ICC EVALUATION SERVICE®

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March 29, 2024

TO: PARTIES INTERESTED IN ANCHOR CHANNELS IN CONCRETE ELEMENTS

SUBJECT: Proposed Revisions to the Acceptance Criteria for Anchor Channels in Concrete Elements, Subject AC232-0624-R1 (HS/MC)

Hearing Information:
WebEx Event Meeting
Tuesday, June 25, 2024
8:00 am Pacific Daylight Time
Click the date above to register

Dear Colleague:

You are invited to comment on revisions to the ICC-ES Acceptance Criteria for Anchor Channels in Concrete Elements (AC232), which will be discussed at the Evaluation Committee hearing noted above. The proposed revisions to the criteria are based on a February 22, 2024 submittal from the Concrete and Masonry Anchor Manufacturers Association (CAMA).

Additional details regarding each of the proposals, with numbering keyed to the attached CAMA letter, dated February 22, 2024, is as follows:

1. AC232 is currently silent regarding the channel lip strength in shear in the perpendicular direction, $V_{sl,y}$, for channel bolts spaced closer together than the critical spacing $s_{chb,cr}$. The proposed equation uses the identical method listed for tension in AC232 section D.5.1.3.3 for reduced spacing.

2. This proposal permits the calculation of the strength of the connection between the anchor and the channel for fillet welded connections using the provisions of ANSI/AISC 360-22.

3. The proposed change to Equation 7.9 is to the calculation of the load applied in the seismic shear test for cases where the channel bolt strength governs the testing. The current factor of 0.7 would be appropriate to use if the calculation was based on the specified channel bolt strength f_{utb}, however since the actual steel strength $f_{u,test}$ is used in the calculation, a factor of 0.6 is deemed more appropriate.

4. The units for the alpha factors in Equations 8.13a and 8.13b, and 8.14a and 8.14b have been deleted. Strength modification factors are empirical and should not carry any units.

5. The proposed change applies to section 8.16.3.2, not section 8.16.5 as noted in the CAMA letter. This proposal clarifies that the seismic tension strength value from testing can be reported for larger channels sizes or channel bolt diameters, rather than transferring the calculated $\alpha_{N,seis}$ value from the tested size to untested sizes.

6. and 7. Correct typos in the subscripts by adding commas where required for $M_{s,flex,seis}$.

8. The proposed change to section 8.17.3.2 is analogous to item 5 above, but for the case of seismic shear in the perpendicular direction instead of seismic tension.

9. Regarding the proposed changes to sections 8.19.3.1 and 8.19.3.2, ICC-ES staff requests additional supporting information before including this proposed change. The interaction between the channel bolt and anchor channel for shear loading in the longitudinal direction is highly dependent on these two specific components working together properly. The applicability to extrapolate this strength to additional sizes requires additional supporting information, such as the results of tests supporting such a proposal. Therefore, the proposed change outlined in the letter from CAMA has not been included in the accompanying draft revisions to the Acceptance Criteria.

10. Additional notation added to section 2.2 as proposed in support of the above changes.

Should the Evaluation Committee approve the proposed revision, no new mandatory compliance date will be enforced; current applicants will need to consider the approved requirements. ICC-ES staff will work with existing report holders of published reports to verify that they have incorporated these requirements.

You are invited to submit written comments on this or any other agenda item, or to attend the Evaluation Committee hearing and present your views 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. Comments are to be received by **April 25, 2024.** These written comments will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site shortly after the deadline for submission. Written comments that are not submitted by this deadline will not be considered at the meeting.

   c. Rebuttal comments, from the proponent noted in this letter, are to be received by **May 16, 2024**. They will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site shortly after the deadline for submission. Written rebuttal comments that are not submitted by the deadline will not be considered at the meeting.

d. If you want to make a visual presentation at the hearing, it must be received in PowerPoint format. The presentation is to be received by **May 30, 2024.** These will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site after the deadline for submission. Presentations that are not submitted by the deadline cannot be presented at the meeting. **Note:** Videos will not be posted on the web site.

   Presentations will be retained with other records of the meeting.

e. ICC-ES will post to the web site, on **June 11, 2024**, memos by the ICC-ES staff, responding to the previously received public comments.

f. If you miss the deadlines for submission of written comments and visual presentations, your verbal comments can be presented at the meeting.

g. Proposed criteria, written public comments, visual presentations, and responses by ICC-ES staff for this agenda item are all available on our website.

2. Regarding verbal comments and presentations:

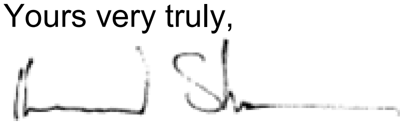
   Please plan to speak for not more than ten minutes. As noted above, visuals are to be in PowerPoint format.

3. 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.

4. 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 3996, or Manuel Chan, P.E., S.E., Principal Structural Engineer at extension 3288. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,



Howard Silverman, PE
Director Anchors and Fastening

HS/MC/ls

Encl.

cc: Evaluation Committee

CONCRETE AND MASONRY ANCHOR MANUFACTURERS ASSOCIATION

Thomas Associates
Executive Director

February 22, 2024

Howard Silverman
ICC Evaluation Services, LLC.
Western Regional Office
3060 Saturn Street, Suite 100
Brea, CA 92821

Email: hsilverman@icc-es.org

SUBJECT: Draft letter for proposed changes to AC232

Dear Mr. Howard Silverman,

CAMA proposes the attached changes to AC232 for consideration at the June 2024 Committee hearing.

1. Modify Section D.6.1.4.1, b) as follows:

   b) The nominal strength of the channel lips to take up shear loads transmitted by a channel bolt to the channel, $V_{sl,y}$*, shall be taken from the ICC-ES Evaluation Service Report.*

   This value is valid only if the center-to-center distance between two channel bolts, s_{chb}*, is at least* $s_{chb,cr}$*. If the requirement is not met, then the value* $V_{sl,y}$ *given in the ICC-ES Evaluation Service Report shall be reduced by the factor*

   $$\frac{1}{1+\sum_{i=2}^{n+1}\left[\left(1-\frac{s_{chb,i}}{s_{chb,cr}}\right)^2\cdot\frac{V_{ua,i}^b}{V_{ua,1}^b}\right]}$$

   (Equation reference to be added for ACI 318-08, ACI 318-11, ACI 318-14, ACI 318-19)

   If no tests have been performed, the value $s_{chb,cr}$ *shall be taken as* $2b_{ch}$*, where the center-to-center spacing between channel bolts shall not be less than 3-times the bolt diameter,* d_s*.*

2. Add the following text to the end of Section 7.3.5:

   Exception: For systems where the channel-to-anchor connection is manufactured using fillet welds, Test No. 1 may be omitted and replaced by fillet weld design calculation in accordance with ANSI/AISC 360-22, Section J2. Limitations in Section J2.b for the manufacturing procedure shall be respected.

3. Modify Section 7.13.3.1 as follows:

$V_{ss} = ~~0.7~~\underline{0.6} \cdot A_{se,V} \cdot f_{u,test}$, lbf (N) Eq. (7.9)

where:

$A_{se,V}$ = effective cross-sectional area of the channel bolt in shear, in² (mm²).

$f_{u,test}$ = steel strength of channel bolt used in the simulated seismic shear tests, psi (MPa).

4. Modify Section 8.11 as follows

$$\alpha_{ch,N} = 0.7\left[\frac{N_k}{24 \cdot \sqrt{f_c'} \cdot h_{ef}^{1.5} \cdot \psi_{s,N}}\right] \leq \left(\frac{h_{ef}}{7.1}\right)^{0.15} \leq 1$$ (Normal weight concrete)~~, lbf^1/2/in^1/3~~ Eq. (8.13a)

$$\alpha_{ch,N} = 0.7\left[\frac{N_k}{10 \cdot \sqrt{f_c'} \cdot h_{ef}^{1.5} \cdot \psi_{s,N}}\right] \leq \left(\frac{h_{ef}}{180}\right)^{0.15} \leq 1$$ (Normal weight concrete)~~, N^1/2/mm^1/3~~ Eq. (8.13b)

5. Modify Section 8.16.5 as follows:

8.16.5 ~~If larger channel bolts than tested according to Section 7.12 shall be recognized for seismic loading, test the smallest channel bolt size that results in failure of the anchor channel. Apply $\alpha_{N,seis}$ in accordance with 8.16.4. In this case the factor $\alpha_{N,seis}$ may also be applied to the combination of anchor channel and channel bolt where the anchor channel bolt governed, whereby the determination of $N_{sa,seis}$, $N_{sl,seis}$, $N_{sc,seis}$, and $M_{s,flex}$,seis shall be in accordance with 8.16.4.~~ <u>If seismic recognition is sought for untested larger channel sizes or bolt diameters, it shall be permitted to transfer the strength from a smaller tested channel size or bolt diameter to the larger untested size. The factor $\alpha_{N,seis}$ for untested sizes shall be calculated as follows:</u>

$$\alpha_{N,seis} = \frac{N_{eq,reduced,smaller}}{N_{eq,larger}}$$

6. Modify Section 8.16.3.3 by adding a comma to the term $M_{sflex,seis} \longrightarrow M_{s,flex,seis}$

7. Modify Section 8.16.4 by adding a comma to the term $M_{sflex,seis} \longrightarrow M_{s,flex,seis}$

8. Modify Section 8.17.3.2 as follows:

8.17.5 ~~If larger channel bolts than tested according to Section 7.13 shall be recognized for seismic loading, test the smallest channel bolt size that results in failure of the anchor channel. Apply $\alpha_{V,seis,y}$ in accordance with 8.17.4. In this case the factor $\alpha_{V,seis,y}$ may also be applied to the combination of anchor channel and channel bolt where the anchor channel bolt governed whereby the determination of $V_{sa,y,seis}$, $V_{sl,y,seis}$, and $V_{sc,y,seis}$ shall be in accordance with 8.17.4.~~ <u>If seismic recognition is sought for untested larger channel sizes or bolt diameters, it shall be permitted to transfer the strength from a smaller tested channel size or bolt diameter to the larger untested size. The factor $\alpha_{v,seis,y}$ for untested sizes shall be calculated as follows:</u>

$$\alpha_{V,seis,y} = \frac{V_{eq,reduced,smaller}}{V_{eq,larger}}$$

9. Add Sections 8.19.3.1 and 8.19.3.2 as follows:

8.19.3.1 If the channel bolt strength governs (V_{ss} is used to calculate V_{eq} according to Eq. (7.12)), the reduction factor $\alpha_{V,seis,x}$ shall only be applied to the specific combination of anchor channel and anchor channel bolt tested.

8.19.3.2 If seismic recognition is sought for untested larger channel sizes or bolt diameters, it shall be permitted to transfer the strength from a smaller tested channel size or bolt diameter to the larger untested size. The factor $\alpha_{v,seis,x}$ for untested sizes shall be calculated as follows:

$$\alpha_{V,seis,x} = \frac{V_{eq,reduced,smaller}}{V_{eq,larger}}$$

10. To accommodate proposed changes No. 5, No. 8, and No. 9, add the following notations to Section 2.2:

$N_{eq,reduced,smaller}$ applied tension load on the smaller tested anchor channel size or bolt diameter (from which transfer of results is sought) in the simulated seismic tension test

$N_{eq,larger}$ maximum tension load to be applied on the larger anchor channel size or bolt diameter (to which transfer of results is sought) in the simulated seismic tension test

$V_{eq,reduced,smaller}$ applied shear load on the smaller anchor channel size or bolt diameter (from which transfer of results is sought) in the simulated seismic shear test

$V_{eq,larger}$ maximum shear load to be applied on the larger anchor channel size or bolt diameter (to which transfer of results is sought) in the simulated seismic shear test

Thank you for your attention to these comments. If you have any questions, please do not hesitate to contact CAMA.

Sincerely,

CRAIG H. ADDINGTON

CHA/als

CC: Omar Al Mansouri, CBST

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

PROPSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR ANCHOR CHANNELS IN CONCRETE ELEMENTS

AC232

Proposed March 2024

Previously approved August 2021, October 2019, February 2019, June 2018, June 2017, October 2016, May 2016, February 2016, October 2015, June 2015, February 2015, October 2014, June 2014, February 2014, October 2013, June 2013, February 2013, October 2012, June 2012, October 2011, June 2011, October 2010

(Previously editorially revised July 2015, October 2013, May 2013)

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes, and may include other codes, as applicable. For alternative materials design and methods of construction and equipment, see Section 104.2.3 of the 2024 International Building Code® (IBC), Section 104.11 of the 2021 IBC and earlier editions, and Section R104.11 of the 2021 IRC and earlier editions.

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 ANCHOR CHANNELS IN CONCRETE ELEMENTS (AC232)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for the adequacy of anchor channels in normal-weight or lightweight concrete elements to be used in an ICC Evaluation Service, LLC (ICC-ES), evaluation report under the 2021, 2018, 2015, 2012 and 2009 *International Building Code*® (IBC), and the 2021, 2018, 2015, 2012 and 2009 *International Residential Code*® (IRC). Bases for acceptance are IBC Section 104.11, and IRC Section R104.11.

The reason for the development of this criteria is to establish guidelines for the evaluation of the use of anchor channels in concrete, since the prescriptive requirements of Chapter 19 of the IBC do not include requirements for establishing the structural capacities of anchor channels used to create connections between structural concrete and attachments.

1.2 Scope: Anchor channels are alternatives to cast-in-place anchors described in Section 1901.3 of the 2021, 2018 and 2015 IBC, Section 1908 and 1909 of the 2012 IBC, and Sections 1911 and 1912 of the 2009 IBC. The anchor channels evaluated in this criteria may also be used where an engineered design is permitted in accordance with Section R301.1.3 of the IRC.

1.3 Codes and Referenced Standards

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

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

1.3.3 ACI 211.1-91 (2002), Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete, American Concrete Institute.

1.3.4 ACI 211.2-98 (2004), Standard Practice for Selecting Proportions for Structural Lightweight Concrete, American Concrete Institute.

1.3.5 ACI 318, Building Code Requirements for Structural Concrete, American Concrete Institute.

1.3.6 ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete, American Concrete Institute.

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

1.3.8 ASTM A283/A283M-03 (reapproved 2007). Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates, ASTM International.

1.3.9 ASTM A1011/A1011M-10: Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low Alloy, High-Strength Low Alloy with Improved Formability, and Ultra-High Strength, ASTM International.

1.3.10 ASTM B695, Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel, ASTM International.

1.3.11 ASTM C31, Standard Practice for Making and Curing Concrete Test Specimens in the Field, ASTM International.

1.3.12 ASTM C33-03, Standard Specification for Concrete Aggregates, ASTM International.

1.3.13 ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International.

1.3.14 ASTM C42, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete, ASTM International.

1.3.15 ASTM C150, Standard Specification for Portland Cement, ASTM International.

1.3.16 ASTM C330, Standard Specification for Lightweight Aggregates for Structural Concrete, ASTM International.

1.3.17 ASTM E8-04, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International.

1.3.18 ASTM E119-07, Standard Test Method for Fire Tests of Building Construction and Materials, ASTM International.

1.3.19 ASTM E488-10, Standard Test Method for Strength of Anchors in Concrete and Masonry Elements, ASTM International.

1.3.20 AWS D1.1-2004, Structural Welding Code – Steel, American Welding Society.

1.3.21 ISO 21930-2017, Sustainability in Buildings and Civil Engineering Works – Core Rules for Environmental Product Declaration of Construction Products and Services, International Organization for Standardization (ISO).

1.3.22 UL 263, Standard for Fire Tests of Building Constructions and Materials, Underwriters Laboratories Inc.

1.3.23 The applicable editions of referenced standards are given in Table 1.

1.4 Definitions:

Definitions are presented in Section 2.1 of Annex A.

1.5 Notations:

Notations are presented in Section 2.2 of Annex A.

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted:

2.1.1 Product Description: Anchor channels 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 Height, width and length of anchor channel.

2.1.1.4 Dimensions and spacing of anchors.

2.1.1.5 Method of connecting anchors to channel.

2.1.1.6 Geometry of channel bolt.

2.1.1.7 Permitted manufacturing tolerances.

2.1.1.8 Basic materials, including appropriate physical properties before and after manufacture and protective coatings, shall be described. If the anchor

5.3 A qualifying inspection shall be conducted at each manufacturing facility when required by the ICC-ES Acceptance Criteria for Inspections and Inspection Agencies (AC304).

5.4 Periodic special Inspection shall be provided for anchor channels loaded by a tension load and/or a shear load perpendicular to the longitudinal channel axis in accordance with Section 1704 of the IBC and Section 10.3 of Annex A. For anchor channels loaded by a shear load in direction of the longitudinal channel axis, the level of special inspection is given in Table 9.1. It depends on the results of reliability tests (see Annex A, Section 8.20). The manufacturer shall submit inspection procedures to verify proper installation.

6.0 EVALUATION REPORT REQUIREMENTS

The evaluation report shall include the following:

6.1 Description:

Basic Information required by Section 2.1 of this criteria, including product description, installation procedures and identification information.

6.2 Information and statements as set forth in Section 9.0 of Annex A.

6.3 Minimum member thickness and minimum edge distances shall be specified in the evaluation report.

6.4 When anchor channels are evaluated for exterior exposure or damp environment, Section 3.1 of this criteria applies.

6.5 Special Inspection:

Special inspection details based on information described in Section 5.4 and Annex A, Section 10 of this criteria shall be included in the evaluation report.

6.6 Optional Information:

The evaluation report may include information on seismic use, based on the evaluation under this criteria:

6.6.1 Information on seismic use.

Strength design values determined in accordance with Section 3.1 of Annex A may be converted to values suitable for use with allowable stress design load combinations in accordance with Section 3.2 of Annex A.

6.6.2 The evaluation report shall note that the use of anchor channels in lightweight concrete is beyond the scope of the report.

Exception: The use of anchor channels in lightweight concrete shall be determined provided tests No. 6 and No. 8 in accordance with Table 4.1 of Annex A have been performed in lightweight concrete. If these test series have been conducted in all- lightweight concrete, the results may also be used for evaluation in sand-lightweight concrete. If these test series have been conducted in sand-lightweight concrete only, the results may not be used for evaluation in all-lightweight concrete.

7.0 ENVIRONMENTAL PRODUCT DECLARATION (Optional)

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.■

n_1	number of anchor rows in direction 1 perpendicular to the edge
p	web thickness of I-anchor, as shown in Figure 1 of this annex, in. (mm)
s	spacing of anchors in direction of longitudinal axis of channel, in. (mm)
s_{chb}	center-to-center distance between channel bolts in direction of longitudinal axis of channel, in. (mm)
$s_{ch,x}$	center-to-center spacing of adjacent end anchors of anchor channels in linear configuration, in. (mm)
$s_{ch,y}$	axis-to-axis spacing of two anchor channels in parallel configuration, in. (mm)
s_{cr}	anchor spacing required to develop full concrete capacity in absence of anchor reinforcement, in. (mm)
$s_{cr,N}$	critical anchor spacing for tension loading, concrete breakout, in. (mm)
s_{max}	maximum allowable spacing of anchors connected to channels, in. (mm)
s_{min}	minimum allowable spacing of anchors connected to channels, in. (mm)
$s_{cr,Nb}$	critical anchor spacing for tension loading, concrete blow-out, in. (mm)
$s_{cr,V}$	critical anchor spacing for shear loading, concrete edge breakout, in. (mm)
t	thickness of channel lips, in. (mm)
t_{fix}	thickness of fixture as shown in Figure 3 of this annex, in. (mm)
t_h	thickness of head portion of headed anchor, as shown in Figure 1 of this annex, in. (mm)
v	coefficient of variation
w_A	width of I-shaped anchor, as shown in Figure 1 of this annex, in. (mm)
x	distance between end of channel and nearest anchor, in. [mm]
z	internal lever arm of the concrete member, in. (mm)
A_{brg}	bearing area of anchor head, in.^{2} (mm^2)
A_i	ordinate at the position of the anchor I, as illustrated in Figure RD.3.1.1 (Figure 17.2.1.1, ACI 318 (-14, -19)) of this annex, in. (mm)
$A_{se,N}$	effective cross-sectional area of anchor or channel bolt in tension, in.^{2}, (mm^2)
$A_{se,V}$	effective cross-sectional area of channel bolt in shear (mm^2)
F_k	characteristic failure load of a test series calculated according to Eq. (8.5), lbf (N)
F_{test}	test result from a test series, lbf (N)
$F_{test,x}$	test result from test series *x*, lb (N)
I_y	moment of inertia of the channel about principal y-axis, in.^{4} (mm^4), as illustrated in Figure 1 of this annex
M_1	bending moment on fixture around axis in direction 1, lbf-in (Nm)
M_2	bending moment on fixture around axis in direction 2, lbf-in (Nm)
$M_{s,flex}$	nominal flexural strength of the anchor channel, lbf-in (Nm)
$M_{s,flex,allowable,ASD}$	allowable bending moment due to tension loads for use in allowable stress design environments, lbf (N)
$M_{s,s}$	flexural strength of the channel bolt, lbf-in (Nm)
$M^0_{s,s}$	nominal flexural strength of the channel bolt, lbf-in (Nm)
$M_{u,flex}$	bending moment on the channel due to tension loads, lbf-in (Nm)
N_b	basic concrete breakout strength of a single anchor in tension, lbf (N)
N_{ca}	nominal strength of anchor reinforcement to take up tension loads, lbf (N)
N_{cb}	concrete breakout strength of a single anchor of anchor channel in tension, lbf (N)
N_{eq}	maximum tension load to be applied in simulated seismic tension test, lbf (N)
$N_{eq,smaller}$	seismic tension load applied on the tested anchor channel size or bolt diameter for use in calculating $\alpha_{N,seis}$
$N_{eq,larger}$	seismic tension load required in accordance with section 7.12 on the untested anchor channel size or bolt diameter for use in calculating $\alpha_{N,seis}$
N_i	intermediate tension load to be applied in the simulated seismic tension test, lbf (N)
N_k	characteristic tension failure load calculated according to Eq. (8.5), lbf (N)

$V_{cp,x}$ nominal pry-out strength in longitudinal channel axis of a single anchor, lbf (N)

V_{eq} maximum shear load to be applied in the simulated seismic shear test, lbf (N)

$V_{eq,smaller}$ seismic shear load applied on the tested anchor channel size or bolt diameter for use in calculating $\alpha_{V,seis,y}$

$V_{eq,larger}$ seismic shear load required in accordance with section 7.13 on the untested anchor channel size or bolt diameter for use in calculating $\alpha_{V,seis,y}$

V_i intermediate shear load to be applied in the simulated seismic shear test, lbf (N)

V_k characteristic shear failure load calculated according to Eq. (8.5), lbf (N)

V_m minimum shear load to be applied in the simulated seismic shear test, lbf (N)

$V_{n,y}$ lowest nominal steel strength from all appropriate failure modes under shear perpendicular to the channel axis, lbf (N)

$V_{n,x}$ lowest nominal steel strength from all appropriate failure modes under shear loading in longitudinal channel axis, lbf (N)

V_{nc} nominal shear strength of one anchor from all concrete failure modes (lowest value of V_{cb} (anchor channels with anchor reinforcement to take up shear loads) or V_{ca} (anchor channels with anchor reinforcement to take up shear loads) and V_{cp})

V_{ns} Nominal steel strength of anchor channel loaded in shear (lowest value of V_{sa}, V_{sc}, and V_{sl})

$V_{ns,a}$ nominal shear strength for steel failure of anchor or connection between anchor and channel (lowest value of V_{sa} and V_{sc})

$V_{sa,y}$ nominal shear steel strength perpendicular to the channel axis of a single anchor, lbf (N)

$V_{sa,x}$ nominal shear steel strength in longitudinal channel axis of a single anchor, lbf (N)

$V_{sa,y,seis}$ nominal seismic shear steel strength perpendicular to the channel axis of a single anchor, lbf (N)

$V_{sa,x,seis}$ nominal seismic shear steel strength in longitudinal channel axis of a single anchor, lbf (N)

$V_{sc,y}$ nominal shear strength of connection between one anchor bolt and the anchor channel, lbf (N)

$V_{sc,x}$ nominal shear strength in longitudinal channel axis of connection between one anchor bolt and the anchor channel, lbf (N)

$V_{sc,y,seis}$ nominal seismic shear strength perpendicular to the channel axis of connection between one anchor bolt and the anchor channel, lbf (N)

$V_{sc,x,seis}$ nominal seismic shear strength in longitudinal channel axis of connection between one anchor bolt and the anchor channel, lbf (N)

$V_{sl,y}$ nominal shear steel strength perpendicular to the channel axis of the local bending of the channel lips, lbf (N)

$V_{sl,x}$ nominal shear steel strength in longitudinal channel axis of connection between channel bolt and channel lips, lbf (N)

$V_{sl,y,seis}$ nominal seismic shear steel strength perpendicular to the channel axis of the local bending of the channel lips, lbf (N)

$V_{sl,x,seis}$ nominal seismic shear steel strength in longitudinal channel axis of connection between channel bolt and channel lips, lbf (N)

V_{ss} nominal strength of channel bolt in shear, lbf (N)

$V_{ss,M}$ nominal strength of channel bolt in case of shear with lever arm, lbf (N)

V_{ua} factored shear load on anchor channel, lbf (N)

$V_{ua,x}$ factored shear load on anchor channel in longitudinal channel axis, lbf (N)

$V_{ua,y}$ factored shear load on anchor channel perpendicular to the channel axis, lbf (N)

V_{ua}^{a} factored shear load on a single anchor of the anchor channel, lbf (N)

$V_{ua,x}^{a}$ factored shear load on a single anchor of the anchor channel in longitudinal channel axis, lbf (N)

Tension	Symbol	Governing stress	Ductile steel	Brittle steel
anchor	N_{sa}	f_{uta}	0.75(0.80)	0.65(0.75)
connection	N_{sc}	f_{utc}	0.75(0.80)[1]	0.60(0.65)
channel lips	N_{sl}	f_{utc}	0.75(0.80)	0.65(0.75)
bolt	N_{ss}	f_{utb}	0.75(0.80)	0.65(0.75)
bending	$M_{s,flex}$	f_{yc}	0.85(0.90)	0.65(0.75)
Shear				
anchor	V_{sa}	f_{uta}	0.75(0.80)	0.65(0.75)
connection	V_{sc}	f_{utc}	0.75(0.80)[1]	0.65(0.75)
channel lips	V_{sl}	f_{utc}	0.75(0.80)	0.65(0.75)
bolt	V_{ss} and $V_{ss,M}$	f_{utb}	0.65(0.70)	0.60(0.65)

[1] The strength reduction factor for ductile steel may only be used if the scatter of the failure loads in the tests according to Table 4.1, Test No. 1 is v ≤ 7% and the displacement at peak load is 0.2 in. (5.1 mm) or greater.

For bolts in shear where bending of the bolt occurs the strength reduction factors for bolts in tension shall be used.

D.5.1.3, Section 17.4.1.3 (ACI 318-14), Section 17.6.1.3 (ACI 318-19) *– For anchor channels the nominal steel strength shall be determined as follows:*

D.5.1.3.1, Section 17.4.1.3.1 (ACI 318-14), Section 17.6.1.3.1 (ACI 318-19) *– The nominal strength, N_{sa}, of a single anchor shall be computed in accordance with D.5.1.2, Section 17.4.1.2 (ACI 318-14), Section 17.6.1.2 (ACI 318-19).*

D.5.1.3.2, Section 17.4.1.3.2 (ACI 318-14), Section 17.6.1.3.2 (ACI 318-19) *– The nominal strength, N_{sc}, of the connection between anchor and anchor channel shall be taken from the ICC-ES Evaluation Service Report.*

D.5.1.3.3, Section 17.4.1.3.3 (ACI 318-14), Section 17.6.1.3.3 (ACI 318-19) *– The nominal strength of the channel lips to take up tension loads transmitted by a channel bolt, N_{sl}, shall be taken from the ICC-ES Evaluation Service Report.*
This value is valid only if the center-to-center distance between two channel bolts, s_{chb}, is at least $s_{chb,cr}$. If this requirement is not met, then the value N_{sl} given in the ICC-ES Evaluation Service Report shall be reduced by the factor

$$\frac{1}{1+\sum_{i=2}^{n+1}\left[\left(1-\frac{s_{chb,i}}{s_{chb,cr}}\right)^2\cdot\frac{N_{ua,i}^b}{N_{ua,1}^b}\right]}$$

(D-3.a, ACI 318-08), (D-2.a, ACI 318-11), (17.4.1.3~~.3~~, ACI 318-14), (17.6.1.3~~.3~~, ACI 318-19)

If no tests have been performed, the value $s_{chb,cr}$ shall be taken as $2b_{ch}$, where the center-to-center spacing between channel bolts shall not be less than 3-times the bolt diameter, d_s .

D.5.1.3.4, Section 17.4.1.3.4 (ACI 318-14), Section 17.6.1.3.4 (ACI 318-19) *– The nominal strength of the channel bolt, N_{ss}, shall be taken from the ICC-ES Evaluation Service Report and shall not exceed the value determined in accordance with Eq. (D-3.b, ACI 318-08), (D-2.b, ACI 318-11), (17.4.1.3.4, ACI 318-14), (17.6.1.3.4, ACI 318-19).*

$$N_{ss} = A_{se,N} \cdot f_{utb}$$

(D-3.b, ACI 318-08), (D-2.b, ACI 318-11), (17.4.1.3.4, ACI 318-14), (17.6.1.3.4, ACI 318-19)

where $A_{se,N}$ is the effective cross-sectional area in tension, in^2 (mm^2); and f_{utb} shall be taken as the smaller of 1.9 f_{yb} and 125,000 psi (860 MPa*).*

D.5.1.3.5, Section 17.4.1.3.5 (ACI 318-14), 17.4.1.3.5 (ACI 318-19) *– The nominal bending strength of the anchor channel, $M_{s,flex}$, shall be taken from the ICC-ES Evaluation Service Report.*

D.5.2.10, Section 17.4.2.10 (ACI 318-14), Section 17.6.2.7 (ACI 318-19) *– Concrete breakout strength of anchor channel in tension*

For anchor channels where h_{ch}/h_{ef} ≤ 0.4, the effective embedment depth is determined according to Figure 3a). For anchor channels where 0.4 < h_{ch}/h_{ef} ≤ 0.5, the concrete cone resistance may be calculated using one of the following options:

a = internal lever arm, in. (mm) (as illustrated in Figure RD.6.1.4.1 (Figure 17.5.1.4.1, ACI 318-14, Figure 17.7.1.3.1, ACI 318-19))

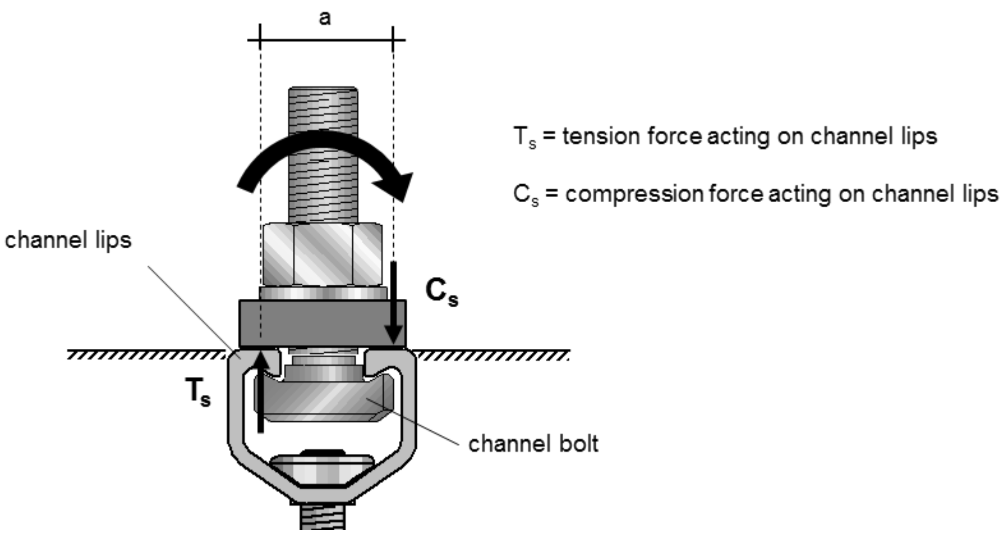


FIGURE RD.6.1.4.1 (FIGURE 17.5.1.4.1, ACI 318-14, FIGURE 17.7.1.3.1, ACI 318-19) —DEFINITION OF INTERNAL LEVER ARM

b) The nominal strength of the channel lips to take up shear loads transmitted by a channel bolt perpendicular to the channel, $V_{sl,y}$, shall be taken from the ICC-ES Evaluation Service Report.

This value is valid only if the center-to-center distance between two channel bolts, s_{chb}, is at least $s_{chb,cr}$. If this requirement is not met, then the value $V_{sl,y}$ given in the ICC-ES Evaluation Service Report shall be reduced by the factor:

$$\frac{1}{1+\sum_{i=2}^{n+1}\left[\left(1-\frac{s_{chb,i}}{s_{chb,cr}}\right)^2\cdot\frac{V^b_{ua,i}}{V^b_{ua,1}}\right]}$$

(D-19.a, ACI 318-08), (D-29.a, ACI 318-11), (17.5.1.3, ACI 318-14), (17.7.1.3, ACI 318-19)

If no tests have been performed, the value $s_{chb,cr}$ shall be taken as $2b_{ch}$, where the center-to-center spacing between channel bolts shall not be less than 3-times the bolt diameter, d_s.

c) The nominal strength of one anchor, $V_{sa,y}$, to take up shear loads perpendicular to the channel shall be taken from the ICC-ES Evaluation Service Report.

d) The nominal strength of the connection between one anchor and the anchor channel, $V_{sc,y}$, to take up shear loads perpendicular to the channel shall be taken from the ICC-ES Evaluation Service Report.

Exception: If Test No. 1 is performed with non-serrated channels in combination with standard channel bolts and anchor or connection failure occurs in all tests, adequacy for the use of locking channel bolts in combination with non-serrated channels shall be included without further testing.

In Test No. 2 (determination of the channel lip strength) tests shall be allowed to be performed with anchor channels with additional anchors cast into low-strength concrete with anchor spacing $s \geq s_{min}$ where s_{min} shall not be taken less than 1 inch (25 mm). It shall be allowed to replace the anchor by an anchor of same type but higher steel strength. The distance between the end of the channel and the anchor axis shall correspond to the minimum value specified by the manufacturer for the tested channel size. In one test series, insert one channel bolt over one anchor and apply the load directly to channel bolt. In a second series, insert two channel bolts with one channel bolt over the end anchor and the second channel bolt spaced with s_{chb} at least 1 inch (25 mm) to the first channel bolt and apply the load equally to both channel bolts. A fixture with the following dimensions shall be used: width = b_{ch}, thickness = d_f. The fixture shall be shimmed with steel strips having a thickness = 1/8 inch (3.2 mm) located on each side of the anchor channel (similar to Figure 7.1). The diameter of the hole in the fixture shall be approximately 10 percent larger than the diameter of the shaft of the channel bolt. The channel bolt shall be pre-tensioned in accordance with Section 5.5. The test shall be conducted according to Figure 5.4. However, the support spacing may be reduced to ≥ 1.0 h_{ef} in every direction. Direct contact between the test stand and the channel profile is not permitted.

The failure load, the corresponding displacement, and the failure mode shall be recorded.

Exception: For systems where pre-tensioning of the channel bolt does not result in deformation of the channel lips, it shall be permitted to perform the tests without a pretension load in the channel bolt. The ITEA shall verify that the pretension corresponding to the installation torque does not result in deformation of the channel lips.

7.3.5 Conduct of tests (all types of channel bolts): For Test No. 3, test the channel bolts in a section of channel that is sufficiently restrained to cause failure of the channel bolt (see Figure 5.8a). If the channel bolt is intended to be used for different channel sizes, conduct the tests in the channel profile with the maximum width of the slot between the channel lips. Insert the channel bolt in the channel profile and apply the load with a coupling nut to avoid thread failure. Alternatively, in case of standard channel bolts, channel bolts may be tested in a steel template (see Figure 5.8b). This template shall represent the inner profile of the channels (angle of channel lips and maximum width of the slot) to be included for evaluation.

Exception: For systems where the channel-to-anchor connection is manufactured using fillet welds, Test No.1 may be omitted and replaced by fillet weld design calculation in accordance with ANSI/AISC 360-22, Section J2. Limitations in Section J2.b for the manufacturing procedure shall be observed.

7.4 Bending Tests (Table 4.1, Test No. 4):

7.4.1 The purpose of this test is to measure the bending strength of the channel taking account of the restraint of the deformation of the outer ends of the channel by the concrete.

7.4.2 Required tests: The tests shall be performed with all sizes and materials of anchor channels. Anchor channels with two anchors with a maximum spacing and the minimum distance between the end of the channel and the anchor axis as specified by the manufacturer and with an anchor type that provides the lowest anchor strength shall be tested. The channel bolt with the smallest head size and maximum steel strength that, when tested, still results in steel failure of a part of the anchor channel other than the channel bolt shall be used. If the largest channel bolt size still results in bolt failure, the bolt failure load shall be taken as the load corresponding to bending failure. In case of locking channel bolts in combination with non-serrated channels, test all channel bolt sizes.

7.4.2.1 If the failure load in the bending tests, $N_{s,flex}$ computed in accordance with Eq. (7.1) is smaller than the nominal strength N_{sl} (Section 8.6 of this annex), then additional tests with $s<s_{max}$ shall be performed. The anchor spacing shall be chosen such that the failure loads for the failure modes “bending of channel” and “local failure of channel lips” are about equal.

contact area between fixture and concrete surface. Insert a channel bolt over one anchor and prestress it in accordance with Section 5.5 of this annex. Apply a shear load via the channel bolt to the anchor channel.

7.13.3.1 Subject the anchor channel to the sinusoidal shear loads specified in Table 7.2 and Figure 7.7 of this annex, whereby V_{eq} is given by Eq. (7.7) V_m is given by Eq. (7.10) and V_i is given by Eq. (7.11).

$$V_{eq} = 0.5 \cdot V_s \text{, lbf (N)} \qquad \text{Eq. (7.7)}$$

where:

V_s = minimum value of the mean failure load V_{ref} in accordance with Eq. (7.8) and V_{ss} in accordance with Eq. (7.9), lbf (N)

$$V_{ref} = V_{m,8} \cdot \frac{f_{ut,test}}{f_{ut,test,8}} \cdot \frac{t_{test}}{t_8} \text{, lbf (N)} \qquad \text{Eq. (7.8)}$$

$V_{m,8}$ = mean failure load of reference tests in accordance with Table 4.1, Test No.8, lbf (N).

$f_{ut,test}$ = steel strength of the anchor channel used in simulated seismic shear tests, psi (MPa).

$f_{ut,test,8}$ = steel strength of the anchor channel used in reference tests, psi (MPa).

t_{test} = thickness of channel lips of anchor channel seismic test specimen, in. (mm).

t_8 = thickness of channel lips of anchor channel reference test specimen (Table 4.1, Test No. 8), in. (mm).

V_{ss} = 0.$\underline{6}$~~7~~·$A_{se,V}$·$f_{ut,test}$, lbf (N) Eq. (7.9)

where:

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

$f_{ut,test}$ = steel strength of channel bolt used in the simulated seismic shear tests, psi (MPa).

$$V_m = \frac{V_{eq}}{2} \text{, lbf} \qquad \text{Eq. (7.10)}$$

$$V_i = \frac{V_{eq} + V_m}{2} \text{, (N)} \qquad \text{Eq. (7.11)}$$

7.13.3.2 If service condition shear tests (Table 4.1, Test No. 8) have not been performed, it shall be permitted to insert in Eq. (7.8) the mean failure load, the channel steel strength and the thickness of the channel lips of Test No. 2, Table 4.1 as $V_{m,8}$, $f_{ut,test,8}$ and t_8, respectively.

7.13.3.3 The frequency of loading shall be between 0.1 and 2 Hz. 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 7.8 of this annex.

7.13.3.4 Record the, anchor displacement and applied shear load. Plot the load-displacement history in the form of hysteresis loops.

7.13.3.5 Following completion of the simulated seismic-shear cycles, load the anchor channel in shear to failure. Record the maximum shear load (residual shear capacity), the corresponding displacement, and plot the load-displacement response.

8.9.6 If it is required to perform tests according to Section 7.5.4, the following evaluation is required instead of Section 8.9.2.

8.9.6.1 Evaluate the 95-percent fractile of the anchor tension force by Eq. (8.10) replacing N_m by the mean measured anchor tension forces and v_{test} by the coefficient of variation of the measured anchor tension forces.

8.9.6.2 The 95-percent fractile of the anchor forces measured at T = 1.3 T_{inst} shall fulfill the requirements of Annex A, Section 8.9.2.

8.9.6.3 From the results of the measured prestressing forces acting on the channel bolt the mean friction factor k shall be calculated according to Eq. (8.11) at T = 1.3 T_{inst}, solving for k and replacing $N_{95\%}$ by N_m. Furthermore, the coefficient of variation of the friction factor shall be calculated assuming a normal distribution. Report the factor k and the coefficient of variation.

8.10 Assessment of the Minimum Edge Distance and Minimum Spacing (splitting failure due to installation) (Test No. 6 in accordance with Table 4.1):

The minimum spacing s_{min} and minimum edge distance $c_{a,min}$ shall be evaluated from the results of tests on anchor channels with two anchors in accordance with Section 7.6 of this annex and reported in Section 9.5 of this annex. The characteristic torque moment, T_k, at which a hairline crack has been observed at one anchor of the anchor channel shall fulfil Eq. (8.12).

$$T_k \geq \gamma_{inst} \cdot T_{inst} \cdot \left(\frac{f_{c,\,test}}{f_c'}\right)^{0.5} \cdot lbf\text{-}in,\ (N\text{-}m) \qquad \text{Eq. (8.12)}$$

where:

γ_{inst} = 1.3 anchorages in cracked concrete

= 1.7 anchorages in non-cracked concrete

8.11 Assessment of Concrete Breakout Strength Under Tension Load (Test No. 7 in accordance with Table 4.1):

The results of the Test No. 7 shall determine the profile factor $\alpha_{ch,N}$ to be used in Eq. (D-7b, ACI 318-08), (D-6b, ACI 318-11), (17.4.2.10b, ACI 318-14), (17.6.2.7b, ACI 318-19) which shall be reported in Section 9.5 of this criteria.

The factor $\alpha_{ch,N}$ shall be computed in accordance with Eq. (8.13), but in no case shall $\alpha_{ch,N}$ exceed 75% of the value calculated in accordance with Eq. (8.13) (without upper limits) with the mean failure load N_{test} obtained from Test No. 7 substituted for the characteristic failure load N_k.

$$\alpha_{ch,N} = 0.7\left[\frac{N_k}{24 \cdot \sqrt{f_c'} \cdot h_{ef}^{1.5} \cdot \psi_{s,N}}\right] \leq \left(\frac{h_{ef}}{7.1}\right)^{0.15} \leq 1 \quad \text{(normal weight concrete), for imperial units } ~~lbf^{1/2}/in^{1/3}~~ \qquad \text{Eq. (8.13a)}$$

$$\alpha_{ch,N} = 0.7\left[\frac{N_k}{10 \cdot \sqrt{f_c'} \cdot h_{ef}^{1.5} \cdot \psi_{s,N}}\right] \leq \left(\frac{h_{ef}}{180}\right)^{0.15} \leq 1 \quad \text{(normal weight concrete), for SI units } ~~N^{1/2}/mm^{1/3}~~ \qquad \text{Eq. (8.13b)}$$

where:

N_k = characteristic failure load applied to one anchor calculated according to Eq. (8.5) and normalized according to Eq. (8.1), lbf (N)

h_{ef} = embedment depth, inch (mm)

f'_c = See Eq. (8.1), psi (MPa)

$\Psi_{s,N}$ = factor according to Eq. (D-9a, ACI 318-08), (D-8a, ACI 318-11), (17.4.2.10.1a, ACI 318-14)

The factor $\alpha_{ch,N}$ shall be stated in steps of 0.1 and shall be rounded down to the nearest tenth.

8.12 Assessment of the Steel Strength Under Shear Load (Test No. 8 in accordance with Table 4.1):

The 5 percent-fractile of the measured failure loads as normalized by Eq. (8.3) shall be computed by Eq (8.5) and denoted as $V_{sl,y}$, $V_{sa,y}$, *and* $V_{sc,y}$. These values assessed for lightweight concrete may not exceed the values assessed in normal-weight concrete. These values shall be reported in Section 9.5 of this annex.

8.12.1 If tests have been performed according to 7.8.3.1, the shear strength of the middle anchor calculated according to Section D.3.1.1.3 from the 5%-fractile of the failure loads normalized according to Eq. (8.3) shall be denoted as $V_{sa,y}$ *and* $V_{sc,y}$.

8.13 This section is intentionally left blank.

8.14 Assessment of the Concrete-Breakout Strength Under Shear Load (Test No. 10 in accordance with Table 4.1):

The results of the Test No. 10 shall determine the profile factor $\alpha_{ch,V}$ to be used in Eq. (D-22.a), which shall be reported in Section 9.5 of this criteria.

The factor $\alpha_{ch,V}$ shall be computed in accordance with Eq. (8.13), but in no case shall $\alpha_{ch,V}$ exceed 75% of the value calculated in accordance with Eq. (8.13) (without upper limits) with the mean failure load V_{test} obtained from tTest No. 10 substituted for the characteristic failure load V_k.

$$\alpha_{ch,V}=0.7\left[\frac{V_k}{(c_{a,1})^{4/3}\cdot\sqrt{f_c'}\cdot\psi_{s,V}}\right]\leq 10.5$$ (normal weight concrete), for imperial units ~~lbf^1/2/in^1/2~~ Eq. (8.1~~3~~4a)

$$\alpha_{ch,V}=0.7\left[\frac{V_k}{(c_{a,1})^{4/3}\cdot\sqrt{f_c'}\cdot\psi_{s,V}}\right]\leq 7.5$$ (normal weight concrete), for SI units~~N^1/2/mm^1/2~~ Eq. (8.1~~3~~4b)

where:

V_k = characteristic failure load applied to one anchor calculated according to Eq. (8.5) and normalized according to Eq. (8.1), lbf (N)

$c_{a,1}$ = edge distance, inch (mm)

f_c' = See Eq. (8.1), psi (MPa)

$\Psi_{s,V}$ = factor according to Eq. (D-24b)

The factor $\boldsymbol{\alpha_{ch,V}}$ shall be stated in steps of 0.1 and shall be rounded down to the nearest tenth.

8.15 [This section is intentionally left blank]

8.16 Assessment of Performance Under Seismic Tension (Test No. 12 in accordance with Table 4.2):

8.16.1 All anchor channel systems in a test series shall complete the simulated seismic-tension load history specified in Table 7.1 and Figure 7.6 of this annex. Failure of an anchor channel system to develop the required tension resistance in any cycle before completing the loading history specified in Table 7.1 and Figure 7.6 of this annex shall be recorded as an unsuccessful test. The mean residual capacity of the anchor channel system in the test series shall be at least 160 percent of N_{eq} as given by Eq. 7.3).

8.16.2 Successful completion of the cyclic loading history and fulfilment of the residual tension capacity requirement of this Section shall be reported.

8.16.3 If the anchor channel system fails to fulfil the above requirements at N_{eq}, it shall be permitted to conduct the test with reduced cyclic tension loads conforming to the loading history specified in Table 7.1 and Figure 7.6 of this annex whereby $N_{eq,reduced}$, $N_{i,reduced}$ and $N_{m,reduced}$ are substituted for N_{eq}, N_i and N_m, respectively. All anchor channel systems in a test series shall complete the simulated seismic-tension load history. Failure of an anchor channel system to develop the required tension resistance in any cycle prior to completing the loading history given Table 7.1 and Figure 7.6 of this annex shall be recorded as an unsuccessful test. The mean residual capacity of the anchor channel system in the tension test series shall be at least 160 percent of the reduced peak load $N_{eq,reduced}$. Successful completion of the reduced cyclic loading history and fulfilment of the residual tension capacity requirement of this section shall be recorded together with the reduction factor $\alpha_{N,seis}$ as given by Eq. (8.15).

$$\alpha_{N,seis} = \frac{N_{eq,reduced}}{N_{eq}} \qquad \text{Eq. (8.15)}$$

8.16.3.1 If the channel bolt strength governs (N_{ss} is used to calculate N_{eq} according to Eq. (7.3)), the reduction factor $\alpha_{N,seis}$ shall only be applied to the specific anchor channel system (specific combination of anchor channel and anchor channel bolt) tested.

8.16.3.2 If larger channel bolts than tested according to Section 7.12 shall be recognized for seismic loading, test the smallest channel bolt size that results in failure of the anchor channel. Apply $\alpha_{N,seis}$ in accordance with 8.16.4. In this case the factor $\alpha_{N,seis}$ may also be applied to the combination of anchor channel and channel bolt where the anchor channel bolt governed, whereby the determination of $N_{sa,seis}$, $N_{sl,seis}$, $N_{sc,seis}$, and $M_{sflex,seis}$ shall be in accordance with 8.16.4. If seismic recognition is sought for larger channel sizes or bolt diameters other than tested according to Section 7.12, it shall be permitted to transfer the strength from a smaller tested channel size or bolt diameter to larger, untested sizes. The factor $\alpha_{N,seis}$ for untested sizes shall be calculated as follows:

$$\alpha_{N,seis} = \frac{N_{eq,smaller}}{N_{eq,larger}}$$

8.16.3.3 Only one set of values for $N_{sa,seis}$, $N_{sl,seis}$, $N_{sc,seis}$, and $M_{s,flex,seis}$ shall be reported for each channel profile and material, and only one value $N_{ss,seis}$ shall be reported for each channel bolt diameter, type, and material.

8.16.4 The reduction factor $\alpha_{N,seis}$ shall be used to determine $N_{sa,seis}$, $N_{sl,seis}$, $N_{sc,seis}$, $N_{ss,seis}$, and $M_{s,flex,seis}$ from the values N_{sa}, N_{sl}, N_{sc}, N_{ss} and $M_{s,flex}$ determined in accordance with Sections D.5.1.3, 8.5, 8.6, 8.7 and 8.8 of this annex, respectively.
Following is a clarification of how to apply the factor $\alpha_{N,seis}$.

$N_{sl,seis} = \alpha_{N,seis} \cdot N_{sl}$ Eq.(8.15a)

$N_{sa,seis} = \alpha_{N,seis} \cdot N_{sa}$ Eq.(8.15b)

$N_{sc,seis} = \alpha_{N,seis} \cdot N_{sc}$ Eq.(8.15c)

$N_{ss,seis} = \alpha_{N,seis} \cdot N_{ss}$ Eq.(8.15d)

$M_{s,flex,seis} = \alpha_{N,seis} \cdot M_{s,flex}$ Eq.(8.15e)

8.17 Assessment of Performance Under Seismic Shear (Test No. 13 in accordance with Table 4.2):

8.17.1 All anchor channel systems in a test series shall complete the simulated seismic-shear load history specified in Table 7.2 and Figure 7.7 of this annex. Failure of an anchor channel system to develop the required shear resistance in any cycle before completing the loading history specified in Table 7.2 and Figure 7.7 of this annex shall be recorded as an unsuccessful test. The mean residual capacity of the anchor channels system in the test series shall be at least 160 percent of V_{eq} as given by Eq. (7.7).

8.17.2 Successful completion of the cyclic loading history and fulfilment of the residual shear capacity requirement of this Section shall be reported.

8.17.3 If the anchor channel system fails to fulfil the above 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 7.7 of this annex whereby $V_{eq,Reduced}$, $V_{i,Reduced}$ and $V_{m,reduced}$ are substituted for V_{eq}, V_i and V_m, respectively. All anchor channel systems in a test series shall complete the simulated seismic-shear load history. Failure of an anchor channel system to develop the required shear resistance in any cycle prior to completing the loading history given in Table 7.2 and Figure 7.7 of this annex shall be recorded as an unsuccessful test. The mean residual capacity of the anchor channel system in the shear test series shall be at least 160 percent of the reduced peak load $V_{eq,reduced}$. Successful completion of the reduced cyclic loading history and fulfilment of the residual shear capacity requirement of this section shall be recorded together with a reduction factor $\alpha_{v,seis,y}$ given by Eq. (8.16).

$$\alpha_{V,seis,y} = \frac{V_{eq,reduced}}{V_{eq}} \qquad \text{Eq. (8.16)}$$

8.17.3.1 If the channel bolt strength governs (V_{ss} is used to calculate V_{eq} according to Eq. (7.7)), the reduction factor $\alpha_{V,seis,y}$ shall only be applied to the specific combination of anchor channel and anchor channel bolt tested.

8.17.3.2 ~~If larger channel bolts than tested according to Section 7.13 shall be recognized for seismic loading, test the smallest channel bolt size that results in failure of the anchor channel. Apply $\alpha_{V,seis,y}$ in accordance with 8.17.4. In this case the factor $\alpha_{V,seis,y}$ may also be applied to the combination of anchor channel and channel bolt where the anchor channel bolt governed whereby the determination of $V_{sa,y,seis}$, $V_{sl,y,seis}$, and $V_{sc,y,seis}$ shall be in accordance with 8.17.4.~~ If seismic recognition is sought for larger channel sizes or bolt diameters other than tested according to Section 7.13, it shall be permitted to transfer the strength from a smaller tested channel size or bolt diameter to larger, untested sizes. The factor $\alpha_{V,seis}$ for untested sizes shall be calculated as follows:

$$\alpha_{V,seis,y} = \frac{V_{eq,smaller}}{V_{eq,larger}}$$

8.17.3.3 Only one set of values for $V_{sa,seis,y}$, $V_{sl,seis,y}$, and $V_{sc,seis,y}$ shall be reported for each channel profile and material, and only one value $V_{ss,seis}$ shall be reported for each channel bolt diameter, type, and material.

8.17.4 The reduction factor $\alpha_{v,seis,y}$ shall be used to determine $V_{sa,y,seis}$, $V_{sc,y,seis}$, $V_{sl,y,seis}$ and $V_{ss,seis}$ from the values $V_{sa,y}$, $V_{sc,y}$, $V_{sl,y}$ and V_{ss} determined in accordance with Sections D.6.1.4 of this annex, respectively.

Following is a clarification of how to apply the factor $\alpha_{V,seis,y}$.

$$V_{sl,y,seis} = \alpha_{v,seis,y} \cdot V_{sl,y} \qquad \text{Eq.(8.16a)}$$

$$V_{sa,y,seis} = \alpha_{v,seis,y} \cdot V_{sal,y} \qquad \text{Eq.(8.16b)}$$

$$V_{sc,y,seis} = \alpha_{v,seis,y} \cdot V_{scl,y} \qquad \text{Eq.(8.16c)}$$

$$V_{ss,seis} = \alpha_{v,seis,y} \cdot V_{ss} \qquad \text{Eq.(8.16d)}$$

8.18 Assessment of the Steel Strength Under Shear Load Acting in Longitudinal Channel Axis (Test No. 15 in accordance with Table 4.2):

The measured failure loads shall be normalized according to Section 8.1.3 Eq. (8.2). The 5 percent-fractile of the normalized measured failure loads shall be computed by Eq (8.5). This value shall be denoted as $V_{sl,x}$ and reported in Section 9.5 of this annex.

8.19 Assessment of Performance Under Seismic Shear in Longitudinal Channel Axis (Test No. 14 in accordance with Table 4.2):

8.19.1 All anchor channel systems in a test series shall complete the simulated seismic-shear load history specified in Table 7.2 and Figure 7.7 of this annex. Failure of an anchor channel system to develop the required shear resistance in any cycle