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Study of the Thermal Behavior of the Plaster Reinforced Vegetable Fiber

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Abstract: *This study focused on the characterization of a heat insulating material, aims to determine the thermal characteristics of the plaster reinforced with vegetable fibers. It intends to replace the fibers of sisal generally used in practice to strengthen the plaster is replaced by those of the RheckthophyllumCamerunense (RC), a fiber of humid equatorial forests, in applications such as the manufacture of the staff, separating walls of dwellings. The objective of this work is to make a comparative assessment of the thermal diffusivity using a material composed of high porous plaster, non-reinforced and strengthened with the new plant fiber. It also aims to study the influence of the architecture of the RC fibers. The testing of thermal transfer by infrared thermography without contact are conducted on the composite plates. The resolution of the heat equation by finite difference with Matlab program permit the identification of the thermal diffusivity by fitting the theoretical thermogramme representation on the measures curve. The results reveal that the vegetable fibers increase the thermal performance of the plaster; that the RC fibers favor the isolation function better than the fibers of sisal and that their random distribution in the material proved to be more favorable.*
Keywords: *Plaster; vegetable fiber; infrared thermography; thermal diffusivity.*

I. Introduction

The plaster is a high availability material of construction resulting from the cooking of the gypsum, followed by grinding. It is also the same material striker plate with water and hardened. Former used as coated inside and outside, it is presently commonly used in buildings for his qualities: favorable to the protection of the environment, quite malleable, of low density, remarkable functional properties (fire, thermal and phonic insulation, regulator of the hygrometry of enclosures)[1], decorative (columns, cornices, moldings and rosettes staff), etc. This material, in Cameroon, is reinforced by the fibers of sisal to manufacture the staff. The fibers of sisal are imported from Mexico, Brazil or eastern Africa.

The characteristics in the thermal transfer of the plaster are available in the literature, it is thus recognized as a good thermal insulator [1, 2, 3]. The thermal insulation characteristics of the plaster reinforced with oakum was study by BRAHIM M.S. OULD and other [4] in 2010. Contrariwise, no information is available on the insulation properties of the plaster reinforced with RC.

The objective of this work is to study in a comparative manner the thermal properties of the plaster reinforced by fibers of sisal on one hand and the fibers of RheckthophyllumCamerunense (RC) of the other part. It also aims to study the influence of the architecture of the fibers of RC on the thermal properties of the composite plaster/fibers. The fibers of RC are extracted by our care of the fresh aerial roots of a climbing plant non-parasitical from humid equatorial forests according to the protocol described in the literature [5]. They are harvested in the regions of Zoetele and Ngomedzap south of Cameroon. The fibers of sisal are obtained from trade through the store SOCSUBA in Douala-Cameroon, their exact origin is not known. The plant has been discovered by the botanist C. Nteppe [5] and the properties of the fibers are favorable for the use in the mechanical engineering and civil engineering [7, 8, 9]. Out of the expected performances, the use of a local fiber for the strengthening of the plaster would reduce the cost of the material and extend its use.

II. Material And Methods

2.1 Non-reinforced plaster

Plates of 210x297x10 mm of plaster non-reinforced are manufactured. They are inserted in a framework of polystyrene. An infrared camera Jade Cedip III-MWIR (Fig. 1) is used to capture the temperature field on one face (B) of the test piece. The heat is projected by a projector on the other side (A) as shown in the simplified diagram of the manipulation of the figure 2.This camera has infrared detectors characterized by a wavelength range of 3.5 to 5 micrometers. The integration time used for the measurements is 1500 microseconds. The thermal resolution to the ambient temperature is approximately 0.02 degrees Celsius. The frequency of acquisition (fa) used is equal to 1 Hertz. In fact, each image corresponds to the average image of 10 images (the unit is used with an acquisition of 100 Hz). The spatial resolution in temperature, corresponding here to the pixel size on the specimen, is equal to 320x240 mm. The test pieces are not particularly prepared for the thermographic measurements. Usual for metallic materials, a thin layer of black paint is applied to the specimens to obtain an emissivity close to 1. In the case of plaster, in study, its emissivity is close to 1 (0.93) [9], there is more of interest to apply a layer of black paint on the surface of the material. A model program on Matlab using the method of finite difference and taking into account the parameters characterizing the inbound flow of one side and the convection of the other side as well as the thermal diffusivity allows to approach the experimental thermogramme.

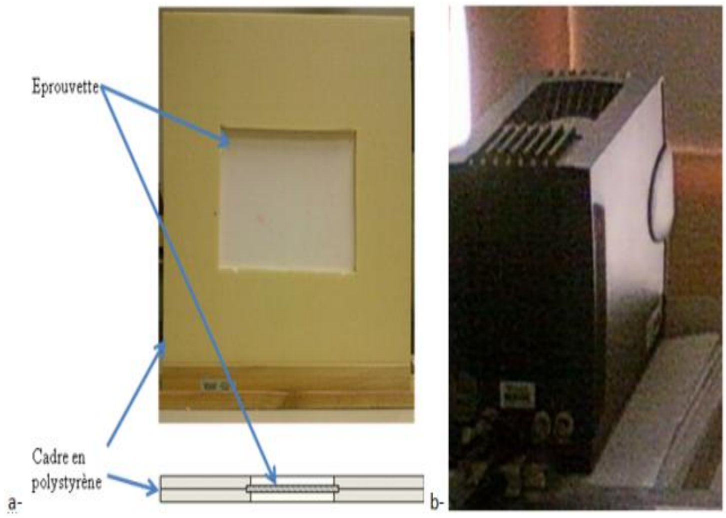

Figure 1: Infrared thermography: a- test piece in test configuration b- infrared camera

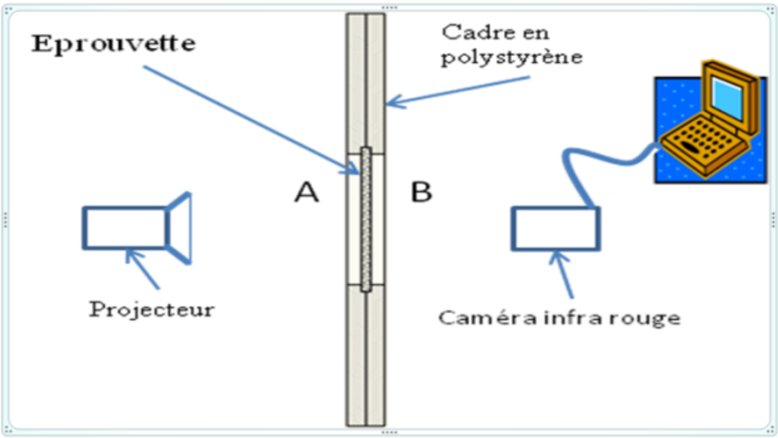

Figure 2: Schematic Diagram of the manipulation

2.2 Plaster reinforced with vegetable fibers

The plates of 210x297x12 mm of composite plaster/sisal fiber-reinforced oriented [0°/ 90°/ 45°/ -45] following four layers (F4D) are manufactured. The experimental device and method are the same as those presented in paragraph 2.1.

2.3 Influence of the architecture of the fibers of RC

2.3.1 Unorientated fibers

The experimental device remains the same as previously as well as the methods used. The test piece is a plate of composite plaster/RC of 210x297x14 mm. It is reinforced with fibers of random orientation to a proportion of 3%.

2.3.2 Unidirectional Fibers

The test piece is a plate of 210x297x14 mm of composite plaster/RC, the orientation of the reinforcements is free unidirectional fibers to a proportion of 3% also. The operative part of the test is identical.

2.3.3 Woven Fibers

The test piece is a plate of 210x297x14 mm in composite of plaster weave woven fiber-reinforced RC (figure 3).

Figure 3: Fiber RCfabric

III. Results And Discussion

3.1 Thermal diffusivityof non-reinforced plaster

Fig. 4 shows the thermogramme for the variation of the temperature as a function of time. The thermal diffusivity representation used is identified by registration of the theoretical curve on the experimental thermogramme.

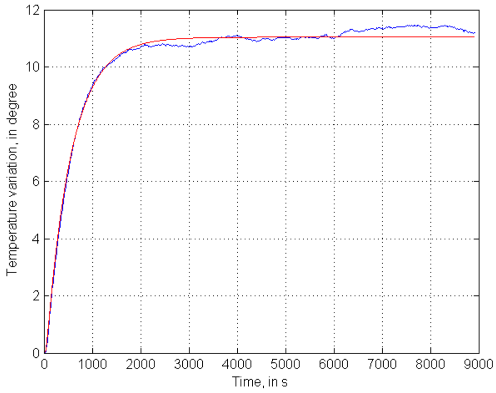

Figure 4: Thermogramme of the plaster plate non-reinforced

It is observed that at the end of 40 minutes, the variation of the temperature stabilizes. The theoretical curve is identified to the experimental for a thermal diffusivity of $3{,}1.10^{-7}m^2s^{-1}$. It is therefore the thermal diffusivity of plasterboard tested, non-reinforced mixed in a ratio of E/P=1. This value is congruent with the values calculated from the parameters (thermal conductivity, specific heat and density) collected in the literature (between 3.10^{-7}-3,73.10^{-7}). Conformity which allows to validate the method of measurement.

3.2 Thermal diffusivityof the plaster reinforced with sisal

The experimental thermogramme of temperature variations in function of time, approach by the theoretical curve, is presented in Fig. 5.

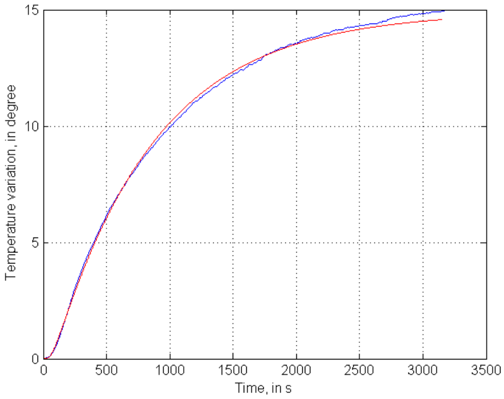

Figure 5: Thermogramme plate composite of plaster/sisal F4D

The theoretical curve is identified with the experimental curve when the thermal diffusivity is $2{,}77.10^{-7}m^2s^{-1}$. This value is the thermal diffusivity of the measured sample of plaster reinforced with fibers of sisal. The variation of the temperature stabilizes beyond 50 minutes. There is a drop of the thermal diffusivity of the plaster because of the presence of the fibers. This is result reflects a reality already mentioned in a contribution in 2010 [4] relating a coefficient of thermal diffusivity of plaster reinforced of the oakum equals to$2{,}07.10^{-7}m^2s^{-1}$.

3.3 Thermal diffusivity of the plaster reinforced with RC
The results, in the form of a thermogramme, are given on the Fig. 6.

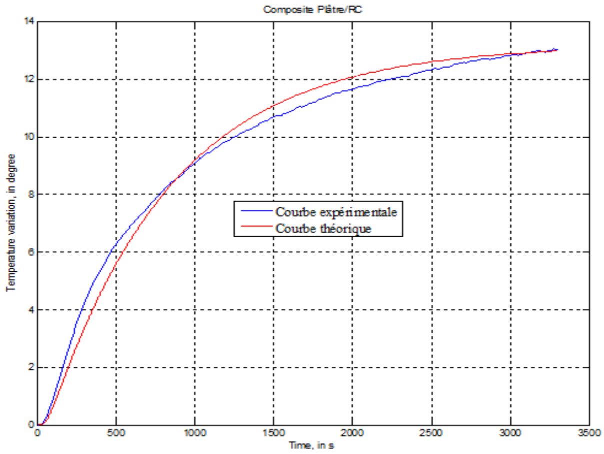

Figure 6: Thermogramme plate composite of plaster/RC F4D

The identification by registration of theoretical curves and experimental occurs when the thermal diffusivity is equal to $2{,}65.10^{-7}m^2s^{-1}$. This value is considered as the thermal diffusivity of the sample of plaster reinforced RC fiber tested. The variation of the temperature also stabilizes beyond 50 minutes.

3.4 Influence of the architecture of the fibers of RC
3.4.1 Unorientated fibers
The diagram on Fig. 7 shows the experimental curve approximated by the theoretical curve of the numerical values of the variation of the temperature in function of time.

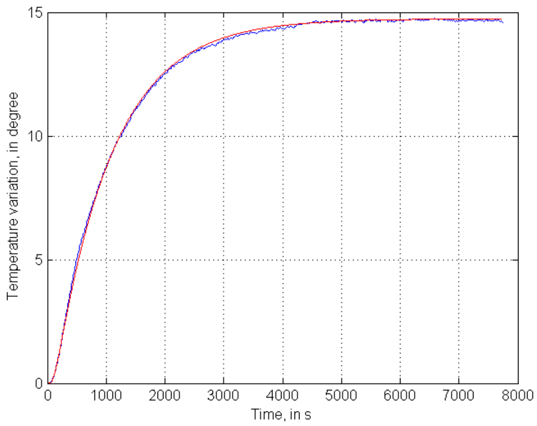

Figure 7: Thermogramme of the plate of the composite FNO

The variation of the temperature stabilizes beyond 50 minutes. The theoretical curve is identified fairly well with the experimental thermogramme for a value of the thermal diffusivity equals to $2{,}15.10^{-7}m^2s^{-1}$. This value is therefore the thermal diffusivity of the composite plaster/RC tested with fibers randomly oriented. It is less than the value obtained as well when the material is not reinforced that when the reinforcement is the sisal.

3.4.2 Unidirectional Fibers

The value of the thermal diffusivity permit to identify the experimental thermogramme to the theoretical curve Fig. 8. It is the value of the thermal diffusivity of this tested piece of plaster/RC mixed in ratio of E/P=1 and the fibers orientated in a unique direction. The thermal equilibrium also held beyond 50 minutes. A time which remains higher than that recorded with the plaster plate non-reinforced. For this configuration of the RC fibers architecture, the thermal diffusivity is lower than when the material is non-reinforced or that the reinforcement is the sisal$2{,}25.10^{-7}m^2s^{-1}$.

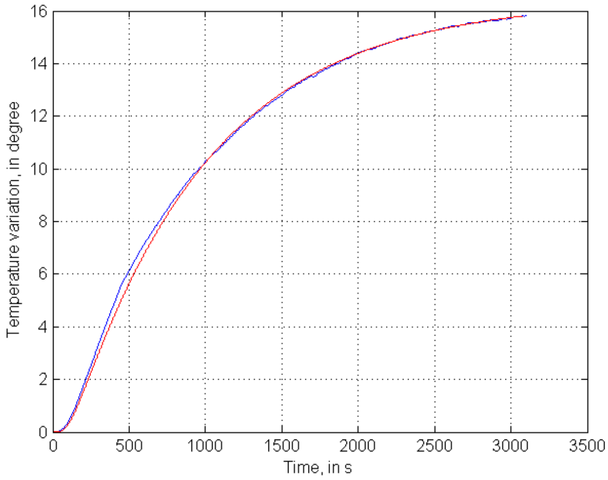

Figure 8: Thermogramme of the plate of the composite F1D

3.4.3 Woven Fibers

The diagram of temperature variation in function of time which results from the thermographic testing of this sample is shown in Fig. 9.

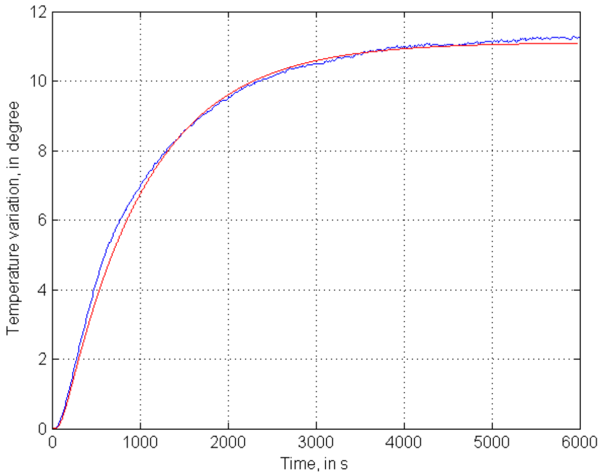

Figure 9: Thermogramme of the plate of the composite FT

The theoretical curve is identified to the experimental thermogramme for a thermal diffusivity equals to $2{,}3.10^{-7}m^2s^{-1}$. It is retained as the value of the thermal diffusivity of the composite of plaster/RC with woven reinforcement. The variation in temperature is also stabilized beyond 50 minutes. The composite reinforced with RC, again, slowed down the heat transfer between the two faces better than when the plaster is non-reinforced or reinforced with sisal fibers.

IV. Conclusion

The measures of thermal transfer carried out permit to determine the thermal diffusivityof plates of samples of plaster non-reinforced, plaster reinforced respectively of sisal and RC. The results show firstly that the plaster reinforced with vegetable fiber reduces the kinetics of heat transfer through the material. It also appears that the strengthening by the RC contributes more to the function of heat insulation of the plaster compared to fibers of sisal. The more important porosity of RCfibers would explain this result. Plasterboard RC fiber-reinforced with the same proportion of fibers, but of a different architecture are therefore tried to identify the influence. The results reveal that for a better exploitation of its influence, the architecture non-oriented fibers is recommendable.

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