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Elaboration and Characterization of Facing Blocks Made of Laterite and Cement: Influence of Cement on Strength

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Abstract

Lateritic soils are found in practically all regions of the country in Côte d'Ivoire. In order to produce quality materials with these laterites, that of Dabou was used and stabilized with Portland cement. Characterization tests on the briquettes thus produced revealed that the ideal cement content for which the briquettes can be used in construction is 20%. At this content, they have flexural strengths of 3.5 MPa dry and 2.5 MPa wet much higher than the standard (greater than or equal to 0.6 MPa). The incorporation of Portland cement into the laterite makes it possible to limit the dimensional variations linked to the departure of excess mixing water. Cement also improves the strength of facing blocks to water absorption and surface wear. In terms of wear strength, the cement content which allows the facing blocks to hold well in accordance with the standard and other factors is 20%. The presence of cement in contents greater than 10% allows, through its crystallization, the formation of cement hydrates which will occupy the spaces left free between the laterite particles, which gives good cohesion between the particles. These results confirm once again that the laterite-cement facing blocks can be used in construction with 20% cement.

Keywords

Laterite, Portland Cement, Crystallization, Facing Blocks, Strength

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1. Introduction

Faced with the high request for housing in African cities due to the population explosion, most developing countries have initiated a policy of low cost housing. It has become essential to make use of the reserve of local materials. It is therefore in this context that one of the many laterites in the country was used for the production of facing blocks.

Thus in this study, facing blocks are manufactured with a TERSTARAM press and subjected to characterization tests which made it possible to assess the influence of cement on the mechanical and physical performance of facing blocks.

2. Materials and Method

2.1. Raw Materials

The raw material for this study consists of laterite and Portland cement.

The laterite used has been the subject of a characterization [1]. This laterite is taken from a quarry located near the locality of Dabou (West of Abidjan, South of Côte d'Ivoire).

It is a clay sand composed of 62% sand (quartz and feldspar), 20% clay (mainly composed of kaolinite and illite) and 18%

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silt. It is mainly composed of SiO_2(59.4%) of Al_2O_3(22.3%) and Fe_2O_3(7.42%).

The cement is CPJ composite cement (CEMII/B). It is composed of 65% clinker and 30% filler (granite powder).

It's guaranteed nominal resistance is 32.5 MPa [2]. Its specific surface measured with a pycnometer is 2800 cm^2/g with a density of 3.1. It is a monomodal cement, the majority of the particles have a size of 20 µm.

2.2. Experimental Methods

The laterite is first air-dried and then crushed. Then it is passed through a 1 mm sieve. The passer-by obtained is mixed with cement contents varying from 0 to 50% (mass percentages).

This mixture is mixed with water and then kneaded until a homogeneous paste is obtained. This mixing water content is determined from the Norton test [3]. It corresponds to that which allows the various doughs produced to have constant maneuverability. It corresponds to a water/cement ratio of 0.6 [4].

A quantity of paste thus obtained is introduced into the mold of the TERSTARAM press (manual press with static compaction).

It is then compacted and the block is demolded and dried for 28 days in the laboratory at a temperature of 26°C and a humidity of 70%. The compaction force is around 2 MPa.

2.2.1. Determination of Shrinkage on Drying and Weight Loss

$Sd = \frac{V_t - V_0}{V_0} * 100$ The mass as well as the dimensions are measured everyday during the 28 days so that with these measurements, the drying shrinkage(Sd) and the weight loss(Wl) are defined by the formulas 1and 2:

$$Wl = \frac{M_t - M_0}{M_0} * 100 \quad (1)$$

$$Wl = \frac{M_t - M_0}{M_0} * 100 \quad (2)$$

Where Vt and Mt represent the volume and mass of the test piece after t days of storage, Vo and Mo represent the volume and mass of the test piece after 28 days of storage.

2.2.2. Determination of the Porosity and the Water Absorption Coefficient by Capillarity

The porosity was measured according to the procedure recommended by the AEPC-AFREM [5]. The porosity is given by the expression (3).

$$n = \frac{M_3 - M_1}{M_3 - M_2} * 100 \quad (3)$$

Where *n*, M_3, M_2, and M_1 represent respectively:

n is the porosity;

M_3: the mass of the water saturated sample weighed in air;

M_2: mass of the water saturated sample weighed in water and

M_1: mass of the dried sample

Similarly, the water absorption coefficient (W_a) was determined according to CRATerre [6]. This coefficient is given by the formula 4:

$$W_a = \frac{m_w + m_d}{S.\sqrt{t}} * 100 \quad (4)$$

Where:

W_a is the water absorption coefficient in%

m_w is the mass of the wet sample, in kilograms.;

m_d is the mass of the dry sample, in kilograms;

s is the surface of the submerged face, in square meters:

t is the time in seconds

2.2.3. Mechanical Properties

The mechanical properties are summarized in the 3-point bending test and the wear test.

The three (3) point bending test is carried out according to standard NFB51-008 and is carried out using a hydraulic press. Bending strength expressed in MPa is given by the formula 5:

$$Sb = \frac{3FL}{2be^2} \quad (5)$$

Where F: the load measured at failure,

L: distance between the two support points,

b:width of the test piece, e: thickness of the test piece

Wear test makes it possible to characterize material durability, to assess the extent some types of degradation and appreciate the ability of materials to resist surface erosion. For the measurement of wear, the device used was developed by [4].

The device consists of a small carriage resting on four wheels, below which finds a steel point fixed. The carriage is mounted on two rails which, by means of their two ends. The device is fixed to the support through the metal rods. The wheels have a translational movement along the metal rods. The truck is loaded with a mass of 3 kg.

A wrist pulls the cart which is moves on the wheels. We characterize the wear of the facing blocks by the loss of weigth after 25 application cycles on the faces of the facing blocks constituting the internal and external facing of the future wall.

3. Result and Discussion

3.1. Mechanical Properties

3.1.1. Three (3) Bending Test

Facing blocs are materials used for coating walls. They are generally subjected to the impacts of projectiles. The impact of these projectiles on these blocs is made at precise points which translate a bending stress. To do this, we determined the flexural strength of the blocs for each cement content. The results obtained are shown in Figure 1. They are the means calculated on 5 samples after 28 days.

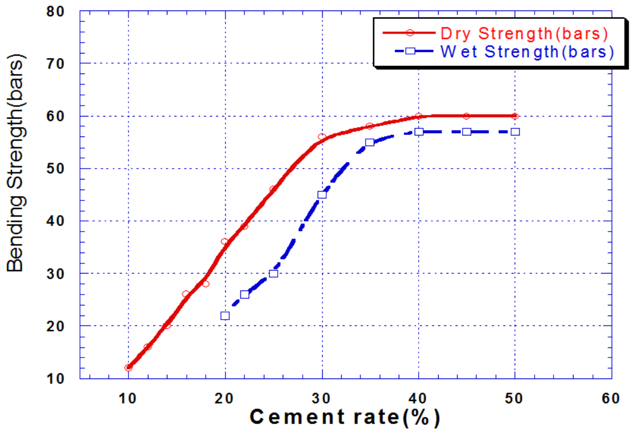

Figure 1. Curves of the bending strength.

This figure shows that the bending strength of dry blocs varies with the cement content. From 0 to 10% cement, it is impossible to obtain results on the blocs because of the sensitivity of the measuring devices and their too low resistances. From 10 to 30% of cement, the bending strengths increase and from 30% of cement, they stabilize around 60 bars for dry blocs. We note that there is even a proportionality between the strength and the cement content.

This variation in strength with the cement content according to [4, 7-9] can be explained by the cohesion between the different complexes formed (clay-cement; sand-cement and clay-sand).Infact, in the presence of the cement, the laterite forms with the complexes thanks to the pozzolanic reaction between the clay fraction of the laterite and the cement. When the cement content is above 10%, the amount of bonds between the different complexes leads to the formation of an increasingly stable matrix.

The placement of this skeleton of the block contributes to the increase in flexural strength.

From 0 to 5% of cement, the strength is zero because the blocks dissolve in water because of the absence of stable bonds between all the laterite particles. On the other hand, the increase in strength from 10% cement is due to the establishment of connections between the complexes thanks to the large quantity of cement which ensures the formation of the skeleton of the blocks.

The stabilization of the evolution of the flexural strength from 30% of cement shows that from this cement content, any additional of cement is useless because, this increase no contributes to the improvement of laterite-cement blocks strength. This is explained by the fact that from 30% of cement, the volume of cement is sufficient to form enough bonds between all the particles of the laterite and therefore, its increase becomes useless. Before this limit cement content, the curve of the flexural strength of the laterite-cement blocks is a straight line. This aspect of the curve reflects the gradual increase in the improvement of the strength of the facing blocks in connection with the evolution of the volume of cement. This confirms the results of the work of [10, 11] studying the stabilization with cement of lateritic soils (geo-concrete) as a function of the cement content. In view of these results, to make acceptable facing blocks at the flexural strengths, the cement content must be between 10 and 30%.

Figure 1 also shows that on wet blocks, the flexural strengths increase with the cement content.

In contrast, the blocks do not resist after 24 hours of immersion for the wet bending test when the samples contain less than 20% cement. But beyond 20%, we observe a proportionality identical to the case of dry samples.

3.1.2. Effect of Cement on Wear

The blocks are immersed in water for 48 hours and dried in the sun for 72 hours, then the opposite side to constitute the exterior facade of the future wall is brushed with a wire brush for 25 cycles. The results obtained are shown in Figure 2.

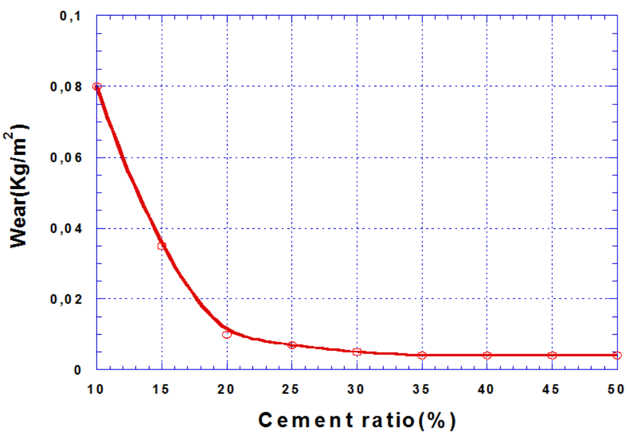

Figure 2. Wear strength curve.

This figure shows that for contents below 10%, it is impossible to determine the strength to wear, because the blocks dissolve completely in water upon immersion during the 48 hours. This figure also shows that wear decreases with the cement content.

Indeed, it drops very quickly between10 and 20% of cement then it tends towards stabilization at 0.005 kg/m^2 beyond 30% of cement. Above 30% of cement, wear becomes constant because these welling due to water and the shrinkage associated with drying are zero.

The cohesion between the particles is very strong. Thus brushing, the mass loss of the block is very low. Figure 3 shows the surface condition of the blocks after measuring the wear. The depth of the lines left by brushing decreases with increasing cement content.

Figure 3. Surface condition of the blocks after wear.

The cement incorporated in the briquettes therefore has the effect of limiting this surface erosion. In Côte d'Ivoire, the pressure exerted by atmospheric conditions on a surface would produce surface erosion of 2.5 kg/m^2 [4]. Our study shows that for cement contents less than or equal to 20%, there is a loss of mass in wear less than 2.5 Kg/m^2.

Thus 20% of cement is the ideal and minimum cement content from which laterite-cement blocks can be used in construction without their surfaces being protected.

Simular results are obtained by some authors during their studies on the stabilization of sand by latex [12] and on the stabilization of sand by cement with the addition of glass powder [13].

3.2. Physical Properties

3.2.1. Influence of Cement on Dimensional Variations During Drying

Dimensional variations made of drying shrinkage and evaporation. They were measured for 28 days on the blocks after demolding. The figure 4 below presents the results of the study at the drying shrinkage of facing blocks.

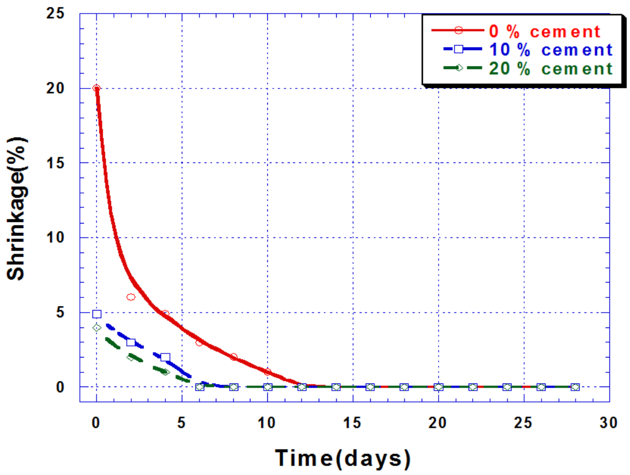

Figure 4. Curve of the variation in shrinkage.

The graphs show that the shrinkage on drying of laterite-cement facing blocks decrease over time.

The graph can be subdivided into three parts which are:

1. The first, between the first and the fourth day, corresponds to a straight line where the withdrawal is proportional to time. The slope of this straight line represents the speed of withdrawal. It's constant and strong;
2. The second, between the fourth and the tenth day, is equivalent to the concavity of the curve. The speed of withdrawal decreases overtime;
3. The third after the tenth day corresponds to the constant part of the curve. The withdrawal speed is zero.

For blocks which contain cement (20% and 40%), the first part of the curve is reduced because of the cement which modifies the duration of the withdrawal as a whole.

This is explained by the fact that the hydrated cement crystallizes between the laterite particles in the blocks (the specific surface of the cement being larger than that of the laterite). Thus, the pores are reduced, which reduces the bringing to get her of the particles therefore the shrinkage.

Similarly, the drop in shrinkage with the cement content would be due to the extent of crystallization of the latter between the laterite particles.

On the other hand, the drop in shrinkage over time is due to the decrease in the amount of water likely to be able to evaporate.

In short, during the drying of the facing blocks, the amount of shrinkage seems to be due to the evaporation of the excess mixing water. This departure from the water would occur simultaneously with the withdrawal and would be influenced by the cement content.

To better explain these phenomena, let's also examine the evaporation of water as a function of time.

3.2.2. Influence of Cement on Open Porosity

The porosity values shown in Figure 5 correspond to the average measured on three blocks of the same cement content.

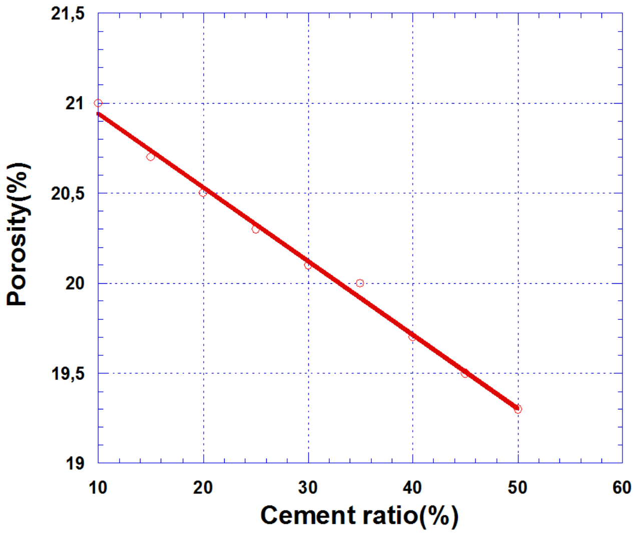

Figure 5. Porosity curve of laterite-cement bloc as a function of cement content.

The curve shows that for cement contents of less than 10%., the porosity cannot be measured because the blocks are totally or partially dissolved in water. From 10 to 50% of cement, the porosity drops from 21 to 19.30%.

The drop in porosity is linked to the crystallization of the cement between the laterite particles. Cement, dissolving in water, naturally occupies the space between the laterite particles and helps to close the pores accessible to water.

This drop in porosity is also observed by [14, 15] during these studies on the stabilization of laterite by starch.

Since the water absorption capacity of materials is linked to porosity, let's examine the absorption coefficients of blocks because it is generally responsible for most of the damage in the building.

3.2.3. Influence of Cement on the Absorption Coefficient

Figure 6 shows the variation of the absorption ratio as function of the cement content.

We observe that the absorption ratio decreases with the cement content. It drops from 0.08 to 0.055% when the cement content increases from 10 to 30%. Above 30% cement, it stabilizes at 0.055%.

The drop in the absorption coefficient from 10 to 30% of cement is due to the gradual closure of the capillaries. Above this cement level, the absorption coefficient is practically constant because the porosity would have become constant. The coefficient of optimal water absorption in construction imposed by the standard [16-18] measured according to the Haller test must be less than or equal to 0.15%.

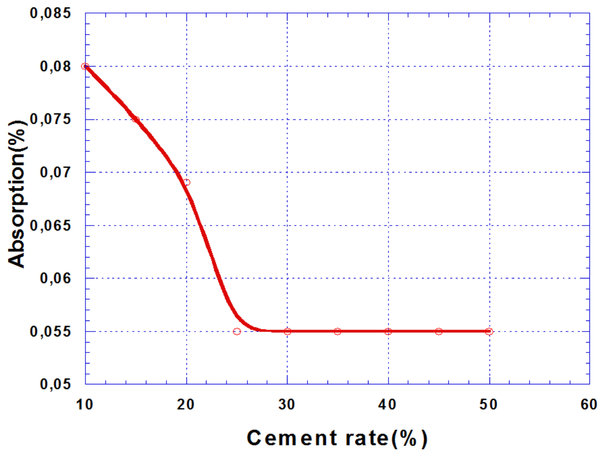

Figure 6. Absorption ratio as a function of cement rate.

According to this standard, 10% of cement would be the ideal cement content for the blocks to have an acceptable absorption coefficient, that is to say capable of with standing the aging caused by water. These results further confirm that above 30% of cement, its increase has no effect on the properties of laterite cement blocks.

Some authors have obtained similar results during their study on the stabilization of laterite by latex [19, 20].

4. Conclusion

At the end of this study of the influence of the binder on the structure of facing blocks based on laterite stabilized with cement, we can say that the incorporation of Portland cement in the laterite allows to limit dimensional variations, also ensures mechanical strength, water absorption.

The best physical and mechanical strength of blocks is obtained at a rate of 20% of cement.

In the light of all these results and by comparing the laterite-based facing blocks with other materials in the construction field, we retain the content of 20% cement as the ideal value for it to be used in construction, because at this content, the cement by its crystallization occupies the interstices of the lateritic matrix.

Thus it contributes to improving the porosity and the permeability, which leads to better mechanical strengths.

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