Mix Design and Performance Assessment of Cost-Effective Ultrahigh Performance Concrete

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Ultrahigh performance concrete (UHPC) is a type of fiber-reinforced cementitious concrete composite with superior performance in comparison to conventional concrete. Concretes that belong to the UHPC-class of materials have excellent strength (>18 ksi in compression, and >0.75 ksi in tension), and superior durability. These properties are attributed to the use of very low water-to-cementitious materials ratio, high particle packing density, and due to the use of whisker-type micro-steel fiber reinforcement. Despite such superior properties, the main challenge associated with the wider adoption of UHPC-class materials is the capability to produce such materials with low cost and ease of production. Commercially made UHPC-class materials cost greater than $2000 per cubic yard of concrete, which is 20 times the cost of conventional concretes. However, in the long run, the life-cycle costs for UHPC-class materials are far lower than conventional concretes.

Nonetheless, it was critical to gain an understanding on how to economically produce UHPC-class material, with a lack of published mix design guidelines. A database of UHPC-class materials, mixture proportions and performance were assembled. A statistical correlation was established between the mixture constituents, mixture proportions, and mechanical performance of these materials. The validity of the established model was assessed by producing more than 130 trial mixtures of UHPC-class materials using several domestically sourced cementitious materials, sands, fibers, and admixtures. The particle size distribution of the mix constituents was determined to determine the extent to which the degree of particle packing impacted the mechanical performance of these materials. The cost of these mixtures was also determined. This research endeavor resulted in several UHPC-class mixture designs that were both economically viable and exceeded the threshold performance requirements of UHPC-class materials (in accordance with the American Association of State Highway and Transportation Officials design guidelines).