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Influence of the Decoction of Nere Seeds on the Physical and Mechanical Properties of Earthen Materials

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Abstract: This study aims to revalue local materials which are full of important characteristics for the construction of homes. It deals with the influence of the decoction of the seeds of the Nere tree on the physical and mechanical properties of laterite-based earth blocks. To do this, the mixing water used for mixing the materials is replaced by the nere decoction. Two types of blocks were developed: earth blocks incorporated with rice straw and earth blocks without straw. They were subjected to the study of density, wear test and capillary rise. Using water to mix the materials, the density of the blocks is equal to 1.26 and 1.22; wear is equal to 1.30 g/cm^2 and 1.09 g/cm^2 and capillary rise is equal to 3.4 cm and 4.4 cm, respectively for samples containing rice straw or not. On the other hand, when the nere decoction is used for mixing, the density of the blocks is equal to 0.74 and 0.75; wear is equal to 0.41 g/cm^2 and 0.38 g/cm^2 and capillary rise is equal to 2 cm and 2.6 cm respectively for samples containing rice straw or not. Replacing water with nere decoction reduces the density of the earth blocks but improves their resistance to wear and capillary rise. It appears from this study that the decoction of nere seeds improves the quality of local materials and can therefore be rehabilitated in the construction of tropical countries.

Keywords: *Local materials, valorization, decoction, nere seed, block of earth*

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1. Introduction

Ivory Coast is a tropical country whose climate favors the formation of laterite or raw earth. Laterite is a red or brown soil rich in iron oxide and alumina that forms by weathering of rocks in tropical climates. In the past, this material was used for the construction of homes. Several methods have been implemented to design resistant materials. To do this, we add either fonio [1], hemp [2], rice straw and nere decoction [3] or other fibers.

These different housing methods tended to disappear with the discovery of cement, used for the manufacture of sand bricks and joints. The authors cited above tend, through their work, to revalue these different local materials. It is with this vision that this study was initiated. Its objective is to note the influence of the decoction of nere seeds on the blocks of earth containing rice straw.

2. Materials and Methods

2.1. Raw Material

To make the earth blocks, laterite, sand, rice husks, nere decoction and mixing water were used (Figure 1).

- The laterite comes from the locality of Adiopodoumé, a village located near kilometer 17 in the municipality of Yopougon (Abidjan). It is made up of 51.7% silt and clay, 48.0% sand and 0.20% gravel [4];
- the rice husks come from the Bécouéfin village located on the link of the Akoupé-Abengourou sub-prefecture. They are collected after harvesting and hulling the rice stalks. Their density is 0.47 [4].
- The decoction of nere seeds was used as an adjuvant in the case of this study and made it possible to improve the workability of the mixture. This method was once used by the people of Benin for the construction of traditional banco houses [3].

2.2. Study Methods

2.2.1. Characterization of Raw Materials

Néré seeds were prepared to obtain the decoction. It is obtained after boiling the néré seeds in a certain quantity of water for 6 hours at 80°C. Also, the tests carried out on the raw materials are the Atterberg limits and the water absorption of rice husks.

2.2.1.1. Atterberg Limit

The Atterberg limits are measured on the fine elements of laterite (fraction passing through a sieve of 0.4) according to standard NF P 94-051 [5]. These are parameters for identifying fines, making it possible to know the liquid limit in the cup (W_L) as well as the plasticity of the roller (W_P). From these results, we deduce the plasticity index (I_p) following the relationship below and which characterizes the consistency of the soils.

$$I_P = W_L - W_P \quad (1)$$

2.2.1.2. Measurement of Water Absorption of A Plant Fiber

Fiber absorption was evaluated following the recommendations of Rilem TC 236 BBM for plant aggregates [3]. This characterization corresponds to the quantity of water absorbed by the rice husk fibers as a function of time. A mass of 10 g of rice husk fibers is weighed dry then immersed in water at different times (1 min, 30 min, 1 h, 2 h, 3 h, 4 h, 6 h, 8 h, 10 h, 12 h, 24 h, 48 h). The fibers are collected and subsequently spun using a salad spinner at a rate of 100 revolutions of the spinners per second. These procedures were carried out on 12 samples to determine the absorption coefficient in percentage (%) which is expressed by the equation

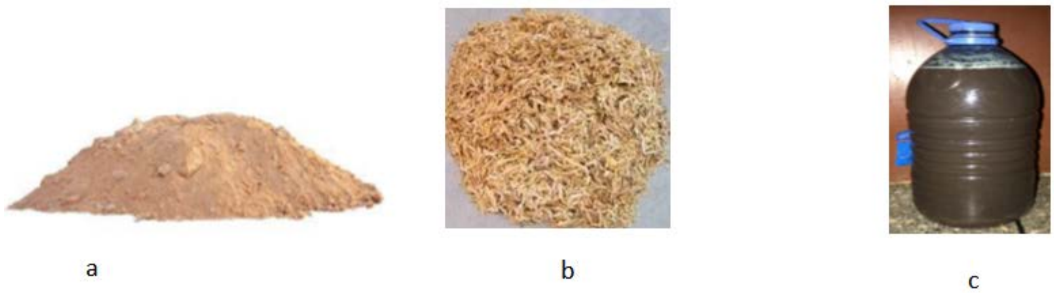
$$W(t) = 100\frac{mh - ms}{ms} \quad (2)$$

With W (t): absorption coefficient in%;
mh (g): the wet mass after spinning;
ms (g): dry mass

2.2.2. Preparation of Samples

Four series of samples are made using different formulations summarized in Table 1. Figure 2 and Figure 3 present the methodology for preparing the test pieces as well as some samples prepared.

For each formulation, 18 samples are made and the test tube preparation process is summarized in the diagram below.



a) Laterite; b) Rice husks; c) Decoction of **nere**

Figure 1. Raw materials

Table 1. Formulations of the different test tubes

Material designation	Decoction/soil ratio	Proportion Laterite (%)	Water/soil Ratio	Proportion Rice husk (%)
Laterite + water (EL)	-	100	0,35	-
Laterite + rice husk + water (ELB)	-	100	0,35	2
Laterite + nere decoction (NL)	0,35	100	-	-
Laterite + rice husk + nere decoction (NLB)	0,35	100	-	2

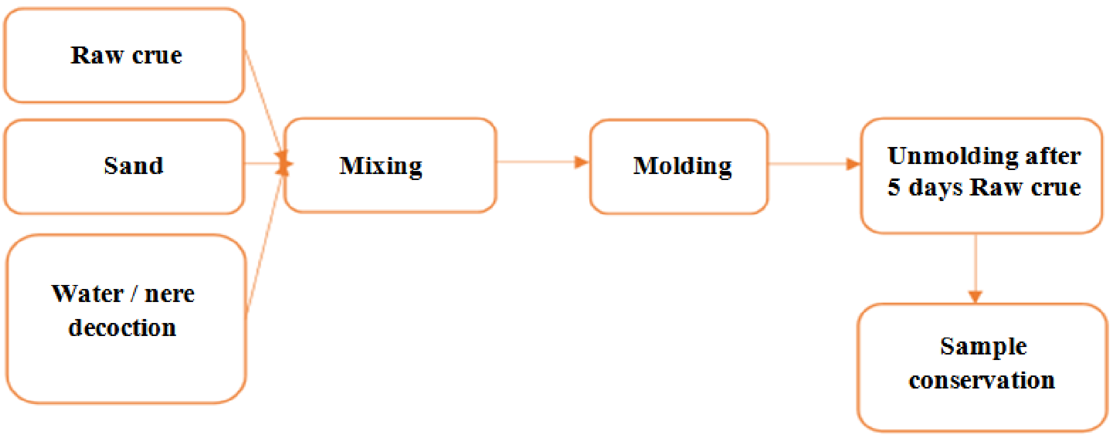


Figure 2. The test tube preparation process

(a): EL ; (b): NL ; (c): NLB ; (d): ELB

Figure 3. Different series of samples

2.2.3. Characterization of Samples

The different physical properties such as density and absorption (capillary rise) were determined on the earth blocks. Also, their resistance to wear has been highlighted

2.2.3.1. Briquette Density Measurement

The density of the briquettes is measured according to standard NF P 94-410 [6]. The determination of the density is done according to equation 3.

$$\rho = \frac{Ms}{Vs} \quad (3)$$

ρ: the density of the briquette (g/cm^3),
MS: the average mass of 5 briquettes (g),
VS: volume of a briquette (cm^3)

2.2.3.2. Hair Lift

Capillary rise refers to the migration of humidity in walls in contact with damp ground and due to the porous structure of the material which constitutes them. It highlights the porosity of the material which reflects its resistance.

The principle of this test is to introduce 0.5 mm of the size of the material into 0.5 mm of water for 1 min. Then using a graduated ruler, measure the length from the highest wet level to the entire dry surface of the material.

$$RC = I_i - I_f \quad (4)$$

RC: capillary rise (cm),
li: the length of the dry material before immersion (cm),
lf: the length of the dry material after immersion (cm)

2.2.3.3. Wear Test

The wear test makes it possible to characterize the hardness of the material. It consists of making translation movements along the material for 25 cycles and determining the mass loss of particles torn from the material.

The test equipment consists of a small 3 kg cart resting on four wheels, below which a metal brush is fixed. The trolley rests on two rails which fit together at their two ends. A wrist allows you to pull the cart which moves on the wheels (Figure 4).

$$\mu = \frac{Mi - Mf}{Sf} \quad (5)$$

μ = wear (g/$cm2$),
Mi = the mass of the dry sample before brushing (g),
Mf = the mass of the dry sample after brushing (g),
Sf = brushed surface (cm^2)

Figure 4. Wear resistance testing equipment

3. Results and Discussion

3.1. Atterberg limit of laterite

The results are recorded in the Table.

Table 2. Earth plasticity index used for our samples

Sample	W_L (%)	W_P (%)	I_P
Laterite	88	43	45

The parameters for identifying the liquidity limit (WL) and plasticity of the laterite studied are respectively equal to 88% and 43%. This makes it possible to obtain a plasticity index equal to 45% greater than 40%, which according to standard NF P 94-051 [5] therefore corresponds to a very plastic floor**.** These data confirm the abundant presence of fine in the laterite, namely 51.7% [4]. The plasticity index being very high, this raw material will have good particle cohesion. The author [7] found during this work 57.06 % of fines contained in the laterite which he used to make his samples.

3.2. Absorption of Rice Husk Fibers

Figure 5 shows the absorption curve of the ball fibers. The curve presents 03 absorption phases as a function of time. In the first times from 0 to 240 min there is a strong growth of the curve with an absorption rate ranging from 0 to 118% then the growth slows down from 240 min until

1440 min and the absorption rate is between 116 and 138% finally it remains constant from 1440 min. The absorption rate is 138%. Indeed, these different phases show the classic absorption kinetics of rice husk fibers with a rapid absorption speed in the first hours, followed by a slowed speed to end at a constant absorption speed. This progression is consistent with that of [8] but differs in terms of the absorption rate because the rice husk fibers used in our study have a water absorption rate higher than that of [8] which is of 100%.

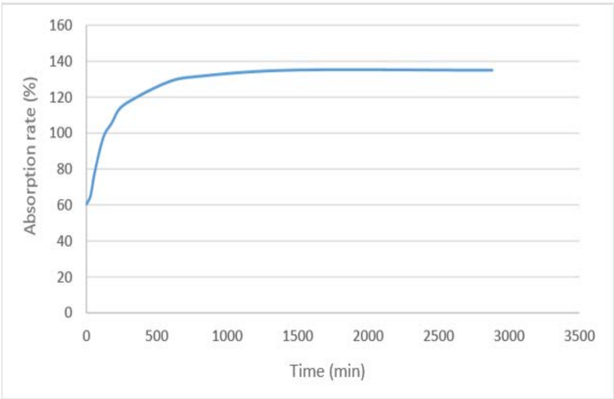


Figure 5. Water absorption curve of rice husk fibers

3.3. Influence of the Decoction of Nere Seeds on the Density of the Samples

The results obtained are presented in the form of a histogram in Figure 6.

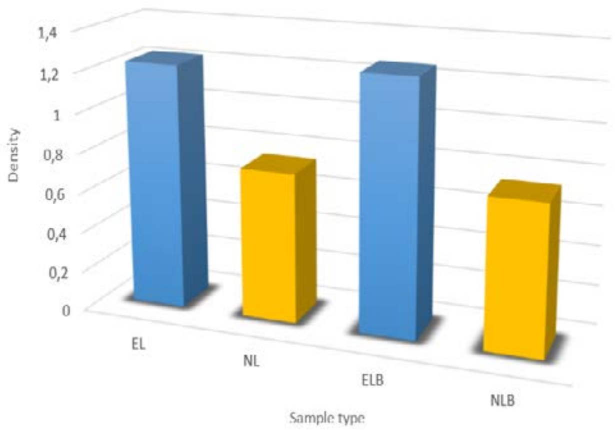


Figure 6. Apparent density of samples

The density varies depending on the composition of the samples. The samples not containing the decoction of nere seeds (EL and ELB) have a density respectively equal to 1.22 and 1.26 unlike those which contain the decoction (NL and NLB) which have respective densities equal to 0.75 and 0.74.

It appears that EL and ELB are denser than NL and NLB. By comparing NL and NLB, we see that the density of the NLB samples drops considerably by 0.52 compared to those of NL (0.47).

This drop can be linked to the incorporation of straw in NLB because the absorption test of rice straw showed that it has a low density equal to 0.47. Replacing water with the decoction of néré seeds led to a reduction in the density of the samples. This behavior of the materials can be linked to a fairly extensive evaporation of the nere decoction but also to the fact that it has a viscous nature [3]. According to this author, the density of the test tubes decreases with the addition of nere decoction.

Indeed, during the work of [7] on the density of the decoction of nere seeds and that of water, the results showed that the density of the decoction of nere seeds was 1.044 higher than that of the water which is 1.

Thus, given that the decoction of nere seeds is denser than water, after evaporation of this solution and drying of the materials, their mass drops considerably. This is what leads to the drop in the density of the materials containing the decoction of nere seeds.

3.4. Influence of Nere Seed Decoction on Wear Resistance

Figure 7 in the form of a histogram presents the results obtained on the wear resistance of the samples.

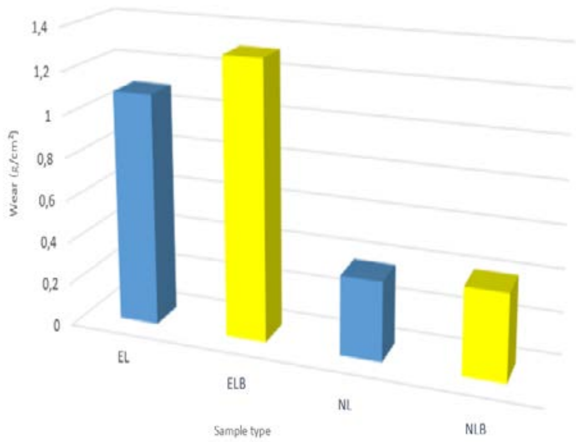


Figure 7. Resistance to wear test

The wear test results show that samples not containing nere seed decoction (EL and ELB) wear significantly compared to those containing it. The values are respectively equal to 1.09 and 1.30 g/cm^2 for the EL and ELB samples then 0.38 and 0.41 g/cm^2 respectively for NL and NLB.

In the absence of rice straw (NL) the data goes from 1.09 to 0.38 g/cm^2 and in the presence of it (NLB), they go from 1.30 to 0.41 g/cm^2. The straw incorporated into the material also reduces wear because the rice straw does not crumble [9].This helps reduce wear and tear on materials made of straw. The addition of nere decoction to the composition of the samples allowed the particles of the material to be more resistant to wear and to reduce the mass of particles torn off. The decoction of nere seeds used as an adjuvant improves the physical appearance of materials and reduces their crumbling. These results are consistent with those of [10]. His work showed that the use of the decoction of nere in the mixture with raw earth made it this mixture much more manageable. But also, made the surface of the test pieces smoother, which therefore prevented crumbling. These results are consistent with those of [7] who after the characterization of his samples confirmed that the decoction of **nere** increases the resistance of the earthen banco (material).

3.5. Influence of the Decoction of Nere Seeds on Capillary Rise

Figure 8 presents the results obtained on the samples.

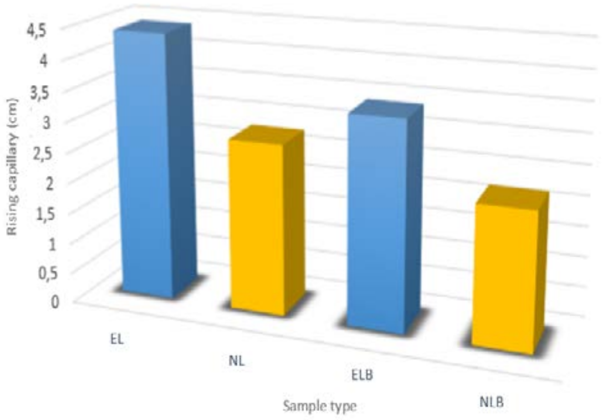


Figure 8. Capillary rise of water from samples

The EL and ELB samples not containing nere seed decoction had higher capillary rise than those which contained it. The data are respectively equal to 4.4 cm and 3.4 cm. The samples prepared with the nere decoction (NL and NLB) have capillary rises of 2.6 cm and 2 cm respectively. The addition of the decoction leads to the reduction of pores in the materials.

By comparing NL and NLB, we see that the capillary rise of the NLB samples drops by 1.8 cm compared to those of NL which drops by 1.4 cm. When the material contains rice straw, capillary rise is low because the rice straw also absorbs a certain quantity of water from humidity. Which also reduces the rise of water in the materials. The addition of the decoction promoted the impermeability of the material and therefore made it possible to reduce the pores in order to avoid a large rise of water in the capillaries.

These results are consistent with the results of [11] who in his work on laterite blocks showed that these blocks treated with nere decoction absorb less water.

4. Conclusion

This study focused on the influence of the decoction of nere seeds on the density, wear resistance and capillary rise of water of laterite and rice husk composite materials.

The use of nere decoction for the mixture of raw materials lowers the density of the material, improves its resistance to wear and reduces its capillary rise. It appears from this study that the decoction of nere seeds improves the quality of local materials and can therefore be rehabilitated in the construction of tropical countries.

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