REQUIREMENTS FOR GLASS FIBRE REINFORCED POLYMER (GFRP) REINFORCING BAR

1.0 SCOPE

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

2.0 REFERENCES

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

**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 Fibre Reinforced Polymer (GFRP) Reinforcing Bars

**CSA Standards**

S6-14  Canadian Highway Bridge Design Code  
S806-12  Design and Construction of Building Components with Fibre- Reinforced Polymers  
S807-10  Specification for Fibre Reinforced Polymers

**ASTM International**

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 7617 - 2011  Standard Test Method for Transverse Shear Strength of Fiber-Reinforced Polymer Matrix Composite Bars  
E 1640 - 2013  Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis
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 Fibre Reinforced Polymer (GFRP)** means a fibre-reinforced composite with a polymeric matrix and continuous fibre 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 fibre 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) for bent bars and anchor headed bars, a lot shall consist of no more than 2000 bars;
d) bent bars of congruent shape may be considered as the same lot for establishing the number of samples for QC and QA testing;
e) bars manufactured by different machines for multiple lines of production shall be considered as separate lots;
f) bars shall be considered as a separate lot if there is an interruption in production or change in batch of raw material; and
g) 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.

### 4.0 DESIGN AND SUBMISSION REQUIREMENTS

#### 4.01 Design Requirements

Design shall be according to CSA S6 and the Structural Manual.

#### 4.02 Submission Requirements

##### 4.02.01 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 subsection of this Special Provision;
   iii. The average and standard deviation of test results; and
   iv. The minimum result for tensile strength, tensile elongation, transverse shear strength, and bend strength obtained from testing of the required samples.

4.02.02 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.

4.02.03 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) Contamination of placed or partially embedded bars from concrete splatter from an adjacent concreting operation.
b) Movement of bars from concreting operations that will leave partially embedded bars out of tolerance for subsequent work.

5.0 MATERIALS

5.01 GFRP Bar Types

Bars shall be grade III.

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. Companies and products that are conditionally prequalified might not have been in full production yet; it is the responsibility of the Contractor to ensure that the contractual requirements can be met, including all quality control testing and delivery schedule.

5.02 Material Requirements of Bars

The bars shall be according to the qualification requirements in CSA S807, and Tables 1 & 2 of this specification. In case of discrepancies between CSA S807 and Tables 1 & 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. Fibre reinforcement in the bars shall be continuous E-glass or E-CR glass fibres according to ASTM D 578.

5.03 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 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

5.04 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.

5.05 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 fibres, cracks, kinks, surface pitting, and discoloration.

Fabrication tolerances shall be according to OPSS 905.

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 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 manufacturer’s 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) The bars shall not be dragged, dropped or impacted. 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. 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 (30) 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.
7.02 Surface Condition of Bars

The bars shall be free of mud, oil, concrete or other contaminants, and surface finish defects that adversely affect bonding strength or other properties at the time the concrete is placed.

The bars shall be protected from contamination caused by concrete splatter during adjacent placements. Any concrete 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.

7.03 Placing of the GFRP

The bars shall be placed according to OPSS 905 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 900 mm.

d) Bar support chairs shall not exceed 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) Bent bars shall not be field cut. Field cutting of straight 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.

7.04 Quality Control

7.04.01 General

All GFRP materials shall meet the mechanical, physical and durability properties specified in this specification.
7.04.02 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.

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

For any property, a lot 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 19 or less; however, when the number of test samples is greater than 20, one test result may be beyond the specified limit.

8.0 QUALITY ASSURANCE

8.01 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.

8.02 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 2.2 m by the Contractor. If a lot of straight bars does not contain any pieces that may be cut down to a length of 2.2 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 50.

8.03 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.

8.04 Defects or Deficiencies

8.04.01 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.
8.04.02 Visual & Dimensional

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

The MTO “Guidelines for Inspection and Acceptance of Glass Fibre Reinforced Polymer (GFRP) Reinforcing Bars” shall also be used as a basis for field inspection and rejection of the bars.

8.05 Consequences of Rejection

All rejected GFRP lots or bars shall be replaced. 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.

9.0 MEASUREMENT FOR PAYMENT - Not Used

10.0 BASIS OF PAYMENT

10.01 Glass Fibre Reinforced Polymer Reinforcing Bar - Item

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

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

<table>
<thead>
<tr>
<th>Designated Bar Diameters</th>
<th>Minimum Specified Longitudinal Tensile Strength kN</th>
<th>Longitudinal Modulus of Elasticity Gpa (Min)</th>
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<th>Minimum Specified Longitudinal Tensile Strength kN</th>
<th>Longitudinal Modulus of Elasticity Gpa (Min)</th>
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<tbody>
<tr>
<td>13</td>
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<td>490</td>
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</tbody>
</table>

Note:
1. Tensile strength and modulus are given for the straight portion of the bent bar.
<table>
<thead>
<tr>
<th>Property</th>
<th>Standard for Test</th>
<th>Specified Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-sectional area</td>
<td>CSA S806, Annex A, Determination of Cross-Sectional Area of FRP Reinforcement.</td>
<td>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 13 mm to 20 mm; 115% for bar diameter greater than 20 mm; and 145% for bar diameter less than 13 mm. Nominal cross-sectional area shall be according to CSA-S807.</td>
</tr>
<tr>
<td>Longitudinal tensile strength for straight bars and straight portion of the bent bars</td>
<td>ASTM D 7205; or CSA S806, Annex C, Test Method for Tensile Properties of FRP Reinforcements.</td>
<td>Minimum values defined in Table 1</td>
</tr>
<tr>
<td>Longitudinal tensile modulus and ultimate elongation (for straight bars and straight portion of the bent bars)</td>
<td>ASTM D 7205; or CSA S806, Annex C, Test Method for Tensile Properties of FRP Reinforcements.</td>
<td>Minimum values of tensile modulus defined in Table 1; the ultimate elongation shall not be less than 1.2%.</td>
</tr>
<tr>
<td>Transverse shear strength</td>
<td>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.</td>
<td>≥ 180 MPa for Grade III</td>
</tr>
<tr>
<td>Longitudinal tensile strength of FRP bent bars at bend locations</td>
<td>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.</td>
<td>Minimum strength at the bend shall be at least 45% of the minimum strength of straight portion of GFRP bent bars. (Note 4)</td>
</tr>
<tr>
<td>Fibre content</td>
<td>The relevant of the following: ASTM D 3171 (Method I of Procedure G), ASTM E 1131, and ASTM D 2584.</td>
<td>Glass fibre content ≥ 70% by Weight.</td>
</tr>
<tr>
<td>Void content</td>
<td>ASTM D 2734 or ASTM D 5117</td>
<td>≤ 1% (ASTM D 2734); or if no voids or longitudinal cracks are observed after 15 min. of ASTM D 5117 test, this criterion shall be deemed to have been met.</td>
</tr>
<tr>
<td>Water absorption at 50 ºC for straight bars, straight portion and curved portion of bent bars and grids</td>
<td>ASTM D 570 Water Absorption of Plastics: Procedures 7.1 &amp; 7.4, except that both tests shall be conducted at 50 ºC (Note 2)</td>
<td>&lt; 0.25% for 24-hour immersion ≤ 0.45% after 1 week immersion (168 hours) for the long-term immersion test.</td>
</tr>
<tr>
<td>Property</td>
<td>Standard for Test</td>
<td>Specified Limits</td>
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<tr>
<td>Cure ratio for straight bars, straight portion and curved portion of bent bars and grids</td>
<td>Test Method according to Appendix A of CSA S807; Calibration of DSC by Indium according to ASTM D 5028</td>
<td>≥ 95% of Cure Required for all straight bars and bent bars.</td>
</tr>
<tr>
<td>Wet glass transition temperature</td>
<td>ASTM D 3418 (Note 3) or ASTM E 1640</td>
<td>DSC ≥ 100 °C DMA ≥ 110 °C</td>
</tr>
<tr>
<td>Pullout Capacity of anchor headed bars</td>
<td>Embedded in concrete block (Note 1)</td>
<td>100 kN for 15 mm diam. bar with a maximum slip of 0.5 mm.</td>
</tr>
</tbody>
</table>

Table 2 Notes:
1. Test may be conducted with high early strength concrete after the concrete reaches 30 MPa strength.
2. Test is conducted at 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 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.