Clinkering and early age hydration characterization of Belite-Alite Calcium Sulfoaluminate (BACSA) cements

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Abstract

Belite Calcium SulfoAluminate (BCSA) cements, also known as sulfobelite cements, have been developed as OPC substitutes. BCSA cements contain belite as main phase (>50 wt%) and ye´elimite as the second content phase (~30 wt%). BCSA are less calcite demanding materials than OPC, with the consequent diminution of carbon dioxide emissions from decarbonation in the kiln. Although BCSA cements have been proposed as a sustainable alternative to OPC, an important technological problem is associated to them: these materials develop low mechanical strengths at intermediate hydration ages (3, 7 and 28 days). One of the proposed solutions to this problem is the activation of BCSA clinkers by preparing clinkers with high percentage of coexisting alite and ye'elimite. These clinkers are known Belite-Alite Calcium Sulfoaluminate (BACSA) cements. Their manufacture may produce 15% less CO_2 than OPC. Alite is the main component of OPC and is responsible for early mechanical strengths. The reaction of alite and ye´elimite with water will develop cements with high mechanical strengths at early ages, while belite will contribute to later curing times. Moreover, the high alkalinity of BACSA cement pastes/mortars/concretes will facilitate the use of supplementary cementitious materials with pozzolanic activity which also contribute to decrease the CO_2 footprint of these ecocements.

In this work, four BACSA clinkers with different compositions (belite ~ 70-55 wt %, alite ~ 10-15 wt % and ye'elimite ~ 10-15 wt %) were synthesized (at laboratory scale). Lime, gypsum, kaolin and sand were used as raw materials and clinkering temperatures from 1280 to 1300 ºC were studied. Every BACSA clinker was chemically and mineralogically characterized through X-ray fluorescence and laboratory X-ray powder diffraction (LXRPD), the latter in combination with the Rietveld methodology to obtain the full phase assemblage including amorphous contents. The clinker with the targeted composition (belite ~ wt 60 %, alite ~ 13 wt % and ye'elimite ~ 10 wt %) was chosen to perform the scaling-up (5 kg). To do so, the processing parameters (milling time and clinkering conditions) have been optimized.

Finally, the hydration of the corresponding BACSA cement pastes (prepared with the scaled-up clinker and gypsum) was studied through rheological measurements (at very early hydration time), calorimetry and impedance spectroscopy (first 24 h), and LXRPD in combination with the Rietveld methodology and G-factor method, at 1 and 7 hydration days to determine degree of hydration.

Originality

Our key challenge is to design "New formulations of optimised belite-alite calcium sulfoaluminate (BACSA) which must develop mechanical strengths comparable to those of ordinary Portland cement, OPC, with a reduction in CO_2 emissions of at least 15% when compared to OPC production."

Because of that, BACSA clinkers with high amounts of alite and ye'elimite are desired. However, a good raw meal combination is far from being well-established. This work reports a study of the different combinations of belite-alite calcium sulfoaluminate raw materials with different mineralogical compositions and the scale-up of the selected one. Both cement phase assemblage and hydration mechanisms of the corresponding cement pastes are also being correlated.

Keywords*: BACSA cement, clinkering, hydration, Rietveld Quantitative Phase Analysis, X-ray powder diffraction*

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