Concrete Protection Products, Inc.

Fiberglass Rebar (GFRP Rebar)

October, 2013

Product Guide Specification

Specifier Notes: This product specification is written according to the Construction Specifications Institute (CSI) Format, including *MasterFormat* (1995 Edition), *SectionFormat*, and *PageFormat*, contained in the CSI *Manual of Practice.* This section must be carefully reviewed by the Engineer to meet the requirements of the project and local building code. Coordinate with other specification sections and the drawings. Delete all "Specifier Notes" after editing this section.

SECTION 03205
FIBER REINFORCED POLYMER (FRP) BARS FOR CONCRETE REINFORCEMENT

Specifier Notes: This section covers Pultrall **V•ROD™** fiber reinforced polymer (FRP) bars used for internal concrete reinforcement. These products are suitable where 1) harsh environments cause corrosion of steel rebar, 2) electromagnetic neutrality is required of reinforcing bars, 3) thermal insulation is required of reinforcing bars, or 4) weight savings are needed (GFRP bars weigh roughly ¼ the weight of equivalent size steel bars).

The references below should be referred to by the Engineer regarding the application of FRP bars for concrete reinforcement. Additional information is also available from Pultrall, Inc. and their United States distributor – Concrete Protection Products, Inc. - for use with these documents, and for information and assistance in editing this section for the specific applications.

- **ACI 440.1R-06** "Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars," ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2006), 44p.
- **"LRFD Bridge Design Guide Specifications** for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings," American Association of State Highway and Transportation Officials, Washington, D.C., (2009), 68p.
- **ACI 440.5-08** "Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars," ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2008), 5p.
- **ACI 440.6-08** "Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement," ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2008), 6p.
- **ACI 440R-07** "Report on Fiber-Reinforced Polymer (FRP) Reinforcement for Concrete Structures," ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2007), 100p.
- **ACI 440.4R-04** "Prestressing Concrete Structures with FRP Tendons," ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2004), 35p.
- **ACI 440.7R-10** "Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Unreinforced Masonry Structures" ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2010), 46p.
- **CAN/CSA-S806-02** "Design and Construction of Building Components with Fibre-Reinforced Polymers", Canadian Standards Association, Toronto, Ontario, Canada, (2007), 218p.
- **CAN/CSA-S6-06** "Canadian Highway Bridge Design Code" Canadian Standards Association, Toronto, Ontario, Canada, (2006), 1078p.

- **CAN/CSA-S807-10** “Specification for Fibre-Reinforced Polymers” Canadian Standards Association, Toronto, Ontario, Canada, (2010), 44p.
- **ACI 440.3R-12** “Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures,” ACI Committee 440, American Concrete Institute, Farmington Hills, Mich., (2012), 23p.
- **ASTM Standard D7205**, 2006 (2011), "Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars," ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/D7205_D7205M-06R11, www.astm.org.
- **ASTM Standard D7337**, 2012, "Standard Test Method for Tensile Creep Rupture of Fiber Reinforced Polymer Matrix Composite Bars," ASTM International, West Conshohocken, PA, 2012, DOI: 10.1520/D7337_D7337M-12, www.astm.org.
- **ASTM Standard D7617**, 2011, "Standard Test Method for Transverse Shear Strength of Fiber Reinforced Polymer Matrix Composite Bars," ASTM International, West Conshohocken, PA, 2011, DOI: 10.1520/D7617_D7617M-11, www.astm.org.
- **ASTM Standard D7705**, 2012, "Standard Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction," ASTM International, West Conshohocken, PA, 2012, DOI: 10.1520/D7705_D7705M-12, www.astm.org.

PART 1 GENERAL

1.1 SECTION INCLUDES – Glass fiber reinforced polymer (GFRP) bars for concrete reinforcement.

1.2 DESIGN REQUIREMENTS

The design philosophy adopted for FRP bars allows consideration to be given to either 1) FRP rupture or 2) concrete crushing as the mechanism that controls failure. It is based on limit states design principles. An FRP-reinforced concrete member is designed based on its required strength, and then checked for serviceability criteria. In most cases, serviceability criteria limits will control the design.

Design engineers should consider the appropriateness of reinforcing concrete with FRP rebars keeping in mind the following basic points in their designs:

- The stress-strain relationship for FRP is linear up to failure.
- Direct substitution of FRP rebar in a concrete member designed with steel rebar is not possible in most cases.
- Strain compatibility should be used to calculate the factored resistance of a member.
- Glass FRP rebar should be limited to a maximum sustained stress of 25% of the guaranteed design tensile strength, at the serviceability limit state.

1.3 SUBMITTALS

A. Product Data: Submit manufacturer’s product data, including material and mechanical properties.
B. Test Reports: Submit manufacturer’s certified test reports for source quality control testing for material and mechanical properties.

1. Each bar size.
2. Each type of fiber reinforcement specified.
3. Each type of resin matrix specified.

1.4 QUALITY ASSURANCE - Preplacement Meeting: Convene a preplacement meeting [2] [_____] weeks before the start of placing of FRP bars. Require attendance of parties directly affecting work of this section, including the Contractor, Engineer, concrete subcontractor, and FRP bar manufacturer's representative. Review placing of FRP bars and coordination with other work.

1.5 DELIVERY, STORAGE, AND HANDLING

A. General: Deliver, store, and handle FRP bars in accordance with manufacturer's instructions to prevent damage.

B. Storage:

1. Do not store FRP bars directly on ground. Place timber pallets under bars to keep them free from dirt and mud and to provide easy handling.
2. Store FRP bars under covers to avoid direct sunlight and chemical substances if stored for extensive periods of time outdoors.

C. Handling: GFRP bars are very flexible in comparison to steel bars; use a spreader bar when moving bundles of bars.

PART 2 PRODUCTS

2.1 MANUFACTURER : Pultrall, Inc., 700 9th Street, Thetford-Mines, Quebec, Canada, G6G 6Z5.

2.2 SUPPLIER: Concrete Protection Products, Inc., 627-C Graves Street, Kernersville, NC 27284.
Phone: 336/993-2461 FAX: 336/996-2732
Website: www.fiberglassrebar.com
Email: sales@fiberglassrebar.com

2.3 FIBER REINFORCED POLYMER (FRP) BARS FOR CONCRETE REINFORCEMENT

A. Fiber Reinforced Polymer (FRP) Bars: V•ROD™ FRP Bars for concrete reinforcement. Surface of FRP bar is provided with a sand coating that inhibits longitudinal movement of bar relative to concrete.

B. Binding Material: Binding material is composed of modified vinyl ester resin with a maximum volume fraction of 35 percent.
Fiber Reinforcement: Continuous glass fibers with a minimum volume fraction of 65 percent.

C. Available Products:

V•ROD - #2 (1/4 inch diameter) STANDARD fiberglass rebar
V•ROD - #3 (3/8 inch diameter) STANDARD fiberglass rebar
V•ROD - #4 (1/2 inch diameter) STANDARD fiberglass rebar
V•ROD - #5 (5/8 inch diameter) STANDARD fiberglass rebar
V•ROD - #6 (3/4 inch diameter) STANDARD fiberglass rebar
V•ROD - #7 (7/8 inch diameter) STANDARD fiberglass rebar
V•ROD - #8 (1 inch diameter) STANDARD fiberglass rebar

NOTE: The above bar diameters are available in a HM version (with higher tensile and modulus mechanical properties), and a LM version (with lower tensile and modulus mechanical properties) on a special order basis. Larger diameter fiberglass rebar is also available on special order basis.

2.3 BAR IDENTIFICATION: FRP bars shall be imprinted with bar identification.

Company Symbol (a) *	Fiber Type (b) *	Bar Size (c) *	Grade (d)	Modulus of Elasticity (e) *	Batch Number (f) *
V•ROD	G	#4	F100	6	xx-xx-xx

- - denotes a required entry
    a. Company Symbol: Pultrall, Inc..
    b. Fiber Type: A symbol to indicate type of fiber (i.e., G for glass, C for carbon, A for aramid, or H for a hybrid).
    c. Bar Size: A numerical number corresponding to diameter of bar in number of eights of an inch.
    d. Grade: A symbol corresponding to grade of bar corresponding to the minimum guaranteed design tensile strength in units of 10 (i.e., F90, F100).
    e. Modulus of Elasticity: A number corresponding to modulus of bar in units of million psi (i.e., 5.7, 6, 7, 9.2, etc).
    f. Batch Number: A batch number identifying manufacturing date and lot number for reference and traceability.

2.4 DIMENSIONS:

Nominal Diameter and Sectional Area

US Size	Nominal Diameter (inches)	Area (in^2)	Weight (lb/ft)	Soft Metric Size	Nominal Diameter (mm)	Area, (mm^2)	Weight (g/m)
#2	0.250	0.049	0.064	#6	6.350	31.669	95
#3	0.375	0.110	0.122	#10	9.525	71.256	181
#4	0.500	0.196	0.200	#13	12.700	126.677	298
#5	0.625	0.307	0.328	#16	15.875	197.933	488
#6	0.750	0.442	0.443	#19	19.050	285.024	659
#7	0.875	0.601	0.596	#22	22.225	387.949	887
#8	1.000	0.785	0.761	#25	25.400	506.709	1132

2.5 TENSILE PROPERTIES:

Bar Size		Tensile Modulus of Elasticity		Guaranteed Design Tensile Strength		Tensile Strain	Poisson's Ratio
		E_T		f_{fu}		ε_{fu}	μ
mm	in	Gpa	Msi	Mpa	Ksi	%	(-)
#6	#2	52.5 +/- 2.5	7609 +/- 363	990	143	1.89	0.25
#10	#3	52.5 +/- 2.5	7609 +/- 363	1100	159	2.10	0.21
#13	#4	52.5 +/- 2.5	7609 +/- 363	1140	165	2.17	0.26
#16	#5	52.5 +/- 2.5	7609 +/- 363	1130	164	2.15	0.25
#19	#6	52.5 +/- 2.5	7609 +/- 363	1110	161	2.11	0.25
#22	#7	52.5 +/- 2.5	7609 +/- 363	1100	159	2.10	0.25
#25	#8	52.5 +/- 2.5	7609 +/- 363	800	116	1.52	0.28

2.6 SHOP BENDING:

A. GFRP bars are made of a thermoset resin. Bending must be carried out before full curing of the uncured bars. No field bending or alteration is possible.

B. Shape bent uncured FRP bars with a gradual transition, avoiding sharp angles that might damage fibers, as specified in the following table.

C. Tensile Strength of a 90 Degree Bend: Approximately 50 to 60 percent of guaranteed design strength of a straight bar (see Supplier for latest values).

US Size	Nominal Diameter (inches)	90 and180 Degree Bend Radius R (inches) – cannot be changed	Soft Metric Size	Nominal Diameter, mm	90 and180 Degree Bend Radius R (mm) – cannot be changed
#3	0.375	1.5	#10	9.53	38
#4	0.500	2.0	#13	12.70	51
#5	0.625	2.5	#16	15.88	64
#6	0.750	3.0	#19	19.05	76
#7	0.875	4.0	#22	22.23	102
#8	1.000	4.0	#25	25.40	102

2.7 COEFFICIENT OF THERMAL EXPANSION (C.T.E.):

1. Longitudinal Direction: 6.2 x 10^{-6} per degree C (3.5 x 10^{-6} per degree F).
2. Transverse Direction: 23.8 x 10^{-6} per degree C (13.2 x 10^{-6} per degree F).

2.8 BOND DEPENDENT FACTOR AND DEVELOPMENT LENGTH (must be verified by designer):

The Bond Dependent Factor, K_b = 0.8

US Size	Nominal Diameter, in	Development Length, inch per ACI 440.1R-06	Development Length, inch per CSA-S806	Splice Length per ACI 440.1R27 – class A	Splice Length per ACI 440.1R27 – class B
#2	0.250	7.45	7.51	9.69	11.93
#3	0.375	10.85	10.94	14.11	17.37
#4	0.500	13.43	13.54	17.46	21.49
#5	0.625	16.15	16.28	21.00	25.84
#6	0.750	18.62	18.76	24.20	29.79
#7	0.875	20.69	20.84	26.90	33.11
#8	1.000	23.12	23.31	30.05	36.99

A minimum overlap length of 40 diameters is required when overlapping bars to obtain longer lengths.

2.9 DURABILITY: Durability testing of GFRP bars has been conducted by a number of universities and research centers throughout the world, covering a large variety of different environments and evaluation conditions. Contact Supplier with a complete listing of the environment in which you are considering use of the bars, and a summary of current testing for that environment will be provided.

2.10 SOURCE QUALITY CONTROL

Quality Control Testing: Quality control shall be carried out under the requirements of an ISO 9002 certified facility by testing FRP bars before use, to ensure required performance. Test reports from testing conducted by an independent testing agency can be used when available. Perform following quality control tests in accordance with standard test methods (see References).

A. Guaranteed ultimate tensile strength, tensile modulus of elasticity, and ultimate strain.
B. Bent bars tensile strength.

C. Fatigue strength.
D. Bond strength.
E. Durability in alkaline environments.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine areas to receive GFRP bars. Notify the Engineer if areas are not acceptable. Do not begin placing GFRP bars until unacceptable conditions have been corrected.

3.2 PLACING

A. Place GFRP bars in accordance with CRSI Placing Reinforcing Bars, unless otherwise specified.
B. Place GFRP bars accurately in accordance with approved placing drawings, schedules, typical details, and notes.
C. Field Cutting: Field cut GFRP bars with high speed grinding cutter or saw. Do not shear bars.
D. Field Bending: Do not field bend GFRP bars.
E. Securing: Secure GFRP bars in formwork to prevent displacement by concrete placement or workers.
F. Supports: Place and support GFRP bars accurately using plastic or non-corrosive chairs before concrete placement is started. GFRP bars should be supported at about 1/2 - 2/3 of the distance normally used for steel rebar, as the GFRP bar is much more flexible.
G. Fastening: Fasten GFRP bars with coated tie wire, stainless steel tie wire, or nylon ties.
H. Form Ties: Use plastic or nylon form ties.
I. Splicing: Use lap splices, whenever continuity is required in the reinforcement. Do not use mechanical connections or welded splices.
J. Tolerances: Do not exceed placing tolerances specified in ACI 117.
K. Cleaning: Remove form oil from FRP bars by wiping bars with solvents before placing concrete.