

# ABC-UTC Non-Proprietary UHPC Workshop

## Testing Methods and Quality Control

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## Outline

- General testing methods
- Flow testing
- Compressive strength
- Tension testing
- Other testing methods



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## Testing

- Methods require modification for properties of UHPC – ASTM C1856
  - Flow table testing with modification (ASTM C1437)
  - Specimens made using ASTM C31/C192 with placement in a single layer and no tamping
  - Specimen size modifications; e.g. 3 in. x 6 in. cylinders for compression (ASTM C39)
  - Increased load rates (e.g. 150 psi/s for compression)
  - Cylinders must be ground plane; no capping is allowed

## Testing

- Flexural strength using ASTM C1609
- Modulus of elasticity using ASTM C469
- Creep using ASTM C512
- Length change using ASTM C157
- Abrasion resistance using ASTM C944
- Freeze-thaw resistance using ASTM C666
- Chloride ion penetration resistance using ASTM C1202

## Flow

- ASTM C1856 and C1437
  - No table drops
  - Wait two minutes to measure diameters
  - Maximum and minimum diameters to nearest 1/16 in.



## Flow



## Flow

- Effect of increasing steel fibers and HRWR



No fibers



4% Fibers



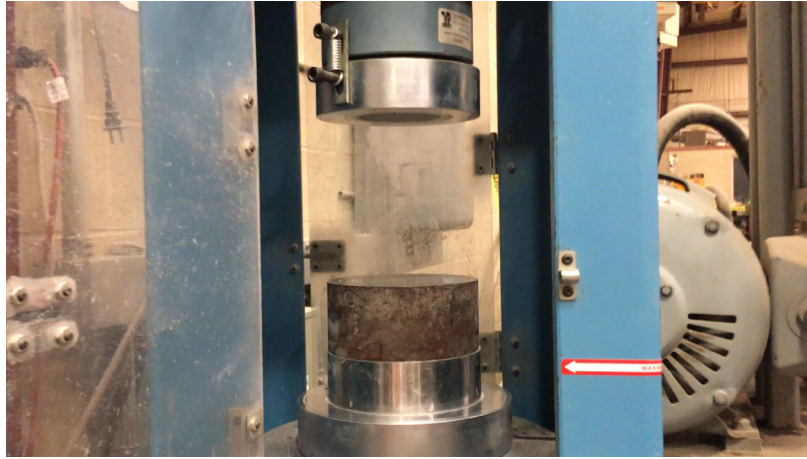
6% Fibers

## Compressive Strength

- ASTM C1856 and ASTM C39
- Typically sets of three 3 in. x 6 in. cylinders
  - Must be ground plane within 0.002 in. (0.05 mm)
  - Ends must be perpendicular within 0.5°
  - No capping
- Load rate  $145 \pm 7$  psi/sec ( $1.0 \pm 0.05$  MPa/sec)
- Platens must be hardened steel



## Compressive Strength



## Compressive Strength

- 0% Fibers
- 19,460 psi



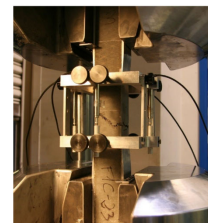
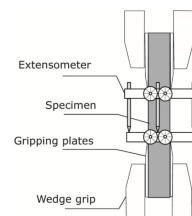
## Compressive Strength

- 2% Fibers
- 17,570 psi



## Direct Tension

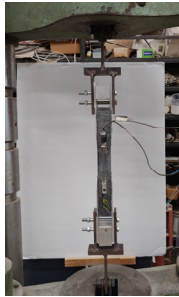
- Direct tension strength is an important consideration due to post-crack ductility and contribution to behavior
  - 2 in. (51 mm) square cross-section specimen examined extensively by FHWA (e.g. Graybeal and Baby 2013) and recently approved as AASHTO Standard T397
  - Other test methods used are not standardized



(Haber et al. 2018)

## Direct Tension

- Modified test method used at University of Oklahoma
  - Difficult to get proper alignment
  - Can induce bending in the test specimen



Modified direct tensions test specimen



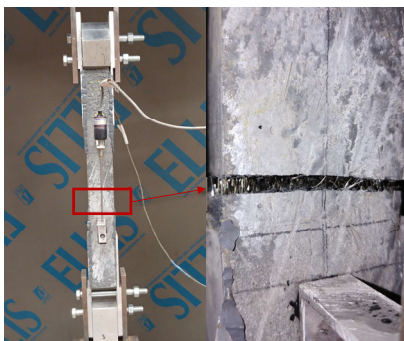
Specimen with 2% steel fibers exhibiting bending



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## Direct Tension



Specimen with 1% steel fibers



Specimen with 2% steel fibers



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## Flexural Strength

- ASTM C1856 and ASTM C1609
  - Third point loading
  - Span equal to 3x depth
  - Deflection controlled test with rate varying with deflection
- Specimen size based on fiber length

TABLE 3 Dimensions of Beams for Measuring Flexural Strength

Maximum Fiber Length ( $l_f$ )	Nominal Prism Cross Section
< 15 mm [0.60 in.]	75 mm by 75 mm [3 in. by 3 in.]
15 mm to 20 mm [0.60 in. to 0.80 in.]	100 mm by 100 mm [4 in. by 4 in.]
20 mm to 25 mm [0.80 to 1.00 in.]	150 mm by 150 mm [6 in. by 6 in.]
>25 mm [1.00 in.]	200 mm by 200 mm [8 in. by 8 in.]

(ASTM C1856)

TABLE 1 Rate of Increase in Net Deflection

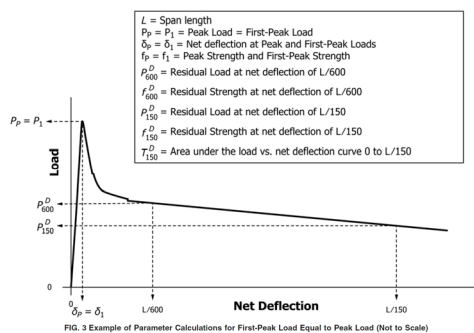
Beam size <sup>a</sup>	Up to net deflection of L/900	Beyond net deflection of L/900
100 by 100 by 350 mm [4 by 4 by 14 in.]	0.025 to 0.075 mm/min [0.001 to 0.003 in./min]	0.05 to 0.20 mm/min [0.002 to 0.008 in./min]
150 by 150 by 500 mm [6 by 6 by 20 in.]	0.035 to 0.10 mm/min [0.0015 to 0.004 in./min]	0.05 to 0.30 mm/min [0.002 to 0.012 in./min]

<sup>a</sup>The initial loading rate up to deflection of L/900 for other sizes and shapes of specimens shall be based on reaching the first-peak deflection 40 to 100 s after the start of the test. Beyond a net deflection of L/900, the rate of increase of net deflection shall not exceed 8 times the initial rate.

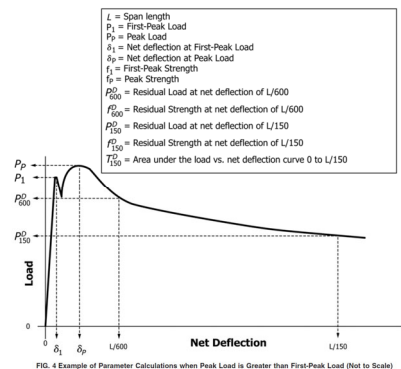
(ASTM C1609)

## Flexural Strength

- ASTM C1856 and ASTM C1609



Example of parameter calculations for first peak load equal to peak load (ASTM C1609)



Example of parameter calculations when peak load is greater than first peak load (ASTM C1609)



## Other Testing

- Modulus of Elasticity
  - ASTM C1856 and ASTM C469
  - Linear voltage differential transformers or similar for deflection measurement
  - Load rate  $145 \pm 7$  psi/sec ( $1.0 \pm 0.05$  MPa/sec)
- Creep in Compression
  - ASTM C1856 and ASTM C512
  - At least six 3 in. (75 mm) by 6 in. (150 mm) cylinders
  - Ends ground plain similar to compressive strength specimens
  - Load to 40% of specified compressive strength

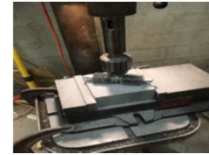
## Other Testing

- Length Change
  - ASTM C1856 and ASTM C157 or C341
  - 3 in. by 3 in. by 11.25 in. specimens
- Freeze-Thaw Resistance
  - ASTM C1856 and ASTM C666 Procedure A (wet during freezing and thawing)
  - 300 cycles or 90% relative dynamic modulus
  - Other limits may be specified



## Other Testing

- Abrasion Resistance
  - ASTM C1856 and ASTM C944
  - Use double load – 44 lbf (197 kN)
- Rapid Chloride Ion Penetrability (RCIP)
  - ASTM C1856 and ASTM C1202
  - Cannot be utilized with steel fibers
- Bond strength
  - ASTM C1583
  - May be used to evaluate bond of overlays



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## Questions?



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