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Sustainability of Stabilized Earth Blocks to Water Erosion

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Abstract*— Stabilized earth blocks are made from earth, associated with binders dosed in small quantities and water. They represent a very inexpensive and ecological material. They have good thermal and acoustic characteristics, a good fire resistance and are biodegradable and reversible. Defects or disadvantages of this material are the low mechanical strength compared to other types of concrete, in addition to susceptibility to water. Our work investigates the sustainability of stabilized earth blocks to water erosion. The first part of our work includes a description of the blocks laboratory manufacturing process. It is followed by a study of the blocks mechanical behavior, based on the influence of additions of different dosages of cement (C), lime (L) and mixing of both (C+L), on the dry and wet strength and an analysis of capillary absorption on blocks dosed at 6,8 and 10% of stabilizer. The study is finished by a discussion of the results.

***Index Terms*— Earth Blocks, Stabilization, Strength, Sustainability, Water.**

I. INTRODUCTION

The earthen constructions are generally subject to degradation due to changes undergone by the earth during atmospheric variations (wind, sunstroke, precipitation...). The earth absorbs and releases moisture and tends to swell or shrink with changes in humidity of the ambient air. These conditions in addition to their unaesthetic nature reduce the bearing capacity of structures and therefore reduce their life. The factors responsible for the degradation of earth construction are difficult to quantify and reproduce. We must consider those among them who are causing destruction, in order to develop measurement methods characterizing the sustainability of the system [1]. Our work aims to study the behaviour of stabilized earth blocks to water erosion.

II. MANUFACTURE OF BLOCKS

A. The soil

The principle of building with earth is to use local materials, i.e. available nearby. For this, we chose to extract earth for blocks manufacture from a site near the laboratory of our faculty. Lands that are generally extracted are not all good for the construction, certain qualities are required: the land must contain particles of different sizes so that they can become entangled in each other. A minimum of plasticity to ensure cohesion between the grains during compaction. The Land should not be too clayey, because it can cause cracks due to swelling or shrinkage. The Land must not contain chemical elements in quantities that could be prejudicial to stabilization, hardening or durability of the finished material. The granulometric curve of the soil used is shown in Figure 1 and its characteristics, in table 1.

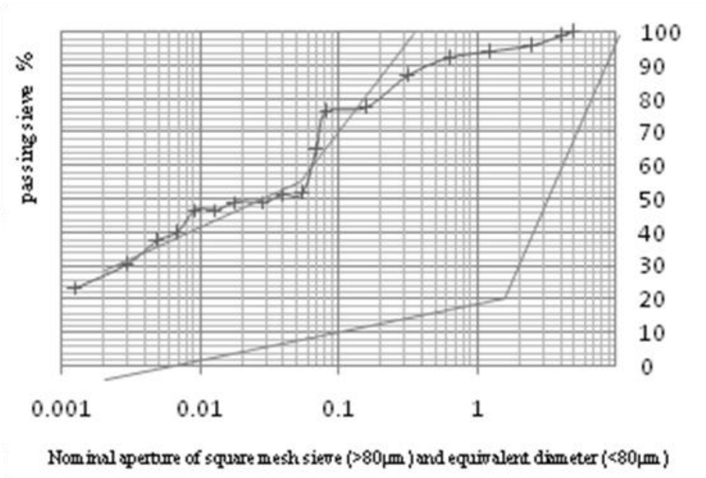

Fig1: Grading curve of the soil (by screening and sedimentation methods).

Table1: Soil characteristics

Plasticity index	23
Maximum dry density	1.71
Optimum water%	19
pH	8.25
Value of methylene blue	3.25
Organic matter %	0.31
Chloride %	0.017
Carbonate %	24.12
Sulphate%	traces
Mineralogical analysis	
Montmorillonite %	51.73
Illite %	26.45
Kaolinite %	21.8

The identified soil is generally apt for the stabilization; it remains to determine the most appropriate treatment.

B. The stabilization

Stabilization is a group of processes, which are applied to a soil in order to improve its characteristics, in particular, mechanical behavior and durability to water. There are various methods of stabilization, which vary depending on the action with which stabilizers are acting. This action may be mechanical (compaction), physical (fiber or by modifying the grain size), physicochemical (hydrophobic zing agents, binders) or by baking. In our work we have chosen a physico-chemical stabilization based on two binders: cement CPJ CEM II (Table2) and lime (Table3). The extracted soil was dried in an oven then crushed and sieved (5mm mesh). The grinding is necessary, to ensure an intimate mixture of the components. It was then stabilized with cement, lime and the mixture of both at 50%. The binders were incorporated in percentage by weight of the dry land. Dosages vary from 5%

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to 10%. Regarding the addition of the mixture, the lime (L) was incorporated followed by cement (C) with a rest period of one day between the two incorporations. Because prior treatment with lime will dry wet materials thereby reducing the plasticity for a better incorporation of cement because it provides a rapid rigidification. The amount of mixing water corresponds to the optimum water content proctor for cementations mixtures, and to the optimum water content proctor + % 3 for lime mixtures, because lime requires more water to hydrate.

Table 2: Cement characteristics

Specific surface area (cm^2/g)	3900
Time of initial setting (mn)	155
Final setting time (mn)	260
Expansion "Le Chatelier (mm)	1
Loss on ignition	8.48
K_2O (%)	0.66
Na_2O (%)	0.04
MgO (%)	1.98
SO_3 (%)	2.32
Chloride (%)	0.016
SiO_2(%)	17.52
Al_2O_3(%)	4.63
Fe_2O_3 (%)	2.99
CaO (%)	62.54

Table 3: Chemical elements contented in the lime

Al_2O_3(%)	1.12
S_2O_3 (%)	0.4
CaO (%)	44.24
SiO_2 (%)	4.3
SO_4 (%)	0.83

Compaction was performed by a manual press which compacts in static mode. Blocks have dimensions 23.11.4.7 cm^3. After demoulding, the blocks were damp cured, the cure consists of a watering for a week and a wet conservation during 14 days to prevent premature drying and to allow to stabilizer to harden. The drying was performed at ambient laboratory temperature.

III. CHARACTERIZATION OF BLOCKS AND DURABILITY

A. Compressive strength

The crush test was performed to estimate the compressive strength (figure 2, 3 and 4), because it is the most representative for the blocks. As humidity affects the mechanical performance of the material, the compressive strength was measured for dry blocks (Rs) and humid blocks (Rh) who underwent immersion in water for 24 hours. The crushing tests were performed at 28th day.

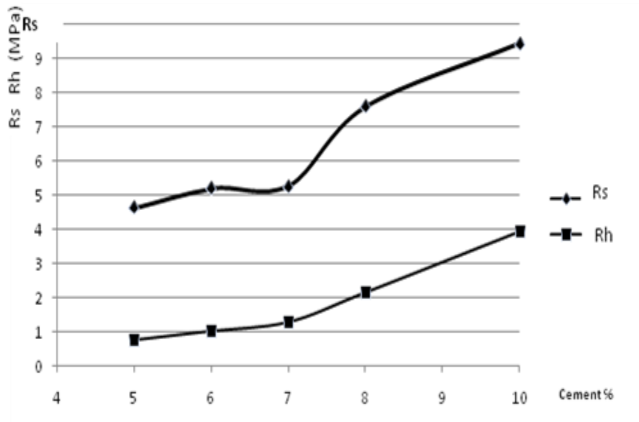

Fig 2: Influence of cement content on the dry and wet compressive strength Rs, Rh

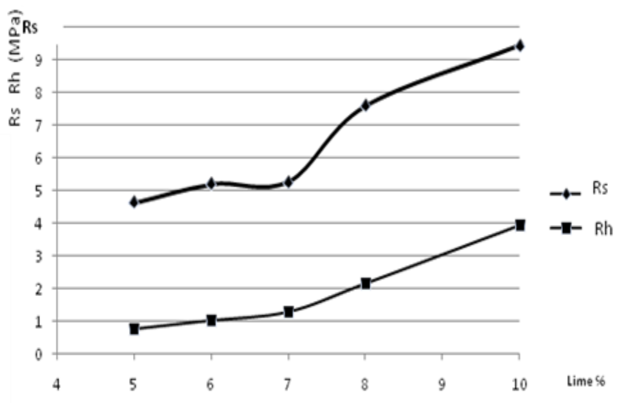

Fig 3: Influence of lime content on the dry and wet compressive strength Rs,Rh

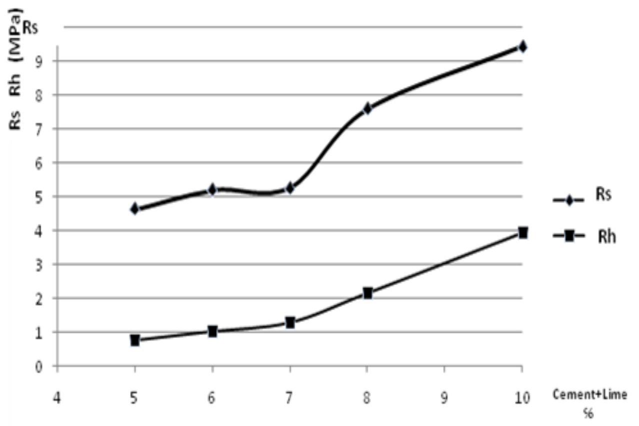

Fig 4: Influence of cement+lime content on the dry and wet compressive strength Rs, Rh

B. Coefficient of water resistance

The coefficient of water resistance (figure 5) characterizes the stability of materials in water. It is determined from ratio of dry strength to wet strength.

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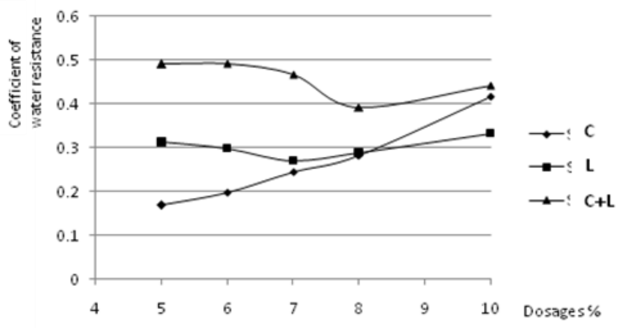

Fig 5: Coefficient of resistance to water.

C. Capillary absorption

The absorption by capillarity was measured with the device below (figure 6). The blocks are dried in an oven at 40˚C and then partially immersed in a water tank equipped with an overflow which ensures a constant level of immersion (5 mm of height of the block). The absorption coefficient by capillarity (figure7) is measured after 10 min of immersion [6].

$$Cb = \frac{100 \times (mh - md)}{s \times \sqrt{t}} \quad [6] \qquad (1)$$

mh - md : Mass of water in [g] absorbed by the bloc during the test.
S: Submerged face area [cm^2].
t : Immersion time [min]. t =10 min

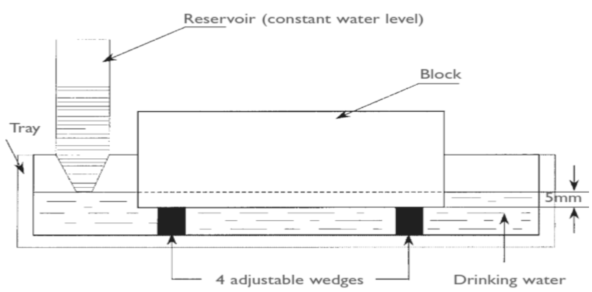

Fig 6: Measure of absorption by capillary [6].

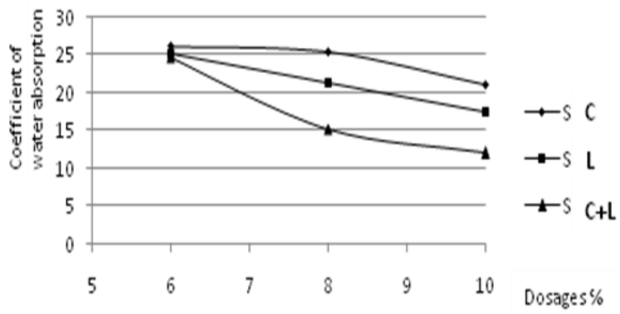

Fig 7: Coefficient of water absorption by capillary versus dosages in Cement(C), Lime (L) and mix of Cement+Lime (CL).

IV. Analysis

The dry compressive strength, increases with the dosage of stabilizer. The best dry strengths were obtained with the mixture of cement + lime and the lowest, with lime. The increase in resistance is particularly notable from 7% of cement and 7% of mixing, while the curves are more flattened between 5% and 7%. This suggests that strengths developed at this stage are much more due to the effect of compaction rather than to effect of hydrates. Concerning wet compressive strengths, they are very low compared to the dry ones, but evolve in the same direction. Resistance losses are greater for blocks stabilized with cement. This allows us to deduce that they are the most sensitive to water. We can conclude that the blocks stabilized with the mixture (cement+lime) exhibit better mechanical behaviour whether they are dry or wet. Reference [2] found similar results. Indeed, the compressive strengths increase with dosage of stabilizer: 5-7% of cement, 8-12 % of lime and (5 +3) to (8 +4) % of cement + lime. The Best strengths were obtained for a content of (8 +4) % of cement + lime. The resistances are due one hand, to the compaction and the other hand to the effect of binders. Indeed, the hydration reaction of cement produced a hydrated cement gel which acts on the sandy and gravelly fractions. C-H-S and $C_4A\hat{S}H_{12}$ products have a good binding capacity and generate binding forces responsible for the sinking of the fractions involved, in creating a rigid structure in the ground. This inert and anisotropic system brings stiffness to the ground [3]. The liberated lime reacts with the clay fraction. The reaction results in the formation of binders. This reaction is mainly pozzolanic.

The strength loss can be explained by the presence of moisture in the block. When a block of earth is contacted with water, it tends to absorb and retain it. The high affinity that have clay minerals to water, promotes this absorption. In addition, moisture weakens the van der Waals forces between the surface of the sand particles and the cement hydrates.

When the block is in the saturated state, it is subject to internal pressures that develop inside the pores. The accumulation of these forces can lead to a stress discharge which is accompanied by a dispersion of the unassembled particles, or particles that are partly affected by the stabilization. It leads also to the dissolution of the calcium hydroxide contained in the hardened cement paste. The dissolution process is irreversible, the phenomenon of leaching can occur [4]. An intense leaching increases the porosity of the material and makes it more permeable (Neville, 1995) cited in [3]. Coefficient of water resistance, increases with the cement content. It remains more or less constant for lime stabilized blocks and cement + lime mixture. The values obtained are lower than the limit set by the AFNOR standard XP P13-901, which is equal to 0.5. This shows a bad behaviour at the wet state, which is causing loss of strength. Reference [2], found the coefficient of water resistance of about 0.7, for cement+lime dosage (8+4) % and the order of 0.72, for resin + cement dosage (8+50) %. Reference [3], found better values of coefficient of water resistance up to 0.9 with micro silicates. Reference [5] Interested to thermal performance has coefficients in the order of 0.4.

All blocks absorb water by capillary. Generally, less the blocks absorb water, the more their performance is better. Mixing cement + lime provides a better behaviour to water (less absorption) which leads to a better resistance to wet. These results confirm previous results on the resistance of wet blocks. Reference [7] cited in [2] showed that the water absorption decreased with the cement content, while the

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dosage in lime had an opposite effect. Moreover, the addition of micro silicates significantly reduces water absorption, as shown in [3] (cited in [2]).

V. CONCLUSION

We can conclude that firstly, identification tests are important because they allow defining characteristics of the earth, in order to situate them in relation to the suitability criteria, and therefore orient about choice of the stabilizer. The behaviour of the blocks differs depending on the treatment and dosage incorporated. The compressive strengths in dry and wet conditions increase with the dosage of binder. Mixing cement + lime yielded the best resistance. Cement stabilized blocks are less resistant to wet. The different formulations have determined the best treatment. It is the mixture of cement + lime which has proved the best suitable treatment, and this, from the point of view of strength and of durability. Better compaction could generally improved behaviour blocks moisture because as previously mentioned, the press used was manual and required a lot of effort to compact the blocks at their maximum density. We finally conclude that by using available lands in the environment, which have not necessarily ideal properties for the construction, there may be an appropriate treatment that achieves fairly satisfactory results, provided it complies with the good rules of implementation and take into account the cost of stabilizing products.

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