Designation: C 900 – 94

Standard Test Method for Pullout Strength of Hardened Concrete[1]

This standard is issued under the fixed designation C 900; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers determination of the pullout strength of hardened concrete by measuring the force required to pull an embedded metal insert and the attached concrete fragment from a concrete test specimen or structure.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

E 4 Practices for Load Verification of Testing Machines[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

3. Summary of Test Method

3.1 A metal insert is embedded in fresh concrete. After the concrete has hardened, the insert is pulled by means of a jack reacting against a bearing ring. The pullout strength is determined by measuring the maximum force required to pull the insert from the concrete mass.

4. Significance and Use

4.1 For a given concrete and a given test apparatus, the pullout strength can be related to other strength test results. Such strength relationships depend on the configuration of the embedded insert, bearing ring dimensions, depth of embedment (see 5.1.2), and level of strength development in that concrete. Prior to use, these relationships must be established for each system and each new combination of concreting materials. Such relationships tend to be less variable where both pullout test specimens and other strength test specimens are of consistent size and cured under similar conditions.

NOTE 1—Published reports **(1-14)**[3] by different researchers present their experiences in the use of pullout test equipment.

4.2 Pullout tests are used to determine whether the in-place strength of concrete has reached a specified level so that, for example:

(*1*) post-tensioning may proceed;

(*2*) forms and shores may be removed; or

(*3*) winter protection and curing may be terminated.

4.3 When planning pullout tests and analyzing test results, consideration should be given to the normally expected decrease of concrete strength with increasing height within a given concrete placement in a structural element.

5. Apparatus

5.1 The apparatus requires three basic sub-systems: a pullout insert, a loading system, and a load-measuring system.

NOTE 2—A center-pull hydraulic jack with a suitable pressure gage and bearing ring have been used satisfactorily.

5.1.1 The insert shall be made of metal that does not react with cement. The insert shall consist of a cylindrical head to be embedded in fresh concrete. A shaft to fix embedment depth shall be firmly attached to the head. The insert shaft may be removeable and threaded to the insert head or it may be an integral part of the insert. Metal components of the insert and attachment hardware shall be of similar material to prevent galvanic corrosion.

5.1.2 The loading system shall consist of a bearing ring to be placed against the hardened concrete surface concentrically around the insert shaft (see Fig. 1), and a loading apparatus with the necessary load-measuring devices that can be readily attached to the pullout shaft.

5.1.3 The test apparatus shall include centering features that ensure that the bearing ring is concentric with the insert shaft, and that the applied load is axial to the pullout shaft, perpendicular to the bearing ring, and uniform on the bearing ring.

5.2 Equipment dimensions shall be determined as follows (see Fig. 1):

5.2.1 The diameter of the head of the insert (d_2) shall be determined by the specifier. The thickness of the insert head and the yield strength of the metal shall be sufficient to avoid yielding of the insert during test. The sides of the insert head shall be smooth.

NOTE 3—Typical sizes are 25 and 30 mm (1 and 1.2 in.) in diameter, but smaller and larger sizes have been used.

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[1] This test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive Testing of Concrete.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] The boldface numbers refer to the list of references at the end of this test method.

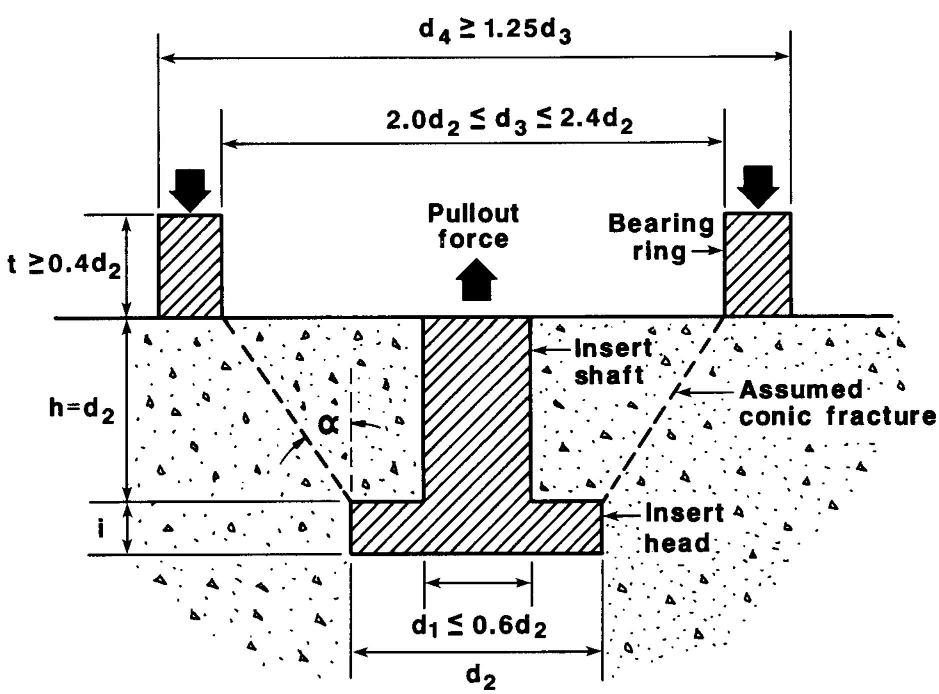

FIG. 1 Schematic Cross Section of Pullout Test

NOTE 4—The pullout insert may be coated with a release agent to minimize bonding with the concrete, it may be tapered to minimize side friction during testing. The insert head shall be provided with the means, such as a notch, to prevent rotation in the concrete if the insert shaft has to be removed prior to performing the test. As a further precaution against rotation of the insert head, all threaded hardware shall be checked prior to installation to ensure that it is free-turning and can be easily removed.

5.2.2 The length of the pullout insert shaft shall be such that the distance from the insert head to the concrete surface (h) equals the diameter of the insert head (d_2). The diameter of the insert shaft at the head (d_1) shall be no more than 0.60 times the head diameter.

5.2.3 The bearing ring shall have an inside diameter (d_3) of 2.0 to 2.4 times the insert head diameter, and shall have an outside diameter (d_4) of at least 1.25 times the inside diameter. The thickness of the ring (t) shall be at least 0.4 times the pullout insert head diameter.

5.2.4 Tolerances for dimensions of the pullout test inserts shall be ±2 % within a given system.

NOTE 5—The limits for dimensions and configurations for pullout test inserts and apparatus are intended to accommodate various systems.

5.2.5 The loading apparatus shall have sufficient capacity to provide the loading rate prescribed in 7.4 and exceed the maximum load expected.

NOTE 6—Hydraulic pumps that provide a uniform loading rate may give more uniform test results than pumps that apply the load intermittently.

5.2.6 Gages shall have a least division not larger than 5 % of the minimum value in the intended range of use.

NOTE 7—For the most accurate results, gages should have a maximum value indicator that preserves the value of the ultimate load when ultimate failure and subsequent stress release occur.

5.2.7 Pullout apparatus shall be calibrated at least once a year and after all repairs or adjustments. Calibration shall be by one of the methods in Practices E 4, or with a compression testing machine conforming to the requirements of Test Method C 39 using the calibration procedures described in the Annex to this test method.

6. Sampling

6.1 Pullout test locations shall be separated so that the clear spacing between inserts is at least ten times the pullout insert head diameter. Clear spacing between the inserts and the edges of the concrete shall be at least four times the head diameter. Inserts shall be placed so that reinforcement is outside the expected conical failure surface by more than one bar diameter, or the maximum size of aggregate, whichever is greater.

6.2 When pullout test results are used to assess the in-place strength in order to allow the start of critical operations, such as formwork removal or application of post tensioning, at least five individual pullout tests shall be performed for a given placement for every 115 m^3 (150 yd^3), or a fraction thereof, or for every 470 m^2 (5000 ft^2), or a fraction thereof, of the surface area of one face in the case of slabs or walls.

NOTE 8—Inserts shall be located in those portions of the structure that are critical in terms of exposure conditions and structural requirements.

7. Procedure

7.1 Attach the pullout inserts to the forms using bolts or by other acceptable methods that firmly secure the insert in its proper location prior to concrete placement. All inserts for the same tests shall be embedded to the same depth and each shaft shall be perpendicular to the formed surface.

NOTE 9—Inserts may be manually placed into unformed horizontal concrete surfaces. The inserts shall be embedded into the fresh concrete by means that ensure a uniform embedment depth and a plane surface perpendicular to the axis of the insert shaft. Installation of inserts shall be performed or supervised by experienced personnel. Experience indicates that pullout strengths are of lower value and more variable for manually-placed surface inserts than for inserts attached to the formwork.

7.2 When the concrete is to be tested, remove all hardware used for securing the pullout inserts in position. Before mounting the loading system, remove any debris or surface abnormalities to ensure a smooth bearing surface that is perpendicular to the axis of the insert.

7.3 Use a bearing ring for all surface pullout-test configurations. Place the bearing ring around the pullout insert shaft, connect the pullout shaft to the hydraulic ram, and tighten the pullout assembly snugly against the bearing surface, checking to see that the bearing ring is centered around the shaft and flush against the concrete.

7.4 If the insert is to be tested to rupture of the concrete, load at a uniform rate, that will cause pullout rupture to occur in 120 ± 30 s. Record the maximum gage reading to the nearest half of the least division on the dial. If the insert is to be tested only to a specified level for acceptance, load at a uniform rate that will reach the specified level in 120 ± 30 s.

8. Calculation

8.1 Convert test readings to force on the basis of calibration data.

8.2 When a stress calculation is desired, compute a nominal normal stress on the assumed conical fracture surface by dividing the pullout force by the area of the frustum and multiplying by the sine of one-half the apex angle. The following equations may be used:

$$f_n = (P/A) \text{ sine } a \quad (1)$$

$$\text{sine } a = (d_3 - d_2)/2S \quad (2)$$

$$A = \pi S\,(d_3 + d_2)/2 \quad (3)$$

$$S = \sqrt{h^2 + ((d_3 - d_2)/2)^2} \quad (4)$$

where:

f_n = nominal normal stress, MPa (psi),
P = pullout force, N (lbf),
a = ½ the frustum apex angle or: $\tan^{-1}(d_3 - d_2)/2h$
A = fracture surface area, mm^2 (in.^{2}),
d_2 = diameter of pullout insert head, mm (in.),
d_3 = inside diameer of bearing ring or large base diameter of assumed conic frustum, mm (in.),
h = height of conic frustum, from insert head to large-base surface, mm (in.), and
S = slant height of the frustum, mm (in.)

9. Report

9.1 Report the following information:

9.1.1 Dimension of the pullout insert and bearing ring (sketch or define dimensions),

9.1.2 Identification by which the specific location of the pullout test can later be determined,

9.1.3 Date and time when the pullout test was performed.

9.1.4 Maximum load, N (lbf),

9.1.5 Description of any surface abnormalities beneath the reaction ring at the test location,

9.1.6 Abnormalities in the ruptured specimen and in the loading cycle,

9.1.7 Concrete curing methods used and moisture condition of the concrete at time of test, and

9.1.8 Other information regarding unusual job conditions that may affect the pullout strength.

10. Precision and Bias

10.1 *Precision*—Based on the data summarized in ACI 228.1 R-89 **(14)** for pullout tests with embedment of about 25 mm (1 in.), the average coefficient of variation for tests made on concrete with maximum aggregate of 19 mm (¾ in.) by a single operator using the same test device is 8 %[4]. Therefore, the range in individual test results, expressed as a percentage of the average, should not exceed the following:

Number of Tests	Acceptable range, (percent of average)
5	31 %
7	34 %
10	36 %

10.2 *Bias*—The bias of this test method cannot be evaluated since pullout strength can only be determined in terms of this test method

[4] This number represents the (1s%) limit as described in Practice C 670.

ANNEX

(Mandatory Information)

A1. CALIBRATION OF PULLOUT-HYDRAULIC LOADING SYSTEM

A1.1 Calibrate the pullout-hydraulic loading system (pump, gage, and hydraulic jack) with a testing machine meeting the applicable requirements of Test Method C 39.

A1.2 Place the hydraulic jack between the two testing machine bearing blocks. Position the jack and bearing blocks to ensure concentric and axial loading, and extend the piston to the level anticipated for actual pullout testing. Carefully position the testing machine head against the pullout jack.

NOTE—Protection of the bearing blocks will be required to prevent damage to the test machine. Cold-rolled steel plate at least 13 mm (½ in.) thick is recommended.

A1.3 Using the hydraulic pump, apply loads progressively over the range of anticipated use, and record the hydraulic pressure gage reading and the testing machine load at each calibration load level. With available center-pull jacks, friction in the system produces different calibration curves on an increasing series of loads than on decreasing loads and therefore only increasing loads should be used. In general, readings should be taken at approximately 20 load levels distributed within the range of loads anticipated in use.

A1.4 Using readings obtained during calibration loading, calculate a linear regression equation using the least-squares curve-fitting method. Pullout testing may occur within a narrow range of the capacity of the pullout jack. If the test results fall within a narrow range, calculate the regression equation based on calibration readings in that range, excluding those outside the test range.

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