

GLASS FIBRE REINFORCED POLYMER REINFORCING BAR – Item No.

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**ONTARIO
PROVINCIAL
STANDARD
SPECIFICATION**

**OPSS.PROV 1640
NOVEMBER 2023**



REQUIREMENTS

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

~~1.0~~

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1640.01 **SCOPE**

This ~~Special Provisions~~specification covers the requirements for ~~the fabrication and placement of~~ all glass fibre reinforced polymer (GFRP) internal reinforcement ~~for used in~~ concrete ~~structures~~work.

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1640.02 **REFERENCES**

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

Ontario Provincial Standard Specifications, Construction

~~OPSS 905~~ — ~~Steel~~ OPSS 950 Glass Fibre Reinforced Polymer (GFRP) Reinforcement for Concrete

Ontario Ministry of Transportation Publications

Designated Sources for Materials (DSM)

~~Guidelines for Inspection and Acceptance of Glass Fibre Reinforced Polymer (GFRP) Reinforcing Bars Structural Manual~~

CSA Standards

~~S6-19 Canadian Highway Bridge Design Code~~

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
~~E1640-18~~ E23 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

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

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1640.03

DEFINITIONS

For the ~~purposes~~purpose of this ~~Special Provisions~~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 ~~a fibre reinforced composite with a polymeric matrix and continuous fibre reinforcement of glass~~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 a concrete component of a bridge structure such as bridge deck, barrier wall, pier cap, etc defined in OPSS 950.~~

Sublot means a part of a production lot.

~~4.0~~1640.04 **DESIGN AND SUBMISSION REQUIREMENTS**

~~4~~1640.04.01 **Design Requirements**

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

~~4.02~~ **Submission Requirements**

~~4.02~~1640.04.01 ~~GFRP .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 ~~GFRP Bar~~the Identification subsection, the GFRP quality control report shall identify the colour code used. Colours shall conform to AMS-STD-595A.

~~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 at least seven Days prior to delivery of the bars. An Engineer's seal and signature shall be affixed on the Working Drawings verifying that they are in conformance with the Contract Documents.~~

1640.05

~~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 materials present on the bars, such as those described in the Surface Condition subsection.~~

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

5.0 MATERIALS

51640.05.01 GFRP Bar Supplier

~~All bars shall be supplied by a manufacturer listed on the ministry's DSM.~~

5.02 Material Requirements of 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 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.

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.

51640.07.03.01.01 Bent and Anchor Headed Bar Tags

Bar tags shall contain ~~the~~ 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~~structural component.

51640.07.03.01.02 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.

51640.07.04 Associated Hardware

~~Only hardware, including spacers and support devices, approved by the Owner shall be used with GFRP reinforcement and the hardware shall meet the following requirements:~~

- ~~a) All supports or support systems shall be capable of withstanding the loads to be placed on them;~~
- ~~b) Fastening of the bars shall be with coated tie wire, stainless steel wire or nylon ties;~~
- ~~c) Bar chairs for supporting GFRP bars shall be non-metallic;~~
- ~~d) Concrete chairs shall not be used to support GFRP bars except in footings and against granular surfaces.~~

5.05 ~~GFRP 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.~~

~~Fabrication tolerances shall be according to tolerances for reinforcing steel bars in the RSIC Manual of Standard Practice.~~

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.~~

~~Placement of the GFRP reinforcement shall not proceed until the Contract Administrator has received the Request to Proceed and GFRP quality control report and issued a Notice to Proceed.~~

~~Delivery, handling, storage, and protection of the bars shall be according to the manufacturer's instructions and the following:~~

- ~~a) Bars shall be lifted, transported, and stored using multiple support points to protect the bars from damage. Support points shall be no more than 4.0 m from one another. Bars shall be lifted using nylon or padded 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.~~
- ~~b) Bars shall be stored clear of ground contact on suitable protective cribbing to protect the bars from contamination or damage. Stacks or bundles of bars shall have adequate blocking to prevent contact between the layers of bundles. GFRP bars shall be stored separately from reinforcing steel bars.~~
- ~~c) 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 these unacceptable actions or that show 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.~~
- ~~d) Bars shall be covered with opaque, white polyethylene sheeting 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 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.~~
- ~~e) Before and after placing, bars shall be protected from any construction operations in their immediate vicinity such as abrasive blasting, pressure washing and concrete spatter from adjacent concrete placement by adequate covering or wrapping with protective material.~~
- ~~f) After placing, bars 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.~~

~~g) Movement of bars from concreting operations that may leave partially embedded bars out of tolerance for subsequent work shall be prevented. This may be done by using more ties and tie points, temporary bars for cage stability, or other means approved by the Contract Administrator.~~

~~7.02~~ ~~Placing of the GFRP~~

~~GFRP reinforcement shall be placed according to the tolerances in OPSS 905. Bars shall be accurately placed in the positions as specified in the Contract Documents and held in the correct location during the operations of placing and consolidating concrete.~~

~~Bars shall be tied at least at every third intersection. The maximum untied length of any bar shall be 900 mm.~~

~~For slab on girder type decks, the bottom layer of deck reinforcement shall be tied to the shear studs or shear stirrups on each girder at approximately 1.5 m centres.~~

~~Bar support chairs shall not exceed 900 mm average spacing.~~

~~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.~~

~~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.~~

~~7.03~~ ~~Surface Condition~~

~~The bars shall be free of mud, oil, concrete or other contaminants, and surface finish defects that adversely affect bond 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.~~

~~7.04~~ ~~Cutting~~

~~The field cutting of straight bars may be carried out only when permitted in writing by the Contract Administrator. Field cutting shall be with a high speed cutter, fine blade saw, diamond blade, or masonry saw; bars shall not be flame or shear cut. Cut ends shall be sealed if required~~

~~by the GFRP reinforcing bar manufacturer. Cut ends shall be inspected for damage and repaired as required by the Contract Administrator.~~

~~Bent bars shall not be field cut.~~

~~7.05~~ ~~Bending~~

~~Field bending shall not be permitted.~~

~~7.06~~ ~~GFRP Reinforcing Bar Defects, Deficiencies and Damage~~

~~All bars shall be inspected for any defects and deficiencies up to the date of completion of the placement of concrete.~~

~~Any damage to a GFRP reinforcing bar resulting in visible fibres, other than at cut ends; or any cut or defect greater than 0.7 mm deep for bars of size 15 or less and 1.0 mm deep for larger bars shall be cause for rejection and the bar shall not be incorporated into the Work.~~

~~7.06.01~~ ~~Repair of GFRP Reinforcing Bar Defects, Deficiencies and Damage~~

~~All visible damage to the GFRP reinforcing bars exceeding 2 percent of surface area per 300 mm length of bar ($2\% * \text{Circumference of bar} * 300 \text{ mm}$) and not resulting in rejection by the Contract Administrator shall be repaired by lap splice of a new GFRP reinforcing bar adjacent to the damaged portion. The appropriate lap length shall be provided on either side of the damage according to the Contract Administrator.~~

~~7.07~~ ~~Quality Control~~

~~71640.07.04.01~~ ~~General~~

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

~~71640.07.04.02~~ ~~Production Lot Size~~

~~71640.07.04.02.01~~ ~~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.

~~71640.07.04.02.02~~ ~~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, ~~a separate~~. 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.

71640.07.0305 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.

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1640.07.0406 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.

8.0 1640.08 QUALITY ASSURANCE

~~8.01~~ ~~General~~
~~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.

~~8.02~~ ~~Sampling~~

~~Prior to placing the GFRP, the Contract Administrator shall randomly select five samples for quality assurance testing from each subplot. The straight bar samples shall be cut to a length of 2.2 m by the Contractor. If a subplot 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 five samples at random from each subplot. 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~~

~~1640.08.02~~ ~~Fourier Transform Infrared Spectroscopy~~

At the discretion of the Owner, ~~quality assurance~~ Fourier transform infrared spectroscopy (FTIR) testing for any number of sublots ~~and for any number of properties listed in Table 1 shall~~ may be conducted by a laboratory designated by the Owner. The testing shall be performed according to the methods and requirements ~~listed in Table 1. The results shall be provided to the Contractor when they are available~~ of ASTM E1252 or ASTM E168.

~~8.04~~ ~~Defects or Deficiencies~~

~~8.04.01~~ ~~Test Results~~

~~A GFRP subplot shall be rejected if any one of the tested quality assurance samples fails to meet the limits in Table 1 for the tested property.~~

~~8.04.02~~ ~~Visual & Dimensional~~

~~Individual GFRP bars that do not meet the specified finishing, surface conditions, or dimensional tolerances as described in this specification shall be rejected, removed, and replaced.~~

~~The 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.~~

~~9.0 MEASUREMENT FOR PAYMENT – Not Used~~

~~10.0 BASIS OF PAYMENT~~

~~10.1 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.~~

~~All GFRP Sublots or bars rejected by the Contract Administrator shall be removed and replaced with new bars meeting the requirements of this specification at no extra cost to the Owner.~~

~~If any structural component incorporates rejected GFRP lots or bars, then that structural component shall be rejected by the Contract Administrator and the structural component shall be removed and replaced at no extra cost to the Owner.~~

~~**TABLES:**~~

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.
e	ASTM D570 Water Absorption of Plastics: Procedures 7.1 & 7.4, except that both tests shall be conducted at 50 °C (Note 2 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
Pullout Capacity of anchor headed bars	Embedded in concrete block (Note 1)	100 kN for 15 mm diam. bar with a maximum slip of 0.5 mm.
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.		

**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.