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Standard Specification for Fiber-Reinforced Concrete[1]

This standard is issued under the fixed designation C1116/C1116M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers all forms of fiber-reinforced concrete that are delivered to a purchaser with the ingredients uniformly mixed, and that can be sampled and tested at the point of delivery. It does not cover the placement, consolidation, curing, or protection of the fiber-reinforced concrete after delivery to the purchaser.

1.2 Certain sections of this specification are also applicable to fiber-reinforced concrete intended for shotcreting by the dry-mix process when sampling and testing of concrete is possible only at the point of placement. In this case, the sections dealing with batching plant, mixing equipment, mixing and delivery, and measurement of workability and air content, are not applicable.

1.3 This specification does not cover thin-section glass fiber-reinforced concrete manufactured by the spray-up process that is under the jurisdiction of ASTM Subcommittee C27.40.

1.4 The values stated in either SI units 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.

1.5 The following precautionary statement pertains only to the test method portion, Sections 15 and 18, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A820/A820M Specification for Steel Fibers for Fiber-Reinforced Concrete
C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C94/C94M Specification for Ready-Mixed Concrete
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 Specification for Portland Cement
C172 Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C387 Specification for Packaged, Dry, Combined Materials for Mortar and Concrete
C567 Test Method for Determining Density of Structural Lightweight Concrete
C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C684 Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens (Withdrawn 2012)[3]
C685/C685M Specification for Concrete Made by Volumetric Batching and Continuous Mixing
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
C1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels
C1385/C1385M Practice for Sampling Materials for Shotcrete

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

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[2] 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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

C1399 Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete
C1436 Specification for Materials for Shotcrete
C1480 Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application
C1550 Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)
C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
C1604/C1604M Test Method for Obtaining and Testing Drilled Cores of Shotcrete
C1609/C1609M Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)
C1666/C1666M Specification for Alkali Resistant (AR) Glass Fiber for GFRC and Fiber-Reinforced Concrete and Cement
D6942 Test Method for Stability of Cellulose Fibers in Alkaline Environments
D7357 Specification for Cellulose Fibers for Fiber-Reinforced Concrete
D7508/D7508M Specification for Polyolefin Chopped Strands for Use in Concrete

2.2 *ACI Standards and Reports:*
211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[4]
211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete[4]
506.2 Specification for Materials, Proportioning and Application of Shotcrete[4]

3. Terminology

3.1 *Definitions*

3.1.1 For definitions of terms used in this specification, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *manufacturer, n*—the producer who furnishes the fiber-reinforced concrete.

3.2.2 *purchaser, n*—the owner, or representative thereof, who buys the fiber-reinforced concrete.

4. Classification

4.1 This specification classifies fiber-reinforced concrete by the material type of the fiber incorporated.

NOTE 1—The performance of fiber-reinforced concrete depends upon the susceptibility of the fibers to physical damage during mixing or shotcreting and to chemical damage on exposure to the cement paste solution, which is highly alkaline and may also contain carbon dioxide, chlorides, sulfates or oxygen. Improper methods of fiber addition to a concrete mix can lead to balling of some types of fiber; consult manufacturer for advice as to correct method before use. The magnitude of improvements in the mechanical properties of the concrete or shotcrete imparted by fibers can also reflect the material characteristics, geometry, and design of the fiber type.

4.1.1 *Type I Steel Fiber-Reinforced Concrete*—Contains stainless steel, alloy steel, or carbon steel fibers conforming to Specification A820/A820M.

4.1.2 *Type II Glass Fiber-Reinforced Concrete*—Contains alkali-resistant (AR) glass fibers conforming to Specification C1666/C1666M.

4.1.3 *Type III Synthetic Fiber-Reinforced Concrete*—Contains synthetic fibers for which documentary evidence can be produced confirming their resistance to deterioration when in contact with the moisture and alkalis present in cement paste and the substances present in admixtures throughout the anticipated useful life of the structure (see Note 2 and 4.2). When Type III fiber-reinforced concrete contains polyolefin fibers, they shall conform to Specification D7508/D7508M.

NOTE 2—Fibers such as polyolefins (polypropylene and polyethylene), nylon, and carbon have been shown to be durable in concrete.

4.1.4 *Type IV Natural Fiber-Reinforced Concrete*—Contains natural fibers for which documentary evidence can be produced confirming their resistance to deterioration when in contact with the moisture and alkalis present in cement paste and the substances present in admixtures throughout the anticipated useful life of the structure. When Type IV fiber-reinforced concrete contains cellulose fibers they shall conform to Specification D7357.

NOTE 3—The classification, natural fibers, refers to a population of fibers that are manufactured from natural fibrous resources and are used for the first time in concrete. Depending on the initial raw material and the manufacturing process employed to produce the fiber, the final physical and chemical fiber properties in this general classification can vary greatly. Some natural fibers are susceptible to deterioration from exposure to alkalis; Test Method D6942 may be used to determine the susceptibility of these fibers to deterioration as a result of exposure to alkalis in concrete. Conversely, many other natural fiber types are highly resistant to alkalis and can remain in concrete with no degradation for the complete product life cycle.

4.2 When the purchaser chooses to permit the use of fibers other than those complying with the classifications in 4.1, the manufacturer or supplier shall show evidence satisfactory to the purchaser that the type of fiber proposed for use shows resistance to deterioration when in contact with the moisture and alkalis present in cement paste and the substances present in admixtures throughout the anticipated useful life of the structure.

5. Basis of Purchase

5.1 The basis of purchase for fiber-reinforced concrete shall be in accordance with the *Basis of Purchase* Sections of Specification C94/C94M or Specification C685/C685M.

6. Ordering Information

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

6.1.1 Type of fiber-reinforced concrete required. See Section 4.

6.1.2 Type of cement at the purchaser's option, otherwise the cement shall be Type 1 meeting the requirements of Specification C150;

6.1.3 Designated size, or sizes, of coarse aggregates;

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

6.1.4 Slump required at the point of delivery, or when appropriate the point of placement, subject to the tolerances hereinafter specified;

6.1.5 Air content when air-entrainment is required, based on the air content of samples taken at the point of discharge, or when appropriate the point of placement, subject to the tolerances hereinafter specified;

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 produce adequate durability. Air contents higher than the levels shown may reduce strength without contributing further to freeze-thaw resistance.

6.1.6 When structural lightweight concrete is specified, the purchaser shall specify the density as freshly mixed density, equilibrium density, or oven-dry density.

NOTE 5—The freshly mixed density of lightweight concrete, that is the only density determinable at the time of delivery, is always higher than the equilibrium density or oven-dry density. Definitions of, and methods for determining or calculating freshly mixed, equilibrium, and oven-dry densities of lightweight concrete are covered in Test Methods C138/C138M and C567.

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

6.1.8 One of the following Options A, B, or C, shall be used as the basis for determining the proportions of the fiber-reinforced concrete of the quality required.

6.2 *Option A:*

6.2.1 When the purchaser assumes responsibility for mixture proportioning, the following parameters shall also be specified by the purchaser:

6.2.1.1 The cement content in kilograms per cubic metre [pounds per cubic yard],

6.2.1.2 If supplementary cementitious materials are required, the type, and amounts to be used in kilograms per cubic metre [pounds per cubic yard], or in percentages by mass of cement,

6.2.1.3 The maximum allowable amount of mixing water in litres per cubic metre [gallons per cubic yard], including surface moisture on the aggregates, but excluding water absorbed by the aggregate,

6.2.1.4 If air-entraining admixtures are required, the type, name, and dosage range to be used to achieve the specified air content, (see 6.1.4),

6.2.1.5 If chemical admixtures are required, the type, name, and dosage range to be used, and:

6.2.1.6 The type of fibers to be used and the amount in kilograms per cubic metre [pounds per cubic yard], (see Classification Section 4).

NOTE 6—The dosage of air-entraining, water-reducing (including high-range), accelerating, and retarding admixtures needed to satisfy the material performance requirements varies. Therefore, dosage ranges should be specified to ensure that the material performance requirements can be met.

NOTE 7—The purchaser, in selecting requirements for which he assumes responsibility should give consideration to requirements for workability, placeability, durability, surface texture, and density. The purchaser is referred to ACI Practices 211.1 and 211.2 for selecting proportions that will result in concrete suitable for various types of structures and conditions of exposure, and to ACI Report 544.3R[5] for selecting concrete and fiber parameters suitable for fiber-reinforced concrete. For guidance on selecting proportions for fiber-reinforced shotcrete, the purchaser is referred to ACI Reports 506.1R[6] and 506.R[7] and ACI Specification 506.2.

6.2.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of concrete, furnish a statement to the purchaser giving the sources, relative densities, sieve analyses, and saturated surface-dry masses of fine and coarse aggregates, and the amount of mixing water per cubic metre [per cubic yard] that will be used in the manufacture of each class of concrete ordered by the purchaser.

6.3 *Option B:*

6.3.1 When the purchaser requires the manufacturer to assume full responsibility for mixture proportioning (see Note 7), the purchaser shall also specify the following:

6.3.1.1 Requirements for flexural performance determined in accordance with one of the following: Test Method C1399, C1550 or C1609/C1609M, using samples obtained at the point of discharge, or when appropriate at the point of placement. At the option of the purchaser, compressive strength (Test Method C39/C39M) shall be specified when the flexural requirements are considered inadequate for ensuring the quality of the matrix of the fiber-reinforced concrete. Unless accelerated curing and testing in accordance with the warm water or boiling water procedures of Test Method C684 is specified, tests shall be performed after standard moist curing in accordance with Practices C31/C31M at 28 days, or such other ages as are specified by the purchaser.

NOTE 8—While flexural strength at first peak is affected by the type and amount of fibers, it is more dependent on the characteristics of the mortar or concrete matrix, so it is recommended that the purchaser, when specifying flexural strength at first peak, consider factors known to influence the strength of normal concrete such as, water-cement ratio, aggregate maximum size, and the presence of chemical or supplementary cementitious materials.

6.3.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of concrete, furnish a statement to the purchaser giving the sources, relative densities, sieve analyses, and saturated surface-dry masses of fine and coarse aggregates, the dry masses of cement and supplementary cementitious materials, the type, dimensions, and weight of fibers, the quantities, types and names of chemical and air-entraining admixtures (if any), and the amount of mixing water per cubic metre [per cubic yard] 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 the proportions selected will produce fiber-reinforced concrete of the quality specified.

6.4 *Option C:*

[5] ACI 544.3R-08, "Guide for Specifying, Proportioning and Production of Fiber-Reinforced Concrete," American Concrete Institute (ACI), PO Box 9094 Farmington Hills, MI 48333-9094.

[6] ACI 506.1R-08, "Guide to Fiber-Reinforced Shotcrete," American Concrete Institute (ACI), PO Box 9094 Farmington Hills, MI 48333-9094.

[7] ACI 506R-05, "Guide to Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094.