



# Standard Specification for Ready-Mixed Concrete<sup>1</sup>

This standard is issued under the fixed designation C 94/C 94M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope\*

1.1 This specification covers ready-mixed concrete as defined in 3.2.2. Requirements for quality of concrete shall be either as hereinafter specified or as specified by the purchaser. In any case where the requirements of the purchaser differ from these in this specification, the purchaser's specification shall govern. This specification does not cover the placement, consolidation, curing, or protection of the concrete after delivery to the purchaser.

1.2 The values stated in either SI units, shown in brackets, or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in 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.<sup>2</sup>)*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

<sup>1</sup> 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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<sup>2</sup> See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

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

- C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field
- C 33 Specification for Concrete Aggregates
- C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C 125 Terminology Relating to Concrete and Concrete Aggregates
- C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
- C 150 Specification for Portland Cement
- C 172 Practice for Sampling Freshly Mixed Concrete
- C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
- C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
- C 260 Specification for Air-Entraining Admixtures for Concrete
- C 330 Specification for Lightweight Aggregates for Structural Concrete
- C 494/C 494M Specification for Chemical Admixtures for Concrete
- C 567 Test Method for Determining Density of Structural Lightweight Concrete
- C 595 Specification for Blended Hydraulic Cements
- C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
- C 637 Specification for Aggregates for Radiation-Shielding Concrete
- C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
- C 1017/C 1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
- C 1064/C 1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
- C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
- C 1157 Performance Specification for Hydraulic Cement
- C 1240 Specification for Silica Fume Used in Cementitious Mixtures

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

**C 1602/C 1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete**

2.2 *ACI Documents:*<sup>4</sup>

**CP-1** Technician Workbook for ACI Certification of Concrete Field Testing Technician—Grade I

**211.1** Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

**211.2** Standard Practice for Selecting Proportions for Structural Lightweight Concrete

**301** Standard Specifications for Structural Concrete

**305R** Hot Weather Concreting

**306R** Cold Weather Concreting

**318** Building Code Requirements for Structural Concrete and Commentary

2.3 *Other Documents:*

**Bureau of Reclamation Concrete Manual** <sup>5</sup>

### 3. Terminology

3.1 *Definitions:*

The terms used in this specification are defined in Terminology **C 125**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *concrete, central-mixed, n*—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*—concrete partially mixed in a stationary mixer with mixing completed in a truck mixer.

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

### 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 **C 138/C 138M**. 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 **C 172**.

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

### 5. Materials

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

5.2 *Cementitious Materials*

5.2.1 *Hydraulic Cement*—Hydraulic cement shall conform to Specification **C 150**, Specification **C 595**, or Specification **C 1157**.

5.2.2 *Supplementary Cementitious Materials*—Coal fly ash or natural pozzolans shall conform to Specification **C 618**. Ground granulated blast furnace slag shall conform to Specification **C 989**. Silica fume shall conform to Specification **C 1240**.

5.2.3 *Cementitious concrete mixtures*—Cementitious concrete mixtures shall contain the kind(s) and class(es) of hydraulic cement(s) and the kind(s) and class(es) of supplementary cementitious material(s) as specified by the purchaser. If hydraulic cement specification or type is not provided then the requirements of portland cement Type I or Type II conforming to Specification **C 150** shall apply or other cementitious materials that have a demonstrated ability to satisfy the intended use.

5.3 *Aggregates*—Normal weight aggregates shall conform to Specification **C 33**. Lightweight aggregates shall conform to Specification **C 330** and heavyweight aggregates shall conform to Specification **C 637**.

5.4 *Water*—Water shall conform to Specification **C 1602/C 1602M**.

5.5 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification **C 260** (**Note 2**).

5.6 *Chemical Admixtures*—Chemical admixtures shall conform to either Specification **C 494/C 494M** or **C 1017/C 1017M** as applicable (**Note 2**).

**NOTE 2**—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 3**—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 shall specify 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 When air-entrained concrete is specified, the air content of the samples taken at the point of discharge from the transportation unit (see Section **8** and **Table 1** for the total air content and tolerances) (**Note 4**),

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

6.1.5 When structural lightweight concrete is specified, the mass per unit volume as wet mass, air-dry mass, or oven-dry mass (**Note 5**), and

6.1.6 If desired, any of the optional requirements of **Table 2** in Specification **C 1602/C 1602M**.

**NOTE 4**—In selecting the specified air content, the purchaser should consider the exposure conditions to which the concrete will be subjected. Air contents less than shown in **Table 1** may not give the required resistance to freezing and thawing, which is the primary purpose of

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

<sup>5</sup> Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

**TABLE 1 Recommended Total Air Content for Air-Entrained Concrete<sup>A,B</sup>**

Exposure Condition <sup>C</sup>	Total Air Content, %						
	Nominal Maximum Sizes of Aggregate, in. [mm]						
	¾ [19.0]	½ [12.5]	¼ [9.5]	1 [25.0]	1½ [37.5]	2 [50.0]	3 [75.0]
Mild	3.5	4.0	4.5	3.0	2.5	2.0	1.5
Moderate	5.0	5.5	6.0	4.5	4.5	4.0	3.5
Severe	6.0	7.0	7.5	6.0	5.5	5.0	4.5

<sup>A</sup> For air-entrained concrete, when specified.

<sup>B</sup> Unless exposure conditions dictate otherwise, it is permissible to reduce air contents recommended above by up to 1 % for concretes with specified compressive strength,  $f'_c$ , of 5000 psi [35 MPa] or above.

<sup>C</sup> For description of exposure conditions, refer to Standard Practice ACI 211.1, Section 6.3.3, with attention to accompanying footnotes.

air-entrained concrete. Air contents higher than the levels shown may reduce strength without contributing any further improvement of durability.

NOTE 5—The mass per unit volume of fresh concrete, which is the only unit mass determinable at the time of delivery, is always higher than the air-dry or oven-dry mass. Definitions of, and methods for determining or calculating air-dry and oven-dry masses, are covered by Test Method C 567.

### 6.2 Option A:

6.2.1 When the purchaser requires the manufacturer to assume full responsibility for the selection of the proportions for the concrete mixture (Note 6), the purchaser shall also specify the following:

6.2.1.1 Requirements for compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 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 6—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.

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

### 6.3 Option B:

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

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

6.3.1.2 Maximum allowable water content in gallons per cubic yard [litres per cubic metre] of concrete, including surface moisture on the aggregates, but excluding water of absorption (Note 6), and

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

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

### 6.4 Option C:

6.4.1 When the purchaser requires the manufacturer to assume responsibility for the selection of the proportions for the concrete mixture with the minimum allowable cement content specified (Note 7), the purchaser shall also specify the following:

6.4.1.1 Required compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 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.

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

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

NOTE 7—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the strength, aggregate size, and slump specified. At the same time, it must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density, in the event specified strength is attained with it. For additional information refer to Standard Practice ACI 211.1 and Standard Practice 211.2 referred to in Note 6.

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 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.

6.5 The proportions arrived at by Options A, B, or C for each class of concrete and approved for use in a project shall be assigned a designation to facilitate identification of each concrete mixture delivered to the project. This is the designation required in 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.

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

## 7. Tolerances in Slump

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

7.1.1 When the project specifications for slump are written as a “maximum” or “not to exceed” requirement:

Specified slump:

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

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

7.1.2 When the project specifications for slump are *not* written as a “maximum” or “not to exceed” requirement:

Tolerances for Nominal Slumps

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

7.2 Concrete shall be available within the permissible range of slump for a period of 30 min starting either on arrival at the job site or after the initial slump adjustment permitted in 12.7, whichever is later. The first and last ¼ yd<sup>3</sup> or ¼ m<sup>3</sup> discharged are exempt from this requirement. If the user is unprepared for discharge of the concrete from the vehicle, the producer shall not be responsible for the limitation of minimum slump after 30 min have elapsed starting either on arrival of the vehicle at the prescribed destination or at the requested delivery time, whichever is later.

## 8. Air-Entrained Concrete

8.1 When air-entrained concrete is desired the purchaser shall specify the total air content of the concrete. See Table 1 for recommended total air contents (Note 2).

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 12.7 is not exceeded (see Note 8).

NOTE 8—Acceptance sampling and testing in accordance with Practice C 172 is not obviated by this provision.

## 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 yd<sup>3</sup> [1 m<sup>3</sup>], 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. Under special circumstances approved by the purchaser, hydraulic cement is permitted to be measured in bags of standard mass (Note 9). No fraction of a bag of hydraulic cement shall be used unless its mass has been determined.

NOTE 9—In the United States the standard mass of a bag of portland cement is 94 lb [42.6 kg] ± 3 %.

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

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 weight or volume to an accuracy of 1 % of the required total mixing water. Added ice shall be measured by weight. In the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete shall be accurately measured; if this proves impractical or impossible the wash water shall be discharged prior to

loading the next batch of concrete. Total water (including any wash water) shall be measured or weighed to an accuracy of  $\pm 3\%$  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  $\pm 3\%$  of the total amount required or plus or minus the amount or dosage required for 100 lb [50 kg] of hydraulic cement, whichever is greater.

NOTE 10—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 when at least one static load test within each quarter of the scale capacity can be shown to be within  $\pm 0.15\%$  of the total capacity of the scale or  $0.4\%$  of the net applied load, whichever is greater.

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

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 11—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 All stationary and truck mixers shall be capable of combining the ingredients of the concrete within the specified time or the number of revolutions specified in 11.5, 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 12—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 13). 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 13—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 nonagitating 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 all water shall be in the drum by the end of the first one fourth of the specified mixing time.

12.3.1 Where no mixer performance tests are made, the acceptable mixing time for mixers having capacities of 1 yd<sup>3</sup> [0.76 m<sup>3</sup>] or less shall be not less than 1 min. For mixers of greater capacity, this minimum shall be increased 15 s for each cubic yard [cubic metre] or fraction thereof of additional capacity (See Note 14).

NOTE 14—Stationary mixers of similar design bearing a Performance Rated plate of the Concrete Plant Manufacturers Bureau have been tested to produce uniformly mixed concrete in accordance with Annex A1 for low slump (< 2 in. [50 mm]) and normal slump (4–6 in. [100–150 mm]) concrete in a mixing time between 30 and 90 sec.

12.3.2 Where mixer performance tests have been made on given concrete mixtures in accordance with the testing program set forth in the following paragraphs, and the mixers have been charged to their rated capacity, the acceptable mixing time is permitted to be reduced for those particular circumstances to a point at which satisfactory mixing defined in 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 13).

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 12.3.3 and 12.3.3.3. 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 15). 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 15—Truck mixers of similar design bearing a Performance Rated plate of the Truck Mixer Manufacturers Bureau have been tested 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 by an incompletely opened gate or seal. Separate samples, each consisting of approximately 2 ft<sup>3</sup> [0.1 m<sup>3</sup> approximately] shall be taken after discharge of approximately 15 % and 85 % of the load (Note 13). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured in accordance with Practice C 172, but shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Between samples, where necessary to maintain slump, the mixer shall be turned in mixing direction at agitating speed. During sampling the receptacle shall receive the full discharge of the chute. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be remixed the minimum amount to ensure uniformity before specimens are molded for a particular test.

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 11.5 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 of the concrete is less than that specified. If the desired slump is less than specified, and unless otherwise stated, obtain the desired slump within the tolerances stated in 7.1.1 or 7.1.2 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 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. Discharge of the concrete shall be completed within 1½ h, or before the drum has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. These limitations are permitted to be waived by the purchaser if the concrete is of such slump after the 1½-h time or 300-revolution limit has been reached that it can be placed, without the addition of water, to the batch. In hot weather, or under conditions contributing to quick stiffening of the concrete, a time less than 1½ h is permitted to be specified by the purchaser.

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

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

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

NOTE 16—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.

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

NOTE 17—In some situations difficulty may be encountered when concrete temperatures approach 90 °F [32 °C]. Additional information may be found in the *Bureau of Reclamation Concrete Manual* and in ACI 305R.

### 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 13). 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 on which is printed, stamped, or written, 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 Water added by receiver of concrete and his initials.

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 ground granulated blast-furnace slag,

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 or recycled slurry,

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 **C 31/C 31M**, using standard moist curing in accordance with the applicable provisions of Practice **C 31/C 31M**.

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

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

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

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

16.1.6 *Sampling Fresh Concrete*—Practice **C 172**.

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

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

16.3 Laboratory reports of concrete test results used to determine compliance with this specification shall include a statement that all tests performed by the laboratory or its agents were in accordance with the applicable test methods or shall note all known deviations from the prescribed procedures (**Note 18**). The reports shall also list any part of the test methods not performed by the laboratory.

**NOTE 18**—Deviation from standard test methods may adversely affect test results.

**NOTE 19**—Deviation from standard moisture and temperature curing conditions is often a reason for low strength test results. Such deviations may invalidate the use of such test results as a basis for rejection of the concrete.

## 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 ACI Concrete Field Testing Technician, Grade I or equivalent. Equivalent personnel certification programs shall include both written and performance examinations as outlined in ACI **CP-1**.

17.3 Samples of concrete shall be obtained in accordance with Practice **C 172**, except when taken to determine uniformity of slump within any one batch or load of concrete (**11.4**, **12.3.3**, **12.5.1**, and **13.4**).

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

17.5 Strength tests as well as slump, temperature, density, and air content tests shall generally be made with a frequency of not less than one test for each 150 yd<sup>3</sup> (115 m<sup>3</sup>). 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 or air content are made, a single sample shall be taken after the discharge of not less than ¼ yd<sup>3</sup> [¼ m<sup>3</sup>]. All other requirements of Practice **C 172** 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 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 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 to Practice **C 31/C 31M**. The specimens shall be cured under standard moisture and temperature conditions in accordance with the applicable provisions of Practice **C 31/C 31M**. The technician performing the strength test shall be certified as an ACI Concrete Strength Testing Technician, Concrete Laboratory Testing Technician—Grade II or by an equivalent written and performance test program covering the relevant test methods. If acceptance is based upon compressive strength test results, the certification requirement is satisfied by certification as an ACI Concrete Laboratory Testing Technician—Grade I or by an equivalent written and performance test program.

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 **6.2.1.1** or **6.4.1.1** (**Note 20**). 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 20**—Additional tests may be made at other ages to obtain information for determining form removal time or when a structure may



be put in service. Specimens for such tests are cured according to the section on Field Curing in Practice **C 31/C 31M**.

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 21**):

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

**NOTE 21**—Due to variations in materials, operations, and testing, the average strength necessary to meet these requirements will be substantially higher than the specified strength. The amount higher depends upon the standard deviation of the test results and the accuracy with which that value can be estimated from prior data as explained in **ACI 318** and **ACI 301**. Pertinent data are given in **Appendix X1**.

18.4.3 When the specified strength is greater than 5000 psi [35 MPa], 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, if any, shall be made. If an agreement on a mutually satisfactory adjustment cannot be reached by the manufacturer and the purchaser, a decision shall be made by a panel of three qualified engineers, one of whom shall be designated by the purchaser, one by the manufacturer, and the third chosen by these two members of the panel. The question of responsibility for the cost of such arbitration shall be determined by the panel. Its decision shall be binding, except as modified by a court decision.

## 20. Keywords

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

# 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:

$$P = (cb) \times 100 \quad (\text{A1.1})$$

where:

$P$  = mass % of coarse aggregate in concrete,

$c$  = saturated-surface-dry mass in lb [kg] of aggregate retained on the No. 4 [4.75-mm] sieve, resulting from washing all material finer than this sieve from the fresh concrete, and

**TABLE A1.1 Requirements for Uniformity of Concrete**

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

<sup>A</sup> "Test for Variability of Constituents in Concrete," Designation 26, *Bureau of Reclamation Concrete Manual*, 7th Edition.<sup>5</sup>

<sup>B</sup> Not less than 3 cylinders will be molded and tested from each of the samples.

<sup>C</sup> Approval of the mixer shall be tentative, pending results of the 7-day compressive strength tests.

$b$  = mass of sample of fresh concrete in mass per unit volume container, lb [kg].

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, lb/ft<sup>3</sup> [kg/m<sup>3</sup>],

$b$  = mass of concrete sample in mass container, lb [kg],

$c$  = saturated-surface-dry mass of aggregate retained on No. 4 [4.75-mm] sieve, lb [kg],

$V$  = volume of mass per unit volume container, ft<sup>3</sup> [m<sup>3</sup>],

$A$  = air content of concrete, %, measured in accordance with 16.1.4 on the sample being tested, and

$G$  = density of coarse aggregate (SSD).

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

*Inch-pound units:*

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

## APPENDIX

### (Nonmandatory Information)

#### X1. Calculation of the Average Compressive Strength ( $f'_{cr}$ ), Necessary to Meet the Strength Requirements of Sections 18.4.1, 18.4.2, and 18.4.3

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 ACI Code and Specifications. 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 statistical formulas that can be used to calculate the required average strength  $f'_{cr}$  when historical statistical data are available. The formula to achieve a satisfactory average of three consecutive strength tests as required in 18.4.1 is (Eq. X1.1) of Table X1.1. The formulas for the minimum strength of an individual strength test result as required in 18.4.2 and 18.4.3 are (Eq. X1.2) and (Eq. X1.3) in Table X1.1. Since the average strength,  $f'_{cr}$ , must be high

enough to conform to both averages of three consecutive tests and the requirements on minimum strength of a test, the one which requires highest average strength ( $f'_{cr}$ ) governs.

X1.1.2 The first step in the process of calculating the over-design above  $f'_c$  or the required average strength is to determine if a record of 30 consecutive tests is available for the proposed mixture or similar mixture with a design strength within 1000 psi [6.6 MPa] of the specified compressive strength proposed for use. If it is a new mixture or strength level and no standard deviation data is available then Table X1.2 provides default levels of over-design equal to 1000, 1200 or  $(1.10f'_c + 700)$  psi.

X1.1.3 Table X1.3 provides calculated values of over-design and required average strength for selected standard deviations and specified strength levels. Because of the large ranges of strength and standard deviations, the gray shaded areas are considered unusual or not likely to be encountered.

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

	Inch-pound System		SI System
Specified Strength $f'_{cr}$ , psi	Required Average Strength $f'_{cr}$ , psi	Specified Strength $f'_{cr}$ , MPa	Required Average Strength $f'_{cr}$ , MPa
$f'_c$ equal to or less than 5000	Use the larger from Eq X1.1 and X1.2 $f'_{cr} = f'_c + 1.34s$ (X1.1) $f'_{cr} = f'_c + 2.33s - 500$ (X1.2)	$f'_c$ equal to or less than 35	Use the larger from Eq X1.1 and X1.2m $f'_{cr} = f'_c + 1.34s$ (X1.1) $f'_{cr} = f'_c + 2.33s - 3.45$ (X1.2m)
greater than 5000	Use the larger from Eq X1.1 and X1.3 $f'_{cr} = f'_c + 1.34s$ (X1.1) $f'_{cr} = 0.90f'_c + 2.33s$ (X1.3)	greater than 35	Use the larger from Eq X1.1 and X1.3 $f'_{cr} = f'_c + 1.34s$ (X1.1) $f'_{cr} = 0.90f'_c + 2.33s$ (X1.3)

where:

$f'_c$  = the specified compressive strength

$f'_{cr}$  = the required average compressive strength

$s$  = the standard deviation

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

Inch-pound System		SI System	
Specified Strength $f'_c$ , psi	Required Average Strength $f'_{cr}$ , psi	Specified Strength $f'_c$ , MPa	Required Average Strength $f'_{cr}$ , MPa
Less than 3000	$f'_c + 1000$	Less than 21	$f'_c + 7.0$
3000 to 5000	$f'_c + 1200$	21 to 35	$f'_c + 8.5$
greater than 5000	$1.10f'_c + 700$	greater than 35	$1.10f'_c + 5.0$

where:  
 $f'_c$  = the specified compressive strength  
 $f'_{cr}$  = the required average compressive strength  
 $s$  = the standard deviation

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

Inch - Pound units						SI metric units							
f <sub>c</sub> , psi Specified Strength	Standard Deviation from field data					no SD data	f <sub>c</sub> , MPa Specified Strength	Standard Deviation from field data					no SD data
	300	500	700	900	1,100			2.0	3.5	5.0	6.0	7.5	
less than 3000	Overdesign above f <sub>c</sub>					f <sub>c</sub> +1000	less than 21	Overdesign above f <sub>c</sub>					f <sub>c</sub> +7.0
3,000	402	670	1,131	1,597	2,063	1,200	21	3.0	5.0	8.5	10.8	14.3	8.5
5,000	402	670	1,131	1,597	2,063	1,200	35	2.7	4.7	8.2	10.5	14.0	8.5
7,000	402	670	938	1,397	1,863	1,400	50	2.7	4.7	6.7	9.0	12.5	10.0
9,000	402	670	938	1,206	1,663	1,800	60	2.7	4.7	6.7	8.0	11.5	11.0
11,000	402	670	938	1,206	1,474	1,800	75	2.7	4.7	6.7	8.0	10.1	12.5
13,000	402	670	938	1,206	1,474	2,000	90	2.7	4.7	6.7	8.0	10.1	14.0
15,000	402	670	938	1,206	1,474	2,200	100	2.7	4.7	6.7	8.0	10.1	15.0
17,000	402	670	938	1,206	1,474	2,400	120	2.7	4.7	6.7	8.0	10.1	17.0

  

Inch - Pound units						SI metric units							
f <sub>c</sub> , psi Specified Strength	Standard Deviation from field data, psi					no data	f <sub>c</sub> , MPa Specified Strength	Standard Deviation, Mpa from field data					No data
	300	500	700	900	1,100			2.0	3.5	5.0	6.0	7.5	
less than 3000	f <sub>cr</sub> , required Average Strength, psi					f <sub>c</sub> +1000	less than 21	f <sub>cr</sub> , required Average Strength, MPa					f <sub>c</sub> +7.0
3,000	3,402	3,670	4,131	4,597	5,063	4,200	21.0	24	26	29	32	35	29.5
5,000	5,402	5,670	6,131	6,597	7,063	6,200	35.0	38	40	43	46	49	43.5
7,000	7,402	7,670	7,938	8,397	8,863	8,400	50.0	53	55	57	59	62	60.0
9,000	9,402	9,670	9,938	10,206	10,663	10,600	60.0	63	65	67	68	71	71.0
11,000	11,402	11,670	11,938	12,206	12,474	12,800	75.0	78	80	82	83	85	87.5
13,000	13,402	13,670	13,938	14,206	14,474	15,000	90.0	93	95	97	98	100	104.0
15,000	15,402	15,670	15,938	16,206	16,474	17,200	100.0	103	105	107	108	110	115.0
17,000	17,402	17,670	17,938	18,206	18,474	19,400	120.0	123	125	127	128	130	137.0

Shaded Areas identify levels of specified strength where the standard deviations should be considered unusual or inappropriate.

**SUMMARY OF CHANGES**

Committee C09 has identified the location of selected changes to this specification since the last issue, C 94/C 94M – 07, that may impact the use of this specification. (Approved January 1, 2009)

- (1) Revised 1.1, 4.1, 4.2, 9.1, and 9.4.
- (2) Added new definitions in Section 3.
- (3) Added new Note 14 and Note 15.

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