| IN-LB | Inch-Pound Units |
|---|---|
| SI | International System of Units |

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

Reported by ACI Committee 355

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# ACI CODE-355.2-24

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

## An ACI Standard

## Reported by ACI Committee 355


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*This Code prescribes testing programs and evaluation requirements for post-installed mechanical anchors intended for use in structural applications addressed by ACI CODE-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 CODE-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.


## CONTENTS




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## CHAPTER 1—GENERAL

### 1.1—Scope

This Code prescribes testing and evaluation requirements for post-installed mechanical anchors intended for use in concrete designed under the provisions of ACI CODE-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 CODE-318 to assign capacity reduction factors and other design parameters.

### 1.2—General

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

### 1.3—Purpose

This Code 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

This Code 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 $10d_a$.

# COMMENTARY

## CHAPTER R1—GENERAL

### R1.1—Scope

This Code prescribes the testing programs required to qualify post-installed mechanical anchors for use with the design method of ACI CODE-318 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 CODE-318 Chapter 17 addresses this situation by basing capacity reduction factors for anchors on anchor performance categories. This Code is intended to develop the data required by ACI CODE-318 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 CODE-318 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). This Code can be used for anchors with those maximum dimensions. While this Code 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 CODE-318 Chapter 17.

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## 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 this Code.

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## CHAPTER 2—NOTATION AND DEFINITIONS

### 2.1—Notation

$A_g$ = cross-sectional area of test member, in.$^2$ (mm$^2$)

$A_s$ = effective stressed cross-sectional area of steel element, in.$^2$ (mm$^2$)

$A_{s,anc}$ = total anchor cross-sectional area equal to the sum of the bolt and sleeve areas in.$^2$ (mm$^2$)

$A_{s,b}$ = effective stressed cross-sectional area of bolt, in.$^2$ (mm$^2$)

$A_{s,sl}$ = effective stressed cross-sectional area of sleeve, in.$^2$ (mm$^2$)

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

$b$ = width of concrete test member, in. (mm)

$C_{ini}$ = initial centric compression force on concrete test member in Table 5.1b, Test 20, lb (N)

$C_{test}$ = centric compression force on concrete test member during crack cycling in Table 5.1b, Test 20, lb (N)

$c$ = edge distance of anchor, in. (mm)

$c_{ac}$ = 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, in. (mm)

$d_m$ = 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)

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

## 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

$F_{ut}$ = mean normalized anchor capacity in test series *i* as calculated using Eq. (A1.4), 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* shall be normalized using Eq. (A1.2), psi (MPa)
$f_{c,ref}$ = concrete compressive strength of the specimen used for the confined reference tests, psi (MPa)
$f_{c,test}$ = mean concrete compressive strength as measured at time of testing, psi (MPa)
$f_{c,test,i}$ = mean concrete compressive strength measured with standard cylinders, for concrete of test series *i*, psi (MPa)
$f_{u,test}$ = mean ultimate tensile strength of anchor steel as determined by test, psi (MPa)
$f_{ut}$ = specified ultimate tensile strength of anchor steel, psi (MPa)
$f_y$ = 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, in. (mm)
$h_{hole}$ = 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% fractile with a 90% 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% of ultimate load measured in tension test, lb (N)
$N_{30\%}$ = mean load at 30% of ultimate load measured in tension tests, lb (N)

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$N_b$ = characteristic tensile capacity of an anchor with a concrete failure mode (5% 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)
$N_k$ = lowest characteristic tensile capacity in reference tests in uncracked concrete for concrete, steel, or pullout failures for the concrete strength of the test member, lb (N)
$N_{max}$ = maximum load to be applied in the seismic tension test in accordance with 10.6.6, lb (N)
$N_{p,cr}$ = nominal pullout strength in tension of a single anchor in cracked concrete, lb (N)
$N_{p,eq}$ = nominal pullout strength in tension of a single anchor for load cases including earthquake loading in accordance with ACI CODE-318, lb (N)
$N_{p,seis}$ = nominal seismic pullout strength in tension of a single anchor, lb (N)
$N_{p,uncr}$ = nominal pullout strength in tension of a single anchor in uncracked concrete, lb (N)
$N_{sa}$ = nominal tensile steel strength of a single anchor in accordance with ACI CODE-318, lb (N)
$N_{sa,seis}$ = nominal seismic tensile steel strength of a single anchor, lb (N)
$N_{st}$ = characteristic tensile steel capacity of an anchor, lb (N)
$N_{st,mean}$ = average ultimate steel capacity determined from tensile tests on full-sized anchor specimens, in accordance with Table 7.3.6a, lb (N)
$N_{sust,con}$ = sustained load used for confined reference tests, lb (N)
$N_u$ = ultimate load measured in a tension test, lb (N)
$N_{u,con,mean}$ = average ultimate load determined from confined reference tests, lb (N)
$N_{u,mean}$ = average ultimate load measured in a tension test series, lb (N)
$N_w$ = tensile load in tests of anchors located in cracks whose opening width is cycled, lb (N)
$N_{w1}$ = first load step in seismic test with crack cycling determined in accordance with 10.6.7.4, lb (N)
$N_{w2}$ = second load step in seismic test with crack cycling determined in accordance with 10.6.7.4, lb (N)
$n$ = number of anchors in a test series
$s_{min}$ = minimum spacing used in Table 5.1a, Test 13, and Table 5.1b, Test 16, in. (mm)
$T$ = applied torque in a test, ft-lb (N-m)
$T_{5\%}$ = 5% fractile of the ultimate torque $T_u$, calculated in accordance with Appendix A2, ft-lb (N-m)
$T_{inst}$ = specified or maximum setting torque for expansion or prestressing of an anchor, ft-lb (N-m)

## COMMENTARY

$n_t$ = number of threads per inch (millimeter)