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RESEARCH ARTICLE

DESIGN OF A MEASURING DEVICE FOR THE IMPLEMENTATION OF A METHOD FOR SIMULTANEOUS DETERMINATION OF CONDUCTIVITY AND DIFFUSIVITY OF BUILDING MATERIALS

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Abstract

The characterization thermo-physical of building materials is crucial to evaluate their energy efficiency. In developing countries like Senegal, the commercially available measuring instruments tend to be costly and not readily accessible.Presents the design This study details the develop ment and experimental validation of a cost-effective and lightweight device design to simultaneously measure the thermal conductivity (λ) and the thermal diffusivity (a) of building materials. This approach is grounded in a simplified physical model that incorporates both the transient and steady-state conditions. Measurements carried out taken on standard materials inclusive plaster and extruded polystyrene allowed to obtain respectively: for plaster, a = 2.9 10 m2/s and λ = 0.25 W/m °C, and for extruded polystyrene, a = 6 10 m2/s and λ = 0.023 W/m °C. These findings which align with existing literature, confirm the accuracy and effectiveness of the proposed device.

Introduction:-

Faced with the challenges of climate change and global warming, improving the energy performance of buildings has become a major priority. In Africa, the energy consumption of buildings a substantial share of national energy expenditure. Enhancing energy efficiency therefore requires the development of new building materials that are adaptedto the local climate and possess strong thermal insulation properties. The thermo-physical characterization of these materials is essential to assess their ability to meet such requirements. The main techniques used to measure thermo-physical properties include the hot plate, hot wire, hot plane, and boxmethods. The latter is known for its simplicity and the reliability of its results, but the available devices remain expensive. In this perspective, our study proposes the design of a more accessible measuring device allowing simultaneous determination of thermal conductivity and diffusivity. This device is intended to characterize both conventional materials and bio-sourced materials (laterite, typha, straw, etc.).

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Methodology:-

Theoretical modelling:-

The thermal field of the studied material is governed by the heat conduction equation (Equation 1) under the appropriate boundary conditions.

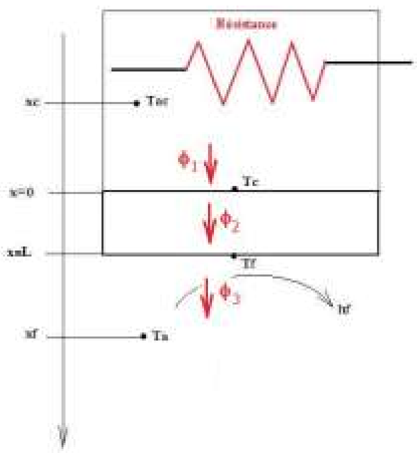

Figure 1: schematization of the model

The thermal field of this sample (**figure 1**) is governed by the equation **[1] [7] [16] [17]**

$$\frac{\partial^2 T(x,t)}{\partial x^2} = \frac{1}{a}\frac{\partial T(x,t)}{\partial t} \tag{1}$$

With the boundary conditions:

- At the front face (x=0):

$$\lambda \left.\frac{\partial T(x,t)}{\partial x}\right|_{x=0} = RI^2 - C(Tac - Ta) \tag{2}$$

- At the rear face (x=L):

$$\lambda \left.\frac{\partial T(x,t)}{\partial x}\right|_{x=L} = hf(Tf - Ta) \tag{3}$$

Where: $T_{ac}(t)$: ambient temperature on the high side depending on the parameter t.
Tf: temperature of the lower face
Ta: ambient temperature on the low side, constant.
R: heating resistor
I: current passing through the resistance

The resolution using the Duhamel method makes it possible to obtain the temperature evolutionand to determine the thermal diffusivityfrom the experimental slopes. The thermal conductivity λ is then determined in the steady state, once the temperatures have stabilized.

Experimental design:-

The device designed is a calorimetric box composed of insulating layers in polystyrene. Heating is provided by a film heater, which generates a unidirectional heat flow. The temperature sensors are placed on both sides of the sample in order to follow the thermal evolution. The lateral insulators ensure minimization of heat losses. (Figures 1 and 2)

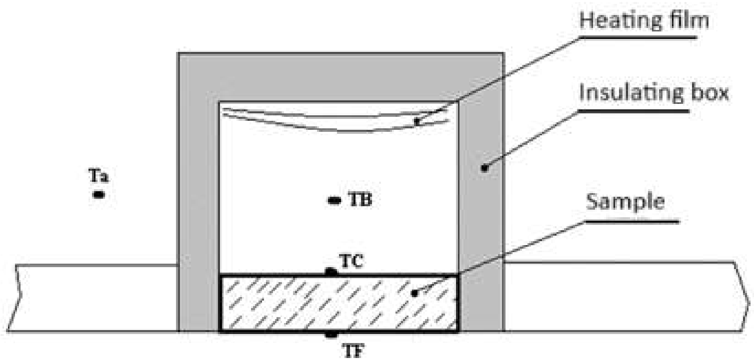

Figure 1: Experimental device


Figure 2: Photo of the experimental

Experimental results:-

Thermal conductivity:

The experimental results are presented in the table below:

Table 1: Different conductivities obtained

Material	Voltage (V)	Speed time	Conductivityλ (W/m·K)
Plaster	220	3 h 30	0,2649
Plaster	220	3 h 00	0,2443
Plaster	200	2 h 30	0,2540

The average conductivity of plaster is $\lambda = 0.25$ W/m K with a relative uncertainty estimated at 7%.

Thermal diffusivity:

Table 2: Different diffusivities obtained

Material	Voltage (V)	Measurement time	Diffusivity a (m 2/s)
Plaster	220	1 h 40	$2{,}89\times10^{-7}$
Plaster	220	1 h 45	$3{,}00\times10^{-7}$
Plaster	200	55 min	$2{,}89\times10^{-7}$

The average diffusivity obtained is a = 2.9 10 m 2/s, with a relative uncertainty of 6%.

Discussion:-

The results obtained are in good agreement with the literature values for both plaster and extruded polystyrene. The designed device demonstrates its ability to faithfully reproduce the thermo-physical properties of materials. However, to ensure the reliability of measurements, the following precautions must be observed: use at least three representative samples, condition the samples before testing, ensure good sensor-sample contact. These recommendations will strengthen the accuracy of the device and allow its extension to the characterization of local bio-sourced materials (typha, straw, laterite).

Conclusion:-

The device developed enables the simultaneous determination of the thermal conductivity and thermal diffusivity of building materials. Lightweight, economical and reproducible, it is a credible alternative to costly commercial devices. The results obtained with plaster and extruded polystyrene confirm the validity of the model and the device. Future work will focus on extending its application to the characterization of local bio-sourced materials for sustainable construction in Senegal.

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