Pergamon

Cement and Concrete Research, Vol. 27, No. 12, pp. 1825–1828, 1997

0008-8846/97 $17.00 + .00

PII S0008-8846(97)00191-9

SILICA FUME–BASIC BLAST FURNACE SLAG SYSTEMS ACTIVATED BY AN ALKALI SILICA FUME ACTIVATOR

I. Rouseková,* A. Bajza,* and V. Živica[1]†

*Faculty of Civil Engineering, Slovak Technical University, Radlinského 11, 813 68 Bratislava, Slovak Republic

†Institute of Construction and Architecture, Slovak Academy of Sciences, Dúbravská cesta 9, 842 20 Bratislava, Slovak Republic

(Communicated by J.P. Skalny)
(Received July 1, 1997; in final form September 8, 1997)

ABSTRACT

This paper deals with the results of research on binder systems based on the use of silica fume. The data obtained show that the optimal proportion of blast furnace slag and alkali activator prepared from silica fume permits the obtaining of interesting materials from the point of view of their technical properties as well as from the possibility of utilizing industrial wastes. The composite developed is hydraulic. It is possible to state that these kinds of binding systems have shown promise of future use. © *1997 Elsevier Science Ltd*

Introduction

It was shown in our previous paper (1) that a silica fume–sodium hydroxide system has binding properties. If a convenient ratio of the binder, sand, and water is used, a composite with the compressive strength of those systems using Portland cement can be obtained. This is very interesting knowledge, which shows the further possibility of silica fume utilization and the development of a building material with no Portland cement content.

The disadvantage of this material is its low stability in water. This indicates the unhydraulic nature of the binder. The solution of this problem would help develop the utilization of binder systems based on silica fume.

The subject of this paper is the results achieved during research on the above-mentioned systems. The aim of the research was the achievement of the system's hydraulicity.

Experimental

The investigation was carried out on 20 × 20 × 20 mm cubes made from mixtures containing silica sand, blast furnace slag (SLG), silica fume (SF), and alkali silica activator (SFA) or sodium hydroxide (N). The proportion of sand was kept constant.

---

[1]To whom correspondence should be addressed.

TABLE 1
Composition and properties of silica fume and blast furnace slag

	Silica fume (%)	Blast furnace slag (%)
Loss on ignition	1.74	0.72
SiO_2	97.07	38.40
CaO	0.54	42.73
Al_2O_3	0.21	8.83
Fe_2O_3	-	0.99
MgO	0.40	5.94
SO_3	-	0.63
S^{2-}	-	0.05
Density (kg/m^3)	2270	2850
Specific surface area (m^2/kg)	19600	200

SFA is a product prepared from silica fume and acts as a very effective activator.

SFA permits the achievement of the same values of compressive strength in mortars containing 90% slag and 10% Portland cement as in cement mortars. It has been found that SFA is more active than NaOH and water glass (2).

Part of the specimens were cured in the air at 20°C and 50% RH, and the others, after 7 days of curing in air, were subsequently stored in water (20°C). After the specific treatment period, the compressive strength, bulk density, hydration products formed, pore structure, specific surface, and morphology of the composites were determined.

Experimental techniques such as XRD (diffractometer Phillips), MIP (porosimeter model 2000 and macroporosity unit 120, Erba Sciences), and SEM (scanning electron microscope Tesla BS 301) were used.

The chemical composition and properties of the silica fume and blast furnace slag used are given in Table 1.

TABLE 2
Properties of composites with the admixture of NaOH after 56 days of hardening

Designation	$\frac{W}{SF + SLG + N}$	$\frac{SLG}{SF}$	$\frac{N}{SF}\cdot 100$ (%)	Curing in air (water) (days)	Bulk density (kg/m^3)	Compressive strength (MPa)
GN1	0.454	1:1	20	56	1640	8.8
				7 (49)	1910	4.4
GN2	0.435	1:1	30	56	1757	10.2
				7 (49)	1953	4.8
GN3	0.490	1:2	20	56	1762	8.8
				7 (49)	1936	2.9
GN4	0.417	2:1	20	56	1638	2.9
				7 (49)	1911	2.4

W, water; SF, silica fume; SLG, blast furnace slag; N, sodium hydroxide.

TABLE 3
Properties of composites with the alkali activator after 56 days of hardening

Designation	$\frac{SFA}{SF + SLG}$	$\frac{SLG}{SF}$	Curing in air (water) (days)	Bulk density (kg/m^3)	Compressive strength (MPa)
GA1	1.22	1:1	56	1900	10.3
			7 (49)	2013	9.1
GA2	1.11	1:1	56	1862	11.1
			7 (49)	2001	9.8
GA3	1.22	1:2	56	1885	11.5
			7 (49)	1980	5.3
GA4	1.05	2:1	56	1892	16.8
			7 (49)	2022	18.2

SFA, alkali silica activator; SF, silica fume; SLG, blast furnace slag.

Results and Discussion

The experimental data obtained are summarized in Tables 2–4.

The results given in Tables 2 and 3 show that the composites with the SFA generally achieved higher values of compressive strength than those with the addition of NaOH. That is especially evident for the GA4 composite with the higher amount of slag (SLG:SF 2:1). This composite also shows the best hydraulic properties, and confirms the higher compressive strength values of water-cured specimens compared to those specimens stored in the air.

Analogously, as with the composites with an admixture of NaOH reported in (1), as well as the composites with the addition of SFA, the study of the microstructure by XRD and SEM has confirmed the amorphous character of the hydration products.

Some more information about the course of the hardening of the composites studied is given in the MIP data. In Table 4, the results of the hardened mixture of optimal composition (GA4) are shown. The experimental data show that water hardening of this composite led to the formation of a pore structure typical of hardened cement binders. At the time of the subsequent water curing, after 7 days of hardening in the air, the volume of the micropores increased, and the total porosity and volume of the macropores and the median of the radius

TABLE 4
Pore structure of hardened composites with the alkali activator (GA4)

Age (days)	Curing in air (water) (days)	Pore volume (mm^3/g) micro <7500 nm	macro >7500 nm	total	Median of pore radius (nm)	Macro pores (%)	Total porosity (%)	Specific surface (m^2/kg)
7	7 (0)	37.9	77.0	114.0	8677	67.0	22.1	362
28	7 (21)	64.3	71.9	136.2	7429	52.8	23.3	2236
56	7 (49)	79.6	48.4	128.0	3191	38.0	20.3	7228
28	28 (0)	29.8	87.9	117.7	10585	74.7	18.9	525
56	56 (0)	29.0	86.1	115.1	11245	74.8	21.9	284

of the pores decreased. These changes were connected with an increase in the specific surface of the hardened mixture.

The experimental results show that storage in the air is less convenient for hardening and results in a pore structure of the composite with a lower quality than that cured in water (the lower volume of micropores indicates the restricted formation of the hydration products, the higher volume of the macropores, and the very high median of the pores' radius).

Conclusion

The results obtained showed the possibility of improving the properties of the binder system through the application of blast furnace slag and an alkali activator of blast furnace slag and alkali activator prepared from silica fume.

This procedure allows for an increase in the compressive strength of the composite and a significant increase in its resistance to water (to improve the hydraulicity of the binder system).

The improved properties of composites containing the alkali activator over those prepared with NaOH confirm the higher effectiveness of the SFA over the NaOH.

Acknowledgment

The authors are grateful to the Slovak Grant Agency for Science (Grant No. 12025/95) for partial support of this work.

References

1. A. Bajza, I. Rouseková, and V. Živica, Cem. Concr. Res. (to be published).
2. V. Živica, Cem. Concr. Res. 23, 1215–1222 (1993).