Designation: ~~C900 – 19~~ C900 – 23

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

This standard is issued under the fixed designation C900; 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. The insert is either cast into fresh concrete or installed in hardened concrete. This test method does not provide statistical procedures to estimate other strength properties.

1.2 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this test method.

1.3 The text of this test method refers to notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C125 Terminology Relating to Concrete and Concrete Aggregates
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
E4 Practices for Force Calibration and Verification of Testing Machines
E74 Practices for Calibration and Verification for Force-Measuring Instruments

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this method, refer to Terminology C125.

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

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

4. Summary of Test Method

4.1 A metal insert is either cast into fresh concrete or installed into hardened concrete. When a measure of the in-place pullout strength is desired, 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. Alternatively, the insert is loaded to a specified load to verify whether a minimum level of in-place pullout strength has been attained.

5. Significance and Use

5.1 For a given ~~concrete and a given~~ test apparatus, pullout strengths can be related to compressive strength test results. Such strength relationships are affected by the configuration of the embedded insert, bearing ring dimensions, depth of embedment, and the type of aggregate (lightweight or normal weight). Before use, the ~~relationships~~relationship must be established experimentally for each test system ~~and each new concrete mixture.~~ using a range of concrete mixtures or the specific concrete mixtures to be used in the project. Such relationships are more reliable if both pullout test specimens and compressive strength test specimens are of similar size, consolidated to similar density, and cured under similar conditions.

NOTE 1—Published reports (**1-~~17~~19**)[4] by different researchers present their experiences in the use of pullout test equipment. Refer to ACI ~~228.1R~~PRC-228.1 (**14**) for guidance on establishing a strength relationship and interpreting test results. ~~The Appendix provides a means for comparing pullout strengths obtained using different configurations.~~

5.2 If a strength relationship has been ~~established experimentally and~~ accepted by the specifier of tests, pullout tests are used to estimate the in-place strength of concrete to establish whether it has reached a specified level so that, for example:

(1) post-tensioning may proceed;
(2) forms and shores may be removed;
(3) structure may be placed into service; or
(4) winter protection and curing may be terminated.

In addition, post-installed pullout tests may be used to estimate the strength of concrete in existing construction.

5.3 ~~When~~In 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.

5.4 The measured pullout strength is indicative of the strength of concrete within the region represented by the conic frustum defined by the insert head and bearing ring. For typical surface installations, pullout strengths are indicative of the quality of the outer zone of concrete members and can be of benefit in evaluating the cover zone of reinforced concrete members.

5.5 Cast-in-place inserts require that their locations in the structure be planned in advance of concrete placement. Post-installed inserts can be placed at any desired location in the structure provided the requirements of 7.1 are satisfied.

5.6 This test method is not applicable to other types of post-installed tests that, if tested to failure, do not involve the same failure mechanism and do not produce the same conic frustum as for the cast-in-place test described in this test method (**16**).

6. Apparatus

6.1 The apparatus requires three basic sub-systems: a pullout insert, a loading system, and a load-measuring system (Note 2). For post-installed inserts, additional equipment includes a core drill, a planing tool to prepare a flat bearing surface, a grinding tool to undercut a groove to engage the insert, and an expansion tool to expand the insert into the groove.

NOTE 2—A center-pull hydraulic jack with a pressure gauge that has been standardized according to Annex A1 and that reacts against a bearing ring has been used ~~satisfactorily.~~as a satisfactory loading system.

6.1.1 Cast-in-place inserts shall be made of metal that does not react with the constituents of the concrete. The insert shall consist of a cylindrical head and a shaft to fix embedment depth. The shaft shall be attached firmly to the center of the head (see Fig. 1). The insert shaft shall be threaded to the insert head so that it can be removed and replaced by a stronger shaft to pullout the insert, or it shall be an integral part of the insert and ~~also~~ function as the pullout shaft. Metal components of cast-in-place inserts and

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

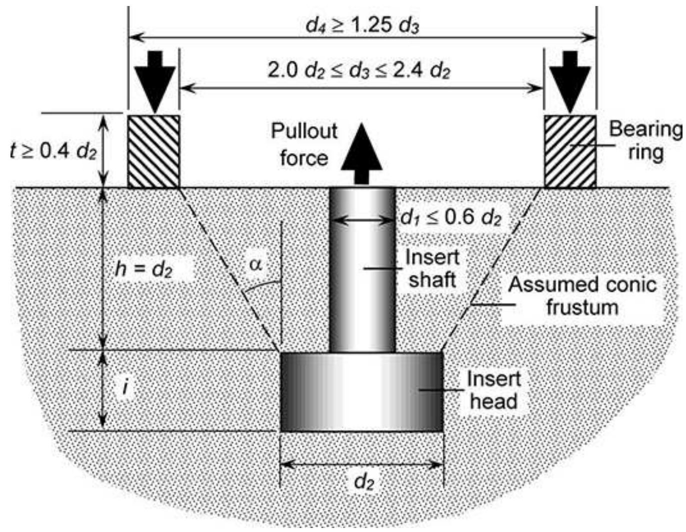

FIG. 1 Schematic Cross ~~Section~~ Sectional View of Cast-in-Place Pullout Test

attachment hardware shall be of similar material to prevent galvanic corrosion. Post-installed inserts shall be designed so that they will fit into the ~~drilled~~core holes, and can be expanded subsequently to fit into the grooves that ~~are~~ have been undercut at ~~a predetermined~~the required depth (see Fig. 2).

NOTE 3—A successful post-installed system uses a split ring that is coiled to fit into the core hole and then expanded into the groove.

6.1.2 The loading system shall consist of a bearing ring to be placed against the hardened concrete surface (see Figs. 1 and 2) and a tensile loading apparatus, with a load-measuring device that can be attached to the pullout shaft.

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

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

6.2.1 The diameter of the insert head (d_2) is the basis for defining the test geometry. The thickness of the insert head and the yield strength of the metal shall be sufficient to prevent yielding of the insert during test. The sides of the insert head shall ~~be smooth~~ have a surface similar to a regular matte finish of cold-rolled steel (see Note 5). The insert head diameter shall be at least ⅔ of the nominal maximum size of aggregate.

NOTE 4—Typical ~~insert diameters~~ diameters of commercially-available inserts are 25 and 30 mm, but larger diameters have been used (**1, 3**).Appendix X1 provides the equation to calculate the nominal tensile stress on the assumed conic frustum shown in Fig. 1. This nominal stress can be used to compare pullout strengths obtained with test systems having different insert diameters. Tests (**15**) have shown that nominal maximum aggregate sizes up to 1.5 times the head diameter do not have significant effects on the strength relationships. Larger aggregate sizes may result in increased scatter of the test results because the large particles can interfere with ~~normal~~ pullout of the conic frustum.

NOTE 5—~~Cast-in-place~~Cast-in-place inserts may be coated with a release agent to ~~minimize~~reduce bonding with the concrete, and they may be tapered to ~~minimize~~reduce side friction during testing. The insert head should 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~~ before performing the test. As a further precaution against rotation of the insert head, all threaded hardware should be checked ~~prior to~~ before installation to ~~ensure~~confirm that it is free-turning and can be ~~easily removed.~~removed easily. A thread-lock compound is recommended to prevent loosening of the insert head from the shaft during installation and during vibration of the surrounding concrete.

6.2.2 For cast-in–place inserts, the distance from the insert head to the concrete surface (h) shall equal the diameter of the insert head (d_2). The diameter of the insert shaft at the head (d_1) shall not exceed 0.60 d_2.

6.2.3 For post-installed inserts, the groove to accept the expandable insert shall be cut so that the distance between the bearing surface of the groove and concrete surface equals the insert diameter after expansion (d_2). The difference between the diameters of the undercut groove (d_2) and the core hole (d_1) shall be sufficient to prevent localized failure and ~~ensure that~~ result in the extraction of a conic frustum of concrete ~~is extracted~~ during the test (see Note 6). The expanded insert shall bear uniformly ~~on~~over the ~~entire~~ bearing area of the groove.

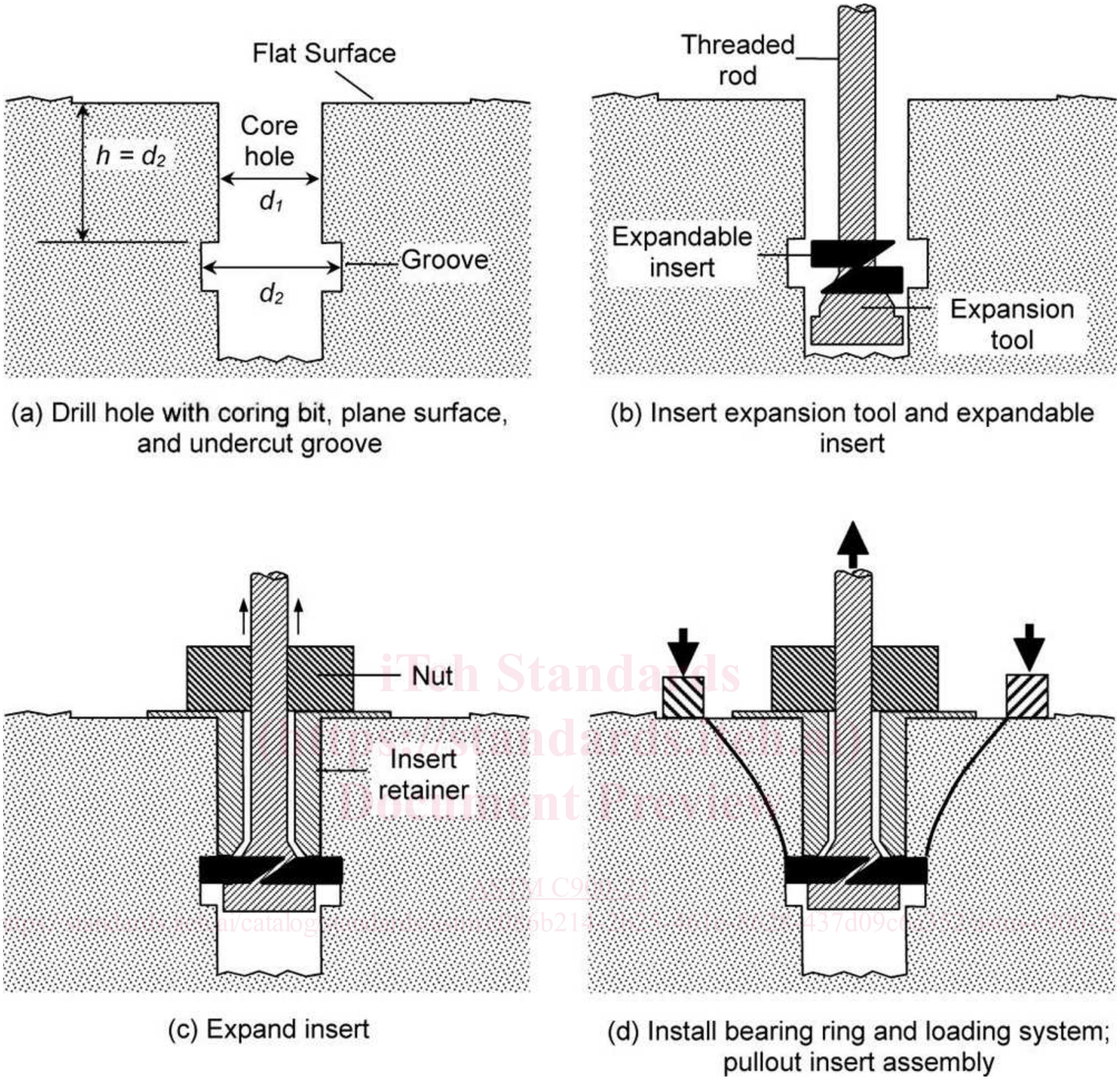

FIG. 2 Schematic of Procedure for Post-Installed Pullout Test

NOTE 6—A core hole diameter of 18 mm and an undercut groove diameter of 25 mm have been used successfully.

6.2.4 The bearing ring shall have an inside diameter (d_3) of 2.0 to 2.4 times the insert head diameter (d_2), and shall have an outside diameter (d_4) of at least 1.25 times the inside diameter. The thickness of the bearing ring (t) shall be at least 0.4 times the pullout insert head diameter. For a given test system, the same bearing ring dimensions shall be used.

6.2.5 Tolerances for dimensions of the pullout test inserts, bearing ring and embedment depth shall be ±2 % within a given system.

NOTE 7—The limits for dimensions and configurations for pullout test inserts and apparatus are intended to accommodate various systems.

6.2.6 The loading apparatus shall be capable of applying load continuously and have sufficient capacity to provide the loading rate prescribed in 8.4.

NOTE 8—Hydraulic pumps that ~~permit continuous loading may give more uniform test results than pumps that apply load intermittently.~~apply load intermittently will increase the variability of test results.

6.2.7 The gauge to measure pullout force is permitted to be of the analog or digital type. Analog gauges shall be designed so that the pullout force can be estimated to the nearest 0.5 kN. Digital gauges shall display the pullout force to the nearest 0.1 kN.

6.2.8 The force gauge shall have a means to preserve the maximum value of the load during a test.

6.2.9 Pullout apparatus shall be standardized in accordance with Annex A1 at least once a year and after all repairs. Standardize the pullout apparatus using a testing machine verified in accordance with Practices E4 or using a Class A load cell as defined in Practice E74. The indicated pullout force based on the developed relationship shall be within ±2 % of the force measured by the testing machine or load cell.

7. Sampling

7.1 *Clear Spacing (see Fig. 3)*—~~Pullout test locations shall be separated so that the~~ The clear spacing between ~~inserts is~~ insert heads shall be at least seven times the ~~pullout~~ insert head diameter. Clear spacing between the ~~inserts~~ insert heads and the edges of the concrete shall be at least 3.5 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~~ If reinforcement cover is less than 1.5 times the head diameter, inserts shall be located so that the clear distance between reinforcement and the inner diameter of the bearing ring is at least the nominal maximum size of ~~aggregate, whichever is greater.~~ aggregate. These clearance requirements also apply to test specimens used to develop strength relationships.

NOTE 9—A reinforcement locator is recommended to assist in avoiding reinforcement when planning the locations of post-installed tests. Follow the manufacturer's instructions for proper operation of such devices.

7.2 *Number of Tests*—~~When~~If pullout test results are used to assess the in-place strength ~~in order~~ to allow the start of critical construction operations, such as formwork removal or application of post tensioning, at least five individual pullout tests shall be performed as follows:

7.2.1 For every 115 m^3, or a fraction thereof, of a given placement; or

7.2.2 For every 470 m^2~~,~~, or a fraction thereof, of the surface area of one face of a slab or wall.

NOTE 10—More than the minimum number of inserts should be provided in case a test result is not valid or testing begins before adequate strength has developed.

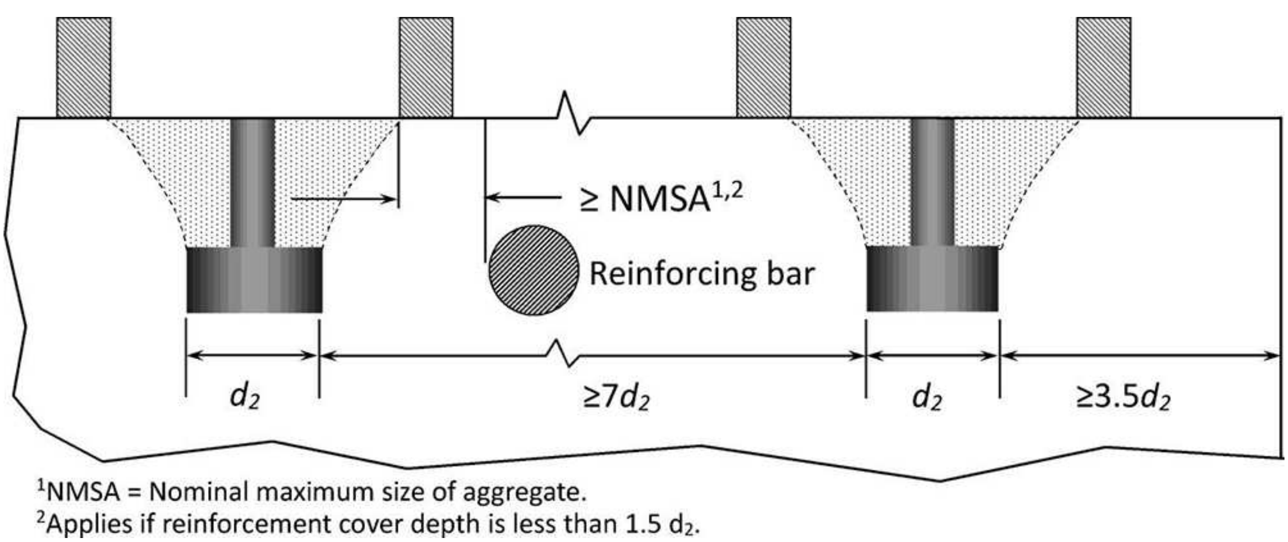

FIG. 3 Clearance Requirements for Cast-In-Place and Post-Installed Pullout Tests

7.2.3 ~~Inserts shall be located in those portions of the structure that are critical in terms of exposure conditions and structural requirements.~~If pullout tests are used for other purposes, the number of tests shall be determined by the specifier of the test.

7.3 *Test Locations—*~~When pullout tests are used for other purposes, the number of tests shall be determined by the specifier of the test.~~Inserts shall be located in those portions of the structure that are critical in terms of exposure conditions and structural requirements.

8. Procedure

8.1 *Cast-in-Place Inserts:*

8.1.1 Attach the pullout inserts to the forms using bolts or by other methods that firmly secure the insert in its proper location ~~prior to~~ before concrete placement. All inserts shall be embedded to the same depth. The axis of each shaft shall be perpendicular to the formed surface.

8.1.2 Alternatively, ~~when~~if instructed by the specifier of tests, manually place inserts into unformed horizontal concrete surfaces. The inserts shall be embedded into the fresh concrete by means that ~~ensure~~ result in a uniform embedment depth and a surface to support the bearing ring that is plane and perpendicular to the axis of the insert shaft. Installation of inserts shall be performed or supervised by personnel trained by the manufacturer or manufacturer's representative.

NOTE 11—Experience indicates that pullout strengths are of lower value and more variable for manually-placed surface inserts than for inserts attached to formwork (**12**).

8.1.3 When pullout strength of the concrete is to be measured, 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 flat bearing surface that is perpendicular to the axis of the insert.~~that interfere with uniform contact of the bearing ring.

8.2 *Post-Installed Inserts:*

8.2.1 The selected test ~~surface shall be flat to~~ location shall provide a suitable working surface for drilling the ~~core and undercutting the groove.~~ core. Drill a core hole ~~perpendicular to the surface to provide a reference point for subsequent operations and to accommodate the expandable insert and associated hardware.~~using the coring bit provided by the manufacturer. The core depth shall be in accordance with the manufacturer's instructions. Break off the core to provide a reference hole for subsequent operations. The use of an impact drill is not permitted.

8.2.2 ~~If necessary, use~~ Use a surface planing tool ~~to prepare a flat surface so that the base of the tool for cutting the groove is supported firmly and so that the bearing ring is supported uniformly during testing. The prepared surface shall be~~in accordance with the manufacturer's instructions to prepare a flat surface that is perpendicular to the axis of the core hole.

8.2.3 Use the grinding tool in accordance with the manufacturer's instructions to undercut a groove of the correct diameter and at the correct depth in the core hole. The groove shall be concentric with the core hole.

NOTE 12—To control the accuracy of these operations, a support system should be used to ~~hold~~maintain the apparatus in the proper position during these steps.

8.2.4 If water is used as a coolant, remove free-standing water from the hole at the completion of the drilling, planing, and undercutting operations. Protect the hole from ingress of additional water until completion of the test.

NOTE 13—Penetration of water into the failure zone could affect the measured pullout strength.

8.2.5 Use the expansion tool to position the expandable insert into the ~~groove~~ core hole and expand the insert to its proper size within the groove in accordance with the manufacturer's instructions.

8.3 *Bearing Ring*—Place the bearing ring ~~around~~ concentric with the pullout insert ~~shaft,~~ shaft and connect the pullout shaft to