Florida Department of Transportation Research

Effects of Portland Cement Particle Size on Heat of Hydration

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Generally, when materials are heated (or cooled), they expand (or contract) to a greater or lesser extent. Even a material as rock-like as concrete is susceptible to thermal effects, and expansion joints are used for this reason: to allow concrete to expand and contract without buckling.

Thermal expansion of concrete is especially important for concrete poured in massive forms. Setting concrete generates heat as chemical components react and form bonds to produce concrete's characteristic strength. However, concrete conducts heat poorly, and the heat inside a massive pour may take more time to dissipate than the outer regions, which can cool faster. Contraction of outer layers over inner layers can cause cracks, reducing the concrete's strength, structural integrity, and service life. The potential for thermal cracking is increased by high temperatures, common throughout Florida.

Recently, ASTM International and the American Association of State Highway and Transportation Officials (AASHTO) have aligned their Portland cement standards, raising concerns at departments of transportation, including Florida's, about accurately estimating the heat generated by widely used Portland cement Type II mixtures.

In this project, University of South Florida researchers studied two factors important in heat generation in concrete: particle fineness, omitted from the standard; and tricalcium phases, which are variable in it. Researchers examined standard methods for estimating heat generated by setting concrete and the validity of excluding fineness.

From five sources, the researchers obtained eleven mixtures representing a range of fineness (Blaine air permeability test) and tricalcium phases. Sand conforming to ASTM C778-08 and distilled water were used. Specimens were cured in a saturated lime solution to prevent leaching of calcium hydroxide from hydrated paste during extended curing, especially at high temperatures.

The stretch of concrete pavement shows the effects of thermal cracking.

Cement samples were extensively characterized. They were assayed for a variety of metal oxides using chemical methods and quantitative x-ray crystallography, with some expected discrepancies between the two methods. Particle size measurements of cement samples were made with the Blaine test and laser scattering turbidimetry. Additional measurements included heat of hydration using an isothermal calorimeter, activation energy, and density. Dynamic measurements included following the hydration process with x-ray diffraction and restrained shrinkage measurements (ASTM C 1581M-09a).

Fineness and particle size distribution affected heat generated during the hydration of cement. Coarser cements appeared to have a lower restrained shrinkage and longer time to crack initiation. The heat of hydration according to the study methods differed from the standard heat index expression. Together these findings show the relevance of fineness measurement and the need for more accurate measures of heat of hydration, especially in applications for which heat rise during setting is a particular concern. More precise characterization of cement mixtures will help to reduce cracking and produce more durable and effective concrete structures.

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For more information, visit http://www.dot.state.fl.us/research-center