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Research Article

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Thermomechanical Characterization of Mixtures of Laterite and Wood Chips

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Abstract In Senegal, thermal insulation in buildings, caused by rising temperatures due to global warming, is a major problem that requires relevant responses. In addition to this scourge, add the high cost of construction. Indeed, the price of construction does not increase because of the materials used, notably Portland cement among others. However, to solve these problems, researchers are considering the use of local materials such as laterite in order to reduce the cost of construction but also to mix them with thermal insulators like wood, which will make it possible to improve the thermal properties of the Laterite-wood chip composite.
It is in this sense that our study will be mainly focused on the thermomechanical characterization of mixtures of laterite and wood compounds. This study showed that the best mechanical strengths were obtained at 1% and 2% of chips in the mixture while thermal strengths increased with the quantity of chips.

Keywords Characterization, Thermomechanics, Wood chips, thermal insolation, resistance

1. Introduction

Due to their geographical location, countries like Senegal naturally benefit from a climate that is not lenient in terms of heat almost throughout the year. This situation, combined with global warming, which is becoming more and more noticeable, is leading to a remarkable rise in temperatures in these areas. Therefore, the great insulation which results from this phenomenon is responsible for the heating of homes and to compensate for this, populations resort to cooling or air circulation devices, which generates high energy costs [1].

With the low income of these populations, there is an urgent need to direct research into new alternative construction materials with not only low thermal conductivity, which would make it possible to reduce energy costs but also at low cost. Earthen materials such as baked clay bricks, compressed earth bricks, tiles, etc., are known for their high thermal inertia. However, their thermal properties (thermal conductivity, thermal diffusivity, etc.) are poorly known or almost non-existent compared to their mechanical characteristics.

It is in this logic that this present article is part and relates through an experimental study the thermomechanical characteristics of mixtures of laterite and fraké chips.

Indeed, a certain number of tests have been carried out on our sample materials (laterite) and on our composite materials (mixture between laterite and wood chips). These are characterization tests (particle size analysis, sedimentometry, Atterberg limits and specific weight), mechanical tests (compressive resistance) and thermal tests (conductivity). At the end of this work, we will not only be able to improve thermal comfort in the building but also considerably reduce the price of construction knowing that the basic materials used are local, available and very inexpensive.

2. Materials and Methods

The laterite used in this work comes from the Mont-Rolland laterite quarry in the Thiès region, Senegal. Geotechnical characterization tests were carried out on these samples before mixing them with wood chips. These shavings are those of fraké wood (tropical wood species known as Terminalia Superba its scientific name) [2].

The water used to mix these raw materials is drinking water from the tap [3].

The tests listed below were carried out during this work according to French standards:

- Particle size analysis and sedimentometry [4-5]
- Atterberg limits: Liquidity limit and plasticity limit [6]
- Determination of specific weight [7]
- Compressive strength [8]
- Determination of conductivity by the asymmetric hot wire method [9-10]

3. Results & Discussion

The grain size analysis and sedimentometry of our laterite sample showed that 46.8% of the elements passed through an 80µm sieve. They also showed that the sample is made up of 25% gravel, 18% coarse sand, 18% fine sand, 11% silt and 28% clay (Fig. 1).

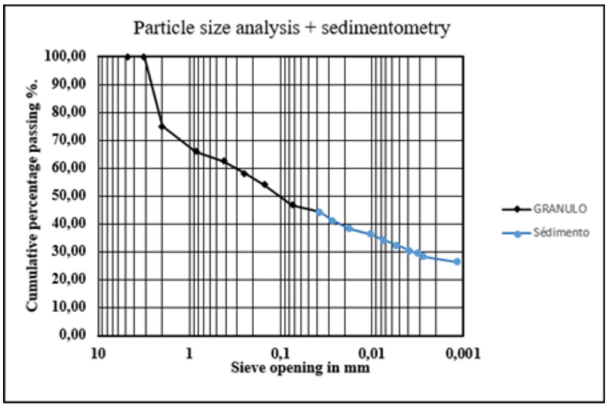

Figure 1: Particle size analysis & sedimentometry,

The study of the state of consistency of our material (table 3 & fig. 2) gave a liquidity limit (W_L) of 38.45%, a plasticity limit (W_P) of 20.52% and the value of the plasticity index (I_P) deduced from the first values is 17.93%.

Table 1*:* Atterberg limits: Limit of liquidity and plasticity

Essai : Limites d'Atterberg (NF P94 051)

Date 14/01/2023
Carrière Mont Rolland
Nature de l'échantillon Latérite

	Limite de liquidité					Limite de plasticité	
Nombre de coups	15	19	23	27	31	B1	B2
N° de la Tare	A1	A2	A3	A4	A5	5,93	5,83
Poids Total Humide en g	11,35	11,64	13,92	13,31	10,92	5,29	5,22
Poids Total Sec en g	8,79	8,96	10,65	10,25	8,56	2,2	2,22
Poids total tare en g	2,42	2,18	2,23	2,21	2,19	0,64	0,61
Poids net de l'eau en g	2,56	2,68	3,27	3,06	2,36	3,09	3
Poids matériau sec en g	6,37	6,78	8,42	8,04	6,37	20,71	20,33
Teneur en eau (%)	40,19	39,53	38,84	38,06	37,05		
Résultats			$WL_=$	38,45		$W_{P=}$	20,52
						$I_{P=}$	17,93

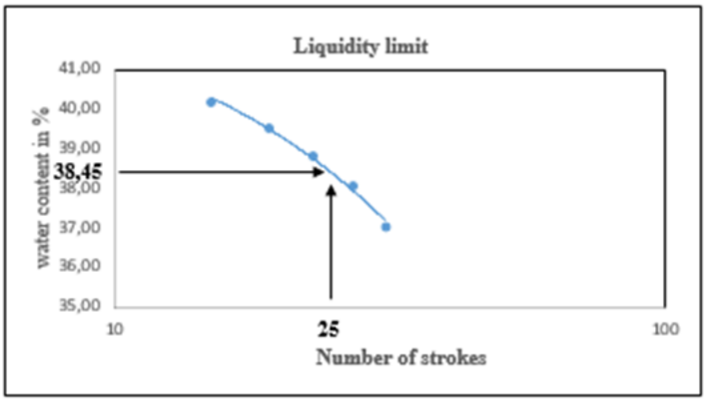

Figure 2: Determination of the liquidity limit

According to the Technical Guide for the Creation of Embankments and subgrade layers **(GTR, 1992),** a plasticity index of between 12 and 25% indicates a moderately clayey sample (fig.3) [11].

Figure 3: Classification of soil according to its plasticity index Ip

According to Casagrande 1948 and Howard 1977, a value of the liquidity limit W_L of a sample located between 30 and 50%, allows us to affirm that the clay contained in the sample is inorganic of average plasticity from which we have a **sandy, moderately clayey soil of medium plasticity** [12].

Having become aware of the importance of the withdrawal limit W_S, **Zondjé Poanguy Bernadin Bohi, 2008** after studying the withdrawal limit of fifty samples from various origins, it is established a correlation between the withdrawal limit and that of plasticity. Thus, the following formula makes it possible to determine the withdrawal limit [13].

$$\mathbf{W_s = 0.6W_P + 4.3}$$

Which means that the shrinkage limit of our laterite sample is equal to:

$$\mathbf{W_s = 16.61\%}$$

Figure 4 represents the state of consistency of our laterite.

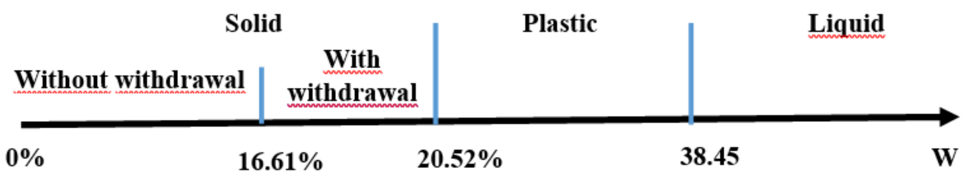

Figure 4: Consistency of laterite

The determination of the weight of the solid particles of the Mont-Rolland laterite gave a value of 2.70g/cm ^{3}.

According to the work of **Pao- Tsung Huang et al,** a specific weight value greater than 2 g/cm ^{3} indicates that the soil has a high mineral content [14]. **Surendra Roy et al** showed that a value of G_s between 2.7 and 2.80g/cm ^{3} indicates that the clay contained in the soil is mineral [15].

4. Mixing process

The mixtures were made with percentages of fraké chips ranging from 1% to 5% and the mass of each mixture is taken equal to 5000g. The table represents the quantity of chips in each mixture:

Table 2: Composition of laterite-chip mixes

Percentage of Chips	Mass of Chips (g)	Mass of Laterite (g)	Water (ml)
0%	0	5000	820
1%	50	4950	826
2%	100	4900	832
3%	150	4850	837
4%	200	4800	843
5%	250	4750	849

The raw materials were sieved with the 5 mm sieve to maximize the cohesion of the mixture then mixed dry to obtain a homogeneous mixture. The mixing water is gradually added to the mixture while mixing (figure 5).

Figure 5: (a) dry mix; (a) wet mix

Cylindrical test pieces 11x22cm were made for each type of mixture and after 7 days of drying, the compressive strength was determined using a hydraulic press (figure 6).

Figure 6: Determination of compressive strength

Figure 7 illustrates the evolution of the average value of mechanical resistance as a function of the percentage of wood chips in the mixture. We see that at 0% chips the average value of the resistance is 0.49MPa, at 1% chips we notice an increase in compressive strength until reaching its maximum which is 0.79MPa, at 2% of chips we observe a reduction in resistance compared to 1% chips but the latter remains greater than that at 0% chips and is equal to 0.651MPa. Beyond 2% the drop in mechanical resistance is notable and equal to 0.451MPa, 0.392MPa and 0.374MPa respectively at 3%, 4% and 5% of wood chips.

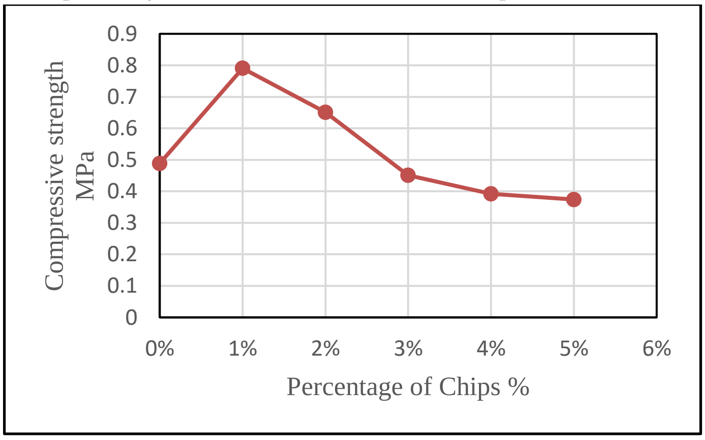

Figure 7: Evolution of mechanical strength as a function of the percentage of wood chips

At 1% shavings the compressive strength increases compared to 0% because the wood shavings reinforce the structure of the Laterite-Shavings composite. In fact, the laterite plays the role of binder and the chips that of reinforcement. The more the quantity of reinforcement increases in the mixture and that of the binder is sufficient to ensure perfect coating of the reinforcement particles, the higher the mechanical resistance. At 2% chips the resistance is lower compared to 1% chips but remains higher than at 0%. This may be due to the fact that at 2% the Laterite-Shavings composite begins to be weakened by the presence of the shavings and the cohesion is no longer perfect. Beyond 2% chips, the mechanical resistance to compression of mixtures of laterite and wood chips drops because the quantity of binder is no longer sufficient to coat all the wood particles in addition to this, the low mechanical inertia wood chips thus increasing in the mixture, contributes to the drop in the dry density of the composites which explains a drop in resistance noted successively at 3%, 4% and 5% of chips.

Using the asymmetric hot wire device, we determined the thermal characteristics of the mixtures, in particular the thermal conductivity, and the results are listed in Table 3.

Table 3: Thermal conductivity of mixtures

	0%	**1%**	**2%**	**3%**	**4%**	**5%**
Conductivity λ ($W.m^{-1}.K^{-1}$)	0,766	0,632	0,536	0,393	0,283	0,205

Figure 8 represents the evolution of thermal conductivity as a function of the percentage of chips in the mixture. Indeed, the value of this parameter decreases as the quantity of chips increases in the mixture.

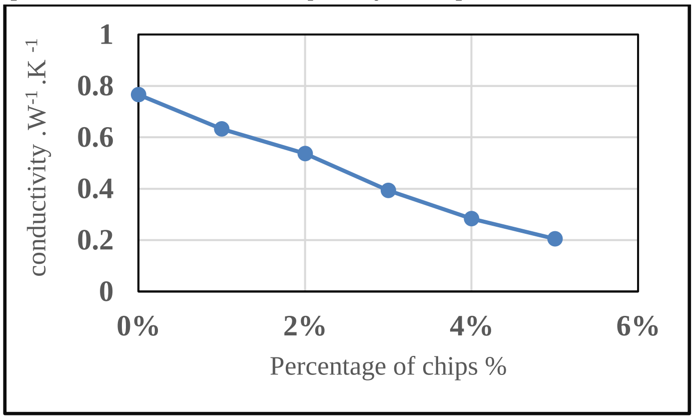

Figure 8: Evolution of thermal conductivity as a function of the percentage of chips

Knowing the thermal conductivity, we came to the conclusion that the thermal resistance of the mixtures by considering that the composites have a thickness of 20cm. Thermal resistance is nothing more than the thickness of the material divided by its thermal conductivity. Table 4 reports the thermal resistance of the different mixtures.

Table 4: Thermal resistance of mixtures

	0%	**1%**	**2%**	**3%**	**4%**	**5%**
Thermal Résistance Rth ($W^{-1}.m^2.K$)	0,261	0,316	0,373	0,509	0,707	0,976

Figure 9 represents the evolution of the thermal resistance of a 20cm thick wall of the laterite-chip composite as a function of the percentage of chips. This curve shows that this resistance increases with the quantity of chips in the mixture, this can be explained by the insulating nature of the wood chips. In fact, wood has a thermal conductivity of between 0.1-0.21 $W.m^{-1}.K^{-1}$ [16], its incorporation into mixtures reduces the thermal conductivity of the laterite-chip composite compared to the pure mixture (0% chips), this plus the quantity of chips increases which consequently explains the increase in thermal resistance in depending on the percentage of chips.

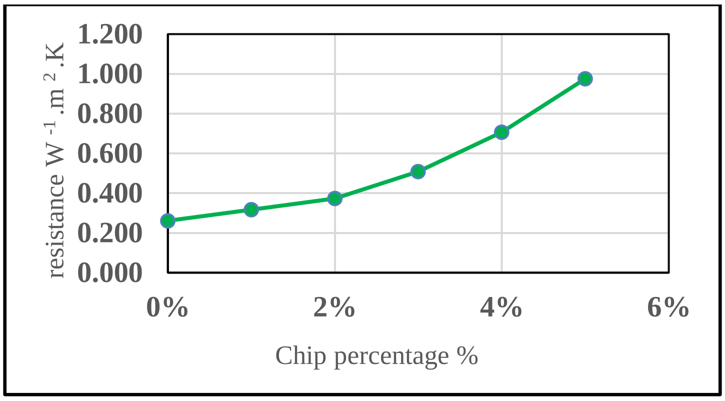

Figure 9: Evolution of the Thermal Resistance of a 20 cm thick wall as a function of the percentage of chips

After having determined the mechanical resistance and the thermal resistance of the mixtures, we attempted to gather the two curves (figure 10) in this case those of the evolution of the mechanical resistance and the thermal resistance as a function of the percentage of chips. in the mixture. This will allow us to understand the thermomechanical characteristics of the mixtures.

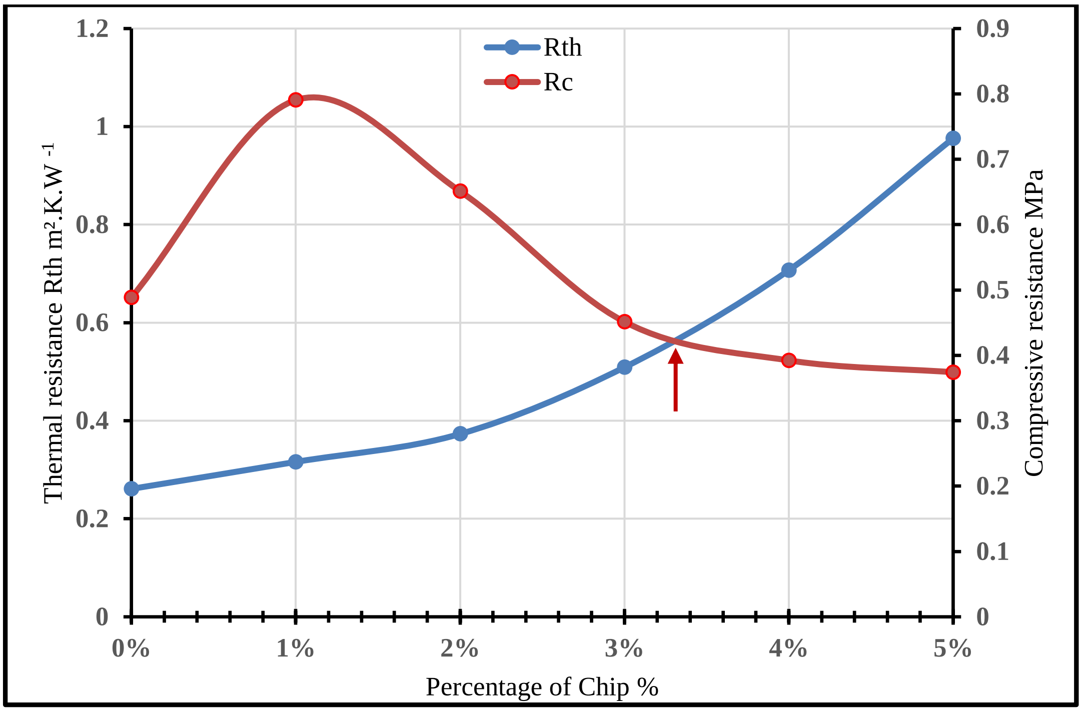

Figure 10: Evolution of the compressive strength and thermal resistance of a 20cm thick wall as a function of the percentage of chips.

The analysis of Figure 9 showed that the percentages 1% and 2% of chips provide the best mechanical resistances respectively 0.79 MPa and 0.651 MPa while the thermal resistance is equal respectively to 0.316 W.m $^{-1}$.K $^{-1}$ and 0.373 W.m $^{-1}$. K $^{-1}$. The intersection between the two curves occurs at 3.3% chips, the thermal resistance is better compared to 0% chips and is equal to 0.58 W.m $^{-1}$.K $^{-1}$, as for the mechanical one, it is equal at 0.42 MPa and this value is lower than that obtained at 0% chips.

Conclusion

Montrolland quarry in the region of Thiès, Senegal and fraké chips, a tropical wood species. This study showed that at 1% and 2% chips the compressive strength values are maximum while the thermal ones are relatively higher compared to the pure mixture but remain low and there is a point of intersection between the two curves where the compressive resistance crumbled until reaching a value below that of the pure mixture while the thermal resistance increased by 45% compared to the pure mixture. The idea of this work is the valorization of local materials such as laterite but also to have good thermal inertia when using composites. However, for proper use of the Laterite-Shavings composite without any safety concerns, it must be improved in order to increase its mechanical resistance. This improvement will be achieved by introducing Portland Cement into the mixtures in varied proportions.

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