



Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers procedures for making and curing test specimens of concrete in the laboratory under accurate control of materials and test conditions using concrete that can be consolidated by rodding or vibration as described herein.

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

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 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field²
- C 70 Test Method for Surface Moisture in Fine Aggregate²
- C 125 Terminology Relating to Concrete and Concrete Aggregates²
- C 127 Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate²
- C 128 Test Method for Density, Relative Density (Specific Gravity) and Absorption of Fine Aggregate²
- C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete²
- C 143/C 143M Test Method for Slump of Hydraulic Cement Concrete²
- C 172 Practice for Sampling Freshly Mixed Concrete²
- C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method²

- C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method²
- C 330 Specification for Lightweight Aggregates for Structural Concrete²
- C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance²
- C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically²
- C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes³
- C 566 Test Method for Total Moisture Content of Aggregate by Drying²
- C 617 Practice for Capping Cylindrical Concrete Specimens²
- C 1064 Test Method for Temperature of Freshly Mixed Portland-Cement Concrete²
- C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation²
- 2.2 *American Concrete Institute Publications:*⁴
 - 211.3 Practice for Selecting Proportions for No-Slump Concrete
 - 309 Guide for Concrete Consolidation

3. Significance and Use

3.1 This practice provides standardized requirements for preparation of materials, mixing concrete, and making and curing concrete test specimens under laboratory conditions.

3.2 If specimen preparation is controlled as stipulated herein, the specimens may be used to develop information for the following purposes:

- 3.2.1 Mixture proportioning for project concrete,
- 3.2.2 Evaluation of different mixtures and materials,
- 3.2.3 Correlation with nondestructive tests, and
- 3.2.4 Providing specimens for research purposes.

NOTE 1—The concrete test results for concrete specimens made and cured using this practice are widely used. They may be the basis for

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

³ *Annual Book of ASTM Standards*, Vol 04.01.

⁴ Available from the American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333-9094.

acceptance testing for project concrete, research evaluations, and other studies. Careful and knowledgeable handling of materials, mixing concrete, molding test specimens, and curing test specimens is necessary. Many laboratories performing this important work are independently inspected or accredited. Practice C 1077 identifies and defines duties, responsibilities, including minimum responsibilities of the laboratory personnel and minimum technical requirements for laboratory equipment used. Many laboratories ensure qualified technicians by participating in national certification programs such as the American Concrete Institute Laboratory Technician Program or an equivalent program.

4. Apparatus

4.1 *Molds, General*—Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall conform to the dimensions and tolerances specified in the method for which the specimens are required. Molds shall hold their dimensions and shape under all conditions of use. Watertightness of molds during use shall be judged by their ability to hold water poured into them. Test procedures for watertightness are given in the section on Test Methods for Elongation, Absorption, and Watertightness of Specification C 470/C 470M. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable nonreactive release material before use.

4.2 *Cylinder Molds:*

4.2.1 *Molds for Casting Specimens Vertically* shall conform to the requirements of 4.1 and Specification C 470/C 470M.

4.2.2 *Horizontal Molds for Creep Test Cylinders* shall conform to the requirements of 4.1 and to the requirements for symmetry and dimensional tolerance in the section on General Requirements except for verticality requirements of Specification C 470/C 470M. The use of horizontal molds is intended only for creep specimens that contain axially embedded strain gages. Molds for creep cylinders to be filled while supported in a horizontal position shall have a filling slot parallel to the axis of the mold which extends the full length to receive the concrete. The width of the slot shall be one half the diameter of the specimen. If necessary the edges of the slot shall be reinforced to maintain dimensional stability. Unless specimens are to be capped or ground to produce plane ends, the molds shall be provided with two machined metal end plates at least 1 in. [25 mm] thick and the working surfaces shall comply with the requirements for planeness and surface roughness given in the section on Capping Plates of Practice C 617. Provision shall be made for fixing both end plates firmly to the mold. The inside surface of each end plate shall be provided with at least three lugs or studs approximately 1 in. [25 mm] long, firmly fastened to the plate for embedment in the concrete. One base plate shall be drilled from the inside at an angle to permit the lead wire from the strain gage to exit the specimen through the edge of the plate. Provision shall be made for accurately positioning the strain gage. All necessary holes shall be as small as possible to minimize disturbance to subsequent strain measurements and shall be sealed to prevent leakage.

4.3 *Beam and Prism Molds* shall be rectangular in shape

(unless otherwise specified) and of the dimensions required to produce the desired specimen size. The inside surfaces of the molds shall be smooth and free from indentations. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed $\frac{1}{8}$ in. [3 mm] for molds with depth or breadth of 6 in. [150 mm] or more, or $\frac{1}{16}$ in. [2 mm] for molds of smaller depth or breadth. Except for flexure specimens, molds shall not vary from the nominal length by more than $\frac{1}{16}$ in. [2 mm]. Flexure molds shall not be shorter than $\frac{1}{16}$ in. [2 mm] of the required length, but may exceed it by more than that amount.

4.4 *Tamping Rods*—Two sizes are specified in ASTM methods. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded, if preferred.

4.4.1 *Larger Rod*, $\frac{5}{8}$ in. [16 mm] in diameter and approximately 24 in. [600 mm] long.

4.4.2 *Smaller Rod*, $\frac{3}{8}$ in. [10 mm] in diameter and approximately 12 in. [300 mm] long.

4.5 *Mallets*—A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb [0.6 ± 0.20 kg] shall be used.

4.6 *Vibrators:*

4.6.1 *Internal Vibrators*—The vibrator frequency shall be at least 7000 vibrations per minute [115 Hz] while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one fourth the diameter of the cylinder mold or one fourth the width of the beam or prism mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. [75 mm].

NOTE 2—For information on size and frequency of various vibrators and method to periodically check vibrator frequency, see ACI 309.

4.6.2 *External Vibrators*—The two types of external vibrators permitted are either table or plank. The external vibrator frequency shall be 3600 vibrations per minute [60 Hz] or higher.

4.6.3 Provisions shall be made for clamping the mold securely to the apparatus for both types of vibrators.

NOTE 3—Vibratory impulses are frequently imparted to a table or plank vibrator through electromagnetic means, or by use of an eccentric weight on the shaft of an electric motor or on a separate shaft driven by a motor.

4.7 *Small Tools*—Tools and items such as shovels, pails, trowels, wood float, blunted trowels, straightedge, feeler gage, scoops, rulers, rubber gloves, and metal mixing bowls shall be provided.

4.8 *Slump Apparatus*—The apparatus for measurement of slump shall conform to the requirements of Test Method C 143/C 143M.

4.9 *Sampling and Mixing Pan*—The pan shall be flat-bottom and of heavy-gage metal, watertight, of convenient depth, and of sufficient capacity to allow easy mixing by shovel or trowel of the entire batch; or, if mixing is by machine, to receive the entire batch on discharge of the mixer and allow remixing in the pan by trowel or shovel.

4.10 *Wet-Sieving Equipment*—If wet-sieving is required, the

equipment shall conform to the requirements of Practice C 172.

4.11 *Air Content Apparatus*—The apparatus for measuring air content shall conform to the requirements of either Test Methods C 231 or C 173.

4.12 *Scales*—Scales for determining the mass of batches of materials and concrete shall be accurate within 0.3 % of the test load at any point within the range of use.

NOTE 4—In general the mass of small quantities should not be determined on large capacity scales. In many applications the smallest mass determined on a scale should be greater than about 10 % of the maximum capacity of the scale; however, this will vary with the performance characteristics of the scale and the required accuracy of the determination. Acceptable scales used for determining the mass for concrete materials preferably should determine mass accurately to about 0.1 % of total capacity and the foregoing precaution is applicable. However, certain analytical and precision balances are exceptions to this rule and should weigh accurately to 0.001 %. Particular care must be exercised in measuring small quantities of material by determining the difference between two much larger masses.

4.13 *Temperature Measuring Device*—The temperature measuring device shall conform to the requirements of Test Method C 1064.

4.14 *Concrete Mixer*—A power-driven concrete mixer shall be a revolving drum, tilting mixer, or suitable revolving pan or revolving-paddle mixer capable of thoroughly mixing batches of the prescribed sizes at the required slump.

NOTE 5—A pan mixer is usually more suitable for mixing concrete with less than 1-in. [25 mm] slump than a revolving drum mixer. The rate of rotation, degree of tilt, and rated capacity of tilting mixers are not always suitable for laboratory mixed concrete. It may be found desirable to reduce the rate of rotation, decrease the angle of tilt from the horizontal, and use the mixer at somewhat less than the manufacturer's rated capacity.

5. Specimens

5.1 *Cylindrical Specimens*—Cylinders for such tests as compressive strength, Young's modulus of elasticity, creep, and splitting tensile strength may be of various sizes with a minimum of 2-in. [50-mm] diameter by 4-in. [100-mm] length. Where correlation or comparison with field-made cylinders (Practice C 31/C 31M) is desired, the cylinders shall be 6 by 12 in. [or 150 by 300 mm]. Otherwise, dimensions should be governed in accordance with 5.4 and the specific test method concerned.

NOTE 6—When molds in SI units are required and not available, equivalent inch-pound unit size mold should be permitted.

5.1.1 Cylindrical specimens for tests other than creep shall be molded and allowed to harden with the axis of the cylinder vertical.

5.1.2 Cylindrical creep specimens may be cast with the cylindrical axis either vertical or horizontal and allowed to harden in the position in which cast.

5.2 *Prismatic Specimens*—Beams for flexural strength, prisms for freezing and thawing, bond, length change, volume change, etc., shall be formed with their long axes horizontal, unless otherwise required by the method of test in question, and shall conform in dimension to the requirements of the specific test method.

5.3 *Other Specimens*—Other shapes and sizes of specimens for particular tests may be molded as desired following the

general procedures set forth in this practice.

5.4 *Specimen Size versus Aggregate Size*—The diameter of a cylindrical specimen or minimum cross-sectional dimension of a rectangular section shall be at least three times the nominal maximum size of the coarse aggregate in the concrete as defined in Terminology C 125. Occasional over-size aggregate particles (of a size not normally found in the average aggregate grading) shall be removed by hand picking during the molding of the specimens. When the concrete contains aggregate larger than that appropriate for the size of the molds or equipment to be used, wet-sieve the sample as described in Practice C 172.

5.5 *Number of Specimens*—The number of specimens and the number of test batches are dependent on established practice and the nature of the test program. Guidance is usually given in the test method or specification for which the specimens are made. Usually three or more specimens are molded for each test age and test condition unless otherwise specified (Note 7). Specimens involving a given variable should be made from three separate batches mixed on different days. An equal number of specimens for each variable should be made on any given day. When it is impossible to make at least one specimen for each variable on a given day, the mixing of the entire series of specimens should be completed in as few days as possible, and one of the mixtures should be repeated each day as a standard of comparison.

NOTE 7—Test ages often used are 7 and 28 days for compressive strength tests, or 14 and 28 days for flexural strength tests. Specimens containing Type III cement are often tested at 1, 3, 7, and 28 days. For later test ages, 3 months, 6 months, and 1 year are often used for both compressive and flexural strength tests. Other test ages may be required for other types of specimens.

6. Preparation of Materials

6.1 *Temperature*—Before mixing the concrete, bring the concrete materials to room temperature in the range from 68 to 86°F [20 to 30°C], except when the temperature of the concrete is stipulated. When a concrete temperature is stipulated, the method proposed to obtain the concrete temperature needs approval of the stipulator.

6.2 *Cement*—Store the cement in a dry place, in moisture-proof containers, preferably made of metal. The cement shall be thoroughly mixed to provide a uniform supply throughout the tests. It shall be passed through a 850- μ m [No. 20] or finer sieve to remove all lumps, remixed on a plastic sheet, and returned to sample containers.

6.3 *Aggregates*—In order to preclude segregation of a coarse aggregate, separate into individual size fractions and for each batch recombine in the proper proportions to produce the desired grading.

NOTE 8—Only rarely is a coarse aggregate batched as a single size fraction. The number of size fractions will generally be between 2 and 5 for aggregate smaller than 2½ in. [60 mm]. When a size fraction to be batched is present in amounts in excess of 10 %, the ratio of the opening of the larger to the smaller sieve should not exceed 2.0. More closely sized groups are sometimes advisable.

6.3.1 Unless fine aggregate is separated into individual size fractions, maintain it in a damp condition or restore to a damp condition until use, to prevent segregation, unless material uniformly graded is subdivided into batch size lots using a

sample splitter with proper size openings. If unusual gradings are being studied, the fine aggregate may need to be dried and separated into individual sizes. In this instance, if the total quantity of fine aggregate required is larger than can be efficiently blended in a single unit, then the individual size fractions should be determined in a mass required for each individual batch. When the total quantity of fine aggregate needed for the complete investigation is such that it can be thoroughly mixed, blended, and maintained in a damp condition, then it should be handled in that manner. Determine the specific gravity and absorption of aggregates in accordance with either Test Methods C 127 or C 128.

6.3.2 Before incorporating in concrete, prepare the aggregate to ensure a definite and uniform condition of moisture. Determine the weight of aggregate to be used in the batch by one of the following procedures:

6.3.2.1 Determine the mass of low-absorption aggregates (absorption less than 1.0 %) in the room-dry condition with allowance made for the amount of water that will be absorbed from the unset concrete (Note 9). This procedure is particularly useful for coarse aggregate which must be batched as individual sizes; because of the danger of segregation it can be used for fine aggregate only when the fine aggregate is separated into individual size fractions.

NOTE 9—When using aggregates with low absorption in room-dry condition the amount of water that will be absorbed by the aggregates before the concrete sets may be assumed to be 80 % of the difference between the 24-h absorption of the aggregates determined by Test Methods C 127 or C 128, and the amount of water in the pores of the aggregates in their room-dry state, as determined by Test Method C 566.

6.3.2.2 Individual size fractions of aggregate may be weighed separately, recombined into a tared container in the amounts required for the batch, and immersed in water for 24 h prior to use. After immersion the excess water is decanted and the combined weight of aggregate and mixing water determined. Allowance shall be made for the amount of water absorbed by the aggregate. The moisture content of the aggregates may be determined in accordance with Test Methods C 70 and C 566.

6.3.2.3 The aggregate may be brought to and maintained in a saturated condition, with surface moisture contained in sufficiently small amounts to preclude loss by draining, at least 24 h prior to use. When this method is used, the moisture content of the aggregate must be determined to permit calculation of proper quantities of the damp aggregate. The quantity of surface moisture present must be counted as a part of the required amount of mixing water. Surface moisture in fine aggregate may be determined in accordance with Test Methods C 70 and C 566, making due allowance for the amount of water absorbed. The method outlined here (moisture content slightly exceeding absorption) is particularly useful for fine aggregate. It is used less frequently for coarse aggregate because of the difficulty of accurately determining the moisture content, but if used, each size fraction must be handled separately to ensure that the proper grading is obtained.

6.3.2.4 Aggregates, fine or coarse, may be brought to and maintained in a saturated surface-dry condition until batched for use. This method is used primarily to prepare material for

batches not exceeding $\frac{1}{4}$ ft³ [0.007 m³] in volume. Care must be taken to prevent drying during weighing and use.

6.4 *Lightweight Aggregates*—The procedures for specific gravity, absorption, and preparation of aggregates mentioned in this practice pertain to materials with normal absorption values. Lightweight aggregates, air-cooled slag, and certain highly porous or vesicular natural aggregate may be so absorptive as to be difficult to treat as described. The moisture content of lightweight aggregate at the time of mixing may have important effects on properties of freshly mixed and hardened concretes such as slump loss, compressive strength, and resistance to freezing and thawing.

6.5 *Admixtures*—Powdered admixtures that are entirely or largely insoluble, that do not contain hygroscopic salts and are to be added in small quantities, should be mixed with a portion of the cement before introduction into the batch in the mixer so as to ensure thorough distribution throughout the concrete. Essentially insoluble materials which are used in amounts exceeding 10 % by mass of cement, such as pozzolans, should be handled and added to the batch in the same manner as cement. Powdered admixtures which are largely insoluble but contain hygroscopic salts may cause balling of cement and should be mixed with the sand. Water-soluble and liquid admixtures should be added to the mixer in solution in the mixing water. The quantity of such solution used shall be included in the calculation of the water content of the concrete. Admixtures, incompatible in concentrated form, such as solutions of calcium chloride and certain air-entraining and set-retarding admixtures, should not be intermixed prior to their addition to concrete. The time, sequence, and method of adding some admixtures to a batch of concrete can have important effects on concrete properties such as time of set and air content. The method selected must remain unchanged from batch to batch.

NOTE 10—The mixing apparatus and accessories shall be thoroughly cleaned to ensure that chemical additions or admixtures used in dissimilar batches of concrete do not affect subsequent batches.

7. Procedure

7.1 *Mixing Concrete:*

7.1.1 *General*—Mix concrete in a suitable mixer or by hand in batches of such size as to leave about 10 % excess after molding the test specimens. Hand-mixing procedures are not applicable to air-entrained concrete or concrete with no measurable slump. Hand mixing should be limited to batches of $\frac{1}{4}$ ft³ [0.007 m³] volume or less. Mixing procedures are given in 7.1.2 and 7.1.3. However, other procedures may be used when it is desired to simulate special conditions or practices, or when the procedures specified are impracticable. A machine-mixing procedure suitable for drum-type mixers is described. It is important not to vary the mixing sequence and procedure from batch to batch unless the effect of such variation is under study.

7.1.2 *Machine Mixing*—Prior to starting rotation of the mixer add the coarse aggregate, some of the mixing water, and the solution of admixture, when required, in accordance with 6.5. When feasible, disperse the admixture in the mixing water before addition. Start the mixer, then add the fine aggregate, cement, and water with the mixer running. If it is impractical

for a particular mixer or for a particular test to add the fine aggregate, cement, and water while the mixer is running, these components may be added to the stopped mixer after permitting it to turn a few revolutions following charging with coarse aggregate and some of the water (Note 11). Mix the concrete, after all ingredients are in the mixer, for 3 min followed by a 3-min rest, followed by a 2-min final mixing. Cover the open end or top of the mixer to prevent evaporation during the rest period. Take precautions to compensate for mortar retained by the mixer so that the discharged batch, as used, will be correctly proportioned (Note 12). To eliminate segregation, deposit machine-mixed concrete in the clean, damp mixing pan and remix by shovel or trowel until it appears to be uniform.

NOTE 11—An experienced operator may add water incrementally during mixing to adjust to the desired slump.

NOTE 12—It is difficult to recover all of the mortar from mixers. To compensate for this difficulty one of the following procedures may be used to ensure the correct final proportions in the batch:

(1) *“Buttering” the Mixer*—Just prior to mixing the test batch, the mixer is “battered” by mixing a batch proportioned to simulate closely the test batch. The mortar adhering to the mixer after discharging is intended to compensate for loss of mortar from the test batch.

(2) *“Over-Mortaring” the Mix*—The test mix is proportioned by the use of an excess mortar, the amount established in advance, to compensate for that which, on the average, adheres to the mixer. In this case the mixer is cleaned before mixing the test batch.

7.1.3 Hand Mixing—Mix the batch in a watertight, clean (Note 10), damp, metal pan or bowl, with a bricklayer’s blunted trowel, using the following procedure when aggregates have been prepared in accordance with 6.3.2.1, 6.3.2.3, and 6.3.2.4.

7.1.3.1 Mix the cement, powdered insoluble admixture, if used, and fine aggregate without addition of water until they are thoroughly blended.

7.1.3.2 Add the coarse aggregate and mix the entire batch without addition of water until the coarse aggregate is uniformly distributed throughout the batch.

7.1.3.3 Add water, and the admixture solution if used, and mix the mass until the concrete is homogeneous in appearance and has the desired consistency. If prolonged mixing is necessary because of the addition of water in increments while adjusting the consistency, discard the batch and make a new batch in which the mixing is not interrupted to make trial consistency tests.

7.1.4 Mixed Concrete—Select the portions of the batch of mixed concrete to be used in tests for molding specimens so as to be representative of the actual proportions and condition of the concrete. When the concrete is not being remixed or sampled cover it to prevent evaporation.

7.2 Slump, Air Content, Yield, and Temperature:

7.2.1 Slump—Measure the slump of each batch of concrete immediately after mixing in accordance with Test Method C 143/C 143M.

NOTE 13—The slump test is unsuitable for concrete so dry that it slumps less than ¼ in. [6 mm]. No-slump concrete may be tested by one of several means described in ACI 211.3.

7.2.2 Air Content—Determine the air content, when required, in accordance with either Test Methods C 173 or C 231. Test Method C 231 should not be used with concretes made

with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. Discard the concrete used for the determination of air content.

7.2.3 Yield—Determine the yield of each batch of concrete, if required, in accordance with Test Method C 138. Concrete used for slump and yield tests may be returned to the mixing pan and remixed into the batch.

7.2.4 Temperature—Determine the temperature of each batch of concrete in accordance with Test Method C 1064.

7.3 Making Specimens:

7.3.1 Place of Molding—Mold specimens as near as practicable to the place where they are to be stored during the first 24 h. If it is not practicable to mold the specimens where they will be stored, move them to the place of storage immediately after being struck off. Place molds on a rigid surface free from vibration and other disturbances. Avoid jarring, striking, tilting, or scarring of the surface of the specimens when moving the specimens to the storage place.

7.3.2 Placing—Place the concrete in the molds using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. It may be necessary to remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop or trowel around the top edge of the mold as the concrete is discharged in order to ensure a symmetrical distribution of the concrete and to minimize segregation of coarse aggregate within the mold. Further distribute the concrete by use of a tamping rod prior to the start of consolidation. In placing the final layer the operator shall attempt to add an amount of concrete that will exactly fill the mold after compaction. Do not add nonrepresentative samples of concrete to an underfilled mold.

7.3.2.1 Number of Layers—Make specimens in layers as indicated in Table 1.

7.4 Consolidation:

7.4.1 Methods of Consolidation—Preparation of satisfactory specimens requires different methods of consolidation. The methods of consolidation are rodding, and internal or external vibration. Base the selection of the method on the slump, unless the method is stated in the specifications under which the work is being performed. Rod or vibrate concrete

TABLE 1 Number of Layers Required for Specimens

Specimen Type and Size	Mode of Consolidation	Numbers of Layers of Approximate Equal Depth
Cylinders:		
Diameter, in. [mm]		
3 or 4 [75 to 100]	rodding	2
6 [150]	rodding	3
9 [225]	rodding	4
up to 9 [225]	vibration	2
Prisms and horizontal creep		
Cylinders:		
Depth, in. [mm]		
up to 8 [200]	rodding	2
over 8 [200]	rodding	3 or more
up to 8 [200]	vibration	1
over 8 [200]	vibration	2 or more

with slump greater than or equal to 1 in. [25 mm]. Vibrate concrete with slump less than 1 in. (Note 14). Do not use internal vibration for cylinders with a diameter less than 4 in. [100 mm], and for beams or prisms with breadth or depth less than 4 in.

NOTE 14—Concrete of such low water content that it cannot be properly consolidated by the methods described herein is not covered by this practice. Provisions for specimens and methods of testing will be found in the standards concerned. There are concretes that can be consolidated by external vibration, but additional forces on the surface are required to embed the coarse aggregate thoroughly and consolidate the mixture. For such mixtures the following procedures may be followed: using external vibration fill 6 by 12-in. [150 by 300-mm] cylinder molds in 3 in. [75 mm] lifts using a 10-lb [4.5-kg] cylindrical surcharge, or 3 by 6-in. [75 by 150-mm] cylinder molds in 2 in. [50 mm] lifts using a 2.5-lb [1-kg] cylindrical surcharge. The surcharge should have a diameter ¼ in. [6 mm] less than the inside of the mold. Simultaneously each lift should be compacted by external vibration with the surcharge on the top surface of the concrete, until the mortar begins to ooze around the bottom of the surcharge.

7.4.2 *Rodding*—Place the concrete in the mold, in the required number of layers of approximately equal volume. Rod each layer with the rounded end of the rod using the number of strokes and size of rod specified in Table 2. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm]. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single-use molds which are susceptible to damage if tapped with a mallet. After tapping, spade the concrete along the sides and ends of beam and prism molds with a trowel or other suitable tool.

7.4.3 *Vibration*—Maintain a uniform duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 15). Overvibration may cause segregation. Fill the molds and vibrate in the required number of approximately equal layers (Table 2). Place all the

concrete for each layer in the mold before starting vibration of that layer. When placing the final layer, avoid overfilling by more than ¼ in. [6 mm]. When the finish is applied after vibration, add only enough concrete with a trowel to overfill the mold about ⅛ in. [3 mm], work it into the surface and then strike it off.

NOTE 15—Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate the concrete with a slump greater than 3 in. [75 mm]. Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

7.4.3.1 *Internal Vibration*—In compacting the specimen insert the vibrator slowly and do not allow the vibrator to rest on or touch the bottom or sides of the mold or strike embedded items such as strain meters. Slowly withdraw the vibrator so that no large air pockets are left in the specimen.

7.4.3.2 *Cylinders*—The number of insertions of the vibrator is given in Table 3. When more than one insertion per layer is required, distribute the insertions uniformly within each layer. Allow the vibrator to penetrate into the layer below approximately 1 in. [25 mm]. After each layer is vibrated, tap the outside of the mold at least 10 times with the mallet to close the holes that remain and to release entrapped air voids. Use an open hand to tap cardboard or single-use metal molds that are susceptible to damage if tapped with a mallet.

7.4.3.3 *Beams, Prisms, and Horizontal Creep Cylinders*—Insert the vibrator at intervals not exceeding 6 in. [150 mm] along the center line of the long dimension of the specimen, or along both sides but not in contact with the strain gage in the case of creep cylinders. For specimens wider than 6 in. [150 mm], use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer approximately 1 in. [25 mm]. After each layer is vibrated, tap the outsides of the mold sharply at least 10 times with the mallet to close holes left by vibrating and to release entrapped air voids.

7.4.4 *External Vibration*—When external vibration is used, take care to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface (Note 14).

7.5 *Finishing*—After consolidation by any of the methods, strike off the surface of the concrete and float or trowel it in accordance with the method concerned. If no finish is specified, finish the surface with a wood or magnesium float. Perform all finishing with the minimum manipulation necessary to produce

TABLE 2 Diameter of Rod and Number of Roddings to be Used in Molding Test Specimens

Cylinders		
Diameter of Cylinder, in. [mm]	Diameter of Rod in. [mm]	Number of Strokes/Layer
2 [50] to <6 [150]	¾[10]	25
6 [150]	⅝ [16]	25
8 [200]	⅝ [16]	50
10 [250]	⅝ [16]	75
Beams and Prisms		
Top Surface Area of Specimen, in. ² [cm ²]	Diameter of Rod in. (mm)	Number of Roddings/Layer
25 [160] or less	¾[10]	25
26 to 49 [165 to 310]	¾[10]	one for each 1 in. ² [7 cm ²] of surface
50 [320] or more	⅝ [16]	one for each 2 in. ² [14 cm ²] of surface
Horizontal Creep Cylinders		
Diameter of Cylinder in. [mm]	Diameter of Rod in. [mm]	Number of Roddings/Layer
6 [150]	⅝[16]	50 total, 25 along both sides of axis



TABLE 3 Number of Vibrator Insertions per Layer

Specimen Type and Size	Number of Insertions per Layer
Cylinder: Diameter, in. [mm]	
4 in. [200 mm]	1
6 in. [150 mm]	2
9 in. [225 mm]	4

a flat even surface that is level with the rim or edge of the mold and which has no depressions or projections larger than $\frac{1}{8}$ in. [3 mm].

7.5.1 *Cylinders*—After consolidation finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits, or with a wood float or trowel. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste which is permitted to harden and cure with the specimen. See the section on Capping Materials of Practice C 617.

7.5.2 *Horizontally Cast Creep Cylinders*—After consolidation strike off the specimen with a trowel or float, then trowel the minimum amount required to form the concrete in the opening concentrically with the rest of the specimen. Use a screed curved to the radius of the specimen to more precisely shape and finish the concrete in the opening.

8. Curing

8.1 *Initial Curing*—To prevent evaporation of water from unhardened concrete, cover the specimens immediately after finishing, preferably with a nonabsorptive, nonreactive plate or a sheet of tough, durable impervious plastic. Specimens shall be stored immediately after finishing until the removal of the molds to prevent loss of moisture from the specimens. Select an appropriate procedure or combination of procedures that will prevent moisture loss and is nonabsorptive and nonreactive with the concrete. When wet burlap is used for covering, the burlap must not be in contact with the fresh concrete surface and care must be exercised to keep the burlap wet until the specimens are removed from the molds. Placing a sheet of plastic over the burlap will facilitate keeping it wet. To prevent damage to specimens, protect the outside of cardboard molds from contact with wet burlap or other sources of water until the molds are removed. Record the maximum and minimum ambient temperatures during the initial curing.

8.2 *Removal from Molds*—Remove the specimens from the molds 24 ± 8 h after casting. For concrete with prolonged setting time, molds shall not be removed until 20 ± 4 h after final set. If needed, determine the setting times in accordance with Test Method C 403/C 403M.

8.3 *Curing Environment*—Unless otherwise specified all specimens shall be moist cured at $73.5 \pm 3.5^\circ\text{F}$ [$23.0 \pm 2.0^\circ\text{C}$] from the time of molding until the moment of test (Note 16). Storage during the first 48 h of curing shall be in a vibration-free environment. As applied to the treatment of demolded specimens, moist curing means that the test specimens shall have free water maintained on the entire surface area at all times. This condition is met by using water storage tanks or a moist room in accordance with the requirements of Specifica-

tion C 511. Cure structural lightweight concrete cylinders in accordance with Specification C 330.

NOTE 16—The temperature within damp sand and under wet burlap or similar materials will always be lower than the temperature in the surrounding atmosphere if evaporation takes place.

8.4 *Flexural Strength Test Specimens*—Cure the flexural strength test specimens in accordance with 8.1 and 8.2 except that while in storage for a minimum period of 20 h immediately prior to testing they shall be immersed in water saturated with calcium hydroxide at $73 \pm 3^\circ\text{F}$ [$23 \pm 2^\circ\text{C}$]. At the end of the curing period, between the time the specimen is removed from curing until testing is completed, drying of the surfaces shall be prevented.

NOTE 17—Relatively small amounts of drying of the surface of flexural strength specimens will induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9. Precision and Bias

9.1 Data to establish precision statements for various testing required by this standard were obtained in the Concrete Proficiency Sample Program of the Cement and Concrete Reference Laboratory.

9.2 The single-operator standard deviations for slump, unit weight, air content, and 7-day compressive strength of trial batches have been found to be 0.7 in., 0.9 lb/ft³, 0.3 %, and 203 psi, respectively; therefore the results of properly conducted tests on two trial batches made in the same laboratory should not differ by more than 2.0 in., 2.5 lb/ft³, 0.8 %, and 574 psi, respectively. This precision statement is considered applicable to laboratory trial batches proportioned to contain prescribed quantities of materials and to have a constant water-cement ratio. The values should be used with caution for air-entrained concrete, concrete with slump less than 2 in. [50 mm] or over 6 in. [150 mm], or concrete made with other than normal weight aggregate or aggregate larger than 1 in. [25 mm] nominal maximum size.

9.3 The multilaboratory standard deviations for slump, unit weight, air content, and 7-day compressive strength of trial batches have been found to be 1.0 in., 1.4 lb/ft³, 0.4 %, and 347 psi, respectively; therefore, the results of properly conducted tests on single trial batches made in two different laboratories should not differ by more than 2.8 in., 4.0 lb/ft³, 1.1 %, and 981 psi, respectively. This precision statement is considered applicable to laboratory trial batches proportioned to contain prescribed quantities of materials and to have a prescribed water-cement ratio. The values should be used with caution for air-entrained concrete, concrete with slump less than 2 in. [50 mm] or over 6 in. [150 mm], or concrete made with other than normal weight aggregate or aggregate larger than 1 in. [25 mm] nominal maximum size.

9.4 *Bias*—The procedures for the test methods in 9.3 have no bias because the values obtained from each of those test methods are defined only in terms of the test method.

10. Keywords

10.1 concrete; cylinders; laboratory; prisms; strength testing

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