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Substitution of the aggregate by solid waste of blast furnance in the preparation of concrete

Naoual Handel, Belaid Hafsi, Assia Touati, Yassine Djabbar
LGMRIU , Civil Engineering Department, Centre Universitaire Mouhamed Cherif Messadia, Souk-Ahras, Algeria

Abstract
In this study we sought to use the Crushed Crystallized slag of blast furnace. It is used as aggregate in preparing slag concrete filling of steel columns. It is produce by totally or partially replacing the calcareous gravel by Crushed Crystallized slag. The study is comparison between slag concrete and ordinary concrete. The characterization of these concretes was made based on their mechanical properties: i.e., compressive strength, tensile strength and elastic modulus, and their durability: capillary, absorption of water, and hydraulics shrinkage. The experimental results showed a beneficial effect is bound-up by the percentage of slag used in concrete.

Keywords: Concrete, slag concrete, crystallized slag, performance, characteristic of the material.

1. Introduction
Crystallized slag from blast furnace of the El Hajar steel complex, Algeria, can be identified as a new building material in the preparation of concrete. The uses of industrial waste as a substitute material helps save a large share of natural resources and protect the environment. This material was used as filling element in steel tubes [19] and [20], performance ameliorations in mechanical strength and also at level of durability have been recorded. The concrete used has not fact object a comprehensive study to identify the different properties of concrete containing crystallized slag. For this, we conducted a comparative study of concretes containing slag aggregate and concrete ordinary.

In this work, recovery slag in concrete preparation was made at two levels: by substituting 50% crushed limestone gravel by crystallized slag; and the substitution of 100% crushed limestone gravel by crystallized slag.

2. Experimental procedure

2.1 Materials and concrete mix design
Concrete mixes containing either natural or crystallized slag aggregates were studied and compared. Three different mix designs were investigated for the concrete with natural and crystallized slag aggregate. The first of these was a control mix and did not contain any granulated blast furnace slag, and is designated by Mix1. Two of the mixes contained 50% replacement of natural aggregates with crystallized slag is designated by Mix2 and one contained 100% slag, is designated by Mix3. The cement used was CPJ 42.5 Type CEMII Portland cement. Three types of aggregates are used in the preparation of concrete study; the physical properties of aggregates are presented in (Table 1.) The complete proportions for the mixes Mix1, Mix2, Mix3 are given in (Table 2).

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Table.1: Characteristics physics of the aggregates

Aggregates	Granul -arity (d/D)	bulk density (kg/m3)	unit weight (kg/m3)	fines Modulus	Porosity (%)	Water content (%)	Water Absorption
NS	0/2.5	1500.	2650.	2.07	43.	0.31	-
NG	5/10	1450.	2700.	-	46.	1.01	1.83
CCS	5/10	1310.	2670.	-	51.	0 .75	5.
50% NG +50 % CCSS	5/10	1378.	2650.	-	48.	0.9	4.

Table 2: The mix proportions and properties

Type of Concrete		Cement (kg/m3)	Sand 0/2.5 (kg/m3)	NG 5/10 (kg/m3)	CCSS (kg/m3)	W/C	Slump (mm)
Normal Concrete	Mix1	350.	811.32	1095.77	-	0.60	60.
Partially Slag Concrete	Mix2	350.	811.32	537.74	537.74 (50%)	0.61	60.
Slag Concrete	Mix3	350.	811.32	-	1055.18 (100%)	0.65	60.

3. Results and discussion

3.1 Consistencies of concrete

The consistency is determined using the standard NF P 18-451 [10]. The three types of concrete: concrete Mix 1, Mix 2 slag concrete, and slag concrete Mix3 are formulated with a plastic consistency, with a slump of about 6 ± 1 [9]. The ratio E/C is quasi-proportional and can be explained by the following consideration: The cavities, which are found in crystallized slag, absorb water.

3.2 Density and area occluded

The density is determined using the standard NF EN 12350-6 [17], and the air content is determined using the standard NF EN 12350-7 [18]. As for a conventional concrete, the density of slag concrete depends on its formulation and its implementation. Normally obtained on wet concrete values ≥ 2.4, which is obtained for the three concretes Mix1 = 2.46, Mix2 = 2.44, and Mix3 = 2.43, as shown in (Figure 1) The search for a high compactness is justified to have good mechanical properties.

The air content for Dmax = 10mm must be less than or equal to 3%. This is the case for ordinary concrete Mix1, but the percentage of entrained air increases with the substitution of aggregates of crystallized slag, which has a porous body; this is the reason for which there was an increase in the value of air-entrained concrete slag Mix 2 and Mix 3, as shown in (Figure 2).

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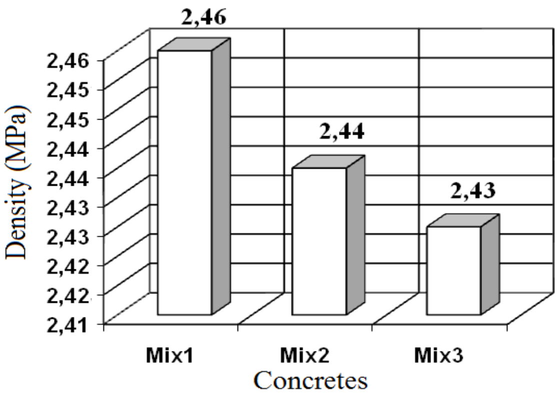

Figure 1: Density of different concretes

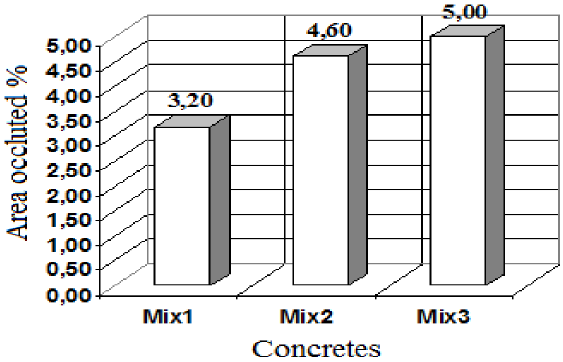

Figure 2: Area occluded (%) of different concretes

3.3 Compressive strength

The strength is determined using the standard BS 1881[11]. The evaluation of compressive strength in time of the three concretes is shown in (Figure 3) These strengths are obtained by crushing the average of 03 cubic specimens of 10x10x10 cm, to 7, 14, 28 and 180 days. A first exploitation of the results shows the kinetics of stiffening slightly different between the concrete slag Mix2 and Mix3 compared to concrete Mix1. We note that the compressive strength of slag concrete Mix2 [fc7 = 24.46MPa, fc14= 28.87MPa, fc28 = 34MPa, and fc180 = 34.20MPa], respectively higher than that of ordinary concrete Mix1 [fc7 = 16.50MPa, fc14= 19MPa, fc28 = 22.00MPa and fc180 = 25.60MPa] and that of the slag concrete Mix3 [fc7 = 19.50MPa, fc14= 20MPa, fc28 = 25.00MPa et fc180 = 28.20MPa, This shows that binding paste-aggregate concrete slag Mix2 is better because of the surface texture of aggregate. The evaluation of the compressive strength of three types of concrete was found to increase with time, and this is consistent with prior research on slag concrete resistance [1,5,20].

3.4 Tensile strength

The Tensile strength is determined using the standard BS 1881[12]. The splitting tensile strengths of the concrete mixes are compared in (Figure 7). We notice that at 28 days there is not a great difference in the splitting tensile strength of concrete slag Mix2 and Mix3 compared to ordinary concrete Mix1, by contrast to age 180, the splitting tensile strength of mixes contained 50% replacement of natural aggregates with crystallized slag (Mix2) was increased compared to concrete Mix1 and Mix3. This shows a good adhesion between the components (paste, granules) slag concrete Mix2. Increase in Tensile strength when a crystallized slag aggregate is used is consistent with other findings [1, 5].

3.5 Elastic modulus

The secant modulus of deformation of the three types of concrete was calculated from the curves constraint-strain shown in (Figures 5, 6 and 7).

These curves are determined with strain gauges during the crushing of cylindrical specimens 16X32 cm. The values of the secant modulus of deformation of the three types of concrete Mix1, Mix2 and Mix3 are respectively 28,400, 36,600, and 30,700 MPa. Note that the slag concrete Mix2, where we substituted 50% of limestone gravel, is stiffer than Mix1 and Mix3.

3.6 Capillarity

The capillarity is determined using the standard NF P 18-502 [14]. The results presented in (Figure 8) are the average of three prismatic specimens 7x7x28 cm. These results show that the capillary rise is low for concrete

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Mix2 (C = 0.60%) and Mix3 (C = 0.80%) compared to ordinary concrete Mix1 (C = 0.70%). Therefore, the use of crushed slag as aggregate in concrete does not increase its permeability. The pores of the slag are closed, which means that the cavities don't communicate between each other.

3.7 Water absorption by immersion

The results presented in (Figure 8)are the average of three prismatic specimens 7x7x28 cm. the absorption by immersion of concrete slag Mix2 and Mix3 which are set to 6.10 and 6.90, respectively, are close to that of ordinary concrete Mix1 which is set to 6.20.

3.8 Hydraulic shrinkage

The shrinkage is determined using the standard NF P 15-433 [15]. The evolution of hydraulic shrinkage over time of the three concretes is shown in (Figure 9) the latter shows that shrinkage of slag concrete Mix2 and Mix3 is greater than that of natural aggregate concrete Mix1. The cavities that are in the crystallized slag have a negative influence on the Shrinkage of slag concretes

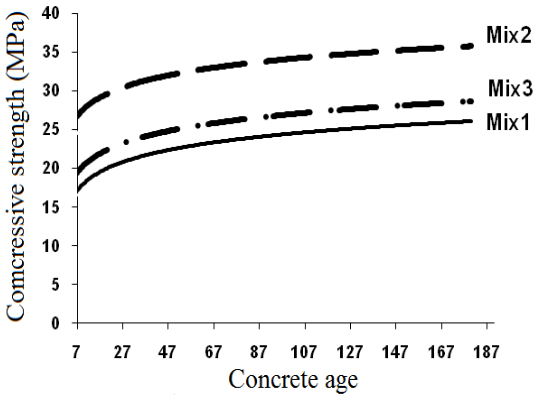

Figure 3: Compressive strength of different concretes

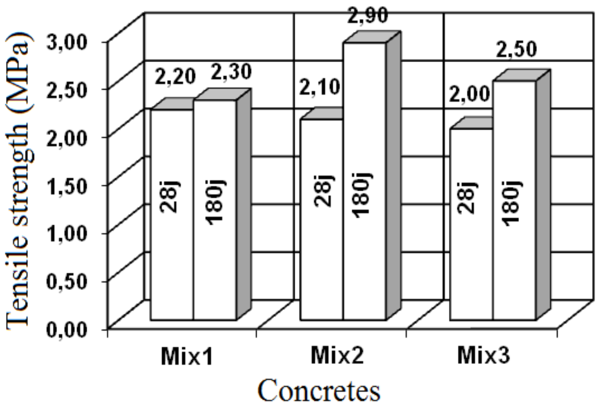

Figure 4: Tensile strength of different concretes

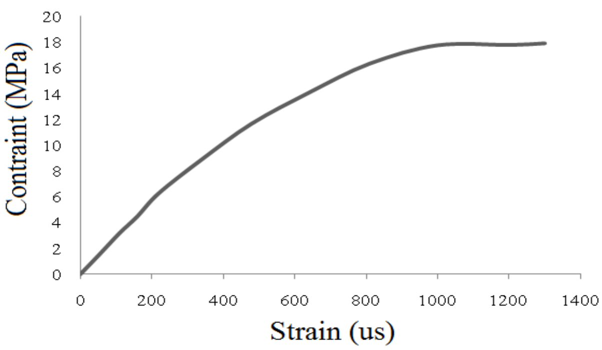

Figure 5: Contraint-strain of concrete Mix1

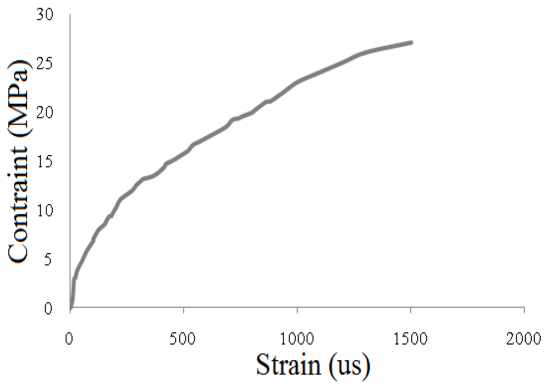

Figure 6: Contraint-strain of concrete Mix2

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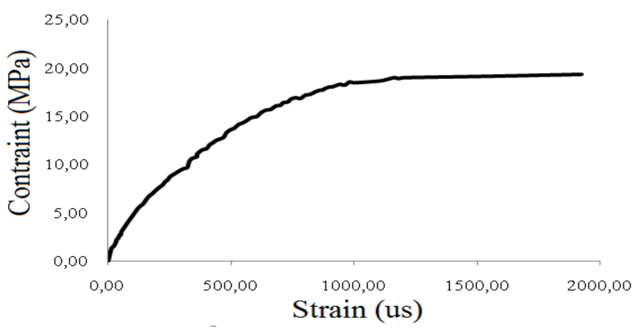

Figure 7: Contraint-strain of concrete Mix3

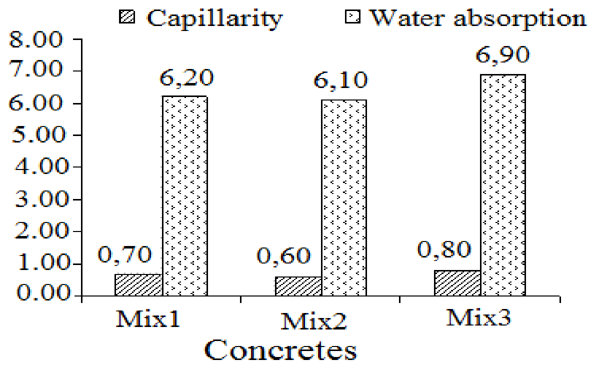

Figure 8: Water absorption by immersion and capillarity

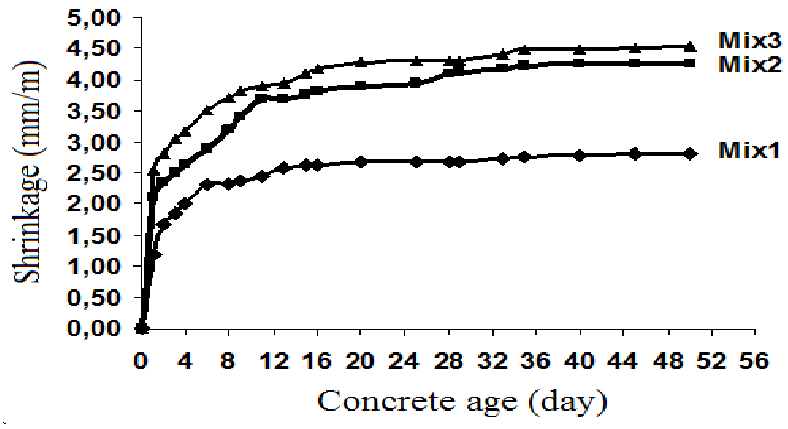

Figure 9: Shrinkage hydraulic of different concretes

Conclusions

This paper reports a series of tests on three concretes type, normal concrete Mix1, partially slag concrete Mix2 containing 50% crushed crystallized slag stones and slag concrete Mix3 containing 100% crushed crystallized slag stones. Based on the results of this study, the following conclusions can be drawn within the scope of these tests:

- The use of granulated slag as aggregate in concrete, contributes to the improvement of certain mechanical and physical properties including compressive strength.
- The concrete Mix2 (substitution of 50% of limestone gravel granulated slag) has the best compressive strengths compared to those obtained with conventional concrete Mix1 and slag concrete Mix3 (substitution of 100% of the limestone gravel granulated slag).
- The tensile strength of three types of concrete (Mix1, Mix2, and Mix3) are comparable and have similar values.
- The slag concrete Mix2 is more rigid and higher Young's modulus than conventional concrete Mix1 and slag concrete Mix3.

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