GEOPOLYMER ULTRAHIGH PERFORMANCE CONCRETE: MATERIAL AND PERFORMANCE

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During the last two decades, considerable progress has been made in the development of ultra-high-performance concrete (UHPC) with ordinary Portland cement (OPC). UHPC represents a major development step over high performance concrete (HPC), through the achievement of very high compressive strength (over 20,000 psi or 140 MPa) and superior durability due to very low permeability compared to high-performance concrete; in some cases, fibers are included to achieve improved ductility. Despite these performance advantages, deployment of Portland cement-based UHPC has been slow, in part due to the relatively high compared to that of conventional concrete components. In addition, the higher content of Portland cement in UHPC, high temperature steam curing, and use of relatively large amounts of superplasticizers increase the cost and CO_2 footprint. Geopolymer-based UHPCs have the potential for significant advantages over comparable OPC-based materials. We have developed a range of low-cost, low-CO_2 footprint, geopolymer UHPC (GUHPC) formulations. The main characteristics of these GUHPCs include: 1) Increased homogeneity by excluding aggregates >9.5mm, 2) Increased packing density through use of micro- and nano-particles, 3) Very low water-to-binder ratio through chemically tailored activator compositions and use of intensive mixing; 4) Composite binders yielding hybrid calcium aluminosilicate hydrate (C-A-S-H) and alkali aluminosilicate hydrate (A-A-S-H) gels to improve product properties; and 5) Regulation of set times using a very effective inorganic retarder.

Figure 1 shows compressive strength growth curves of several of these GUHPCs, indicating rapid strength gain and very high final strength. Samples have been studied for freeze-thaw resistance, shrinkage, alkali-silica reactions, acid resistance (up to 10% H_2SO_4), rebar corrosion, Young's modulus and Poisson's ratio, expansion in sulfate solution and water, natural carbonation, and bond strength by slant shear. Effects of curing temperatures on materials performance were also investigated. Field testing now extends to five-year outside weathering exposure (-15°C to +45°C, ice, rain, and snow) showed no deterioration of mechanical durability. In this paper, we will review the development, characterization, and properties of these materials and prospective applications.

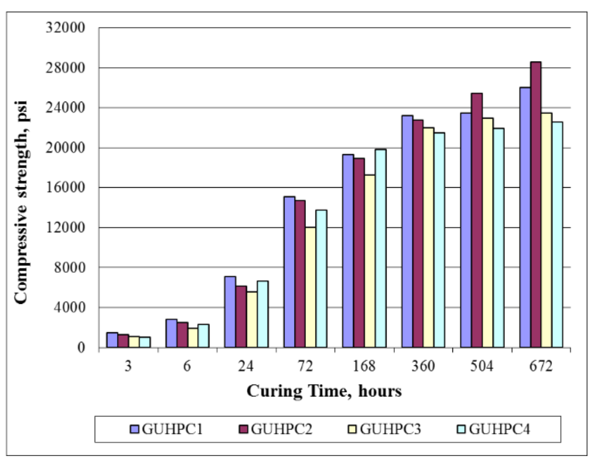

Figure 1 – Compressive strength as a function of curing time at room temperature