~~Designation:E488–96 (Reapproved 2003)~~ Designation: E488/E488M – 10

Standard Test Methods for Strength of Anchors in Concrete ~~and Masonry~~ Elements[1]

This standard is issued under the fixed designation E488/E488M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

~~1.1These test methods cover procedures for determining the static, seismic, fatigue and shock, tensile and shear strengths of post-installed and cast-in-place anchorage systems in structural members made of concrete or structural members made of masonry. Only those tests required by the specifying authority need to be performed.~~

~~1.2These test methods are intended for use with such anchorage devices designed to be installed perpendicular to a plane surface of the structural member.~~

~~1.3Whereas combined tension and shear as well as torsion tests are performed under special conditions, such tests are not covered in the methods described herein.~~

~~1.4While individual procedures are given for static, seismic, fatigue and shock testing, nothing herein shall preclude the use of combined testing conditions which incorporate two or more of these types of tests, (such as seismic, fatigue and shock tests in series), since the same equipment is used for each of these tests.~~

1.1 These test methods address the tensile and shear strengths of post-installed and cast-in-place anchors in test members made of cracked or uncracked concrete. Loadings include quasi-static, seismic, fatigue and shock. Environmental exposures include freezing and thawing, moisture, decreased and elevated temperatures and corrosion. These test methods provide basic testing procedures for use with product-specific evaluation and acceptance standards and are intended to be performed in a testing laboratory. Product-specific evaluation and acceptance standards may add specific details and appropriate parameters as needed to accomplish the testing. Only those tests required by the specifying authority need to be performed.

1.2 These test methods are intended for use with post-installed and cast-in-place anchors designed for installation perpendicular to a plane surface of a test member.

1.3 This standard prescribes separate procedures for static, seismic, fatigue and shock testing. Nothing in this standard, however, shall preclude combined tests incorporating two or more of these types of loading (such as seismic, fatigue and shock tests in series).

1.4 Both inch-pound and SI units are provided in this standard. The testing may be performed in either system and reported in that system and the results converted to the other. However, anchor diameters, threads, and related testing equipment shall be in accordance with either inch-pound or SI provisions.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C33/C33M Specification for Concrete Aggregates
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C150/C150M Specification for Portland Cement
C330/C330M Specification for Lightweight Aggregates for Structural Concrete

---

[1] These test methods are under the jurisdiction of ASTM Committee E06 on Performance of Buildings and are the direct responsibility of Subcommittee E06.13 on Structural Performance of Connections in Building Construction.

~~Current edition approved May 10, 2003. Published June 2003. Originally approved in 1976. Last previous edition approved in 1996 as E488–96. DOI: 10.1520/E0488-96R03.~~

Current edition approved Oct. 1, 2010. Published February 2011. Originally approved in 1976. Last previous edition approved in 2003 as E488 – 96 (2003). DOI: 10.1520/E0488_E0488-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E4 Practices for Force Verification of Testing Machines
E171Specification for Atmospheres for Conditioning and Testing Flexible Barrier Materials
8/E8M Test Methods for Tension Testing of Metallic Materials
E468 Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials
E575 Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies
Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies
E631 Terminology of Building Constructions
E2265 Terminology for Anchors and Fasteners in Concrete and Masonry
F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets (Metric)
F1624 Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique
G5 Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements

2.2 *ANSI Standards:*[3]

ANSI B212.15 American National Standard for Cutting Tools—Carbide-Tipped Masonry Drills and Blanks for Carbide-Tipped Masonry Drills

3. Terminology

3.1

3.1 *Definitions:*

3.1.1 For definitions of general terms related to building construction used in this standard, refer to Terminology E631, and for definitions of terms related to anchoring, refer to Terminology E2265.

3.2 *Definitions of Terms Specific to This Standard:*

3.1.1*adhesive anchor*—a post-installed anchor that derives its holding strength from the chemical compound between the wall of the hole and the anchor rods. The materials used include epoxy, cementitious material, polyester resin, and other similar types.

3.1.2*anchor spacing*—the distance between anchors measured centerline to centerline, in mm (in.); also, the minimum distance between reaction points of the test frame.

3.1.3*cast-in-place anchor*—an anchor that is installed prior to the placement of concrete and derives its holding strength from plates, lugs, or other protrusions that are cast into the concrete.

3.1.4*displacement*—movement of an anchor relative to the structural member. For tension tests, displacement is measured along the axis of the anchor, and for shear tests, displacement is measured perpendicular to the axis of the anchor, in mm (in.).

3.1.5*edge distance*—side cover distance or the distance from the centerline of an anchor to the nearest edge of a structural member, in mm (in.); also, minimum distance from the centerline to the test frame.

3.1.6*embedment depth*—distance from the test member surface to the installed end of the anchor, in mm (in.), prior to the setting of the anchor.

3.1.7*expansion anchor*—a post-installed anchor that derives its holding strength through a mechanically expanded system which exerts forces against the sides of the drilled hole.

3.1.8*fatigue test*—a laboratory test that applies repeated load cycles to an anchorage system for the purpose of determining the fatigue life or fatigue strength of that system.

3.1.9*LVDT*—a linear variable differential transformer used for measuring the displacement or movement of an anchor or anchor system.

3.1.10*post-installed anchor*—an anchor that is installed after the placement and hardening of concrete.

3.1.11*run-out*—a condition where failure did not occur at a specified number of load cycles in a fatigue test.

3.1.12*safe working loads*—the allowable or design load obtained by applying factors of safety to the ultimate load of the anchorage device, kN (lbf).

3.1.13*seismic test*—a laboratory test that applies load cycles of varying magnitude and frequency to an anchorage system for the purpose of simulating a seismic event (earthquake).

3.1.14*shear test*—a test in which an anchor is loaded perpendicular to the axis of the anchor and parallel to the surface of the structural member.

3.1.15*shock test*—a laboratory test that simulates shock loads on an anchorage system by the application of a short duration external load.

3.1.16*static test*—a test in which a load is slowly applied to an anchor according to a specified rate such that the anchor receives one loading cycle.

3.1.17*structural member*—the material in which the anchor is installed and which resists forces from the anchor.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.18 *tensile test*—a test in which an anchor is loaded axially in tension.

3.1.19 *undercut anchor*—a post-installed anchor that derives its holding strength from an expansion of an embedded portion of the anchor into a portion of the hole that is larger in diameter than the portion of the hole between the enlarged section and the surface of the structural member. The enlarged diameter section of the hole is predrilled or enlarged by an expansion process during setting of the anchor.

3.2 *Symbols*:

3.2.1 *load-controlled undercut anchor*, *n*—a post-installed anchor that derives its tensile holding strength by the mechanical interlock provided by installing the anchor by tensioning, which causes the sleeve to expand into the predrilled undercut.

3.2.2 *post-installed anchor*, *n*—an anchor that is installed after the placement and hardening of concrete.

3.2.3 *run-out*, *n*—a condition in which failure does not occur within the specified number of load cycles in a fatigue test.

3.2.4 *standard temperature*, *n*—73°F (23°C) ± 8°F (6°C).

3.2.5 *test member*, *n*—the base material in which the anchor is installed and which resists forces from the anchor.

3.3 *Symbols:*

d fix

h_{ef} c_a	=	effective depth of embedment of an anchor in mm (in.). distance from the center of an anchor shaft to the edge of test member, in. (mm).
c_{min}	=	minimum distance from the center of an anchor shaft to the edge of test member, determined from tests, in. (mm).
d	=	nominal diameter of anchor to be tested, in. (mm).
d_{fix}	=	diameter of hole in shear sleeve, ≥d, in. (mm).
d_{hole}	=	diameter of drilled borehole in test specimen, in.(mm).
d_m	=	diameter of carbide-tipped drill bit with diameter on low end of tolerance range for new bit, representing moderately used bit, in. (mm).
d_{max}	=	diameter of carbide-tipped drill bit with diameter on high end of tolerance range for new bit, representing bit as large as would be expected in use, in. (mm).
d_{min}	=	diameter of carbide-tipped drill bit with diameter below low end of tolerance range for new bit representing a well-used bit, in. (mm).
d_o	=	outside diameter of post-installed anchor, in. (mm).
$d_{opening}$	=	diameter of hole in confining plate for confined tension tests, in. (mm).
F_s F_{cr}	=	safe working load in kN (lbf). crack-inducing force, applied to reinforcing bars, lb (N).
h f'_c	=	thickness of the structural member in mm (in.). specified concrete compressive strength, psi (MPa).
$f'_{c,ref}$	=	specified compressive strength of reference concrete test member, psi (MPa).
$f'_{c,test}$	=	specified compressive strength of concrete test member, psi (MPa).
h_v h_{ef}	=	anchor embedment depth in mm (in.). effective embedment depth, measured from the concrete surface to the deepest point at which the anchor tension load is transferred to the concrete, in. (mm).
s h_{min}	=	anchor spacing in mm (in.) measured centerline to centerline. minimum member thickness, in. (mm).
c h_{nom}	=	edge distance in mm (in.) measured from centerline of anchor to edge. distance between embedded end of concrete screw and concrete surface, in. (mm).
d n_{ct}	=	nominal anchor diameter in mm (in.). number of test cycles.
Δ_T n_{pt}	=	uncorrected displacement for tension tests in mm (in.). number of permitted pretest crack cycles.
Δ_S $N_{p,cr}$	=	uncorrected displacement for shear tests in mm (in.). characteristic pullout resistance in cracked concrete for the minimum specified concrete strength of 2500 psi (17 MPa), as determined from tests in cracked concrete, lb (N).
A_N and B_N $N_{st,mean}$	=	instrument readings at a given load in mm (in.). mean ultimate steel capacity determined from tensile tests on full-sized anchor specimens, lb (N).
A_I and B_I $N_{sust,l}$	=	initial instrument readings in mm (in.). sustained load, lb (N).
$\bar{\Delta}_T$ $N_{sust,con}$	=	average displacement at maximum load for tension tests in mm (in.). sustained load used for confined reference tests, lb (N).
$\bar{\Delta}_S$ $N_{sust,ft}$	=	average displacement at maximum load for shear tests in mm (in.). specified constant tension load, lb (N).
n $N_{u,con,mean}$	=	number of test samples. mean ultimate load determined from confined reference tests, lb (N).
N_T $N_{u,mean}$	=	total number of load cycles in tension fatigue test. mean ultimate load determined from tests, lb (N).
N_S N_w	=	total number of load cycles in shear fatigue test. tensile load in tests of anchors located in cracks whose opening width is cycled, lb (N).
$\bar{N}_T$ s_{min}	=	average number of load cycles in tension fatigue test. minimum anchor spacing, determined from test, in. (mm).
$\bar{N}_S$ t_{fix}	=	average number of load cycles in shear fatigue test. effective thickness of shear sleeves (see d), in. (mm).
Δ_{FT} t_{pl}	=	displacement of anchor occurring at maximum load for tension fatigue test mm (in.). thickness of confining plate for tension tests, ≥d, in. (mm).

Δ_{FS} T_{inst}	=	displacement of anchor occurring at maximum load for shear fatigue test mm (in.). specified or maximum setting torque for expansion or prestressing of an anchor, ft·lb (N·m).
A_{fu} and B_{fu} T_{screw}	=	maximum displacement instrument readings for fatigue tests mm (in.). specified maximum setting torque to prevent anchor failure during installation, ft-lb (N-m).
A_{fi} and B_{fi} W_1	=	initial displacement instrument readings for fatigue tests mm (in.).
Δ_{FT} largest crack width during test, in. (mm).		
W_2	=	average maximum displacement for tension fatigue tests mm (in.).
Δ_{FS} smallest crack width during test, in. (mm).		
W_3	=	average maximum displacement for shear fatigue tests mm (in.).largest crack width at beginning of test, in. (mm).
ℓ_{side}	=	side length of test cube, in. (mm).

4. Significance and Use

4.1These test methods are intended to provide data from which applicable design data and specifications are derivable for a given anchorage device used in a structural member of concrete, masonry and related products and for qualifying anchors or anchorage systems.

4.2The test methods shall be followed to ensure reproducibility of the test data.

4.1 These test methods are intended to provide reproducible data from which acceptance criteria, design data, and specifications can be developed for anchors intended to be installed in concrete.

5. Apparatus

5.1 ~~*Equipment*~~Testing Equipment :

~~5.1.1*Laboratory*—Suitable equipment shall be used to perform tests to generate data required to publish load tables or to obtain listings from approval agencies, building officials, etc. Calibrated electronic load and displacement measuring devices which meet the sampling rate of loading specified herein shall be used. The equipment shall be capable of measuring the forces to an accuracy within ± 1% of the anticipated ultimate load, when calibrated in accordance with Practices E4. The load and displacement measuring devices shall be capable of providing data points at least once per second in order to produce continuous load versus displacement curves. A minimum of 120 data points per instrument shall be obtained and recorded for each individual test. The readings shall be obtained prior to reaching peak load. The instruments shall be positioned to measure the vertical movement of the anchor with respect to points on the structural member in such a way that the instrument is not influenced during the test by deflection or failure of the anchor or structural member. The testing device shall be of sufficient capacity to prevent yielding of its various components and shall ensure that the applied tension loads remain parallel to the axes of the anchors and that the applied shear loads remain parallel to the surface of the structural member during testing.~~

5.1.1 *General*—Use calibrated electronic load and displacement measuring devices meeting the specified sampling rate. Use load-measuring equipment with an accuracy of ±1 % of the anticipated ultimate load and calibrated in accordance with Practices E4. Use displacement measuring devices with an accuracy of ±0.001 in. (±0.025 mm) and crack-width measuring devices with an accuracy of ±0.0005 in. (±0.013 mm). For recording load and displacement measurements, use a data-acquisition system capable of recording at least 120 data points per instrument for each individual test, prior to reaching peak load. The testing equipment shall have sufficient capacity to prevent yielding of its components under the anticipated ultimate load, and shall have sufficient stiffness to ensure that the applied tension loads remain parallel to the axes of the anchors and that the applied shear loads remain parallel to the surface of the test member during testing.

5.1.2 ~~*Field Tests*—Suitable equipment shall be used to perform tests required to verify correct installation or provide proof loads on anchors installed at a specific job site. Calibrated load cells which meet the specified rate of loading given herein shall be used. The equipment shall be capable of measuring the forces to an accuracy within ± 2% of the applied load, when calibrated in accordance with Practices E4. For field tests which require displacement measurements, use either manually read dial gages or electronic load and displacement measuring devices, provided they are capable of generating a minimum of 50 data points prior to reaching peak load. For field tests requiring displacement measurements, the instrument(s) shall be positioned to measure the vertical movement of the anchor with respect to points on the structural member in such a way that the instrument is not influenced during the test by deflection or failure of the anchor or structural member. The testing device shall be of sufficient capacity to prevent yielding of its various components and shall ensure that the applied tension loads remain parallel to the axes of the anchors and that the applied shear loads remain parallel to the surface of the structural member during testing.~~

~~5.2*Tension Test*—Examples of suitable systems for applying tension pull-out forces are shown in Figs. 1 and~~ Tension Test Equipment—The support for the tension test equipment shall be of sufficient size to prevent failure of the surrounding test member. The loading rod shall be of sufficient diameter to develop the anticipated ultimate strength of the anchorage hardware with an elastic elongation not exceeding 10 % of the anticipated elastic elongation of the anchor, and shall be attached to the anchorage system by a connector that will minimize the direct transfer of bending stress to the anchor. The displacement measuring device(s) shall be positioned to measure the movement of the anchors with respect to points on the test member so that the device is not influenced during the test by deflection or failure of the anchor or test member. See Fig. 1 and Fig. 2 ~~2 in which a single anchor specimen is shown. The test system support shall be of sufficient size to prevent failure of the surrounding structural member. The loading rod shall be of such size to develop the ultimate strength of the anchorage hardware with minimal elastic elongation and shall be attached to the anchorage system by means of a connector that will minimize the direct transfer of bending stress through the connection.~~

~~5.3*Shear Test*—Examples of suitable systems for applying shear forces are shown in Figs. 3 and~~ for examples of typical test setups.

NOTE 1—Other support geometries are acceptable.

Table 1 gives the minimum required clear distance from the test support to the anchor for tension and shear loading.

5.1.3 *Shear Test Equipment*—Position the displacement-measuring device(s) to measure displacement in the direction of the applied load only. Place the device on the test member so that the sensing element bears perpendicularly on the anchor or on a contact plate located on the loading plate, or use another method that restricts deflections other than those in the direction of the applied load. See Fig. 4 ~~4 in which a single anchor specimen is shown. The components of the test fixture shall be of sufficient size and strength to prevent their yielding during ultimate capacity tests on the anchorage system.~~

~~5.4*Loading Plate*—The thickness of the loading plate in the immediate vicinity of the test anchor shall be equal to the nominal bolt diameter to be tested, ± 1.5 mm (± 1⁄16 in.), representative of a specific application.~~

~~5.4.1The hole in the loading plate shall have a diameter 1.5 mm ± 0.75 mm (0.06 mm ± 0.03 in.) greater than the test anchor. The initial shape of the hole in the loading plate shall correspond to that of the anchor cross section and shall be maintained throughout all tests. Worn or deformed holes shall be repaired. Insert sleeves of the required diameter shall be periodically installed in the loading plate to meet these requirements.~~

~~5.4.2For shear testing, the contact area between the loading plate through which the anchor is installed and the structural member~~

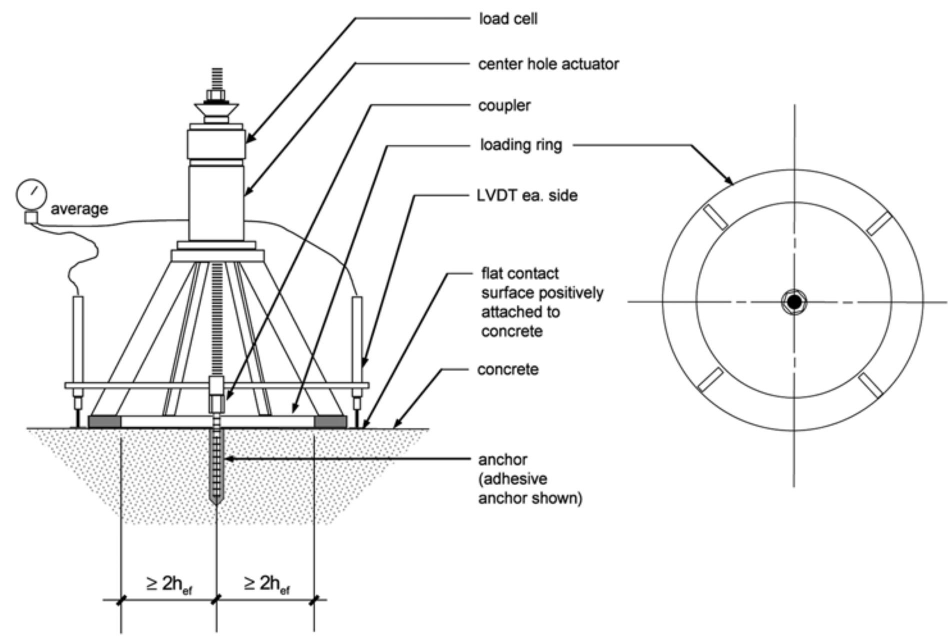

FIG. 1 Example of Unconfined Tension Test Setup – Displacement Measurement with Dual LVDTs

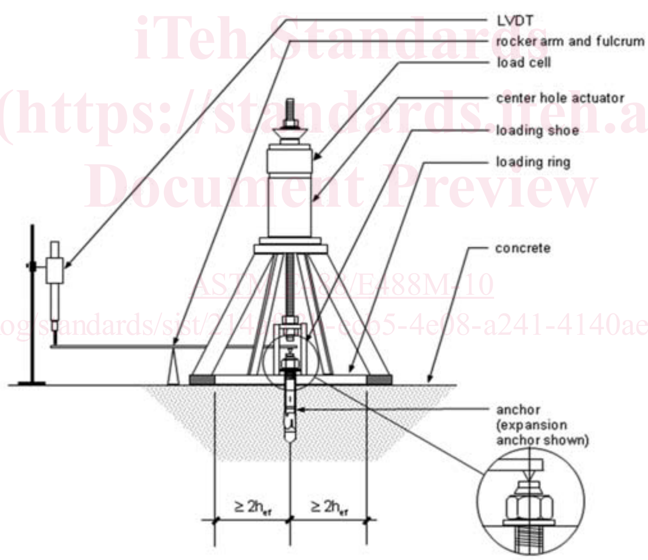

FIG. 2 Example of Unconfined Tension Test Setup – Displacement Measurement from top of Anchor

~~shall be as given in~~ for a typical example of a shear test setup. For tests on anchor groups, the axis of the displacement-measuring device shall coincide with the centroid of the group. Table 1 ~~, unless otherwise specified. The edges of the shear loading fixture shall be chamfered or have a radius to prevent digging in of the loading plate.~~

~~5.5~~*~~Anchor Displacement Measurement~~*~~— For anchor tests that require displacement measurements, the displacement measurements shall be made using LVDT device(s) or equivalent which provide continuous readings with an accuracy of at least 0.025 mm (0.001 in.). Dial gages having an accuracy of 0.025 mm (0.001 in.) are permitted in field testing or for general tests where precise displacement measurements are not required.~~

~~5.5.1~~*~~Tension Test~~*gives the minimum required clear distance from the test support to the anchor shear loading toward a free edge.

5.2 *Group Test Equipment*—Measure the simultaneous displacement of all anchors or groups of anchors tested. Only one set of displacement-measuring devices is required for a group of anchors. Displacement measurements as described in 5.1.1 include components of deformation not directly associated with displacement of the anchor relative to the test member, such as elastic elongation of the loading rod, deformation of the loading plate, sleeves, shims, attachment hardware, and local test member material. Using supplementary measuring devices or calibration test data for the installed test set-up with a rigid anchor replacing the anchor to be tested, identify such deformation components and subtract them from the total measured displacement. To evaluate

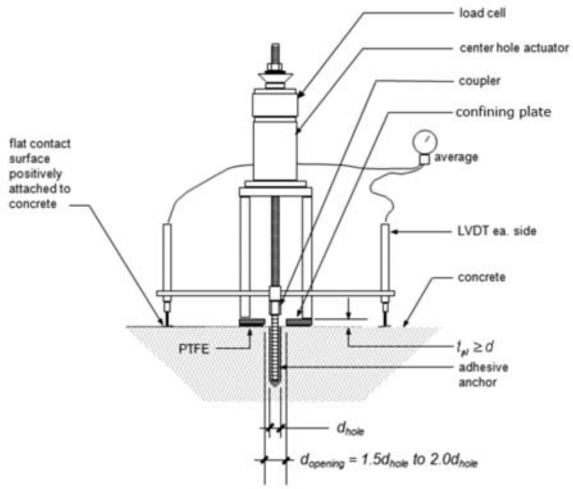

FIG. 3 Example of Confined Tension Test Setup – Adhesive Anchor Shown

TABLE 1 Minimum Clearance Requirements for Test Equipment Supports

All Anchors	
Spacing Between Test Supports	Distance from Anchor to Edge of Test Support
Tension Loads	
4.0 h_{ef}	2.0 h_{ef}
Shear Loads	
4.0 c_a	2.0 c_a

the findings, use the average displacement indicated by the instruments in each group.

5.3 *Loading Plates*:

5.5.1.1*Single Anchor*—The displacement measuring device(s) shall be positioned to measure the vertical movement of the anchors with respect to points on the structural member in such a way that the device is not influenced during the test by deflection or failure of the anchor or structural member.

5.5.1.2*Group of Anchors*—Displacement measurements shall be made on all anchors or group of anchors tested simultaneously except that only one set of instruments needs to be used for a group of anchors tested as a closely spaced cluster. Displacement measurements as described in 5.5 include components of deformation not directly associated with displacement of the anchor relative to the structural member. Include components of deformation such as elastic elongation of the loading rod anchor stem, deformation of the loading plate, sleeves, shims, attachment hardware, and local structural member material. Deduct all of the elongations from these sources from the total displacement measurements by using supplementary measuring devices or calibration test data for the installed test set-up with rigid specimen replacing the anchor to be tested. The displacement to be used for the evaluation of the findings is the average displacement indicated by both instruments mounted symmetrically equidistant from the centroid of the cluster as shown in

5.3.1 For tension loading the plate thickness t_{fix} in the immediate vicinity of the test anchor shall be equal to or greater than the nominal anchor diameter to be tested.

5.3.2 For shear testing the plate thickness t_{fix} in the immediate vicinity of the test anchor shall be equal to the nominal anchor diameter to be tested, –1⁄16 +1⁄8 in. (–1.5 +3.0 mm). The hole in the loading plate shall have a diameter of 0.06 ± 0.03 in. (3.0 ± 1.5 mm) greater than the specified diameter of the test anchor unless another diameter is specified. The shape of the hole in the loading plate shall correspond to that of the anchor cross section. When sleeve inserts of the required diameter are used they shall be periodically inspected and replaced to meet these requirements and prevent eccentric loading of sleeve. See Fig. 5 .

5.5.2*Shear Test*—The displacement measuring device(s) shall be positioned to measure displacement in the direction of the applied load. The device shall be placed on the structural member to allow the sensing element to bear perpendicularly on the anchor or on a contact plate located on the loading plate as shown in for a representative shear plate with sleeves. The contact area between the loading plate through which the anchor is installed and the test member shall be as given in Table 2, unless otherwise specified. Chamfer or smooth the edges of the loading plate so that it does not dig into the concrete. Place a sheet of polytetrafluoroethylene (PTFE) or other friction-limiting materials with a minimum thickness of 0.020 in. (0.5 mm) between the loading plate and base material surface. The friction-limiting material shall prevent contact of the loading plate with the base material.

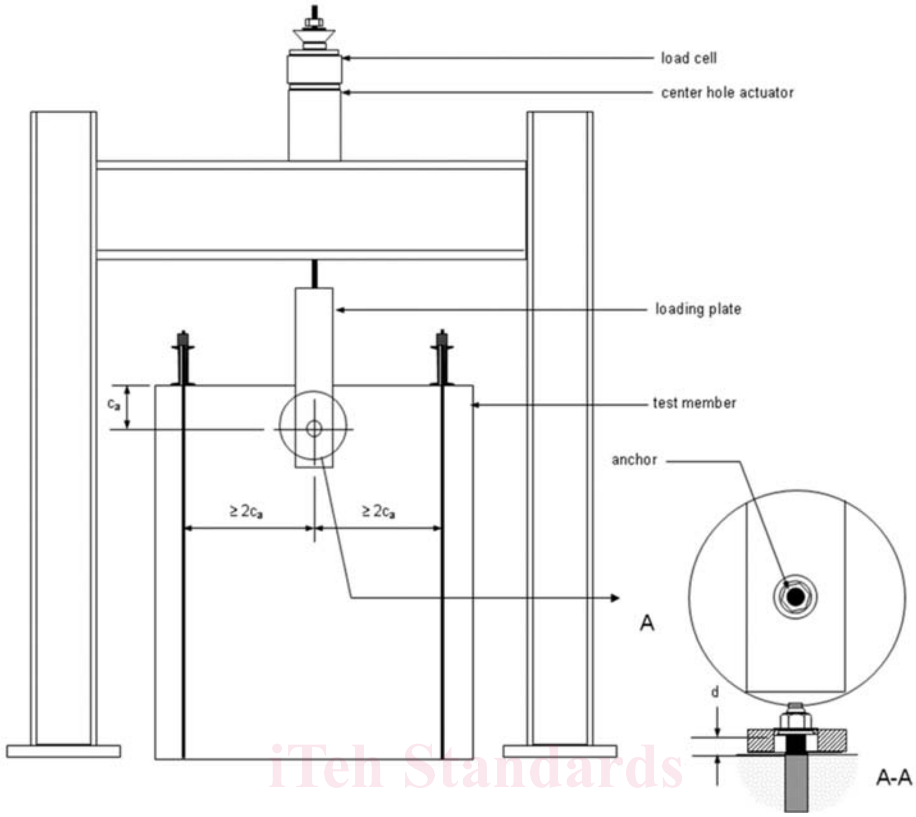

FIG. 4 Example of a Shear Test Setup

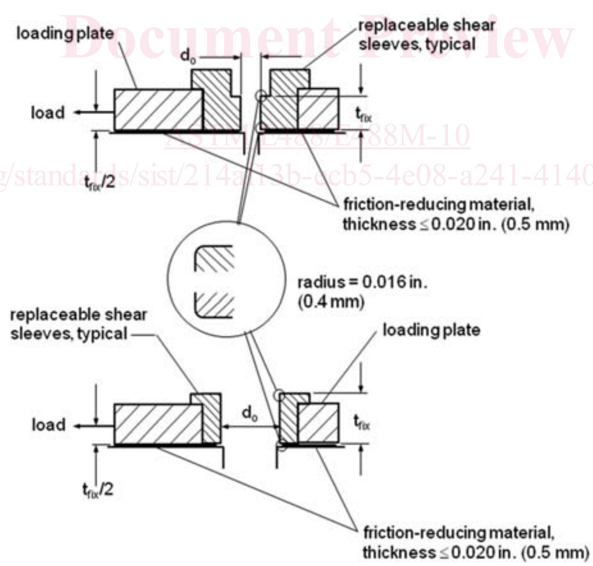

FIG. 5 Example of Shear Plate with Sleeves

5.4 *Unconfined and Confined Test Equipment*:

5.4.1 *Unconfined Tests*—Fig. 1 and Fig. 2 show a typical unconfined tension test setup with supports spaced as required to permit the unrestricted development of a conical concrete fracture surface. The values given in Table 1 for required clearances between the anchor and the test support shall be considered to satisfy this requirement.

5.4.2 *Confined Tests*—Fig. 3 ~~or other method which prevents extraneous deflections. For tests on clusters of anchors, the instrument shall lie on a plane through the axis of the shear loading rod or plate. An extension of the axis of the shear loading rod or plate shall pass through the centric axis of the cluster of anchors.~~ shows a typical confined tension test setup for anchors, in which the reaction force is transferred into the concrete close to the anchor. The confining plate shall have a hole with diameter between 1.5 d_{hole} and 2.0 d_{hole}, and a thickness $t_{fix} \geq d$. Place a sheet of polytetrafluoroethylene (PTFE) or other friction-limiting

TABLE 2 Shear Loading Plate Bearing Area as a Function of Anchor Diameter

Anchor Diameter, d_o in. (mm)	Shear Loading Plate Contact Area,[A,B] in.^{2} (cm^2)	
	minimum	maximum
<⅜ (<10)	8 (50)	12 (80)
⅜ $\leq d_o <$ ⅝ (16)	12 (80)	18 (115)
⅝ $\leq d_o <$ ⅞ (22)	18 (115)	25 (160)
⅞ $\leq d_o <$ 2 (50)	25 (160)	40 (260)
$d_o \leq$ 2 (50)	40 (260)	60 (385)

[A] Shear loading plate contact area with PTFE or other friction-limiting material.
[B] Calculated uniform bearing stress on contact area due to self-weight of loading plate and associated loading apparatus shall not exceed 5 psi (0.03 MPa).

materials with a minimum thickness of 0.020 in. (0.5 mm) between the loading plate and base material surface. The friction-limiting material shall prevent contact of the confining plate with the base material.

5.5 *Cracked Concrete Testing*:

5.5.1 *Equipment for Controlling Cracks*—The test apparatus shall be capable of controlling the crack width. A typical tension test setup for cracked concrete is shown in Fig. 6.

NOTE 2—Fig. 6 shows testing of multiple anchors. Smaller test members can be used for testing single anchors.

6. Test Specimens

6.1 *Anchorage System*—The anchors or anchorage system shall be representative of the type and lot to be used in field construction, and shall include all accessorythe attachment hardware normally required for its use, that is, all attachment hardware. use.

6.2 *Anchor Installation*—Install the anchorage device in accordance with the manufacturer's procedures and tools, or, where specific deviation is justified, in accordance with good field methods.

6.3*Anchor Placement*—Individually test all anchors as specified in the test program. The anchors shall be tested at distances equal to or greater than those given in Table 2. The distances in Table 2 are not intended for design of attachments. Table 2 test support requirements are not prohibited from being reduced for bonded anchors with embedments equal to or greater than 20 anchor diameters. For anchors intended to be field-installed at spacings less than specified in Table 2 in groups of two or more, test at the intended spacings or edge distances per the requirements of 8.3 at the selected spacing and edge distance intervals to assign reduction factors.

6.4*Structural Member*—The structural member in which the anchor is to be embedded shall be representative of the materials and configuration intended for field use. The structural member is not prohibited from being steel-reinforced. The location and

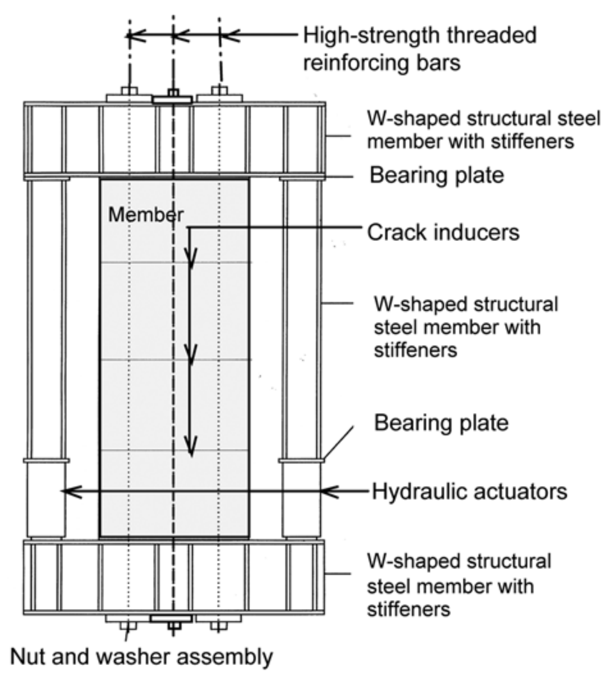

FIG. 6 Example of Test Setup for Cracked Concrete

orientation of any reinforcement embedded in concrete or masonry members shall be evaluated. The overall size of the test specimen shall not be reduced unless the requirements in 6.4.1-6.4.3.1 are met.

6.4.1The depth of the structural member shall be equal to the minimum member depth specified by the manufacturer. The structural member shall be at least 1.5 *Test Member*—The requirements of the test member in which the anchor is to be embedded and tested shall be specified. The location and orientation of any reinforcement embedded in concrete members shall meet the requirements of 6.3 and 6.4.

6.2.1 *Concrete Test Members*:

6.2.1.1 *Casting and Curing of Concrete Test Members*—Concrete used in testing shall meet the requirements of Sections 6.2.1.2 through 6.2.1.4 (*3*) (*b*) unless otherwise specified.

6.2.1.2 Cast test members either horizontally or vertically. If the member is cast vertically, the maximum height of a concrete lift shall be 5 ft (1.5 m). In general, the thickness of the test member depends on the testing requirements. The test member shall be at least 1.5 h_{ef} in thickness so long as the depth is suitable for normal installation of the anchor and does not result in premature failure of either the structural member or anchor, unless the specific test application requires a lesser thickness. The structural member will act as a beam if the spacing between reaction supports is greater than the thickness of the member. A structural member with a thickness of at least 1.5 *thick, unless the specific test application requires a specific thickness.*

6.2.1.3 *Surface Finish*—The surface of the test member shall be a formed or steel-troweled finish unless otherwise specified.

6.2.1.4 *Concrete for Test Members*—Concrete for test members shall meet the requirements of 6.2.1.4 (*1*) through 6.2.1.4 (*3*) (*b*).

(1) Aggregates—For normalweight concrete, use aggregates conforming to Specification C33/C33M, with a maximum size of 1 in. (25 mm) or Specification C330/C330M for lightweight concrete.

(2) Cement—Use only portland cement conforming to Specification C150/C150M for normalweight concrete or lightweight concrete, unless otherwise specified. If any other cementitious materials (for example, slag, fly ash, silica fume, or limestone powder) or chemical admixtures (for example, air-entraining agents, water reducers, high-range water reducers, shrinkage-compensating admixtures, corrosion inhibitors, set retarders, and set accelerators) are used in the concrete test members, report them.

(3) Concrete Strength—Compressive strength specimens shall be prepared and tested in accordance with Practice C31/C31M and Test Method C39/C39M.

(a) Cure concrete cylinders in accordance with Practice C31/C31M or Test Method C39/C39M under the same environmental conditions as the test members. Remove molds from the cylinders at the same time that the forms are removed from the test members. Unless otherwise specified, at the time of anchor testing, the concrete shall be at least 21 days old. Establish the compressive strength of the concrete test member at the time of anchor testing by interpolation between the strengths of control samples at the start and at the end of testing, or at closer intervals as specified. Alternately, test enough control samples to plot a strength-versus-age graph, and use interpolation to estimate the concrete strength at the day of test.

(b) When evaluating the test results, if there is a question whether the strength of the concrete cylinders represents the concrete strength of the test member, verify the compressive strength of at least three cores with diameters from 3 to 6 in. (75 to 150 mm), taken from the test member outside of the zones where the concrete has been damaged by the anchor test. Prepare the core samples, test them in the dry condition, and evaluate the results in accordance with the provisions of Test Method C42/C42M.

6.3 *Uncracked Concrete Test Members*—Use test members that are unreinforced, except as permitted by 6.3.1.

6.3.1 The test member shall be permitted to contain reinforcement to allow handling, the distribution of loads transmitted by the test equipment, or both. Place such reinforcement so that the capacity of the tested anchor is not affected. This requirement shall be considered to be met if the reinforcement is located outside a cone of concrete whose vertex is at the anchor, whose base is perpendicular to the direction of load, and whose internal vertex angle is 120 degrees.

6.4 *Cracked Concrete Test Members*—Test members shall be permitted to contain reinforcement to allow handling, the distribution of loads transmitted by test equipment, or both. Place the reinforcement so that the capacity of the tested anchor is not affected. See Fig. 7 for a representative concrete test member for cracked concrete.

6.4.1 The crack width shall be approximately uniform throughout the member thickness. The thickness of the test member shall be not less than the greater of 1.5 h_{ef} will minimize bending during the application of the tensile load to the test anchor. In general, the thickness of the test member shall be equal to the minimum member depth specified by the manufacturer.

6.4.2The length and width of the structural member shall ensure that no shear or tension failure spall intersects either the outside edges of the structural member or the bearing contact points of the test frame. The overall size of the test specimen shall only be reduced when the minimum requirements in 6.4.1 are met.

6.4.3*Surface Finish*—The surface of the structural member where the loading fixture or loading plate bears on the member shall be a form-work or steel-trowel finish unless otherwise specified.

6.4.3.1For static shear tests, a sheet of tetrafluoroethylene (TFE), polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), or perfluoroalkoxy (PFA) of 0.5 ± 0.1 mm (0.020 ± 0.004 in.) thickness and corresponding to the area required according to Table 1 shall be placed between the shear plate and the surface of the structural member. and 4 in. (100 mm). To control the location of cracks and to help ensure that the anchors are installed to the full depth in the crack, crack inducers shall be permitted to be installed in the member, provided that they are not situated so as to influence the test results. For test members that use