Designation: C94/C94M – 17a

Standard Specification for Ready-Mixed Concrete[1]

This standard is issued under the fixed designation C94/C94M; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification covers ready-mixed concrete as defined in 3.2.2 (Note 1). Requirements for quality of ready-mixed concrete shall be either as stated in this specification or as ordered by the purchaser. When the purchaser's requirements, as stated in the order, differ from those in this specification, the purchaser's requirements shall govern. This specification does not cover the placement, consolidation, curing, or protection of the concrete after delivery to the purchaser.

NOTE 1—Concrete produced by volumetric batching and continuous mixing is covered in Specification C685. Fiber-reinforced concrete is covered in Specification C1116.

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 produces ready-mixed concrete. The purchaser buys ready-mixed concrete.

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.

1.5 *This standard does not purport to address all 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.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged use.[2])

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C33/C33M Specification for Concrete Aggregates
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C125 Terminology Relating to Concrete and Concrete Aggregates
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150/C150M Specification for Portland Cement
C172/C172M Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C260/C260M Specification for Air-Entraining Admixtures for Concrete
C330/C330M Specification for Lightweight Aggregates for Structural Concrete
C494/C494M Specification for Chemical Admixtures for Concrete
C567/C567M Test Method for Determining Density of Structural Lightweight Concrete
C595/C595M Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

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

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

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

C637 Specification for Aggregates for Radiation-Shielding Concrete
C685 Specification for Concrete Made by Volumetric Batching and Continuous Mixing
C989/C989M Specification for Slag Cement for Use in Concrete and Mortars
C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
C1116 Specification for Fiber-Reinforced Concrete and Shotcrete
C1157/C1157M Performance Specification for Hydraulic Cement
C1240 Specification for Silica Fume Used in Cementitious Mixtures
C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete
C1798/C1798M Specification for Returned Fresh Concrete for Use in a New Batch of Ready-Mixed Concrete

2.2 *ACI Documents:*[4]
ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete
ACI 301 Standard Specifications for Structural Concrete
ACI 305R Guide to Hot Weather Concreting
ACI 306R Guide to Cold Weather Concreting
ACI 318 Building Code Requirements for Structural Concrete and Commentary

2.3 *Other Documents:*[5]
NIST 105-1 National Institute of Standards and Technology Handbook

3. Terminology

3.1 *Definitions*—The terms used in this specification are defined in Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *concrete, central-mixed, n*—ready-mixed concrete mixed completely in a stationary mixer.

3.2.2 *concrete, ready-mixed, n*—concrete manufactured and delivered to a purchaser in a fresh state.

3.2.3 *concrete, shrink-mixed, n*—ready-mixed concrete partially mixed in a stationary mixer with mixing completed in a truck mixer.

3.2.4 *concrete, truck-mixed, n*—ready-mixed concrete completely mixed in a truck mixer.

3.2.5 *water, target batch, n*—quantity of water to be added to the batch through the water measuring system after compensating for the quantity of ice, if used, surface moisture on the aggregates and water in the admixtures, when applicable, and by subtracting a quantity of water that is anticipated to be added at the jobsite or in transit to adjust slump or slump flow of the concrete batch.

4. Basis of Purchase

4.1 The basis of purchase shall be a cubic yard or cubic metre of fresh concrete as discharged from the transportation unit.

4.2 The volume of fresh concrete in a given batch shall be determined from the total mass of the batch divided by the density of the concrete. The total mass of the batch shall be determined as the net mass of the concrete in the batch as delivered, including the total mixing water as defined in 9.3. The density shall be determined in accordance with Test Method C138/C138M. The yield shall be determined as the average of at least three measurements, one from each of three different transportation units sampled in accordance with Practice C172/C172M.

NOTE 2—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.

5. Materials

5.1 In the absence of designated applicable material specifications, the following material specifications shall be used:

5.2 *Cementitious Materials:*

5.2.1 *Hydraulic Cement*—Hydraulic cement shall conform to Specification C150/C150M, Specification C595/C595M, or Specification C1157/C1157M.

5.2.2 *Supplementary Cementitious Materials*—Coal fly ash or natural pozzolans shall conform to Specification C618. Slag cement shall conform to Specification C989/C989M. Silica fume shall conform to Specification C1240.

5.3 *Aggregates*—Normal weight aggregates shall conform to Specification C33/C33M. Lightweight aggregates shall conform to Specification C330/C330M and heavyweight aggregates shall conform to Specification C637.

5.4 *Water*—Water shall conform to Specification C1602/C1602M.

5.5 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification C260/C260M (Note 3).

5.6 *Chemical Admixtures*—Chemical admixtures shall conform to Specification C494/C494M or C1017/C1017M as applicable (Note 3).

NOTE 3—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.

NOTE 4—Interchanging kinds, characteristics, types, classes, or grades

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

[5] NIST Handbook 105-1 (revised 1990), "Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures-1. Specifications and Tolerances for Field Standard Weights (NIST Class F)," National Institute of Standards and Technology., U.S. Dept. of Commerce, http://www.nist.gov/pml/wmd/upload/105-1.pdf.

of the materials permitted in ready-mixed concrete may produce concrete of different properties.

5.7 *Returned Fresh Concrete*—Returned fresh concrete, when permitted by the purchaser, shall conform to Specification C1798/C1798M.

NOTE 5—Specification C1798/C1798M provides requirements for using, measuring, and reporting returned fresh concrete. These requirements are in addition to those stated herein. The purchaser may further clarify which concrete within an order, such as specific mixtures or applications, may incorporate returned fresh concrete.

6. Ordering Information

6.1 In the absence of designated applicable general specifications, the purchaser's order shall include the following:

6.1.1 Designated size, or sizes, of coarse aggregate,

6.1.2 Slump, or slumps, desired at the point of delivery (see Section 7 for acceptable tolerances),

6.1.3 Slump flow, or flows, desired at the point of delivery (see Section 7 for acceptable tolerances),

6.1.4 Total air content at the point of delivery for concrete that will be exposed to cycles of freezing and thawing or anticipated exposure of the concrete (see Section 8 for sampling for air content tests and tolerances).

NOTE 6—Table 1 provides total air contents for concrete that vary by exposure condition and aggregate size. Total air contents less than those shown in Table 1 may be specified or used for concrete that is not subject to freezing and thawing. This may be done to improve workability and cohesiveness, reduce the rate of bleeding, reduce the water content for a given consistency, or achieve required lightweight concrete density. Specified total air contents higher than those shown in Table 1 may reduce strength without any further improvement of durability.

Exposure conditions for freezing and thawing environments in Table 1 correspond to the following:

Moderate Exposure—Concrete exposed to freeze-thaw cycles but not in contact with the ground or with limited exposure to water, limiting the ability to cause saturation of a portion of the concrete prior to freezing. The concrete shall not receive deicing salts or other aggressive chemicals. Examples include: exterior beams, columns, walls, girders, footings below the frost line, or elevated slabs where application of deicing salt is not anticipated. The air content requirements for this exposure are consistent with those for Exposure Class F1 of ACI 318.

Severe Exposure—Concrete exposed to freeze-thaw cycles while in contact with the ground or with frequent exposure to water, potentially causing saturation of a portion of the concrete prior to freezing. The concrete may receive deicing chemicals or other aggressive chemicals. Examples include: pavements, bridge decks, curbs, gutters, sidewalks, canal linings, or exterior water tanks or sumps. The air content requirements for this exposure are consistent with those for Exposure Classes F2 and F3 of ACI 318.

6.1.5 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,

6.1.6 When lightweight concrete is specified, the equilibrium density,

NOTE 7—The density of fresh concrete is the only measurable density of lightweight concrete at the time of delivery. The density of fresh concrete is always higher than the equilibrium or oven-dry density. Therefore, for acceptance of lightweight concrete based on density at the time of delivery, a relationship between the equilibrium density and density of fresh concrete needs to be established. Definitions of, and methods for determining or calculating equilibrium and oven-dry density, are covered by Test Method C567/C567M.

6.1.7 When high-density or heavyweight concrete is specified, the density of fresh concrete, and

NOTE 8—High-density or heavyweight concrete typically contains aggregate with a relative density of 3.3 or greater conforming to Specification C637. This concrete is used for radiation shielding or other applications where higher density is required by design. For acceptance of density at the time of delivery, a relationship between the fresh density and the density of hardened concrete required by design should be established.

6.1.8 If desired, any of the optional requirements of Table 2 in Specification C1602/C1602M.

6.1.9 Purchaser shall state any drum revolution limit as to when the concrete discharge must begin. If no drum revolution limit is stated by purchaser, the manufacturer shall determine and communicate the limit to the purchaser prior to delivery.

6.2 If a project specification applies, the order shall include applicable requirements for the concrete to be produced in compliance with the specification.

6.3 If the type, kind, or class of cementitious materials in 5.2.1 and 5.2.2 are not designated by the purchaser, it is permitted to use cementitious materials in concrete mixtures that will satisfy the concrete properties and other requirements of the purchaser as ordered.

6.4 *Option A:*

6.4.1 When the purchaser requires the manufacturer to assume full responsibility for the selection of the proportions for the concrete mixture (Note 9), the purchaser shall also specify the following:

6.4.1.1 Requirements for compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 18. 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 18). Unless otherwise specified the age at test shall be 28 days.

NOTE 9—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.

TABLE 1 Total Air Content for Air-Entrained Concrete Exposed to Cycles of Freezing and Thawing

Exposure Condition (See Note 6)	Total Air Content, % Nominal Maximum Sizes of Aggregate, mm [in.]						
	9.5 [⅜]	12.5 [½]	19.0 [¾]	25.0 [1]	37.5 [1½]	50.0 [2]	75.0 [3]
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

6.4.2 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 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. The manufacturer shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified.

6.5 *Option B:*

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

6.5.1.1 Cement content in kilograms per cubic metre [pounds per cubic yard] of concrete,

6.5.1.2 Maximum allowable water content in litres per cubic metre [gallons per cubic yard] of concrete, including surface moisture on the aggregates, but excluding water of absorption (Note 9), and

6.5.1.3 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.

6.5.2 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.

6.6 *Option C:*

6.6.1 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 10), the purchaser shall also specify the following:

6.6.1.1 Required compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 18. 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 18). Unless otherwise specified the age at test shall be 28 days.

6.6.1.2 Minimum cement content in kilograms per cubic metre [pounds per cubic yard] of concrete.

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

NOTE 10—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 or slump flow 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 9.

6.6.2 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.

6.7 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 14.1.7 and supplies information on concrete proportions when they are not given separately on each delivery ticket as outlined in 14.2. A certified copy of all proportions as established in Options A, B, or C shall be on file at the batch plant.

6.8 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.

6.9 The manufacturer shall obtain the purchaser's permission to incorporate returned fresh concrete.

7. Slump or Slump Flow

7.1 Unless other tolerances are indicated by the purchaser, the following shall apply.

7.1.1 When slump is stated as a "maximum" or "not to exceed" requirement:

Tolerances for "Maximum" or "Not to Exceed" Slumps

For Slump of:	Tolerance
75 mm [3 in.] or less	+0 and – 40 mm [1½ in.]
More than 75 mm [3 in.]	+0 and – 65 mm [2½ in.]

7.1.1.1 The maximum or not to exceed slump provision shall be used only if a job site water addition is permitted by the specification in accordance with 12.7.

7.1.2 When slump is stated as a target or nominal slump:

Tolerances for Target or Nominal Slumps

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

7.1.3 When the purchaser states a slump flow requirement for self-consolidating concrete:

Tolerances for Slump Flow

For Slump Flow	Tolerance
Less than or equal to 550 mm [22 in.]	±40 mm [1 ½ in.]
More than 550 mm [22 in.]	±65 mm [2 ½ in.]

7.1.4 The tolerances for slump or slump flow apply to the values stated in the order when adjustments in accordance with 12.7 and 12.8 are permitted.

7.2 Concrete shall be available within the permissible range of slump or slump flow for a period of 30 min starting either on arrival at the job site or after the initial slump adjustment permitted in 12.7, whichever is later. The first and last ¼ m^3 [¼ yd^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 or slump flow 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.

8. Air-Entrained Concrete

8.1 Unless otherwise specified, for air-entrained concrete the total air contents in Table 1 shall apply based on the exposure condition stated in the purchase order. It is permitted to reduce the total air content values in Table 1 by one percentage point for concretes with a specified compressive strength greater than or equal to 35 MPa [5000 psi]. Total air content that differs from the values in Table 1 is permitted for concrete not exposed to cycles of freezing and thawing (Note 6).

8.2 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.

8.3 When a preliminary sample taken within the time limits of 12.7 and prior to discharge for placement shows an air content below the specified level by more than the allowable tolerance in accordance with 8.2, 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 6.1.9 is not exceeded (see Note 11).

NOTE 11—Acceptance sampling and testing in accordance with Practice C172/C172M is not obviated by this provision. Increasing the air content may increase the slump or slump flow.

9. Measuring Materials

9.1 Except as otherwise specifically permitted, cementitious materials shall be measured by mass. When supplementary cementitious materials are used in the concrete mixtures, the cumulative mass is permitted to be measured with hydraulic 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 hydraulic cement shall be measured before supplementary cementitious materials. When the quantity of cementitious material exceeds 30 % of the full capacity of the scale, the measured quantity of the hydraulic cement shall be within ±1 % of the required mass, and the cumulative measured quantity of hydraulic cement plus supplementary cementitious materials shall also be within ±1 % of the required cumulative mass at each intermediate weighing. For smaller batches to a minimum of 1 m^3 [1 yd^3], the measured quantity of the hydraulic cement and the measured cumulative quantity of hydraulic cement plus supplementary cementitious materials used shall be not less than the required amount nor more than 4 % in excess. When the purchaser requires alternate methods of measuring cementitious materials, measurement methods and reporting shall be stated in the order (see Note 12).

NOTE 12—Cementitious materials in bags may be used when requested or permitted by the purchaser.

9.2 Aggregate shall be measured by mass. The quantity of aggregate weighed shall be the required dry mass plus the total moisture content (absorbed and surface) of the aggregate.

9.2.1 For individual weigh batchers, the quantity of aggregate weighed shall be within ±2 % of the required mass; except if the required quantity of aggregate is less than 15 % of scale capacity, the quantity of aggregate weighed shall be within ±0.3 % of scale capacity.

9.2.2 For cumulative weigh batchers, if the required quantity of aggregate is equal to or greater than 30 % of the scale capacity, the quantity of aggregate weighed shall be within ±1 % of the required mass at each successive weighing. If the required quantity of aggregate is less than 30 % of the scale capacity, the quantity of aggregate weighed shall be within ±0.3 % of scale capacity at each successive weighing.

NOTE 13—The batching accuracy limit of 0.3 % of scale capacity establishes a reasonable minimum weighing tolerance that is independent of the quantity of material being weighed.

9.3 Mixing water shall consist of batch water (water weighed or metered at the plant), ice, free moisture on the aggregates, wash water retained in the mixer before batching, water added at the jobsite in accordance with 12.7 or by an automated truck mixer system in accordance with 12.8, and water introduced from admixtures if the quantity added increases the water-cementitious materials ratio by more than 0.01 (Note 14). The batch water shall be measured by mass or volume to an accuracy of ±1 % of the mixing water established by the designed mixture proportions. Ice shall be measured by mass. In the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete shall be measured; if this proves impractical or impossible the wash water shall be discharged before loading the next batch of concrete. Quantity of mixing water shall be accurate to within ±3 % of the amount established by the designed mixture proportions.

NOTE 14—Mixing water is the total amount of water in a batch less the water absorbed by the aggregates. Mixing water is used to calculate the water-cementitious materials ratio (w/cm).

9.4 Chemical admixtures in powdered form shall be measured by mass. Liquid chemical admixtures shall be batched by mass or volume. Admixtures 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 50 kg [100 lb] of hydraulic cement, whichever is greater.

NOTE 15—Admixture dispensers of the mechanical type capable of adjustment for variation of dosage, and of simple calibration, are recommended.

10. Batching Plant

10.1 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.

10.2 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.

10.3 Scales shall be considered accurate if their accuracy is verified through the normally used capacity in accordance with Table 2 and load indicated relative to applied test load is within ±0.15 % of the total capacity of the scale or 0.4 % of the net applied load, whichever is greater. The minimum quantity and sequence of applied test loads used to verify material scales shall conform to Table 2 and its notes.

10.4 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.

10.5 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 9.3. 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 16—The scale accuracy limitations of the National Ready Mixed Concrete Association Plant Certification meet the requirements of this specification.

11. Mixers and Agitators

11.1 Mixers include stationary mixers or truck mixers. Agitators include truck mixers or truck agitators.

11.1.1 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. If 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.

11.1.2 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. If the concrete is truck mixed as described in 12.5, or shrink mixed as described in 12.4, the volume of mixed concrete shall not exceed 63 % of the total volume of the drum or container. If the concrete is central mixed as described in 12.3, 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.

11.2 Stationary and truck mixers shall be capable of producing uniformly mixed concrete within the specified time in 12.3 or the specified number of revolutions in 12.5. The capability to produce and discharge uniformly mixed concrete shall be determined in accordance in Annex A1, if required.

NOTE 17—The sequence or method of charging the mixer will have an important effect on the uniformity of the concrete.

11.3 The agitator shall be capable of maintaining the mixed concrete in a uniformly mixed condition. The capability to

TABLE 2 Minimum Field Standard Weights and Test Loads[A]

Device Capacity	Minimum (in terms of device capacity)		Minimum Loads for Verification of Scale Accuracy
	Field Standard Weights	Test Loads[C]	
0 to 2000 kg [0 to 4000 lb]	100 %	100 %	
2001 to 20 000 kg [4001 to 40 000 lb]	Greater of[B] 10 % or 500 kg [1000 lb]	50 %[D]	Field standard weights or test load to used capacity, if greater than minimum specified. Strain-load tests[E] are permitted to be used above test load minimums. During initial verification, a scale shall be tested to full capacity.

[A] If the configuration and set up of the scale system prevents access or application of adequate field standard weights or if an unsafe condition is created by the verification process then the use of the scale above the verified position shall be discontinued until corrective measures have been completed.
[B] Field standard weights used in verifying accuracy of weighing devices shall comply with requirements of NIST Handbook 105-1.
[C] The term "test load" means the sum of the combination of field standard weights and any other applied load used in the conduct of a test using substitution test methods. Substitution Test—In the substitution test procedure, material or objects are substituted for field standard weights, or a combination of field standard weights and previously quantified material or objects, using the scale under test as a comparator. Additional test weights or other known test loads may be added to the known test load to verify the accuracy of higher weight ranges on the scale.
[D] The scale shall be tested from zero to at least 10 % of scale capacity using field standard weights, and then to at least 50 % of scale capacity using a series of substitution load tests that utilize field standard weights equaling at least 10 % of scale capacity.
[E] A strain-load test shall be conducted to verify the accuracy from 50 % of scale capacity to the used capacity of the scale. At least one load test shall be performed in each quarter of scale capacity. Strain-Load Test—In the strain-load test procedure, an unknown quantity of material or objects are used to establish a reference load or tare to which field standard weights or substitution test loads are added.

maintain and discharge uniformly mixed concrete shall be determined in accordance in Annex A1, if required.

11.4 Slump tests of individual samples can be used to provide a quick check of the probable degree of uniformity. Sampling and testing shall be in accordance with Annex A1. If the difference in slump exceeds the limits in Annex A1, the mixer or agitator shall not be used unless the condition is corrected, except as provided in 11.5.

11.5 Use of the equipment not conforming to 11.2 is permitted if operated with a longer mixing time, a smaller load, or a more efficient charging sequence. If required, the uniformity of concrete shall be evaluated in accordance with Annex A1.

11.6 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. If these condition are considered extensive enough to affect the mixer performance, Annex A1 establishes the basis to determine whether correction of deficiencies is required or if the correction of the deficiencies is adequate.

12. Mixing and Delivery

12.1 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:

12.1.1 *Central-Mixed Concrete.*

12.1.2 *Shrink-Mixed Concrete.*

12.1.3 *Truck-Mixed Concrete.*

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

12.3 *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 non-agitating equipment approved by the purchaser and meeting the requirements of Section 13, 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 the target batch water shall be in the drum by the end of the first one fourth of the specified mixing time; or in accordance with the central concrete mixer manufacturer's recommended charging sequence.

12.3.1 If no mixer performance tests are made, the acceptable mixing time for mixers having capacities of 0.76 m^3 [1 yd^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 metre [cubic yard] or fraction thereof of additional capacity (See Note 18).

NOTE 18—Stationary mixers of similar design bearing a Performance Rating plate of the Concrete Plant Manufacturers Bureau have been tested for their ability to produce uniformly mixed concrete in accordance with Annex A1 for low slump (< 50 mm [2 in.]) and normal slump (100–150 mm [4–6 in.]) concrete in a mixing time between 30 and 90 s.

12.3.2 If mixer performance tests have been made in accordance with Annex A1, the acceptable mixing time is permitted to be reduced to the time equal to or greater than that used in the qualification testing. If 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. Mixer performance tests shall be repeated whenever the appearance of the concrete or a comparison of coarse aggregate content of separate samples as described in Annex A1 indicates that adequate mixing has not been accomplished.

12.4 *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 the minimum time required to intermingle the ingredients. After transfer to a truck mixer the amount of mixing at the designated mixing speed shall be that necessary to meet the requirements for uniformity of concrete as indicated in Annex A1. Additional turning of the mixer, if any, shall be at a designated agitating speed.

12.5 *Truck-Mixed Concrete*—Concrete that is completely mixed in a truck mixer for 70 to 100 revolutions at the mixing speed designated by the manufacturer shall produce uniformly mixed concrete as defined in Annex A1. The start of mixing shall be when all the materials have been loaded in the mixer. If requirements for uniformity of concrete indicated in Annex A1 are not met with 100 revolutions of mixing that mixer shall not be used until the condition is corrected, except as provided in 11.5. If 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.

NOTE 19—Truck mixers of similar design bearing a Performance Rating plate of the Truck Mixer Manufacturers Bureau have been tested for their ability to produce uniformly mixed concrete in accordance with Annex A1.

12.6 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.

12.7 For concrete delivered in truck mixers, no water from the truck water system or elsewhere shall be added after the initial introduction of water during batching, except as permitted in 12.8, and if on arrival at the job site the slump or slump flow needs to be increased to comply with the requirement stated in the purchase order. Unless otherwise stated, obtain the required slump or slump flow within the tolerances stated in 7.1.1, 7.1.2, or 7.1.3with the addition of water, or water-reducing admixture, or both. The maximum quantity of water or water-reducing admixture that can be added at the job site shall be determined by the manufacturer and shall not exceed the maximum water content for the batch as established by the designed mixture proportions. Adjusting the concrete mixture with water or water-reducing admixture shall be done before discharge of concrete, except when obtaining a preliminary

sample in accordance with 17.6. Additional water shall be injected into the mixer under pressure and direction of flow to allow for proper distribution within the mixer. After the additions, the drum shall be turned at least 30 revolutions at mixing speed. The quantity of water or water-reducing admixture added shall be recorded.

12.8 For truck mixers with automated water or water-reducing admixture measurement and slump or slump flow monitoring equipment defined in 12.8.1and if permitted by the purchaser, water, or water-reducing admixture, or both, may be added during transportation to the job site. Such additional water shall be injected into the mixer under such pressure and direction of flow to allow for proper distribution within the mixer. The water content of the batch shall not exceed that established by the designed mixture proportions. If water or water-reducing admixture is added, the mixer shall be turned at least 30 drum revolutions at mixing speed. Said mixing shall take place after the last water or water-reducing admixture addition but before the start of discharge. The acceptance or rejection of concrete based on slump or slump flow shall be in accordance with Section 17.

12.8.1 The automated slump or slump flow monitoring equipment shall be capable of obtaining one or more physical measurements on the truck mixer related to concrete slump or slump flow and providing an indication of slump or slump flow based on pre-established correlations. The slump or slump flow measurement equipment shall report in terms of slump or slump flow. The device for the measurement of water shall be accurate to ±3 % of the amount added with said device. The device for the measurement of water-reducing admixture shall be accurate to the greater of ±3 % of the amount added or ±30 mL [±1 fl oz]. Upon request by the purchaser, the manufacturer shall submit data no older than 6 months substantiating the accuracy of the devices used for the measurement of water or water-reducing admixture. The equipment shall have controls to prevent discharge of water at pre-set limits to avoid exceeding the maximum water content for the batch as established by the designed mixture proportions.

12.9 Discharge of the concrete shall be completed within 1 ½ h after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. This limitation may be waived by the purchaser if the concrete is of such slump or slump flow after the 1½-h time has been reached that it can be placed, without the addition of water to the batch. In hot weather, or under conditions contributing to rapid stiffening of the concrete, a time less than 1 ½ h is permitted to be specified by the purchaser.

12.10 If a drum revolution limit (6.1.9) for start of discharge is specified by the purchaser, this limit shall govern.

NOTE 20—Depending on the project requirements, the technology is available to the manufacturer to alter fresh concrete properties (such as setting time, slump or slump flow, and air content). On some projects, the manufacturer may request changes to certain fresh concrete properties due to the distance or projected transportation time between the batch plant and the point of delivery.

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

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

NOTE 21—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.

12.12 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 22—In some situations difficulty may be encountered when concrete temperatures approach 32 °C [90 °F]. Additional information may be found in ACI 305R.

13. Use of Nonagitating Equipment

13.1 If the use of non-agitating transportation equipment is approved by the purchaser, the concrete shall be manufactured in a central mix plant. The following limitations shall apply:

13.2 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 from the weather if required by the purchaser.

13.3 The concrete shall be delivered to the site of the work with a satisfactory degree of uniformity. Satisfactory degree of uniformity is defined in Annex A1.

13.4 Slump tests of individual samples obtained and tested in accordance with Annex A1 can be used for a quick check of the probable degree of uniformity. If these slumps differ by more than the limits in Table A1.1, the nonagitating equipment shall not be used unless the conditions are corrected as provided in 13.5.

13.5 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.

14. Batch Ticket Information

14.1 The manufacturer of the concrete shall furnish to the purchaser with each batch of concrete before unloading at the site, a delivery ticket containing information concerning said concrete as follows:

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

14.1.2 Serial number of ticket,

14.1.3 Date,

14.1.4 Truck number,

14.1.5 Name of purchaser,

14.1.6 Specific designation of job (name and location),

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

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

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

14.1.10 Amount of water added at the request of the purchaser or the purchaser's designated representative and their initials.

14.1.11 Type and quantity of admixture or other adjustments made to the batch after batching.

14.1.12 For trucks equipped with automated water or water-reducing admixture measurement and slump or slump flow monitoring equipment as defined in 12.8.1, the total amount of water or water-reducing admixture added by said equipment.

14.1.13 Revolution limit as determined by the manufacturer in accordance with 6.1.9.

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

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

14.2.2 Type, brand, and amount of cement,

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

14.2.4 Grade, brand, and amount of slag cement,

14.2.5 Type, brand, and amount of silica fume,

14.2.6 Type, brand, and amount of admixtures

14.2.7 Type, brand, and amount of fiber reinforcement,

14.2.8 Source and amount of each metered or weighed water,

14.2.9 Information necessary to calculate the mixing water, as listed in 9.3,

14.2.10 Maximum size of aggregate,

14.2.11 Mass (amount) of fine and coarse aggregate,

14.2.12 Ingredients certified as being previously approved, and

14.2.13 Signature or initials of producer's representative.

15. Plant Inspection

15.1 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.

16. Practices, Test Methods, and Reporting

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

16.1.1 *Compression Test Specimens*—Practice C31/C31M, using standard moist curing in accordance with the applicable provisions of Practice C31/C31M.

16.1.2 *Compression Tests*—Test Method C39/C39M.

16.1.3 *Yield, Mass per Cubic Foot*—Test Method C138/C138M.

16.1.4 *Air Content*—Test Method C138/C138M; Test Method C173/C173M or Test Method C231/C231M.

16.1.5 *Slump*—Test Method C143/C143M.

16.1.6 *Slump Flow*—Test Method C1611/C1611M.

16.1.7 *Sampling Fresh Concrete*—Practice C172/C172M.

16.1.8 *Temperature*—Test Method C1064/C1064M.

16.2 The testing agency performing acceptance tests of concrete shall meet the requirements of Practice C1077.

16.3 Testing agency reports of concrete test results used to determine compliance with this specification shall include a statement that all tests performed by the testing agency or its agents were in accordance with the applicable test methods or shall note all known deviations from the prescribed procedures (Note 23). The reports shall also list any part of the test methods not performed by the testing agency.

NOTE 23—Deviation from standard test methods may adversely affect test results.

NOTE 24—Deviation from standard moisture and temperature curing requirements of Practice C31/C31M 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.

17. Sampling and Testing Fresh Concrete

17.1 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.

17.2 Tests of concrete required to determine compliance with this specification shall be made by a certified technician in accordance with Practice C1077.

17.3 Samples of concrete shall be obtained in accordance with Practice C172/C172M, except when taken to determine uniformity of slump within any one batch or load of concrete (11.4, 13.4, and Annex A1).

17.4 Slump or slump flow, air-content, density, and temperature tests shall be made at the time of discharge 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.

17.5 Strength tests as well as slump or slump flow, temperature, density, and air content tests shall generally be made with a frequency of not less than one test for each 115 m^3 [150 yd^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.

17.6 If preliminary checks of slump, slump flow, or air content are made, a single sample shall be taken after the discharge of not less than ¼ m^3 or ¼ yd^3. All other requirements of Practice C172/C172M shall be retained. If the preliminary measurement of slump (12.7) or air content (8.3) falls outside the specified limits, address as indicated in section 17.6.1 or 17.6.2 as appropriate.

17.6.1 If the measured slump or slump flow, 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.

17.6.2 If the measured slump or slump flow, or air content, or both is less than the lower limit, permit adjustments in accordance with 12.7 or 8.3 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.

18. Strength

18.1 When strength is used as a basis for acceptance of concrete, standard specimens shall be made in accordance with Practice C31/C31M. The specimens shall be cured under standard moisture and temperature conditions in accordance with the applicable provisions of Practice C31/C31M. 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.

18.2 For a strength test, at least two standard test specimens shall be made from a composite sample secured as required in Section 17. A test shall be the average of the strengths of the specimens tested at the age specified in 6.4.1.1 or 6.6.1.1 (Note 25). 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 25—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 C31/C31M.

18.3 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.

18.4 To conform to the requirements of this specification, strength tests representing each class of concrete must meet the following two requirements (Note 26):

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

18.4.2 When the specified strength is 35 MPa [5000 psi] or less, no individual strength test (average of two cylinder tests) shall be more than 3.5 MPa [500 psi] below the specified strength, f'_c.

NOTE 26—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 214R[6] and ACI 301. Pertinent data are given in Appendix X1.

18.4.3 When the specified strength is greater than 35 MPa [5000 psi], no individual strength test (average of two cylinder tests) shall be less than $0.90\,f'_c$.

19. Failure to Meet Strength Requirements

19.1 In the event that concrete tested in accordance with the requirements of Section 18 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 or adjustments, if any, shall be made to the mixture proportions, production process, or testing procedures.

NOTE 27—ACI 318-14, Sections 26.12.4 and R26.12.4 (commentary) address when and how low strength test results can be investigated.

20. Keywords

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

[6] ACI 214R-11, "Guide to Evaluation of Strength Test Results of Concrete," available from American Concrete Institute, Farmington Hills, MI, www.concrete.org, 2011, 16 pp.

ANNEX

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 Significance and Use

A1.1.1 This annex provides procedures to evaluate the ability of stationary and truck mixers to produce uniformly mixed concrete. The procedures described herein can also be used to determine the required minimum mixing revolutions in truck mixers for shrink mixed concrete and for evaluating the uniformity of concrete mixtures delivered in nonagitating equipment.

A1.1.2 The sequence and method of charging mixers has a significant effect on the ability to produce uniformly mixed concrete. The procedures in this annex can also be used to evaluate the effect of batching sequence for charging or loading mixers of acceptable condition.

A1.1.3 It is not the intent that this complete evaluation be performed on mixers at an established frequency. For equipment in operation, a visual inspection of the condition of the

mixer for blade wear and hardened concrete buildup can be conducted as an alternative. If one mixer of a specific design has been evaluated by procedures in this annex, it can be assumed that mixers of essentially the same design and of different sizes will also produce uniformly mixed concrete. A selected portion of this evaluation, such as comparison of slump or coarse aggregate content, can also be performed as a quick indication of the uniformity of concrete mixtures.

A1.2 Concrete Mixture, Load Size, and Mixing

A1.2.1 Unless the intent is to evaluate special project situations or concrete mixtures, the concrete mixture used for this evaluation should be typical of that produced in the production facility. Recommended mixture characteristics include the following:

A1.2.1.1 Cementitious materials content of 300 to 350 kg/m^3 [500 to 600 lb/yd^3],

A1.2.1.2 Coarse aggregate size No. 57 or No. 67 from Specification C33/C33M,

A1.2.1.3 Fine aggregate fineness modulus 2.5 to 3.0,

A1.2.1.4 Target slump of 100 to 150 mm [4 to 6 in.] or for paving operations at 25 to 50 mm [1 to 2 in.], and

A1.2.1.5 Air content of 4 to 6 %.

A1.2.2 The load size used for this evaluation shall be within –20 % and +10 % of the rated mixing capacity of the mixer.

A1.2.3 Use a batching sequence of concrete materials that has been used previously with success or in accordance with the recommendation of the mixer manufacturer. Use alternative procedures if the purpose is to evaluate the effect of batching sequence.

NOTE A1.1—The standards of the Truck Mixer Manufacturers Bureau, TMMB 100 and of the Concrete Plant Manufacturers Bureau, CPMB 100, provide recommendations for batching sequence.

A1.2.4 For stationary mixers, mix concrete at the mixing speed and minimum duration recommended by the mixer manufacturer. The start of mixing time shall be from the time all solid materials are in the mixer. Mixing time is taken as the earlier of when the mixer is stopped or when the first material is discharged. Use a suitable timing device, accurate to 1 s, to measure and record the time duration of mixing.

A1.2.5 For truck mixers, mix concrete at a mixing speed exceeding 12 r/min or at the speed recommended by the manufacturer. Complete mixing using between 70 and 100 revolutions of the drum at mixing speed. To determine the mixer drum revolutions, the start of mixing shall be when all the materials have been loaded in the mixer. Record the number of revolutions at mixing speed.

A1.3 Sampling

A1.3.1 Separate samples, each consisting of approximately 0.1 m^3 [2 ft^3] shall be taken after discharge of approximately 15 % and 85 % of the load (Note A1.2). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured in accordance with Practice C172/C172M, but shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be covered to prevent moisture loss or contamination. Remix the minimum necessary before performing the tests.

A1.3.2 *Sampling From Stationary Mixers*—Samples of concrete shall be obtained immediately after mixing duration is completed, in accordance with one of the following procedures:

A1.3.2.1 *Alternative Procedure 1*—The mixer shall be stopped, and the required samples removed by any suitable means from the mixer at approximately equal distances from the front and back of the drum, or

A1.3.2.2 *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 samples that are obtained from widely separated portions, but not from the very ends of the batch (Note A1.2).

A1.3.3 *Sampling From 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. For the duration between obtaining samples, the mixer shall be turned in the mixing direction at agitating speed. Obtain samples by intercepting the full discharge stream from the chute without stopping and starting the discharge during the collection of the sample.

A1.3.4 *Sampling From Nonagitating Equipment*—Obtain the two samples from approximately 15 % and 85 % of the discharge from the nonagitating equipment in accordance with Practice C172/C172M. Mix the portions obtained from each location into uniformly mixed samples.

NOTE A1.2—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.

A1.4 Slump

A1.4.1 Perform the slump test on each sample in accordance with Test Method C143/C143M. Start the slump test within 5 min after the sample was obtained.

A1.5 Density (Unit Weight) and Yield

A1.5.1 Determine the density of each sample in accordance with Test Method C138/C138M. Use the measure for measurement of air content by Test Method C231/C231M unless the concrete contains a larger nominal maximum size coarse aggregate than is appropriate for this measure.

A1.5.2 Calculate the density (unit weight) of each sample as follows:

$$D = \frac{M}{V} \qquad \text{(A1.1)}$$

where:

D = measured density (unit weight), kg/m^3 [lb/ft^3]
M = net mass of concrete in the measure, kg [lb], and
V = volume of the measure, m^3 [ft^3].

A1.5.3 From the average density (unit weight) of the two samples, calculate the yield of the batch in accordance with Test Method C138/C138M.

A1.6 Air Content

A1.6.1 Measure the air content of each sample in accordance with Test Method C231/C231M. Use Test Method C173/C173Mif the concrete is made with lightweight aggregate or if the coarse aggregate in the concrete has an aggregate correction factor larger than 0.5 % when determined in accordance with Test Method C231/C231M.

A1.7 Air-Free Density (Unit Weight)

A1.7.1 Calculate the air-free density (unit weight) of each sample as follows:

$$\text{air-free density} = \frac{D}{100 - A} \times 100 \qquad (A1.2)$$

where:

D = measured density, kg/m^3 [lb/ft^3] , and
A = measured air content on that sample, %.

A1.8 Coarse Aggregate Content

A1.8.1 Use the concrete in the measure used to measure density (unit weight) to determine the coarse aggregate content. If a separate portion of the sample is used, the concrete sample shall be at least 15 kg [35 lb]. Place the concrete in an adequately sized container and determine the net mass of the fresh concrete.

A1.8.2 Wash each sample over a 4.75 mm (No. 4) sieve sufficiently to remove the cement and most of the fine aggregate. Determine the mass of the wet coarse aggregate, store in a plastic bag and transport it to a laboratory facility. Dry the coarse aggregate in an oven at 230°C [110°F] for 16 ± 2 h. Sieve the coarse aggregate over a 4.75 mm (No. 4) sieve to remove any fine aggregate particles. Determine the mass of dry coarse aggregate in each sample.

A1.8.3 Express the mass of dry coarse aggregate as a percentage of the mass of the original concrete sample:

$$\text{coarse aggregate content, \%} = \frac{c}{M} \times 100 \qquad (A1.3)$$

where:

c = mass of dry coarse aggregate, kg [lb], and
M = net mass of same fresh concrete sample, kg [lb].

A1.9 Compressive Strength

A1.9.1 Make at least three 150 × 300 mm [6 × 12 in.] or 100 × 200 mm [4 × 8 in.] cylinders from each concrete sample. Cure the specimens in accordance with Practice C31/C31M, except that the cylinders shall be immersed in water immediately after molding with the temperature maintained between the required temperature limits for initial curing of the standard curing procedures in Practice C31/C31M for the first 24 h. Transport the cylinders to the laboratory facilities after 24 h and cure in accordance with the standard curing procedures of Practice C31/C31M.

A1.9.2 Test the cylinders in accordance with Test Method C39/C39M at an age of seven days. If the strength of an individual cylinder differs from the average strength of either sample by more than 9.5 %, this value can be disregarded for determining the average strength for the sample.

A1.9.3 Average the strength of the cylinders from each sample and express that value as a percentage of the average of all cylinders made from that batch. Calculate the difference in strength between each sample as a percentage of the overall average.

A1.10 Report

A1.10.1 Report the following information:

A1.10.1.1 Purpose of the evaluation.

A1.10.1.2 Type and description of mixer and rated mixing capacity.

A1.10.1.3 Concrete mixture proportions, batch quantities, density (unit weight), and yield of the batch.

A1.10.1.4 Mixing duration for stationary mixers or number of revolutions at mixing speed for truck mixers.

A1.10.1.5 Slump of each sample and the difference between samples, mm [in.].

A1.10.1.6 Air content of each sample and the difference between samples, %.

A1.10.1.7 Air-free density (unit weight) of each sample and the difference between samples, kg/m^3 [lb/ft^3].

A1.10.1.8 Coarse aggregate content of each sample and the difference between samples, %.

A1.10.1.9 Average strength in MPa [psi] and percent of overall average for each sample and the percent difference between samples.

A1.11 Requirements for Uniformity of Concrete

A1.11.1 The maximum permitted difference for each property obtained from the two different samples of the same batch are as provided in Table A1.1. Test results conforming to the limits of all five properties listed in Table A1.1 shall indicate uniform concrete within the limits of this specification.

TABLE A1.1 Requirements for Uniformity of Concrete

Test	Maximum Permissible Difference
Air-free density (unit weight), kg/m^3 [lb/ft^3]	16 [1.0]
Air content, %	1.0
Slump, mm [in.]:	
If average slump is less than 100 mm [4 in.]	25 [1.0]
If average slump is 100 to 150 mm [4 to 6 in.]	40 [1.5]
Coarse aggregate content, %	6.0
Average compressive strength at 7 days for each sample,[A] %	7.5[A]

[A]Approval of the mixer shall be tentative, pending results of the 7-day compressive strength tests.

APPENDIX

(Nonmandatory Information)

X1. CALCULATION OF THE AVERAGE COMPRESSIVE STRENGTH (f'_{cr}) NECESSARY TO MEET THE STRENGTH REQUIREMENTS OF 18.4

X1.1 Section 18.4 of this specification contains the same strength requirements as those contained in ACI 318 and ACI 301, except it does not require the submittal of the data and calculation of the average strength, f'_{cr} necessary to meet those requirements. This Appendix does not include all of the detailed requirements of the ACI Code and Specification that will govern a submittal for their respective purposes. The following material is intended to guide users of this specification when no formal submittal is required.

X1.1.1 Table X1.1 provides the statistically-based formulas to calculate the required average strength f'_{cr} when strength test records from previous projects are available. The strength test results are used to establish the standard deviation, s. At least 30 consecutive test results are required to obtain a robust estimate of the standard deviation. If the number of tests is between 15 and 30, the calculated standard deviation is multiplied by a factor to allow for the uncertainty of the estimated standard deviation. The factor is a linear interpolation between 1.16 for 15 tests and 1.00 for 30 tests. The test record should be obtained from a similar mixture with a specified strength within 7 MPa [1000 psi] of the specified strength for the new project for which the average compressive strength is being determined. The equations are related to the strength acceptance criteria in 18.4 and establish less than a 1% chance of failing these criteria if concrete is produced to achieve the required average strength at the same degree of variability implied by the standard deviation used. Because the average strength, f'_{cr}, must be high enough to conform to both averages of three consecutive test results and the requirements on minimum strength of an individual test result, the highest average strength (f'_{cr}) determined from these two equations governs. More detailed guidance on this subject matter is available in ACI 214R.[6]

TABLE X1.1 Required Average Compressive Strength when Data are Available to Establish a Standard Deviation

Specified Strength, f'_c	Required Average Strength, f'_{cr}	
≤ 35 MPa [5000 psi]	Use the larger from Eq X1.1 and X1.2 [X1.2M]:	
	$f'_{cr} = f'_c + 1.34s$	(X1.1)
	$f'_{cr} = f'_c + 2.33s - 500$	(X1.2)
	$[f'_{cr} = f'_c + 2.33s - 3.5]$	[X1.2M]
> 35 MPa [5000 psi]	Use the larger from Eq X1.1 and X1.3:	
	$f'_{cr} = f'_c + 1.34s$	(X1.1)
	$f'_{cr} = 0.90\, f'_c + 2.33s$	(X1.3)

where:

f'_c = specified compressive strength,
f'_{cr} = required average compressive strength, and
s = standard deviation.

TABLE X1.2 Required Average Compressive Strength When Data Are Not Available to Establish Standard Deviation

Specified Strength, f'_c, MPa [psi]	Required Average Strength, f'_{cr}	
	[MPa]	psi
< 21 [3000]	$[f'_c + 7.0]$	$f'_c + 1000$
21 to 35 [3000 to 5000]	$[f'_c + 8.3]$	$f'_c + 1200$
> 35 [5000]	$[1.10\, f'_c + 5.0]$	$1.10\, f'_c + 700$

X1.1.2 If it is a new mixture or strength level and a strength test record is not available to establish a standard deviation then Table X1.2 provides default levels of strength overdesign.

X1.1.3 Table X1.3 provides calculated values of overdesign and required average strength for selected standard deviations and specified strength levels that might be considered typical. More exact values are obtained from X1.1.2.

TABLE X1.3 Overdesign Necessary to Conform to Specified Compressive Strength

Inch-Pound Units						Required Overdesign		SI Units					
Specified Strength, f'_c, psi	Standard Deviation from Test Record, psi					No data SD unknown	Specified Strength, f'_c, MPa	Standard Deviation from Test Record, MPa					No Data SD Unknown
	300	400	500	600	700			2.0	2.5	3.5	4.0	5.0	
	Overdesign above f'_c							Overdesign above f'_c					
<3000						1000	<21						7.0
3000	400	540	670	810	1130	1200	20	2.7	3.4	4.7	5.8	8.2	8.3
4000	400	540	670	810	1130	1200	30	2.7	3.4	4.7	5.8	8.2	8.3
5000	400	540	670	810	1130	1200	35	2.7	3.4	4.7	5.8	8.2	8.3
6000	400	540	670	800	1030	1300	40	2.7	3.4	4.7	5.8	7.7	9.0
Required Average Strength													
Specified Strength, f'_c, psi	Standard Deviation from field data, psi					No data SD unknown	Specified Strength, f'_c, MPa	Standard Deviation from field data, MPa					No Data SD Unknown
	300	400	500	600	700			2.0	2.5	3.5	4.0	5.0	
	f'_{cr}, Required Average Strength, psi							f'_{cr}, Required Average Strength, MPa					
<3000						f'_c + 1000	<21						f'_c + 7.0
3000	3400	3540	3670	3810	4130	4200	20	22.7	23.4	24.7	25.8	28.2	28.3
4000	4400	4540	4670	4810	5130	5200	30	32.7	33.4	34.7	35.8	38.2	38.3
5000	5400	5540	5670	5810	6130	6200	35	37.7	38.4	39.7	40.8	43.2	43.3
6000	6400	6540	6670	6800	7030	7300	40	42.7	43.4	44.7	45.8	47.7	49.0

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C94/C94M – 17) that may impact the use of this standard. (Approved Aug. 1, 2017.)

(1) Added Specification C1798/C1798M to list of ASTM referenced documents in 2.1.
(2) Added 5.7, 6.9.
(3) Added new Note 5 and renumbered subsequent notes accordingly.

Committee C09 has identified the location of selected changes to this standard since the last issue (C94/C94M–16b) that may impact the use of this standard. (Approved March 1, 2017.)

(1) Added 7.1.1.1.
(2) Revised 9.2 – 9.2.2 and Note 13.
(3) Revised 11.2-11.6, 12.3.2, 12.4, 12.5, and 13.1-13.4.
(4) Extensive revision to Annex A1.
(5) Revised Note 27.