

An ACI Standard

# Qualification of Post-Installed Adhesive Anchors in Concrete (ACI 355.4-19) and Commentary

Reported by ACI Committee 355

ACI 355.4-19(21)



American Concrete Institute  
*Always advancing*



## Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at <http://concrete.org/Publications/DocumentErrata.aspx>. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, through electronic subscription, or reprint, and may be obtained by contacting ACI.

ACI codes, specifications, and practices are made available in the ACI Collection of Concrete Codes, Specifications, and Practices. The online subscription to the ACI Collection is always updated, and includes current and historical versions of ACI's codes and specifications (in both inch-pound and SI units) plus new titles as they are published. The ACI Collection is also available as an eight-volume set of books and a USB drive.

American Concrete Institute  
5880 Country Club Drive  
Farmington Hills, MI 48331  
Phone: +1.248.848.3700  
Fax: +1.248.848.3701

# Qualification of Post-Installed Adhesive Anchors in Concrete (ACI 355.4-19) and Commentary

An ACI Standard

Reported by ACI Committee 355

Lee W. Mattis  
Chair

Monzer M. Allam  
Neal S. Anderson  
Jacques A. Bertrand  
T. J. Bland  
Peter J. Carrato  
Harry A. Chambers\*  
Ronald A. Cook

Rolf Eligehausen  
Werner A. F. Fuchs  
Branko Galunic  
Brian C. Gerber  
Herman L. Graves  
Andra Hoermann-Gast  
Brent E. Hungerford

Amy S. Kolczak  
Thomas A. Kolden  
Anthony J. Lamanna  
Nam-Ho Lee  
Robert R. McGlohn  
Giovanni Muciaccia  
Jake Olsen

John E. Pearson  
Edson Rodriguez  
John F. Silva  
Howard Silverman  
Patrick J. E. Sullivan  
J. Bret Turley  
Curtis R. Yokoyama  
Jian Zhao

\*Deceased.

#### Consulting members

Edwin G. Burdette  
Robert W. Cannon  
Neil M. Hawkins  
Paul R. Hollenbach

Conrad Paulson  
Dan R. Stoppenhagen  
Harry Wiewel\*

*This standard prescribes testing programs and evaluation requirements for post-installed adhesive anchors intended for use in concrete under the design provisions of ACI 318M. Testing and assessment criteria are provided for various conditions of use, including seismic loading; sustained loading; aggressive environments; reduced and elevated temperatures; and for determining whether anchors are acceptable for use in uncracked concrete only, or acceptable for use both in cracked and uncracked concrete. Criteria are provided for establishing the characteristic bond strength, reductions for adverse conditions, and the anchor category and associated job-site quality control requirements.*

*The official version of this ACI document uses inch-pound units. A conversion of an ACI document into SI units is for the convenience of users. Care has been taken to ensure that the conversion is correct;*

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

*however, ACI does not guarantee its accuracy. Official interpretation of this ACI document shall be based only on the U.S. customary units.*

**Keywords:** adhesive anchors; cracked concrete; fasteners; post-installed anchors; qualification procedures; uncracked concrete.

## CONTENTS

### Chapter 1—Introduction and scope, p. 3

- 1.1—Introduction
- 1.2—Scope
- 1.3—Units of measurement

### Chapter 2—Notation and definitions, p. 5

- 2.1—Notation
- 2.2—Definitions

### Chapter 3—General requirements, p. 12

- 3.1—Test organization
- 3.2—Variables and options

ACI 355.4M-19 supersedes ACI 355.4M-11, and was adopted and published August 2021.

Copyright © 2021, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

- 3.3—Test requirements
- 3.4—Assessment for multiple anchor element types for adhesive anchors
- 3.5—Assessment for alternate drilling methods

#### **Chapter 4—Requirements for test specimens, anchor installation, and testing, p. 18**

- 4.1—Testing by ITEA and manufacturer
- 4.2—Test samples
- 4.3—Concrete for test members
- 4.4—Requirements for test members
- 4.5—Anchor installation
- 4.6—Drill bit requirements
- 4.7—Test methods
- 4.8—Tests in cracked concrete
- 4.9—Changes to products

#### **Chapter 5—Requirements for anchor identification, p. 24**

- 5.1—Basic requirements
- 5.2—Verification
- 5.3—Fingerprinting adhesive materials
- 5.4—Packaging

#### **Chapter 6—Reference tests, p. 25**

- 6.1—Purpose
- 6.2—Required tests
- 6.3—Conduct of tests

#### **Chapter 7—Reliability tests, p. 26**

- 7.1—Purpose
- 7.2—Required tests
- 7.3—Conduct of tests
- 7.4—Reliability tests
- 7.5—Sensitivity to hole cleaning—dry concrete
- 7.6—Sensitivity to hole cleaning—saturated concrete
- 7.7—Sensitivity to hole cleaning—water-filled hole
- 7.8—Sensitivity to hole cleaning—submerged concrete
- 7.9—Sensitivity to mixing effort
- 7.10—Sensitivity to installation in water-saturated concrete
- 7.11—Sensitivity to installation in water-filled hole—saturated concrete
- 7.12—Sensitivity to installation in submerged concrete
- 7.13—Sensitivity to crack width—low-strength concrete
- 7.14—Sensitivity to crack width—high-strength concrete
- 7.15—Sensitivity to crack width cycling
- 7.16—Sensitivity to freezing and thawing
- 7.17—Sensitivity to sustained loading at standard and maximum long-term temperature
- 7.18—Sensitivity to installation direction
- 7.19—Torque test

#### **Chapter 8—Service-condition tests, p. 33**

- 8.1—Purpose
- 8.2—Required tests
- 8.3—Conduct of tests
- 8.4—Tension tests in uncracked and cracked concrete
- 8.5—Tension tests at elevated temperature
- 8.6—Tension tests with decreased installation temperature

- 8.7—Establishment of cure time at standard temperature
- 8.8—Durability assessment
- 8.9—Verification of full concrete capacity in a corner
- 8.10—Determination of minimum spacing and edge distance to preclude splitting
- 8.11—Tests to determine shear capacity of anchor elements with nonuniform cross section
- 8.12—Simulated seismic tension tests
- 8.13—Simulated seismic shear tests

#### **Chapter 9—Supplemental tests, p. 39**

- 9.1—Round-robin tests
- 9.2—Tests to determine minimum member thickness

#### **Chapter 10—Assessment of anchors, p. 40**

- 10.1—Analysis of data
- 10.2—Normalization of anchor capacities for measured concrete bond and steel strengths
- 10.3—Establishing characteristic values
- 10.4—Assessment of characteristic tension capacity associated with concrete breakout and pullout
- 10.5—Assessment of steel tension capacity
- 10.6—Assessment of steel shear capacity
- 10.7—Assessment of minimum member thickness
- 10.8—Assessment of maximum tightening torque
- 10.9—Assessment of behavior under crack cycling
- 10.10—Assessment of freezing-and-thawing behavior
- 10.11—Assessment of sustained load behavior
- 10.12—Assessment of performance associated with installation direction
- 10.13—Assessment of performance at elevated temperature
- 10.14—Assessment of performance with decreased installation temperature
- 10.15—Assessment for cure time at standard temperature
- 10.16—Assessment of durability requirement
- 10.17—Assessment of performance in corner test
- 10.18—Assessment of performance in minimum spacing and edge distance test
- 10.19—Assessment of performance under seismic tension
- 10.20—Assessment of performance under seismic shear
- 10.21—Establishment of hole cleaning procedures
- 10.22—Establishment of on-site quality control and installation conditions
- 10.23—Assessment based on installation and environmental conditions
- 10.24—Assessment for fire exposure

#### **Chapter 11—Data presentation, p. 54**

- 11.1—General requirements
- 11.2—Contents of evaluation report
- 11.3—Data presentation

#### **Chapter 12—Independent testing and evaluation agency requirements, p. 54**

- 12.1—General requirements
- 12.2—Certification

#### **Chapter 13—Quality control requirements, p. 54**

- 13.1—Quality assurance program

- 13.2—Quality control manuals
- 13.3—Special inspection

**Chapter 14—References, p. 55**

- 14.1—Referenced standards and reports
- 14.2—Cited references

**CHAPTER 1—INTRODUCTION**

**1.1—Introduction**

This standard prescribes testing and evaluation requirements for post-installed adhesive anchor systems intended for use in concrete under the provisions of ACI 318M. Criteria are separately prescribed to determine the suitability of adhesive anchors used in uncracked concrete only, or in both cracked and uncracked concrete. Criteria are prescribed to determine the design parameters and performance category for adhesive anchors. Included are assessments of the adhesive anchor system for bond strength, reliability, service conditions, and quality control. Special inspection (13.3) is required during anchor installation as noted in 10.22. Table 1.1 provides an overview of the scope.

***RI.1** This standard prescribes the testing programs required to qualify post-installed adhesive anchor systems for design in accordance with ACI 318M, Appendix D. Appendix D requires that anchors be tested either for use exclusively in uncracked concrete or for use in cracked and uncracked concrete conditions, whereby it is understood that the presence of cracking may occur at any time over the service life of the anchors. Test and assessment criteria are provided for various conditions, including loads (seismic and sustained), environmental with regard to humidity and temperature, and determination if anchors are acceptable for use in cracked or uncracked concrete. Refer to Cor and Konz (2001) for a review of factors that influence adhesive anchor behavior. Refer to Fuchs et al. (1995) for background on the concrete breakout design model and to Eberhausen et al. (2006) and Zamora et al. (2003) for a discussion of bond models for adhesive and grouted anchors. For a discussion of issues associated with the qualification and design of systems for post-installed reinforcing bars, refer to Spieth et al. (2001).*

**1.2—Scope**

This standard applies only to post-installed adhesive anchors as defined herein.

***RI.2** Adhesive anchors resist tension loads with a combination of adhesion and mechanical bond (micro-interlock). Different anchor designs and adhesive types may exhibit a range of performance characteristics. In particular, the sensitivity of adhesive anchors to variations in installation and service-condition parameters (such as hole cleaning, installation orientation, and cracked concrete characteristics) may vary widely from each system. ACI 318M addresses this situation by matching capacity reduction factors to anchor performance categories that are, in turn, established through a series of reliability tests.*

**1.2.1** This standard applies to anchors with a diameter  $d_a$  of 6 mm or larger. The drilled hole shall be approximately

**Table 1.1—Overview of anchor systems**

Anchor type	Embedded part	Assessment criteria	
		Uncracked concrete	Cracked and uncracked concrete
Adhesive anchor	Threaded rods, deformed reinforcing bars, or internally threaded steel sleeves with external deformations	Table 3.1	Table 3.2 or Table 3.3

cylindrical with a diameter  $d_o \leq 1.5d_a$ . This standard applies to anchors with an anchor embedment depth  $h_{ef}$  of less than four diameters ( $4d_a$ ), or 41 mm, and an embedment depth not exceeding  $20d_a$ .

***RI.2.1** The minimum diameter of 6 mm is based on practical considerations regarding the limits of structural anchor applications. The upper limit on the ratio of hole diameter to anchor element diameter provides a demarcation between conditions where a single bond strength can be used to evaluate anchor strength and conditions where bond strengths at both the anchor interface and concrete interface must be determined to evaluate anchor strength. In addition, the value of 1.5d<sub>a</sub> is based on consideration of typical practice whereby most organic adhesives are used with thin bond lines to limit both adhesive shrinkage and creep of the anchor when under load. The design method deemed to satisfy the anchor design requirements of ACI 318M, Appendix D is based on an analysis of an anchor database with a maximum diameter of 50.8 mm. While ACI 355.4M gives no limitations on maximum anchor diameter, for anchors beyond this dimension, the testing authority should decide if the tests described in this standard are applicable or if alternative tests and analyses are more appropriate. It may also be desirable to reconsider those tests where only small, medium, and large diameters are tested when the upper diameter is much larger than 38 mm.*

*A limitation on the minimum embedment length of adhesive anchors is necessary to ensure conformance with the design method deemed to satisfy the anchor design requirements of ACI 318M, Appendix D.*

**1.2.2** The minimum member thickness shall not be less than the value given by Eq. (10-21). Values of  $\Delta h$  in Eq. (10-21) shall be permitted if they are verified by tests according to Table 3.1, Test no. 14, and Table 3.2, Test no. 20, or Table 3.3, Test no. 15.

**1.2.3** This standard does not address the following systems and use conditions:

1. Bulk adhesives mixed in open containers without automatically controlled metering and mixing of adhesive components.
2. Adhesives to adhere structural elements to concrete surfaces outside of a drilled hole.
3. Adhesive anchors in aggressive environments not specifically considered in this standard.
4. Adhesive anchors to resist fatigue or shock loading.
5. Injection-type adhesive anchor systems for horizontal and upwardly inclined installations that do not employ a piston plug or similar device to provide back pressure during the adhesive injection process.