July 2010

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 for concrete reinforcement. One of the main reasons for considering FRP bars for concrete reinforcement is that steel corrodes in concrete subjected to harsh environments, resulting in loss of strength and structural integrity. Highway structures are particularly prone to this corrosion, as they are exposed to the outdoor environment and to de-icing salts in colder climates. It is essential that all tensile reinforcing elements, including FRP bars to be used in concrete structures, retain sufficient strength capabilities during the expected life of the concrete structure.

V•ROD FRP bars are a suitable alternative to steel reinforcing bars when reinforced concrete is:

1. Exposed to de-icing salts.
2. Built in or close to seawater.
3. Subjected to other corrosive agents.
4. Required to maintain low electric conductivity or electromagnetic neutrality.
5. Required to save weight. **V•ROD** FRP bars are 25% of the weight of equivalent size steel bar.

Specifier Notes: 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 for use with these documents, and for information and assistance in editing this section for the specific applications.

1. CAN/CSA-**S806-02**, "Design and Construction of Building Components with Fibre-Reinforced Polymers", Canadian Standards Association, Toronto, Ontario, Canada, (May 2002).
2. CAN/CSA-**S6-06** "Canadian Highway Bridge Design Code" Canadian Standards Association, Toronto, Ontario, Canada, (December 2006), 800p.
3. 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, 158p.
4. ACI 318-95, "Building Code Requirements for Concrete" (1995), American Concrete Institute, Farmington Hills, MI, 347 pp.
5. ACI 440.1R-03 2003 "Guide for the Design and Construction of Concrete Reinforced with FRP Bars," American Concrete Institute, Farmington Hills, Mich.
6. ACI 440R-96, "State-of-the-Art Report on Fiber Reinforced Plastic Reinforcement for Concrete Structures" (1996), American Concrete Institute, Farmington Hills, MI, 68 pp.
7. "Placing Reinforcing Bars" (1992), Concrete Reinforcing Steel Institute, Schaumburg, IL.
8. "Recommendation for Design and Construction of Concrete Structures Using Continuous Fiber Reinforcing Materials" (1997), Japan Society of Civil Engineers, Tokyo, Japan, 325 pp.

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Fiber reinforced polymer (FRP) bars for concrete reinforcement.

1.2 RELATED SECTIONS

Specifier Notes: Edit the following list as required for the project. List other sections with work directly related to the FRP bars.

A. Section 03300 - Cast-in-Place Concrete.
B. Section 03400 - Precast Concrete.

1.3 REFERENCES

Specifier Notes: List standards referenced in this section, complete with designations and titles. This article does not require compliance with standards, but is merely a listing of those used.

A. ACI 117 - Specifications for Tolerances for Concrete Construction and Materials.
B. CRSI Placing Reinforcing Bars.

1.4 DESIGN REQUIREMENTS

Specifier Notes: Consult with design references mentioned above for complete structural design recommendations with **V•ROD** FRP bars. Consult also with Pultrall, for updates on material / product development efforts.

A. Do not substitute FRP reinforcing bars for steel reinforcing bars on an equal area basis, due to differences in material properties.
B. Specifically design reinforced concrete members for FRP 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 FRP bars based on value of modulus of elasticity of FRP bars.
D. In most cases, concrete reinforced with FRP 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 FRP bars shall be limited to a maximum of 25 percent of the guaranteed design strength.

1.5 SUBMITTALS

A. Comply with Section 01330 – Submittal Procedures.
B. Product Data: Submit manufacturer's product data, including material and mechanical properties.
C. 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 fiber reinforcement specified.
3. Each type of resin matrix specified.

1.6 QUALITY ASSURANCE

Specifier Notes: Describe requirements for a meeting to coordinate the placing of the FRP bars and the concrete.

A. 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.

1.7 DELIVERY, STORAGE, AND HANDLING

Specifier Notes **V•ROD** FRP bars are made with a matrix of synthetic resin, rendering them liable to surface damage. Therefore, care is advised in the delivery, storage, handling, and placing of these bars.

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.

Specifier Notes**: V•ROD** FRP bars are very light and flexible. Hoisting bundles of FRP bars should be performed carefully. Use a spreader bar during hoisting so the FRP bars will not bend excessively and can be handled with ease.

C. Handling: Use a spreader bar when hoisting bundles of FRP bars.

PART 2 PRODUCTS

2.1 MANUFACTURER : Pultrall, Inc., 700 9th Street, ThetfordMines, Quebec, Canada, G6G 6Z5. Phone (418) 335-3202. Fax (418) 335-5117.
Email mario.guenette@pultrall.com or bernard.drouin@pultrall.com
Web Site http//www.pultrall.com.

2.2 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.
C. Fiber Reinforcement: Continuous E-glass fibers with a minimum volume fraction of 65 percent.

Specifier Notes: At present, there are seven standard available **V•ROD** FRP bar sizes (larger sizes are available on a custom basis). They are designated:
V-ROD / G # 2 / 114-6681 / xxxxxx / yyyy V-ROD / G # 3 / 111-6580 / xxxxxx / yyyy V-ROD / G # 4 / 103-6710 / xxxxxx / yyyy V-ROD / G # 5 / 99-6986 / xxxxxx / yyyy V-ROD / G # 6 / 95-6899 / xxxxxx / yyyy V-ROD / G # 7 / 91-6725 / xxxxxx / yyyy V-ROD / G # 8 / 87-7522 / xxxxxx / yyyy

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

Product Symbol (a)	Fiber Type (b)	Bar Size (c)	Grade (d)	Modulus of Elasticity (e)	Batch Number (f)	Length of bar (g)
V-ROD	G	#4	103	6710	xxxxxx	yyyy

a. Company Symbol: **V•ROD** from 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 eight of an inch.
d. Grade: A symbol corresponding to grade of bar corresponding to the minimum guaranteed design strength in units of thousands psi (i.e., 100 = 100 000 psi).
e. Modulus of Elasticity: A number corresponding to modulus of bar in units of thousands psi (i.e., 6000 = 6 000 000 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 (GFRP)

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	31.7	85
#3	0.375	0.110	0.113	#10	9.525	71.3	174
#4	0.500	0.196	0.182	#13	12.700	126.7	294
#5	0.625	0.307	0.286	#16	15.875	197.9	436
#6	0.750	0.442	0.413	#19	19.050	285.0	630
#7	0.875	0.601	0.561	#22	22.225	388.0	837
#8	1.000	0.785	0.733	#25	25.400	506.7	1084

Specifier Notes: Tested per standards developed by ACI; consult Pultrall or ACI for a complete description of the test procedures.

2.5 TENSILE PROPERTIES (GFRP V•ROD STANDARD):

Note 1: the following figures must not be used to calculate the strength of the bent portion of a bent bar. Please refer to the bent bar technical data sheet for bent bar properties.
Note 2: the following figures do not apply to **V•ROD HM** or **V•ROD LM** bars.

Bar Size		Tensile Modulus of Elasticity		Guaranteed Design Tensile Strength		Shear Strength (preliminary results)		Ultimate Strain in Tension	Poisson's Ratio
		E_T		f_{fu}		F_s		ε_{fu}	ν
mm	in	Gpa	Msi	Mpa	Ksi	Mpa	Ksi	%	
#6	#2	46.1	6.68	784	114	200	29.0	1.90	0.25
#10	#3	45.4	6.58	765	111	200	29.0	1.89	0.21
#13	#4	46.3	6.71	708	103	200	29.0	1.70	0.26
#16	#5	48.2	6.99	683	99	200	29.0	1.56	0.25
#19	#6	47.6	6.90	656	95	200	29.0	1.53	0.25
#22	#7	46.4	6.73	625	91	200	29.0	1.49	0.25
#25	#8	51.9	7.52	597	87	200	29.0	1.30	0.28

Specifier Notes: **V•ROD** FRP bars are made of a thermoset resin. No field bending is possible. Please contact Pultrall for a complete description of the test procedure.

2.6 SHOP BENDING:

A. Bent bars must be manufactured at Pultrall. The standard inside bend radius = 4x diameter of bar.
B. Tensile Strength of a 90 Degree Bend: Approximately 40 percent of guaranteed design strength of a straight bar.

US Size	Nominal Diameter (inches)	90 and 180 Degree Bend Inside Bend Radius (inches)	Soft Metric Size	Nominal Diameter (mm)	90 and 180 Degree Bend Inside Bend Radius (mm)
#2	0.250	1.0	#6	6.35	25
#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	3.5	#22	22.23	89
#8	1.000	4.0	#25	25.40	102

Specifier Notes: Please contact Pultrall for a complete description of the test procedure or for more details on the coefficient of thermal expansion of **V•ROD** FRP bars.

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

Bar Size	#2	#3	#4	#5	#6	#7	#8
Longitudinal Direction αT (10^{-6}/ ℃)	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Longitudinal Direction αT (10^{-6}/ ℉)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Transverse Direction αT (10^{-6} / ℃)	23.8	23.8	23.8	23.8	23.8	23.8	23.8
Transverse Direction αT (10^{-6} / ℉)	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Specifier Notes: Please contact Pultrall for a complete description of the test procedure or refer to Research Summary Bulletins for more details on the bond strength of **V•ROD** FRP bars.

2.8 BOND DEPENDENT FACTOR AND DEVELOPMENT LENGTH: (ACI 440.1R-06 Clause 11.3)

Bond Dependent Factor, K_b = 0.8

US Size	Nominal Diameter (in)	Development Length (in)	Soft Metric Size	Nominal Diameter (mm)	Development Length (mm)
#2	0.250	12.15	#6	6.35	309
#3	0.375	16.57	#10	9.5	421
#4	0.500	19.49	#13	12.7	495
#5	0.625	23.59	#16	15.9	599
#6	0.750	25.24	#19	19.0	641
#7	0.875	26.82	#22	22.2	681
#8	1.000	28.90	#25	25.0	734

A minimum overlap length of 40 diameters is required.

Specified Notes: Durability testing of **V•ROD** FRP 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. Please contact Pultrall with a complete listing of the environments in which you are considering use of the bars, and a summary of current testing for that environment will be provided.

2.9 DURABILITY:

Effect of Alkaline Solution (pH 13.5) on Tensile Strength Properties
of **V•ROD** Reinforcing Bars at 60 °C

Duration in 60 °C Solution pH 13.5	Avg. Peak Load (kN)	Avg. Peak Stress (MPa)	Avg. Disp. Stiffness (N/mm) **	Avg. Total Decrease in Peak Stress (%)	Avg. Total Decrease in Disp. Stiffness (%)
Control (Unconditioned)	133	717	6215	-	-
78 Days (approx. 11 weeks)	123	668	5880	7	5
118 Days (approx. 17 weeks)	110	595	6207	17	0
(approx. 25 weeks)	92	495	6329	26	-8

** Displacement stiffness was calculated by determining best fit line of linear section of Load vs. Elongation Graphs – not from peak values.

2.10 SOURCE QUALITY CONTROL

Quality Control Testing: Quality control shall be carried out under the requirements of an ISO 9001 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 (available from Pultrall or ACI):

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.

Quality control at the production facility is performed according to Statistical Process Control of the ultimate tensile strength, tensile modulus, polymer cure, reinforcement content and linear weight.

PART 3 EXECUTION

3.1 EXAMINATION

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

Specifier Notes: Placing of FRP bars is performed similarly as for uncoated steel reinforcing bars, and common practices should apply with some key exceptions, as specified below.

3.2 PLACING

A. Place FRP bars in accordance with CRSI Placing Reinforcing Bars, unless otherwise specified.

B. Place FRP bars accurately in accordance with approved placing drawings, schedules, typical details, and notes.

C. Field Cutting:

1. Field cut FRP bars with high speed grinding cutter or saw. Do not shear bars.

Specifier Notes: **V•ROD** FRP 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.

D. Field Bending: Do not field bend FRP bars.
E. Securing: Secure FRP bars in formwork to prevent displacement by concrete placement or workers.
F. Supports: Place and support FRP bars accurately using plastic or non-corrosive chairs before concrete placement is started. FRP bars should be supported at about 2/3 of the distance normally used for steel rebar, as the FRP bar is much more flexible.
G. Fastening: Fasten FRP bars with coated tie wire, stainless steel tie wire, or nylon ties.
H. Form Ties: Use plastic or nylon form ties.

Specifier Notes: Research is currently being conducted on the use of grout-filled or resin-filled sleeves similar to the double-frustum-shaped sleeve used as a mechanical splice connection. The Engineer must approve the use of these sleeves.

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.

END OF SECTION