Effect of Moisture on the Mechanical Properties of Rhectophyllum Camerunense Natural Fiber Plaster Composites

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Abstract

The aim of this work focuses on the study of effect of moisture on the mechanical properties of natural fiber composite (NFC) plaster/Rhectophyllum camerunense (RC). Indeed, the treated and untreated RC fiber reinforced plaster composites are fabricated and submitted to hygrothermal ageing in an environmental enclosure of 23%, 54% and 75% relative humidities at 23°C. Flexural test was carryout under a threepoint bending approach to NF EN 6583 standard. Five specimens were tested for each case. the results indicate that the flexural properties of all the composites decreased with the increasing of moisture due to degradation of the fiber matrix interface.

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Introduction

Natural fiber and its composites are hydrophilic materials. Moisture content in natural fiber composites (NFC) significantly affects their physical and mechanical properties. Moisture transfer in these composites influences dimensional stability and durability. The absorbed moisture results in to the deterioration of mechanical properties since the water not only affects the unfilled polymer matrices physically and/or chemically but also attacks the hydrophilic natural fiber as well as the fibermatrix interface [1]. The works of Rangaraj and Smith Dhakal et al., Le Duigou et al., Hu et al., Assarar et al., deal with water sorption of composites reinforced by biobased fibers [2-6]. For example, in their work on the water uptake of a flax fiber composite material Assarar et al., [6]

showed an increase of the water content absorbed, compared to a material consisting of the same matrix reinforced with glass fibers [6]. Le Duigou et al., studied the behavior of a composite PLLA/flax in immersion in sea water. The weight gain curves showed the influence of the cellulose fibers. The saturated moisture contents of the specimens were around 5.6%. Secondly, Le Duigou et al., [4] showed a loss of the mechanical properties of the composite and an irreversible damage of the fiber/matrix interface during wet ageing [4]. As mentioned before, this interface is a critical area considering the moisture absorption. The water diffusing in the composite material creates hydrogen bonds with the fibers, which can lead to the reduction of the interactions between the fibers and the matrix. To prevent this phenomenon, fi-

ber surface properties could be modified by physical treatments (cold plasma treatment and corona treatment) and chemical treatments (maleic anhydride, organosilanes, isocyanates, sodium hydroxide, permanganate, alkali and peroxide) in order to promote adhesion [1, 7]. Many works have been done on RC fibers by some authors as Béakou et al., Noutegomo et al., Noutegomo et al., for characterization and study of the diffusion behavior of water vapor sorption in RC fiber and NFC [8-10]. The results indicated that moisture content increases with the relative humidity for RC and NFC. Moisture diffusion has been shown to be Fickian for RC fibers and non – Fickian for NFC. The aim of this work is to expose NFC at relative humidities of 23, 54 and 75% until saturation and then do flexural test to evaluate the influence of humidity on mechanical properties.

Material and methods

Material

RC fibers were used in this study. They were extracted from the roots of plants harvested in the wet equatorial forests of the center Cameroon. The roots used were fresh. We used NaOH powder for surface treatment. We also use the thermostatic oven of Memmert mark to dry samples of NFC. A balance PMI 400 mark with a precision of 0.001g were used to carry out weighing. Three chemical salts were used to prepare saturated aqueous solutions to create relative humidity in a small enclosure according to NF EN ISO 483: 200601 standard [9]. We also used a wood mould with internal dimensions of 115×20×20mm³ for the production of samples. The conditioning small enclosure was made up with the plastic bottles. Flexural test was carryout under a threepoint bending approach to NF EN 6583 standard. Some materials used are presented on figure 1.

Figure 1. Material used: aPlaster; bRC fiber; c Flexural machine.

Methods

The extraction of fibers was made by our care according to an unstandardized method used at the reference [8]. The NaOH chemical or alkali treatment used in this study was expected to improve fibermatrix adhesion in the composites. The alkali treatment is the most common method that is used for the treatment of natural fiber because this method is simple, inexpensive and effective. For the preparation, the fibers are immersed in an alkaline solution prepared starting from the dissolution of 10g pastilles NaOH in 190cm³ distilled water as presented on figure 2. This solution has a concentration of 5%. Solutions of higher concentration would have a very harmful effect on the properties of treated fibers. The processing time is 4H at room temperature. After treatment, the fiber was washed and rinsed several times with distilled water, neutralized with 2 wt% of chloridric acid and washed again.

Figure 2. Alkaline Treatment of RC fibers.

Afterwards fibers were dried at the ambient temperature during 24 H and then in oven at 100°C during 3h. The processing of samples consists in mixing water and plaster until obtaining a paste then versed it in the mould. The ratio water/composite in term of mass is 1 and the ratio fibers/matrix is 02 %. Thereafter we introduce fibers into the paste and mixing. The processing period was 3min. The adsorption moisture procedure is described by NF EN ISO 483: 200601 standard. The saturated salt solutions were prepared with distilled water 24H before at 23±1°C to have 23, 54 and 75% relative humidities in small enclosures. The NFC were dried to 65°C for 48H and introduced into a desiccator to avoid reabsorption of ambient moisture. For each environmental condition five specimens were introduced in small enclosure as presented in Figure 4. Periodic gravimetric measurements were achieved until the saturation. After saturation, flexural test was performed using the 3point bending method.

Figure 4. The specimens in small enclosure for adsorption moisture.

Results and Discussions

Flexural tests were carried out on 5 specimen of each type of material: unreinforced plaster, treated and untreated composites. Flexural Properties as strength, modulus and deflexion have been determined and the results presented in tables 1, 2 and 3 for the relative humidities of 23, 54, and 75%. The curve force/displacement of following figure 5, 6, 7 illustrate their behavior for various moistures.

RH	Properties	A	B	C	D	C	Average	S.D
23%	f (mm)	0.15	0.14	0.16	0.12	0.14	0.15	0.016
	E (MPa)	288.5	205.11	225.83	282.48	255.76	224.76	36.10
	σ_{max} (MPa)	0.59	0.53	0.55	0.59	0.62	0.59	0.035
	f (mm)	0.15	0.17	0.16	0.16	0.18	0.16	0.023
54%	E (MPa)	225.65	190.22	214.93	219.77	209.12	215.83	13.58
	σ_{max} (MPa)	0.53	0.57	0.54	0.54	0.52	0.54	0.028
	f (mm)	0.17	0.2	0.18	0.17	0.18	0.18	0.013
75%	E (MPa)	189.94	201.01	185.09	213.57	168.27	191.56	15.24
	σ_{max} (MPa)	0.42	0.51	0.55	0.51	0.55	0.51	0.045

Table 1. Flexural Properties of plaster with the relative humidity

Figure 5. The curve force/displacement with moisture of plaster

HR	Properties	A	B	C	D	C	Average	S.D
23%	f (mm)	0.36	0.33	0.32	0.38	0.34	0.346	0.019
	E (MPa)	253.13	268.01	284.77	253.13	268.01	265.41	11.75
	σ_{max} (MPa)	0.843	0.801	0.801	0.843	0.843	0.827	0.02
	f (mm)	0.45	0.40	0.42	0.38	0.4	0.41	0.02
54%	E (MPa)	231.37	234.51	231,37	249.16	241.62	237.60	6.88
	σ_{max} (MPa)	0.675	0.675	0.633	0.675	0.675	0.666	0.017
	f (mm)	0.42	0.44	0.46	0.45	0.5	0.45	0.024
75%	E (MPa)	223.74	208.83	232.03	202.09	195.78	212.49	13.48
	σ_{max} (MPa)	0.548	0.590	0.590	0.590	0.548	0.574	0.02

Table 2. Characteristics of the Untreated RC Plaster Composites with the Reative Humidity.

Figure 6. The curve force/displacement with relative humidity of the untreated RC plaster composites.

The characteristics of the treated RC plaster composites are presented in the following table 3 and the curve force/displacement of the figure 7 illustrate their behavior for various moistures. f is the maximum deflection, E the modulus and σ_{max} the maximum strength.

HR	Properties	A	B	C	D	E	Average	S.D
23%	f (mm)	0,66	0,66	0,64	0,65	0,64	0,65	0,008
	E (MPa)	377,65	401,86	304,97	353,88	310,81	351,53	41,92987
	σ_{max} (MPa)	0,99	0,95	0,87	0,89	1,09	0,957	0,078588
	f (mm)	0,70	0,74	0,74	0,73	0,75	0,73	0,015
54%	E (MPa)	343,13	328,01	344,77	333,13	318,01	333,13	11,06714
	σ_{max} (MPa)	0,94	1,01	0,87	0,89	0,92	0,9137	0,048826
	f (mm)	0,83	0,81	0,82	0,83	0,80	0,82	0,011
75%	E (MPa)	300,3	296,7	350,77	303,41	368,56	306,8	33,29
	σ_{max} (MPa)	0,873	0,892	0,864	0,888	0,911	0,8859	0,0175

Table 3. Characteristics of the treated RC plaster composites with the relative humidity.

Figure 7. The curve force/displacement with relative humidity of the treated RC plaster composites.

Table 4 Summarizes the mechanical characteristics of various materials and the graphs of figure 8 illustrate the variations of mechanical characteristics of various materials with the relative humidity.

Properties	Unreinforced plaster			Untreated composite			Treated composite		
	23%	54%	75%	23%	54%	75%	23%	54%	75%
f (mm)	0.15	0.16	0.18	0.346	0.41	0.454	0.65	0.71	0.82
E (MPa)	224.76	215.83	191.56	265.41	237.60	212.49	351.53	316.38	306.8
σ_{max} (MPa)	0.59	0.54	0.51	0.82	0.66	0.61	0.95	0.91	0.88

Table 4. Summary of the mechanical characteristics of various materials.

A

B

C

Figure 8. Evolution of the mechanical characteristics of materials with the relative humidity: a maximum deflection; b modulus; c strength.

It is noticed that whatever the material, mechanical properties decrease with the increasing of moisture. The reinforcement of plaster by fibers improves its properties in flexion. The alkaline treatment of fibers still improves it more. The plaster which is a fragile material receives the ductile character of the RC fiber during the reinforcement. The ductility is more improved when fibers are treated with NaOH. This is explained by the fact that the treatment eliminates fibers from the impurities, reduce a quantity of hemicellulose and waxes making thus rough the fiber surface. This roughness improves the interface and permit a better fixing or adhesion of the matrix on fiber. For a relative humidity of 23 %, the reinforcement by untreated RC fibers improves its strength of 38.98 % and 61.01 % when the fibers are treated. With regard to the modulus one notes an improvement of 18.08 % for untreated fibers composites and 56.40 % for the reinforcement by treated fibers.

On the other hand, we notice a diminution of the modulus of 4.13 % when we pass from 23 to 54 % of humidity then to 12.66 % when it is 75 % of moisture. We also observe a diminution of the strength for 9.25 % when we pass from 23 to 54% of humidity then to 5.88 % when it is 75 % of moisture.

For the case of the untreated fiber plaster composite we observe that modulus decreases for 11.73 % when we pass from 23 to 54% of humidity then to 11.81% when it is 75 % of moisture. The same decrease is observe for the strength for 24.25% when we pass from 23 to 54 % of humidity then to 8.20 % when it is 75 % of moisture.

For the case of treated fiber plaster composite, we observe a diminution of modulus for 11.11 % when we pass from 23 to 54 % of humidity then to 3.12 % when it is 75 % of moisture. We also observe a decrease of the strength for 4.39 % when we pass from 23 to 54 % of humidity then to 3.40 % when it is 75 % of moisture. We mark at the end that mechanical properties decreases with the increasing of moisture for all materials. We can explain this by the fact that moisture reduce the cohesion between matrix and fibers. We mote that the unreinforced plaster is very fragile and that the reinforcement improves this brittleness by a transfer of the ductility of the RC fiber towards the plaster. The treatment of fibers still improves more the mechanical properties of the composite. This treatment removes impurities from fibers, reduce the chemical content responsible for its absorbent nature and modifies the surface quality while making it rough. All this makes it possible to reduce the vacuums in material, a better fixing between the reinforcement and the

matrix for good improvement of this interface.

Conclusion

The aim of this work was to study of effect of moisture on the mechanical properties of NFC plaster/RC. We have fabricated three types of materials the evaluate that effect: unreinforced plaster, treated and untreated RC plaster composites. Those materials have been submitted to hygrothermal ageing in an environmental enclosure of 23%, 54% and 75% relative humidities at 23°C. Flexural test was carryout under a threepoint bending approach. Five specimens were tested for each case. The results indicate that the flexural properties of all the composites decreased with the increasing of moisture due to degradation of the fiber matrix interface. The fibers contained in the composite absorb water and lose their dimensional stability. they change volume and thus weaken the matrix [1]. Decreased in flexural properties after humidity exposure is due to formation of hydrogen bonding between the water molecules and cellulose fiber [1, 4]. Others authors also observe the decrease of mechanical properties when moisture increases [1-6]. This leads to dimensional and colour variation of composites product and poor interfacial bonding between the fiber and matrix, causing a decrease in the flexural properties. We mote that the unreinforced plaster is very fragile and the reinforcement improves this brittleness by a transfer of the ductility of the RC fiber towards the plaster. The treatment of fibers still improves more the mechanical properties of the composite. This treatment removes impurities from fibers, reduce the chemical content responsible for its absorbent nature and modifies the surface quality while making it rough. All this makes it possible to reduce the vacuums on surface material, a better fixing between the reinforcement and the matrix for good improvement of this interface.

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None

Conflicts of interest

The authors declare there is no conflict of interests.

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