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Study of the durability of stabilized earth based on recycled sediment

Studiul durabilității pământului stabilizat pe baza de sedimente reciclate

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Abstract. *The durability of blocks made by earth can be improved considerably by the addition of different stabilizers. In this work, two stabilizers have been used: cement. The elaborated specimens are evaluated by various laboratory tests, and durability is evaluated by examination of walls exposed to real climatic conditions. It has been noted that all treated walls showed no signs of deterioration after 2 years exposure in real climatic conditions even though the laboratory test conditions are more severe compared to the natural climatic conditions of the region of Algiers where this present work has been carried out. The blocs stabilized by cement showed the best durability behavior.*
Key words: *Recycled Sediment; Stabilizers; durability tests; Climatic conditions exposure.*

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1 Introduction

To limit the vulnerability of raw earth construction to the adverse effects of the environment, the solution is to stabilize the granular material. Earthen construction is sensitive to water, which causes rapid deterioration of the material under severe weather conditions. Speeded up tests are used to compare the performances of stabilized earthen blocks used under laboratory exposure conditions for block making. However, it is not possible to test the complex series of conditions such as rain, sun, temperature, humidity, and wind in the laboratory. It is noted that little work has been carried out relating the performance of the blocks under almost the same conditions to that of real walls.

Some research works on the stabilization by mechanical way of the compressed earth blocks on the effect of type of compaction (dynamic, static and vibro-static) on the mechanical performance and the durability of the stabilized earth blocks, resulting from the region of Algiers East, were led by Bahar and al [1]. It was found that the three different compaction methods used did not significantly affect the dry density of the soil. Mechanical stabilization by dynamic compaction seems to give better results compared to static or vibro-static compaction. For dry blocks, dynamic compaction was found to provide the highest compressive strength at all levels of cement stabilization (0% to 20%). Undoubtedly, earth was the first building material used by man.

Bahar and Benazzoug[2] has studied the effect of chemical stabilizers and their combinations on the durability of a clay or sand was investigated ; The results showed that the improvement of the durability of the earth material can be done by a treatment based on cement and lime, which allows to obtain interesting properties on sands and clays. The durability is considerably improved by the mixed treatment.

A study of the adhesion of compressed earth masonry elements was carried out by Walker and al. [3]. The blocks were made of reconstituted earth stabilised with cement. The blocks were compacted using a manual press. Two mortar formulations were used: cement/lime/sand and earth/cement. The results revealed the formation of etringite in the interface in the presence of water, which influences the mechanical behaviour of the masonry. The higher the clay content, the higher the water content of the blocks needed to achieve higher bond strength. The results showed a low bond strength of the earth mortars, while increasing the clay content caused the bond strength to drop considerably.

For the tests carried out by Walker [4], Cement does not play a major role in consistency measurements either. As far as workability is concerned, a mortar with cement is more workable, but the clay content of the soil must be taken into account. If the clay contains less than 12% colloids, workability is guaranteed.

Within the framework of this work, a certain number of tests related to durability (drying wetting tests, erosion, natural aging). These tests would offer the possibility to appreciate the resistance of the blocks towards water and help to optimize the choice for a better quality of blocks.

Materials and Methods

1.1 Materials

1.1.1 Sediments

The material used as raw material for the elaboration of the blocks is the sediments of the Koudiat- Acerdoune dam in the Bouira region (fig. 1).

Figure 1: dam of Koudiat-Acerdoune.

The chemical analysis of sediments FRX represent 57.91% SiO_2, 8.81% Al_2O_3, 11.91% CaO,0.52% TiO_2, 4.40% Fe_2O_3, 0.88% MgO, 0.51% Na_2O and 0.86% K_2O.
The particle size distribution (the relative content of clay, sand and gravel) of the sediment (fig.2) was obtained according to the standards NF P94-057[5] and NF P94-056[6] .
It is mainly composed of sand (37%) particles, with 13.63% of fine particles, which reveal that the sediment corresponds to a sandy lime soil.

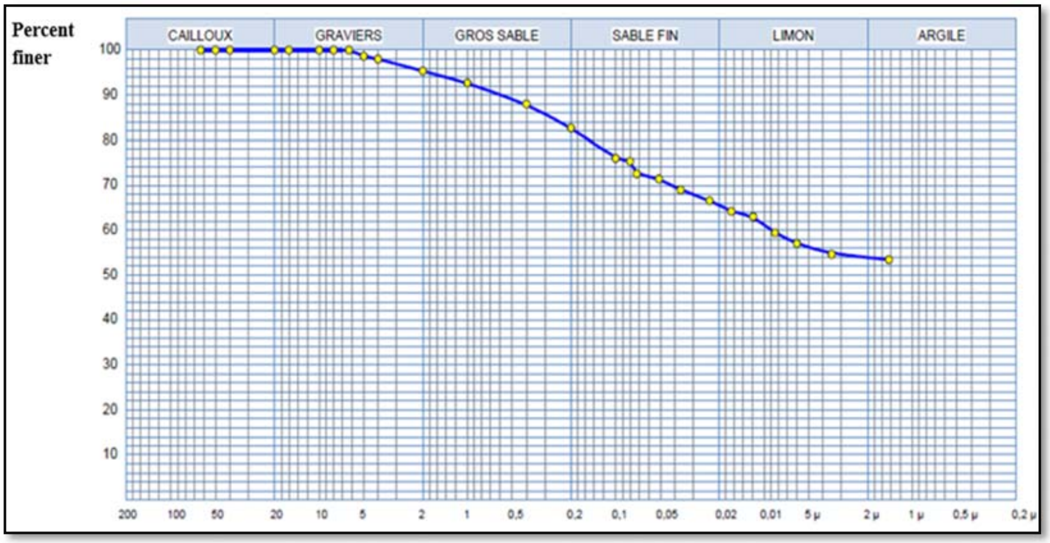

Figure 2: Grain size distribution of the tested sediment.

The Atterberg limit determined according to NF P94-051[7], the sediment represents 36.49% of liquid limit, plastic limit of 23.58% and plasticity index of 12.42 %.

According to the classification according to GTR 1992 [8], we can classify the sediments in the soil type A_2.

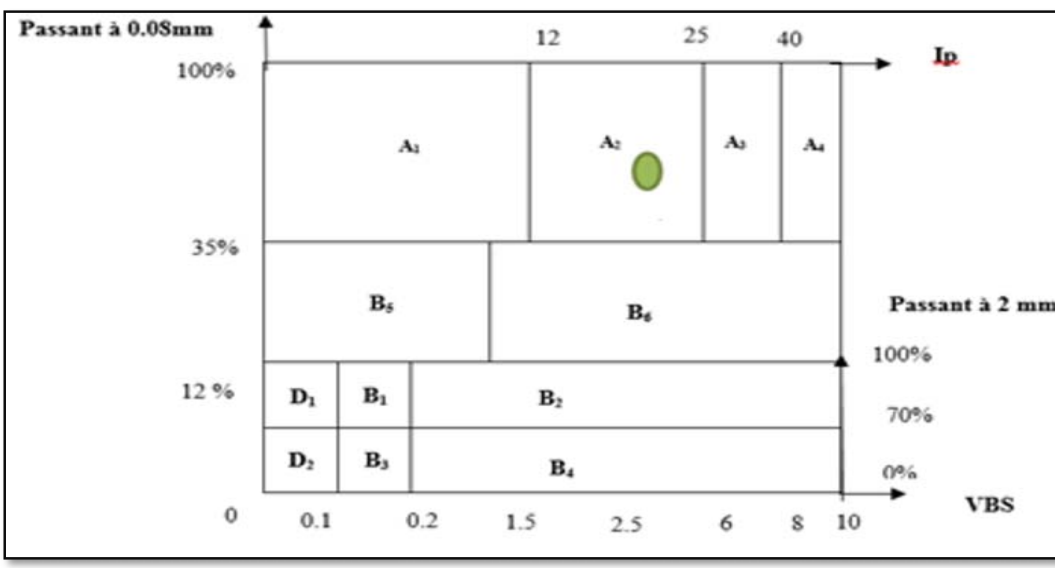

Figure 3: Sediment classification according to GTR 1992.

1.1.2 Cement and lime

In this work, we used a compound Portland cement. The type of cement is a CEM II of strength class 42.5 R according to EN 197-1 (2001).
Figure 4 represents the particle size curve by laser of cement used. The curve shows that the volume of particles with a diameter of less than 10 µm is the range of 50 %, the volume of particles is a little larger for cement, and the large diameters have a dimension more than 50µm.
The type of lime is to be used in principle; the preference is never the less given to the air lime of Ghardaia, figure 5 represents the granulometric curve by laser of the lime used.

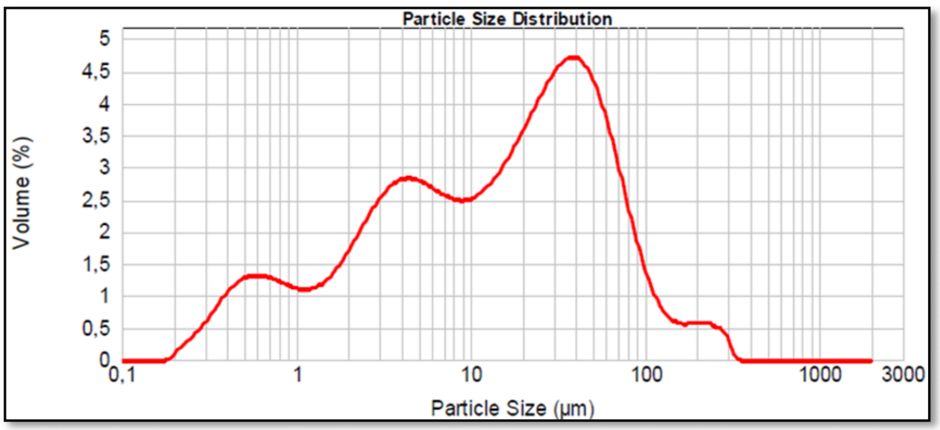

Figure 4: Particle size analysis of cement.

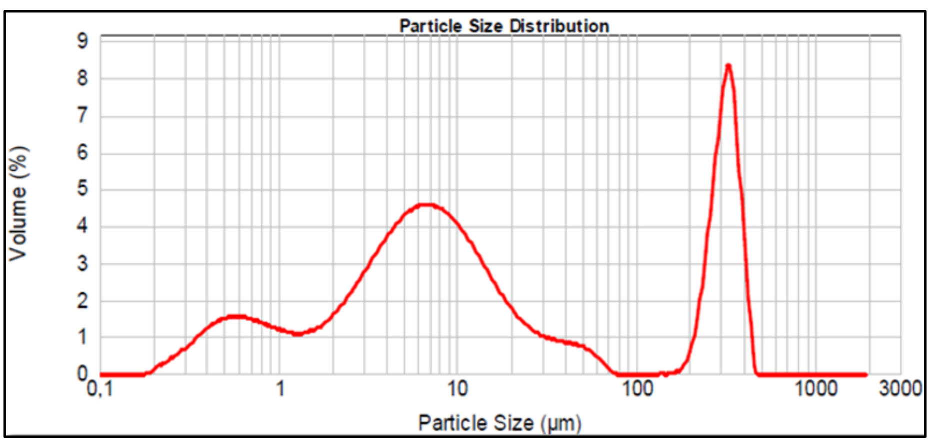

Figure 5: Particle size analysis of lime.

1.2 Experimental methods

1.2.1 Preparation of specimens

The preparation of specimens accordance with NF P94-093 standard [9]; and local recommendations[10]. The compaction of the blocks stabilize with the cement and the lime were achieved by using a hydraulic semi-automatic press with of length is 295 mm, the width is 140 mm and 90 mm of height. The different treatments were carried out according to the different contents and variants:

1. Blocks with: 6%; 8%; 10% and 15% cement
2. Blocks with: 5%; 8% and 10% lime.

The stabilized blocks have undergone various laboratory tests such as flexural strength; wetting and drying test; durability tests.

A. Flexural strength

Flexural strength test is carried out in accordance with NF P18-407[6] (fig .6), with a semi-hydraulic pressure and a compaction of 7MPa.

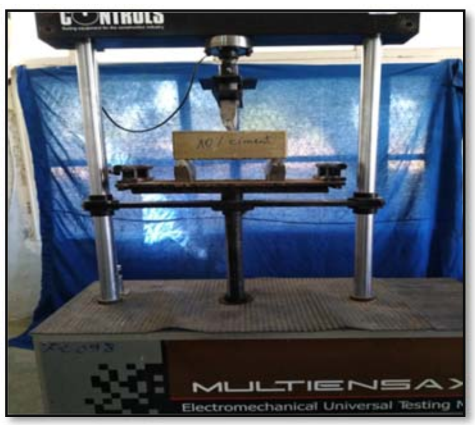

Figure 6: flexural strength test.

B. Shrinkage

The drying shrinkage (fig.7) test of the blocks [11], according to the following procedure:

- Weigh the blocks sealed on each block with an epoxy resin two measuring pads L_1.
- Place the blocks in the oven at a temperature of not less than 33 °C and not more than 45 °C).

- Dry the blocks to constant mass, the mass is considered constant when two successive weighing carried out at 24 h intervals show a decrease in mass < 0.1percentage of the initial mass.
- After drying, remove the blocks from the oven and place them in the laboratory;
- After 6 hours of stabilization, measure the distance between blocks: L_2.
- The shrinkage is calculated according to the following formula (1):

$$R = \frac{L1-L2}{L2} X\, 100 \quad (1).$$

Figure 7: Shrinkage test.

C. Wetting and drying test

This test is carried out according to the ASTM D 559-57 [12]; it consists of immersing the blocs stabilize of cement end the lime in water for a period of 5 hours and then removed to be dried in an oven at 71 °C for a period of 42 h. This operation is repeated six times[13].

D. Durability test

For the realization of the test, we used only stabilized blocks with a dosage of 8% cement and blocks with a dosage of 10% lime.

For this, we proceeded to the exposure of two walls in real climatic conditions for 22 months (fig .8).The area of exposure is in the southwest of Algiers (Algeria). The average humidity is about 70%. During the exhibition, the extreme temperatures vary between 38.6 °C and 6.3 °C, recorded respectively in July and January. The built walls are visited periodically and visual inspections have been scheduled every 3 months.

Figure 8: Walls built and exposed - February 2019.

2 Results and discussion

2.1 Flexural strength

From figure 9, it can be seen that the flexural strength increases with increasing binder dosage (cement and lime). This increase is mainly due to the good resistance offered by the binder. Blocks stabilized with cement showed higher strengths than those stabilized with lime.

Overall, it can be observed that the values of the mechanical tensile strength of the blocks are greater than 1MPa. However, it can be seen that the value of the mechanical tensile strength of blocks with 15% cement at 2.80MPa is the highest compared to other formulations. Although the value of mechanical tensile strength with 5% lime at 1.25MPa is the lowest.
We can note an improvement of the mechanical resistance to traction respectively of 1.40, 1.75, 2.50 and 2.80MPa for dosages of cement of 6, 8, 10 and 15% compared to the studies of Ngouama[14] and Barro[15], and significantly in conformity with the standard decreed by CRA-terre[16].

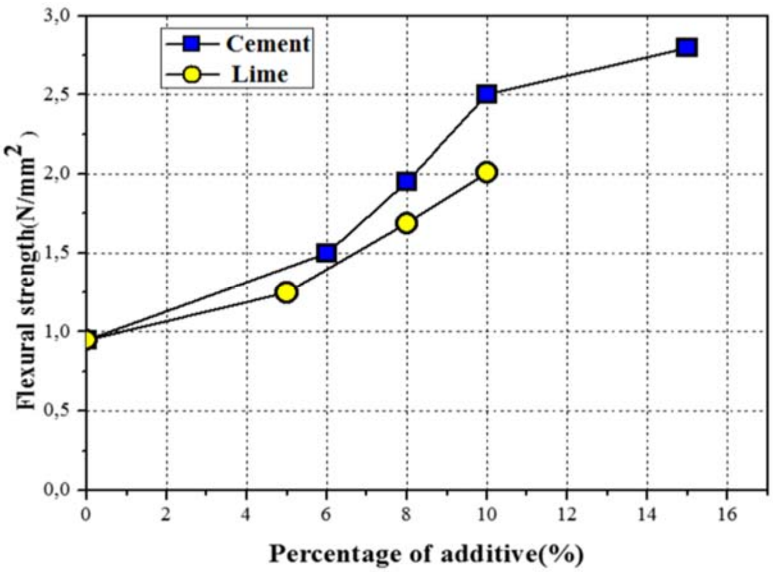

Figure 9: Flexural strength of elaborated blocks.

The strength increases significantly for 5% to 10% of lime with 1.25 MPa and 1.89 MPa respectively, this growth in strength is due to the increase in the potential of exchangeable calcium cations provided by the lime, there is an improvement of up to 10% compared to O.Izemmouren [17], which found 1.39 MPa of mechanical strength to the traction for a dosage of 10% lime.

2.2 Shrinkage

The results of block shrinkage versus additive content are shown in figure 10. The results show that the shrinkage decreases with the increase of the percentage of additives.
The blocks stabilized by cement show less shrinkage compared to the blocks stabilized by lime, because of the hydration phase of cement.
We can note an improvement of shrinkage with values of 0.71, 0.59, 0.42, and 0.33 mm/m for cement dosages 6, 8, 10 and 15% and 0.81, 0.75 and 0.61 mm/m for lime dosages.
According to the technical performances of earth blocks stabilized in CRATERRE-EAG[16], the results are acceptable.

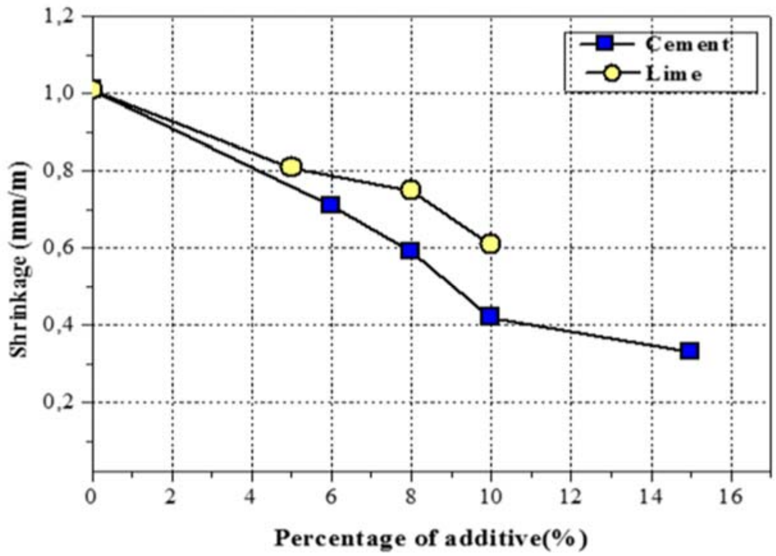

Figure 10: Shrinkage of elaborated blocks.

2.3 Wetting and drying test

Figure 11 shows the state of block stabilized with 10% cement and 5% lime after 6 cycles. The wetting/drying test appears to be very severe. The corners of the blocs are the main defects, for the bloc reinforce with 10% cement the surface weathering, including pitting and chipped edges for the bloc reinforce with 5% lime. This test could be adapted to estimate the water resistance of stabilized blocks by reducing the number of cycles.

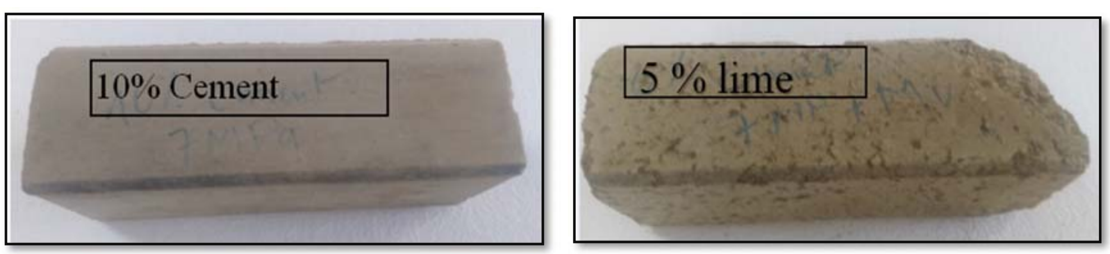

Figure 11: Wetting and drying test.

Figures 12 and 13 show that the weight losses after six wet-dry cycles do not exceed 5%.The weight loss decreases when increasing the dosage of bender.

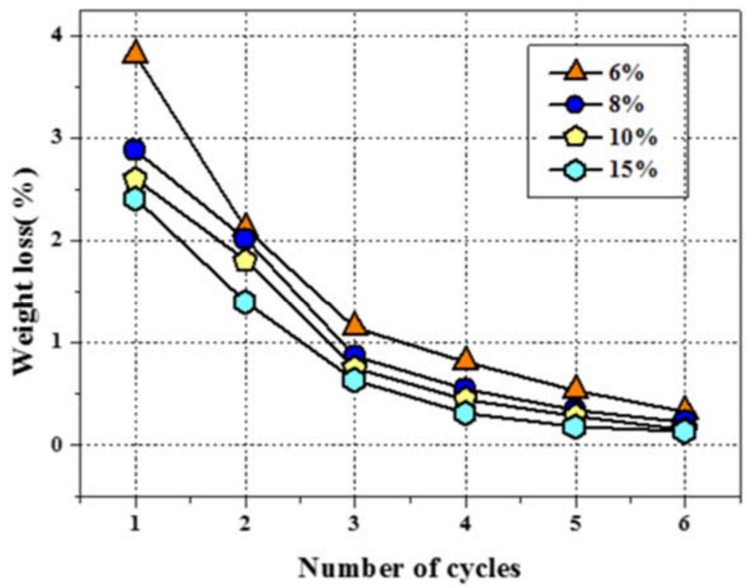

Figure 12: The weight loss for blocks stabilized by cement.

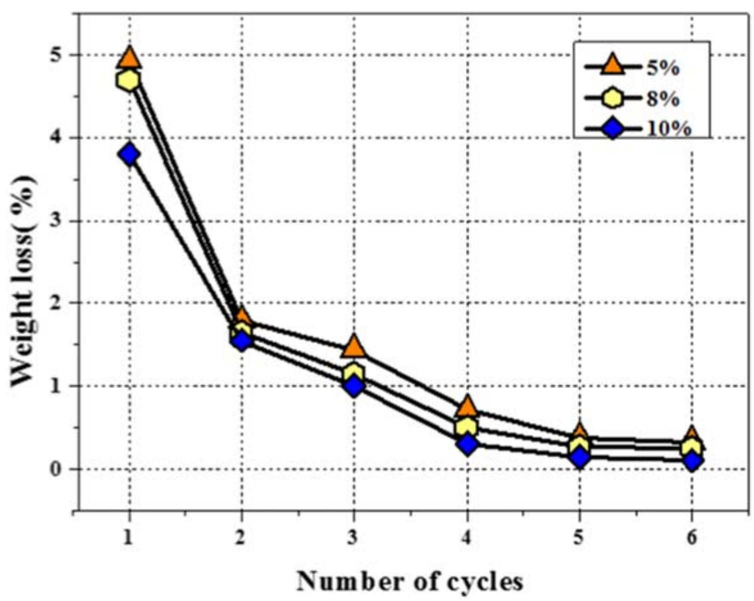

Figure 13: The weight loss for blocks stabilized by lime.

Lime stabilization only interacts with the clay phases. The proportion of minerals representing the clay phases (Kaolinite + Illite) is lower than 15%. Blocks treated with 15%, cement and 10% lime are also affected by an irrecoverable loss of mass, with respectively a maximum cumulative weight loss of 2.41% and 3.8%. This finding confirms the conclusions of Guettala [9].

2.4 Durability test

The changes included surface roughness, surface pitting, cracking and loss of mass. The survey of the wall shows about that the defects included surface wearing away and cracking (fig.14). The location of the cracking is mostly in the middle parts of amounts of the blocks and the wearing away mostly involves the corners. Differential wearing away appears at the front of these walls; this points that the change does not continue at the same rate from one area of the block to another. Guettela [13] confirmed this after exposing walls with blocks with 10% lime for 48 months..

Figure 14: Wall condition stabilized by 10% lime (November 2020).

Figure 15: Wall condition stabilized with 8% cement (November 2020).

After 22 months, the wall built with blocks stabilize with 8% cement shows no signs of wearing away, but a small piece of block disappears from the first line (fig.15). On the other hand, the earth blocks with 10% lime showed an indication of group of flowers was noted. The upper surface of the wall built with blocks containing 8% cement shows no signs of worsening or rusting and crumbling, but a small surface roughness.

He also stated the importance of the hit/effect of limits, guidelines such as drop size, drop size distribution [18].

3 Conclusion

The present work deals with the valorization and recycling of sediments of the Koudiat Acerdoune dam in the field of construction. The experimental campaign was undertaken to evaluate the mechanical strength, water resistance and durability of cement and lime blocks.

However many conclusions can be drawn:

- The strength increases significantly as the cement content increases.
- An increase in the strength is recorded for the stabilized blocks compacted with an effort of 7MPa. This improvement up to 2.80MPa and 1.89MPa for the blocks stabilized with 15% cement and 10% lime, respectively, compared to the reference blocks.
- The stabilization of the blocks made by sediment improves considerably the durability of the walls.
- The results of durability test show that walls built by blocks stabilized with cement and lime blocks show negligible degradation after exposure to real climatic conditions for several months.

Through this experimental study and according to the geotechnical, chemical descriptions, the recycling of the sediment from dams can reduce can reduce the environmental impact.

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