Assessing the Reactivity of Industrial By-Products in Calcium Aluminate Cement-Based Formulations

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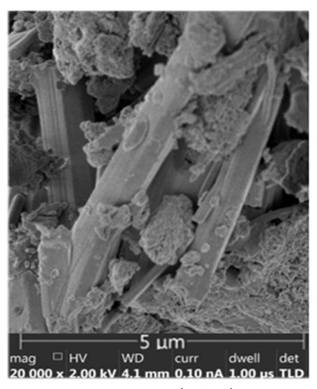
ABSTRACT

The use of supplementary cementitious materials (SCM) has been under extensive research in the past decade as a critical pathway in reducing the substantial carbon dioxide emission associated with cement production. In this study, three types of industrial by-products (iron residue slags, fumed fayalite slag and bottom ash) were incorporated in a calcium aluminate cement (CAC)-based formulation to assess their potential as novel SCM. The highest reactivity index was obtained for the mortars containing the highly amorphous slags exhibiting substantial strength development in the later curing ages (90 days). This suggests the potential for the valorization of these non-conventional SCM in cementitious applications.

INTRODUCTION

CAC (high-alumina cement) **+ HH** (calcium sulphate hemihydrate) **= ettringite binder** (special applications such as self-levelling underlayment, refractory, and in aggressive environment)

Reactivity of innovative industrial by-products in this ettringite binder ?



ettringite (SEM), $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$

MATERIALS

4 metal-depleted industrial by-products :

- slowly-cooled iron residue slag (FS) (zinc industry – 49 % amorphous)
- granulated iron residue slag (zinc industry – 92 % amorphous)
- fumed fayalite slag
- municipal waste incinerator bottom ash

1 quartz filler

1 commercial CAC cement (Secar 51) and hemihydrate

METHODS

1- Mortars :

- CAC / HH mass ratio equal 4.5
- water to binder (w/b) ratio of 0.5
- air curing conditions
- SCM incorporated keeping the volume substitution consistent with those of the mortars incorporating 30 wt.% granulated FS

2- Isothermal calorimetry :

- Ex-situ experiment using TAM Air Isothermal Calorimeter at 20° C

RESULTS

The results of the isothermal calorimetry test presented in Figure 1a suggest that the addition of SCM only affected the kinetics and extent of hydration but did not seem to alter the hydration mechanism at least in the early stage. On the other hand, the cumulative heat release graph presented in Figure 1b shows that the addition of the SCM lowered the heat release in the paste samples.

From the results presented in Figure 2, it can be seen that the substitution with the SCM significantly decreased the compressive strength after 7 and 28 days, to the same extent for all blend types. It was not until 90 days that the strength significantly increased for granulated FS yielding the highest strength among the ternary blends.

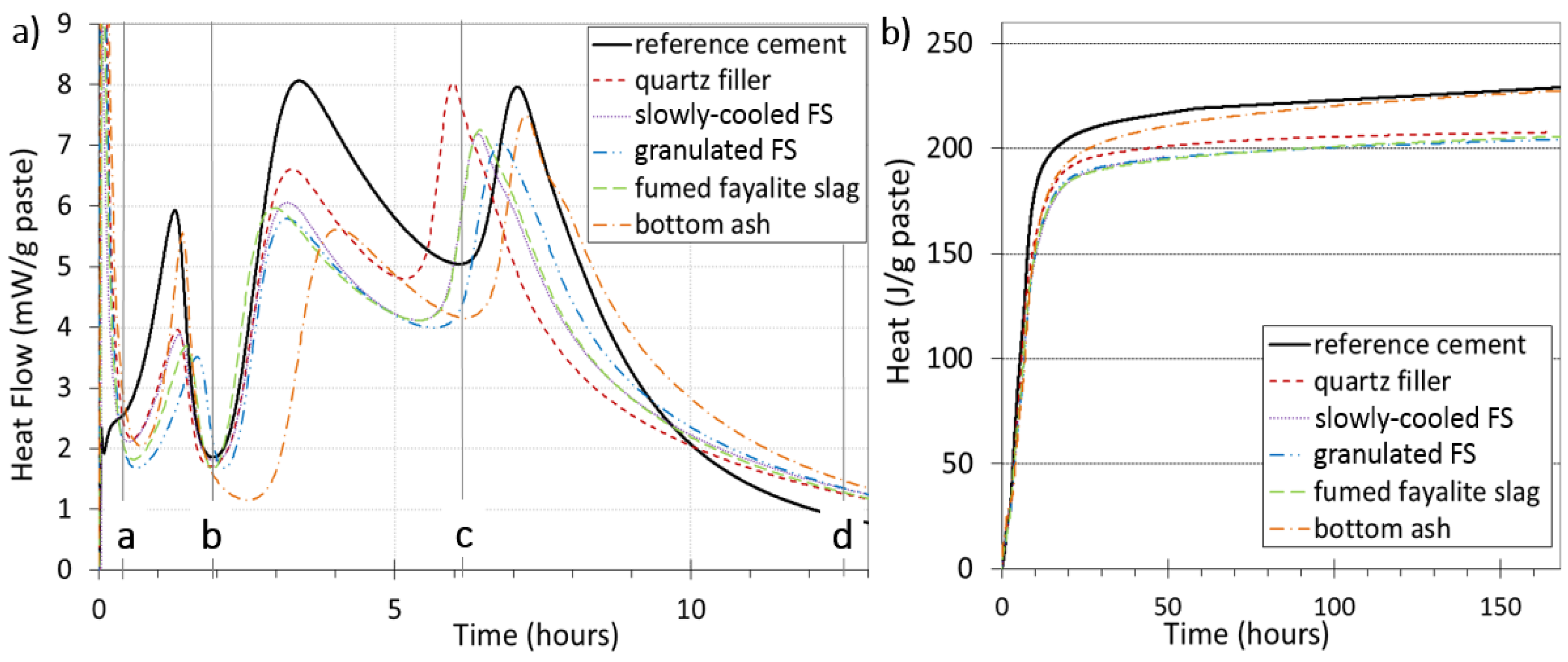


Figure 1: a) Heat flow and b) cumulative heat release curve derived from the isothermal calorimetry test at 20 °C for 10 g of paste (binder + water) samples for each blend type.

$$\textbf{reactivity index} = \frac{\text{compressive strength of mortar containing SCM}}{\text{compressive strength of reference cement mortar}}$$

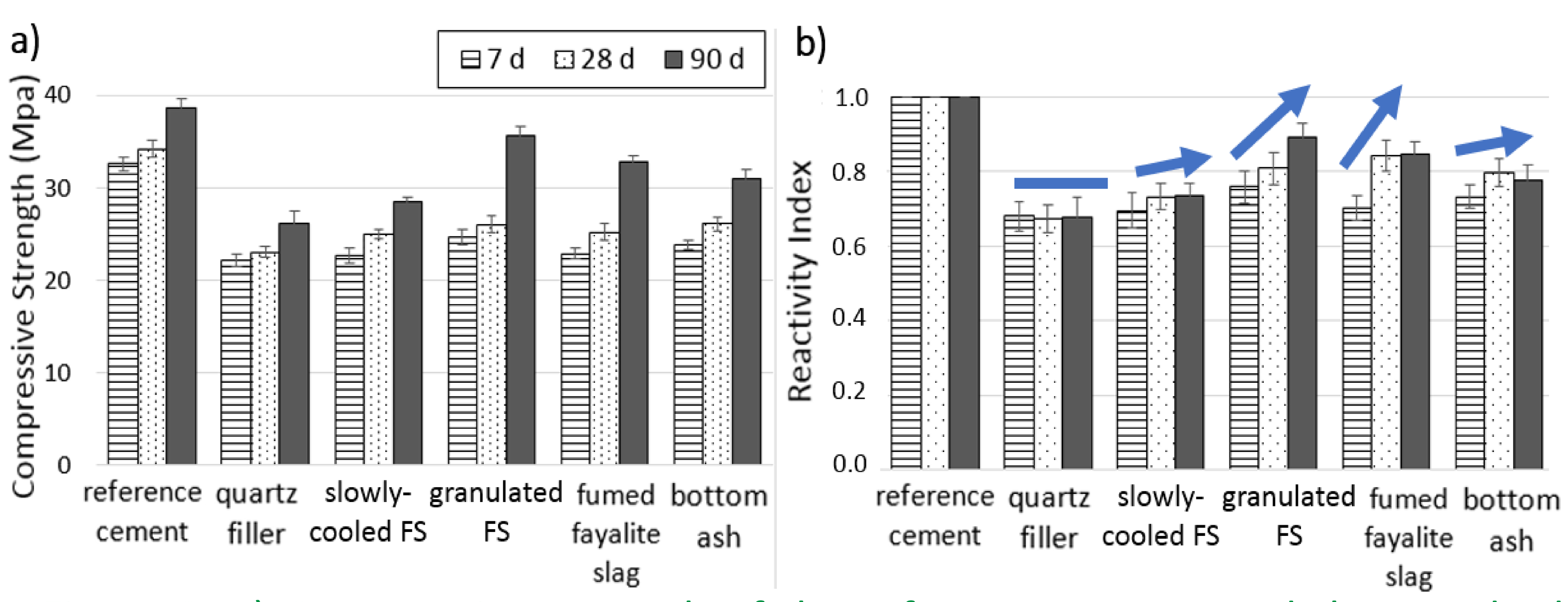


Figure 2: a) Compressive strength of the reference cement and the standard mortars incorporating SCM; b) reactivity index calculated from the compressive strengths.

CONCLUSIONS

✓Highest reactivity index for mortars containing **highly amorphous slags** which could indicate their potential for valorisation as SCM

✓The addition of industrial by-products **reduced the early strength** (7 days) of the mortars which is a challenge that needs to be overcomed particularly for CAC applications

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