An ACI Standard

Qualification of Post-Installed Mechanical Anchors in Concrete (ACI 355.2-19) and Commentary

Reported by ACI Committee 355

ACI 355.2-19

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ACI 355.2 prescribes testing programs and evaluation requirements for post-installed mechanical anchors intended for use in concrete under the design provisions of ACI 318. Criteria are prescribed for determining whether anchors are acceptable for use in uncracked concrete only, or in cracked as well as uncracked concrete. Performance categories for anchors are established, as are the criteria for assigning anchors to each category. The anchor performance categories are used by ACI 318 to assign capacity reduction factors and other design parameters.

Keywords: anchors; cracked concrete; expansion anchors; fasteners; mechanical anchors; post-installed anchors; screw anchors; undercut anchors.

ACI 355.2R-19 supersedes 355.2-07, became effective April 8, 2019, and was published June 2019.

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CHAPTER 1—SCOPE

1.1 ACI 355.2 prescribes testing and evaluation requirements for post-installed mechanical anchors intended for use in concrete designed under the provisions of ACI 318. Criteria are prescribed to determine whether anchors are acceptable for use in uncracked concrete only, or in cracked as well as uncracked concrete. Criteria are prescribed to determine the performance category for each anchor. The anchor performance categories are used by ACI 318 to assign capacity reduction factors and other design parameters.

1.2 ACI 355.2 describes the tests required to qualify a post-installed mechanical anchor or anchor system for use under the provisions of ACI 318.

1.3 ACI 355.2 applies to post-installed mechanical anchors (torque-controlled expansion anchors, displacement-controlled expansion anchors, undercut anchors, and screw anchors) placed into predrilled holes and anchored within the concrete by mechanical means.

1.4 ACI 355.2 applies to expansion, undercut, and screw anchors with a minimum effective embedment depth of 1-1/2 in. (40 mm) and with a nominal diameter of 1/4 in. (6 mm) or larger. Screw anchors are limited to a maximum effective embedment of $10d_a$ (refer to R1.4).

1.5 The values stated either in inch-pound units or SI units are to be separately regarded. Within the text, the SI units are shown in parentheses. The values in each system are

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CHAPTER R1—SCOPE

R1.1 ACI 355.2 prescribes the testing programs required to qualify post-installed mechanical anchors for use with the design method of ACI 318-19 Chapter 17, where it is assumed that anchors have been tested either for use in uncracked concrete or for use in cracked and uncracked concrete. This testing is performed in concrete specimens controlled by the testing laboratory as a means of simulating concrete, both cracked and uncracked, that might occur in actual structures. Post-installed mechanical anchors exhibit a range of working principles, proprietary designs, and performance characteristics. ACI 318-19 Chapter 17 addresses this situation by basing capacity reduction factors for anchors on anchor performance categories. ACI 355.2 is intended to develop the data required by ACI 318-19 Chapter 17 to confirm an anchor's reliability and place it in the appropriate anchor category.

Procedures for making and controlling cracks in test members have been published. Also, ASTM E488/E488M includes some details for cracked concrete test members similar to those in this document. ASTM E488/E488M also has detailed test procedures for testing in cracked concrete.

R1.4 The design method deemed to satisfy the anchor design requirements of ACI 318-19 Chapter 17 is based on an analysis of a database of anchors with a maximum diameter of 2 in. (50 mm) and an embedment depth not greater than 25 in. (635 mm). ACI 355.2 can be used for anchors with those maximum dimensions. While ACI 355.2 gives no limitations on maximum anchor diameter or embedment depth, for anchors beyond these dimensions, the testing authority should decide if the tests described herein are applicable or if alternative tests and analyses are more appropriate. The minimum diameter of 1/4 in. (6 mm) is based on practical considerations regarding the limit of structural anchor applications. The current database of screw anchors contains products with an embedment up to $h_{ef} = 10d_a$ due to practical limits of manufacturing and ability to install at deep embedments. This database has been shown to satisfy the design requirements of ACI 318-19 Chapter 17. Additional research for deeper embedments would be required to further expand the scope of ACI 355.2 for screw anchors.

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not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems shall result in nonconformance with ACI 355.2.

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CHAPTER 2—DEFINITIONS AND NOTATION

2.1—Definitions

2.1.1 *anchor category*—classification for an anchor that is established by the performance of the anchor in reliability tests.

2.1.2 *anchor group*—number of anchors of approximately equal effective embedment depth with each anchor spaced at less than three times its embedment depth from one or more adjacent anchors.

2.1.3 *anchor system*—similar anchors that vary only due to diameter or embedment depth; a product line of a single manufacturer.

2.1.4 *characteristic value*—5 percent fractile (value with a 95 percent probability of being exceeded, with a confidence of 90 percent).

2.1.5 *concrete breakout failure*—concrete failure mode that develops a breakout or edge failure of the test member due to setting of the anchor or to applied loads.

2.1.6 *cracked concrete*—concrete test member with a single, full-depth, approximately uniform width crack.

2.1.7 *displacement-controlled expansion anchor*—post-installed anchor that is set by expansion against the side of the drilled hole through movement of an internal plug in the sleeve or through movement of the sleeve over an expansion element (plug); once set, no further expansion can occur.

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

2.1.9 *pullout failure*—failure mode in which the anchor pulls out of the concrete without development of the full steel or concrete capacity.

2.1.10 *pull-through failure*—failure mode in which the anchor body pulls through the expansion mechanism without development of the full steel or concrete capacity.

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CHAPTER R2—DEFINITIONS AND NOTATION

R2.1—Definitions

R2.1.4 *characteristic value*—The characteristic value is used for design in ACI 318-19 Chapter 17. The characteristic value is less than the average by a percentage of the average and based on the number of tests conducted, the confidence level that the code-writing body elects to use, and an accepted failure rate. The characteristic value or 5 percent fractile (value with a 95 percent probability of being exceeded, with a confidence of 90 percent) has been selected for the design of anchorages.

R2.1.5 *concrete breakout failure*—Concrete breakout failure includes concrete breakout under tension load, edge breakout from tension or shear, or combinations of these, as shown in Fig. 5.5.3a and 5.5.3b.

R2.1.8 *pullout failure*—Pullout failure occurs if the anchor does not sufficiently engage the concrete to produce a steel or concrete breakout failure. The entire anchor slips out of the drilled hole at a load lower than that corresponding to concrete breakout. While a concrete breakout may occur as part of the pullout failure, it will be at a shallower embedment depth than for a full concrete breakout failure.

R2.1.9 *pull-through failure*—Pull-through failure occurs if the anchor shank pulls through the expansion mechanism, which remains in the drilled hole. The anchor shank slips out of the drilled hole at a load lower than that corresponding to concrete breakout.

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2.1.11 *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 concrete during installation.

2.1.12 *setting of an anchor*—process of activating the load-transfer mechanism of an anchor in a drilled hole.

2.1.13 *splitting failure*—concrete failure mode in which the concrete fractures along a plane passing through the axis of the anchor or anchors.

2.1.14 *statistical equivalence*—statistical equivalence of two groups of test results shall be determined by two one-sided *t*-test (TOST) in accordance with ASTM E2935 at a significance $\alpha = 0.10$ for an assumed symmetrical equivalence limit $E = 15$ percent. For this purpose, the equivalence or nonequivalence of variances shall be established with the F-test or with Levene's test with $\alpha = 0.10$.

2.1.15 *steel failure*—failure mode in which the steel anchor parts fracture.

2.1.16 *test series*—group of tests having the same parameters.

2.1.17 *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 cone(s) into the expansion sleeve(s); after setting, tensile loading can cause additional expansion (follow-up expansion).

2.1.18 *uncracked concrete*—test member that remains uncracked, unless the crack is part of a failure mode.

2.1.19 *undercut anchor*—post-installed anchor that develops its holding strength from the mechanical interlock provided by undercutting of the concrete, achieved either by a special tool or by the anchor itself during installation.

2.2—Notation

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

c_{ac} = critical edge distance required to develop the basic strength as controlled by concrete breakout of a single post-installed anchor in tension in

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R2.1.12 *statistical equivalence*—The two one-sided t-Test (TOST) is used in place of the Student's t-test to establish equivalency of data sets because it appropriately associates the significance (α) with consumer risk instead of producer risk.

R2.1.18 *uncracked concrete*—Under ACI 355.2, anchors for use in uncracked concrete are tested in concrete that is uncracked and is expected to remain so unless the anchor causes cracking as part of the failure mode.

R2.2—Notation

$A_{se,N}$ = 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)

For post-installed anchors having a reduced cross-sectional area anywhere along the anchor length, the effective cross-sectional area of the anchor should be provided