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RESEARCH ARTICLE

THERMOMECHANICAL CHARACTERIZATION OF MATERIAL MIXTURES BASED ON CLAY, 0/5 LATERITE, AND RED WOOD CHIPS FOR SUSTAINABLE CONSTRUCTION

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Abstract

In Senegal, locally available materials such as clay, laterite, and red wood chips offer promising opportunities for the development of sustainable and affordable building materials. This study investigates composites made from Sébikotane clay, Mont-Rolland laterite, and red wood chips, with red wood chip contents ranging from 0% to 10%. The results showed that compressive strength ranged from 0.610 MPa to 0.853 MPa, reaching a maximum value of 1.310 MPa at 2% red wood chips. Thermal conductivity decreased significantly from 0.77 $W \cdot m^{-1} \cdot K^{-1}$ to 0.24 $W \cdot m^{-1} \cdot K^{-1}$ with increasing red wood chip content, resulting in improved thermal resistance and enhanced indoor comfort. These composites exhibit mechanical properties suitable for non-load-bearing wall applications while providing effective thermal insulation. Overall, they promote the use of local resources and contribute to the development of sustainable and low-cost housing.

Introduction:-

The search for new construction materials derived from local resources, as well as the valorization of waste materials, is part of a sustainable development approach. In Senegal, concrete remains the most widely used material; however, the cost of its components has risen sharply. Between April 2022 and April 2023, the prices of certain materials rose significantly: Class 32.5 R cement increased by 7.2%, while gravel and dune sand saw increases of 2.7% and 3%, respectively [1]. This situation, combined with the increasing scarcity of resources, reinforces the need to turn to local and cost-effective alternatives. Earth-based materials, such as laterite and clay, which are available at low cost, offer a viable alternative for sustainable and affordable construction. Furthermore, with the rise in temperatures projected for Senegal (up to 4.9°C by 2090 [2]), these materials possess good thermal regulation properties, thereby helping to improve building comfort. This study aims to investigate the potential of local materialssuch as clay, laterite, and red wood chips through athermomechanical study of their mixtures. Clay is used as a binder, while laterite and red wood chips serve as reinforcing materials. Identification tests were conducted

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on the raw materials, followed by mechanical and thermal testson the various composites obtained. Optimizing clay-laterite-red wood chip mixtures appears to be a promising solution for developing sustainable building materials, reducing construction costs, and limiting environmental impacts. The goal is therefore to design high-performance composites that can be used in the construction industry.

Materials and Methods:-

The clay and laterite used for sample preparation were collected in Sébikotane, approximately 40 km east of Dakar, and in Mont-Rolland, located in the Pambal district (Tivaouane department), approximately 15 km northwest of Thiès. The red wood shavings were obtained from a local carpentry shop and underwent no pretreatment before being added to the mixtures.

The samples were subjected tothe following tests:-

- ✓ Particle size analysis by sieving and sedimentation [3-4]
- ✓ Atterberg limits: liquid limit and plastic limit [5-7]
- ✓ Specific gravity [8-9]
- ✓ Determination of compressive strength using a hydraulic press [10-12]
- ✓ Determination of thermal conductivity using the asymmetric hot-wire method [13-14]

Results and Discussion:-

Identification of Sébikotane Clay:-

The particle size analysis of the Sébikotane clay, conducted by sieving and sedimentation, showed the following: 7.57% gravel, 18.43% coarse sand, 32% fine sand, 17% silt, 25% clay, and more than 60% of the total grain mass passes through an 80 µm sieve.

Determination of the Atterberg limits for our Sébikotane clay sample yielded the following values:-

- Liquidity limit WL = 55%
- Plasticity limit WP = 23%
- Plasticity index IP = 32%

A plasticity index between 25% and 40% indicates the clayey nature of the soil under study [15].

Composition of mixtures:-

The mixtures were prepared using percentages of redwood chips ranging from 0% to 10% (Table 1)

Table 1: Percentage of components in each mixture

Red wood chips (%)	Laterite (%)	Clay (%)
0	40	60
2	40	58
4	40	56
6	40	54
8	40	52
10	40	50

Figure 1 shows the dry mixtures consisting of 1-mm-sieve-sized clay, 0/5-grade laterite, and red wood chips that pass through a 5-mm sieve.

Figure 1: Dry mixing of the various components

Preparation of Test Specimens [16]:-

- ✓ A dry mixture is first prepared by combining the clay soil and laterite to ensure a homogeneous distribution of the granular components.
- ✓ The red wood chips are then incorporated into the dry soil–laterite mixture to ensure their uniform distribution within the solid matrix.
- ✓ Water is added gradually to control the material's moisture content.
- ✓ The mixture is then continuously mixed until a homogeneous paste of normal consistency is obtained, suitable for molding.
- ✓ Test specimens are prepared in 11 × 22 cm cylindrical molds for mechanical testing, and in the form of 10 × 10 × 3 cm plates for thermal testing, thereby ensuring standardized geometry.
- ✓ Compaction is performed using a standardized impact table, allowing for uniform placement of the material and a reduction in internal voids. The molds are filled in two successive layers, each subjected to a defined number of impacts to ensure uniform density and eliminate air bubbles trapped in the matrix (see Figure 2)

Figure 2: Test specimens of the various mixtures studied

Mechanical Results:-

The variation in compressive strength at 28 days as a function of the percentage of red wood chips in the mixture is shown in Figure 3. The results show that at 0% red wood chips, the compressive strength is 0.61 MPa. It increases with the amount of red wood chips, reaching a maximum value of 1.310 MPa at 2% red wood chips. Between 4% and 6% red wood chips, the compressive strength decreases gradually but remains higher than that obtained at 0% red wood chips, with respective values of 1.133 MPa and 1.132 MPa. Above 6% red wood chips, we observe a drop in strength, with values of 0.858 MPa and 0.853 MPa at 8% and 10% red wood chips, respectively

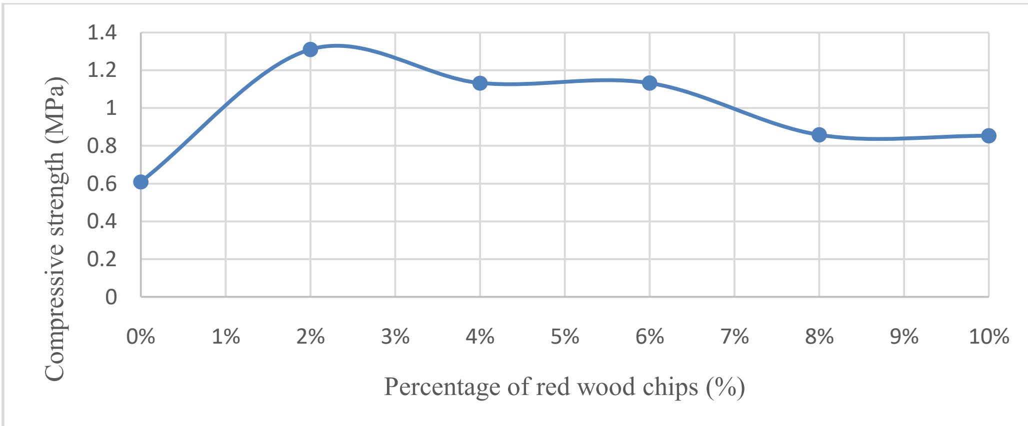

Figure 3: Variation in compressive strength.

In these composites, clay acts as a binder, while 0/5 laterite and red wood chips serve as reinforcing agents. When the amount of binder is sufficient to ensure proper bonding and adhesion of all the reinforcing particles, the mixture achieves good cohesion. We then observe an improvement in compressive strength with the addition of 2, 4, 6, 8, and 10% red wood chips, since all the values obtained are higher than that of the control sample (0% wood chips). Furthermore, as the amount of red wood chips in the mixture increases, the clay has greater difficulty ensuring proper bonding between the particles, which leads to the embrittlement of the composites and consequently a decrease in strength. This explains the decrease in strength observed beyond 2% red wood chips.

Thermal Results:-

The thermal conductivity tests conducted on mixtures of clay,laterite, and redwood chips using test specimens measuring 10×10×3 cm yielded the results shown in (Figure 4)

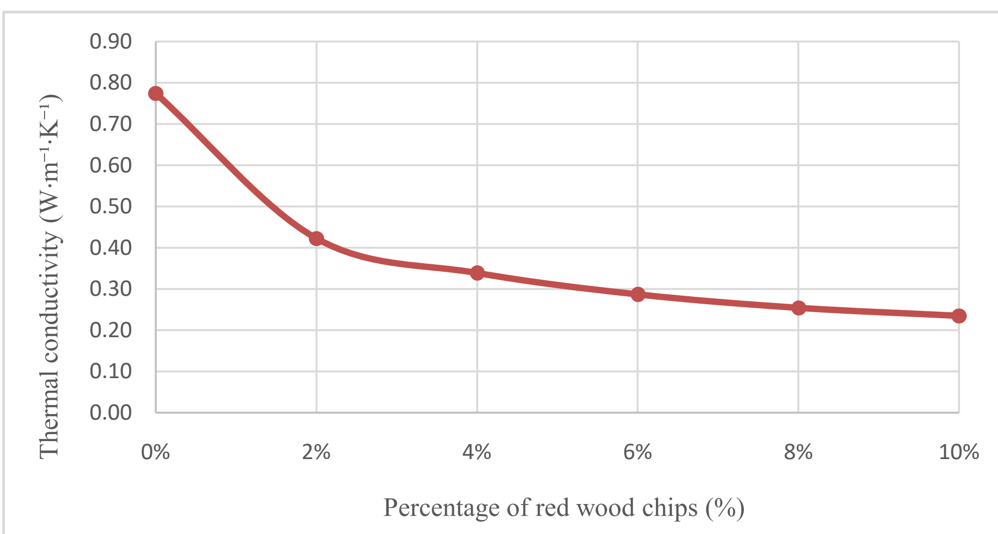

Figure 4: Variation in thermal conductivity.

Figure 4 shows that thermal conductivity decreases as the percentage of red wood chips increases. This decrease is due to the fact that red wood chips have lower thermal conductivity than the mixture of 1-mm-sieve-passed clay and 0/5-grade laterite, which improves the material's insulating properties. Figure 5 shows the variation in thermal resistance for a 20 cm wall.

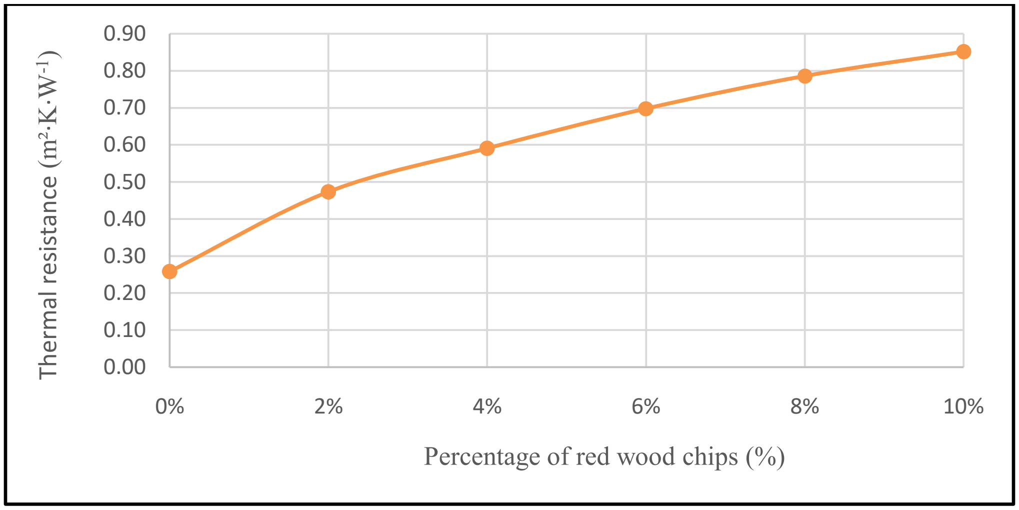

Figure 5: Changes in thermal resistance.

Thermomechanical results [17–21]:-

According to Figure 6, the optimal mixture consists of 6% red wood chips (passing through a 5 mm sieve), 40% laterite (0/5 grain size class), and 54% clay (passing through a 1 mm sieve). These results confirm that the incorporation of red wood chips is an effective approach for improving the thermomechanical properties of clay–laterite composites. Although the maximum compressive strength is obtained at 2% red wood chips, the mixture containing 6% red wood chips was selected as the optimal formulation due to its best balance between mechanical and thermal performance. At this content, the compressive strength remains sufficient for non-load-bearing wall applications, while the thermal resistance is significantly enhanced.

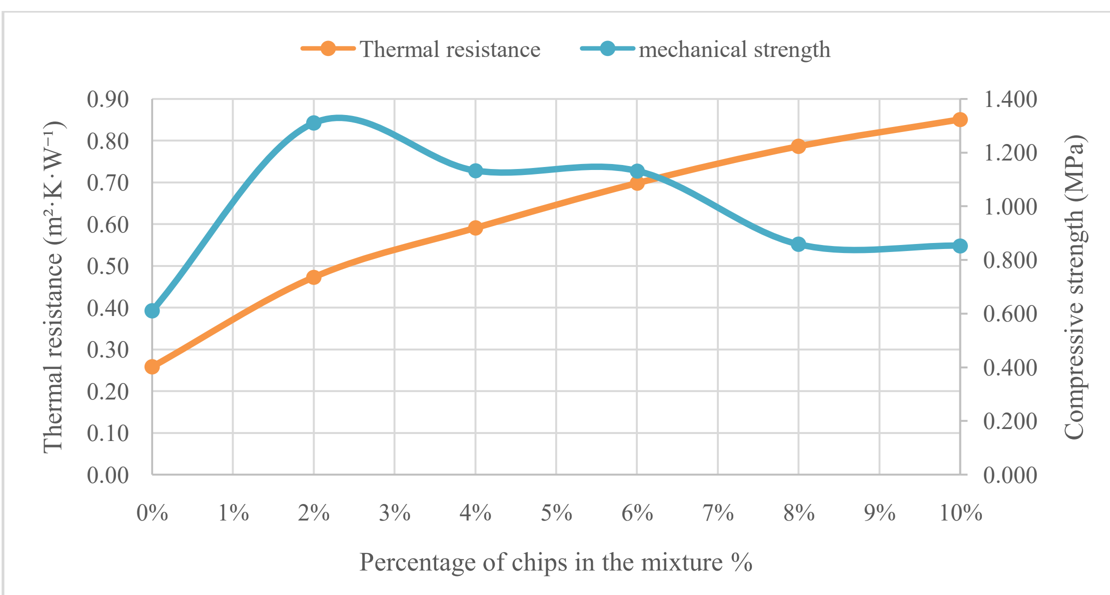

Figure 6: Effect of redwood chip content on the thermomechanical performance of a 20-cm-thick wall.

Analysis of the dry density of these composites yielded an average value of 1616 kg/m³ for formulations containing 6% red wood chips. The mechanical strengths required (Table 2) for the use of these composites in the construction of 3-meter-high infill walls (non-load-bearing walls) were determined using the equation (1). The required strength corresponds to the minimum capacity a brick must have to support the loads exerted by the masonry elements located above it (Figure 7).

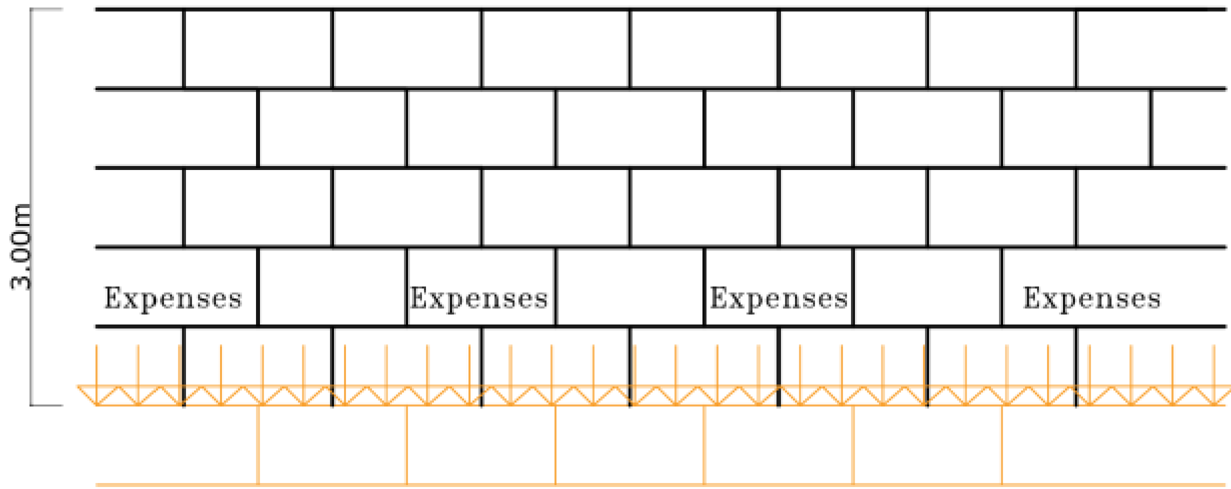

Figure 7: Schematic representation of the loads

Table 2: Required resistance

Red wood chip content (%)	6%
Required strength in MPa, with a 10% safety factor	0.052

Required resistance = $\rho \times g \times H$ (1)
Where:
ρ = dry density of the composite in (kg/m³)
g = acceleration due to gravity in (m/s²)
H = height of the wall above (m)

The compressive strength required for the use of composites containing 6% red wood chips as non-load-bearing walls is estimated at 0.052 MPa. The measured compressive strength (1.132 MPa) is approximately 21 times higher than the required value. From a mechanical point of view, these results indicate that the developed composites are more than sufficient for use as infill wall materials. From a thermal point of view, the thermal resistance of two configurations (laterite–clay–6% red wood chips and cement mortar) was evaluated for a 20-cm-thick wall, and the results are presented in Table 3. These values are compared with those obtained for a cement-based wall (approximately 0.16 $m^2 \cdot K \cdot W^{-1}$) and for a composite wall made of a mixture of laterite (40%), clay (54%), red wood chips (6%), and cement.

Table 3: Thermal resistance of various composites

	Laterite-Clay-6% Red Wood Chips (LAC6)	Cement Mortar (CM)
Thermal Resistance in $m^2 \cdot K \cdot W^{-1}$	0.70	0.16

Conclusion:-

In conclusion, this study identified an optimal formulation consisting of 40% laterite, 54% clay, and 6% red wood chips. The resulting composite exhibited a compressive strength of 1.132 MPa and a thermal resistance of 0.70 $m^2 \cdot K \cdot W^{-1}$, demonstrating a suitable balance between mechanical and thermal performance. The compressive strength obtained was approximately 21 times higher than the minimum requirements for earthen construction materials, confirming the potential of this composite for building applications. Furthermore, the incorporation of 6% red wood chips significantly improved its thermal insulation performance. These findings highlight the potential of this locally sourced composite as a sustainable construction material with reduced environmental impact, particularly suitable for hot climatic regions.

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