DURABILITY OF LIME STABILIZED EARTH BLOCKS

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ABSTRACT

The main drawback of earth construction is the rapid deterioration of the material under severe weather conditions. The objective of this work is to improve the behaviour of stabilised blocks of earth blocks against water attacks. The blocks manufactured with one type of earth were tested in compressive strength as dry blocks and after immersion, in intensive sprinkling and in absorption. Tests of wetting-drying. The tests of freeze- thaw were also carried out. The results show the influence of the different manufacturing parameters: compacting intensity, sand content and lime content on the mechanical strength in the dry state as well as in the wet state, water resistance coefficient, the weight loss and the absorption.

1. INTRODUCTION

For economical reasons and by studying what already has been done until now, scientists and builders consider that it is judicious to try to improve the life span of construction materials (*Ghoumari* 1989). The durability prevision of stabilized earth blocks is still a controversial matter amongst construction actors. In order to know the limits of this kind of material destined to construction, it is intended to find solutions that can improve its life span by the know how of its general use as well as its mass treatment (additions of binders, compacting energies,…).

Obtaining a durable material would need a treatment which would result in a sufficient mechanical strength as well as low sensitivity to water attacks (*Guettala*, and *Mezghiche* 1995). These two main conditions should be preceded by a very precise study of parameters related to the grading and mineralogy of these materials.

The type and the content of the binders, aggregates grading, compacting stresses and water content would be adapted as conditions of making of these materials, [(*Guettala* and *al* 1998, *Guettala* and *al* 1997). In this present work, we have tried to improve the durability of earth blocks by several methods: by the additions of lime (5, 8 and 12%), sand content (0, 10, 20, 30 and 40%) and the compacting stresses (5, 7.5, 10, 12.5, 15, 17.5 and 20 MPa).

2. SOIL PHYSICAL CHARACTERISTICS

Soil samples of the region of Biskra (south east of Algeria) have been taken as reference samples and subjected to several laboratory tests under ASTM normalization, (ASTAM 1993).

2.1 Grading Aggregate Analysis

In figure 1, the grading curves of the soils as well as the corrected soils with sand and limits of the recommended zone for compressed earth blocks are represented (*Doat* and *al* 1981). It is noted through these curves that soil and corrected soil with contents of 10, 20 and 30 % of sand are very close to the lowr limit of recommended zone; whereas corrected soil with content of 40 % of sand is out of the recommended limit zone.

2.2 Atterberg Limits

According to Michel (Michel 1976), the best earth soils for stabilization are those with low plasticity index (P.I) and the product (P.I x M) in the vicinity of 500 to 800, where M is the percentage of mortar, in this case P.I x M = 644, see Table 1.

Table 1 : Atterberg's limits.

Sample	WL	WP	PI	Ws	Wa	Ca	PIxM
N 1 Biskra	31 P.Z[(1)]	17 P.Z	14 P.Z	10 P.Z	9.5	0.77 A.A[(2)]	644

2.3 Chemical Analysis

Clay analysis has been accomplished in the cement factory of Hamma Bouziane (Constantine, east of Algeria) using Fluorescence X ray, in accordance to NF6 P 15-467. The obtained results showing the constituents of the soil are presented in Table 2.

Table 2 : Chemical Composition of the Soil.

Sample	CONTENT (%)					
	SiO_2	AL_2O_3	Fe_2O_3	MgO	CaO	SO_3
N 1	32.22	2.24	0.53	0.03	31.8	5.81
Sample	CONTENT (%)					
	K_2O	Na_2O	CL	TiO_2	MnO	F.W(1)
N 1	0.15	0.03	0.005	0.2	0.02	26.9

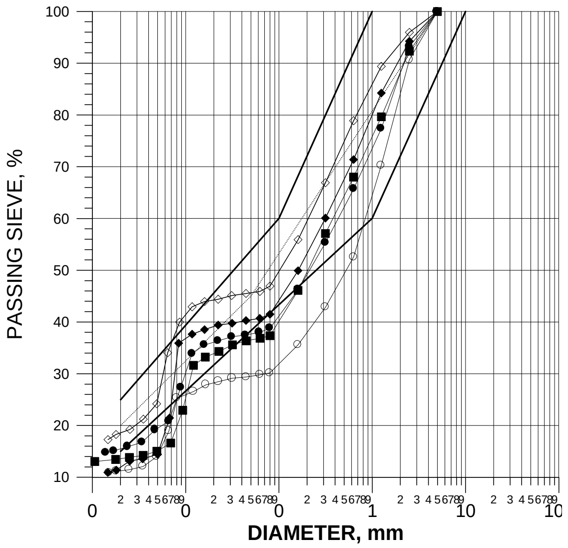
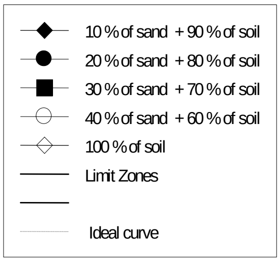


Figure 1 : Grading curves Aggregate analysis of used soil, corrected soil and the recommended limit zone of stabilized earth concrete.



2.4 Mineralogical Analysis

To differentiate the clay soils, a mineralogical analysis by X rays is important. The analyses have been carried out in the geology laboratory of Boumerdes (Algiers, Algeria) using a diffractometre SIEMENS 500, interfaced to a computer for data collecting. Tests have been conducted on aggregates passing on sieves of 80 microns. The obtained results see Table 3 show that the soil is composed mainly of kaolin (non-expansive and non-absorbent) and illites.

Table 3 : Soil Mineralogical constituents.

Sample	Clayey minerals (%)			Non clayey minerals (%)	
	kaolin	illites	I. M(1)	Quartz	Calcite
N 1	45	40	15	5	10

(1)P.Z: Preference Zone.

(2)A.A: Average Activity.

2.5 Physical Characteristics of Sand

Using France's AFNOR (AFNOR 1984)] regulations, the sand samples have been tested and found the following results;

- Disturbed Apparent Density (ρo) = 1520 kg/m^3 Specific Mass (γ) = 2640 kg/m^3
- Fineness Modulus (F.M) = 2.33
- Sand Equivalence Value by Sight (SE) = 70 ; Value by Test (SE_t) = 64

3. INFLUENCE OF SAND CONTENT

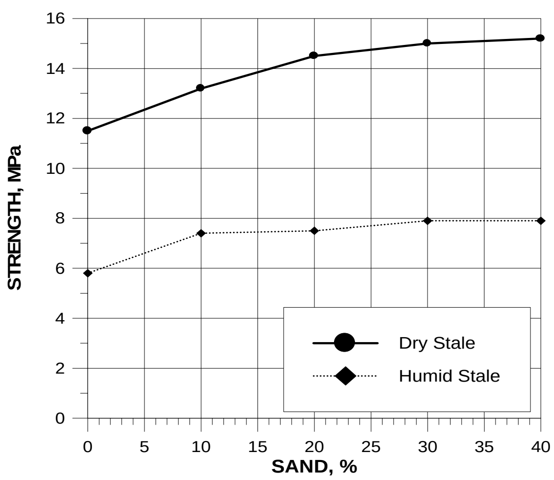
In order to determine the influence of sand content on the mechanical strength, durability and the optimal quantity of soil- sand mix, several blends have been used (0 – 40%) with lime content of 8% and a compacting stress of 10 MPa. Samples have been stored in a humid environment.

3.1 Compressive Strength

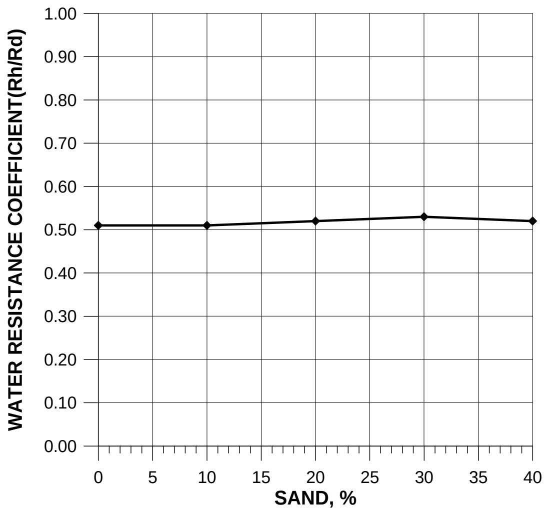
Figure 2a, shows that the mechanical compressive strength of dry and humid sand-soil samples increases with increasing the sand content. However, in percentage terms, the compressive strength evolution is 30% for dry samples and 36 % for humid samples, when the concentration of sand is 30%.

3.2 Water Strength Coefficient

The water strength coefficient is determined from the compressive strength ratio for dry and humid states. Figure 2b shows that the sand content does not affect the water strength coefficient which varies between 0.51 and 0.53 when sand content varies between 0 and 40%.



a) Mechanical strength



b) Water strength coefficient

Figure 2 : Sand content influences on compressive strength and water strength. Coefficient with 8% lime stabilizer and 10 MPa compacting stress.

3.3 Water Absorption

The absorption capacity of earth stabilized blocks gives a general idea on the presence and importance of voids. When a volume of soil subjected to the action of a stress, the material is compressed and the voids ratio decreases. As the density of soil is increased, its porosity is reduced and less water can penetrate it (*Houben* and *Guillaud* 1984).

3.4 Capillary Absorption

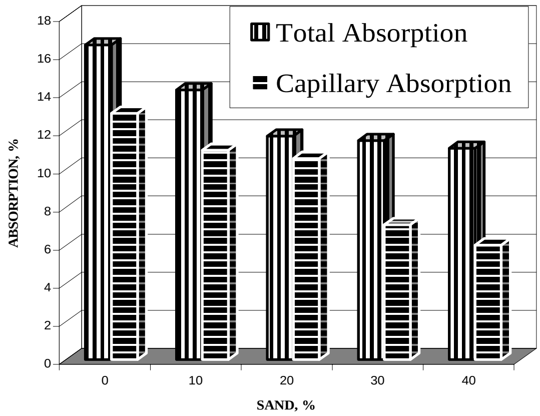
Capillary absorption test consists of placing the soil sample on a humid surface with voids, constantly water saturated, and measuring its weight after 7 days. Absorption is evaluated in percentage of dry weight. Figure 3a, shows that the absorption diminishes by 20% when the sand content increases by 30%.

3.5 Total Absorption

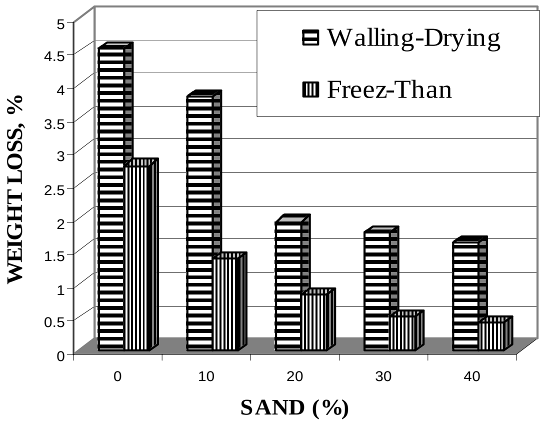
The present test consists of immersing the soil samples in water and measuring the increase in weight during 24 hours. The absorption is evaluated in dry weight percentage. Figure 3a, shows the decreasing of the total absorption by 9% above 20% of sand content.

3.6 Wetting and Drying Test

This test is carried out according to the ASTM D 559-57; it consists of immersing soil samples in water a for period of 5 hours and then removed to be dried in an at 71 °C for a period of 42 hours. The procedure is repeated for 12 cycles, samples are brushed every cycle to remove the fragment of the material affected by the wetting and drying cycles. For presented in the diagrams of weight (*Houben* and *Guillaud* 1984); Figure 3b. As it can be seen from the histograms, the weight loss diminishes by 65% when the sand content is added by 30%, and then it increases only by 4% on the addition of 10% of sand.



a) Absorption



b) weight loss

Figure 3 : Influence of sand content on the absorption and loss of weight (8% lime and compacting stress of 10 MPa)

3.7 Freeze - Thaw

Following the procedure described by ASTM D560, the freeze-thaw test consists of placing a soil sample on an absorbent water saturated material in a refrigerator at a temperature of -23°C for a period of 24 hours and then removed. The sample is then thawed in a moist environment at a temperature of 21°C for a period of 23 hours and then removed and brushed. The test is repeated for 12 freeze-thaw cycles and then dried in an oven to obtain a constant weight (*Houben* and *Guillaud* 1984). The weight loss is then calculated and reported on diagrams, Figure 3b. We can see clearly that there is no big effect in the weight loss above the value of 30% sand content. This value is taken for further investigations.

4. INFLUENCE OF THE COMPACTING STRESS AND THE LIME CONTENT

In the following section, the effect of the compacting stresses (5, 7.5, 10, 12.5, 15, 17.5 and 20 MPa) and the lime content (5, 8, and 12 %) on the mechanical compressive strength on dry and humid sand samples is studied. Also the durability (wetting and drying, freeze-thaw) and capillary tests with the optimal sand content of 30% are carried out.

4.1 Mechanical Compressive Strength in Dry Samples

Figure 4 shows clearly that the compressive strength evolution is the same for the different lime content: the compressive strength increases with increasing the compacting stress until 17.5 MPa, which is the optimal compacting stress. The compressive strength increases by 70 % and then decreases again by 7% when the compacting stress reaches 20 MPa for the case of 8% lime content sample. We can see also from Figure 4 that the compressive strength increases with the increase of lime content but in an irregular manner: Changing from 5% to 8% lime has resulted in 54% increase in strength whereas the increase from 8% to 12% lime has resulted only in 18% increase in strength, using a compacting stress of 10 MPa.

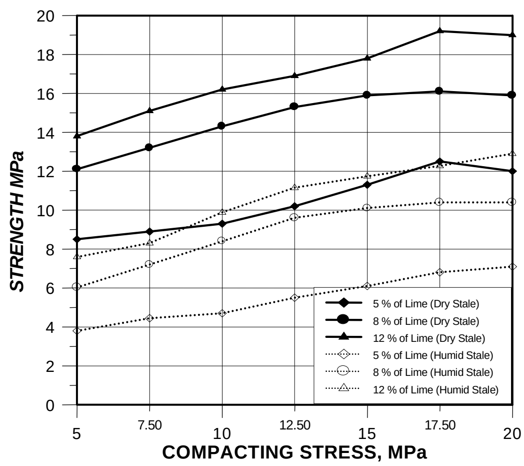


Figure 4 : Influence of compacting force and cement content on the water strength coefficient

4.2 Mechanical Compressive Strength in Humid Samples

The mechanical strength of humid soil sample increases with increasing the compacting stresses, Figure 4. The strength evolution is 70% when the compacting stress passes from 5 to 20 MPa. However, the evolution is not regular: it starts with 19% from 5 to 7.5 MPa and only 5% for a compacting stresses variation of 12.5 to 15 MPa for the case of 8% lime content sample. The mechanical compressive strength also increases when increasing the lime content for humid samples. Like in the case of dry samples, the compressive strength evolution is not regular.

4.3 Water Strength Coefficient

The water strength coefficient evolution depends on the lime percentage and on the compacting stresses, Figure 5. It increases with increase of lime content and the compacting stresses. For 8% of lime and a compacting stress range of 5 - 20 MPa, the strength coefficient increases from 0.5 to 0.66. And for 15 MPa, the water strength coefficient takes the values of 0.54, 0.64 and 0.66 for the lime content of 5, 8 and 12% respectively.

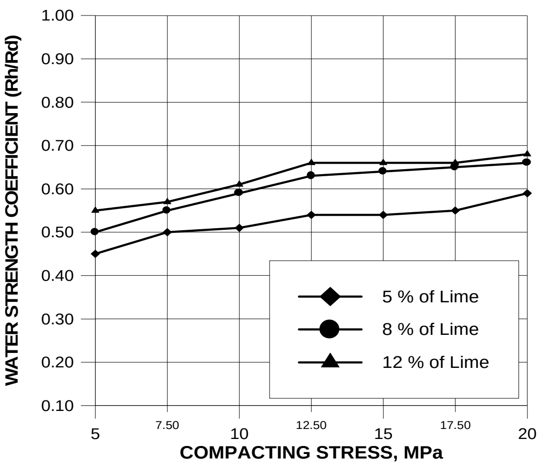


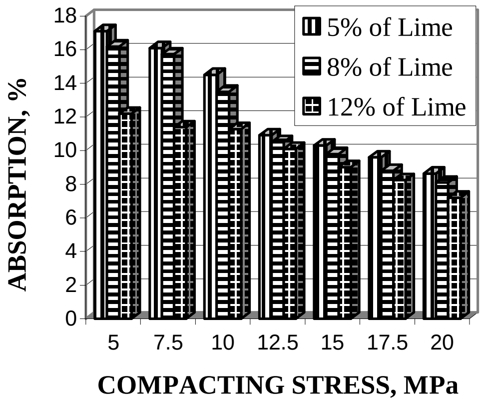
Figure 5 : Influence of compacting force and cement content on the mechanical strength

4.4 Total Absorption

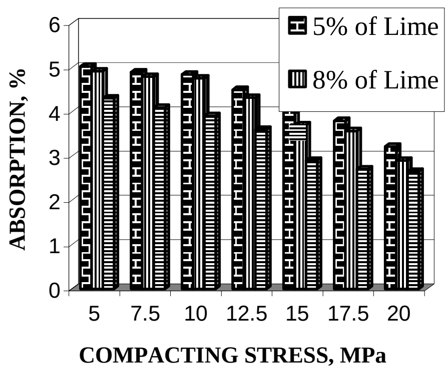
Figure 6a, shows that the absorption decreases when increasing the compacting stresses. At and above the value of 12.5 MPa, the effect is much more important. We also noticed that the increase in lime content decreases the water absorption factor and the effect is much more important up to the value of the compacting stress of 10 MPa when the lime content passes from 8 to 12%.

4.5 Capillary Absorption

Figure 6b, shows that the capillary absorption decreases when increasing the compacting stresses and the lime content. For instance, it varies from 3.8 to 2.7% when the lime content varies from 5 to 12% with a compacting stress of 17.5 MPa. And for the case of 8% lime sample, the capillary absorption percentage varies from 4.9 to 2.9% when the compacting stress varies from 5 to 20 MPa.



a) Total Absorption



b) Capillary Absorption

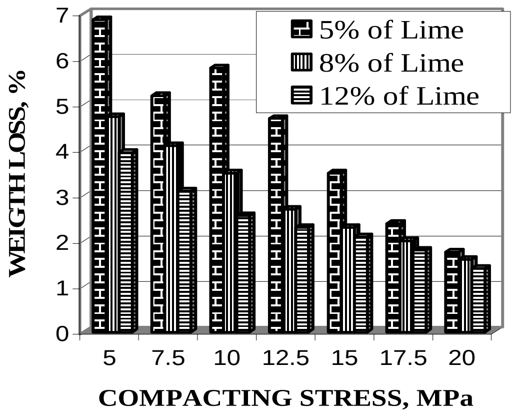
Figure 6 : Influence of the compacting stress and lime content on the absorption.

4.6 Wetting and Drying Test

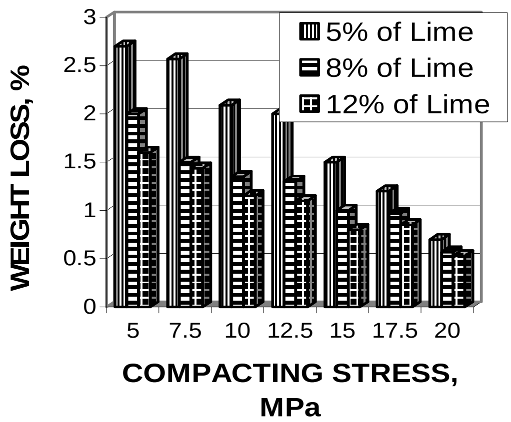
Figure 7a shows that the loss in weight diminishes when increasing the compacting stress and the lime content. The weight loss evolution is not regular. For the case of 5% lime, the weight loss is very important up to 15 MPa. For the cases of 8 and 12% lime, the effect of lime on the weight loss is important for the compacting stresses up to 12.5 MPa. Above this value the addition of lime is less significant.

4.7 Freeze-Thaw Test

Figure 7b shows that the weight loss diminishes when increasing the compacting stress and the lime content as in the case of wetting and drying test discussed previously. For the 5% lime sample, the weight loss changes from 2.7 to 0.7% when the compacting stress varies from 5 to 20 MPa. And the weight loss is very important with low compacting stresses.



a) Wetting and drying test



b) freeze- thaw test

Figure 7 : Influence of compacting stress and lime content on the weight loss.

5. CONCLUSION

The present work showed the important influence of sand content, the compacting stress and the lime content on the behaviour of stabilized earth blocks with respect to water attacks as well as elucidating certain points:

The principal effect of the stabilization with the lime is to prevent water attacks. We would achieve then a good stabilization if we could obtain a durable material with a limited loss in mechanical strength in a wet state (Guettala and al 2000).

The sand content does not affect considerably the compressive strength and the water strength coefficient. However, the sand content diminishes the weight loss and water absorption.

Increasing the compacting stress from 5 to 20 MPa and the lime content from 5 to 12% improve the compressive strength in dry as well as wet state and the water strength coefficient. We notice also that the increase of these two parameters decrease the weight loss and the water absorption.

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