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DETERMINATION OF THERMAL CONDUCTIVITY OF TOW PLASTER AND KAPOK PLASTER MATERIALS BY NUMERICAL METHOD: INFLUENCE OF THE HEAT EXCHANGE COEFFICIENT IN TRANSITIONAL REGIM

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ABSTRACT
This article presents a numerical method for determining the thermal conductivity of local materials, kapok plaster and tow plaster. It consists of heating the front face of a wall made from these two materials and at the same time insulating its rear face. We simultaneously study the curves of the evolution of the heat flux density as a function of time on the rear face and the evolution of the temperature gradient as a function of time between the heated face and the insulated face. Thermal conductivity is obtained when reaching steady state; when the evolution of the heat flux density and the temperature gradient no longer depend on time. The results showed that the theoretical value of thermal conductivity is obtained when the material has reached its equilibrium state. And the values obtained for different values of the convective exchange coefficients are appreciably equal to the experimental value.

KEYWORDS: Conductivity-Numerical method-heat exchange coefficient- Transitional regim.

1. INTRODUCTION
The thermal conductivity of local materials is an important thermal property that governs the transfer of heat flow. The complexity of the materials makes its thermal conductivity dependent on physical and chemical properties, such as water content, porosity, density, texture and mineral composition of the material [1]. Different empirical models have been proposed for estimating the thermal conductivity of materials. However, these models are mainly obtained from data from laboratory experiments by measurement techniques, including steady-state methods such as shielded hot plate method [2], transient methods including single line heat source probe [3,4]. and the double probe heat pulse method [5-7], the impulse method of Flash [8], the method of Giovanny [8], the method of marshal and Devisme [9] the method of the hot wire.

In this work we propose a method for determining thermal conductivity. Finally for the validation of this method on the application for kapok plaster and tow plaster materials [10, 11].

2. MATERIALS AND METHODS
A material of thickness L is heated on its front face and the rear face is insulated (it is assumed that there is no exchange with the interior environment) then. We simultaneously study the evolution curves of the heat flux density as a function of time on the rear face and the evolution of the temperature gradient as a function of time between the heated face and the insulated face.

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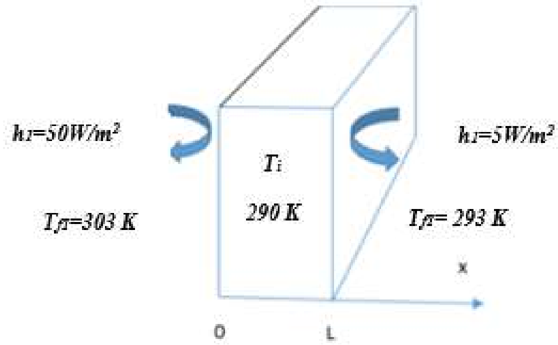

Figure 1 Insulated material on the back side

The equation for heat without a heat sink is given by the following expression

$$\frac{\partial^2 T(x,t)}{\partial^2 x} - \frac{1}{\alpha}\frac{\partial T(x,t)}{\partial x} \qquad (1)$$

Where $\alpha = \frac{\lambda}{\rho c}$ (2)

- $\boldsymbol{\alpha}$ is the thermal diffusivity of the material assumed to be uniform.
- λ is the thermal conductivity of the material
- **c** the specific heat

Equations (2) and (3) reflect the conservation of heat flux at the surface of the material and equation (4) represents the initial condition.

$$\begin{cases} h_1\left(T(0,t) - T_{f1}\right) = \lambda \dfrac{\partial T(x,t)}{\partial t}|x = 0 & (3) \\ h_1\left(T(L,t) - T_{f2}\right) = \lambda \dfrac{\partial T(x,t)}{\partial t}|x = L & (4) \\ T(x,0) = T^0 & (5) \end{cases}$$

The expression of the heat flux density is given by:

$$\phi(x,t,h_1,h_2,\alpha) = -\lambda \frac{\partial T(x,t)}{\partial x} \qquad (6)$$

The finite difference discretization method applied to the equations allows us to obtain:
The temperatures expressions on the two faces

$$\begin{cases} T_i^{j+1} = AT_i^j + 2PT_2^j + CT_{f1} & (7) \\ T_i^{j+1} = BT_i^j + 2PT_{M-1}^j + DT_{f2} & (8) \\ T_i^1 = T^0 & (9) \end{cases}$$

Where ,

- **i** is locates the variable space
- **j** is the locates the variable temp
- $\boldsymbol{T_i^j}$ is the temperature at node i at date j
- **M** represents the number of nodes along the space x
- **N** the number of nodes along time t

We set ,

$$P = \alpha \frac{\Delta T}{\Delta x^2} \qquad (10)$$

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$$A = \left[(1-2P) - \frac{2h_1\Delta x}{\lambda}\right] \quad (11)$$

$$B = \left[(1-2P) - \frac{2h_2\Delta x}{\lambda}\right] \quad (12)$$

$$C = \frac{2h_1\Delta x}{\lambda} \quad (13)$$

$$D = \frac{2h_2\Delta x}{\lambda} \quad (14)$$

The temperature expression inside the wall ,

$$T_i^{j+1} = (1-2P)T_i^j + T_{i-1}^j \quad (15)$$

where $1 \leq i \leq M-1$ et $1 \leq j \leq N$

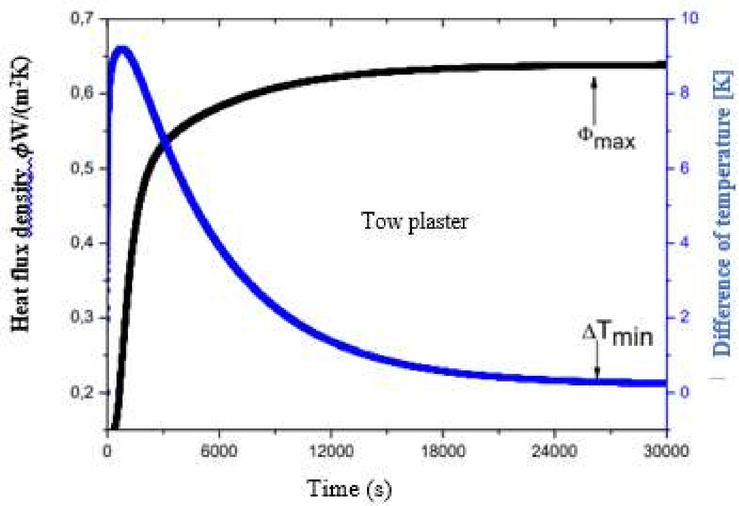
And the flux density expression

$$\phi_j^i = -\lambda \frac{[T_{i+1}^j(h_1,h_2,\alpha) - T_i^j(h_1,h_2,\alpha)]}{\Delta x} \quad (16)$$

3. RESULTS AND DISCUSSION

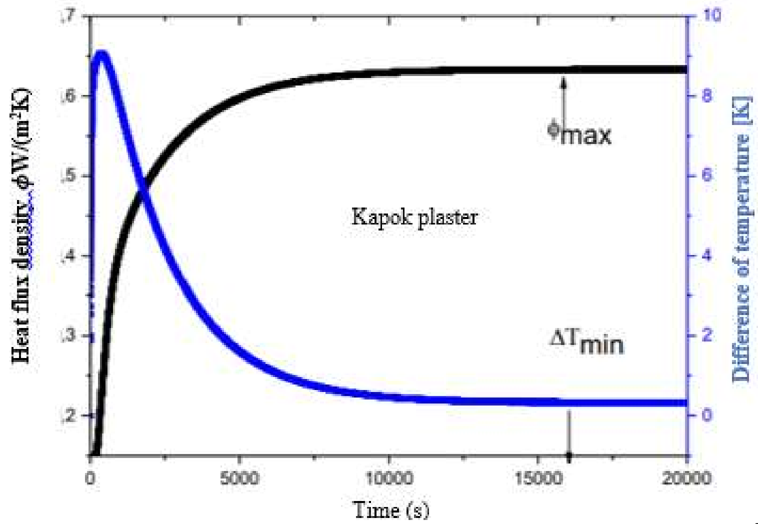
The thermal conductivity of the plane material based on tow plaster of 5cm thickness is determined by plotting the heat flux density profiles and the temperature gradient, see figures 2 and 3. ΔT_{min} between the front face and the rear face during time and the maximum value of the flux density ϕ_{max} which crosses the material over time

Figure 2



Evolution of the heat flux density and the temperature difference as a function of time; h1 =50 W/ m²K; h2 =5W/m²K ; N=100000 ; M=100; x=5cm.

Figure 3



Evolution of the heat flux density and the temperature difference as a function of time; h_1=50 W/ m^2K; h_2 =5W/m^2K ; N=100000 ; M=100; x=5cm.

Figures 2 and 3 show the evolution of the heat flux density and the temperature gradient as a function of time. The temperature gradient is positive and reaches a maximum (heat accumulation) for low excitation times then decreases to tend towards a minimum constant value.

The heat flux density gradient increases and tends towards a maximum for sufficiently long excitation times.

We calculate the theoretical value of the thermal conductivity of materials for different values of the front face exchange coefficient from the following relationship:

$$\lambda_{th} = \frac{\phi_{max}(h_1)}{\Delta T_{min}} \qquad (11)$$

The tables below show the theoretical values of the thermal conductivity of the plaster tow and the plaster kapok for different values of the front face exchange coefficients h_1 [12].

Table1: The theoretical values of the thermal conductivity of the material two plaster under the influence of the front face exchange coefficient h_1

h_1 (W/ m²K)	15	30	45	60	75	90
ϕ_{max}(W/m²)	0.63	0.63	0.63	0.63	0.63	0.63
ΔT_{min}	0.323	0.21	0.20	0.20	0.20	0.20
Theorical values λ_{th}	0.13	0.15	0.1575	0.1575	0.1575	0.1575
Experimental value λ_e	0.15	0.15	0.15	0.15	0.15	0.15

Table 1 shows the theoretical values of the thermal conductivity of the material under the influence of the front face exchange coefficient h_1. There is an increase in the value of the theoretical thermal conductivity of the material for coefficients between 15 and 30W /m².K For exchange coefficients greater than 30, the theoretical value of thermal conductivity remains constant and equal to 0.1575. 1 .This result shows that the proposed thermal conductivity measurement method is reliable. We calculate the thermal conductivity of the kapok plaster material using the same calculation method.

Table2: The theoretical values of the thermal conductivity of the material Kapok plaster under the influence of the front face exchange coefficient h_1

h_1 (W/ m²K)	15	30	45	60	75	90
Maximum flux density ϕ_{max}(W/m²)	0.63	0.63	0.63	0.63	0.63	0.63
Minimum difference of temperature ΔT_{min} [K]	0.323	0.21	0.20	0.20	0.20	0.20
Theorical values of thermal conductivity λ_{th}	0.13	0.15	0.1575	0.1575	0.1575	0.1575
Experimental value of thermal conductivity λ_e	0.15	0.15	0.15	0.15	0.15	0.15

Table 2 shows the theoretical values of the thermal conductivity [13] of the kapok plaster material under the influence of the front face exchange coefficient h1. For exchange coefficients between 15 and 45, the theoretical value of the conductivity [14],[15] is lower than the value experimental value of 0.01. On the other hand, for exchange coefficients greater than or equal to 60, the theoretical value is exactly equal to the experimental value. These exchange coefficients make it possible to reach the steady state; it is the heat conduction phenomena that dominate**.**

4. CONCLUSION

In this article, we have proposed a method for the thermal determination of the conductivity of plaster tow and Kapok plaster materials. The influence of the exchange coefficient was highlighted. The theoretical values of the acquired conductivity were compared with those acquired experimentally. The results showed that these values are obtained when the steady state has established.

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