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Standard Specification for Fiber-Reinforced Concrete[1]

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.

~~1.4The~~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~~ Terminology Relating to Fatigue and Fracture Testing

C 31/C 31M~~Practice for Making and Curing Concrete Test Specimens in the Field~~ Terminology Relating to Fatigue and Fracture Testing

C 39/C 39M~~Test Method for Compressive Strength of Cylindrical Concrete Specimens~~ Terminology Relating to Fatigue and Fracture Testing

C 42/C 42M~~Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete~~ Terminology Relating to Fatigue and Fracture Testing

C 94/C 94M~~Specification for Ready-Mixed Concrete~~ Terminology Relating to Fatigue and Fracture Testing

C 125~~Terminology Relating to Concrete and Concrete Aggregates~~ Terminology Relating to Fatigue and Fracture Testing

C 138/C 138M~~Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete~~ Terminology Relating to Fatigue and Fracture Testing

C 143/C 143M~~Test Method for Slump of Hydraulic-Cement Concrete~~ Terminology Relating to Fatigue and Fracture Testing

C 150~~Specification for Portland Cement~~ Terminology Relating to Fatigue and Fracture Testing

C 172~~Practice for Sampling Freshly Mixed Concrete~~ Terminology Relating to Fatigue and Fracture Testing

C 173/C 173M~~Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method~~ Terminology Relating to Fatigue and Fracture Testing

C 192/C 192M~~Practice for Making and Curing Concrete Test Specimens in the Laboratory~~ Terminology Relating to Fatigue and Fracture Testing

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[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 231~~Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method~~ Terminology Relating to Fatigue and Fracture Testing
C 387~~Specification for Packaged, Dry, Combined Materials for Mortar and Concrete~~ Terminology Relating to Fatigue and Fracture Testing
C 567~~Test Method for Determining Density of Structural Lightweight Concrete~~ Terminology Relating to Fatigue and Fracture Testing
C 666/C 666M~~Test Method for Resistance of Concrete to Rapid Freezing and Thawing~~ Terminology Relating to Fatigue and Fracture Testing
C 684~~Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens~~ Terminology Relating to Fatigue and Fracture Testing
C 685/C 685M~~Specification for Concrete Made by Volumetric Batching and Continuous Mixing~~
C887~~Specification for Packaged, Dry, Combined Materials for Surface Bonding Mortar~~ Terminology Relating to Fatigue and Fracture Testing
C 887 Terminology Relating to Fatigue and Fracture Testing
C 995~~Test Method for Time of Flow of Fiber-Reinforced Concrete Through Inverted Slump Cone~~ Terminology Relating to Fatigue and Fracture Testing
C 1077~~Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation~~ Terminology Relating to Fatigue and Fracture Testing
C 1140~~Practice for Preparing and Testing Specimens from Shotcrete Test Panels~~ Terminology Relating to Fatigue and Fracture Testing
C 1385/C 1385M~~Practice for Sampling Materials for Shotcrete~~ Terminology Relating to Fatigue and Fracture Testing
C 1399~~Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete~~ Terminology Relating to Fatigue and Fracture Testing
C 1436~~Specification for Materials for Shotcrete~~ Terminology Relating to Fatigue and Fracture Testing
C 1480~~Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application~~ Terminology Relating to Fatigue and Fracture Testing
C 1550~~Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)~~ Terminology Relating to Fatigue and Fracture Testing
C 1602/C 1602M~~Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete~~ Terminology Relating to Fatigue and Fracture Testing
C 1604/C 1604M~~Test Method for Obtaining and Testing Drilled Cores of Shotcrete~~ Terminology Relating to Fatigue and Fracture Testing
C 1609/C 1609M~~Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)~~ Terminology Relating to Fatigue and Fracture Testing
C 1666/C 1666M Terminology Relating to Fatigue and Fracture Testing
D 6942 Terminology Relating to Fatigue and Fracture Testing
D 7357 Terminology Relating to Fatigue and Fracture Testing

2.2 *ACI Standards and Reports:*
211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[3]
211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete[3]
506.2 Specification for Materials, Proportioning and Application of Shotcrete[3]

3. Terminology

~~3.1Terminology used in this specification is defined in Terminology C125~~
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*—the contractor, subcontractor, supplier, or producer who furnishes the fiber-reinforced concrete.~~ manufacturer, *n*—the producer who furnishes the fiber-reinforced concrete.
3.2.2 ~~*purchaser*—the owner or representative thereof.~~ 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. 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~~

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

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. The magnitude of improvements in the mechanical properties of the concrete imparted by fibers also reflects the material characteristics of the fiber type with fibers having a high modulus of elasticity and tensile strength being more effective on an equivalent volume basis than fibers of low modulus and strength.

4.1.1 *Type I Steel Fiber-Reinforced Concrete*—Contains stainless steel, alloy steel, or carbon steel fibers. This specification classifies fiber-reinforced concrete by the material type of the fiber incorporated.

NOTE 1—Steel fibers are not easily damaged by the mixing or shotcreting processes and uncoated steel fibers are chemically compatible with the normally alkaline environment within cement paste. Concrete may be detrimental to some coatings, such as zinc. Carbon steel fibers will rust under conditions that cause rusting of conventional steel, for example, in the near-surface portion of concrete subject to carbonation. 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.

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 glass fibers.

NOTE 2—Glass fibers in concrete subjected to wetting, humid atmosphere, or contact with moist ground have the potential to react with the alkalies present in cement paste thereby weakening the fibers. They also tend to become embrittled by hydration products penetrating the fiber bundles and filling the interstitial spaces between the individual glass filaments. Both mechanisms cause reductions in strength, toughness, and impact resistance with age. The alkali-resistant (AR) types of glass fiber developed for use with cement are more resistant to alkalies than the E-glass and other types not marketed specifically for use in cement, and should be used in conjunction with established techniques for suppressing the alkali-silica reaction, for example, use of a low-alkali cement or a mineral admixture, or both. However, even the use of AR-glass fibers does not prevent deterioration in glass fiber-reinforced concrete exposed to moisture for a long period of time, but only slows the rate at which it occurs.

Glass fibers can be damaged by conventional concrete mixing processes employing coarse aggregate, but have been used in shotcrete and in other cementitious matrices such as mechanically mixed masonry mortar (see Specification C887) and thin-section glass fiber-reinforced concrete prepared by the spray-up process (under the jurisdiction of ASTM Subcommittee C27.40). —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 alkalies alkalis present in cement paste or and the substances present in air-entraining and chemical admixtures (see Note 3 2 and 4.2).

NOTE 3—Fibers composed of some polymers may deteriorate when in contact with moisture, alkalies, or some of the ingredients of chemical admixtures. Fibers such as polyolefins (polypropylene and polyethylene), nylon, and carbon have been shown to be durable in concrete. 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. 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 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, for example: natural fibers, metallic fibers other than steel, carbon fibers, and so forth, the producer shall show evidence satisfactory to the purchaser that the type of fiber proposed for use does not react adversely with the concrete matrix, including the constituents of any admixtures present, or with the surrounding environment in the cracked matrix, causing deterioration in mechanical properties with age under the exposure conditions anticipated in the application. , 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.

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 544.3R[4] 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[5] and 506.R[6] 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.

[4] 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.

[5] ACI 506.1R-98, "Committee Report on Fiber Reinforced Shotcrete," 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.