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ACI PRC-239.1-24
TechNote

What is Ultra-High-Performance Concrete (UHPC)?—TechNote

Keywords: compressive strength; durability; fiber-reinforced concrete; permeability; tensile strain capacity; tensile strength.

Introduction

Ultra-high-performance concrete (UHPC) has emerged as a basis for compelling applications in the infrastructure, architecture, security, and even the consumer goods markets. UHPC enables the design, fabrication, construction, and delivery of structural and architectural elements that are distinct from those made of conventional concrete and steel in terms of their structural form, resilience, constructability, and aesthetics. These qualities have led to an increase of its use around the world. There have been major advancements since the American Concrete Institute formed a technical committee focused on UHPC in 2011, leading to the publication of an *Emerging Technology Report* (ACI PRC-239). However, as interest and demand continue to increase, a fundamental question has arisen: What is UHPC?

In a broad sense, UHPC is a material with mechanical and durability properties that exceed those attainable with conventional or high-performance concretes, including low permeability, high compressive strength, and sustained post-cracking tensile resistance. UHPC's durability properties are largely attributable to a dense cementitious matrix that has a discontinuous pore structure that inhibits the ingress of deleterious substances, such as chlorides. UHPC typically exhibits tensile ductility and toughness, attributable to the inclusion of an ample volume of fiber reinforcement. Refer to Fig. 1 for a pretensioned beam undergoing flexural testing.

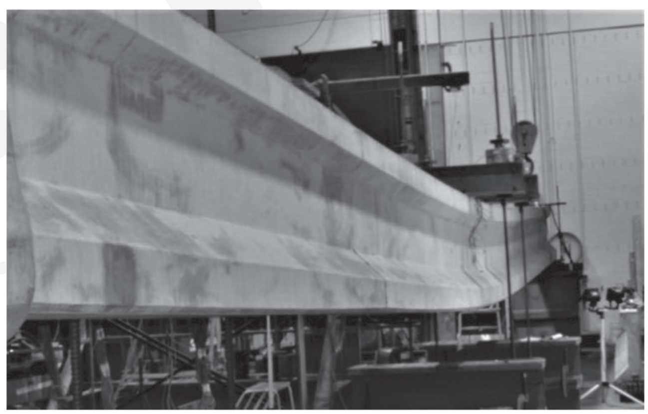

Fig. 1—UHPC pretensioned beam subjected to flexural testing (test result in FHWA-HRT-06-115; photo courtesy of Benjamin Graybeal, Federal Highway Administration [FHWA]).

This class of concrete may be referred to by various names in different parts of the world. Ultra-high-performance fiber-reinforced concrete (UHPFRC) and ultra-high-performance fiber-reinforced cementitious composite (UHPFRCC) may each be encountered. In North America, the "fiber-reinforced" and "cementitious composite" portions of those alternate names have generally been dropped in favor the more succinct term, UHPC.

Constituents

There is no unique formulation that defines UHPC. Rather, UHPC is a classification of cementitious products that meets certain enhanced performance criteria. Most UHPC mixture designs include fine aggregates, portland cement, and one or more supplementary cementitious materials (SCMs) such as silica fume or slag. Coarse aggregates greater than 0.2 in. (5 mm) diameter are not commonly included. High-range water-reducing admixtures (HRWRAs) and other chemical-based performance modifiers are commonly used as well. The water-binder ratio (w/b) of UHPC is usually between 0.15 and 0.25.

Particle packing concepts are engaged in the design of UHPC mixtures, with progressively smaller particles filling the gaps between larger constituents. Particle packing facilitates the creation of the denser microstructure that is commonly present in UHPC formulations. It also facilitates the creation of UHPC mixtures that, when freshly mixed, have a grout- or mortar-like consistency that will flow with minimal agitation similar to self-consolidating or even self-leveling cementitious composites. The high paste content and fine constituents of UHPC generally permit it to closely replicate formwork surfaces, allowing detailed surface features to be created. Refer to Fig. 2 for a photo of fresh UHPC being placed.

Fiber reinforcement is commonly added to the cementitious matrix to combat brittleness and enhance the tensile performance of the UHPC. A high concentration of discontinuous fiber reinforcement, frequently exceeding 1.5% by volume, allows this class of concrete to exhibit unique tensile properties that exceed those attainable with more conventional fiber-reinforced concretes (refer to documents produced by ACI Committee 544 for information on these concretes). Depending on the application and the desired performance, the fibers may be made of steel, other metals, or nonmetallic materials (for example, polyvinyl alcohol, polyethelene, polyoxymethylene, and polypropylene). The shape, length, and aspect ratio of fibers are critical