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REVIEW

# Valuation of Laterite in Low-cost Building in West Africa

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ABSTRACT

The study of the performance of raw clay bricks has made it possible to develop laterite in Eco village construction projects. Identification tests (particle size analysis, Atterberg limits, Proctor, shrinkage limit, and sand equivalent) made it possible to characterize the laterite, the sand, and the E1 mixture (70% laterite and 30% sand). By adding binders to E1, three other types of mixtures E2, E3, and E4 have been proposed. The improved E1 sample:(1) At 2.5% of cement gives E2; (2) At 10% of lime gives E3; (3) with 0.8% lignosulfonates. After making the bricks using the samples E1, E2, E3, and E4, we perform uniform compression test at 3, 7, and 21 days. All samples have simple compressive strengths greater than 0.5 MPa (in accordance with standard NF EN 771-1) after 3 days. Their evolution from 0.5 to 2.5 MPa, between 3 and 7 days, shows a jump of 1.5. From 7 to 21 days the evolution curve of the Rc shows a slight ascension then a plateau pace (2.5, 2.51, 2.56 MPa). From these results, we concluded that they were used according to the area and the type of climate. The use of the sample E1 is proposed in arid zones or with low rainfall, the sample E2, and E3 in the rainy zones without risk of capillary rise and the sample E4 in the rainy zones with the risk of capillary rise.

## 1. Introduction

Faced with the current environmental challenges linked to climate change and the depletion of resources (United Nations Environment Program, 2016), the building sector must renew its design practices and methods while taking into account economic and health criteria and comfort. UN-Habitat estimates that 3 billion human beings will be poorly housed by 2030. Given its availability, raw earth constitutes a viable alternative in the construction sector in order to meet the needs of the world population [1]. However, scientific studies must be carried out on this material in order to define manufacturing conditions within the reach of the target population. Indeed, despite its many ecological, thermal, and economic advantages, raw earth has the disadvantage of deteriorating under the effect of climatic conditions. It is therefore essential to take precautions in order to increase its durability [1]. In this study, it will be a question of improving the laterite with sand, lime, cement, or lignosulfonates.

The objective is to contribute to the improvement and development of local building materials made from laterite blocks. Specifically, this study aims to:

(1) Define the properties of lateritic and clay materials;

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(2) Improve performance by adding lime, cement, and lignosulfonates.

## 2. Characterization of Materials

### 2.1 Laterite and Sand

Laterite is a residual rock. Its composition is rich in iron hydroxide and aluminum hydroxide. They appear in the form of red earth mainly due to oxidized iron and which contain nodules (an abnormal size of generally rounded shape) harder due to the recrystallization and the dissolution of the oxides of iron and alumina [2]. When this phenomenon occurs in superficial horizons, it generates the birth of what is called the "lateritic breastplate".

Laterite is taken from the Bambey area.

The whitish-colored sand is extracted from the bottom of the dry water points. The following tests were carried out: particle size, determination of the dry density, Atterberg limits, and shrinkage limit.

### 2.2 Manufacture of Earth Bricks

Analysis of the laterite results shows that it has a clay fraction. In order to keep the plasticity index lower than 25, we added 30% of sand to make an E1 sample of raw earth. The sample shows the granular skeleton shown in the figure 1.

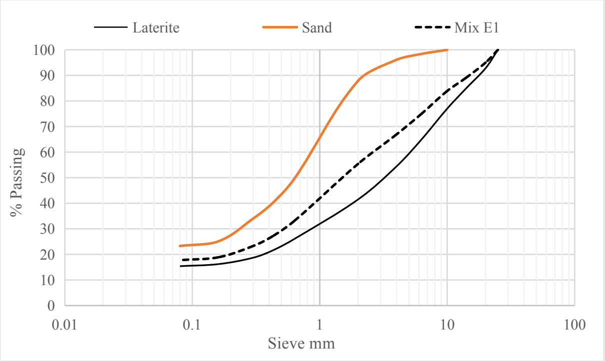


**Figure 1.** grading of laterite-sand-mix E1

The characteristics of the materials are summarized in Table 1.

**Table 1.** Results of laterite and sand identification test

| Materials | Mdd (g/cm³) | Liquid limit | Plasticity index | Shrinkage limit | Sand equivalent |
|---|---|---|---|---|---|
| **Laterite** | 1.982 | 42 | 26 | 8 | NC |
| **Sand** | 1.892 | 21 | 10 | NC | 89 |
| **E1 (70% laterite+30% sand** | 1.99 | 39 | 23 | 5 | NC |

From E1 we prepared three other samples (E2, E3 and E4) whose composition is defined in Table 2.

**Table 2.** Composition of study's samples

| Materials | Laterite | Sand | Additive |
|---|---|---|---|
| **E1** | 70% | 30% | NC |
| **E2** | 70% | 30% | 2.5% cement |
| **E3** | 70% | 30% | 10% lime |
| **E4** | 70% | 30% | 0.8% Lignosulfonates |

E1 and E3 are wetted to the optimum water content and compacted @ 90% of the modified Proctor optimum.

E2 and E4 are lateritic concrete. The molding is done with a sag of 60 cm.

Eighteen samples were made from each mixture, which will be overwritten in groups of six at 3, 7 and 21 days.

Figure 2 shows the illustration of earth brick construction.

**Figure 2.** Earth brick construction

Sample E1 is burned over a wood fire to give it hardening and thermal insulation properties. Traditional bricks are classified in type (a) and (b) insulating masonry. A traditional brick with an R> 1m².K / W is more than four times more insulating than a common aggregate concrete block (R = 0.23 m².K / w) [3,4]. The thermal performance of traditional bricks and their accessories gives them a strong ability to correct thermal bridges.

The compressive strength results are shown in Table 2.

**Table 2.** Compressive Strength of E1, E2, E3 and E4

| Materials | Additive | 3 days (MPa) | 7 days (MPa) | 21 days (MPa) |
|---|---|---|---|---|
| **E1** | NC | 0.50 | 2.00 | 2.01 |
| **E2** | 2,5% cement | 0.60 | 2.50 | 2.54 |
| **E3** | 10% lime | 0.65 | 2.51 | 2.51 |
| **E4** | 0.8% Lignosulfonates | 0.61 | 2.52 | 2.56 |

### 2.3 Analysis and Interpretation

Analysis of the results shows a first trend from the first



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three days: E1, E2, E3, E4 have Rc ≥ 0.5 MPa (requirement of standard NF EN 771-1) [4].

Sample E1, without additive, burned at 285°c has the following Rc: 0.5 MPa @ 3 days, 2.0 MPa @ 7 days and 2.01 MPa @ 21 days. The increase in resistance took place between three and seven days with a jump of 1.5 MPa. Between 7 and 21 days we observed a slight increase which presents a plateau-like appearance on the evolution curve.

Sample E2, E3 and E4 show the same trend in the evolution of compressive strength. This trend is illustrated in Figure 3.

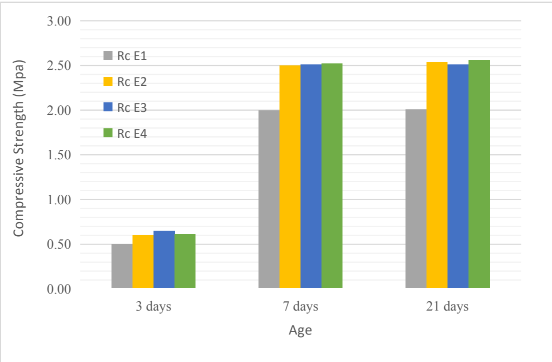


**Figure 3.** Evolution of Rc according to ages

All of the samples studied present the minimum specifications for their use in construction.

(1) The firing of raw clay bricks has increased the compressive strength and given its thermal insulation properties.

(2) In sample E2, the cement served as a binder, thus improving the stability of the brick, and will help prevent rising damp.

(3) In sample E3, lime replaces cement and plays the same role.

(4) Various hypotheses have been proposed to explain the interaction of lignosulfonates with clay fractions VAN OLPHEN (1963) envisages the adsorption of organic molecules on the lateral surfaces of clay crystallites at the level of the surface cations of the octahedral and tetrahedral layers of the sheets [5,6]. On sample E4 we observed that lignosulfonates would have the property of adsorbing on any surface having chemical carboxylic or hydroxyl groups capable of giving rise to hydrogen bonds; which hardens the brick and increases its compressive strength.

## 3. Conclusion and Recommendations

The objective of this study is the development of laterite in Eco village construction projects. The standardized geotechnical tests were carried out at the laboratory of Compagnie Sahélienne d' Entreprises.

The results obtained to meet the technical specifications of standard NF EN771-1. The evolution of resistance to compression shows a first phase of maturity between 3 and 7 days and stabilization between 7 and 2 days, from where we propose a period of cleaning of 14 days of earth bricks before the implementation of the buildings.

Depending on the area and the type of climate, we make the following recommendations:

(1) Use sample E1 in arid areas or with low rainfall

(2) Use the sample E2 and E3 in rainy areas without risk of capillary rise

(3) Use the E4 sample in rainy areas with the risk of capillary rise.

So we can say that in the face of current environmental concerns, raw earth returns to the spotlight thanks to its many advantages. Raw earth can be used in new construction, renovation, and rehabilitation both in traditional and contemporary ways. Raw earth has many qualities and is a material for the future.

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