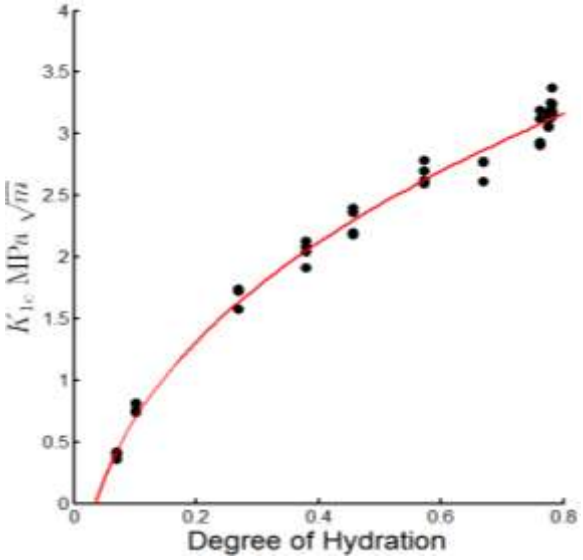
Early Age Fracture Resistance

Problem

Mechanical properties, including fracture resistance, are directly linked to hydration of cement, which is governed by its chemistry, fineness, curing time and temperature. In order to improve mechanical properties at earlier ages, the properties of the cement can be optimized or admixtures can be included in the mix to accelerate the hydration, but first a method must be determined to evaluate these properties as a function of the curing time, or more accurately, the degree of hydration.

Approach

To study the link between tensile strength, fracture properties and degree of hydration, scratching, splitting tensile and isothermal calorimetry tests were performed on a series of cement paste specimens made with a white OPC at the following ages: 7, 8, 12, 18, 24, 36, 48, 96, 168, 336 and 672 hours (28 days). A single batch of OPC, 100 grams with a w/c = 0.4, was prepared for each age with a consistent procedure, and all scratch and splitting specimens were taken from the same batch.



Simple relationship between early age fracture toughness and degree of hydration. The red line is a fit using a power law to show the trend.

The calorimetry test was run for about 280 hours to give the power (per gram of cement) vs. curing time, the integral of this relationship from 0 to time *t* gives a good indication of the degree of hydration at time *t*. The power for longer times was determined from extrapolation of the tail of the recorded data. A Rockwell probe was used in the micro-scratch test to scratch the surface of the specimens to determine the fracture toughness at that age. The tensile strength was calculated from split cylinder tests, with an adjustment for the bearing strip effect. Irwin's characteristic length, which is proportional to the fracture process zone size, was also calculated.

Findings

The excellent repeatability of the tests and convergence of the raw data allows the increase of fracture toughness and splitting strength at different curing ages to be determined. We found the fracture toughness, tensile strength and Irwin's characteristic length all increase with increasing degree of hydration. The relationships between these fracture and strength properties and degree of hydration will continue to be studied.

Impact

Bringing together the correct recipe of experiments (scratching, splitting and calorimetry), the relationships between these mechanical properties and hydration degree were determined. More importantly, once expanded to other compositions, these findings can be used as predictive tools for many industrial uses.

More

Research presented by Dr. C. Hoover, in collaboration with Prof. F.-J. Ulm.

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