
Standard Method of Test for

Uniaxial Tensile Response of Ultra-High Performance Concrete

AASHTO Designation: T 397-24¹

Revised: 2024

Technical Subcommittee: 3c, Hardened Concrete



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1. SCOPE

- 1.1. This test method covers the testing of ultra-high performance concrete materials (UHPC) in uniaxial tension. In particular, the method obtains the stress–strain behavior and mechanical response parameters of UHPC specimens in uniaxial tension.
- This test method is intended for use as a means through which key tensile mechanical parameters of strain hardening fiber reinforced concretes, such as UHPC, are quantified. Use of this test method to assess the performance of strain softening fiber reinforced concretes, continuously reinforced concretes, or conventional concretes may be feasible; however, some aspects of the results analysis portion of the method (see Sections 9 through 12) will not be applicable.
- 1.2. The values stated in either SI units or inch-pound units are to be regarded separately as standard. The inch-pound units are shown in parentheses. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.
- 1.3. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*
- 1.4. The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.
- 1.5. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED STANDARDS

- 2.1. *AASHTO Standard:*
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories

2.2.

ASTM Standards:

- C1856/C1856M, Standard Practice for Fabricating and Testing Specimens of Ultra-High Performance Concrete
- C469/C469M, Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
- E4, Standard Practices for Force Verification of Testing Machines
- E6, Standard Terminology Relating to Methods of Mechanical Testing
- E8/E8M, Standard Test Methods for Tension Testing of Metallic Materials
- E83, Standard Practice for Verification and Classification of Extensometer Systems
- E1012, Standard Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

3. TERMINOLOGY

3.1. Refer to ASTM E6 for a complete listing of terminology related to mechanical testing.

3.2. *Definitions of Terms Specific to this Standard:*

3.2.1. *effective cracking strength ($f_{t,cr}$)*—the stress corresponding to the intersection of a strain offset to the initial elastic stress–strain response and the captured stress–strain response in the inelastic region (see Figure 1).

3.2.2. *elastic tensile strength ($f_{t,el}$)*—the elastic limit of the material beyond which the material has exhibited discrete cracking of the cementitious composite (Figure 1).

3.2.3. *peak tensile strength ($f_{t,peak}$)*—the maximum tensile stress that a material can sustain, including both pre- and post-cracking stresses (Figure 1).

3.2.4. *localization stress ($f_{t,loc}$)*—the first stress value at which the stress begins to continuously decrease with increasing strain (Figure 1).

3.2.5. *strain at effective cracking strength ($\epsilon_{t,cr}$)*—the strain that corresponds to the effective cracking strength, $f_{t,cr}$ (Figure 1).

3.2.6. *tensile strain limit ($\epsilon_{t,lim}$)*—the strain at which the tensile resistance permanently decreases to a value less than the effective cracking strength, $f_{t,cr}$ (Figure 1).

3.2.7. *localization strain ($\epsilon_{t,loc}$)*—the first strain value at which the stress begins to continuously decrease with increasing strain. This strain corresponds to the localization stress, $f_{t,loc}$ (Figure 1).

3.2.8. *strain at peak strength ($\epsilon_{t,peak}$)*—the strain that corresponds to the peak tensile stress, $f_{t,peak}$ (Figure 1).

3.2.9. *strain offset*—the strain value added to a linear fit of the elastic stress–strain response to create a parallel line that intersects the measured stress–strain response of a test specimen after the elastic limit (0.02 percent offset in Figure 1).

3.2.10. *tensile strain hardening response*—a response characterized by increasing uniaxial tensile resistance after initial cracking of the material (see Note 1).

Note 1—The post-cracking resistance is provided by a sufficient concentration of fiber reinforcement capable of resisting a stress greater than the stress at initial cracking of the cementitious matrix.

- 3.2.11. *tensile strain softening response*—a response characterized by decreasing uniaxial tensile resistance after initial cracking of the material (see Note 2).
- Note 2**—The post-cracking resistance is provided by fiber reinforcement that is not capable of resisting a stress greater than the stress at initial cracking of the cementitious matrix.
- 3.2.12. *grip*—the device that holds opposing sizes of each end of a test specimen during load application.

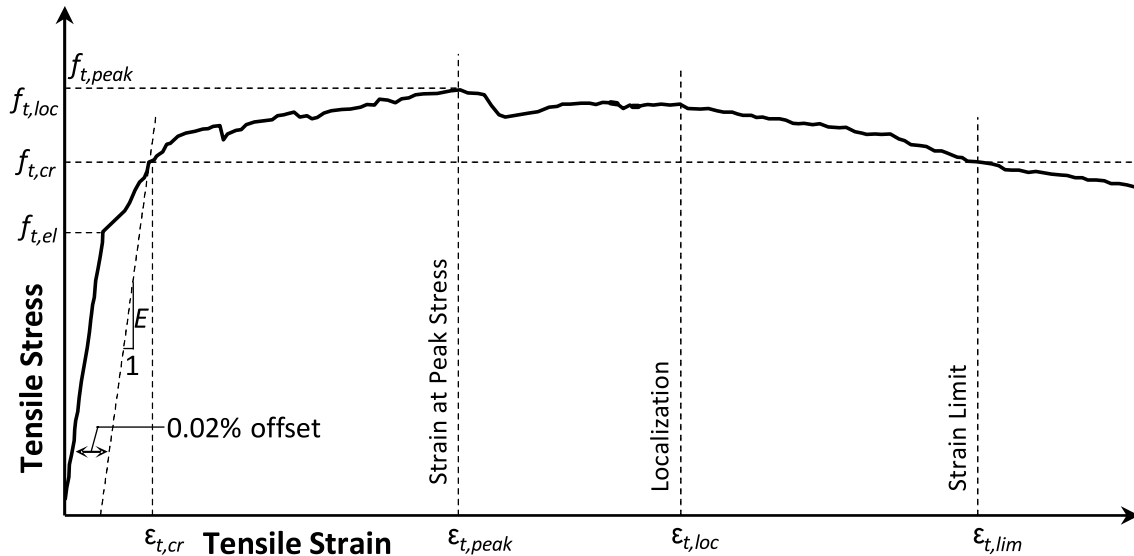


Figure 1—Idealized Typical Tensile Stress–Strain Response of UHPC Specimen (see Sections 3.2.1 through 3.2.9)

- 3.2.13. *grip pressure*—the amount of transverse pressure applied to the side of a test specimen by the grip (see Note 3).
- Note 3**—The grip pressure serves as the normal force generating the friction between the grip plates and the test specimen or the transfer plates on the side of the test specimen.
- 3.2.14. *transfer plate*—the sheet of material adhered to opposing sides of each end of a test specimen. It is located between the test specimen and the grip during the test.
- 3.2.15. *dress*—to lightly abrade the corners of the test specimen in order to remove any excess concrete or stray fiber reinforcement.
- 3.2.16. *fiber segregation*—an uneven distribution of fiber reinforcement within the concrete caused by a difference between the density of the fresh cementitious material and the fiber reinforcement.
- 3.2.17. *fixity*—the relative resistance of one grip to another in terms of rotational or translational movement after the test specimen has been gripped (see Note 4).
- Note 4**—In this test method, a high level of fixity is desired.

4. SUMMARY OF TEST METHOD

- 4.1. This test method consists of applying a uniaxial tensile load to a cast or cut prismatic ultra-high performance concrete test specimen. The mechanical response of the test specimen is captured. The tensile stress in the specimen is calculated by dividing the applied load by the cross-sectional area of the specimen. The tensile strain is calculated by dividing the observed deformation over a

gauge length by the gauge length. Together, the uniaxial tensile stress–strain response of the material is obtained. Subsequent analyses provide engineering parameters defined in this standard.

5. SIGNIFICANCE AND USE

- 5.1. This test method provides information on the strength and tensile behavior of UHPC materials under uniaxial tension loads (see Note 5). The information is used to qualify UHPC materials as meeting specified requirements, to enable comparisons between materials, and to further develop UHPC mixture formulations (see Note 6). The test method may also produce information useful for quality control of a product used on a construction project.

Note 5—Care should be exercised in the interpretation of a tensile response determined through this test method. The captured tensile response is not an intrinsic property of the tested concrete. The response will depend on the size and shape of the specimen; batching and mixing procedures; mix proportions and constituent materials; methods of sampling, molding, and fabrication; age at testing; and temperature and moisture conditions during curing.

Note 6—The results of tension tests of specimens cast in molds or cut from structural components may not represent the tensile response of the entire structural component in service. Placement methods and conditions, as well as manufacturing-induced characteristics should be considered when assessing material properties.

6. APPARATUS

- 6.1. *Testing Machine*—Machines used for tension testing shall conform to the requirements of ASTM E4. The testing machine shall have sufficient capacity and be capable of providing the loading rates prescribed in Sections 8.6 and 8.7.

- 6.2. *Gripping Devices:*

- 6.2.1. *General Requirements*—Gripping devices such as those shown in Figure 2 shall be used to transmit the force applied by the testing machine to the test specimen. They shall be rigidly affixed to the testing machine, and fully restrict all rotational and translational movement of the gripped portion of the test specimen. Photographs and dimensioned drawings of an example flat grip device are provided in Appendix X2 (see Figures X2.1 and X2.2).

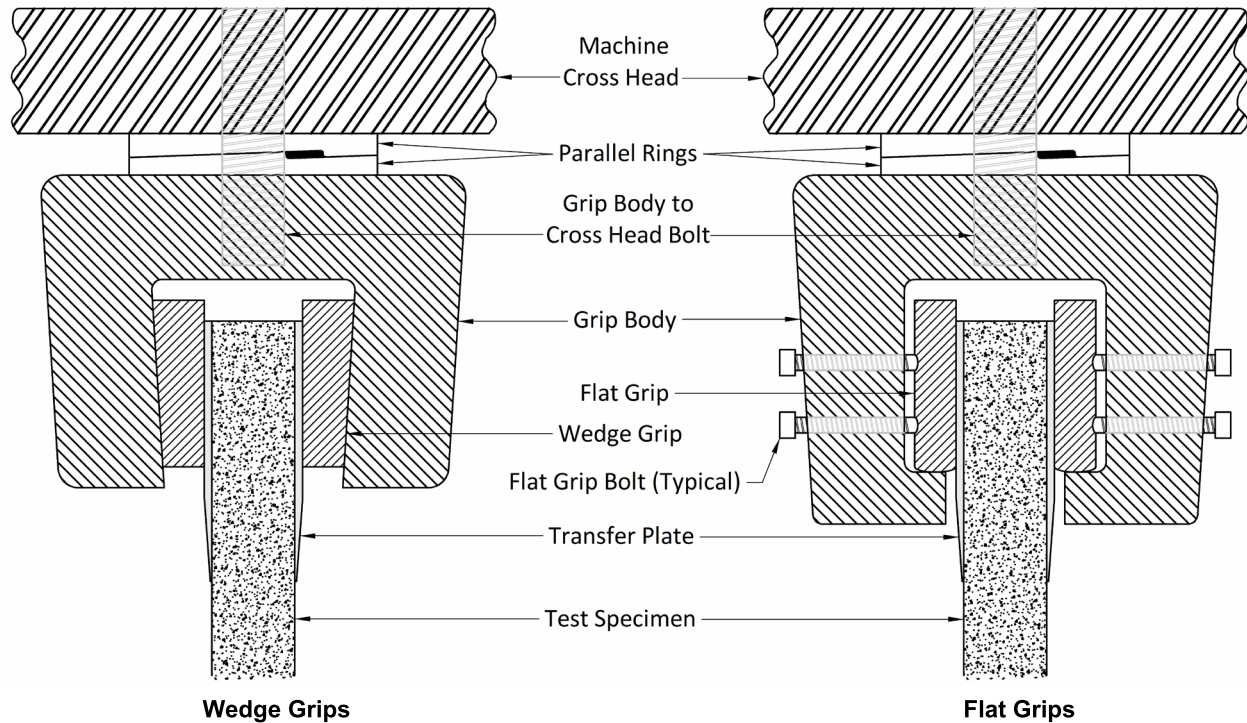


Figure 2—Gripping Devices

6.2.2. *Alignment*—The centroidal axis of the test specimen shall coincide with the centerline of the heads of the testing machine, and the centerlines of the heads shall align with one another (see Note 7).

Note 7—Alignments of the machine heads, the gripping devices, and the specimen should be carefully checked prior to gripping the test specimen. Proper alignments help to ensure as close to pure axial tensile stress as is feasible within the gauge length of the test specimen during testing. Misalignments will induce bending and shear stresses in the test specimen, and generally leads to incorrect measurement of tensile characteristics. See also Appendix X6 for discussions on causes, effects, and methods to identify excessive misalignments; and ASTM E1012 for grip alignment methods.

6.2.3. *Grip Plates*—A pair of grip plates shall apply a uniform normal force onto two parallel faces on each end of the test specimen which provides sufficient frictional resistance to restrict slippage during testing. The plates shall be wedge shaped or flat as shown in Figure 2. Wedge grips may be manually or mechanically actuated.

6.3. *Deformation Measurement Device:*

6.3.1. Deformation shall be measured through the use of a set of devices that collectively measure the movement of one cross-sectional plane of the test specimen relative to another (see Note 8). These planes are at right angles to the applied force as well as the longitudinal centroidal axis of the specimen. A parallel ring extensometer apparatus (Figure 3) should be used for these measurements (Note 9). Four electronic displacement transducers are mounted in the upper ring, and the bearing points for the transducers are located on the lower ring. The two rings are mounted onto the test specimen at the cross-sectional planes of interest prior to the start of the test, and the gauge length is the distance between the upper and lower ring attachment bolts. The average of the transducer readings represents the axial deformation over the gauge length.

Note 8—Movement of the testing machine crosshead is not an acceptable measure of the deformation of the test specimen. The crosshead movement is inclusive of machine, fixturing, and test specimen straining; therefore, strain values based on crosshead movement are not indicative of

test specimen strain. Additionally, the crosshead movement offers no indication of non-uniaxial deformations being imparted onto the test specimen; therefore, this type of measurement offers insufficient feedback on the execution of the test.

Note 9—Appendix X2 (Section X2.3) provides further discussions on parallel ring extensometers. See also ASTM E83. Other types of measuring devices may also be employed such as non-contact laser-based sensors or surface bonded measurement devices.

- 6.3.2. The measuring device shall provide adequate sensitivity and measurement range to capture the strain corresponding to the cracking strength, the elongation corresponding to crack localization, and the ultimate strain capacity (Note 10).

Note 10—The cracking strain may occur at less than 100 microstrain while the ultimate strain capacity may be more than 10,000 microstrain. For a 100-mm [4-in.] gauge length, these values would correspond to displacements of 0.01 and 1 mm [0.0004 and 0.04 in.], respectively.

- 6.3.3. The device shall be capable of separately measuring deformations on all faces of the test specimen (Note 11).

Note 11—Any induced bending in the test specimen is determined by examining the individual transducer measurements. See also Appendix X6 (Section X6.3).

- 6.4. *Data Acquisition System*—The load and deformation measurements shall be simultaneously recorded through an automated data acquisition system. Data capture and recording with a sampling frequency of at least 2 Hz is required.

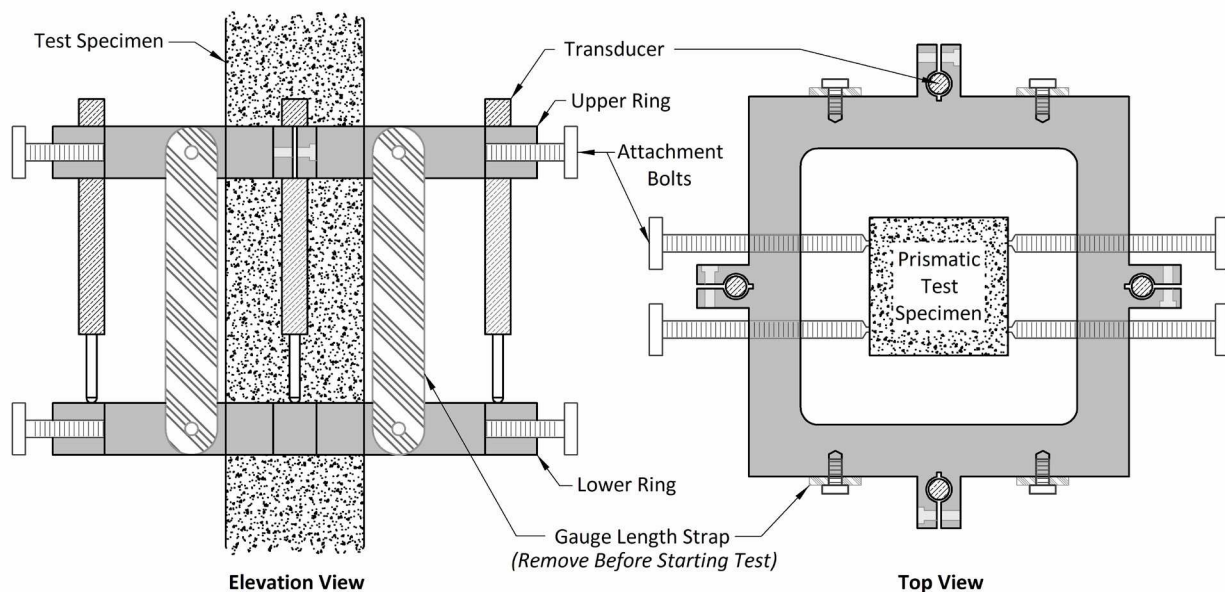


Figure 3—Parallel Ring Extensometer Apparatus

7. TEST SPECIMENS

General—Test specimens consist of a rectangular prismatic element with constant cross-section, and are permitted to be cast or cut from a larger sample (see Figure 4). Reinforcing or transfer plates should be affixed to opposing faces of the test specimen at the gripping locations (see Note 12).

Note 12—Transfer plates serve to reinforce the test specimen at the gripping locations, helping alleviate local stresses induced by the gripping process. The likelihood of completing a successful test with failure occurring within the gauge length is increased when these plates are used.

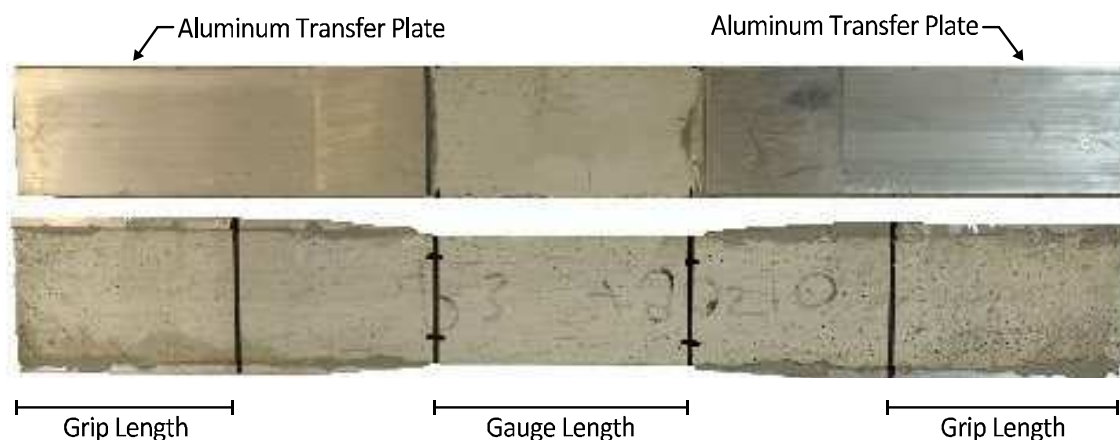


Figure 4—Test Specimen with Transfer Plates

7.1. *Prismatic Test Specimen:*

7.1.1. *Cross-Sectional Dimensions:*

- 7.1.1.1. *Material Characterization Test Specimens*—The width and thickness of the test specimen shall each be at least 2.5 times greater than the length of the longest fiber reinforcement. A 50-mm [2-in.] square cross-section is typically used for fiber reinforced concretes containing fibers with lengths not exceeding 19 mm [0.75 in.] (see Note 13).

Note 13—Cross-sectional dimensions less than 50 mm [2 in.] should be avoided as discontinuities in the cementitious matrix (e.g., voids from small air bubbles unintentionally cast into the material) can unduly influence the test results. Cross-sectional dimensions greater than 100 mm [4 in.] should be avoided. Test specimens of this size may be difficult to grip such that slip, rotation, or localized crushing or cracking may occur.

- 7.1.1.2. *Structural Component Test Specimens*—The width and thickness of the test specimen shall be in accordance with Section 7.2.1.1 unless the width or thickness of the structural component is less than that required by Section 7.2.1.1 (see Note 14). For test specimens not in accordance with Section 7.2.1.1, the dimension (width or thickness) not in compliance shall correspond to the actual dimension of the structural component (see Note 15).

Note 14—A structural component may have a least dimension that is significantly less than 2.5 times the fiber length. For example, UHPC panels may be as thin as 25 mm [1 in.] and have fibers that are 15 mm [0.6 in.] or more in length.

Note 15—Test specimens intended to replicate material behavior under actual structural component service conditions should, if possible, mimic the least cross-sectional dimension of the structural component.

- 7.1.2. *Length*—The length of a test specimen without transfer plates shall be sufficient to allow for the gripping of each end plus the gauge length. The length of test specimens with transfer plates shall be greater than the length of the transfer plates plus the gauge length. For a 50-mm [2-in.] square cross-section specimen without transfer plates, a 300 mm [12 in.] length is typically used. For a 50-mm [2-in.] square cross-section specimen with transfer plates, a 425-mm [17-in.] length is typically used (see Note 16).

Note 16—A longer grip length may be required for specimens that can resist larger applied forces, such as specimens with a larger cross-sectional area.

- 7.2. *Geometric Tolerances*—The tolerance for cross-sectional dimensions of test specimens cast in open or closed forms, or for those that are sawn or cut from larger pieces shall be ± 2 percent (see Note 17). The tolerance for length of test specimens shall be ± 2 percent.

Note 17—Due to potential irregularities in the screeded surface of test specimens cast in open forms, the tolerance in the cross-sectional dimension at right angles to the screeded surface may be increased to ± 3 percent.

- 7.3. *Test Specimen Fabrication:*

- 7.3.1. *Fresh Concrete:*

- 7.3.1.1. *Molds*—Samples prepared from freshly mixed concrete shall be cast into sturdy molds capable of producing test specimens with uniform prismatic dimensions (see Figure 5 and Note 18).

Note 18—See also Appendix X1 (Section X1.2) for further discussions on mold types and construction.

- 7.3.2. *Self-Consolidating Concrete*—The concrete shall have an ASTM C1856 flow diameter of at least 175 mm [7 in.]. Concrete shall be cast into the mold in one lift. The placement point for the concrete into the mold shall remain stationary at one end of the prism and shall be away from specimen's gauge length by a minimum distance equal to two times the fiber length. For open-top molds, the placement point may traverse the length of the mold to top off the final 10 percent of the pour. The concrete shall not be internally vibrated, but the mold may be externally vibrated during and after filling (see Note 19).

Note 19—Overly aggressive external vibration may cause fiber segregation.



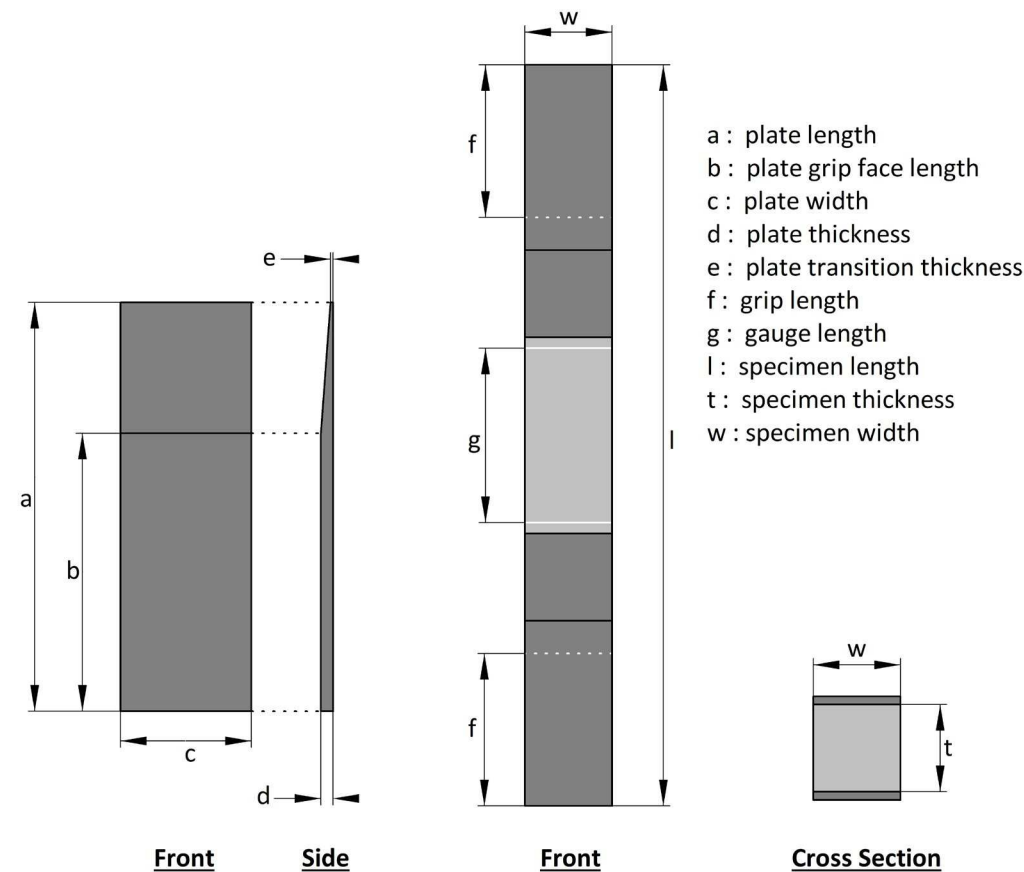
Figure 5—Steel Double Open-Top Mold

- 7.3.2.1. *Concrete Requiring Vibration for Consolidation*—The concrete shall have an ASTM C1856 flow diameter of 175 mm [7 in.] or less. Concrete shall be cast into the mold in one lift. Concrete placement point may traverse along the length of the mold. External vibration shall be applied to consolidate the concrete (see Note 19).

- 7.3.2.2. *Curing*—After the mold is filled, the sample shall be covered by a non-absorptive sheet or plate, and stored in a manner that prevents moisture loss. Unless otherwise specified by the owner or

specifier, samples shall be cured at $23 \pm 2^{\circ}\text{C}$ [$74 \pm 2^{\circ}\text{F}$] from the time of molding until the time of the test.

- 7.3.3. *Hardened Concrete*—For test specimens cut from components or fabricated samples of hardened concrete, the cutting process shall not cause damage in the finished surface of the test specimen.
- 7.4. *Transfer Plates*—Transfer plates should be affixed at the ends of test specimens as shown in Figures 4 and 6 (see Note 20).
- Note 20**—Transfer plates reduce local stresses induced in test specimens through the gripping process. Further discussions concerning the design of transfer plates are provided in Appendix X1 (Section X1.3).



TRANSFER PLATE			TEST SPECIMEN with TRANSFER PLATES		
Dimensions a through e			Dimensions l, w, t, g, and f		
Dimension	mm	in.	Dimension	mm	in.
a	160	6.25	l	432	17
b	108	4.25	w	50	2
c	50	2	t	50	2
d	5	0.188	g	102	4
e	1	0.04	f	89	3.5

Figure 6—Transfer Plate Design and Location on a 50 mm × 50 mm [2 in. × 2 in.] × 432 mm [17 in.] Long Test Specimen

7.5. *Specimen Preparation:*

- 7.5.1. *Dressing of Edges*—The corners of test specimens shall be dressed such that cross-sectional dimensions are within the tolerances specified in Section 7.3 (see Note 21). If transfer plates are to be used, test specimens shall be dressed prior to installation of the plates.

Note 21—Molding or cutting of prismatic specimens may result in stray fibers or concrete extending beyond corners of test specimen cross-sections.

- 7.5.2. *Installation of Transfer Plates*—The surfaces of the transfer plates and the test specimen shall be roughened and cleaned prior to installation of the plates. Transfer plates shall be affixed to the surface of test specimens through the use of an adhesive that has a minimum tensile capacity of 14 MPa [2 ksi], a minimum compressive strength of 35 MPa [5 ksi], and a minimum modulus of elasticity of 5 GPa [700 ksi]. The adhesive shall be compatible with the plate and the concrete in terms of strength, stiffness, and chemical reactivity. The transfer plates shall be firmly held to the test specimen until the adhesive has cured (see Figure 7 and Note 22).

Note 22—A high strength, high stiffness structural epoxy is compatible with aluminum transfer plates and concrete test specimens. Clamping the transfer plates to the test specimen using vice clamps as shown in Figure 7f is recommended. See also Appendix X1 (Section X1.4) for further discussion.



(a) Unroughened (Left) and Sand Blasted Roughened (Right) Transfer Plates



(b) Test Specimen after Dressing and Surface Cleaning



(c) Adhesive Application on Test Specimen and Transfer Plates



(d) Test Specimen with Transfer Plates Installed



(e) Clamping of One Test Specimen with Six C-Clamps



(f) Clamping of Two Test Specimens with Two Vise Clamps

Figure 7—Installation of Transfer Plates

- 7.5.3. *Deformation Measurement Device Attachment Points*—The deformation measurement device shall be installed on the test specimen such that it measures deformations across the gauge length. Attachment points for the device shall be marked on the specimen prior to the installation of the

device. Attachment points shall be on cross-sections unrestrained by transfer plates or grip plates (see Figure 8).

- 7.6. *Gauge Length*—The gauge length over which deformations will be measured (see Figures 4 and 6) shall be greater than both the largest test specimen cross-sectional dimension and three times the longest employed fiber length. The gauge length shall be measured to an accuracy of 0.25 mm [0.01 in.] and recorded for each test specimen (see Note 23). If the deformation measurement device contacts the test specimen, the contact points shall be marked on the specimen to facilitate specimen performance characterization.
- Note 23**—A 100 mm [4 in.] gauge length is commonly used for fiber reinforced concretes containing fibers with lengths not exceeding 25 mm [1 in.]. Gauge lengths of 100 mm [4 in.] or more are recommended as they provide a more accurate indication of the overall average behavior of the material; however, a gauge length longer than 150 mm [6 in.] is not recommended.

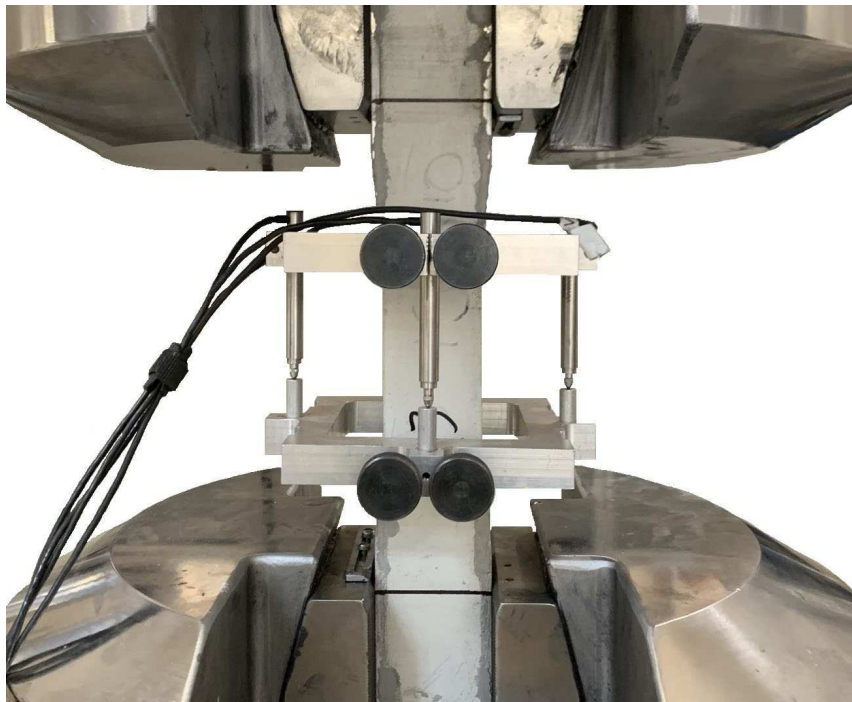


Figure 8—Attachment of Measurement Device

- 7.7. *Specimen Measurement*—The cross-sectional dimensions (width and thickness) of each test specimen shall be recorded at each end of the gauge length and at the center of the gauge length. The average the three values from each dimension shall be the measured cross-sectional dimensions.
- 7.8. *Tested Specimen Set*—A minimum of three specimens shall be successfully tested. Tests that result in cracking and/or strain localization outside of the gauge length are considered unsuccessful. At the discretion of the owner or specifier, the minimum required number of successful tests are permitted to be increased (see Note 24).
- Note 24**—Cracking or strain localization outside of the gauge length may be likely and the results will not reflect the measurement of all desired engineering properties. Consequently, preparation of a large number of test specimens may be necessary depending on the material being tested and the engineering parameters desired to be measured. See also Appendix X4 (Section X4.1.1).

8. PROCEDURE

- 8.1. *General*—The testing procedure involves providing rotational fixity to the ends of a test specimen and subsequently applying axial load along the longitudinal axis of the specimen (see Note 25). As load is applied, the load on and axial deformation of a uniform cross-section in the middle of the test specimen is continuously monitored. Measurements shall be captured beginning prior to gripping the upper portion of the test specimen and continue through the completion of the test.

Note 25—Typical test setups employ servo-hydraulic frames using either wedge or flat grips (see Figure 9).

- 8.2. *Check Alignment of the Testing Machine*—Verify that the upper and lower grips on the testing machine are translationally and angularly aligned with one another and the axis of the testing machine (see Note 26).

Note 26—Misalignment can induce significant stresses into a test specimen increasing the likelihood of a test wherein cracking and/or strain localization occurs outside of the gauge length. Aligning the machine to achieve Class 5 in accordance with ASTM E1012 is an effective method.

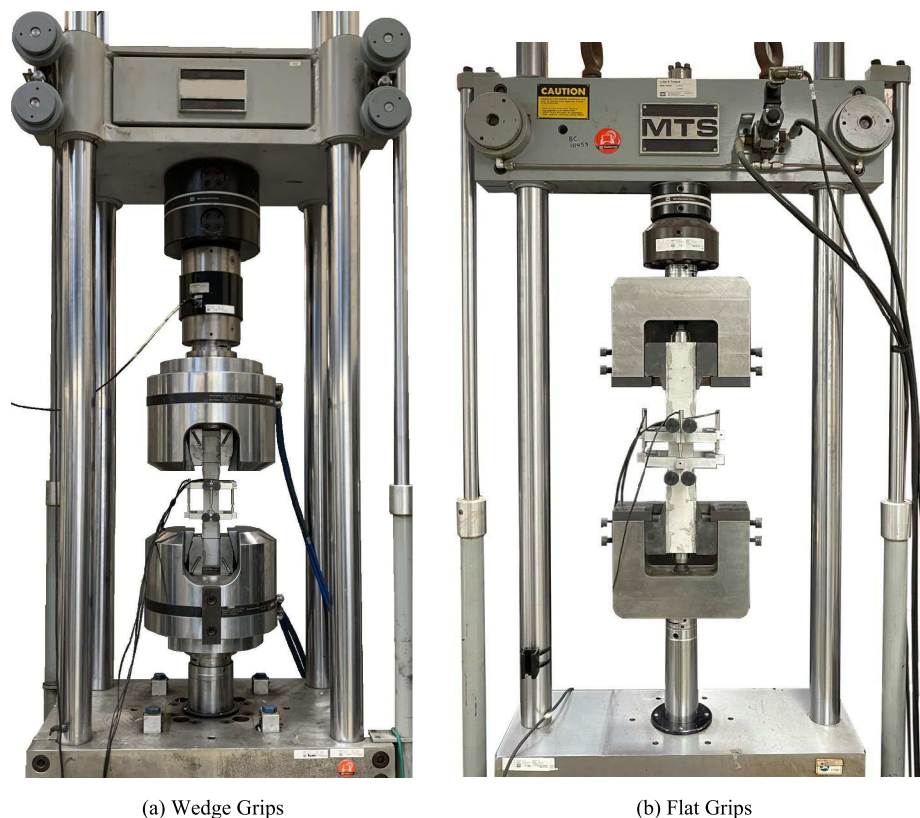


Figure 9—Overall Test Setup in Servo-Hydraulic Frame with Wedge Grips and Flat Grips Holding Test Specimen

- 8.3. *Install Deformation Measurement Device*—Properly align and firmly affix the parallel ring extensometer device to the test specimen. After installation, confirm that deformations are being measured (see Note 27).

Note 27—If an alternative measurement system is used, such as a non-contact measurement device or a surface bonded measurement device, ensure that the device is properly installed and operational.

- 8.4. *Install Specimen into Testing Machine:*
- 8.4.1. Position the testing machine crosshead such that the upper and lower grips are correctly located to accept the insertion of the test specimen, and open the grips enough to allow for insertion of the test specimen. The testing machine should be in a displacement-control configuration.
- 8.4.2. Position the test specimen within the lower grip and tighten the grip such that the centerline and axis of the test specimen aligns with the centerline of the grip. If using a flat plate grip, snug tight the grip plates prior to concurrently torquing opposing bolts. If using a wedge grip, tighten the wedge.
- 8.4.3. Adjust the testing machine such that the upper portion of the test specimen is correctly positioned within the upper grip.
- 8.4.4. Zero the load and deformation readings.
- 8.4.5. Begin recording load and deformation data.
- 8.4.6. Monitor the load on the test specimen while tightening the upper grip. If using a flat plate grip, snug tight the grip plates prior to concurrently torquing opposing bolts. If using a wedge grip, tighten the wedge (see Note 28).
- Note 28**—This step may be completed in load-control or in displacement-control configuration as long as the applied tensile or compressive load on the test specimen remains below 1 kN [225 lb]. See also Appendix X3 (Section X3.1.5).
- 8.4.6.1. If load-control was used in Section 8.4.6, set the testing machine into a displacement-control condition.
- 8.5. *Grip Pressure*—The grip pressure on the upper and lower grips shall be sufficient to hold the test specimen without allowing slippage during the test (see Note 29).
- Note 29**—The minimum acceptable pressure is optimal because larger grip pressures may induce larger transverse stresses in the specimen, potentially leading to early failure. See also Appendix X2 (Sections X2.2.1 and X2.2.2) for examples of grip pressures used in typical test setups that employed wedge and flat grips.
- 8.6. *Compressive Loading*—If the testing machine is capable, apply a compressive load on the specimen via a constant crosshead displacement such that a stress of 7 ± 3 MPa/min [1.0 ± 0.5 ksi/min] is induced in the specimen. Load until the stress in the cross-section is at least 3.5 MPa [0.5 ksi] but not more than 7.0 MPa [1.0 ksi] (see Note 30).
- Note 30**—Dependent on the testing machine's axial stiffness, a constant crosshead displacement rate of between approximately 0.08 mm/min and 0.152 mm/min [0.003 in./min and 0.006 in./min] commonly produces the desired stress rate. A displacement rate at or near the lower bound should be used in a testing machine with lesser stiffness (i.e., a machine whose capacity is close to that of the capacity of the specimen). Displacement rates within the range specified are expected to produce nearly identical results. See also Appendixes X3 (Section X3.1.7) and X5 (Sections X5.2.2, X5.2.3, and X5.2.5).
- 8.7. *Tensile Loading*—Apply a tensile load on the specimen via a constant crosshead displacement such that a stress of 7 ± 3 MPa/min [1.0 ± 0.5 ksi/min] is induced in the specimen during the elastic portion of the loading (see Notes 30 and 31). Maintain the constant crosshead displacement rate throughout the tensile loading. End the test after the peak load has been reached and the load has subsequently decreased to less than 50 percent of the maximum load attained (see Note 32). At the discretion of the owner or specifier, the test may be concluded when the load reaches a predetermined value that is less 50 percent of the maximum load attained (see Note 33).

Note 31—The rate of application of the tensile load should be set while the response of the specimen is still in the elastic range. The peak of the elastic response is designated $f_{t,el}$ in Figure 1. See also Appendix X3 (Section X3.1.8).

Note 32—The maximum load attained is designated by $f_{t,peak}$ in Figure 1.

Note 33—See also Appendix X3 (Section X3.1.9).

- 8.8. *Conclude Testing*—Halt the loading of the test specimen. Stop recording load and deformation data. Release the upper grip. Release the lower grip. Remove the specimen from the testing machine (Note 34).

Note 34—See also Appendix X3 (Section X3.1.11).

9. ASSESSMENT OF SPECIMEN PERFORMANCE

- 9.1. *General*—The performance of each test specimen shall be assessed and the response classified. Classification is based on the measured stress–strain response and the distress observed in the test specimen as prescribed in Section 9.2. The stress–strain response shall be developed based on the calculations in Section 10 (see Note 35).

Note 35—See also Appendix X4.

- 9.2. *Classify Test Specimen Response*—Classify the response of each specimen tested as either Type H, S, or N (see Figures 10 and 11). A tension strain hardening response is generally indicative of Type H. Type S indicates a strain softening response, and Type N indicates minimal post-cracking resistance. Type H responses shall be further subclassified as H-1, H-2, H-3, or H-4 in accordance with Figure 10 and Section 10.3.2.

- 9.2.1. *Type H-1 and H-2*—These are tensile strain hardening responses wherein the entire stress–strain behavior of the test specimen has been captured. The test specimen exhibited multiple cracking and localization within the gauge length. Full analysis of this test result is possible. Two stress–strain trends are commonly observed: Type H-1 where the post-cracking, prelocalization stress is generally increasing until the peak stress is reached, and Type H-2 where the post-cracking, prelocalization stress is approximately constant with increasing strain.

- 9.2.2. *Type H-3*—This is a tensile strain hardening response wherein crack localization occurred outside of the gauge length. The elastic and initial inelastic portion of the response may be viable. The latter portion of the response including the strain at localization was not captured and thus cannot be determined.

- 9.2.3. *Type H-4*—This is a response indicative of non-uniaxial loading being imparted on the test specimen. Bending stresses will cause premature cracking. For comparison, this response is similar to Type H-1 and H-2 except that the test setup imparted non-negligible bending during the initial loading of the test specimen. A Type H-4 result is indicative of problems with the test setup, not necessarily problems with the material being tested.

- 9.2.4. *Type S*—This is a tensile strain softening response. Multiple cracks in the specimen will be minimal. The fiber reinforcement within the cementitious matrix is not capable of sustaining the same load level as was sustained by the cementitious matrix prior to cracking.

- 9.2.5. *Type N*—This is a response indicative of minimal, if any, post-cracking resistance within the test specimen. This type of response is typically observed with concrete materials containing no fiber reinforcement.