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Research Article

Effect of Granulated Slag on the Durability of Compressed Earth Bricks Based of Sulfate-Bearing Soil

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***Abstract* –** This work deals with the problem of stabilizing compressed earth bricks that contain a significant amount of sulphate. The objective of this study is to analyze the effect of the addition of lime-activated granulated slag (GS) on compressed earth bricks (CEB.) based on sulphate-bearing soil to improve its mechanicals resistance and especially its sensitivity to water. In this context, a soil stabilized with an 8% lime content of the dry mix weight and four slag contents (10%, 20%, 30% and 40%) of the weight of the lime was used. The samples were subjected to mechanical strength tests in dry and wet compression and also to durability tests: total absorption, drying / wetting, swelling. The results showed that the addition of granulated slag with lime can improve the mechanical properties and durability of compressed earth bricks based on sulphate soil.

Keywords – Compressed Earth Brick, Granulated Slag, Lime, Mechanical Strength, Durability

I. INTRODUCTION

Several studies have used finely ground granulated slag to treat the problem of soils that contain sulphate [1-3] they have shown the beneficial effect of slag on the durability of these soils. In addition, in [4], the authors conducted a study on the stabilization of earth bricks compressed by slag activated by lime and cement. He showed that bricks stabilized by slag with lime give better resistance and durability than bricks stabilized by slag with cement. The mechanism of the reaction in a mixture containing lime, slag and soil in the presence of water is divided into two distinct reactions: - the first reaction is called the ion exchange reaction, it is fast as the result of exothermic reaction, this is known as ground improvement or modification - the second reaction is pozzolanic reaction, it is slow and known as stabilization/solidification [5, 6].The main objective of this work was to study the effect of the use of granulated slag, the mechanical properties and durability of the CEB.

II. MATERIALS AND METHOD

A. *Materials*

The materials used in this study for making compressed earth bricks were soil and crushed sand as the main matrix; lime (L) and granulated slag (GS) as stabilizers.

- The soil used in our research finds their belonging in the region of Biskra. (Algeria). It is characterized by its availability and abundance in the region. Table. 1 shows the mineralogical composition and physical properties of the soil. The chemical composition indicated in Table 2 was examined using the X-ray fluorescence method. The chemical analysis of the soil revealed the presence of a high level of sulfur trioxide SO_3 (6.21%). This rate exceeds the recommended limits for soil stabilization.

- The sand used in all brick mixes is crushed sand from quarries in the Biskra region (Algeria).

- La chaux utilisée dans cette étude est de la chaux

Table 1. Chemical composition of soil, lime and granulated slag (GS) (%)

Oxide	Soil	Lime	LG
SiO_2	34.33	1.35	40.92
CaO	20.45	82.77	41.30
Al_2O_3	14.99	10.63	10.63
MgO	0.88	1.83	4.45
Fe_2O_3	2.39	3.27	1.51
SO_3	06.21	0.11	0.36
K_2O	0.50	0.151	1.05
Na_2O	0.13	0.064	0.19
P_2O_5	0.06	-	0.02
TiO_2	0.21	-	0.38
L.O.I	19.85	-	-0.8

- La chaux utilisée dans cette étude est de la chaux vive (CaO) produite dans la ville de Hassasna, Unité Erco, wilaya de Saida. Le laitier granulé obtenu par trempe (rapide) est fourni par le haut fourneau d'Elhadjer (Algérie). Il se présente sous forme de sable de granulométrie 0-5 et de couleur gris clair. Ce laitier est broyé au niveau du laboratoire. La composition chimique et les caractéristiques physiques de la chaux et du laitier sont présentées dans le tableau 1 et le tableau 2 respectivement.

B. Composition of mixtures, preparation of samples

Before mixing we must make sure that our mixture is really dry. To do this, the soil and the crushed sand must be dried in an oven for 24 hours at 60°C. Afterwards, the mixture is mixed dry (soil + crushed sand) for 2 minutes in a cement mixer, then the binders are added and the mixing is continued for one minute [10]. Water is added to the mixture and mixing is continued for 2 minutes. The material is placed and compacted immediately after mixing. Details of the proportions of experimental mixtures of CEB are given in Table 3. The compaction of the specimens is of the static type. During all the stages of this study, the mixtures were subjected to a compaction stress of 10 MPa. The bricks are cured in a humid atmosphere, the bricks of which are covered with plastic fabric at 28, 56, 90 and 180 days. Before submitting the CEBs to the tests, they must be dried in an oven to constant mass.

C. Test method

-The compressive strength in the dry state is used to determine the nominal resistance in simple compression of
compressed raw earth bricks according to standard XP P 13-

Table 2. Physical characteristics of lime and slag

	Specific density (Kg/m3)	Apparent density (Kg/m^3)	specific surface (Kg/m^3)
Lime	2230	1490	300
Slag	2910	1210	450

901. Is to subject a sample consisting of two half-blocks superimposed and bonded by a joint of cement mortar to simple compression until rupture.

- The wet compressive strength test is identical to the dry compressive strength test, except that the sample is wetted by complete immersion for two hours.

- The total absorption test consists of immersing the brick in a water tank for 24 hours, and measuring the increase in wet weight compared to the weight of the brick in the dry state.

- CEB swelling is measured according to the following procedure (standard XP 13-901). First, the bricks are sealed using an epoxy resin from the two according measuring pads. Then the blocks are placed in a tank of water for 96 hours. The bricks are left drained for 10 minutes and finally the distance between the studs is measured.

- To determine the resistance and the behavior of the CEB when it undergoes rainfall alternations (saturation in winter and drying in summer), a set of wetting-drying tests were carried out on the different bricks studied according to the ASTM D559-03 standard. . In the present study, 12 drying-wetting cycles were applied. Each cycle consists of wetting the BTC for 5 hours in introducing it into water at room temperature (22°C), then drying the CEB in an oven at 60°C for an additional 48 hours. The blocks are brushed at each cycle to remove the fragment of material affected by the drying-wetting cycles. Mass loss is expressed as a percentage reduction in dry mass relative to the original mass.

Table 2. Physical characteristics of lime and slag

Soil (%)	Crashed sand (%)	Lime (%)	GS(%)
70	30	10	0
			10
			20
			30
			40
In relation to the global dry mixture			Par rapport au poids de la chaux

III. RESULT AND DISCUSSION

III.1 Effect of granulated slag on mechanical strengths

The results of the dry compressive strength as a function of the dosage in additions for different curing times are shown in Figure 1. It can be seen that the dry compressive strength DCS increases as a function of the slag dosage up to 30%, for the 40% dosage, the resistance remains almost constant. RCS also increases with cure time. All the DCS values of the bricks with additions are higher than the bricks without additions for the different curing times. The brick stabilized with 30% GS and cured at 28 reaches a value of 16 MPa. These significant results testify to the beneficial effect of slag on the improvement of long-term DCS.

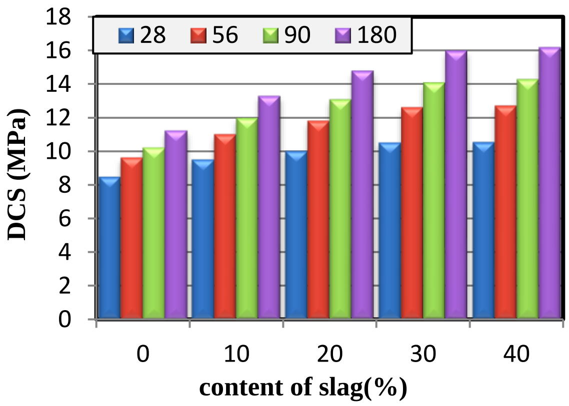

Fig 1. Influence of slag dosage on dry compressive strength for different curing

Fig.2 shows the variation in wet compressive strength as a function of curing time and slag dosage. Through this figure, we also note, as in the case of the dry compressive strength, that there is an increase in the WCS with the increase in the cure time for different dosages of GS. The WCS value for the bricks stabilized with 30% slag and cured at 180 days reaches 14.15 MPa. This shows that the slag improves the long-term WCS by chemical (pozzolanic) effect.

III.2 Effect of granulated slag on durability

In order to study the effect of slag dosage over time on the durability of CEBs stabilized by 10% lime, three different dosages of 10, 20 and 30% relative to the mass of lime were used, and this for a cure time of 28 days going to 180 days.

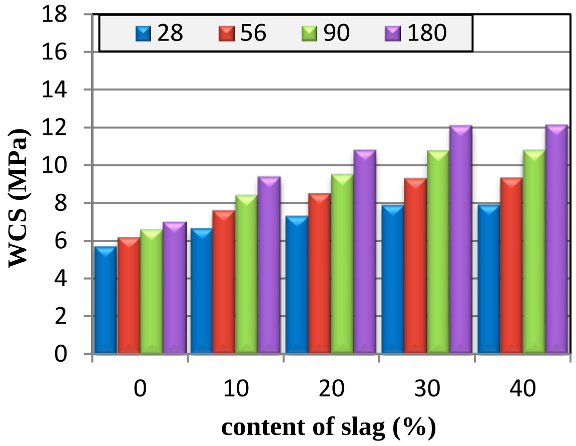

Fig 2. Influence of slag dosage on dry compressive strength for different curing

The bricks were compacted with a compaction stress of 10 MPa and stored in the laboratory at room temperature.

- La Fig. 3 représente la variation de l'absorption totale en fonction du dosage de laitier pour différents temps de cure. On constate que l'absorption totale diminue avec l'augmentation du dosage de laitier pour différents temps de cure. En termes de pourcentage, cette évolution est de 38.31 % dans la gamme de 0 % à 30 % de GS, à l'âge de 28 jours. À 56, 91 et à 180 jours, l'absorption totale est nettement diminuée et témoigne de la formation de nouveaux hydrates qui remplissent les vides.

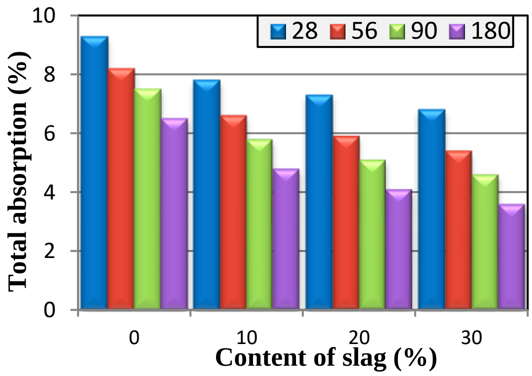

Fig.3 Influence of slag content on total absorption for different curing times.

À titre d'exemple, pour la brique curée à 180 jours et 30 % de GS, le gain de l'absorption totale est d'environ 5.7 % par rapport à la brique curée à 28 jours de l'ordre de 61.29 % de diminution.

-The results obtained show the favorable effect of the addition of slag on weight loss after twelve wetting drying cycles (Fig. 4). All the bricks stabilized by the addition of slag are less than 5%. Therefore, CEB can be used for building construction in humid regions where the annual rainfall is greater than 500 mm. The significant decrease in weight loss with increasing curing time is mainly due to the slowness of the pozzolanic reactions generated by the soil-lime and lime-additions reaction.

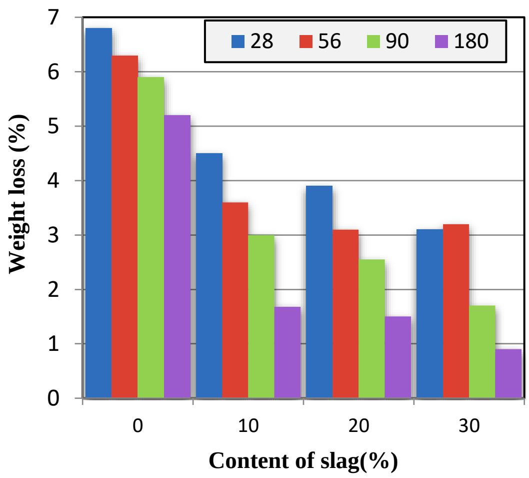

Fig. 4 Influence of slag content on weight loss for different curing times

- Fig. 5 shows the effect of slag content on swelling for different curing times. From this figure, it can be seen that the swelling by emersion is reduced with the increase in the content of slag and curing time. At 28 days, the analysis of the values shows that the reduction in swelling is: 16.8% for 30% GS. With increasing cure time, this swelling continues to decrease to the value of 0.068%, obtained by adding 30% of GS at 180 days. Swelling thanks to the formation of cementing binders resulting from the pozzolanic reaction developed over time [7].

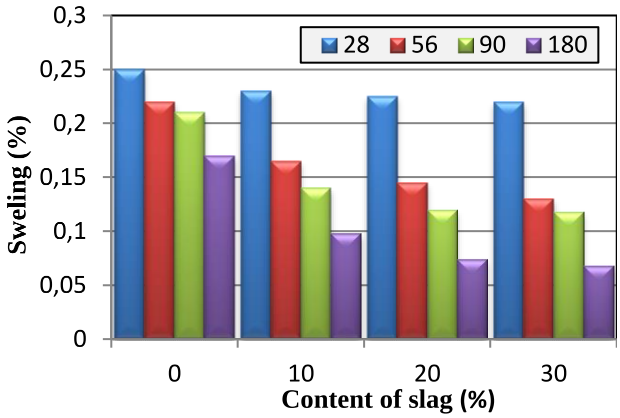

Fig.5 Influence of slag content on total swelling for different curing times.

IV. CONCLUSION

In light of the results obtained along this experimental study, the following conclusions can be drawn:

- The addition of 30% of the slag considerably improves the medium and long-term mechanical resistance, especially the resistance to wet compression.

- The rate of increase in resistance increases with the increase in the dosage of additions over time. At an age of cure (28-56 days), the rates of strength increase tend to be greater when compared to that at an age of (56-90).

- The total absorption and the swelling deprived with the increase in the dosage of slag up to a content of 30% in the medium and long term. At 28 days of age, a slight decrease in total absorption and swelling. From 56 days this decrease is significant.

- The incorporation of 30% slag improves the weight loss (Wetting drying test) of BTC in the medium and long term. The weight loss values are below the limits recommended by the ASTM D559 standard.

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