Efficiency of Different Types of Addition onto the Hydration Kinetics of Portland Cement

Authors : Marine Regnier, Pascal Bost, Matthieu Horgnies

Abstract : Some of the problems to be solved for the concrete industry are linked to the use of low-reactivity cement, the hardening of concrete under cold-weather and the manufacture of pre-casted concrete without costly heating step. The development of these applications needs to accelerate the hydration kinetics, in order to decrease the setting time and to obtain significant compressive strengths as soon as possible. The mechanisms enhancing the hydration kinetics of alite or Portland cement (e.g. the creation of nucleation sites) were already studied in literature (e.g. by using distinct additions such as titanium dioxide nanoparticles, calcium carbonate fillers, water-soluble polymers, C-S-H, etc.). However, the goal of this study was to establish a clear ranking of the efficiency of several types of additions by using a robust and reproducible methodology based on isothermal calorimetry (performed at 20°C). The cement was a CEM I 52.5N PM-ES (Blaine fineness of 455 m^2/kg). To ensure the reproducibility of the experiments and avoid any decrease of the reactivity before use, the cement was stored in waterproof and sealed bags to avoid any contact with moisture and carbon dioxide. The experiments were performed on Portland cement pastes by using a water-to-cement ratio of 0.45, and incorporating different compounds (industrially available or laboratory-synthesized) that were selected according to their main composition and their specific surface area (SSA, calculated using the Brunauer-Emmett-Teller (BET) model and nitrogen adsorption isotherms performed at 77K). The intrinsic effects of (i) dry powders (e.g. fumed silica, activated charcoal, nano-precipitates of calcium carbonate, afwillite germs, nanoparticles of iron and iron oxides , etc.), and (ii) aqueous solutions (e.g. containing calcium chloride, hydrated Portland cement or Master X-SEED 100, etc.) were investigated. The influence of the amount of addition, calculated relatively to the dry extract of each addition compared to cement (and by conserving the same water-to-cement ratio) was also studied. The results demonstrated that the X-SEED®, the hydrated calcium nitrate, the calcium chloride (and, at a minor level, a solution of hydrated Portland cement) were able to accelerate the hydration kinetics of Portland cement, even at low concentration (e.g. 1%wt. of dry extract compared to cement). By using higher rates of additions, the fumed silica, the precipitated calcium carbonate and the titanium dioxide can also accelerate the hydration. In the case of the nano-precipitates of calcium carbonate, a correlation was established between the SSA and the accelerating effect. On the contrary, the nanoparticles of iron or iron oxides, the activated charcoal and the dried crystallised hydrates did not show any accelerating effect. Future experiments will be scheduled to establish the ranking of these additions, in terms of accelerating effect, by using low-reactivity cements and other water to cement ratios.

Keywords : acceleration, hydration kinetics, isothermal calorimetry, Portland cement
Conference Title : ICCBM 2016 : International Conference on Construction and Building Materials
Conference Location : Copenhagen, Denmark
Conference Dates : June 27-28, 2016