

*Glass Fiber Reinforced Polymer Rebar (GFRP) Specification*

## 1. Scope

This Special Provision covers the requirements for the fabrication and placing of glass fiber reinforced polymer (GFRP) reinforcing bar as internal reinforcement of concrete components.

## 2. References

This Special Provision refers to the following standards, specifications or publications:

### **ACI CODE-440.11-22**

Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars—Code and Commentary

### **Ontario Provincial Standard Specifications, Construction**

OPSS 905 Steel Reinforcement for Concrete

### **Ontario Ministry of Transportation Publications**

Structural Manual

Guidelines for Inspection and Acceptance of Glass Fiber Reinforced Polymer (GFRP) Reinforcing Bars

### **CSA Standards**

S6-14 Canadian Highway Bridge Design Code

S806-12 Design and Construction of Building Components with Fiber- Reinforced Polymers

S807-10 Specification for Fiber Reinforced Polymers

### **ASTM International**

D7957-22 Standard Specification For Solid Round Glass Fiber Reinforced Polymer Bars For Concrete Reinforcement

D8505-23 Standard Specification for Basalt and Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement

D 570 - 1998 (R2010) Standard Test Method for Water Absorption of Plastics

D 578 - 2005 (R2011) Standard Specification for Glass Fiber Strands

D 2584 - 2011 Standard Test Method for Ignition Loss of Cured Reinforced Resins

D 2734 - 2009 Void Content of Reinforced Plastics

D 3171 - 2011 Standard Test Method for Constituent Content of Composite Materials

D 3418 - 2012 Test Method for Transition Temperatures of Polymers by Thermal Analysis (DTA or DSC).

D 5028 - 2009 Curing Properties of Pultrusion Resin by Thermal Analysis

D 5117 - 2009 Standard Test Method for Dye Penetration of Solid Fiberglass Reinforced Pultruded Stock

D 7205 - 2006 (R2011) Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars

D 7617 - 2011 Standard Test Method for Transverse Shear Strength of Fiber-Reinforced Polymer Matrix Composite Bars

E 1131 - 2008 (R2014) Standard Test Method for Compositional Analysis by Thermogravimetry

E 1640 - 2013 Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis

#### **American Concrete Institute Publications**

ACI 440.3R04 Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures

#### **AASHTO GFRP-2018**

AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete

### **3. Definitions**

For the purposes of this Special Provision, the following definitions apply:

**Congruent Shape** means shapes that are congruent in every way with the same number of bends and angles, except that the length of the straight portions could be different.

**Glass Fiber Reinforced Polymer (GFRP)** means a fiber-reinforced composite with a polymeric matrix and continuous fiber reinforcement of glass.

**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.

**Lot** means glass fiber reinforced polymer reinforcing bars made from the same batch of resin from the resin supplier. In addition:

- a) straight bars, bent bars and anchor headed bars shall be divided into separate lots;
- b) for straight bars, bent bars and anchor headed bars, a lot shall consist of bars of the same grade and diameter;
- c) bent bars of congruent shape may be considered as the same lot for establishing the number of samples for QC and QA testing;
- d) bars manufactured by different machines for multiple lines of production shall be considered as separate lots;
- e) bars shall be considered as a separate lot if there is an interruption in production or change in batch of raw material;
- f) a lot shall consist of no more than seven 7 Days of continuous production

**Structural Component** means a major portion of a bridge structure such as bridge deck, barrier, wall, pier cap, etc.

**Wet Glass Transition Temperature** means the glass transition temperature, determined when the sample is fully saturated.

## **4. Design and Submission Requirements**

### **4.1 Design Requirements**

Design shall be according to CSA S6, CSA S806, ACI, AASHTO and the Structural Manual.

### **4.2 Submission Requirements**

#### **4.2.1 Manufacturer's Certificate of Conformance**

A Manufacturer's Certificate of Conformance and two copies of the 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 each shipment of the GFRP reinforcement from the plant. The GFRP Quality Control report shall contain the following information:

a) Production information including:

- i. Supplier;
- ii. Lot number of bars;
- iii. Batch number of resin;
- iv. The start and end date of production for each production lot of material; and
- v. The total linear metres produced in each lot for straight bars or the total number of bars in each lot for bent bars and anchor headed bars.

b) Summary of all material test results listed in order as identified in Table 2 with the following information for each property:

- i. The actual number of samples tested for each lot;
- ii. The result of every test as specified in the Quality Control;
- iii. The average and standard deviation of test results;
- iv. The minimum result for tensile strength, tensile elongation, transverse shear strength and bend strength obtained from testing of the required samples.

#### **4.2.2 Working Drawings**

One hard-copy set and one electronic copy of GFRP Working Drawings, including supporting documentation, shall be submitted to the Contract Administrator for information purposes at least 7 Days prior to delivery of the bars. An Engineer's seal and signature shall be affixed on the working Drawings verifying that they are consistent with the Contract Documents.

The Working Drawings shall include the following information:

- a) Bar placing drawings that include quantity, bar size, location and spacing for all bars;
- b) Bar schedule that includes quantity, bar size, type, length and bending dimensions.

The supporting documentation shall include the following information:

- a) Manufacturer's instructions on how to deliver, handle, store and protect the bars.
- b) Manufacturer's recommended materials and procedures for removal of unacceptable material present on the bars.

A sealed and signed copy of the Working Drawings shall be kept at the site before and during the placing of bars.

When the Contractor intends to substitute bars, a proposal shall be submitted for approval by the Owner. Submission of the proposal and the Working Drawings shall be at least 3 weeks before bar installation.

#### **4.2.3 Protection Plan for Placed and Partially Embedded Bars**

At least 7 Days prior to the commencement of installation of the bars, a plan describing the methods to be used to protect bars shall be submitted to the Contract Administrator. The protection plan shall address the following hazards and situations:

- a) Movement of bars from concreting operations that will leave partially embedded bars out of tolerance for subsequent work.
- b) Protection from UV-Sun light if stored more than 40 Days.

## **5. Materials**

### **5.1 Manufacturer**

#### **MST Rebar Inc.**

200A Hanlan Road, Woodbridge

Ontario L4L 3P6

Web: [www.MSTBAR.com](http://www.MSTBAR.com)

Email: info@mstbar.com

### **5.2 GFRP Bar Types**

Bars shall be grade III with minimum modulus of 8700 ksi (60GPa). Bars should have an integral rib with minimum bond strength of 2900 psi (20 MPa) to provide maximum adhesion.

All bars in the same structural component shall be supplied by the same manufacturer; there shall be no mixing of products from different manufacturers in a component unless permitted in the contract Documents.

Where the Contract Documents specify a particular product, there shall be no substitution unless approved by the Owner.

### **5.3 Material Requirements of Bars**

The bars shall be according to the qualification requirements in CSA S807 and Tables 1 and 2 of this specification. In case of discrepancies between CSA S807 and Tables 1 and 2, the more stringent requirement shall apply. The physical and durability properties of the bars shall meet or exceed the requirements for a durability classification of D1 as per CSA S807.

Binding material for the bars shall be composed of thermoset vinyl ester resin that is homogeneous throughout the cross-section of the bar. Fiber reinforcement in the bars shall be with boron-free glass fibers according to ASTM D 578.

#### **5.4 GFRP Bar Identification**

All bars to be used in the Work shall be legibly stamped by the manufacturer with the following information at no more than 6.5 feet (2.0 m) spacing for straight bars and at least once per piece for bent bars and anchor headed bars:

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

#### **5.5 Associated Hardware**

Fastening of the bars shall be with coated tie wire, stainless steel wire or nylon ties. Bar chairs for supporting bars shall be plastic.

#### **5.6 GFRP Workmanship and Finish**

The bars shall be uniform in diameter/size and free of defects that would be 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 fibers, cracks, kinks, surface pitting and discoloration. Sand-coated bars are not permitted. Only bars with integral ribs can be used.

### **6. Equipment - Not Used**

### **7. Construction**

#### **7.1 Delivery, Handling, Storage and Protection of GFRP Bars**

A Request to Proceed shall be submitted to the Contract Administrator upon completion of fabrication of the GFRP and prior to shipping from the plant.

The GFRP shall not be shipped from the plant until the Contract Administrator has received the manufacturer's Certificate of Conformance and GFRP Quality Control report, Request to proceed and issued a Notice to Proceed.

The Notice to Proceed shall be specific as to which reports were verified and include reference to lot numbers and bar sizes and other information, such as date of issue, where necessary for clarity.

Delivery, handling, storage and protection of the bars shall be according to the manufacturers instructions and the following to prevent damage:

- a) The bars shall be lifted, transported and stored using multiple support points to prevent damage to the bars from sagging. Support points shall be no more than 4.0 m from one another. Bars shall be lifted using nylon slings or padded wire rope slings. Lifting of bundles of bars shall be with a strong back, spreader bar, multiple supports or

a platform bridge. Bars shall be bundled and supported to prevent damage during transportation. Bars shall be stored clear of the ground on suitable protective cribbing. Stacks or bundles of bars shall have adequate blocking to prevent contact between the layers of bundles. Bars shall be stored separately from reinforcing steel bars with the bar tags maintained and clearly visible until ready for placing;

b) Bars shall not be struck by hammers or any other equipment at any time. Bars that have been subjected to any of the previous unacceptable actions or that show obvious signs of damage, shall be rejected, removed and replaced. Bars subject to removal shall be marked and removed in the presence of the Contract Administrator;

c) The bars shall be covered with opaque white polyethylene during storage (if more than 1.5 months). Bars installed in the structure or formwork, including those partially embedded in concrete, shall be protected from the elements by covering with opaque white polyethylene sheeting or equivalent protective material when the exposure time is expected to exceed or exceeds thirty (40) Days. The protection shall be adequately supported and secured in place. This protection shall be maintained until its removal is required for preparation for subsequent concrete placement;

d) The bars shall be protected from any abrasive blasting or pressure washing operation in their immediate vicinity by adequate covering or wrapping with protective material;

e) The bars, after placing, shall be protected from construction operations and traffic such that the bar and its finishing are not damaged. The surfaces shall be kept free of contamination and damage and the GFRP bars shall be protected from loading which may damage the bars.

## **7.2 Surface Condition of Bars**

The bars shall be with integral rib to provide maximum bond strength to the concrete. Bars shall have a consistent ribs along the bar.

The bars shall be free of mud, and contamination shall be removed immediately while the concrete is still plastic without damaging the bars. Removal of other materials present on the bars shall be according to the materials and methods recommended by the bar manufacturer.

## **7.3 Placing of the GFRP**

The bars shall be placed according to local provincial standard for rebar with the following modifications unless otherwise specified in the Contract Documents:

- a) The bars shall be accurately placed in the positions shown in the Contract Documents and held in the correct location during the operations of placing and consolidating concrete;
- b) Bars shall be tied at least at every third intersection;
- c) The maximum untied length of any bar shall be 35 in (900 mm);
- d) Bar support chairs shall not exceed 35 in (900 mm) average spacing in each direction;
- e) Bars within the formwork shall be secured to prevent movement during concrete

placement. The bars shall be supported or tied to resist settlement, floating upward or movement in any direction during concrete placement. For overlays and other horizontal placement where there is no bottom mat of steel reinforcement to tie down the GFRP, the GFRP mat shall be anchored down directly to the concrete or formwork to prevent it from floating upward;

f) Field bending shall not be permitted;

g) Field cutting of straight and bent bars will be permitted only with the approval of the Contract Administrator. The field cutting shall be with a high speed cutter, fine blade saw, diamond blade or masonry saw. The bars shall not be shear cut.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of the placing of the GFRP.

The next operation after the completion of the installation of GFRP shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

## **7.4 Quality Control**

### **7.4.1 General**

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

### **7.4.2 Number of Samples**

The minimum number of samples required shall be 5 from each lot of straight bars, anchor headed bars and bent bars. If more than 5 samples are tested, then all the results are to be reported.

### **7.4.3 Determination of Properties**

Manufacturers 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 2.

The limits of the various properties shall be as specified in Table 2.

## **8 Quality Assurance**

### **8.1 General**

The acceptance of the bars shall be according to the requirements of this specification. Bars not meeting the requirements of the Contract Documents shall be rejected and shall not be included in the Work.

### **8.2 Sampling**

Prior to placing the GFRP, the Contract Administrator shall randomly select 5 samples for quality assurance testing from each lot. The straight bar samples shall be cut to a length of 5 ft (1.5 m) by the Contractor. If a lot of straight bars does not contain any pieces that may be cut down to a length of 5 ft (1.5 m), then the length requirement shall be waived and samples shall be taken from the available lengths as supplied. For bent bars and anchor headed bars, the Contract Administrator shall select 5 samples at

random from each lot. Samples are not required for bent bars of a particular diameter and shape or anchor headed bars, if the total number required in the Contract for each respective bar type is less than 150.

### **8.3 Testing**

At the discretion of the Owner, quality assurance testing for any number of lots and for any number of properties listed in Table 2 for each lot, shall be conducted by a laboratory designated by the Owner. The testing shall be performed according to the methods and requirements listed in Table 2 and shall be performed on the 5 quality assurance samples. The results will be provided to the Contractor when they are available. All the test method shall follow CSA S807, S806 and ASTM D7957.

### **8.4 Defects or Deficiencies**

#### **8.4.1 Test Results**

A GFRP lot shall be rejected if any one of the tested quality assurance samples fails to meet the limits in Table 2 for the tested property.

#### **8.4.2 Visual and Dimensional**

GFRP that does not meet the specified finishing, surface conditions or dimensional tolerances shall be rejected.

Any GFRP with sand coating on top must be rejected. Sand must be tested to ensure there is no reaction with concrete.

### **8.5 Consequences of Rejection**

All rejected GFRP lots or bars shall be replaced or fixed if possible at the expenses of the manufacturer. The replacements shall be subjected to the requirements of this specification. If any work incorporates rejected GFRP lots or bars, then that work shall be rejected.

## **9 Measurement for Payment - Not Used**

## **10 Basis of Payment**

### **10.1 Glass Fiber Reinforced Polymer Reinforcing Bar**

Payment at the Contract price for the above tender item shall be full compensation for all labor, Equipment and Material to do the work including grouted dowels at

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Rejected GFRP lots or bars shall be replaced at no additional cost to the Owner.

## **11 Mechanical properties**



**Table 1**  
**Tensile Strength and Modulus of Grade III GFRP Bars**  
*English units*

Straight Bars			Bent Bars (Note 1)		
Designated Bar Diameters	Minimum Specified Longitudinal Tensile Strength kips	Longitudinal Modulus of Elasticity ksi (Min)	Designated Bar Diameters	Minimum Specified Longitudinal Tensile Strength kips	Longitudinal Modulus of Elasticity ksi (Min)
#3	16	8700	#3	16	7200
#4	29		#4	29	
#5	45		#5	45	
#6	64		#6	64	
#8	110				

*Metric units*

Straight Bars			Bent Bars (Note 1)		
Designated Bar Diameters	Minimum Specified Longitudinal Tensile Strength kN	Longitudinal Modulus of Elasticity GPa (Min)	Designated Bar Diameters	Minimum Specified Longitudinal Tensile Strength kN	Longitudinal Modulus of Elasticity GPa (Min)
10	71	60	10	71	50
13	130		13	130	
15	200		15	200	
20	284		20	284	
25	490				

Notes:

1. Tensile strength and modulus are given for the straight portion of the bent bar.
2. Strength of the bend shape should be minimum of 87 ksi (600MPa) for all sizes.



**Table 2**  
**Quality Control Test Requirements**

<b>Property</b>	<b>Standard for Test</b>	<b>Specified Limits</b>
Cross-sectional area	CSA S806, Annex A, Determination of Cross-Sectional Area of FRP Reinforcement.	Minimum area not less than 95% of the nominal cross-sectional area. Maximum area not more than 120% of the nominal cross-sectional area for bar diameter 1/2 in -3/4 in (13 mm to 20 mm); 115% for bar diameter greater than 3/4 in (20 mm); and 145% for bar diameter less than 1/2 in (13 mm). Nominal cross-sectional area shall be according to CSAS807.
Longitudinal tensile strength for straight bars and straight portion of the bent bars	ASTM D 7205; or CSA S806, Annex C, Test Method for Tensile Properties of FRP Reinforcements.	Minimum values defined in Table 1
Longitudinal tensile modulus and ultimate elongation (for straight bars and straight portion of the bent bars).	ASTM D 7205; or CSA S806, Annex C, Test Method for Tensile Properties of FRP Reinforcements.	Minimum values of tensile modulus defined in Table 1; the ultimate elongation shall not be less than 1.2%.
Transverse shear strength of straight bars	ACI 440.3R-04, 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 D 7617.	≥ 26 ksi (180 MPa) for Grade III
Longitudinal tensile strength of FRP bent bars at bend locations	ACI 440.3R-04, Test Method B.5, Test Method for Strength of FRP Bent Bars and Stirrups at Bend Locations (Note 1) or ACI 440.3R-04, Test Method B.12, Test Method for Determining the Effect of Corner Radius on Tensile Strength of FRP Bars.	Minimum strength at the bend shall be at least 87 ksi (600MPa).
Fiber content	The relevant of the following: ASTM D 3171 (Method I of Procedure G), ASTM E 1131 and ASTM D 2584.	Glass fiber content ≥ 70% by Weight.
Water absorption at 50 °C for straight bars, straight portion and curved portion of bent bars and grids	ASTM D 570 Water Absorption of Plastics: Procedures 7.1 and 7.4, except that both tests shall be conducted at 50 °C (Note 2)	< 0.25% for 24-hour immersion ≤ 0.45% after 1-week immersion (168 hours) for the long-term immersion test.
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 D 5028	≥ 95% of Cure Required for all straight bars and bent bars.
Wet glass transition temperature	ASTM D 3418 (Note 3) or ASTM E 1640	DSC ≥ 212 °F (100 °C) DMA ≥ 230 °F (110 °C)

Notes:

1. Test may be conducted with high early strength concrete after the concrete reaches 4300 psi (30 MPa) strength.
2. Test is conducted at 120 °F (50 °C) for both 24-hour immersion and long-term immersion, in order to shorten the time required for the test.
3. Samples shall be saturated according to ASTM D 570, except that the temperature of 120 °F (50 °C) shall be used for conditioning. A hermetically sealed pan shall be used to prevent volatilization.
4. Minimum strength of straight portion according to Table 1.

This document has followed and used current OPS GFRP document from Ministry of Transportation of Ontario (MTO).

## **12 Specifying MST-BAR on the engineering drawing**

### **STRUCTURAL GLASS FIBER REINFORCED POLYMER [GFRP] REINFORCEMENT**

BAR MARKS WITH THE PREFIX GIII DENOTE GRADE III GLASS FIBRE REINFORCED POLYMER BARS. GLASS FIBRE REINFORCED POLYMER REINFORCING BARS SHALL BE GRADE III MEETING ALL THE REQUIREMENTS OF ASTM D8505/D8505M-23 (STRAIGHT), ASTM D7957 (BENT) AND THE FOLLOWING:

- a. STRAIGHT BARS SHALL HAVE INTEGRAL DEFORMED RIBS AND BOND STRENGTH TESTED ACCORDING TO ASTM D7913 SHALL HAVE A MINIMUM CHARACTERISTIC VALUE > 2900 PSI (20 MPa) AND SLIP AT LOADED END < 0.02" (0.5 mm).
- b. THE BOND DEPENDENT COEFFICIENT ( $K_b$ ) ACCORDING TO CSA S806-12 ANNEX S SHALL BE < 0.8 FOR STRAIGHT BARS.
- c. MINIMUM TENSILE STRENGTH: 145 KSI (1000 MPa) FOR ALL SIZES
- d. MINIMUM MODULUS OF ELASTICITY: STRAIGHT: 8700KSI (60GPa); BENT: 7200KSI (50 GPa)
- e. MINIMUM SHEAR STRENGTH: 29 KSI (200 MPa)

NOTE: GROOVED/MILLIED BARS NOT ALLOWED