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RESEARCH ARTICLE

PHYSICAL CHARACTERIZATION OF STARCH-COTTON FIBER COMPOSITE SHEETS

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Abstract

Biobased materials had been identified as replacements for materials produced with chemical binders. Panels made from "**starch-cotton fiber waste**" composite materials fit perfectly into the category of biobased materials. The aim of this study was to measure the physical properties of starch-cotton fiber composite sheets. For sheets manufactured in 300x300x100mm^3, the density and dimensional stability properties (water content, absorption rate, dimensional and volumetric swelling) were calculated. Density was determined in accordance with NF EN 323. Swellings were determined in accordance with EN 317. Water content was measured in accordance with EN 322. The sheets were manufactured with starch/water and starch/cotton fiber mass ratios respectfully equal to 0.25 and 1. We obtained an average water content of **4.27%** and an absolute density**γs =1.13g/cm^3**. The average absorption coefficient measured was **62.88%.** The measurement of dimensional variations showed that the panels underwent little deformation in the length and width directions. The average was 2%. In the thickness direction, on the other hand, dimensional variation was very high. This averaged 44%. The latter reflects the porosity of the material.

Introduction:-

The Republic of Benin is one of the top two cotton-producing countries in West Africa. A field survey identified (14) types of residue from cotton processing. Most of this waste is unexploited and takes up unnecessary portions of land. Even though they are biodegradable, farmers have to get rid of them quickly to save space and prepare their fields. This waste is therefore partly burnt, contributing to the evolution of CO2 levels in nature.

The introduction of agro-materials (derived from plant or animal biomass) is one approach to a solution for managing agricultural waste in general, and cotton waste in particular.

For Rowell, eco-composite materials can be produced in different configurations (Rowell, 2008) Either from natural fibers and a polymer matrix, or from synthetic fibers and a biopolymer matrix, or from a 100% biobased composite, all components of which are derived from biomass (biopolymer matrix reinforced with natural fibers).

The water absorption capacity of composites as well as their classical mechanical properties such as tensile, flexural, shear have been reported in the work of Alix et al. (L. Yan and K. Jayaraman, 2014)Abdulnasir et al. (Nasir, 2015)

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and Akil et al. (Akil, 2009). They showed that the mechanical behavior of natural-fiber composites is very different from that of conventional synthetic-fiber composites. They also showed that these eco-composites have relatively high mechanical properties thanks to their low masses. Natural fibers have been adopted for their low cost, availability and, above all, to preserve the ecological advantages of the bio-polymers used.

Thus Miss BOUDJEMA HayetLatifa (Latifa, et al., 2016) used the fibers extracted from a plant called "arroche maritime" (AtriplexHalimus) or "G'ttaf" in Arabic, which is one of the most abundant plant resources in Algeria, to manufacture an eco-material. In his work on the characterization and optimization of a biosourced composite for housing, YoannBrouard has highlighted aspects relating to the processing of rapeseed and sunflower co-products, their microstructure, porosity, thermal conductivity and capillary absorption capacity (Brouard, et al., 2018). Recently another work on natural fibers "Elaboration and characterization of a composite material based on olive wood flour" by Nesrine BOUHAMED (BOUHAMED, 2020)exploited plant reinforcements derived from olive wood processing, introduced in the form of olive wood flour (OWF) into a polypropylene polymer matrix.

The properties of natural-fiber composites are of interest to all areas of engineering. However, the fibers used vary from one project to another. This is due to their availability in different regions of the world. All the fibers used by the above-mentioned researchers are in short supply in West Africa, and particularly in Benin.

In this study, we produce biobased eco-composites from cotton waste fibers using a 100% biobased binder, cassava starch. Physical characteristics such as density and dimensional stability properties are measured. The results obtained showed that the composite has very interesting characteristics for use in building construction.

Materials And Methods:-

Cotton waste: cotton fibres

The cotton waste used in our work comes from fields and factories in Benin. The waste is processed with a manual defibrator to obtain the fibers. These fibers have an absolute density of 0.29 g/cm^3 and a water content of 12.71%.

Binder: cassava starchpowder

The starch used is produced from field-grown cassava. It has a water content of 17.03%, with absolute and bulk densities of 1.26 g/cm^3 and 0.70g/cm^3 respectively.

Composite formulation and preparation

Our previous work has enabled us to select a formulation for our composite. In fact, to dose the binder, we used a **"Starch/Water"** mass ratio equal to 0.25. This led us to use 200g of starch powder for 800ml of water. The **"starch/cotton fiber waste"** mass ratio used is 1, so the quantity of cotton fiber used for one formulation is 200g. The slabs are produced in molds measuring 300x300x100 mm^3. Mixing for each preparation is carried out manually. After preparing the binder for around 5 min, we leave it to cool for around 10 min before adding the defibered cotton fibers. Kneading is meticulous, ensuring that the starch penetrates all the fibers. This process takes between 5 and 10 minutes. The resulting mixture is then placed in the mold for compaction under a pressing force varying between 11 and 50 KN, depending on thickness, in a hydraulic press. The material is demolded 5 min after the mold has been removed from the press. After demolding, the material is placed in an oven at 105°C for 24 hours. Once the composite has been removed from the oven, it is then stored in the open air of the laboratory for the loss of any remaining water within it for a week. On the seventh day, the panel is put back into the mold and the whole assembly is placed back under the press to undergo compression under loads ranging from 500 to 2000KN. This is where we obtain the final shape of our panel, which has a relatively flat surface.

Analysismethods

The physical properties we determined were: absolute density and dimensional stability properties. The dimensional stability properties we looked for are water content, water absorption and swelling (volumetric and three-dimensional).

Density was measured in accordance with NF EN 323. Dimensional stability properties are measured in accordance with EN 324-1. Water content is determined in accordance with EN 322

Swelling is measured in accordance with EN317.

Results and Discussion:-

Panel appearance

The resulting panels looked as follows:

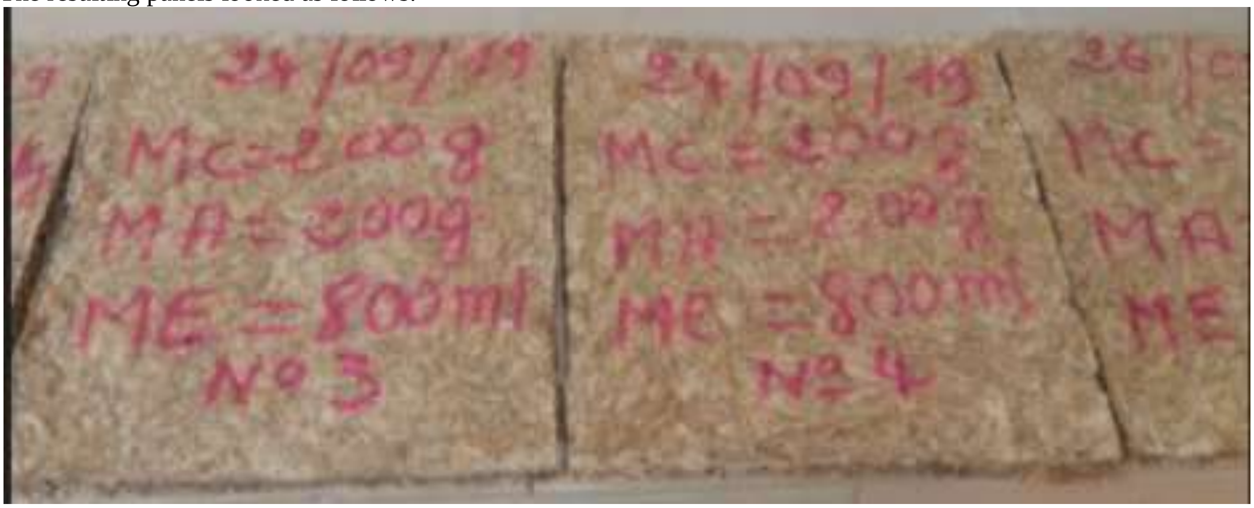

Photo 1: -Machined panel.

We used a sawmill to obtain the standardized dimensions. Following this process, we obtained the final shape of our panel, which presented a fairly flat surface.

Absolute density

The average of the three specimens measured gave a dry density of:

$\gamma s = 1.13 g/cm^3$

This was higher than the value recommended for low-density panels in American standard ANSI 20081, 1999 (LD-1 Low Density Class I, 550 ± 10% kg.m-3).

Overall, the densities of the panels obtained using our operating protocol were higher than those obtained by MAHDI KECHAOU (KECHAOU, 2019) in 2019, which ranged from 320 to 350 kg/m^3.

Water content

It is summarized in the following table:

Table 1: - Water content.

Test no.	A1	A2	A3	A4	A5	A6
Wetweight	13,1	13,1	13,2	12,2	12,2	12,8
Dry weight	12,6	12,5	12,6	11,6	11,6	12,3
Water weight	0,5	0,6	0,6	0,6	0,6	0,5
Water content (%)	3,97%	4,80%	4,76%	5,17%	5,17%	4,07%
Average w (%) :	4,7%					

The weight of water contained per unit weight of dry material was **4.7%.**

Water absorption

The results of the water absorption noted CA (%) are given in the table below:

Table 2: - Water absorption.

Test no.	A1	A2	A3	A4	A5	A6
Dry weight P1	12,6	12,5	12,6	11,6	11,6	12,3
Wet weight P2 after 24h	33,8	32,6	32,7	32,6	32,4	33,1
Water weight	21,2	20,1	20,1	21	20,8	20,8

Pe= P2-P1						
CA absorption coefficient (%) CA=Pe/P2	62,72%	61,66%	61,47%	64,42%	64,20%	62,84%
Arithmeticmean SALES (%)			62,88%			

The average water absorption of our material was **62.88%.**

Swelling

□The results in the three directions are as follows:

Table 3: -Swelling in all three directions.

Test tubes	L	l	e	L'	l'	e'	Length	Width	Thickness
A1	50	50	7	51	51	10	2%	2%	43%
A2	51	50	6,5	52	51	9,5	2%	2%	46%
A3	50	49	7	51	50	10	2%	2%	43%
A4	50	50	7	51	51	10	2%	2%	43%
A5	49	49	7	50	50	9,5	2%	2%	36%
A6	50	50	7	51	51	10	2%	2%	43%

The variation in length and width is not too great. It is 2%, which is not the case for thickness, reflecting the material's porosity. The variation averages 44% in this direction. These results are in line with the work of (Dix, 1999) who referred to the thickness porosity of the primary and secondary walls of reinforcing fibers.

Volume swelling

The results of this swelling are shown in the table below, confirming that our panel should not be used in contact with water. The calculated average thickness swelling is approximately 48%, with an average deviation of ±2%. Measures must be taken to prevent our panel coming into contact with moisture, as this could lead to the formation of micro-cracks in the composite.

Ishaya M. Dagwa and Josiah O. Ohaeri, (Dagwa, et al., 2014) in their publication on "Evaluation of the properties of OPEBF/banana/unsaturated polyester glass fiber-reinforced hybrid composites."

Table 4: - Volumetricswelling.

Test tube	L	l	e	L'	l'	e'	Volume
A1	50	50	7	51	51	10	48,63%
A2	51	50	6,5	52	51	9,5	52,00%
A3	50	49	7	51	50	10	48,69%
A4	50	50	7	51	51	10	48,63%
A5	49	49	7	50	50	9,5	41,31%
A6	50	50	7	51	51	10	48,63%

Conclusion:-

The physical characterization of the starch-cotton fiber composite has highlighted the very interesting properties of this material. The benefits of using plant fibers as reinforcements in composite materials are well established. Natural fiber composites are inexpensive and environmentally friendly. They have a low density and are biodegradable. Compared with synthetic fiber composites, they are more reliable and offer a number of advantages. The "cottonstarch fiber" composite is also a natural-fiber composite and is no exception to the abovementioned advantages. In this publication, we have determined the physical characteristics of this material after outlining its formulation methodology. The true density found isγ_s **=1.13g/cm^3.** The dimensional stability of the "cotton-starch fiber" sheet was studied. The average water content of our dry material is **4.7%. The** average water absorption of the material is **62.88%.** Swelling was determined in all three directions. It is considerable in thickness, with a calculated average of around **44%.** Finally, the volume swelling of the material is calculated and averages **48%.** From these results, we can conclude that our panel, like other natural-fiber panels, has poor moisture resistance. We still need to characterize our panel mechanically in order to define it better.

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