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Standard Specification for Ready-Mixed Concrete[1]

This standard is issued under the fixed designation C 94/C 94M; 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.

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

ε[1] NOTE—Updated Referenced Documents in Section 2 and throughout, July 2003.

1. Scope

1.1 This specification covers ready-mixed concrete manufactured and delivered to a purchaser in a freshly mixed and unhardened state as hereinafter specified. Requirements for quality of concrete shall be either as hereinafter specified or as specified by the purchaser. In any case where the requirements of the purchaser differ from these in this specification, the purchaser's specification shall govern. This specification does not cover the placement, consolidation, curing, or protection of the concrete after delivery to the purchaser.

1.2 The values stated in either SI units, shown in brackets, 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 As used throughout this specification the manufacturer shall be the contractor, subcontractor, supplier, or producer who furnishes the ready-mixed concrete. The purchaser shall be the owner or representative thereof.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field[2]

C 33 Specification for Concrete Aggregates[2]

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

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[3]

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete[2]

C 143/C 143M Test Method for Slump of Hydraulic Cement Concrete[2]

C 150 Specification for Portland Cement[3]

C 172 Practice for Sampling Freshly Mixed Concrete[2]

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method[2]

C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle[3]

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[2]

C 260 Specification for Air-Entraining Admixtures for Concrete[2]

C 330 Specification for Lightweight Aggregates for Structural Concrete[2]

C 494/C 494M Specification for Chemical Admixtures for Concrete[2]

C 567 Test Method for Determining Density of Structural Lightweight Concrete[2]

C 595 Specification for Blended Hydraulic Cements[3]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete[2]

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars[2]

C 1017/C 1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete[2]

C 1064/C 1064M Test Method for Temperature of Freshly Mixed Portland-Cement Concrete[2]

C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation[2]

C 1157 Performance Specification for Hydraulic Cement[3]

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.40 on Ready-Mixed Concrete.

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

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

D 512 Test Methods for Chloride Ion in Water[4]
D 516 Test Method for Sulfate Ion in Water[4]
2.2 *ACI Documents:*[5]
CP-1 Technician Workbook for ACI Certification of Concrete Field Testing Technician–Grade I
211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete
301 Standard Specifications for Structural Concrete
305R Hot Weather Concreting
306R Cold Weather Concreting
318 Building Code Requirements for Structural Concrete and Commentary
2.3 *Other Documents:*
Bureau of Reclamation Concrete Manual[6]
AASHTO T26 Method of Test for Quality of Water to be Used in Concrete[7]

3. Basis of Purchase

3.1 The basis of purchase shall be the cubic yard or cubic metre of freshly mixed and unhardened concrete as discharged from the mixer.

3.2 The volume of freshly mixed and unhardened concrete in a given batch shall be determined from the total mass of the batch divided by the mass per unit volume of the concrete. The total mass of the batch shall be calculated either as the sum of the masses of all materials, including water, entering the batch or as the net mass of the concrete in the batch as delivered. The mass per unit volume shall be determined in accordance with Test Method C 138/C 138M from the average of at least three measurements, each on a different sample using a ½-ft^3 [14-L^3] container. Each sample shall be taken from the midpoint of each of three different truck loads by the procedure outlined in Practice C 172.

NOTE 1—It should be understood that the volume of hardened concrete may be, or appear to be, less than expected due to waste and spillage, over-excavation, spreading forms, some loss of entrained air, or settlement of wet mixtures, none of which are the responsibility of the producer.

4. Ordering Information

4.1 In the absence of designated applicable general specifications, the purchaser shall specify the following:

4.1.1 Designated size, or sizes, of coarse aggregate,

4.1.2 Slump, or slumps, desired at the point of delivery (see Section 6 for acceptable tolerances),

4.1.3 When air-entrained concrete is specified, the air content of the samples taken at the point of discharge from the transportation unit (see Section 7 and Table 1 for the total air content and tolerances) (Note 2),

4.1.4 Which of Options A, B, or C shall be used as a basis for determining the proportions of the concrete to produce the required quality, and

4.1.5 When structural lightweight concrete is specified, the mass per unit volume as wet mass, air-dry mass, or oven-dry mass (Note 3).

NOTE 2—In selecting the specified air content, the purchaser should consider the exposure conditions to which the concrete will be subjected. Air contents less than shown in Table 1 may not give the required resistance to freezing and thawing, which is the primary purpose of air-entrained concrete. Air contents higher than the levels shown may reduce strength without contributing any further improvement of durability.

NOTE 3—The mass per unit volume of fresh concrete, which is the only unit mass determinable at the time of delivery, is always higher than the air-dry or oven-dry mass. Definitions of, and methods for determining or calculating air-dry and oven-dry masses, are covered by Test Method C 567.

4.2 *Option A*:

4.2.1 When the purchaser requires the manufacturer to assume full responsibility for the selection of the proportions for the concrete mixture (Note 4), the purchaser shall also specify the following:

4.2.1.1 Requirements for compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 17. The purchaser shall specify the requirements in terms of the compressive strength of standard specimens cured under standard laboratory conditions for moist curing (see Section 17). Unless otherwise specified the age at test shall be 28 days.

NOTE 4—The purchaser, in selecting requirements for which he assumes responsibility should give consideration to requirements for workability, placeability, durability, surface texture, and density, in addition to those for structural design. The purchaser is referred to Standard Practice ACI 211.1 and Standard Practice ACI 211.2 for the selection of proportions that will result in concrete suitable for various types of structures and conditions of exposure. The water-cement ratio of most structural lightweight concretes cannot be determined with sufficient accuracy for use as a specification basis.

[4] *Annual Book of ASTM Standards*, Vol 11.01.
[5] Available from American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331.
[6] Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.
[7] Available from the American Association of State Highway and Transportation Officials, 444 N. Capitol St., NW, Suite 225, Washington, DC 20001.

TABLE 1 Recommended Total Air Content for Air-Entrained Concrete[A,B]

Exposure Condition[C]	Total Air Content, % Nominal Maximum Sizes of Aggregate, in. [mm]						
	⅜ [9.5]	½ [12.5]	¾ [19.0]	1 [25.0]	1½ [37.5]	2 [50.0]	3 [75.0]
Mild	4.5	4.0	3.5	3.0	2.5	2.0	1.5
Moderate	6.0	5.5	5.0	4.5	4.5	4.0	3.5
Severe	7.5	7.0	6.0	6.0	5.5	5.0	4.5

[A] For air-entrained concrete, when specified.
[B] Unless exposure conditions dictate otherwise, it is permissible to reduce air contents recommended above by up to 1 % for concretes with specified compressive strength, f'_c, of 5000 psi [35 MPa] or above.
[C] For description of exposure conditions, refer to Standard Practice ACI 211.1, Section 6.3.3, with attention to accompanying footnotes.

4.2.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry masses of cement and saturated surface-dry-masses of fine and coarse aggregate and quantities, type, and name of admixtures (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. He shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified.

4.3 *Option B*:

4.3.1 When the purchaser assumes responsibility for the proportioning of the concrete mixture, he shall also specify the following:

4.3.1.1 Cement content in bags or pounds per cubic yard [kilograms per cubic metre] of concrete,

4.3.1.2 Maximum allowable water content in gallons per cubic yard [litres per cubic metre] of concrete, including surface moisture on the aggregates, but excluding water of absorption (Note 4), and

4.3.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used under this option without the written approval of the purchaser.

4.3.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser giving the sources, densities, and sieve analyses of the aggregates and the dry masses of cement and saturated-surface-dry masses of fine and coarse aggregate and quantities, type and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser.

4.4 *Option C*:

4.4.1 When the purchaser requires the manufacturer to assume responsibility for the selection of the proportions for the concrete mixture with the minimum allowable cement content specified (Note 5), the purchaser shall also specify the following:

4.4.1.1 Required compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 17. The purchaser shall specify the requirements for strength in terms of tests of standard specimens cured under standard laboratory conditions for moist curing (see Section 17). Unless otherwise specified the age at test shall be 28 days.

4.4.1.2 Minimum cement content in bags or pounds per cubic yard [kilograms per cubic metre] of concrete.

4.4.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used.

NOTE 5—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the strength, aggregate size, and slump specified. At the same time, it must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density, in the event specified strength is attained with it. For additional information refer to Standard Practice ACI 211.1 and Standard Practice 211.2 referred to in Note 4.

4.4.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry masses of cement and saturated surface-dry masses of fine and coarse aggregate and quantities, type, and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. He shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified. Whatever strengths are attained the quantity of cement used shall not be less than the minimum specified.

4.5 The proportions arrived at by Options A, B, or C for each class of concrete and approved for use in a project shall be assigned a designation to facilitate identification of each concrete mixture delivered to the project. This is the designation required in 13.1.7 and supplies information on concrete proportions when they are not given separately on each delivery ticket as outlined in 13.2. A certified copy of all proportions as established in Options A, B, or C shall be on file at the batch plant.

4.6 The purchaser shall ensure that the manufacturer is provided copies of all reports of tests performed on concrete samples taken to determine compliance with specification requirements. Reports shall be provided on a timely basis.

5. Materials

5.1 In the absence of designated applicable specifications covering requirements for quality of materials, the following specifications shall govern:

5.1.1 *Cement*—Cement shall conform to Specification C 150, Specification C 595, or Specification C 1157 (see Note 6). The purchaser shall specify the type or types required, but if no type is specified, the requirements of Type I as prescribed in Specification C 150 shall apply.

NOTE 6—These different cements will produce concretes of different properties and should not be used interchangeably.

5.1.2 *Aggregates*—Aggregates shall conform to Specification C 33 or Specification C 330 if lightweight concrete is specified by the purchaser.

5.1.3 *Water*:

5.1.3.1 The mixing water shall be clear and apparently clean. If it contains quantities of substances which discolor it or make it smell or taste unusual or objectionable or cause suspicion, it shall not be used unless service records of concrete made with it or other information indicates that it is not injurious to the quality of the concrete. Water of questionable quality shall be subject to the acceptance criteria of Table 2.

5.1.3.2 Wash water from mixer washout operations is permitted to be used for mixing concrete provided tests of wash water comply with the physical test limits of Table 2. Wash water shall be tested at a weekly interval for approximately 4 weeks, and thereafter at a monthly interval provided no single test exceeds the applicable limit (Note 7). Optional chemical limits in Table 3 shall be specified by the purchaser when

TABLE 2 Acceptance Criteria for Questionable Water Supplies

	Limits	Test Method
Compressive strength, min % control at 7 days	90	C 109/C 109M[A]
Time of set, deviation from control, h: min	from 1:00 early to 1:30 later	C 191[A]

[A] Comparisons shall be based on fixed proportions and the same volume of test water compared to control mix using city water or distilled water.

TABLE 3 Optional Chemical Limits for Wash Water

	Limits	Test Method[A]
Chemical requirements, maximum concentration in mixing water, ppm[B]		
Chloride as Cl, ppm:		D 512
Prestressed concrete or in bridge decks	500[C]	
Other reinforced concrete in moist environments or containing aluminum embedments or dissimilar metals or with stay-in-place galvanized metal forms	1000[C]	
Sulfate as SO_4, ppm	3000	D 516
Alkalies as (Na_2O + 0.658 K_2O), ppm	600	
Total solids, ppm	50 000	AASHTO T26

[A] Other test methods that have been demonstrated to yield comparable results are permitted to be used.
[B] Wash water reused as mixing water in concrete is allowed to exceed the listed concentrations if it can be shown that the concentration calculated in the total mixing water, including mixing water on the aggregates and other sources does not exceed the stated limits.
[C] For conditions allowing use of $CaCl_2$ accelerator as an admixture, the chloride limitation is permitted to be waived by the purchaser.

appropriate for the construction. The testing frequency for chemical limits shall be as given above or as specified by the purchaser.

NOTE 7—When recycled wash water is used, attention should be given to effects on the dosage rate and batching sequence of air-entraining and other chemical admixtures, and a uniform amount should be used in consecutive batches.

5.1.4 *Mineral Admixtures*—Coal fly ash and raw or calcined natural pozzolan shall conform to Specification C 618 as applicable.

5.1.5 *Ground Granulated Blast-Furnace Slag*—Ground granulated blast- furnace slag shall conform to Specification C 989.

5.1.6 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification C 260 (Note 8).

5.1.7 *Chemical Admixtures*—Chemical admixtures shall conform to either Specification C 494/C 494M or C 1017/C 1017M as applicable (Note 8).

NOTE 8—In any given instance, the required dosage of air-entraining, accelerating, and retarding admixtures may vary. Therefore, a range of dosages should be allowed which will permit obtaining the desired effect.

6. Tolerances in Slump

6.1 Unless other tolerances are included in the project specifications, the following shall apply.

6.1.1 When the project specifications for slump are written as a "maximum" or "not to exceed" requirement:

	Specified slump:	
	If 3 in. [75 mm] or less	If more than 3 in. [75 mm]
Plus tolerance:	0	0
Minus tolerance:	1½ in. [40 mm]	2½ in. [65 mm]

This option is to be used only if one addition of water is permitted on the job provided such addition does not increase the water-cement ratio above the maximum permitted by the specifications.

6.1.2 When the project specifications for slump are *not* written as a "maximum" or "not to exceed" requirement:

Tolerances for Nominal Slumps

For Specified Slump of:	Tolerance
2 in. [50 mm] and less	±½ in. [15 mm]
More than 2 through 4 in. [50 to 100 mm]	±1 in. [25 mm]
More than 4 in. [100 mm]	±1½ in. [40 mm]

6.2 Concrete shall be available within the permissible range of slump for a period of 30 min starting either on arrival at the job site or after the initial slump adjustment permitted in 11.7, whichever is later. The first and last ¼ yd^3 or ¼ m^3 discharged are exempt from this requirement. If the user is unprepared for discharge of the concrete from the vehicle, the producer shall not be responsible for the limitation of minimum slump after 30 min have elapsed starting either on arrival of the vehicle at the prescribed destination or at the requested delivery time, whichever is later.

7. Air-Entrained Concrete

7.1 When air-entrained concrete is desired the purchaser shall specify the total air content of the concrete. See Table 1 for recommended total air contents (Note 8).

7.2 The air content of air-entrained concrete when sampled from the transportation unit at the point of discharge shall be within a tolerance of ± 1.5 of the specified value.

7.3 When a preliminary sample taken within the time limits of 11.7 and prior to discharge for placement shows an air content below the specified level by more than the allowable tolerance in accordance with 7.2, the manufacturer may use additional air entraining admixture to achieve the desired air content level, followed by a minimum of 30 revolutions at mixing speed, so long as the revolution limit of 11.7 is not exceeded (see Note 9).

NOTE 9—Acceptance sampling and testing in accordance with Practice C 172 is not obviated by this provision.

8. Measuring Materials

8.1 Except as otherwise specifically permitted, cement shall be measured by mass. When mineral admixtures (including

ground granulated blast-furnace slag, coal fly ash, silica fume, or other pozzolans) are specified in the concrete proportions, the cumulative mass is permitted to be measured with cement, but in a batch hopper and on a scale which is separate and distinct from those used for other materials. The mass of the cement shall be measured before mineral admixtures. When the quantity of cement exceeds 30 % of the full capacity of the scale, the quantity of the cement shall be within± 1 % of the required mass, and the cumulative quantity of cement plus mineral admixtures shall also be within ±1 % of the required mass. For smaller batches to a minimum of 1 yd^3 [1 m^3], the quantity of the cement and the cumulative quantity of cement plus mineral admixture used shall be not less than the required amount nor more than 4 % in excess. Under special circumstances approved by the purchaser, cement is permitted to be measured in bags of standard mass (Note 10). No fraction of a bag of cement shall be used unless its mass has been determined.

NOTE 10—In the United States the standard mass of a bag of portland cement is 94 lb [42.6 kg] ±3 %.

8.2 Aggregate shall be measured by mass. Batch mass measurements shall be based on dry materials and shall be the required masses of dry materials plus the total mass of moisture (both absorbed and surface) contained in the aggregate. The quantity of aggregate used in any batch of concrete as indicated by the scale shall be within ±2 % of the required mass when the mass is measured in individual aggregate weigh batchers. In a cumulative aggregate weigh batcher, the cumulative weight after each successive weighing shall be within ±1 % of the required cumulative amount up to that point when the scale is used in excess of 30 % of its capacity. For cumulative weights for less than 30 % of scale capacity, the tolerance shall be ±0.3 % of scale capacity or ±3 % of the required cumulative weight, whichever is less.

8.3 Mixing water shall consist of water added to the batch, ice added to the batch, water occurring as surface moisture on the aggregates, and water introduced in the form of admixtures. The added water shall be measured by weight or volume to an accuracy of 1 % of the required total mixing water. Added ice shall be measured by weight. In the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete shall be accurately measured; if this proves impractical or impossible the wash water shall be discharged prior to loading the next batch of concrete. Total water (including any wash water) shall be measured or weighed to an accuracy of ±3 % of the specified total amount.

8.4 Admixtures in powdered form shall be measured by mass. Liquid admixtures shall be batched by mass or volume. Admixtures, except mineral admixtures (see 8.1), measured by either mass or volume, shall be batched with an accuracy of ±3 % of the total amount required or plus or minus the amount or dosage required for 100 lb [50 kg] of cement, whichever is greater.

NOTE 11—Admixture dispensers of the mechanical type capable of adjustment for variation of dosage, and of simple calibration, are recommended.

9. Batching Plant

9.1 Bins with adequate separate compartments shall be provided in the batching plant for fine and for each required size of coarse aggregate. Each bin compartment shall be designed and operated so as to discharge efficiently and freely, with minimum segregation, into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is approached, the material shall be shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully.

9.2 Indicating devices shall be in full view and near enough to be read accurately by the operator while charging the hopper. The operator shall have convenient access to all controls.

9.3 Scales shall be considered accurate when at least one static load test within each quarter of the scale capacity can be shown to be within ±0.2 % of the total capacity of the scale.

9.4 Adequate standard test weights shall be available for checking accuracy. All exposed fulcrums, clevises, and similar working parts of scales shall be kept clean. Beam scales shall be equipped with a balance indicator sensitive enough to show movement when a weight equal to 0.1 % of the nominal capacity of the scale is placed in the batch hopper. Pointer travel shall be a minimum of 5 % of the net-rated capacity of the largest weigh beam for underweight and 4 % for overweight.

9.5 The device for the measurement of the added water shall be capable of delivering to the batch the quantity required within the accuracy required in 8.3. The device shall be so arranged that the measurements will not be affected by variable pressures in the water supply line. Measuring tanks shall be equipped with outside taps and valves to provide for checking their calibration unless other means are provided for readily and accurately determining the amount of water in the tank.

NOTE 12—The scale accuracy limitations of the National Ready Mixed Concrete Association Plant Certification meet the requirements of this specification.

10. Mixers and Agitators

10.1 Mixers will be stationary mixers or truck mixers. Agitators will be truck mixers or truck agitators.

10.1.1 Stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles, and the maximum capacity in terms of the volume of mixed concrete. When used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed.

10.1.2 Each truck mixer or agitator shall have attached thereto in a prominent place a metal plate or plates on which are plainly marked the gross volume of the drum, the capacity of the drum or container in terms of the volume of mixed concrete, and the minimum and maximum mixing speeds of rotation of the drum, blades, or paddles. When the concrete is truck mixed as described in 11.5, or shrink mixed as described in 11.4, the volume of mixed concrete shall not exceed 63 % of the total volume of the drum or container. When the concrete is central mixed as described in 11.3, the volume of concrete in

the truck mixer or agitator shall not exceed 80 % of the total volume of the drum or container. Truck mixers and agitators shall be equipped with means to readily verify the number of revolutions of the drum, blades, or paddles.

10.2 All stationary and truck mixers shall be capable of combining the ingredients of the concrete within the specified time or the number of revolutions specified in 10.5, into a thoroughly mixed and uniform mass and of discharging the concrete so that not less than five of the six requirements shown in Table A1.1 shall have been met.

NOTE 13—The sequence or method of charging the mixer will have an important effect on the uniformity of the concrete.

10.3 The agitator shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity as defined by Annex A1.

10.4 Slump tests of individual samples taken after discharge of approximately 15 % and 85 % of the load will provide a quick check of the probable degree of uniformity (Note 14). These two samples shall be obtained within an elapsed time of not more than 15 min. If these slumps differ more than that specified in Annex A1, the mixer or agitator shall not be used unless the condition is corrected, except as provided in 10.5.

NOTE 14—No samples should be taken before 10 % or after 90 % of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and end of the load.

10.5 Use of the equipment is permitted when operation with a longer mixing time, a smaller load, or a more efficient charging sequence will permit the requirements of Annex A1 to be met.

10.6 Mixers and agitators shall be examined or their mass determined as frequently as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examined to detect wear of blades. When such changes are extensive enough to affect the mixer performance, the proof-tests described in Annex A1 shall be performed to show whether the correction of deficiencies is required.

11. Mixing and Delivery

11.1 Ready-mixed concrete shall be mixed and delivered to the point designated by the purchaser by means of one of the following combinations of operations:

11.1.1 *Central-Mixed Concrete*.

11.1.2 *Shrink-Mixed Concrete*.

11.1.3 *Truck-Mixed Concrete*.

11.2 Mixers and agitators shall be operated within the limits of capacity and speed of rotation designated by the manufacturer of the equipment.

11.3 *Central-Mixed Concrete*—Concrete that is mixed completely in a stationary mixer and transported to the point of delivery either in a truck agitator, or a truck mixer operating at agitating speed, or in nonagitating equipment approved by the purchaser and meeting the requirements of Section 12, shall conform to the following: The mixing time shall be counted from the time all the solid materials are in the drum. The batch shall be so charged into the mixer that some water will enter in advance of the cement and aggregate, and all water shall be in the drum by the end of the first one fourth of the specified mixing time.

11.3.1 Where no mixer performance tests are made, the acceptable mixing time for mixers having capacities of 1 yd^3 [0.76 m^3] or less shall be not less than 1 min. For mixers of greater capacity, this minimum shall be increased 15 s for each cubic yard [cubic metre] or fraction thereof of additional capacity.

11.3.2 Where mixer performance tests have been made on given concrete mixtures in accordance with the testing program set forth in the following paragraphs, and the mixers have been charged to their rated capacity, the acceptable mixing time is permitted to be reduced for those particular circumstances to a point at which satisfactory mixing defined in 11.3.3 shall have been accomplished. When the mixing time is so reduced the maximum time of mixing shall not exceed this reduced time by more than 60 s for air-entrained concrete.

11.3.3 *Sampling for Uniformity Tests of Stationary Mixers*—Samples of concrete for comparative purposes shall be obtained immediately after arbitrarily designated mixing times, in accordance with one of the following procedures:

11.3.3.1 *Alternative Procedure 1*—The mixer shall be stopped, and the required samples removed by any suitable means from the concrete at approximately equal distances from the front and back of the drum, or

11.3.3.2 *Alternative Procedure 2*—As the mixer is being emptied, individual samples shall be taken after discharge of approximately 15 % and 85 % of the load. The method of sampling shall provide that the samples are representative of widely separated portions, but not from the very ends of the batch (Note 14).

11.3.3.3 The samples of concrete shall be tested in accordance with Section 17, and differences in test results for the two samples shall not exceed those given in Annex A1. Mixer performance tests shall be repeated whenever the appearance of the concrete or the coarse aggregate content of samples selected as outlined in this section indicates that adequate mixing has not been accomplished.

11.4 *Shrink-Mixed Concrete*—Concrete that is first partially mixed in a stationary mixer, and then mixed completely in a truck mixer, shall conform to the following: The time of partial mixing shall be minimum required to intermingle the ingredients. After transfer to a truck mixer the amount of mixing at the designated mixing speed will be that necessary to meet the requirements for uniformity of concrete as indicated in Annex A1. Tests to confirm such performance shall be made in accordance with 11.3.3 and 11.3.3.3. Additional turning of the mixer, if any, shall be at a designated agitating speed.

11.5 *Truck-Mixed Concrete*—Concrete that is completely mixed in a truck mixer, 70 to 100 revolutions at the mixing speed designated by the manufacturer to produce the uniformity of concrete indicated in Annex A1. Concrete uniformity tests shall be made in accordance with 11.5.1 and if requirements for uniformity of concrete indicated in Annex A1 are not met with 100 revolutions of mixing, after all ingredients including water, are in the drum, that mixer shall not be used until the condition is corrected, except as provided in 10.5.

When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of blades are permitted to be regarded as satisfactory. Additional revolutions of the mixer beyond the number found to produce the required uniformity of concrete shall be at a designated agitating speed.

11.5.1 *Sampling for Uniformity of Concrete Produced in Truck Mixers*—The concrete shall be discharged at the normal operating rate for the mixer being tested, with care being exercised not to obstruct or retard the discharge by an incompletely opened gate or seal. Separate samples, each consisting of approximately 2 ft^3 [0.1 m^3 approximately] shall be taken after discharge of approximately 15 % and 85 % of the load (Note 14). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured in accordance with Practice C 172, but shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Between samples, where necessary to maintain slump, the mixer shall be turned in mixing direction at agitating speed. During sampling the receptacle shall receive the full discharge of the chute. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be remixed the minimum amount to ensure uniformity before specimens are molded for a particular test.

11.6 When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed in a stationary mixer, any turning during transportation shall be at the speed designated by the manufacturer of the equipment as agitating speed.

11.7 When a truck mixer or agitator is approved for mixing or delivery of concrete, no water from the truck water system or elsewhere shall be added after the initial introduction of mixing water for the batch except when on arrival at the job site the slump of the concrete is less than that specified. Such additional water to bring the slump within required limits shall be injected into the mixer under such pressure and direction of flow that the requirements for uniformity specified in Annex A1 are met. The drum or blades shall be turned an additional 30 revolutions or more if necessary, at mixing speed, until the uniformity of the concrete is within these limits. Water shall not be added to the batch at any later time. Discharge of the concrete shall be completed within 1½ h, or before the drum has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. These limitations are permitted to be waived by the purchaser if the concrete is of such slump after the 1½-h time or 300-revolution limit has been reached that it can be placed, without the addition of water, to the batch. In hot weather, or under conditions contributing to quick stiffening of the concrete, a time less than 1½ h is permitted to be specified by the purchaser.

11.8 Concrete delivered in cold weather shall have the applicable minimum temperature indicated in the following table. (The purchaser shall inform the producer as to the type of construction for which the concrete is intended.)

Minimum Concrete Temperature as Placed

Section Size, in. [mm]	Temperature, min, °F [C]
<12 [<300]	55 [13]
12–36 [300–900]	50 [10]
36–72 [900–1800]	45 [7]
>72 [>1800]	40 [5]

The maximum temperature of concrete produced with heated aggregates, heated water, or both, shall at no time during its production or transportation exceed 90°F [32°C].

NOTE 15—When hot water is used rapid stiffening may occur if hot water is brought in direct contact with the cement. Additional information on cold weather concreting is contained in ACI 306R.

11.9 The producer shall deliver the ready mixed concrete during hot weather at concrete temperatures as low as practicable, subject to the approval of the purchaser.

NOTE 16—In some situations difficulty may be encountered when concrete temperatures approach 90°F [32°C]. Additional information may be found in the Bureau of Reclamation Concrete Manual and in ACI 305R.

12. Use of Nonagitating Equipment

12.1 Central-mixed concrete shall be transported in suitable nonagitating equipment approved by the purchaser. The proportions of the concrete shall be approved by the purchaser and the following limitations shall apply:

12.2 Bodies of nonagitating equipment shall be smooth, watertight, metal containers equipped with gates that will permit control of the discharge of the concrete. Covers shall be provided for protection against the weather when required by the purchaser.

12.3 The concrete shall be delivered to the site of the work in a thoroughly mixed and uniform mass and discharged with a satisfactory degree of uniformity as prescribed in Annex A1.

12.4 Slump tests of individual samples taken after discharge of approximately 15 % and 85 % of the load will provide for a quick check of the probable degree of uniformity (Note 14). These two samples shall be obtained within an elapsed time of not more than 15 min. If these slumps differ more than that specified in Table A1.1, the nonagitating equipment shall not be used unless the conditions are corrected as provided in 12.5.

12.5 If the requirements of Annex A1 are not met when the nonagitating equipment is operated for the maximum time of haul, and with the concrete mixed the minimum time, the equipment shall only be used when operated using shorter hauls, or longer mixing times, or combinations thereof that will result in the requirements of Annex A1 being met.

13. Batch Ticket Information

13.1 The manufacturer of the concrete shall furnish to the purchaser with each batch of concrete before unloading at the site, a delivery ticket on which is printed, stamped, or written, information concerning said concrete as follows:

13.1.1 Name of ready-mix company and batch plant, or batch plant number,

13.1.2 Serial number of ticket,

13.1.3 Date,

13.1.4 Truck number,

13.1.5 Name of purchaser,

13.1.6 Specific designation of job (name and location),

13.1.7 Specific class or designation of the concrete in conformance with that employed in job specifications,

13.1.8 Amount of concrete in cubic yards (or cubic metres),

13.1.9 Time loaded or of first mixing of cement and aggregates, and

13.1.10 Water added by receiver of concrete and his initials.

13.2 Additional information for certification purposes as designated by the purchaser and required by the job specifications shall be furnished when requested; such information as:

13.2.1 Reading of revolution counter at the first addition of water,

13.2.2 Type, brand, and amount of cement,

13.2.3 Class, brand, and amount of coal fly ash, or raw or calcined natural pozzolans,

13.2.4 Grade, brand, and amount of ground granulated blast-furnace slag,

13.2.5 Type, brand, and amount of silica fume,

13.2.6 Type, brand, and amount of admixtures

13.2.7 Type, brand, and amount of fiber reinforcement,

13.2.8 Source and amount of each metered or weighed water or recycled slurry,

13.2.9 Information necessary to calculate the total mixing water. Total mixing water includes free water on aggregates, batch water (metered or weighed) including ice batched at the plant, wash water retained in the mixing drum, and water added by the truck operator from the mixer tank,

13.2.10 Maximum size of aggregate,

13.2.11 Mass (amount) of fine and coarse aggregate,

13.2.12 Ingredients certified as being previously approved, and

13.2.13 Signature or initials of producer's representative.

14. Plant Inspection

14.1 The manufacturer shall afford the inspector all reasonable access, without charge, for making necessary checks of the production facilities and for securing necessary samples to determine if the concrete is being produced in accordance with this specification. All tests and inspection shall be so conducted as not to interfere unnecessarily with the manufacture and delivery of concrete.

15. Practices, Test Methods, and Reporting

15.1 Test ready-mixed concrete in accordance with the following methods:

15.1.1 *Compression Test Specimens*—Practice C 31/C 31M, using standard moist curing in accordance with the applicable provisions of Practice C 31/C 31M.

15.1.2 *Compression Tests*—Test Method C 39/C 39M.

15.1.3 *Yield, Mass per Cubic Foot*—Test Method C 138/C 138M.

15.1.4 *Air Content*—Test Method C 138/C 138M; Test Method C 173/C 173M or Test Method C 231.

15.1.5 *Slump*—Test Method C 143/C 143M.

15.1.6 *Sampling Fresh Concrete*—Practice C 172.

15.1.7 *Temperature*—Test Method C 1064/C 1064M.

15.2 The testing laboratory performing acceptance tests of concrete shall meet the requirements of Practice C 1077.

15.3 Laboratory reports of concrete test results used to determine compliance with this specification shall include a statement that all tests performed by the laboratory or its agents were in accordance with the applicable test methods or shall note all known deviations from the prescribed procedures (Note 17). The reports shall also list any part of the test methods not performed by the laboratory.

NOTE 17—Deviation from standard test methods may adversely affect test results.

NOTE 18—Deviation from standard moisture and temperature curing conditions is often a reason for low strength test results. Such deviations may invalidate the use of such test results as a basis for rejection of the concrete.

16. Sampling and Testing Fresh Concrete

16.1 The contractor shall afford the inspector all reasonable access and assistance, without charge, for the procurement of samples of fresh concrete at time of placement to determine conformance of it to this specification.

16.2 Tests of concrete required to determine compliance with this specification shall be made by a certified ACI Concrete Field Testing Technician, Grade I or equivalent. Equivalent personnel certification programs shall include both written and performance examinations as outlined in ACI CP-1.

16.3 Samples of concrete shall be obtained in accordance with Practice C 172, except when taken to determine uniformity of slump within any one batch or load of concrete (10.4, 11.3.3, 11.5.1, and 12.4).

16.4 Slump, air-content, density, and temperature tests shall be made at the time of placement at the option of the inspector as often as is necessary for control checks. In addition, these tests shall be made when specified and always when strength specimens are made.

16.5 Strength tests as well as slump, temperature, density, and air content tests shall generally be made with a frequency of not less than one test for each 150 yd^3 (115 m^3). Each test shall be made from a separate batch. On each day concrete is delivered, at least one strength test shall be made for each class of concrete.

16.6 If preliminary checks of slump or air content are made, a single sample shall be taken after the discharge of not less than ¼ yd^3[¼ m^3]. All other requirements of Practice C 172 shall be retained. If the preliminary measurement of slump (11.7) or air content (7.3) falls outside the specified limits, address as indicated in section 16.6.1 or 16.6.2 as appropriate.

16.6.1 If the measured slump or air content, or both is greater than the specified upper limit, a check test shall be made immediately on a new test sample. In the event the check test fails, the concrete shall be considered to have failed the requirements of the specification.

16.6.2 If the measured slump or air content, or both is less than the lower limit, permit adjustments in accordance with 11.7 or 7.3 or both, as appropriate, and obtain a new sample. If the sample of the adjusted concrete fails, a check test shall be made immediately on a new sample of the adjusted concrete. In the event the check test fails, the concrete shall be considered to have failed the requirements of the specification.

17. Strength

17.1 When strength is used as a basis for acceptance of concrete, standard specimens shall be made in accordance to Practice C 31/C 31M. The specimens shall be cured under standard moisture and temperature conditions in accordance with the applicable provisions of Practice C 31/C 31M. The technician performing the strength test shall be certified as an ACI Concrete Strength Testing Technician, Concrete Laboratory Testing Technician—Grade II or by an equivalent written and performance test program covering the relevant test methods. If acceptance is based upon compressive strength test results, the certification requirement is satisfied by certification as an ACI Concrete Laboratory Testing Technician—Grade I or by an equivalent written and performance test program.

17.2 For a strength test, at least two standard test specimens shall be made from a composite sample secured as required in Section 16. A test shall be the average of the strengths of the specimens tested at the age specified in 4.2.1.1 or 4.4.1.1 (Note 19). If a specimen shows definite evidence other than low strength, of improper sampling, molding, handling, curing, or testing, it shall be discarded and the strength of the remaining cylinder shall then be considered the test result.

NOTE 19—Additional tests may be made at other ages to obtain information for determining form removal time or when a structure may be put in service. Specimens for such tests are cured according to the section on Field Curing in Practice C 31/C 31M.

17.3 The representative of the purchaser shall ascertain and record the delivery-ticket number for the concrete and the exact location in the work at which each load represented by a strength test is deposited.

17.4 To conform to the requirements of this specification, strength tests representing each class of concrete must meet the following two requirements (Note 20):

17.4.1 The average of any three consecutive strength tests shall be equal to, or greater than, the specified strength, f'_c, and

17.4.2 No individual strength test shall be more than 500 psi [3.5 MPa] below the specified strength, f'_c.

NOTE 20—Due to variations in materials, operations, and testing, the average strength necessary to meet these requirements will be substantially higher than the specified strength. The amount higher depends upon the standard deviation of the test results and the accuracy with which that value can be estimated from prior data as explained in ACI 318 and ACI 301. Pertinent data are given in Table 4.

18. Failure to Meet Strength Requirements

18.1 In the event that concrete tested in accordance with the requirements of Section 17 fails to meet the strength requirements of this specification, the manufacturer of the ready-mixed concrete and the purchaser shall confer to determine whether agreement can be reached as to what adjustment, if any, shall be made. If an agreement on a mutually satisfactory adjustment cannot be reached by the manufacturer and the purchaser, a decision shall be made by a panel of three qualified engineers, one of whom shall be designated by the purchaser, one by the manufacturer, and the third chosen by these two members of the panel. The question of responsibility for the cost of such arbitration shall be determined by the panel. Its decision shall be binding, except as modified by a court decision.

19. Keywords

19.1 accuracy; blended hydraulic cement; certification; ready-mixed concrete; scales; testing

TABLE 4 Overdesign Necessary to Meet Strength Requirements[A]

Number of Tests[B]	Standard Deviation, psi					Unknown
	300	400	500	600	700	
15	466	622	851	1122	1392	[C]
20	434	579	758	1010	1261	[C]
30 or more	402	526	665	898	1131	[C]
	Standard Deviation, MPa					
	2.0	3.0	4.0	5.0	Unknown	
15	3.1	4.7	7.3	10.0	[C]	
20	2.9	4.3	6.6	9.1	[C]	
30 or more	2.7	4.0	5.8	8.2	[C]	

[A] Add the tabulated amounts to the specified strength to obtain the required average strengths.

[B] Number of tests of a concrete mixture used to estimate the standard deviation of a concrete production facility. The mixture used must have a strength within 1000 psi [7.0 MPa] of that specified and be made with similar materials. See ACI 318.

[C] If less than 15 prior tests are available, the overdesign should be 1000 psi [7.0 MPa] for specified strength less than 3000 psi [20 MPa], 1200 psi [8.5 MPa] for specified strengths from 3000 to 5000 psi [20 to 35 MPa] and 1400 psi [10.0 MPa] for specified strengths greater than 5000 psi [35 MPa].

ANNEX

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 The variation within a batch as provided in Table A1.1 shall be determined for each property listed as the difference between the highest value and the lowest value obtained from the different portions of the same batch. For this specification the comparison will be between two samples, representing the first and last portions of the batch being tested. Test results conforming to the limits of five of the six tests listed in Table A1.1 shall indicate uniform concrete within the limits of this specification.

A1.2 *Coarse Aggregate Content,* using the washout test, shall be computed from the following relations:

TABLE A1.1 Requirements for Uniformity of Concrete

Test	Requirement, Expressed as Maximum Permissible Difference in Results of Tests of Samples Taken from Two Locations in the Concrete Batch
Mass per cubic foot [mass per cubic meter] calculated to an air-free basis, lb/ft^3[kg/m^3]	1.0 [16]
Air content, volume % of concrete	1.0
Slump:	
If average slump is 4 in. [100 mm] or less, in. [mm]	1.0 [25]
If average slump is 4 to 6 in. [100 to 150 mm], in. [mm]	1.5 [40]
Coarse aggregate content, portion by mass of each sample retained on No. 4 [4.75-mm] sieve, %	6.0
Mass per unit volume of air-free mortar[A] based on average for all comparative samples tested, %.	1.6
Average compressive strength at 7 days for each sample,[B] based on average strength of all comparative test specimens, %	7.5[C]

[A] "Test for Variability of Constituents in Concrete," Designation 26, *Bureau of Reclamation Concrete Manual,* 7th Edition.[6]
[B] Not less than 3 cylinders will be molded and tested from each of the samples.
[C] Approval of the mixer shall be tentative, pending results of the 7-day compressive strength tests.

$$P = (c/b) \times 100 \qquad \text{(A1.1)}$$

where:
P = mass % of coarse aggregate in concrete,
c = saturated-surface-dry mass in lb [kg] of aggregate retained on the No. 4 [4.75-mm] sieve, resulting from washing all material finer than this sieve from the fresh concrete, and
b = mass of sample of fresh concrete in mass per unit volume container, lb [kg].

A1.3 *Mass per Unit Volume of Air Free Mortar* shall be calculated as follows:
Inch-pound units:

$$M = \frac{b - c}{V - \left(\frac{V \times A}{100} + \frac{c}{G}\right)} \qquad \text{(A1.2)}$$

SI units:

$$M = \frac{b - c}{V - \left(\frac{V \times A}{100} + \frac{c}{G}\right)} \qquad \text{(A1.3)}$$

where:
M = mass per unit volume of air-free mortar, lb/ft^3 [kg/m^3],
b = mass of concrete sample in mass container, lb [kg],
c = saturated-surface-dry mass of aggregate retained on No. 4 [4.75-mm] sieve, lb [kg],
V = volume of mass per unit volume container, ft^3 [m^3],
A = air content of concrete, %, measured in accordance with 15.1.4 on the sample being tested, and
G = density of coarse aggregate (SSD).