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Standard Test Method for Penetration Resistance of Hardened Concrete[1]

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1. Scope

1.1 This test method covers the determination of the resistance of hardened concrete to penetration by either a steel probe or pin.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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.* For specific hazard statements, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.2 *ANSI Standard:*

A10.3 Safety Requirements for Powder Actuated Fastening Systems[3]

3. Terminology

3.1 *Definitions:*

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

4. Summary of Test Method

4.1 A driver delivers a known amount of energy to either a steel probe or pin. The penetration resistance of the concrete is determined by measuring either the exposed lengths of probes that have been driven into the concrete or by measuring the depth of the holes created by the penetration of the pins into the concrete.

5. Significance and Use

5.1 This test method is applicable to assess the uniformity of concrete and to delineate zones of poor quality or deteriorated concrete in structures.

5.2 This test method is applicable to estimate in-place strength, provided that a relationship has been experimentally established between penetration resistance and concrete strength. Such a relationship must be established for a given test apparatus (see also 9.1.5), using similar concrete materials and mixture proportions as in the structure. Use the procedures and statistical methods in ACI 228.1R for developing and using the strength relationship.[4]

NOTE 1— Since penetration results may be affected by the nature of the formed surfaces (for example, wooden forms versus steel forms), correlation testing should be performed on specimens with formed surfaces similar to those to be used during construction. Additional information on the factors affecting penetration test results and summaries of past research are available.[4,5]

5.3 Steel probes are driven with a high-energy, powder-actuated driver, and probes may penetrate some aggregate particles. Probe penetration resistance is affected by concrete strength as well as the nature of the coarse aggregate. Steel pins are smaller in size than probes and are driven by a low energy, spring-actuated driver. Pins are intended to penetrate the mortar fraction only; therefore, a test in which a pin strikes a coarse aggregate particle is disregarded.

5.4 This test method results in surface damage to the concrete, which may require repair in exposed architectural finishes.

[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] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] ACI 228.1R-95, "In-Place Methods to Estimate Concrete Strength," Report of ACI Committee 228 on Nondestructive Testing, American Concrete Institute, Farmington Hills, MI.

[5] Malhotra, V. M., and Carette, G. G., "Penetration Resistance Methods," Chapter 2 in *Handbook on Nondestructive Testing of Concrete*, Malhotra, V. M., and Carino, N. J., eds., CRC Press, Boca Raton, FL, 1991, pp. 19–38.

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

6. Apparatus[6]

6.1 *Resistance Testing With Probes:*

6.1.1 *Driver Unit*—The driver unit shall be capable of driving the probe into the concrete with an accurately controlled amount of energy so that the probe will remain firmly embedded. The driver unit shall incorporate features to prevent firing when not properly placed in the positioning device on the concrete surface.

NOTE 2—A powder-actuated device conforming to ANSI A10.3 has been used successfully.

6.1.1.1 For a specified energy loading, the variation of the velocity of standard probes propelled by the standard driving unit shall not have a coefficient of variation greater than 3 % for any ten tests made by accepted ballistic methods.

NOTE 3—A conventional counter chronograph and appropriate ballistic screens may be used to measure velocity at 2 m [6.5 ft] from the end of the driving unit.

6.1.2 *Probe*— The probe shall be a hardened alloy-steel rod plated for corrosion protection, with a blunt conical end that can be inserted into the driver unit and driven into the concrete surface so that it remains firmly embedded and the length of the projecting portion can be measured. The hardness shall be between Rockwell 44 HRC and 48 HRC. The exposed end of the probe shall be threaded to accommodate accessories designed to facilitate measurement and withdrawal.

NOTE 4—If probes are to be removed from the concrete, a device, consisting of a nut that can be screwed onto the end of the probe by a wrench and spacers that can be slipped over the probe for the nut to bear against, will serve to withdraw the probes.

6.1.2.1 The length of probes shall be 79.5 ± 0.4 mm [3.13 ± 0.02 in.].

6.1.3 *Measurement Equipment:*

6.1.3.1 *Measuring Instrument*—A measuring instrument, such as a caliper, depth gage, or other measuring device, and associated equipment, shall be used to measure the exposed length of a probe to the nearest 0.5 mm [0.025 in.].

6.1.3.2 The measuring equipment shall include a reference base plate or other device that is supported on the concrete surface at three equally spaced points at least 50 mm [2 in.] from the probe to be measured.

NOTE 5—In order to hold the reference base plate against the surface of the concrete when measurements in the horizontal direction or in the bottom of an overhead concrete surface are being made, a plate retainer consisting of a spring and a nut that can be screwed onto the threaded end of the probe may be used.

NOTE 6—A probe-measuring cap that can be screwed onto the threaded end of the probe has been used to facilitate measuring exposed length and to compensate for the height of the reference base plate.

6.1.4 *Positioning Device*—A device to be placed on the surface of the concrete for positioning and guiding the probe and driver unit during firing will be used.

NOTE 7—This may be a single-positioning device or a triangular device with holes at the three corners that permits the firing of three probes in a triangular pattern in accordance with 7.1.1.

6.2 *Resistance Testing with Pins:*

6.2.1 *Driver Unit*—The driver shall be a device capable of driving a pin into the concrete with an accurately controlled amount of energy. The pin will be forced into the concrete, creating a hole so that the depth of penetration can be measured.

NOTE 8—A spring-actuated driver unit with a spring stiffness of 49.7 kN/m [284 lb/in.] has been successfully used to test concrete with strength in the range of 3 to 28 MPa [450 to 4000 psi].

6.2.2 The spring-actuated driver requires regular verification of the amount of energy transferred to the pin. Servicing is required whenever there is reason to question its proper operation.

NOTE 9—The amount of energy transferred to the pin can be verified using calibration blocks supplied by the manufacturer. Pins are driven into the blocks using the spring-actuated driver, and the measured penetration is compared to manufacturer's specifications. If the penetration does not meet the manufacturer's specification, the driver unit should be serviced.

6.2.3 *Pin*—The pin shall be a hardened alloy-steel drill rod, heat treated to Rockwell hardness 62 to 66 HRC, with one end sharpened and the other end blunt. The dimensions of the pins shall be uniform within ±2.0 %. Each pin shall be used only once and then discarded.

NOTE 10—A pin with approximate length of 30 mm [1.2 in.], a diameter of 3.6 mm [0.14 in.] and a tip machined at an angle of 22.5 degrees with its longitudinal axis, has been used successfully in the driver unit described in Note 8.

6.2.4 *Measuring Equipment:*

6.2.4.1 *Measuring Instrument*—A depth gage with a reference plate shall be used to measure the depth of penetration of the pin tip into the concrete to the nearest 0.001 in. [0.025 mm].

6.2.4.2 The measuring rod of the depth gage shall have a diameter and a tip angle that are less than that of the pin.

6.2.4.3 The test equipment shall include an air blower to clean the small hole created by a pin before measurement of the depth of penetration.

7. Hazards

7.1 *Resistance Testing With Probes:*

7.1.1 Exercise care in the operation of the driver unit to prevent unexpected or inadvertent discharge of a probe.

7.1.2 Wear safety goggles, hearing protection, and other appropriate protective equipment when driving probes into concrete.

7.1.3 The driving unit, if powder actuated, shall conform to the applicable requirements of ANSI A10.3.

7.1.4 If reinforcing bars or other metal embedments in the concrete are suspected to have cover depths shallower than the anticipated probe penetration, select test positions so that probes will not strike such embedded items (Note 11).

NOTE 11—The location of reinforcement may be established using reinforcement locators or metal detectors. Follow the manufacturer's instructions for proper operation of such devices.

7.2 *Resistance Testing with Pins:*

7.2.1 Use care in the operation of the spring actuated driver to prevent injury from the inadvertent firing of the pin.

7.2.2 Personnel should wear safety goggles and other appropriate protective equipment when performing the test.

[6] Apparatus to conduct these tests is available commercially.

8. Sampling

8.1 *Resistance Testing With Probes:*

8.1.1 The concrete to be tested must have reached a sufficient degree of resistance to penetration so that the probe will not penetrate more than one half the thickness of the concrete member and will remain firmly embedded. No probe shall be located less than 175 mm [7 in.] from any other probe, nor less than 100 mm [4 in.] from the edge of a concrete surface.

8.1.2 A minimum of three firmly embedded test probes in a given test area shall constitute one test. If the range of three valid probe penetration measurements exceeds the value in the third column of Table 1, make a fourth measurement and discard the measurement with the greatest deviation from the average. If the three remaining measurements still do not meet the limit given in Table 1, select a different test area and obtain three new measurements.

NOTE 12—The number of tests to be taken depends on the intended use of the results. Refer to ACI 228.1R[4] for recommendations.

8.2 *Resistance Testing with Pins:*

8.2.1 The concrete to be tested must have reached a sufficient degree of resistance to penetration so that the pin does not penetrate to a depth greater than the exposed length of the pin when inserted into the hammer of the driver.

NOTE 13—For the driver unit described in Note 8, the exposed length is 7.6 mm [0.30 in.].

8.2.2 No pin penetration shall be located less than 50 mm [2 in.] or more than 150 mm [6 in.] from any other pin penetration, nor less than 50 mm [2 in.] from the edge of a concrete surface.

8.2.3 The average depth of penetration measured for six pins driven into the concrete in a given test area shall constitute one test. See Note 12.

8.2.4 Discard a reading when the pin obviously hit a coarse aggregate or an entrapped air void, and perform a new test. If the range of six valid pin penetration measurements exceeds the value in the third column of Table 2, make a seventh measurement and discard the measurement with the greatest deviation from the average. If the six remaining measurements still do not meet the limit given in Table 2, select a different test area and obtain six new measurements.

TABLE 1 Precision^A for Resistance Testing with Probes

Maximum Size of Aggregate	(1s) Limit^B, mm [in.]	Maximum Range of Three Individual^C Measurements, mm [in.]	(d2s) Limit^D Maximum Difference Between Two Tests (Each test calculated as the average of three measurements), mm [in.]
No. 4 (Mortar)	2.0 [0.08]	6.6 [0.26]	3.3 [0.13]
25 mm [1-in.]	2.5 [0.10]	8.4 [0.33]	4.1 [0.16]
50 mm [2 in.]	3.6 [0.14]	11.7 [0.46]	5.6 [0.22]

^{A} These values represent indexes of precision as described in Practice C670.
^{B} These values are the single-operator standard deviations for tests made on concrete with the maximum size aggregate shown in Column 1.
^{C} These values are the maximum allowable ranges for groups of three individual measurements made close together, either as individual measurements or by using the triangular positioning device.
^{D} A difference larger than the values given indicates a high probability that there is a statistically significant difference in the concrete in the two areas represented by the two groups of three measurements each.

TABLE 2 Precision^A for Resistance Testing with Pins

Material	(1s) Limit^B, mm [in.]	Maximum Range of Six Individual^C Measurements, mm [in.]	(d2s) Limit^D Maximum Difference Between Two Tests (Each test calculated as the average of six measurements), mm [in.]
Concrete 3–28 MPa [450–4000 psi]	0.4 [0.016]	1.62 [0.064]	0.5 [0.018]

^{A} These values represent indexes of precision as described in Practice C670.
^{B} These values are the single-operator standard deviations for tests on concrete shown in Column 1.
^{C} This value is the maximum allowable range for groups of six individual measurements made in a 300 mm [12 in.] diameter region.
^{D} A difference larger than the values given indicates a high probability that there is a statistically significant difference in the concrete in the two areas represented by the two groups of six measurements each.

9. Procedure

9.1 *Resistance Testing With Probes:*

9.1.1 Concrete surfaces to be tested that are coarser than burlap dragged finishes shall be ground over an area larger than that covered by the positioning device and reference base plate.

9.1.2 Place the positioning device on the surface of the concrete at the location to be tested. Mount a probe in the driver unit, position the driver in the positioning device, and fire the probe into the concrete. Follow the safety directions supplied with the apparatus.

9.1.3 Remove the positioning device and tap the probe on the exposed end with a small hammer to ensure that it has not rebounded and to confirm that it is firmly embedded. Reject loose probes.

9.1.4 Place the reference base plate over the probe and position it so that it bears firmly on the surface of the concrete without rocking or other movement. If the surface of the concrete has been raised around the base of the probe, remove the crushed concrete to allow the reference base plate to lie flat. If necessary, install plate retainers and probe-measuring caps. Measure the distance from the reference base plate to the end of the probe, or to the upper surface of the measuring cap, to the nearest 0.5 mm [0.025 in.]. Verify that requirements of 8.1.2 are met. If a probe is more than 10 degrees from perpendicular with respect to the surface of the concrete, discard that probe and embed another. Determine the average exposed probe length.

NOTE 14—Mechanical and electronic devices are available to facilitate determining the average exposed length of the probes.

9.1.5 When tests are to be made on concrete having a density of approximately 2000 kg/m^3 [125 lb/ft^3] or less, and on all concrete with strengths less than 17 MPa [2500 psi], decrease the amount of energy delivered to the probe by the driver or use a larger-diameter probe, or both. Decrease the delivered energy by positioning the probe further down the barrel of the driver unit, as recommended by the manufacturer. Do not use the low-power setting if the probes are not firmly embedded in the concrete. Separate strength relationships must be developed for different probe sizes and power level settings.

NOTE 15—Probes of 79.5-mm [3.13-in.] overall length and 7.9-mm [0.31-in.] diameter, with the penetrating end diameter reduced to 6.4 mm [0.25 in.] for approximately 14.3 mm [0.56 in.] in length, have been found satisfactory for testing concrete having a density of 2000 kg/m^3 [125 lb/ft^3] or greater. A 7.9-mm [0.31-in.] diameter and 79.5-mm [3.13-in.] length probe should be used with concrete having a density of less than 2000 kg/m^3 [125 lb/ft^3]. A change in section or shoulder has been found to be helpful in preventing rebound after setting.

9.2 *Resistance Testing with Pins:*

9.2.1 Concrete surfaces to be tested which are heavily textured, soft, or consist of loose mortar shall be ground flat with an abrasive stone consisting of medium grain texture silicon carbide or equivalent material. The area to be ground for each pin penetration measurement shall be at least as large as the bearing area of the driver. The area shall be sufficiently flat if there is no visible gap between the surface and a pin laid sideways on the surface.

9.2.2 Insert a new pin into the spring-actuated driver unit.

9.2.3 Load the spring-actuated driver unit by compressing the spring until the trigger mechanism engages.

9.2.4 Place the driver unit firmly against the perpendicular to the surface of the concrete to be tested. Pull the trigger to release the spring and drive the pin into the concrete surface. Remove the unit including the pin.

9.2.5 Clean the pin hole using the air blower device.

9.2.6 Insert the depth gage into the pin hole and measure the depth of penetration to the nearest 0.02 mm [0.001 in.].

10. Report

10.1 For probe or pin tests, report the following information:

10.1.1 Identification of the location tested in the concrete construction and the type of concrete member tested,

10.1.2 Description of concrete mixture including type of coarse aggregate,

10.1.3 Description of surface finish and, if required, the surface preparation used prior to testing.

10.1.4 Approximate locations of test areas, and

10.1.5 Date and time of testing.

10.2 For probe tests, report the following information:

10.2.1 Driver unit identification number and energy level used in testing,

10.2.2 Dimensions of probes,

10.2.3 Approximate thickness of member tested,

10.2.4 The exposed lengths of the probes and the average exposed length in each test area, and

10.2.5 Description of unusual conditions, including tests rejected for data analysis.

10.3 For pin tests, report the following information:

10.3.1 Driver unit identification number,

10.3.2 Approximate thickness of member tested,

10.3.3 The penetration depths of the pins and the average penetration depth in each test area, and

10.3.4 Description of unusual conditions, including tests rejected for data analysis.

11. Precision and Bias

11.1 *Precision*—The data used to develop the precision statements were obtained using apparatus and measurements in inch-pound units. The precision indexes given in Table 1 and Table 2 are conversions of the inch-pound values given in parentheses.

11.2 *Resistance Testing With Probes:*

11.2.1 The indexes of precision given in Table 1 apply to measurements obtained by a single operator using the same instrument on the same concrete, that is, concrete made with the same materials, procedures, equipment, and curing conditions.

11.3 *Resistance Testing with Pins:*

11.3.1 The single-specimen, single-operator, driver, day precision is 0.4 mm [0.016 in.] (1s) as defined in Practice C670.

11.3.2 The indexes of precision given in Table 2 apply to measurements obtained by a single operator using the same instrument on the same concrete, that is, concrete made with the same materials, procedures, equipment, and curing conditions.

11.4 *Bias*—This test method has no bias because penetration resistance is defined in terms of this test method.

12. Keywords

12.1 concrete strength; concrete uniformity; in-place strength; in-place test; penetration resistance