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November 17, 2023

TO: **PARTIES INTERESTED IN MECHANICAL ANCHORS IN CRACKED AND UNCRACKED MASONRY ELEMENTS**

SUBJECT: Proposed Revisions to the Acceptance Criteria for Mechanical Anchors in Cracked and Uncracked Masonry Elements, (AC01), Subject AC01-0224-R1 (MC/HS).

Hearing Information:
WebEx Event Meeting
Wednesday, February 21, 2024
8:00 am Pacific Standard Time
Click the date above to register

Dear Colleague:

You are invited to comment on proposed revisions to AC01, which will be discussed at the Evaluation Committee hearing noted above. The proposed revisions are based on a letter and a criteria draft received from the Concrete and Masonry Anchor Manufacturer Association (CAMA), on October 24, 2023. The letter from CAMA along with a revised draft is attached to this staff letter. The proposed revisions can be summarized as follows:

1. Editorial revisions for clarification and correction purposes; including terminology, code section referencing and updated figures throughout the criteria.
2. Clarification of batch requirements for testing, as indicated in Tables 4.1, 4.2, 4.3 and 4.4 of the proposed revisions.
3. Allowance for additional testing scenarios for the simulated seismic shear tests as indicated in Section 7.8 of the proposed revisions.
4. Provide guidance for the assessment of characteristic tensile capacity associated with masonry breakout and pullout in cracked masonry, as indicated in Section 8.5 of the proposed revisions.

In addition to the proposed revisions to AC01, ICC-ES staff seeks input from the public regarding the following:

AC01 was substantially revised during the Evaluation Committee Hearing of February 2021, to incorporate provisions for LFRD strength design methodology and cracked masonry for mechanical anchors (merging ASD allowable stress design methodology AC01 for expansion anchors and AC106 for screw anchors in masonry under a single criteria). The efforts were a result of CAMA, the anchor industry, and The Masonry Society (TMS) working together to support the direction of the TMS 402/602 Code standard committee in developing LFRD strength design methodology and cracked masonry provisions for post-installed mechanical anchors.

As of today, TMS 402/602 Code allows the applicability of both Allowable Stress Design (ASD) and LRFD strength design in general. Considering the current situation, with regards to how the compliance date for AC01 affects the industry, ICC-ES staff recommends that the current compliance date of AC01 be moved 18 months from the AC hearing date to August 21, 2025.

Should the committee approve the proposed revisions to the criteria, the ICC-ES staff will consider the applicability of any changes to the existing compliance date taking public comments into consideration. Compliance with the revised criteria for applicants already complying with the cracked masonry provisions of AC01 will therefore be at the option of existing report holders. However, it should be noted that current applicants for new reports will be required to address any changes that are approved by the committee.

For existing reports under AC01 approved March 2018 or AC106, report holders will need to demonstrate compliance with the new provisions before the compliance date, or face mandated revisions or suspension or cancellation of their reports. Data packages will need to be accompanied by an application, along with appropriate fees, including significant technical review and additional item fees as applicable.

You are invited to submit written comments on this or any other agenda item and attend the Evaluation Committee hearing to support your written comments in person. If you wish to contribute to the discussion, please note the following:

1. Regarding written comments and presentations:

    a. You should submit these via e-mail to es@icc-es.org by the applicable due date.

    b. The deadline for submitting written comments is **December 14, 2023.** These comments will be forwarded to the committee and posted on the ICC-ES web site shortly after the deadline. Comments that are not submitted by this deadline will not be considered at the meeting.

    c. The deadline for submitting rebuttal comments, from the proponent noted in this letter, is **January 10, 2024**. These comments will be forwarded to the committee and posted on the ICC-ES web site shortly after the deadline. . Comments that are not submitted by the deadline will not be considered at the meeting.

    d. The deadline for submitting a presentation is **January 24, 2024.** If a company wants to present a visual presentation at the hearing, it shall be received in PowerPoint format. These will be forwarded to the committee and posted on the ICC-ES web site approximately two weeks before the hearing. Presentations that are not submitted by the deadline cannot be presented at the meeting. **Note:** Videos will not be posted on the web site.

   e. ICC-ES staff memo addressing public comments, rebuttal comments, and presentations (as deemed necessary) will be posted to the ICC-ES web site on **February 7, 2024**.

2. Keep in mind that all materials submitted for committee consideration are part of the public record and will not be treated as confidential. It is the presenter's responsibility to certify to ICC-ES staff that no materials infringe copyright.

3. Please do not communicate with committee members before the meeting about any items on the agenda.

We appreciate your interest in the work of the Evaluation Committee. If you have any questions, please contact me at (800) 423-6587, extension 3288, or Howard Silverman, P.E. Senior Staff Engineer, at extension 3996. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,

Manuel Chan, P.E., S.E.
Principal Structural Engineer

MC/ls

Encl.

cc: Evaluation Committee

October 24, 2023

Vincent Chui
ICC Evaluation Services, LLC.
Western Regional Office
3060 Saturn Street, Suite 100
Brea, CA 92821
vchui@icc-es.org

SUBJECT: Proposed Changes to AC01

Dear Vincent,

CAMA is submitting a proposal for revisions of AC01 – Acceptance Criteria for Mechanical Anchors in Cracked and Uncracked Masonry Elements and AC58 – Acceptance Criteria for Adhesive Anchors in Cracked and Uncracked Masonry Elements.

This proposal for AC01 includes the following revisions:

1. Chapter 3 design edits to correct and clarify terminology and references.
2. Chapter 4 clarifications of batch requirements for testing
3. Chapter 7 corrections and allowances for additional testing scenarios
4. Chapter 8 clarifications of calculations
5. Appendix A design edits to correct and clarify Canadian design terminology.
6. Updates to figures

We believe that these changes will provide important clarity to the execution of testing programs and publication of ESRs on these recently overhauled Acceptance Criteria documents.

If you have any questions, please contact the CAMA office.

Sincerely,

CRAIG H. ADDINGTON
Concrete and Masonry Manufacturers Association

ICC EVALUATION SERVICE, LLC, RULES OF PROCEDURE FOR THE EVALUATION COMMITTEE

1.0 PURPOSE

The purpose of the Evaluation Committee is to review and approve acceptance criteria on which evaluation reports may be based.

2.0 MEMBERSHIP

2.1 The Evaluation Committee has a membership of not fewer than nine, with one of the members named by the ICC-ES president each year to serve as the chairman–moderator.

2.2 All members of the committee shall be representatives of a body enforcing regulations related to the built environment.

2.3 Persons are appointed to the committee by the ICC-ES president, from among individuals who have formally applied for membership.

2.4 The ICC-ES Board of Managers, using simple majority vote, shall ratify the nominations of the president.

2.5 Committee membership is for one year, coinciding with the calendar year. Members may be renominated and reappointed.

2.6 In the event that a member is unable to attend a committee meeting or complete a term on the committee, the ICC-ES president may appoint a replacement to fill in at the meeting or for the remainder of the member's term. Any replacement appointed for only one meeting must have prior experience as a member of the Evaluation Committee. Appointments under this section (Section 2.6) are subject to ratification as noted in Section 2.4.

3.0 MEETINGS

3.1 The Evaluation Committee shall schedule meetings that are open to the public in discharging its duties under Section 1.0, subject to Section 3.0.

3.2 All scheduled meetings shall be publicly announced. There shall be three to six meetings per year (as necessary).

3.3 More than half of the Evaluation Committee members, counting the chairman, shall constitute a quorum. A majority vote of members present is required on any action. To avoid any tie vote, the chairman may choose to exercise or not exercise, as necessary, his or her right to vote.

3.4 In the absence of the chairman–moderator, Evaluation Committee members present shall elect an alternate chairman from the committee for that meeting. The alternate chairman shall be counted as a voting committee member for purposes of maintaining a committee quorum and to cast a tie-breaking vote of the committee.

3.5 Minutes shall be kept and shall be the official record of each meeting.

3.6 An electronic record of meetings may be made by ICC-ES if deemed necessary; no other audio, video, electronic recordings of the meetings will be permitted. Visual aids (including, but not limited to, charts, slides, videos, or presentation software) viewed at meetings shall be permitted only if the presenter provides ICC-ES before the presentation with a copy of the visual aid in a medium which can be retained by ICC-ES with its record of the meeting and which can also be provided to interested parties requesting a copy.

3.7 Parties interested in the deliberations of the committee should refrain from communicating, whether in writing or verbally, with committee members regarding agenda items. All written communications and submissions regarding agenda items must be delivered to ICC-ES and shall be considered nonconfidential and available for discussion in open session of an Evaluation Committee meeting. Such materials will be posted on the ICC-ES web site (www.icc-es.org) prior to the meeting. Comments and submissions not meeting the following deadlines will not be considered at the meeting:

- Initial comments on agenda items shall be submitted at least 28 days before the scheduled meeting.
- A rebuttal comment period shall follow, whereby rebuttal comments to the initial comments may be submitted by the proponent at least 21 days before the scheduled meeting.
- Those planning on giving a visual presentation at the meeting must submit their presentation, in PowerPoint format only, at least 10 days before the scheduled meeting.

The committee reserves the right to refuse recognition of communications which do not comply with the provisions of this section.

4.0 CLOSED SESSIONS

Evaluation Committee meetings shall be open except that at the discretion of the chairman, staff counsel may be necessary. Also, matters related to clients or potential clients covered by confidentiality requirements of ICC-ES Rules of Procedure for Evaluation Reports are discussed only during closed meetings.

5.0 ACCEPTANCE CRITERIA

5.1 Acceptance criteria are established by the committee to provide a basis for issuing ICC-ES evaluation reports on products and systems under codes referenced in Section 2.0 of the Rules of Procedure for Evaluation Reports. They also clarify conditions of acceptance for products and systems specifically regulated by the codes.

Acceptance criteria may involve a product, material, or method of construction. Consideration of any acceptance criteria must be in conjunction with a current and valid application for an ICC-ES evaluation report, an existing ICC-ES evaluation report, or as otherwise determined by the ICC-ES President.

EXCEPTIONS: The following acceptance criteria are controlled by the ICC-ES executive staff and are not subject to committee approval:

- The Acceptance Criteria for Quality Documentation (AC10)
- The Acceptance Criteria for Test Reports (AC85)
- The Acceptance Criteria for Inspections and Inspection Agencies (AC304)

5.2 Procedure:

5.2.1 Proposed acceptance criteria shall be developed by the ICC-ES staff and discussed in open session with the Evaluation Committee during a scheduled meeting, except as permitted in Section 4.0 of these rules.

5.2.2 Proposed acceptance criteria shall be available to interested parties at least 30 days before discussion at the committee meeting.

5.2.3 The committee shall be informed of all pertinent written communications received by ICC-ES.

5.2.4 Attendees at Evaluation Committee meetings shall have the opportunity to speak on acceptance criteria listed on the meeting agenda, to provide information to committee members. In the interest of fairness, each speaker requesting to testify on a proposed acceptance criteria or proposed changes to an existing acceptance criteria will be given the same amount of time, as follows:

a. A 10-minute time limit applies to speakers giving their first testimony on any item, which applies to both verbal testimony and/or visual presentations.

b. A 5-minute time limit applies to speakers returning to the microphone to offer additional testimony and/or to rebut testimony given by others.

c. A 2-minute time limit applies to speakers offering testimony on the staff recommendation to criteria.

Should a company have multiple speakers, the speaker time limits above apply the company, in that multiple speakers from the same company shall share the testimony time, i.e., multiple speakers from the same company shall not each get their own testimony times. Time limits do not include time needed to answer questions from the staff and/or committee members. The chairman–moderator shall have limited authority to modify time limitations on testimony. The chairman–moderator shall also have the authority to adjust time limits as necessary in order to get through the hearing agenda.

An automatic timing device shall keep time for testimony and shall provide the time remaining to the speaker testifying. Interruptions during testimony will not be tolerated. It is the responsibility of the chairman–moderator to maintain decorum and order during all testimony.

5.3 Approval of any action on an acceptance criteria shall be as specified in Section 3.3 of these rules. Possible actions made by the Evaluation Committee include: Approval; Approval with Revisions; Disapproval; or Further Study. The Evaluation Committee must give the reason(s) for any Disapproval or Further Study actions with specific recommendations.

5.4 Actions of the Evaluation Committee may be appealed in accordance with the ICC-ES Rules of Procedure for Appeal of Acceptance Criteria or the ICC-ES Rules of Procedure for Appeals of Evaluation Committee Technical Decisions.

6.0 COMMITTEE BALLOTING FOR ACCEPTANCE CRITERIA

6.1 Acceptance criteria may be revised without a public hearing following a 30-day public comment period and a majority vote for approval by the Evaluation Committee (i.e., alternative criteria development process), when at the discretion of the ICC-ES executive staff, the subject is a revision that requires formal action by the Evaluation Committee.

6.2 Negative votes must be based upon one or more of the following, for the ballots to be considered valid and require resolution:

a. *Lack of clarity*: There is insufficient explanation of the scope of the acceptance criteria or insufficient description of the intended use of the product or system; or the acceptance criteria is so unclear as to be unacceptable. (The areas where greater clarity is required must be specifically identified.)

b. *Insufficiency*: The criteria is insufficient for proper evaluation of the product or system. (The provisions of the criteria that are in question must be specifically identified.)

c. *The subject of the acceptance criteria is not within the scope of the applicable codes*: A report issued by ICC-ES is intended to provide a basis for approval under the codes. If the subject of the acceptance criteria is not regulated by the codes, there is no basis for issuing a report, or a criteria. (Specifics must be provided concerning the inapplicability of the code.)

d. *The subject of the acceptance criteria needs to be discussed in public hearings*. The committee member requests additional input from other committee members, staff or industry.

6.3 An Evaluation Committee member, in voting on an acceptance criteria, may only cast the following ballots:

- Approved
- Approved with Comments
- Negative: Do Not Proceed

7.0 COMMITTEE COMMUNICATION

Direct communication between committee members, and between committee members and an applicant or concerned party, with regard to the processing of a particular acceptance criteria or evaluation report, shall take place only in a public hearing of the Evaluation Committee. Accordingly:

7.1 Committee members receiving an electronic ballot should respond only to the sender (ICC-ES staff). Committee members who wish to discuss a particular matter with other committee members, before reaching a decision, should ballot accordingly and bring the matter to the attention of ICC-ES staff, so the issue can be placed on the agenda of a future committee meeting.

7.2 Committee members who are contacted by an applicant or concerned party on a particular matter that will be brought to the committee will refrain from private communication and will encourage the applicant or concerned party to forward their concerns through the ICC-ES staff in writing, and/or make their concerns known by addressing the committee at a public hearing, so that their concerns can receive the attention of all committee members.■

Revised November 2023

PROPOSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR MECHANICAL ANCHORS IN CRACKED AND UNCRACKED MASONRY ELEMENTS

AC01

Proposed November 2023

Compliance date – February 16, 2024

Previously approved July 2023, February 2021, March 2018, November 2015, May 2012, December 2009, December 2006, June 2005, October 2004, April 2002, November 2001, January 2001, January 1999, September 1997, January 1993

(Previously editorially revised, February 2023, May 2014 and August 2013)

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes. (Some reports may also reference older code families such as the BOCA National Codes, the Standard Codes, and the Uniform Codes, or other codes as designated by the ICC-ES president.) Section 104.11 of the *International Building Code®* reads as follows:

> **The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.**

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports

PROPOSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR MECHANICAL ANCHORS IN CRACKED AND UNCRACKED MASONRY ELEMENTS (AC01)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for mechanical anchors in masonry elements to be addressed in an ICC-Evaluation Service, LLC (ICC-ES), evaluation report under the 2021, 2018, 2015, 2012, 2009 and 2006 *International Building Code*® (IBC) and the 2021, 2018, 2015, 2012, 2009 and 2006 *International Residential Code*® (IRC). The basis of evaluation is IBC Section 104.11 and IRC Section R104.11. The reason for the development of this criteria is to provide guidelines for the evaluation of alternative anchors to those addressed by the code (IBC or IRC).

See Appendix A of this criteria for requirements for mechanical anchors in masonry elements to be addressed in an evaluation report under the *National Building Code of Canada*® 2020 (NBCC).

1.2 Scope: This Acceptance Criteria applies to post-installed mechanical anchors including torque-controlled expansion anchors, displacement-controlled expansion anchors, undercut anchors, and screw anchors placed into predrilled holes and anchored within reinforced masonry, and unreinforced masonry not otherwise addressed by criteria established for use with URM construction in the International Existing Building Code (IEBC) Appendix A, Chapter A1. See ACI 355.2-19 Section 3.1 for illustrations of all anchor types. The minimum effective embedment of anchors installed in grouted masonry shall be 1-1/2 inches (38 mm). The nominal diameter of anchors shall be between 3/16 in. (5 mm) and 1 in. (25 mm). Screw anchors are limited to a maximum effective embedment of $10\,d_a$. (Refer to ACI 355.2-19 Section R1.4.) Where not limited by the thickness of the concrete masonry unit face shell, anchors installed in ungrouted concrete masonry units shall have a minimum effective embedment of 1-1/2 inches (38 mm). Anchors in solid clay masonry shall have a minimum effective embedment of 1-1/2 inches (38 mm). Anchors evaluated under this criteria are alternatives to anchors permitted under Section 8.1.3 of TMS 402-16 and TMS 402-13/ACI 530-13/ASCE 5-13 (Section 2.1.4 of TMS 402-11/ACI 530-11/ASCE 5-11) as referenced in Section 2107.1 of the IBC or Section R301.1.3 of the IRC. The anchors may be used both in masonry that is assumed to remain uncracked for the service life of the anchor and in masonry that may experience cracking over the service life of the anchor. The design of anchors installed in unreinforced masonry shall be predicated on the assumption that the masonry remains uncracked. Criteria is prescribed to determine the performance category for each anchor. The performance categories are used by the design section provided in Section 3 to assign capacity reduction factors and other design parameters.

Table 1.1 summarizes the various masonry materials and construction types that are within the scope of this acceptance criteria under which the applicant may choose to have the anchors evaluated.

1.2.1 This acceptance criteria does not address shock and high-cycle fatigue loading as noted in Section 10.2.4.

1.2.2 This acceptance criteria references sections, tables, and figures in both this acceptance criteria and ACI 318 with the following method used to distinguish between the two document references:

- References to sections, tables, and figures originating from ACI 318 are *italicized*, with the leading reference corresponding to 318-19 and the parenthetical reference corresponding to 318-14 and 318-11. For example, Section 2.2 in ACI 318-19, which is analogous to Section 2.2 of ACI 318-14 and Section D.1 in ACI 318-11, will be displayed as *ACI 318 Section 2.2 (Section 2.2 and Section D.1)*.

1.2.3 References to sections, tables, and figures originating from the current document are displayed without font changes.

1.3 Codes and referenced standards: Where standards are referenced in this criteria, these standards shall be applied consistently with the code upon which compliance is based. For standards referenced in this criteria and the applicable code, editions of standards applicable to evaluation referenced by the IBC and IRC are summarized in Table 1.2.

1.3.1 2021, 2018, 2015, 2012, 2009, 2006 *International Building Code*® (IBC), International Code Council.

1.3.2 2021, 2018, 2015, 2012, 2009, 2006 *International Residential Code*® (IRC), International Code Council.

1.3.3 2016 TMS 402, *Building Code Requirements for Masonry Structures*, The Masonry Society.

1.3.4 2013 TMS 402/ACI 530/ASCE 5, *Building Code Requirements for Masonry Structures*, American Concrete Institute/Structural Engineering Institute of the American Society of Civil Engineers/The Masonry Society.

1.3.5 2011 TMS 402/ACI 530/ASCE 5, *Building Code Requirements for Masonry Structures*, American Concrete Institute/Structural Engineering Institute of the American Society of Civil Engineers/The Masonry Society.

1.3.6 ICC-ES AC10 *Acceptance Criteria for Quality Documentation.*

1.3.7 ICC-ES AC85 *Acceptance Criteria for Test Reports.*

1.3.8 ICC-ES AC193 *Acceptance Criteria for Mechanical Anchors in Concrete Elements.*

1.3.9 ICC-ES AC304 *Inspections and Inspection Agencies.*

1.3.10 ACI 318-19, -14, -11 *Building Code Requirements for Structural Concrete,* American Concrete Institute.

1.3.11 ACI 355.2-19 *Qualification of Post-Installed Mechanical Anchors in Concrete*, American Concrete Institute.

1.3.12 ANSI B 212.15-1994, *American National Standard for Cutting Tools – Carbide Tipped Masonry Drills* *and Blanks for Carbide-Tipped Masonry Drills,* American National Standards Institute.

1.3.13 ASTM A153, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware,* ASTM International.

1.3.14 ASTM B695, *Standard Specification for Coatings of Zinc Mechanically Deposited on Iron And Steel*, ASTM International.

1.3.15 ASTM C55, *Standard Specification for Concrete Building Brick,* ASTM International.

1.3.16 ASTM C62, *Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale),* ASTM International.

1.3.17 ASTM C67, *Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile,* ASTM International.

1.3.18 ASTM C90, *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM International.

1.3.19 ASTM C126, *Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units,* ASTM International.

1.3.20 ASTM C129, *Standard Specification for Nonloadbearing Concrete Masonry Units,* ASTM International.

1.3.21 ASTM C140, *Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units,* ASTM International.

1.3.22 ASTM C216, *Standard Specification for Facing Brick (Solid Masonry Units Made From Clay or Shale),* ASTM International.

1.3.23 ASTM C270, *Standard Specification for Mortar for Unit Masonry,* ASTM International.

1.3.24 ASTM C476, *Standard Specification for Grout for Masonry,* ASTM International.

1.3.25 ASTM C652, *Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale)*, ASTM International.

1.3.26 ASTM C1019, *Standard Test Method for Sampling and Testing Grout for Masonry,* ASTM International.

1.3.27 ASTM C1314, *Standard Test Method for Compressive Strength of Masonry Prisms,* ASTM International.

1.3.28 ASTM C1892, *Standard Test Methods for Strength of Anchors In Masonry,* ASTM International.

1.3.29 ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* ASTM International.

1.3.30 ASTM E2935, *Standard Practice for Conducting Equivalence Testing in Laboratory Applications,* ASTM International.

1.3.31 ASTM F606, *Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets,* ASTM International.

1.3.32 UL 263, *Standard for Fire Tests of Building Construction and Materials,* Underwriters Laboratories Inc.

1.4 Definitions: Definitions included in the IBC, IRC, ACI 318, ACI 355.2 and AC193 are applicable to this criteria. In addition, the following definitions apply:

1.4.1 Anchor Category: Classification for an anchor that is established by the performance of the anchor in reliability tests.

1.4.2 Anchor Diameter: Nominal diameter of the anchor. For internally threaded anchors, the anchor diameter shall be taken as the bolt diameter threaded into the internal threads.

1.4.3 Anchor Installation: Unless otherwise noted, the process defined by the Manufacturer's Printed Installation Instructions (MPII) for installation of the subject anchor. Anchor installation parameters may include but are not limited to: masonry type, strength and condition of masonry at time of installation, hole drilling method, hole size, hole cleaning and preparation requirements, anchor installation, maximum tightening torque, and installer safety requirements.

1.4.4 Anchor System: An anchor product line for which the component materials, functioning principles and installation parameters are consistent. An anchor system may consist of several anchor diameters, each associated with a specific anchor embedment, or multiple embedments associated with each anchor diameter.

1.4.5 Batch: See Figure 4.1 for illustration of batch concept.

1.4.5.1 CMU Or Brick Unit: Set of units from the same production run comprising constituent materials from the same sources.

1.4.5.2 Grout: Grout from the same load (i.e., from a single truckload or single mixer load).

1.4.5.3 Masonry: Assembled masonry product comprising the same combination of CMU/brick unit batch, grout batch, and mortar batch, as applicable.

1.4.5.4 Mortar: Mortar with the same lot number.

1.4.6 Bed Joint: Horizontal mortar joint between two masonry courses.

1.4.7 Breakout Capacity, Tension: Strength corresponding to a volume of masonry surrounding an anchor or group of anchors separating from the masonry wall.

1.4.8 Brick Construction Type: Brick masonry construction combining the following consistent properties: brick unit type (Section 1.4.9), mortar type, and number of wythes.

1.4.9 Brick Unit Type: A unique combination of the following brick unit properties: brick material type and classification as dictated by a recognized standard; specified dimensions; ratio of net to gross cross-sectional area in cored planes; and degree of frogging.

For example, a brick unit type could be as follows: Grade MW ASTM C216 brick with 3 5/8 x 2 1/4 x 7 5/8 in. dimensions, an 80% ratio of net to gross cross-sectional area in cored planes, and no frogging.

1.4.10 Cell: Cored or extruded void space in the center of masonry units.

1.4.10.1 Cell Length: The dimension of an individual cell parallel to the length of the unit.

1.4.10.2 Cell Thickness—the dimension of an individual cell parallel to the thickness of the wall in the installed condition.

1.4.11 Characteristic Value—5 percent fractile (value with a 95 percent probability of being exceeded with a confidence of 90 percent.

1.4.12 Cracked Masonry

1.4.12.1 For design purposes, cracked masonry conditions shall be assumed where analysis indicates that cracking could occur ($f_t \geq f_r$) in the vicinity of the anchor due to service loads or deformations, including wind and seismic loading, over the service life of the anchorage, where f_r is defined in TMS 402/ACI 530/ASCE 5-11 Section 3.1.8, TMS 402/ACI 530/ASCE 5-13 Section 9.1.9, and TMS 402-16 Section 9.1.9.

1.4.12.2 For testing and assessment purposes, a masonry test member that is cracked at the anchor location at the beginning of the test.

1.4.12.3 Displacement-Controlled Expansion Anchor—post-installed anchor that is set by expansion against the side of the drilled hole through movement of an internal mandrel in the sleeve or through movement of the sleeve over an expansion element (mandrel); once set, no further expansion can occur.

1.4.13 Embedment Depth

1.4.13.1 Effective: for expansion and undercut anchors measured from the masonry surface to the deepest point at which the anchor tension load is transferred to the masonry, in. (mm). For screw anchors, the effective embedment depth is approximated. The effective embedment depth for all mechanical anchors is provided by the manufacturer.

1.4.13.2 Nominal: the distance from test member surface to installed end of anchor which is measured prior to setting of the anchor.

1.4.14 Head Joint—vertical mortar joint between two masonry units in the same course and wythe.

1.4.14.1 Hollow— Head joint in CMU construction employing closed-ended units. All head joints in CMU construction with closed-ended units shall be assumed to have mortar only over the depth of each face shell with voids behind the mortar irrespective of degree of mortar/grout application during construction. See Sections 3.3.1.2, and 3.3.2.21, Figure 3.2, and Figure 3.3 for design assumptions associated with hollow head joints.

1.4.14.2 Solid: Head joint in fully grouted CMU employing open-ended units. See Figure 3.2 for illustration.

1.4.15 High-Strength Masonry: For the purposes of anchor testing and assessment prescribed within this document, high-strength masonry is limited to fully grouted CMU test specimens with a grout compressive strength greater than or equal to 5,000 psi.

1.4.16 Independent Testing And Evaluation Agency (ITEA): A laboratory accredited in conformance with Section 2.2.1 having responsibility for the testing and assessment of an anchor product in accordance with this criteria.

1.4.16.1 Designated Testing Laboratory: A laboratory designated by the ITEA to perform testing in accordance with this criteria.

1.4.17 Low-Strength Masonry: For the purposes of anchor testing and assessment prescribed within this document, low-strength masonry contains the following characteristics by masonry type, where anchor test results shall be normalized to the following values below in accordance with Section 8.3:

1.4.17.1 Low-Strength Brick: Brick masonry with a unit compressive strength equal to the minimum permissible strength in the applicable ASTM/other standard for that brick type.

1.4.17.2 Low-Strength Fully Grouted CMU: Masonry with unit compressive strength of 2,000 psi (13.8 MPa) and grout compressive strength of 2,000 psi (13.8 MPa) (minimum values permitted by ASTM C90 and TMS 402).

1.4.17.3 Low-Strength Ungrouted CMU: Masonry with unit compressive strength of 2,000 psi (13.8 MPa).

1.4.18 Manufacturer's Printed Installation Instructions (MPII): Published instructions for correct anchor installation under all covered installation conditions as supplied in product packaging by the manufacturer of the post-installed mechanical anchor system. The MPII shall include information on storage conditions and all restrictions on installation conditions.

1.4.19 Pullout Capacity: The strength corresponding to an anchoring device or a major component of the device sliding out from the masonry without breakout out a substantial portion of the surrounding masonry.

1.4.20 Pullout Failure: Failure mode in which the anchor pulls out of the masonry without development of the full steel or masonry capacity.

1.4.21 Pull-Through Failure: Failure mode in which the anchor body pulls through the expansion mechanism without development of the full steel or masonry capacity.

1.4.22 Report: Document containing information related to the mechanical anchor being evaluated.

1.4.22.1 Assessment: Report prepared in accordance with the requirements of Section 2.2.1 as the basis for an Evaluation Report.

1.4.22.2 Evaluation: Report issued by ICC-ES in accordance with this acceptance criteria.

1.4.22.3 Test: Report prepared in accordance with Section 2.3 to describe testing performed to support the assessment of a product in accordance with this acceptance criteria.

1.4.23 Residual Capacity: Ultimate static test capacity of an anchor (tension or shear) after Reliability or Service Condition tests have been completed.

1.4.24 Screw Anchor: Post-installed anchor that is a threaded mechanical fastener placed in a predrilled hole; anchor derives its tensile holding strength from the mechanical interlock of the fastener threads with the grooves cut into masonry during installation.

1.4.25 Setting Of An Anchor: Process of activating the load-transfer mechanism of an anchor in a drilled hole.

1.4.26 Static Load: In testing, load applied quasi-statically to failure complying with ASTM C1892.

1.4.27 Statistically Equivalent: Two groups of test results shall be considered statistically equivalent if there are no significant differences between the means of the two groups. Statistical equivalence shall be demonstrated using a two-one-sided t-test (TOST) in accordance with ASTM E2935 at a significance α = 0.10 for an assumed symmetrical equivalence limit E = 15%. For this purpose, the equivalence or nonequivalence of variances shall be established with the F-test or with Levene's test with α = 0.10.

1.4.28 Steel Failure: Failure of the anchor characterized by fracture of the anchor element.

1.4.29 Test Member: The masonry member receiving anchors to be tested.

1.4.30 Test Series: A group of identical anchors tested under identical conditions. Identical anchors originate from the same batch, use identical anchor elements, and are installed with identical equipment. Identical conditions are diameter, length, embedment, spacing, edge distance, masonry type, test member thickness, and masonry strength.

1.4.31 Torque-Controlled Expansion Anchor: Post-installed expansion anchor that is set by the expansion of one or more sleeves or other elements against the sides of the drilled hole through the application of torque, which pulls the mandrel(s) into the expansion sleeve(s); after setting, tensile loading may cause additional expansion (follow-up expansion).

1.4.32 Ultimate Load: The maximum load recorded in a test.

1.4.33 Uncracked Masonry

1.4.33.1 For design purposes, uncracked masonry conditions may be assumed where analysis indicates no cracking ($f_t < f_r$) in the vicinity of the anchor due to service loads or deformations, including wind and seismic loading, over the service life of the anchorage, where f_r is defined in TMS 402/ACI 530/ASCE 5-11 Section 3.1.8, TMS 402/ACI 530/ASCE 5-13 Section 9.1.9, and TMS 402-16 Section 9.1.9.

1.4.33.2 For testing and assessment purposes, a masonry test member that is uncracked at the anchor location at the beginning of the test.

1.4.34 Undercut Anchor: Post-installed anchor that develops its holding strength from the mechanical interlock provided by undercutting of the masonry, achieved either by a special tool or by the anchor itself during installation.

1.5 Notations: Notations included in the IBC, IRC, ACI 318, ACI 355.2 and AC193 are applicable to this criteria. In addition, the following notation also applies:

$A_{se,N}$ = effective cross-sectional area of anchor in tension, in.^{2} (mm^2)

$A_{se,V}$ = effective cross-sectional area of anchor in shear in.^{2} (mm^2)

$c_{a,\min}$ = minimum edge distance permitted with a reduced capacity for grouted CMU construction ($c_{a,\min,g}$); for ungrouted CMU construction ($c_{a,\min,ug}$); and for brick masonry construction ($c_{a,\min,br}$), in. (mm)

c_{cr} = least edge distance permitted to consider full capacity of an individual anchor for grouted CMU construction ($c_{cr,g}$); ungrouted CMU construction ($c_{cr,ug}$); and for brick masonry construction ($c_{cr,br}$), in. (mm)

$c_{HJ,test}$ = tested distance from the center of the head joint, in. (mm) (See Sections 5.2.2.2 and 7.4.2.4 for illustration.)

$c_{\min,HJ}$ = minimum distance from the head joint desired for qualification, in. (mm) (See Sections 5.2.2.2 and 7.4.2.4 for illustration.)

d_a = nominal outside diameter of post-installed anchor, in. (mm)

d_o = nominal diameter of drilled hole in the masonry, in. (mm)

E = Effect of horizontal $\left(E_h\right)$ and vertical $\left(E_v\right)$ earthquake-induced forces

F_k = characteristic capacity for a test series, calculated in accordance with Eq. (8-10), lb. (N)

$F_{u,test,i}$ = mean anchor capacity as determined from test series i lb. (N)

$\bar{F}_x$ = mean capacity of test series x, lb. (N)

f'_m = specified 28-day compressive strength of masonry, psi (MPa)

f'_g = specified 28-day compressive strength of grout, psi (MPa)

$f_{b,i}$ = unit compressive strength corresponding to reported masonry strength i, psi (MPa)

$f_{b,i(28+)}$ = ASTM C140 unit compressive strength tested at or beyond 28 days from manufacture, psi (MPa)

$f_{b,i(t)}$ = unit compressive strength at age t, in days, of grout during testing, psi (MPa)

$f_{b,test,x}$ = unit compressive strength tested in accordance with ASTM C140 for series x, psi (MPa)

$f_{g,i}$ = grout compressive strength corresponding to reported masonry strength i, psi (MPa)

$f_{g,i(28)}$ = best-fit (i.e., calculated, not tested) 28-day grout compressive strength using least-square regression of ASTM C1019 test data in Eq. (8-1), psi (MPa)

$f_{g,i(t)}$ = grout compressive strength at age t, in days, of grout during testing, psi (MPa)

$f_{g,test,x}$ = grout compressive strength tested in accordance with ASTM C1019 for series x psi (MPa)

f_m = masonry compressive strength, psi (MPa)

f_r = masonry modulus of rupture, psi (MPa); defined in TMS 402/ACI 530/ASCE 5-11 Section 3.1.8, TMS 402/ACI 530/ASCE 5-13 Section 9.1.9, and TMS 402-16 Section 9.1.9

f_t = masonry tensile strength, psi (MPa)

$f_{ut,test}$ = mean ultimate tensile strength of anchor steel as determined by test, psi (MPa)

f_{uta} = minimum specified tensile strength of threaded rod, psi (MPa)

h_b = effective embedment depth of the anchor element installed in the face shell of the unit, measured from the masonry surface to the face-shell-to-grout interface, in. (mm)

h_{ef} = the effective embedment depth for expansion, undercut, and screw anchors as illustrated in Figure 1.5, in. (mm)

= $0.85(h_{nom} - 0.5h_t - h_s)$ for screw anchors as illustrated in Figure 1.5, in. (mm)

h_{nom} = distance between the embedded end of the expansion, undercut, or screw anchor and the masonry surface, in. (mm)

h_g = effective embedment depth of the anchor element installed in grout, measured from the face-shell-to-grout interface to the effective embedment depth, in. (mm)

h_o = depth of drilled hole, in. (mm)

$h_{o,\max}$ = maximum permissible depth of drilled hole, in. (mm)

= $t_{wall} - \Delta_h$

h_s = length of the embedded end of the screw anchor without full height of thread (= thread runout + length without thread), in. (mm)

h_t = thread pitch, in. (mm)

K = tolerance factor corresponding to a 5 percent probability of non-exceedance with a confidence of 90 percent derived from a noncentral t distribution for which the population standard deviation is unknown (values for specific samples sizes n are provided in Table 8.1)

k = effectiveness factor

l_{brick} = greatest length of brick in installed condition; orthogonal to axis of anchor installation in the face of the masonry wall, in. (mm)

N_{eq} = maximum tensile load to be applied in the simulated seismic tension test, lb. (N)

N_{int} = intermediate tensile load to be applied to in the simulated seismic tension test, lb. (N)

N_k = characteristic tensile capacity of an anchor, i.e., the 5-percent fractile of test results, lb. (N)

$N_{k,i}$ = characteristic tensile capacity from reliability test series in masonry batch or test member i calculated in accordance with Eq. (8-10), lb. (N)

$N_{k,o}$ = characteristic tensile capacity of an anchor in reference test series, lb. (N)

$N_{k,o,i}$ = characteristic tensile capacity from reference test series in masonry batch or test member i calculated in accordance with Eq. (8-10), lb. (N)

$N_{k(cr,uncr)}$ = characteristic capacity in cracked or uncracked masonry, respectively, lb. (N)

$N_{k,seis(cr,uncr)}$ = seismic tensile capacity, lb. (N)

N_m = minimum tensile load to be applied to an anchor in the simulated seismic tension test, lb. (N)

$\overline{N}_{o,i}$ = mean tensile capacity as determined from reference test series in masonry batch i

N_p = characteristic tensile pullout capacity of an anchor, lb. (N)

N_{sa} = characteristic steel tensile capacity of an anchor, lb. (N)

$N_{st,mean}$ = average ultimate steel capacity determined from tensile tests on full-sized anchor specimens, lb. (N)

N_{u,f_m} = peak load measured in a tension test normalized by relevant material properties, lb. (N)

$N_{u,resid}$ = peak residual load measured after conduct of applicable service condition tests, lb. (N)

$N_{u,test}$ = peak load measured in a tension test, lb. (N)

$\overline{N}_{u,i}$ = mean tensile capacity for reliability test series conducted in masonry batch i, lb. (N)

N_w = tensile load applied to anchor during crack width cycling, lb. (N)

n = number of replicates in a test series, number of anchors in an anchor group

$s_{\min}$ = minimum spacing permitted for consideration of multiple anchor capacities in ungrouted CMU construction ($s_{\min,ug}$) and brick masonry construction ($s_{\min,br}$), in. (mm). Refer to Section 3.4.2.2.2 and Section 3.6.2.2.2 for ungrouted CMU and brick construction, respectively.

T_{inst} = specified tightening torque for setting or prestressing of an anchor in accordance with the MPII, ft-lb (kN-m)

T_{screw} = specified maximum installation torque required for setting a screw anchor in accordance with the MPII, ft-lb (kN-m)

t_{brick} = actual thickness of brick unit in installed condition; parallel to axis of anchor installation, in. (mm)

t_f = thickness of face shell, in. (mm)

t_{wall} = actual thickness of wall in installed condition; parallel to axis of anchor installation, in. (mm)

V_{eq} = maximum shear load to be applied in the simulated seismic shear tests, lb. (N)

V_{int} = intermediate shear load to be applied in the simulated seismic shear tests, lb. (N)

V_m = minimum shear load to be applied in the simulated seismic shear tests, lb. (N)

V_{sa} = characteristic shear capacity corresponding to shear failure, lb. (N)

$V_{s,seis}$ = seismic shear capacity as governed by steel failure, lb. (N)

v_x = sample coefficient of variation for test series x equal to the sample standard deviation divided by the mean, percent

w_{str} = length of stretcher leg as pictured in Figures 5.2 and 7.2 in. (mm)

α = ratio of reliability to reference tensile test results

α_{cat2} = additional reduction factor for Anchor Category 2

α_{cr} = ratio of cracked to uncracked tensile capacity in the bed joint (i.e., $\tau_{k,1e} / \tau_{k,1b}$)

α_{fm} = normalization factor accounting for masonry composite strength

α_{futa} = normalization factor accounting for steel strength

$\alpha_{req,cat2}$ = α_{req} corresponding to Anchor Category 2 for corresponding reliability test

$\alpha_{masonry}$ = reduction factor for the inhomogeneity of masonry materials in breakout and pullout strength determination

α_{top} = ratio of cracked to uncracked tensile capacity in top-of-wall tests (i.e., $\tau_{k,1e} / \tau_{k,1b}$)

Δ = anchor displacement within a test, in. (mm)

Δ_h = minimum of 1.5 in. (38 mm) for grouted CMU construction; minimum of 1 in. (25 mm) for solid CMU and solid brick units

Δ_w = change in crack width, in. (mm)

$\Delta_{0.3}$ = displacement at $N = 0.3N_u$, in. (mm)

ϕ = strength reduction factor for masonry failure and steel failure modes corresponding with the Anchor Category

Ω_o = amplification factor to account for overstrength of the seismic-force-resisting system determined in accordance with the general building code.

2.0 Basic information

2.1 General—The following information shall be submitted:

2.1.1 Product description: Anchors shall be described as to:

2.1.1.1 Generic or trade name.

2.1.1.2 Manufacturer's catalog number.

2.1.1.3 Nominal thread size.

2.1.1.4 Nominal anchor or sleeve diameter.

2.1.1.5 Anchor length.

2.1.1.6 Permitted manufacturing tolerances.

2.1.1.7 Basic materials, including appropriate physical properties before and after manufacture and protective coatings, shall be described. If the anchor consists of component parts involving different materials, differences shall be noted.

2.1.1.8 Appropriate National Standards for the Materials of the Anchors: Reports of physical properties for materials used in test specimens shall be submitted. The reports shall be generated by a mill or accredited testing laboratory. Where actual material strength exceeds the specified strength, test results shall be normalized to the specified minimum strength of the anchor material. Where no physical property specification exists, acceptable properties for quality control purposes shall be established by physical property tests.

2.1.2 Manufacturer's Printed Installation Instructions (MPII): Manufacturer's Printed Installation Instructions for installation and application for all covered installation conditions as supplied with product packaging shall be submitted.

2.1.3 Packaging and Identification: Information on anchor packaging and identification shall be determined and reported in accordance with Section 2.1.4. The methods of packaging shall be described. The manufacturer's name or insignia and the anchor types and size shall be marked either directly on the anchor or on the packaging units. The evaluation report number (ESR-XXXX) shall appear on the packaging units. Product identification shall be in accordance with the product identification provisions of the ICC-ES Rules of Procedure for Evaluation Reports.

2.1.4 Requirements For Anchor Identification:

2.1.4.1 Determination of Critical Characteristics of Anchors*:* The anchor manufacturer, in consultation with the ITEA, shall determine the characteristics affecting the identification and performance of the anchor being evaluated. These characteristics may include, but are not limited to, dimensions, constituent materials, surface finishes, coatings, fabrication techniques, and the marking of the anchors and components.

2.1.4.2 Specification of Critical Characteristics of Anchors*:* The manufacturer shall include in the drawings and specifications for the anchor those characteristics determined to be critical.

2.1.4.3 Verification of Conformance To Drawings And Specifications:

2.1.4.3.1 The following characteristics shall be checked by the independent testing and evaluation agency for conformance to the drawings and specifications:

1. Critical dimensions
2. Surface finishes
3. Coatings
4. Fabrication techniques
5. Markings

2.1.4.3.2 Constituent Materials: Critical constituent materials shall be checked by the independent testing and evaluation agency for conformance to mechanical and chemical specifications using certified mill test reports for steels and using similar certified documents for other materials. The reported ultimate strength for anchors for which the ratio of mean tensile strength to mean yield strength exceeds 1.9, or for which the specified tensile strength of the steel exceeds 125,000 psi (862 MPa), shall be limited in accordance with Chapter 17 of ACI 318-19 and 318-14.

2.1.4.3.3 Length identification: Every anchor, if available in more than one length per anchor diameter, shall be marked with the actual numerical length or with a length marking that is visible and legible after installation, according to Table 2.1.

2.1.4.3.4 Durability: When anchors are evaluated for exterior exposure or damp environments, evidence of durability shall be submitted. The steel shall be corrosion-resistant, stainless, or zinc-coated steel. The zinc coating shall be either hot-dipped in accordance with ASTM A153 Class C or D; mechanically deposited in accordance with ASTM B695 with a Class 55 coating having a minimum thickness of 2.1 mils (0.053 mm); or demonstrated through tests to be equivalent to the coatings previously described in this sentence.

2.1.4.3.5 Classification of Anchor Steel as Ductile or Brittle: Tension tests on anchor steel elements shall be conducted in accordance with Table 2.2. Classification of anchors as ductile or brittle shall be made in accordance with Table 2.3 and reported on the data sheet (Section 10).

2.1.4.3.6 Qualification Test Plan: A qualification test plan shall be submitted to and approved by the ICC-ES staff prior to any testing being conducted.

2.2 Conduct of Testing and Assessment:

2.2.1 Requirements for the Independent Testing and Evaluation Agency:

The testing and assessment of anchors under this criteria shall be performed by an Independent Testing and Evaluation Agency (ITEA) or Designated Testing Laboratory that is accredited as a testing laboratory conforming to ISO/IEC 17025 by an accreditation body that is a signatory to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement. The ITEA's accreditation shall include testing and evaluation of anchors in accordance with ASTM C1892, ICC-ES AC193, ACI 355.2, and this criteria.

Subject to prior approval by the ICC-ES, the assessment may also be performed by a separate Evaluation Agency, not engaged in the production or distribution of anchors, having several years of documented experience in the evaluation (assessment) and conduct of testing of anchors.

If the testing is performed by one or more ISO/IEC 17025 accredited laboratories, the ITEA or the separate Evaluation Agency shall be responsible for overseeing the development of the test program, the conduct of the tests, and shall also be responsible for ensuring that all test results are preserved and included in the evaluation.

2.2.2 Testing Laboratories: As a source of test reports, testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.2.3 Testing by the ITEA and Manufacturer:

2.2.3.1 The required minimum sample size of reference, reliability, and service-condition test numbers given in Table 4.1 through Table 4.4 of this Acceptance Criteria shall be performed by the ITEA (Section 2.2.1) or Designated Testing Laboratory. The testing laboratory shall verify that all elements of the test program and analysis are in compliance with this Acceptance Criteria document. The testing laboratory shall conduct or directly verify all testing procedures. Test reports and assessment reports shall be signed by a registered design professional employed or retained by the ITEA.

2.2.3.2 At the discretion of the ITEA, results of additional tests performed by the manufacturer may be considered in the evaluation to those of the ITEA. Such tests shall be conducted with anchors shall be witnessed by the ITEA for conformance with the requirements of this criteria in accordance with Section 2.2.1, and the results shall be shown to be *statistically equivalent* (see Section 1.4.28) to those of the ITEA.

2.3 Test reports: Test reports shall comply with the ICC-ES Acceptance Criteria for Test Reports (AC85) as well as the following, as applicable:

2.3.1 Test reports shall be approved by a registered design professional.

2.3.2 All reporting requirements described in ASTM C1892-20 Section 14.

2.3.3 Reporting requirements prescribed within this acceptance criteria, including:

- Verification of compliance/non-compliance with the “Assessment of results” sections for individual tests.
- Verification that test specimen sampling complies with Section 2.4.
- Manufacturer’s Printed Installation Instructions, including minimum hole cleaning procedures and equipment.
- Section 4.6.1 for masonry requirements
- Section 4.6.2 for test member requirements
- Section 4.6.3 for anchor installation requirements
- Section 4.6.4 for drill bit requirements
- Identification of the test standard used and the date of issue of the standard, and other relevant information concerning the test procedure, justification for any deviations from the referenced test standard, and any critical information relevant to the specific test.
- Mode of failure for each test specimen, e.g., steel rupture masonry cracking, masonry splitting, masonry breakout, anchor pullout, etc.
- Photographs of the test setup and typical failure modes.

2.3.4 Masonry properties: The test report shall describe the masonry properties as set forth in Sections 4.6.1 and 4.6.2 of this acceptance criteria.

2.4 Product sampling: Sampling of the anchors for tests under this criteria shall comply with Section 3.1, 3.3, and 3.4 of AC85 or equivalent.

2.4.1 For anchors in production, the Independent Testing and Evaluation Agency or accredited representative shall visit the manufacturing or distribution facility, shall randomly select anchors for testing, and shall verify that the samples are representative of the production of the manufacturer as supplied to the marketplace. The product characteristics shall be within the tolerance limits reported in the quality documentation and the relevant standards.

2.4.2 To test newly developed anchors that are not in production, use samples produced by the expected production methods. After production has begun, perform identification and reference tests to verify that the constituent materials have not changed and that the performance of the production anchors is statistically equivalent to or greater than that of the anchors originally evaluated.

2.4.3 When internally threaded anchors are supplied without fastening items such as bolts, the manufacturer shall specify the bolts to be used. To achieve masonry breakout or anchor pullout failure, it shall be permitted to use bolts of higher strength than those specified provided that the higher-strength bolts do not change the functioning, setting, or follow-up expansion of the anchors.

2.4.4 For anchor systems manufactured with different production methods or supplied with different materials, pretensioning mechanisms, and/or coatings, perform the torque test in accordance with Section 7.10. If the results do not meet the requirements of 7.10, perform the complete test program for each anchor material, coating, production method, or pretensioning application mechanism.

2.5 Data analysis—Perform analysis in accordance with prescribed procedures for individual tests within this criteria. Documents containing analysis of data shall be sealed by a registered design professional.

2.6 Changes to products— Prior to modifying a mechanical anchor system previously assessed in accordance with AC01, the manufacturer shall report the nature and significance of the change in the system to the ITEA serving as the primary laboratory for the original assessment and to ICC-ES. The ITEA shall determine which tests, if any, shall be performed to determine whether the change in the mechanical anchor system is equivalent to the previously assessed mechanical anchor system. For all changes that might affect the anchor performance, the ITEA or Designated Testing Laboratory shall perform a sufficient number of reference and reliability tests to assess the impact of the change. Test results shall be shown to be *statistically equivalent* to or greater than those of the originally tested product. If the results of the reference and reliability tests cannot be shown to be statistically equivalent to or greater than the results of the original testing, retest and evaluate the modified mechanical anchor system in accordance with the full relevant test program in accordance with AC01.

2.6.1 Tests for determining equivalence of expansion and undercut anchors with multiple production methods, materials, coatings, or prestressing mechanisms (for example, bolt versus nut or other mechanism that that pretensions the bolt at the surface of the masonry) shall be conducted as follows.

2.6.1.1 Determine the pretensioning forces in the anchors with multiple production methods, materials, coatings, or prestressing mechanisms in accordance with the procedure of 7.10.2 at 0.5 T_{inst} and T_{inst} of the anchors of the same diameters and embedment depths. The torques may be different to elicit the same pretensioning force.

2.6.1.2 *Requirement*—Reference and shear tests and, optionally, seismic tests shall be performed on the anchors with multiple production methods, materials, coatings, or prestressing mechanisms and the results shall be statistically equivalent to or greater than the original product.

2.6.1.3 *Requirement*—Reliability and service condition tests may be omitted if all of the following conditions are met:

2.6.1.3.1 Prestressing forces at $0.5T_{inst}$ and T_{inst} demonstrate statistical equivalence between the original and changed product.

2.6.1.3.2 The geometry of the anchors is identical other than the head configuration.

2.6.1.3.3 *For torque-controlled expansion anchors*, the friction between cone and sleeve (internal friction) and the friction between sleeve and masonry (external friction) are identical. This condition shall be considered fulfilled if the anchors are composed of the same material, any coatings are the same, and the surface roughness and hardness of the cone and the sleeve are functionally equivalent.

2.6.1.3.4 *For displacement-controlled expansion anchors*, the degree of expansion of partial and reference expansion are functionally equivalent or greater than the original.

2.6.1.3.5 *For undercut anchors*, the undercut of the masonry shall be identical in the original and changed products for full and partial expansion. In addition, an undercut anchor that exhibits follow-up expansion during loading shall comply with the requirements for torque-controlled expansion anchors in 2.6.1.3.3.

2.6.1.4 If the requirements of 2.6.1.2 and 2.6.1.3 are not met, test the anchors with new combinations of production methods, materials, coatings, or prestressing mechanisms in accordance with Table 4.1 through 4.4 as applicable.

2.6.2 Tests for determining the equivalence of screw anchors with multiple production methods, materials, or coatings shall be conducted as follows:

2.6.2.1 For screw anchors with multiple production methods, materials, or coatings, establish a maximum setting torque, T_{screw}. Perform testing in accordance with the procedures of Section 6.10 on screw anchors of the same diameters and embedment depths.

2.6.2.2 *Requirement*—Maximum setting torque, T_{screw}, shall comply with the requirements of Section 6.10.

2.6.2.3 *Requirement*—The tests shown in Table 2.4 shall be performed on the screw anchors with multiple production methods, materials, or coatings and shall show statistical equivalence to or greater performance than the original product.

2.6.2.4 If the requirements of 2.6.2.2 and 2.6.2.3 are not met, test the screw anchors with multiple production methods, materials, or coatings in accordance with Tables 4.1 through 4.4, as applicable.

3.0 ANCHOR STRENGTH DESIGN

3.1 Design basis: Anchors shall be designed in accordance with the strength design provisions provided in this section.

3.1.1 The strength design of mechanical anchors as described in Section 3.3 is derived substantially from the provisions for post-installed anchors in concrete as contained in ACI 318. This procedure also applies to the design of mechanical anchors in the grouted cells of partially grouted CMU construction (where the location of the grouted cells is known).

3.1.2 The strength design of anchors in ungrouted CMU construction shall be in accordance with Section 3.4. Where the location of grouted cells in partially grouted CMU construction is unknown, all anchors installed in the wall shall be designed in accordance with Section 3.4.

3.2 General Notes and Modifications:

3.2.1 This acceptance criteria references sections, tables, and figures in both this acceptance criteria and ACI 318. Refer to Section 1.2.2 for an explanation of the differentiation between references to these two documents.

3.2.2 Where language from ACI 318 is directly referenced, the following modifications generally apply:

(a) The term “masonry” shall be substituted for the term “concrete” wherever it occurs.

(b) The modification factor to reflect the reduced mechanical properties for mixtures with lightweight aggregate and lightweight units, λ_a, shall be taken as 1.0.

(c) Unless specifically amended by this section, design provisions shall also apply to screw anchors.

(d) In addition to ACI *318 Section 2.2 (Section 2.2 or Section D.1)*, the following definitions shall be used:

masonry, fully grouted—*Concrete masonry unit (CMU) construction in which all cells or spaces are filled with grout.*

Masonry, partially grouted— *Concrete masonry unit (CMU) construction in which designated cells or spaces are filled with grout, while other cells or spaces remain ungrouted.*

Masonry, ungrouted—*Concrete masonry unit (CMU) construction in which none of the cells or spaces are filled with grout.*

Masonry, brick—*Clay brick masonry construction.*

3.2.3 Subsequent sections within this chapter address the design of post-installed anchors in masonry:

- Section 3.3: Strength design in fully grouted concrete masonry unit construction (covering both closed- and open-ended units)
- Section 3.4: Strength design in ungrouted concrete masonry unit construction
- Section 3.5: Strength design in partially grouted concrete masonry unit construction
- Section 3.6: Strength design in brick masonry construction
- Section 3.7: Conversion of strength design capacities to allowable stress design capacities

3.3 Strength Design of Mechanical Anchors in Fully Grouted Concrete Masonry Unit Construction— Strength design of post-installed anchors in fully grouted concrete masonry unit construction shall be conducted in accordance with the provisions for the design of post-installed anchors in concrete in *ACI 318-11 Appendix D, ACI 318-14 Chapter 17 or ACI 318-19 Chapter 17* as modified by this section. Design in accordance with this document cannot be conducted without reference to *ACI 318 (-19, -14 or -11)* with the deletions and modifications summarized in Table 3.1.

3.3.1 *General notes and modifications*—The notes and modifications within this subsection shall apply throughout the design provisions.

3.3.1.1 The following terms shall be replaced wherever they occur:

***ACI 318-11/14/19* term**	**Replacement term**
f'_c	f'_m
N_{cb} , N_{cbg}	N_{mb} , N_{mbg}
$N_{pn} = \psi_{m,P} N_p$	$N_{pn} = \psi_{m,P} N_p$
V_{cb} , V_{cbg}	V_{mb} , V_{mbg}
V_{cp} , V_{cpg}	V_{mp} , V_{mpg}

3.3.1.2 Edge assumptions for design purposes and restrictions for anchor placement are illustrated in Figure 3.2. For CMU construction with hollow head joints (Section 1.4.14.1), in addition to the ends and edges of walls, the nearest head joint on a horizontal projection from the anchor shall be treated as an edge for design purposes. The minimum distance from the nearest adjacent head joint shall be determined by testing in accordance with Section 7.4 and, optionally, 7.5. For anchor groups installed in CMU construction with solid head joints (Section 1.4.14.2), the nearest head joint outside of the group on a horizontal projection to the group shall be treated as an edge. If open-ended units are employed, only the ends and edges of walls shall be considered for edge distance determination. For horizontal ledgers in fully-grouted CMU walls with hollow head joint applications, see Section 3.3.2.24.

3.3.2 Specific modifications: Table 3.1 provides a summary of all applicable *ACI 318-11 Appendix D, ACI 318-14* and *ACI 318-19* sections for the design of post-installed mechanical anchors in fully grouted masonry. Where applicable, modifying sections contained within this document are also provided.

3.3.2.1 *ACI 318 Section 17.1.1 and 17.1.5 (Section 17.1.1-17.1.2* or *Section D.2.3-D.2.4) apply with the general changes prescribed in Section 3.2.2.*

3.3.2.2 *In lieu of ACI 318 Section 17.1.2 (Section 17.1.3* or *Section D.2.3):* Design provisions are included for post-installed expansion (torque-controlled and displacement-controlled), undercut, and screw anchors that meet the assessment criteria of AC01.

3.3.2.3 *ACI 318 Section 17.1.4, 17.2.1 and 17.4.1 (Section 17.1.4-17.2.2 or Section D.2.4-D.3.2) apply with the general changes prescribed in Section 3.2.2.*

3.3.2.4 *In lieu of ACI 318 Section 17.4.2 (Section 17.2.3 or Section D.3.3)*: The design of anchors in structures assigned to Seismic Design Category (SDC) C, D, E, or F shall satisfy the requirements of this section.

3.3.2.4.1 The design of anchors in the plastic hinge zones of masonry structures under earthquake forces is beyond the scope of this acceptance criteria.

3.3.2.4.2 The anchor or group of anchors shall be designed for the maximum tension and shear obtained from the design load combinations that include E , with E_h increased by Ω_o . The anchor design tensile strength shall satisfy the tensile strength requirements of 3.3.2.4.3.

3.3.2.4.3 The anchor design tensile force for resisting earthquake forces shall be determined from consideration of (a) through (c) for the failure modes given in Table 3.2 assuming the masonry is cracked unless it can be demonstrated that the masonry remains uncracked.

a) $\boldsymbol{\phi N_{sa}}$ for a single anchor, or for the most highly stressed individual anchor in a group of anchors
b) 0.75 $\boldsymbol{\phi N_{mb}}$ or 0.75 $\boldsymbol{\phi N_{mbg}}$
c) 0.75 ~~$\boldsymbol{\phi N_{ma}}$~~ <u>$\boldsymbol{\phi N_{pn}}$</u> ~~or 0.75 $\boldsymbol{\phi N_{mag}}$~~<u>for a single anchor, or for the most highly stressed individual anchor in a group of anchors</u>

where ϕ is in accordance with 3.3.2.9.

3.3.2.5 *ACI 318 Section 17.3.1 (Section 17.2.7 or Section D.3.7) applies with the general changes prescribed in Section 3.2.2.*

3.3.2.6 *In lieu of ACI 318 Section 17.5.2 (Section 17.3.1.1 or Section D.4.1.1)*: The design of anchors shall be in accordance with Table 3.2. In addition, the design of anchors shall satisfy 3.3.2.4 for earthquake loading.

3.3.2.7 *ACI 318 Section 17.5.2.3 (Section 17.3.1.3 or Section D.4.1.3)* applies with the general changes prescribed in Section 3.2.2.

3.3.2.8 *ACI 318 Section 17.5.1.2 excluding Section 17.5.2.1 (Section 17.3.2 excluding Section 17.3.2.1 or Section D.4.2 excluding Section D.4.2.1*) applies with the general changes prescribed in Section 3.2.2**.**

3.3.2.9 *In lieu of ACI 318 Section 17.5.3 (Section 17.3.3 or Section D.4.3)*: Strength reduction factor ϕ for anchors in masonry shall be as follows when the load combinations of ~~the legally adopted building code for strength design~~<u>LRFD load combinations of ASCE 7</u> are used:

a) For steel capacity of ductile steel elements as defined in AC01 Section 2.1.4.3.5, ϕ shall be taken as 0.75 in tension and 0.65 in shear. Where the ductility requirements of AC01 Section 2.1.4.3.5 are not met, ϕ shall be taken as 0.65 in tension and 0.6 in shear.

b) For shear crushing capacity ϕ shall be taken as 0.50.

c) For cases where the nominal strength of anchors in masonry is controlled by masonry breakout or pullout strength in tension, ϕ shall be taken as 0.65 for anchors qualifying for Category 1 and 0.55 for anchors qualifying for Category 2 in Section 8.5.4.

d) For cases where the nominal strength of anchors in masonry is controlled by masonry failure modes in shear, ϕ shall be taken as 0.70.

3.3.2.10 *ACI 318 Section 17.6.1 (Section 17.4.1 or Section D.5.1) applies with the general changes prescribed in Section* 3.2.2.

3.3.2.11 *In lieu of ACI 318 Section 17.6.2.1 (Section 17.4.2.1 or Section D.5.2.1):* The nominal breakout strength in tension, N_{mb} of a single anchor or N_{mbg} of a group of anchors, shall not exceed:

a) For a single anchor

$$N_{mb} = \frac{A_{Nm}}{A_{Nmo}} \psi_{ed,N,m} \cdot \psi_{c,N,m} \cdot N_{b,m} \qquad (17.6.2.1a)$$

b) For a group of anchors

$$N_{mbg} = \frac{A_{Nm}}{A_{Nmo}} \psi_{ec,N,m} \cdot \psi_{ed,N,m} \cdot \psi_{c,N,m} \cdot N_{b,m} \qquad (17.6.2.1b)$$

Factors $\psi_{ec,N,m}$, $\psi_{ed,N,m}$, $\psi_{c,N,m}$ are defined in *ACI 318 Section 17.6.2.3.1 (Section 17.4.2.4 or Section D.5.2.4)*, *ACI 318 Section 17.6.2.4 (Section 17.4.2.5 or Section D.5.2.5)*, and Section 3.3.2.14, respectively. A_{Nm} is the projected masonry failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward 1.5 h_{ef} from the centerlines of the anchor, or, in the case of a group of anchors, from a line through a row of adjacent anchors. A_{Nm} shall not exceed $n \cdot A_{Nmo}$, where n is the number of anchors in the group that resist tension. A_{Nmo} is the projected masonry failure area of a single anchor with an edge distance equal to or greater than 1.5 h_{ef}.

$$A_{Nmo} = 9h_{ef}^2 \qquad (17.6.2.1.4)$$

3.3.2.12 *In lieu of ACI 318 Section 17.6.2.2.1 (Section 17.4.2.2 or Section D.5.2.2):* The basic masonry breakout strength of a single anchor in tension in cracked masonry, $N_{b,m}$ shall not exceed

$$N_{b,m(cr,uncr)} = k_{m(cr,uncr)} \sqrt{f'_m}\, h_{ef}^{1.5} \qquad (17.6.2.2.1)$$

where

$k_{m,cr}$ = effectiveness factor for breakout strength in cracked masonry

= $\alpha_{masonry} \cdot k_{c,cr}$

$k_{c,cr}$ = effectiveness factor for breakout strength in concrete

= 17; and

$\alpha_{masonry}$ = reduction factor for the inhomogeneity of masonry materials in breakout strength determination.

= 0.7

3.3.2.13 *ACI 318 Section 17.6.2.1.2, 17.6.2.3.1 and 17.6.2.4 (Section 17.4.2.3-17.4.2.5 or Section D.2.5.2.3-D.5.2.5)* apply with the general changes prescribed in Section 3.2.2**.**

3.3.2.14 *In lieu of ACI 318 Section 17.6.2.5.1(a) (Section 17.4.2.6 or Section D.5.2.6):* For anchors located in a region of a masonry member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted:

$\psi_{c,N,m} = 1.4$ for post-installed anchors, where the value of k_m is 11.9.

3.3.2.15 *ACI 318 Section 17.6.2.6 (Section 17.4.2.7 or Section D.5.2.7)* need not be considered since the modification factor for post installed anchors, ψ_{cp}, is not included in Eq. 17.6.2.1.

3.3.2.16 The following apply with the general changes prescribed in Section 3.2.2**:**

- *ACI 318 Section 17.6.2.1.3 (Section 17.4.2.8 or Section D.5.2.8)*
- *ACI 318 Section 17.5.2.1 (Section 17.4.2.9 or Section D.5.2.9)*

3.3.2.17 *In lieu of ACI 318 Section 17.6.3.1 (Section 17.4.3.1 or Section D.5.3.1):* The nominal pullout strength of a single post-installed expansion, undercut, and screw anchor in tension shall not exceed

$$N_{pn} = \psi_{m,P} N_p \qquad (17.6.3.1)$$

where $\psi_{m,P}$ is defined in 17.6.3.3.

3.3.2.18 *In lieu of ACI 318 Section 17.6.3.2.1 (Section 17.4.3.2 or Section D.5.3.2):* For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated in accordance with AC01 and shall not exceed the breakout strength calculated in accordance with Section 3.3.2.12 associated with f'_m.

3.3.2.19 *The* following apply with the general changes prescribed in Section 3.2.2**:**

- *ACI 318 Section 17.6.3.3 (Section 17.4.3.6 or Section D.6.1.1-D.6.2.2)*
- *ACI 318 Section 17.7.1.1-17.7.2.2 (Section 17.5.1.1-17.5.2.2 or Section D.6.1.1-D.6.2.2)*
- *ACI 318 Section 17.7.2.1.2, 17.7.2.3 and 17.7.2.4 (Section 17.5.2.4-17.5.2.6 or Section D.6.2.4-D.6.2.6)*

- *ACI 318 Section 17.7.2.6 (Section 17.5.2.8 or Section D.6.2.8)*
- *ACI 318 Section 17.7.3 (Section 17.5.3 or Section D.6.3)*
- *ACI 318 Section 17.8 (Section 17.6 or Section D.7)*
- *ACI 318 Section 17.9 (Section 17.7 or Section D.8)*
- *ACI 318 Section 26.13.1.5 and 26.13.2.5 (Section 17.8.1 or Section D.9.1)*

3.3.2.20 *In lieu of ACI 318 Section 17.7.2.5 (Section 17.5.2.7 or Section D.6.2.7)*: For anchors located in a region of masonry construction where *cracking* is anticipated, $\psi_{m,V}$ shall be taken as 1.0. For cases where analysis indicates no cracking at service load levels, it shall be permitted to take $\psi_{m,V}$ as 1.4.

3.3.2.21 *In lieu of ACI 318 Section 17.9 (Section 17.7 or Section D.8)*: Minimum edge distances and spacings shall be determined from tests in accordance with AC01 but shall not be less than the cover requirements of TMS 402/602.

3.3.2.22 *[In addition to the ACI 318 provisions]* For screw anchors with embedment depths $5d_a \le h_{ef} \le 10d_a$ and $h_{ef} \ge 1.5$ in, masonry breakout strength requirements shall be considered satisfied by the design procedures of *ACI 318 Sections 17.6.2 and 17.7.2 (Section 17.4.2 and 17.5.2 or Sections D.5.2 and D.6.2).*

3.3.2.23 *[In addition to the ACI 318 provisions] Masonry crushing strength for anchors in shear*—The nominal strength of an anchor in shear as governed by masonry crushing, V_{mc}, shall be calculated using Eq. (3-1).

$$V_{mc} = 1750\sqrt[4]{f'_m A_{se,V}} \qquad (3\text{-}1)$$

3.3.2.24 [In addition to the ACI 318 provisions] *Determination of shear capacity for bolts in horizontal ledgers in fully-grouted CMU walls with hollow head joint applications with an assumed masonry unit length of 16 inches, standard*— Where six or more anchor bolts are placed at uniform horizontal spacing in continuous wood or steel ledgers connecting floor and roof diaphragms to fully grouted CMU walls constructed with hollow head joints (using closed-end block), in lieu of Section 3.3.1.2, the horizontal and vertical shear capacity of the bolts shall be permitted to be calculated in accordance with Eq. (3-2) and Eq. (3-3), respectively.

$$v_{mb,horiz} = 0.75 \cdot V_{gov,horiz} \cdot \frac{12}{s_{horiz}} \text{ (plf or N/m)} \qquad (3\text{-}2)$$

$$v_{mb,vert} = 0.75 \cdot V_{gov,vert} \cdot \frac{12}{s_{horiz}} \text{ (plf or N/m)} \qquad (3\text{-}3)$$

where

s_{horiz} = horizontal anchor spacing in the ledger, (in). For anchor spacings that are multiples of 8 inches, locate the first anchor in the ledger at least 2 inches from the head joint and the center of the block. See Fig. 3.3. For other anchor spacings, minimum edge distance as specified in the evaluation report shall apply.

$V_{gov,horiz}$ = $\min(V_{sa}, V_{mb,4}, V_{mc}, V_{mp,4})$ (lb or N)

$V_{gov,vert}$ = $\min(V_{sa}, 2 \cdot V_{mb,4}, V_{mc}, V_{mp,4})$ (lb or N)

V_{sa} = shear capacity for a single bolt calculated in accordance with *ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2)* (lb or N)

$V_{mb,4}$ = breakout capacity for a single bolt with edge distance of 4 in. (lb or N)

V_{mc} = crushing capacity for a single bolt calculated in accordance with Eq. (3-1) (lb or N)

$V_{mp,4}$ = pryout capacity for a single bolt with edge distance of 4 in. (lb or N)

3.4 Strength design of qualified post-installed mechanical anchors in ungrouted concrete masonry unit construction

3.4.1 Scope: This section provides strength design requirements for anchors used in ungrouted concrete masonry unit construction, where anchors are used to transmit structural loads by means of tension, shear, or a combination of tension and shear.

3.4.2 General:

3.4.2.1 Anchors shall be designed for critical effects of factored loads as determined by elastic analysis. Plastic analysis approaches shall not be permitted.

3.4.2.2 Group effects shall not be considered. Dimensional requirements specified in Table 3.3 shall be observed for the design of individual anchors as follows:

3.4.2.2.1 The critical edge distance, $c_{cr,ug}$, is the smallest edge distance to consider full capacity of an individual anchor, and the minimum edge distance, $c_{a,\min,ug}$. For anchors installed with edge distances between $c_{cr,ug}$ and $c_{a,\min,ug}$, capacities shall be linearly interpolated. The minimum distance from hollow head joints (Section 1.4.14.1) shall be based on testing conducted in accordance with AC01 Section 7.4 and, optionally, 7.5 as illustrated in Figure 3.2.

3.4.2.2.2 For anchor spacings less than the minimum spacing, $s_{\min,ug}$, to consider contributions of multiple anchors, the strength of the group shall equal the strength of a single anchor.

3.4.3 Seismic design requirements: The design of anchors in structures assigned to Seismic Design Category (SDC) C, D, E, or F shall satisfy the requirements of this section.

3.4.3.1 The provisions of this chapter do not apply to the design of anchors in plastic hinge zones of masonry structures under earthquake forces.

3.4.3.2 The anchor or group of anchors shall be designed for the maximum tension and shear obtained from the design load combinations that include E, with E_h

increased by Ω_o. The anchor design tensile strength shall satisfy the tensile strength requirements of 3.4.3.3.

3.4.3.3 The anchor design tensile force for resisting earthquake forces shall be determined from consideration of (a) and (b) for the failure modes given in Table 3.4 assuming the masonry is cracked unless it can be demonstrated that the masonry remains uncracked.

- ϕN_{sa} for each anchor
- $0.75\phi N_{k,ug}$

where ϕ is in accordance with 3.3.2.9.

3.4.4 Strength design checks shall be in accordance with Table 3.4. In addition, the design of anchors shall satisfy 3.4.3 for earthquake loading.

3.4.5 The strength reduction factors, ϕ, prescribed in Section 3.3.2.9 shall be used for anchors in ungrouted masonry when the ~~load combinations of the legally adopted building code for strength design~~LRFD load combinations of ASCE 7 are used.

3.4.6 Design requirements for tensile loading:

3.4.6.1 Steel strength of anchors in tension: The provisions of *ACI 318 Section 17.6.1 (Section 17.4.1 or Section D.5.1)* shall apply.

3.4.6.2 Pullout strength of anchors in tension: The nominal pullout strength in tension, $N_{k,ug}$, shall be derived from assessment in accordance with Section 8.5.6.

3.4.7 Design requirements for shear loading:

3.4.7.1 Steel strength of anchors in shear: The nominal steel strength of an anchor in shear, V_{sa}, shall be determined in accordance with *ACI 318 Section 17.7.1.2b (Section 17.5.1.2b or Section D.6.1.2b)*

3.4.7.2 Anchorage strength in shear: The nominal strength of an anchor in shear, $V_{s,ug}$ shall be derived from assessment in accordance with AC01 Section 8.6.1.2.

3.4.7.3 Masonry crushing strength of anchors in shear: The nominal strength of an anchor in shear as governed by masonry crushing, $V_{mc,ug}$, shall be evaluated by Eq. (3-1).

3.4.8 Interaction of tensile and shear forces: Anchors designed for combinations of tensile and shear forces shall satisfy the provisions of *ACI 318 Section 17.8 (Section 17.6 or Section D.7)*.

3.4.9 Installation and inspection of anchors: The provisions of *ACI 318 Section 26.13.1.5 and 26.13.2.5 (Section 17.8.1 or Section D.9.1)* shall apply.

3.5 Strength design of qualified mechanical anchors in partially grouted masonry:

3.5.1 Scope: This section provides strength design requirements for anchors used in partially grouted concrete masonry unit construction, where anchors are used to transmit structural loads by means of tension, shear, or a combination of tension and shear.

3.5.2 In all cases, the minimum distance from hollow head joints (Section 1.4.14.1) shall be based on testing in accordance with AC01 Section 7.4 and, optionally, Section 7.5 as illustrated in Figure 3.2**.**

3.5.3 For cases where the location of grouted cells is known, the following provisions shall apply:

a) Group effects shall not be considered between anchors in grouted masonry and anchors in ungrouted masonry.

b) Anchors located in grouted cells shall be designed in accordance with Section 3.3, whereby the distance to the extent of the ungrouted cell shall be taken as a free edge as illustrated in Figure 3.4.

3.5.4 For cases where the location of grouted cells is unknown, the design of anchors shall be in accordance with Section 3.4.

3.6 Strength design of qualified mechanical anchors in clay brick masonry construction:

3.6.1 Scope: This section provides strength design requirements for anchors used in clay brick masonry construction, where anchors are used to transmit structural loads by means of tension, shear, or a combination of tension and shear.

3.6.2 General:

3.6.2.1 Anchors shall be designed for critical effects of factored loads as determined by elastic analysis. Plastic analysis approaches shall not be permitted.

3.6.2.2 Group effects shall not be considered. Dimensional requirements specified in Table 3.5 shall be observed for the design of individual anchors.

3.6.2.2.1 The critical edge distance, $c_{cr,br}$, is the smallest edge distance to consider full capacity of an individual anchor and the minimum edge distance, $c_{a,\min,br}$. For anchors installed with edge distances between $c_{cr,br}$ and $c_{a,\min,br}$, capacities shall be linearly interpolated.

3.6.2.2.2 For anchor spacings less than the minimum spacing, $s_{\min,br}$**,** to consider contributions of multiple anchors, the strength of the group shall equal the strength of a single anchor.

3.6.3 Seismic design requirements: The design of anchors in structures assigned to Seismic Design Category (SDC) C, D, E, or F shall satisfy the requirements of this section.

3.6.3.1 The design of anchors in the plastic hinge zones of masonry structures under earthquake forces is beyond the scope of this acceptance criteria.

3.6.3.2 The anchor or group of anchors shall be designed for the maximum tension and shear obtained from the design load combinations that include E, with E_h

increased by Ω_o. The anchor design tensile strength shall satisfy the tensile strength requirements of 3.6.3.3.

3.6.3.3 The anchor design tensile force for resisting earthquake forces shall be determined from consideration of (a) and (b) for the failure modes given in Table 3.6 assuming the masonry is cracked unless it can be demonstrated that the masonry remains uncracked.

- ϕN_{sa} for each anchor
- $0.75\phi N_{k,br}$

where ϕ is in accordance with 3.3.2.9.

3.6.4 Strength design checks shall be in accordance with Table 3.6. In addition, the design of anchors shall satisfy 3.6.3 for earthquake loading.

3.6.5 The strength reduction factors, ϕ, prescribed in Section 3.3.2.9 shall be used for anchors in ~~ungrouted~~ clay brick masonry when the ~~load combinations of the legally adopted building code for strength design~~LRFD load combinations of ASCE 7 are used.

3.6.6 Design requirements for tensile loading:

3.6.6.1 Steel strength of anchors in tension: The provisions of *ACI 318 Section 17.6.1 (Section 17.4.1 or Section D.5.1)* shall apply.

3.6.6.2 Pullout strength of anchors in tension: The nominal pullout strength in tension, $N_{k,br}$, shall be derived from assessment in accordance with 8.5.7.

3.6.7 Design requirements for shear loading:

3.6.7.1 Steel strength of anchors in shear: The nominal steel strength of an anchor in shear, V_{sa}, shall be determined in accordance with *ACI 318 Section 17.7.1.2b (Section 17.5.1.2b or Section D.6.1.2b).*

3.6.7.2 Anchorage strength in shear: The nominal strength of an anchor in shear, $V_{s,br}$, shall be derived from assessment in accordance with 8.6.1.3.

3.6.7.3 Brick crushing strength of anchors in shear: The nominal strength of an anchor in shear as governed by masonry crushing, $V_{mc,br}$, shall be evaluated by Eq. (3-1).

3.6.8 Interaction of tensile and shear forces: Anchors designed for combinations of tensile and shear forces shall satisfy the provisions of *ACI 318 Section 17.8 (Section 17.6 or Section D.7)*.

3.6.9 Installation and inspection of anchors: The provisions of *ACI 318 Section 26.13.1.5 and 26.13.2.5 (Section 17.8.1 or Section D.9.1)* shall apply.

3.7 Conversion of strength design to allowable stress design:

3.7.1 For post-installed anchors designed using Allowable Stress Design load combinations from the legally adopted building code shall be established using the equations below:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha} \tag{3-4}$$

and

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha} \tag{3-5}$$

where

$T_{allowable,ASD}$ = Allowable tensile load (lb. or N);

$V_{allowable,ASD}$ = Allowable shear load (lb. or N);

N_n = Lowest design strength of an anchor or anchor group in tension as determined in accordance with Table 3.2, Table 3.4, or Table 3.6, as applicable, and 2021, 2018 or 2015 IBC Section 1905.1.8 and 2012 IBC Section 1905.1.9;

V_n = Lowest design strength of an anchor or anchor group in shear as determined in accordance with Table 3.2, Table 3.4, or Table 3.6, as applicable, and 2021, 2018 or 2015 IBC Section 1905.1.8 and 2012 IBC Section 1905.1.9;

α = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α shall include all applicable factors to account for non-ductile failure modes and required overstrength; and

ϕ = relevant strength reduction factor for load case and Anchor Category.

3.7.2 Interaction shall be calculated in compliance *with ACI 318-11 Section D.7, ACI 318-14 Section 17.6* or *ACI 318-19 Section 17.8* as follows:

3.7.2.1 For shear loads $V \le 0.2V_{allowable,ASD}$, the full allowable load in tension shall be permitted.

3.7.2.2 For tensile loads $T \le 0.2T_{allowable,ASD}$, the full allowable load in shear shall be permitted.

3.7.2.3 For all other cases: $\frac{T}{T_{allowable}} + \frac{V}{V_{allowable}} \le 1.2$

4.0 GENERAL TESTING REQUIREMENTS

4.1 Test organization

4.1.1 Perform four types of tests in the following sequence:

- Identification tests to evaluate the anchor's compliance with the critical characteristics (Section 2.1.4)
- Reference tests to establish baseline performance against which subsequent tests are to be compared (Chapter 5)
- Reliability tests to confirm the reliability of the anchor under adverse installation procedures and long-term use (Chapter 6); and

- Service-condition tests to evaluate the performance of the anchor under expected service conditions (Chapter 7). When service-condition tests are performed by both the testing agency and the manufacturer, both entities shall perform at least the minimum number of required tests.

4.1.2 In addition, supplementary tests for multiple drilling methods are required on a conditional basis.

4.2 Variables and options

4.2.1 The assessment of a given anchor system in accordance with this criteria will involve consideration of the following system variables:

1. **Masonry types:** Options are limited to grouted CMU, ungrouted CMU, and brick masonry.
2. **Installation procedures**: Hole cleaning procedures specified in the anchor Manufacturer's Printed Installation Instructions (MPII).
3. **Drilling method**: The default drilling method employs a rotary hammer drill with a carbide bit. For other drilling methods (e.g., core drilling), refer to Section 4.4.
4. **Embedment depth and anchor diameter:** The anchor diameters and associated embedment depth range shall be specified by the manufacturer within the ranges permitted by this standard (Section 1.0).
5. **Anchor element type:** Anchor element types include torque-controlled expansion anchors, displacement-controlled expansion anchors, undercut anchors, and screw anchors with specified material types (e.g., carbon steel, stainless steel)
6. **Masonry condition**: Options are limited to cracked and uncracked masonry.
7. **Loading:** Default loading conditions are quasi-static loading. Qualification for seismic loading is optional in conjunction with qualification for cracked masonry (Sections 7.6 and 7.8).
8. **Drilling depth**: The maximum drilling depth, $h_{o,\max}$, shall be taken as $h_{o,\max} = t_{wall} - \Delta_h$.
9. **Wall location**: The default condition is in the face of the wall. Optional testing for the top of the wall and the end of the wall is provided in Section 7.9.

4.3 Testing requirements:

4.3.1 Testing requirements are provided in Tables 4.1 through 4.4 as described below.

4.3.1.1 Test requirements for recognition to resist static loads and wind loads in uncracked fully grouted CMU construction are defined in Table 4.1.

4.3.1.2 Test requirements for recognition to resist static loads and wind loads in cracked fully grouted CMU construction conditions are defined in Table 4.2.

4.3.1.3 Test requirements for recognition of fully grouted CMU construction to resist seismic loads are defined in Table 4.2; Table 4.1 shall not be used to qualify anchors to resist seismic loads.

4.3.1.4 Test requirements for recognition to resist static loads, wind loads, and optional seismic loads in uncracked ungrouted CMU construction conditions are defined in Table 4.3.

4.3.1.5 Test requirements for recognition to resist static loads, wind loads, and optional seismic loads in uncracked brick masonry construction conditions are defined in Table 4.4.

4.4 Assessment for alternative drilling methods

4.4.1 The qualification of the anchor for use with drilling methods other than carbide bit rotary-hammer drilling shall be predicated on fulfillment of the requirements of this section.

4.4.1.1 Perform supplemental tests in accordance with Table 4.5 using the alternate drilling method. Install anchors in accordance with the Manufacturer's Printed Installation Instructions (MPII).

4.4.1.2 *Requirement*—The results of supplemental tests as required in Section 4.4.1.1 shall be shown to be statistically equivalent to or greater than the results of corresponding tests conducted with carbide rotary-hammer bits in accordance with this criteria. If this requirement is not met, recognition of the alternate drilling method is dependent on the successful completion of all tests as described in this criteria with the exception of the shear capacity of anchor steel and the ASTM F606 tests described in Table 2.2.

4.5 Tests for recognition of additional brick construction types:

4.5.1 For each brick construction type sought for recognition, tests shall be performed on all diameters of anchor elements in accordance with Table 4.4, where, for the purposes of this document, brick construction type is defined in Section 1.4.8. Characteristic capacities from tests conducted with an anchor element in a given brick construction type shall be considered valid for additional untested brick construction types so long as all of the following conditions are fulfilled:

(a) Any additional brick unit types (Section 1.4.9) are composed of the same material type (e.g., clay/shale/similar, concrete) to the originally tested brick unit type;
(b) The additional brick unit types are of equal or greater compressive strength (ASTM C67 for clay/shale/similar, ASTM C140) to the originally tested brick unit type;
(c) The additional brick unit types possess equal or greater ratios of net cross-sectional area to gross cross-sectional area to the originally tested brick unit type as determined in accordance with ASTM C67; and
(d) Recognition is limited to construction comprising an equal or greater number of wythes than in the originally tested brick construction type.

Exception*:* It shall be permitted to obtain recognition for additional brick construction types that do not fulfill the above requirements provided that the following conditions are met:

a. Perform tests with anchor elements in the additional brick construction type in accordance with Table 4.7. The anchor element diameters tested in the additional brick construction type shall correspond to the diameters tested in accordance with Table 4.4 in the original brick construction type and recognition shall be limited to the tested anchor diameters.

b. Brick units are composed of the same material (e.g., clay/shale/similar).

c. Except as determined in accordance with Table 4.7, reduction factors determined for the original brick construction type as applicable in Eqs. (8-22) through (8-24) shall be applied to the pullout strength and shear strength for additional brick element types.

d. Adjust the characteristic tensile pullout strength and characteristic shear strength in uncracked masonry with the ratio of the mean pullout strength for the tested anchor element diameters in the additional brick construction type to the mean pullout capacity for equivalent anchor element diameters in the original brick construction type.

4.6 Test specimen and test setup requirements:

4.6.1 Masonry for test members: Masonry wall test specimens shall be prepared in accordance with Chapter 21 of the IBC and this criteria. Masonry components that comprise specimens shall conform to the following, as applicable.

4.6.1.1 ASTM C90: Hollow and Solid Load-bearing Concrete Masonry Units shall conform to the following criteria.

4.6.1.1.1 All ASTM C90 units used for qualification shall be classified as lightweight with density testing conducted in accordance ASTM C140.

4.6.1.1.2 The difference between the greatest and least cell thickness (1.4.10.2) within ASTM C90 units used for qualification shall not exceed 1 inch. The cell thickness in the center of the cell shall equal the greatest cell thickness.

4.6.1.1.3 A minimum of three ASTM C140 compressive strength tests shall be conducted at or beyond 28 days from manufacture to establish normalization trends. If the age of the units cannot be determined, the compressive strength tests shall be conducted at or beyond 28 days from delivery of the units. It is permitted to conduct additional compressive strength tests to determine more accurate trends.

4.6.1.1.4 In addition to the compressive strength, the testing laboratory shall report the following information about the concrete masonry units:

- Nominal dimensions of the units tested (e.g. 8 x 8 x 16);
- Geometry of the units, including web and face shell thicknesses, cell dimensions, and presence of other distinguishing features (e.g., end flanges);
- ASTM C140 density;
- Unit supplier(s); and
- Constituent materials used within the units (e.g., lightweight aggregate, cement type).

4.6.1.2 ASTM C216, ASTM C62, or ASTM C652: Building Brick composed of clay, shale, or similar.

4.6.1.3 ASTM C55: Concrete Building Brick

4.6.1.4 ASTM C129: Nonloadbearing Concrete Masonry Units.

4.6.1.5 Mortar shall be prepared in accordance with Section 2103 of the IBC or Section R607 of the IRC and ASTM C270. The testing laboratory shall report the mortar composition, type, proportions and compliance with the standard and the anchor shall only be qualified for the mortar tested (e.g., Type N) and mortars with higher compressive strength. Compression tests of mortar are not required.

4.6.1.6 Grout shall be prepared in accordance with Section 2103 of the IBC and Section R609 of the IRC and ASTM C476. The testing laboratory shall report grout composition, type, proportions and compressive strength. It is required to develop a strength-age relationship based on compression tests conducted in accordance with ASTM C1019 at intervals based on Table 4.8 to establish grout strength for normalization purposes during the test period with a minimum of three compressive specimen replicates at every age tested.

4.6.1.7 Test members should be at least 21 days old at the time of anchor installation and testing, as grout younger than this age is considered nonstandard. For tests in test members where grout is between 90 days and 18 months old, anchors shall be tested within 30 days of grout strength testing.

4.6.2 Requirements for test members:

4.6.2.1 Test members shall be fabricated using established construction procedures. Bed joints and head joints shall have a nominal thickness of 3/8 in; head joints shall be buttered with no more than two vertical lines of mortar at both wall faces with the minimum material needed to achieve the 3/8 in. (9.5 mm) nominal joint thickness and 1-1/4 in. (31.8 mm) width. It shall be permitted to remove excess mortar from the inside of the wall prior to grouting.

4.6.2.2 Normalization for test member strength is addressed in Section 8.3. Minimum masonry unit and grout strengths are determined based on requirements in IBC Section 2105 or as specified for the testing program if greater than IBC minimum requirements.

4.6.2.3 Reliability tests shall be conducted in the same masonry batch (i.e., the same grout, mortar, and unit batches) as the reference tests to which they are compared. Figure 4.1 provides batch control requirements for masonry units and grout. A mortar is considered to be from the same lot and batch indicated on its packaging.

4.6.2.4 Determine constituent test member strengths in accordance with Section 4.6.1. Develop strength-age relationships in accordance with Section 8.2.

4.6.2.5 Requirements for grouted CMU test members:

4.6.2.5.1 Dimensional requirements—Test members shall not exceed 8 courses high or 5 units wide as illustrated in Figure 4.4.

4.6.2.5.2 Uncracked grouted CMU test members—For handling and preservation of specimens, uncracked grouted CMU test members may employ the reinforcement scheme described in 4.6.2.5.3.

4.6.2.5.3 Cracked grouted CMU test members—Cracked masonry test members shall be designed to produce cracks of nearly constant width throughout the thickness of the component. Cracks should be spaced in a manner that precludes influence on individual anchors placed in a crack from adjacent cracks as illustrated in Figure 4.2. Place internal reinforcement to control crack width such that there is no influence on anchor performance.

4.6.2.5.3.1 Control crack width using embedded reinforcing bars oriented perpendicular to the intended crack plane and distributed across the test member cross-section at on-center spacing between 8 and 16 inches. The proportion of tensile reinforcement to the gross cross-sectional area of the wall specimen in the crack plane shall be between 0.25 and 0.5 percent.

4.6.2.5.3.2 The centerline-to-centerline distance between any crack-control reinforcement and the anchor shall not be less than $0.4h_{ef}$.

4.6.2.5.3.3 The following methodology shall be followed for crack initiation and opening in grouted CMU:

i. In a test member that has cured for at least 21 days, drill 1 ± 1/8 in. (25 ± 3.2 mm) diameter deep pilot holes into the mid-thickness of mortar joints and through the depth of the test specimen. Space pilot holes at approximately one pilot hole per 16 inches (400 mm) within each bed joint where cracking is desired.
ii. Initiate cracks by inserting expanding semi-cylindrical steel sleeves into the pilot holes and driving steel spikes through the sleeves. After crack initiation, remove the spikes and install the anchor to be tested with the crack bisecting the anchor, resulting in the length axis of the anchor is coincident with the crack plane.
iii. Replace and continue driving the spikes into the expanding sleeve until the specified crack width for the relevant test series is reached. Before applying load to the anchor, the average crack width, as measured by two crack measurement devices straddling the anchor, shall be equal to or greater than the specified crack width for the test series. Individual crack widths shall be between ± 15 percent of the specified crack width.

4.6.2.6 Requirements for ungrouted CMU test members: Test members shall not exceed 8 courses high or 5 units wide as illustrated in Figure 4.5. Testing in individual units (for tests in the center of the cell and in the web) and double units, as illustrated in Figure 4.6, is permitted.

4.6.2.7 Requirements for brick masonry test members: Test members shall not be less than 3 units wide and shall not exceed 6 feet in width or height as illustrated in Figure 4.7.

4.6.3 Anchor installation:

4.6.3.1 General requirements:

4.6.3.1.1 Anchor installation shall be in accordance with the MPII, except as otherwise required within these test criteria.

4.6.3.1.2 Pertinent data such as anchor embedment depth, etc., shall be reported by the testing laboratory. Holes for anchor test specimens shall be drilled and cleaned in accordance with the MPII including diameter and depth. Only tools typically used in field installations are permitted. Brand, model number and size of power tool and drill bit type shall be reported. Compliance with applicable standards shall be reported when appropriate. Drilling mode (e.g. rotation only or hammering with rotation) shall be reported for each base material. All procedures shall be conducted or directly verified by the testing laboratory and any deviations shall be reported.

4.6.3.1.3 All test anchors shall be installed perpendicular to the surface of the test member with a ± 6-degree tolerance in a manner representative of actual field installations.

4.6.3.1.4 Components of the anchor on which the reliability and capacity depend shall not be exchanged. Bolts, nuts, and washers not supplied with the anchors shall conform to the specifications given by the manufacturer and these specifications shall be included in the test report.

4.6.3.1.5 Test members may be compressed during handling but shall not be compressed during performance of anchor tests.

4.6.3.2 For anchors to be tested in tension in cracked CMU, deviation of the crack position from the anchor centerline should be limited to the surface of the member. For anchors to be tested in shear, it is more important that the anchor transect the crack position at the CMU surface. These conditions should be confirmed using a borescope.

4.6.3.2.1 With the test member unloaded, drill the hole for the anchor centered around a hairline crack that is sufficiently planar to ensure that the crack will approximately bisect the anchor location over the embedment depth of the anchor.

4.6.3.2.2 Visually verify positioning of the anchor in the crack before installation by using a borescope or similar device.

4.6.3.2.3 Where the MPII and the evaluation report specify maximum tightening torque values for anchor installation, torque values shall be determined with tests conducted in accordance with Section 7.10. If a maximum tightening torque is not specified, a quarter-turn past hand tightening shall be specified in the evaluation report.

4.6.4 Drill bit requirements:

4.6.4.1 Except for self-drilling anchors and as specified in 4.6.4.2, 4.6.4.3, and 4.6.4.5, holes shall be drilled using carbide-tipped rotary-hammer bits meeting the requirements of ACI 355.2-19. The cutting diameter of drill bits shall conform to the tolerances given in Table 4.9 and shall be checked after every 10 holes drilled to ensure continued compliance.

4.6.4.2 If performing tests with bits of diameter $d_{\max}$, d_{med} , or $d_{\min}$, it shall be permitted to use test bits ground to the desired diameter.

4.6.4.3 Drill bits with diameter $d_{\min}$ correspond to well-worn bits. These diameters are less than the minimum diameters specified for new bits in ANSI B212.15.

4.6.4.4 All service-condition tests use a bit diameter d_{med}.

4.6.4.5 For drill bits not included in the range of diameters given in Table 4.9 and for drill bits not covered by ANSI B212.15, the Independent Testing and Evaluation Agency shall develop diameters for the bits that conform to the concept of $d_{\max}$, d_{med}, and $d_{\min}$

4.6.5 Setting requirements for testing:

4.6.5.1 General torque requirements: If the application of torque for an anchor is specified by the manufacturer, torque each anchor as required in 4.6.5.1.1 and 4.6.5.2 except for reliability tests in 6.5 where the reduced installation effort is required. If no torque for the anchor is specified by the manufacturer, the anchor shall be finger-tight before testing.

4.6.5.1.1 Apply the specified torque T_{inst} using a calibrated torque wrench possessing a measuring error within ±5 percent of the specified torque. Remove the torque wrench and wait 10 minutes. Completely loosen the anchor. Apply a torque of 0.5T_{inst} using the calibrated torque wrench.

4.6.5.2 Setting of torque-controlled expansion anchors: Install torque-controlled expansion anchors in accordance with Table 4.10 and the requirements of 4.6.5.1.

4.6.5.2.1 For the reliability tests performed with reduced installation effort (Table 4.1, Test 4; Table 4.2, Test 5; Table 4.3, Test 3; Table 4.4, Test 3), install and set the anchor with a setting torque of 0.5T_{inst}. Do not reduce the torque from this level.

4.6.5.2.2 For cracked tests, follow the torque application process in Section 4.6.5.1.1 before the crack is widened.

4.6.5.3 Setting of displacement-controlled expansion anchors: Install displacement-controlled expansion anchors with the degree of expansion specified in Table 4.11. The specified degrees of expansion shall be obtained using setting tools based on the number of drops/blows specified in Table 4.12 for partial and reference expansion developed in 4.6.5.3.1 and 4.6.5.3.2. Refer to Figure 4.3 for the test fixture used to establish the partial and reference setting expansions. These tests shall be performed in high-strength masonry and with a drill bit diameter d_{med}.

4.6.5.3.1 Partial expansion: Set a minimum of five anchors using the weight and number of drops from Table 4.12 for partial expansion. For each anchor, measure the depth of the plug from the upper end of the anchor. Calculate the average depth of the plug for the set anchors. Modify (shorten) the manufacturer's setting tool to provide the calculated setting depth. Use this setting tool for Test 4 in Table 4.1, Test 5 in Table 4.2, Test 3 in Table 4.3, and Test 3 in Table 4.4.

4.6.5.3.2 Reference expansion: Prepare a setting tool for Tests 5, 6, and 7 of Table 4.1; Tests 6, 7, and 8 of Table 4.2; or Tests 4, 5, and 6 of Tables 4.3 and 4.4 using the same method described in 4.6.5.3.1, except using the number of drops for evaluation of reference expansion from Table 4.12.

4.6.5.3.3 Setting of undercut anchors: Install undercut anchors as specified in Table 4.13. Table 4.13 provides for combinations of parameters for various undercut anchor types. In other tests prescribed in Tables 4.1 through 4.4, drill a cylindrical hole with a diameter as given in Tables 4.1 through 4.4 and produce the undercut as per manufacturer's printed installation instructions (MPII). For Table 4.1, Test 4, Table 4.2, Test 5, and Tables 4.3 and 4.4, Test 3, set undercut anchors using a combination of the specified setting tolerances that produces the minimum bearing surface in the masonry.

4.6.5.4 Setting of screw anchors:

4.6.5.4.1 Permitted setting methods for screw anchors shall be defined by the manufacturer. For those systems that are to be set with a torque wrench, the installation torque, T_{screw}, shall be specified. For those systems set with a machine (for example, impact screwdriver), the type of machine and maximum power output rating shall be specified. Alternatively, the characteristics of acceptable machines in terms of power output shall be specified.

4.6.5.4.2 For all tests in Table 4.1 through 4.4 (except Tests 9-11 in Table 4.1, Tests 10-12 in Table 4.2, Tests 8-10 in Table 4.3, and Tests 8-10 in Table 4.4), install the screw anchor until the head contacts the fixture and the fixture can no longer be moved by hand.

For those systems that are qualified to be set with either a specified installation torque or with a machine, the anchors shall be set with a torque wrench and the specified installation torque, T_{screw}, shall either be reestablished at a higher level until this condition is satisfied or the anchor shall be deemed unsuitable. For those systems set with a range of machines that satisfy a maximum power output rating specified by the manufacturer, an impact screwdriver with maximum power output specified in the MPII for the anchor size shall be used. The ITEA or Designated Testing Laboratory shall select the screwdriver with maximum power output for this application from the screwdrivers on the market fulfilling the specifications of the anchor manufacturer based on its experience or the results of the pre-tests. Following installation of the anchor in accordance with the MPII, it shall be verified by hand that the fixture is not loose.

4.6.6 Test methods:

4.6.6.1 Test anchors in conformance with ASTM C1892 and this criteria. Where differences occur, this criteria shall take precedence over ASTM C1892.

4.6.6.2 Recorded displacements shall be corrected so that they represent the displacement of the anchor at the masonry surface.

4.6.7 *Confined testing requirements*—Figure 4.4 shows the components comprising a confined tension test setup for anchors, whereby the reaction force is transferred into the masonry in proximity to the anchor element. The hole in the confining plate shall be $1.5d_o$ to $2.0d_o$ and shall be centered in the confining plate. The thickness of the confining plate shall be greater than or equal to d. The distance from the hole to the edge of the confining plate shall not be less than 2 inches (51 mm). The confining plate shall possess a smooth surface. 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.) corresponding to the area of the confining plate shall be placed between the confining plate and the masonry surface.

4.6.8 Unconfined testing requirements:

4.6.8.1 General requirements: Figure 4.5 shows the components comprising an unconfined test setup, whereby the reaction force is transferred into the masonry away from the anchor element.

4.6.8.2 Ungrouted CMU requirements:

4.6.8.2.1 For tests in the center of the cell and in the bed joint, the distance between supports shall be at least large enough to span the length of the cell (i.e., in the long direction of the unit).

4.6.8.2.2 For tests in the center of the web, the distance from the anchor to the supports shall be a minimum of 2 h_{nom}.

4.6.8.3 Brick requirements: The distance from the anchor to the supports shall be no less than 2 h_{nom}.

4.7 Tests in cracked masonry:

4.7.1 Perform tests in masonry test members meeting the requirements of Section 4.6.1. Initiate cracking in the test member. Install the anchor in accordance with 4.6.3 so that the axis of the anchor is coincident with the crack plane. Install instrumentation for monitoring crack opening width. Monitor crack opening width using dial gauges or electronic transducers located roughly symmetrically on either side of the anchor on an axis oriented perpendicular to the crack plane to permit interpolation from the crack width measurement point to the anchor centerline as small as possible; this distance shall not exceed the greater of $1.0h_{ef}$ or 5 in. (127 mm). Increase the crack width by the specified crack value prior to applying external loads to the anchor. Verify by suitable means that the system used for crack formation and the associated test procedures produce cracks that remain parallel during test performance. The crack width, as measured at the opposite face of the test member in line with the anchor location, or as estimated based on the crack width measurement on each side of the test member as close to the opposite face as possible, should be approximately equal to the crack width measured on the anchor side. Verification that the test procedure used for a specific test will produce the appropriate crack geometry shall be performed at the beginning of the test series.

4.7.2 Subject the anchor to the specified loading sequence while monitoring the crack opening width at the surface as required in the specific test.

4.7.3 Record the applied load, corresponding anchor displacement, and crack width during the test as required in the specific test. Use a sampling frequency appropriate for the load or strain rate employed for the test.

5.0 REFERENCE TESTS

5.1 Purpose:

5.1.1 Reference tests shall be performed in each batch of masonry (see Section 4.6.2.3) to obtain baseline values for reliability and service-condition tests where reference values are required to assess the effects of cracking, installation effort, spacing, and edge distance on anchor performance.

5.1.1.1 For all reference tests other than screw anchor reference (Table 4.1, Test 3, Table 4.2, Test 4, and Tables 4.3 and 4.4, Test 2), perform in the unconfined condition (See Section 4.6.8) to establish the basic capacity of the anchors.

5.1.1.2 Perform the screw anchor reference test (Table 4.1, Test 3, Table 4.2, Test 4, and Tables 4.3 and 4.4, Test 2) in the confined condition as described in 4.6.7.

5.2 Required tests:

5.2.1 All tests: Conduct reference tests in the same masonry batch used for the reliability or service condition tests to which they are compared. Reference tests may be used for comparison with more than one series of reliability or service condition tests.

5.2.2 Grouted CMU: Required reference tests are summarized in Table 4.1 for anchors to be qualified for use in uncracked grouted CMU only and in Table 4.2 for anchors to be qualified for use in both uncracked and cracked grouted CMU.

5.2.2.1 Tests shall be conducted in all locations illustrated in Figure 5.1.

5.2.2.2 Figure 5.2 shows the relationship between the tested condition near head joints and the reportable distance to the centerline of a head joint, $c_{min,HJ}$, as follows:

5.2.2.2.1 Where the anchor is installed nearest to a flat-ended head joint as illustrated in Figure 5.2 (a) and (b), $c_{HJ,test} = c_{min,HJ} - 1\ in.$, where $c_{min,HJ}$ is the minimum distance from the head joint desired for qualification.

5.2.2.2.2 Where the anchor is installed nearest to a stretcher-ended head joint as illustrated in Figure 5.2 (c) and (d), $c_{HJ,test} = c_{min,HJ} + w_{str} - 1\ in.$, where $c_{min,HJ}$ is the minimum distance from the head joint desired for qualification.

5.2.3 Ungrouted CMU: Required reference tests are summarized in (Table 4.3) for anchors to be qualified for use in ungrouted CMU. Tests shall be conducted in all locations illustrated in Figure 5.3.

5.2.4 Brick: Required reference tests are summarized in (Table 4.4) for anchors to be qualified for use in brick. Tests shall be conducted in all locations illustrated in Figure 5.4 and as described below:

(a) Hollow portion: installation in mid-height of brick centered within the largest void in the brick

(b) Solid portion: installation in the mid-height of the brick in the most centrally located solid portion
(c) Bed joint: Installation in bed joint, centered within the largest void of either of the adjacent brick units
(d) Head joint: Installation in mid-height of the head joint

5.3 Conduct of tests:

5.3.1 Prepare test members, install anchors and test in accordance with Section 4.6 or Section 4.7.

5.4 Requirements for reference tests:

5.4.1 The coefficient of variation v of the ultimate tensile capacity in any reference test series, including those with an increased number of replicates, shall not exceed 20 percent. If the coefficient of variation obtained from the original or cumulative test series does not meet this requirement, the sample size shall be permitted to be increased. If this requirement is not met, the anchor shall be considered unqualified.

5.4.2 Anchor stiffness from reference tests shall be derived in accordance with Section 8.5.2.

5.4.3 Requirements for masonry breakout and anchor pullout failure:

5.4.3.1 Fully grouted CMU (Tables 4.1 and 4.2)

5.4.3.1.1 Calculate the characteristic tensile pullout capacity, N_p, using the test data in accordance with Section 8.4.1. Normalize N_p to grout and unit compressive strengths of 2,000 psi (13.8 MPa) (corresponding to the minimum permitted strengths) in accordance with Section 8.3.1.

5.4.3.1.2 The reported minimum distance to the centerline of the head joint, $c_{min,HJ}$, shall not exceed the lesser of the results from Section 7.4.3.4 and the following based on tested head joint condition as shown in Figure 5.2:

5.4.3.1.2.1 Where the anchor has been installed nearest to a flat end as illustrated in Figure 5.2 (a) and (b):

$$c_{min,HJ} = c_{HJ,test} + 1\ in. \qquad (5\text{-}1)$$

5.4.3.1.2.2 Where the anchor has been installed nearest to a stretcher end as illustrated in Figure 5.2 (c) and (d):

$$c_{min,HJ} = c_{HJ,test} - w_{str} + 1\ in. \qquad (5\text{-}2)$$

5.4.3.1.3 Figure 5.2 shows the relationship between the tested condition near head joints and the reportable distance to the centerline of a head joint, $c_{min,HJ}$, as follows:

5.4.3.1.3.1 Where the anchor is installed nearest to a flat-ended head joint as illustrated in Figure 5.2 (a) and (b), $c_{HJ,test} = c_{min,HJ} - 1\ in.$, where $c_{min,HJ}$ is the minimum distance from the head joint desired for qualification.

5.4.3.1.3.2 Where the anchor is installed nearest to a stretcher-ended head joint as illustrated in Figure 5.2 (c) and (d), $c_{HJ,test} = c_{min,HJ} + w_{str} - 1\ in.$, where $c_{min,HJ}$ is the minimum distance from the head joint desired for qualification.

5.4.3.2 Ungrouted CMU (Table 4.3): Calculate the characteristic tensile capacity using the test data in accordance with Section 8.4.1. Normalize N_p to a unit compressive strength of 2,000 psi (13.8 MPa) (corresponding to the minimum permitted strengths) in accordance with Section 8.3.2.

5.4.3.3 Brick (Table 4.4): Calculate the characteristic tensile capacity using the test data in accordance with Section 8.4.1. Normalize N_p to the minimum permitted strength permitted by the brick standard in accordance with Section 8.3.3.

5.4.4 Requirement for steel failure: If steel failure occurs for a given diameter and embedment, for the purposes of establishing design values, the failure shall be considered as a pullout failure, where N_p is determined using the methodology prescribed in Section 5.4.3.

6.0 RELIABILITY TESTS

6.1 Purpose: Reliability tests are performed to establish that the anchor is capable of safe, effective behavior under normal and adverse conditions, both during installation and in service.

6.2 Required tests: Reliability test requirements for uncracked fully grouted CMU (Table 4.1), cracked and uncracked fully grouted CMU (Table 4.2), ungrouted CMU (Table 4.3), and clay brick masonry (Table 4.4) are given in this chapter. The results of the reliability tests shall be used to establish the anchor category in accordance with Chapter 8.

6.3 Conduct of tests:

6.3.1 Prepare test members, install anchors, and test in accordance with Section 4.6 or Section 4.7 unless otherwise noted.

6.3.2 Test members for reliability shall be of the same masonry batch as the reference tests.

6.4 Additional details: Reliability tests are intended to assess the sensitivity of the tested systems to variations in installation and service-condition parameters that are likely experienced in practice. They are not intended to address gross installation errors. Gross installation errors are characterized by significant deviations from the MPII or design specifications and include, but are not limited to:

- Deviations from the specified range of embedment depths;
- Use of a nominal diameter drill bit other than that specified; and
- Installation of the product in construction materials other than the masonry types for which the product is qualified.

6.5 Reliability with reduced installation effort:

Refer to Table 4.1, Test 4; Table 4.2, Test 5; Table 4.3, Test 3; Table 4.4, Test 3.

6.5.1 Purpose: These reliability tests are performed to determine the sensitivity of the anchor to adverse installation conditions. Perform these tests under tension loading. These tests do not apply to screw anchors.

6.5.2 General test conditions: Install anchors in the bed joint of grouted and ungrouted CMU. Install anchors in the solid portion of brick. Where qualification in accordance with Table 4.2 is desired, use a minimum crack-opening width of 0.012 in. (0.3 mm). For qualification in accordance with Tables 4.1, 4.3, and 4.4, perform tests in uncracked masonry.

6.5.2.1 Torque-controlled expansion anchors:

6.5.2.1.1 Where qualification in accordance with Table 4.1 or 4.2 is desired, install anchors in fully grouted CMU with high-strength grout.

6.5.2.1.2 Where qualification in accordance with Table 4.3 or 4.4 is desired, install anchors into masonry composed of similar constituent materials as in the balance of the test program.

6.5.2.1.3 Install anchors with setting torque $T = 0.5T_{inst}$ and a drill bit of diameter d_{med}. Refer to Fig. 1.2 for anchor types.

6.5.2.2 Displacement-controlled expansion anchors:

6.5.2.2.1 Where qualification in accordance with Table 4.1 or 4.2 is desired, perform tests on anchors installed in low-strength masonry.

6.5.2.2.2 Where qualification in accordance with Table 4.3 or 4.4 is desired, install anchors into masonry composed of similar constituent materials as in the balance of the test program.

6.5.2.2.3 Install anchors using a drill bit of diameter d_{med}. Refer to ACI 355.2-19 Section 3.1 for illustrations of all anchor types. Installation requirements for displacement-controlled expansion anchors are prescribed in Table 4.11 and in Table 4.12 for partial expansion.

6.5.2.3 Torque-, load-, and displacement-controlled undercut anchors:

6.5.2.3.1 Where qualification in accordance with Table 4.1 or 4.2 is desired, perform tension tests using low- and high-strength masonry. For displacement-controlled undercut anchors, perform tension tests using low-strength masonry.

6.5.2.3.2 Where qualification in accordance with Table 4.3 or 4.4 is desired, perform tension tests using similar constituent materials for masonry as in the balance of the test program.

6.5.2.3.3 Refer to Fig. 1.3 for anchor types. Installation requirements for undercut anchors are prescribed in 4.6.5.3.3.

6.5.3 Assessment of results: The coefficient of variation v of the ultimate tension load in any test series, including those performed with an increased number of replicates, shall not exceed 30 percent. If the coefficient of variation of the original or cumulative test series does not meet this requirement, the sample size shall be permitted to be increased. If the requirement for maximum coefficient of variation is not met, the anchor shall be considered unqualified. The capacity of the anchor as determined in this test series shall be used to establish the anchor category according to Section 8.

6.6 Reliability with large drill bit

Refer to Table 4.1, Test 5; Table 4.2, Test 6; Table 4.3, Test 4; Table 4.4, Test 4.

6.6.1 Purpose: Where qualification in accordance with Tables 4.1, 4.3, and 4.4 is desired, these reliability tests are performed in uncracked masonry to evaluate the sensitivity of the anchor to low-strength masonry and oversized holes. Where qualification in accordance with Table 4.2 is desired, these reliability tests are performed in cracked masonry to evaluate the sensitivity of the anchor to low-strength masonry, oversized holes, and opened cracks.

6.6.2 General test conditions: Perform tests under tension loading in low-strength masonry for all anchor types with a drill bit of diameter d_{max}. For anchor tests in cracked masonry, use a minimum crack-opening width of 0.020 in. (0.5 mm).

6.6.3 Assessment of results: The coefficient of variation v of the ultimate tension load in any test series, including those performed with an increased number of replicates, shall not exceed 30 percent. If the coefficient of variation of the original or cumulative test series does not meet this requirement, the sample size shall be permitted to be increased. If the requirement for maximum coefficient of variation is not met, the anchor shall be considered unqualified. The anchor capacity as determined in this test series shall be used to establish the anchor category according to Section 8.

6.7 Reliability with small drill bit

Refer to Table 4.1, Test 6; Table 4.2, Test 7; Table 4.3, Test 5; Table 4.4, Test 5.

6.7.1 Purpose: Where qualification in accordance with Tables 4.1, 4.3, and 4.4 is desired, these reliability tests are performed in uncracked masonry to evaluate the sensitivity of the anchor to undersized holes in high-strength masonry. Where qualification in accordance with Table 4.2 is desired, these reliability tests are performed in cracked masonry to evaluate the sensitivity of the anchor to undersized holes and opened cracks in masonry constructed with high-strength grout.

6.7.2 General test conditions:

6.7.2.1 Where qualification in accordance with Table 4.1 or 4.2 is desired, perform tests under tension loading in masonry with high-strength grout for all anchor types.

6.7.2.2 Where qualification in accordance with Table 4.3 or 4.4 is desired, perform tension tests using similar constituent materials for masonry as in the balance of the test program.

6.7.2.3 Use a drill bit of diameter d_{min}. In cracked masonry tests, use a minimum crack opening width of 0.020 in. (0.5 mm).

6.7.3 Assessment of results:—The coefficient of variation v of the ultimate tension load in any test series, including those performed with an increased number of replicates, shall not exceed 30 percent. If the coefficient of variation of the original or cumulative test series does not meet this requirement, the sample size shall be permitted to be increased. If the requirement for maximum coefficient of variation is not met, the anchor shall be considered unqualified. The anchor capacity as determined in this test series shall be used to establish the anchor category according to Chapter 8.

6.8 Reliability under repeated load

Refer to Table 4.1, Test 7; Table 4.2, Test 8; Table 4.3, Test 6; Table 4.4, Test 6.

6.8.1 Purpose: These reliability tests are performed to evaluate the performance of the anchor under repeated load in masonry subjected to normal building movements.

6.8.2 General test conditions: Subject the anchor to a pulsating tensile load that varies sinusoidally between a maximum and minimum load. The maximum load N_{max} shall be the smaller of $0.6N_k$ or $0.7A_{se}\,f_y$, where N_k shall be derived from the corresponding reference test location for the tested masonry type. In case of anchors without defined yield strength, or if the yield strength cannot be determined by standard testing methods, f_y shall be taken as $0.8f_{ut}$. The minimum load N_{min} shall be the greater of $0.25N_k$ or the maximum load N_{max}, as determined previously, minus $A_{se} \cdot 17{,}400$ psi (120 MPa). The loading frequency shall be 6 Hz or less. Measure anchor displacement continuously, or up to the maximum load during the first loading, and then after 10, 10^2, 10^3, 10^4, and 10^5 load cycles. At the end of the cyclic loading, test the anchor in tension to failure.

6.8.2.1 Installation of screw anchors: Set the screw anchor on a beveled washer (inclination angle ≥ 4 degrees, hardness ≥ HRC 32, fixture hole oversize ≤ 1/8 in. [3.2 mm]). Install the screw anchor in accordance with 4.6.5.4.2. The most adverse head style shall be identified and tested by the ITEA or Designated Testing Laboratory. The point of maximum dimension of the head shall contact the beveled washer. In cases where the product geometry includes a fillet under the anchor head, or where the head is countersunk, the bevel washer shall be modified such that the fillet shall not be in contact with the bevel washer (refer to Figure 6.1)

Following anchor installation, the screw anchor head is permitted to either partially contact the beveled washer (refer to Fig. 6.1) or fully contact against the washer (refer to Fig. 6.2). Any position of the anchor head within and including the extreme positions shown in Fig. 6.2 shall be acceptable.

6.8.3 Assessment of results: Anchor displacements shall show a stabilization of movement. If this requirement is not met, repeat this test with a reduced maximum load until this condition is met. Reduce the characteristic capacity in proportion to the reduction in maximum load. The coefficient of variation v of the ultimate tension load in any test series shall not exceed 30 percent. The sample size shall be permitted to be increased if the coefficient of variation of the original or cumulative sample size does not meet this requirement. If the requirement for maximum coefficient of variation is not met, the anchor shall be considered unqualified. The residual capacity shall be used to establish the anchor category according to Section 8.

6.9 Reliability of screw anchors for brittle failure

Refer to Table 4.1, Test 8; Table 4.2, Test 9; Table 4.3, Test 7; Table 4.4, Test 7.

6.9.1 Purpose: These reliability tests are intended to verify sufficient insensitivity to stress-induced hydrogen embrittlement cracking under conditions as may occur in service. This test series is not required for anchors fulfilling the requirements of 6.9.1.1 or 6.9.1.2.

6.9.1.1 Exception 1*: Prequalified screw anchors*—Anchor diameters meeting all three items 1), 2), and 3), over the entire length of the fastener excluding the length h_s (refer to Fig. 6.3) are not sensitive to brittle failure and, therefore, do not have to be tested:

1. Core hardness ≤ 36 HRC
2. Case hardness ≤ 55 HRC
3. Case depth ≤ 0.02 in. (0.5 mm); case depth is defined as the depth within the cross section with hardness > 36 HRC

The afore-given values for hardness and case depth represent upper tolerance limits in manufacturing drawings.

To check whether these conditions are fulfilled, measurements shall be performed at least directly below the head, at a distance h_s from the tip of the screw and in the middle between those two points (refer to Fig. 6.3) on three samples per diameter and length from each manufacturing process, material, coating, and design.

The core hardness shall be measured at a depth of 0.020 in. (0.5 mm) from the shank surface, and the case hardness at least at a depth of 0.002 and 0.010 in. (0.05 and 0.25 mm) from the shank surface.

Hardness readings shall be determined using a microhardness indenter (such as Vickers or Knoop) and converted to the Rockwell C scale in accordance with reference ASTM A370.

6.9.1.2 Exception 2*: Tests previously conducted in accordance with AC193*—If reliability tests of screw anchors for brittle failure have been conducted in accordance with AC193, the resulting anchor category data from the AC193 assessment may be applied to the current assessment in lieu of conducting the tests within this section.

6.9.2 General test conditions: Where tests are required, screw anchors shall be installed in an uncracked high-strength grout specimen having a minimum compressive strength of 5000 psi (34.5 MPa) in accordance with the Manufacturer's Printed Installation Instructions (MPII). Where steel failure occurs in the reference tests, the masonry strength corresponding to those tests may be used.

6.9.2.1 *Test method*—Perform five tests on all diameters from each unique combination of manufacturing process, material, coating, and design. Tests shall be conducted at shallow (minimum h_{nom}) and deep embedments (maximum h_{nom}) per diameter. For screw anchors with different head forms, anchors with the most adverse head form shall be tested. If the most adverse head form cannot be readily identified, tests with different head forms shall be performed.

6.9.2.1.1 *Test method*—The borehole shall be drilled with a medium drill bit diameter d_{med}. The grout specimen shall be large enough to preclude splitting failure. Alternatively, the specimen may be cast in a steel ring.

At the screw location, a bottomless container covering an area of at least 15 in.^{2} (9677 mm^2) with a height of at least 1 in. (25.4 mm) shall be affixed to the grout member and filled with a saturated calcium hydroxide solution (Ca(OH)2) having a pH = 12.6 ± 0.1 measured at 77°F ± 2°F (25°C ± 1°C). During the test, the head of the screw shall be submerged in the fluid. The temperature during the test shall be maintained at 77°F ± 9°F (25°C ± 5°C). Furthermore, the pH value shall be kept constant by measuring the pH value after 5 days. If the pH value exceeds the tolerance value, as might occur due to interaction with the masonry, the solution shall be replaced.

The material of the counter electrode shall be stainless steel or activated titanium. The reference electrode is defined by its composition of either saturated calomel or silver chloride (Ag/AgCl). Its accuracy should be controlled by calibration with a new electrode (tolerance ±20 mV). The tip of the reference electrode should be located at a distance equal to approximately $0.5h_{nom}$ from the grout specimen surface (refer to Fig. 6.4). This may be achieved by a bore hole depth equal to approximately $0.5h_{nom}$. The length of the counter electrode should be equal to approximately h_{nom}. Reference and counter electrodes shall be placed in drilled holes with a diameter of approximately 1/16 in. (1.6 mm) larger than the diameter of the electrode. The reference electrode shall be located as close as possible to the screw and shall not be located farther away than 6 in. (152 mm). The distance between reference electrode and counter electrode shall not exceed 2 in. (51 mm). The working electrode is the screw anchor in contact with the test fixture.

Before testing, coatings of any kind shall be partially removed in shape of a longitudinal strip (approximately 1 mm [0.04 in.] over the entire length of the screw) to allow hydrogen evolution on the steel surface. The screw shall be subjected to a constant tension load $N_{sust} = min\{0.7N_{u,mean}, 0.5N_{st,mean}\}$ over a minimum period of 240 hours. For the purposes of this test, $N_{u,mean}$ is the average ultimate tensile load of the confined reference tests, multiplied by $\sqrt{f_{m,test,i}/f_{m,ref}}$

where

$f_{m,test,i}$ = measured compressive strength of the grout used for the brittle failure tests.

$f_{m,ref}$ = measured compressive strength of the grout used for the screw anchor reference tests.

Throughout the duration of the test, the electrochemical potential shall be established and shall be held constant with potentiostatic control or by other appropriate means. If a saturated calomel electrode is used as the reference electrode, the potential shall be maintained at –1200 mV ± 20 mV. Other types of electrodes, such as silver chloride (Ag/ AgCl), may be used with appropriate correction of the potential. A suggested test setup is shown in Fig. 6.5.

Following the constant load portion of the test, unload the screw and perform a confined tension test to failure ($N_{u,resid}$) using the test setup as shown in Fig. 4.4.

6.9.2.1.2 Assessment of results: During the constant load portion of the test (240 hours), no anchor shall fail. The load-displacement behavior as observed in the residual tension test shall conform to the requirements of 8.5.1.1. The failure load shall be compared to confined reference tension tests. The ratio of the residual failure loads to the reference failure loads shall be used to establish the anchor category as described in Chapter 8.

6.9.2.2 *Alternate test method*—In the alternate method, the test is performed unconfined with a beveled washer under the anchor head (refer to Fig. 6.6).

6.9.2.2.1 The borehole shall be drilled with a medium drill bit diameter d_{med}. The grout specimen shall be designed large enough to preclude splitting failure. Alternatively, the specimen may be cast in a steel ring.

The screw anchor shall be set on a beveled washer with an inclination angle greater than or equal to 4 degrees, with a hardness greater than or equal to HRC 32 and with the fixture hole a maximum of 1/8 in. (3.2 mm) greater than the thread diameter. The point of maximum dimension of the head shall contact the beveled washer. The position is shown in Fig. 6.1. Following anchor installation, the screw anchor head may either partially contact the beveled washer (refer to Fig. 6.1) or fully contact the washer (refer to Fig. 6.2). Any position of the anchor head within and including the extreme positions shown in Fig. 6.1 shall be acceptable. For screws with fillets under the head or where the head is a countersunk configuration, refer to 6.8.2.1.

At the screw location, a bottomless container covering an area of at least 15 in.^{2} (9677 mm^2) with a height of at least 1 in. (25.4 mm) shall be affixed to the grout and filled with a saturated calcium hydroxide solution Ca(OH)2 having a pH = 12.6 ± 0.1 measured at 77°F ± 2°F (25°C±1°C). During the test, the head of the screw shall be submerged in the fluid. The temperature during the test shall be maintained at 77°F ± 9°F (25°C ± 5°C). Furthermore, the pH-value shall be kept constant by measuring the pH value after a minimum of 48 hours ± 3 hours. If the pH-value exceeds the tolerance value (as might occur due to interaction with the grout), the solution shall be replaced.

The material of the counter electrode shall be stainless steel or activated titanium. The reference electrode is defined by its composition of either saturated calomel or silver chloride (Ag/AgCl). Its accuracy should be controlled by calibration with a new electrode (tolerance ±20 mV). The tip of the reference electrode shall be located at a distance equal to approximately $0.5h_{nom}$ (refer to Fig. 6.6) from the masonry surface. This may be achieved with a bore hole depth equal to approximately $0.5h_{nom}$. The length of the counter electrode shall be equal to approximately h_{nom}. Reference and counter electrodes shall be placed in drilled holes with a diameter of approximately 1/16 in. (1.6 mm) larger than the diameter of the electrode. The reference electrode should be located as close as possible to the screw and shall not be farther away than 6 in. (152 mm). The distance between reference electrode and counter electrode shall not exceed 2 in. (51 mm). The working electrode is the screw anchor in contact with the test fixture.

Before testing, coatings of any kind shall be partially removed in shape of a longitudinal strip not less than 1/8 in. (3.2 mm) wide along the full length of the screw to allow hydrogen evolution on the steel surface.

The screw shall be subjected to a constant tension load $N_{sust} = min\{0.7N_{u,mean}, 0.5N_{st,mean}\}$ over a minimum period of 100 hours. For the purposes of this test, $N_{u,mean}$ is the average ultimate tensile load of the confined reference tests, multiplied by $\sqrt{f_{m,test,i}/f_{m,ref}}$

where

$f_{m,test,i}$= measured compressive strength of the grout used for the brittle failure tests.

$f_{m,ref}$ = measured compressive strength of the grout used for the screw anchor reference tests.

Throughout the duration of the test, the electrochemical potential shall be established and shall be held constant with potentiostatic control or by other appropriate means. If a saturated calomel electrode is used as the reference electrode, the potential shall be maintained at –1200 mV ± 20 mV. Other types of electrodes, such as silver chloride (Ag/ AgCl), may be used with appropriate correction of the potential. A suggested test setup is shown in Fig. 6.6.

Following the constant load portion of the test, unload the screw and perform a confined tension test to failure ($N_{u,resid}$) using the test setup as shown in Fig. 4.4.

6.9.2.2.2 Assessment of results: During the constant load portion of the test (100 hours), no anchor shall fail. If grout failure occurs, the test shall be repeated. The load-displacement behavior as observed in the residual tension tests shall conform to the requirements of 8.5.1.1. The failure load shall be compared to reference tension tests according to Table 4.1, Test 3; Table 4.2, Test 4; Table 4.3, Test 2; or Table 4.4, Test 2. The ratio of the residual failure loads and the reference test results shall be used to establish the anchor category as described in Chapter 8.

6.10 Reliability of screw anchors based on setting method

6.10.1 These reliability tests shall be performed in uncracked masonry to evaluate the setting method of screw anchors with impact screwdrivers and torque wrenches in accordance with the following options:

1) If an impact screwdriver is specified, perform tests according to 6.10.2.
2) If a torque wrench is specified, perform tests according to 6.10.3 and 6.10.4.
3) If both an impact screwdriver and a torque wrench are specified, perform tests according to 6.10.2, 6.10.3, and 6.10.4.
4) If the manufacturer specifies that a torque-limiting tool shall be used for the installation of the anchor, Table 4.1, Tests 9-11; Table 4.2, Tests 10-12; Table 4.3, Tests 8-10; Table 4.4, Tests 8-10 shall not be required. A torque-limiting tool shall be capable of disengaging from the anchor head within 1 second of the anchor head coming into contact with the test fixture. The independent testing and evaluation agency shall verify that these requirements are met.

6.10.2 Reliability of screw anchors if set with impact screwdriver:

Refer to Table 4.1, Test 9; Table 4.2, Test 10; Table 4.3, Test 8; Table 4.4, Test 8.

6.10.2.1 Purpose: These reliability tests shall be performed to evaluate the setting of screw anchors with impact screwdriver tools. The tests shall be performed in uncracked masonry to determine if impact screwdrivers may be used to set screw anchors correctly and reliably.

6.10.2.2 General conditions: The tests shall be performed in uncracked low-strength masonry using a drill bit diameter of d_{max} and anchors corresponding to the shallowest embedment for each anchor diameter. An impact screwdriver with maximum power output specified in the manufacturer's installation instructions for the anchor size shall be used. The test laboratory shall select the screwdriver with maximum power output for this application from the screwdrivers on the market fulfilling the specifications of the anchor manufacturer based on its experience or the results of the pretests. The manufacturer shall specify whether the product shall be permitted to be loosened and retightened with the impact screwdriver to facilitate attachment or realignment. If this installation procedure is permitted, tests in accordance with 6.10.2.2.1 shall be performed. If this installation procedure is not permitted, tests in accordance with 6.10.2.2.2 shall be performed.

6.10.2.2.1 To qualify anchors for retightening, perform tests according to one of the following options.

Option A:

1) Install the anchor in accordance with the Manufacturer's Printed Installation Instructions (MPII).
2) Back the anchor out of the hole a minimum of one full turn by the method described in the MPII.
3) Retighten the anchor with the impact screwdriver. The maximum power to the head of the screw anchor shall be applied by the impact screwdriver. The screwdriver shall be switched off automatically after 5 seconds.

Option B:

a) Install the anchor in accordance with the MPII.
b) Back the anchor out of the hole a minimum of one full turn by the method described in the MPII.
c) Retighten the anchor with the impact screwdriver. The maximum power to the head of the screw anchor shall be applied by the impact screwdriver. The screwdriver shall be switched off automatically after 3 seconds.
d) Perform separate tests in accordance with 6.10.2.2.2.

Option C:

1) Install the anchor in accordance with 6.10.2.2.2.
2) Back the anchor out of the hole a minimum of one full turn by the method described in the MPII.
3) Retighten the anchor with the impact screwdriver. The maximum power to the head of the screw anchor shall be applied by the impact screwdriver. The screwdriver shall be switched off automatically after 3 seconds.

6.10.2.2.2 For anchors that are not to be qualified for retightening, install the anchor until the anchor head contacts the fixture. In tests performed with the stud-type version, the anchor shall be supported on the bottom of the drilled hole ($h_o = h_{nom}$). The screwdriver shall be switched off automatically after 5 seconds.

6.10.2.3 Assessment of results: No anchor failure (steel rupture or masonry failure) shall occur in all tests. Exception: one anchor failure is allowed if the number of tests is doubled. The manufacturer shall specify that the product may not be loosened and retightened unless one of the three optional tests described in 6.10.2.2.1 are successfully completed.

6.10.3 Reliability of screw anchors if set with a torque wrench and a large drill bit:

Refer to Table 4.1, Test 10; Table 4.2, Test 11; Table 4.3, Test 9; Table 4.4, Test 9.

6.10.3.1 Purpose: These reliability tests shall be performed in uncracked masonry to evaluate the sensitivity of the anchor to low-strength masonry if set with a torque wrench.

6.10.3.2 General test conditions: Perform tests under torque loading in low-strength masonry for all anchor types. Use a drill bit of diameter d_{max} and anchors corresponding to the shallowest embedment for each anchor diameter. Install the anchor with a calibrated torque wrench. In tests performed with the stud-type version, the anchor shall make full contact with the bottom of the drilled hole. Increase the torque up to failure (steel rupture or masonry failure). Determine the ultimate torque moments of the test series T_u and the 5 percent fractile of the ultimate torques.

6.10.3.3 Assessment of results: The maximum torque moment required to set the anchor at the designated setting depth, and to achieve full bearing of the head of the screw against the fixture, shall not exceed T_{screw}. If upon application of the specified installation torque the fixture remains loose, the specified installation torque, T_{screw}, shall either be reestablished at a higher level until this condition is satisfied or the anchor shall be deemed unsuitable.

Equations (6-1) and (6-2) shall be fulfilled. If steel failure occurs in all tests, Eq. (6-2) may be omitted. If Eq. (6-2) is fulfilled, Eq. (6-1) may be omitted.

Tests with steel failure shall satisfy:

$$T_{5\%} \geq 1.4 \cdot \alpha_3 \cdot T_{screw}(f_{u,test}/f_{uta}) \qquad (6\text{-}1)$$

Tests with masonry failure shall satisfy:

$$T_{5\%} \geq 2.0 \cdot \alpha_3 \cdot T_{screw}\left(f_{m,test}/f_m\right)^{0.5} \qquad (6\text{-}2)$$

where

$T_{5\%}$ = 5 percent fractile of the ultimate torque moments, T_u

α_3 = 1.0 for $v \leq 15$ percent

= $1.0 + (v\,(\%) - 15) \cdot 0.03$ for 15 percent < v ≤ 30 percent

v = coefficient of variation of ultimate torque moments

f_m = *1500 psi (10.3 MPa)* (masonry compression strength to which test results are to be normalized) where qualification in accordance with Table 4.1 or 4.2 is desired

= the minimum strength permitted by the applicable standard for all other material types

6.10.4 Reliability of screw anchors if set with a torque wrench and small drill bit:

Refer to Table 4.1, Test 11; Table 4.2, Test 12; Table 4.3, Test 10; Table 4.4, Test 10.

6.10.4.1 Purpose: These reliability tests shall be performed in uncracked masonry to evaluate the sensitivity of the anchor to high-strength masonry if set with a torque wrench.

6.10.4.2 General test conditions:

6.10.4.2.1 Where qualification in accordance with Table 4.1 or 4.2 is desired, perform tests under tension loading in masonry with high-strength grout for all anchor types.

6.10.4.2.2 Where qualification in accordance with Table 4.3 or 4.4 is desired, perform tension tests using similar constituent materials for masonry as in the balance of the test program.

6.10.4.2.3 Use a drill bit of diameter d_{min} and the deepest embedment for each diameter. In tests performed with the stud-type version, the anchor shall make full contact with the bottom of the drilled hole. Increase the torque up to failure. Determine the ultimate torque moments of the test series (T_u) and the 5 percent fractile of the ultimate torque. For anchors that do not fail with the application of 350 ft-lb (475 N-m) of torque, the value of T_u may be taken as 350 ft-lb (475 N-m).

6.10.4.3 Assessment of results: The maximum torque moment required to set the anchor at the designated setting depth, and to achieve full bearing of the head of the screw against the fixture, shall not exceed T_{screw}. If upon application of the specified installation torque the fixture remains loose, the specified installation torque T_{screw} shall either be reestablished at a higher level until this condition is satisfied or the anchor shall be deemed unsuitable.

6.10.4.4 Equations (6-1) and (6-2) shall be fulfilled. In Eq. (6-2), the value of f_g shall be taken as 5000 psi (34.5 MPa) where qualification in accordance with Table 4.1 or 4.2 is desired. If in all tests steel failure occurs, Eq. (6-2) may be omitted.

7.0 SERVICE-CONDITION TESTS

7.1 Purpose: Service-condition tests are performed to determine the basic data required to predict the performance of the anchor under service conditions.

7.2 Required tests: Required service-condition tests are given in Table 4.1 for anchors qualified for use in uncracked fully grouted CMU only, Table 4.2 for anchors qualified for use in both uncracked and cracked fully grouted CMU, Table 4.3 for anchors qualified for use in uncracked ungrouted CMU, and Table 4.4 for anchors qualified for use in uncracked brick masonry. Test requirements for anchors assessed to resist seismic loads are defined in Table 4.2, Table 4.3, and Table 4.4.

7.3 Conduct of tests:

7.3.1 Prepare test members, install anchors, and test in accordance with Section 4.6 unless otherwise noted.

7.3.2 Members for service condition tests shall be of the same masonry batch as the reference tests.

7.4 Service-condition tension test at minimum edge distance and minimum spacing:

Refer to Table 4.1, Test 12a; Table 4.2, Test 13a.

7.4.1 Purpose: This test is performed to ensure that anchors can be properly installed in masonry without premature failure due to incidental over torquing.

7.4.2 General test conditions:

7.4.2.1 Test all diameters of all anchor types in uncracked masonry.

7.4.2.2 For testing in accordance with Tables 4.1 and 4.2, different head joint conditions shall be addressed as follows:

7.4.2.2.1 Where two flat ends are used in the tested joint as illustrated in Figure 7.2 (a) and (d), install two anchors at spacing $s_{test} = s_{min} - 2\ in.$ and edge distance $c = c_{min}$, where s_{min} and c_{min} are the minimum spacing and edge distance desired for qualification, respectively, in a line parallel to the edge of the top or the bottom of a masonry test member with the two anchors bisected by a hollow head joint (see Figure 7.1 and 1.4.14.1).

7.4.2.2.2 Where two stretcher ends are used in the tested joint as illustrated in Figure 7.2 (b) and (e), install two anchors at spacing $s_{test} = s_{min} + 2 \cdot w_{str} - 2\ in.$ and edge distance $c = c_{min}$, where s_{min} and c_{min} are the minimum spacing and edge distance desired for qualification, in a line parallel to the edge of the top or the bottom of a masonry test member with the two anchors bisected by a hollow head joint (see Figure 7.1 and 1.4.14.1).

7.4.2.2.3 Where a flat end meets a stretcher end in the tested joint as illustrated in Figure 7.2 (c) and (f), install two anchors at spacing $s_{test} = s_{min} + w_{str} - 2\ in.$ and edge distance $c = c_{min}$, where s_{min} and c_{min} are the minimum spacing and edge distance desired for qualification, in a line parallel to the edge of the top or the bottom of a masonry test member with the two anchors bisected by a hollow head joint (see Figure 7.1 and 1.4.14.1).

7.4.2.3 The distance to the edge of the bearing plate from the centerline of the corresponding anchor shall be no less than three times the diameter d_o of the anchor being tested. The test member shall be supported with a shear span length (distance from all anchors to the support) of not less than $1.5h_{ef}$. Drilling equipment and setting procedures shall be representative of normal anchor installation as specified by the anchor manufacturer.

7.4.2.4 Optionally, additional combinations of s_{min} and c_{min} are permitted to be tested following the procedures outlined in this section.

7.4.2.5 For torque-controlled anchors and for screw anchors that are either set with an impact screwdriver or with a torque wrench, torque the anchors alternately in increments of $0.2T_{inst}$ using a calibrated torque wrench until additional torque can no longer be taken by the specimen. Record the maximum torque achieved by both anchors.

7.4.2.6 For load-controlled undercut anchors and for screw anchors that are set exclusively with an impact screwdriver, install the anchors according to the manufacturer's installation instructions and load the group of two anchors in an unconfined tension test to failure.

7.4.2.7 For displacement-controlled anchors and undercut anchors that are intended to perform properly without an installation torque, install the anchors according to the manufacturer's installation instructions and load the group of two anchors in an unconfined tension test to failure.

7.4.3 Assessment of results:

7.4.3.1 For torque-controlled expansion and undercut anchors and for screw anchors that are either set with an impact screwdriver or with a torque wrench, the average maximum recorded torque normalized to $f_g = 2000\, psi$ 17 MPa) by Eq. (8-4) shall be greater than the minimum of $1.7T_{inst}$ or $1.0T_{inst}$ + 100 ft-lb (135 N-m). For screw anchors, T_{inst} shall be replaced by T_{screw}.

7.4.3.2 For displacement-controlled expansion and undercut anchors, load-controlled anchors, and screw anchors that are set exclusively with an impact screwdriver, the characteristic failure load shall be equal to or greater than the lesser of:

1) two times the characteristic resistance of the reference tests installed in the cell near the head joint (i.e., Table 4.1 or Table 4.2, Test 1a).
2) the characteristic resistance of a breakout calculation with uncracked masonry in accordance with Section 3.3.2.11.

Repeat the tests with increased values of c_{min} and/or s_{min} as needed until the applicable requirements are met.

7.4.3.3 For all successful tests, the reported minimum spacing, s_{min} (and $s_{min,top}$ for top-of-wall testing), shall be based on the following tested head joint condition as shown in Figure 7.2:

7.4.3.3.1 Where two flat ends are used in the tested joint as illustrated in Figure 7.2 (a) and (d):

$$s_{min} = s_{test} + 2\ in. \tag{7-1}$$

7.4.3.3.2 Where two stretcher ends are used in the tested joint as illustrated in Figure 7.2 (b) and (e):

$$s_{min} = s_{test} - 2w_{str} + 2\ in. \tag{7-2}$$

7.4.3.3.3 Where one flat end meets a stretcher end in the tested joint as illustrated in Figure 7.2 (c) and (f):

$$s_{min} = s_{test} - 2w_{str} + 2\ in. \tag{7-3}$$

7.4.3.4 The reported minimum distance from head joints, $c_{min,HJ}$, shall not exceed the lesser of the value determined in Section 5.4.3.1.2 and $0.5 \cdot s_{min}$ as determined in Section 7.4.3.3.

7.4.3.5 Where multiple combinations of s_{min} and c_{min} are successfully qualified, linear interpolation between the combinations shall be permitted.

7.5 Service-condition tension test at minimum edge distance and minimum spacing at the top of the wall (optional):

7.5.1 Refer to Table 4.1, Test 12b; Table 4.2, Test 13b.

7.5.2 The provisions of Section 7.4 apply with the exception that s_{min} and c_{min} shall be replaced by $s_{min,top}$ and $c_{min,top}$, respectively, as illustrated in Figure 7.2.

7.6 Simulated seismic tension tests (optional):

Refer to Table 4.2, Test 14; Table 4.3, Test 11; Table 4.4, Test 11.

7.6.1 Purpose: These optional tests are conducted to evaluate the performance of anchors in seismic tension, including the effects of cracks for grouted CMU, but without edge effects. The effects of cracking are not considered in ungrouted CMU.

7.6.2 General test conditions for grouted CMU:

Test each anchor diameter at the embedment depths specified in Table 4.2.

7.6.2.1 Install the anchor in a closed crack in accordance with Section 4.7 in the bed joint. If no torque is specified by the MPII, finger-tighten the anchor prior to testing. Open the crack in grouted CMU by Δ_w = 0.020 in. (0.5 mm) where Δ_w is additive to the width of the closed hairline crack after anchor installation. Subject the anchors to the sinusoidal tensile loads specified in Table 7.1 and Figure 7.3 with a cycling frequency between 0.1 and 2 Hz, whereby N_{eq} is given by Eq. (7-4), N_m is given by Eq. (7-6), and N_{int} is given by Eq. (7-5). The minimum load for each load level shall not exceed the larger of 5% N_{eq} or 100 lbs. Conduct load cycling in an unconfined test setup.

7.6.2.2 Following completion of the simulated seismic-tension cycles, open the crack to a width not less than the crack opening width as measured at the end of the cyclic test and load the anchor in tension to failure in a confined test setup. Record the residual tensile capacity, the corresponding displacement; and plot the load-displacement response.

7.6.3 General test conditions–ungrouted CMU and brick:

Test each anchor diameter at the embedment depths specified in Table 4.3 for ungrouted CMU and Table 4.4 for brick. Install the anchor in the center-of-cell location. If no torque is specified by the MPII, finger-tighten the anchor prior to testing. Subject the anchors to the sinusoidal tensile loads specified in Table 7.1 and Figure 7.3 with a cycling frequency between 0.1 and 2 Hz, whereby N_{eq} is given by Eq. (7-4), N_m is given by Eq. (7-5), and N_{int} is given by Eq. (7-6). The minimum load for each load level shall not exceed the larger of 5% N_{eq} or 100 lbs. Conduct load cycling in an unconfined test setup.

7.6.3.1 Following completion of the simulated seismic-tension cycles, load the anchor in tension to failure in an unconfined test setup. Record the residual tensile capacity, the corresponding displacement; and plot the load-displacement response.

$$\cancel{N_{eq} = 0.5\bar{N}_{o,i}\left[\left(\frac{h_g}{h_{ef}}\right)\left(\frac{f_{g,test}}{f_{g,test,i}}\right)^{0.5} + \left(\frac{h_g}{h_{ef}}\right)\left(\frac{f_{b,test}}{f_{b,test,i}}\right)^{0.5}\right]} \tag{7-4}$$

$$N_{eq} = 0.5\bar{N}_{o,i}\left[\left(\frac{h_g}{h_{ef}}\right)\left(\frac{f_{g,test}}{f_{g,test,i}}\right)^{0.5} + \left(\frac{h_b}{h_{ef}}\right)\left(\frac{f_{b,test}}{f_{b,test,i}}\right)^{0.5}\right]$$

$$N_m = \frac{N_{eq}}{2} \tag{7-5}$$

$$N_{\text{int}} = \frac{N_m + N_{eq}}{2} \tag{7-6}$$

where

$\bar{N}_{o,i}$ = mean tensile capacity from applicable reference tests (Table 4.2, Test 1e, Table 4.3, Test 1a; Table 4.4, Test 1b) lb. (N);

$f_{g,test}$ = compressive strength of grout at time of testing, psi (MPa);

$f_{g,test,i}$ = compressive strength of grout corresponding to the tests used to establish $\bar{N}_{o,i}$, psi (MPa);

$f_{b,test}$ = compressive strength of unit at time of testing, psi (MPa);

$f_{b,test,i}$ = compressive strength of unit corresponding to the tests used to establish $\bar{N}_{o,i}$, psi (MPa);

h_{ef} = effective embedment depth, in. (mm);

h_g = portion of embedment within grout, in. (mm); and

h_b = portion of embedment within the unit (including face shell, bed joint, and web), in. (mm).

7.6.4 Assessment of results in grouted CMU, ungrouted CMU, and brick.

7.6.4.1 All anchors in a test series shall complete the simulated seismic tension loading history specified in Table 7.1 and Figure 7.3. Failure of an anchor to develop the required tensile resistance in any cycle prior to completion of the loading history specified in Table 7.1 and Figure 7.3 shall be recorded as an unsuccessful test. The mean residual capacity of the anchors in the test series shall be equal to or greater than 160 percent of N_{eq}, where N_{eq} is defined by Eq. (7-4).

7.6.4.2 Successful completion of the cyclic loading history and fulfillment of the residual tensile capacity requirement of this section shall be noted in Table 10.1.

7.6.4.3 If the anchor does not fulfill the aforementioned requirements at N_{eq}, it shall be permitted to conduct the test with reduced cyclic loads conforming to the loading history specified in Table 7.1 and Figure 7.3, whereby $N_{eq,reduced}$, $N_{\text{int},reduced}$, and $N_{m,reduced}$ are substituted for N_{eq}, N_{int}, and N_m, respectively. All anchors in a test series shall complete the simulated seismic tension loading history. Failure of an anchor to develop the required tensile resistance in any cycle prior to completion of the loading history given in Table 7.1 and Figure 7.3 shall be recorded as an unsuccessful test. The mean residual capacity of the anchors in the test series in the tension test shall be at least 160 percent of the reduced peak load $N_{eq,reduced}$. Report successful completion of the reduced cyclic loading history and fulfillment of the residual tensile capacity requirement together with the resulting capacity $N_{p,eq}$ as defined by Eq. (7-7).

$$N_{p,eq} = N_p \frac{N_{eq,reduced}}{N_{eq}} \tag{7-7}$$

The value of N_p as given in Equation (7-7) is the reported static tensile capacity of the anchor.

7.7 Static shear testing for single anchors without spacing and edge effects:

Refer to Table 4.1, Test 13a; Table 4.2, Test 15a; Table 4.3, Test 13; Table 4.4, Test 13.

7.7.1 Purpose: This test is performed to evaluate the shear capacity of anchors. For anchors evaluated in accordance with Tables 4.1, 4.3 and 4.4, perform shear tests in uncracked low-strength masonry for all anchor diameters at minimum effective embedment h_{ef}. For anchors evaluated in accordance with Table 4.2, perform shear tests in cracked masonry for all anchor diameters at minimum effective embedment h_{ef}. At the option of the manufacturer, additional tests shall be permitted to be performed at deeper embedments.

7.7.2 General test conditions:

7.7.2.1 Perform shear tests away from edges in accordance with ASTM C1892.

7.7.2.2 Testing location: For anchors evaluated in accordance with Tables 4.1 and 4.3, install anchor in the bed joint and load the anchor parallel to the bed joint. For anchors evaluated in accordance with Table 4.2, shear tests shall be performed in cracked masonry with a crack width of 0.012 in. (0.3 mm) with the load applied parallel to the bed joint. For anchors evaluated in accordance with Table 4.4, install anchor in the hollow portion of the brick and load the anchor perpendicular to the bed joint.

7.7.3 Assessment of results: The characteristic shear capacity, V_{sa}, shall be determined in accordance with Eq. (8-10) and normalized in accordance with Eq. (8-8), but shall not exceed the capacity determined in accordance with *ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2).*

7.8 Simulated seismic shear tests:

Refer to Table 4.2, Test 16; Table 4.3, Test 13; Table 4.4, Test 13.

7.8.1 Purpose: These optional tests are conducted to evaluate the performance of anchors in seismic shear loading, including the effects of cracks, but without edge effects.

7.8.2 General test conditions for grouted CMU (all anchor element types): Test each anchor diameter at the embedment depths specified in Table 4.2. Install the anchor in a closed crack in accordance with Section 4.7 within a bed joint. If no torque is specified by the MPII, finger-tighten the anchor prior to testing. Open the crack by Δ_w = 0.020 in. (0.5 mm) where Δ_w is additive to the width of the closed hairline crack after anchor installation. Subject the anchors to the sinusoidal shear loads specified in Table 7.2 and Figure 7.4 with a cycling frequency between 0.1 and 2 Hz with the shear load applied parallel to the direction of the crack, whereby V_{eq} is given by Eq. (7-8), V_m is given by Eq. (7-9), and V_{int} is given by Eq. (7-10). To reduce the potential for uncontrolled slip during load reversal, the alternating shear loading shall be permitted to be approximated by the application of two half-sinusoidal load cycles at the desired frequency connected by a reduced-speed ramped load as shown in Figure 7.5.

7.8.3 General test conditions for ungrouted CMU and brick masonry (all anchor element types)—Test each anchor diameter at the embedment depths specified in Table 4.3 and Table 4.4, respectively. Install the anchor in bed joint. If no torque is specified by the MPII, finger-tighten the anchor prior to testing. Subject the anchors to the sinusoidal shear loads specified in Table 7.2 and Figure 7.4 with a cycling frequency between 0.1 and 2 Hz with the shear load applied parallel to the bed joint, whereby V_{eq} is given by Eq. (7-8), V_m is given by Eq. (7-9), and V_{int} is given by Eq. (7-10). To reduce the potential for uncontrolled slip during load reversal, the alternating shear loading shall be permitted to be approximated by the application of two half-sinusoidal load cycles at the desired frequency connected by a reduced-speed ramped load as shown in Figure 7.5.

$$\cancel{V_{eq} = 0.3 A_{se} f_{ut,test}}\ \underline{V_{eq} = min\,(0.3A_{se}f_{ut,test}\ , 0.5V_{u,x})} \tag{7-8}$$

$$V_m = \frac{V_{eq}}{2} \tag{7-9}$$

$$V_{\text{int}} = \frac{V_m + V_{eq}}{2} \tag{7-10}$$

where

$V_{u,x}$ = normalized tested static shear capacity given by Eq. (8-8) with only α_{mat} or α_{futa} applied based on the predominant failure mode during testing.

Record the crack width, anchor displacement, and applied shear load in accordance with section 4.7. Plot the load-displacement history in the form of hysteresis loops.

For grouted CMU, following completion of the simulated seismic shear cycles, open the crack to a width not less than the crack opening width as measured at the end of the cyclic shear test and load the anchor parallel to the crack in shear to failure. Record the maximum shear load or residual shear capacity and the corresponding displacement and plot the load-displacement response. For ungrouted CMU and brick masonry, following completion of the simulated seismic shear cycles, load the anchor parallel to the bed joint in shear to failure. Record the maximum load or residual capacity and the corresponding displacement and plot the load-displacement response.

7.8.4 Assessment of results:

7.8.4.1 All anchors in a test series shall complete the simulated seismic shear load history specified in Table 7.2 and Figure 7.4. Failure of an anchor to develop the required shear resistance in any cycle prior to completion of the loading history specified in Table 7.2 and Figure 7.4

shall be recorded as an unsuccessful test. The mean residual capacity of the anchors in the test series shall be equal to or greater than 160 percent of V_{eq}, where V_{eq} is defined by Eq. (7-8).

7.8.4.2 Successful completion of the cyclic loading history and fulfillment of the residual shear capacity requirement of this section shall be noted in Table 10.1.

7.8.4.3 If the anchor does not fulfill the aforementioned requirements at V_{eq}, it shall be permitted to conduct the test with reduced cyclic loads conforming to the loading history specified in Table 7.2 and Figure 7.4 whereby $V_{eq,reduced}$, $V_{\text{int},reduced}$, and $V_{m,reduced}$ are substituted for V_{eq}, V_{int}, and V_m, respectively. All anchors in a test series shall complete the simulated seismic shear loading history. Failure of an anchor to develop the required shear resistance in any cycle prior to completion of the loading history given in Table 7.2 and Figure 7.4 shall be recorded as an unsuccessful test. The mean residual capacity of the anchors in the test series in the shear test shall be at least 160 percent of the reduced peak load $V_{eq,reduced}$. Report successful completion of the reduced cyclic loading history and fulfillment of the residual shear capacity requirement together with the resulting capacity $V_{sa,eq}$ as defined by Eq. (7-11).

$$V_{sa,eq} = V_{sa} \frac{V_{eq,reduced}}{V_{eq}} \qquad (7\text{-}11)$$

For a given anchor diameter, all embedment depths greater than the tested embedment depth shall be qualified at the value of $V_{sa,eq}$ for embedment depths determined in accordance with Equation (7-8). Evaluation of $V_{sa,eq}$ for embedment depths between the tested embedments shall be by linear interpolation.

7.8.4.4 For anchor diameters not tested in shear, the minimum values of $\alpha_{V,seis}$ determined for the tested anchor diameters closest to the untested diameters shall be used in Eq. (8-24).

7.8.4.5 Report shear capacities obtained in Table 10.1.

7.8.4.6 For a given anchor diameter, all embedment depths greater than the tested embedment depth shall be qualified at the value of V_s determined in accordance with Section 8.6. Use linear interpolation for the evaluation of V_s for embedment depths between those tested.

7.9 Optional top-of-wall and end-of-wall testing:

Refer to Table 4.1, Test 13b; Table 4.2, Test 15b.

7.9.1 Purpose:—Where top-of-wall qualification is desired, at minimum, static tension (Section 7.9.2) and static shear (Section 7.9.3) tests shall be performed at the minimum top-of-wall edge distance to be qualified. These tests establish tensile pullout capacity and in-plane shear capacities for the top of the wall that may be applied at and beyond the minimum edge distance. Further testing may be performed to refine reportable values at larger edge distances or end-of-wall installations as desired following the provisions within Section 7.9.

7.9.2 Static tension tests at minimum top-of-wall edge distance:

7.9.2.1 Test conditions: Tests shall be performed in the center of the cell at the minimum top-of-wall edge distance sought for recognition.

7.9.2.2 Assessment of results: Determine the characteristic strength and pullout capacity in accordance with Eq. (8-10). Calculate the reported pullout capacity in accordance with Section 8.5.5.2.4.

7.9.3 Static shear testing at minimum top-of-wall edge distance:

7.9.3.1 Test conditions: Tests shall be performed in the center of the cell at the minimum edge distance sought for recognition at the top of the wall with in-plane loading. Load shall be applied toward the nearest head joint.

7.9.3.2 Assessment of results: The characteristic capacity for in-plane (i.e., parallel to edge) loading, $V_{top,par}$, shall be determined in accordance with Eq. (8-10) and normalized in accordance with Eq. (8-8).

7.10 Torque test (optional)

Refer to Table 4.1, Test 14; Table 4.2, Test 17; Table 4.3, Test 14; Table 4.4, Test 14.

7.10.1 Purpose: These optional reliability tests are performed to evaluate the relationship relation between the applied torque moment and the tensile force.

7.10.2 General test conditions: Figure 7.6 shows the test setup. The fixture shall contain all elements shown. The double-sided abrasive paper shall have sufficient roughness to prevent rotation of the washer relative to the test fixture during the application of torque. Other methods of preventing rotation of the washer shall be permitted, provided it can be shown they do not affect the anchor performance. Apply increasing torque and record the torque and corresponding induced tension in the anchor. The washer shall not turn during the application of torque.

7.10.3 Assessment of results:

7.10.3.1 The torque test shall achieve a torque resistance of at least $1.3T_{inst}$. The anchor shall not turn in the anchor hole prior to reaching a torque resistance of $1.3T_{inst}$. In addition, Eq. (7-12) shall be fulfilled. If this requirement is not met, reduce the installation torque T_{inst} as required to fulfill the requirement.

$$N_{95\%} \leq \min\left[F_y; 0.8N_{k,test}\right] \qquad (7\text{-}12)$$

where:

$N_{95\%}$ = 95 percent fractile (90 percent confidence) of the induced tensile force corresponding to $1.3T_{inst}$;

$N_{k,test}$ = characteristic tensile capacity evaluated from Table 4.1, Test 1a or Table 4.2, Test 1a; and

F_y = $A_{se,N} f_{ya}$ for bolts with a defined yield stress, psi (MPa); or

= $0.8 A_{se,N} f_{uta}$ for bolts without a well-defined yield stress, psi (MPa).

7.10.3.2 It shall be permitted to satisfy the requirement of Eq. (7-12) using a calculated value of $N_{95\%}$ in accordance with Eq. (7-13).

$$N_{95\%} = \frac{1.3 T_{inst}}{k_f d_a} \quad (7\text{-}13)$$

where k_f is the friction factor of threads. The friction factor shall be taken as a lower-bound value. For normal threaded rods without lubricants or friction-reducing coatings, $k_f = 0.2$ may be assumed.

8.0 GENERAL ASSESSMENT OF ANCHORS

8.1 Analysis of data:

8.1.1 Analyze data in accordance with the procedures defined within individual tests and this chapter. Report the results in accordance with the requirements of Section 10**.**

8.2 Establishment of masonry strengths and trends:

8.2.1 Grout strength: Establish grout strength trends in accordance with Eq. (8-1).

$$f_{g,i(t)} = f_{g,i(28)} \left(\frac{t}{4 + 0.85t} \right) \quad (8\text{-}1)$$

where

$f_{g,i(t)}$ = compressive strength of grout batch i at age t (days); and

$f_{g,i(28)}$ = best-fit (i.e., calculated, not tested) 28-day grout compressive strength using least-squares regression of ASTM C1019 test data tested at frequencies in accordance with Table 4.8.

8.2.2 Unit strength:

8.2.2.1 It shall be permitted to assume that the concrete masonry unit and clay/shale/similar brick compressive strength based on testing in accordance with ASTM C140 and ASTM C67, respectively, remain constant throughout the test program, i.e.:

$$f_{b,i} = f_{b,i(28+)} \quad (8\text{-}2)$$

$f_{b,i}$ = compressive strength of unit batch i to be used at all ages; and

$f_{b,i(28+)}$ = unit compressive strength resulting from ASTM C140 / ASTM C67 testing at or beyond 28 days from production date.

8.2.2.2 If desired, unit strength trends may be established following the methodology prescribed in Section 8.2.1 in lieu of the simplifying assumption of constant unit strength in Section 8.2.2.1.

8.2.3 Grouted CMU compressive strength: For use in shear test normalization, establish masonry strength trends in accordance with Eq. (8-3)

$$f_{m,i(t)} = 0.59a \cdot f_{b,i} + 0.90(1-a) \cdot f_{g,i(t)} \quad (8\text{-}3)$$

where

$f_{m,i(t)}$ = compressive strength of masonry batch i at age t (days);

a = ratio of the net cross-sectional area to the gross cross-sectional area of the unit;

$f_{g,i(t)}$ = compressive strength of grout batch i at age t (days) established by Eq. (8-1); and

$f_{b,i}$ = compressive strength of unit batch i established by Eq. (8-2).

8.3 Normalization of results:

8.3.1 Normalization of tensile test results for grouted CMU: Irrespective of failure mode, tensile test results shall be normalized in accordance with Eq. (8-4).

$$N_{u,f_m} = N_{u,test} \cdot \alpha_{f_m,i} \quad (8\text{-}4)$$

where

N_{u,f_m} = test result normalized to f_m, lb. (N);

$N_{u,test}$ = individual test result, lb. (N); and

$\alpha_{f_m,i}$ = normalization factor for batch i accounting for masonry unit and grout strength as defined in Eq. (8-5).

8.3.1.1 Masonry unit and grout strength normalization factor:

$$\alpha_{f_m,i} = \left(\frac{h_g}{h_{ef}}\right)\left(\frac{2{,}000\,psi}{f_{g,i(t)}}\right)^{0.5} + \left(\frac{h_b}{h_{ef}}\right)\left(\frac{2{,}000\,psi}{f_{b,i}}\right)^{0.5} \le 1.0 \quad (8\text{-}5)$$

where

$f_{g,i(t)}$ = compressive strength of grout batch i at test age t calculated in accordance with Eq. (8-1), psi (MPa);

$f_{b,i}$ = compressive strength of unit batch i determined in accordance with Eq. (8-2); psi (MPa);

h_{ef} = effective embedment depth, in. (mm);

h_g = portion of embedment within grout, in. (mm); and

h_b = for CMU, the portion of

embedment within the unit (including face shell, bed joint, and web), in (mm).

***R8.3.1** (Commentary to Section 8.3.1) Normalization to a grout strength of 2,000 psi (13.8 MPa) is based on the minimum grout compressive strength permitted by TMS 402/ACI 530/ASCE 5, which references ASTM C1019. Normalization to a unit strength of 2,000 psi (13.8 MPa) is based on the minimum unit strength permitted by ASTM C90 (and tested in accordance with ASTM C140). These ASTM minimums comport with the TMS 402/ACI 530/ASCE 5 minimum specified masonry strength of 1,500 psi (10.3 MPa) by the relation prescribed by Eq.* (8-3). *The use of an exponent of 0.5 for normalization is assumed to be a conservative estimate. It is assumed in Eq.* (8-5) *that the effects of unit strength and grout strength act simultaneously on the capacity.*

8.3.1.1.1 For tests conducted in the web, $h_b = h_{ef}$ and $h_g = 0$ in Eq. (8-5).

8.3.1.1.2 For tests conducted in bed joints, $h_g = h_{ef}$ and $h_b = 0$ in Eq. (8-5).

8.3.2 Normalization of tensile test results for ungrouted CMU: Irrespective of failure mode, tensile test results shall all be normalized in accordance with Eq. (8-6).

$$N_{u,ug,f_m} = N_{u,ug,test} \cdot \alpha_{b,i} \cdot \alpha_{thickness} \qquad (8\text{-}6)$$

where

N_{u,ug,f_m} = normalized test result for anchors installed in ungrouted CMU;

$N_{u,ug,test}$ = mean test result for anchors installed in ungrouted CMU;

$\alpha_{b,i}$ = reduction factor accounting for unit strength

= $\left(\dfrac{2,000\,psi}{f_{b,i}}\right)^{0.5} \leq 1.0$;

$f_{b,i}$ = compressive strength of unit batch i established by Eq. (8-2);

$\alpha_{thickness}$ = reduction factor accounting for tested thickness of the face shell

= $\left(\dfrac{1.25in}{t_{shell}}\right)^{1.5} \leq 1.0$ for tests in the center of the cell and the bed joint;

= 1.0 for tests in the web; and

t_{shell} = measured thickness of the face shell in the center of the cell for test result.

8.3.3 Normalization of tensile test results for brick: Irrespective of failure mode, tensile test results shall all be normalized in accordance with Eq. (8-7).

$$N_{u,br,f_m} = N_{u,br,test} \cdot \alpha_{br,i} \qquad (8\text{-}7)$$

where

N_{u,br,f_m} = test result normalized by brick strength i, lb. (N);

$N_{u,br,test}$ = individual test result, lb. (N);

$\alpha_{br,i}$ = individual test result, lb. (N);

= $\left(\dfrac{f_{br,\min}}{f_{br,i}}\right)^{0.5}$;

$f_{br,\min}$ = minimum brick compressive strength specified by ASTM standard for the brick type tested, psi (MPa); and

$f_{b,i}$ = compressive strength of brick batch i established by Eq. (8-2)

8.3.4 Normalization of shear test results: Irrespective of failure mode, shear test results shall all be normalized in accordance with Eq. (8-8).

$$V_{u,fm,\cancel{fm}} = V_{u,test} \cdot \alpha_{mat} \cdot \alpha_{futa} \qquad (8\text{-}8)$$

where

$\cancel{V_{u,x}}$ $V_{u,fm}$ = test result normalized by unit and grout strength, lb. (N);

$V_{u,test,x}$ = test result from series x, lb. (N);

α_{mat} = normalization factor accounting for masonry strength

= $\left(\dfrac{1,500\,psi}{f_{m,i(t)}}\right)^{0.5}$ for tests in grouted CMU with $f_{m,i(t)}$ defined by Eq. (8-3)

= $\alpha_{b,i}$ as defined in Eq. (8-6) for tests in ungrouted CMU

= $\alpha_{br,i}$ as defined in Eq. (8-7) for tests in brick; and

α_{futa} = normalization factor accounting for steel strength (see below).

8.3.4.1 Steel strength normalization factor

$$\alpha_{futa} = \frac{f_{uta}}{f_{uta,test}} \qquad (8\text{-}9)$$

where

f_{uta} = specified steel tensile strength to which the test result shall be normalized, psi (MPa); and

$f_{u,test,x}$ = measured steel tensile strength corresponding to anchors used for test series x, psi (MPa).

8.4 Establishment of characteristic values:

8.4.1 Evaluate the characteristic capacity—for example, N_k, and V_s—from the mean value and the associated coefficient of variation ν using Eq. (8-10)

$$F_k = \bar{F}_{u,f_m,x}\left(1 - K \cdot v_x\right) \tag{8-10}$$

where

K = tolerance factor corresponding to a 5 percent probability of nonexceedance with a confidence of 90 percent derived from a noncentral t distribution for which the population standard deviation is unknown (values for specific samples sizes n are provided in Table 8.1);

F_k = characteristic capacity (5 percent fractile), lb. (N);

$\bar{F}_{u,f_m,x}$ = mean of test results for test series x normalized in accordance with Section 8.3; and

v_x = coefficient of variation of the population sample corresponding to test series x, percent.

8.5 Assessment of Characteristic Tensile Capacity Associated with Masonry Breakout and Pullout

8.5.1 Overall load-displacement behavior:

8.5.1.1 To be acceptable, the tensile load-displacement behavior of single anchors shall be predictable except as noted in Section 8.5.1.2. Figure 8.1 provides examples of acceptable and unacceptable load-displacement curves for the types of anchors covered in this Acceptance Criteria document. For each anchor tested, neither a load plateau with a corresponding slip greater than 5 percent of the displacement at ultimate load nor a temporary drop in load is not acceptable at load levels less than $\cancel{N_1}$ N_1. For tests in uncracked masonry, $\cancel{N_1}$ N_1 is taken as the lesser of 0.8N_u $\cancel{N_u}$ and $\cancel{A_{se} \cdot f_y}$ $A_{se}f_y$. For tests in cracked masonry, N_1 is taken as the lesser of 0.7 N_u and $A_{se}f_y$. These requirements shall be fulfilled in accordance with Table 8.2.

8.5.1.2 Within a test series, if not more than one test shows a load-displacement curve not complying with Section 8.5.1.1, the anchor shall be considered acceptable provided that two conditions are met:

1) There is no drop in load

2) The deviation is justified as being uncharacteristic of the anchor behavior and is due, for example, to a defect in the test procedure or the base material. Such defects shall be described in detail in the evaluation report and the results of an additional 10 tensile tests shall display load-displacement curves meeting the requirements of Figure 8.1.

8.5.2 Load-displacement behavior at service loads: For each reference test series (combination of anchor diameter and embedment depth), determine the mean anchor stiffness value β from Eq. (8-11) and coefficient of variation ν in the service load range. Report these values as applicable:

$$\beta = \frac{N_{30\%} - N_{10\%}}{\Delta_{30\%} - \Delta_{10\%}} \tag{8-11}$$

8.5.3 Modes of failure:

8.5.3.1 The failure modes for tension loading are masonry breakout failure, steel fracture, pullout or pull-through, test member splitting, and side-face blowout. The failure modes for shear loading are steel failure and masonry breakout for anchors located near an edge. Examples of these failure modes are given in ACI 355.2-19 Figure 5.5.3. Report the failure mode for each individual anchor tested and the strength ($f_{u,test}$ for steel failure, and $N_{p,uncr/cr}$ for breakout, pullout, pull-through failure) for each test series.

8.5.3.2 If multiple failure modes occur within a test series, but one failure mode predominates with the other failure modes demonstrating similar capacities, note the failure modes and failure capacities in the test report. Report the mean failure load, taking into account all results as the failure load associated with the predominant failure mode.

8.5.3.3 If only one embedment depth is listed for a particular anchor diameter and steel fracture is the only failure mode, report $f_{u,test}$ for steel failure. Alternatively, to determine pullout capacity, it shall be permitted to use a higher-strength steel bolt if it can be verified that the bolt does not affect the functioning of the anchor.

8.5.3.4 If more than one embedment depth is specified for a particular anchor diameter, perform tests with embedment depths in accordance with Tables 4.1 through 4.4, as applicable. For all embedment depths, report failure modes, k value for masonry failure, $f_{u,test}$ for steel failure, and N_p for pullout and pull-through failure.

8.5.3.5 For pullout or pull-through failure, calculate $N_{p,uncr/cr}$ based on the test sample size.

8.5.4 Establishment of anchor categories:

8.5.4.1 For each combination of anchor diameter and embedment depth, compute the ratio of the characteristic capacity $N_{k,r}$ in each reliability test to the characteristic capacity $N_{k,o}$ in the corresponding reference test. The corresponding reference test shall be conducted in the same masonry batch with the same crack width, if applicable. Characteristic capacities shall be determined in accordance with Section 8.4, where the K value used in calculating the characteristic capacity in each reliability test shall be equal to the K associated with the number of replicates in the reference tests. Using the least ratio of $N_{k,r} / N_{k,o}$ from all reliability tests, establish the anchor category using Table 8.3. For each diameter, report a single category representing the lowest category determined by the tests at all embedment depths.

8.5.4.2 It shall be permitted to evaluate the ratio $N_{k,r} / N_{k,o}$ on the basis of mean test results provided that the following are satisfied: 1) the difference in the number of replicates in each test series is not greater than five; and 2) the coefficient of variation associated with the test results in all of the reliability test series is less than or equal to the coefficient of variation associated with the corresponding reference tests or less than 10 percent.

8.5.4.3 Where the controlling value of $N_{k,r} / N_{k,o}$ is less than the threshold value for Anchor Category 2 in Table 8.3 but greater than 0.50, the anchor shall be assigned to Anchor Category 2 and an additional reduction factor α_{cat2} for the determination of $N_{k(cr/uncr)}$ shall be determined in accordance with Eq. (8-12). For all other cases, α_{cat2} shall be taken as 1.0.

$$\alpha_{cat2} = \left(\frac{N_{k,r} / N_{k,o}}{0.7} \right) \quad \text{(8-12)}$$

8.5.5 Determination of limiting characteristic capacity in fully grouted CMU:

8.5.5.1 Determine the corresponding pullout capacity $N_{u,nom}$ for each reference and service-condition tension test normalized to grout strength of 2,000 psi (13.8 MPa) and unit strength of 2000 psi (13.8 MPa) using Eq. (8-13).

$$N_{u,nom} = N_{u,f_m} \quad \text{(8-13)}$$

where

N_{u,f_m} = peak tensile load measured in a tension test conducted in test series x normalized to grout strength $f_g = 2{,}000$ psi (13.8 MPa) and unit strength $f_b = 2{,}000$ psi (13.8 MPa) in accordance with Eq. (8-4), lb. (N);

8.5.5.2 Nominal characteristic capacity:

8.5.5.2.1 Determine the normalized nominal characteristic capacity in accordance with Section 5.4.

8.5.5.2.2 For anchors qualified in accordance with Table 4.1 and Table 4.2, reduce the nominal characteristic capacity in uncracked masonry, $N_{k,nom,uncr}$, in accordance with Eq. (8-14) and the nominal characteristic capacity in cracked masonry (Table 4.2 only), $N_{k,nom,cr}$, in accordance with (8-15). Report the limiting characteristic pullout capacity in uncracked masonry, $N_{k,uncr}$, and cracked masonry, $N_{k,cr}$, for each combination of mandatory and optional use conditions specified.

$$N_{k,uncr} = N_{k,nom,uncr} \cdot \alpha_{cat2} \quad \text{(8-14)}$$

$$N_{k,cr} = N_{k,nom,cr} \cdot \alpha_{cat2} \quad \text{(8-15)}$$

where

$N_{k,nom,uncr}$ = uncracked nominal characteristic tensile capacity; taken as the least uncracked nominal capacity observed in reference tests near the head joint, in the bed joint, and in the web, lb. (N);

= $\min\left(N_{k,1a}, N_{k,1b}, N_{k,1c}\right)$ as determined with Section 5.4;

$N_{k,(1a,1b,1c)}$ = characteristic tensile capacities from Table 4.1, Tests 1a, 1b, and 1c, respectively and Table 4.2, Tests 1a, 1b, and 1c, respectively, as determined with Eq. (8-10) and normalized in accordance with Section 8.3, lb. (N);

$N_{k,nom,cr}$ = cracked nominal pullout capacity; taken as $N_{k,nom,uncr} \cdot \alpha_{cr}$, lb. (N); with

α_{cr} = ratio of cracked to uncracked tensile capacity in the bed joint (i.e., $N_{k,1e} / N_{k,1b} \leq 1.0$);

α_{cat2} = reduction factor for Anchor Category 2 as determined in Section 8.5.4.

8.5.5.2.3 Capacity for seismic tension: Further modify the limiting characteristic pullout resistance $N_{k(cr,uncr)}$ for seismic tension loading cases in accordance with Eq. (8-16).

$$N_{k,seis(cr,uncr)} = N_{k(cr,uncr)} \cdot \frac{N_{eq,reduced}}{N_{eq}} \quad \text{(8-16)}$$

where

$N_{eq,reduced}$ = reduced seismic tensile testing loads established for Eq. (7-7), lb. (N);

N_{eq} = calculated seismic tensile testing loads established for Eq. (7-7), lb. (N);

$N_{k,seis(cr,uncr)}$ = pullout capacity under seismic tensile loading, lb. (N).

8.5.5.2.4 Pullout capacity for installations in the top of fully grouted masonry: Further modify the limiting characteristic capacity $N_{k(cr,uncr)}$ for top-of-wall installation cases in accordance with Eqs. (8-17) through (8-19).

$$N_{k,top,uncr} = N_{k,uncr} \cdot \alpha_{top,uncr} \quad (8\text{-}17)$$

where

$N_{k,top,uncr}$ = pullout capacity of top-of-wall installations in uncracked masonry, lb. (N);

$N_{k,uncr}$ = characteristic pullout capacity in uncracked masonry defined in Eq. (8-15), lb. (N);

$\alpha_{top,uncr}$ = reduction factor for uncracked top-of-wall installations, i.e., $N_{k,1\mathrm{d}} / N_{k,nom,uncr}$; and

$N_{k,nom,uncr}$ = uncracked nominal characteristic pullout capacity defined in Eq. (8-15).

$$N_{k,top,cr} = N_{k,top,uncr} \cdot \alpha_{cr} \text{, lb. (N).} \quad (8\text{-}18)$$

where

$N_{k,top,cr}$ = pullout capacity of top-of-wall installations in cracked masonry, lb. (N); and

α_{cr} = ratio of cracked to uncracked tensile capacity in the bed joint (i.e., $N_{k,1\mathrm{e}} / N_{k,1\mathrm{b}}$).

$$N_{k,top,seis(cr,uncr)} = N_{k,top(cr,uncr)} \cdot \frac{N_{eq,reduced}}{N_{eq}} \quad (8\text{-}19)$$

where

$N_{k,top,seis,(cr,uncr)}$ = pullout capacity of top-of-wall installations under seismic tensile loading for cracked and uncracked masonry, respectively, lb. (N); and

$N_{eq,reduced}$ = reduced seismic tensile testing loads established for Eq. (7-7), lb. (N);

N_{eq} = calculated seismic tensile testing loads established for Eq. (7-7), lb. (N);

8.5.6 Capacity of anchors in ungrouted CMU:

8.5.6.1 Determine the uncracked characteristic capacity, $N_{k,ug,uncr}$, in accordance with Eq. (8-20).

$$N_{k,ug,uncr} = \alpha_{drill} \cdot \alpha_{cat2} \cdot N_{k,ug,nom} \quad (8\text{-}20)$$

Where

$N_{k,ug,uncr}$ = uncracked characteristic resistance determined in accordance with Eq. (8-10), lb. (N);

α_{drill} = 0.75 as the default design value and in all cases where rotation-mode-only drilling is employed during qualification testing;

= 1.0 where hammer-mode drilling is employed during qualification testing. The drill type used for testing, as characterized by the impact energy used for testing, shall be reported and the evaluation report shall note the required maximum impact energy permitted. This information shall be included in the MPII;

α_{cat2} = reduction factor for Anchor Category 2 as determined in Section 8.5.4; and

$N_{k,ug,nom}$ = nominal capacity in ungrouted CMU; taken as the least nominal capacity observed in reference tests in the center of the cell, the bed joint, and the web, lb. (N)

= $\min\left(N_{k,ug,1\mathrm{a}}, N_{k,ug,1\mathrm{b}}, N_{k,ug,1\mathrm{c}}\right)$;

8.5.6.2 Tensile capacity for seismic tension: Further modify the limiting characteristic resistance $N_{k,ug}$ for seismic tension loading cases in accordance with Eq. (8-21).

$$N_{k,ug,seis(uncr)} = N_{k,ug(uncr)} \cdot \frac{N_{eq,reduced}}{N_{eq}} \quad (8\text{-}21)$$

where

$N_{k,ug,seis,uncr}$ = characteristic tensile capacity under seismic tensile for uncracked masonry, respectively, lb. (N);

$N_{k,ug,uncr}$ = characteristic tensile capacity for uncracked masonry determined in Eq.(8-20), lb. (N); and

$N_{eq,reduced}$ = reduced seismic tensile testing loads established for Eq. (7-7), lb. (N);

N_{eq} = calculated seismic tensile testing loads established for Eq. (7-7), lb. (N);

8.5.7 Capacity of anchors in brick:

8.5.7.1 Determine the uncracked characteristic capacity, $N_{k,br,uncr}$, in accordance with Eq. (8-22)

$$N_{k,br,uncr} = \alpha_{drill} \cdot \alpha_{cat2} \cdot N_{k,br,uncr} \quad (8\text{-}22)$$

Where

$N_{k,br,uncr}$ = uncracked characteristic resistance determined in accordance with Eq. (8-10), lb. (N);

α_{drill} = 0.75 as the default design value and in all cases where rotation-mode-only drilling is employed during qualification testing;

= 1.0 where hammer-mode drilling is employed during qualification testing. The drill type used for testing, as characterized by the impact energy used for testing, shall be reported and the evaluation report shall note the required maximum impact energy permitted. This information shall be included in the MPII;

α_{cat2} = reduction factor for Anchor Category 2 as determined in Section 8.5.4; and

$N_{k,br,nom}$ = nominal capacity in brick; taken as the least nominal capacity observed in reference tests in the solid portion, the hollow portion, the bed joint, and the head joint, lb. (N)

= $\min\left(N_{k,br,1a}, N_{k,br,1b}, N_{k,br,1c}, N_{k,br,1d}\right)$;

8.5.7.2 Resistance for seismic tension:–Further modify the limiting characteristic resistance $N_{k,br}$ for seismic tension loading cases in accordance with Eq. (8-23)**.**

$$N_{k,br,seis} = N_{k,br} \cdot \frac{N_{eq,reduced}}{N_{eq}} \qquad (8\text{-}23)$$

where

$N_{eq,reduced}$ = reduced seismic tensile testing loads established for Eq. (7-7), lb. (N);

N_{eq} = calculated seismic tensile testing loads established for Eq. (7-7), lb. (N);

$N_{k,br,seis}$ = resistance under seismic tensile loading, lb. (N).

8.6 Assessment of shear capacity:

8.6.1 Static shear capacity:

8.6.1.1 Anchors in grouted CMU: The characteristic shear capacity, $V_{s,gr}$, shall be determined by testing as prescribed in Section 7.7, but shall not exceed the value determined in accordance with *ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2).*

8.6.1.2 Anchors in ungrouted CMU: The characteristic shear resistance, $V_{s,ug}$, shall be reported as equal to $N_{k,ug}$, where $N_{k,ug}$ is determined in accordance with Section 8.5.6, but shall not exceed the value determined in accordance with *ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2).*

8.6.1.3 Anchors in brick masonry: The characteristic shear resistance, $V_{s,br}$, shall be determined by testing as prescribed in Section 7.7, but shall not exceed the value calculated in accordance with *ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2)*.

8.6.2 Seismic shear capacity: Further modify the characteristic shear capacity V_s for seismic load cases in accordance with Eq. (8-24).

$$V_{s,seis(gr,ug,br)} = V_{s(gr,ug,br)} \cdot \frac{V_{eq,reduced}}{V_{eq}} \qquad (8\text{-}24)$$

where

$V_{eq,reduced}$ = reduced seismic shear testing loads established for Eq. (7-11);

V_{eq} = calculated seismic shear testing loads established for Eq (7-11);

$V_{s(gr,ug,br)}$ = characteristic steel shear capacity determined in accordance with Section 8.6.1 for each material type, as applicable; and

$V_{seis(gr,ug,br)}$ = seismic shear capacity specific to each material type.

9.0 Quality control

9.1 The products shall be manufactured under an approved quality control program with inspections by ICC-ES or by a properly accredited inspection agency that has a contractual relationship with ICC-ES.

9.2 Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted to ICC-ES.

9.3 A qualifying inspection shall be conducted at each manufacturing facility when required by the ICC-ES Acceptance Criteria for Inspections and Inspection Agencies (AC304).

10.0 Evaluation report Recognition

10.1 Evaluation report

10.1.1 The evaluation report shall include sufficient information for complete product identification, packaging, Manufacturer's Printed Installation Instructions (MPII), quality control, and design data.

10.1.2 The evaluation report shall also include, but not be limited to, the following:

1) Description of the product;
2) Product labelling and marking, including lot numbers and batches;
3) Anchor performance data in accordance with this criteria as reported in Table 10.1;
4) Anchor identification requirements in accordance with Section 2 of this criteria;
5) Design requirements in accordance with Section 3.0 of this criteria;
6) Special inspection requirements;
7) Verification of masonry type for ungrouted CMU applications;
8) Restrictions on use with respect to masonry cracking as follows:

a) Where the anchor has been qualified in accordance with Table 4.1, Table 4.3 and Table 4.4 anchors are limited to installation in masonry that is uncracked and may be expected to remain uncracked for the service life of the anchor.

b) Where the anchor has been qualified in accordance with Table 4.2, anchors are permitted to be installed in masonry that is cracked or may be expected to crack during the service life of the anchor.

9) As applicable, the following:

a) Anchor elements placed in the top of grouted concrete masonry cells and pullout beams shall be positioned to maintain a minimum distance between the elements and the masonry unit as established by tests but no less than ¼ in. (6.4 mm) in fine grout or ½ in. (12.7 mm) in coarse grout. Anchor elements placed in drilled holes in the face shells of ungrouted CMU units shall be permitted to contact the masonry unit where the elements pass through the face shell, but the portion of the element that is within the grouted cell shall be positioned to maintain a minimum distance between the end of the elements and the masonry unit as established by tests but no less than ¼ in. (6.4 mm) of fine grout between the end of each element and the masonry unit or ½ in. (12.7 mm) of coarse grout between the end of each element and the masonry unit.

b) When anchors are evaluated for exterior exposure or damp environments, evidence of durability shall be submitted. The steel shall be corrosion- resistant, stainless, or zinc-coated steel. The zinc coating shall be either hot-dipped in accordance with ASTM A153 Class C or D; mechanically deposited in accordance with ASTM B695 with a Class 55 coating having a minimum thickness of 2.1 mils (0.053 mm); or demonstrated through tests to be equivalent to the coatings previously described in this sentence. The corrosion-resistant materials shall be tested as set forth in Section 2.1.4.3.4.

10.1.3 Treated wood: Steel anchoring materials in contact with preservative-treated and fire-retardant-treated wood shall be of zinc-coated steel or stainless steel. The coating weights for zinc-coated steel shall be in accordance with ASTM A153 or ASTM B695 with a Class 55 min. coating.

10.2 Evaluation Report Conditions of Use: The evaluation report shall include the following as conditions of use:

10.2.1 (This version applies where recognition is sought for use of anchors in fully grouted concrete masonry unit construction.) **Fully grouted CMU construction*:*** Anchors are recognized for use to resist static tension and static shear loads in fully grouted concrete masonry unit (CMU) construction.

10.2.2 (This version applies where recognition is sought for use of anchors in the open cells of partially grouted concrete masonry unit construction.) **Partially grouted or ungrouted CMU construction:** Anchors are recognized for use to resist static tension and static shear loads in partially grouted or ungrouted concrete masonry unit construction.

10.2.3 (This version applies where recognition is sought for use of anchors in clay brick masonry unit construction.) **Clay brick masonry construction:** Anchors are recognized for use to resist static tension and static shear loads in clay brick masonry construction.

10.2.4 Fatigue and Shock Loading*:* The use of anchors to resist fatigue or shock loading is beyond the scope of this report.

10.2.5 Fire-resistive Construction: Anchors are not permitted to support fire-resistive construction. Where not otherwise prohibited by the legally adopted building code, anchors are permitted for installation in fire-resistive construction provided that at least one of the following conditions is fulfilled:

- Anchors are used to resist wind or seismic forces only, or
- Anchors that support gravity load-bearing structural elements are within a fire-resistive envelope or a fire-resistive membrane, are protected by approved fire-resistive materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards, or
- Anchors are used to support non-structural elements.

10.2.6 (This version applies where recognition is sought for use of anchors in cracked masonry.) **Cracked Masonry:** The design of anchors shall be in accordance with the provisions for cracked masonry where analysis indicates that cracking could occur ($f_t \geq f_r$) in the vicinity of the anchor due to service loads or deformations over the anchor service life.

10.2.7 (This version applies where recognition is sought for use of anchors in uncracked masonry.) **Uncracked Masonry:** The design of anchors may be in accordance with the provisions for cracked masonry where analysis indicates that cracking will not occur ($f_t < f_r$) in the vicinity of the anchor due to service loads or deformations over the anchor service life.

10.2.8 (This version applies where recognition is sought for use of anchors in unreinforced masonry.) **Unreinforced Masonry:** The design of anchors installed in unreinforced masonry shall be predicated on the assumption that the masonry remains uncracked.

10.2.9 Head joints: Design of anchors in fully grouted CMU construction shall avoid location of anchors in head joints.

10.2.10 Seismic Loads:

10.2.10.1 (This version applies where acceptable seismic test data is supplied in accordance with the IBC or the IRC.)

10.2.10.1.1 (This version applies where recognition is sought for use of anchors in fully grouted concrete masonry unit construction.) **Fully Grouted CMU Construction:** Anchors are used to resist seismic tension and shear loads in fully grouted concrete masonry unit construction. Anchors shall not be installed in plastic hinge zones.

10.2.10.1.2 (This version applies where recognition is sought for use of anchors in the open cells of partially grouted concrete masonry unit construction.) **Partially Grouted or Ungrouted CMU Construction:** Anchors are used to resist seismic tension and shear loads in partially grouted or ungrouted concrete masonry unit construction.

10.2.10.1.3 (This version applies where recognition is sought for use of anchors in clay brick masonry unit construction.) **Clay Brick Masonry Construction:** Anchors are used to resist seismic tension and shear loads in clay brick masonry construction.

10.2.10.2 Load Combinations (Allowable Stress Design): When using the allowable stress design load combinations in accordance with 2021 IBC Section 1605.1(2018. 2015, 2012, 2009 and 2006 IBC Section 1605.3.1), allowable loads are not permitted to be increased for seismic or wind loading. When using the alternative allowable stress design load combinations in 2021 IBC Section 1605.2 (2018, 2015, 2012, 2009 and 2006 IBC Section 1605.3.2) that include seismic or wind loads, the allowable shear and tensile loads for anchors are permitted to be increased by 33$^{1}/_{3}$ percent, or the alternative basic load combinations may be reduced by a factor of 0.75.

10.2.10.3 (This version applies where acceptable seismic test data is not supplied in accordance with the IBC or the IRC.)

Use of the anchors to resist seismic loads is beyond the scope of this report. The allowable loads or load combinations for the mechanical anchors shall not be adjusted for anchors subjected to wind loads.

10.2.11 Special inspection

10.2.11.1 Periodic special inspection shall be performed where required in accordance with the legally adopted building code and this report. The special inspector shall be on the jobsite initially during anchor installation to verify anchor type and dimensions, masonry type, masonry compressive strength, anchor identification, hole dimensions, hole cleaning procedures, spacing, edge distances, masonry unit dimensions, anchor embedment, tightening torque, and adherence to the Manufacturer's Printed Installation Instructions (MPII).

10.2.11.2 The special inspector shall verify the initial installations of each type and size of mechanical anchor by construction personnel on site. Subsequent installations of the same anchor type and size by the same construction personnel are permitted to be performed in the absence of the special inspector. Any change in the anchor product being installed or in the personnel performing the installation requires an initial inspection. For ongoing installations over an extended period, the special inspector must make regular inspections to confirm correct handling and installation of the product.

10.3 The strength reduction factors used to develop the allowable breakout and pullout capacities shall be listed in the notes section of the table included in the evaluation report issued by ICC-ES.

10.4 The minimum allowable member thickness shall be specified in the evaluation report and shall be no less than $1.5h_{ef}$ unless other values are substantiated by testing.

10.5 Special inspection:

10.5.1 General inspection requirements: At a minimum, periodic special inspection shall be provided for all anchors.

10.5.1.1 Fully grouted CMU requirements:

1. The general requirements of Section 10.5.1 shall be observed.
2. Installation in head joints shall only be permitted in fully grouted walls constructed with open-ended units as depicted in Figure 1.5.
3. Only systems qualified for installation in grouted CMU shall be permitted.

10.5.1.2 Ungrouted CMU inspection requirements:

1. The general requirements of Section 10.5.1 shall be observed.
2. Installation in head joints shall not be permitted.
3. Only systems qualified for installation in ungrouted CMU shall be permitted.
4. Design assumptions about integrity of the face shell shall be verified; where design is predicated on the preservation of the face shell throughout its thickness (e.g., using rotary-only drilling), hammer-mode drilling shall not be permitted, and no spalling shall be permitted along the entire depth of the borehole.

10.5.1.3 Partially grouted CMU inspection requirements:

1. The general requirements of Section 10.5.1 shall be observed.
2. Installation in head joints shall not be permitted.
3. Installation in grouted and/or ungrouted cells shall correspond with design specifications. The grouting condition shall be verified prior to installation.
4. Anchors installed in grouted cells shall follow the inspection requirements of Section 10.5.1.1.
5. Anchors installed in ungrouted cells shall follow the inspection requirements of Section 10.5.1.2.

10.5.1.4 ASTM C62/C216 solid brick masonry inspection requirements:

1. The general requirements of Section 10.5.1 shall be observed.
2. Only systems qualified for installation in the specified combination of brick unit type (C62 or C216) and grade (MW, SW, or NW) shall be permitted.

10.5.1.5 ASTM C652 hollow brick masonry inspection requirements:

1. The general requirements of Section 10.5.1 shall be observed.

2. Installation in head joints shall not be permitted.
3. Only systems qualified for installation in the specified combination of brick class (H40V, H60V), shell type (solid shell, double shell, or cored shell), and grade (MW, SW, or NW) shall be permitted.

10.5.2 Periodic special inspection: Where required, a program for periodic special inspection shall conform to the following additional requirements:

10.5.2.1 The general requirements of Section 10.5.1 shall be observed.

10.5.2.2 The special inspector shall verify the initial installations of each type and size of mechanical anchor by construction personnel on site as follows:

1. Hole drilling method in accordance with MPII;
2. Hole location, diameter, and depth;
3. Installation outside of head joints (CMU construction only);
4. Hole cleaning, as applicable, in accordance with MPII;
5. Anchor element type, material type, grouting condition, diameter, and length; and
6. Specific requirements to construction type and grouting condition from applicable Section 10.5.1.1 through 10.5.1.5.

Subsequent installations of the same anchor type and size by the same construction personnel shall be permitted to be performed in the absence of the special inspector. Any change in the anchor product being installed or the personnel performing the installation shall require an initial inspection in accordance with the list provided in this section. For ongoing installations over an extended period, the special inspector shall make regular inspections to confirm correct handling and installation of the product.

<u>11.0 ENVIRONMENTAL PRODUCT DECLARATION (Optional):</u>

<u>Environmental impacts shall be assessed via an Environmental Product Declaration (EPD) based on a Life Cycle Assessment (LCA). The LCA and EPD shall be conducted in accordance with ISO 21930 and the appropriate Product Category Rule(s) for the product type.</u>

■

TABLE 1.1—EVALUATION CATEGORIES

Masonry conforming to	Construction types	Qualification	Anchor locations	Design
ASTM C90 - Loadbearing concrete masonry units (CMU)	Uncracked fully grouted CMU	Table 4.1	Fig 1.1b A, B, C*, D, E*, F, G	*ACI 318-11/14/19* amended by Section 3.3 (LRFD) and Section 3.7 (ASD)
ASTM C90 – Loadbearing concrete masonry units (CMU)	Cracked and uncracked fully grouted CMU	Table 4.2	Fig 1.1b A, B, C*, D, E*, F, G	*ACI 318-11/14/19* amended by Section 3.3 (LRFD) and Section 3.7 (ASD)
ASTM C90 - Loadbearing concrete masonry units (CMU) ASTM C129 - Nonloadbearing concrete masonry units (CMU)	Uncracked ungrouted hollow CMU	Table 4.3	Fig 1.1a A, B, D, G	Section 3.4 (LRFD) Section 3.7 (ASD)
ASTM C90 - Loadbearing concrete masonry units (CMU)	Uncracked partially grouted CMU	Table 4.1 Table 4.3	Fig 1.1a A, B, D, F, G	*ACI 318-11/14/19* amended by Section 3.5 (LRFD) and Section 3.7 (ASD)
ASTM C90 - Loadbearing concrete masonry units (CMU)	Cracked and uncracked partially grouted CMU	Table 4.2 Table 4.3	Fig 1.1a A, B, D, F, G	*ACI 318-11/14/19* amended by Section 3.5 (LRFD) and Section 3.7 (ASD)
ASTM C55 - Concrete building brick ASTM C129 - Nonloadbearing concrete masonry units (CMU)	Uncracked solid CMU	Table 4.4	Fig 1.1c A, B, C, D, E, F, G	Section 3.6 (LRFD) Section 3.7 (ASD)
ASTM C62 - Solid building brick ASTM C126 - Ceramic glazed structural clay facing tile, facing brick, and solid masonry units ASTM C216 - Solid clay facing brick ASTM C652 - Hollow clay building brick	Uncracked clay masonry	Table 4.4	Fig 1.1c A, B, C, D, E, F, G	Section 3.6 (LRFD) Section 3.7 (ASD)

*Installation in head and T-joints is only permitted only for fully grouted walls constructed with open-ended units as pictured in Figure 1.1.

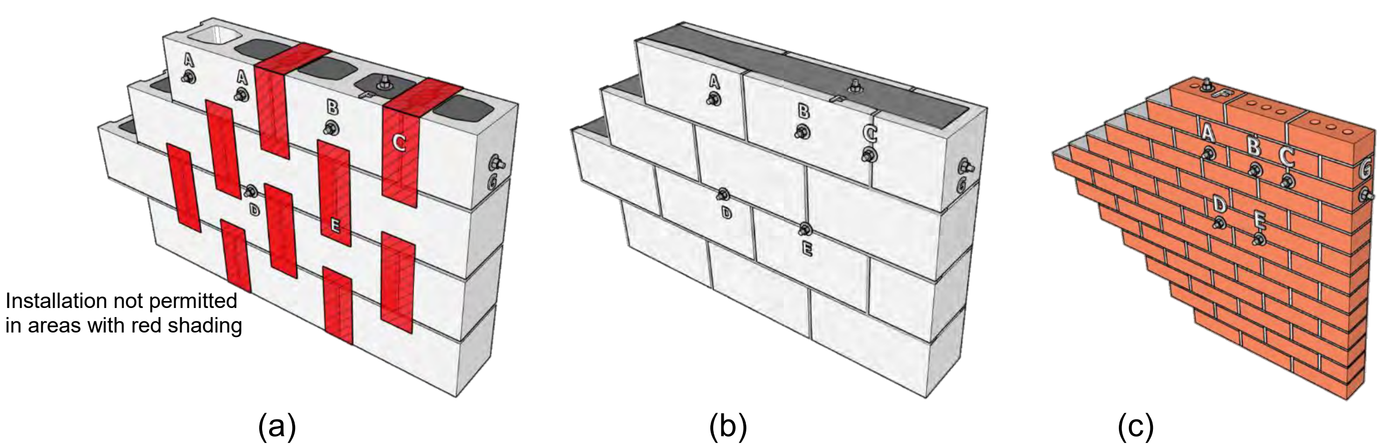


FIGURE 1.1—INSTALLATION LOCATIONS DESCRIBED IN TABLE 1.1: (a) CMU with closed-ended units, (b) CMU with open-ended units, (c) brick masonry. Anchor locations: A- cell (grouted or ungrouted), B- web, C- head joint, D- bed joint, E- T-joint, F- top of wall, G- side of wall.

TABLE 1.2—CROSS-REFERENCED CODE AND STANDARD EDITIONS

STANDARD	2006 IBC	2009 IBC	2012 IBC	2015 IBC	2018 IBC	2021 IBC	2006 IRC	2009 IRC	2012 IRC	2015 IRC	2018 IRC	2021 IRC
ACI 318	2005	2008	2011	2014	2014	2019	2005	2008	2011	2014	2014	2019
ACI 355.2	-	-	2007	2007	2007	2019	-	-	2007	2007	2007	2019
TMS 402/ACI 530/ASCE 5	2005	2008	2011	2013	-	-	2005	2008	2011	2013	-	-
TMS 402	-	-	-	-	2016	2016	-	-	-	-	2016	2016
ASTM A153	2003	2005	2005	2009	2009	2016a	2003	2005	2005	2009	2009	2016a
ASTM B695	2000	2004	2004	2004 (2009)	2004 (2009)	2004 (2016)	2000	2004	2004	2004 (2009)	2004 (2009)	2004 (2016)
ASTM C55	2003	2006e01	2006e01	2011	2014a	2017	2003	2006e01	2006e01	2011	2014a	2017
ASTM C62	2004	2005	2008	2013	2013a	2017	2004	2005	2008	2013	2013a	2017
ASTM C67	2003ae01	2007	2008	2013	2014	2018	2003ae01	-	-	-	-	-
ASTM C90	2003	2006b	2008	2013	2014	2016a	2003	2006b	2008	2013	2014	2016a
ASTM C126	1999	1999 (2005)	1999 (2005)	-	-	-	-	-	-	2013	2015	2015
ASTM C129	2001	2001	2006	-	-	-	2003	2006	2006	2011	2014a	2014a
ASTM C140	2003	2007	2008a	2013	2015	2018	2003	-	-	-	2015	2018
ASTM C216	2004a	2007	2007a	2013	2015	2017a	2004a	2007	2007a	2013	2015	2017a
ASTM C270	2004	2007	2008a	2012a	2014a	2014a	2004	2007	2008a	2012a	2014a	2014a
ASTM C476	2002	2002	2009	-	-	2010	2002	2002	2009	2010	2010	2018
ASTM C652	2004a	2005a	2009	2013	2015	2017a	2004a	2005a	2009	2013	2015	2017a
ASTM C1019	2003	2005	2009	-	-	-	-	-	-	-	-	-
ASTM C1314	2003b	2007	2007	-	-	-	-	-	-	-	-	-
ASTM C1892	-	-	-	-	-	-	-	-	-	-	-	-
ASTM E2935	-	-	-	-	-	-	-	-	-	-	-	-
ASTM F606	-	-	-	-	-	-	-	-	-	-	-	-
UL 263	-	2003	2003	2011	2011	2011	-	2003	2003	2011	2011	2011

[1]Blank entries indicate the standard is not applicable or referenced in the specific code.
[2]For standards referenced in the criteria, editions of standards applicable to various codes are summarized in this table.

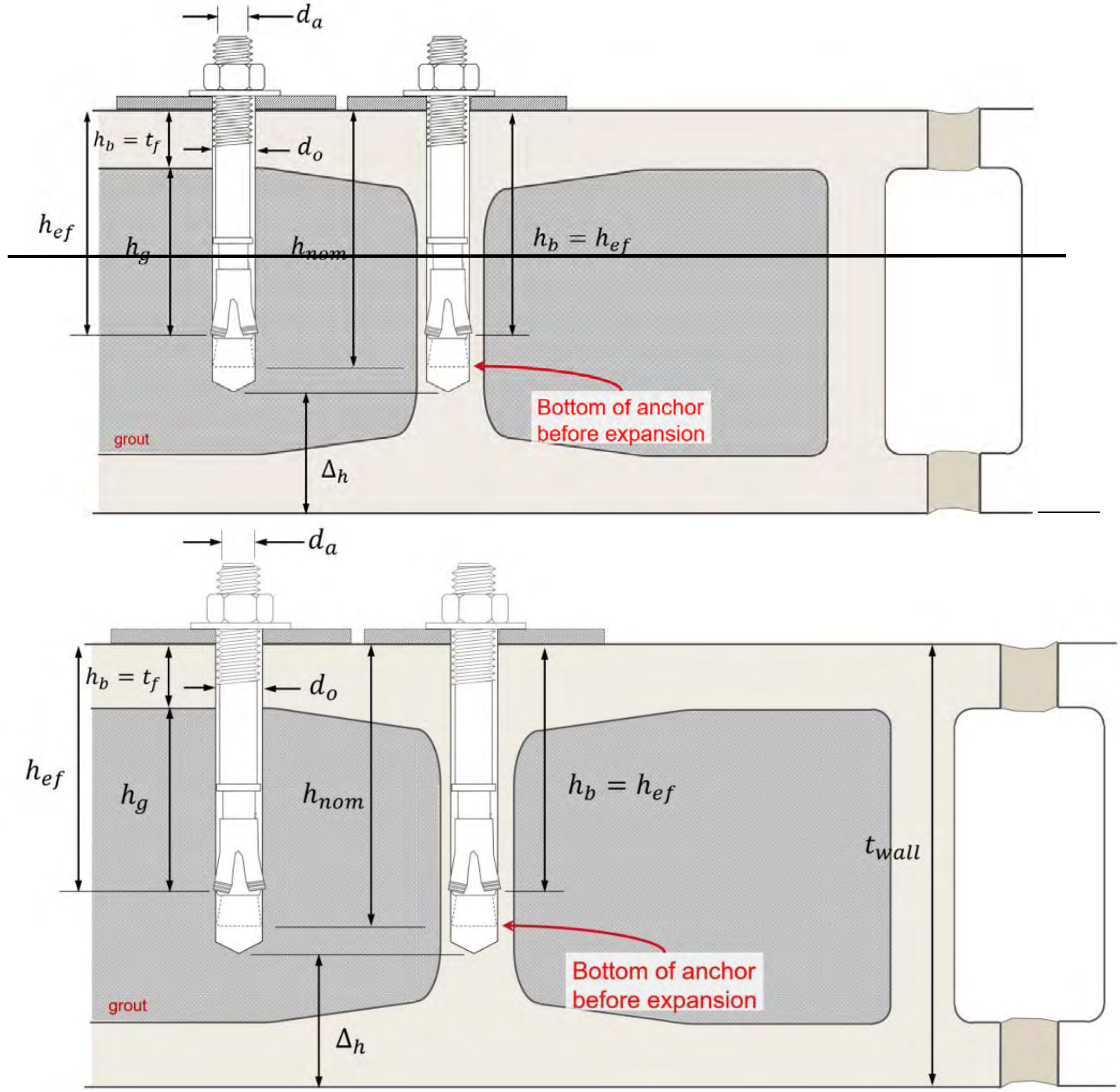


FIGURE 1.2—DIMENSIONAL PARAMETERS FOR ANCHORS IN GROUTED CMU

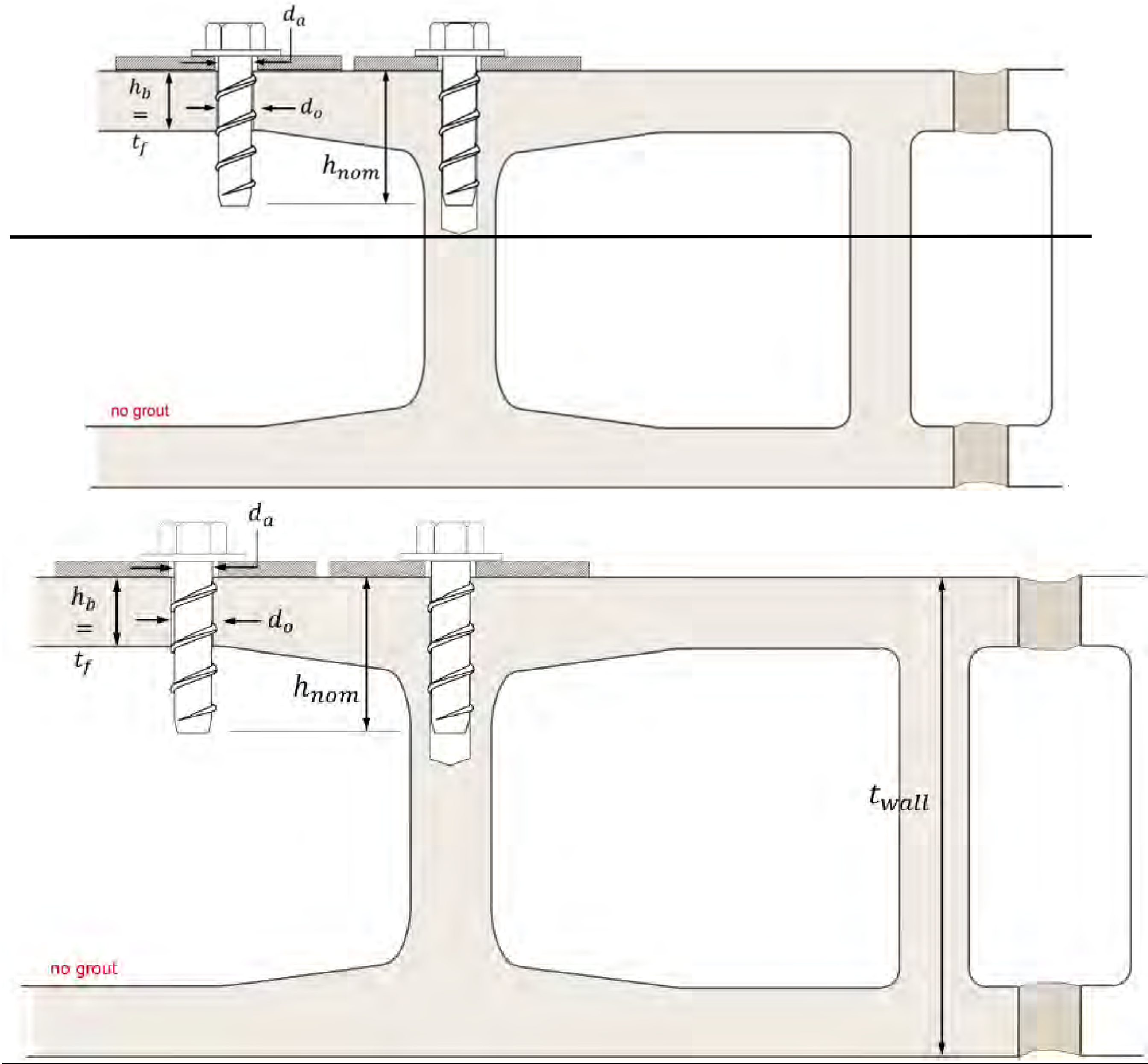
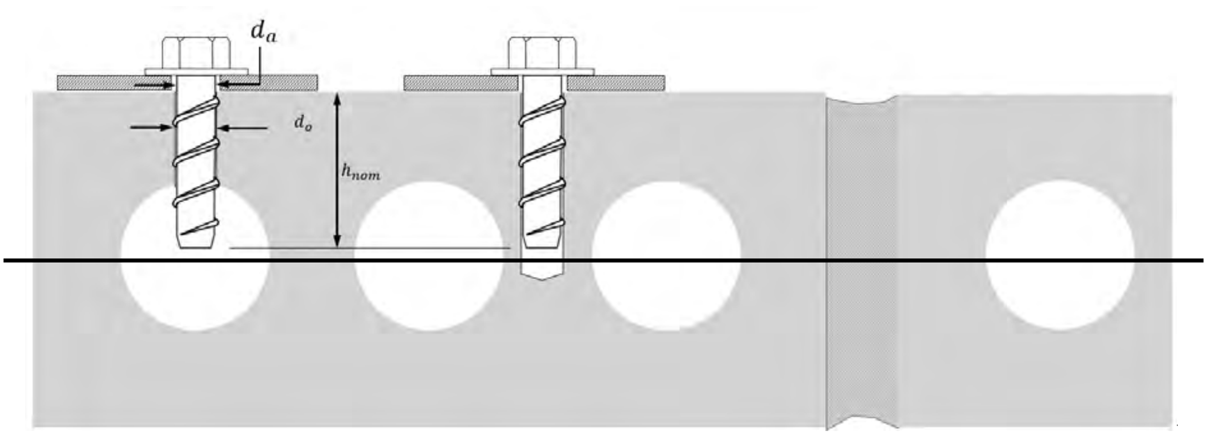


FIGURE 1.3—DIMENSIONAL PARAMETERS FOR ANCHORS IN UNGROUTED CMU



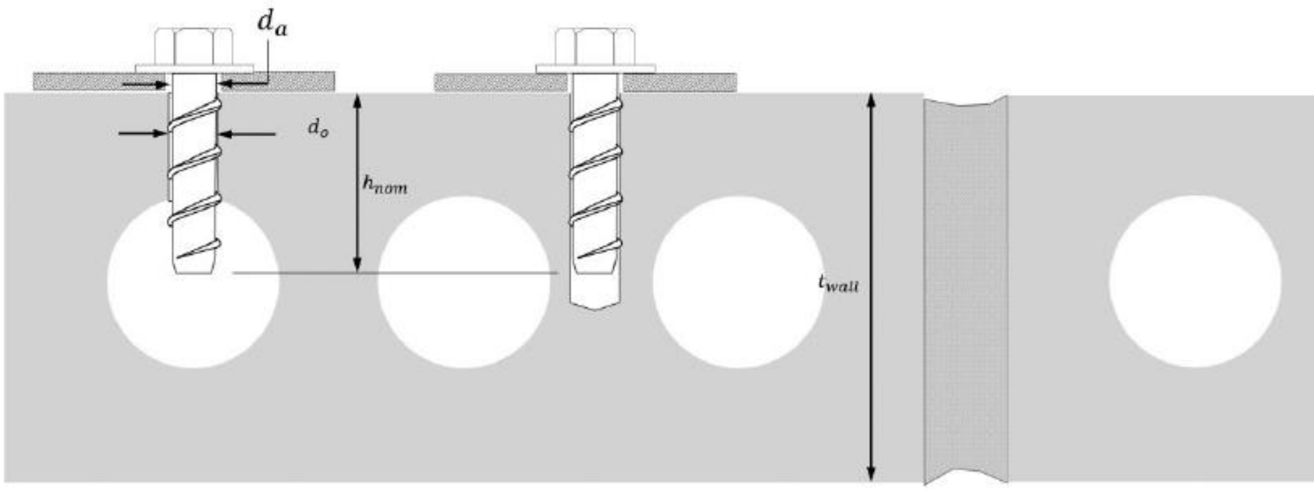


FIGURE 1.4—DIMENSIONAL PARAMETERS FOR ANCHORS IN BRICK UNIT MASONRY

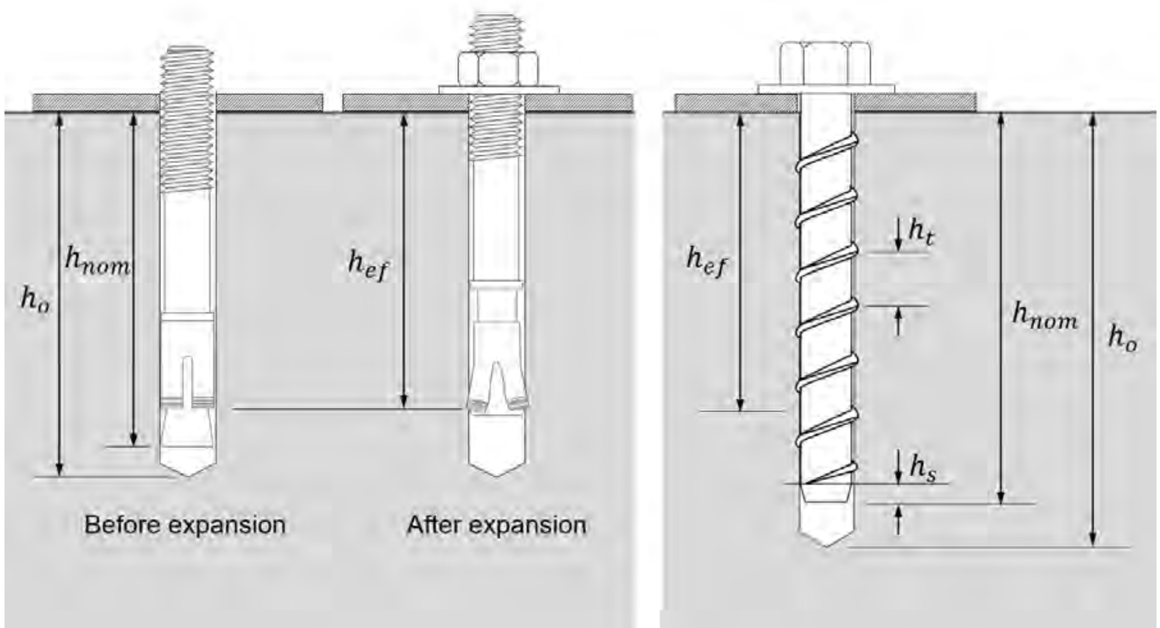


FIGURE 1.5—NOMINAL AND EFFECTIVE EMBEDMENT DEPTH FOR EXPANSION ANCHORS (LEFT) AND SCREW ANCHORS (RIGHT).

TABLE 2.1—LENGTH IDENTIFICATION CODES

Length marking		Length of anchor	
		in.	mm
XX	—	1 < 1-1/2	25 < 38
A	Black	1-1/2 < 2	38 < 51
B	White	2 < 2-1/2	51 < 63
C	Red	2-1/2 < 3	63 < 76
D	Green	3 < 3-1/2	78 < 89
E	Yellow	3-1/2 < 4	89 < 102
F	Blue or purple	4 < 4-1/2	102 < 114
G	Brown	4-1/2 < 5	114 < 127
H	Orange	5 < 5-1/2	127 < 140
I	—	5-1/2 < 6	140 < 152
J	—	6 < 6-1/2	152 < 165
K	—	6-1/2 < 7	165 < 178
L	—	7 < 7-1/2	178 < 191
M	—	7-1/2 < 8	191 < 203
N	—	8 < 8-1/2	203 < 216
O	—	8-1/2 < 9	216 < 229
P	—	9 < 9-1/2	229 < 241
Q	—	9-1/2 < 10	241 < 254
R	—	10 < 11	254 < 267
S	—	11 < 12	267 < 305
T	—	12 < 13	305 < 330
U	—	13 < 14	330 < 366
V	—	14 < 15	366 < 381
W	—	15 < 16	381 < 406
X	—	16 < 17	406 < 432
Y	—	17 < 18	432 < 457
Z	—	18 < 19	457 < 483
AA	—	19 < 20	483 < 508
BB	—	20 < 21	508 < 533
CC	—	21 < 22	533 < 559
DD	—	22 < 23	559 < 584
EE	—	23< 24	584 < 610
FF	—	24 < 25	610 < 635

TABLE 2.2—REQUIRED TENSION TESTS IN ACCORDANCE WITH ASTM F606/F606M-16, 3.6*

ASTM F606/F606M	Tests on machined coupons taken from full-size specimens†				Tension tests on full-size specimens‡
	Yield strength	Tensile strength	Elongation	Reduction of area	
F606 Section	3.6.3	3.6.4	3.6.5	3.6.6	3.4§
Number of replicates	3				3
Anchor diameters tested#	All diameters sought for recognition				

*Or equivalent standard, subject to prior approval by the independent testing and evaluation agency (ITEA).

† Elongation shall be measured over a minimum gauge length of $4d_a$, which is in accordance with ASTM F606/F606M, unless otherwise approved by the ITEA. Machined specimens shall have a turned section as large as feasible and shall have a gauge length $4d_a$ of the specimen. Submission of mill certificates is acceptable for sourced primary tension load transfer elements that meet a national standard and are not subject to subsequent manufacturing processes such as forming, machining, or heat treating prior to incorporation in the anchor assembly.

‡ Tests performed on the primary tension load transfer element of the full-sized anchor, required only for anchors that meet the elongation and reduction of area requirements for classification as ductile according to Table 6.3.6b.

§ Use wedge- or friction-grips to hold unthreaded end of anchor element. Grips shall not reach beyond areas of potential fracture and shall not induce fracture at the point of load transfer.

Tests shall be repeated for all manufacturing processes used for each diameter.

TABLE 2.3—CLASSIFICATION OF ANCHOR STEEL AS DUCTILE OR BRITTLE

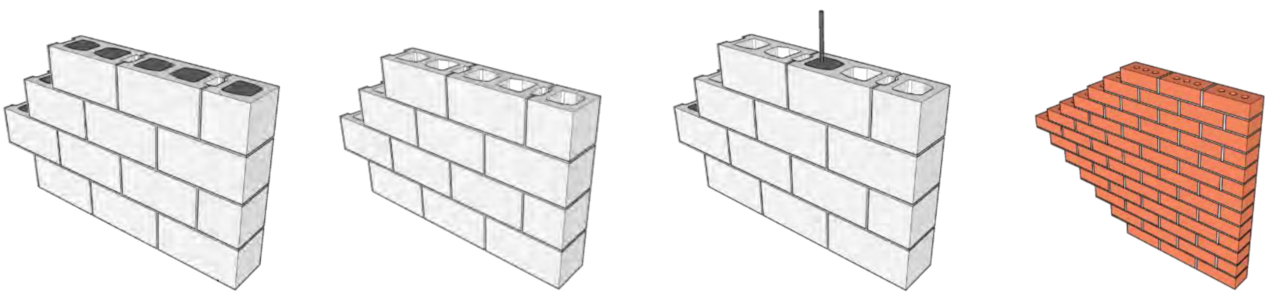
Property	Ductile	Brittle		
Elongation	≥14%	<14%	≥14%	≥14%
Reduction of area	≥30%	≥30%	<30%	≥30%
Characterization of breaks from all full-size tests*	Dimpled, cup, and cone fracture	N/A	N/A	Cleavage (transgranular) or intergranular fracture†

*Photographic record of breaks shall be provided. If examination of breaks is inconclusive, stress-strain or force-displacement curves from full-scale tension tests may also be used to establish classification, subject to approval by independent testing and evaluation agency (ITEA).

†If any replicate exhibits these characteristics, the anchor shall be classified as brittle.

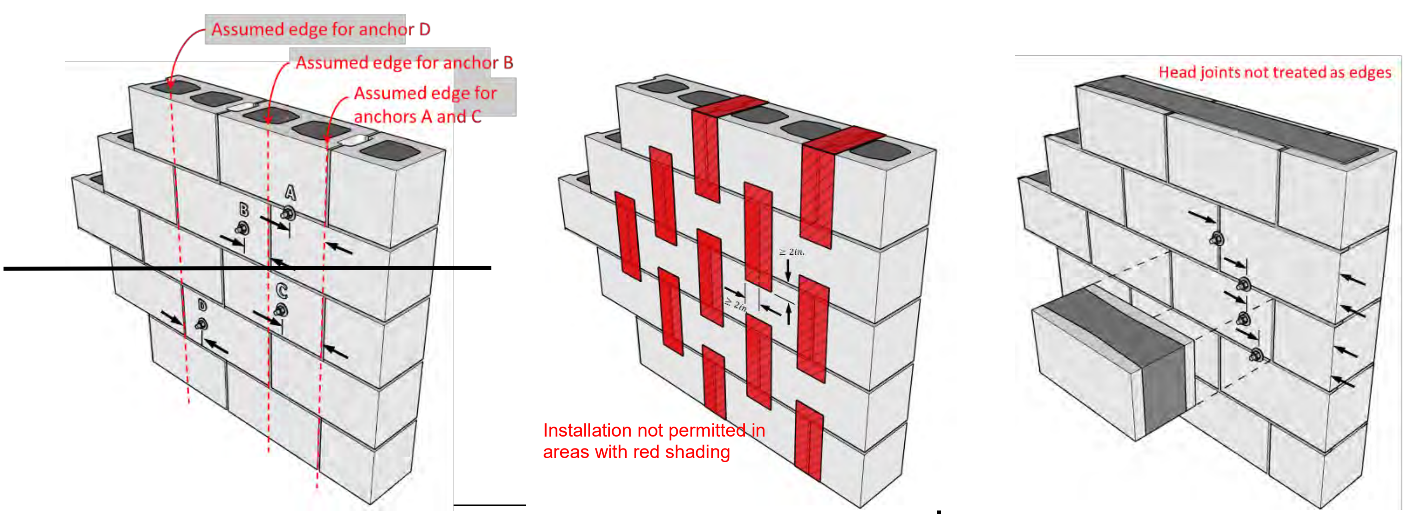
TABLE 2.4—TESTS FOR DETERMINING EQUIVALENCE OF SCREW ANCHORS WITH MULTIPLE PRODUCTION METHODS

	Table 4.1	Table 4.2	Table 4.3	Table 4.4
Required tests	1a, 2, 7, 8, 13a	1a, 2, 3, 8, 9, 15a	1a, 6, 7, 12	1a, 6, 7, 12
Required tests where recognition is desired	1d	1d, 14, 16	11, 13	11, 13



Section 3.3 **Section 3.4** **Section 3.5** **Section 3.6**

FIGURE 3.1—CONSTRUCTION TYPES COVERED FOR DESIGN OF ANCHORAGES IN MASONRY



Hollow head joints **Solid head joints**

(a) *(b)* *(c)*

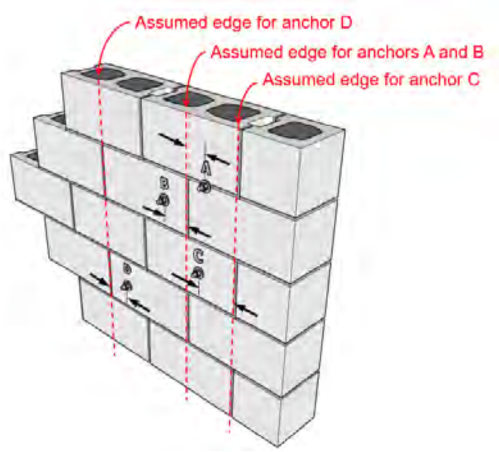


FIGURE 3.2—(a) Edge distance considerations in fully grouted CMU construction with hollow head joints (see Section 1.4.14.1), (b) exclusion zones in fully grouted construction with closed head joints, and (c) edge distance considerations in fully grouted CMU construction with solid head joints (see Section 1.4.14.2). (Note: dimensions to upper and lower edges omitted for clarity.)

TABLE 3.1—ACI 318-19, ACI 318-14 AND -11 SECTIONS APPLICABLE OR MODIFIED BY THIS STANDARD

318-19 section	*318-14 section*	*(318-11 section)*	**Modified by**
2.2	*2.2*	*(2.1)*	unchanged*
2.3	*2.3*	*(D.1)*	3.2.2
17.1.1 and 17.1.5	*17.1.1 – 17.1.2*	*(D.2.1 – D.2.2)*	unchanged*
17.1.2	*17.1.3*	*(D.2.3)*	3.3.2.2
17.1.4, 17.2.1 and 17.4.1	*17.1.4 – 17.2.2*	*(D.2.4 – D.3.2)*	unchanged*
17.4.2	*17.2.3*	*(D.3.3)*	3.3.2.4
17.3.1	*17.2.7*	*(D.3.7)*	unchanged*
17.5.2	*17.3.1.1*	*(D.4.1.1)*	3.3.2.6~~5~~
17.5.2.3	*17.3.1.3*	*(D.4.1.3)*	unchanged*
17.5.1.2 excluding 17.5.2.1	*17.3.2 excluding 17.3.2.1*	*(D.4.2 excluding D.4.2.1)*	
17.5.3	*17.3.3*	*(D.4.3)*	3.3.2.9
17.6.1	*17.4.1*	*(D.5.1)*	unchanged*
17.6.2.1	*17.4.2.1*	*(D.5.2.1)*	3.3.2.11
17.6.2.2.1	*17.4.2.2*	*(D.5.2.2)*	3.3.2.12
17.6.2.1.2, 17.6.2.3.1 and 17.6.2.4	*17.4.2.3 – 17.4.2.5*	*(D.5.2.3 – D.5.2.5)*	unchanged*
17.6.2.5.1(a)	*17.4.2.6*	*(D.5.2.6)*	3.3.2.14
17.6.2.6, 17.6.2.1.3 and 17.5.2.1	*17.4.2.7 – 17.4.2.9*	*(D.5.2.7 – D.5.2.9)*	unchanged*
17.6.3.1	*17.4.3.1*	*(D.5.3.1)*	3.3.2.17~~15~~
17.6.3.2.1	*17.4.3.2*	*(D.5.3.2)*	3.3.2.18~~16~~
17.6.3.3	*17.4.3.6*	*(D.6.1.1 – D.6.2.2)*	
17.7.1.1-17.7.2.2	*17.5.1.1 – 17.5.2.2*	*(D.6.1.1 – D.6.2.2)*	
17.7.2.1.2,17.7.2.3 and 17.7.2.4	*17.5.2.4 – 17.5.2.6*	*(D.6.2.4 – D.6.2.6)*	
17.7.2.5	*17.5.2.7*	*(D.6.2.7)*	3.3.2.20~~18~~
17.7.2.6	*17.5.2.8*	*(D.6.2.8)*	unchanged*
17.7.3	*17.5.3*	*(D.6.3)*	
17.8	*17.6*	*(D.7)*	
17.9	*17.7*	*(D.8)*	3.3.2.21~~19~~
26.13.1.5 and 26.13.2.5	*17.8.1*	*(D.9.1)*	unchanged*
Additional provisions			3.3.2.22~~0~~ - 3.3.2.24~~1~~

*Sections marked as unchanged adopt the general changes prescribed in Section 3.2.2

TABLE 3.2—REQUIRED STRENGTH OF ANCHORS

Failure mode	Single anchor	Anchor group[1]: Individual anchor in a group	Anchor group[1]: Anchors as a group
Steel strength in tension	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$	
Masonry breakout strength in tension	$\phi N_{mb} \geq N_{ua}$		$\phi N_{mbg} \geq N_{ua,g}$
Pullout strength in tension	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$	
Steel strength in shear	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$	
Masonry breakout strength in shear	$\phi V_{mb} \geq V_{ua}$		$\phi V_{mbg} \geq V_{ua,g}$
Masonry crushing strength in shear	$\phi V_{mc} \geq V_{ua}$	$\phi V_{mc} \geq V_{ua,i}$	
Masonry pryout strength in shear	$\phi V_{mp} \geq V_{ua}$		$\phi V_{mpg} \geq V_{ua,g}$

[1]Required strengths for steel failure modes shall be calculated for the most highly stressed anchor in the group.

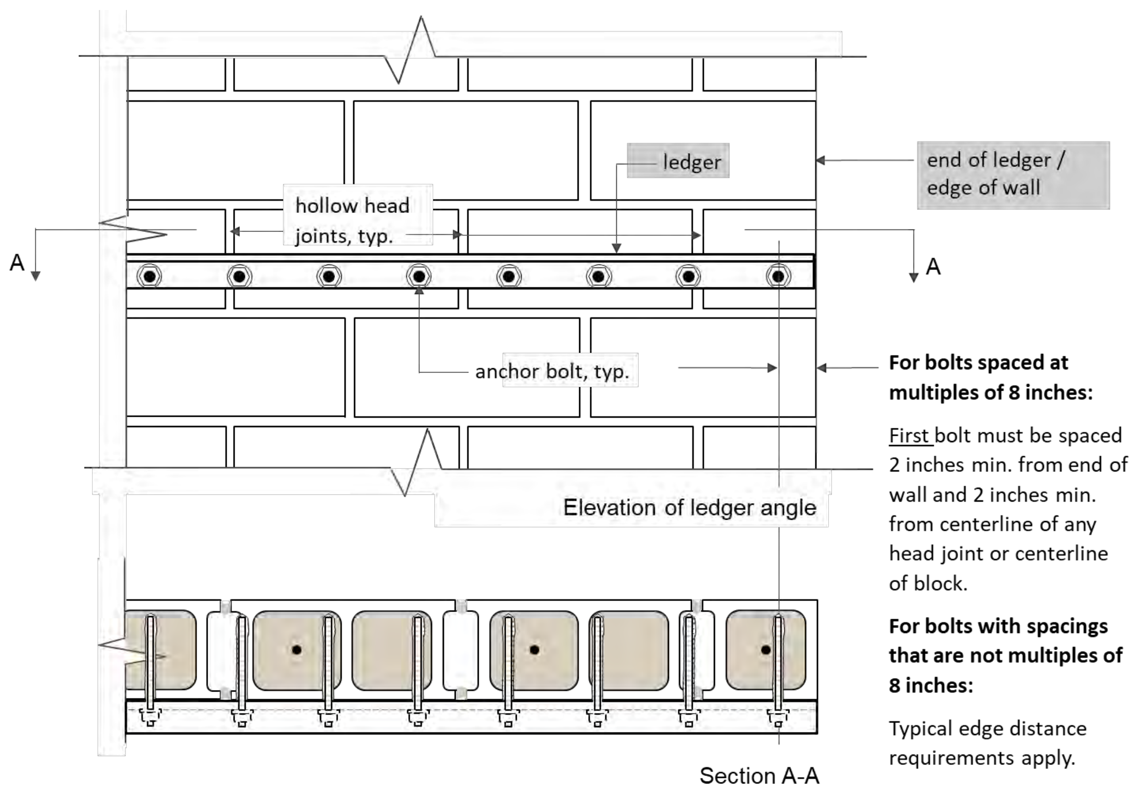


FIGURE 3.3— BOLT LAYOUT IN HORIZONTAL LEDGER, FULLY-GROUTED CMU WALL WITH HOLLOW HEAD JOINTS

TABLE 3.3—DIMENSIONAL REQUIREMENTS FOR POST-INSTALLED ANCHORS INSTALLED IN UNGROUTED CMU.

Load case	Critical edge distance, $c_{cr,ug}$, for full capacity	Minimum edge distance, $c_{a,\min,ug}$	Multiplier at $c_{a,\min,ug}$	Minimum spacing, $s_{\min,ug}$
Tension	4 in. (102 mm)	2 in. (51 mm)	0.8	8 in. (203 mm)
Shear	$12\underline{d_a}\cancel{d_b}$	$6\underline{d_a}\cancel{d_b}$	0.5	8 in. (203 mm)

TABLE 3.4—REQUIRED STRENGTH OF ANCHORS IN UNGROUTED CMU CONSTRUCTION

Failure mode	Single anchor	Capacity reference
Steel strength in tension	$\phi N_{sa} \geq N_{ua}$	8.4
Pullout strength in tension	$\phi N_{k,ug} \geq N_{ua}$	8.5.6
Steel strength in shear	$\phi V_{sa} \geq V_{ua}$	*ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2)*
Anchorage strength in shear	$\phi V_{s,ug} \geq V_{ua}$	8.6.1.2
Masonry crushing strength in shear	$\phi V_{mc,ug} \geq V_{ua}$	(3-1)

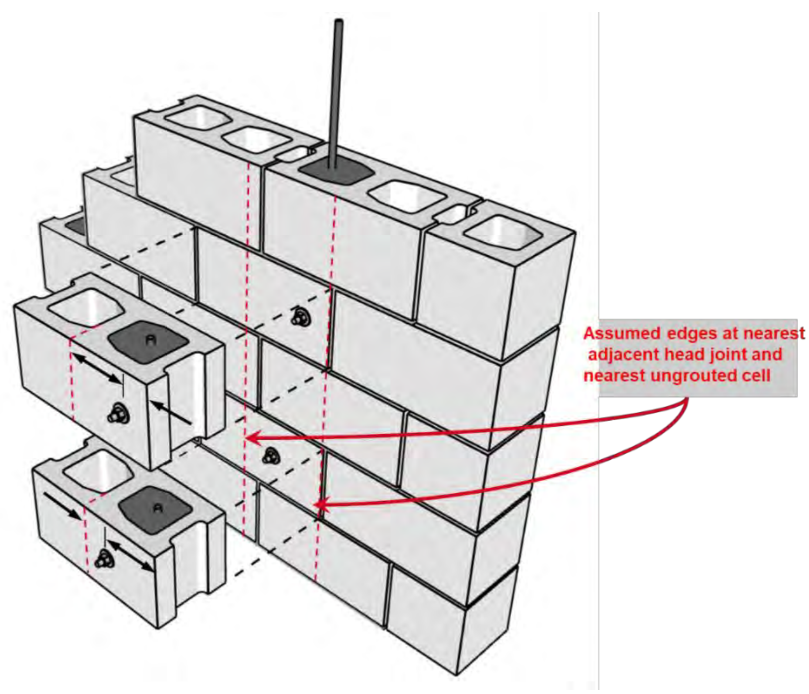


FIGURE 3.4— EDGE DISTANCE CONSIDERATIONS IN PARTIALLY GROUTED CMU CONSTRUCTION WHEN THE LOCATION OF GROUT IS KNOWN

TABLE 3.5—DIMENSIONAL REQUIREMENTS FOR POST-INSTALLED ANCHORS INSTALLED IN BRICK MASONRY CONSTRUCTION

Load case	Critical edge distance, $c_{cr,br}$, for full capacity	Minimum edge distance, $c_{a,\min,br}$	Multiplier at $c_{a,\min,br}$	Minimum spacing, $s_{\min,br}$
Tension	$\max(2h_{ef}, 4\ in.\ (102\ mm))$	4 in. (102 mm)	0.8	8 in. (203 mm)
Shear	12 d_a	6 d_a	0.5	8 in. (203 mm)

TABLE 3.6—REQUIRED STRENGTH OF ANCHORS IN BRICK MASONRY CONSTRUCTION

Failure mode	Single anchor	Reference
Steel strength in tension	$\phi N_{sa} \geq N_{ua}$	8.4
Pullout strength in tension	$\phi N_{k,br} \geq N_{ua}$	8.5.7
Steel strength in shear	$\phi V_{sa} \geq V_{ua}$	*ACI 318 Section 17.7.1.2 (Section 17.5.1.2 or Section D.6.1.2)*
Anchorage strength in shear	$\phi V_{s,br} \geq V_{ua}$	8.6.1.3
Brick crushing strength in shear	$\phi V_{mc,br} \geq V_{ua}$	(3-1)

TABLE 4.1—TEST PROGRAM FOR EVALUATING MECHANICAL ANCHOR SYSTEMS FOR USE IN UNCRACKED FULLY GROUTED CMU CONSTRUCTION

Testing						Assessment				
Test no.	**Test ref.**	**Purpose**	**Test param.**	**Location**	**Masonry‡**	Load & displ.	h_{ef} †	Drill bit dia.	Min. sample size	Batch
Reference tests										
1a	5.0	Reference uncracked LS	Unconfined tension	Cell near head joint^x	Uncracked, LS grout	8.5.1 8.5.2	all	d_{med}	5	1
1b	5.0	Reference uncracked LS	Unconfined tension	Bed joint	Uncracked, LS grout	8.5.1 8.5.2	shallow, deep	d_{med}	5	2
1c	5.0	Reference uncracked LS	Unconfined tension	Web	Uncracked, LS grout	8.5.1 8.5.2	shallow	d_{med}	5	3
1d‖	7.9	Reference uncracked LS	Unconfined tension	Top of wall	Uncracked, LS grout	8.5.1 8.5.2	all	d_{med}	5	4
2	5.0	Reference uncracked HS	Unconfined tension	Bed joint	Uncracked, HS grout	8.5.1	all	d_{med}	5	5
3^§	6.9	Screw anchor reference	Confined tension	See 6.9	Uncracked, HS grout	8.5.1	shallow, deep	d_{med}	5	6
Reliability tests										
4	6.5	Reduced inst. effort	Unconfined tension	Bed joint	Uncracked, grout strength varies⁺	8.5.1	shallow, deep	d_{med}	5	2, 5
5	6.6	Large hole dia.	Unconfined tension	Bed joint	Uncracked, LS grout	8.5.1	shallow, deep	d_{max}	5	2
6	6.7	Small hole dia.	Unconfined tension	Bed joint	Uncracked, HS grout	8.5.1	shallow, deep	d_{min}	5	5
7	6.8	Repeated load	Unconfined tension	Cell near head joint^x	Uncracked, LS grout	8.5.1	shallow, deep	d_{med}	5	1
8^§	6.9	Screws against brittle failure	Confined tension	See 6.9	Uncracked, HS grout	8.5.1	shallow, deep	d_{med}	5	6
9	6.10.2	Screws set with impact driver	Installation only	Center of cell	*Uncracked, LS grout	8.5.1	shallow	d_{max}	15	any
10	6.10.3	Screws set with torque wrench	Installation only	Center of cell	Uncracked, LS grout	8.5.1	shallow	d_{max}	10	any
11	6.10.4	Screws set with torque wrench	Installation only	Center of cell	Uncracked, HS grout	8.5.1	shallow	d_{min}	10	any
Service condition tests										
12a	7.4	Min. edge/spacing	Varies	c_{min} and s_{min}	Uncracked, LS grout	8.5.1	shallow, deep	d_{med}	5	~~1,2,3~~ See FN*
12b‖	7.5	Min. edge and spacing, top of wall	Varies	$c_{min,top}$ and $s_{min,top}$	Uncracked, LS grout	8.5.1	shallow	d_{med}	5	See FN*~~1, 2,3~~
13a	7.7	Static shear away from edges	Shear	Bed joint	Uncracked, LS grout	7.7.3	shallow	d_{med}	5	any
13b‖	7.9	Static shear, top of wall	Shear parallel	Top of wall	Uncracked, LS grout	7.9	shallow	d_{med}	5	any
14‖	7.10	Torque test	Unconfined tension	Cell near head joint^x	Uncracked, LS grout	7.10.3	shallow	d_{med}	5	any

† Where the MPII specify multiple embedment depths for single anchor diameter, test every anchor diameter at the embedments noted.
shallow = lowest anchor embedment for which recognition is sought for a given anchor diameter
deep = highest anchor embedment for which recognition is sought for a given anchor diameter
⁺ Test varies based on anchor type; see test description.
^ Test not conducted in CMU; see test description for material preparation conditions.
§ It shall be permitted to use the results of tests performed in concrete in accordance with AC193 using the same anchor and drilling method.
‖ Optional test.
‡ Anchors shall be normalized to grout and unit strengths of 2,000 psi (13.8 MPa) in accordance with Section 8.3.
x Distance from head joint shall be the minimum distance desired for qualification. See Section 5.2.2.2.
* Batch control varies by anchor type as specified in Section 7.4.3. Where a reference test is used as basis for comparison to the edge and spacing test, the edge and spacing test shall be of the same batch as Test 1a (i.e., batch 1).

TABLE 4.2—TEST PROGRAM FOR EVALUATING MECHANICAL ANCHOR SYSTEMS FOR USE IN CRACKED AND UNCRACKED FULLY GROUTED CMU CONSTRUCTION

Testing							**Assessment**				
Test no.	**Test ref.**	**Purpose**	**Test param.**	**Location**	**Masonry**[‡]	**Crack width** in. (mm)	Load & displ.	h_{ef}[†]	Drill bit dia.	Min. sample size	Batch
					Reference tests						
1a	5.0	Reference uncracked LS	Unconfined tension	Cell near head joint[x]	Uncracked, LS grout	-	8.5.1 8.5.2	all	d_{med}	5	1
1b	5.0	Reference uncracked LS	Unconfined tension	Bed joint	Uncracked, LS grout	-	8.5.1 8.5.2	shallow	d_{med}	5	2
1c	5.0	Reference uncracked LS	Unconfined tension	Web	Uncracked, LS grout	-	8.5.1 8.5.2	shallow	d_{med}	5	3
1d[‖]	7.9	Reference uncracked LS	Unconfined tension	Top of wall	Uncracked, LS grout	-	8.5.1 8.5.2	all	d_{med}	5	4
1e	5.0	Reference cracked LS	Unconfined tension	Bed joint	Cracked, LS grout	0.012 (0.3)	8.5.1 8.5.2	all	d_{med}	5	2
2	5.0	Reference uncracked HS	Unconfined tension	Bed joint	Uncracked, HS grout	-	8.5.1	all	d_{med}	5	5
3	5.0	Reference cracked HS	Unconfined tension	Bed joint	Cracked, HS grout	0.012 (0.3)	8.5.1	all	d_{med}	5	5
4^[§]	6.9	Screw anchor reference	Confined tension	See 6.9	Uncracked, HS grout	-	8.5.1	shallow, deep	d_{med}	5	6
					Reliability tests						
5	6.5	Reduced inst. effort	Unconfined tension	Bed joint	Cracked, grout str. varies[+]	0.012 (0.3)	8.5.1	shallow, deep	d_{med}	5	5
6	6.6	Crack width, large hole dia.	Unconfined tension	Bed joint	Cracked, LS grout	0.020 (0.5)	8.5.1	shallow, deep	$d_{\max}$	5	2
7	6.7	Crack width, small hole dia.	Unconfined tension	Bed joint	Cracked, HS grout	0.020 (0.5)	8.5.1	shallow, deep	$d_{\min}$	5	5
8	6.8	Repeated load	Unconfined tension	Cell near head joint[x]	Uncracked, LS grout	-	8.5.1	shallow, deep	d_{med}	5	1
9^[§]	6.9	Screws against brittle failure	Confined tension	See 6.9	Uncracked, HS grout	-	8.5.1	shallow, deep	d_{med}	5	6
10	6.10.2	Screws set with impact driver	Installation only	Center of cell	Uncracked, LS grout	-	8.5.1	shallow	$d_{\max}$	15	any
11	6.10.3	Screws set with torque wrench	Installation only	Center of cell	Uncracked, LS grout	-	8.5.1	shallow	$d_{\max}$	10	any
12	6.10.4	Screws set with torque wrench	Installation only	Center of cell	Uncracked, HS grout	-	8.5.1	shallow	$d_{\min}$	10	any
					Service condition tests						
13a	7.4	Min. edge and spacing	Varies	c_{min} and s_{min}	Uncracked, LS grout	-	8.5.1	shallow, deep	d_{med}	5	See FN*~~1, 2,3~~
13b[‖]	7.5	Min. edge and spacing, top of wall	Varies	$c_{min,top}$ and $s_{min,top}$	Uncracked, LS grout	-	8.5.1	shallow	d_{med}	5	See FN*~~1, 2,3~~
14[‖]	7.6	Seismic tension	Unconfined cyc. tension, residual test	Bed joint	Cracked, LS grout	0.020 (0.5)	8.5.1 7.6.4	shallow, deep	d_{med}	5	2
15a	7.7	Static shear away from edges	Shear	Bed joint	Cracked, LS grout	~~-~~0.012 (0.3)	7.7.3	shallow	d_{med}	5	~~any~~7
15b[‖]	7.9	Static shear, top of wall	Shear parallel	Top of wall	Uncracked, LS grout	-	7.9	shallow	d_{med}	5	any
16[‖]	7.8	Seismic shear	Cyclic shear, residual test	Bed joint	Cracked, LS grout	0.020 (0.5)	7.8.4	shallow, deep	d_{med}	5	~~any~~7
17[‖]	7.10	Torque test	Unconfined tension	Cell near head joint[x]	Uncracked, LS grout	-	7.10.3	shallow	d_{med}	5	any

For **SI:** 1 inch = 25.4 mm, 1 psi = 6.89 kPa.

† Where the MPII specify multiple embedment depths for single anchor diameter, test every anchor diameter at the embedments noted.
shallow = lowest anchor embedment for which recognition is sought for a given anchor diameter
deep = highest anchor embedment for which recognition is sought for a given anchor diameter
\+ Test varies based on anchor type; see test description.
^ Test not conducted in CMU; see test description for material preparation conditions.
§ It shall be permitted to use the results of tests performed in concrete in accordance with AC193 using the same anchor and drilling method.
x Distance from head joint shall be the minimum distance desired for qualification. See Section 5.2.2.2.
ǁ Optional test.
‡ Anchors shall be normalized to grout and unit strengths of 2,000 psi (13.8 MPa) in accordance with Section 8.3.
* Batch control varies by anchor type as specified in Section 7.4.3. Where a reference test is used as basis for comparison to the edge and spacing test, the edge and spacing test shall be of the same batch as Test 1a (i.e., batch 1).

TABLE 4.3—TEST PROGRAM FOR EVALUATING MECHANICAL ANCHOR SYSTEMS FOR USE IN UNCRACKED, UNGROUTED CMU CONSTRUCTION

Testing						Assessment			
Test no.	**Test ref.**	**Purpose**	**Test param.**	**Location**	**Masonry‡**	Load & displ.	Drill bit dia.	Min. sample size	Batch
Reference tests									
1a	5.0	Reference uncracked	Unconfined tension	Center of cell	Uncracked	8.5.1 8.5.2	d_{med}	5	1
1b	5.0	Reference uncracked	Unconfined tension	Bed joint	Uncracked	8.5.1 8.5.2	d_{med}	5	2
1c	5.0	Reference uncracked	Unconfined tension	Web	Uncracked	8.5.1 8.5.2	d_{med}	5	3
2^#§	6.9	Screw anchor reference	Confined tension	See 6.9	Uncracked	8.5.1	d_{med}	5	4
Reliability tests									
3	6.5	Reduced inst. effort	Unconfined tension	Bed joint	Uncracked	8.5.1	d_{med}	5	2
4	6.6	Large hole dia.	Unconfined tension	Bed joint	Uncracked	8.5.1	$d_{\max}$	5	2
5	6.7	Small hole dia.	Unconfined tension	Bed joint	Uncracked	8.5.1	$d_{\min}$	5	2
6	6.8	Repeated load	Unconfined tension	Center of cell	Uncracked	8.5.1	d_{med}	5	1
7^#§	6.9	Screws against brittle failure	Confined tension	See 6.9	Uncracked, HS grout	8.5.1	d_{med}	5	4
8	6.10.2	Screws set with impact driver	Installation only	Center of cell	Uncracked	8.5.1	$d_{\max}$	15	any
9	6.10.3	Screws set with torque wrench	Installation only	Center of cell	Uncracked	8.5.1	$d_{\max}$	10	any
10	6.10.4	Screws set with torque wrench	Installation only	Center of cell	Uncracked	8.5.1	$d_{\min}$	10	any
Service condition tests									
11ǁ	7.6	Seismic tension	Unconfined cyc. tension, residual test	Center of cell	Uncracked	8.5.1 7.6.4	d_{med}	5	1
12	7.7	Static shear away from edges	Shear	Bed joint	Uncracked	7.7.3	d_{med}	5	~~any~~5
13ǁ	7.8	Seismic shear	Cyclic shear, residual test	Bed joint	Uncracked	7.8.4	d_{med}	5	~~any~~5
14ǁ	7.10	Torque test	Unconfined tension	Center of cell	Uncracked	7.10.3	d_{med}	5	any

† Where the MPII specify multiple embedment depths for a single anchor diameter, test anchor at minimum or maximum embedment depth as noted.
shallow = lowest anchor embedment for which recognition is sought for a given anchor diameter
deep = highest anchor embedment for which recognition is sought for a given anchor diameter
~~x This test may be omitted if tests 2a and 2b are not conducted. (See note #.)~~
\# It shall be permitted to use the results of tests performed for grouted masonry in accordance with Table 4.1 or Table 4.2 using the same product.
^ Test not conducted in ungrouted CMU; see test description for material preparation conditions.
§ It shall be permitted to use the results of tests performed in concrete in accordance with AC193 using the same product.
ǁ Optional test.
‡ Anchors shall be normalized to a unit strength of 2,000 psi (13.8 MPa) in accordance with Section 8.3.

TABLE 4.4—TEST PROGRAM FOR EVALUATING MECHANICAL ANCHOR SYSTEMS FOR USE IN BRICK WALL CONSTRUCTION[↗]

Testing						Assessment				
Test no.	**Test ref.**	**Purpose**	**Test param.**	**Location**	**Masonry[‡]**	Load & displ.	h_{ef} [†]	Drill bit dia.	Min. sample size	Batch
				Reference tests						
1a	5.0	Reference strength	Unconfined tension	Solid portion	Uncracked	8.5.1 8.5.2	all	d_{med}	5	1
1b[×]	5.0	Reference strength	Unconfined tension	Hollow portion	Uncracked	8.5.1 8.5.2	shallow	d_{med}	5	2
1c	5.0	Reference strength	Unconfined tension	Bed joint	Uncracked	8.5.1 8.5.2	shallow	d_{med}	5	3
1d[×]	7.9	Reference strength	Unconfined tension	Head joint	Uncracked	8.5.1 8.5.2	all	d_{med}	5	4
2[^#§]	6.9	Screw anchor reference	Confined tension	See 6.9	Uncracked	8.5.1	shallow, deep	d_{med}	5	5
				Reliability tests						
3	6.5	Reduced inst. effort	Unconfined tension	Solid portion	Uncracked	8.5.1	shallow, deep	d_{med}	5	1
4	6.6	Large hole dia.	Unconfined tension	Solid portion	Uncracked	8.5.1	shallow, deep	d_{max}	5	1
5	6.7	Small hole dia.	Unconfined tension	Solid portion	Uncracked	8.5.1	shallow, deep	d_{min}	5	1
6	6.8	Repeated load	Unconfined tension	Hollow portion[•]	Uncracked	8.5.1	shallow, deep	d_{med}	5	2
7[^#§]	6.9	Screws against brittle failure	Unconfined tension	See 6.9	Uncracked, HS grout	8.5.1	shallow, deep	d_{med}	5	5
8	6.10.2	Screws set with impact driver	Installation only	Solid portion	Uncracked	8.5.1	shallow	d_{max}	15	any
9	6.10.3	Screws set with torque wrench	Installation only	Solid portion	Uncracked	8.5.1	shallow	d_{max}	10	any
10	6.10.4	Screws set with torque wrench	Installation only	Solid portion	Uncracked	8.5.1	shallow	d_{min}	10	any
				Service condition tests						
11[‖]	7.6	Seismic tension	Unconfined cyc. tension, residual test	Hollow portion[•]	Uncracked	8.5.1 7.6.4	shallow, deep	d_{med}	5	2
12	7.7	Static shear away from edges	Shear	Hollow portion[•]	Uncracked	7.7.3	shallow	d_{med}	5	~~any~~6
13[‖]	7.8	Seismic shear	Cyclic shear, residual test	Hollow portion[•]	Uncracked	7.8.4	shallow, deep	d_{med}	5	~~any~~6
14[‖]	7.10	Torque test	Unconfined tension	Hollow portion[•]	Uncracked	7.10.3	shallow	d_{med}	5	any

[↗] Reported values from this test program are only valid for brick construction with all of the following characteristics: same material type (e.g., clay/shale/similar), equal or greater compressive strength (ASTM C67 for clay/shale/similar, ASTM C140 for concrete materials), equal or greater ratios of brick unit net cross-sectional area to gross cross-sectional area, and equal or greater number of wythes used in testing. For additional qualification of brick construction types, refer to Section 4.5.

[†] Where the MPII specify multiple embedment depths for a single anchor diameter, test anchor at minimum or maximum embedment depth as noted.

shallow = lowest anchor embedment for which recognition is sought for a given anchor diameter

deep = highest anchor embedment for which recognition is sought for a given anchor diameter

[×] This test shall be omitted if the net and gross cross-sectional area of the brick units are equal in all dimensions.

[•] This test shall be installed in the solid portion if the net and gross cross-sectional area of the brick units are equal in all dimensions.

[#] It shall be permitted to use the results of tests performed in grouted masonry in accordance with Table 4.1 or Table 4.2 using the same product.

^ Test not conducted in brick; see test description for material preparation conditions

[§] It shall be permitted to use the results of tests performed in concrete in accordance with AC193 using the same product.

[‖] Optional test.

[‡] Anchors shall be normalized to the minimum brick unit strength permitted by the respective brick standard in accordance with Section 8.3.

TABLE 4.5—REQUIRED SUPPLEMENTARY TESTS FOR EACH ALTERNATIVE DRILLING METHOD

Test type	h_{ef}	Dia.	Table 4.1* Test No.	Table 4.2 Test No.	Table 4.3 Test no.	Table 4.4 Test No.
Reference	min	all	1a	1a	1a	1a
			2	2	-	-
			-	3	-	-
Reliability	max	all	4	5	3	3
			5†	6†	4†	4†
			6†	7†	5†	5†

* If the tolerances on the bit diameter do not exceed the limiting values given in Table 4.6, Tests 5 and 6 may be omitted.
†Tests may be conducted with a standard core drill bit diameter (medium) if the tolerances on the core bit diameter, d_m, do not exceed the limiting values given in Table 4.6.

TABLE 4.6—CORE DRILL BIT LIMITING TOLERANCES

Bit diameter		Limits on tolerance	
in.	**mm**	**in.**	**mm**
< 3/4	< 18	+0.004, –0.000	+0.1, –0.0
7/8 to 1-1/4	20 to 30	+0.006, –0.000	+0.15, –0.0
>1-1/4	> 30	+0.008, –0.000	+0.2, –0.0

TABLE 4.7—REQUIRED SUPPLEMENTARY TESTS FOR EACH ADDITIONAL BRICK CONSTRUCTION TYPE

Test type	h_{ef}	Diameters	Table 4.4 Test No.
Reference	all	all	1a
			1bˣ
			1c
			1dˣ
Reliability	deep	SML*	3
			4
			5
Service condition	shallow	SML*	12#
			13#
			14#

ˣ This test may be omitted if the net and gross cross-sectional area of the brick units are equal in all dimensions.
* Where recognition is sought for a maximum of 4 anchor diameters, only the smallest and largest diameters are required to be tested.
S = smallest anchor element diameter for which recognition is sought.
M = middle anchor element diameter for which recognition is sought.
L = largest anchor element diameter for which recognition is sought.
# Where recognition for seismic design qualification is sought.

TABLE 4.8— MAXIMUM TIMES BETWEEN COMPRESSIVE STRENGTH TESTS OF GROUT

Grout age	Maximum time between grout compressive strength tests	COMMENTS
Less than 21 days	3 days	Only required for testing < 21 days.
21 - 35 days	7 days	—
36 - 56 days	14 days	—
57 - 90 days	30 days	—
90 days – 18 months	60 days	See Section 4.6.1.7

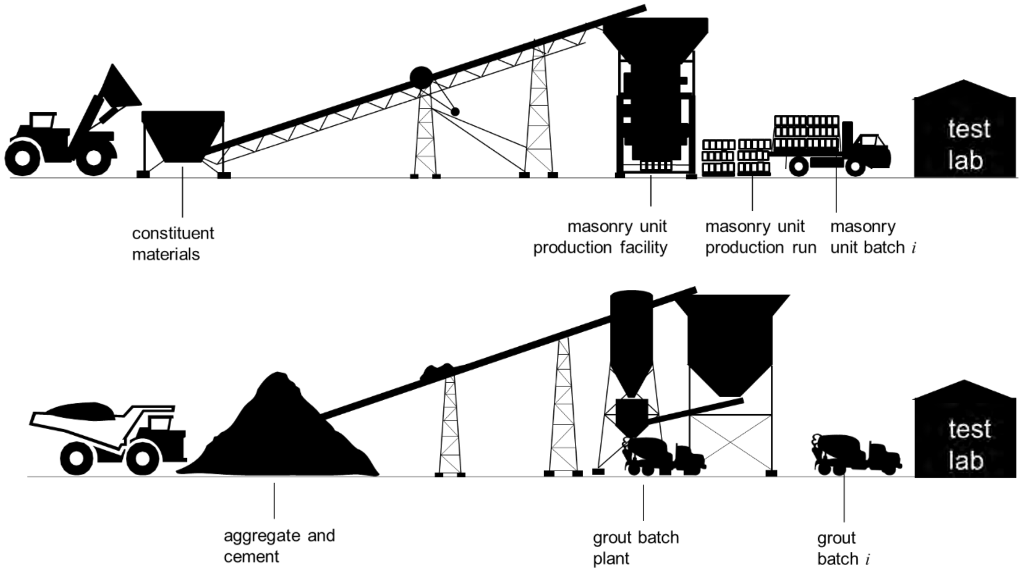


FIGURE 4.1—CONCEPT OF MASONRY BATCHES

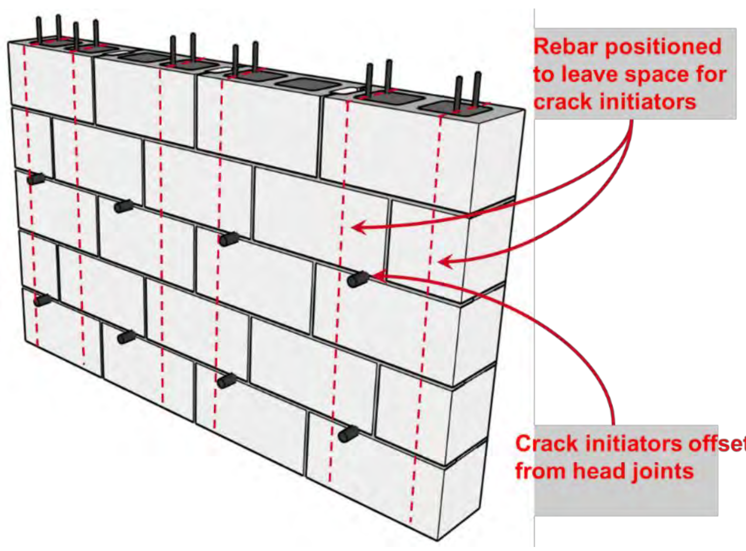


FIGURE 4.2—EXAMPLE OF REINFORCED WALL SPECIMEN FOR CRACKED MASONRY TESTING

TABLE 4.9—REQUIRED DIAMETERS OF CARBIDE DRILL BITS FOR SPECIFIED HOLE DIAMETERS

Nominal dia., in.	Tolerance ranges		
	d_{min}, in.	d_{med}, in.	d_{max}, in.
1/4	0.252 to 0.256	0.260 to 0.263	0.266 to 0.268
5/16	0.319 to 0.323	0.327 to 0.331	0.333 to 0.335
3/8	0.381 to 0.385	0.390 to 0.393	0.396 to 0.398
7/16	0.448 to 0.452	0.458 to 0.462	0.465 to 0.468
1/2	0.510 to 0.514	0.520 to 0.524	0.527 to 0.530
9/16	0.573 to 0.577	0.582 to 0.586	0.589 to 0.592
5/8	0.639 to 0.643	0.650 to 0.654	0.657 to 0.660
11/16	0.702 to 0.706	0.713 to 0.717	0.720 to 0.723
3/4	0.764 to 0.768	0.775 to 0.779	0.784 to 0.787
13/16	0.827 to 0.831	0.837 to 0.841	0.846 to 0.849
27/32	0.858 to 0.862	0.869 to 0.873	0.878 to 0.881
7/8	0.892 to 0.896	0.905 to 0.909	0.914 to 0.917
15/16	0.955 to 0.959	0.968 to 0.972	0.977 to 0.980
1	1.017 to 1.021	1.030 to 1.034	1.039 to 1.042
1-1/8	1.145 to 1.149	1.160 to 1.164	1.172 to 1.175
1-3/16	1.208 to 1.212	1.223 to 1.227	1.235 to 1.238
1-1/4	1.270 to 1.274	1.285 to 1.289	1.297 to 1.300
1-5/16	1.333 to 1.337	1.352 to 1.356	1.364 to 1.367
1-3/8	1.395 to 1.399	1.410 to 1.414	1.422 to 1.425
1-7/16	1.458 to 1.462	1.472 to 1.476	1.484 to 1.487
1-1/2	1.520 to 1.524	1.535 to 1.539	1.547 to 1.550
1-9/16	1.570 to 1.574	1.588 to 1.592	1.605 to 1.608
1-5/8	1.637 to 1.641	1.655 to 1.659	1.673 to 1.675
1-3/4	1.754 to 1.758	1.772 to 1.776	1.789 to 1.792
2	1.990 to 1.994	2.008 to 2.012	2.025 to 2.028

Nominal dia., mm	Tolerance ranges		
	d_{min}, mm	d_{med}, mm	d_{max}, mm
6	6.05 to 6.15	6.20 to 6.30	6.35 to 6.40
7	7.05 to 7.20	7.25 to 7.35	7.40 to 7.45
8	8.05 to 8.20	8.25 to 8.35	8.40 to 8.45
10	10.10 to 10.20	10.25 to 10.35	10.40 to 10.45
11	11.10 to 11.20	11.25 to 11.35	11.45 to 11.50
12	12.10 to 12.20	12.25 to 12.35	12.45 to 12.50
13	13.10 to 13.20	13.25 to 13.35	13.45 to 13.50
14	14.10 to 14.20	14.25 to 14.35	14.45 to 14.50
15	15.10 to 15.20	15.25 to 15.35	15.45 to 15.50
16	16.10 to 16.20	16.25 to 16.35	16.45 to 16.50
18	18.10 to 18.20	18.25 to 18.35	18.45 to 18.50
19	19.10 to 19.20	19.30 to 19.40	19.50 to 19.55
20	20.10 to 20.20	20.30 to 20.40	20.50 to 20.55
22	22.10 to 22.20	22.30 to 22.40	22.50 to 22.55
24	24.10 to 24.20	24.30 to 24.40	24.50 to 24.55
25	25.10 to 25.20	25.30 to 25.40	25.50 to 25.55
28	28.10 to 28.20	28.30 to 28.40	28.50 to 28.55
30	30.10 to 30.20	30.30 to 30.40	30.50 to 30.55
32	32.15 to 32.25	32.35 to 32.50	32.60 to 32.70
34	34.15 to 34.25	34.35 to 34.50	34.60 to 34.70
35	35.15 to 35.25	35.35 to 35.50	35.60 to 35.70
37	37.15 to 37.25	37.35 to 37.50	37.60 to 37.70
40	40.15 to 40.25	40.40 to 40.60	40.70 to 40.80
44	44.15 to 44.25	44.40 to 44.60	44.70 to 44.80
48	48.15 to 48.25	48.40 to 48.60	48.70 to 48.80
52	52.15 to 52.25	52.40 to 52.60	52.80 to 52.95

TABLE 4.10—REQUIRED DEGREE OF SETTING TORQUE FOR TORQUE-CONTROLLED EXPANSION ANCHORS

Table 4.1 Test No.	Table 4.2 Test No.	Table 4.3 Test No.	Table 4.4 Test No.	Required degree of setting torque
4	5	3	3	Partial, 0.5T_{inst}
1a, 1b, 1c, 1d[ǁ], 2, 5, 6, 7, 13a, 13b[ǁ]	1a, 1b, 1c, 1d[ǁ], 1e, 2, 3, 6, 7, 8, 14[ǁ], 15a, 15b, 16	1a, 1b, 1c, 4, 5, 6, 11[ǁ], 12, 13[ǁ]	1a, 1b, 1c, 1d, 4, 5, 6, 11[ǁ], 12, 13[ǁ]	Full*
12a, 12b	13a, 13b	-	-	Special requirements in Section 7.4

* Required degree of setting torque in relation to MPII. After application of full setting torque, reduce to 50% setting torque before testing.
ǁ Where recognition is desired.

TABLE 4.11—REQUIRED DEGREE OF EXPANSION OF DISPLACEMENT-CONTROLLED EXPANSION ANCHORS

Table 4.1 Test No.	Table 4.2 Test No.	Table 4.3 Test No.	Table 4.4 Test No.	Required degree of setting torque
4	5	3	3	Partial, 0.5T_{inst}[†]
5, 6, 7	6, 7, 8	4, 5, 6	4, 5, 6	Reference[†]
1a, 1b, 1c, 1d, 2, 13a, 13b	1a, 1b, 1c, 1d, 1e, 2, 3, 15a, 15b	1a, 1b, 1c, 12	1a, 1b, 1c, 1d, 12	Full*
12a, 12b	13a, 13b	-	-	Special requirements in 7.4

† Refer to 4.6.5.3.1 and 4.6.5.3.2 for definitions.
* Required degree of setting torque in relation to MPII.

TABLE 4.12—PARAMETERS FOR ESTABLISHING PARTIAL AND REFERENCE EXPANSION OF DISPLACEMENT-CONTROLLED ANCHORS

Anchor size	1/4 in. (M6)	5/16 in. (M8)	3/8 in. (M10)	1/2 in. (M12)	5/8 in. (M16)	3/4 in. (M20)
Weight, lb (kg)	10 (4.5)	10 (4.5)	10 (4.5)	10 (4.5)	33 (15)	33 (15)
Height of fall, in. (mm)	18 (450)	18 (450)	18 (450)	18 (450)	24 (600)	24 (600)
Number of drops for evaluation of partial expansion	2	3	4	5	3	4
Number of drops for evaluation of reference expansion	3	5	6	7	4	5

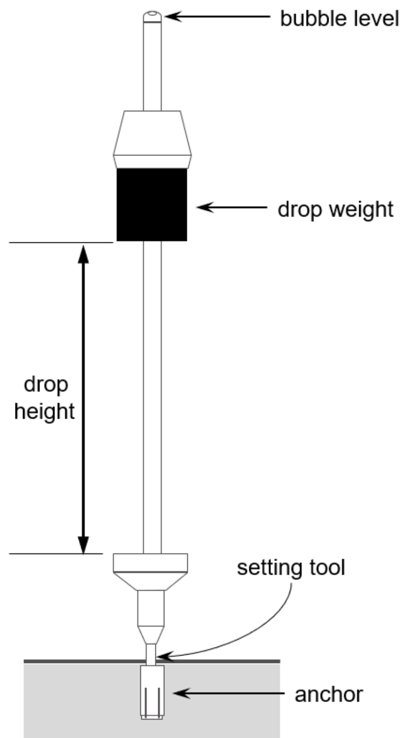


FIGURE 4.3—INSTALLATION TOOL FOR SETTING TESTS OF DISPLACEMENT-CONTROLLED EXPANSION ANCHORS

TABLE 4.13—INSTALLATION REQUIREMENTS FOR UNDERCUT ANCHORS IN RELIABILITY TESTS

Installation requirements	Type of undercut anchor (See ACI 355.2-19 Fig. 3.1c(a) through (f))				
	Load-controlled	**Displacement-controlled**		**Torque-controlled**	
	Type 1 undercut, predrilled	**Types 2 and 3 undercut, predrilled**	**Type 4 undercut, self-drilled**	**Type 5 undercut, predrilled**	**Type 6 undercut, self-drilled**
Bit diameter for cutting cylindrical hole	Maximum	Maximum	Maximum	Maximum	Maximum
Undercutting tool diameter	Minimum specification	Minimum specification	—	Minimum specification	—
Tolerances on length of undercutting tool (where applicable)	Maximum tolerance length	Maximum tolerance length	Maximum	Maximum tolerance length	Maximum tolerance length
Length of sleeve	—	Minimum tolerance length	—	—	—
Length of cylindrical hole	—	Maximum tolerance length	Maximum tolerance length	—	—
Setting of anchor	75% of specified load	Sleeve flush with masonry surface*	Sleeve flush with masonry surface	50 percent of specified torque	50 percent of specified torque or flush to surface

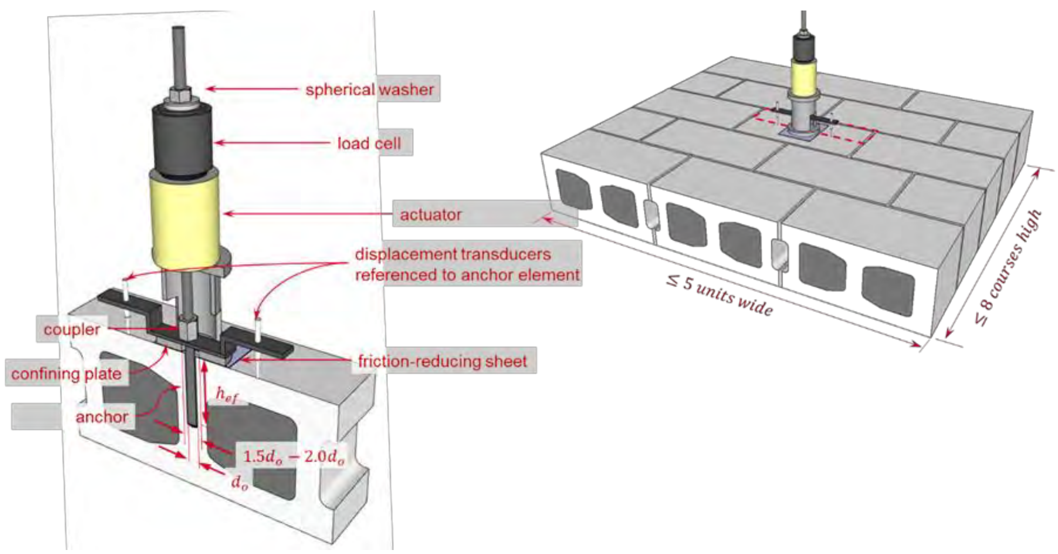


FIGURE 4.4— EXAMPLE OF CONFINED TENSION TEST SETUP (WEB LOCATION SHOWN)

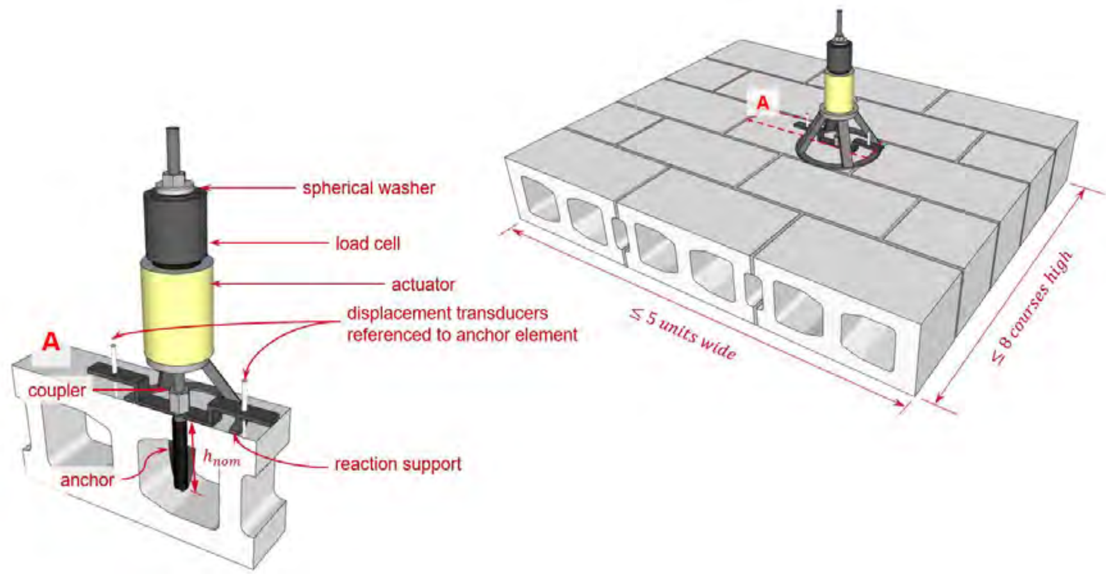


FIGURE 4.5— EXAMPLE OF UNCONFINED TENSION TEST SETUP. (CENTER-OF-CELL LOCATION SHOWN.)

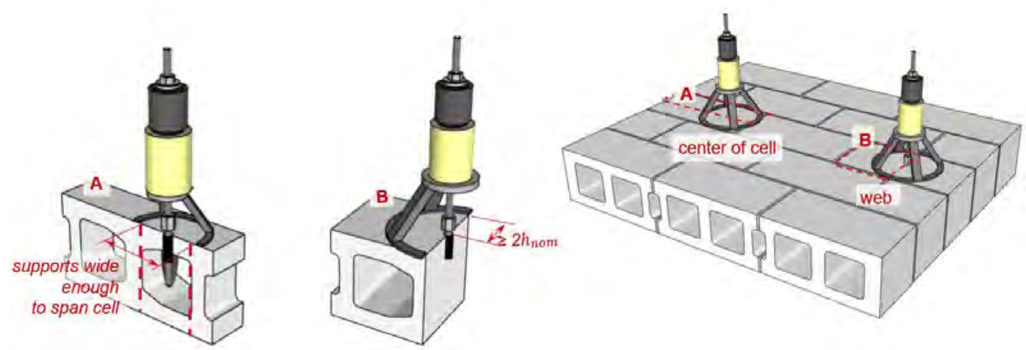


FIGURE 4.6— MINIMUM SUPPORT SPAN IN THE CENTER OF CELL AND BED JOINT (A) AND WEB (B) OF UNGROUTED CMU.

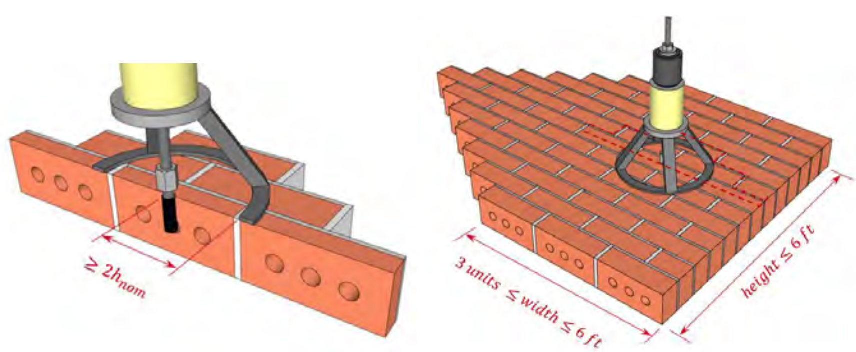


FIGURE 4.7— MINIMUM DIMENSIONS OF TEST MEMBER (LEFT) AND SUPPORT SPAN LENGTH IN BRICK

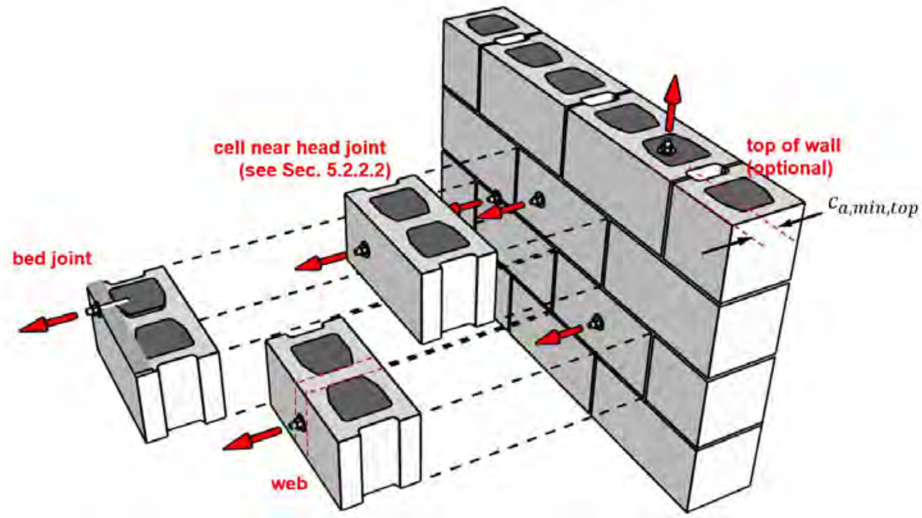


FIGURE 5.1—TESTING LOCATIONS IN TENSION FOR GROUTED CMU

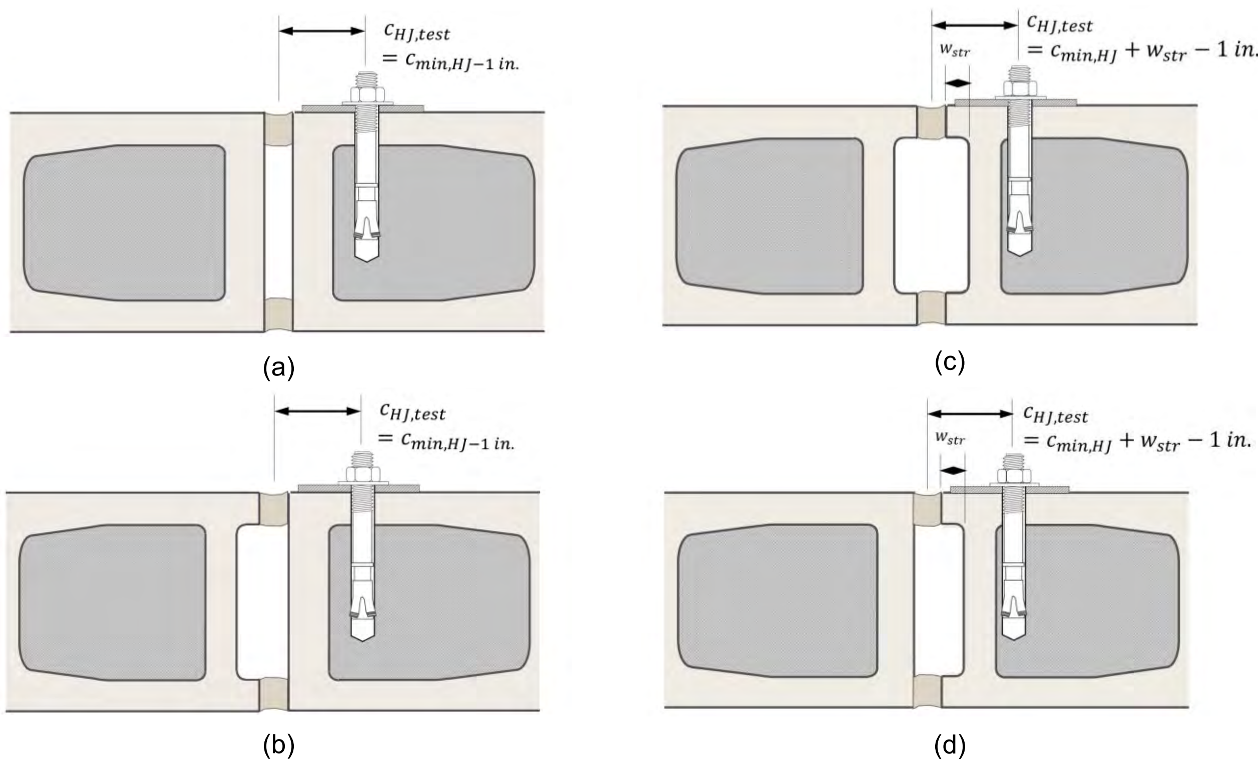


FIGURE 5.2—ILLUSTRATION OF TESTING REQUIREMENTS FOR PROXIMITY TO HEAD JOINT

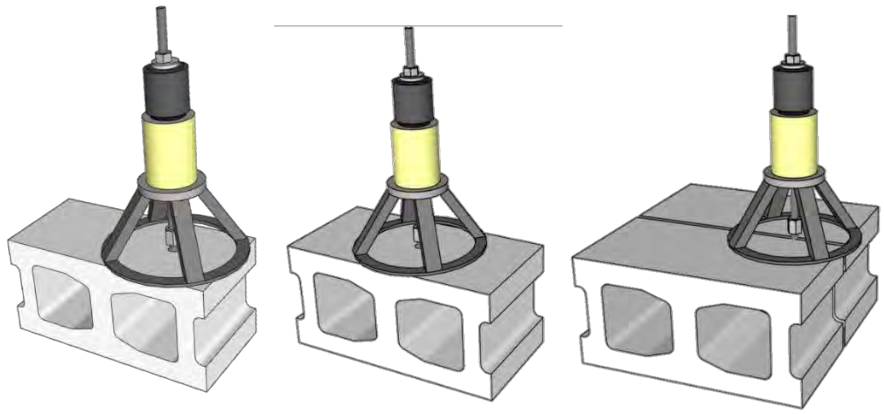


FIGURE 5.3— TESTING LOCATIONS IN THE CENTER OF CELL (LEFT), WEB (MIDDLE), AND BED JOINT (RIGHT) OF UNGROUTED CMU

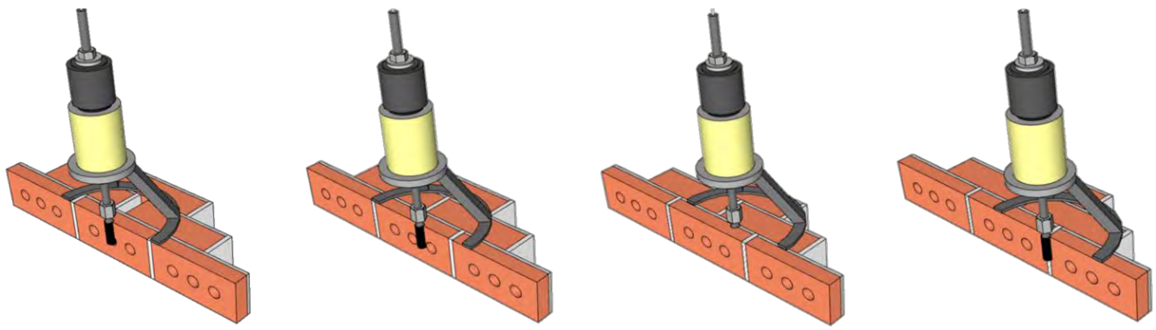


FIGURE 5.4— TESTING LOCATIONS IN THE HOLLOW PORTION (LEFT), SOLID PORTION (MIDDLE-LEFT), BED JOINT (MIDDLE-RIGHT), AND HEAD JOINT (RIGHT) OF BRICK

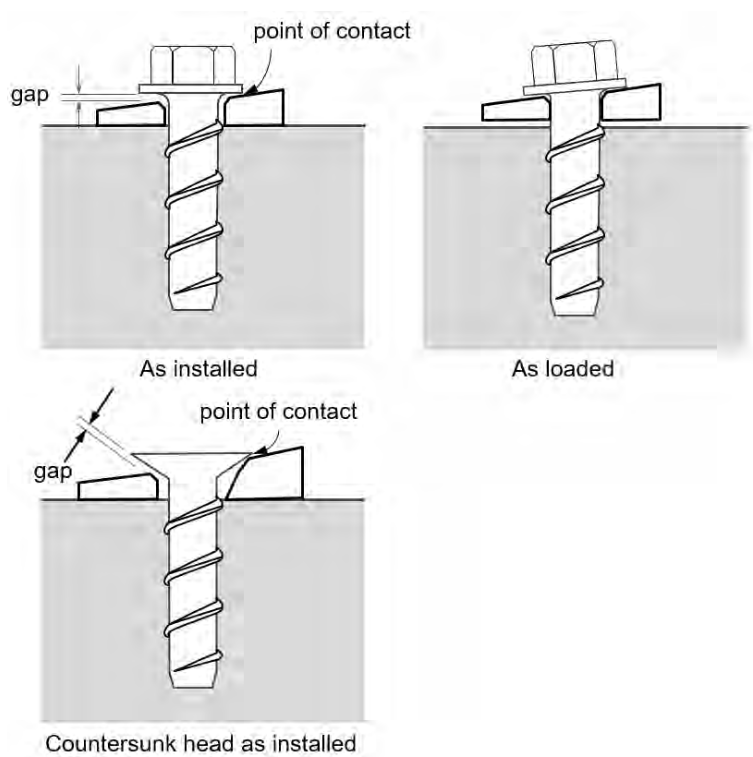


FIGURE 6.1—BEVEL WASHER GEOMETRY FOR DIFFERENT HEAD SHAPES

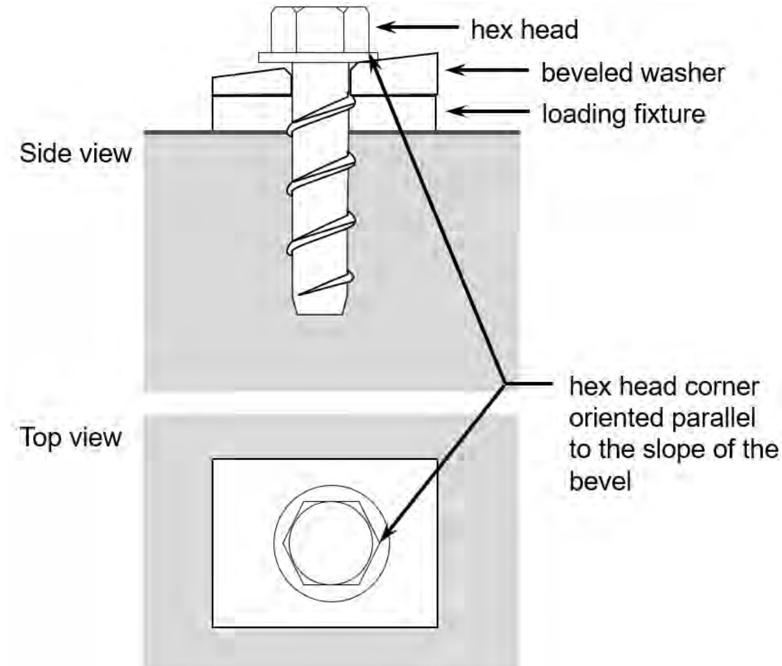


FIGURE 6.2—ACCEPTABLE POSITION OF THE ANCHOR HEAD IN TESTS WITH REPEATED LOADS

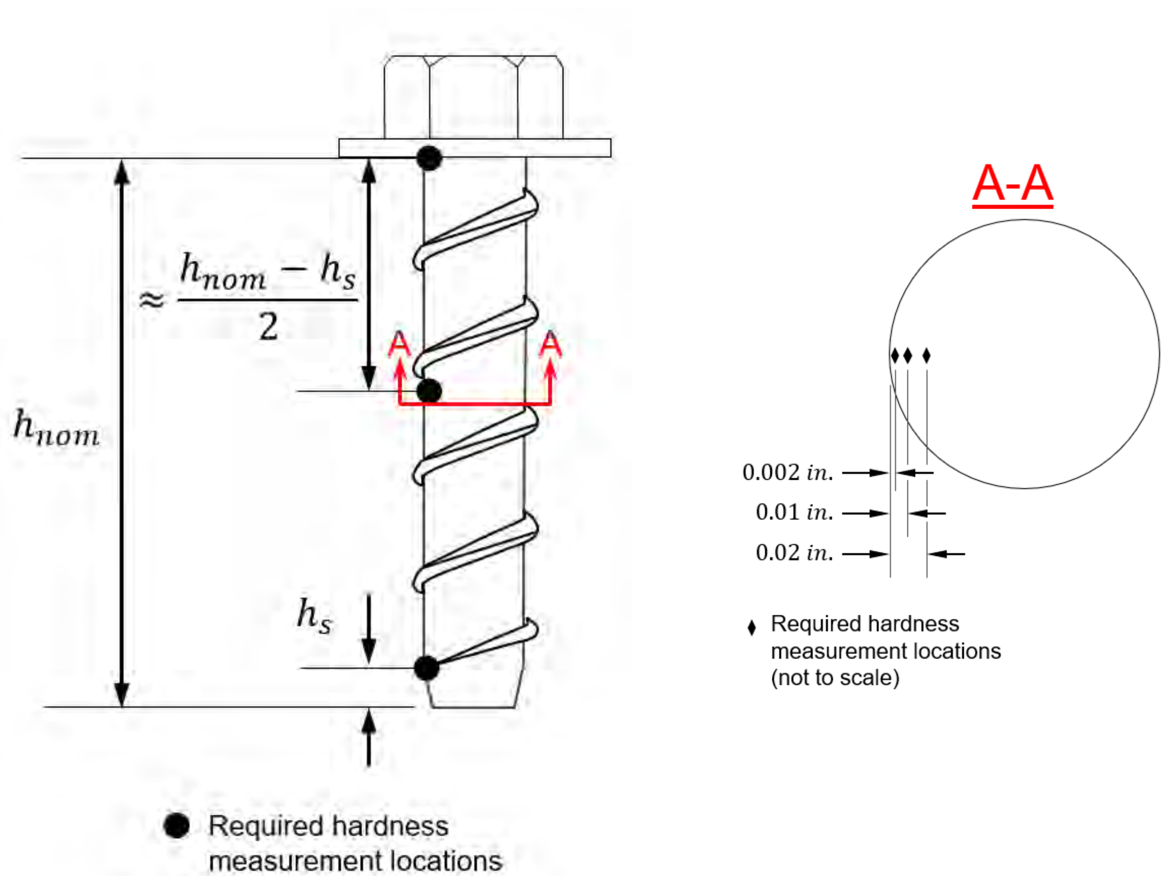


FIGURE 6.3—SCREW ANCHOR WITH SECTIONS FOR HARDNESS MEASUREMENT

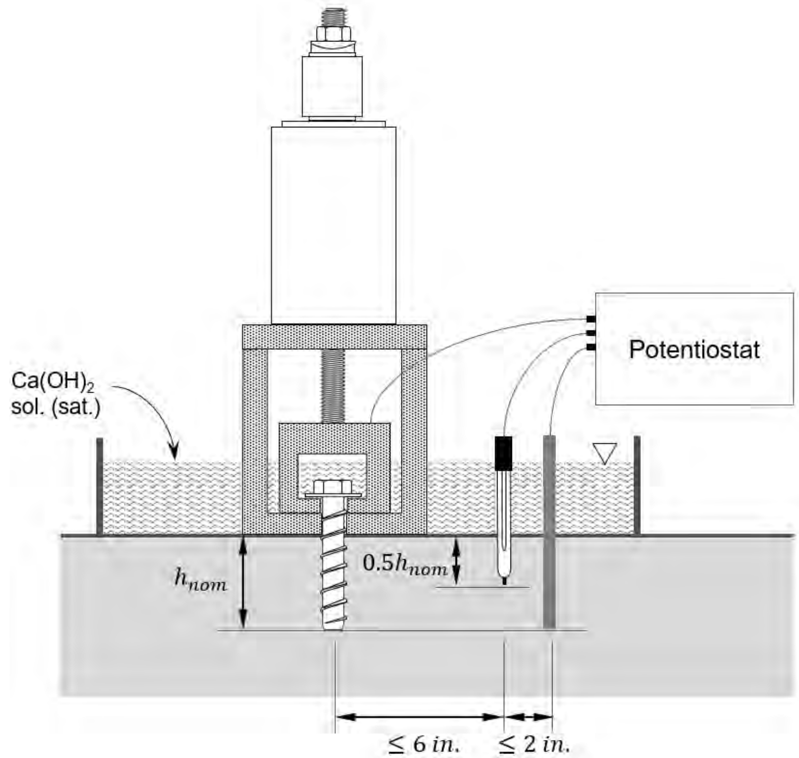


FIGURE 6.4. CONFINED TEST SETUP FOR CHECKING BRITTLENESS OF SCREWS

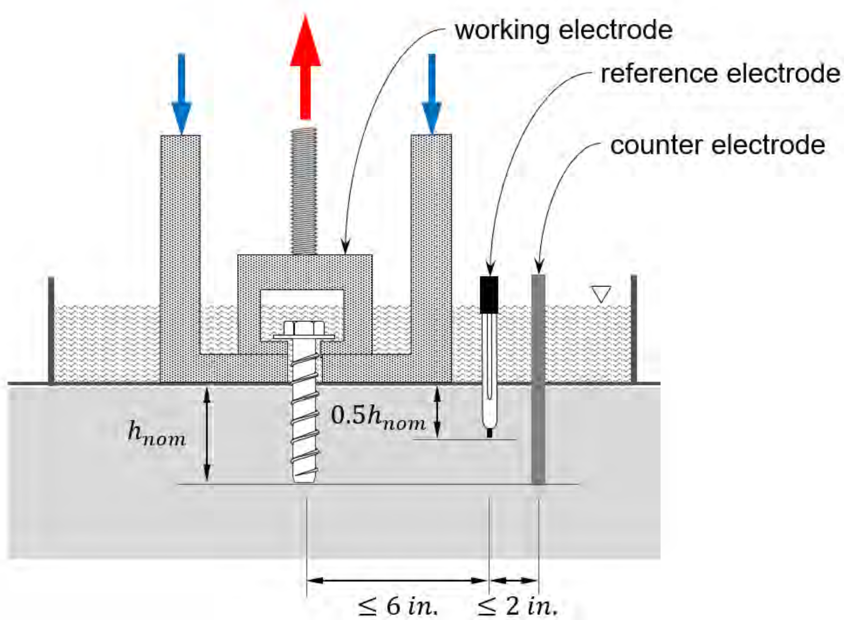


FIGURE 6.5 DETAILS OF ATTACHMENT FOR ANCHOR DURING TESTS FOR BRITTLENESS OF SCREWS

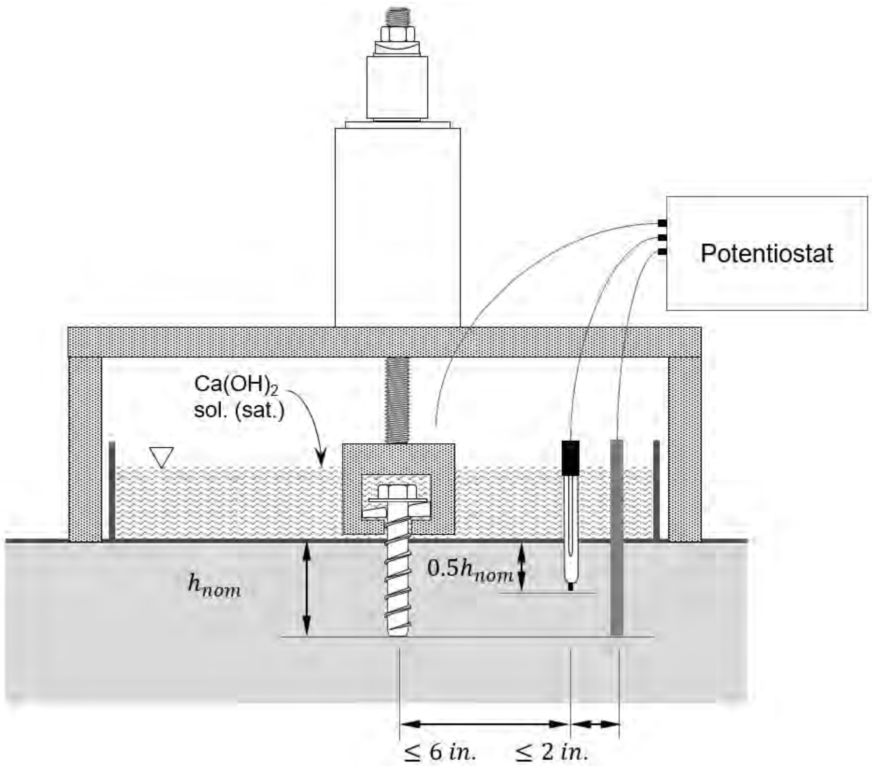


FIGURE 6.6 UNCONFINED TEST SETUP WITH BEVEL WASHER UNDER ANCHOR HEAD FOR CHECKING BRITTLENESS OF SCREWS (METHOD A1).

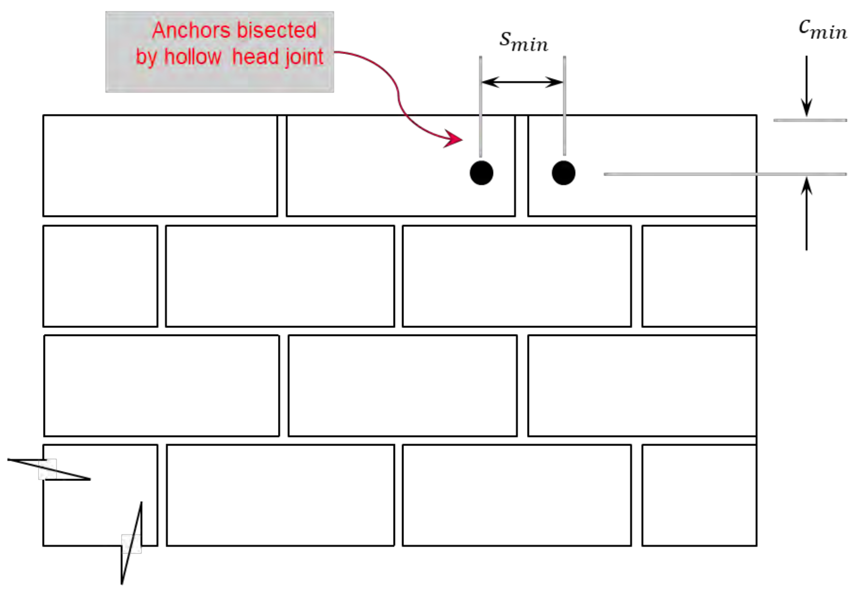


FIGURE 7.1—DEFINITION OF MINIMUM EDGE AND SPACING IN THE FACE OF THE WALL

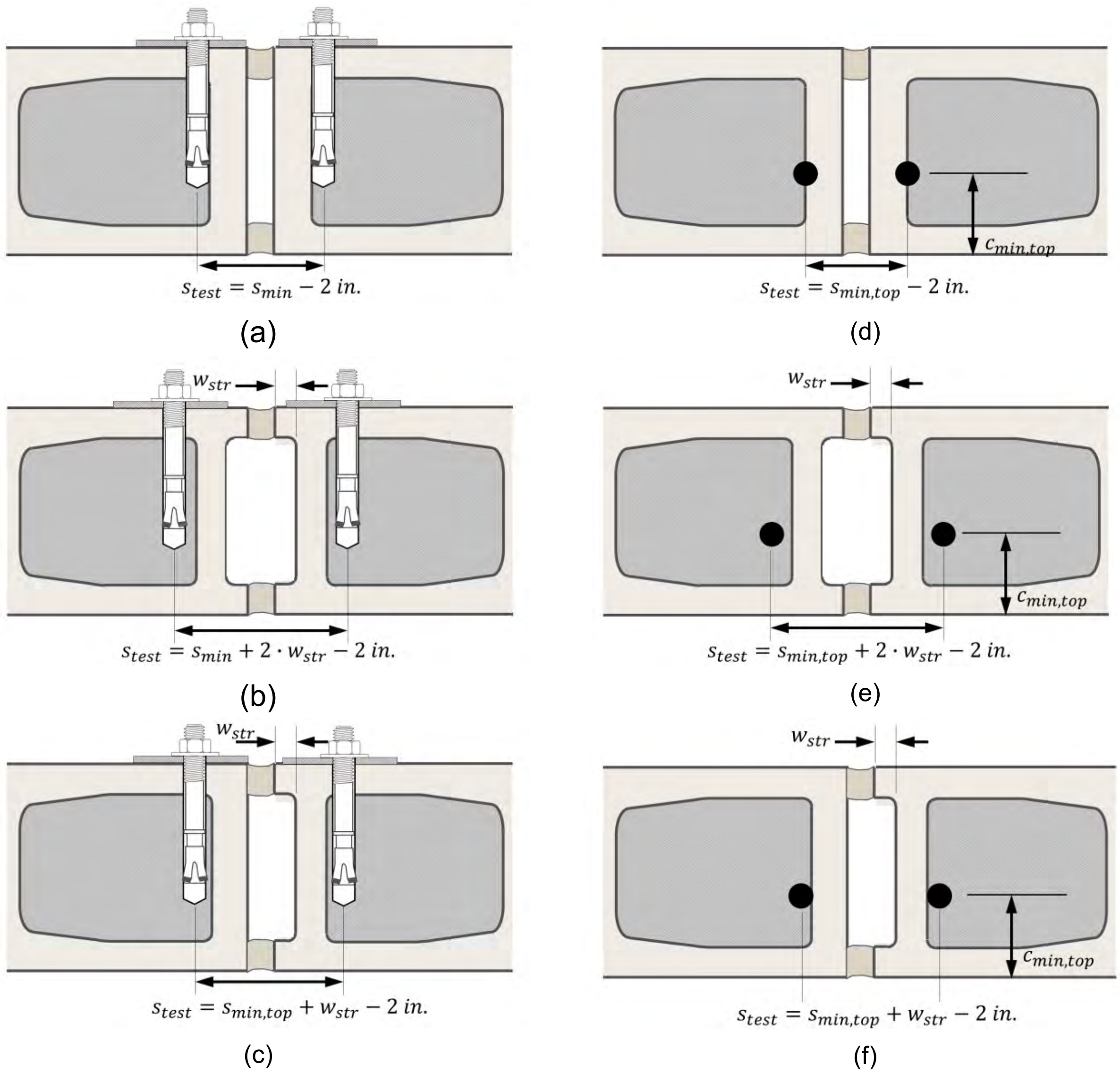


FIGURE 7.2—LOCATION OF ANCHORS FOR MINIMUM EDGE AND SPACING TESTS IN THE FACE (A,B,C) AND TOP (D,E,F) OF THE WALL FOR (A,D) TWO FLAT ENDS, (B,E) TWO STRETCHER ENDS, AND (C,F) ONE FLAT AND ONE STRETCHER END

TABLE 7.1—REQUIRED LOADING HISTORY FOR SIMULATED SEISMIC TENSION TEST

Load level	N_{eq}	N_{int}	N_m
Number of cycles	10	30	100

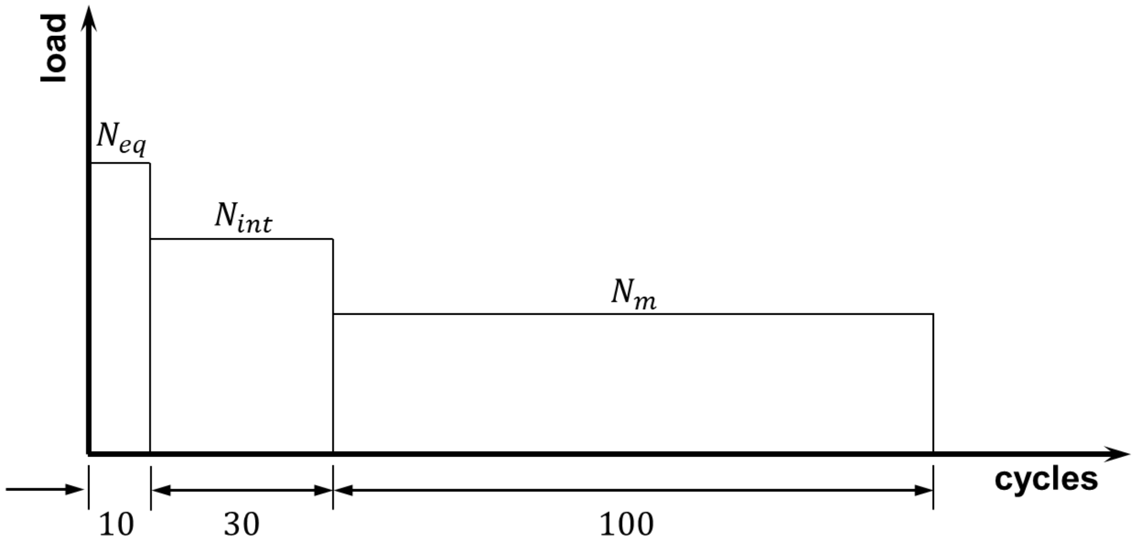


FIGURE 7.3—REQUIRED LOAD HISTORY FOR SIMULATED SEISMIC TENSION TEST

TABLE 7.2—REQUIRED LOADING HISTORY FOR SIMULATED SEISMIC SHEAR TEST

Load level	$\pm V_{eq}$	$\pm V_{\text{int}}$	$\pm V_m$
Number of cycles	10	30	100

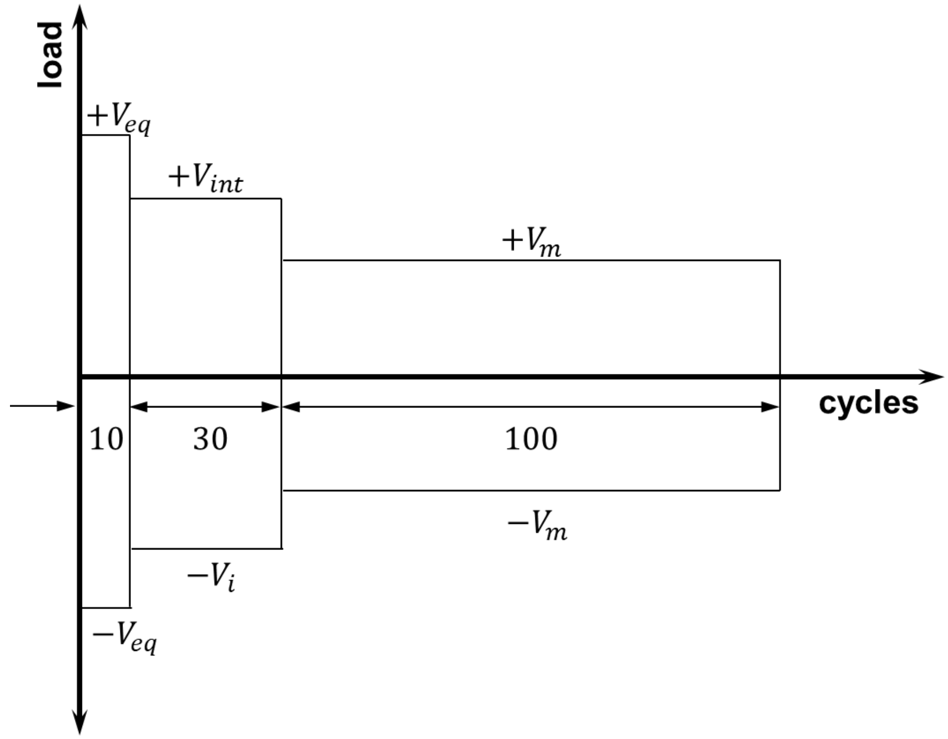


FIGURE 7.4—REQUIRED LOAD HISTORY FOR SIMULATED SEISMIC SHEAR TEST

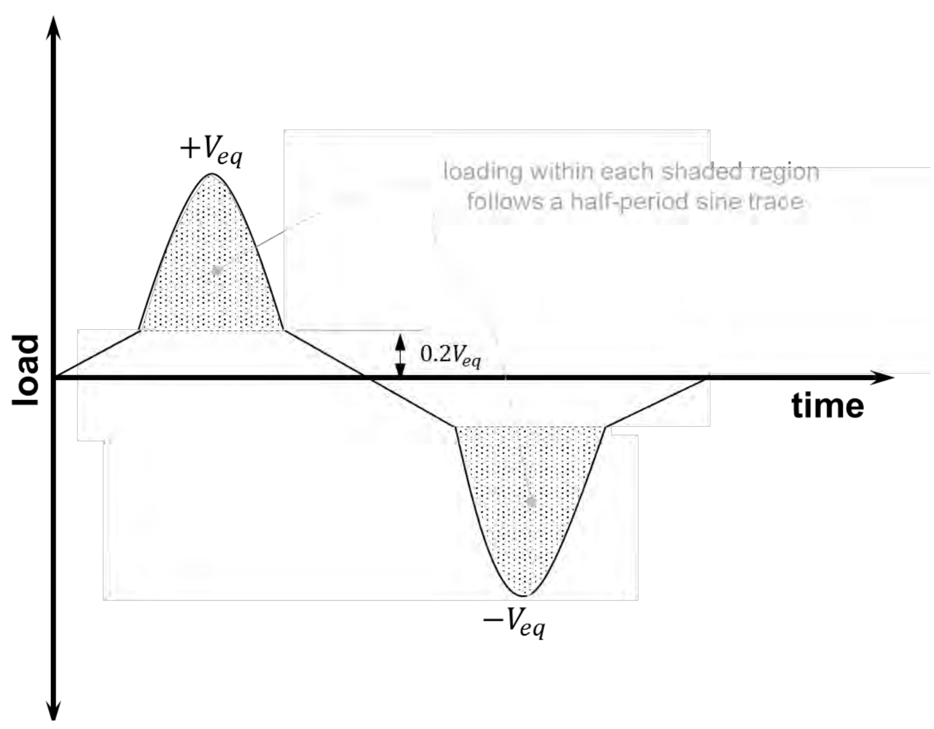


FIGURE 7.5—PERMITTED APPROXIMATION OF SEISMIC SHEAR CYCLE

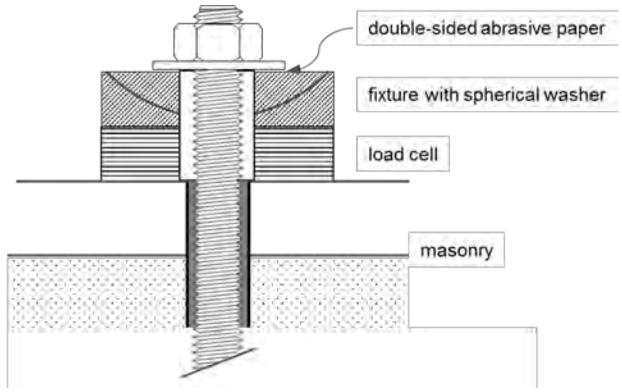


FIGURE 7.6—TORQUE TEST SETUP

TABLE 8.1—STATISTICAL K FACTORS USED FOR DETERMINING CHARACTERISTIC VALUES

Number of tests n	K	Number of tests n	K
3	5.311	21	2.190
4	3.957	22	2.174
5	3.400	23	2.159
6	3.092	24	2.149
7	2.894	25	2.132
8	2.754	26	2.120
9	2.650	27	2.109
10	2.568	28	2.099
11	2.503	29	2.089
12	2.448	30	2.080
13	2.402	35	2.041
14	2.363	40	2.010
15	2.329	45	1.986
16	2.299	50	1.965
17	2.272	60	1.933
18	2.249	120	1.841
19	2.227	240	1.780
20	2.208	∞	1.645

TABLE 8.2—REQUIREMENTS FOR OVERALL LOAD-DISPLACEMENT BEHAVIOR IN ACCORDANCE WITH 8.5.1.2

Test type	Table 4.1	Table 4.2	Table 4.3	Table 4.4
Reference tests	All	All	All	All
Reliability tests	4-6 7 (initial loading and residual capacity) 8 (residual capacity)	5-7 8 (initial loading and residual capacity) 9 (residual capacity)	3-5 6 (initial loading and residual capacity) 7 (residual capacity)	3-5 6 (initial loading and residual capacity) 7 (residual capacity)
Service condition tests	12a, 12b	13a, 13b	-	-

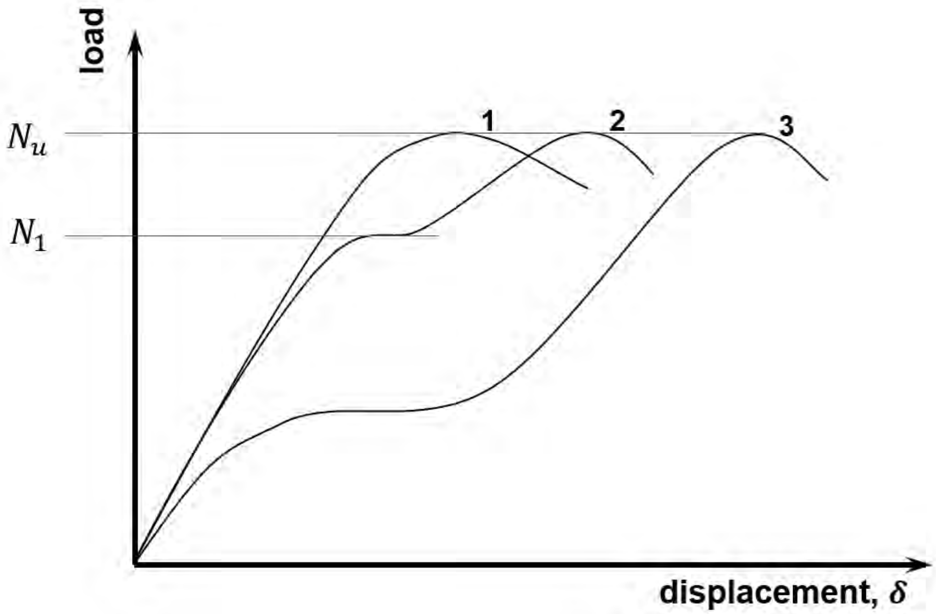


FIGURE 8.1—REQUIREMENTS FOR LOAD-DISPLACEMENT CURVES

TABLE 8.3—ESTABLISHMENT OF ANCHOR CATEGORIES

$N_{k,r} / N_{k,o}$	Anchor Category
≥ 0.80	1
0.70-0.80	2
0.50-0.70	Refer to Sec. 8.5.4.3
≤ 0.50	Anchor is unqualified

TABLE 10.1—SAMPLE FORMAT FOR REPORTING MECHANICAL ANCHOR DATA FOR ANCHORS QUALIFIED FOR USE IN GROUTED MASONRY

Anchor system qualified for use in both cracked and uncracked masonry in accordance with test program of Table 4.2, but without seismic qualification

Characteristic	Symbol	Units	Chapter reference	Nominal anchor diameters				
				Smaller diameters (if any)	⅜ in. (M10)	½ in. (M12)	⅝ in. (M16)	Larger diameters (if any)
Installation information								
Outside diameter	d_o	in. (mm)						
Effective embedment depth	h_{ef}	in. (mm)						
Installation torque	T_{inst}	ft-lb (N-m)						
Minimum field-of-wall edge distance	c_{min}	in. (mm)						
Minimum top-of-wall edge distance	c_{min}	in. (mm)						
Minimum spacing	s_{min}	in. (mm)						
Minimum masonry thickness	h_{min}	in. (mm)						
Critical edge distance	c_{cr}	in. (mm)						
Anchor data								
Category number	1 or 2	—						
Yield strength of anchor steel	f_y	psi (MPa)						
Ultimate strength of anchor steel	f_{uta}	psi (MPa)						
Effective tensile stress area	A_{se}	in.^{2} (mm^2)						
Effective shear stress area	A_{se}	in.^{2} (mm^2)						
Nominal shear strength in shear of a single anchor as governed by steel strength	V_{sa}	lb (N)						
$\psi_{c,N}$ for design in cracked masonry	$\psi_{m,N}$	—		1.0	1.0	1.0	1.0	1.0
$\psi_{c,N} = k_{uncr} / k_{cr}$ for design in uncracked masonry	$\psi_{m,N}$	—						
Nominal pullout capacity in tension of a single anchor in uncracked masonry	$N_{p,uncr}$	lb (N)						
Axial stiffness in service load range	β	lb/in. (kN/mm)						
Coefficient of variation for axial stiffness in service load range	v	%						

*These are values used for k_{cr} and $\psi_{m,N}$ in ACI 318 for anchors qualified for use only in both cracked and uncracked masonry.

APPENDIX A
Evaluation under the *National Building Code of Canada 2020®* (NBCC)

Appendix A shall be used in conjunction with all the sections of this criteria that are not modified within this Appendix A, as applicable. The numbering system within this Appendix A for the modified sections, uses the prefix "A".

A1.0 INTRODUCTION

A1.1 Purpose: The purpose of this appendix is to establish requirements for evaluating the performance of mechanical anchors in masonry elements. This appendix is needed since the 2020 NBCC does not include applicable guidelines for the evaluation of alternative anchors to those addressed by the code (NBCC).

A1.2.2 Table A3.1 shall be used in conjunction with Section 1.2.2 of the acceptance criteria, for the applicable references between CSA A23.3:19 and ACI 318.

A1.3 Additional codes and standards applicable to this appendix:

A1.3.1 *National Building Code of Canada 2020®* (NBCC)

A1.3.2 CSA A23.3:19, Design of Concrete Structures, CSA Group.

A1.3.3 CSA S304-14, Design of Masonry Structures, CSA Group.

A1.4 Definitions: Definitions included in CSA A23.3:19 and CSA S304-14 are also applicable to this appendix.

A1.5 Notations: Notations included in CSA A23.3:19 and CSA S304-14 are also applicable to this appendix.

A3.0 ANCHOR LIMIT STATES DESIGN:

A3.1 Design basis: Anchors shall be designed in accordance with the strength design provisions provided in this section.

A3.1.1 The strength design of mechanical anchors as described in sections A3.3 through A3.7 is derived substantially from the provisions for mechanical anchors in concrete as contained in CSA A23.3:19. This procedure also applies to the design of mechanical anchors in the grouted cells of partially grouted CMU construction (where the location of the grouted cells is known).

A3.1.2 The strength design of anchors in ungrouted CMU construction shall be in accordance with Section A3.4. Where the location of grouted cells in partially grouted CMU construction is unknown, all anchors installed in the wall shall be designed in accordance with Section A3.4

A3.2 General Notes and Modifications:

A3.2.1 This appendix references sections, tables, and figures in both the acceptance criteria and CSA A23.3:19. Refer to Section A1.2.2 for an explanation of the differentiation between references to these two documents.

A3.2.2 Where language from CSA A23.3:19 is directly referenced, the following modifications generally apply:

a) The term "masonry" shall be substituted for the term "concrete" wherever it occurs.
b) The modification factor to reflect the reduced mechanical properties for mixtures with lightweight aggregate and lightweight units, λ_a, shall be taken as 1.0.
c) Unless specifically amended by this section, design provisions shall also apply to screw anchors.
d) In addition to CSA A23.3:19 Clause D.2, the following definitions shall be used:

   Masonry, fully grouted — concrete masonry unit (CMU) construction in which all cells or spaces are filled with grout.

   Masonry, partially grouted — concrete masonry unit (CMU) construction in which designated cells or spaces are filled with grout, while other cells or spaces remain ungrouted.

   Masonry, ungrouted — concrete masonry unit (CMU) construction in which none of the cells or spaces are filled with grout.

   Masonry, brick — clay brick masonry construction

A3.2.3 Subsequent sections within this chapter address the design of post-installed anchors in masonry:

- Section A3.3: Strength design in fully grouted concrete masonry unit construction (covering both closed- and open-ended units).
- Section A3.4: Strength design in ungrouted concrete masonry unit construction.
- Section A3.5: Strength design in partially grouted concrete masonry unit construction.

- Section A3.6: Strength design in brick masonry construction.
- Section A3.7: Conversion of strength design capacities to allowable stress design capacities.

A3.3 Strength Design of Mechanical Anchors in Fully Grouted Concrete Masonry Unit Construction—Strength design of post-installed anchors in fully grouted concrete masonry unit construction shall be conducted in accordance with the provisions for the design of post-installed anchors in concrete in CSA A23.3:19 Annex D as modified by this section. Design in accordance with this document cannot be conducted without reference to CSA A23.3:19 with the deletions and modifications summarized in Table A3.1.

A3.3.1 General notes and modifications—The notes and modifications within this subsection shall apply throughout the design provisions.

A3.3.1.1 The following terms shall be replaced wherever they occur:

CSA A23.3:19 term	Replacement term
f'_c	f'_m
N_{cbr}, N_{cbgr}	N_{mbr}, N_{mbgr}
N_{cpr}	N_{mpr}
V_{cbr}, V_{cbgr}	V_{mbr}, V_{mbgr}
V_{cpr}, V_{cpgr}	V_{mpr}, V_{mpgr}

A3.3.1.2 Edge assumptions for design purposes and restrictions for anchor placement are illustrated in Figure 3.2. For CMU construction with hollow head joints (Section 1.4.14.1), in addition to the ends and edges of walls, the nearest head joint on a horizontal projection from the anchor shall be treated as an edge for design purposes. The minimum distance from the nearest adjacent head joint shall be determined by testing in accordance with Section 7.4 and, optionally, 7.5. For anchor groups installed in CMU construction with solid head joints (Section 1.4.14.2), the nearest head joint outside of the group on a horizontal projection to the group shall be treated as an edge. If open-ended units are employed, only the ends and edges of walls shall be considered for edge distance determination. For horizontal ledgers in fully-grouted CMU walls with hollow head joint applications, see Section A3.3.2.24.

A3.3.2 Specific modifications: Table A3.1 provides a summary of all applicable CSA A23.3:19 clauses for the design of post-installed mechanical anchors in fully grouted masonry. Where applicable, modifying sections contained within this document are also provided.

A3.3.2.1 CSA A23.3:19 Clauses D.1.1 and D.1.2 apply with the general changes prescribed in Section A3.2.2.

A3.3.2.2 In lieu of CSA A23.3:19 Clause D.1.3: Design provisions are included for post-installed expansion (torque-controlled and displacement-controlled), undercut, and screw anchors that meet the assessment criteria of AC01.

A3.3.2.3 CSA A23.3:19 Section D.1.4, D.4.1.1, D.4.1.2 and D.4.2 apply with the general changes prescribed in Section A3.2.2.

A3.3.2.4 In lieu of CSA A23.3:19 Clause D.4.3: The design of anchors in structures in regions where $I_E S(0.2) \geq 0.35$ shall satisfy the requirements of this section.

A3.3.2.4.1 The design of anchors in the plastic hinge zones of masonry structures under earthquake forces is beyond the scope of this appendix.

A3.3.2.4.2 The anchor or group of anchors shall be designed in accordance with CSA A23.3:19 Clause D.4.3.5.3(d) for the maximum tension and shear obtained from the design load combinations that include earthquake effects. The anchor design tensile strength shall satisfy the tensile strength requirements of A3.3.2.4.3.

A3.3.2.4.3 The anchor design tensile force for resisting earthquake forces shall be determined from consideration of (a) through (c) for the failure modes given in Table 3.2 assuming the masonry is cracked unless it can be demonstrated that the masonry remains uncracked.

a) N_{sra} for a single anchor or for every anchor in a group of anchors.
b) $0.75N_{mbr}$ or $0.75N_{mbgr}$.
c) $0.75N_{mpr}$ for a single anchor or for every anchor in a group of anchors.

A3.3.2.5 CSA A23.3:19 Clause D.4.7 applies with the general changes prescribed in Section A3.2.2.

A3.3.2.6 In lieu of CSA A23.3:19 Clause D.5.1.2: The design of anchors shall be in accordance with Table A3.2. In addition, the design of anchors shall satisfy A3.3.2.4 for earthquake loading.

A3.3.2.7 CSA A23.3:19 Clause D.5.1.4 applies with the general changes prescribed in Section A3.2.2.

A3.3.2.8 CSA A23.3:19 Clauses D.5.2.1, D.5.2.3 and D.5.2.4 applies with the general changes prescribed in Section A3.2.2.

A3.3.2.9 In lieu of CSA A23.3:19 Clause D.5.3: resistance modification factor, R, for anchors in masonry shall be as follows when the factored load combinations specified in Annex C of CSA A23.3:19 are used:

(a) For steel resistance of ductile steel elements as defined in Section 2.1.4.3.5, R shall be taken as 0.80 in tension and 0.75 in shear. Where the ductility requirements of Section 2.1.4.3.5 are not met, R shall be taken as 0.70 in tension and 0.65 in shear.
(b) For shear crushing resistance, R shall be taken as 0.80.
(c) For cases where the nominal resistance of anchors in masonry is controlled by masonry breakout in tension, R shall be taken as 1.00 for anchors qualifying for Category 1 and 0.85 for anchors qualifying for Category 2.
(d) For cases where the nominal resistance of anchors in masonry is controlled by masonry failure modes in shear, R shall be taken as 1.00~~15~~.
(e) For cases where the nominal resistance of anchors in masonry is controlled by pullout failure, R shall be taken as 1.00 for anchors qualifying for Category 1 and 0.85~~9~~ for anchors qualifying for Category 2.

A3.3.2.10 CSA A23.3:19 Clause D.6.1 applies with the general changes prescribed in Section A3.2.2.

A3.3.2.11 In lieu of CSA A23.3:19 Clause D.6.2.1: The nominal breakout strength in tension, of a single anchor or of a group of anchors, shall not exceed:

(a) for a single anchor:

$$N_{mbr} = \left[\frac{A_{Nm}}{A_{Nmo}}\right] \Psi_{ed,N,m} \Psi_{c,N,m} N_{br,m} \qquad \textbf{Equation D.3}$$

(b) for a group of anchors:

$$N_{mbgr} = \left[\frac{A_{Nm}}{A_{Nmo}}\right] \Psi_{ec,N,m} \Psi_{ed,N,m} \Psi_{c,N,m} N_{br,m} \qquad \textbf{Equation D.4}$$

Factors $\Psi_{ec,N,m}$, $\Psi_{ed,N,m}$, $\Psi_{c,N,m}$ are defined in Clauses D.6.2.4 and D.6.2.5 of CSA A23.3:19 and Section A3.3.2.14 of this appendix, respectively. A_{Nm} is the projected masonry failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward 1.5h_{ef} from the centerlines of the anchor, or, in the case of a group of anchors, from a line through a row of adjacent anchors. A_{Nm} shall not exceed $n \cdot A_{Nmo}$, where n is the number of anchors in the group that resist tension. A_{Nmo} is the projected masonry failure area of a single anchor with an edge distance equal to or greater than 1.5h_{ef}.

$$A_{Nmo} = 9h_{ef}^2 \qquad \textbf{Equation D.5}$$

A3.3.2.12 In lieu of CSA A23.3:19 Clause D.6.2.2: The factored masonry breakout resistance of a single anchor in tension in cracked masonry, $N_{br,m}$, shall not exceed:

$$N_{br,m} = k_m \, \phi m \sqrt{f'_m} \, h_{ef}^{1.5} \quad R \qquad \textbf{Equation D.7}$$

where

$k_m = \alpha_{masonry} \, k_c$

k_m = effectiveness factor for breakout strength in masonry

k_c = 7.0 for post-installed anchors in masonry

R = as specified in Section A3.3.2.9

$\alpha_{masonry}$ = reduction factor for the inhomogeneity of masonry materials in breakout strength determination = 0.70

ϕm = Resistance factor for masonry (See CSA S304-14 Clause 4.3.2.1)

A3.3.2.13 CSA A23.3:19 Clauses D.6.2.3, D.6.2.4 and D.6.2.5 apply with the general changes prescribed in Section A3.2.2.

A3.3.2.14 In lieu of CSA A23.3:19 Clause D.6.2.6: For anchors located in a region of a masonry member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted:

$\psi_{c,N,m}$ = 1.4 for post-installed anchors

Where analysis indicates cracking at service load levels, $\psi_{c,N,m}$ shall be taken as 1.0 for post-installed anchors.

A3.3.2.15 CSA A23.3:19 Clause D.6.2.7 need not be considered since the modification factor for post installed anchors, ψ_{cp}, is not included in Equations D.3 and D.4.

A3.3.2.16 CSA A23.3:19 Clauses D.6.2.8 and D.6.2.9 apply with the general changes prescribed in Section A3.2.2.

A3.3.2.17 In lieu of CSA A23.3:19 Clause D.6.3.1: The factored pullout resistance of a single post-installed expansion, undercut, and screw anchor in tension shall not exceed

$N_{mpr} = \Psi_{m,p} N_{pr}$ **Equation D.15**

where $\Psi_{m,p}$ is defined in CSA A23.3:19 clause D.6.3.6.

A3.3.2.18 In lieu of CSA A23.3:19 Clause D.6.3.2: For post-installed expansion and undercut anchors, the values of N_{pr} shall be based on the 5 percent fractile of results of tests performed and evaluated in accordance with AC01 and shall not exceed the breakout strength calculated in accordance with Section A3.3.2.12 associated with f'_m.

A3.3.2.19 The following apply with the general changes prescribed in Section A3.2.2:

- CSA A23.3:19 Clause D.6.3.6
- CSA A23.3:19 Clauses D.7.1.1 - D.7.2.2
- CSA A23.3:19 Clauses D.7.2.4 - D.7.2.6
- CSA A23.3:19 Clause D.7.2.8
- CSA A23.3:19 Clause D.7.3
- CSA A23.3:19 Clause D.8
- CSA A23.3:19 Clause D.9
- CSA A23.3:19 Clause D.10.1

A3.3.2.20 In lieu of CSA A23.3:19 Clause D.7.2.7: For anchors located in a region of masonry construction where cracking is anticipated, $\psi_{m,V}$ shall be taken as 1.0. for cases where analysis indicates no cracking at service levels, it shall be permitted to take $\psi_{m,V}$ as 1.4.

A3.3.2.21 In lieu of CSA A23.3:19 Clause D.9: Minimum edge distances and spacings for mechanical anchors shall be determined from tests in accordance with AC01 but shall not be less than the cover requirements of CSA S304-14.

A3.3.2.22 [In addition to the CSA A23.3:19 provisions] For screw anchors with embedment depths $5d_a \leq h_{ef} \leq 10d_a$ and $h_{ef} \geq$ 38.1mm, masonry breakout resistance requirements shall be considered satisfied by the design procedures of CSA A23.3:19 Clauses D.6.2 and D.7.2.

A3.3.2.23 [In addition to the CSA A23.3:19 provisions] Masonry crushing resistance for anchors in shear—The factored resistance of an anchor in shear as governed by masonry crushing, V_{mcr}, shall be calculated using Equation A3-1.

$V_{mcr} = 5360 \sqrt[4]{f'_m A_{ab}}\ \phi m$ R **Equation A3-1**

Where f'_m and A_{ab} carry the unit of N/mm^2 and mm^2, respectively.

A3.3.2.24 [In addition to the CSA A23.3:19 provisions] Determination of shear capacity for anchors in horizontal ledgers in fully-grouted CMU walls with hollow head joint applications with an assumed masonry unit length of 406 mm (16 inches), standard: Where six or more anchors are placed at uniform horizontal spacing in continuous wood or steel ledgers connecting floor and roof diaphragms to fully grouted CMU walls constructed with hollow head joints (using closed-end block), in lieu of Section A3.3.1.2, the horizontal and vertical shear capacity of the anchors may be permitted to be calculated in accordance with Equations A3-2 and A3-3, respectively.

$V_{mbr,horiz} = 0.75\, V_{gov,horiz} \frac{12}{s_{horiz}}$ (N/mm) **Equation A3-2**

$V_{mbr,vert} = 0.75\, V_{gov,vert} \frac{12}{s_{horiz}}$ (N/mm) **Equation A3-3**

where

S_{horiz} = horizontal anchor spacing in the ledger, (mm). For anchor spacings that are multiples of 200 mm, locate the first anchor in the ledger at least 50 mm from the head joint and the center of the block. See Fig. 3.3. For other anchor spacings, minimum edge distance as specified in this standard shall apply.

$V_{gov,horiz}$ = min (V_{sar}, $V_{mbr,4}$, V_{mcr}, $V_{mpr,4}$), (N)

$V_{gov,vert}$ = min (V_{sar}, $2V_{mbr,4}$, V_{mcr}, $V_{mpr,4}$), (N)

V_{sar} = factored shear resistance for a single anchor calculated in accordance with CSA A23.3:19 Clause D.7.1.2, (N).

$V_{mbr,4}$ = factored breakout resistance for a single anchor with edge distance of 100 mm, (N).

V_{mcr} = factored crushing resistance for a single anchor calculated in accordance with Equation A3-1, (N).

$V_{mpr,4}$ =factored pryout resistance for a single anchor with edge distance of 100 mm, (N).

A3.4 Strength design of post-installed mechanical anchors in ungrouted concrete masonry unit construction

A3.4.1 Scope: This section provides strength design requirements for mechanical anchors used in ungrouted concrete masonry unit construction, where anchors are used to transmit structural loads by means of tension, shear, or a combination of tension and shear.

A3.4.2 General:

A3.4.2.1 Anchors shall be designed for critical effects of factored loads as determined by elastic analysis. Plastic analysis shall not be permitted.

A3.4.2.2 Group effects shall not be considered. Dimensional requirements specified in Table A3.3 shall be considered for the design of individual anchors as follows:

A3.4.2.2.1 The critical edge distance, $c_{cr,ug}$, is the smallest edge distance to consider full capacity of an individual anchor and the minimum edge distance, $c_{a,min,ug}$. For anchors installed with edge distances between $c_{cr,ug}$ and $c_{a,min,ug}$, capacities shall be linearly interpolated. The minimum distance from hollow head joints (Section 1.4.14.1) shall be based on testing conducted in accordance with AC01 Section 7.4 and, optionally, 7.5 as illustrated in Figure 3.2.

A3.4.2.2.2 For anchor spacings less than the minimum spacing, $S_{min,ug}$, to consider contributions of multiple anchors, the strength of the group shall equal the strength of a single anchor.

A3.4.3 Seismic design requirements: The design of anchors in structures in regions where $I_E S(0.2) \geq 0.35$ shall satisfy the requirements of this section.

A3.4.3.1 The provisions of this chapter do not apply to the design of anchors in plastic hinge zones of masonry structures under earthquake forces.

A3.4.3.2 The anchor or group of anchors shall be designed in accordance with CSA A23.3:19 Clause D.4.3.5.3(d) for the maximum tension and shear obtained from the design load combinations that include earthquake effects. The anchor design tensile strength shall satisfy the tensile strength requirements of A3.4.3.3.

A3.4.3.3 The anchor design tensile force for resisting earthquake forces shall be determined from consideration of (a) and (b) for the failure modes given in Table A3.4 assuming the masonry is cracked unless it can be demonstrated that the masonry remains uncracked.

a) N_{sra} for a single anchor or for every anchor in a group of anchors.
b) 0.75 $N_{kr,ug}$.

A3.4.4 The design of anchors shall be in accordance with Table A3.4. In addition, the design of anchors shall satisfy Section A3.4.3 for earthquake loading.

A3.4.5 The resistance modification factor, R, prescribed in Section A3.3.2.9 shall be used for anchors in ungrouted masonry when the factored load combinations specified in Annex C of CSA A23.3:19 are used.

A3.4.6 Design requirements for tensile loading:

A3.4.6.1 Steel strength of anchors in tension: The factored steel resistance of an anchor in tension, N_{sar}, shall be determined in accordance with CSA A23.3:19 Clause D.6.1.

A3.4.6.2 Pullout strength of anchors in tension: The factored pullout resistance in tension, $N_{kr,ug}$, shall be calculated in accordance with Equation A3-4:

$N_{kr,ug} = \phi m$ R $N_{k,ug}$ **Equation A3-4**

where $N_{k,ug}$ shall be derived from assessment in accordance with Section 8.5.6.

A3.4.7 Design requirements for shear loading:

A3.4.7.1 Steel strength of anchors in shear: The factored steel resistance of an anchor in shear, V_{sar}, shall be determined in accordance with CSA A23.3:19 Clause D.7.1.

A3.4.7.2 Anchorage strength in shear:
The factored resistance of an anchor in shear, $V_{sr,ug}$,shall be calculated in accordance with Equation A3-5:

$V_{sr,ug} = \phi m$ R $V_{s,ug}$ **Equation A3-5**

where $V_{s,ug}$ shall be derived from assessment in accordance with AC01 Section 8.6.1.2.

A3.4.7.3 Masonry crushing strength of anchors in shear: The factored resistance of an anchor in shear as governed by masonry crushing, $V_{mcr,ug}$, shall be determined by Equation A3-1.

A3.4.8 Interaction of tensile and shear forces: Anchors designed for combinations of tensile and shear forces shall satisfy the provisions of CSA A23.3:19 Clause D.8.

A3.4.9 Installation and inspection of anchors: The provisions of CSA A23.3:19 Clause D.10.1 shall apply.

A3.5 Strength design of qualified mechanical anchors in partially grouted masonry:

A3.5.1 Scope: This section provides strength design requirements for anchors used in partially grouted concrete masonry unit construction, where anchors are used to transmit structural loads by means of tension, shear, or a combination of tension and shear.

A3.5.2 In all cases, the minimum distance from hollow head joints (Section 1.4.14.1) shall be based on testing in accordance with AC01 Section 7.4 and, optionally, Section 7.5 as illustrated in Figure 3.2.

A3.5.3 For cases where the location of grouted cells is known, the following provisions shall apply:
a) Group effects shall not be considered between anchors in grouted masonry and anchors in ungrouted masonry.
b) Anchors located in grouted cells shall be designed in accordance with Section A3.3, whereby the distance to the extent of the ungrouted cell shall be taken as a free edge as illustrated in Figure 3.4.

A3.5.4 For cases where the location of grouted cells is unknown, the design of anchors shall be in accordance with Section A3.4.

A3.6 Strength design of qualified mechanical anchors in clay brick masonry construction:

A3.6.1 Scope: This section provides strength design requirements for anchors used in clay brick masonry construction, where anchors are used to transmit structural loads by means of tension, shear, or a combination of tension and shear.

A3.6.2 General:

A3.6.2.1 Anchors shall be designed for critical effects of factored loads as determined by elastic analysis. Plastic analysis approaches shall not be permitted.

A3.6.2.2 Group effects shall not be considered. Dimensional requirements specified in Table A3.5 shall be observed for the design of individual anchors.

A3.6.2.2.1 The critical edge distance, $c_{cr,br}$, is the smallest edge distance to consider full capacity of an individual anchor and the minimum edge distance, $c_{a,min,br}$. For anchors installed with edge distances between $c_{cr,br}$ and $c_{a,min,br}$, capacities shall be linearly interpolated.

A3.6.2.2.2 For anchor spacings less than the minimum spacing, $S_{min,br}$, to consider contributions of multiple anchors, the strength of the group shall equal the strength of a single anchor.

A3.6.3 Seismic design requirements: The design of anchors in structures in regions where $I_E S(0.2) \geq 0.35$ shall satisfy the requirements of this section.

A3.6.3.1 The design of anchors in the plastic hinge zones of masonry structures under earthquake forces is beyond the scope of this appendix.

A3.6.3.2 The anchor or group of anchors shall be designed in accordance with CSA A23.3:19 Clause D.4.3.5.3(d) for the maximum tension and shear obtained from the design load combinations that include earthquake effects. The anchor design tensile strength shall satisfy the tensile strength requirements of A3.6.3.3.

A3.6.3.3 The anchor design tensile resistance for resisting earthquake seismic forces shall be determined from consideration of (a) and (b) for the failure modes given in Table A3.6 assuming the masonry is cracked unless it can be demonstrated that the masonry remains uncracked.

(a) N_{sra} for a single anchor or for every anchor in a group of anchors.
(b) 0.75 $N_{kr,br}$.

A3.6.4 The design of anchors shall be in accordance with Table A3.6. In addition, the design of anchors shall satisfy Section A3.6.3 for earthquake loading.

A3.6.5 The resistance modification factor, R, prescribed in Section A3.3.2.9 shall be used for anchors in clay brick masonry when the factored load combinations specified in Annex C of CSA A23.3:19 are used.

A3.6.6 Design requirements for tensile loading:

A3.6.6.1 Steel strength of anchors in tension: The factored steel resistance of an anchor in tension, N_{sar}, shall be determined in accordance with CSA A23.3:19 Clause D.6.1.

A3.6.6.2 Pullout strength of anchors in tension: The factored pullout resistance in tension, $N_{kr,ug}$, shall be calculated in accordance with Equation A3-6:

$N_{kr,br} = \phi m \text{ R } N_{k,br}$ **Equation A3-6**

where $N_{k,br}$ is the nominal pullout resistance value in tension and shall be derived from assessment in accordance with 8.5.7.

A3.6.7 Design requirements for shear loading:

A3.6.7.1 Steel strength of anchors in shear: The factored steel resistance of an anchor in shear, V_{sar}, shall be determined in accordance with CSA A23.3:19 Clause D.7.1.2b.

A3.6.7.2 Anchorage strength in shear: The factored resistance of an anchor in shear, $V_{sr,br}$,shall be calculated in accordance with Equation A3-7:

$V_{sr,br} = \phi m \text{ R } V_{s,br}$ **Equation A3-7**

where $V_{s,br}$ is the nominal anchor resistance value in shear and shall be derived from assessment in accordance with 8.6.1.3.

A3.6.7.3 Brick crushing strength of anchors in shear: The factored resistance of an anchor in shear as governed by masonry crushing, $V_{mcr,br}$, shall be determined by Equation A3-1.

A3.6.8 Interaction of tensile and shear forces: Anchors designed for combinations of tensile and shear forces shall satisfy the provisions of CSA A23.3:19 Clause D.8.

A3.6.9 Installation and inspection of anchors: The provisions of CSA A23.3:19 Clause D.10.1 shall apply.

A3.7 Conversion of strength design to allowable stress design:

A3.7.1 For post-installed mechanical anchors designed using factored load combinations in accordance with Annex C of CSA A23.3:19, allowable loads shall be established using the equations below:

$T_{allowable,ASD} = \frac{N_{\cancel{n}r}}{\alpha} \cancel{\phi m \text{ R}}$ **Equation A3-8**

and

$V_{allowable,ASD} = \frac{V_{r\cancel{n}}}{\alpha} \cancel{\phi m \text{ R}}$ **Equation A3-9**

where

$T_{allowable,ASD}$ = Allowable tensile load (kN);

$V_{allowable,ASD}$ = Allowable shear load (kN);

N_{nr} = Lowest factored design ~~strength~~ resistance of an anchor or anchor group in tension as determined in accordance with Table A3.2, Table A3.4, or Table A3.6, as applicable (kN);

V_{rn} = Lowest factored design ~~strength~~ resistance of an anchor or anchor group in shear as determined in accordance with Table A3.2, Table A3.4, or Table A3.6, as applicable, (kN);

α = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α shall include all applicable factors to account for non-ductile failure modes and required overstrength.

~~ϕm = Resistance factor for masonry (See CSA S304-14 Clause 4.3.2.1)~~

~~R = Resistance modification factor (See Section A3.3.2.9)~~

A3.7.2 Interaction shall be calculated in compliance with CSA A23.3:19 Clause D.8 as follows:

(a) For shear loads $V \leq 0.2V_{allowable,ASD}$, the full allowable load in tension shall be permitted.

(b) For tensile loads $T \leq 0.2T_{allowable,ASD}$, the full allowable load in shear shall be permitted.

(c) For all other cases:

$$\frac{T}{T_{allowable}} + \frac{V}{V_{allowable}} \leq 1.2$$

TABLE A3.1 — ACI 318-14 and CSA A23.3:19 CLAUSES APPLICABLE OR MODIFIED BY THIS APPENDIX

ACI 318-14 Section	CSA A23.3:19 Clause	Modified by
17.1.1 - 17.1.2	D.1.1 - D.1.2	Unchanged*
17.1.3	D.1.3	A3.3.2.2
17.1.4	D.1.4	Unchanged*
2.3	D.2	A3.2.2
2.2	D.3	Unchanged*
17.~~1.4~~2.1 – 17.2.2	D.4.1.1 - D.4.2	Unchanged*
17.2.3	D.4.3	A3.3.2.4
17.2.7	D.4.7	Unchanged*
17.3.1.1	D.5.1.2	A3.3.2.6
17.3.1.3	D.5.1.4	Unchanged*
17.3.2 excluding 17.3.2.1	D.5.2 excluding D.5.2.2	
17.3.3	D.5.3	A3.3.2.9
17.4.1	D.6.1	Unchanged*
17.4.2.1	D.6.2.1	A3.3.2.11
17.4.2.2	D.6.2.2	A3.3.2.12
17.4.2.3 – 17.4.2.5	D.6.2.3, D.6.2.5	Unchanged*
17.4.2.6	D.6.2.6	A3.3.2.14
17.4.2.7 – 17.4.2.9	D.6.2.7 - D.6.2.9	Unchanged*
17.4.3.1	D.6.3.1	A3.3.2.17
17.4.3.2	D.6.3.2	A3.3.2.18
17.4.3.6	D.6.3.6	Unchanged*
17.5.1.1 – 17.5.2.2	D.7.1.1 - D.7.2.2	
17.5.2.4 – 17.5.2.6	D.7.2.4 - D.7.2.6	
17.5.2.7	D.7.2.7	A3.3.2.20
17.5.2.8	D.7.2.8	Unchanged*
17.5.3	D.7.3	
17.6	D.8	
17.7	D.9	A3.3.2.21
17.8.1	D.10.1	Unchanged*
Additional provisions		A3.3.2.22 - A3.3.2.24

*Sections marked as unchanged adopt the general changes prescribed in Section A3.2.2

TABLE A3.2—REQUIRED STRENGTH OF ANCHORS

Failure mode	Single anchor	Anchor group*	
		every anchor in a group	Anchors as a group
Steel strength in tension	$N_{sar} \geq N_{fa}$	$N_{sar} \geq N_{fa,i}$	
Masonry breakout strength in tension	$N_{mbr} \geq N_{fa}$		$N_{mbgr} \geq N_{fa,g}$
Pullout strength in tension	$N_{mpr} \geq N_{fa}$	$N_{mpr} \geq N_{fa,i}$	
Steel strength in shear	$V_{sar} \geq V_{fa}$	$V_{sar} \geq V_{fa,i}$	
Masonry breakout strength in shear	$V_{mbr} \geq V_{fa}$		$V_{mbgr} \geq V_{fa,g}$
Masonry crushing strength in shear	$V_{mcr} \geq V_{fa}$	$V_{mcr} \geq V_{fa,i}$	
Masonry pryout strength in shear	$V_{mpr} \geq V_{fa}$		$V_{mpgr} \geq V_{fa,g}$

*Required strengths for steel failure modes shall be calculated for the most highly stressed anchor in the group.

TABLE A3.3—DIMENSIONAL REQUIREMENTS FOR POST-INSTALLED ANCHORS INSTALLED IN UNGROUTED CMU.

Load case	Critical edge distance, $c_{cr,ug}$, for full capacity	Minimum edge distance, $c_{a,min,ug}$	Multiplier at $c_{a,min,ug}$	Minimum spacing, $S_{min,ug}$
Tension	100 mm	50 mm	0.8	200 mm
Shear	$12d_a$	$6d_a$	0.5	200 mm

TABLE A3.4—REQUIRED STRENGTH OF ANCHORS IN UNGROUTED CMU CONSTRUCTION

Failure mode	Single anchor
Steel strength in tension	$N_{sar} \geq N_{fa}$
Pullout strength in tension	$N_{kr,ug} \geq N_{fa}$
Steel strength in shear	$V_{sar} \geq V_{fa}$
Anchorage strength in shear	$V_{sr,ug} \geq V_{fa}$
Masonry crushing strength in shear	$V_{mcr,ug} \geq V_{fa}$

TABLE A3.5—DIMENSIONAL REQUIREMENTS FOR POST-INSTALLED ANCHORS INSTALLED IN BRICK MASONRY CONSTRUCTION

Load case	Critical edge distance, $c_{cr,br}$, for full capacity	Minimum edge distance, $c_{a,min,br}$	Multiplier at $c_{a,min,br}$	Minimum spacing, $S_{min,br}$
Tension	Max ($2h_{ef}$, 100mm)	100 mm	0.8	200 mm
Shear	$12d_a$	$6d_a$	0.5	200 mm

TABLE A3.6—REQUIRED STRENGTH OF ANCHORS IN BRICK MASONRY CONSTRUCTION

Failure mode	Single anchor
Steel strength in tension	$N_{sar} \geq N_{fa}$
Pullout strength in tension	$N_{kr,br} \geq N_{fa}$
Steel strength in shear	$V_{sar} \geq V_{fa}$
Anchorage strength in shear	$V_{sr,br} \geq V_{fa}$
Brick crushing strength in shear	$V_{mcr,br} \geq V_{fa}$