Journal of Sustainable Construction Materials and Technologies
Web page info: https://jscmt.yildiz.edu.tr
DOI: 10.14744/jscmt.2021.02

Journal of Sustainable Construction Materials and Technologies

Original Article

Study of thermal and mechanical properties of typha leaf - clay panels

Younouss DIEYE[1*], Pape M. TOURE[1], Seckou BODIAN[1], Prince M. GUEYE[1], Mactar FAYE[2], Vincent SAMBOU[1]

[1]*Laboratoire d'Energétique Appliquée (LEA), Université Cheikh Anta Diop, Dakar-Fann, Sénégal*
[2]*Université Alioune Diop de Bambey, Bambey, Sénégal*

ARTICLE INFO

Article history
Received: 18 March 20211
Accepted: 04 October 2021

Key words:
Clay, mechanical strength, thermal conductivity, thermal effusivity, typha

ABSTRACT

This study contributes to the valorization of typha as local materials of building for thermal insulation. We will examine the influence of the binder content and granulometry on the mechanical and thermal properties of typha - clay panels. The plant of typha is used in different granulometries such as powdered typha and defibrated typha. The results showed that compressive strength, thermal conductivity and effusivity depend on the particle size of the typha and also the binder. The panels of defibrated typha have a better thermal insulation performance (0.085 $W.m^{-1}.K^{-1}$ for 66.66%), which is comparable with many of natural insulating materials. The panels also have low thermal effusivities which show that they have low thermal inertia.

Cite this article as: Dieye Y, Toure PM, Bodian S, Gueye PM, Faye M, Sambou V. Study of thermal and mechanical properties of typha leaf - clay panels. J Sustain Const Mater Technol 2021;6:4:135–142.

1. INTRODUCTION

Despite a massive industrialization of construction methods with increasingly efficient materials and the use of new technologies in the field of buildings, in recent years we have witnessed the development of a new generation of materials based on renewable plant resources to make in the face of environmental problems. This desire has strongly pushed engineers, researchers and public authorities to organize a reflection on the development of these materials and more particularly in the field of insulation in order to reduce the energy consumption of buildings by using materials with an insulating potential very important and a low economic and environmental cost [1–3]. The synthetic insulation available are imported and expensive [4]. It is therefore necessary to develop insulating materials of plant origin as an alternative to imported insulators.

Many studies have been conducted to investigate thermophysical and mechanical behavior of such bio-based materials. Bruijn et al. [5] studied the mechanical properties of a hemp concrete based on a lime and cement binder. They found that, for the dosages with the presence of the cement, the mechanical strength increases according to the proportion of cement in the mixture of 0.15 MPa to 0.83 MPa. Ashori et al. [6] evaluated the mechanical performance of various panels of eucalyptus, mesquite, saltcedar (Tamarix stricta) and date palm fibers and a formaldehyde resin binder. They concluded that for all types of panels, the modulus of rupture and modulus of elasticity increase as the resin content increases from 9% to 11%. Lertsutthi-

***Corresponding author.**
*E-mail address: younouss.dieye@ucad.edu.sn

Published by Yıldız Technical University Press, İstanbul, Turkey

wong et al. [7] studied the mechanical performance of an insulation board based on corn husks and a binder derived from solid waste paper tissue. They concluded that when the binder/fiber mass ratio varies from 0.33 to 3, the modulus of rupture and modulus of elasticity vary respectively from 1.3 to 5 MPa and from 21 to 196 MPa. Cuk et al. [8] studied the influence of two types of binder on the properties of a wood particle board. They showed that the mechanical properties of particle boards produced were better with melamine-formaldehyde resin (flexural strength of 13.42 MPa) than with melamine-urea-formaldehyde resin (11.06 MPa). Cerezo [9] evaluated the evolution of the thermal characteristics of hemp concrete according to the binder dosage. It has achieved an excellent performance of hemp concrete as a thermal insulation with conductivities ranging between 0.06 and 0.19 $Wm^{-1}.K^{-1}$ for densities ranging from 200 to 840 $kg.m^{-3}$. Chikhi et al. [10] investigated the thermal performance of a bio composite based on date palm fibers. They have shown that the increase in the fiber content decreases the density of the material from 1130 to 743 $kg.m^{-3}$ corresponding to 43% and increases its porosity. This reduction in density decreases the thermal conductivity from 0.449 to 0.177 $W.m^{-1}.K^{-1}$. Awwad et al. [11] studied the behavior of three hemp-concrete mixed with about 1%, 2%, and 4% hemp material by concrete volume. The tests results confirm the potential of incorporating raw hemp material in local masonry blocks while satisfying minimum strength (11.7 to 2.6 MPa), and reducing thermal conductivity (1.248 to 0.984 $W.m^{-1}.K^{-1}$) requirements. Chinta et al. [12] have studied the thermal insulation and some mechanical properties and physical properties of a new composite construction material composed of gypsum and natural fibers. The results showed that the incorporated natural fibers changed the rheological and mechanical behavior of the material and increase considerably its ductility and a decrease in thermal conductivity and bulk density is recorded. Moussa et al. [13] have tested a new agromaterial based on hemp and starch. The measured thermal conductivity was 0.08 $W\ m^{-1}.K^{-1}$ at 23°C. In the paper, authors deal with the study of Typha australis fibers to make a building material. Typha australis is an aquatic plant which is found on wetland and belongs to the Typhaceae family. This plant which can reach a height up to 3 m [14] rapidly spreads via seeds and roots. In very short time it takes over water areas. It is usual to see ponds that are completely surrounded by typha. Typha australis have affected irrigation in the valley of Senegal. It spreads rapidly over the areas and affecting other crops. So, abundant amount of it forced one to find its usefulness in insulation. The global objective of our study is to transform the harmful Typha australis as an opportunity by its transformation as a building material.

Concerning Typha fibers, previous investigations have been carried out to elaborate Typha clay and Typha–cement mixtures [15–17]. Results show that thermal behavior of composite made of Typha fibers and clay has low thermal conductivity ranging from 0.065 to 0.112 $W\ m^{-1}.K^{-1}$ [17]. However, there is no information about the study of lengths of typha fibers on the mechanical and thermal performances of such materials in the literature.

Figure 1. Typha leaves powder.

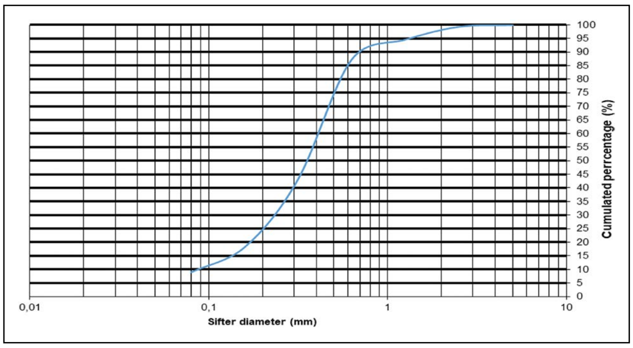

Figure 2. Granulometric graph of typha powder used.

The aim of this study is to determine the mechanical and thermal properties of fiber-based construction materials of typha australis. The effect of typha granulometry on properties is also looked at. Then, experimental methods to determine the following properties are detailed: apparent, absolute density, thermal properties (effusivity and conductivity), and the compressive strength. Experimental results are presented and the influence of the granular of Typha and ratio on the material's properties is discussed.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1 Typha

The typha used was extracted at the Niayes zone of the Dakar Technopole. The raw material thus extracted was dried for two weeks under the sun before being transformed. We obtained two types of typha leaf granules: powder typha and defibrated typha.

For the powdered typha, the dried typha leaves were cut into small pieces with the aid of an ax as shown in Figure 1. After cutting, the typha pieces obtained were crushed in powder form by an existing grinding machine in the market (Fig. 1). The particle size study of Typha powder was carried out by sieving using standard square mesh sieves with diameters ranging from 5 mm to 0.08 mm. Figure 2

Figure 3. Typha leaves defibrated.

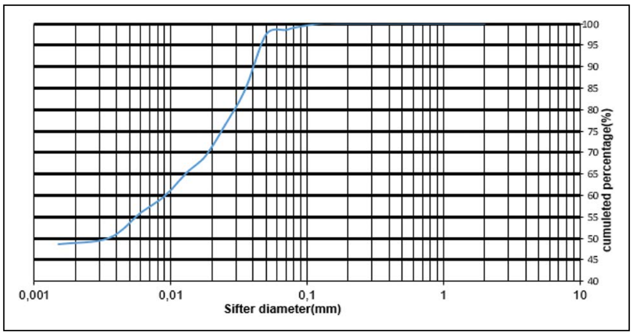

Figure 4. Granulometric graph of clay used.

summarizes the particle size distribution that make up the typha powder. The density and the water content of the typha powder are respectively 128.38 kg.m^{-3} and 12.24%. The density was measured according to French standards NF ISO 11272. First, we determined the bulk density by weighing a mass of samples in 500 mL test pieces. The experiment was repeated 3 times. The water content is obtained using an oven at a temperature of 105 °C.

The defibrated typha is also mainly from the leaves. The leaves represent 80% of the mass of the plant; after extraction, they were crushed before being defibrated by hand. The defibrated typha leaves obtained have lengths up to 15 cm as reflect in Figure 3. The length of the leaves of typha defibrated is determined by means of a vernier caliper. The bulk density is 61 kg.m^{-3}.

2.1.2 Clay

The clay used is a by-product of local quarries that does not require processing. The clay used as a binder in this study is a clay from the Souvenir Square in Dakar (bulk density of 1400 kg.m^{-3}). A grain size analysis is carried out on the clay to determine the dimensions of the grains and the weight percentages of the different families of grains which constitute it. This study was made using sieves with diameters between 0.0015 mm and 2 mm. The granulometric curve obtained is shown in Figure 4. The researchers noted that 99% of the weight of the grains passes the sieve

Table 1. Atterberg limits of the clay

Atterberg limits	Clay
Liquid limit, WL (%)	44. 3
Plastic limit, WP (%)	17.6
Plasticity index PI (%)	26.7

0.08 mm. The liquidity limit was measured by the method of the dish of Casagrande (WL) and the plasticity limit by the method of the roller (WP). These measures were realized according to NF P94-051 standard. The Atterberg limits were used to determine the plasticity index of the studied materials. The plasticity index (PI) is the difference between the liquid limit and the plastic limit. It is a measure of the plasticity of a soil.

$$PI = WL - WP \quad (1)$$

where PI is the plasticity index; WL is the liquidity limit and WP represents the plasticity limit.

The consistency limits of the clay, which included the plastic limit (WP), liquid limit (WL) and plastic index (PI) are reported in Table 1 The plasticity index shows that the clay is plastic.

2.1.3 Formulation of Samples

2.1.3.1 Preparation of the Binder

To avoid water competitions between the binder and the typha leaves, the binder is prepared separately. Typha leaves can absorb up to 80% of its weight in water and most of this absorption takes place rapidly. The mixture should contain as much binder as possible and adequate water content to avoid mixing wet typha leaves and dry binder. The binder is prepared so that its adhesion is important and that it has the power to spread easily on typha particles and ensure their bonds. The clay was mixed directly with the corresponding amount of mixing water before being kneaded with an E095 type kneader. The mixer has a specific speed of 62 rpm and a capacity of 5 liters. The mixture was kneaded for 5 minutes in order to have a viscous liquid that sticks, before pouring the amount of typha.

2.1.3.2 Preparation of Samples

After preparation of the binder, the necessary amounts of typha are poured directly into the binder mixture at the kneader. The weight percentage of the binder was varied and the binder / water ratio set at 1: 1. The mixing time is 5 minutes in total for the mixture to be homogeneous, after preparation of the binder.

The fresh mixture of typha leaf - binder obtained is then put and packed in standardized molds of dimensions 4 cm x 4 cm x 16 cm for mechanical tests and 10 cm x 10 cm x 2 cm for thermal tests (Fig. 5, 6). After sample preparation, the filled molds are placed in the ambient environment of the laboratory of about 27°C, for 24 hours before being demolded. After demolding, the samples were dried in the open air

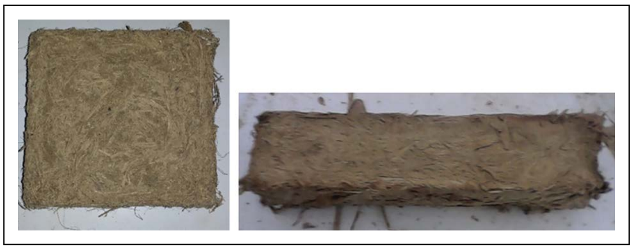

Figure 5. Picture of a typha powder sample.

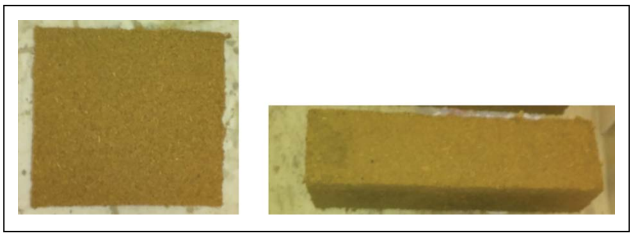

Figure 6. Picture of a typha defibrated sample.

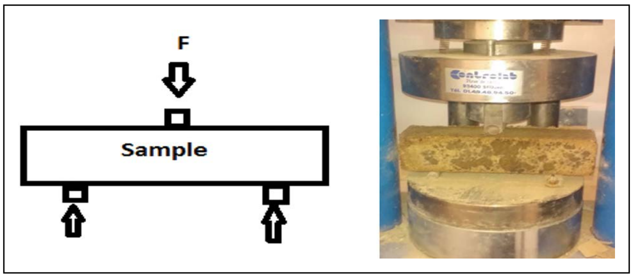

Figure 7. Flexural test.

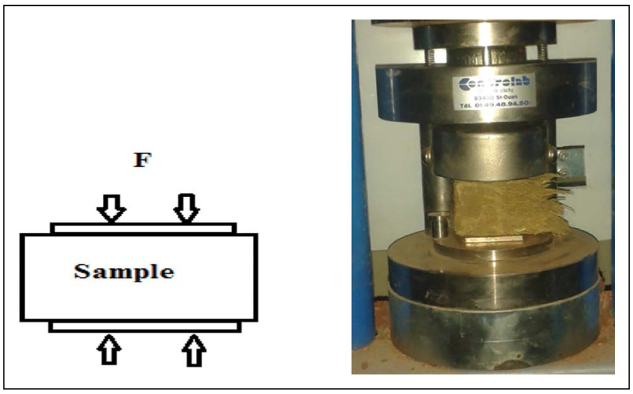

Figure 8. Compression test.

under the sun for two weeks, the time they are dried before carrying out the characterization tests. The masses of the different constituents of typha panels are shown on the Table 2. For each formulation, 3 samples were measured.

2.2 Methods

2.2.1 Mechanical Characterization

To characterize the solidity of the material, the mechanical behavior was evaluated by three-point compression and bending tests preceded by the measurement of the apparent density.

Table 2. Masses of the different compounds

Samples	Binder percentage (%)	Clay mass (g)	Typha leaves mass (g)	Water mass (g)
E_1	66.67	160	80	160
E_2	72.73	213	80	213
E_3	80	320	80	320
E_4	88.89	640	80	640

2.2.1.1 Bulk Density

Apparent density was determined after sample drying using a 0.01 g precision scale for weighing and a 0.01 mm precision vernier caliper to measure sample sizes. For each composition, 5 measurements were made, in order to obtain an average.

2.2.1.2 Mechanical Test

Mechanical characterization consists in determining the compressive strength and the tensile strength. This characterization was carried out using a mechanical press type E0160 with a maximum pressure of 250 kPa, in accordance with the standard NF EN 196-1.

2.2.1.2.1 Flexural Test

For the determination of the flexural strength a prismatic sample of dimensions 4 cmx 4 cmx 16 cm was placed on the press as shown in Figure 7 The sample is based on two simple supports, and the load F is applied to the center of the sample as shown in the schema of Figure 7. For each formulation, two samples were tested.

2.2.1.2.2 Compression Test

Compression tests are carried out on dry samples after they are broken for flexural test, at a constant rate of loading of 2 kN/s with the mechanical press. Figure 8 shows the disposition of the sample for the determination of compressive strength. For each composition, 4 trials were used.

These tests involve applying to a standard sample of the material a force F and measuring its breaking stress. The mechanical strength of a material describes its response to applied loads; it is the breaking stress. The maximum stress that the sample can withstand before rupture is called the breaking stress or the resistance to compression or bending. It is defined by:

$$\sigma = \frac{F}{S} \quad \text{(MPa)} \qquad (1)$$

S is the sample section in mm^2, F is the force applied (N)

2.2.2 Thermal Characterization

A measurement of thermal characterization of a material is based on the observation of its response to a thermal disturbance. The hot plane method is used to determine the

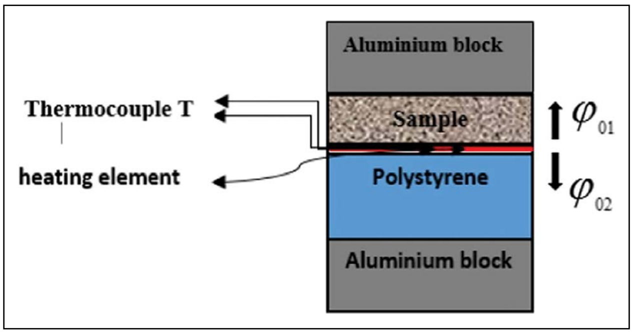

Figure 9. Schema of the experimental asymmetrical hot plate device.

thermal conductivity and effusivity of materials. The measuring device is made as shown in Figure 9. The heating element of small thickness is inserted between the sample to be characterized and a polystyrene block of 5 cm thickness and the whole is delimited by two aluminum blocks of 4 cm thickness. The sample of the material to be characterized is parallelepiped with the following dimensions 10 cmx 10 cmx 2 cm. Throughout the experiment, it is assumed that the heat transfer is 1D and that the temperature at the aluminium block is considered constant.

The thermal quadrupole method [18] is used to solve the thermal transfer problem. Indeed, by placing oneself in the Laplace space, the equation of heat depends only on the space variable.

$$\begin{bmatrix}\theta_s\\ \phi_{01}\end{bmatrix}=\begin{bmatrix}1 & 0\\ CsSp & 1\end{bmatrix}\begin{bmatrix}1 & R_C\\ 0 & 1\end{bmatrix}\begin{bmatrix}A & B\\ C & D\end{bmatrix}\begin{bmatrix}0\\ \phi_1\end{bmatrix}\begin{bmatrix}A_1 & B_1\\ C_1 & D_1\end{bmatrix}=\begin{bmatrix}0\\ \phi_1\end{bmatrix} \quad (2)$$

$$\begin{bmatrix}\theta_s\\ \phi_{02}\end{bmatrix}=\begin{bmatrix}A_i & B_i\\ C_i & D_i\end{bmatrix}\begin{bmatrix}0\\ \phi_2\end{bmatrix} \quad (3)$$

With:

$$A = D = \cosh\left(\frac{E}{\lambda}\sqrt{p}\,e\right);\ B = \frac{\sinh\left(\frac{E}{\lambda}\sqrt{p}\,e\right)}{ES\sqrt{p}};\ C = ES\sqrt{p}\sinh\left(\frac{E}{\lambda}\sqrt{p}\,e\right)$$

$$A_i = D_i = \cosh\left(\frac{E_i}{\lambda_i}\sqrt{p}\,e_i\right);\ B_i = \frac{\sinh\left(\frac{E_i}{\lambda_i}\sqrt{p}\,e_i\right)}{E_i S\sqrt{p}};\ Ci = E_i S\sqrt{p}\sinh\left(\frac{E_i}{\lambda_i}\sqrt{p}\,e_i\right)$$

λ is the sample thermal conductivity; E the sample thermal effusivity; e the sample thickness; λ_i the polystyrene thermal conductivity; E_i the polystyrene thermal effusivity; e_i the polystyrene thickness; θ_s the Laplace transform of the temperature Ts(t); *Cs* the thermal capacity of the heating element per area unit: $Cs=\rho_s c_s e_s$; R_c the thermal contact resistance between the heating element and the sample; ϕ_1 the Laplace transform of heat flux input on the upper aluminum block; ϕ_2 the Laplace transform of heat flux input on the lower aluminum block; ϕ_{01} the Laplace transform of the heat flux density living the heating element (upstream); ϕ_{02} the Laplace transform of the heat flux density living the heating element (downstream)

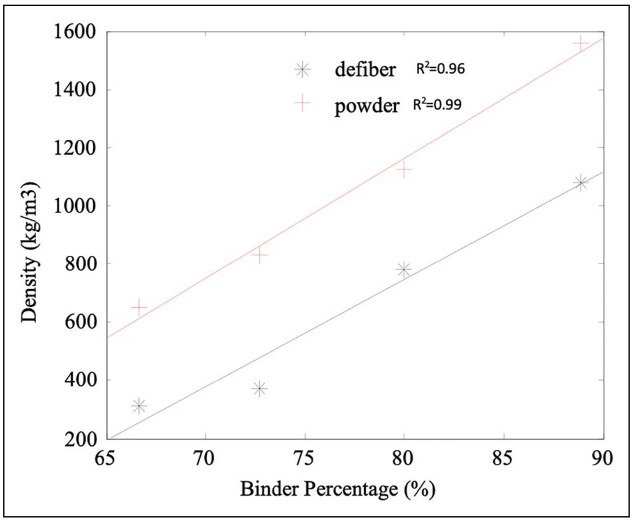

Figure 10. Variation curve of density in function of the binder percentage.

After developing the matrix products (2) and (3), the following relations were obtained:

$$\theta_s = \phi_0 \frac{1}{\left(\frac{D_1}{B_1}+\frac{D_i}{B_i}\right)} \quad (4)$$

3. RESULTS AND DISCUSSION

3.1 Mechanical Results

3.1.1 Apparent Density

The researchers present the evolution of the density according to the binder. We also look at the influence of the type of typha aggregates on the density of the panels. This is illustrated in Figure 10 showing, for the clay binder, the effect of the type of aggregates on the density, but also the change in the density of panels based on typha of powder and defibrated typha according to the percentage of clay binder. The density varies from 314 kg.m^{-3} to 1078 kg.m^{-3} for the defibrated typha and from 652 kg.m^{-3} to 1559 kg.m^{-3} for the powdered leaves, when the mass percentage of clay varies from 66.66% to 88.89%. We observe that the values of the density vary almost linearly as a function of the binder content. This can be explained by the fact that the binder has a higher density. As a result, the greater the amount of binder the more dense the material, the greater the density. The results also show that the type of fibers of the typha leaves influences the density of the panels. Typha powder sheet panels have higher densities. For 66.66% binder, the typha powder board is 2.1 times higher than the defibrated panel and this is due to the fact that the typha powder leaves are denser.

Figure 11. Flexural strength.

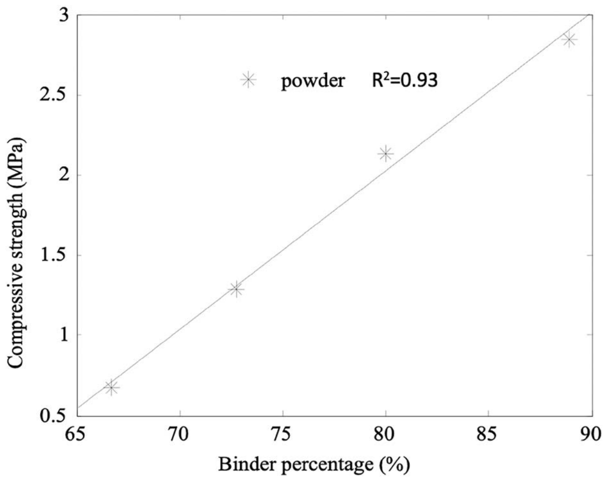

Figure 12. Variation curve of compressive strength in function of the binder percentage for typha powder.

3.1.2 Flexural Strength

Typha powder panels have low flexural strength; after applying the load, the panels break quickly. The values are so low that the machine can not display the results and this is due to the particle size of the typha aggregates. In the case of panels based on defibrated typha sheets, the force applied to the panel up to the maximum load causes a deformation of the latter without breaking (Fig. 11). The results obtained are characteristic of a ductile material, which withstands very high deformation levels without breaking. This is due to the particle size of the fibers, the panels have an elastoplastic behavior, a strong deformability under stress and the possibility of recovery efforts even after reaching the maximum mechanical strength. The particle size significantly affects the flexural strength of the panels.

3.1.3 Compressive Strength

The measurement results show an increase in the compressive strength of the panels as a function of the mass concentration of binder. The values of the resistance increase almost linearly according to the percentage of binder Figure 12 illustrates the variation in the compressive strength of the panels based on powdered typha leaves and clay binder. The resistance increases from 0.67 MPa to 2.84 MPa depending on the mass percentage of clay. This can be explained by the fact that, the higher the dosage of the binder, the greater the binding of the fibers is important, thus increasing their mechanical performance. The level of mechanical performance of the panels depends on the thickness of the layer of the binder encapsulating the particles. The mechanical properties of the samples are related to the binder dosage. These results are comparable to those of hemp-lime concrete [5], whose compressive strength values vary from 0.15 MPa to 0.83 MPa as a function of the hemp to binder mass ratio.

For the boards of defibrated typha leaves, the application of the load causes a deformation of the materials and not a rupture that is due to the length of the fibers. The defibrated typha boards are ductile compared to those in powder. We can conclude that the particle size of the typha leaves greatly influences the compressive strength.

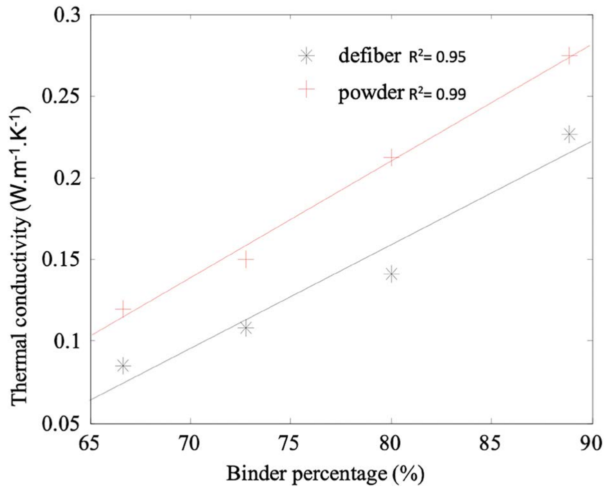

Figure 13. Dry panel thermal conductivity in function of the binder.

3.2 Thermal Results

3.2.1 Thermal Conductivity

The thermal conductivity λ ($W.m^{-1}.K^{-1}$) is an important quantity that characterizes the thermal insulation capacity of a material. More the material is insulating, the lower is the coefficient λ. The analysis of the curve shows a quasi-linear increase in the thermal conductivity of the dry panels as a function of the amount of binder. The thermal conductivity values of the panels increase as the concentration of binder increases.

Regarding the particle size, for the same type of binder, we have also illustrated in Figure 13 the influence of the length of typha leaf on the thermal conductivity. By comparing the panels of defibrated typha sheets with those of powder for the clay binder, we find that the defibrated typha boards have better thermal insulation properties. The thermal conductivity of the panels varies respectively from 0.085 to 0.227 $W.m^{-1}.K^{-1}$, for the defibrated typha sheets and from 0.120 to 0.275 $W.m^{-1}.K^{-1}$ for leaves in powder, depending on the binder content. For 66.66% binder, the defibrated typha board is about 41.2% more insulating than the board of typha powder sheets. This difference is due to the difference of the type of fibres, the typha consists essentially of pores which constitute the internal structure of the plant, to which are added the air holes between the particles of typha and in the form of powder, the typha loses its properties.

The results on the conductivity are similar to those obtained on hemp concrete [19] ranging from 0.06 to 0.19 $W.m^{-1}.K^{-1}$ relative to the binder dosage. The values relatively low of the thermal conductivity of typha provide high wall thermal resistances that allow them to meet thermal requirements.

3.2.2 Thermal effusivity

Thermal effusivity describes the speed with which a material absorbs and releases heat. The lower is the thermal effusivity, the faster the material will heat up with less energy. The measurement results of the thermal effusivity of the typha panels are shown in the figure. In a similar way to the thermal conductivity, we observe that in the dry state, the thermal effusivity of the panels increases as a function of the increase in the mass concentration of binder. The curve evolves in a quasi - linear way. By increasing the dosage rate by binder, it follows an increase in thermal effusivity which demonstrates the influence of the proportion of binder on the effusivity of the panels. The thermal effusivity of the panels depends on the density, the thermal conductivity and also the heat capacity. By increasing the dosage by bonding panels, we are seeing an increase in density and thermal conductivity thus implying an increase in thermal effusivity.

The figure also illustrates the influence of the type of fibres on thermal effusivity. For the same type of binder, it is clearly observed that the type of the typha fibers have a significant effect on the thermal effusivity of the panels. The effusivity changes respectively by 170.9 $J.m^{-2}.°C^{-1}.s^{-\frac{1}{2}}$ to 473.1 $J.m^{-2}.°C^{-1}.s^{-\frac{1}{2}}$ for the defibrated typha leaves and 265.2 $J.m^{-2}.°C^{-1}.s^{-\frac{1}{2}}$ to 728.2 $J.m^{-2}.°C^{-1}.s^{-\frac{1}{2}}$ for powdered sheets, depending on the percentage of binder (Fig. 4). Comparing the results obtained for the panels of leaves of typha defibrated with those of typha leaves in powder form as in the Figure 14, the researchers notice that the boards based on powdered leaves are more effusive and this can be explained by the fact that the powdered leaves are denser and less porous than those defibrated. For 66.66% binder, the typha powder board is 1.9 times more effusive, this explains the effect of the type of fibres on effusivity.

The values obtained are comparable to those of hemp concrete - lime of 206.9 $J.m^{-2}.°C^{-1}.s^{-\frac{1}{2}}$ for a dry density of 413 kg/m^3 [20] and 267 $J.m^{-2}.°C^{-1}.s^{-\frac{1}{2}}$ for a dry density of 440 $kg.m^{-3}$ [21].

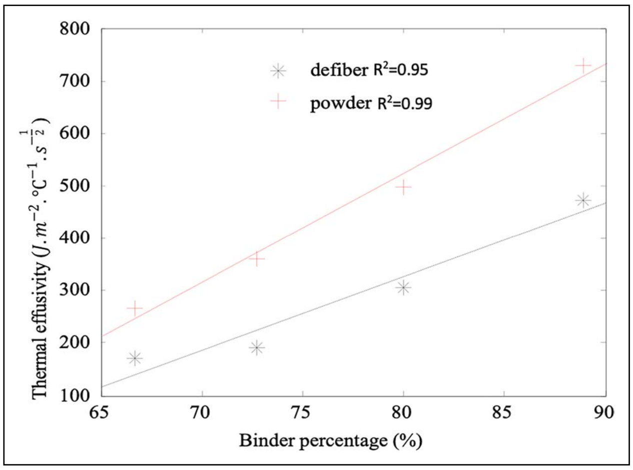

Figure 14. Dry panel thermal effusivity in function of the binder.

4. CONCLUSION

During this study, we were interested in the development of typha materials for the building while relying on mechanical and thermal characterization.

From a mechanical point of view, the results showed that the flexural strength of panels depends on typha aggregates. The finer is the typha aggregates, the lower is the flexural strength. In the case of compressive strength, the results depend on the nature of the binder and the aggregates used. The panel of typha powder and clay with a binder content of 88.89% and a density of 1559 $kg.m^{-3}$ has the best compressive strength at 2.84 MPa.

The thermal conductivity and effusivity of the panels were evaluated. They increase almost linearly depending on the binder content. The results also showed that the type of typha aggregates affect thermal conductivity. Regarding the influence of the size of the aggregates, it has been shown that for 66.66% of binder content, the panel of defibrated typha sheets is about 41.2% more insulating than the panel of typha powder sheets. Measurement of thermal effusivity has shown that typha panels are weakly effusive. Thermal effusivity increases with increasing binder content. It is concluded that the boards made from powdered leaves are more effusive. The use of these typha panels in the building will contribute to the reduction of energy consumption. This type of material is not also water resistant.

ACKNOWLEDGEMENTS

We thank the Coordinator of Project of Thermal Insulation Material Production on base of Typha in Senegal (PNEEB/TYPHA) and the director of the Applied Energy Laboratory (LEA).

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The authors declared that this study has received no financial support.

PEER-REVIEW

Externally peer-reviewed.

REFERENCES

[1] Meukam, P., Jannot, Y., Noumowe, A., & Kofane, T. (2004). Thermo physical characteristics of economical building materials. *Construction and Building Materials*, 18(6), 437–443. [CrossRef]

[2] Millogo, Y., Morel, J. C., Aubert, J. E., & Ghavami, K. (2014). Experimental analysis of Pressed Adobe Blocks reinforced with Hibiscus cannabinus fibers. *Construction and Building Materials*, 52, 71–78. [CrossRef]

[3] Bal, H., Jannot, Y., Quenette, N., Chenu, A., & Gaye, S. (2012). Water content dependence of the porosity, density and thermal capacity of laterite based bricks with millet waste additive. *Construction and Building Materials*, 31, 144–150. [CrossRef]

[4] Tettey, U. Y. A., Dodoo, A., & Gustavsson, L. (2014). Effects of different insulation materials on primary energy and CO2 emission of a multi-storey residential building. *Energy and Buildings*, 82, 369–377. [CrossRef]

[5] de Bruijn, P. B., Jeppsson, K. H., Sandin, K., & Nilsson, C. (2009). Mechanical properties of lime–hemp concrete containing shives and fibres. *Biosystems Engineering*, 103(4), 474–479. [CrossRef]

[6] Ashori, A., & Nourbakhsh, A. (2008). Effect of press cycle time and resin content on physical and mechanical properties of particleboard panels made from the underutilized low-quality raw materials. *Industrial Crops and Products*, 28(2), 225–230. [CrossRef]

[7] Lertsutthiwong, P., Khunthon, S., Siralertmukul, K., Noomun, K., & Chandrkrachang, S. (2008). New insulating particleboards prepared from mixture of solid wastes from tissue paper manufacturing and corn peel. *Bioresource Technology*, 99(11), 4841–4845. [CrossRef]

[8] Cuk, N., Kunaver, M., & Medved, S. (2011). Properties of particleboards made by using an adhesive with added liquefied wood. Materiali in Tehnologije, 45(3), 241–245.

[9] Cérézo, V. (2005). Propriétés mécaniques, thermiques et acoustiques d'un matériau à base de particules végétales: approche expérimentale et modélisation théorique [Doctoral dissertation, Institut National des Sciences Appliquées, Lyon. (French)

[10] Chikhi, M., Agoudjil, B., Boudenne, A., & Gherabli, A. (2013). Experimental investigation of new biocomposite with low cost for thermal insulation. *Energy and Buildings*, 66, 267–273. [CrossRef]

[11] Awwad, E., Choueiter, D., & Khatib, H. (2013). Concrete masonry blocks reinforced with local industrial hemp fibers and hurds. *Proceedings 3rd International Conference On Sustainable Construction Materials And Technology*, Kyoto, Japan, 28, 18–21.

[12] Chinta, S. K., Katkar, P. M., Jafer, M. M. (2013). Natural fibres reinforced gypsum composites. *International Journal of Engineering and Management Sciences*, 4(3), 318–325.

[13] Moussa, T., Maalouf, C., Lachi, M., Umurigirwa, S., Mai, T. H., & Henry, J. F. (2016). Development and performance evaluation of a hemp–starch composite. *Journal of Building Physics*, 40(3), 278–295. [CrossRef]

[14] Ponnukrishnan, P., Thanu, M. C., & Richard, S. (2014). Mechanical characterization of Typha Domingensis natural fiber reinforced polyester composites. *International Journal of Research Science and Technology Engineering Mathematics*, 6, 241-244.

[15] Diatta, M. T., Gaye, S., Thiam, A., & Azilinon, D. (2011). Détermination des propriétés thermo-physique et mécanique du typha australis. In Congres SFT, Perpignan, (France).

[16] Dieye, Y., Sambou, V., Faye, M., Thiam, A., Adj, M., & Azilinon, D. (2017). Thermo-mechanical characterization of a building material based on Typha Australis. *Journal of Building Engineering*, 9, 142–146. [CrossRef]

[17] Niang, I., Maalouf, C., Moussa, T., Bliard, C., Samin, E., Thomachot-Schneider, C., Lachi, M., Pron, H., Mai, T. H., & Gaye, S. (2018). Hygrothermal performance of various Typha–clay composite. *Journal of Building Physics*, 42(3), 316–335. [CrossRef]

[18] Maillet, D., André, S., Batsale, J. C., Degiovanni, A., & Moyne, C. (2000). *Solving the Heat Equation through Integral Transforms*. Wiley.

[19] Collet, F., & Pretot, S. (2014). Thermal conductivity of hemp concretes: Variation with formulation, density and water content. *Construction and Building Materials*, 65, 612–619. [CrossRef]

[20] Collet-Foucault, F. (2004). *Caractérisation hydrique et thermique de matériaux de génie civil à faibles impacts environnementaux* [Doctoral Dissertation, Rennes, INSA].

[21] Evrard, A. (2008). *Transient hygrothermal behaviour of lime-hemp materials* [Doctoral Dissertation, Université catholique de Louvain].