



**MATERIAL SPECIFICATION FOR GLASS FIBRE
REINFORCED POLYMER (GFRP) REINFORCEMENT FOR CONCRETE**

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1640.01	SCOPE

This specification covers the requirements for all glass fibre reinforced polymer (GFRP) internal reinforcement used in concrete work.

1640.02 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 950 Glass Fibre Reinforced Polymer (GFRP) Reinforcement for Concrete

Ontario Ministry of Transportation Publications

Designated Sources for Materials (DSM)

CSA Standards

S806-2012(R2017) Design and Construction of Building Structures with Fibre-Reinforced Polymers
S807-19 Specification for Fibre-Reinforced Polymers

ASTM International

D570-98(2018)	Standard Test Method for Water Absorption of Plastics
D578/D578M-18	Standard Specification for Glass Fibre Strands
D2584-18	Standard Test Method for Ignition Loss of Cured Reinforced Resins
D3171-15	Standard Test Methods for Constituent Content of Composite Materials
D3418-15	Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D5028-17	Standard Test Method for Curing Properties of Pultrusion Resins by Thermal Analysis
D7205/D7205M-06(2016)	Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
D7617/D7617M-11(2017)	Standard Test Method for Transverse Shear Strength of Fiber-Reinforced Polymer Matrix Composite Bars
E168-16R23	Standard Practices for General Techniques of Infrared Quantitative Analysis
E1131-20	Standard Test Method for Compositional Analysis by Thermogravimetry
E1252-98(2021)	Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis
E1640-23	Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis

American Concrete Institute Publications

ACI 440.3R-12	Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures
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Reinforcing Steel Institute of Canada

RSIC Manual of Standard Practice, 2018

Society of Automotive Engineers (SAE)

AMS-STD-595A-2017 Colors Used in Government Procurement

1640.03 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Congruent Shape means bent bar shapes with the same number of bends and angles that coincide exactly when superimposed except the length of the straight portions which could be different.

Glass Fibre Reinforced Polymer (GFRP) means as defined in OPSS 950.

Glass Transition Temperature means the midpoint of the temperature range over which an amorphous material changes from a brittle and vitreous state to a plastic state, or vice versa.

Production Lot means any batch of GFRP bar produced from start to finish with the same batch of constituent materials used with the same proportions without changing any production parameter, without interruption in production and without change of equipment setup, such as cure temperature or line speed.

Spiral means continuously fabricated GFRP reinforcement in the form of a cylindrical helix.

Structural Component means as defined in OPSS 950.

Sublot means a part of a production lot.

1640.04 DESIGN AND SUBMISSION REQUIREMENTS

1640.04.01 Submission Requirements

1640.04.01.01 Quality Control Report

A GFRP quality control report for all materials delivered to the site shall be submitted to the Contract Administrator upon completion of the fabrication and prior to placing any GFRP reinforcement in the Work.

The GFRP quality control report shall contain the following information:

- a) Production information including:
 - i. Supplier;
 - ii. Bar classification: fibre type, tensile strength, modulus of elasticity, grade of GFRP, durability and diameter of bar;
 - iii. Production lot and subplot numbers;
 - iv. Resin batch number;
 - v. The start and end date of each production lot and subplot of material; and,
 - vi. The total linear metres produced in each production lot and subplot for straight bars or the total number of bars in each production lot and subplot for bent bars and anchor headed bars. Production lot and subplot sizes shall be in accordance with the Production Lot Size subsection of this specification.
- b) Summary of all material test results listed in order as identified in Table 1 including:
 - i. The number of samples tested for each property;
 - ii. The results of each sample for all tests specified in the Quality Control subsection of this specification;
 - iii. The average and standard deviation of test results; and,
 - iv. The test method used.
- c) The quality control report shall contain an affirmation confirming that the production and test results meet the requirements of this specification.

For bent bars and anchor headed bars that are marked with a unique colour according to the Identification subsection, the GFRP quality control report shall identify the colour code used. Colours shall conform to AMS-STD-595A.

1640.05 MATERIALS

1640.05.01 GFRP Bars, Dowel Bars, Anchor-Headed Bars and Spirals

Bars shall be grade III according to CSA S807.

The bars shall be according to the requirements in CSA S807 and Tables 1, 2 and 3 of this specification. The physical and durability properties of the bars shall meet or exceed the requirements for a durability classification of D1 according to CSA S807.

Binding material for the bars shall be composed of thermoset vinyl ester resin matrix that is homogeneous throughout the cross section of the bar. Fibre reinforcement in the bars shall be continuous E-CR glass fibres according to ASTM D578.

1640.07 PRODUCTION

1640.07.01 Manufacture

The manufacture of GFRP bars shall be by a manufacturer listed in the Designated Sources for Materials (DSM) listing for Glass Fibre Reinforced Polymer – Reinforcing Bar.

The standard fabricating tolerances for all bars, straight or bent, shall be according to tolerances for reinforcing steel bars in the RSIC Manual of Standard Practice.

1640.07.02 Workmanship and Finish

The bars shall be uniform in diameter/size and free of defects that are detrimental to the mechanical properties and durability. The surface finish shall be uniform, free of voids and air pockets, and similar to the product tested for qualification. Defects include, but are not limited to, exposed fibres, cracks, kinks, surface pitting, and uneven or patchy discoloration.

Bulging of the cross section on the inside of the bend or along the start of bend on a bent bar shall measure less than 4 mm or 25% of the bar diameter, whichever is smaller. Bars with bulges exceeding this limit shall be rejected and replaced on a bar by bar basis and rejected bars shall not be incorporated into the Work.

1640.07.03 Identification

All bars to be used in the Work shall be legibly stamped by the manufacturer with the following information at no more than 2.0 m spacing for straight bars and at least once per piece for bent bars and anchor headed bars:

- a) Manufacturer's name and symbol;
- b) Type of fibre;
- c) Designated bar diameter;
- d) Grade designation;
- e) Designated modulus of elasticity;
- f) Production lot or batch number.

1640.07.03.01 Bent and Anchor Headed Bars

Where it is not practical to stamp bent or anchor headed bars, they may be identified with bar tags and paint.

1640.07.03.01.01 Bent and Anchor Headed Bar Tags

Bar tags shall contain information according to the GFRP Bar Identification subsection, the identifiable paint marking colour code, and include the shape description. Tags shall be maintained legible and clearly visible on the bars until the bars are placed in the structural component.

1640.07.03.01.02 Paint Marking

The paint used to mark the bars shall not have any detrimental effects on the GFRP bars. The paint shall be durable to maintain legibility within a construction environment and be both insoluble in water and resistant to ultraviolet (UV) degradation and discolouring.

Each subplot shall be identified by a colour according to AMS STD 595A that can be easily distinguished from other sublots and the bar's own colour. The colour shall be applied to each bar tag and both ends of all bars in the subplot. Sublot colour shall be identified in the GFRP quality control report.

1640.07.04 Quality Control

1640.07.04.01 General

All GFRP materials shall meet the mechanical, physical and durability properties specified in this specification.

1640.07.04.02 Production Lot Size

1640.07.04.02.01 Straight Bars

The production lot size of straight bars shall be a maximum of 60,000 m of bars of the same grade and diameter and be divided into sublots. Sublots shall be a maximum of 20,000 m. In addition:

- a) Bars manufactured by different machines for multiple lines of production shall be considered as separate production lots;
- b) Bars shall be considered as a separate production lot if there is an interruption in production or change in batch of raw material; and,
- c) A production lot shall consist of no more than seven Days of continuous production.

1640.07.04.02.02 Bent Bars and Anchor Headed Bars

The production lot size of bent bars and anchor headed bars shall be a maximum of 6,000 pieces of the same grade and diameter and be divided into Sublots. Sublots shall be a maximum of 2,000 pieces. In addition:

- a) Bent bars of congruent shape may be considered as the same production lot for establishing the number of samples;
- b) Bars manufactured by different machines for multiple lines of production shall be considered as separate production lots;
- c) Bars shall be considered as a separate production lot if there is an interruption in production or change in batch of raw material; and,
- d) A production lot shall consist of no more than seven Days of continuous production.
- e) A production lot of anchor headed bars shall be comprised of only one production lot of straight bars. Additional production lots of straight bars shall not be permitted in a production lot of anchor headed bars.
- f) A subplot of anchor headed bars shall be comprised of only one subplot of straight bars.

1640.07.05 Number of Samples

The minimum number of samples required shall be five from each subplot of straight bars, anchor headed bars, and bent bars. If more than five samples are tested, then all the results are to be reported.

1640.07.06 Determination of Properties

Manufacturer's quality control test requirements for mechanical, physical, and durability properties of the bars for various tests and reporting shall be determined as specified in Table 1 for the first subplot of each production lot. The limits of the various properties shall be as specified in Table 1. For subsequent sublots in each production lot, the quality control tests shall include:

- a) Fibre content;
- b) Glass transition temperature;
- c) Cure ratio;
- d) 24 hour and 1-week water absorption.

For any property, a subplot shall be rejected and the associated GFRP shall not be included in the Work if any one of the samples fails to meet the specified limit when the number of test samples for a specific property is 20 or less. When the number of tested samples is greater than 20, a maximum of 5% of tested samples may fail to meet the specified limit.

If the initial subplot has failures in any of the quality control tests not listed in a) to d) above, then all subsequent sublots of that production lot shall not be incorporated into the work unless they are subject to all quality control tests specified in Table 1.

1640.08 QUALITY ASSURANCE

1640.08.01 Inspection of Fabrication Facility

The Owner reserves the right to carry out inspections and tests at such times as the Owner may consider necessary to ensure that the materials supplied are according to this specification

Materials failing to comply with the requirements of this specification shall be rejected and replaced.

The Owner shall be granted access to the manufacturing and distribution facilities, as well as the finished product storage and loading areas for inspection purposes.

1640.08.02 Fourier Transform Infrared Spectroscopy

At the discretion of the Owner, Fourier transform infrared spectroscopy (FTIR) testing for any number of sublots may be conducted by a laboratory designated by the Owner. The testing shall be performed according to the methods and requirements of ASTM E1252 or ASTM E168.

Table 1
Quality Control Test Requirements

Property	Standard for Test	Specified Limits
Cross-sectional area	CSA S806, Annex A, Determination of Cross-Sectional Area of FRP Reinforcement.	Minimum and maximum area limits are as defined in Table 3.
Longitudinal tensile strength for straight bars and straight portion of the bent bars	ASTM D7205; or CSA S806, Annex C, Test Method for Tensile Properties of FRP Reinforcements.	Minimum values defined in Table 2
Longitudinal tensile modulus and ultimate elongation (for straight bars and straight portion of the bent bars)	ASTM D7205; or CSA S806, Annex C, Test Method for Tensile Properties of FRP Reinforcements.	Minimum values of tensile modulus defined in Table 2; the ultimate elongation shall not be less than 1.2%.
Transverse shear strength	ACI 440.3R-12, Test Method B.4, Test Method for Transverse Shear Strength of FRP Bars; or CSA S806, Annex L, Test Method for Shear Properties of FRP Rods; or, ASTM D7617.	≥ 180 MPa for Grade III
Strength of FRP bent bars and stirrups at bend locations.	CSA S807 Annex E, Method of test for determining the strength of the bent portion of FRP reinforcing bars.	Minimum values defined in Table 2.
Fibre content	The relevant of the following: ASTM D 3171 (Method I of Procedure G), ASTM E 1131, and ASTM D2584.	Glass fibre content ≥ 70% by Weight.
Water absorption at 50 °C for straight bars, straight portion and curved portion of bent bars and grids	ASTM D570 Water Absorption of Plastics: Procedures 7.1 & 7.4, except that both tests shall be conducted at 50 °C (Note 1)	For 24-hour immersion: ≤ 0.25% for bars of size 15 and larger ≤ 0.30% for bars smaller than size 15 For 1-week (168 hours) immersion: ≤ 0.45% for all bar sizes
Cure ratio for straight bars, straight portion and curved portion of bent bars and grids	Test Method according to Appendix A of CSA S807; Calibration of DSC by Indium according to ASTM D5028	≥ 95% of Cure
Dry glass transition temperature	ASTM D3418 or ASTM E1640	DSC ≥ 100 °C DMA ≥ 110 °C
Notes: 1. Test is conducted at 50 °C for both 24-hour immersion and long-term immersion.		

**Table 2
Tensile Strength and Modulus of Grade III GFRP Bars**

Straight Bars			
Designated Bar Diameter	Minimum Specified Longitudinal Tensile Strength kN	Longitudinal Modulus of Elasticity GPa (Min)	
13	129	60	
15	199		
20	284		
22	387		
25	510		
Bent Bars			
Designated Bar Diameter	Minimum Specified Longitudinal Tensile Strength of Straight Portion kN	Minimum Specified Longitudinal Tensile Strength at Bend (Bend Strength) kN	Longitudinal Modulus of Elasticity GPa (Min)
13	129	58.1	50
15	199	89.6	
20	255.6	116.4	
22	329	150.9	
25	433.5	198.9	

**Table 3
Designated Bar Diameter and Nominal Area**

Designated Bar Diameter (Note 1)	Nominal Cross-Sectional Area (mm²) (Note 2)	Minimum Measured Cross-Sectional Area (mm²)	Maximum Measured Cross-Sectional Area (mm²)
13	129	119	169
15	199	186	251
20	284	268	347
22	387	365	460
25	510	476	589

Notes:

1. The nominal cross-sectional area is not based on designated diameter. These designated diameters shall be used for the calculation of the bond strength and the apparent horizontal shear strength.
2. These nominal cross-sectional area values shall be used for the determination of properties.

WARRANT: Always with this tender item.