J. Mater. Environ. Sci. 6 (12) (2015) 3430-3435
ISSN: 2028-2508
CODEN: JMESCN

The effect of lime on alumino-silicate and cement on the behavior of compressed earth blocks

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Abstract
Our research presents experimental results of chemical analysis and uniaxial compression tests cylindrical samples of four types of earth associated with 4% and 7% of cement dosage, allow to analyze the influence of the chemical elements of the clay and cement on the mechanical characteristics of earth blocks, namely: the Young modulus, the compressive strength and the deformation limit. The principal chemical constituents of clays of the four earth are: lime (CaO), quartz (SiO_2), dolomite ($CaMg(CO_3)_2$) and the alumino-silicate. These elements have amplified the improved behavior of the material by the addition of cement. Indeed, the strong presence of lime stabilized clay by quartz cementation and reacting the alumino-silicate with calcium hydroxide ($Ca(OH)_2$) in the presence of water, to form compounds with binding properties and the cement matrix to strengthen links between the grains of earth.

Keywords: Lime, Alumino-silicate, Compressive strength, Young modulus, Deformation limit.

Introduction
The process of stabilizing the raw earth is applied systematically in the field of construction, and with the objective to improve its mechanical performance. The technology of compressed earth block is used in this sense with stabilizing additives, the best known of which are cement, lime and fibers. However, it is found that the results of this stabilization are positive as a function of the chemical composition and particle size of the earth. The chemical analyzes are performed on four types of soil to study the efficacy of chemical elements clay [1,2,3,4,28] and the addition of cement on the mechanical behavior of compressed earth blocks stabilized [5-13].

2 Testing Procedure
2.1 Materials
Earth used in this study are taken from four different sites:

- Ouarzazate, in the south, referenced to as ***O***;
- Fez, mid-east, referenced to as ***F***;
- Settat, centre, referenced to as ***S***;
- Rabat, west-North, referenced to as ***R***.

They are extracted in accordance with recommendations issued by the International Laboratory CRA Terre, Table1 summarizes the granular fraction 4 earth:
Table 1 shows that the soil materials ***O*** and ***F*** have almost the same gravel-sandy texture, inversely to the other two materials ***S*** and ***R*** which are more clay dominant with a tendency of the ***R*** to be finer than ***S***.

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Identification of soil is completed by the analysis of the clay part to determine the states of consistency called Atterberg limits namely: the plastic limit 'W_P' and the plastic limit 'W_l', the difference between these two limit is equal to the plasticity index 'I_P'. Table 2 also picks the coefficient of activity '***Ca***' and *B*lue value.

Table 1: Granular fractions the four earth***O***, ***F***, ***S*** and ***R***

	granular Fractions			
	Gravel	***Fine sand***	***Silts***	***Clay***
O	20	56	17	7
F	28	52	12	8
S	14	50	16	20
R	1	70	5	25

Table 2: States of consistency the soil***O***, ***F***, ***S*** and ***R***

	Ip(%)	***Ca***	***Blue value (cm^2)***
O	15	2.14	18.2
F	10	1.28	48.9
S	13	0.68	29.3
R	7	0.27	21.5

From the classification table of the activity coefficient [10], we found that the earth ***O*** is active and the earth***R*** is the most inactive.

2.2 Chemical analysis of four soil

- Chemical analysis reveals that the soil***O*** consists principally of alumino-silicate materials (61.4%) and the carbonate lime (32.4%). The organic matter content is 0.6%.
- The main constituents of chemical elements from the clay soil***F*** are calcite($CaCO_3$), with a content SiO_2(22.3%) high due to the concentration of quartz and dolomite.
- Chemical analysis of the soil***S*** shows 68% of alumino-silicate elements and 16% the carbonate lime. However, magnesium carbonate marks a proportion of 6%. The rate of the organic material is 0.8%.
- The percentage of organic matter in the earth ***R*** is only 0.44%. The chemical constitution is dominated by alumino-silicate elements (88.5%) with a percentage of iron oxide of 3.6%.

2.3 Test mode

Compression testing of four earth ***O***, ***F***, ***S*** and ***R*** are also performed on cylindrical specimens of dimensions h = 120mm and diameter = 80mm. These specimens are made by a static compaction with an effort of 2 MPa associated with the different dosages of cement 4% and 7% (Figure 1).
The samples were previously cured for 28 days: 14 days under plastic and 14 following days in open air.

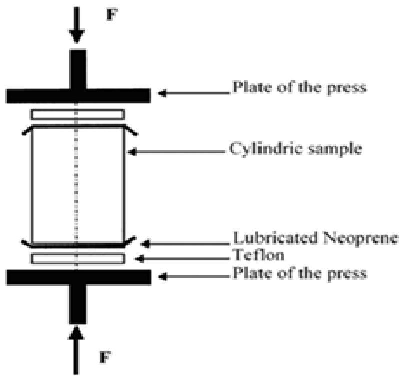

Figure 1: Experimental material of compression test

3 Results and discussions

3.1 Effect of the chemical constituents of the clay and cement on the mechanical behavior of the soil material

The experimental results of the average compressive strength 'Rc', the Young modulus ‘E’ and the strain limit' ε_{lim} 'of four earth blocks, associated with different dosages of cement, are summarized in table3.

Table 3: Experimental results means the mechanical characteristicsof soil***O***, ***F***, ***S*** and ***R***

		E(Mpa)	***Rc(Mpa)***	***ε_{lim} (%)***
O	***4%***	421	1,59	0,529
	7%	585	3,17	0,618
F	***4%***	326	2,24	0,858
	7%	509	3,69	0,809
S	***4%***	277	1,30	0,575
	7%	357	1,61	0,542
R	***4%***	82	0,54	0,998
	7%	135	0,99	1,000

Table 3 shows that the Young modulus and the compressive strength of four types of soil increase with the cement content of 4% to 7%. Which is in agreement with all recent studies [1,5,7,11,12,13] which have shown that the mechanical characteristics increase with the cement in a proportion of 4% to 10%. However, this increase varies from material to the other.

The percentage of 4% by weight of cement was judged by several studies [15,16,17] as the optimum technical - economic. The work by Cherraj M., Bouabid H. and al. [18] used to model and predict this optimum with more precision.This increase is due to the granular texture of each earth. Indeed, the two soil***F*** and ***O*** contains over 20% gravel and less than 8% clay, and present a greater rigidity than the other two soil ***S*** and ***R***.

The results of chemical analyzes show that the soil ***F*** is formed principally quick lime CaO (31.8%), quartz (SiO_2) and dolomite ($CaMg(CO_3)_2$), and soil ***O*** contains 32.4 % lime and 61.4% of alumino-silicate.

According to Mertens and al. [19], the quartz is not a binder, it constitutes a portion of the fraction of fine sand, the results obtained by Dekayir and al. [20], Allali and al. [28] shows that the quartz grains are cemented by calcite which is the product of the carbonation lime. This latter once mixed with water possesses the property of to do quickly taking in agglomerating of the inert particles such as quartz and sand by the following reaction [1,4,14,20]:

$$CaO + H_2O = Ca(OH)_2 \text{ (portlandite)}$$

Whence, the clay is stabilized by carbonation lime (the binder phase) by absorption of carbon dioxide (CO_2) from the area, this reaction is possible in the presence of water and presents by [1.20]:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$

Bessenouci and al. [21] have concluded that the alumino-silicate has a property of being a bonding by chemical reaction with calcium hydroxide ($Ca(OH)_2$) in the presence of water at ordinary temperature. While the hydrated cement matrix of the earth reacts in two ways [1,13,22,23,24]: strong reaction with sandy-gravel skeleton and a very low reaction with the clay which is already stabilized by the reaction of lime and water. The latter gives the calcium hydroxide ($Ca(OH)_2$) which reacts with the alumino-silicate in the presence of water to form compounds possessing binding properties.

Hence the compressive strength 'Rc' increases substantially as a function of the cement rate and the limit strain varies in the opposite direction. So intake of conjugated cement a strong presence of lime contributes to the block rigidity and reduced as a result its deformability (ductility) [1,13]. Whence, the particles soil of ***F*** and ***O*** are much coated with the cement and the clay matrix, thereby improving the bonds between the grains.

By against, clayey earth ***R*** containing 25% clay and 70% of the sand is less resistant and deformability is quite important because the strain limit reached almost 1%. The results of the chemical analysis shows that the clay contains a rate of 88.5% of alumino-silicate, knowing that, this last it is not a linking without chemical reaction with calcium hydroxide ($Ca(OH)_2$) and water. Therefore, reducing the compressive strength is attributed to the effect of weakening the clay minerals of alumino-silicate is a linking between the cement paste and the inert soil matrix, it ensures cohesion between the grains and allows a distribution of the stresses when loading [1,13,25, 26,27]. Previous studies [5,7,11,12,22] concluded that earth containing a greater clay content is difficult to stabilize. She needs more cement. It is recommended to change the granular composition by the addition of sand or gravel to improve its characteristics.
Figures 2, 3 and 4 gives the evolution of the compressive strength, the Young modulus and the limit deformation of compressed earth blocks of four soil***O***, ***F***, ***S*** and ***R***.

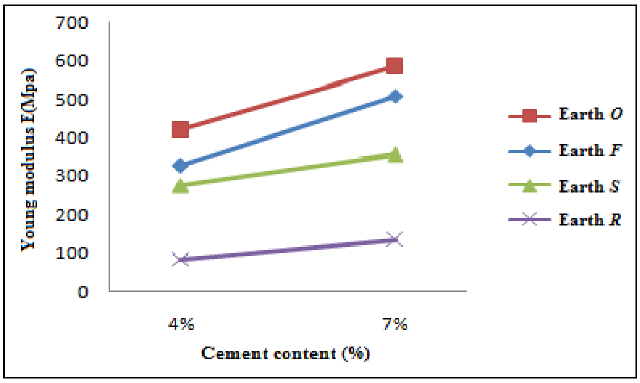

Figure 2: Evolution of the Young modulus of four earth cement function

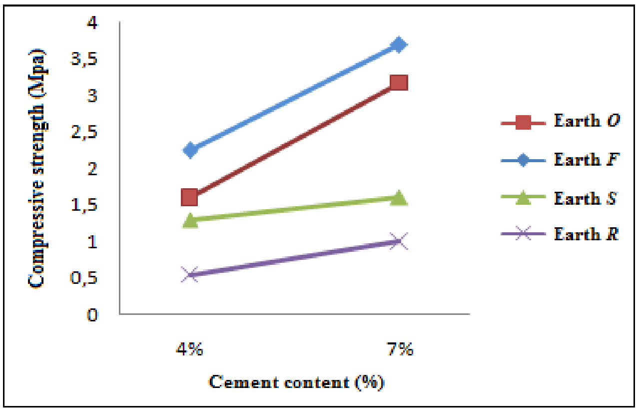

Figure 3: Evolution of the compressive strength of four earth cement function

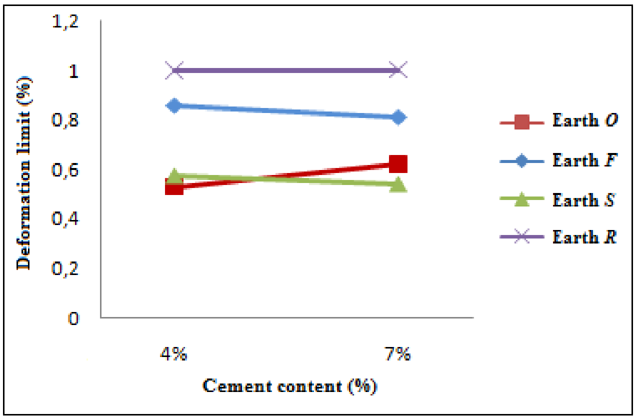

Figure 4: Evolution of the deformation limit of fourearth cement function

3.2. Failure mode of the soilO, F, S and R

When overwriting test specimens, visible cracks are observed while initiating at the specimen. These cracks are aligned along the height of the specimen with increasing effort until rupture. The nature and direction of these cracks differ according to the granular texture of the earth and the cement dosage rate:

For a low stress on the test specimens of the two soil***O*** and ***F*** with 4% by weight of cement, cracks are initiated on the upper and lower of the specimen surface. When effort increases, the specimen continues to resist loadingdespite cracks that are aligned along its height, and the failure mode of the specimen with 7% cement does not differ much from that of 4 % cement. However,these cracks are initiated in the mid-height of the specimen and propagated a little inclined towards the base surfaces. This shows that the dominance of gravel and sand makes it more fragile material (Figure a).

For the earth ***S***, the limit strain is of the order of 0.5%, cracks are initiated at the mid-height of the specimen and propagated inclined to the horizontal until it reaches the edges. Hence, the behavior of the material ***S*** presentscertain deformability (ductility) (Figure b).

The ***R*** material has a perfectly ductile behavior and limit strain almost 1%. Moreover, there has been a rupture engendered by cracks in the middle of the specimen and then propagating too inclined planes to the horizontal (Figure c). So, the clayearthmakes the deformablematerial (ductile) [13].

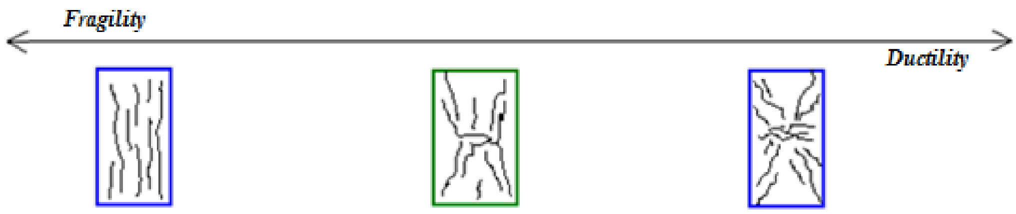

Figure a: Rupture fragile Soil ***O*** and ***F*** **Figure b:** Rupture intermediate Soil ***S*** **Figure c:** Rupture ductile Soil ***R***

Figure 5: Failure modes

Conclusion

In the lightof the results ofexperimental testsreported in this study, we can conclude that:

- Thecompressive strengthandthe Young modulusincrease with thecementratefrom 4%to 7%.This increaseisdue to the granular texture of each earth; the presence of lime in the clay constituents has the property of quartz cement and react with the alumino-silicate and water to create compounds having binding properties. Therefore, the cement addition amplified the linkages between the sandy-gravel skeleton and the clay matrix is stabilized by these chemical constituents to make the material resistant and consequently reducing its deformability (ductility).
- The presence of alumino-silicate without lime in the chemical compositions of clay makes the low clay matrix to ensure cohesion between the cement paste and grains of earth and this gives rise to a less resistant material with a fairly large deformability, the example of the soil ***R***.
- The block compressive strength strongly depends of cement the content and clay. It increases with the increase in the cement dosage rate and the lime stabilizes other chemical constituents of the clay such as quartz and alumino-silicate.
- Cracksare initiatedatastress levelof about40% to 50% of the maximum load.Beyondthis threshold, thebehavior becomesnonlinearapparentlybecause ofthe formation ofcracks.Thematerial continuesall the sameto resistloading upthe damage.

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