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**Research Article**

# Contribution to the Thermal Behavior of a New Material: Clay/Fiber Alfa

[1]Yassine Elhamdouni, [1]Abdelhamid Khabbazi, [1]Chaimaa Benayad, [1]Soumia Mounir and [2]Abdallah Dadi
[1]Laboratoire Énergétique, Université Med V-Agdal, Ecole Mohamedia d'Ingénieurs, Matériaux et Environnement (LEME), 227 Avenue Prince Héritier EST-Salé, Marocco
[2]Institut Universitaire Des Sciences et Techniques, Abeche, Tchad

**Abstract:** Clay and alfa fiber are abounding, natural and renewable materials, they have thermal and acoustical ownership very interesting. In the present job, we studied the thermal behavior of the different samples of dimensions 10×10×3 $cm^3$ by blending Clay with a different percentages of fibers alfa (0.5, 1, 2, 3 and 4%, respectively). Then we compare thermal ownership of this new materials (clay+alfa) with the only Clay to valorize the addition of fibers alfa and her use with Clay as insulating material. Results point out that the new composite material is lighter and less effusive, its capacity to delay the transmission of warmth is superior to that of the only clay and its use as outside wall should give an energy saving over 30%.

**Keywords:** Clay, fiber alfa, insulating material, method of the hot plate, thermal conductivity

## INTRODUCTION

In front of the challenge by housing in Morocco (more than one hundred and twenty thousand housing units each year to meet the needs of new family) and the remarkable growth of energy consumption in the building sector (more than 40% energy total) and also the low power of Purchase of the population of developing countries such as Morocco (particularly in the rural areas). Efforts have been directed toward the development of new methods of construction using local materials such as clay and natural fibers.

In order to respond to this problem, the goal of this study is to propose a new alternative material which has two very attractive features.

**Less costly:** It constitutes of local materials and abundant (almost all) such that the clay and fiber alfa.

**More isolating:** He has thermal properties very important (a thermal resistance high, least effusif, more lightweight with a energy gain important).

This study, therefore, fits into this context of sustainable development and to reduce poverty especially in the field of energy and construction.

The use of a material thermal insulating requires first of all the knowledge of thermophysical ownership, especially if it is about a natural material, lasting and ecological as Clay and alfa.

The objective of this job is to characterize ownership thermophysical by a new material based on Clay and alfa fiber (Fig. 1). In order to do that, we base principally on the method of the hot plan transitional (Jannot *et al*., 2010b) (because this one allows to characterize the thermal effusivity E) and also method of hot plan in regime permanent (Homari *et al*., 2007; Jannot *et al*., 2010a) to determine thermal conductivity and at the end the method of flash (Degiovanni, 1977) which has us allows to have the thermal diffusivity. Certain studies have already established and published on materials at the root of clay and alfa. Laaroussi *et al*. (2013) studied Thermal properties of a sample prepared using mixtures of clay bricks.

Also, Pierre (2004) studied the mechanical and thermal characteristics of the bricks of earth stabilized with the aim of use in building.

Bahloul *et al*. (2009) had as objective to determine the effect of fibers alfa on the mechanical and thermal resistance of mortar of cement. After his studies on 3 samples of cement mortar with different percentages of fibers alfa (conservation in free air, conservation to freshwater, conservation of sea-water).

They found that the tensile strength by bending of the sample retained in free air increases with the increase in the percentages of fibers alfa. It is for this reason also our choice is door to the fibers alfa.

Finally, Martin (1984) studied the strengthening of the earth by vegetable fibers. These references show interest that it introduces clay (earth) and alfa fiber, which are abounding materials in Morocco, likely to be exclusive materials in the applications of thermal insulation.

Several studies of characterization, by the method of hot plan in transitional and permanent regime, were

**Corresponding Author:** Yassine Elhamdouni, Laboratoire Énergétique, Université Med V-Agdal, Ecole Mohamedia d'Ingénieurs, Matériaux et Environnement (LEME), 227 Avenue Prince Héritier EST-Salé, Marocco


Fig. 1: The different samples cylindrical

Fig. 2: The different masses of alfa used (not treated)

Table 1: Chemical analysis of used clay

| Constituents | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_5$ | P.F | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percentages (%) | 45.79 | 15.68 | 12.83 | 0.17 | 6.26 | 9.60 | 3.54 | 1.39 | 2.84 | 0.60 | 0.31 | 99.01 |

accomplished and published. We cite that Jannot *et al*. (2010a) used it to characterize the slim insulating materials. Bal *et al*. (2012) adopted it to characterize a material based on Laterite and millet waste additive.

Finally Gaye (2001) represented in detail the different methods of measurements of the mechanical, acoustical and thermal ownership of the local materials in the Senegal in his State thesis in the chapter 3, notably the three methods of measure of thermal conductivity in permanent regime. This motivated us to adopt these methods and to apply them to our new material.

## EXPERIMENTAL APPROACH

**Used materials:**

**Clay (earth):** In this study, we use clay from the region of Ksar Elkebir (northern Morocco) whose main chemical characteristics are given in Table 1.

**Fiber alfa (*Stipa tennacissima* T):** The fibers of alfa are retained for reasons of availability and economy. We specify that the fiber alfa "*Stipa tennacissima* T" is not treated, to use it easily in building that is to say stems with different diameters and of different length (Fig. 2).

Fibers alfa are mainly composed of 45% of cellulose, 24% of hémicellulose, 24% of lignine, 2% of cinder and 5% of wax (Ben Brahim and Ben Cheikh, 2007). The beams of fibers alfa are characterized by a medium diameter of 113 µm (90-120 µm) and a density of 0.89 g/cm$^3$ (Bessadok *et al*., 2007). On top of that fibers alfa have stems which are hard, long and thick, the analysis of view Electronic Microscope with sweeping (MEB) (Fig. 3) shows that the surface of the stem is harsh what allows to create a very good link between fibers and clay.

**Water of mixing:** After several tries of estimate of the quantity of necessary water to thin the pate of clay and have a normal consistency, we found that the quantity of water must prove following relation:

$$\frac{Ea}{A} = 0.20 \quad (1)$$

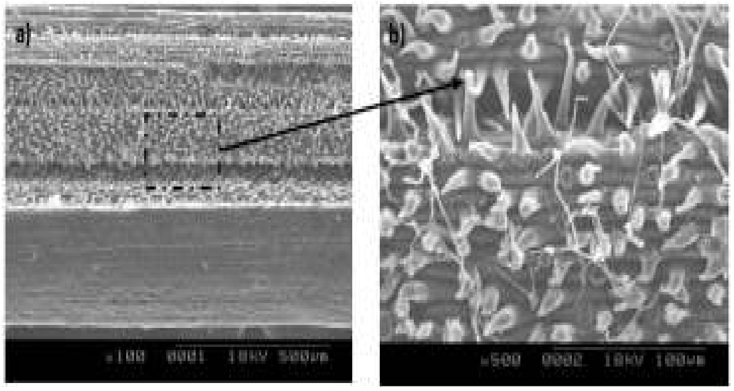


Fig. 3: Picture MEB of a surface of fiber alfa and its expansion (Mohamed, 2012)

Table 2: Characteristics different studied samples

| Samples | Fibers alfa (%) | Numbers of samples | Medium densities ($\frac{Kg}{m3}$) |
|---|---|---|---|
| R1: 100% clay | 0 | 3 | 2213.19 |
| E2: 0.5% alfa | 0.5 | 3 | 2075.60 |
| E3: 1% alfa | 1 | 3 | 1916.70 |
| E4: 2% alfa | 2 | 3 | 1806.66 |
| E5: 3% alfa | 3 | 3 | 1642.97 |
| E6: 4% alfa | 4 | 3 | 1583.25 |

With $E_a$ and A are, respectively the quantity of water (g) and the quantity of clay dryness (g).

**Preparation of samples:** We proceeded the preparation of samples on which will be based our job: we fill the apparent volume of dimensions of 100×100×30 mm³, by fibers alfa, then we add mortar of clay so that clay occupies the space inter-alfa. We prepared samples (Fig. 1), every three sample corresponding to a percentage of alfa very definite (0.5, 1, 2, 3 and 4%, respectively) to take into account the effect of addition of fibers on thermophysical ownership of middle. Besides, we prepared three samples of the only clay, having the same dimensions as the fifteen others, to compare the variation of thermophysical ownership some mixture, in function of the percentages of alfa, with those of the only clay.

Samples are kept in a étuve in a temperature of 60°C, to eliminate present humidity in the pores of every sample, they are dried up to a constant mass. Afterwards, we measure their dry masses then we wrap them in plastic bags so that they keep a content of uniform water almost zero. The measurements which we shall perform will then be taken on these dry samples.

From the knowledge of dimensions and masses dry samples of the new material, we can easily determine their apparent densities:

$$\rho_{clay+alfa} = \frac{m_{clay+alfa}}{V_{clay+alfa}} \quad (2)$$

Table 2 introduces the different samples and their densities.

## PRINCIPLE OF USED METHODS

**Method of the hot plate centered in permanent regime for the determination of thermal conductivity:** Thermal conductivity was determined by method plate hot centered in permanent regime (Homari *et al*., 2007; Jannot *et al*., 2010a). This method is based on the measure of the temperature in the centre of the heating element interposed between the sample and the foam of polyethylene, Fig. 4 illustrates the fundamental schema of method, the sample, of dimensions 30×100×100 mm$^3$ is put on a heating element of section 100×100 mm² equal to that of the sample. They put, under the heating element, an insulating foam of dimensions 10×100×100 mm$^3$ and of conductivity of 0.04 W/m/K, so that the majority of the flux of warmth, issued by the heating element, pass towards the sample to be characterized (from above). The assembly sample, heating element and insulating foam is put between two blocks of aluminum of dimensions 50×100×100 mm$^3$, these last have as role, thanks to their big conductivity, to make attain the system towards thermal equilibrium as quickly as possible.

One thermocouple is glued together on the centre of the lower face of the heating up element to measure the temperature $T_0$, other one to measure the temperature $T_1$ of the not heated face of the sample and a third to measure the temperature $T_2$ of the not heated face of the insulating foam. With this shape, we can write:

$$Ø = ø1 + ø2;\ ø1 = \frac{λ1}{e1}(T0 - T1);ø2 = \frac{λ2}{e2}(T0 - T2) \quad (3)$$

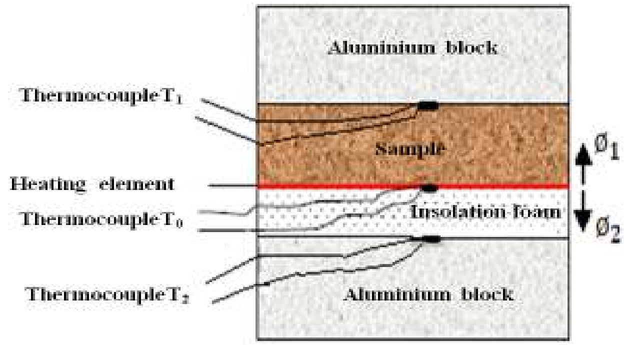


Fig. 4: Experimental device of the hot plate method in steady state regime

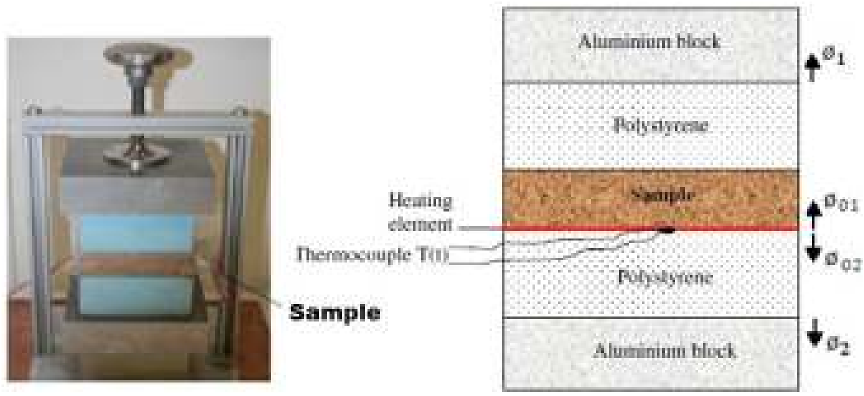


Fig. 5: View and schema of the experimental hot plate

$Ø_1$ the heat flux through the sample, $Ø_2$ the heat flux through the insulation foam, $ø$ the total flux emitted by the heating element. $\lambda_1$ the thermal conductivity of the sample as we seek to determine, $e_1$ the thickness of the sample. $\lambda_2$ = 0.04 W/m/K and $e_2$ = 10 mm are successively thermal conductivity and thickness of the insulating foam. But the heating element is an electrical resistance R dissipating a heat flux by Joule effect when it is crossed by an electric current électrique (I) under the effect of a voltage (U), so:

$$ø = \frac{U^2}{R.S} \tag{4}$$

Combining Eq. (3) and (4):

$$\lambda_1 = \frac{e_1}{T_0 - T_1}\left[\frac{U^2}{R.S} - \frac{\lambda_2}{e_2}(T_0 - T_2)\right] \tag{5}$$

Equation (5) allows us to determine the thermal conductivity of the sample once the system attains permanent regime.

**The method of hot plate in transitional regime to measure the thermal effusivity:** The thermal effusivity is measured by using the method of the transitional hot plate (Jannot *et al*., 2010b; Laaroussi *et al*., 2013). We used here the recent asymmetrical experimental implement (represented on the Fig. 5).

An element of heating plan having the section of 10×10 $cm^2$ is put under the sample. One thermocouple of type K with two sons accomplished with a 0.005 mm diameter is glued together on the lower face of the heating element.

This arrangement is disposed between two extruded polystyrene blocks having a thickness of 5 cm fixed between two aluminum blocks with a thickness of 4 cm.

The flux of warmth is sent to the heating element and the transitional temperature T (t) am recorded. Since the thermocouple is in contact with polystyrene that is a deformable material, the presence of the thermocouple does not increase the thermal contact resistance between the heating element and the polystyrene. Furthermore, since polystyrene is an insulating material, this thermal resistance will be neglected. The system is modeled with the hypothesis that the heat transfer remains unidirectional (1D) at the center of the sample during the experiment. Considering the very low value of the heat flux reaching the aluminum blocks through the polystyrene and their high thermal capacity, their temperatures are supposed equal and constant.

Within these hypotheses, one can write:

$$\begin{bmatrix}\theta\\ \Phi_{01}\end{bmatrix}=\begin{bmatrix}1 & 0\\ C_h & 1\end{bmatrix}\begin{bmatrix}1 & R_c\\ 0 & 1\end{bmatrix}\begin{bmatrix}A & B\\ C & D\end{bmatrix}\begin{bmatrix}A_i & B_i\\ C_i & D_i\end{bmatrix}=\begin{bmatrix}A_1 & B_1\\ C_1 & D_1\end{bmatrix}\begin{bmatrix}0\\ \Phi_1\end{bmatrix} \quad (6)$$

$$\begin{bmatrix}\theta\\ \Phi_{02}\end{bmatrix}=\begin{bmatrix}A_i & B_i\\ C_i & D_i\end{bmatrix}\begin{bmatrix}0\\ \Phi_2\end{bmatrix} \quad (7)$$

With,

$$\Phi_0=\frac{\o}{p}=\Phi_{01}+\Phi_{02} \quad (8)$$

where,

- $\theta$ : The Laplace transform of the temperature $T(t)$
- $\Phi_{01}$ : The Laplace transform of the heat flux density living the heating element (upstream)
- $\Phi_{02}$ : The Laplace transform of the heat flux density living the heating element (downstream)
- $\Phi_0$ : The Laplace transform of the total heat flux density produced in the heating element
- $\o_0$ : The heat flux density produced in the heating element
- $C_h$ : The thermal capacity of the heating element per area unit: $C_h = \rho_h\, c_h\, e_h$
- $Rc$ : The Thermal contact resistance between the heating element and the sample
- $\Phi_1$ : The Laplace transform of heat flux density input on the upper aluminum block
- $\Phi_2$ : The Laplace transform of heat flux density input on the lower aluminum block:

$$A=D=\cosh\left(\frac{\rho c}{E}e\sqrt{p}\right);\ B=\frac{\sinh\left(\frac{\rho c}{E}e\sqrt{p}\right)}{E\sqrt{p}};\ C=E\sqrt{p}\,\sinh\left(\frac{\rho c}{E}e\sqrt{p}\right) \quad (9)$$

$$A_i=D_i=\cosh\left(\sqrt{\frac{p}{a_i}}e_i\right);\ B=\frac{\sinh\left(\sqrt{\frac{p}{a_i}}e_i\right)}{\lambda_i\sqrt{\frac{p}{a_i}}};\ C=\lambda_i\sqrt{\frac{p}{a_i}}\sinh\left(\sqrt{\frac{p}{a_i}}e_i\right) \quad (10)$$

where,

- E = The sample thermal effusivity
- ρc = The sample thermal capacity
- e = The sample thickness
- $\lambda_i$ = The Polystyrene thermal conductivity
- $a_i$ = The polystyrene thermal diffusivity
- $e_i$ = The Polystyrene thicness

Combining those five equations, the system leads to:

$$\theta(p)=\frac{\Phi_0(p)}{\frac{D_1}{B_1}+\frac{D_i}{B_i}} \quad (11)$$

The principle of the method is to estimate the value of the parameters $E$, $R_c$ and $C_h$ that minimize the sum of the quadratic error $\Psi=\sum_{j=0}^{N}\left[T_{exp}(t_j)-T_{mod}(t_j)\right]^2$ between the experimental curve and the theoretical curve calculated with relation (11). The inverse Laplace transformation is realized by use of the De Hoog (1982).

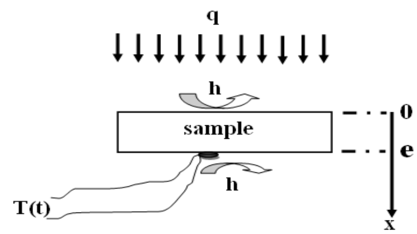


Fig. 6: Fundamental schema of method flash

**The method of flash to measure the thermal diffusivity:** The characterization of the thermal diffusivity is performed by method flash (Degiovanni, 1977; Parker *et al*., 1961) which comes from the resolution of equation warmth in the space of the place with the aid of the method of quadripole (Khabbazi *et al*., 2013).

The sample accepts a bright flux of high power capacity (1000 w) during very short time ($T_0$). A thermocouple in contact with the back face allows to record the elevation of his temperature has leave the instant when the face before receipt flash (Fig. 6).

The matrix of transfer of warmth is expressed by the product of three following matrices:

$$\begin{bmatrix}1 & 0\\ h & 1\end{bmatrix}\begin{bmatrix}\cosh(ke) & \frac{\sinh(ke)}{\lambda k}\\ \lambda k.\sinh(ke) & \cosh(ke)\end{bmatrix} \quad (12)$$

With: $k=\sqrt{\frac{p}{a}}$; p is the Laplace parameter and a is the diffusivity of the sample. λ and e are successevely thermal conductivity and thickness of the sample.

The expression of temperature rise in the Laplace space is:

$$\theta\,(p)=\frac{\frac{q}{p}(1-e^{-\zeta.p})}{h^2\frac{\sinh(k.e)}{\lambda k}+2h\cosh(k.e)+\lambda k.\sinh(k.e)} \quad (13)$$

ζ the time during which the lamp is on.

After the realization of the numerical reversal of this expression by the algorithm of De Hoog (1982), the theoretical value of expression of the temperature will be obtained. The algorithm of Levenberg-Marquardt (Marquardt, 1963) is used for the estimate of parameters has, q and h allow to reduce the quadratic error between the experimental thermogram recorded on the lower face of sample and the theoretical expression of the temperature (the complete model).

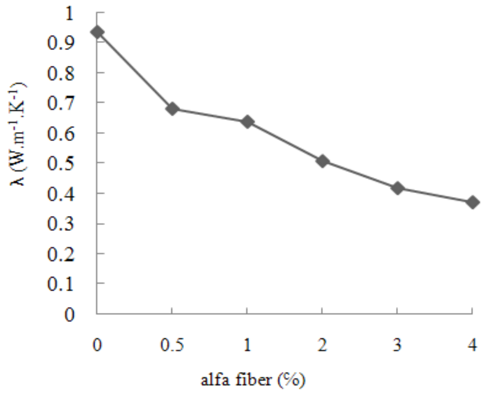


Fig. 7: Evolution of the thermal conductivity based on the percentages alfa

Besides, thermogram experimental am used to calculate the experimental value of the thermal diffusivity of the Model Parker (Parker *et al.*, 1961) and the model Degiovanni (Degiovanni, 1977) to compare these values with those of the complete model.

## RESULTS AND DISCUSSION

**Thermal behavior:**

**Method of the hot plate centered at the permanent regime for the determination of the thermal conductivity:** The application of this method to samples has allowed to characterize their thermal conductivities based on the percentages of alfa (Fig. 7).

Thermal conductivity with tendency to diminish according to the growth of the percentages of fibers, this is perfectly logical since the more they augment the percentages of fibers, the more the sample contains pores which are at the origin of this reduction.

Thermal conductivity is diminish in a significant way according to the density of sample, so that the sample becomes less insulating with the growth of its density (Table 3). The presence of fibers alfa makes the lighter sample and ameliorates its thermal insulation.

**Thermal effusivity by the asymmetrical transitional method of the hot plate:** We apply method to three resumptions, for each samples, to take into account the error of measure, then we adopt the average of these three experiments as result of characterization. For every thermogram obtained further to experimentation, we apply the method of Levenberg-Marquard (Marquardt, 1963) to identify parameters (E, ρc, Rc, Ch) which minimize the gap between the thermogram experimental and the thermogram simulated relating to the model 1D of the method of hot plan.

Figure 8 Presents the curves of these two thermogram with their residues as a function of time, as well as the sensitivity curves to the thermo-gram identification parameters chosen.

Table 3: The thermal conductivity of the different samples studied in function to density

| Samples | Fibers alfa (%) | Medium densities ($kg/m^3$) | Conductivity thermal (W/m/K) | Error of measure of conductivity thermal (%) |
|---|---|---|---|---|
| R1 | 0 | 2213.19 | 0,938 | 0.72 |
| E1 | 0.5 | 2075.60 | 0.683 | 0.95 |
| E2 | 1 | 1916.70 | 0.640 | 0.75 |
| E3 | 2 | 1806.66 | 0.509 | 0.93 |
| E4 | 3 | 1642.97 | 0.419 | 0.99 |
| E5 | 4 | 1583.25 | 0.372 | 0.89 |

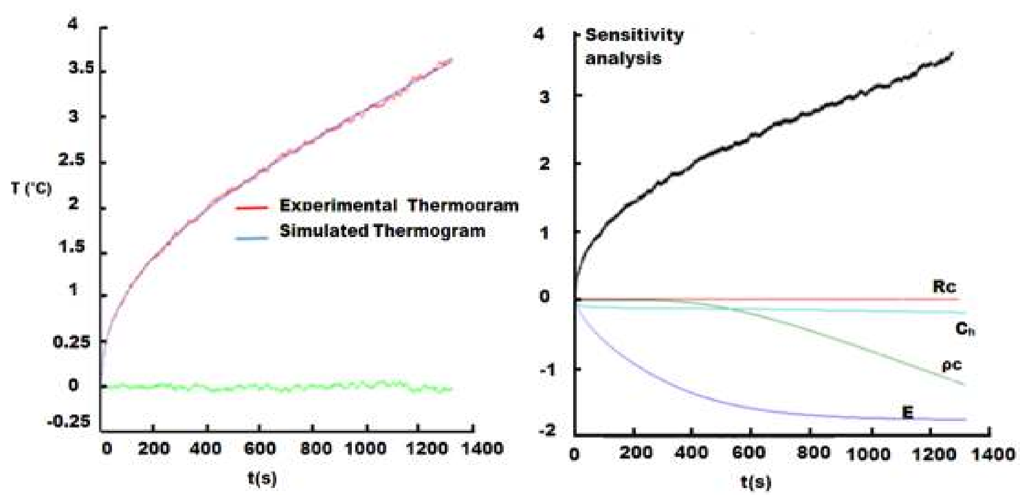


Fig. 8: Curves experimental and modeling of the hot plate of temperature, with residues, obtained for the sample E2 (1% alfa) (to the left) and the analysis of feelings of the parameters of adjustment (to the right)

Table 4: The values of thermal effusivity in function of the percentages of fibers alfa

| Samples | Fibers alfa (%) | E ($J/m^2/K.sec^{1/2}$) | Measurement error (%) |
|---|---|---|---|
| R1 | 0 | 1244.14 | 0.74 |
| E1 | 0.5 | 1040.98 | 0.82 |
| E2 | 1 | 983.01 | 1.20 |
| E3 | 2 | 851.90 | 0.98 |
| E4 | 3 | 739.50 | 0.65 |
| E5 | 4 | 688.00 | 1.00 |

Table 5: The values of thermal diffusivities in function of the percentages of fibers alfa

| Samples | Fibers alfa (%) | $ax10^{-7}$ parker ($m/sec^2$) | $ax10^{-7}$ digouvani ($m/sec^2$) | $ax10^{-7}$ model complet ($m/sec^2$) |
|---|---|---|---|---|
| R1 | 0 | 4.968 | 5.392 | 5.66 |
| E2 | 0.5 | 4.013 | 4.280 | 4.30 |
| E3 | 1 | 4.021 | 4.305 | 4.25 |
| E4 | 2 | 3.631 | 3.531 | 3.55 |
| E5 | 3 | 3.524 | 3.306 | 3.21 |
| E6 | 4 | 3.352 | 3.021 | 2.93 |

We remark that at the beginning of experience, both thermogram are confused. But around 400 sec, they start to make a small difference: the experimental thermogram does more obey the 1 day model, 3D model takes place in the sample and we can no longer say that the sample behaves like semi-infinite medium. The question that will arise: what exact time of experience the 3D effect takes place?

Question which we answered by simulating the hypotheses of experience on the tool of simulation COMSOL. We realize the simulation of the elevation of temperature in the centre of the face heated for h 0 (transfer 1D) and h 10 $W/m^2/K$ (Transfer 3D), to obtain the $t_{max}$ of the experience corresponding to 1% of difference between the thermogram relating to h 0 and that relating to h = 10 $W/m^2/K$. (h being the coefficient of convect if transfer on the lateral surface of the sample). The result of this simulation gives us a $t_{max}$ 300 sec, beyond this $t_{max}$, the three-dimensional transfer sets up in the sample, the hypothesis of semi-infinite middle is not valid anymore and any value calculated beyond this $t_{max}$ does not have physical sense and is considered false.

However, the analysis of the sensitivities of parameters to the thermogram allows us to deduce that the calculation of the effusivity E can be done from the first second of the experience (short time) and that to 300 sec, the calculated value can be considered as reliable value. While the calculation of the thermal capacity ρc can start only from 350 and 400 sec the thermo-gram is not sensitive enough to the calculation of this value. Conclusion: the method of the hot plan transitional we will only identify the parameter effusivity without being able to identify the thermal capacity.

We also notice that the thermogram is no sensitive to parameter Rc, this implicates that the resistance of contact is so small that it does not have considerable influence on the thermogram. Also, sensitivity to Ch parameter is very small, which means that its value has no effect on the calculation of other parameters.

Table 4 represents the results of identification of the thermal effusivity of samples, corresponding to a $t_{max}$ 300 sec.

The thermal effusivite decreases as a function of percentage of fiber alfa, this is mainly caused by the fact that more than one has a growth of the percentages of fibers, more material is becoming more and more porous, therefore the speed propagation of heat idling under the effect of the air pockets, Where the material becomes less effusif.

**The method of flash to measure the thermal diffusivity:** The results of thermal diffusivities for each sample are presented in Table 5.

The results of thermal diffusivity obtained by the model Parker have a significant difference in comparison with those of the complete model; this is due to the fact that Parker *et al*. (1961) considers only half the time of the thermogram and do not take into account the descent of the thermogram.

On the contrary, the model Degiovanni agrees well with the complete model, because Degiovanni (1977) offers to calculate the value of the diffusivity with correlations corresponding to several points of the thermogram.

Results (For every sample) indicated in the Table 5 are the average of three experiments, the error of medium measure corresponding to the diffusivity does not exceed 3%.

The thermal diffusivity diminishes in function of the growth of the percentages of fibers (Table 5). Therefore more contains fibers alfa, the less he allows the transmission of warmth, this result is important in thermal insulation: an insulating material must not only have one weak thermal conductivity but must also allow to postpone the transmission of warmth.

**The specific heat:** Another element allowing to characterize the thermal ownership of materials is the specific heat. This greatness characterizes the capacity of the material to store warmth. We deducted warmth from both following relations (14) (15):

$$C_{\text{éff}} = \frac{E2}{\lambda \times \rho} \quad (14)$$

Table 6: Values of specific heat of different samples

| Samples | C dif (J/Kg/k) | C éff (J/kg/k) | Ecart (%) |
|---|---|---|---|
| R1: 100% clay | 748.22 | 745.93 | 0.30 |
| E2: 0.5% alfa | 765.96 | 764.22 | 0.22 |
| E3: 1% alfa | 785.91 | 788.01 | 0.26 |
| E4: 2% alfa | 792.84 | 789.04 | 0.48 |
| E5: 3% alfa | 794.55 | 794.59 | 5.03 |
| E6: 4% alfa | 799.15 | 804.55 | 0.67 |

Table 7: Comparison of the properties of the new composite material (clay + alfa) and the clay only

| Samples | Energie saving (%) | Lightness ratio (%) |
|---|---|---|
| E2: 0.5% alfa | 27.18 | 6.21 |
| E3: 1% alfa | 31.77 | 13.39 |
| E4: 2% alfa | 45.73 | 18.36 |
| E5: 3% alfa | 55.33 | 25.76 |
| E6: 4% alfa | 60.34 | 28.46 |

$$C_{dif} = \frac{\lambda}{a \times \rho} \quad (15)$$

We are going to note $C_{éff}$ referring to the method of hot plan (because his calculation is based on the values of effusivity obtained by the method of hot plan) and $C_{dif}$ referring to the method of flash (because its counting was based on the values of diffusivity obtained by the method of flash).

Specific heat of the results obtained from these two relations are presented in Table 6.

We plot evolutions of $C_{éff}$ and $C_{dif}$ in function of the percentages of fibers alfa (Fig. 9).

We remark that values obtained by both methods are perfectly identical (the relating error of measure between both methods do not exceed 1% for every point of measure) (Table 6), what shows that values measured of the thermal effusivity by the method of transitional hot plan and values measured of thermal diffusivity by method flash are dependable and correct. We also note that the presence of fibers alfa augments considerably the thermal capacity compared with that of the only clay.

**Practical interest of this new composite material:** If they compare between both outside walls constituted by (the new composite material and other one in the only clay) having the same thickness and are subjected to the same gradient of temperature, they can deduct the report of the flux of warmth which crosses two of these walls:

$$\frac{\phi_{clay+alfa}}{\phi_{argile}} = \frac{\lambda_{clay+alfa}}{\lambda_{argile}} \quad (16)$$

This allows the calculation of the economy of energy by using the new material as outside wall:

$$Energie_{saving} = 100x\left(1 - \frac{\phi_{clay+alfa}}{\phi_{clay}}\right) \quad (17)$$

We apply relations (15) and (16) for the different samples and we obtain the economy of energy in function of percentages of fibers (Table 7).

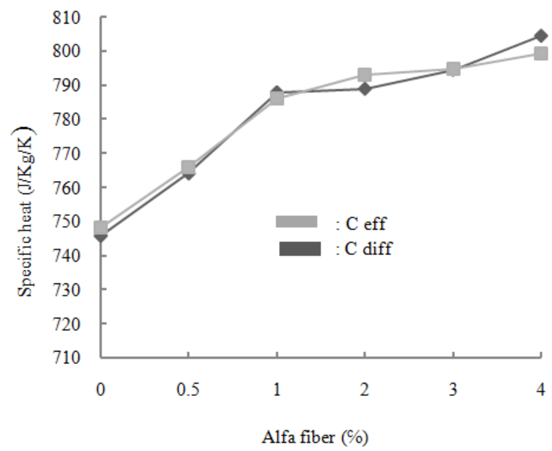


Fig. 9: Evolution of thermal conductivity in function of the percentages of fibers alfa

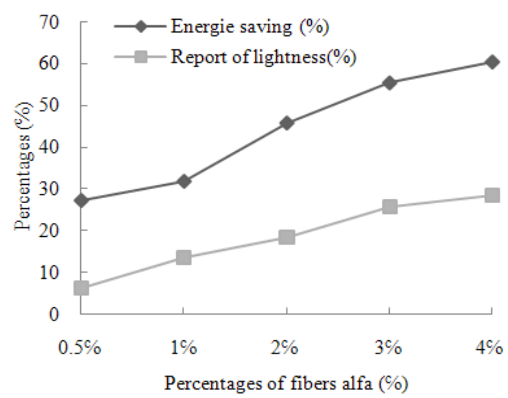


Fig. 10: The evolution of energy economy and the report of lightness in function of the percentages of fibers alfa

We can also determine the report of lightness from the following relationship:

$$\text{Report of lightness} = \frac{\rho_{clay} - \rho_{clay+alfa}}{\rho_{clay}} \quad (18)$$

Then we trace the evolution of these two parameters (energy economy and lightness report) on the basis of the percentages of fiber alfa (Fig. 10).

According to the Fig. 10 we notice when we increase the percentages of fibers, the energy economy and the report of lightness increases so that the sample becomes more and more insulation with the energy economy maximum.

## CONCLUSION

This study presents the experimental study of the thermophysical ownership of the new material (clay+alfa), in function to the percentages of fibers.

We used the method of the hot plan permanent to determine the thermal conductivity of the two materials (clay only and clay+alfa).

We found that the conductivity of our composite material (clay+alfa) can go down from 27 to 60% by report has clay only.

We used also the method of transitional hot plan and flash method to determine the effusivity E, diffusivity a. From these two values (E and a) we have shown that this material is less effusive and its ability to delay the transmission heat is higher compared to the clay alone.

On the other hand, we showed, in function of results obtained, that the characteristics of this new material have a good practical interest for that this material is used as thermal insulating material, thanks to its lightness and its good energetic economy compared with clay alone.

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