Influence of the clinker SO₃ on the cement characteristics

Sayed Horkoss, Roger Lteif, Toufic Rizk

1. Introduction

Portland cement clinker is a hydraulic material composed mainly of tricalcium silicate (C₃S), dicalcium silicate (C₂S), tricalcium aluminate (C₃A) and tetracalcium aluminoferrite (C₄AF). The abundance, size, reactivity and distribution of these phases are affected by complex interactions between the heating and cooling regime as well as the raw feed characteristics such as chemical and mineralogical composition, particles size distribution and homogenization.

The clinker nodules are ground with gypsum, which serves to control setting, to a fine powder named Portland cement.

The amount of cement SO₃ comprises the clinker SO₃ and that added during clinker grinding. In ordinary Portland cement clinker the SO₃ is usually below 1%. During the past years, the thermal valorization of industrial wastes, tires and solvents as well as the usage of high-sulfur fuel in the cement kilns have gained ground. This change has increased the sulfate levels in Portland cement clinker, moderates sulfate resistance (type II, the calculated C₃A<8%) and alite as well as the alite/belite ratio, leading to a modification in the cement quality.

The objective of this paper is to evaluate the rate of strength development and the level of sulfate resistance for cements produced with high SO₃ clinker at low alkali level.

2. Experiment and methods

Thirteen clinker samples were sampled during the production process at Cimenterie Nationale S.A.L. Based on the ASTM C150 requirements, the types of cement clinker samples were: Twelve cements produced without any addition of sulfate (type I at 1.1), and that of type V at 1.1. The sulfate resistance was measured using the ASTM C1356 for the evaluation of the clinker phases in clinker by microscope. The optic microscope (ZEISS – Axioskop 40) and the party concretions and homogenization.

The clinker nodule is composed of a porous mass with a high percentage of calcium silicate (C₃S) and calcium aluminate (C₃A) phases. The clinker is then ground with gypsum to form the Portland cement. The sulfate content in the clinker influences the sulfate resistance of the cement. For these reasons, cements produced from a clinker containing high sulfate and low alkali, have slower strength development and higher sulfate resisting level than that produced with low sulfate clinker.

In order to minimize the interaction of other factors with the influence of clinker sulfur on the clinker phases, the following parameters were monitored (Table 1):

1. The aluminum module in the Type II clinker was fixed at 1.2 ± 0.05 and that of Type V at 1.1.
2. The SM was fixed at 2.40 ± 0.04.
3. The variation, in the percentages of P₂O₅, TiO₂, MgO, was controlled.
4. The percentages of alkalis were assured in the lowest level.

Due to the very low burnability of the kiln feed, the clinker was produced without any addition of fluxes or mineralizers. The sampling was done under stable kiln operation. The percentage of kiln inlet oxygen was maintained between 2 and 3%. The free lime of the clinker was ≤ 1%.

The clinker samples were crushed and ground in the laboratory mill. The evaluation of cement characteristics was done using the following standards:

1. ASTM C114 for the determination of the chemical composition. The chemical analysis was done using ARL 9800 – XRF machine, calibrated by NIST standard samples. The Claiss machine was used for samples preparation.
2. ASTM C1365 for the determination of the proportion of phases in Portland-cement clinker using X-Ray Powder. The ARL X'TRA Diffractometer with Copper tube, using Rietveld method was used.
3. ASTM C1356 for the evaluation of the clinker phases in clinker by microscope. The optic microscope (ZEISS – Axioskop 40) and the