MECHANICAL PROPERTIES OF FLY ASH GEOPOLYMERS CONTAINING STEELMAKING LADLE SLAG

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ABSTRACT
The effect of adding steelmaking ladle slag to fly ash based geopolymers has been studied. For that, flexural and compression strengths were evaluated at 7 and 28 days after curing. It can be concluded that the increase in fly ash content has a relevant effect on the various mechanical properties.

Keywords: Geopolymer, Fly Ash, Wastes, EN 1015-11, Compression, Flexural, Resistance

INTRODUCTION
Geopolymers are inorganic materials, which form covalently bonded non-crystalline (amorphous) interconnections consisting of layers of alkaline activated aluminosilicates. Other factors, particularly at the level of geopolymerization, are the Si / Al ratio, the type and concentration of the alkaline solution, temperature, curing conditions, and additives, such as slags and fibers [1]. Presently, geopolymeric materials are increasingly important in the technological aspect of modern society. Its effectiveness in the substitution of common Portland cement has been one of the base points for the successful implementation of the geopolymeric materials, either by the greater applicability to a wide range of applications, by the greater ease of workability or by the superior mechanical properties [2,3,4].
The properties and uses of geopolymers are being explored in a number of scientific and industrial fields, such as inorganic chemistry, multidisciplinary physicochemical branches, colloid chemistry, mineralogy, geology, as well as in the construction sector replacing cementitious and ceramic materials. Geopolymers also benefit from the ability to incorporate various waste materials such as those from mining and metallurgical industries. These properties are dependent on the composition and chemical bonds as well as on the porosity [5].

EXPERIMENTAL PROCEDURES
Steelmaking ladle slag (LS) has been added to class F fly ash (FA), being activated with a sodium silicate and sodium hydroxide solution. Slag composition, obtained by X-ray fluorescence spectrometry, contained 63 % CaO, 19 % SiO_2, 6,7 % SO_3, 5,1 % MgO and 1,5 % F. On the other hand, fly ash contained 55 % SiO_2, 20 % Al_2O_3, 10 % Fe_2O_3 and 1,7 % CaO. Sodium Silicate had density of 43 ºBe and NaOH solution was taken at 10 M of concentration. A feldspatic sand with grain size lower than 2 mm was used as inert.
Two different mixtures were employed:

- Mixture 1: 19 % FA, 5 % LS, 5 % NaOH (10 M), 12,5 % silicate and 58,5 % sand;
- Mixture 2: 25 % FA, 3 % LS, 4 % NaOH (10 M), 13 % silicate and 55 % sand;

Paralelipipedic samples were cast in iron molds, with 160 x 40 x 40 [millimeters] size. Then the cast samples were cured in an oven at 80 ºC, with no controlled humidity, during 24 hours. Two conditions for the samples were considered: at air, in a laboratory, at 20 ºC; immersed in water, at 20 ºC. The compression test samples were obtained from the flexural resistance test: each sample for flexural resistance testing resulted in 2 samples for compression resistance tests. For each mixture/ condition, two paralepipipedic samples were produced. Then compression and three point flexural strength (FS) tests were done, at 7 and 28 days after curing. Compression strength (CS) and flexural strength (FS) determination followed standard EN 1015-11.

RESULTS

Figure 1 and Figure 2 represent the flexural and compression strength curves obtained.

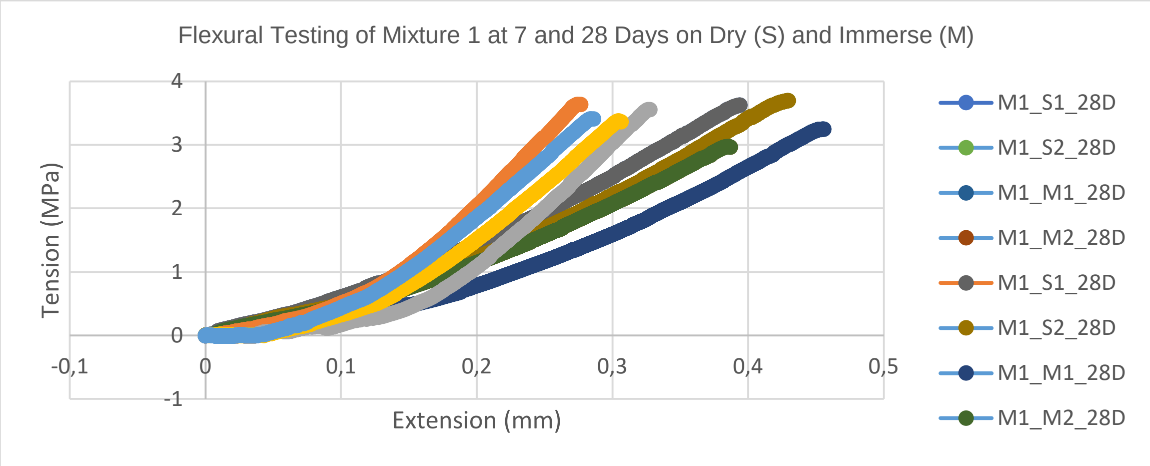

Figure 7 - Flexural Testing of Mixture 1 at 7 and 28 Days on Dry (S) and Immerse (M) Conditions

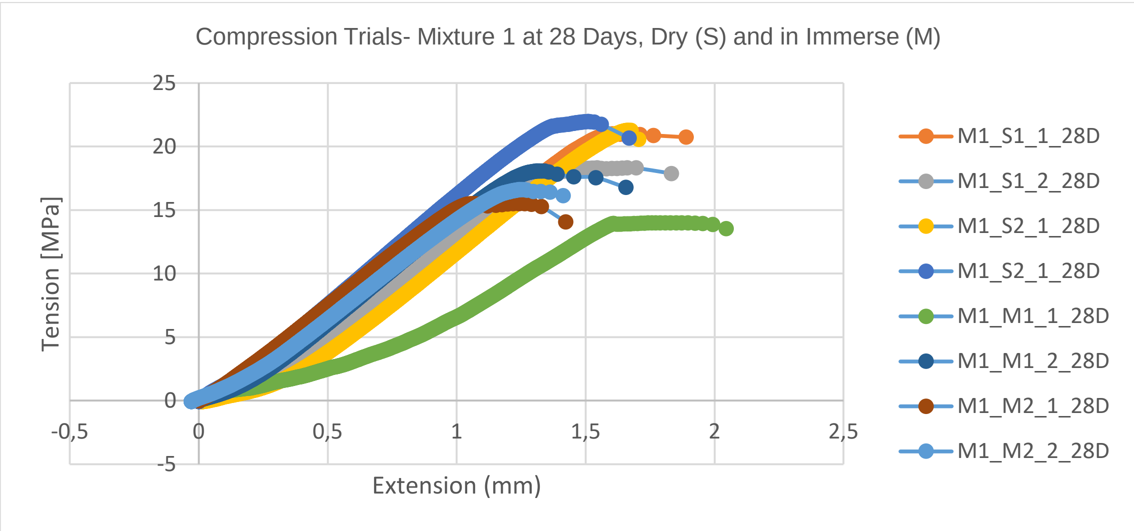

Figure 8 - Compression Testing of Mixture 1 at 28 Days on Dry (S) and Immerse (M) Conditions

Table 1 presents the results obtained for the several conditions and curing time.

Table 3 - Flexural and Compression Results for Mixtures 1 and 2

Sample	Rest	Time (Days)	Max. Load [MPa] (Flexural)	Max. Load [MPa] (Compression)
M1S1_7	Air	7	3,64	19,4 19,1
M1S2_7	Air	7	3,55	18,2 18,5
M1M1_7	Water	7	3,38	16,9 16,6
M1M2_7	Water	7	3,41	14,1 16,4
M1S1_28	Air	28	3,63	21,0 18,3
M1S2_28	Air	28	3,70	21,3 21,0
M1M1_28	Water	28	3,25	14,0 18,1
M1M2_28	Water	28	2,97	15,5 16,6
M2S1_7	**Air**	7	5,22	20,3 20,4
M2S2_7	Air	7	4,14	22,9 22,8
M2M1_7	Water	7	3,49	20,6 11,4
M2M2_7	Water	7	3,70	17,7 13,9
M2S1_28	Air	28	5,55	26,8 28,6
M2S2_28	Air	28	5,81	**28,0** **28,1**
M2M1_28	Water	28	2,03	19,8 16,4
M2M2_28	Water	28	4,04	21.3 20,6

CONCLUSIONS

Through the various tests, it is possible to conclude the following:

- Mechanical resistance increases with the amount of fly ash in the mixture;
- Water immersion gives materials less resistance comparing with air conditions. For the immersion condition, the change in resistance from 7 to 28 days is not significant.

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