

Commentary on Evaluating the Performance of Post-Installed Mechanical Anchors in Concrete (ACI 355.2R-00)

Reported by ACI Committee 355

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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. ACI 318 differentiates between cracked and uncracked concrete. In ACI 318, it is assumed that anchors for anchoring to concrete have been tested either for use in uncracked concrete or for use in cracked and uncracked concrete. Today, many different post-installed mechanical anchors are available for use in concrete. These anchors exhibit a range of working principles, proprietary designs, and performance characteristics. ACI 318 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 to confirm an anchor's reliability and place it in the appropriate anchor category.

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R1.4—While ACI 355.2 gives no limitations on maximum anchor diameter or embedment, the design method deemed to satisfy the anchor design requirements of ACI 318 Appendix D is based on an analysis of a database of anchors with a maximum diameter of 2 in. (51 mm) and an embedment not greater than 25 in. (0.64 m). ACI 355.2 can be used for anchors with those maximum dimensions. For anchors beyond these dimensions, the testing authority should decide if the tests described here are applicable or if alternative tests and analyses are more appropriate. The minimum diameter of 1/4 in. (6.4 mm) is based on practical considerations regarding the limit of structural anchor applications.

R2.1.5—Concrete breakout failure includes concrete cone breakout under tension load, edge breakout from tension or shear, or combinations of these, as shown in Fig. 6.3 and 6.4.

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

R2.1.9—Pull-through failure occurs when 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 cone breakout.

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R2.1.12—The statistical equivalence determination uses a one-sided *t*-test because the mean of a test series is compared to the mean of another reference test series. The hypothesis is that the mean of the reference test is greater than (or less than) the mean of the second series of anchor tests.

R2.1.16—Under ACI 355.2, anchors for use in uncracked concrete are tested in concrete that is uncracked and expected to remain so, unless the anchor causes cracking as part of the failure mode.

R2.2—Notation

A_{se} = The characteristic tensile steel capacity can be taken as the minimum specified steel strength or can be calculated from tests. For expansion anchors with reduced cross-sectional area for the expansion mechanism, the effective cross-sectional area of the anchor should be provided by the manufacturer. For threaded bolts, ANSI/ASME B1.1 defines A_{se} as:

$$A_{se} = \frac{\pi}{4} \left(d_o - \frac{0.9743}{n_t} \right)^2$$

where n_t is the number of threads per inch.

R3.1—Experience shows that plastic hinge regions in reinforced concrete structures subjected to earthquake loading typically develop crack widths well in excess of the crack widths anticipated by ACI 355.2.

R5.1—ACI 355.2 follows a four-step procedure (covering four types of tests) to check the suitability of the anchor for structural purposes (within the use limits established by ACI 318) and to establish a performance category for the anchor that can be used with the design approach established by ACI 318. The four test types are identification, reference, reliability, and service-condition tests. Flow charts giving the testing sequences are presented in Fig. R1 through R6.

Identification tests are required to determine if the anchor complies with fabrication requirements and to establish a baseline for quality assurance.

Reference tests serve two functions. They establish the characteristic resistance to be used in the design of single anchors with large edge distances and spacings. They are also intended to be compared with results of the reliability tests. For the reference tests, anchors should be installed according to manufacturer's instructions.

Reliability tests serve two functions: the first is to establish the anchor categories used in ACI 318; and the second is to check the reliability of the anchor under sustained loads and variable loads. The anchor should be capable of safe and effective behavior under normal and adverse conditions, both during installation and in service. Factors included are sensitivity to variations of:

- Installation conditions in concrete;
- Drill bit diameter;
- Sustained and variable loads on the anchor;
- Crack width (for anchors for use in cracked and uncracked concrete only); and
- Crack width associated with long-term and variable loading of the structure (for anchors for use in cracked and uncracked concrete only).

To reduce the scope of the required test program, the effects of these factors on anchor performance are combined in the required tests.

The procedures prescribed for checking the reliability of an anchor and assigning an anchor category to it consider possible on-site deviations from the manufacturer's specified installation procedure. ACI 355.2, however, does not cover gross installation errors, which are assumed to be prevented by appropriate training and site inspection. Such gross errors include but are not limited to: drill bits of the wrong diameter; inappropriate drilling methods; improper setting tools; inappropriate setting methods; and failure to clean, dry, or otherwise prepare the drilled hole as required by the manufacturer.

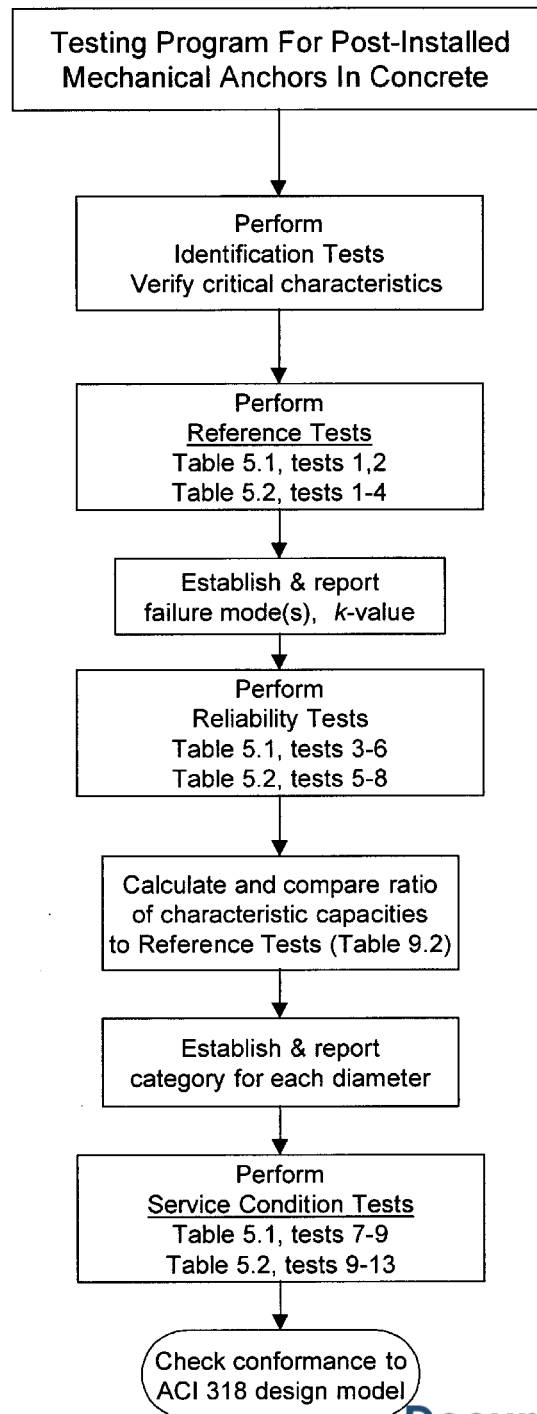


Fig. R1—Flow chart for overall testing program

To represent normal conditions, the repeated load test (Table 5.1, Test 6) and the test in which the crack width is cycled (Table 5.2, Test 8) are performed with a drill bit of diameter d_m .

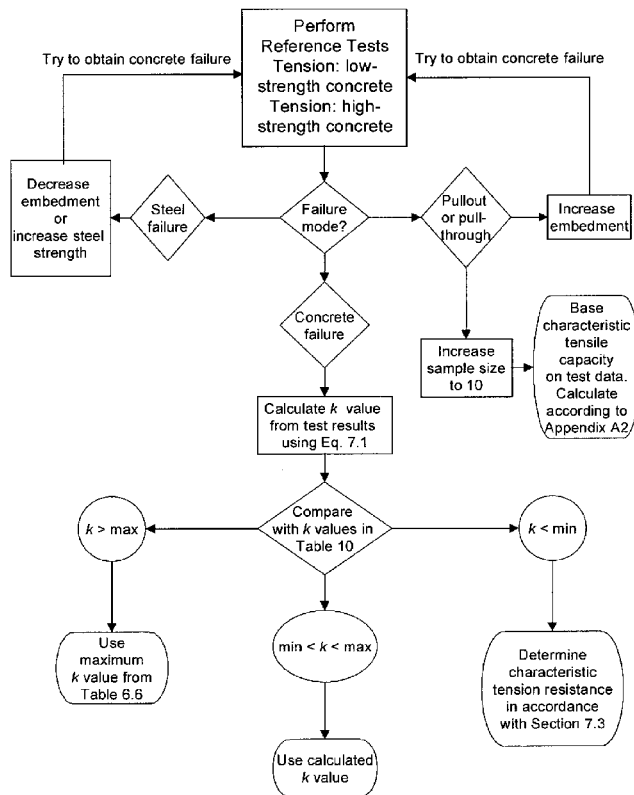


Fig. R2—Flow chart for reference tests.

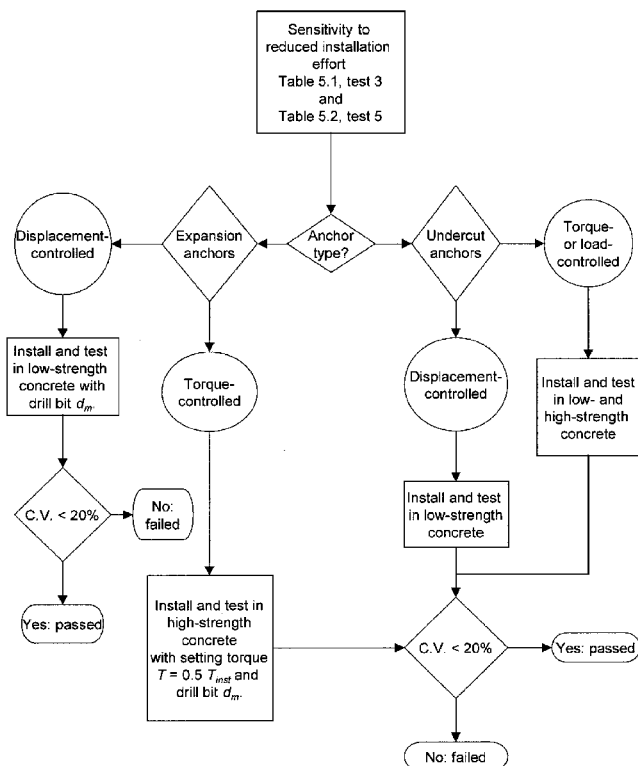


Fig. R3—Flow chart for tests with reduced installation effort.

The selected combination of conditions is intended to minimize the test program while maintaining an acceptable level of safety of the entire connection. The observed anchor capacities from the reliability tests can be lower than from the reference tests, provided that the reduction is limited and well defined. The low probability of observed anchor capacity occurrence associated with the reference test conditions is assumed to compensate for the reduced capacity, in effect maintaining a relatively constant probability of failure. Based on the magnitude of the reduction, the anchor category is established.

R5.2—Prototypes can be used for testing if the anchor samples are prepared in the same manner as expected for production. Identification and reference tests are performed on the production samples and their performance is compared statistically to the results of the tested prototypes to determine if additional tests need to be performed.

R5.2.2—If different materials, such as carbon steel rather than stainless steel, or different production methods, such as cold-forming rather than machining, are used for a given anchor diameter, reference tests should be performed for each type and compared statistically. If they are statistically equivalent, then only one set of reliability and service-condition tests needs to be performed for the anchors.

R6.1—The purpose of the requirements governing the concrete used in test specimens is to reduce the variables that might affect anchor performance, thereby making the test results more reproducible. Various cementitious materials and concrete admixtures can affect anchor performance, increasing the scatter of test data. The influence of different concrete

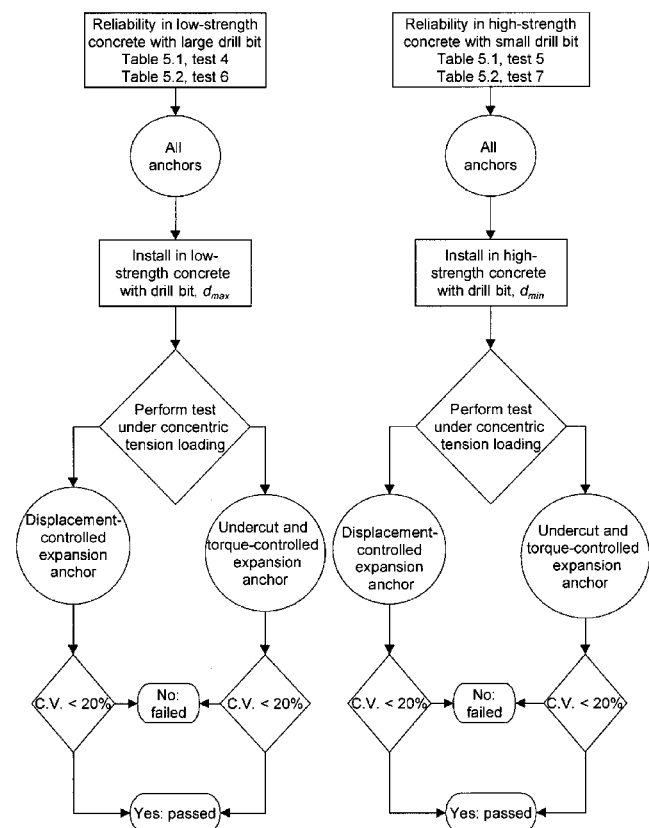
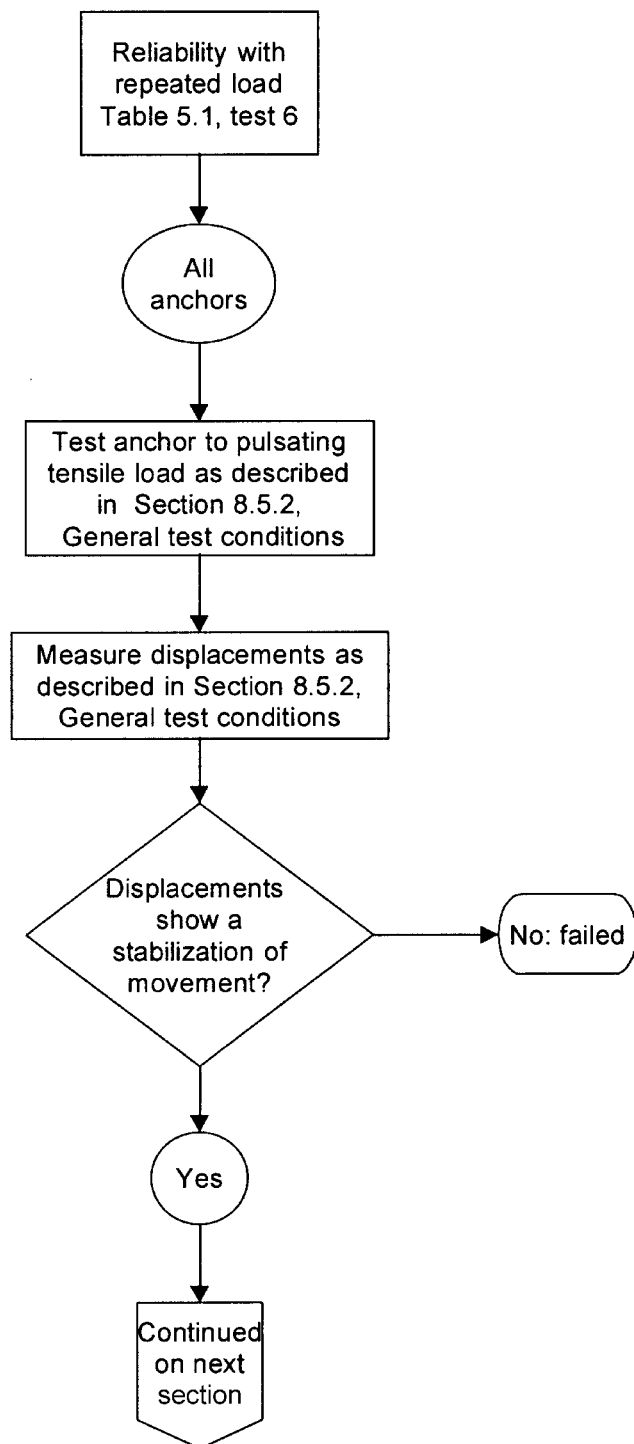


Fig. R4—Flow chart for reliability tests for sensitivity to large and small holes.

mixtures on anchor performance is part of the consideration in establishing the capacity reduction factors in the design method of ACI 318.

R6.1.2—Testing is performed in plain concrete with no cementitious replacements or concrete admixtures added to the concrete. With such concrete, the anchors are approved for use with mixtures that contain these materials. If the tests are performed with concrete mixtures that contain cementitious replacements or admixtures, then the anchors are approved only for that mixture proportion.



R6.1.3—Experience indicates that the performance of some expansion anchor types may be adversely affected in high-strength concrete. ACI 318 establishes an upper limit of 8,000 lb/in.² (55 MPa) on the specified concrete compressive strength for which the design method is applicable. Elsewhere in the Code, a lower limit on specified compressive strength of 2,500 lb/in.² (17 MPa) is established. Actual in-place concrete strength can be 15 to 20% higher than specified.

R6.2.2—The tests in this program are based on the assumption that the holes are drilled by carbide-tipped, rotary-hammer drill bits. If the anchors are installed into holes drilled by another standard method, such as with diamond-core bits, the manufacturer should prescribe the drill bits, associated tolerances, and drilling procedures. The bit toler-

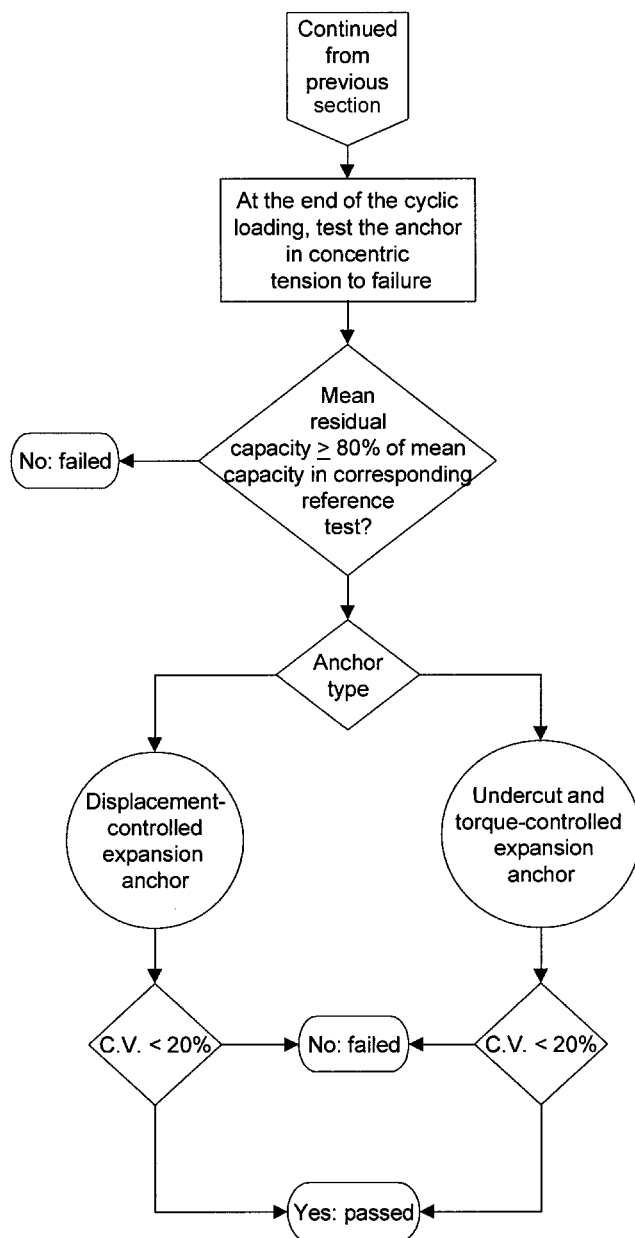


Fig. R5—Flow chart for reliability tests with repeated loads.