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Study Of The Soil Stabilization Mechanism By Natural Stabilizers – Case Sweet Potato - Banana - Zebu Manure

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Abstract – The general objective of this study is to develop a new process for stabilizing laterites at a lower cost. Instead of using traditional stabilizers, especially cement and lime, we opted to use different natural stabilizers for stabilizating lateritic soils. On one hand, we use plants particularly leaves, stems and starches of sweet potatoes, as well as leaves and fluids of the banana trunk. On the other hand, we propose the stabilization of laterite with zebu manure and some additives such as sugar, urea. Zebu manure from slaughterhouse waste is therefore easy to find. Sweet potato and banana plants are also easy to find since they are abundant and exist all year long. These are the reasons which led us to use them for the treatment of laterites in material for construction.
For each type of stabilizer, we varied its mass percentage in the earth-stabilizer mixture at rates of 5%, 10%, 15%, 20% per mass. Then manufacturing tests were carried out in our laboratory and made it possible to determine the optimal dosage of the various
Inputs. To do this, this study was conducted with the aim of examining the mechanical properties of the Compressed Earth Block (CEB) with used natural stabilizers. This study of the geotechnical, physical and mechanical characteristics of the soil aims to facilitate a rapid identification of the soil, then the implementation of stabilization procedures and the practical determination of the compaction conditions. With sweet potato plant, the whole can be a good binder for laterite stabilization. Our product composed of 85% of laterite and 15% of whole stabilizer (leaves+stem), gives the best result with a compressive strength of 3.9 MPa in the dry state and 1.7 MPa in the humid state. With banana tree, the binder is 10% for the liquid from banana trunk in this work. This dosage offers the maximum dry strength of 4.25 and 5.0 MPa. And finally, in the presence of organic products (sugar, urea), we obtain the reduction of the ferric oxide of the laterite, which saturated with zebu manure gives compacted test specimens, whose resistance to dry compression can reach 17 MPa and which is water resistant. Indeed, after immersion of 24 hours, their strengths still reach 5.2 MPa.

Keywords – Laterite, Stabilization, Natural Stabilizers, Leaf, Stem, Whole And Starch, Sweet Potato, Banana, Zebu Manure, Sugar, Urea, Microbial Reduction, Compressive Strength, Porosity.

I. Introduction

In Madagascar, like many developing countries, housing is an essential element for people so that they can live with dignity. Unfortunately, Malagasy people face a crucial problem of economic housing. The construction method requires incessant increase of the price of hardware materials, yet they are out of reach of the majority of the Malagasy population. This economic housing crisis of such magnitude urgently requires new solutions. These are the reasons that led us to make the best use of local resources, particularly laterite, an abundant raw material, omnipresent in all regions of the island of Madagascar, by mixing with various compounds of natural substances readily available as stabilizers, particularly sweet potato leaf, stem, whole (leaf plus stem) and starch, banana leaf and trunk, and zebu manure. Therefore, we aim to develop local building materials that are inexpensive and easy to manufacture. So it is essential to know if the inclusion of these natural stabilizers with laterite could improve the mechanical strength and water resistance of the resulted materials. The mechanical performance verification was done using a Test Well Universal Hydraulic Press.

II. Materials And Methods

2-1- Laterite

2-1-1- Sampling sites

The lateritic soils that we used for the experimental part of our work were sampled in the district of AlakamisyFenoarivo, about 0.5m to 1m deep, with geographical coordinates: Latitude: 18 ° 56'33.09 "; Longitude 47 ° 25'35.55 ".

Figure 1: Location map of Alakamisy sample collection sites

2-1-2 Identification of materials

2-1-2-1 Chemical and mineralogical analysis of the studied laterites

The elemental chemical analysis carried out established that Alakamisy laterite consists of Kaolinite as a clay mineral. An appreciable amount of iron oxides and hydroxides in various forms such as Maghemite, Goethite and Hematite, shows that the sample is a ferralitic soil.

2-1-2-2 Particle size identification of the soil

The test consists of classifying the different grains constituting the sample using a series of sieves, nested on top of each other, the size of the openings of which decreases from top to bottom.

Based on that identification, granulometrically, clay soil and the sample are rich in fine particles. The percentage of the sieve at 0.080 mm brings us into the realm of silt and clay.

2-1-2-3 The limits of Atterberg

The Atterberg limits are obtained from tests to determine the liquidity limit and the plasticity limit in accordance with standards "NF P 94 - 051, October 1993". The results obtained are represented in the following table:

Table 1: Atterberg limits of laterite

Natural water content W%	31 ,6
Liquidity limit wL (%)	77 ,6
Plasticity limit wp (%)	48,6
Plasticity indexIp (%)	29
Consistency index Ic (%)	1,6

Note that the sample is classified in the field of plastic clay. This is verified by the plasticity index result of this sample; Ip> 17 is therefore a clay type soil, more precisely classified in the field of plastic clay.

2-1-2-4 The blue test

The methylene blue test was performed to determine the activity of clay in the soil sample. It represents the amount of blue that can be adsorbed on the internal and external surfaces of soil particles.

Depending on the analysis, the result of the blue value (VBS) 1.2 is between 0.2 and 2.5; we can therefore say that this sample is a loamy soil that is not very plastic and sensitive to water.

2-1-2-5 Compressibility

The objective of the test is to find the optimum water content corresponding to maximum dry density, by the Proctor test.

The results of the Proctor test of the laterite sample are given in the following table.

Table 2: Optimum Proctor references and natural water content of the sample.

Maximum dry density (T / m3)	1,6
Optimal water content (%)	23,3
Natural water content (%)	31,6

These results show us that these soil samples are of good quality if they should be used in the construction of structures or compacted earth material.

2.2 Composition of the mixture

For each type of natural stabilizer, we stabilized the laterites at rates of 5%, 10%, 15%, 20% per mass. The percentage of additives used was gradually increased in order to evaluate the selected stabilizers and to obtain a material capable of having better resistance to various solicitations. The objective of these various experimental trials is to find the optimal doses for the soil stabilization.

2.3 Determination of the characteristics of stabilized soil

The performance of stabilized products is evaluated by determining:

- the porosity;
- the compressive strengths in the dry state and in the wet state, by means of the simple compression test

2.4 Optimal water content for molding

The resistance of test specimens is directly related to their dry density: the higher it is, the better the resistance (Laurent G, 1985). Therefore, the aim of the test is to find the optimum water content corresponding to maximum dry density. To find the optimum water content, we produced several test pieces with different water contents. The optimum water content is the one, which makes it possible to manufacture the test specimen with the highest dry density. It is 20% for all experiments.

2.5 Naming of samples

To clearly distinguish the samples from one another, the following notations was adopted to specify the nature and proportion of the stabilizer used

- For the sweet potato plant

CESBL: Compressed Earth Brick with Leaf
CESBS: Compressed Earth Brick with Steam
CESBW: Compressed Earth Brick with Whole
CESBS: Compressed Earth Brick with Starch

- For the banana tree

CEBBL: Compressed Earth Brick with Banana Leaf
BCETBT: Brick of Compressed Earth with the Trunk of the Banana Tree

- For the zebu manure

CEBM: the laterite + liquid Manure mixture
CEBMSa: the mixture of laterite + liquid Manure + Sand 5% -
CEBMSaSu5: The mixture of laterite + liquid Manure + 5% Sand + 5% Sugar

CEBMSaSu10: The mixture of laterite + liquid Manure + 5% Sand + 10% Sugar
CEBMSaSu15: The mixture of laterite + liquid Manure + 5% Sand + 15% Sugar
CEBMSaSu20: The mixture of laterite + liquid Manure + 5% Sand + 20% Sugar

2.6 Manufacturing process

The diagram of the compressed earth brick manufacturing process is described in order to fully understand the different stages of the laterite stabilization and CEB manufacturing process that we followed during our experiments.

This process includes:

- The extraction and preparation of laterite;
- The preparation of the stabilizer;
- The dosage and mixing of the constituents;
- Kneading the mixture in the presence of water;
- Molding and compacting;
- Demoulding;
- The ripening cure;
- Drying and storage

The methodological diagram is summarized in the figure below.

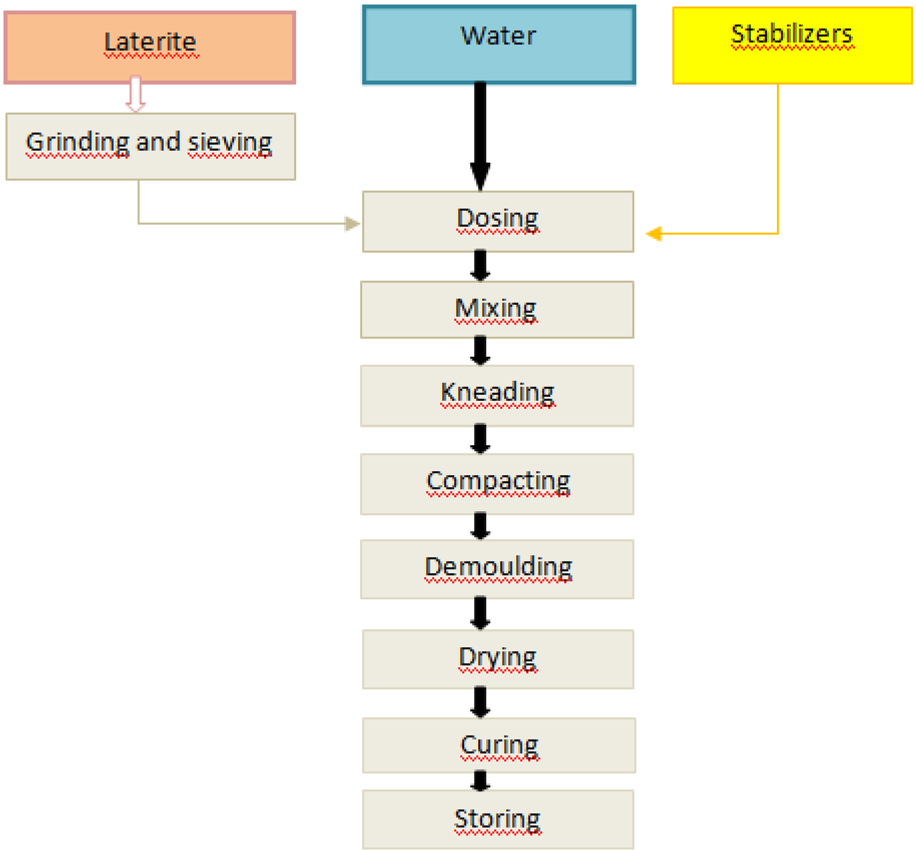

Figure 2: BTC manufacturing process

III. Results And Discussions

3.1 Results "case of the sweet potato plant"

3.1.1 Research of the plant content for optimal hardening

This test consists of adding gradualy an amount of the different parts of the sweet potato plant, the rate of addition was: 5, 10, 15 and 20%.

- Search for the optimum leaf content of the sweet potato

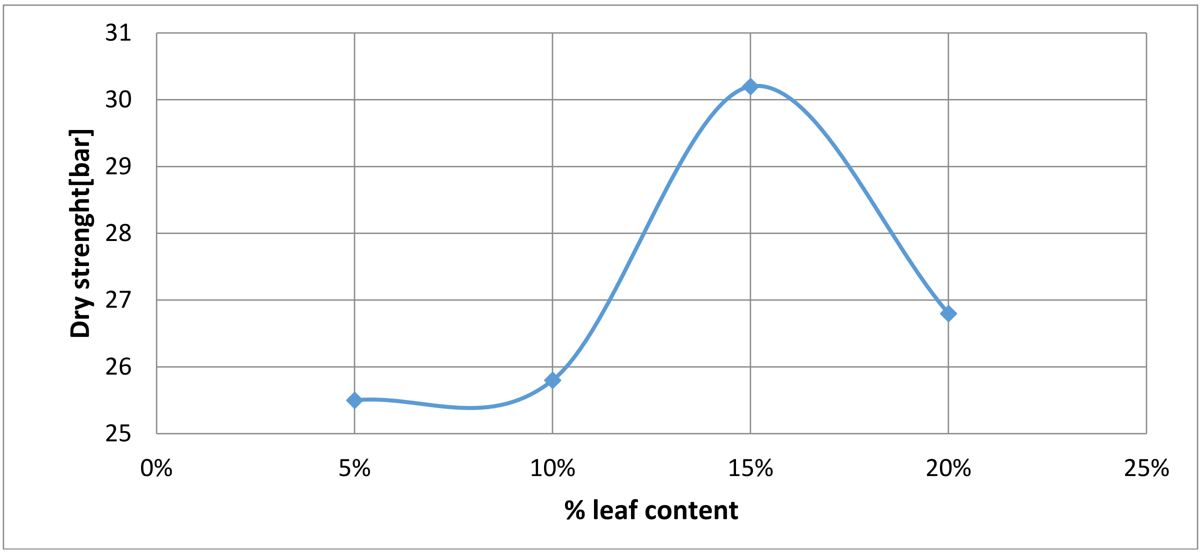

Figure 3: Influence of potato leaf content on dry strength

- Search for the optimum stem content of the sweet potato

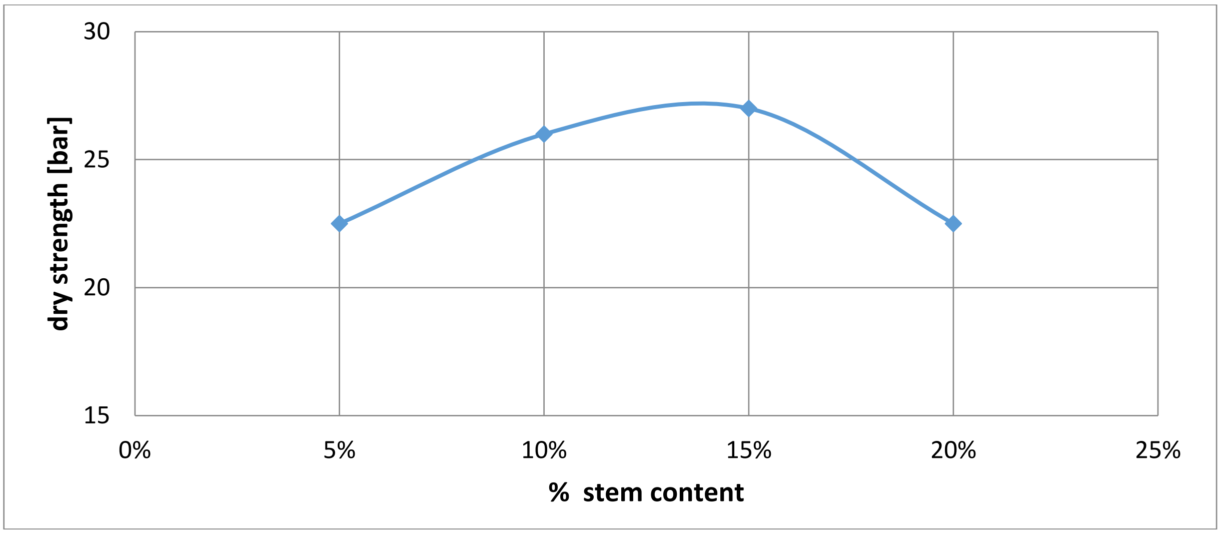

Figure 4: Influence of potato stem content on dry strength

➤ Search for the optimal whole content of the sweet potato

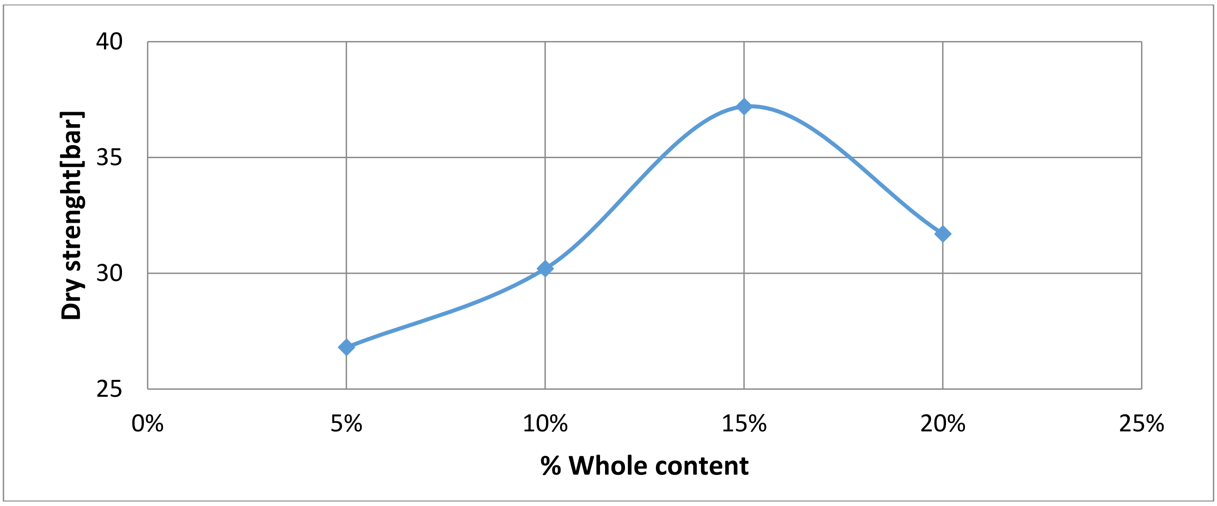

Figure 5: Influence of whole potato content on dry strength

These curves show that the addition of the additive at a dose of 15% for the three parts of the plant "stem, leaf and whole" allows to obtain interesting mechanical strengths in the dry state compared to other dosages. We want to compare the results with the next test with 15% for the three parts of the plant.

<u>3.1.2 Influence of the used part of the sweet potato on the resistance of briquettes</u>

a) Resistance in dry state "CEBLSW 15%": leaf, stem, or whole 15%

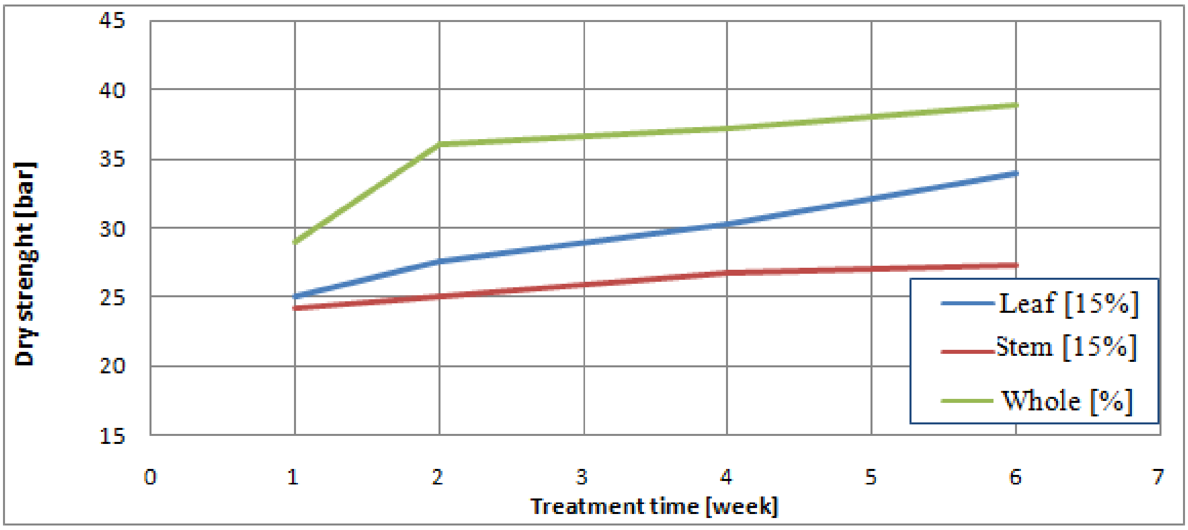

Figure 6: Evolution of resistance Rc on dry samples “CEBLSW 15%” as a function of treatment time and of the part of the plant.

From the above curve, we observed that the three curves increase strictly in a continuous way with the processing time. It is also noted that with a dosage of 15% of the additive (that is to say 85% of laterite), the treatment with the whole shows the best results. The stem is the less effective.

b) " CEBLSW 15%" wet resistance: leaf, stem, or whole 15%

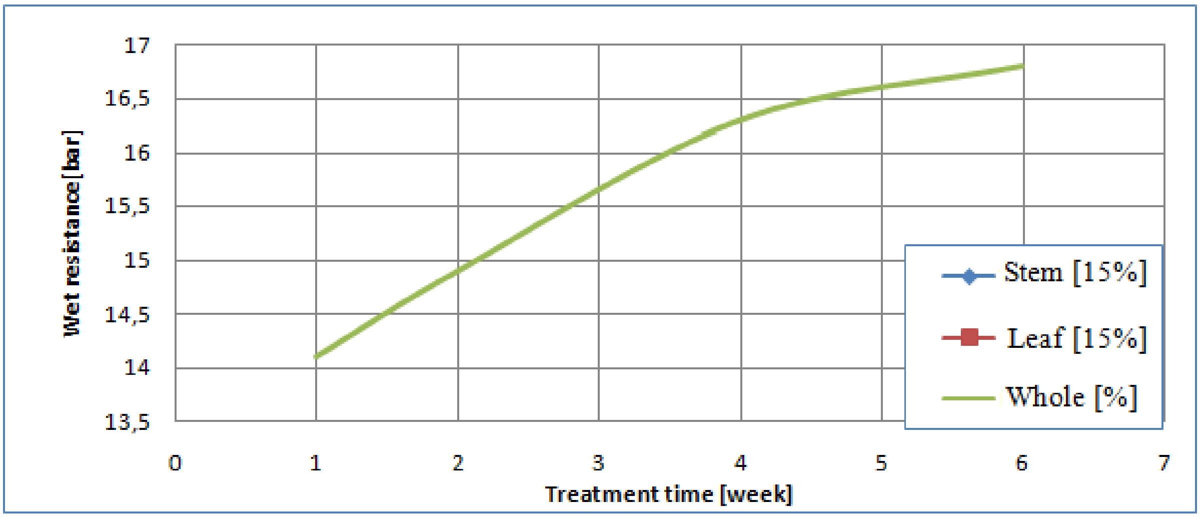

Figure 7: Evolution of resistance Rc on wet samples “CEBLSW 15%”according to the function of treatment time and of the part of the plant.

From the above curve, a wet strength result could not be obtained for the leaf and stem test of sweet potato. After 24 hours of immersion in water the test pieces disintegrated.

But with the entire 15% dosage, the test tube withstands treatment well; this part of the sweet potato gives the best results, the curve increases continuously over time.

3.2 Discussion on the use of the different parts of the sweet potato plant

By analyzing the changes in dry Rc obtained either as a function of treatment time or as a function of the percentages of the plant incorporated, this incorporation can provide an improvement on the

Compressive strength of the soil. This change on hardening degree suggests that sweet potato plants may play a chemical hardening role. This is due to the intrinsic properties of the plant.

Then, figures above (fig 3, fig 4 and fig 5) demonstrate that the rate of 15% gives the best results whatever the part of the plant used “stem or leaf or whole”.

If we want to compare the results with this rate of 15% for the three parts of the sweet potato plant, we noticed that the treatment with the whole part of the plant allows to obtain a better mechanical resistance compared to those of the treated soil with the other parts of the plant. This result is due to the nature and mechanisms of the entire physico-chemical phenomena involved in this stabilization: as a binder for the juice and as reinforcements for the fibers.

Finally, according to the result of the compressive strength in the wet state, on briquettes with 5%, 10% and 20% of the whole plant, there is degradation of the peripheries of the sections of them after a few days of soaking in water (fig7). The more water infiltrates, the more the briquettes gradually degrade. After approximately a week, the briquettes dosed at 5%, 10% and 20% are completely degraded while those treated with 15% binder resist the treatment. This means that the most effecient is effectively 15%.

3.3 Results "Banana case"

3.3.1 Influence of the banana trunk content on briquettes

We will show simultaneously the results of two different tests, using the binders such as trunk juice and thick liquid from the banana trunk in order to find the best stabilizers for laterite.

a) Compressive strength in the dry state and dose of the trunk

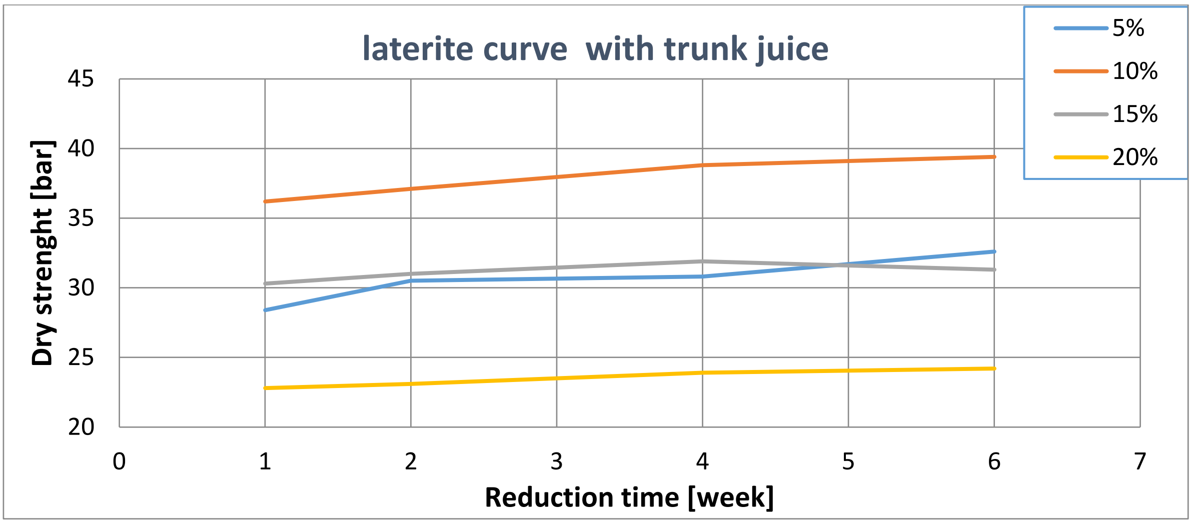

Figure 8: evolution of resistance Rc on dry samples as a function of treatment time and the rate of trunk juice

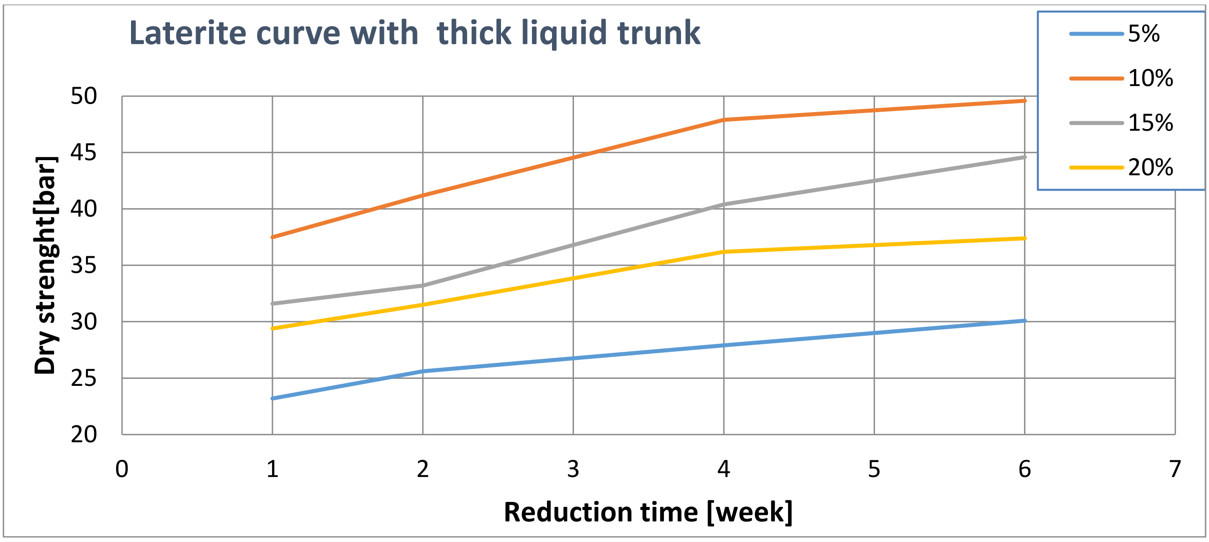

Figure 9: evolution of the resistance Rc on dry samples according to the function of treatment time and the rate of thick liquid in the trunk

In the dry state, regarding to the two tests, the observation of the results obtained is: the two curves increase continuously and the curves of the laterite with the thick liquid of the trunk are increased compared to those of the juice of banana trunk. Then, we notice that the content of 10% is the best for the two processes.

b) Compressive strength in the wet state and dose of trunk juice

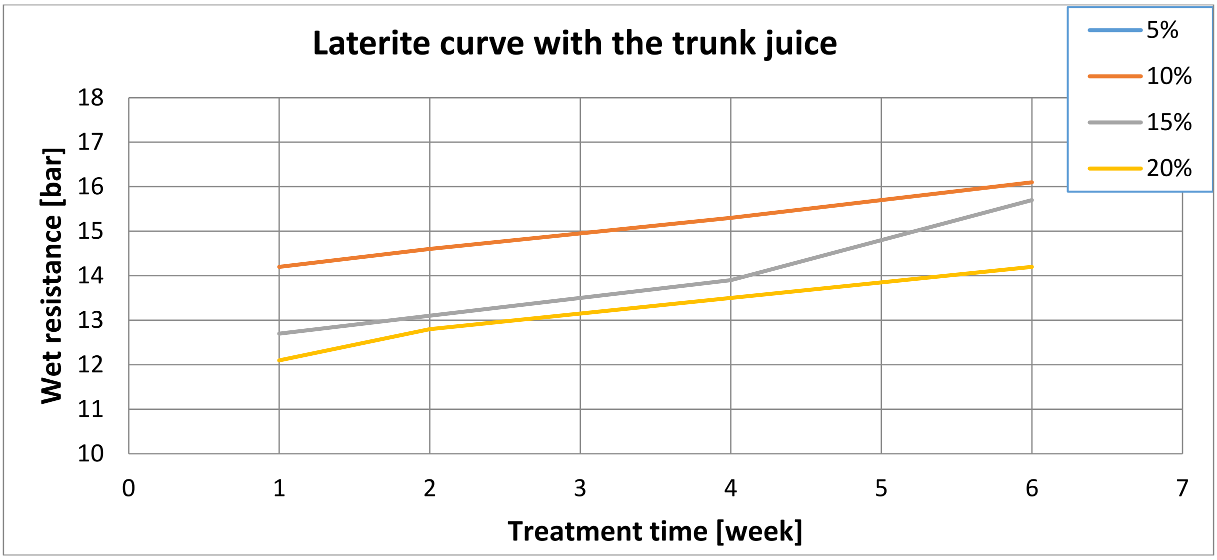

Figure 10: evolution of Rc resistance on wet samples according to the function of treatment time and dose of trunk juice

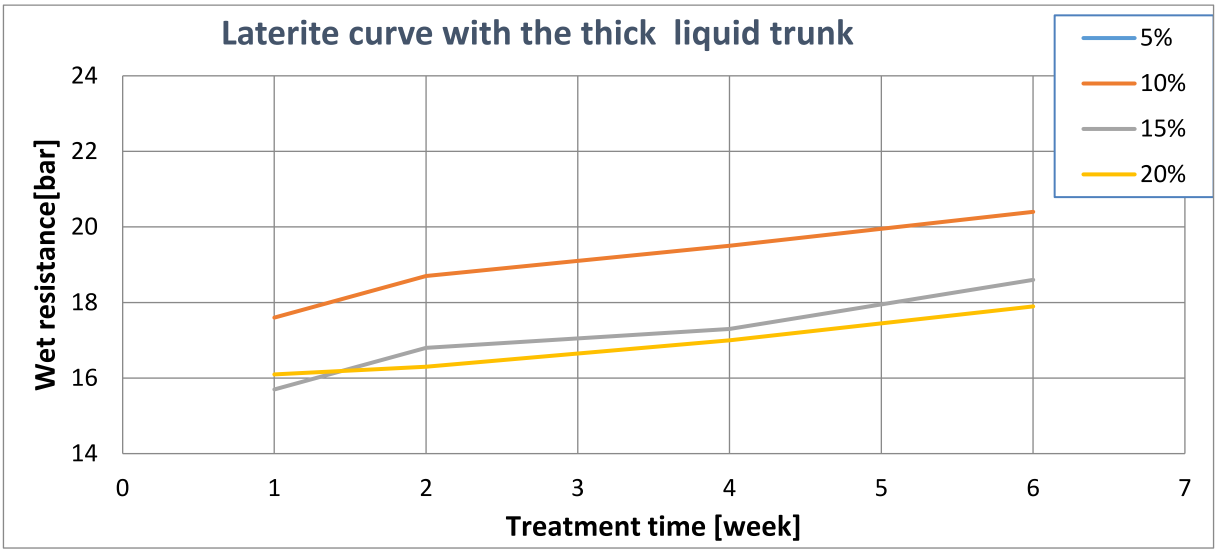

Figure 11: evolution of resistance Rc on wet samples according to the function of treatment time and dose of the thick liquid

We observed that adding a proportion of banana trunk juice improves the wet compressive strength of this material. Besides, the addition of the "thick liquid trunk" mixture results in an increase of the wet compressive strength of the samples.

By comparing the compressive strengths of the two bricks, we it can say that the bricks stabilized with thick liquid stabilizers are the best.

c) Porosity and dose of the liquid of the banana trunk

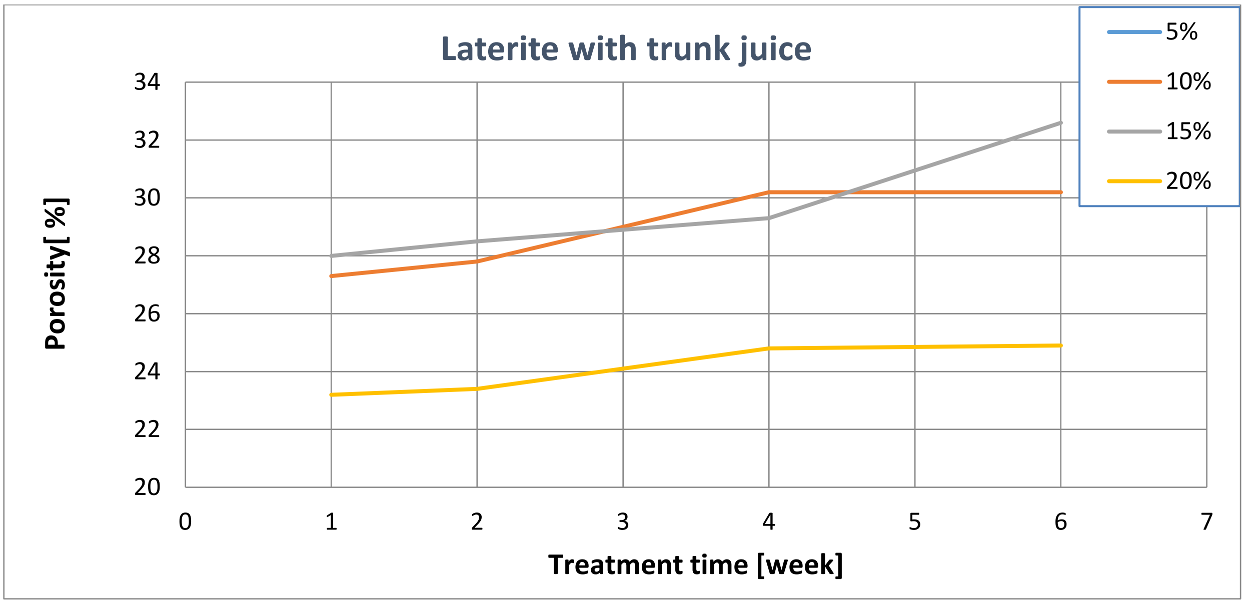

Figure 12: evolution of the porosity rate of the samples according to the function of treatment time and dose of trunk juice

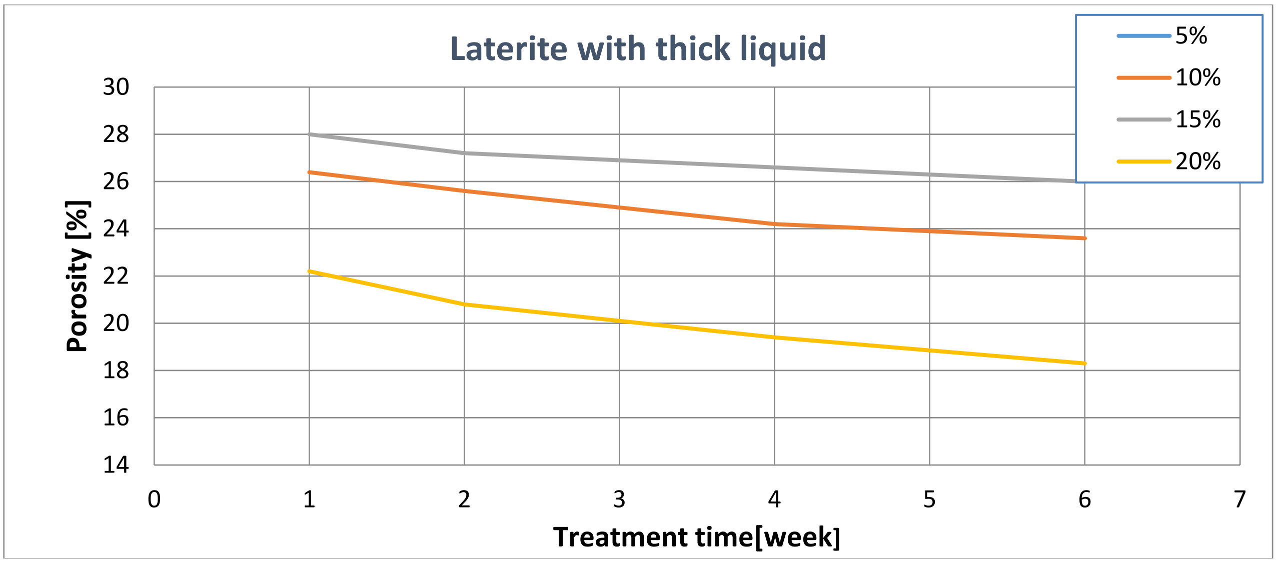

Figure 13: variation rate of the porosity of samples according to the function of treatment time and dose of thick liquid

From the graphs above, using the juice from the trunk, it is observed that free water reacts with the materials, entering the pores of the briquettes; it greatly influences the swelling behavior of the material being processed. On the other hand; for the thick liquid, the use as the main binder in the materials decreases the porosity of the bricks.

3.4 Discussion about the use of the banana trunk

For each test performed, two different figures were obtained since this is the comparison study of two binders such as trunk juice and thick liquid from banana trunk in order to find the best stabilizers for laterite.

In general, the curves evolve in a continuous way. The role of liquid binder in the banana trunk is therefore significant. The 10% content is the best for both processes. Then, from the graphs above, the resistance curves of laterite with thick trunk fluid are increased compared to those of banana trunk juice. This is due to the presence of bound water in the thick fluid of the trunk. Bound water contains monomeric sugars (pentoses) in the trunk. On the other hand, for other tests with juice from the banana tree trunk, the presence of a larger quantity of water during the preparation of the binders is harmful; materials coagulate, but not bound. Consequently, the force of cohesion of bound water decreases.

Then, the results of the wet strength test again verify that the bricks treated with the thick liquid stabilizers are better. This means that in the wet state, for briquettes made from the thick liquid of the trunk, the presence of bound water, fixed on the structural polymers by physisorption on the hemicelluloses, strengthens them. The forces involved are electrostatic or of the hydrogen bond type with hydroxyl groups. Therefore, the binding force with the bound water goes into the materials, affects the particles inside the materials and fills the pores of the briquettes. This leads to an improvement in the wet resistance of the bricks.

Finally, by comparing the porosity, we can say that using the thick liquid binder significantly decreases the value of the porosity compared to the trunk juice with the content of 10% as the optimal dose. This is due to the presence of the monomeric sugars and that is why we have the low porosity and the high hardness due to the cohesion of the components.

3.5 Results "case of zebu manure"

3.5.1 Influence of adding liquid manure, sand and sugar on briquettes.

The tests were carried out to observe the results that could be obtained for each variant. The variants adopted are:

- the witness (without stabilizing agent) - noted: Witness;
- the laterite + liquid manure mixture - noted: CEB;
- the mixture of laterite + liquid manure + 5% sand - noted CEBSa5;
- the mixture of laterite + liquid manure + 5% sand + 5% sugar - noted CEBSa5Su5.

a) Compressive strength at dry state "Witness, CEB, CEBSa5, CEBSa5Su5"

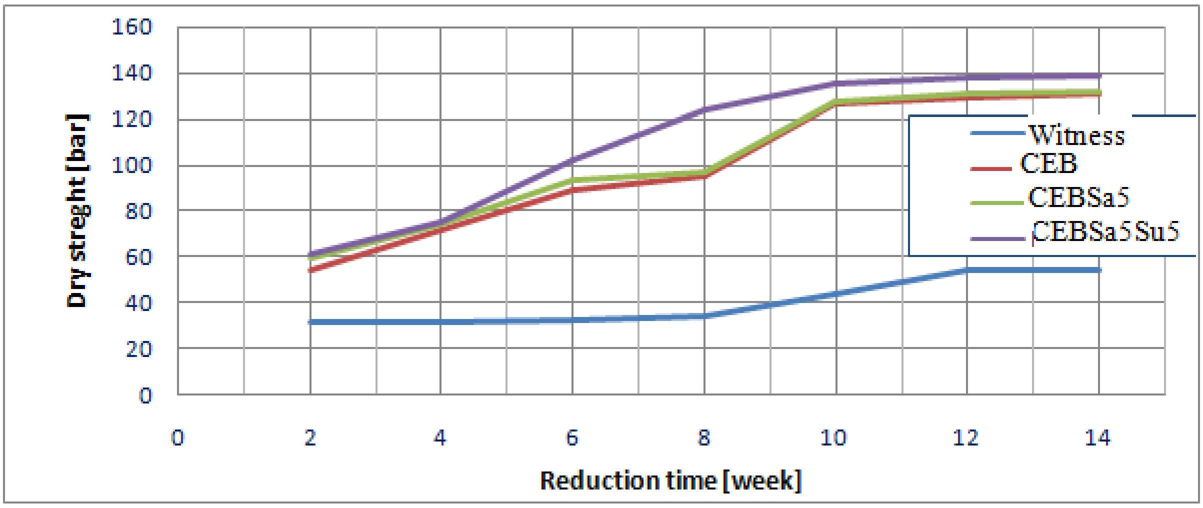

Figure 14: Evolution of resistance dry strength at dry state according to the function of time - Liquid manure

The result of the first test without liquid manure « Witness »: from the 2nd to the 8th week, no change is observed in mechanical resistance. Then over time, the resistance increases slightly and then stabilizes from the 12th week.

Then, when liquid manure is added to the samples (CEB), all the consistency parameters increase and the influence of the addition on the dry strength is very neat.

Then, adding 5% sand to the liquid manure sample (CEBSa5) does not change much the behaviour.

Finally, the addition of sugar at a rate of 5% (CEBSa5Su5) causes a very neat increase in compressive strength at dry state.

b) Compressive strength at wet state "Witness, CEB, CEBSa5, CEBSa5Su5"

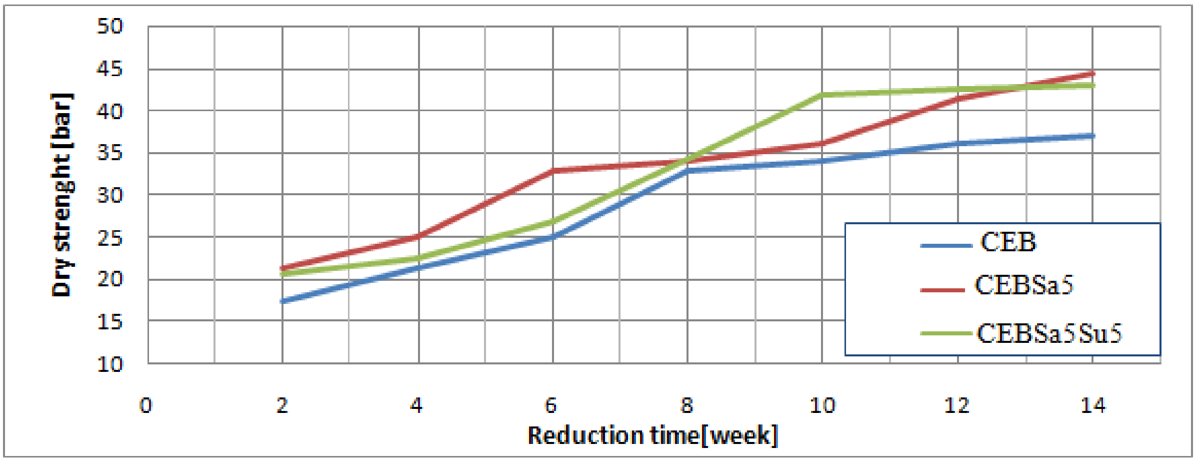

Figure 15: Evolution of the resistance Rc at wet state according to the function of time - Liquid manure

Results were not obtained with the witness because the test piece did not withstand the immersion treatment for 24 hours in water and disintegrated.

It can be seen that the three curves of the compressed earth blocks stabilized with liquid manure are continuously increasing, with a fairly low growth rate of 1.67 bar / week. This means that stabilization with liquid manure can improve the water resistance of CEB.

c) Porosity "CEB, CEBSa5, CEBSa5Su5"

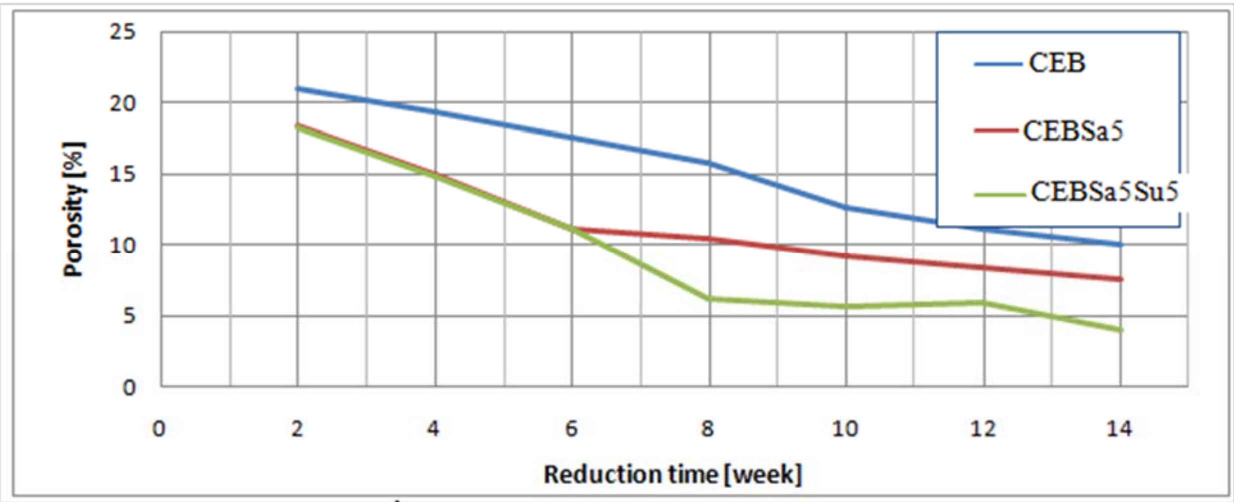

Figure 16: Evolution of porosity according to the function of the time reduction.

The porosity rate of the 3 samples tested exhibits a general decreasing rate until the 8th week and then stabilizes at a rate <10%. This shows a gradual reduction of the size of the pores and even the partial gradual disappearance of these pores by precipitation of the newly formed elements within them.

We can also stress the fact that the addition of sugar at 5% improves significantly the compactness of the test tubes; the sugar promotes the action of microorganisms.

3.5.2 Determining the optimal dose of sugar

We have seen that the saturation of liquid manure promotes the rapid development of microorganisms in the soil. For the liquid manure samples, additions of respectively 5%, 10% and 15% of sugar were tested in order to determine the optimal dose which would allow the best improvement of the efficiency of the manure.

a) Compressive strength at dry state and dose of sugar

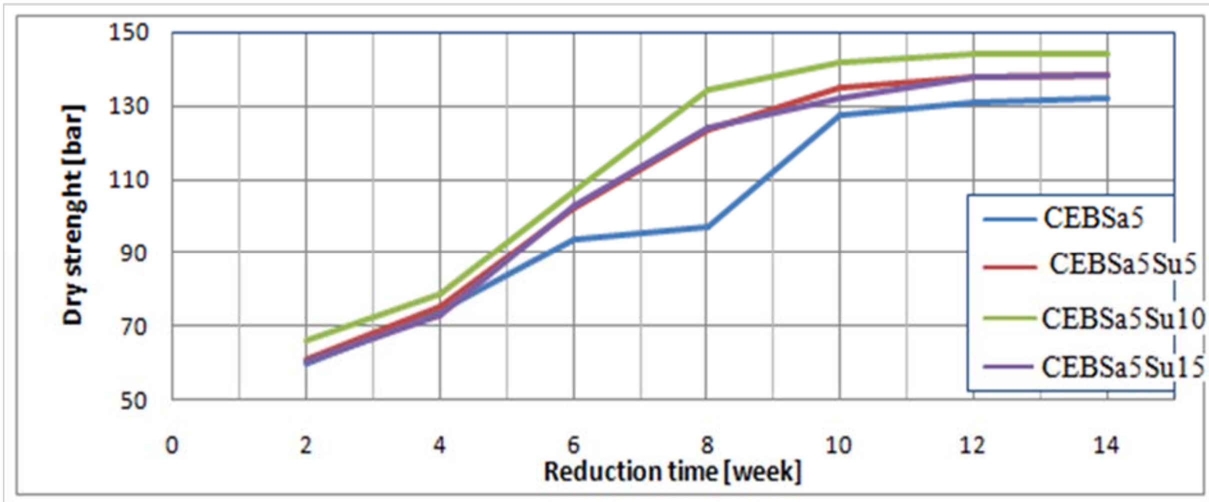

Figure 17: Evolution of the resistance Rc at dry state according to the function of time and the sugar level

The effect of sugar additions is evidenced by an increase in resistance. However, the amount of sugar is limited to 10%, because a dose of 15% does not lead to an additional increase, but does lead to a decrease in resistance.

b) Compressive strength at wet state and dose of sugar

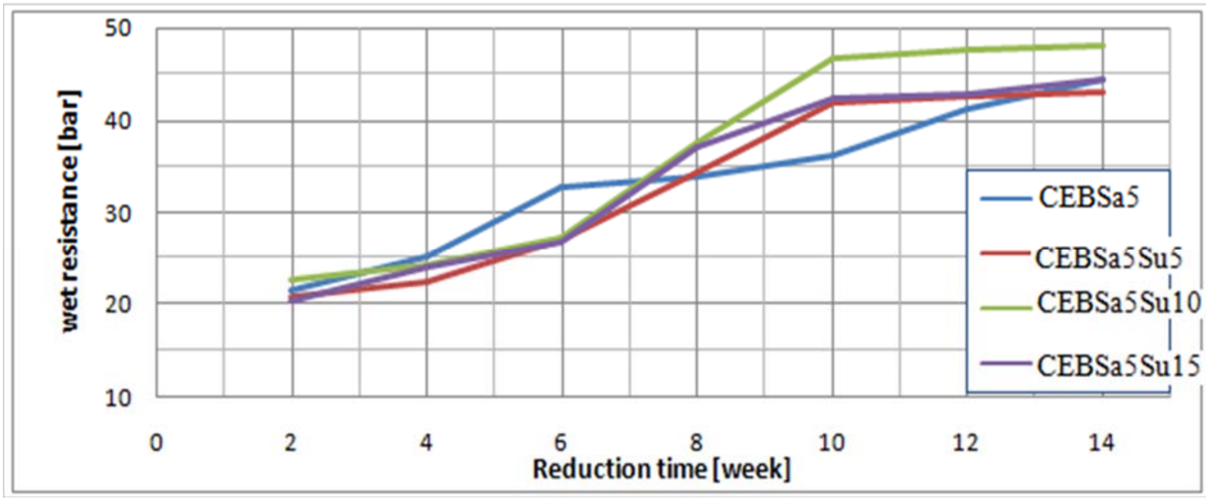

Figure 18: Evolution of the resistance Rc at wet state according to the function of time and the sugar level

The wet compressive strength of the laterite saturated with liquid manure was measured, with increasing amounts of the added sugar.

The curves obtained again highlight the same hardening processes linked to additions of increasing sugar content and relating to microbial activity observed in the case of dry samples of the same composition: the optimum dose of sugar is 10%.

c) Porosity and dose of sugar

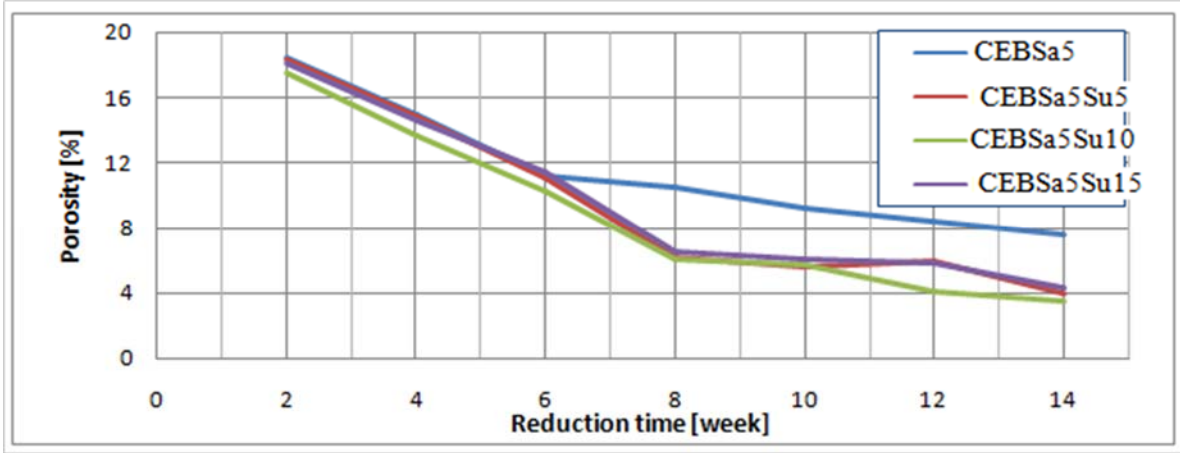

Figure 19: Evolution of porosity according to the function of time and of the sugar level

The decrease of the curves from the 2nd to the 8th week is normal in terms of the kinetics of microbial activity and the reduction process that follows. This test confirms the optimum sugar level of 10% to which the minimum porosity corresponds regardless of the reduction time.

3.6 Discussions "case of zebu manure and additives"
3.6.1 Discussion of the results of the use of zebu manure

When liquid manure is added to the samples at saturation, all consistency parameters increase. This is due to the fact that the presence of manure provides additional nutrients to the ferro-reducing microorganisms of the soil in the medium. It ensures the rapid multiplication of microorganisms.

The consequences in terms of the properties of CEB are a densification of the molecular structures of the soil (contribution of carbon chains, and above all chemical obstructions of the inter-granular interstices of the soil), and therefore an additional source of stabilization of the lateritic earth in addition to compaction. . This translates into a neat increase in compressive strength in both dry and wet conditions, as well as in the compactness of CEB. Therefore, the resulting CEB have higher mechanical strengths and are more resistant to water (which is the main enemy of earth constructions).

3.6.2 Discussion of the results of the use of sand

In terms of resistance, the addition of 5% sand does not bring much change in soil behavior due to the action of the manure. Indeed sand is an inert constituent.

We could say that the addition of sand is necessary to correct the grain size of the soil, and lower its plasticity index. This results in a neat decrease in soil porosity followed by an increase in the difficulty of penetrating water into the structure of the CEB and therefore its resistance to water.

3.6.3 Discussion of the results of the use of sugar

In a preliminary test, it was verified that the addition of sugar significantly improves the properties of CEB, in terms of mechanical strengths in dry and wet state and porosity. A second test made it possible to determine the optimum amount of sugar to add, which is 10%.

Sugar has a strong reducing character, and it also has the ability to form chemical bonds due to the presence of carbon chains. This could bring a clear improvement in the results obtained with liquid manure.

The effects of sugar additions are evidenced by an increase of the strength and compactness of the soil. We believe that these enhancing effects of hardening and compactness of sugar additions are linked to the availability, for ferro-reducing microorganisms, of increasing amounts of nutrients, allowing an increasingly important multiplication. The consequence of this multiplication is the further intensification of the microbial reduction of iron in the soil. We can deduce that the additions of increasing amounts of sugar reinforce the action of the liquid manure materialized by a significant reduction in the porosity of the soil studied (a reduction of 6%) by the precipitation of iron III ions in solution in the form of low soluble ferrous compounds. This results in a densification of the structure of the CEB, and therefore of its mechanical resistance, and also helps to eliminate the possibility of water penetration into the pores.

The optimum sugar content is 10%, which means that for this proportion, the amount of additional nutrients necessary for microorganisms is reached. Any additional sugar intake at this level is unnecessary and leads to slowing or even stopping microbial activity. Either way, using a large amount of sugar is uneconomical because it is a foodstuff.

Finally, with the simultaneous use of manure and sugar, the 8 week period is suitable as a maturation time for microbial reduction. It should be noted that from the 10th week the behaviour of CEB begins to stabilize: this is the performance limit of the binders studied.

IV. Conclusion

In conclusion, laterite is one of the most common raw materials in Madagascar and its valorisation is possible as a construction material, but its performance depends on the effectiveness of the treatments it is subjected to.

In this study, we studied methods of stabilization of laterites by different parts of the sweet potato plant and banana, then by the zebu manure with some additives such as sugar and urea.

The studies were carried out on a laterite from AlakamisyFenoarivo, relatively representative of the laterites of the Malagasy Central Highlands. A granulometric correction was necessary by adding 5% of sand because of the great fineness of the sample.

The stabilization of the laterite added to the different parts of the sweet potato plant allowed us to find that the best results are obtained with 15% of the entire "stem + leaf" of the sweet potato.

The stabilization of the laterite with the banana tree allowed us to know that the best results is 10% of the thick liquid of the banana tree trunk.

The stabilization of the laterite by the zebu manure with the addition of 5% sand and 10% sugar resulted in the best CEB (Compacted Earth Block) CEBSa5Su10. The CEB obtained has mechanical strengths at dry and wet conditions that can compete with those of other types of materials of the same family.

The optimal treatment time is around 10 weeks, but the CEB can already be used under the best conditions from the 8th week.

We find this method of making CEB to be technically-economical and also more environmentally friendly through the use of natural stabilizers.

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