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Communication

Liquid concentration changes during slag cement hydration by alkali activation

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Abstract

Alkali-activated slag cement without ordinary portland cement (OPC) has received much attention in the view of energy saving and its many excellent properties. Ion concentration change in the liquid during the slag hydration was studied to investigate the hydration process. The ion concentration change of liquid phase during hydration was different depending on the activator and the hydration time. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Ground slag has a latent hydraulic reactivity, which can be activated by proper activators. Na-containing compounds have many advantages in terms of slag activation and mechanical strength development. Alkali-activated slag exhibits different properties depending on the type of activators, composition, and atomic coordination state of ions in the slag.[1–3] The objective of this study is to investigate the liquid concentration changes during hydration process of alkali-activated slag by two Na-containing compounds.

2. Experimental

The chemical composition of slag used in this study was shown in Table 1 and slag was ground to 4000 cm^2/g in a ball mill. Reagent grade NaOH and $Na_2SiO_3 \cdot 9H_2O$ were used as Na-containing activators. Heat liberation test was carried out by microconduction calorimeter. The water-to-solid ratio is 0.4 and concentrations of activator in Na_2O base are 2, 4, and 6 wt.% of slag at 20°C. Liquid analysis was carried out by various equipment: concentration of Ca and Na ions by AAS and Si, Al, and Mg ions by ICP/MASS where concentration of solution was 0.3 N NaOH and Na_2SiO_3, and water-to-solid ratio is 10 at 20°C.

3. Results and discussion

The heat liberation curves slag in NaOH–slag system and $Na_2SiO_3 \cdot 9H_2O$–slag system are shown in Figs. 1 and 2, respectively. NaOH–slag system did not show any dormant period but $Na_2SiO_3 \cdot 9H_2O$–slag system showed a dormant period. The difference in heat liberation curves between two systems is due to their different hydration process. Slag dissolution rate was found to increase with increasing NaOH content, but the amount of Na_2SiO_3 did not affect slag dissolution rate. The heat liberation curve of $Na_2SiO_3 \cdot 9H_2O$ system was similar to that of ordinary portland cement (OPC) except the time interval of the dormant period. The ion concentration change in liquid phase was shown in Figs. 3 and 4, where concentrations of Ca and Na

Table 1
Chemical composition of slag (wt.%)

CaO	MgO	Al_2O_3	SiO_2	Fe_2O_3	Na_2O
41.9	5.5	16.3	34.8	0.5	0.75

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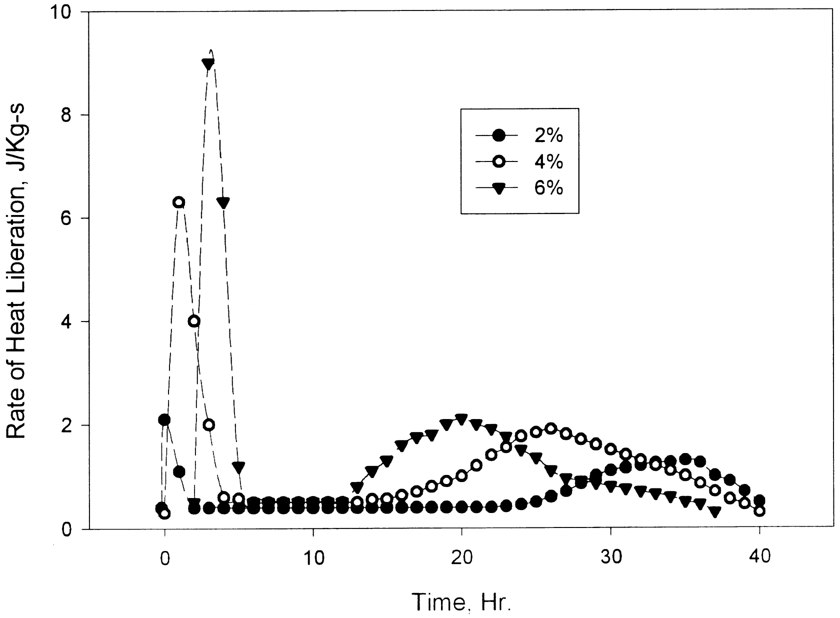

Fig. 1. Heat liberation curves of hydration with time in $Na_2SiO_3 \cdot 9H_2O$ system.

ions were measured by AAS and concentrations of Si, Al, and Mg ions were measured by ICP/MASS. In NaOH–slag system (Fig. 3), the quantities of eluted aluminum, silicon, calcium, and magnesium are in the order of $Al_2O_3 > SiO_2$>-CaO>MgO. There was a period of remarkable $Al(OH)_4^-$ elution in NaOH solution between 1 and 3 days. Slag sources became Al poor structure after elution of $Al(OH)_4^-$, and CaO elution was restricted due to the formation of gel film on the slag surface and the elution of MgO hardly occurred as shown in Fig. 3. This is due to the fact that MgO-containing mineral or glass phase was not activated by NaOH as shown in Fig. 3.

In $Na_2SiO_3 \cdot 9H_2O$–slag system (Fig. 4), the quantities of eluted calcium, aluminum, and magnesium up to 6 h was in the order of CaO>Al_2O_3>MgO. The elution of CaO in glass phase was remarkably increased up to 6 h and decreased abruptly after 6 h. The reason for the remarkable elution of CaO was due to the weak formation of a gel film by Na^+ ions retained in glass phase. The quantities of $Al(OH)_4^-$ kept a certain level during the hydration process without any

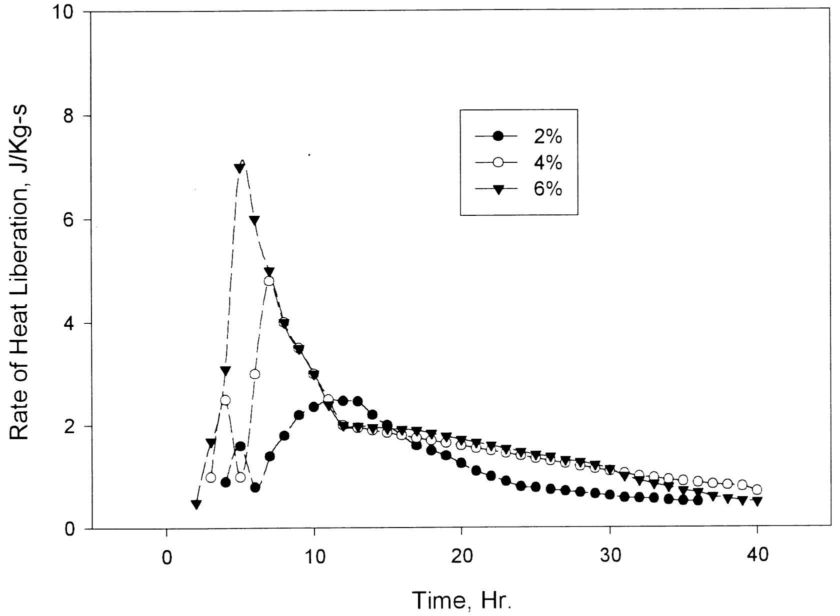

Fig. 2. Heat liberation curves of hydration with time in NaOH system.

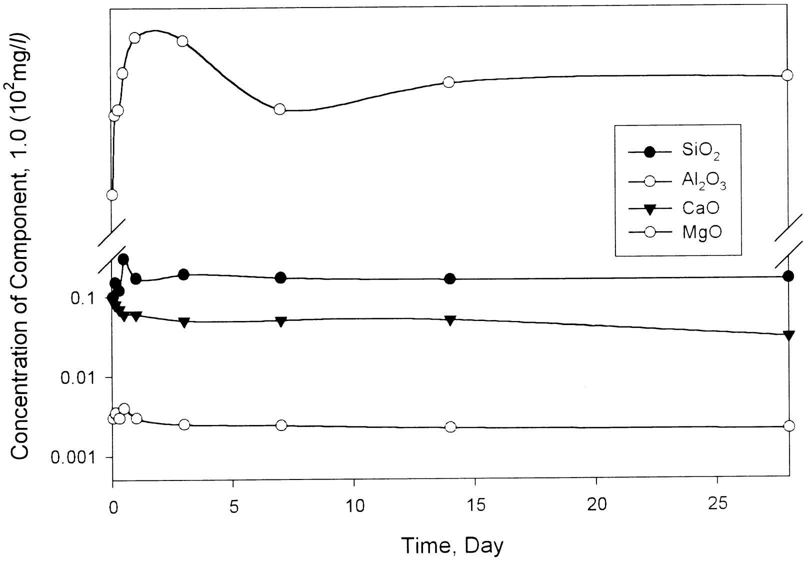

Fig. 3. Ion concentration change of liquid phase with activation time in NaOH system (0.3 N Na base), where concentrations of Ca and Na ions were measured by AAS and concentrations of Si, Al, and Mg ions were measured by ICP/MASS.

peculiar elution of $Al(OH)_4^-$ unlike the NaOH–slag system. MgO was eluted a little until 6 h and then decreased gradually similar to the case of CaO. From this result, MgO-containing mineral was found to be well activated by $Na_2SiO_3 \cdot 9H_2O$ as shown in Fig. 4.

4. Conclusions

NaOH–slag system did not show a dormant period but $Na_2SiO_3 \cdot 9H_2O$–slag system showed dormant period longer than that of OPC. The ion concentration change of liquid phase during hydration were different depending on the activator and the hydration time.

References

[1] C. Shi, R.L. Day, A calorimetric study of early hydration of alkali–slag cements, Cem. Concr. Res. 25 (6) (1995) 1333–1346.

[2] S. Wang, K.L. Scrivener, Hydration products of alkali activated slag cement, Cem. Concr. Res. 25 (3) (1995) 561–571.

[3] F. Collins, J.G. Sanjayan, Early age strength and workability of slag pastes activated by NaOH and Na_2CO_3, Cem. Concr. Res. 28 (5) (1998) 655–664.

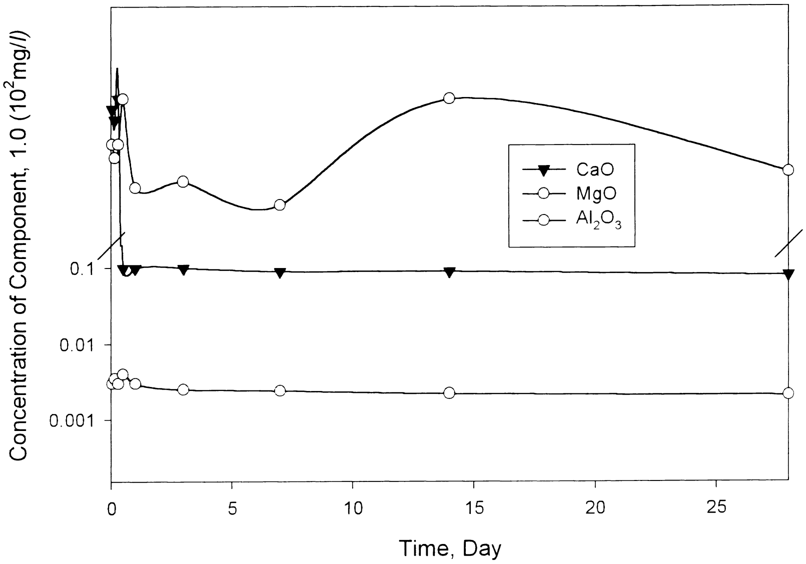

Fig. 4. Ion concentration change of liquid phase with activation time in $Na_2SiO_3 \cdot 9H_2O$ system (0.3 N Na base), where concentrations of Ca and Na ions were measured by AAS and concentrations of Si, Al, and Mg ions were measured by ICP/MASS.