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6 **THERMOMECHANICAL CHARACTERIZATION OF MATERIAL MIXTURES**
7 **BASED ON CLAY, 0/5 LATERITE, AND RED WOOD CHIPS FOR**
8 **SUSTAINABLE CONSTRUCTION.**
9

10 **Abstract:**

11 In Senegal, the availability and low cost of local materials, such as clay, laterite, and wood chips, present a real
12 opportunity for the production of sustainable building materials. In this context, their use is particularly relevant for
13 the construction of suitable social housing.

14 With this in mind, this study focuses on mixtures of Sebikotane clay, Mont-Rolland laterite, and red wood chips. To
15 this end, thermomechanical tests were conducted on various mixtures composed of a variable proportion of clay,
16 40% laterite, and wood chips, with the latter incorporated at levels ranging from 0% to 10%.

17 These analyses show that the compressive strengths obtained are significantly higher than those required for infill
18 walls constructed with these mixtures. Furthermore, the thermal resistances obtained improve the thermal comfort of
19 the dwelling.

20 In conclusion, these results demonstrate that incorporating clay, laterite, and red wood chips into building materials
21 significantly reduces the costs of social housing while optimizing the thermomechanical performance of buildings.
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24 **Keywords:**

25 Clay, thermomechanical, characterization, sustainable construction, red wood chips, laterite, materials, mixtures.
26

27 **Introduction:**

28 The search for new construction materials derived from local resources, as well as waste recovery, are part of a
29 sustainable development approach. In Senegal, concrete remains the most widely used material, but the cost of its
30 components has risen sharply. Between April 2022 and April 2023, the prices of certain materials rose significantly:
31 Class 32.5 R cement increased by 7.2%, while gravel and dune sand saw increases of 2.7% and 3%, respectively [1].
32 This situation, combined with the increasing scarcity of resources, reinforces the need to turn to local and cost-effective
33 alternatives. Earth-based materials, such as laterite and clay, which are available at low cost, offer a viable alternative
34 for sustainable and affordable construction. Furthermore, with the rise in temperatures projected for Senegal (up to
35 4.9°C by 2090 [2]), these materials possess good thermal regulation properties, thereby helping to improve building
36 comfort.
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38 This article aims to highlight the potential of local materials such as clay, laterite, and wood chips through
39 a thermomechanical study of their mixtures. Clay is used as a binder, while laterite and wood chips serve as structural
40 reinforcing materials. Identification tests were conducted on the raw materials, followed by mechanical and thermal tests
41 on the various composites obtained.

42 Optimizing clay-laterite mixtures appears to be a promising solution for developing sustainable building materials,
43 reducing costs, and limiting environmental impact. The goal is thus to design high-performance composites that can be
44 used in the construction industry.

45 **2. Materials and Methods**

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

50 The samples underwent the following tests:

- 51 ✓ Particle size analysis by sieving and sedimentation [3-4]
- 52 ✓ Atterberg limits: liquid limit and plastic limit [5-7]
- 53 ✓ Specific Gravity [8-9]
- 54 ✓ Determination of compressive strength using a hydraulic press [10-12]

55 ✓ Determination of thermal conductivity using the asymmetric hot-wire method [13-14]

56 3. Results and Discussion

57 3.1. Identification of Sebikotane Clay

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

61 Determination of the Atterberg limits for our Sebikotane clay sample yielded the following values:

- 62 • Liquidity limit WL = 55%
- 63 • Plasticity limit WP = 22.72%
- 64 • Plasticity index IP = 32.28%

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

66 3.2. Composition of mixtures

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

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Table 1: Percentage of components in each mixture

chavings (%)	Latérite (%)	Clay (%)
0	40	60
2	40	58
4	40	56
6	40	54
8	40	52
10	40	50

70

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

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Figure 1: Dry mixing of the various components

78 3.3. Preparation of Test Specimens [16]

- 79 ✓ A dry mixture is first prepared by combining the clay soil and laterite to ensure a homogeneous distribution of the
80 granular components.
- 81 ✓ The wood chips are then incorporated into the dry soil–laterite mixture to ensure their uniform distribution within
82 the solid matrix.
- 83 ✓ Water is added gradually to control the material’s moisture content.
- 84 ✓ The mixture is then continuously mixed until a homogeneous paste of normal consistency is obtained, suitable for
85 molding.
- 86 ✓ Test specimens are prepared in 11 x 22 cm cylindrical molds for mechanical testing, and in the form of 10 x 10 x
87 3 cm plates for thermal testing, thereby ensuring standardized geometry.
- 88 ✓ Compaction is performed using a standardized impact table, allowing for uniform placement of the material and a
89 reduction in internal voids. The molds are filled in two successive layers, each subjected to a defined number of
90 impacts to ensure uniform density and eliminate air bubbles trapped in the matrix (see Figure 2)



92
93 **Figure 2: Test specimens of the various mixtures studied**

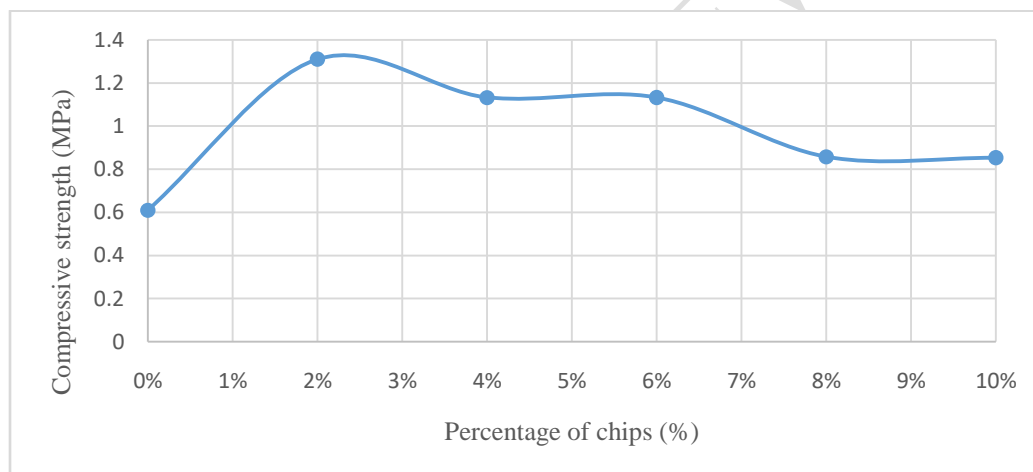
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95 **3.4. Mechanical Results**

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97 The variation in compressive strength at 28 days as a function of the percentage of wood chips in the mixture is shown
98 in Figure 3.

99 The results show that at 0% wood chips, the compressive strength is 0.61 MPa. It increases with the amount of wood
100 chips, reaching a maximum value of 1.310 MPa at 2% wood chips. Between 4% and 6% wood chips, the compressive
101 strength decreases gradually but remains higher than that obtained at 0% wood chips, with respective values of 1.133
102 MPa and 1.132 MPa.

103 Above 6% wood chips, we observe a drop in strength, with values of 0.858 MPa and 0.853 MPa at 8% and 10% wood
104 chips, respectively

105



106
107 **Figure 3: Variation in compressive strength.**

108 In these composites, clay acts as a binder, while 0/5 laterite and wood chips serve as reinforcing agents. When the
109 amount of binder is sufficient to ensure proper bonding and adhesion of all the reinforcing particles, the mixture
110 achieves good cohesion. We then observe an improvement in compressive strength with the addition of 2, 4, 6, 8, and
111 10% wood chips, since all the values obtained are higher than that of the control sample (0% wood chips).

112 Furthermore, as the amount of wood chips in the mixture increases, the clay has greater difficulty ensuring proper
113 bonding between the particles, which leads to the embrittlement of the composites and consequently a decrease in
114 strength. This explains the decrease in strength observed beyond 2% wood chips.

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118 **3.5. Thermal Results**

119 The study of the thermal conductivity of a clay-laterite-wood chip mixture in 10×10×3 cm test specimens yielded the
120 following results (Figure 4)

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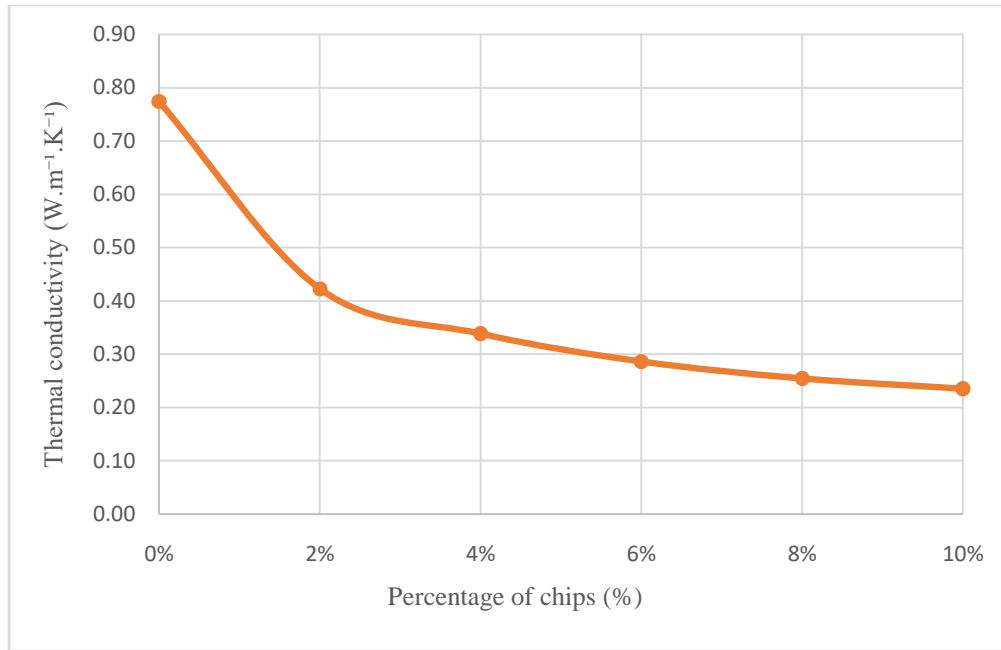


Figure 4: Variation in thermal conductivity.

Figure 4 shows that thermal conductivity decreases as the percentage of wood chips increases. This decrease is due to the fact that 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.

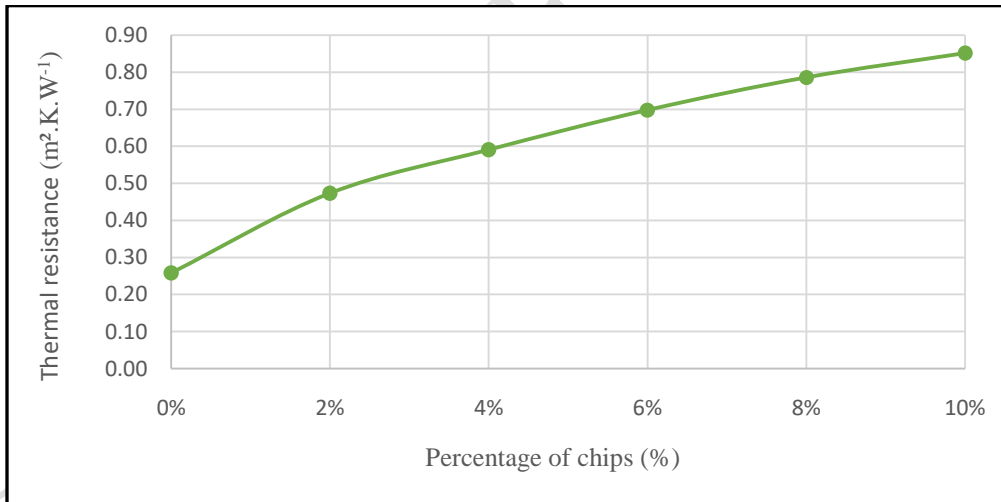
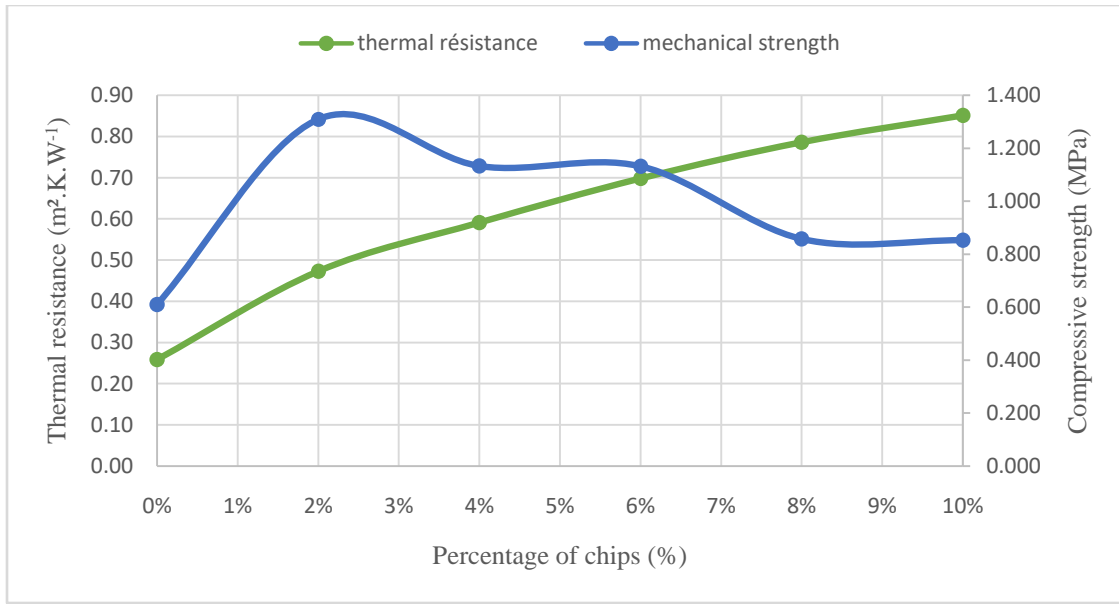


Figure 5: Changes in thermal resistance.

3.6. Thermomechanical results [17–21]

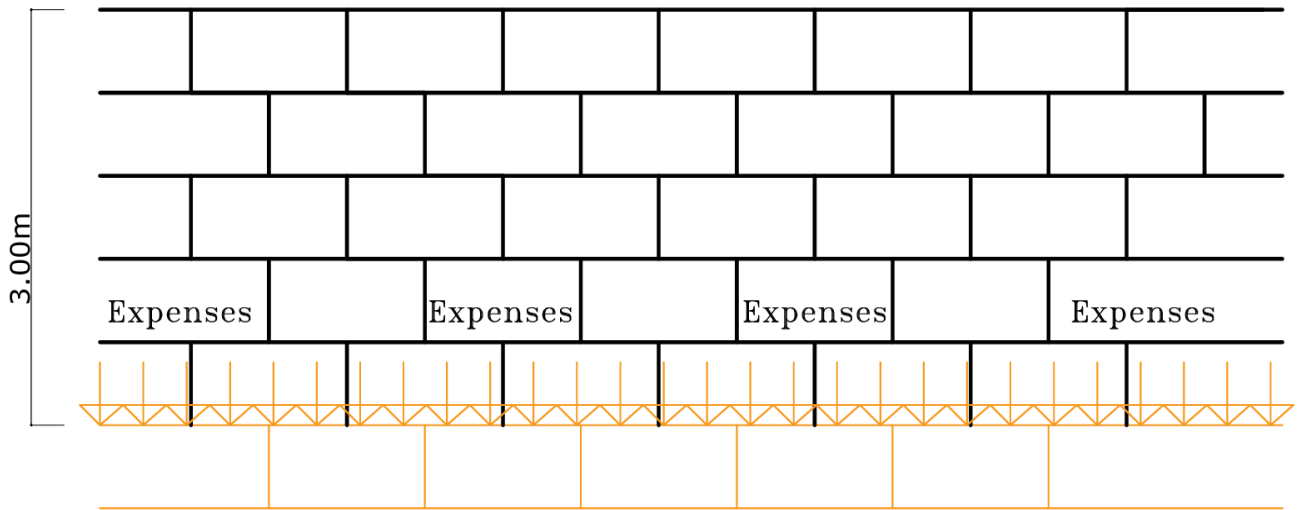
According to Figure 6, we can conclude that the optimal mixture consists of 6% red wood chips (passing through a 5-mm sieve), 40% laterite (0/5 grain size class), and 54% clay (passing through a 1-mm sieve). These results confirm that the addition of wood chips is an effective approach for optimizing the thermomechanical properties of clay-laterite composites.



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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% 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).



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Figure 7: Schematic representation of the loads

Table 2: Required resistance

Chip rate	6%
Required strength in MPa, with a 10% safety factor	0.052

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$$\text{Required resistance} = d \times g \times H \text{ in (MPa)} \quad (1)$$

Where:

159 d = dry density of the composite in kg/m³
 160 g = acceleration due to gravity in m/s²
 161 H = height of the wall above in meters
 162 The compressive strength required for the use of composites containing 6% wood chips as non-load-bearing walls is
 163 estimated at 0.052 MPa. The measured strength (1.132 MPa) is approximately 21 times the required strength. From a
 164 mechanical standpoint, the strengths are more than sufficient for the composites to be used as infill walls.
 165 Thermally, the determination of the thermal resistance of two composites (laterite-clay-6% wood chips and cement
 166 mortar) for a 20 cm thick wall yielded the results presented in Table 3.
 167 These results are compared to those obtained for a cement wall (approximately 0.16 m² .K.W⁻¹) and for a wall made of a
 168 mixture of laterite (40%), clay (54%), wood chips (6%), and cement.
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Table 3: Thermal resistance of various composites

	Laterite-Clay-6% Wood Chips (LAC6)	Cement Mortar (CM)
Thermal Resistance in m ² .K.W ⁻¹	0.70	0.16

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173

$$\phi = \frac{\Delta T}{R_{th}} \quad (2)$$

174

175 Taking into account the various thermal resistances, equation (2) allows us to calculate the heat flux across the walls per
 176 unit area

177 where:

178 ϕ :heat flux in W/m²

179 ΔT :temperature difference between the exterior and interior in kelvins (K)

180 R_{th} :thermal resistance in m².K.W⁻¹

181 For walls located in the same environment, with the same heat flux and the same outdoor temperature, using the
 182 equation, we can compare the temperature difference ΔT of LAC6 composites with that of cement.

183 Equation (3) can be derived from Equation (2):
 184

$$\Delta T(LAC6) = \frac{R_{th}(LAC6)}{R_{th}(C)} \Delta T(C) \quad (3)$$

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186 $\Delta T(LAC6)$: temperature difference – Color of a laterite, clay, and wood chip wall (LAC6 composite)

187 $\Delta T(C)$: temperature difference – Color of a cement wall (C composite)

188 $R_{th}(LAC6)$: thermal resistance of a laterite, clay, and wood chip wall (LAC6 composite)

189 $R_{th}(C)$: thermal resistance of a cement wall (C composite)

190 By applying the equation numerically to all composites, we obtain the following relationships:

$$\Delta T(LAC6) = 4.375 \Delta T(C)$$

193 These results show that the laterite-clay-wood-chip wall reduces indoor temperatures by 4.375 times more than the
 194 cement mortar wall.

195 **4. Conclusion**

196 In conclusion, the study identified an optimal formulation consisting of 40% laterite, 54% clay, and 6% wood chips.
 197 This mixture exhibits a remarkable balance of performance characteristics, with a mechanical strength of 1.132 MPa and
 198 a thermal resistance of 0.70 m².K.W⁻¹.

199 Furthermore, this mechanical strength is approximately 21 times higher than the minimum requirements for use in
 200 construction, thus confirming its suitability for structural applications.

201 Thermally, these composites demonstrate significant insulating performance. Compared to a reference material such as
 202 cement mortar, the composite containing 6% cement achieves a 4.375-fold greater reduction in indoor temperature.

203 These results indicate that composites made from laterite, clay, and wood chips constitute a sustainable, economical, and
 204 energy-efficient building solution, particularly well-suited to hot climates.
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