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Thermal Characterization of Composite Bricks Based on Laterite, Typha and / or Rice Hull

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Abstract This study focuses on the valuation of local materials in order to build economical, sustainable and resilient housing. The objective is to determine the thermal properties of composite bricks made from a mixture of laterite and straw (rice hull and typha) with proportions of between 3 and 6%. The thermal characteristics including conductivity and thermal effusivity were obtained from the hot plane method. The results showed that the addition of straws increases the energy performance of composite bricks. Thus, for 6% of straw, the thermal conductivity decreases by 52%, 53% and 63% respectively for the typha, the rice hull and the typha-rice hull mixture. The thermal effusivity, for 6% of straw, decreases by 45%, 50% and 62% respectively for the typha, the rice hull and the typha-rice hull mixture. This characterization made it possible to show that these bricks have good thermal inertia and high conductivity compared to standard cement-based bricks.

Keywords: *composite brick, laterite, rice hull, typha, thermal conductivity, thermal effusivity*

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1. Introduction

The scarcity of energy and global warming and their consequences for the environment are matters of concern today. Climate change is becoming a threat in all sectors.

Thus, in the building sector, the energy bill is very high [1]. It consumes around 35% of the world's final energy and releases more than 38% of carbon dioxide (CO_2) [2].

To preserve the environment, resilient solutions such as mitigation and adaptation [3] must be advocated.

This study always comes into the case of the valuation of local materials such as laterite, typha and rice hull. It is part of the global context of the fight against climate change [4,5].

The objective is to find an optimal formulation in order to offer a durable, economical and resilient material. This involves thermal characterization of bricks made from mixtures of laterite, sand, typha and / or rice hull [6].

Thus, the conductivity, resistance and thermal effusivity will be determined by the hot plane method.

2. Methodology

This study is a continuation of the work already carried out. This study is still part of the formulation and optimization of local ecological materials. It completes the characterization of composite bricks made with straw. The samples are made from local materials. They are obtained from a mixture of laterite and straw (rice hull and typha) with proportions of between 3 and 6%. These mixtures are stabilized with 1% cement and sand [6].

As a reminder, different compositions were made aiming to find an optimal formulation.

Thermal tests were carried out on bricks of 10 cm x 10 cm x 2 cm dimensions. These tests make it possible to determine the following thermal characteristics: conductivity and thermal effusivity and then deduce the thermal resistance.

Thermal conductivity λ ($W.m^{-1}K^{-1}$) is the amount of energy passing through 1 m^2 of material one meter thick and, for a difference of 1 degree in temperature.

Thermal resistance denoted R ($W^{-1}.m^2.K$) measures the resistance that a thickness of material opposes to the passage of heat. It depends on the thermal conductivity and the thickness of the material. A material is insulating if its resistance is very high.

The effusivity E ($J.K^{-1}m^{-2}s^{-1/2}$) is the ability of a material to exchange heat with its environment.

Different methods are used to determine the above thermal parameters such as guarded hot plate, mini hot plate, hot wire, hot tape, hot plate methods etc. [7,8]

In this study the hot plane method was used. The principle consists in applying a step of constant heat flow to the heating resistance and we note the change in temperature Ts(t) at the center of this same resistance in which a thermocouple has been placed. During the time when the disturbance has not reached the other faces, i.e.

the hypothesis of the semi-infinite medium is valid (time during which Te(t) has not varied), we can consider that the transfer at the center of the sample is unidirectional. The modeling of the heat transfers makes it possible to calculate the evolution of the temperature at the center of the sample as illustrated in Figure 1. An estimation method makes it possible to calculate the values of thermal effusivity, of thermal capacitance (probe + heating resistor) and the contact resistance at the sample/probe interface which minimize the difference between the theoretical and experimental Ts (t) curves [8].

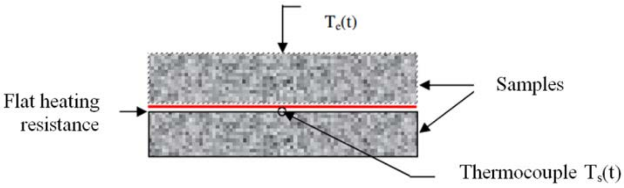

Figure 1. Hot plan method assembly diagram [8]

The experimental protocol is described below. The hot plane test involves superimposing the sample between two polystyrene insulators and two aluminum plates with a heated probe just below the sample. After assembly, the assembly is tightened with a load to have the contact resistance Rc which is 40.10^{-6}. Figure 2 shows the experimental setup.

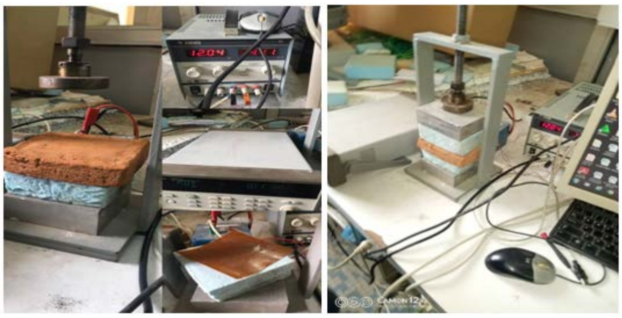

Figure 2. Experimental apparatus

A voltage of 10 V is set at the voltage generator to heat the underside of the material before starting the test. Thus, the temperature is measured in time steps of 100 ms. As a reminder, the measured flow must be unidirectional with this time step.

The estimation of effusivity (E), conductivity (λ) and resistance (R) is essentially based on the residue curve (difference between the theoretical curve and the experimental curve) and the sensitivity curves (E, λ, Rc).

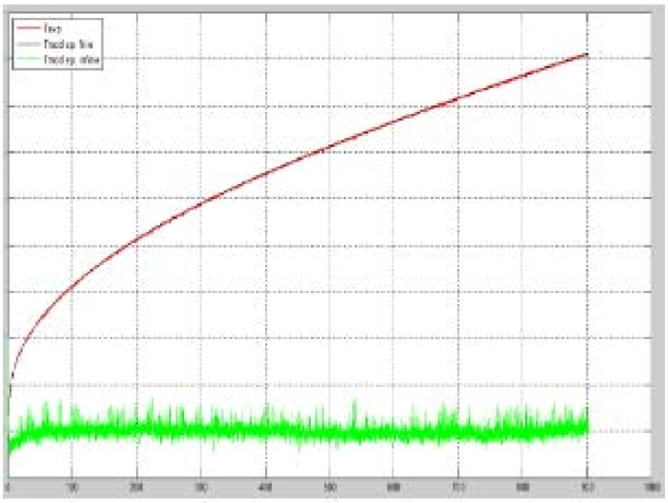

Figure 3. Residue curve of experimental and theoretical values for brick with 3% rice hull

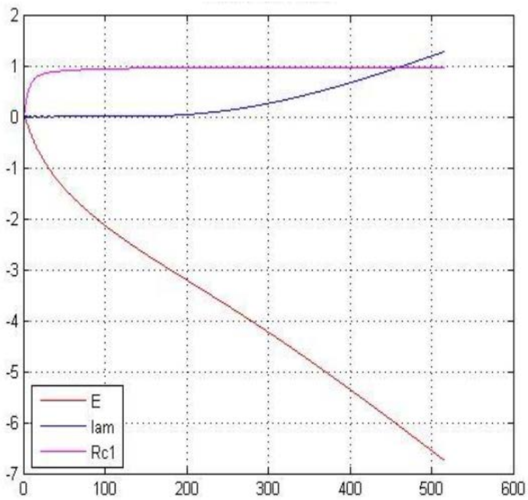

Figure 4. Reduced sensitivity curve for brick with 3% rice hull

The objective is to have results which coincide with a residual curve (Figure 3) centered around zero and a sensitivity curve (Figure 4) sensitive to temperature.

3. Results

3.1. Thermal Conductivity

The average thermal conductivity of bricks with dimensions of 2 cm x 10 cm x 10 cm, depending on the type of straw and their percentages, is summarized in Table 1.

Table 1. The thermal conductivity λ ($W.m^{-1}K^{-1}$) of bricks depending on the type of straw and their percentages

Straw percentage (%)	0%	3%	4%	5%	6%
Typha	0,854	0,726	0,581	0,478	0,408
Rice hull	0,854	0,547	0,438	0,407	0,381
Rice hull + Typha	0,854	0,409	0,382	0,340	0,315

3.2. Thermal Conductivity Resistance

The average thermal conduction resistance R, for bricks with dimensions of 2 cm x 10 cm x 10 cm, depending on the type of straw and their percentages, is given in Table 2.

Table 2. The thermal resistance R ($W^{-1}m^2K$) of the bricks according to the type of straw and their percentages

Straw percentage (%)	0%	3%	4%	5%	6%
Typha	0,035	0,041	0,052	0,063	0,074
Rice hull	0,035	0,055	0,069	0,074	0,079
Rice hull + Typha	0,035	0,073	0,079	0,088	0,095

3.3. Thermal Effusivity

The average effusivity E ($J.K^{-1}m^{-2}s^{-1/2}$) of the bricks, depending on the type of straw and their percentages are mentioned in Table 3 below.

Table 3. Thermal effusivity E ($J.K^{-1}m^{-2}s^{-1/2}$) of the bricks depending on the type of straw and their percentages

Straw percentage (%)	0%	3%	4%	5%	6%
Typha	1345,7	1119,2	937,7	809,5	738,9
Rice hull	1345,7	842,6	774,4	739,3	667,2
Rice hull + Typha	1345,7	744,0	654,3	619,7	515,2

4. Discussions

4.1. Thermal Conductivity

The thermal conductivity of the samples is shown in Figure 5.

The analysis of Figure 5 shows that the thermal conductivity (λ) of bricks without straws is equal to 0.854 $W.m^{-1}K^{-1}$. It decreases with the addition of 6% straws until:

- 0.408 $Wm^{-1}K^{-1}$ for the typha:
- 0.381 $Wm^{-1}K^{-1}$ for the rice hull
- 0.315 $Wm^{-1}K^{-1}$ for the rice hull plus typha mixture.

Analysis of the results shows that the values found fall within the range of values for thermal conductivity of similar materials [4,9,10]. Likewise, the thermal conductivity decreases depending on the type of straws as shown in Figure 6.

Figure 6 shows that for 6% of straw, the thermal conductivity decreases by 52%, 53% and 63% respectively for the typha, the rice hull and the typha-rice hull mixture. Hence the decrease in thermal conductivity depending on the percentage but also on the type of straw.

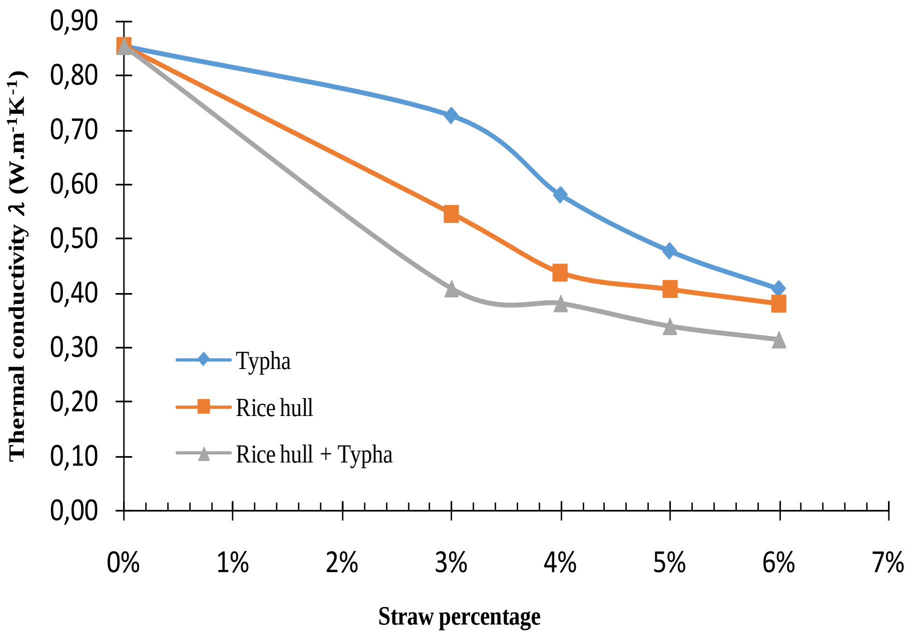

Figure 5. The thermal conductivity λ ($W.m^{-1}K^{-1}$) of the bricks as a function of the type of straws and their percentages

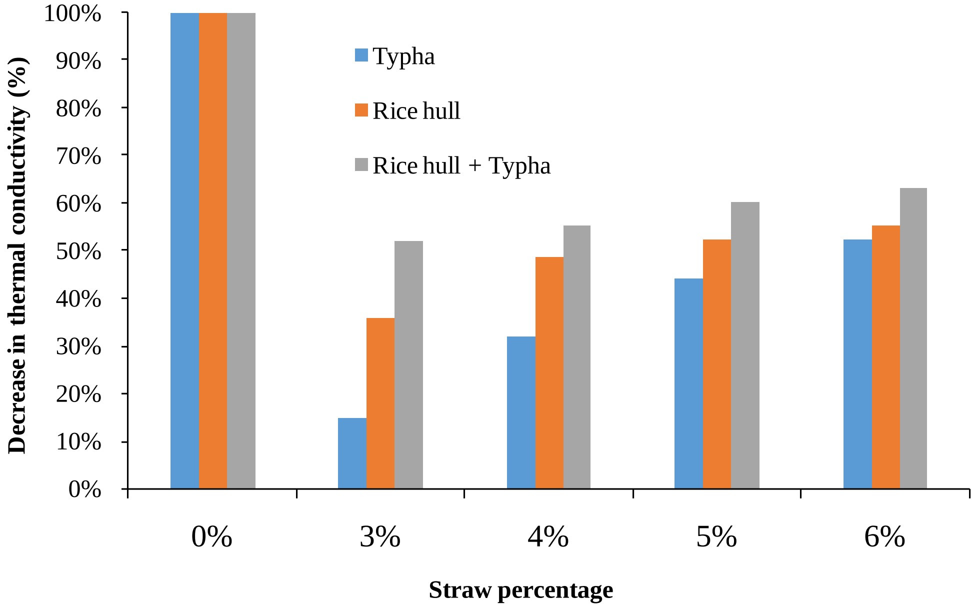

Figure 6. Decrease in thermal conductivity as a function of the percentage of straws

In fact, this decrease can be explained in the general context by the thermal behavior of these composite bricks which depends on the porosity of the materials used, ie typha and rice hull [11,12]. Thus, when the material contains a large network of closed pores there is no convection and more than half of the air contained in the material is immobile which leads to a drop in the thermal conductivity of the material and therefore the resistance. thermal (R) is high.

In addition, the bricks based on typha have a higher conductivity followed by those with rice hull and the one with the typha - rice hull mixture. This finding corroborates the results already obtained by previous studies [6].

4.2. Thermal Resistance

Thermal resistance (R) is one of the most important parameters in the thermal characterization of materials. It is expressed as a function of the thermal conductivity λ ($W.m^{-1}K^{-1}$) and the thickness e (m) of the material.

The change in thermal resistance as a function of the percentage of straws is shown in Figure 7.

The Figure 7 shows that the thermal resistance increases with the addition of straws.

Thus, it grows from 35 10^{-3} $W^{-1}m^2K$ for bricks without straws to (for 6% of straw):

- 74 10^{-3} $W^{-1}m^2K$ for the typha
- 79 10^{-3} $W^{-1}m^2K$ for the rice hull
- 95 10^{-3} $W^{-1}m^2K$ for the rice hull plus typha mixture.

The thermal resistance of bricks made from the rice hull plus typha mixture is higher than that of bricks made from a single straw. This is justified by the law of mixtures relating to the properties of composites on the one hand and on the other hand by the high porosity 40.22% to 6% of straw of the bricks with bricks designed with the mixture of straws [6].

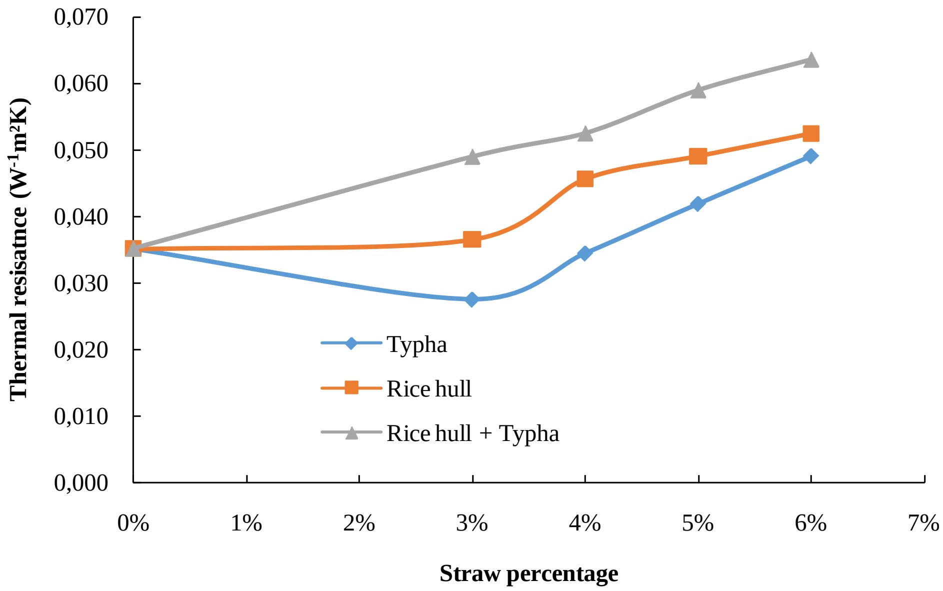

Figure 7. Thermal conductivity as a function of the percentage of straws

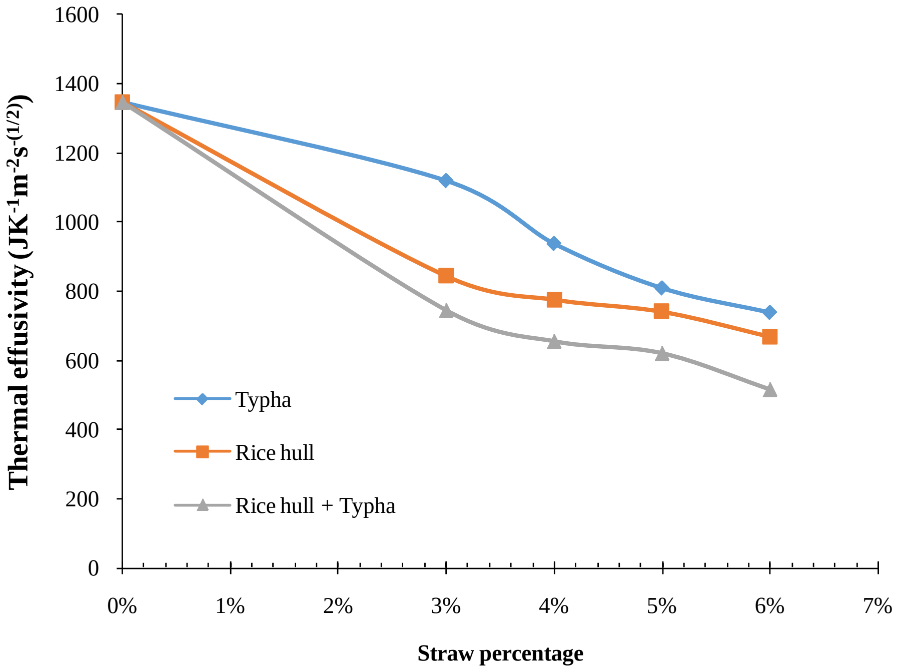

Figure 8. Effusivity E (JK^{-1}m^{-2}s$^{-1/2}$) of the bricks depending on the type of straw and their percentages

4.3. Thermal Effusivity

The effusivity of the samples is shown in Figure 8.

This curve shows that the effusivity of the samples varies between 1345.7 for bricks without straw at (6% straw):

- 738.9 J.K^{-1}m^{-2}s$^{-1/2}$ for the typha
- 667.2 J.K^{-1}m^{-2}s$^{-1/2}$ for the rice hull
- 515.2 J.K^{-1}m^{-2}s$^{-1/2}$ for the rice hull plus typha mixture.

Analysis of this curve shows that the addition of fibers decreases the mass of the material. However, thermal effusivity varies proportionally depending on the mass of the material. Hence the decrease in mass leads to a decrease in its thermal inertia [14,15]. And consequently a decrease in effusivity depending on the percentage of straw added. It is also noticed that the thermal conductivity and effusivity of bricks with rice hull and typha are lower than those of bricks made from the mixture of rice hulls or typha.

5. Conclusion

In the context of climate change, thermal properties play a decisive role in the choice of building materials. A good optimization of these properties makes it possible to reduce the energy bill.

This study showed that adding straw increases the energy performance of composite bricks.

Thus, for 6% of straw, the thermal conductivity decreases by 52%, 53% and 63% respectively for the typha, the rice hull and the typha-rice hull mixture.

Likewise, for 6% of straw, the thermal effusivity decreases by 45%, 50% and 62% respectively for the typha, the rice hull and the typha-rice hull mixture.

These results show that these bricks have good inertia and high thermal resistance compared to standard cement-based bricks.

In perspective, further studies will be carried out as part of a standardization and method of large-scale production of these types of bricks.

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