Engineering of $CaO-Al_2O_3-FeO_x-SiO_2$ slags for hybrid cements

Jorn VAN DE SANDE[1,2,3], Roberto MURILLO ALARCÓN[2,3], Yiannis PONTIKES[2], Hubert RAHIER[1]

[1] Vrije Universiteit Brussel, Department of Materials and Chemistry, 1050 Brussels, Belgium

[2] KU Leuven, Department of Materials Engineering, 3001 Leuven, Belgium

[3] SIM vzw, Technologiepark 935,BE-9052 Zwijnaarde, Belgium

INTRODUCTION

Ordinary Portland cement (OPC) is a large contributor to the global anthropogenic CO_2 production, about 8-9% of the total[1]. Alternatives with lower eco-impact such as geopolymers and hybrid cements are investigated. Hybrid cements consist of 5-30% OPC mixed with a source that is used for inorganic polymer synthesis, such as fly ash or slags, and an alkali activator with a lower alkalinity compared to activators used for IP synthesis, such as sodium carbonates or sulfates[2].

In this work, the effect of the slag chemistry of synthetic $CaO-Al_2O_3-FeO_x-SiO_2$ slags for the synthesis of hybrid cements, using Na_2SO_4 as activator, was investigated. The influence of the chemistry was investigated on the reactions using isothermal calorimetry and on the 2, 7 and 28 d compressive strength.

METHODS AND MATERIALS

Melting and quenching of $CaO-Al_2O_3-SiO_2-FeO_x$ slags with $(FeO+CaO)/(SiO_2+Al_2O_3)$ = 1.2-2.2, FeO/CaO = 2-12 and Al_2O_3/SiO_2 = 0.1-0.2 in an induction furnace

→ Milling to a Blaine specific surface area of 4000 ± 200 cm^2/g

→ Characterization of the chemical and mineralogical composition of the slag by XRF and XRD

→ Synthesis of Hybrid cement pastes in 2x2x2 cm^3 molds with 80 wt% slag and 20 wt% OPC (CEM I) with an addition of solid Na_2SO_4 to have 1.5 M Na_2SO_4 using a w/b = 0.4

→ Curing at 95% RH before compressive strength testing

Calorimetry of the same pastes

RESULTS

Table 1: Chemical composition of the studied slags in wt%, the $(FeO+CaO)/(SiO_2+Al_2O_3)$, FeO/CaO and Al_2O_3/SiO_2 molar ratios and the amorphous content in wt%.

	Chemical composition				Molar ratios			Amorphous fraction
Slag	FeO	SiO_2	CaO	Al_2O_3	$(FeO+CaO)/(SiO_2+Al_2O_3)$	FeO/CaO	Al_2O_3/SiO_2	
S-L-L-L	41.2	35.5	16.6	6.0	1.34	1.93	0.10	>98
S-L-L-H	39.8	31.6	16.5	11.5	1.33	1.88	0.21	>98
S-L-H-L	55.9	33.6	3.7	6.4	1.36	11.94	0.11	92
S-L-H-H	57.4	28.1	3.6	10.5	1.51	12.62	0.22	>98
S-M-M-L	56.1	27.7	10.4	5.2	1.89	4.20	0.11	97
S-H-L-L	49.9	25.4	19.3	4.8	2.21	2.01	0.11	94
S-H-H-L	66.7	23.6	4.4	4.7	2.29	11.76	0.12	67
S-H-H-H	64.4	22.4	4.5	8.2	2.16	11.22	0.21	88

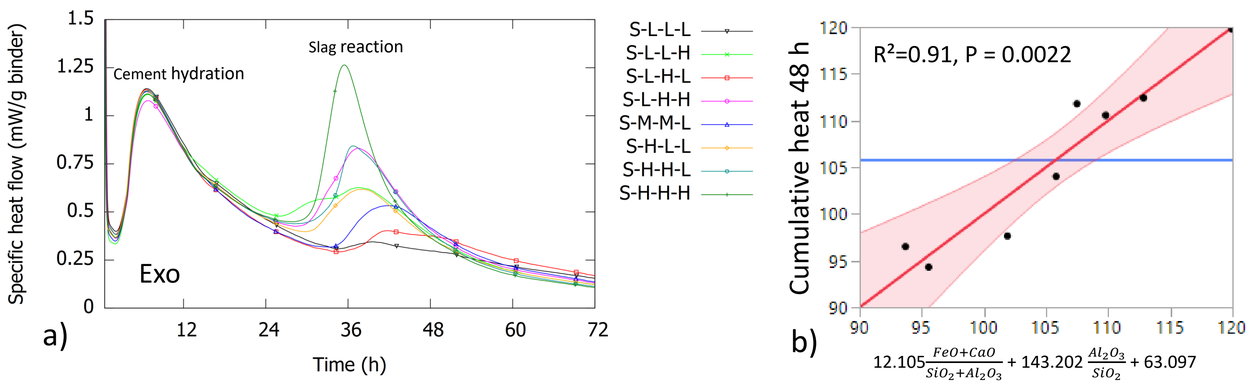

Figure 1: a) heat flow, b) relationship between the 48 h cumulative heat and the slag chemistry (molar ratios).

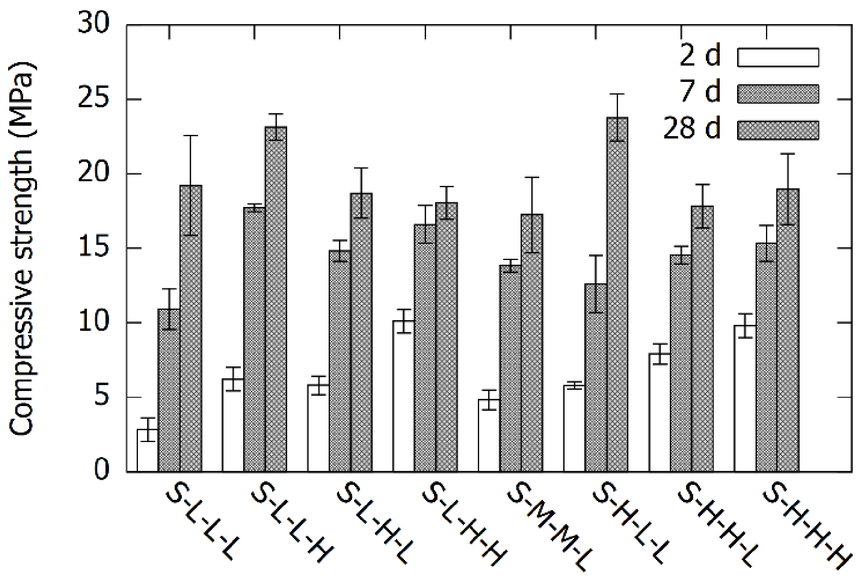

Figure 2: Compressive strength at 2, 7 and 28 days of hybrid cements synthesized from the different slags.

In Figure 2, the compressive strength at 2, 7 and 28 days is shown. The 2 d strength is significantly influenced by all three molar ratios (Figure 3a). The predicted 2 d strength is as follows:

$$2\text{ d (MPa)} = 2.17\frac{FeO+CaO}{SiO_2+Al_2O_3} + 0.25\frac{FeO}{CaO} + 29.13\,\frac{Al_2O_3}{SiO_2} - 3.18$$

For 7 and 28 d, no statistically significant relationship was found between strength and slag chemistry. However a relationship between slag chemistry and strength gain (7 over 2 d compressive strength) has been found (Figure 3b). The highest compressive strength at 28 days was for the slags with higher CaO content (lowest FeO/CaO molar ratios), i.e. S-L-L-L, S-L-L-H and S-H-L-L.

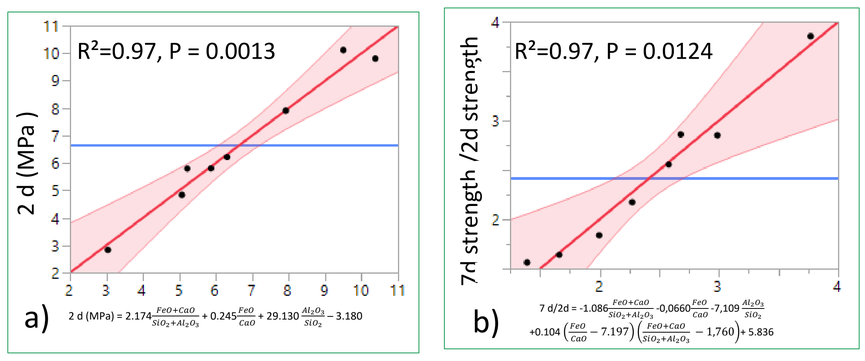

Figure 3: a) 2 d Compressive strength in MPa as a function of molar ratios, b) 7d/2d compressive strength as a function of molar ratios

CONCLUSIONS

In the studied range of $CaO-Al_2O_3-FeO_x-SiO_2$ slags, a relationship between 2 d strength and the slag chemistry was found. For 28 d strength, the FeO/CaO ratio of the slag was proven to be the most important. These results allow to propose well-defined slag chemistries for different products and performance requirements (low and early strength requirements).

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