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Physico-mechanical Characterization of Composite Bricks from Laterite, Typha and/or Rice Hull

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Abstract This study is part of the valuation of local materials in order to build economic, sustainable and resilient housing. The objective is to characterize composite bricks made from a mixture of laterite and straw (rice hull and typha) with proportions between 3 to 6%. These mixtures are stabilized with 1% cement and with proportions of 48.5 and 50% sand. The physical and mechanical characteristics were obtained from water immersion absorption and compression tests, respectively. The results show that the high immersion water absorption and porosity of these composite bricks is due to the low density of typha and rice hull and therefore the durability of these bricks is low. To overcome this problem, the use of plaster is recommended. On the other hand, the compressive strength of all the bricks varies between 2.09 to 3.64 MPa. This resistance falls within the range of admissible values for earthen bricks. These resistances are sufficient to build a two-story house [3,8,10].

Keywords: *composite brick, laterite, rice hull, typha, compressive strength, porosity*

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1. Introduction

Climate change is a phenomenon that affects all sectors. Natural resources are becoming increasingly scarce. The building sector is characterized by expensive and energy-consuming structures [1]. So, to preserve our environment, mitigation and adaptation to climate change must be a challenge [2].

This study, which focuses on the valuation of local materials such as laterite, typha and rice hull, falls within the framework of adaptation to climate change [3,4]. The objective is to find an optimal formulation in order to offer a durable, economical and resilient material. This involves determining the physical and mechanical characteristics of bricks made from mixtures of laterite, sand, typha and or rice hull.

Before any mixture, laterite and sand identification tests will be made. These tests will determine the particle size, sand equivalent and specific gravity of the laterite and sand. Water immersion absorption as well as porosity will be determined. In addition, the compressive strength of bricks made from laterite mixtures, sand and straw will be studied.

2. Methodology

This work is the beginning of a series of research which forms part of a study of formulation and optimization of local ecological materials. The samples are made from local materials. They are obtained from a mixture of laterite and straw (rice hull and typha) with proportions of 3 to 6%. These mixtures are stabilized with 1% cement and 48.5% of sand. Before any formulation, identification tests were carried out on the laterite of the Sindia quarry (Senegal) (Figure 1) and the sand of Keur Morry (Senegal) (Figure 1). These tests make it possible to determine the specific weight, the particle size and the sand equivalent.

Figure 1. Laterite (left) and sand (right) quarries

The specific gravity gives an idea of the density of the soil and guides on the best method to use for an accurate classification of soils.

The granulometry makes it possible to determine the size and the respective weight percentages of the different grain classes of the sample.

The sand equivalent tells us about the cleanliness of the sample, especially the presence of fine particles. The cleanliness of the aggregate is a very important parameter in the bricks formulation.

The typha and the rice hull (Figure 2) were collected in Ross Béthio in the Department of Saint Louis (Senegal). It should be noted that in this area, those straws are available in sufficient quantity.

Figure 2. Preparation of Typha and rice hull samples

As for cement, class II (Portland cement CEM II-32.5) is used to stabilize the mixture.

Bricks were made for different formulations (Figure 3). The dimensions of all the bricks are 5cm x 5 cm x 15 cm. Water absorption and mechanical tests were carried out on these bricks.

Figure 3. Example of brick formulation (laterite, typha, rice hull and cement)

The absorption test makes it possible to evaluate the quantity of water retained by the porosity of the aggregates in order to take it into account for the effective water dosage during the formulation of concrete. Porosity is obtained from the absorption coefficient of the material. Porosity influences two parameters: the durability and the mechanical resistance of the material.

The tests were carried out according to the NBN B 15-215 standard. [5]. The samples are immersed in a water tank at 20 ± 2 °C for 48 hours and were dried for 24 hours in an oven.

Water absorption by immersion (Abs) is expressed as a percentage of dry mass and is calculated by the following relationship [5].

$$Abs(\%) = \frac{m_{wet} - m_{dry}}{m_{dry}} x100. \quad (1)$$

The calculation of the porosity is deduced directly from that of the absorption of water by immersion. We just have to multiply the water absorption by immersion (in %) by the dry specific mass of the brick, expressed in kg/cm^3 or in g/cm^3.

For mechanical strength, crushing tests were carried out on the bricks. A 2000 kN capacity compression machine was used to determine the 28-day compressive strength of the samples. The compressive strength is obtained by the ratio of the maximum force on the section of the brick.

3. Results

3.1. Soil Identification

The results of the identification tests are shown in Table 1.

Table 1. Specific weight, sand equivalent and coefficient of uniformity and coefficient of curvature

Materials	δ_s	ES		Cu	Cc
		ES_p on piston	ES_v on sight		
Laterite	2,66	-	-	129.167	0,181
Sand	2,42	67;31	69,75	1.688	0.88

The grain size curves are shown in Figure 4 below. They are completed by a sedimentology.

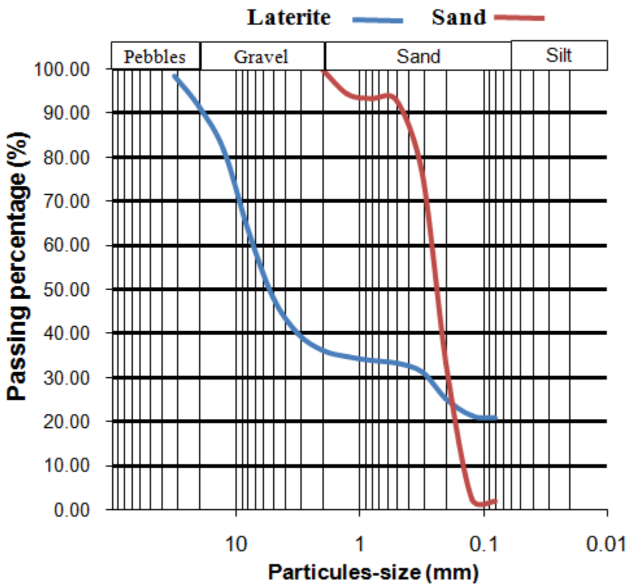

Figure 4. Granulometric curves of laterite and sand

The results of the modified Proctor test give a density (γdmax) equal to 2.233 g/cm^3 and an optimum water content (Wopt) equal to 7.4 %, i.e. an addition of water of 4% of the mass, equivalent to 240 ml.

3.2 Bricks Compressive Strength

The average compressive strength (σ_{moy}) at 28 days of bricks with dimensions of 5 cm x 12 cm x 15 cm, depending on the type of straw and their percentages, is summarized in Table 2.

Table 2. The average compressive strength (σ_{moy}) at 28 days in MPa of the bricks according to the type of straw and their percentages

Straw percentage (%)	0%	3%	4%	5%	6%
Typha	1,97	2,09	2	2,26	1,96
Rice hull	1,97	2,29	2,43	3,18	1,6
Rice hull + Typha	1,97	2,81	2,80	3,00	3,61

3.3. Brick Absorption and Porosity

The absorption and porosity of the bricks, depending on the type of straw and their percentages are reported in Table 3 and Table 4, respectively.

Table 3. Absorption (%) of bricks according to the type of straw and their percentages

Straw percentage (%)	0%	3%	4%	5%	6%
Typha	18,06	19,75	19,75	28,38	31,96
Rice hull	18,06	17,53	17,85	18,8	21,57
Rice hull + Typha	18,06	18	19,28	20,32	24,86

Table 4. Porosity (%) of bricks according to the type of straw and their percentages

Straw percentage (%)	0%	3%	4%	5%	6%
Typha	31,56	33,56	35,44	39,89	41,44
Rice hull	31,56	32,22	32,33	32,44	35,67
Rice hull + Typha	31,56	33,22	34,11	34,89	40,22

4. Discussions

4.1 Specific Weights

Table 1 shows that the specific gravity of the laterite and the sand are respectively equal to 2.66 g/cm^3 and 2.42 g/cm^3. Indeed, a material consists of light particles if the specific weight is less than 2.6 g/cm^3 and if the latter is greater than 2.6 g/cm^3, the material is composed of heavy particles [5].

Thus, the laterite used in this study consists of heavy particles while sand consists of light particles.

4.2 Sand Equivalent

The sand equivalent is produced for the purpose of measuring the property of sands on a fraction of aggregate. However, the very fine elements contained in the aggregates have a very significant influence on the preparation of concrete. Table 1 shows that the mean values of piston sand equivalent (ES_P) and sight sand equivalent (ES_V) are respectively equal ESP = 67.31 and ES_V = 69.75. These results show that the sand used is slightly clayey. The properties of those types of sand are admissible for the preparation of hydraulic concrete [5].

4.3. Granulometry

The use of the grain size curve gives a uniformity coefficient of 129.167. It indicates that the laterite has a spread grain size because the coefficient of uniformity is greater than 4. However, the coefficient of curvature Cc is equal to 0.181. This coefficient, less than 1, shows that the laterite collected has a poorly graded particle size, that is to say that there is a predominance of grain sizes over others.

Casagrande's unified classification system provided additional soil characteristics. The results show that more than 50% of particles are retained on the 80 µm sieve; which indicates the presence of coarse-grained soil. In addition, more than 50% of the coarse grains are retained on the 5 mm sieve which characterizes gravel. Finally, we have a percentage of passers through the sieve of 80 µm less than 5% which with Cc and Cu confirm that we have a poorly graded particle size. We can therefore note that the laterite has a particle size containing many fine particles.

4.4. Water Absorption by Immersion and Porosity

The results of the immersion absorption tests are shown in the figure below.

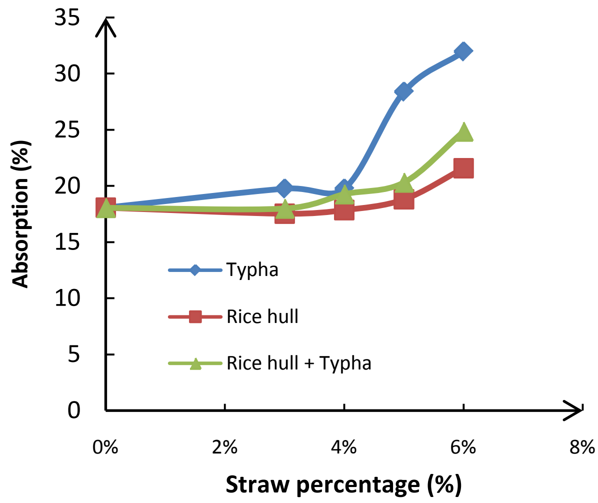

Figure 5. Absorption (%) of bricks according to the type of straw and their percentages

The results of the porosity tests are shown in the figure below.

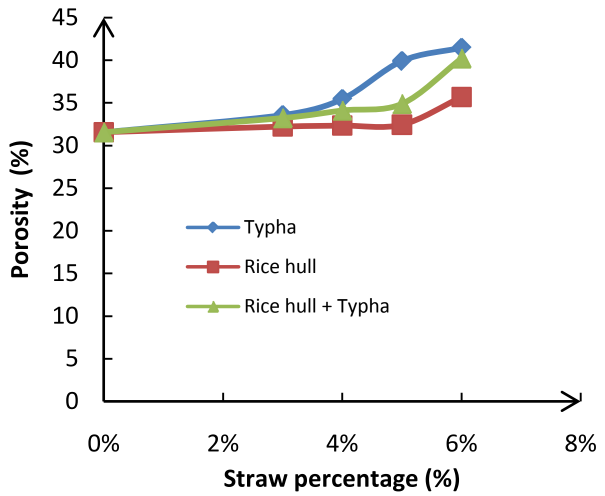

Figure 6. Porosity (%) of bricks depending on the type of straw and their percentages

Figure 5 and Figure 6 show that water immersion absorption and porosity increase with the addition of straws. The absorption varies for typha between 19.75 (3%) to 31.96 (6%) and the porosity between 33.56 (3%) and 41.44 (6%). As for the rice hull, absorption varies between 17.53 (3%) to 21.57 (6%) and for porosity it varies between 32.22 (3%) and 35.67 (6%). The water absorption by immersion of bricks made from the mixture of rice hull and typha varies between 18 (3%) to 24.86 (6%) concerning the porosity it varies between 33.22 (3%) and 40.22 (6%). Thus, water absorption by immersion and porosity, for bricks with rice hull and / or typha, increase with the percentage of typha and / or rice hull [7,8]. Likewise, we can note that those two parameters are higher for bricks with typha. This is explained by the high porosity of typha due to the presence of capillaries which makes the particles light. For rice hull, its low density gives it a lower absorbency than typha

In addition, these results show that the absorption and porosity of the mixture of rice hull and typha are lower than the values obtained with the rice hull alone and are higher than the values obtained with the rice hull. This is justified by principle of mixtures relating to the properties of composites. The addition of rice hull, with a grain size finer than that of typha, helps to strengthen cohesion by reducing empty spaces, resulting in a decrease in porosity and consequently water absorption by immersion [7,8].

In summary, the high immersion water absorption and porosity of these bricks is due to the low density of typha and rice hull and therefore the durability of these bricks is low. To overcome this problem, the use of plaster is recommended.

4.5. Mechanical Resistance

The results of the compression tests are shown in Figure 7 below.

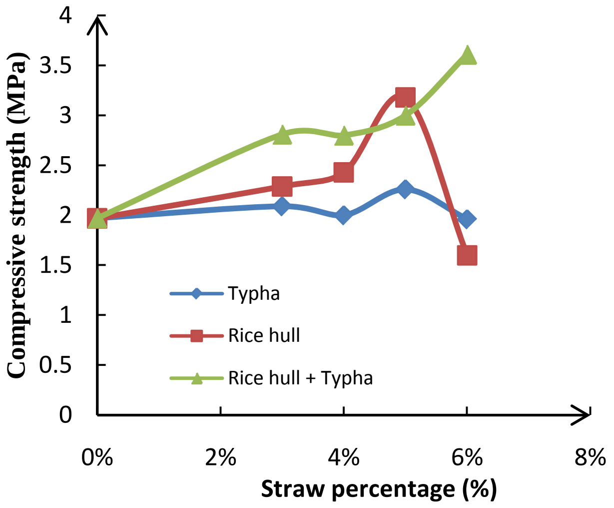

Figure 7. Average compressive strengths of bricks depending on the type of straw and their percentages

This figure shows two parts: an increase in the compressive strength of bricks based on rice hulls or typha between 3% to 5% and a decrease between 5% and 6%. For the mixture of rice hull and typha, the compressive strength varies between 2.81 MPa to 3.64 MPa respectively for 3% and 6% of the mixture of straws.

Figure 7 shows that the compressive strength of the rice hull is higher than that of the typha bricks. This observation is justified by the fine grain size of the hull compared to that of typha. This result corroborates those of the porosity tests.

In addition, the compressive strength of the mixture of rice hull and typha is greater than that taken separately. According to the principle of mixtures, the properties of a composite are obtained from a combination of properties of the elements which compose it, hence this increase on average of 0.68 MPa compared to the rice hull and 0.98 MPa compared to typha [9].

In summary, the compressive strength of all the bricks varies between 2.09 to 3.64 MPa. This resistance falls within the range of admissible values for earthen bricks. These resistances are sufficient to build a two-story house [3,8,10].

5. Conclusion

The choice of a material is based on several criteria, the most important of which are mechanical and physical parameters.

The physical characterization of the bricks shows that the absorption and porosity of the bricks are high therefore the durability is low. To overcome this problem, the use of plasters on the exposed face is recommended.

On the other hand, the compressive strength of all the bricks (2.09 to 3.64 MPa) falls within the range of the admissible resistance values for clay bricks.

In perspective, a thermal characterization of the composite bricks will be made to assess the variation of the parameters according to the different formulations.

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