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Research Results

TPF-5(366): Development of Structural Design Guide for Ultra High-Performance Concrete

Evaluation of AASHTO T 397, Standard Method of Test for Uniaxial Tensile Response of Ultra-High-Performance Concrete

Geotechnical/ Structures

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WHAT WAS THE NEED?

Ultra-high-performance concrete (UHPC) is a cementitious material made of graded fine particles and fibers. It achieves ultra-high strength, durability, ductility, and toughness. The fibers improve tensile ductility in the post-elastic range and increase fracture energy. Although prior studies have confirmed that UHPC outperforms conventional, high-performance, and fiber-reinforced concrete, no standard direct tension test method has been established to define specimen geometry, support conditions, and load protocol to characterize the tensile behavior of UHPC. A promising approach is the AASHTO T 397 test method; however, its reliability, repeatability, and consistency across varying conditions needed independent evaluation.

WHAT WAS OUR GOAL?

This study aimed to independently evaluate the reliability and repeatability of a direct tension test method for UHPC, developed by the Federal Highway Administration (FHWA) and adopted by the American Association of State Highway and Transportation Officials (AASHTO) as AASHTO T 397.

WHAT DID WE DO?

A two-part study to evaluate AASHTO T 397 was conducted using commercially available UHPC:

- Part one evaluated the effects of UHPC type and fiber volume fraction. Three UHPC mixtures were prepared with fiber contents of 1%, 2%, and 3%. A total of 216 direct tension specimens were tested at six independent laboratories to assess the method's repeatability and reliability. Compression tests were also performed to

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compare compressive and tensile properties.
- Part two examined additional variables, including different fiber types, fiber volumes, specimen shapes, and cross-sections. This phase assessed the tensile behavior of UHPC specimens with alternative fibers and compared the performance of square prism specimens, tested per AASHTO T 397, to dogbone-shaped specimens. The study also investigated the influence of testing machine capacity on test outcomes.

WHAT WAS THE OUTCOME?

The study produced the following key results:

- The AASHTO T 397 test method established UHPC's direct tension response with sufficient fiber content, achieving a 60% to 70% success rate with carefully prepared specimens.
- The different phases of UHPC's tensile response were clearly identified from load-deformation curves, with localized cracking starting at the onset of the crack straining phase.
- When more than 30 successful tests were conducted for a UHPC type, tensile responses remained within 1.5 times the standard deviation.
- Tensile strength increased directly with fiber volume, and higher fiber content extended the multi-cracking phase for all mixtures.
- The crack straining phase length depended on UHPC type, not fiber volume.
- Average and characteristic tensile properties could be established with just 15 successful tests.
- Dogbone and square prism specimens produced comparable tensile responses when tested with the same gauge length.

WHAT IS THE BENEFIT?

Direct tension tests have the potential to provide the tensile response of UHPC and identify its various phases with much less computational effort than bending or wedge splitting tests. The direct tensile test procedure developed by the FHWA has been adopted by the American Association of State Highway and Transportation Officials (AASHTO) as AASHTO T 397 and is available for immediate use with the recommendations outlined in this study.

LEARN MORE

Evaluation of AASHTO T 397, Standard Method of Test for Uniaxial Tensile Response of Ultra-High Performance Concrete: Tech Transfer Summary, TPF-5(366), June 2024 - Iowa Publications Online

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