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# Evaluation of alkali-activated ground granulated blast furnace slag cements produced with potassium acetate

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## ABSTRACT

For the production of alkali-activated blast furnace slag (AAS) cements, the hazard associated with handling hydroxide-based activators has stimulated research into a range of alternative activators. This study evaluated the feasibility of utilizing potassium acetate as an activator. Reference samples were produced with potassium hydroxide (KOH), formulated with equivalent cation content to those produced with potassium acetate, to evaluate the effectiveness of acetate solutions as potential activators for producing AAS cements. Isothermal calorimetry tests were conducted to assess the reaction kinetics, while X-ray diffraction of hardened pastes cured for up to 28 days was conducted to identify the phase assemblages. Compressive strength tests were also conducted on hardened paste samples. The results showed that potassium acetate promotes the reaction of blast furnace slag; however, the reaction of potassium acetate-AAS paste is slower than that of KOH-AAS paste. No significant differences in the semi-crystalline phase assemblages were identified when using acetate or hydroxide activators, although it is clear that a lower degree of slag reaction is achieved at a given time, when using an acetate solution as an activator. This was consistent with the significantly lower 28-day compressive strength observed for potassium acetate-AAS pastes, compared to KOH-AAS pastes.

**Keywords:** alkali-activated slag cement; compressive strength; phase assemblage; potassium acetate; reaction kinetics.

## 1. Introduction

Ground granulated blast furnace slag (GGBS) is one of the most widely used precursors for producing alkali-activated cements. Potassium hydroxide and potassium silicate are commonly used as alkaline activators. The limitations of handling large volumes of corrosive solutions has led to interest in a range of alternative activators <sup>[1]</sup>. Metal acetates have yet to be investigated in detail as alternative activators, but previous results have demonstrated their potential <sup>[2]</sup>. In this study, alkali-activated slag cements were produced with potassium acetate or potassium hydroxide activators, to compare their behaviour in terms of reaction kinetics, evolution of phase assemblages, and strength development.

## 2. Materials and methods

The GGBS used had an oxide composition as shown in Table 1. The specific surface area was 1.25 m<sup>2</sup>/g, and the  $d_{50}$  was 10.75  $\mu$ m.

**Table 1.** Oxide composition (wt.%) measured by XRF, LOI is loss on ignition at 900 °C.

Composition	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>	TiO <sub>2</sub>	LOI
	36.30	9.70	43.85	6.28	0.3	0.26	0.37	1.48	0.59	0.87

AAS pastes were prepared with a constant water to binder (slag + solid activator) ratio (w/b) of 0.3 and a constant 4 wt.% K<sub>2</sub>O activator dose with respect to the mass of GGBS. The alkaline solutions were prepared by dissolving potassium hydroxide (KOH, Honeywell, 98%) or potassium acetate (abbreviated as KAc, anhydrous, Alfa Aesar, 99%) into distilled water. A summary of the mix designs is presented in Table 2. AAS pastes were produced by mixing the slag and activating solution in a high-shear mixer for 3 min at low speed (139 rpm) followed by 2 min at high speed (591 rpm). The pastes were cast in 15 mL centrifuge tubes, sealed and placed in a water bath at 20°C for up to 28 days.

**Table 2.** Mix proportions alkali-activated slag cement pastes.

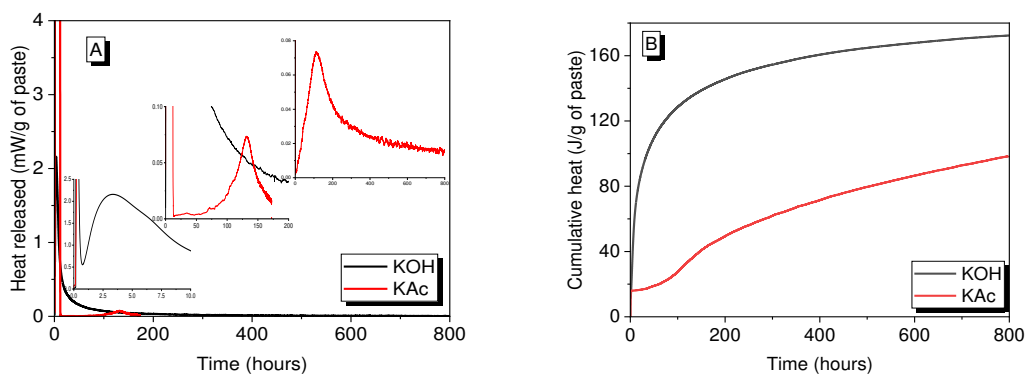
Activator	GGBS (g)	K <sub>2</sub> O (%)	Activator (g)	w/b	pH of activating solution	Water (g)
KOH	100	4	7.22	0.3	14	32.17
KAc	100	4	8.34	0.3	13.2	32.5

Heat evolution was measured in a TAM Air isothermal calorimeter at 20 ± 0.02°C for 28 days. A Bruker D8 X-ray diffractometer was used with CuK $\alpha$  radiation ( $\lambda$  = 0.1541 nm), a 8-50 °2 $\theta$  range, step size of 0.02 °2 $\theta$  and a step duration of 3 s/step. Paste cubes (25 × 25 × 25 mm) were cast for compressive strength measurements.

### 3. Results and discussions

#### 3.1 Isothermal calorimetry

For KOH-AAS, the acceleration period showed an onset after 1 hour and the maximum heat release occurred at 4 hours (Figure 1.A).



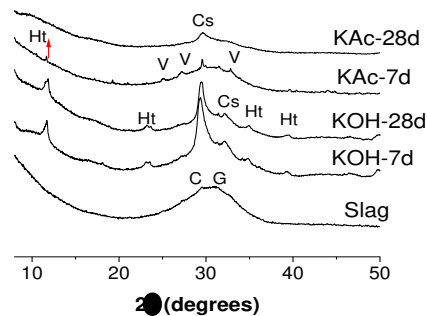
**Figure 1.** (A) Heat release and (B) cumulative heat curves for KOH / KAc activated pastes.

An asymmetric deceleration period was followed by high heat release for the first 30 hours, and then low heat release for the next 300 hours. For KAc-AAS, a pre-induction peak occurred within the first few hours after mixing, before a 40-hour induction period. Maximum heat release occurred after 128 hours. Cumulative heat values of KAc-AAS were significantly smaller compared to KOH-AAS (Figure 1.B). The longer induction period and slower acceleration period of KAc-AAS was attributed to slower dissolution of slag by the KAc activating solution, as a result of

its lower pH (Table 2).

### 3.2 X-ray diffraction

In the unreacted slag, the crystalline phases gehlenite (Powder diffraction file (PDF) # 00-029-0285) and calcite (PDF # 01-083-0577) were observed. For KOH-AAS, the main crystalline reaction products identified were calcium silicate hydrate (C-S-H) (PDF # 029-0329) along with hydrotalcite (PDF # 01-089-0460) at both 7 days and 28 days (Figure 2). For KAc-AAS, C-S-H and hydrotalcite, as well as traces of vaterite (a calcium carbonate polymorph) (PDF # 01-074-1867) were also observed at 7 days. After 28 days, only C-S-H was observed as the main crystalline reaction product.



**Figure 2.** X-ray diffraction patterns of AAS pastes cured up to 28 days. Cs – C-S-H, G – gehlenite, Ht – hydrotalcite, C – calcite, V – vaterite

### 3.3 Compressive strength

KAc-AAS samples did not hardened after 7 days of curing. At 28 days, KAc-AAS samples hardened, but exhibited a compressive strength of approximately half that of the KOH-AAS samples (Table 3). The slow strength evolution of KAc-AAS is consistent with the slow reaction rate identified by isothermal calorimetry (Figure 1).

**Table 3.** Compressive strength of AAS paste cubes. Error values correspond to one standard deviation of 3 measurements.

Activator	7 days (MPa)	28 days (MPa)
KOH	29.9 ± 2.7	39.3 ± 3.8
KAc	-	18.9 ± 2.6

## 4. Conclusion

KAc can be used as an alkaline activator for GBBS. However, compared to KOH, use of KAc resulted in significantly slower reaction kinetics at an equivalent alkali content, and hence lower compressive strength. Future work will investigate the potential of KAc-activated GGBS as water-repellant coating materials.

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