Florida Method of Test for Tensile Strength and Relative Toughness of Ultra-High-Performance Concrete by Double-Punch

Designation: FM 5-626

1. Scope

1.1 This test method covers the determination of the tensile strength and relative toughness of cylindrically cast specimens of Ultra-High-Performance Concrete (UHPC).

1.2 This test method does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices prior to use.

2. Reference Documents

ASTM C31/C31M - Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C39/C39M - Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C192/C192M - Practice for Making and Curing Concrete Test Specimens in the Laboratory

ASTM C1856/C1856M - Standard Practice for Fabricating and Testing Specimens of Ultra-High-Performance Concrete

UNE 83515 - Fiber Reinforced Concrete. Determination of Cracking Strength, Ductility and Residual Tensile Strength. Barcelona Test.

3. Terminology

Ultra-High-Performance Concrete (UHPC) is a cementitious composite material composed of an optimized gradation of granular constituents, a water-to-cementitious materials ratio less than 0.25, and a high percentage of discontinuous internal fiber reinforcement, with compressive strength greater than 17,000 psi (120 MPa), sustained post-cracking tensile strength greater than 725 psi (5 MPa), and a discontinuous pore structure that significantly enhances durability.

4. Summary of Test Method

This test method consists of situating a UHPC cylinder with equal height and diameter between two cylindrical steel punches with diameters of one fourth of the cylinder diameter, centered on the parallel surfaces of the UHPC specimen. A compressive force is then applied to the steel punches at a constant load rate to produce tensile stresses on the UHPC cylinder. A load versus displacement curve is plotted. The tensile stress is then calculated based on specimen dimensions and load applied to produce a stress versus displacement curve, from which a relative toughness is calculated.

5. Significance and Use

5.1 This test method has been designed to ensure fiber quantity and distribution in the mix is consistent.

5.2 The results of this test method may be affected by the formulation, materials, proportions, and mixing procedures.

5.3 Sample fabrication, curing, and the age of the specimen will affect the results of this test.

6. Apparatus

6.1 Testing Machine - The testing machine must meet all the requirements of **Section 6** of **ASTM C39**. This includes, but is not limited to, bearing blocks, platens, and spacers.

6.2 Steel Punches - Two steel disks used to apply loading to the top and bottom faces of the test specimen. Disks will have a hardness of at least 90 HRB. The two disks shall be 1.50 ± 0.01 inches (38 ± 0.25 mm) in diameter and 1.00 ± 0.25 inches (25 ± 6 mm) in height. The bearing surfaces shall be plane to within 0.002 inch (0.05 mm) and parallel to each other.

6.3 Displacement Indication System - A real-time displacement indicator used to measure the linear distance the bearing face movement over the duration of the test. The displacement indicator will be adjustable, mounted parallel to the vertical axis of the machine, with a minimum range of 0.50 inches (12.5 mm) and a minimum precision of 0.001 inches (0.025 mm). The indication system display may be analog or digital and visible to the technician while the test is being performed.

The displacement indicator may be an integral part of the testing machine, a Linear Variable Differential Transformer (LVDT), or an independent dial indicator.

7. Test Specimens

7.1 Sample fresh UHPC in accordance **ASTM C1856**.

7.2 Make cylindrical test specimens in accordance **ASTM C1856**, vertically cast in a mold 6 inches (150 mm) in diameter and 12 inches (300 mm) in height.

7.3 Cure cylindrical test specimens in accordance **ASTM C1856**.

7.4 If required, thermally treat cylindrical test specimens in accordance **ASTM C1856**.

7.5 Saw Cut the UHPC test specimen at half of the height for a perpendicular plane at the axis of symmetry of the specimen. Prepared test specimens will be cylinders 6.00 ± 0.50 inches (150 ± 12.5 mm) in height and 6.00 ± 0.10 inches (150 mm ± 2.5 mm) in diameter. Both the top and bottom portions of the specimen will be tested. Prepare both ends of the top and bottom portions in accordance with **ASTM C1856**, as required for compressive strength testing.

8. Procedure

8.1 Measure the height of the specimen to the nearest 0.01 inches (0.25 mm) at three locations evenly distributed around the circumference of the cylinder. Compute the average height and record to the nearest 0.01 inches (0.25 mm).

8.2 Measure the diameter of the specimen to the nearest 0.01 inches (0.25 mm) at two locations taken at right angles to each other at about mid-height of the specimen. Compute the average diameter and record to the nearest 0.01 inches (0.25 mm).

8.3 Place the specimen between the two steel punches so that each punch is in the center of the concrete's circular face. Place the specimen and punches in the testing machine and align the axis of the specimen with the center of thrust of the upper bearing block, reference **Figure 1**.

Note 1: To ensure the correct centering, it is recommended to use a disk made of cardboard, plastic, or thick paper with an external diameter of 6 inches (150 mm) and an internal diameter of 1.55 inches (39 mm).

8.4 Prior to testing the specimen, adjust the load indicator on the compression machine to zero.

8.5 Place the displacement indicator in the machine to measure the change in distance between the upper machine frame and the lower bearing block. Ensure the displacement indicator has a minimum of 0.40 inches (10 mm) of available displacement in compression.

8.6 Prior to testing the specimen, adjust the displacement indicator to zero.

8.7 Apply the load to the specimen continuously and without shock, The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a force rate on the specimen of 100-200 lbf/s until the load reaches 10,000 lbf.

8.8 Record the displacement indicator reading when the load reaches 10,000 lbf.

8.9 When the load reaches 10,000 lbf, adjust the load applied at a rate of movement (platen to crosshead measurement) corresponding to a force rate on the specimen of 200-400 lbf/s until the displacement reaches 0.30 inches (7.5 mm).

Note 2: Some machines may include settings that will stop testing after the load drops a certain percentage from the peak load. Adjust this setting so the machine will continue until the 0.30-inch displacement is reached.

8.10 While loading the concrete specimen, collect and record data pairs of load versus displacement by recording the displacement indicator and the load displayed by the testing machine at the same time. Data pairs will be recorded using increments of no greater than 0.01 inches (0.25 mm) for the first 0.10 inch (0.25 mm) of displacement and increments no greater than 0.02 inches (0.50 mm) for the next 0.20 inches (0.50 mm) of displacement.

8.11 Testing may be discontinued after the displacement indicator has shown at least 0.30 inches (0.75 mm) of displacement.

Note 3: Some machines may have the ability to automatically record the load versus displacement data.

8.12 In addition to the loads recorded at specified displacements, record the maximum load carried by the specimen during the test.

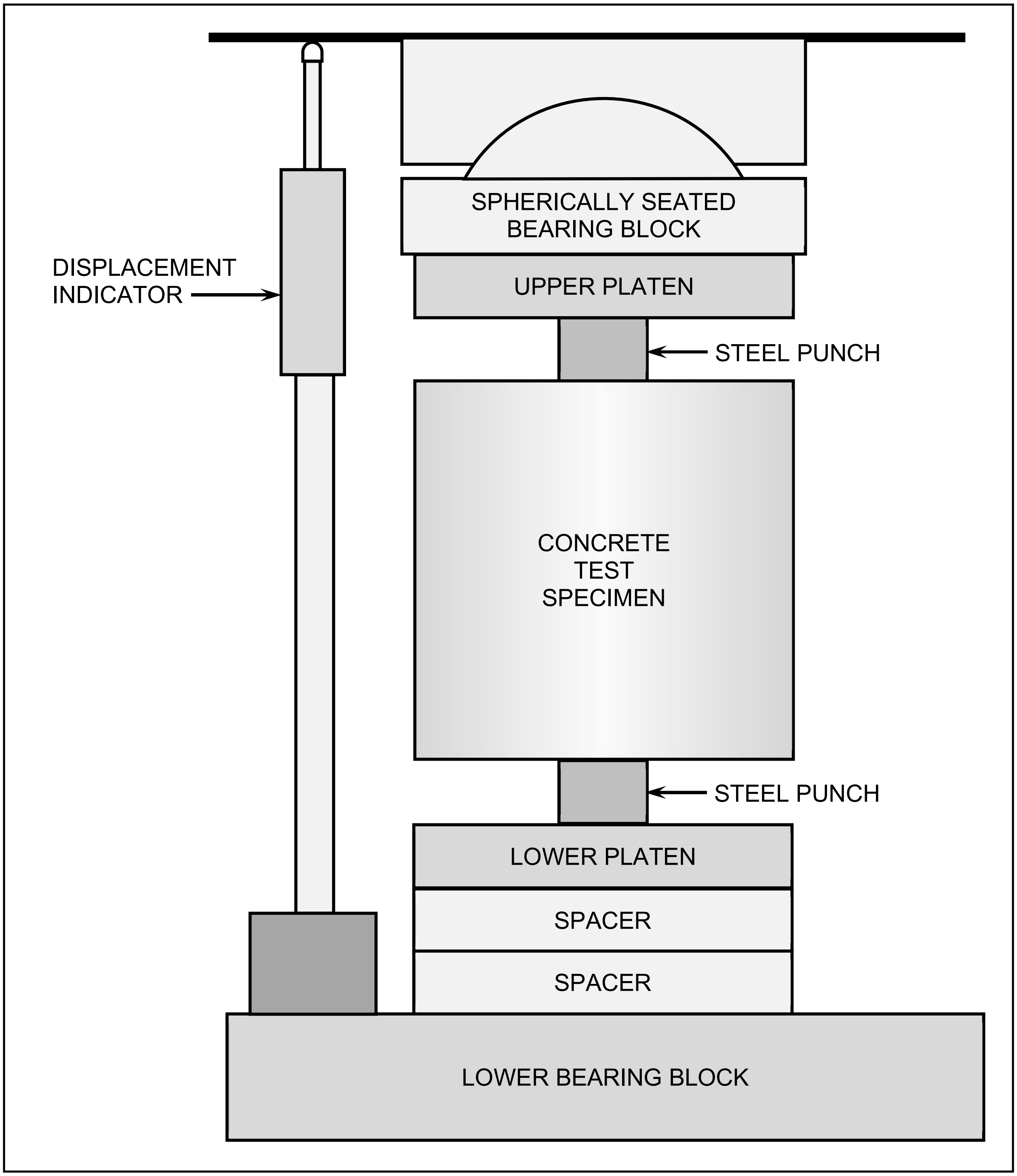

Figure 1 - Compression Testing Setup

9. Calculations

9.1 Calculate the Tensile Stress (f_t) from the loads recorded at each crosshead displacement and for the maximum load using **Equation 1**.

$$f_t = \frac{4\,P_f}{9\,\pi\,a\,H} \qquad [1]$$

Where: f_t = tensile stress (psi)

P_f = load (lbf)

a = diameter of the steel punch (in)

H = height of the specimen (in)

9.2 Plot the data pairs of tensile stress versus specified displacements, reference **Figure 2**.

9.3 Calculate the Relative Toughness (T) as the area under the tensile stress versus displacement curve up until the endpoint of 0.30 inches using **Equation 2**.

$$T = \sum \frac{f_{t,n-1} + f_{t,n}}{2} \times (y_n - y_{n-1}) \qquad [2]$$

Where: T = specimen's relative toughness (psi·in)

$f'_{t,n}$ = stress for data point n (psi)

$f'_{t,n-1}$ = stress at the data point directly preceding n (psi)

y_n = axial displacement of the machine for data point n (in)

y_{n-1} = axial displacement of the machine for the data point directly preceding n (in)

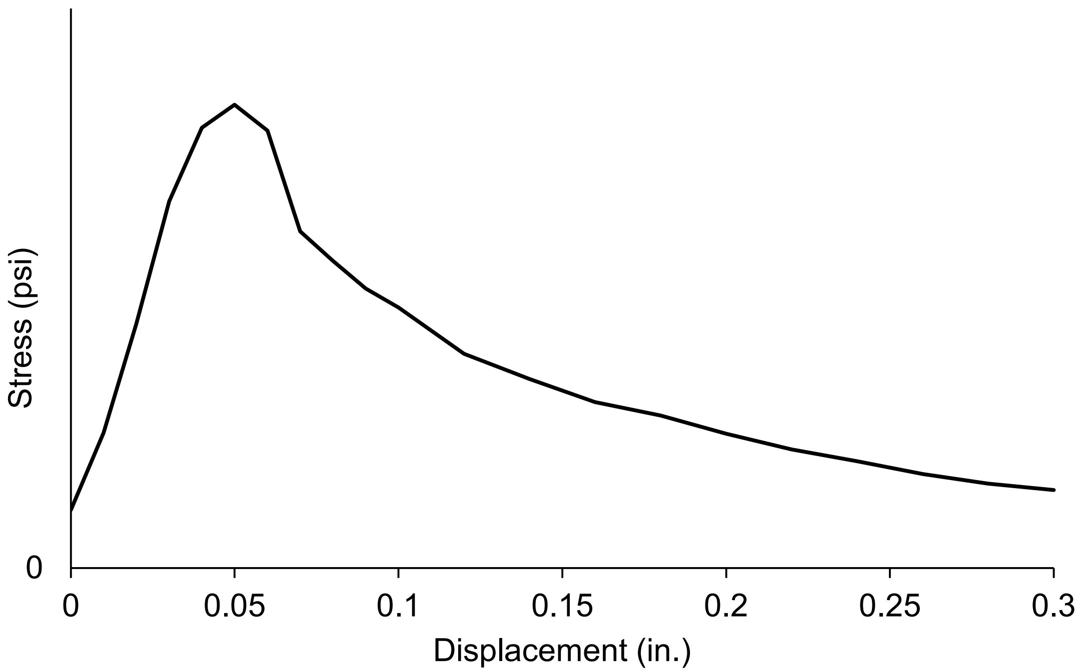

Figure 2 - Plot of Tensile Stress versus Displacement

10. Report

Report the following information:

10.1 Specimen Identification (i.e., Project number, date sampled, lot number, etc.).

10.2 Location, top or bottom of cylinder.

10.3 Specimen curing conditions.

10.4 Specimen age, days.

10.5 The average measured height and diameter of each specimen to the nearest 0.01 inches (0.25 mm).

10.6 Raw data pairs of displacement to the nearest 0.001 inches (0.025 mm) and loads to the nearest 100 lbf.

10.7 Calculated tensile stresses to the nearest 10 psi at the measured displacements.

10.8 Maximum load to the nearest 100 lbf (0.45 kN).

10.9 Calculated maximum Tensile Stress (ft) to the nearest 10 psi (0.1 MPa).

10.10 Average maximum Tensile Stress (ft) of top and bottom portions to the nearest 10 psi (0.1 MPa).

10.11 Plot of calculated tensile stress versus displacement.

10.12 Relative Toughness (T) to the nearest 10 psi·inches (0.1 Mpa·mm).

10.13 Average Relative Toughness (T) of top and bottom portions to the nearest 10 psi·inches (0.1 Mpa·mm).