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Designation: D7957/D7957M – 22

Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D7957/D7957M; 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 glass fiber reinforced polymer (GFRP) bars, provided in cut lengths and bent shapes and having an external surface enhancement for concrete reinforcement. Bars covered by this specification shall meet the requirements for geometric, material, mechanical, and physical properties described herein.

1.2 Bars produced according to this standard are qualified using the test methods and must meet the requirements given by Table 1. Quality control and certification of production lots of bars are completed using the test methods and must meet the requirements given in Table 2.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables) shall not be considered as requirements of the specification.

1.4 The following FRP materials are not covered by this specification:

1.4.1 Bars made of more than one load-bearing fiber type (that is, hybrid FRP).

1.4.2 Bars having no external surface enhancement (that is, plain or smooth bars, or dowels).

1.4.3 Bars with geometries other than solid, round cross sections.

1.4.4 Pre-manufactured grids and gratings made with FRP materials.

1.5 This specification is applicable for either SI (as Specification D7957M) or inch-pound units (as Specification D7957).

1.6 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials

D570 Test Method for Water Absorption of Plastics

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D2584 Test Method for Ignition Loss of Cured Reinforced Resins

D3171 Test Methods for Constituent Content of Composite Materials

D3878 Terminology for Composite Materials

D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars

D7617/D7617M Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars

D7705/D7705M Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction

D7913/D7913M Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing

[1] This specification is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.10 on Composites for Civil Structures.

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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.

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TABLE 1 Property Limits and Test Methods for Qualification[A]

Property	Limit	Test Method
Mean Glass Transition Temperature	Midpoint temperature ≥100 °C [212 °F]	ASTM E1356
Mean Degree of Cure	≥95 %	ASTM E2160
Mean Measured Cross-Sectional Area	Table 3	ASTM D7205/D7205M, subsection 11.2.5.1
Guaranteed[B] Ultimate Tensile Force	Table 3	ASTM D7205/D7205M
Mean Tensile Modulus of Elasticity	≥44,800 MPa [6 500 000 psi]	ASTM D7205/D7205M
Mean Ultimate Tensile Strain	≥1.1 %	ASTM D7205/D7205M
Guaranteed[B] Transverse Shear Strength	≥131 MPa [19 000 psi]	ASTM D7617/D7617M
Guaranteed[B] Bond Strength	≥7.6 MPa [1100 psi]	ASTM D7913/D7913M
Mean Moisture Absorption to Saturation	≤1.0 % to saturation at 50 °C [122 °F]	ASTM D570, subsection 7.4
Mean Alkaline Resistance	≥80 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F]	ASTM D7705/D7705M, Procedure A
Guaranteed[B] Ultimate Tensile Force of Bent Portion of Bar	≥60 % of the values in Table 3	ASTM D7914/D7914M

[A]For the determination of the mean and guaranteed properties, at least 24 samples shall be obtained in groups of eight or more from three or more different production lots. The mean and guaranteed properties shall satisfy the limits.
[B]Guaranteed property is defined in 3.2.4.

TABLE 2 Property Limits and Test Methods for Quality Control and Certification[A,B]

Property	Limit	Test Method
Fiber Mass Content	≥70 %	ASTM D2584 or ASTM D3171
Glass Transition Temperature	Midpoint temperature ≥100 °C [212 °F]	ASTM E1356
Degree of Cure	≥95 %	ASTM E2160
Measured Cross-Sectional Area	Table 3	ASTM D7205/D7205M, subsection 11.2.5.1
Ultimate Tensile Force	Table 3	ASTM D7205/D7205M
Tensile Modulus of Elasticity	≥44 800 MPa [6 500 000 psi]	ASTM D7205/D7205M
Ultimate Tensile Strain	≥1.1 %	ASTM D7205/D7205M
Moisture Absorption in 24 h	≤0.25 % in 24 h at 50 °C [122 °F]	ASTM D570, subsection 7.4

[A]For the determination of each of the property limits, five random samples shall be obtained from each production lot. Each individual sample shall satisfy the property limits.
[B]For bent bars, the tests are performed on the straight portion of the bars.

TABLE 3 Geometric and Mechanical Property Requirements

Bar Designation No.	Nominal Dimensions		Measured Cross-Sectional Area Limits mm² [in.²]		Minimum Guaranteed Ultimate Tensile Force kN [kip]
	Diameter mm [in.]	Cross-Sectional Area mm² [in.²]	Minimum	Maximum	
M6 [2]	6.3 [0.250]	32 [0.049]	30 [0.046]	55 [0.085]	27 [6.1]
M10 [3]	9.5 [0.375]	71 [0.11]	67 [0.104]	104 [0.161]	59 [13.2]
M13 [4]	12.7 [0.500]	129 [0.20]	119 [0.185]	169 [0.263]	96 [21.6]
M16 [5]	15.9 [0.625]	199 [0.31]	186 [0.288]	251 [0.388]	130 [29.1]
M19 [6]	19.1 [0.750]	284 [0.44]	268 [0.415]	347 [0.539]	182 [40.9]
M22 [7]	22.2 [0.875]	387 [0.60]	365 [0.565]	460 [0.713]	241 [54.1]
M25 [8]	25.4 [1.000]	510 [0.79]	476 [0.738]	589 [0.913]	297 [66.8]
M29 [9]	28.7 [1.128]	645 [1.00]	603 [0.934]	733 [1.137]	365 [82.0]
M32 [10]	32.3 [1.270]	819 [1.27]	744 [1.154]	894 [1.385]	437 [98.2]

D7914/D7914M Test Method for Strength of Fiber Reinforced Polymer (FRP) Bent Bars in Bend Locations
E1356 Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
E2160 Test Method for Heat of Reaction of Thermally Reactive Materials by Differential Scanning Calorimetry

3. Terminology

3.1 *Definitions:*

3.1.1 Terminology C904 defines terms relating to chemical-resistant nonmetallic materials. Terminology D3878 defines terms relating to high-modulus fibers and their composites.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bar, n*—a straight or bent element with a solid, round cross section in the straight portion, having surface enhancement that intends to provide mechanical interlock with concrete.

3.2.2 *bend angle, n*—the intentional deviation of a portion of a bar from the main axis of the bar, measured in degrees.

3.2.3 *bend diameter, n*—the inside diameter of a bent bar, as provided in Table 4.

TABLE 4 Minimum Inside Bend Diameter of Bent Bars[A]

Bar Designation, mm [U.S. Standard]	Minimum Bend Diameter mm [in.]
M6 [2]	38 [1.50]
M10 [3]	58 [2.25]
M13 [4]	76 [3.00]
M16 [5]	96 [3.75]
M19 [6]	114 [4.50]
M22 [7]	134 [5.25]
M25 [8]	152 [6.00]

[A]Bent bars of designation M29 [9] and M32 [10] are not included in this specification.

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3.2.4 *guaranteed property, n*—a characteristic value provided by the manufacturer less than or equal to the mean minus three standard deviations of the samples tested according to a specified method.

3.2.5 *mean property, n*—a value provided by the manufacturer less than or equal to the mean of the samples tested according to a specified method.

3.2.6 *measured cross-sectional area, n*—the average cross-sectional area of a representative bar, including deformations, lugs, sand coating, or any bond-enhancing surface treatment, measured according to Test Method D7205/D7205M.

3.2.7 *nominal bar diameter, n*—a standard diameter of a bar, as described in Table 3.

3.2.8 *nominal cross-sectional area, n*—a standard cross-sectional area of a bar, as described in Table 3.

3.2.9 *production lot, n*—determined by the manufacturer, as any batch of bar produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

3.2.10 *size designation, n*—an alphanumeric identifier corresponding to the bar designation number of Table 3.

3.2.11 *surface enhancement, n*—protrusions, lugs, sand coatings, deformations, or any additional surface treatment that provides means of mechanically transmitting force between the bar and the concrete surrounding the bar in such construction.

3.2.12 *test, certification, n*—an optional test, specified by the purchaser, to certify that the material provided for a given project meets the requirements of the specification.

3.2.13 *test, qualification, n*—a test completed under the supervision of the manufacturer to ensure conformance of material to the requirements of a specification.

3.2.14 *test, quality control, n*—a test completed on each production lot of material, under the supervision of the manufacturer, to ensure that the process of manufacturing the product remains under control.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for material ordered to this specification. Such requirements shall include:

4.1.1 Name of the FRP material (manufacturer's description),

4.1.2 Quantity of each individual bar length,

4.1.3 Bar designation number (size),

4.1.4 Cut length, and

4.1.5 For bent bars, the shape of the bend, the diameter of the bend, and the length of the legs.

4.1.6 Production lot certification report, if desired.

NOTE 1—Descriptive bar list part numbering can be helpful in communicating the designer's intent to the fabricator, supplier, placement of the reinforcing, procurement, and job site inspection. An example of descriptive part numbering for GFRP bars is shown in Appendix X1.

5. Constituent Materials and Manufacture

5.1 *Reinforcing Fibers*—Glass fibers shall be in the form of continuous unidirectional rovings.

5.2 *Matrix Resins:*

5.2.1 Vinyl ester thermoset resin systems are permitted, provided the finished product meets the physical and durability requirements of this specification.

5.2.2 The base polymer in the resin system should not contain any polyester.

5.3 *Manufacturing Process:*

5.3.1 Process or material modifications are not permitted during the production of a single production lot.

5.3.2 The manufacturer shall document the process used and report the date(s) of production and quantity of material produced in the production lot.

5.3.3 The manufacturer shall maintain a documented quality control plan that details the activities of the process monitoring, production inspection, and record keeping. The plan shall be made available to customers upon request.

5.3.3.1 The manufacturer shall use all tests in Table 2 as part of the quality control process. A record of these quality control tests shall be kept for each lot of material and shall be made available to the purchaser upon request. The manufacturer may use other tests as part of internal quality control processes. Results from such tests are not required to be reported.

6. Physical Properties

6.1 *Fiber Mass Content*—The fiber mass content shall be determined by Test Method D2584 or Test Methods D3171, at a frequency and number of specimens as indicated in Section 10. The fiber mass content is calculated as the mass of the longitudinal fibers divided by the mass of the longitudinal fibers plus resin. Excluded from this calculation are the materials added to the bar for bond enhancement. The fiber mass content shall be in accordance with the limit given in Table 2.

6.2 *Glass Transition Temperature*—The glass transition temperature shall be determined using specimens cut from the as-produced bar, by Test Method E1356, at a frequency and number of specimens as indicated in Section 10. Test results for the first temperature scan shall be used to determine the glass transition temperature. The glass transition temperature shall be in accordance with the limits given in Tables 1 and 2.

6.3 *Degree of Cure*—The degree of cure shall be determined using specimens cut from the as-produced bar, by Test Method E2160, at a frequency and number of specimens as indicated in Section 10. The degree of cure shall be in accordance with the limits given in Tables 1 and 2.

6.4 *Bar Sizes:*

6.4.1 Bar size and measured cross-sectional area, as described below, are established on straight sections of bar.

6.4.2 The size designation of bars meeting this specification shall be in bar number designations or metric equivalents consistent with the practice for steel bars as described in Specification A615/A615M.

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6.4.3 Mechanical properties reported in this specification are established based on the nominal cross-sectional area as provided in Table 1.

6.4.4 The measured cross-sectional area of the bar shall be determined by Test Method D7205/D7205M, subsection 11.2.4.1, based on the method given in Test Methods D792, and shall be measured on the as-manufactured bar, including surface enhancements, at a frequency and number of specimens as indicated in Section 10. The measured cross-sectional area shall be within the minimum and maximum area limits provided in Tables 1 and 2.

7. Mechanical Properties

7.1 *Ultimate Tensile Force*—The ultimate tensile force shall be determined by Test Method D7205/D7205M, at a frequency and number of specimens as indicated in Section 10. The ultimate tensile force shall be in accordance with the limits provided in Tables 1 and 2.

7.2 *Tensile Modulus of Elasticity*—The tensile modulus of elasticity shall be determined by Test Method D7205/D7205M, at a frequency and number of specimens as indicated in Section 10. The tensile modulus of elasticity shall be in accordance with the limits given in Tables 1 and 2.

7.3 *Ultimate Tensile Strain*—The ultimate tensile strain shall be calculated by dividing the ultimate tensile force by the product of the nominal cross-sectional area and the tensile modulus of elasticity.[3] The ultimate tensile strain shall be in accordance with the limits given in Tables 1 and 2.

7.4 *Transverse Shear Strength*—The transverse shear strength shall be determined by Test Method D7617/D7617M at a frequency and number of specimens as indicated in Section 10. The transverse shear strength shall be in accordance with the limit given in Table 1.

7.5 *Bond Strength:*

7.5.1 The bond strength shall be determined by Test Method D7913/D7913M, at a frequency and number of specimens as indicated in Section 10. The bond strength shall be in accordance with the limit given in Table 1.

7.5.2 If a range of otherwise identically produced bar sizes is offered, bond tests on either odd or even bar size designations covering the full range of produced bar sizes may be used.

8. Durability Properties

8.1 *Moisture Absorption*—Specimens shall be tested by Test Method D570, subsection 7.4, at a frequency and number of specimens as indicated in Section 10. The moisture absorption shall be in accordance with the limits given in Tables 1 and 2.

8.2 *Resistance to Alkaline Environment:*

8.2.1 The resistance to alkaline environments is determined by Test Method D7705/D7705M, at a frequency and number of specimens as indicated in Section 10. The ultimate tensile force after exposure to the alkaline environment shall be in accordance with the limit given in Table 1.

8.2.2 If a range of otherwise identically produced bar sizes is offered, alkaline resistance tests on either odd or even bar size designations covering the full range of produced bar sizes may be used.

9. Requirements for Bent Bars

9.1 *Bend Diameter*—Bends in bars shall be formed only while the resin is in a physical liquid state. The geometric properties for bent bars shall be as shown in Table 4.

9.2 *Properties of Bends:*

9.2.1 The ultimate tensile force of the bent portion of bars shall be determined by Test Method D7914/D7914M, at a frequency and number of specimens as indicated in Section 10. The ultimate tensile force of the bent portion shall be in accordance with the limit given in Table 1.

9.2.2 *Ultimate Tensile Force and Tensile Modulus of Elasticity of Straight Portion of Bent Bar:*

9.2.2.1 When it is possible to extract a straight portion from a bent bar of sufficient length, such an element shall be tested in tension by Test Method D7205/D7205M, at a frequency and number of specimens as indicated in Section 10. The ultimate tensile force and tensile modulus of elasticity shall be in accordance with the limits given in Table 2.

9.2.2.2 When the bend shape does not allow for tensile testing of one of its straight portions, straight bars produced under the same production lot conditions of the bent bar and of sufficient length for tension testing shall be tested by Test Method D7205/D7205M, at a frequency and number of specimens as indicated in Section 10. The ultimate tensile force and tensile modulus of elasticity shall be in accordance with the limits given in Table 2.

10. Sampling

10.1 *Product Qualification*—For the determination of the mean and guaranteed properties, at least 24 samples shall be obtained in groups of eight or more from three or more different production lots. The mean and guaranteed properties shall satisfy the limits as given in Table 1.

NOTE 2—Manufacturers may use more than the minimum sampling stated by this standard. The benefit of testing a larger number of specimens when developing guaranteed and mean values is to increase the likelihood of compliance in quality control and certification testing.

10.2 *Quality Control and Certification*—For the determination of each of the property limits, five random samples shall be obtained from each production lot. Each individual sample shall satisfy the property limits as given in Table 2.

10.3 Tests for qualification shall be repeated if there is a process or constituent material change.

10.4 Samples from each production lot to be used for preparing test specimens shall be selected by the manufacturer on a random basis.

11. Rejection

11.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

[3] The calculation method is based upon the assumption that the stress-strain behavior is linear elastic (straight line).

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11.2 For quality control and certification, if an individual test result is not within the limits given in Table 2, that production lot shall be rejected as not meeting this specification.

12. Product Certification

12.1 When specified in the purchase order or contract, the purchaser shall be furnished certification stating samples representing each lot have been tested and inspected as indicated in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished. Test reports may be transmitted to the purchaser by electronic services. The content of the electronically transmitted document shall conform to any existing agreement between the purchaser and the seller.

12.2 If the purchaser intends to perform additional or independent certification testing, requirements thereof, such as the need for additional test specimens, shall be provided to the manufacturer.

12.3 The test report shall include the information listed in the reporting sections of the test methods in Table 2, and shall indicate the production lot, traceable through the identifying markings on the bars.

13. Markings and Traceability

13.1 Straight bars shall each be indelibly marked, at regular intervals along the length, spaced not more than 2 m [72 in.] between intervals, with the following information:

13.1.1 ASTM specification number.

13.1.2 Manufacturer's mark.

13.1.3 Size designation.

13.1.4 Production lot number.

13.2 Bent bars may include information noted in 13.1 by an attached tag only and shall include the shape description.

APPENDIX

(Nonmandatory Information)

X1. MANUFACTURER'S BAR DESCRIPTION

X1.1 A manufacturer's bar description is helpful for communications between the designer, procurement personnel, bar manufacturer, and job site inspectors. Examples are as follows:

X1.2 RB(X)-(Y), where RB is the manufacturer's mark, X is the inch-pound or SI bar size designation, and Y is the length of the bar in inches or centimeters. As an example, for an RB3-240 bar in the inch-pound system, RB is the manufacturer's mark, 3 is the bar size designation, and 240 is the bar length in inches.

X1.3 For bent shapes, BRB(X)-(A)-(Y)-(Z), where BRB is the manufacturer's mark for a bent shape, X is the inch-pound or SI bar size designation, A is the bend angle or shape code of the bend from the main axis or shape description for a compound bent shape, Y is the length of the first leg of the bend, Z is the length of the second leg of the bend, and so on.

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