Designation: D8505/D8505M – 23

Standard Specification for Basalt and Glass Fiber Reinforced Polymer (FRP) Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D8505/D8505M; 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 basalt and glass fiber reinforced polymer (BFRP and GFRP, respectively) bars, provided in straight (longitudinal) cut lengths, of solid round cross-section, and having a surface enhancement for internal concrete reinforcement applications. Bars covered by this specification shall meet the requirements for geometric, material, mechanical, and physical properties as described herein.

1.2 Subsection 1.6 defines the type of FRP bars that are out of the scope of this specification.

1.3 Bars produced according to this standard are qualified using the test methods and must meet the requirements given in 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.

1.4 The standard sizes and dimensions of FRP bars and their number designations are given in Table 3.

1.5 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.

1.6 The following FRP bar materials are not covered by this specification:

1.6.1 Bars made of more than one load-bearing fiber types or different grade fibers (that is, hybrid FRP).

1.6.2 Bars made from fibers other than glass or basalt.

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

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

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

1.6.6 Bent bars (that is, bars that are not made of straight, continuous lengths).

NOTE 1—Bent bars may include stirrups and hoops. Refer Specification D7957/D7957M for GFRP bent bar specifications.

1.7 This specification is applicable for either SI (as Specification D8505M) or US units (as Specification D8505).

1.8 The values stated in either SI units or US units are to be regarded as standard. Within the text, the US units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.9 *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.*

1.10 *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.*

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

Property	Limit	Test Method
Mean Glass Transition Temperature	≥ 100 °C [212 °F] (DSC) ≥ 110 °C [230 °F] (DMA)	E1356 D7028
Mean Degree of Cure	≥ 95 %	E2160
Mean Measured Cross-Sectional Area	Table 3	D7205/D7205M, subsection 11.2.4.1
Guaranteed[B] Ultimate Tensile Force	Table 3	
Guaranteed Ultimate Tensile Strength	Report value	
Mean Tensile Modulus of Elasticity	≥ 60 000 MPa [8 700 000 psi]	D7205/D7205M
Mean Tensile Modulus of Elasticity (using measured Cross-Sectional Area)	Report value	
Mean Ultimate Tensile Strain	≥ 1.1 %	
Mean Transverse Shear Strength	≥ 152 MPa [22 000 psi]	D7617/D7617M
Mean Apparent Horizontal Shear Strength	≥ 37.9 MPa [5 500 psi]	D4475
Mean Bond Strength	Table 3	D7913/D7913M
Mean Moisture Absorption	≤ 0.25 % in 24 hrs. at 50 °C [122 °F], and ≤ 1.0 % to saturation at 50 °C [122 °F]	D570, subsection 7.4
Mean Alkaline Resistance	≥ 80 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F]	D7705/D7705M, Procedure A
	≥ 75 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F]	D7705/D7705M, Procedure B set an initial tensile strain equal to 3000 microstrain

[A] For the determination of the mean and guaranteed properties, at least 24 specimens (that is, test repetitions) 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 3.2.2.

TABLE 2 Property Limits and Test Methods for Quality Control and Certification of Production Lots[A]

Property	Limit	Test Method
Fiber Mass Content	≥ 70 %	D2584 or D3171
Glass Transition Temperature	≥ 100 °C [212 °F] (DSC) ≥ 110 °C [230 °F] (DMA)	E1356 D7028
Degree of Cure	≥ 95 %	E2160
Measured Cross-Sectional Area	Table 3	D7205/D7205M, subsection 11.2.4.1
Ultimate Tensile Force	Table 3	
Guaranteed Ultimate Tensile Strength	Report value	
Mean Tensile Modulus of Elasticity	≥ 60 000 MPa [8 700 000 psi]	D7205/D7205M
Mean Tensile Modulus of Elasticity (using measured Cross-Sectional Area)	Report value	
Ultimate Tensile Strain	≥ 1.1 %	
Mean Apparent Horizontal Shear Strength	≥ 37.9 MPa [5 500 psi]	D4475
Moisture Absorption in 24 h	≤ 0.25 % in 24 hrs. at 50 °C [122 °F]	D570, subsection 7.1

[A] For the determination of each of the property limits, five random specimens (i.e. test repetitions) shall be obtained from each production lot. Each individual specimen shall satisfy the property limits.

TABLE 3 Geometric and Mechanical Property Requirements

Bar Designation Number	Nominal Dimensions		Measured Cross-Sectional Area Limits mm² [in.²]		Minimum Guaranteed Ultimate Tensile Force kN [kip]	Minimum Bond Strength MPa [psi]
	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]	33 [7.4]	9.6 [1400]
M10 [3]	9.5 [0.375]	71 [0.11]	67 [0.104]	104 [0.161]	71 [16.0]	
M13 [4]	2.7 [0.500]	129 [0.20]	119 [0.185]	169 [0.263]	124 [27.9]	
M16 [5]	15.9 [0.625]	199 [0.31]	186 [0.288]	251 [0.388]	181.5 [40.8]	
M19 [6]	19.1 [0.750]	284 [0.44]	268 [0.415]	347 [0.539]	254.9 [57.3]	
M22 [7]	2.2 [0.875]	387 [0.60]	365 [0.565]	460 [0.713]	337.2 [75.8]	
M25 [8]	25.4 [1.000]	510 [0.79]	476 [0.738]	589 [0.913]	422.1 [94.9]	7.6 [1100]
M29 [9]	8.7 [1.128]	645 [1.00]	603 [0.934]	748 [1.159]	511.5 [115.0]	
M32 [10]	32.3 [1.270]	819 [1.27]	744 [1.154]	950 [1.473]	617.0 [138.7]	

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

D578/D578M Specification for Glass Fiber Strands

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

D3950 Specification for Strapping, Nonmetallic (and Joining Methods)

D3953 Specification for Strapping, Flat Steel and Seals

D4475 Test Method for Apparent Horizontal Shear Strength of Pultruded Reinforced Plastic Rods By the Short-Beam Method

D4649 Guide for Use of Stretch Films and Wrapping Application

D4675 Guide for Selection and Use of Flat Strapping Materials[1]

D5728 Practices for Securement of Cargo in Intermodal and Unimodal Surface Transport

D7028 Test Method for Glass Transition Temperature (DMA Tg) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA)

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

D7957/D7957M Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement

D8448/D8448M Specification for Basalt Fiber Strands

E1356 Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry (Withdrawn 2023)[3]

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 composites materials.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bar, n*—a straight element with a solid, round cross section, having surface enhancement.

3.2.2 *bar designation, n*—an alphanumeric identifier corresponding to the standard size of the bar, as given in Table 3.

3.2.3 *guaranteed property, n*—a characteristic value provided by the manufacturer more than or equal to the mean minus three standard deviations, where the mean is obtained from at least 24 specimens (that is, test repetitions) in groups of eight or more from three or more different production lots.

3.2.4 *mean property, n*—a value provided by the manufacturer equal to the average of a defined set of tested specimens (that is, test repetitions) according to a specified standard test method.

3.2.5 *measured cross-sectional area, n*—the cross-sectional area of the finished manufactured bar, including deformations, lugs, sand coating or any bond-enhancing surface treatment, measured according to Test Method D7205/D7205M, subsection 11.2.4.1.

3.2.6 *nominal bar diameter, n*—a standard diameter of a bar, as given in Table 3.

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

3.2.8 *production lot, n*—any batch of bar produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter (for example, cure temperature or speed of production).

3.2.9 *production lot number, n*—a unique identification (number, alphanumerical, and/or symbols) assigned by the manufacture to each bar production lot whereby it provides traceability to the raw materials and manufacturing information.

3.2.10 *standard deviation, n*—a value that indicate the extent of deviation of a defined set of tested specimens (that is, test repetitions) according to a specified standard test method.

3.2.11 *surface enhancement, n*—any surface treatment, part of the manufacturing process, that provides means of mechanically transmitting force between the bar and the concrete surrounding the bar, which may include for example protrusions, lugs, sand coating, and/or deformations.

3.2.12 *test, certification, n*—an optional test, specified by and completed under the supervision of the purchaser, to certify that the bar or material provided for a given project or production lot 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 the bar or material to the requirements of a specification.

3.2.14 *test, quality control, n*—a test completed on each production lot of a bar or material, under the supervision of the manufacturer, to ensure that the process of manufacturing the bar remains under control and that the bar is within specification.

[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.

4. Ordering Information

4.1 The purchaser is responsible to specify all requirements that are necessary for material ordered to this specification.

4.2 Orders for FRP bars for concrete reinforcement under this specification shall contain at minimum the following information:

4.2.1 Name of the FRP material (as identified by the manufacturer's description),

4.2.2 Bar standard designation number (standard size), as given in Table 3,

4.2.3 Quantity (number of bar pieces),

4.2.4 Cut length of each individual straight bar, and

4.2.5 ASTM specification number and year of issue.

4.3 The purchaser shall have the option to specify additional requirements as necessary, including but not limited to, the following:

4.3.1 Copy of the report of the quality control tests, as given in Table 2,

4.3.2 Requirements for inspection as indicated in Section 12,

4.3.3 Special packaging requirements, and

4.3.4 Other requirements, if any.

NOTE 2—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 FRP bars is shown in Appendix X1.

5. Constituent Materials and Manufacture

5.1 *Reinforcing Fibers:*

5.1.1 Basalt fibers shall be in the form of continuous unidirectional rovings, conforming to Specification D8448/D8448M.

5.1.2 Glass fibers shall be in the form of continuous unidirectional rovings conforming to Specification D578/D578M (that is, boron free glass fibers).

5.2 *Matrix Resins*—Vinyl ester and epoxy thermoset polymer resins are permitted, provided that the physical and durability properties of bars as listed in this specification are met.

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 and assign a unique production lot number.

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 9. 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 all materials added to the bar for bond enhancement purposes only. Any excluded materials as part of this property shall be described and reported. The fiber mass content shall be in accordance with the mean given in Table 2.

NOTE 3—Materials added to the bar for bond enhancement purposes may include for example sand granules, exterior non-longitudinal fibers such as a helically wrapped fibers. All matrix resin components (such as fillers and other additives) shall be part of the calculation.

6.2 *Glass Transition Temperature*—The glass transition temperature (T_g) shall be determined using specimens cut from the as-produced bar, by Test Method E1356 or Test Method D7028, at a frequency and number of specimens as indicated in Section 9. The mean glass transition temperature shall be in accordance with the limits given in Table 1 and Table 2.

6.2.1 The T_g shall be determined from the midpoint of the first temperature scan when using Differential Scanning Calorimetry (DSC) per Test Method E1356.

6.2.2 The T_g shall be determined from the loss modulus when using Dynamic Mechanical Analysis (DMA) per Test Method D7028.

6.2.3 For qualification testing, if a range of otherwise identically produced bar sizes is offered, the T_g on either odd or even bar size designations covering the full range of produced bar sizes may be used.

6.3 *Degree of Cure:*

6.3.1 *Degree of Cure*—The degree of cure shall be determined from the as-produced bar, by Test Method E2160, at a frequency and number of specimens as indicated in Section 9. The mean degree of cure shall be in accordance with the limits given in Table 1 and Table 2.

6.3.2 For qualification testing, if a range of otherwise identically produced bar sizes is offered, the degree of cure on either odd or even bar size designations covering the full range of produced bar sizes may be used.

6.4 *Bar Sizes:*

6.4.1 The standard 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, as given in Table 3.

6.4.2 *Measured Cross-Sectional Area*—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 Method D792, at a frequency and number of specimens as indicated in Section 9. The measured cross-sectional area shall be measured on the as-manufactured bar, where the length of the test specimen shall be sufficiently long to include all surface enhancements. The measured cross-sectional area shall be within the minimum and maximum area mean given in Table 1 and Table 2.

7. Mechanical Properties

7.1 Mechanical properties reported in this specification are calculated by using the nominal cross-sectional area as given in Table 3, unless otherwise specified in this specification.

7.2 *Ultimate Tensile Force:*

7.2.1 *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 9. The resultant guaranteed ultimate tensile force, as defined in 3.2.2, shall be in accordance with the limits given in Table 3.

7.2.2 *Mean Ultimate Tensile Force*—The ultimate tensile force shall be computed based on the frequency and number of specimens as indicated in Section 9, and the mean value shall be reported and used as a reference value as indicated in 8.2.1.

7.2.3 *Guaranteed Ultimate Tensile Strength*—The guaranteed ultimate tensile strength shall be calculated by dividing the guaranteed ultimate tensile force by nominal cross-sectional area, the value shall be reported for informational purposes only.

7.3 *Mean Tensile Modulus of Elasticity:*

7.3.1 The tensile modulus of elasticity shall be determined by Test Method D7205/D7205M, at a frequency and number of specimens as indicated in Section 9. The mean tensile modulus of elasticity shall be in accordance with the limits given in Table 1 and Table 2.

7.3.2 The tensile modulus of elasticity shall also be calculated using the measured cross-sectional area as defined in 6.4.2. The mean tensile modulus of elasticity computed from the measured cross-sectional area shall be reported for informational purposes only.

7.4 *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. The mean ultimate tensile strain value shall be in accordance with the limits given in Table 1 and Table 2.

NOTE 4—The calculation method is based upon the assumption that the stress-strain behavior is linear elastic (straight line).

7.5 *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 9. The mean transverse shear strength shall be in accordance with the limit given in Table 1.

7.6 *Apparent Horizontal Shear Strength*—The apparent horizontal (short beam) shear strength shall be determined by Test Method D4475, where the span for the anvils (supports) shall meet the range based on the ratios allowed within Test Method D4475, and maintained constant for all subsequent testing, at a frequency and number of specimens as indicated in Section 9. The mean apparent horizontal shear strength shall be in accordance with the limit given in Table 1 and Table 2.

NOTE 5—If the D4475 specified anvil (support) does not fit the bar specimen being tested, the next corresponding support size can be used to test the bar specimen.

7.7 *Bond Strength:*

7.7.1 The bond strength shall be determined by Test Method D7913/D7913M, at a frequency and number of specimens as indicated in Section 9. The mean bond strength shall be in accordance with the limit given in Table 3.

7.7.2 For qualification testing, 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*—The moisture absorption shall be tested by Test Method D570, 7.4 based on the conditions given in Table 1, at a frequency and number of specimens as indicated in Section 9. The moisture absorption shall be in accordance with the mean given in Table 1 and Table 2.

8.2 *Resistance to Alkaline Environment:*

8.2.1 The resistance to alkaline resistance shall be determined by exposing bars following Test Method D7705/D7705M, based on the conditions given in Table 1 at a frequency and number of specimens as indicated in Section 9, and as specified in 8.2.2 and 8.2.3. The mean percentage of the alkaline resistance shall be in accordance with the limit given in Table 1, where the alkaline resistance is computed as the ratio between the ultimate tensile force after alkaline environment exposure to the mean ultimate tensile force, as indicated in 7.2.2.

8.2.2 Procedure A of Test Method D7705/D7705M shall be performed in all bar size designations covering the full range of produced bar sizes.

8.2.3 Procedure B of Test Method D7705/D7705M shall be performed for qualification testing on either odd or even bar size designations up to and including standard bar designation number M25 [8], as given in Table 3.

9. Sampling

9.1 *Product Qualification:*

9.1.1 For the determination of the mean and guaranteed properties, at least 24 specimens (that is, test repetitions) 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.

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

9.1.3 Sampling method for product qualification shall be random and representative of the process and constituents used by the manufacturer in accordance with established quality control processes.

9.2 *Quality Control and Certification:*

9.2.1 For the determination of each of the properties, five random specimens (that is, test repetitions) shall be obtained from each production lot. Each individual specimen (that is, test repetition) shall satisfy the property limits as given in Table 2.

9.2.2 Specimens to be used for quality control testing shall be sampled by the manufacturer in accordance with established quality control processes.