Designation: C1666/C1666M – 08 (Reapproved 2015)

Standard Specification for Alkali Resistant (AR) Glass Fiber for GFRC and Fiber-Reinforced Concrete and Cement[1]

This standard is issued under the fixed designation C1666/C1666M; 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 minimum requirements for alkali resistant (AR) glass fibers intended for use in glass fiber-reinforced concrete (GFRC) by spray-up, glass fiber-reinforced concrete premix, fiber-reinforced concrete, and other cementitious based products.

1.2 This specification provides for AR glass fiber types and configurations that can be readily incorporated into concrete mixes, typical physical properties, minimum zirconia content, and prescribes testing procedures to establish conformance to these requirements.

1.3 This specification does not address the types of coatings or lubricants used in the manufacturing process of the fibers.

1.4 In the case of conflict between a more stringent requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of a conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail. The purchase order requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by the waiving of a test requirement or by making a test requirement less stringent.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. 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.

1.6 *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]

D578 Specification for Glass Fiber Strands
D1577 Test Methods for Linear Density of Textile Fibers
D2256 Test Method for Tensile Properties of Yarns by the Single-Strand Method
D3800 Test Method for Density of High-Modulus Fibers
D4963 Test Method for Ignition Loss of Glass Strands and Fabrics

2.2 *ISO Standards:*[3]

ISO 1887 Textile Glass—Determination of Combustible-Matter Content
ISO 1888 Textile Glass—Staple Fibres or Filaments—Determination of Average Diameter
ISO 1889 Reinforcement Yarns—Determination of Linear Density
ISO 3341 Textile Glass Yarns—Determination of Breaking Force and Breaking Elongation

2.3 *EN Standards:*[4]

EN 14649 Precast Concrete Products—Test Method for Strength Retention of Glass Fibre in Cement and Concrete

2.4 *Japanese Industrial Standards:*[5]

JISR 3420 Testing Methods of Textile Glass Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *alkali resistant (AR) glass fiber, n*—a glass fiber product that is resistant to the alkaline conditions that exist in matrices such as those based on Portland cement, and that are

[1] This specification is under the jurisdiction of ASTM Committee C27 on Precast Concrete Products and is the direct responsibility of Subcommittee C27.40 on Glass Fiber Reinforced Concrete.

Current edition approved May 1, 2015. Published June 2015. Originally approved in 2007. Last previous edition approved in 2008 as C1666/C1666M – 08. DOI: 10.1520/C1666_C1666M-08R15.

[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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, http://www.cenorm.be.

[5] Available from Japanese Standards Organization (JSA), 4-1-24 Akasaka Minato-Ku, Tokyo, 107-8440, Japan, http://www.jsa.or.ja.

used for the reinforcement of cement, mortar, and concrete products. The resistance is due mostly to the specific composition of the glass.

3.1.2 *chopped strands, n*—strands, as defined in 3.1.9, chopped to discrete lengths, usually between 3 and 50 mm [0.125 and 2 in.].

3.1.3 *filament, n*—a single glass fiber, sometimes referred to as monofilament.

3.1.4 *GFRC, n*—glass fiber-reinforced concrete, sometimes referred to as GRC.

3.1.5 *matrix, n*—the concrete (or mortar) without the glass fiber reinforcement.

3.1.6 *roving, n*—a number of parallel, continuous, not twisted, strands wound together to form a cylindrical package.

3.1.7 *scrim or net, n*—glass fiber roving or yarn strands laid in two directions at 90° and then bonded together to form a non-woven stable structured textile fabric.

3.1.8 *size, n*—coatings applied to filaments during manufacture that facilitate the processing of glass fibers and bond the filaments together. Different sizings can provide different performance characteristics of the fibers.

3.1.9 *strand, n*—several parallel filaments of consistent diameter, bonded together with a size.

3.1.10 *tex, n*—the weight in grams of one kilometre of strand or roving.

3.1.11 *woven roving, n*—glass fiber roving products that are produced by weaving into a structured textile fabric.

3.1.12 *yarn, n*—glass fiber strands that are twisted together.

4. Classification

4.1 AR glass fibers are available in three forms as follows:

4.1.1 *Type I, Roving*—Avariety of different roving are manufactured with different processing characteristics, which makes them suitable for particular applications such as chopping and spraying, weaving and scrim manufacture, filament winding, and chopped strand production.

4.1.2 *Type II, Chopped Strands*—Available in lengths from 3 mm [0.125 in.] to 50 mm [2.0 in.]. Chopped strands are designed to remain either as integral bundles of filaments (usually referred to as integral strands) or to breakdown into individual filaments (filamentize) during mixing (usually referred to as water dispersible strands).

4.1.3 *Type III, Textiles*—Available as woven, knitted, or non-woven fabrics.

5. Ordering Information

5.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for the product under this specification. Such requirements to be considered include, but are not limited to, the following:

5.1.1 ASTM designation and year of issue.

5.1.2 Quantity in kilograms [pounds or tons] for rovings or chopped strands or in square metres [square feet or square yards] for textiles.

5.1.3 Type or types permissible (see 4.1).

5.1.4 Manufacturer's product code, if not included in code, tex shall be specified for roving, length shall be specified for chopped strands, and weight/unit area or number of strands/unit length shall be specified for textiles.

5.1.5 Whether certificate of analysis by the manufacturer is required.

6. Materials and Manufacture

6.1 The materials and manufacturing methods used shall be such that the fibers produced conform to the requirements in this specification.

7. Chemical Composition

7.1 Alkali resistant glass fiber shall have a minimum of 16 % by mass of zirconium dioxide.

8. Mechanical Properties

8.1 The AR glass fiber roving or chopped strands shall be deemed to comply with the requirements of this specification if the results obtained on test samples comply with the values specified in Table 1.

9. Performance Requirements

9.1 The strength of AR glass fiber shall be measured according to EN 14649.

9.2 Users of AR glass fibers shall require that manufacturers of AR glass fiber show independent validation of performance in the SIC test.

10. Workmanship, Finish, and Appearance

10.1 The roving, chopped strands, or textiles shall be free from oil, grease, and other contaminants. A roving package shall be free from obvious damage and shall not be deformed

TABLE 1 Test Requirements

Property	Specification Value	Method of Test
Zirconia content (ZrO_2)	16 % min	X-ray fluorescence[A]
Density	2.68 ± 0.3 g/cm^3 [167.0 ± 19 lb/ft^3]	ASTM D3800
Tensile Strength	1.0–1.7 Gpa [145 × 10^3–246 × 10^3 psi]	ASTM D2256, ISO 3341, JISR 3420
Range of Filament Diameters	8–30 µm [31× 10^{-5}-118 × 10^{-5} in.]	ASTM D578, ISO 1888, JISR 3420
Roving tex	±10 % of manufacturer's nominal	ASTM D1577, ISO 1889, JISR 3420
Strand length	±3 mm [±0.118 in.] of manufacturer's nominal	Caliper—Average of 20 measurements
End count	±20 % of manufacturer's nominal	Physical count
Loss on ignition	<3 %	ASTM D4963, ISO 1887, JISR 3420
Strength retention	Minimum value after 96 ± 1 h in water at 80 ±1°C [176 ± 2 °F] ≥250 MPa [36 250 psi] for water dispersible strands ≥350 MPa [50 750 psi] for integral strands	EN 14649

[A]Any party that is interested in doing this test should contact an AR glass fiber manufacturer before running it so as to avoid possible erroneous results.

11. Inspection

11.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the purchased order or contract, the manufacturer may use his own or any other suitable facility for the performance of the inspection and test requirements specified herein unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

12. Rejection and Rehearing

12.1 *Rejection:*

12.1.1 If any test fails to conform to the requirements of this specification, it shall be cause for rejection of the material represented by the test. Material that is found to be defective subsequent to its acceptance at the manufacturer's works may be rejected, and manufacturer notified.

12.1.2 Rejection of fibers shall be reported to the manufacturer promptly and in writing, stating the lot number from the bag or the box of the rejected fibers. Samples representing fibers rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

12.2 *Rehearing*—When any test fails to meet the requirements of Table 1, a retest shall be allowed. This retest shall be performed on twice the number of randomly selected specimens originally tested. The results of the retest shall meet the requirements of this specification or the lot shall be rejected.

13. Certification

13.1 *Certificate of Compliance/Analysis*—The producer or supplier shall furnish a certificate of compliance/analysis when specified in the purchase order or contract. The certificate of compliance/analysis shall state that the product was manufactured, sampled, tested, and inspected in accordance with this specification (including year of issue) and any other requirements stated in the purchase order or contract, and that it meets such requirements.

13.2 *Test Reports*—When specified in the purchase order or contract, test reports shall be furnished to the purchaser containing the results of all tests required by this specification (including year of issue), and any other requirements designated in the purchase order or contract.

13.3 A signature or notarization is not required; however, the document shall clearly identify the organization submitting the document. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

14. Packaging and Package Marking

14.1 The product shall be packaged to provide adequate protection during normal handling and transportation. The type of packaging and gross mass (weight) of containers shall, unless otherwise agreed upon, be at the manufacturer's discretion provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

14.2 Each shipping container shall be clearly labeled and show manufacturer's name or trademark, product code, lot number or manufacturing code, and net mass (weight). At the manufacturer's discretion other information may be given.

15. Keywords

15.1 AR glass fibers; GFRC; glass fiber-reinforced concrete; glass fiber-reinforced concrete premix; SIC test; zirconia

APPENDIX

(Nonmandatory Information)

X1. COMMENTS PERTINENT TO USERS OF ALKALI RESISTANT (AR) GLASS FIBER

X1.1 The minimum zirconia content of 16 % was established by testing of a wide range of glass formulations that contained several different contents of zirconia (**1**, **2**).[6] Also several other compounds, such as TiO_2, were also evaluated and discounted as being inferior to zirconia in conferring alkali resistance (**1**, **2**).

X1.2 Although glass fibers with a minimum content of 16 % zirconia content demonstrate good resistance to alkali attack, some loss in flexural strength may occur in glass fiber reinforced concrete composites with high fiber content, in the range of 3 to 5 % (mass %). Composites with fiber contents less than 3 % do not exhibit much change in flexural strength with time (**3**). The flexural strength reduction always stabilizes after a certain amount of time depending on exposure conditions and there is no further reduction (**2**). The reduction in strength of high fiber content glass fiber reinforced concrete (GFRC) is well documented and has been understood since the introduction of GFRC in 1970 (**2**). The Precast/Prestressed Concrete Institute (PCI) has developed a design procedure that takes full account of any changes in strength and it is recommended that those using GFRC should consult the PCI manual (**4**). The design procedure is incorporated in the GFRC section in the International Building Code. The use of pozzolans, such as silica fume, metakaolin, Class C and F fly ash, and pulverized borosilicate glass (usually referred to as E glass), when incorporated in sufficient quantity can have

[6] The boldface numbers in parentheses refer to a list of references at the end of this standard.

beneficial effects on long-term properties of GFRC (**2**). AR glass fiber manufacturers should be consulted about the use of pozzolans in GFRC. Special cements and supplementary cementing materials (SCMs) that consume the free lime in Portland cement, such as calcium sulpho-aluminate cements, and slag have excellent long-term properties when reinforced with AR glass fibers (**5**).

X1.3 AR Glass fiber strands are not single fibers but are bundles of very fine filaments. The good flexural strength that is attained by GFRC composites (in excess of 17 Mpa [2,500 psi]) is possible because approaching the stress limit the fiber bundles exhibit pull out of some of the filaments. This allows the composite to strain and carry further load after the concrete has started to crack thereby providing higher flexural strength. Calcium hydroxide (Portlandite) is crystallized from the free lime in the Portland cement and some of these crystals may form within the fiber bundles. The effect of this is to reduce the capacity for fiber pull out, which in turn reduces the strain at failure and the resultant flexural strength. Pozzolans, SCM's and special cements should provide improved long-term structural properties by preventing, or reducing, the crystallization of Portlandite by consuming the free lime before it can form into Portlandite.

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