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RESEARCH ARTICLE

THERMAL CONDUCTIVITY OF RICE HUSK ASH MORTAR REINFORCED WITH SUGARCANE BAGASSE

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Abstract

Today, construction is a very important lever on which we can act to preserve a viable environment. It must be said that there is still a great need to use air conditioning to ensure thermal comfort in buildings; this implies the need to look for materials with good thermal properties. This study evaluates the thermal conductivity of a rice husk ash mortar reinforced with sugarcane bagasse. Its aim is to offer an alternative to conventional materials that consume more energy. To achieve this, we formulated an M0 mortar in which the cement is replaced by 10% rice husk ash (RHA); we then substituted the M0 mortar with 3%, 6% and 10% sugarcane bagasse in volume fraction, resulting in the MCB3, MCB6 and MCB10 mortars. Finally, the thermal conductivities were measured on three specimens of each of the formulations, and the average of the three values was taken as the thermal conductivity of the formulation in question. The thermal probe method is used to measure the thermal conductivities of mortars. The results of the tests show that the thermal conductivity of the mortars decreases as the volume of sugarcane bagasse increases. The maximum thermal conductivity was obtained with the M0 mortar, with a value of 0.42W/°K/m. The minimum thermal conductivity is presented by the MCB10 mortar with a value of 0.316W/°K/m. The MCB10 material can be used as an alternative to conventional bricks to provide better thermal insulation for our buildings.

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Introduction:-

Construction is one of the determining factors in development. Today, construction has taken off to a greater extent, although materials are now very well selected. Today, it's not just a question of production, but of sustainable construction. This is why, for more than a decade, construction designers have been turning to renewable materials (Amin and Abdelsalam, 2019)(Khoso et al., 2022). One field in which renewable materials are very well used is aeronautics. However, renewable materials are mainly of plant origin, which are much more widely used in polymer matrices. In recent years, more research has been carried out into the possible uses of plant-based reinforcement

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materials and cementitious matrices. For example, (Acodji et al., 2020) studied the service life of materials reinforced with sugarcane bagasse, while (Datchossa et al., 2023a) showed that incorporating sugarcane bagasse increases the flexural strength of cementitious matrix mortars. Other authors have shown the effect of sugarcane bagasse on the mechanical properties of mortars reinforced with sugarcane bagasse (Datchossa et al., 2023a). (Passoli et al., 2023) have also shown that the use of sugarcane bagasse in construction is highly advantageous in that it reduces the quantity of bagasse burnt and therefore reduces greenhouse gas emissions. To the best of our knowledge, none of these studies has investigated the thermal conductivity of sugarcane bagasse mortars.

The present work proposes to evaluate the thermal conductivity of a cementitious mortar containing rice husk ash as pozzolan and sugarcane bagasse as reinforcement.

Materials and Methods:-

Formulation of rice husk ash mortar reinforced with sugarcane bagasse.

The mortar used in our study is obtained as follows:
- Replacing 10% of the cement mass with rice husk ash: this is the optimum adopted in the work of (Datchossa et al., 2023b);
- Prepare mortars reinforced with sugarcane bagasse by replacing the volume fraction of rice husk ash mortar with sugarcane bagasse.

The different formulations resulting from the variation in the rate of sugarcane bagasse in the rice husk ash mortar are summarised in the table below.

Table 1:- Formulation of the different mortars.

ID composites	OPC (%)	RHA (%)	Fibre BCS (% vol.)
M0	90	10	-
MCB3	90	10	3
MCB6	90	10	6
MCB10	90	10	10

Measuring thermal conductivity

The test we used to determine the thermal conductivity of our mortar is the quasi-steady-state thermal probe test.

1. **Standard:** ASTM International, 2014
2. **Principle:** This method involves creating a linear thermal disturbance in the medium and measuring the variation in temperature as a function of time.

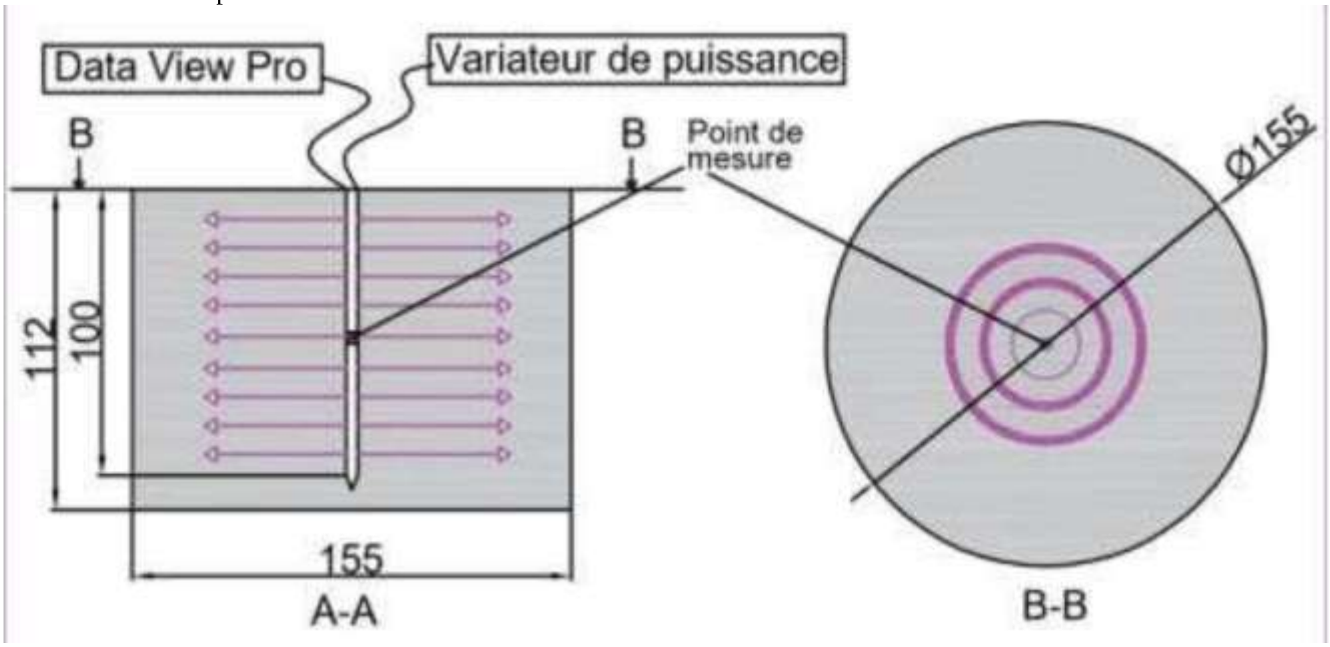

Figure 1:- Schematic diagram for measuring thermal conductivity(Adjagboni et al., 2020).

Production of test specimens

The test specimens used to measure the thermal conductivity of rice husk ash mortar reinforced with sugarcane bagasse were obtained by compacting the latter in PVC cylinders 155mm in diameter and 112mm high. Three (03) specimens were made per formulation to determine the thermal conductivities.

Measurement and acquisition

Measurement:-

1. Insert the thermal needle probe into the sample either by pushing it into a pre-drilled hole (dense sample) to a depth equal to the length of the probe or by pushing it into the sample. Care should be taken to ensure that the stem of the thermal probe is fully embedded in the sample and not left partially exposed.
2. Leave the sample for a moment for its temperature to stabilize.
3. Connect the heating wire of the thermal probe to the constant current source (dimmer).
4. Connect the wires from the data acquisition system to the computer so that the temperature readings can be taken.
5. Apply a known constant current to the heating wire.
6. Record temperature readings at 0 s, 5 s, 10 s, 15 s, 30 s, 45 s, and 60 s, then take measurements at 30 s intervals for a minimum of 1000 s.
7. Switch off the constant current source once the measurement time has elapsed and record the temperature readings until the temperature has stabilized.
8. Plot the temperature data as a function of the logarithm of time on a semi-logarithmic graph.
9. Select the linear portion of the curve (quasi-stationary phase) and draw a straight line through the points (linear regression).
10. Select the times $t1$ and $t2$ at the appropriate points on the straight line and read the corresponding temperatures $T1$ and $T2$.
11. At the end of the test, weigh the sample to determine its dry density and take a representative sample of the sample to determine its water content at the end of the test.

Acquisition

The variable speed drive connected to the temperature sensor supplies power to the heating resistor (heating wire) inside the sensor. The data acquisition system connected to the thermal probe is responsible for collecting temperature values as a function of time. It communicates with the thermal probe by means of a control program containing the test parameters, which are:

1. Current supplied by the drive: $\boldsymbol{I} = \mathbf{0}, \mathbf{15A}$.
2. Probe resistance: $\boldsymbol{Rsonde} = \mathbf{54\Omega}$.
3. Probe length: $\boldsymbol{l} = \mathbf{0}, \mathbf{1m}$.
4. Heating element length $\boldsymbol{L} = \mathbf{0}, \mathbf{216m}$.
5. Current voltage $\boldsymbol{U} = \mathbf{8}, \mathbf{1V}$.

The program is written in Python language by (Adjagboni et al., 2020). Once the connection between the probe and the acquisition system is established, the control program is sent to the acquisition system, which takes care of collecting the temperature values every second. Once all the necessary measurements have been made, the temperatures are recorded in an output file that will be used to calculate the thermal conductivity.

Calculating thermal conductivity

Before taking any measurements, the thermal probe must be calibrated. Calibrating the device involves calibrating it to assess its efficiency and accuracy on the one hand, and to define a correction factor used to correct the measurements on the other. The correction factor $C\lambda$ is defined by the ASTM D5334 standard as the ratio between the thermal conductivity $\lambda matériau$ of the known material and that measured using the probe noted $\lambda mesurée$, as follows:

$$C_\lambda = \frac{\lambda_{\text{material}}}{\lambda_{\text{measured}}} \tag{1}$$

The calibration material must have a thermal conductivity within the following range:

(0,2 $<\lambda<$ 5 $W/m.K$)

There are several materials used to calibrate this tool, including dry gully sand and fine coal dust. Both materials have well-documented thermal conductivities, the values of which are given in Table 2.

Table 2:- Conductivités thermiques des matériaux utilisées lors de la phase de calibration.

Material	**λ (W/(m.°C))**	**Condition**	**Reference**
Dry gullysand	0.400	$\rho = 1600\ kg/m3$	Propriétés thermiques des matériaux - Four à pain romain en argile (canalblog.com)
Fine coaldust	0.12	$30 \leq (°C) \leq 150$	http://fourmailletard.canalblog.com /archives/2008/12/13/12589580.html

Data analysis

The curve in Figure 2 corresponds to the ideal result of a thermal conductivity test. The coefficient λ is determined by considering the temperature values during the quasi-steady state portion.

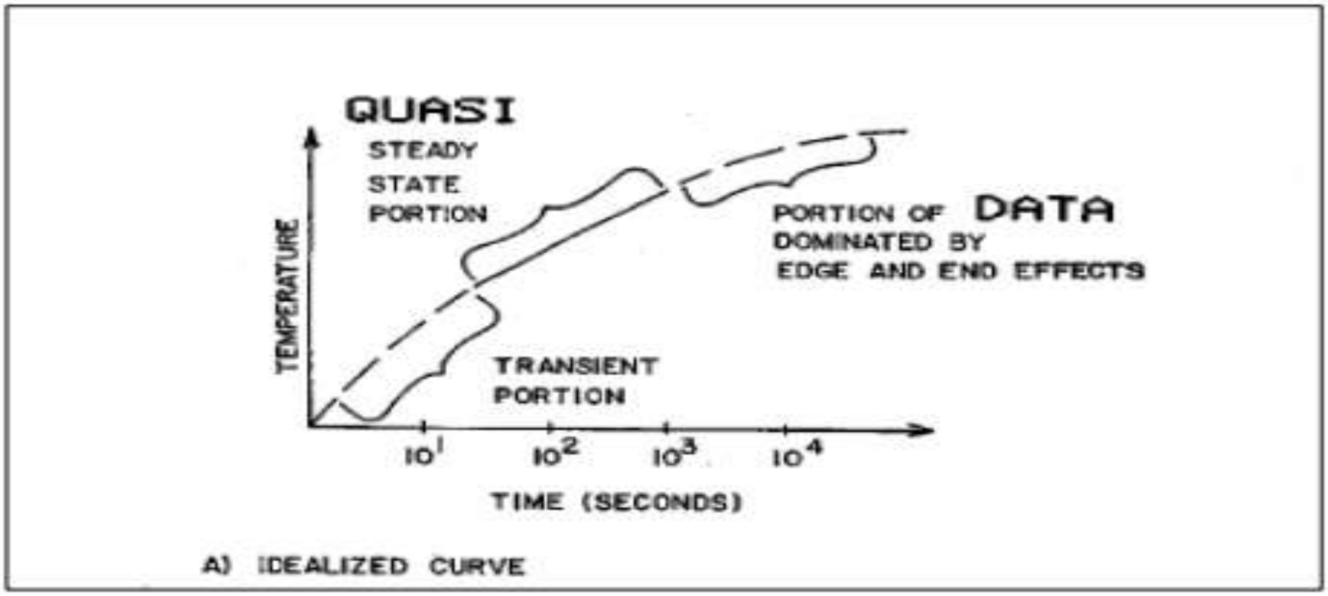

Figure 2:-Typical changes in temperature over time **(ASTM D 5334, 2008)**.

According to ASTM D5334, the transient phase of the test should not be considered when processing the results. This is because when the heat source is generated along the probe, it must pass through the material that makes up the probe before reaching the experimental material (Kömle et al., 2013). The non-linear part at the beginning therefore corresponds to the heating of the probe and must be removed from the analysis.

For the heating phase, we then obtain a series of points in the (ln(t), T) plane that can be interpolated by a straight line whose slope will be notedS_h.

The thermal conductivity of the medium is then given by relationship 1. The probe required a calibration phase which must also be considered when calculating the thermal conductivity. To do this, relationship 2 also includes the calibration coefficient C_λ.

$$\lambda = C_\lambda \frac{Q}{4\pi(T_2 - T_1)} \ln\left(\frac{t_2}{t_1}\right) \tag{0}$$

Where :

$$Q = \frac{RI^2}{L} = \frac{UI}{L} \tag{3}$$

If wetake :

$$S_h = \frac{(T_2 - T_1)}{\ln(t_2) - \ln(t_2)} = \frac{(T_2 - T_1)}{\ln(\frac{t_2}{t_1})} \quad (4)$$

λbecomes :

$$\lambda = C_\lambda \frac{Q}{4\pi S_h} \quad (5)$$

Where :

Q: linear power supplied to the medium (W/m).

R: resistance of the thermal probe (Ω).

I: constant current flowing through the heating resistor (A).

L: length of heating element (m).

λ : thermal conductivity (W/ (m.K)).

C_λ : correction factor.

t_1 and t_2 : measurement time (s).

$T_1 et T_2$: the temperatures corresponding to times t_1 and t_2 respectively.

Sh : slope of the linear regression.

The thermal conductivity value adopted for a given formulation is the arithmetic mean of the conductivity determined on three specimens of the same formulation.

Results and Discussion:-

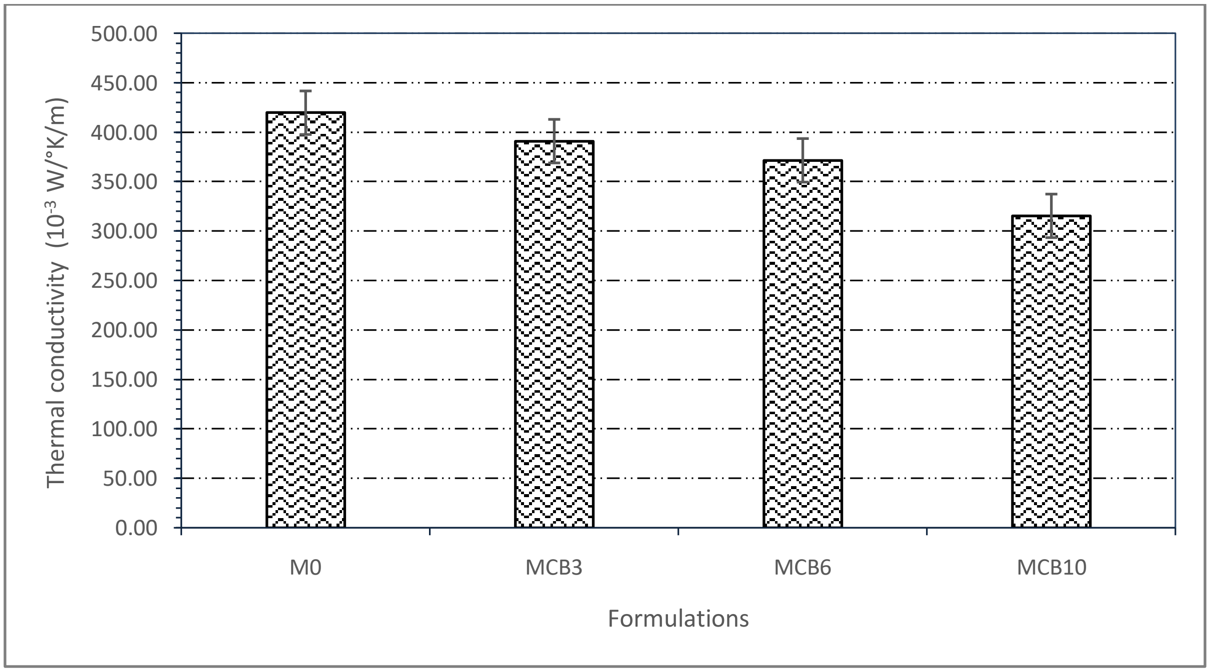

Figure 3:- Changes in the thermal conductivity of MCB as a function of the sugarcane bagasse content.

Figure 3 shows the evolution of the thermal conductivity of rice husk ash mortars reinforced with sugarcane bagasse. In this figure, we can see that the M0 mortar has the highest thermal conductivity value. This means that ordinary mortar conducts more heat than rice husk ash mortar reinforced with sugarcane bagasse, because it has a higher thermal conductivity (Gouasmi et al., 2016,Benmansour, 2015). In addition, we note a drop in the thermal conductivity of the mortar with the rate of sugarcane bagasse in it. The same observation was made by (Bentchikou et al., 2007)(Mustapha et al., 2017). This drop in conductivity with the rate of sugarcane bagasse can be explained by the fact that with the increase in the rate of bagasse there is an increase in porosity in the material, as hammered out above. The conductivity values obtained on our mortars are within the same orders of magnitude as those found by (Mohaine et al., 2017)(Poullain et al., 2005).

Conclusion:-

This study assessed the thermal conductivity of rice husk ash mortars reinforced with sugarcane bagasse. The results of the work showed a fall in the thermal conductivity of rice husk ash mortars with an increase in the volume fraction of sugarcane bagasse. The lowest thermal conductivity was obtained with MCB10 mortar; sugarcane bagasse is porous and increases the thermal insulation of mortars. MCB10 mortar is more suitable for use as a thermal insulator in constructions where this mortar must play a filling role.

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