



Standard Specification for Ready-Mixed Concrete¹

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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 non-conformance 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 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.

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
- 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

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

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

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

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,

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>.



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 5—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 6—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 7—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 8), 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 8—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.

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.

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

Exposure Condition (See Note 5)	Total Air Content, %						
	Nominal Maximum Sizes of Aggregate, mm [in.]						
	9.5 [¾]	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

6.5 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 8), 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 9), 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 9—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 8.

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.

7. Tolerances in 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.]

7.1.2 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 [1½ in.]
More than 550 mm [22 in.]	± 65 mm [2½ in.]

7.1.4 The slump tolerances are applicable when water addition in accordance with 12.7 is 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 m³ [¼ yd³] 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 5**).

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 10**).

NOTE 10—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 m³ [1 yd³], 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 11**).

NOTE 11—Cementitious materials in bags may be used when requested or permitted by the purchaser.

9.2 Aggregate shall be measured by mass. Batch mass measurements shall be based on dry materials and shall be the required mass of dry materials plus the total mass of moisture (both absorbed and surface) contained in the aggregate.

9.2.1 For aggregates measured in individual or cumulative weigh batchers, when the required intermediate or final mass is less than 30 % of the scale capacity the aggregate mass shall be within ± 0.3 % of scale capacity or within ± 3 % of the required mass, whichever is less.

9.2.2 When aggregates are measured in an individual weigh batcher and the required mass of aggregate is equal to or

greater than 30 % of the scale capacity, the quantity of aggregate shall be within ± 2 % of the required mass. When aggregates are measured in a cumulative aggregate weigh batcher, and the required intermediate and final cumulative mass of aggregate components is equal to or greater than 30 % of the scale capacity, the quantity of aggregate at each successive weighing shall be within ± 1 % of the required mass.

NOTE 12—The batching accuracy limit of 0.3 % of scale capacity establishes a reasonable minimum weighing tolerance limit that is independent of the quantity of material being weighed. It generally governs for smaller batch quantities weighed in weigh batchers (scales).

9.3 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 mass or volume to an accuracy of 1 % of the required total mixing water. Added 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 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.

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 13—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.

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.

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 14—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 will be stationary mixers or truck mixers. Agitators will be 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. 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.

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. When 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. When 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 Mixers shall be capable of combining the ingredients of the concrete within the specified time for stationary mixers in 12.3 or the specified number of revolutions for truck mixers in 12.5, 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 15—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 thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity as defined by Annex A1.

11.4 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 16). 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 11.5.

NOTE 16—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.

11.5 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.

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. 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.

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 Where 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 17](#)).

NOTE 17—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 ($< 50 \text{ mm}$ [2 in.]) and normal slump ($100\text{--}150 \text{ mm}$ [$4\text{--}6 \text{ in.}$]) concrete in a mixing time between 30 and 90 s.

12.3.2 When 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 [12.3.3](#) 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.

12.3.3 *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:

12.3.3.1 *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

12.3.3.2 *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 16](#)).

12.3.3.3 The samples of concrete shall be tested in accordance with Section 18, 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.

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 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 [12.5.1](#). 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, 70 to 100 revolutions at the mixing speed designated by the manufacturer to produce the uniformity of concrete indicated in [Annex A1](#) (see [Note 18](#)). Concrete uniformity tests shall be made in accordance with [12.5.1](#) 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 [11.5](#). 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.

NOTE 18—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](#).

12.5.1 *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. 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 16](#)). 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. 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.

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 truck mixers satisfying the requirements of 12.5 for mixing 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 or slump flow of the concrete is less than that specified, and except as permitted separately in 12.9. If the desired slump or slump flow is less than specified, and unless otherwise stated, obtain the desired slump or slump flow within the tolerances stated in 7.1.1, 7.1.2, or 7.1.3 with a one-time addition of water. Do not exceed the maximum water content for the batch as established by the designed mixture proportion. A one-time addition of water is not prohibited from being several distinct additions of water provided that no concrete has been discharged except for slump or slump flow testing. All water additions shall be completed within 15 min from the start of the first water addition. 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 drum shall be turned an additional 30 revolutions, or more if necessary, at mixing speed to ensure that a homogenous mixture is attained. Water shall not be added to the batch at any later time.

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

NOTE 19—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, air content, etc.). 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.

12.9 For truck mixers with automated water measurement and slump or slump flow monitoring equipment defined in 12.9.1 and if permitted by the purchaser, water 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 is added, the mixer shall be rotated for an additional 30 drum revolutions, or more if necessary, at mixing speed to ensure a homogeneous mix is attained. Said mixing shall take place after the last water addition but before the start of discharge. The acceptance or rejection of concrete based on slump or slump flow shall be according to Section 17 of this specification.

12.9.1 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 added to the truck mixer shall be accurate to $\pm 3\%$ of the amount added with said device. Upon request by the purchaser, the manufacturer shall submit data no older than 6 months substantiating the accuracy of the device for the measurement of water added. 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.

12.10 Discharge of the concrete shall be completed within $1\frac{1}{2}$ h after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. This limitation is not prohibited from being waived by the purchaser if the concrete is of such slump or slump flow after the $1\frac{1}{2}$ -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 $1\frac{1}{2}$ h is permitted to be specified by the purchaser.

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 20—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 21—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 When the use of non-agitating transportation equipment is approved by the purchaser, the concrete shall be manufactured in a central mix plant. The proportions of the concrete shall be approved by the purchaser and 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 against the weather when required by the purchaser.

13.3 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.

13.4 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 16**). 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 **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 by purchaser of the concrete or the purchaser's designated representative and his initials.
- 14.1.11 For trucks equipped with automated water measurement and slump or slump flow monitoring equipment as defined in **12.9.1**, the total amount of water added by said equipment.
- 14.1.12 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 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,

- 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 22**). The reports shall also list any part of the test methods not performed by the testing agency.

NOTE 22—Deviation from standard test methods may adversely affect test results.

NOTE 23—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, 12.3.3, 12.5.1, and 13.4).

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 m³ [150 yd³]. 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 m³ or ¼ yd³. 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 24). 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 24—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 25):

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 25—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 214R⁶ 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 26—Section R5.6.3.4 of the ACI 318–11 Commentary and Section 5.6.5 of ACI 318–11 and its respective Commentary address when and how low strength test results and the quality of in-place concrete 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 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:

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

where:

- P = mass % of coarse aggregate in concrete,
 c = saturated-surface-dry mass in kg [lb] of aggregate retained on the 4.75-mm [No. 4] 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, kg [lb].

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

Inch-Pound Units:

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

SI Units:

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

where:

- M = mass per unit volume of air-free mortar, kg/m³ [lb/ft³],
 b = mass of concrete sample in mass container, kg [lb],
 c = saturated-surface-dry mass of aggregate retained on 4.75-mm [No. 4] sieve, kg [lb],
 V = volume of mass per unit volume container, m³ [ft³],
 A = air content of concrete, %, measured in accordance with 16.1.4 on the sample being tested, and
 G = density of coarse aggregate (SSD).

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

^A Not less than 3 cylinders will be molded and tested from each of the samples.

^B 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

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 a 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]	$[1.10 f'_c + 5.0]$	$1.10 f'_c + 700$

tion 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

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 over-design.

X1.1.3 Table X1.3 provides calculated values of over-design 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				SI Units			
Specified Strength, f'_c psi	Standard Deviation from Test Record, psi			Specified Strength, f'_c , MPa	Standard Deviation from Test Record, MPa		
	300	400	500		2.0	2.5	3.5
	Overdesign above f'_c				Overdesign above f'_c		
	700	600	500		4.0	5.0	No Data SD Unknown
<3000				<21			
3000				20			7.0
4000				30			8.3
5000				35			8.3
6000				40			9.0
Required Average Strength							
Specified Strength, f'_c psi	Standard Deviation from field data, psi			Specified Strength, f'_c , MPa	Standard Deviation from field data, MPa		No Data SD Unknown
	300	400	500		2.0	2.5	
	Required Average Strength, psi				Required Average Strength, MPa		
	700	600	500		4.0	5.0	
<3000				<21			$f'_c + 7.0$
3000				20			28.3
4000				30			38.3
5000				35			43.3
6000				40			49.0

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C94/C94M–16) that may impact the use of this standard. (Approved Aug. 1, 2016.)

(1) Deleted Note 8 and renumbered subsequent notes.

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