Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2024, 11(11):15-20**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Contribution to the Thermal Characterisation of Clay Bricks Mixed with Typha

Oumar DIALLO[1*], Macodou THIAM[1], Alioune Badara DIONE[1], Harouna Mamadou BAL[1], Salif GAYE[1]

[1]Laboratoire de Matériaux d’Énergétique, d’Electricité et d’Economie (LM3E), Institut Universitaire de Technologie de l’Université Iba Der THIAM de Thiès, Sénégal

Abstract: For several decades now, clay has been used as a building material, but it is also attracting renewed interest, as can be seen from a review of some of the work in this field [1]-[2]-[3]-[4]. The main reason for this is that the production process for cement-based materials has been identified as having convincing reasons for contributing in large part to global warming. In the search for thermal comfort at lower cost, the use of natural insulating materials such as typha has been considered. Typha is an upright, unbranched, knotless perennial rhizomatous grass that can grow up to 3.50 m high [5]. According to some sources, its presence has a negative impact on agricultural activities, biodiversity and river navigation, and causes the proliferation of certain diseases [6]-[7]. Its use in construction to improve the thermal properties of bricks is a real boon to eliminating the nuisances it causes.

This study provided information on the thermal characteristics of clay bricks mixed with typha aggregates.

Six samples of clay bricks with typha content (0%, 0.7%, 1%, 1.6%, 2% and 3.5% by mass) were designed and subjected to a transient thermal characterisation method: the asymmetric hot wire, to estimate their thermal properties.

The results show that in our study range, the thermal conductivity of the brick fell from 0,92 $W.m^{-1}.k^{-1}$ to 0,37 $W.m^{-1}.k^{-1}$, a reduction of around 40%.

Keywords: Thermal Characterisation, Clay Bricks, Typha

1. Introduction

Clay has long been used by the world's population to build earthen structures. Economic and technological development has brought with it other, more resistant and durable materials (cement-based concrete, lime, bitumen, etc.) that are taking the place of clay in every construction project. But the problems of global warming, which are becoming more and more persistent, are forcing us to seek out and use more environmentally friendly materials that do not emit greenhouse gases, can reduce energy requirements and, above all, offer appreciable thermal comfort. Among these materials, we have targeted clay by determining its thermo-physical properties with a view to reducing heat transfer due to the temperature gradient across the walls of the dwelling. According to the literature, a mud brick should have a thermal conductivity value of around 1.1 $W.m^{-1}.C^{-1}$ [8].

As for typha, which is an aquatic monocotyledonous plant of great length that takes root in stagnant water, several studies have shown that its thermal conductivity is well below 0.065 $W.m^{-1}.K^{-1}$. So a building material made from clay and typha could have quite interesting thermal properties that could provide thermal comfort. Several authors have worked on determining the thermo-physical and mechanical properties of typha australis combined with concrete and certain earth-based materials such as clay and laterite [9]-[10]-[11]-[12]-[13]-[14].

2. Materials and Methods for Measuring Thermal Properties

Materials and sampling

The clay used to design the samples was collected from the Thiky clay quarries in the Mbour department and the Typha quarry at the Pikine technopole. The photos in Figure 1 show the natural appearance of the materials in their raw state.

Figure 1: Natural aspect of the clay extraction quarry and Typha field

To design the bricks, both materials were processed. Ground and powdered clay. Dried and chopped typha. The images in Figure 2 show how they look.

Figure 2: Powdered clay and chopped typha

The materials were mixed and exposed to the sun for days to obtain samples measuring 10x10x3 cm^3 whose mass compositions are recorded in the following table.

Table 1: Mass composition of samples

Sr N°	Mass of clay (g)	Mass of typha (g)	Percentage of typha (%)
1	420	0	0
2	417	3	0,7
3	415	5	1
4	413	7	1,6
5	411	9	2
6	405	15	3,5

Figure 3 shows the samples obtained and subjected to the measurement method.

Figure 3: The samples

Measurement of Thermal Properties

For reasons of availability and simplicity of use, the hot-wire method is used to characterise the samples. More specifically, we have opted for the asymmetric hot-wire method because of the difficulties involved in obtaining perfectly identical samples.

The principle of the measurement involves placing a hot wire between the surfaces of a polystyrene and the sample to be characterised [15]-[16]. When a flow of heat is applied to the sample, the direction of heat propagation is assumed to be radial while the disturbance has not yet reached the other faces of the sample: the sample is assumed to be a semi-infinite medium. Starting from a well-adapted quadrupole model, we can then establish the expression for the Laplace transform of Ts(t) in the form:

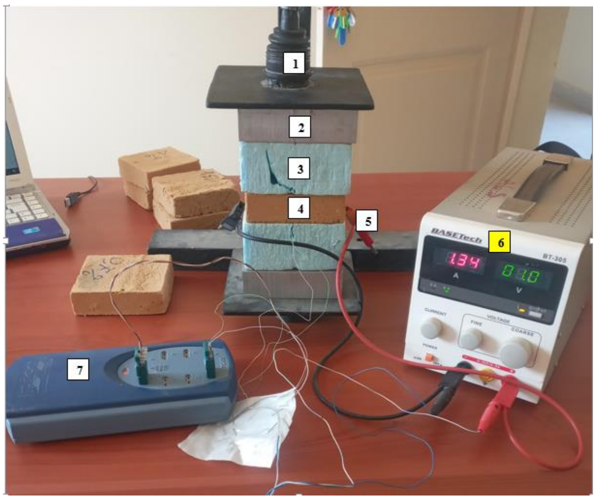
$$\theta_s = \frac{\varphi_0}{P} \cdot \frac{A_0 + \frac{A_0 R_0 + B_0}{Z}}{C_0 + \frac{C_0 R_0 + D_0}{Z}}$$

$$A_0 = 1 \text{ et } B_0 = \frac{1}{2\pi\lambda L q r_0} \cdot \frac{I_0(qr_0)}{I_1(qr_0)} - \frac{1}{\rho c_s \pi r_0^2 Lp} \qquad et \qquad C_0 = \rho c_s \pi r_0^2 Lp \text{ et } D_0 = \frac{qr_0}{2} \frac{I_0(qr_0)}{I_1(qr_0)}$$

θ_s: Laplace transform of the difference Ts(t) – Ts(t=0)
θ: Laplace transform of the difference T(t) – T(t=0)
Rc: Contact resistance at sample/heating resistor interface
λ: Thermal conductivity of the sample
a: Thermal diffusivity of the sample
p: Laplace variable
r_0: Radius of heating wire
L: Length of heating wire
φ_0: Power dissipated by the heating resistor
I_0, I_1, K_0, K_1 Bessel's functions.

By performing a limited first-order expansion of the Bessel functions, the Laplace transform tables can be used to calculate the values of the thermal conductivity λ, the heat capacity C and the contact resistance Rc.

After inverting the temperature in Laplace space into real space, we can use the plot of the Ts(t) - Ts(0) function as a function of ln(t). This produces a straight line with slope $\frac{\varphi_0}{4\pi\lambda L}$ the determination of which gives an approximate value for the thermal conductivity λ. This value will subsequently be used to iteratively run the full model program.



1= Clamping device; 2= Aluminum block; 3= Polystyrene; 4= Sample; 5= Hot wire embedding; 6= Stabilized power supply; 7= Data logger

Figure 4 : assembly of the asymmetric hot-wire method

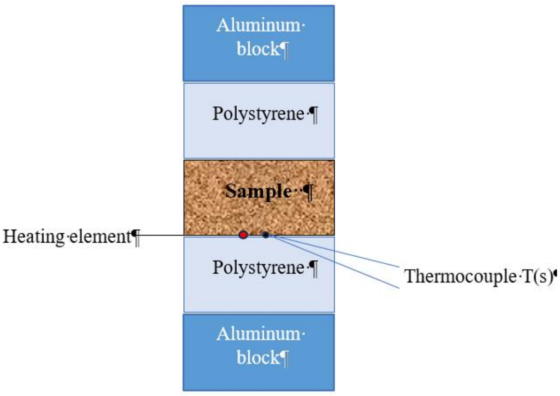


Figure 5 : Experimental set-up

3. Résultats

Présentation des résultats

The calculation software (MATLAB) used to estimate the thermal parameters of the samples is based on theoretical curves to estimate the values of the thermal parameters. The curves showing the variation in temperature as a function of time were displayed for a material with a thermal conductivity of 1.1W.m^{-1}.s^{-1}. This value was gradually increased by 2, 5, 10 and 50% to see how the curves evaluated.

The temperature vs. time curves for our samples subjected to the asymmetric hot-wire method are shown below. This allowed us to extract the values of the thermal parameters of the samples.

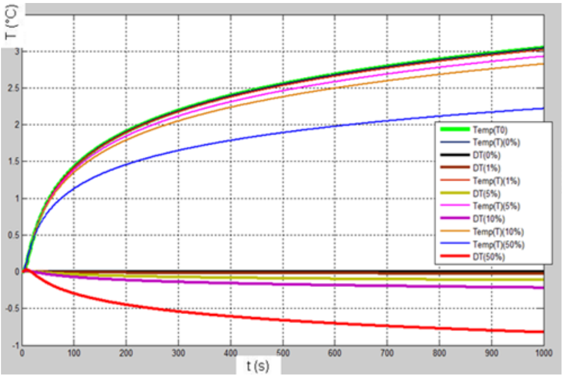


Figure 6: Theoretical temperature curves

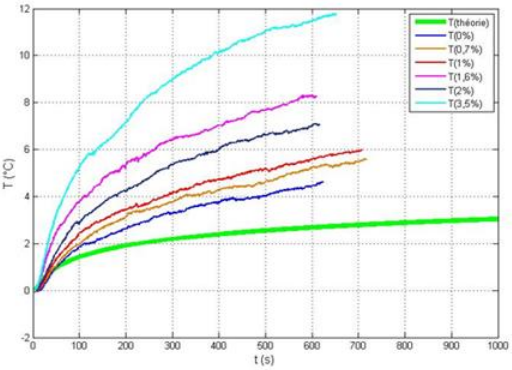


Figure 7: Experimental temperature curves

The values for thermal conductivity, thermal diffusivity and heat capacity for each estimated sample are listed in the table below.

Table 2: Summary of measurement results

Sample	**Thermal conductivity ($W.m^{-1}.k^{-1}$)**	**Thermal diffusivity (m².s^{-1})**	**Thermal capacity (J.m³.s^{-1})**
N°1: (100% clay)	0,92	0,25.10^{-7}	3653363
N°2: (99.3% mass of clay; 0.7% mass of typha)	0,84	27.10^{-7}	312942
N°3: (99% % mass of clay; 1%	0,78	2,28.10^{-7}	3363424

mass of typha)			
N°4: (98.4% % mass of clay; 1.6% mass of typha)	0,59	$5,20.10^{-7}$	1140495
N°5: (98% % mass of clay; 2% mass of typha)	0,58	$3,11.10^{-7}$	1864532
N°6: (96.5% % mass of clay; 3.5% mass of typha)	0,38	$3,16.10^{-7}$	1198325

Analysis of Results

The values in the previous table enabled us to plot the thermal conductivity of the clay bricks as a function of their typha content.

The temperature vs. time curves for the six samples have virtually the same shape as the theoretical curve.

The brick made entirely of clay (sample No. 1) has a thermal conductivity of 0.92 $W.m^{-1}.k^{-1}$. The thermal conductivities of the other samples decrease with typha content. This gives the descending curve in Figure 7.

The drop in thermal conductivity is most noticeable when the typha mass increases from 1% to 1.6% and from 2% to 3.5%.

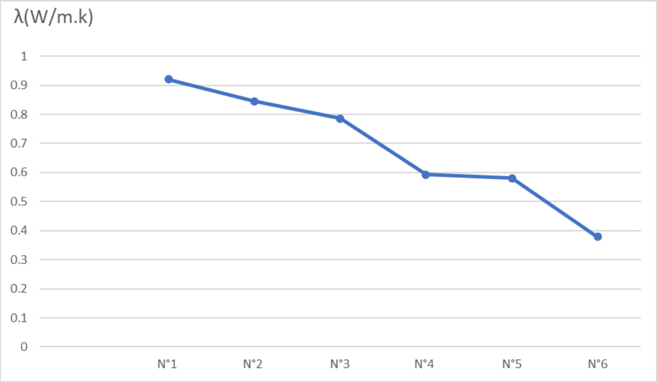


Figure 7: Thermal conductivity curve for bricks as a function of typha content

Interpretation

The thermal conductivity of the clay-only brick is 0.92 $W.m^{-1}.k^{-1}$, different from that found in the literature. This difference can be explained by the different types of clay and the conditions under which the samples were designed and measured.

The presence of typha, with its low thermal conductivity, considerably lowers the thermal conductivity of the brick. Less than 4% (3.5%) by mass of typha reduces the thermal conductivity of the brick from 0.92 to 0.38 $W.m^{-1}.k^{-1}$, i.e. a 59% reduction in the thermal conductivity of the brick.

The much higher temperature difference of samples N°2 and N°4 at time t = 100s than the other samples is due to a higher contact resistance of samples N°2 and N°4 than the others.

4. Conclusion

This document is a contribution to the study of the thermal characteristics of clay bricks mixed with typha. The results of the study show that clay bricks mixed with typha can contribute considerably to improving the thermal insulation properties of bricks. This provides thermal comfort in hot areas. These bricks can also help to moderate energy consumption due to the use of air conditioning in urban areas by reducing heat transfer flows through the walls of buildings.

References

[1]. A. DIOP, M. THIAM, M. B. NDIAYE, O. DIALLO, H. BAL, and S. GAYE Improving the stability of the inflatable soil of Diamnaidio by using typha Australis in order to value it in the partition wall. Journal of Building Construction and Planning Research. ISSN: 2328-4889, Vol 8, pp. 273-284, December 2020. https://doi.org/10.4236/jbcpr.2020.84.18

[2]. A. DIOP, M. B. NDIAYE, H. BAL, M. THIAM, and S. GAYE. Thermal characterization of dry soil/typha Australis materials for improving the energy performance of buildings. Journal of Scientific and Engineering Research, ISSN: 2394-2630, 2020, 7(12):177-184. Jsaer.com/archive/volume-7-Issue-12-2020/

[3]. A. DIOP, M. B. NDIAYE, M. THIAM, H. BAL, O. DIALLO and S. GAYE Analysis and mechanical exploitation of the soil clay of Diamniadio with Typha Australis. Journal of Engineering and Applied Sciences. 2021, Volume-15, Issue-23,pp. 3741-3746, ISSN: 1816-949X.

[4]. A. S. DIAW, H. BAL, O. DIALLO, M. B. NDIAYE, M. WADE, S. GAYE. Thermophysical characterization of typha concrete with a view to its integration into construction. Journal of Building Construction and Planning Research, 2021, 9, 56-65. ISSN: 2328-4889. 10.4236/jbcpr.2021.91005.

[5]. https://www.cerema.fr/fr/actualites/tyccao-utiliser-typha-materiau-batiments-combustible-afrique

[6]. https://www.agroalimentaire.sn/le-typha-une-plante-envahissante-utilisee-comme-isolant-dans-le-batiment/

[7]. https://www.francetvinfo.fr/monde/afrique/environnement-africain/le-typha-cette-plante-nuisible-qui-peut-rapporter-gros_3059863.html

[8]. BAL H. Modélisation et mesure de propriétés thermiques d’un milieu poreux humide: Brique de laterite avec gousse de mil. Thèse de Doctorat. Ecole supérieure polytechnique de l’Université Cheikh Anta DIOP de Dakar, 2011.

[9]. DIATTA M., GAYE S., THIAMA. and AZILINON D. Détermination des propriétés thermo-physique et mécanique du typha australys. https://www.sft.asso.fr/Local/dir/user-3775/documents/actes/congres_2011/communications/140.pdf

[10]. DIAW I., FAYE M., BODIAN S. and SAMBOU V. Effect of chimical treatment on the the physical properties. Fluid Dynamics and Materials Processing doi: 10.32604/fdmp.2022.021968

[11]. DIAW I, FAYE M, HANS S, SALLET F, SAMBOU V. Variabilité des performances mécaniques des matériaux isolants ciment-typha. Journal de physique du bâtiment. 2023;47(3):284-300. doi:10.1177/17442591231203245

[12]. A. S. DIAW, H. BAL, M. WADE and S. GAYE. Use of typha australis in the habitat for the improvement of energy efficiency of buildings. Journal of Scientific and Engineering Research, 2018 5(1): 164-171

[13]. A. GAYE, M. B. NDIAYE, O. DIALLO, H. BAL, and S. GAYE. Optimization of the mechanical formulation of typha concrete. International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-10 Issue-3, January 2021.

[14]. M. DIOUF, D. SOW, H. BAL, S. SOW, El A. THIAM, I. LY. Thermomechanical characterization of mixtures of frake chips and clay materials from Sebikone for use in social housing. International Journal of Engineering Sciences and Research Technology. ISSN: 2277-9655, Volume-10 Issue-10, October 2021. DOI: https://doi.org/10.29121/ijesrt.v10.i10.2021.2

[15]. H. BAL, Y. JANNOT, N. QUENETTE, A. CHENU and S. GAYE. Water content dependence of the porosity, density and the thermal capacity of laterite based bricks with millet waste. Construction and Building Materials 31(2012) 144-150.

[16]. H. BAL, Y. JANNOT, S. GAYE and F. DEMEURIE. Measurement and modelisation of the thermal conductivity of a wet porous medium: Laterite based bricks with millet waste additive. Construction and Building Materials 41(2013) 586-593.