

Use of Alternative Binder: Influence of Latex Content on Physical and Mechanical Properties of Laterite Stabilized with Raw Rubber Latex

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Abstract

Raw rubber Latex contents, from 0% to 30% were used to stabilize lateritic samples to provide an alternative to cement stabilization. These samples were submitted to physical tests (water resistance test, absorption test) and mechanical tests (dry compressive strength test). The results indicate that samples made of latex content less than 15% dissolve completely into water. So it was impossible to make sample with these contents. Samples with 15% of raw rubber content or more are steady after water resistance test. The absorption rate of these samples decreases as the latex content increases. It goes from 14.45% for the samples at 15% to 5.87% for those at 30%. Therefore, the compressive strength test indicates that the resistance increases from 0.37 MPa for samples without latex to 3.15 MPa for those at 30% of latex content. Also, the rheological study shows that the samples pass from a brittle behaviour to a plastic behaviour when the latex content increases. The behaviour of the sample according to these different tests shows that this material can be used in several activity areas, such as construction, road building and sports area.

Keywords

Laterite, Raw Rubber Latex, Sample, Stabilization, Characterization

1. Introduction

The earth is used in many works, as evidenced by achievements in many places on the planet. After being abandoned for the benefit of “modern” building materials, especially concrete and steel, it is now the subject of renewed interest in many countries for his undeniable advantages [1]. Sand and laterite are the main

raw materials in these projects, most of which use a cold stabilizer based on hydraulic binders such as cement.

The production of clinker, the main component of cement, generates a significant release of CO₂, which is estimated at 5% of the annual CO₂ production in the world [2]. Avoiding the emission of this greenhouse gas and air pollution related to the manufacture of clinker is an important problem of stabilization and is the subject of many researches in the cement industry through the use of cementitious supplementary with hydraulic or pozzolanic properties [3] [4] [5]. Therefore, using other types of ecological binder is one of the solutions.

Rubber latex is a raw material from rubber tree, which grows under tropical climate. It is a material present in Côte d'Ivoire where numerous rubber plantations are exploited. Besides, this country is the first African producer and the seventh in the world with more than 800,000 t of dry rubber [6]. This study aims to stabilize the laterite with raw rubber latex for applications. It also aims to promote otherwise raw rubber latex through its use as a binder. To do this, a methodology has been developed to make samples and they have been submitted to tests.

2. Material and Methods

2.1. Material

The raw materials used for this study are raw rubber latex (collected in private rubber plantations near Abidjan) and laterite (taken inside the campus of Felix Houphouet-Boigny University).

2.2. Elaboration

Laterite extracted from the site is dried in open area for a week and pass to sieve of 2 mm of diameter. Before making samples, the sieve pass was subjected to granulometric analysis (sieve size and sedimentometric analyses). After collection, 3% of ammonia (NH₃) was added to latex, to delay coagulation. That solution is directly used as binder to make samples according to **Figure 1**. For this study raw rubber latex was directly used to spoil the laterite. The mass proportions of latex added to the laterite are 15%, 20%, 25%, and 30%. Indeed for raw rubber content less than 15%, the quantity is not enough to consolidate the samples so it was impossible to make blocks. The samples produced are (5 × 5 × 8) cm³ in size.

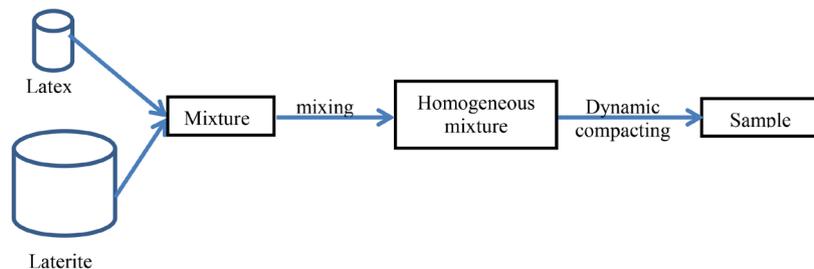


Figure 1. Sample elaboration process.

2.3. Sample Characterization

Water resistance

Water resistance test is used to estimate the stability of the material after immersion into the water. This test consists of drying samples into an oven at 60°C until constant mass and immersing them into water for 4 days. After removed them, the behaviour and surface aspect (appearance) of samples are examined. The same observations are made again after 48 hours of drying.

Water absorption

Water can penetrate through most interstitial pore into a material and cause its disintegration. Water absorption was determined by the following procedure:

Sample is dried into an oven at 60°C until constant mass, and weighed (M_s). They are immersed in water for 24 hours, to obtain (M_h), the wet mass.

Absorption is given by the following formula:

$$n = \frac{V_v}{V_T} \times 100 = \frac{M_h - M_s}{\rho V_T} \quad (1)$$

n : absorption (%), V_v : Void volume, V_T : Total volume, M_h : wet weight, and M_s : dry weight.

Compressive strength test and rheological study

The compressive strength test consists of submitting the samples to a load until they break. This test reflects the resistance of the samples to a force and also the quality of the bonds between the different constituents. The compressive strength for each type of sample is given by the following formula:

$$\sigma = \frac{F}{S} \quad (2)$$

with

σ : resistance (MPa),

F : force (MPa),

S : surface where force is applied (mm²).

During this test two displacement sensors LVDT were put on the samples to determine the deformations; one for horizontal deformations and the other for vertical deformations. The data collected were used to study the rheological properties of the samples through stress-strain curves.

3. Results and Discussions

Characterization of Laterite

The results of particle size analysis obtained by sieve size analysis and sedimentometric analysis are given by the granulometric curve presented in **Figure 2**.

This graph shows that this lateritic soil is composed of 10% clay ($\Phi \leq 2 \mu\text{m}$), 20% silt ($2 \mu\text{m} \leq \Phi < 63 \mu\text{m}$), 68% sand ($63 \mu\text{m} \leq \Phi < 2 \text{mm}$) and 2% gravel ($\Phi \geq 2 \text{mm}$). According to [7], it is silty sand.

The curve is included in textural diagram of earth recommended for making compressed earth blocks (**Figure 3**) [8]. According to standard ARS 680 [8] this soil sample can be used for compressed earth blocks (CEB).

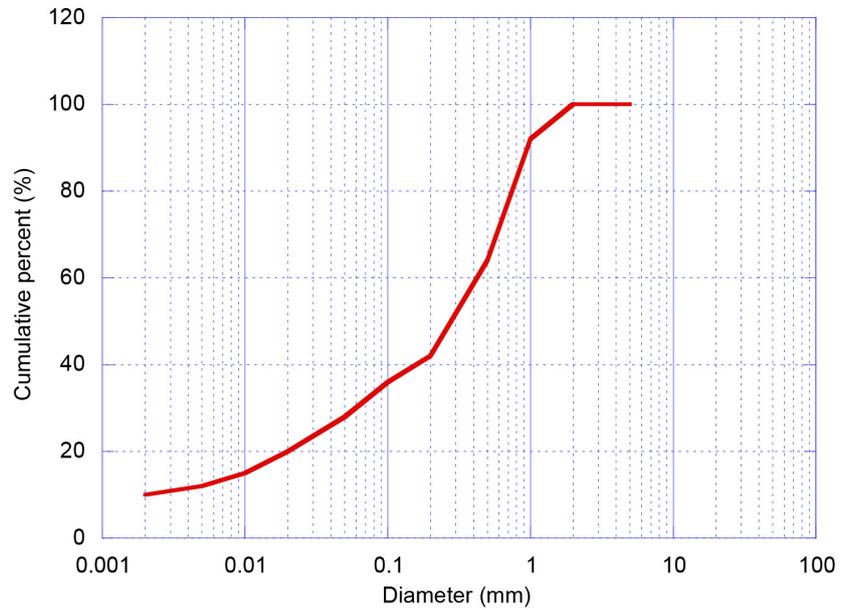


Figure 2. Particle size distribution of laterite.

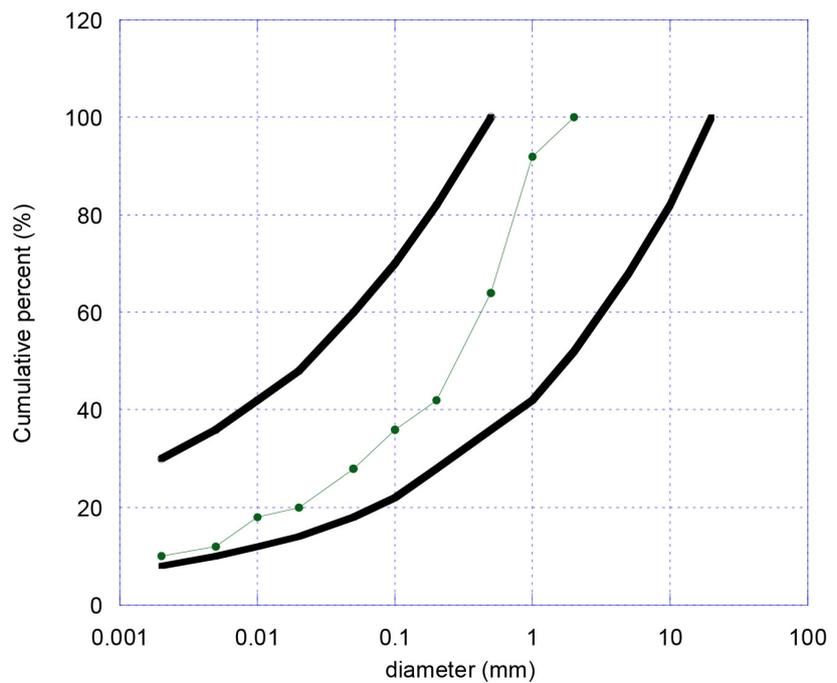


Figure 3. Textural diagram of earth recommended for compressed earth block.

Water resistance

The use of a material depends on its weather resistance. The samples were observed after four days into water (96 hours) and the results are shown in **Table 1**.

This table shows three behaviours: the samples without latex dissolve completely. Those at 15% do not show visible damage but the immersion water is coloured and from 20% of latex the sample are steady. These three states are related to the rate and mode of action of the latex.

Table 1. Condition of sample after staying into water.

Latex content (%)	Behaviour
0	Rapid total dissolution
15	Coloration of immersion water no apparent damage on sample
20	steady
25	steady
30	steady

The total dissolution of samples without latex is caused by the rupture of the bonds between the laterite particles under water pressure. The immersion water of sample at 15% of latex is coloured because the particles which are not coated by rubber latex are in contact with the water. So these particles transfer their red colouring to the immersion water. The samples are stable into water from 20% because the amount of latex is sufficient to maintain the laterite particles. Indeed [9] showed that the coagulated latex forms an envelope around the particles (Figure 4). This shell around the particles isolates them from the water and prevents a direct contact between the water and the particles of the laterite, which makes dissolution impossible.

From this analysis, it appears that a minimum content of 20% of latex would be required to stabilize the samples under the experimental conditions described above.

Absorption test

Absorption rates of the different series of samples are shown in Figure 5.

The absorption rate decreases as the amount of raw rubber latex increases in the samples. It goes from 14.45 to 5.87 when raw rubber latex content varies from 15% to 30%. The measurement on samples without rubber latex was impossible because of their rapid dissolution.

The decrease in the rate of absorption could be related to the coagulation of the rubber latex which forms a shell around the particles. Furthermore, the coagulation of the latex between the laterite particles contributes to close the pores accessible to water, which considerably reduces absorption of water.

Compressive strength test

Compressive strength results obtained on the different samples are presented in Figure 6.

The compressive strength of sample increases as rubber latex content increases. It goes from 0.37 MPa for sample without rubber latex to 3.15 MPa when the latex content is 30%. Indeed, the rubber latex used as a binder reinforces the bonds and closes the pores between the laterite particles. An observation of the microstructure indicates that the latex coats and forms a shell around the particles (Figure 7(a) and Figure 7(b)) but also creates a network that binds the particles like a net (Figure 7(c)).

The compressive strength measured is similar to those obtained by and [10]

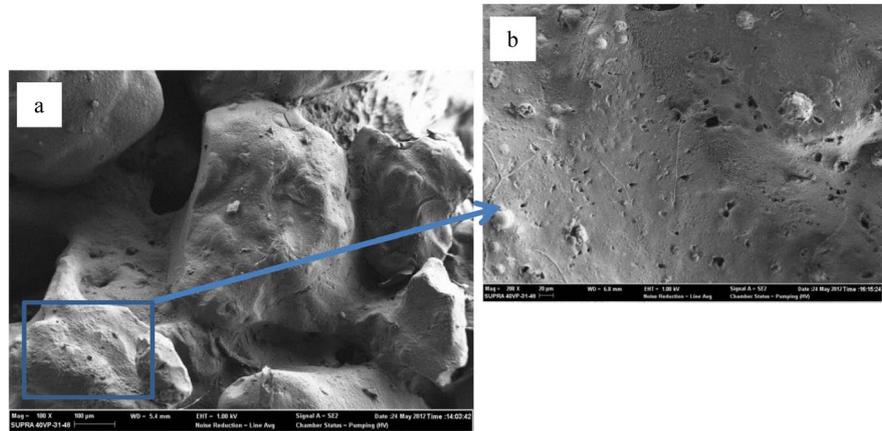


Figure 4. Microstructure of samples showing the coating of laterite particles by rubber latex. (a) Sand particles coated with rubber latex; (b) Zoom on the latex shell covering the sand particles.

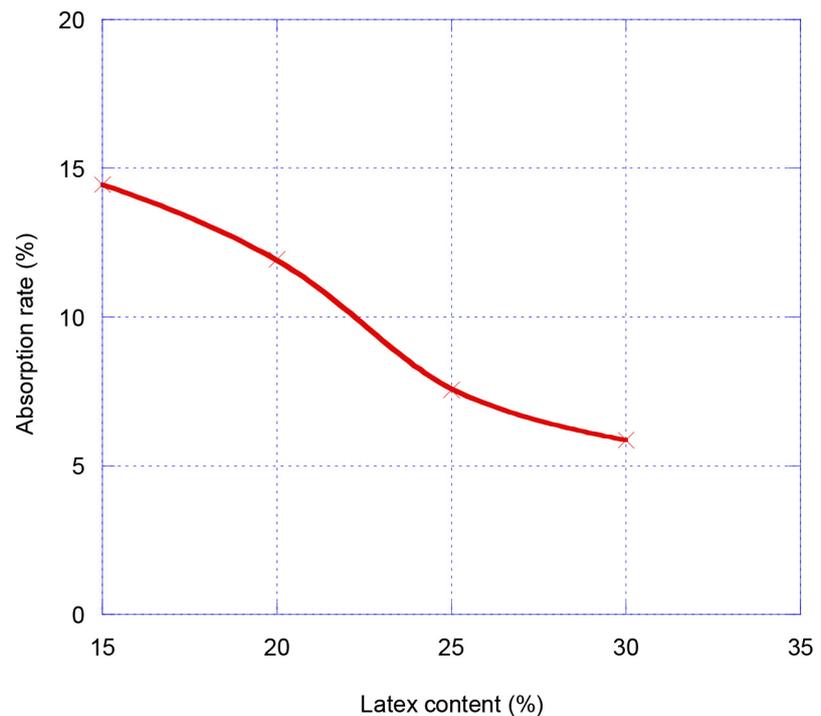


Figure 5. Variation of absorption rate according to rubber latex content.

[11] [12] on comparable materials. Their works were focused respectively on the use of Nere extract [10] [11] and shea [12] for the stabilization of compressed earth blocks (CEB). They are also similar to adobe and compressed adobe studied by [13].

Rheological behaviour

From stress strain curves (Figure 8) young's modulus of samples according to their raw rubber content has been determined. Table 2 shows that young modulus of samples decreases with latex content. So they become more and more ductile. This plastic behaviour is a consequence of the coagulation of the rubber

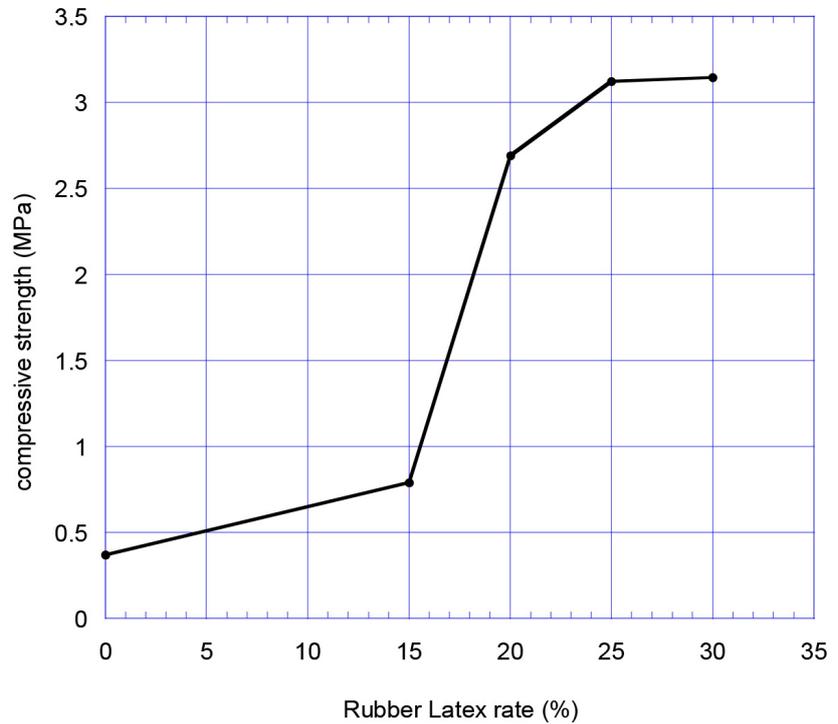


Figure 6. Variation in compressive strength according to rubber latex content.

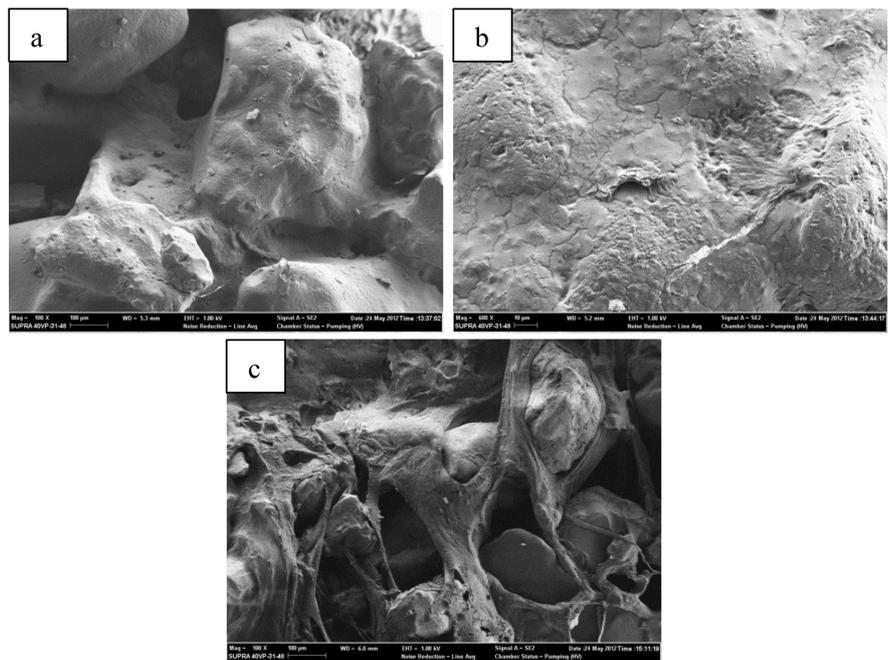
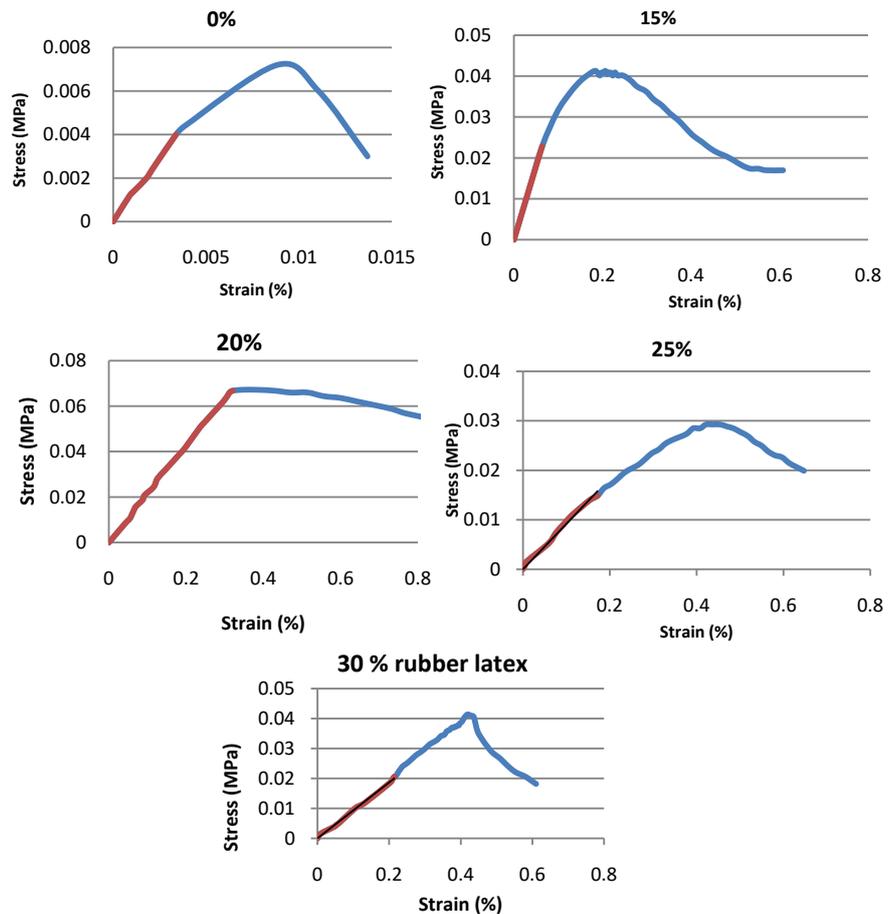


Figure 7. Microscopic observation of bonding mode between the laterite particles and rubber latex.

latex on the microstructure of the samples. Indeed this behaviour is favoured by the presence of latex between the particles as shown in **Figure 7**. This coagulated latex will increase the mobility of the particles and increases the deformability of the samples. The latex shell around the particles increases their mobility because

Table 2. Young modulus of samples.

Rubber latex content (%)	Young modulus (MPa)
0	115.7
15	37.5
20	21.5
25	9.1
30	9.0

**Figure 8.** Stress-strain curve of sample with different rubber latex content.

of its elasticity. This elasticity increases the deformability of the samples, hence an increase in the plastic behaviour.

According to [14] the acquired properties allow considering the use in many areas including that of road construction, the development of play space. The concentration of raw rubber latex depends on area of used but 20% or more is needed.

4. Conclusions

This study is a contribution to the use of raw rubber latex as an alternative binder to substitute Portland cement. Rubber latex, which is one of the basic raw

materials for the pneumatics industry, can be valorized otherwise.

Thus studied laterite, which is silty sand, can be stabilized with raw rubber latex. The results indicate that 20% of latex would be required to stabilize the samples. The compression strength measurement shows that it increases with the latex content. Similarly, there is an improvement in physical properties such as the absorption rate which decreases when the latex content increases. The study of the rheological properties shows that the incorporation of the latex makes it possible to pass from a brittle behaviour to a semi-ductile behavior.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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