Thermomécanical characterization of adobe bricks made from cattail.

Abstract

This study focuses on the thermomechanical characterization of adobe bricks made from cattail. The objective is to design test specimens with a cattail content ranging from 0 to 2%. The properties measured include density, compressive strength, thermal conductivity, and thermal effusivity.

The density of the bricks studied ranges from 1705.45 to 1878.85 kg/m^3.

The adobe bricks tested mechanically exhibit a compressive strength at 28 days ranging from 2.92 to 5.56 MPa, thus exceeding the standard of 2 MPa and meeting the standard requirements for earthen masonry construction. Their thermal conductivity ranges from 0.769 to 0.371 $W \cdot m^{-1} \cdot K^{-1}$, while their thermal effusivity ranges from 652.919 to 915.770 $W \cdot s^{-1/2} \cdot m^{-1} \cdot K^{-1}$. This study shows that the thermal characteristics are favorable compared to those of standard bricks.

Keywords:

Adobe, Cattail, Compressive Strength, Thermal Conductivity

Introduction-:

The industrial revolution, particularly the exploitation of fossil fuels and manufacturing, has led to increased production of greenhouse gases (CO_2, methane, etc.). The Intergovernmental Panel on Climate Change (IPCC), in its 5th report of 2014, indicates a 0.85°C increase in the average global temperature between 1880 and 2012, alongside an 80% increase in greenhouse gas emissions since 1970[1]. To reduce the carbon footprint of buildings, a major lever, it is crucial to use environmentally friendly materials. The building sector is a major contributor to energy consumption and greenhouse gas emissions, making it an essential lever for achieving the 2050 climate goals according to GlobalABC& UNEP[2]. The lack of insulation in concrete buildings exacerbates this energy consumption, highlighting the importance of thermal insulation to reduce both energy consumption and CO_2 emissions[3][4][5].

This study aims to propose building components (bricks) using bio-based materials such as adobe (clay, limestone, sand, laterite, water) and cattail (Typha). Specifically, it seeks to develop different formulations of cattail-based adobe bricks, characterize their thermomechanical properties, and then propose bricks that meet the required specifications.

This study focuses on evaluating the physical, mechanical, and thermal properties of composite bricks modified by the incorporation of cattail fibers. The other constituents (limestone, sand, laterite, water) are used in fixed quantities. The effect of cattail fibers on the properties of the composite bricks will be analyzed by developing five formulations incorporating between 0 and 2% cattail by mass. Mixture A00, free of cattail, serves as a baseline for comparison. This approach allows for the isolation of the impact of cattail fibers on the brick properties.

Site presentation: -

Senegalese soil is rich and contains a large number of clay and laterite deposits[6]. The latter are used for road construction, and clay, formerly used in building construction, is now primarily reserved for pottery and tiles. Clay samples from Thicky and laterite from the Sindia quarry, located in the Thiès region (western Senegal, 14°50′ N, 17°06′ W, see Figure 1), served as the basis for this study. Bandia limestone was used in our research. As illustrated in Figure 1, the Sindia quarries (for laterite) and the Thicky quarry (for clay) were exploited to obtain the necessary materials.

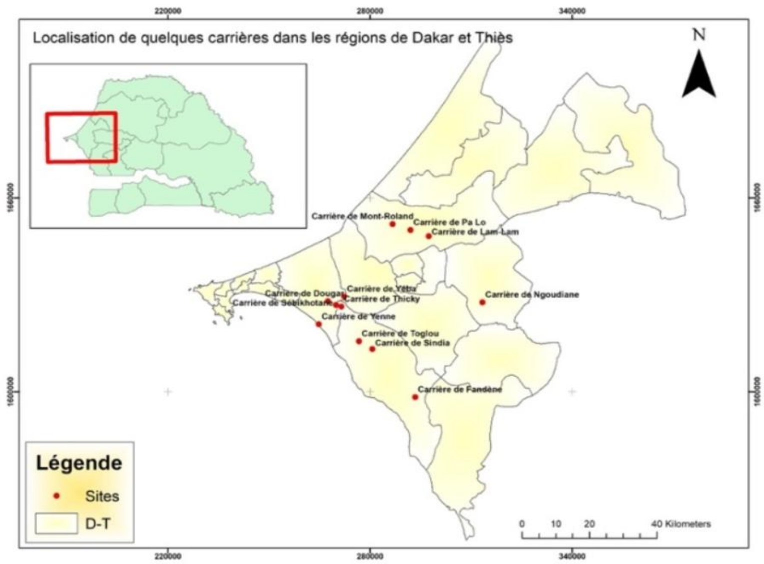

Figure 1:-Location of quarries in the Thiès region[7]

Raw materials: -

Mineral materials: -

Figure 2 shows the raw materials for the manufacture of adobe bricks: laterite (a), Keur Mori sand (b), limestone (c) and clay (d). These components are intended to be mixed with typha to produce bricks for comparative evaluation.

Figure 2:-The raw materials to be used for the formulation of laterite adobes: Sindia (a), keur mori sand (b), Bandia limestone (c) and thicky clay (d)

Plant fibers: -

Typha:-

The cattail fibers underwent solar drying prior to use. This process aimed to reduce their moisture content, thereby improving their preservation and adhesion within the mixture. The availability of naturally dried cattails facilitated their use in this research.Typha (Figure 3), a stem plant rich in structural fibers, is a prized building material in Africa. Studies have validated its potential for brickmaking, and its fibrous properties improve mechanical strength while promoting the development of insulating products.

Figure 3:-Typha fiber

Materials and methods: -

Materials: -

The production of the adobe bricks required various laboratory equipment for processing the raw materials, mixing, shaping, and analyzing the samples. The components (laterite, clay, sand, limestone, and cattail fibers) were collected from their sources before being transported to the laboratory. The cattail fibers, once dried, were ground into powder using three separate mills (BR1, BR2, and HP) to vary the particle size and examine the impact of the grinding process on the properties of the adobe bricks. The mineral constituents were then crushed and passed through sieves of 0.315 mm (sand), 0.50 mm (clay), and 2 mm (laterite and limestone). The materials were weighed electronically and then mixed in a mixing tank with water gradually added until a uniform paste was formed. The paste was then molded into metal containers, compacted, and removed from the molds before being air-dried for testing. Characterizing the samples required a mechanical press for compression tests and an asymmetrical hot plate system for measuring thermal conductivity. Additional tools such as calipers, a ruler, buckets, spatulas, trowels, and graduated containers were used for dimensional control and mixture preparation.

Methods: -

Typha preparation: -

In our case study, we weighed 100 kg of Typha for each type of grinding (BR1, BR2, and manual HP). We used four different sieve diameters (25 mm, 15 mm, 10 mm, and 2 mm). It is important to note that we must do everything possible to minimize losses during grinding. Figure 4 shows the Typha transformation process, from sun-drying to grinding (BR1, BR2, and manual HP) to the final product after sieving.

Figure 4:-Product after crushing Typha according to three methods

Adobe formulation: -

Adobe, the Spanish term for mud brick, is a building material made of earth bricks mixed with water, soil (or clay), silt, and sand in specific proportions. Table 1 shows the quantities of the materials (%) with the variation in the percentage of cattail (Typha). Mixtures A01, A02, A03, and A04 incorporate 0.5%, 1%, 1.5%, and 2% cattail fibers, respectively. The proportions of limestone (18%), sand (25%), laterite (25%), and water (18%) remain unchanged in all formulations. However, the clay content (14% to 12%), the binding agent ensuring cohesion, gradually decreases to compensate for the increase in cattail fibers, guaranteeing a total composition of 100%.

Table 1:-Quantity of materials (%) with variation of Typha

Formulation	Limestone (%)	Sand (%)	Laterite (%)	Typha (%)	Clay (%)	Water (%)
A00 (0%)	18	25	25	0	14	18
A01 (0.5%)	18	25	25	0.5	13.5	18
A02 (1%)	18	25	25	1	13	18
A03 (1.5%)	18	25	25	1.5	12.5	18
A04 (2%)	18	25	25	2	12	18

Figure 5 shows adobe bricks made from typha.

Figure 5:-Typha-based adobe bricks

Natural water content: -

The water content of a soil allows us to determine the amount of water present in the natural soil sample. The natural water content of a soil sample is determined by drying a quantity of soil at 105°C in an oven. This process involves calculating the ratio between the mass of water that evaporates and the mass of the dried soil. The water content of each sample was measured using the oven drying method, in accordance with the experimental standard. This involves determining the mass of water removed by drying in an oven at a temperature of 105°C.

The determination of natural water content is based on the formula[8]below:

$$\boldsymbol{W}(\%) = \frac{\boldsymbol{M_1 - M_2}}{\boldsymbol{M_2}}\ \mathbf{100} \qquad \textbf{(1)}$$

$M_1 - M_2$: Body of water (Mw)

M_1: The mass of water in the soil (sample);

M_2: The mass of solid particles of the soil (sample) after being placed in an oven at 105°C for 24 hours.

Figure 6 shows the quantity of wet soil before the study, designated by M1.

Figure 6:-Measurement of the wet mass of soil material samples before oven drying

Density: -

Apparent density is the mass of the body per unit volume. The mass of the body is determined by weighing it using a balance accurate to 0.01 g. Density is calculated using the following expression:

$$\rho = \frac{m}{V} \quad (2)$$

m: Mass of the sample in kg;

V: Sample volume in m3.

Specimen packaging: -

Mechanical characterization: -

Using a 2000 kN press following a standard protocol (see Figure 7), mechanical tests were conducted. Samples were positioned and aligned on the machine platform using 10 cm square adobe bricks. Compressive strength measures a material's ability to withstand a vertical load without excessive deformation in the longitudinal and transverse directions. The 28-day compressive strength of the samples was determined[9]. Compressive strength is obtained by calculating the ratio between the maximum force exerted on the cross-section of the resulting brick. The tests were carried out at the mechanical laboratory of the UFR/SI of UIDT Thiès.

Figure 7:-Mechanical press

Thermal characterization: -

The determination of the thermophysical parameters of a material can be carried out using several techniques, including thetransient hot plate method[10].The hot plate method is an adaptation of the hot wire method to a planar geometry. The principle involves using a simple, thin electrical resistor. A thermocouple consisting of two wires, each 0.03 mm in diameter, is attached to the surface of the probe approximately at its center. This probe is inserted between the sample of material to be characterized (bricks measuring 10 x 10 x 1.7 cm³) and a polystyrene block of the same cross-section and 4 cm thickness. Contact between all the elements is ensured by a clamp, which must be properly tightened after the various elements are stacked.Figure 8 is a photo of the ESP-UCAD measuring device used.

Figure 8:-Conductivity measuring device

Results and discussion:-

Typha particle size:-

The results of the three grinding methods obtained are presented in Table 2 below.

Table 2:-Typha particle size analysis results

		Typha particle size		
		HP manual		
Sieve (mm)	**Refusal (g)**	**Cumulative refusals (g)**	**Cumulative Refusals %**	**% passers-by**
25	7800	7800	78	22
15	620	8420	84.2	15.8
10	100	8520	85.2	14.8
2	60	8580	85.8	14.2
Sieve bottom	60	8640	86.4	13.6
		Loss = 13.6		
		BR2		
25	6240	6240	62.4	37.6
15	1100	7340	73.4	26.6
10	520	7860	78.6	21.4
2	1040	8900	89	11
Sieve bottom	440	9340	93.4	6.6
		Loss = 6.6		
		BR1		
25	5420	5420	54.2	45.8
15	1240	6660	66.6	33.4
10	620	7280	72.8	27.2
2	1020	8300	83	17
Sieve bottom	780	9080	90.8	9.2
		Loss = 9.2		

To continue our study, we will rely on the results from the BR2 crusher. Particle size analysis of the cattails revealed various fiber size classes. For adobe production, the selected fraction is between 2 and 10 mm. This selection is explained by the optimal balance achieved in terms of cohesion, homogeneity, and workability with this size range. Beyond 10 mm, while fibers improve tensile strength, they cause bulking problems: poor dispersion in the soil substrate and difficult compaction. On the other hand, fibers shorter than 2 mm, considered fine, provide only minimal mechanical reinforcement. They tend to increase the specific surface area of the mixture, which leads to higher water consumption and can negatively impact mechanical performance. Therefore, a fiber length between 2 and 10 mm seems ideal to promote good fiber-matrix adhesion, enhance resistance to cracking and obtain a more homogeneous final material.

Figure 9 shows the particle size distribution curve of the typha obtained by the crushers (BR1, BR2, HP). BR2 will be used in our subsequent research.

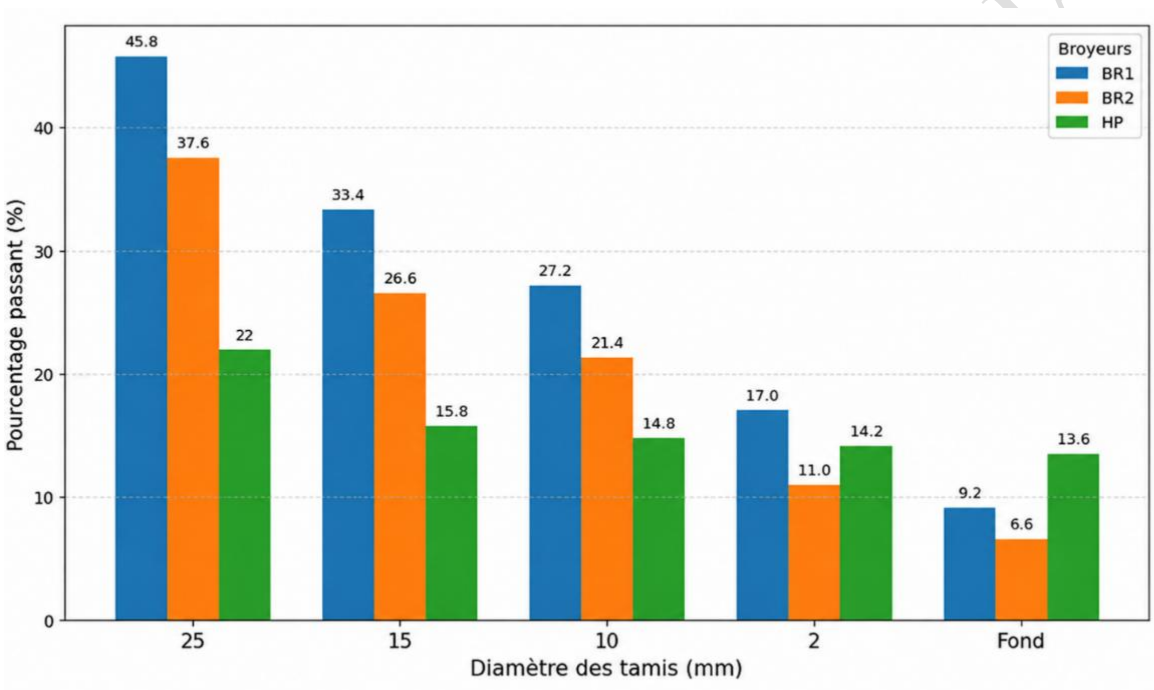

Figure 9:-Typha grain size histogram

Water content:-

The results of the natural water content of the materials are presented in Figure 10.

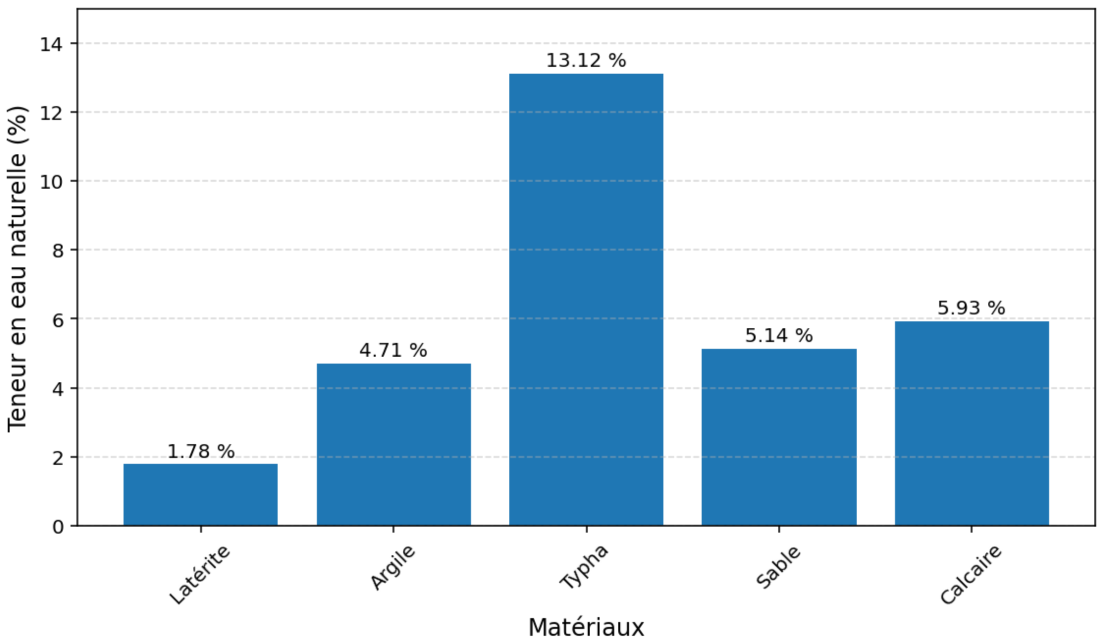

Figure 10:-Histogram of natural water content of materials

The study of the intrinsic moisture content of the materials reveals significant disparities due to their intrinsic characteristics, internal structure, and water retention capacity. The results range from 1.78% to 13.12%, highlighting a divergent water absorption rate between the mineral components and the plant material. Laterite, at 1.78%, has the lowest content, attributable to its compactness and the low presence of fine water-retaining particles. Clay, on the other hand, shows a higher moisture content (4.71%) due to its clay minerals with a large specific surface area, which are conducive to water absorption and retention. Typha stands out with the highest rate (13.12%), a consequence of its fibrous and alveolar structure. Its lignocellulosic cell channels facilitate substantial water storage, indicating marked hygroscopy. Sand and limestone exhibit average moisture contents (5.14% and 5.93%, respectively), primarily due to their porosity and the possible presence of micropores that retain water to a moderate degree. In summary, the data show that the water absorption potential of plant-based materials far surpasses that of mineral materials. The high intrinsic water content of Typha therefore necessitates rigorous management during composite manufacturing to control the water-to-dry-matter ratio, density, and mechanical and hygrothermal properties. Consequently, pre-drying the fibers or adjusting the amount of added water appears essential to ensure greater uniformity and optimize the performance of the resulting materials.

Compression resistance:-

The results of the mechanical characterization of all adobe formulations are recorded in Table 2 below.

Table 2:-Results of the mechanical characterization of all adobe formulations

Formulation	Typha (%)	Test 1 (N)	Test 2 (N)	Test 3 (N)	Average load (N)	Standard deviation (N)	Average resistance (MPa)	Density kg/m3
A00	0.0	29,120	29,180	29,315	29,205	100	2.92	1878.85
A01	0.5	50,980	51,180	51,224	51,128	130	5.11	1825.75
A02	1.0	53,090	53,250	53,368	53,236	140	5.32	1781.50
A03	1.5	54,310	54,460	54,580	54,450	136	5.45	1742.60
A04	2.0	55,540	55,690	55,825	55,685	143	5.57	1705.45

Figure 11 represents the density as a function of the percentage of typha.

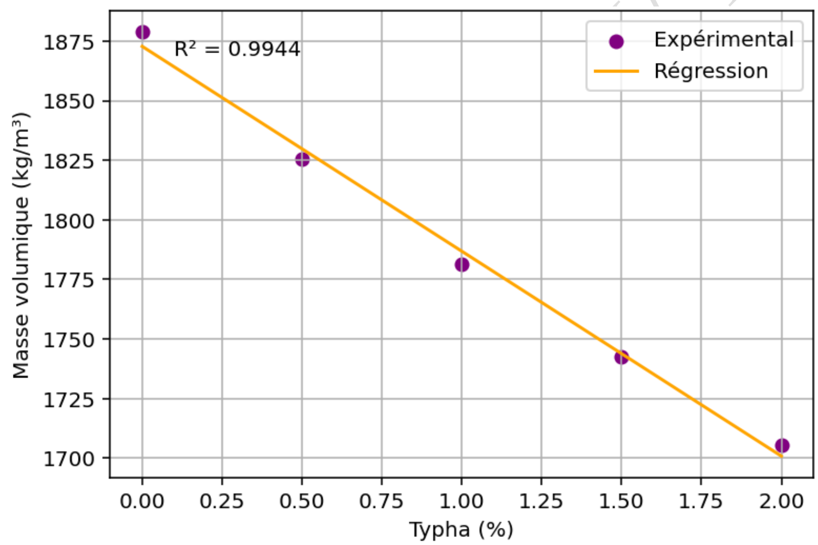

Figure 11:-Density as a function of the percentage of typha

Analysis of the graph reveals a marked inverse linear relationship, where increasing the typhafiber content leads to a significant decrease in density. This correlation, quantified by an R^2 of 0.9944 and $\rho = -86.2T+1872.4$, indicates that the typha content almost entirely explains the observed variation in density. The residuals remain small, with a standard deviation of only 5.63 kg/m³, indicating that the model is capable of accurately representing the experimental behavior. Specifically, the density decreases from 1880 kg/m³ in the absence of typha to 1706 kg/m³ with a 2% incorporation, a reduction of 174 kg/m³. The difference of 145.82 kg/m³ (7.88%) between the theoretical (1851.27 kg/m³) and experimental (1705.45 kg/m³) density of the 2% typha composite suggests that the law of mixtures provides an adequate estimate. However, the measured value, lower than predicted, highlights the influence of the material's actual structure. Contrary to the ideal theoretical model (homogeneous, compact material without voids), the Typha composite exhibits marked porosity due to the plant fibers.

These fibers reduce compactness, promote air voids at the fiber-matrix interfaces, and lead to significant water absorption by the Typha. Particle size analysis revealed that the Keur Mori sand (with a maximum diameter of 0.315 mm) is composed of fine particles. Consequently, there is some adhesion, albeit weak, between the sand and the other constituents, resulting in lower mechanical strength for the bricks produced. Therefore, the addition of limestone (limestone acts as a matrix) with a maximum diameter of 2 mm increases the mechanical resistance of the bricks, not forgetting the clay which acts as reinforcement (clay acts as cohesion and glue between the different particles), which explains the good mechanical resistance obtained.

The gradual addition of cattails provides increased structural lightness, lightening the material in a linear, predictable, and controlled manner, without plateaus or saturation within the studied range. These observations align with the research of Bousshine et al. (2021)[11].Noudeyonou et al. (2023)[12]and Wade et al. (2023)[13]. These studies demonstrate that by incorporating cattail fibers into a clay matrix, porosity increases and the density of the composites gradually decreases. In summary, the use of cattail is a powerful and specific tool for adapting the material's density to its intended use. A dosage of 1% to 1.5% ensures an optimal compromise, combining significant weight reduction with the maintenance of mechanical properties.

Figure 12 shows compressive strength as a function of density.

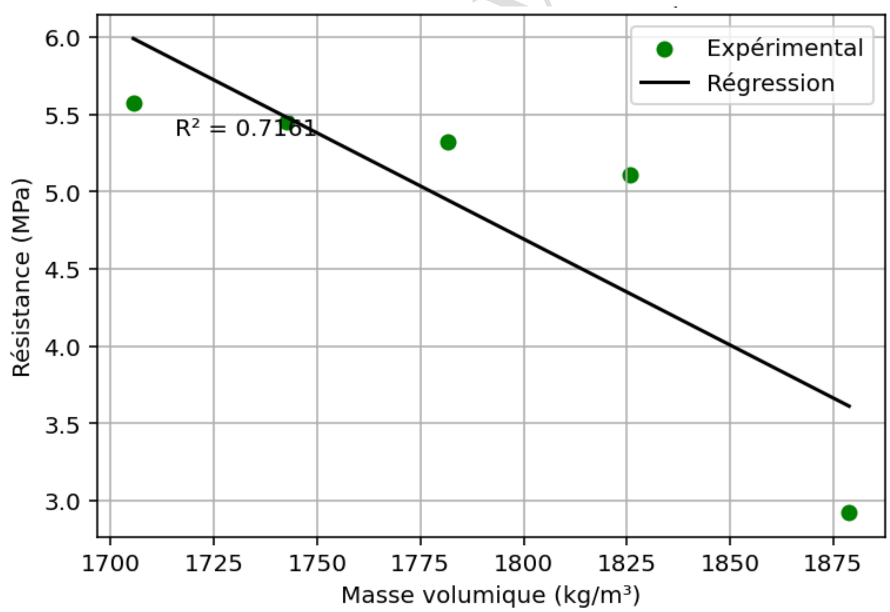

Figure 12:-Compressive strength as a function of density

The data presented illustrate an inverse relationship between the density (kg/m³) and the compressive strength (MPa) of the samples, with values ranging from 1700 to 1880 kg/m³ and from 2.9 to 5.6 MPa. The observed trend, represented by the regression line, suggests that increasing density does not necessarily lead to a systematic improvement in strength. The composite nature of earth-fibers, characterized by their heterogeneity, explains this observation. The density of such materials is affected not only by compactness but also by the quantity and distribution of fibers, as well as by intrinsic porosity. Unlike conventional cementitious binders where density is a good indicator of strength, materials of biological origin exhibit a more complex relationship. Their mechanical performance is primarily determined by the microstructure, the adhesion between fibers and matrix, and the porosity structure, rather than by density alone.The influence of density on the compressive strength of bricks shows no correlation with brick density, justified by a weak correlation of R² = 0.716. This lack of correlation with density was found by Walker[14]. on earthen bricks having the same composition.Research by Danso et al. (2017)[15], Millogo et al. (2014)[16]and Kinuthia (2014)[17]They arrive at a similar conclusion: adding plant fibers to earthenmaterials tends to decreasedensity due to theirlow bulk density and increasedporosity. This reduction contributes to making the material lighter and improving its thermal insulation. However, an excessive concentration of fibers, leading to the formation of voids and breaks in the matrix, causes a progressive decrease in mechanical strength. This research therefore highlights the need to find an ideal balance to optimize lightness, thermal insulation, and mechanical strength. In summary, it appears that bulk density alone is insufficient as a criterion for the mechanical performance of these materials. Optimizing their composition, particularly the fiber content and degree of compaction, is essential to simultaneously increase their density and strength.

Figure 13 shows compressive strength as a function of typha content.

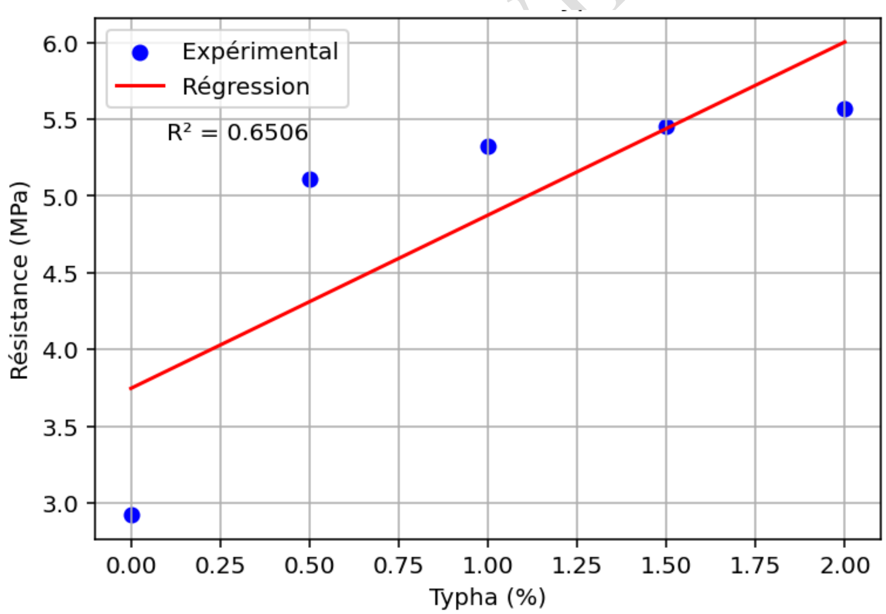

Figure 13:-Compressive strength as a function of typha content.

Adding cattail fibers to composite panels significantly improves their compressive strength, as demonstrated by the increase from 2.92 MPa for the reference material to 5.57 MPa for a 2% cattail formulation. These fibers reinforce the matrix, internal cohesion, and restrict microcrack propagation. Linear regression analysis revealed a strong correlation between the proportion of cattail and compressive strength, with a coefficient of determination of R^2 = 0.6506. This moderate positive correlation suggests that 65% of the variability in strength is attributable to the fiber percentage. The deviations observed around the regression line indicate that other variables, such as fiber dispersion quality, compaction level, porosity, fiber-binder adhesion, and production methods, also impact the mechanical performance of the panels.

These observations align with existing data concerning bio-based composites reinforced with plant fibers. Previous research, by authors such as Oti and Kinuthia (2012)[17]and Millogo et al. (2014)[16]These studies demonstrate that a moderate incorporation of natural fibers confers superior mechanical properties through matrix reinforcement, reduced crack propagation, and improved stress distribution. However, this work also highlights that higher fiber percentages can lead to increased porosity and dispersion problems, thus negating the mechanical improvements achieved.

The study confirms that cattail fibers are an excellent reinforcing agent for bio-based composite panels. Their addition significantly improves compressive strength and utilizes an abundant but problematic local plant, thus promoting sustainable, mechanically efficient, and environmentally friendly construction solutions, particularly suited to tropical areas.

After analyzing and interpreting the results, we can conclude that particle size, material percentage, application conditions, and compaction all influence the mechanical performance of the adobe bricks. It should also be noted that despite technical shortcomings in the design of these bricks, the resulting material is nonetheless very robust from a mechanical standpoint.

Thermal: -

Table 3 shows the effusivity, thermal conductivity and density values of all adobe formulations.

Table 3:-Effusivity and thermal conductivity values of adobes

Formulation	Percentage (%)	Thermal conductivity ()$W.m^{-1}.K^{-1}$	Thermal effusivity ()$W.s^{\frac{-1}{2}}.m^{-1}.K^{-1}$
A00	0%	0.769	915,770
A01	0.5%	0.613	809,012
A02	1%	0.523	769,210
A03	1.5%	0.435	715,687
A04	2%	0.371	652,919

Figure 14 shows the thermal effusivity as a function of the percentage of typha.

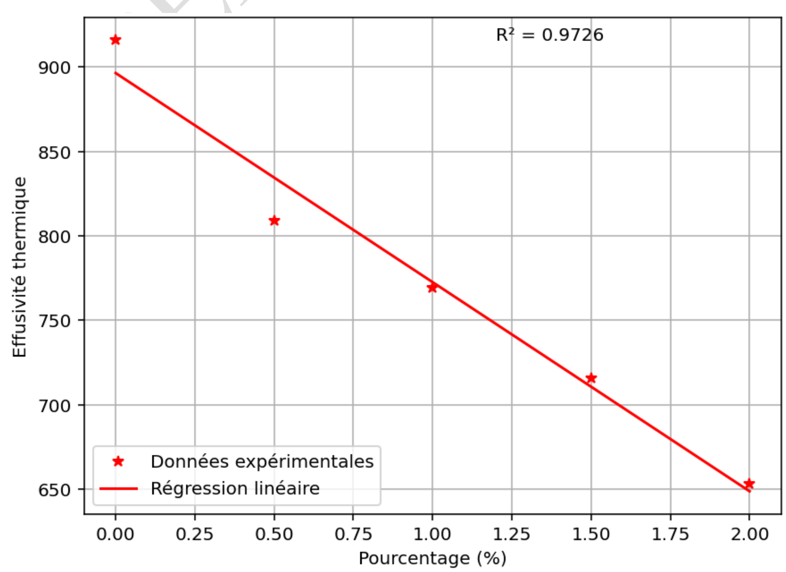

Figure 14:-Thermal effusivity as a function of the percentage of typha

The graphical results demonstrate a strong negative linear correlation between thermal effusivity and the typha content in the composite material. This trend is described by the regression equation $E = -128.4T + 897.2$, with a high coefficient of determination ($R^2 = 0.9726$). The small deviations between the experimental and predicted values (residual standard deviation of 17.6) confirm the reliability of the regression model within the formulation range studied.The incorporation of typha, even at a low dose (2%), leads to a significant decrease in thermal effusivity, from 915 to 652 $Jm^{-2}.K^{-1}.s^{-1/2}$. Thermal effusivity, representing the heat exchange capacity of a material with its environment, is thus reduced by typha due to its low conductivity and density, limiting the rapid absorption and release of heat and enhancing the thermal insulation effect as its proportion increases.Indeed, cattail is an organic material with pores, so adding it increases the material's porosity. Furthermore, the more porous the material, the lower its thermal conductivity and effusivity.In agreement with recent research, Palumbo et al. (2022)[18]observed a near-linear decrease in the thermal effusivity of miscanthus and hemp fiber-based composites as the plant fiber content increased. Similarly, the studies by Cérézo et al. (2023)[19]Studies on hemp-lime concrete confirm that reducing effusivity by adding fibers significantly improves summer comfort by limiting heat transfer through the walls. In summary, the gradual integration of cattail (Typha) represents a promising method for reducing heat transmission in materials and optimizing the thermal comfort of buildings. The optimal dosage is 2% for maximum reduction, while a proportion of 1% to 1.5% ensures a good compromise between improving comfort and preserving the mechanical properties of the matrix.

Figure 15 shows the thermal conductivity as a function of the percentage of typha.

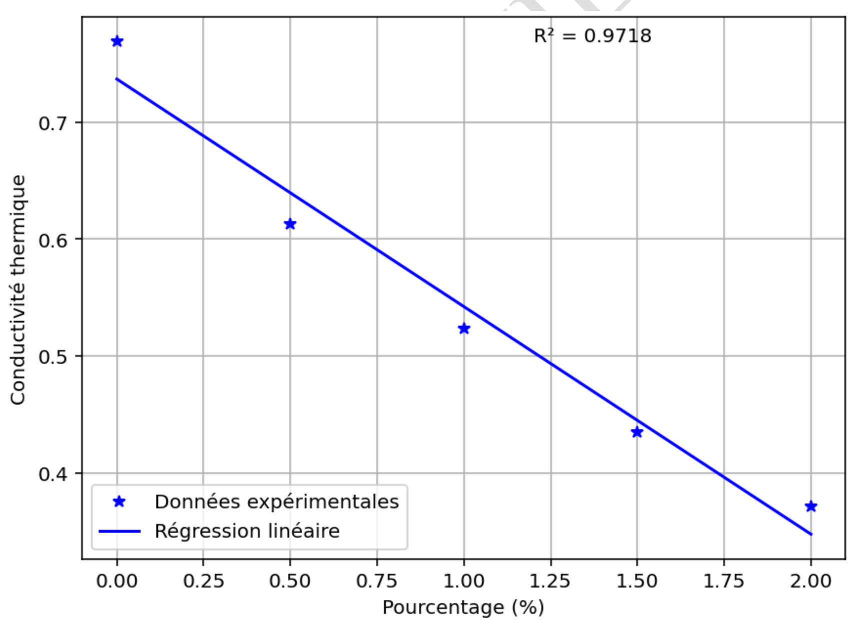

Figure 15: -Thermal conductivity as a function of the percentage of typha

The thermal conductivity of the composite material decreases linearly with increasing percentage of cattail (Typha), as confirmed by an R^2 of 0.9718. A 2% increase in cattail content leads to a decrease in thermal conductivity of 0.395 $Wm^{-1}.K^{-1}$, from 0.770 to 0.375 $Wm^{-1}.K^{-1}$. The intrinsic thermal insulation of cattail fibers, characterized by their porous cellular structure and low density, hinders thermal conduction within the mineral matrix. By creating areas of low conductivity and diverting heat flow, these fibers increase the length of conduction paths, thereby reducing the overall efficiency of heat transfer. The presence of air in the interfibrillar spaces of cattail (thermal conductivity of approximately 0.026 $Wm^{-1}.K^{-1}$) significantly improves the insulation of the composite, an effect that increases with the amount of fiber. It should be noted that adding 0% to 2% cattail results in a proportionally greater decrease in thermal conductivity than decreases in density and effusivity. Consequently, thermal conductivity proves to be the parameter most responsive to the addition of plant fibers in this composite, confirming the effectiveness of cattail in enhancing its insulating properties. These observations corroborate recent studies by Laborel-Préneron et al. (2022)[20]. on earth-plant fiber composites, which have shown that a measured increase in the proportion of natural fibers can reduce the thermal conductivity of building materials by 40 to 60%. (2022)[20].

In summary, incorporating cattail (Typha) is a particularly effective strategy for improving the insulation of composite materials, with a reduction in thermal conductivity of over 50% at just 2% fiber content. These materials thus meet the criteria for moderate thermal insulation in sustainable building standards, making cattail a preferred bio-based additive for developing lightweight, insulating, and environmentally friendly building materials suitable for the hot climates of Senegal and sub-Saharan Africa.

Figure 16 shows thermal conductivity as a function of density.

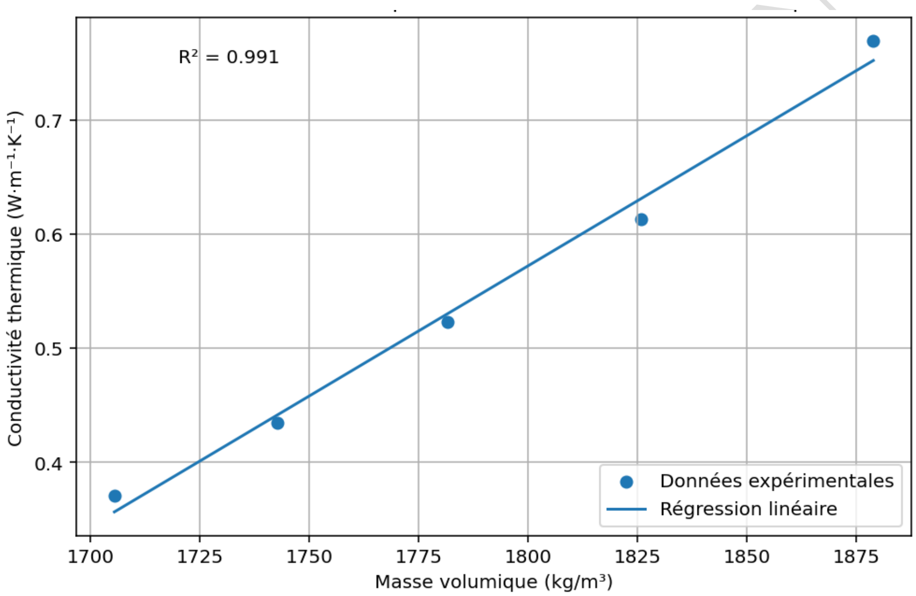

Figure 16:-Thermal conductivity as a function of density.

The relationship between thermal conductivity and density in composite materials is almost perfectly linear and increasing (R^2=0.991). Density, explaining 99.1% of the variation in conductivity, proves to be the most reliable predictor of thermal performance. Experimental values show a proportional increase in conductivity (from 0.375 to 0.770 $Wm^{-1}.K^{-1}$) with density (from 1706 to 1880 kg/m³).

The high density of the matrix, resulting from dense mineralization and low porosity, allows for more direct and efficient heat transfer. Conversely, reduced density, caused by an excess of cattails, generates air-trapping porosity, which lengthens conduction paths and impairs thermal efficiency. These observations, consistent with previous work, confirm the decrease in density and thermal conductivity induced by cattails, highlighting their physical correlation and the function of cattails as a lightweight and insulating element in the composite.Denser materials tend to have higher thermal conductivity, as the particles are more tightly bound and can transmit heat more efficiently.The conclusions of our study align with the observations of Elfordy et al.[21]and Walker and Pavia[14]on the positive correlation between density and thermal conductivity of bio-based composites, as well as with the results of Laborel-Préneron et al. (2022)[20]. These studies identify density as a determining factor in the thermal properties of plant-fiber-based building materials. It is therefore established that density is the most reliable indicator of thermal performance. Controlling the typha content to adjust this density is thus the main technical lever for simultaneously improving the lightness and insulation of bio-based composite panels.

Thermal characterization shows that the overall conductivity of the bricks is low, therefore their thermal resistance is high. These bricks are inert and have low thermal conductivity; thus, their use in a building limits heat transfer and ensures thermal comfort within the building.

Conclusion:-

This study aimed to design and test bio-based adobe bricks enriched with cattail fibers to examine how their addition affects the material's physical, mechanical, and thermal properties. Specifically, the objective was to create five mixtures with cattail content ranging from 0 to 2%, and to measure their density, compressive strength, and thermal conductivity and effusivity, with the goal of identifying the composition that performs best in terms of strength and insulation.

The gradual addition of cattail fibers improves the properties of the bricks. Their density decreases by approximately 9.3%, from 1878.85 to 1705.45 kg/m^3, thus lightening the material. Simultaneously, the compressive strength nearly doubles, increasing from 2.92 to 5.57 MPa, significantly exceeding the 2 MPa threshold for compressed earth bricks. This strengthening is due to the structural effect of the cattail fibers and their strong bond with the earth.

The thermal properties exhibit exceptional performance. Thermal conductivity is reduced by approximately 51%, from 0.769 to 0.371 $W \cdot m^{-1} \cdot K^{-1}$, and thermal effusivity decreases by nearly 29%, from 915.77 to 652.92 $W \cdot s^{-1/2} \cdot m^{-1} \cdot K^{-1}$. These improvements demonstrate that cattail significantly enhances the insulating power of bricks by restricting heat transfer and improving comfort in homes.

This study highlights the remarkable effectiveness of cattail fibers as a natural reinforcement in the manufacture of adobe bricks. They reduce the weight of the material while enhancing its mechanical and thermal properties. Cattail fiber combinations between 1% and 2%, with a marked preference for 1.5%, proved to be the most effective, balancing strength, lightness, and insulation. These findings underscore the significant potential of cattail for creating sustainable and environmentally friendly building materials, well-suited to the Senegalese climate and the tropical regions of sub-Saharan Africa.

In summary, this thermal and mechanical investigation confirms that adobe bricks have considerable advantages in terms of durability, strength and energy efficiency.Looking ahead, to better understand the behavior of these materials and their transfer to concrete applications in the sustainable construction sector, several research directions are possible. The first approach involves optimizing brick formulation by analyzing the effect of various parameters, such as the percentage of Typha incorporation, its particle size, its orientation, and its pretreatment (dried, alkaline-treated, or mineralized). These studies would improve the interaction between the plant fibers and the clay matrix, while controlling the material's intrinsic porosity.A detailed analysis of the hygrothermal characteristics of bricks, including their capacity to absorb and release water, their vapor permeability, their moisture conductivity, and the interactions between heat and humidity, offers a different perspective. This data is fundamental for predicting wall performance in real-world environments, especially in tropical zones characterized by significant fluctuations in humidity and temperature.

Bibliographical references:-

[1] "5th report"IPCC Assessment Report on Climate Change and its Future Developments - European Transition Observatory. Accessed: 4 July 2026. [Online]. Available at: https://transition-europe.eu/publication/5eme-rapport-devaluation-du-giec-sur-les-changements-climatiques-et-leurs-evolutions/

[2] " THE"Buildings, a sector at the forefront of France's 2050 carbon neutrality goals." Accessed: June 29, 2026. [Online]. Available at: https://www.carbone4.com/article-batiment-snbc?utm_source=chatgpt.com

[3] P.Meukam, Y. Jannot, A. Noumowe, and TC Kofane, “Thermo physical characteristics of economical building materials”, Constr. Build. Mater., vol. 18, no. 6, p. 437-443, July. 2004, doi: 10.1016/j.conbuildmat.2004.03.010.

[4] Y.Millogo, J.-C. Morel, J.-E. Aubert, and K. Ghavami, “Experimental analysis of Pressed Adobe Blocks reinforced with Hibiscus cannabinus fibers”, Constr. Build. Mater., vol. 52, p. 71-78, Feb. 2014, doi: 10.1016/j.conbuildmat.2013.10.094.

[5] H. Bal, Y.Jannot, N. Quenette, A. Chenu, and S. Gaye, “Water content dependence of the porosity, density and thermal capacity of laterite based bricks with millet waste additive”, Constr. Build. Mater., vol. 31, p. 144-150, June 2012, doi: 10.1016/j.conbuildmat.2011.12.063.

[6] « (PDF) Explanatory note of the cardGeological map of Senegal at 1:500,000, Northwest, Northeast and Southwest sheets, ResearchGate. Accessed: July 1, 2026. [Online]. Available from: https://www.researchgate.net/publication/273863054_Notice_explicative_de_la_carte_geologique_du_Senegal_a_1500000_feuilles_nord-ouest_nord-est_et_sud-ouest

[7] PS Faye, A. Dione, I.Ndoye, S. Pene, F. Samb, and IK Cissé, “Contribution to the Geotechnical Mapping of Lateritic Gravels in Western Senegal for Road Construction in Senegal, West Africa”, Am. J. Civ. Eng. Archit., vol. 14, no. 1, p. 1-10, Jan. 2026, doi: 10.12691/ajcea-14-1-1.

[8] BTTouolak, FT Nya, EN Haulin, E. Yanne, and JM Ndjaka, “Compressed Bricks Made of Makabaye and Pitoaré Clay: Implementation and Production”, Adv. Mater. Phys. Chem., vol. 05, no. 06, p. 191-204, 2015, doi: 10.4236/ampc.2015.56020.

[9] Mr. Fall, D.Sarr, EM Cissé, and D. Konaté, “Physico-Mechanical Characterization of Clay and Laterite Bricks Stabilized or Not with Cement,” Open J. Civ. Eng., vol. 11, no. 01, p. 60-69, 2021, doi: 10.4236/ojce.2021.111004.

[10] “Thermal Properties of a Sample Prepared Using Mixtures of Clay Bricks”,*Energy Procedia*, vol. 42, p. 337-346, Jan. 2013, doi: 10.1016/j.egypro.2013.11.034.

[11] H.Limami, I. Manssouri, K. Cherkaoui, and A. Khaldoun, “Mechanical and physicochemical performances of reinforced unfired clay bricks with recycled Typha-fibers waste as a construction material additive,” Clean. Eng. Technol., vol. 2, p. 100037, June 2021, doi: 10.1016/j.clet.2020.100037.

[12] J.Noudeyonou, E. Allognon-Houessou, H. Hounkpatin, and B. Kounouhewa, “Study of the Physical Properties of a Clay-Typha Composite Agro-Material,” Int. J. Sustain. Green Energy, Jan. 2023, doi: 10.11648/j.ijrse.20231201.11.

[13] "Mechanical characterization of a compressed earth block, stabilized with cement and reinforced with cattail fibers. Accessed: July 1, 2026. [Online]. Available at: https://pubs.sciepub.com/ajcea/11/3/4/index.html?utm_source=chatgpt.com

[14] Walker and Pavia, “The influence of constituents on the properties of the bio-aggregate composite hemp-lime”,*Construction. Build. Matter.*, vol. 159, p. 9-17, Jan. 2018, doi: 10.1016/j.conbuildmat.2017.10.109.

[15] H.Danso, B. Martinson, M. Ali, and J. Williams, “Mechanisms by which the inclusion of natural fibers enhance the properties of soil blocks for construction,” J. Compos. Mater., vol. 51, no. 27, p. 3835-3845, Nov. 2017, doi: 10.1177/0021998317693293.

[16] Y.Millogo, J.-C. Morel, JE Aubert, and K. Ghavami, “Experimental analysis of Pressed Adobe Blocks reinforced with Hibiscus cannabinus fibers,” Constr. Build. Mater., vol. 52, p. 71-78, Feb. 2014, doi: 10.1016/j.conbuildmat.2013.10.094.

[17] “The durability of compressed earth-based masonry blocks - University of South Wales”.Accessed: 1 July 2026. [Online]. Available from: https://pure.southwales.ac.uk/en/publications/the-durability-of-compressed-earth-based-masonry-blocks/?utm_source=chatgpt.com

[18] Mr. Palumbo, AMLacasta, N. Holcroft, A. Shea, and P. Walker, “Determination of hygrothermal parameters of experimental and commercial bio-based insulation materials,” Constr. Build. Mater., vol. 124, p. 269-275, Oct. 2016, doi: 10.1016/j.conbuildmat.2016.07.106.

[19] C.Véronique, "Mechanical, thermal and acoustic properties of a plant-based particle material: experimental approach and theoretical modeling," Doctoral thesis, École Nationale des Travaux Publics de l'État, France, Lyon, 2005. [Online]. Available at: https://www.researchgate.net/profile/Veronique-Cerezo/publication/37813495

[20] H.Ratsimbazafy, A. Laborel-Préneron, C. Magniont, and P. Evon, “Comprehensive Characterization of Agricultural By-Products for Bio-Aggregate Based Concrete,” Constr. Technol. Archit., vol. 1, p. 77-84, Jan. 2022, doi: 10.4028/www.scientific.net/CTA.1.77.

[21] S.Elfordy, F. Lucas, F. Tancret, and L. Goudet, “Mechanical and thermal properties of lime and hemp concrete (“hempcrete”) manufactured by a projection process”, Constr. Build. Mater., vol. 22, no. 10, p. 2116-2123, Oct. 2008, doi: 10.1016/j.conbuildmat.2007.07.016.