Concrete Protection Products, Inc.

Fiberglass Rebar (GFRP Rebar)

Product Guide Specification

April, 2007

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.

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

Notes to Specifier: This section covers **V•ROD** glass fiber reinforced polymer (GFRP) bars used for internal concrete reinforcement. These products are suitable for use 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 the supplier (Concrete Protection Products, Inc.) for use with these documents, and for information and assistance in editing this section for specific applications.

1. ACI 440.1R-06 (2006) “Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars”, American Concrete Institute, Farmington Hills, MI.
2. ACI 440.3R-04 (2004), “Guide for Test Methods for Fiber Reinforced Polymers (FRP) for Reinforcing and Strengthening Concrete Structures”, American Concrete Institute, Farmington Hills, MI.
3. ACI 117-06 (2006) "Specifications for Tolerances for Concrete Construction and Materials” American Concrete Institute, Farmington Hills, MI.
4. ACI 301-05 (2005) “Specifications for Structural Concrete”, American Concrete Institute, Farmington Hills, MI.
5. CAN/CSA-S806-02, “Design and Construction of Building Components with Fibre-Reinforced Polymers”, Canadian Standards Association, Toronto, Ontario, Canada, (May 2002).
6. CAN/CSA-S6_06 “Canadian Highway Bridge Design Code”, Canadian Standards Association, Toronto, Ontario, Canada, (December 2006).
7. ISIS Canada 2001a “Reinforcing Concrete Structures with Fiber Reinforced Polymers,” Design Manual No. 3, The Canadian Network of Centers of Excellence on Intelligent Sensing for Innovative Structures, ISIS Canada Corporation, Winnipeg, Manitoba, Canada.

PART 1 GENERAL

1.1 SECTION INCLUDES - Glassfiber reinforced polymer (GFRP) bars for concrete reinforcement.

1.2 DESIGN REQUIREMENTS

A. Do not substitute GFRP reinforcing bars for steel reinforcing bars on an equal area basis, due to differences in material properties.

B. Specifically design reinforced concrete members for GFRP bars, taking into account properties of material and effects on strength, deflection, and crack width.

C. In most cases, deflection will control design of concrete structures reinforced with GFRP bars based on value of modulus of elasticity of GFRP bars.

D. In most cases, concrete reinforced with GFRP bars can be designed either through Ultimate Design

Method or Working Stress Method (Alternative Design Method). In the case of the Working Stress Method, working stress of GFRP bars shall be limited to a maximum of 25 percent of the guaranteed design strength.

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 performed by an independent testing agency.

1. Each bar size.
2. Each type of resin matrix specified.

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

1.5 DELIVERY, STORAGE, AND HANDLING

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

B. Storage:

1. Do not store GFRP bars directly on ground. Place timber pallets under bars to keep them free from dirt and mud and to provide easy handling.
2. Store GFRP bars under covers to avoid direct sunlight and chemical substances.
3. Handling: GFRP rebars are very flexible; use a spreader bar when hoisting 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: sam@fiberglassrebar.com

2.3 GLASSFIBER REINFORCED POLYMER (GFRP) BARS FOR CONCRETE REINFORCEMENT

A. V•ROD fiberglass bars for concrete reinforcement. Surface of GFRP bar is provided with a sand coating that promotes bond adhesion of bar to concrete.

B. Binding Material: Binding material is composed of 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 - G#2-F114-6.7
V•ROD - G#3-F111-6.7
V•ROD - G#4-F103-6.7
V•ROD - G#5-F99-7.0
V•ROD - G#6-F95-6.9
V•ROD - G#7-F91-6.7
V•ROD - G#8-F89-7.4

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

V•ROD	G	#4	F100	6	xx-xx-xx

a. Company Symbol: V•ROD

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 1/8s of an inch.

d. Grade: A symbol corresponding to grade of bar corresponding to the minimum guaranteed design tensile strength in units of 10.

e. Modulus of Elasticity: A number corresponding to modulus of bar in units of million psi.

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	0.052	#6	6.350	31.669	77.4
#3	0.375	0.110	0.113	#10	9.525	71.256	168.4
#4	0.500	0.196	0.182	#13	12.700	126.677	271.4
#5	0.625	0.307	0.286	#16	15.875	197.933	425.0
#6	0.750	0.442	0.413	#19	19.050	285.024	614.4
#7	0.875	0.601	0.641	#22	22.225	387.949	953.6
#8	1.000	0.785	0.733	#25	25.400	506.709	1090.1

2.5 TENSILE PROPERTIES:

Bar Size		Tensile Modulus of Elasticity		Ultimate Tensile Strength		Guaranteed Design Tensile Strength		Ultimate Strain in Tension	Poisson's Ratio
		E_T		F_u		f_{fu}		ε_{fu}	μ
mm	in	Gpa	Msi	Mpa	Ksi	Mpa	Ksi	%	
#6	#2	46.1	6681	877	127	788	114	1.90	0.25
#10	#3	46.2	6.696	852	123	765	111	1.84	0.21
#13	#4	46.4	6.725	791	115	710	103	1.70	0.26
#16	#5	48.2	6.986	761	110	683	99	1.58	0.25
#19	#6	47.6	6.899	730	106	656	95	1.53	0.25
#22	#7	46.4	6.725	695	101	625	91	1.50	0.25
#25	#8	51.0	7.391	681	99	611	89	1.34	0.28

2.6 SHOP BENDING:

A. GFRP bars are made of a thermoset resin. Bending must be carried out before the full curing of the FRP bars. No field bending or alteration is possible. Consult Pultrall for a complete description of the test procedure.

B. Shop bend 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.

US Size	Nominal Diameter (inches)	90 and180 Degree Bend Radius R (inches)	Soft Metric Size	Nominal Diameter, mm	90 and180 Degree Bend Radius R (mm)
#2	0.250	1.0 / 1.25	#6	6.35	25 / 32
#3	0.375	2.375 / 2.625	#10	9.53	60 / 67
#4	0.500	2.625 / 2.875	#13	12.70	67 / 73
#5	0.625	3.00 / 3.375	#16	15.88	76 / 86
#6	0.750	3.50 / 4.00	#19	19.05	89 / 102
#7	0.875	4.00 / 4.50	#22	22.23	102 / 115
#8	1.000	4.50 / 5.00	#25	25.40	114 / 127

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

1. Longitudinal Direction: 5.5 – 6.4 x 10^{-6} per degree C (3.0 – 3.5 x 10^{-6} per degree F).
2. Transverse Direction: 35 - 37 x 10^{-6} per degree C (19.4 – 20.5 x 10^{-6} per degree F).

2.8 BOND DEPENDENT FACTOR AND DEVELOPMENT LENGTH:

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:

A. 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.