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Standard Specification for Fiber-Reinforced Concrete¹

This standard is issued under the fixed designation C 1116/C 1116M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

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

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

A 820/A 820M Specification for Steel Fibers for Fiber-Reinforced Concrete

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

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

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 94/C 94M Specification for Ready-Mixed Concrete

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 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

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

C 387 Specification for Packaged, Dry, Combined Materials for Mortar and Concrete

C 567 Test Method for Determining Density of Structural Lightweight Concrete

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C 684 Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens

C 685/C 685M Specification for Concrete Made by Volumetric Batching and Continuous Mixing

~~C 887 Specification for Packaged, Dry, Combined Materials for Surface Bonding Mortar~~

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.

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

- C 995 Test Method for Time of Flow of Fiber-Reinforced Concrete Through Inverted Slump Cone³
- C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
- C 1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels
- C 1385/C 1385M Practice for Sampling Materials for Shotcrete
- C 1399 Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete
- C 1436 Specification for Materials for Shotcrete
- C 1480 Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application
- C 1550 Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)
- C 1602/C 1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
- C 1604/C 1604M Test Method for Obtaining and Testing Drilled Cores of Shotcrete
- C 1609/C 1609M Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)
- C 1666/C 1666M Specification for Alkali Resistant (AR) Glass Fiber for GFRC and Fiber-Reinforced Concrete and Cement
- D 6942 Test Method for Stability of Cellulose Fibers in Alkaline Environments
- D 7357 Specification for Cellulose Fibers for Fiber-Reinforced Concrete

2.2 ACI Standards and Reports:

- 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete⁴
- 211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete⁴
- 506.2 Specification for Materials, Proportioning and Application of Shotcrete⁴

3. Terminology

3.1 Definitions

3.1.1 For definitions of terms used in this specification, refer to Terminology C 125.

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 a fiber-reinforced concrete depends strongly upon the susceptibility of the fibers to physical damage during the mixing or shotcreting process, their chemical compatibility with the normally alkaline environment within cement paste, and their resistance to service conditions encountered within uncracked concrete or as a consequence of cracking, involving, for example, carbon dioxide, chlorides, or sulfates in solution with water and oxygen or ultraviolet light in the atmosphere. 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. 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 A 820/A 820M.

4.1.2 *Type II Glass Fiber-Reinforced Concrete*—Contains alkali-resistant (AR) glass fibers conforming to Specification C 1666/C 1666M.

4.1.3 *Type III Synthetic Fiber-Reinforced Concrete*—Contains synthetic fibers for which documentary evidence can be produced confirming their long-term 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).

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 long-term 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 D 7357.

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

² Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, <http://www.aci-int.org>.

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

⁴ ACT 544.3R-93, "Guide for Specifying, Proportioning, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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

fiber properties in this general classification can vary greatly. Some natural fibers are susceptible to deterioration from exposure to alkalis; Test Method D 6942 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 ~~long-term~~ 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 C 94/C 94M or Specification C 685/C 685M.

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 C 150;

6.1.3 Designated size, or sizes, of coarse aggregates;

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

6.1.4.1 Slump shall be specified when it is anticipated to be 2 in. [50 mm] or more, and time of flow shall be specified when slump is anticipated to be less than 2 in. [50 mm]. Slump or time of flow shall not be specified for shotcrete placed by the dry process.

NOTE 4—The time of flow of fiber-reinforced concrete through an inverted slump cone, determined in accordance with Test Method C 995, is a better indicator than slump (Test Method C 143/C 143M) of the appropriate level of workability for fiber-reinforced concrete placed by vibration because such concrete can exhibit very low slump due to the presence of fibers and still be easily consolidated. Mixtures with a time of flow of 8 to 15 s are readily consolidated by vibration. Consolidation becomes more difficult with increase in time of flow, and is extremely difficult even when using internal vibration if the time of flow exceeds 30 s. Mixtures with a time of flow less than 8 s should be evaluated in terms of slump because the time of flow is too short to determine with satisfactory precision, or may not be determinable because the fiber-reinforced concrete flows freely through the inverted cone.

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 5—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 6—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 C 138/C 138M and C 567.

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

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 pounds per cubic yard [or kilograms per cubic metre],

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

6.2.1.3 The maximum allowable amount of mixing water in gallons per cubic yard or litres per cubic metre, 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 pounds per cubic yard [or kilograms per cubic metre], (see Classification Section 4).

NOTE 7—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 8—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 544.3R⁴ 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 506.1R⁵ and 506.R⁶ 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 506.1R⁶ and 506.R⁷ 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 yard or cubic metre 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 8), 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 C 1399, C 1550 or C 1609/C 1609M, 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 C 39/C 39M) 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 C 684 is specified, tests shall be performed after standard moist curing in accordance with Practices C 31/C 31M at 28 days, or such other ages as are specified by the purchaser.

NOTE 9—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 yard or cubic metre 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:

6.4.1 When the purchaser requires the manufacturer to assume responsibility for mixture proportioning with the minimum allowable cement content specified (see Note 8), the purchaser shall also specify the following:

6.4.1.1 Requirements for flexural performance determined in accordance with one of the following: Test Method C 1399, C 1550, or C 1609/C 1609M, using samples obtained at the point of discharge, or when appropriate the point of placement. At the option of the purchaser, compressive strength (Test Method C 39/C 39M) 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 C 684 is specified, tests shall be performed after standard moist curing in accordance with Practices C 31/C 31M at 28 days, or such other ages as are specified by the purchaser (see Note 9).

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

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 10—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the mechanical properties, aggregate size, and workability specified. It must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density. For additional information refer to ACI Practices 211.1 and 211.2.

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 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 yard or cubic metre 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.

⁴ ACI 506.1R-98, "Committee Report on Fiber Reinforced Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

⁵ ACI 544.3R-93, "Guide for Specifying, Proportioning, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

⁶ ACI 506R-05, "Guide to Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

⁶ ACI 506.1R-98, "Committee Report on Fiber Reinforced Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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