggundu. and al (2015) obtained the same calcination temperature on the rice husk, and determined a reactive pozzolan.

(a) (b)

Figure 4 : (a) Rice husk - (b) rice husk ash obtained after calcination

2.1.3 Sand

The sand used comes from the Dekoungbe quarry, of the MINEX company which was extracting on a large scale, sand, in Benin, of granulometry presented in figure5.

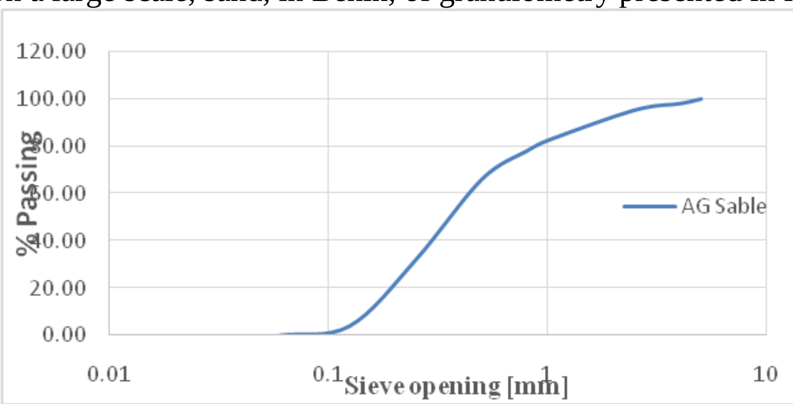

Figure 5. Sand particle size analysis curve

2.1.4 water

The water used for the formulation of the composite was produced by 'the Société Nationale des Eaux du Bénin' (SONEB) with a pH of 6.7.

2.1.5 Cement

The hydraulic binder used was the Cement Portlant with physical characteristics given in Table 1.

Table 1. The physical characteristics of cement

Apparent density	1,073
Volumic mass	3,01
Beginning of setting	3h05
End of setting	4h39
Specific surface (Blaine)	3155
Expansion	1,5
Refusal on sieve 0.08	10,92
Refusal on sieve 0.16	0,8

The mechanical characteristics of this cement are given in Table 2.

Table 2. Mechanical characteristics of cement

Number of days	Compressive strength (MPa)
2days	13,2
7 days	24,2
28 days	33,0

2.2 Equipment

The tests are carried out in the laboratories:

• Laboratory equipment "LEMA", Department of Civil Engineering, Doctoral School of Engineering Sciences, Abomey Calavi, Benin;

• Equipment of the laboratory of the School of Sciences and Techniques of Building and Roads (ESTBR) of Abomey in Benin;

• Isa Yakubu, Department of Chemical Engineering Ahmadu Bello, University Zaria Kaduna State.

Figure 6: TGA Apparatus 4000 BY Perkin Elmer
Figure 7: Tensile and compression testing machine

2.3 Methods

2.3.1 Molding of test pieces

The control samples were obtained according to the cement / sand mass fraction of 1/3 and the water / cement ratio (W / C) fixed at 0.7, according to the protocol of the European Standard, "196–1, (1995). Different rates of substitution of sand with reinforcements of sugar cane bagasse (2.5%, 5%, 7.5% and 10%). The cement was substituded at a rate of 10% by the pozzolana of rice husk ash. Specimens of dimensions 4cm x 4cm x 16cm are made and kept in the laboratory.

The principle of the formulation of the composite was that in Figure 8:

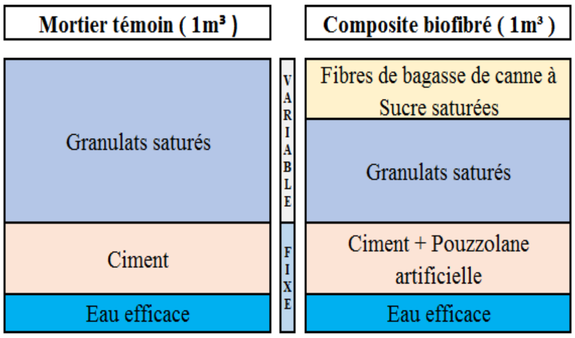

Figure 8: Schematization of the principle of formulation by volume substitution in the saturated state.

Figure 9 : Molding of test pieces

Figure 10: stripped test pieces

RESULTS

The mineralogy of the ash from the rice husk produced was determined by X-ray diffractometry (XRD). The protocols of the DRX and FX tests that J. D. Martín-Ramos, J. L. Díaz-Hernández and all (2012); Khaled. Boughzala, Nabil. Fattah, and al, used, are based on linear correspondences between the intensities diffracted by each crystalline phase and their proportion in the powder of rice husk ash, are followed for the results of curve 6 and the determination of the constituents mineralogical content of the ash obtained, Table 3.

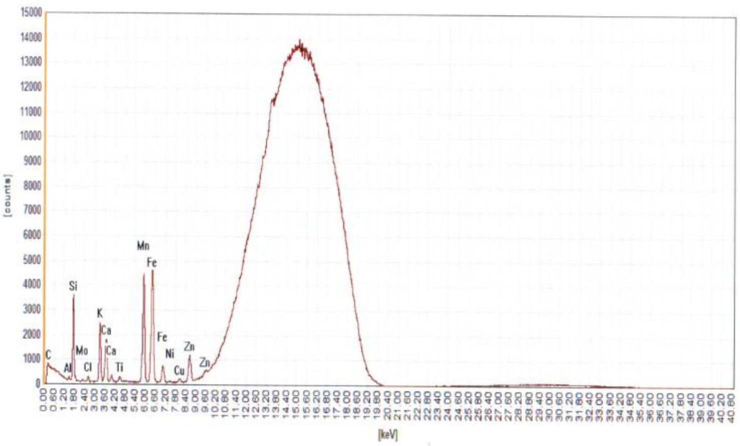

Figure 11: DRX diagram of ash from the husk of elaborated rice

Table 3. Chemical constituents of rice husk ash

	Chemical constituents (% by mass)							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	$S0_3$	K_2O	Na_2O
Rates %	98,78	0,1	0,24	0,41	2,64	0,05	1,93	0

The value of the activity index had been determined by Mouhamadou. Amar, Mahfoud. Benzerzour, and al, given by the ratio between the compression resistance of the standard reference mortar (M) at 28 days (NF EN 196-1) and the mortar of 25% substitution of the cement mass (25C) by the rice husk pozzolana. This formula is applied and gave us the value of the index for the elaborated rice husk pozzolana.

$$i_a = \frac{R_{C28j}(M)}{R_{C28j}(25C)} \quad (1)$$

$$i_a = 0,71$$

The composite was formulated in:
fixing the W / C ratio at 0.7 which gave good handling of the material;
Jonathaan. Page, (2017) ; Valery. Doko, Emmanuel. Olodo, (2016) and al, evaluated the volume of the granular skeleton (SG), in the saturated state of the fibers, in accordance with the principle of formulation by volume substitution in the saturated state by the expression:

$$V_{SG} = \frac{1m^3 - V_C - E_{eff}}{1 + W_{FBCS}} \quad (2)$$

Where WFBCS is the water absorption coefficient, C the amount of cement and Eeff the effective amount of water.
Standard NF EN 206-1 (1995) defined effective water as follows:

$$E_{eff} = E_{gr} + E_{adj} + E_{cent} - E_{abs} \quad (3)$$

where:, E_{gr} is the water from the aggregates; E_{adj}, the water provided by the adjuvants; E_{cent} , the water provided by the manufacturing unit; E_{abs} , the water absorbed by the aggregates.
In accordance with standard EN 196-1, these test pieces were crushed at a speed of 50 N / s.
The results of the compressive test of the manufactured test pieces, with the variation of the fiber rates (2.5%; 5%; 7.25% and 10%), have been shown by the respective stress-strain curves, plotted in Figure 12.

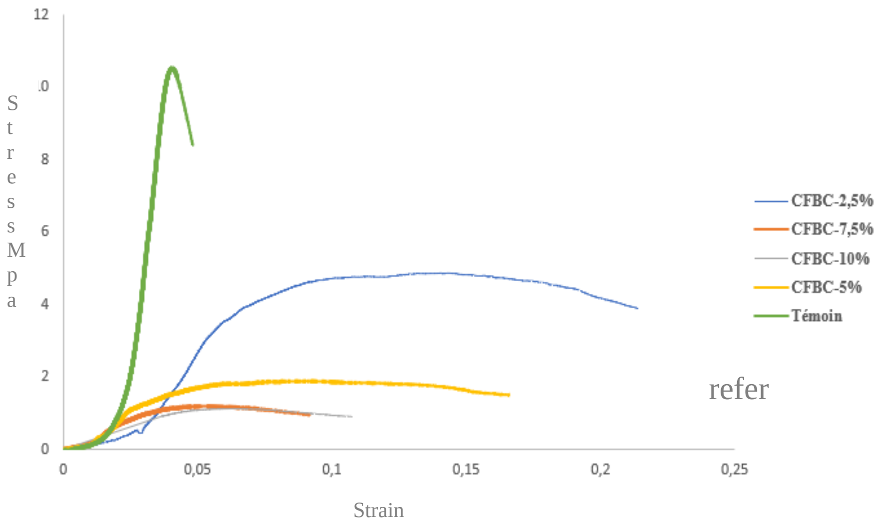

Figure 12: Compression behavior curves for composites at 28 days of age.

The trend curves have been drawn for the study of the elastic domain of the material. The slopes of these curves were Young's modulus of 2.5% to 10% fiber substituted test pieces. The different values of Young's modules have been grouped in Table 4 below.

Table 4. Young's modules of the materials in function with variation in fiber content at 28 days of age.

Materials	Young's modulus (E) in MPa
CFBC-2,5%	6,70
CFBC-5%	9,88
CFBC-7,5%	17,14
CFBC-10%	24,46

The three-point bending test on the mortars made it possible to draw the different curves in Figure13.

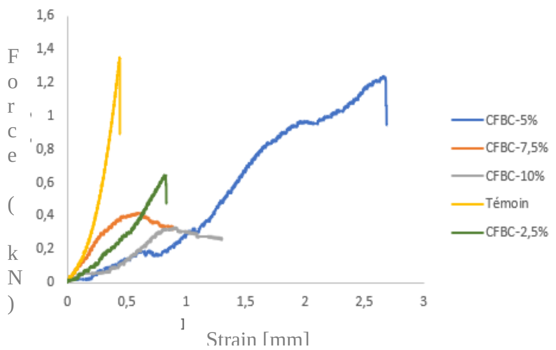

Figure 13. Stress-strain curves in bending

According to the European Standard, "196–1, (1995), the breaking strength in bending was given by the relation

$$Rf = \frac{1,5\,x\,F_f\,x\,l}{b^3} [14]. \qquad (4)$$

The values of the tensile strengths of the composites have been represented in Figure 14

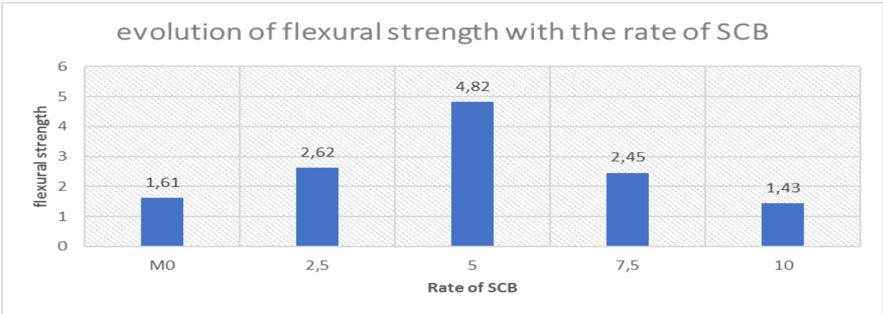

Figure 14. Stress at break in bending of composites at 28 days of age.

DISCUSSION

The curve from the XRD test, Figure 6 and X-ray fluorescence spectrometry (2020), Table 3, showed the presence of an amorphous silica (Si), with a significant rate of 98.78%, which characterizes the pozzolanity of the rice husk ash. The resistance index determined for the husk of rice of 0.71 is between 0.67 and 1, located in the characterization range of pozzolanic products, according to ASTM Standard C618-08a (2008). The results of compressive crushing tests on test pieces made at fiber substitution rates of (2.5% ; 5% ; 7.25% and 10%), given by the stress-strain curves in Figure 1., show that the increase in the percentage of fibers causes the material's breaking stress to drop considerably. The three-point bending tests have shown that, up to a substitution rate of 5%, the bending resistance, of 4.82 MPa, is higher than that of the other substitutions, which decreases at a breaking stress in bending 7.71 MPa for a 10% fiber absorption rate. This is confirmed by David Sedan's conclusions on the behavior of fibrous materials. Table 4 shows Young's modulus values which increase with the increase in fiber content substitution, 25% - 6.70 MPa; 5% - 9.88 MPa; 7.5% - 17.14 MPa; 10% - 24.46MPa. We conclude that the bagasse fibers make the material more elastic. This is interpreted by a quasi-linear phase, which is similar to the behavior of pure cement, therefore a load mainly supported by the matrix, which is gradually transferred to the fibers. Once the maximum bending stress of 4.82 MPa, applied is reached, there is a sudden drop in load, delayed which reflects the resumption of the load by the fibers. We deduce by an approximation that the propagation of cracks in the material is limited by the fibers. Also a displacement which can be associated with a progressive rupture of the fiber-matrix interfaces followed by loosening, and a rupture of the fibers.

CONCLUSION

Compression tests showed the anisotropy of the material. The substitution of sand by fibers makes it possible to obtain a multi-functional material for civil engineering works available to the engineer, the use of which would make it possible to lighten the structures of constructions. The use of this material would reduce global warming. Finally, we note that this elaborate composite of materials from renewable resources, obtained with low energy demand, contributes to the reduction of greenhouse gas emissions and also to the lightening of the structures incorporating these plant reinforcements.

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