IN-LB Inch-Pound Units

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Post-Installed Mechanical Anchors in Concrete—Qualification Requirements and Commentary

Reported by ACI Committee 355

ACI CODE-355.2-22

American Concrete Institute
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First Printing: September 2022
ISBN: 978-1-64195-192-0

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ACI CODE-355.2 prescribes testing programs and evaluation requirements for post-installed mechanical anchors intended for use in structural applications addressed by ACI 318 and subjected to static or seismic loads in tension, shear, or combined tension and shear. 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.

This Code was developed by an ANSI-approved consensus process.

ACI CODE-355.2-22 supersedes ACI 355.2R-19 and was adopted and published in September 2022.

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CHAPTER 1—GENERAL

1.1—Scope

ACI CODE-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—General

ACI CODE-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—Purpose

ACI CODE-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—Applicability

ACI CODE-355.2 applies to expansion, undercut, and screw anchors with a minimum effective embedment depth of 1-1/2 in. and with a nominal diameter of 1/4 in. or larger. Screw anchors are limited to a maximum effective embedment of $10d_a$.

COMMENTARY

CHAPTER R1—GENERAL

R1.1—Scope

ACI CODE-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 CODE-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.

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—Applicability

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. and an embedment depth not greater than 25 in. ACI CODE-355.2 can be used for anchors with those maximum dimensions. While ACI CODE-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. 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.

CODE	COMMENTARY

1.5—Interpretation

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 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 CODE-355.2.

CODE

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—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 uncracked concrete without supplementary reinforcement to control splitting, in. (mm)

c_{min} = minimum allowable edge distance as determined from testing and given in manufacturer's data sheets, in. (mm)

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

d_f = diameter of the hole in the testing fixture

d_m = diameter of carbide-tipped drill bit with diameter on low end of tolerance range for new bit, representing moderately used bit, in. (mm)

d_{max} = diameter of carbide-tipped drill bit with diameter on high end of tolerance range for new bit, representing bit as large as would be expected in use, in. (mm)

d_{min} = diameter of carbide-tipped drill bit with diameter below low end of tolerance range for new bit, representing a well-used bit, in. (mm)

$F_{5\%}$ = characteristic capacity in test series, as calculated using Eq. (A2.2), lb (N)

F_m = mean failure capacity, lb (N)

$F_{m,i}$ = mean normalized capacity in test series i, as calculated using Eq. (A1.2), lb (N)

F_{ut} = mean normalized anchor capacity in test series i as calculated using Eq. (A1.4), lb (N)

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

f_c' = specified compressive strength of concrete, psi (MPa)

$f_{c,m,i}$ = concrete compressive strength to which test results for test series i are to be normalized using Eq. (A1.2), psi (MPa)

$f_{c,ref}$ = the concrete compressive strength of the specimen used for the confined reference tests

$f_{c,test}$ = mean concrete compressive strength as measured at time of testing

$f_{c,test,i}$ = mean concrete compressive strength measured with standard cylinders, for concrete of test series i, psi (MPa)

f_{ut} = specified ultimate tensile strength of anchor steel, psi (MPa)

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

COMMENTARY

CHAPTER R2—NOTATION AND DEFINITIONS

R2.1—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)

CODE

f_y = specified yield strength of anchor steel, psi (MPa)
h = thickness of structural member, measured perpendicular to concrete surface where the anchor is installed, in. (mm)
h_{ef} = effective embedment depth for expansion, undercut, and screw anchors
h_{hole} = overall depth of the drilled hole, in. (mm)
h_{min} = minimum member thickness, specified by the anchor manufacturer, in. (mm)
h_{nom} = distance between the embedded end of the expansion, undercut, or screw anchor, and the concrete surface, in. (mm)
h_s = length of the embedded end of the screw anchor without full height of thread (= thread runout + length without thread), in. (mm)
h_t = thread pitch, in. (mm)
K = statistical constant (one-sided tolerance factor) used to establish 5 percent fractile with a 90 percent confidence, whose value depends on the number of tests (Appendix A2)
k = effectiveness factor, whose value depends on the type of anchor
k_{cr} = effectiveness factor for anchors tested in cracked concrete
k_m = mean effectiveness factor
k_{uncr} = effectiveness factor for anchors tested in uncracked concrete
N = normal force (generally tensile), lb (N)
N_1 = minimum tension load above which variations in the load-displacement curve are acceptable, as prescribed in 6.5.1.1, lb (N)
$N_{10\%}$ = mean load at 10 percent of ultimate load measured in tension test, lb (N)
$N_{30\%}$ = mean load at 30 percent of ultimate load measured in tension tests, lb (N)
N_b = characteristic tensile capacity of an anchor with a concrete failure mode (5 percent fractile of test results), lb (N)
$N_{b,o}$ = characteristic tensile capacity in reference tests, lb (N)
$N_{b,r}$ = characteristic tensile capacity in reliability tests, lb (N)
N_{eq} = maximum tension load to be applied in the simulated seismic tension test in accordance with Table 10.5.2, Fig. 10.5.2, and Eq. (10.5.2), lb (N)
$N_{eq,reduced}$ = reduced maximum tension load at which the anchor successfully completes the simulated seismic tension test, lb (N)
N_i = intermediate tension load to be applied in the simulated seismic tension test in accordance with Table 10.5.2 and Fig. 10.5.2, lb (N)
$N_{i,reduced}$ = reduced intermediate tension load at which the anchor successfully completes the simulated seismic tension test, lb (N)

COMMENTARY