Florida Department of Transportation

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KEVIN J. THIBAULT, P.E.
SECRETARY

July 14, 2021

Khoa Nguyen
Director, Office of Technical Services
Federal Highway Administration
3500 Financial Plaza, Suite 400
Tallahassee, Florida 32312

Re: State Specifications Office
Section: **932**
Proposed Specification: **9320300 NONMETALLIC ACCESSORY MATERIALS FOR CONCRETE PAVEMENT AND CONCRETE STRUCTURES.**

Dear Mr. Nguyen:

We are submitting, for your approval, two copies of the above referenced Supplemental Specification.

The changes are proposed by Steve Nolan to add language to Tables 932-7 and 932-8, distinguishing CFRP Cable from CFRP bars. Acceptance data was added to Table 932-7.

Please review and transmit your comments, if any, within two weeks. Comments should be sent via email to daniel.strickland@dot.state.fl.us.

If you have any questions relating to this specification change, please call me at 850-414-4130.

Sincerely,

Signature on file

Daniel Strickland, P.E.
State Specifications Engineer

DS/dh
Attachment
cc: Florida Transportation Builders' Assoc.
State Construction Engineer

NONMETALLIC ACCESSORY MATERIALS FOR CONCRETE PAVEMENT AND CONCRETE STRUCTURES.

(REV ~~5-3~~7-13-21)

ARTICLE 932-3 is deleted and the following substituted:

932-3 Fiber Reinforced Polymer (FRP) Reinforcing Bars.

932-3.1 General: Obtain FRP reinforcing bars from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

Use only solid, round, thermoset basalt fiber reinforced polymer (BFRP), glass fiber reinforced polymer (GFRP) or carbon fiber reinforced polymer (CFRP) reinforcing bars. Single or multi-wire CFRP strands are permitted as spirals for reinforcing in concrete piling where specified in the ~~Plans~~Contract Documents. Bars shall be manufactured using pultrusion, variations of pultrusion, or other suitable processes noted in the producer's Quality Control Plan, subject to the approval of the State Materials Office (SMO). For BFRP and CFRP bars only vinyl ester or epoxy resin systems are permitted. For GFRP, use only bars manufactured using vinyl ester resin systems and glass fibers classified as E-CR or R that meet the requirements of ASTM D578.

932-3.2 Bar Sizes and Loads: The sizes and loads of FRP reinforcing bars shall meet the requirements in Table 932-6. The measured cross-sectional area, including any bond enhancing surface treatments, shall be determined according to Table 932-7.

Table 932-6
Sizes and Tensile Loads of FRP Reinforcing Bars

Bar Size Designation	Nominal Bar Diameter (in.)	Nominal Cross-Sectional Area (in^2)	Measured Cross-Sectional Area (in^2)		Minimum Guaranteed Tensile Load (kips)		
			Minimum	Maximum	BFRP and GFRP Bars	CFRP (Type II) ~~Strands~~ (Single & 7-Wire Strands~~)~~	CFRP (Type I) Bars
2.1-CFRP	0.21	0.028	0.026	0.042	-	7.1	-
2	0.250	0.049	0.046	0.085	6.1		10.3
~~2.1-CFRP[q]~~	~~0.21~~	~~0.028~~	~~0.026~~	~~0.042~~	-	~~7.1~~	-
2.8-CFRP[q]	0.280	0.051	0.048	0.085	-	13.1	-
3	0.375	0.11	0.104	0.161	13.2		20.9
3.8-CFRP[q]	0.380	0.09	0.087	0.134		23.7	
4	0.500	0.20	0.185	0.263	21.6		33.3
5	0.625	0.31	0.288	0.388	29.1		49.1
6	0.750	0.44	0.415	0.539	40.9		70.7
6.3-CFRP[q]	0.630	0.19	0.184	0.242	-	49.8	
7	0.875	0.60	0.565	0.713	54.1		-
7.7-CFRP[q]	0.770	0.29	0.274	0.355	-	74.8	

Table 932-6 Sizes and Tensile Loads of FRP Reinforcing Bars							
8	1.000	0.79	0.738	0.913	66.8		-
9	1.128	1.00	0.934	1.137	82.0		-
10	1.270	1.27	1.154	1.385	98.2		-
~~q - Large tow grade carbon fiber (257 ksi)~~							

932-3.3 Material Requirements: Producers shall submit to the State Materials Office (SMO), a test report of the physical and mechanical property requirements in Table 932-7 and Table 932-8 as applicable for the types and sizes of FRP reinforcing produced. Qualification testing shall be conducted by an independent laboratory approved by the Department for performing the FRP test methods.

Three production LOTS shall be randomly sampled at the production facility by a designee of the SMO. The minimum number of specimens per production LOT shall be as indicated in Table 932-7 and Table 932-8. The coefficient of variation (COV) for each test result shall be less than 6%. Outliers shall be subject to further investigation per ASTM E178. If the COV exceeds 6%, the number of test specimens per production LOT may be doubled, a maximum of two times, to meet the COV requirement. Otherwise, the results shall be rejected. A production LOT is defined as a LOT of FRP reinforcing produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

Table 932-7 Physical and Mechanical Property Requirements for Straight FRP Reinforcing Bars			
Property	Test Method	Requirement	Specimens per LOT
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	5[n]
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	5[m]
Long-Term Moisture Absorption	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	5[m]
Glass Transition Temperature (Tg)	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F	3[m]
Total Enthalpy of Polymerization (Resin)	ASTM E2160	Identify the resin system used for each bar size and report the average value of three replicates for each system	--
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	3[n]
Measured Cross-Sectional Area	ASTM D7205	Within the range listed in Table 932-6	10[n]
Guaranteed Tensile Load[a]		≥ Value listed in Table 932-6	
Tensile Modulus		≥6,500 ksi for BFRP and GFRP ≥18,000 ksi for C~~R~~FRP (Type I) Bars > 22,400 ksi for CFRP (~~-~~ Type II) Strands	
Alkali Resistance with Load	ASTM D7705; Procedure B, set sustained load to 30% of value in Table 932-6; 3 months test duration, followed by tensile strength per ASTM D7205	≥ 70% Tensile strength retention for BFRP & GFRP ≥ 95% Tensile strength retention for CFRP	5[m]
Transverse Shear Strength	ASTM D7617	>22 ksi	5[n]
Horizontal Shear Strength[p]	ASTM D4475	>5.5 ksi	5[n]
Bond Strength to Concrete, Block Pull-Out	ACI 440.3R, Method B.3 or ASTM D7913	>1.1 ksi for Bars >0.9 ksi for Strands	5[m]

a – Guaranteed tensile load shall be equal to the average test result from all three lots minus three standard deviations.
n – Tests shall be conducted for all bar sizes produced.
m – Tests shall be conducted for the smallest, median, and largest bar size produced.
p – Only required for BFRP bars.

932-3.3.1 Additional Requirements for Bent FRP Bars: For all bars produced by bending straight solid FRP bars before the resin is fully cured, the minimum inside bend radius shall be at least three times the nominal diameters for bar sizes 2 through 8; and four times the nominal diameters for sizes 9 and 10.

The straight portion of a bent FRP reinforcing bar shall be extracted with sufficient length for tensile testing according to Table 932-8. When the bent shape does not allow for the tensile testing of one of its straight portions, test specimens produced at the same time during the same production LOT shall be used.

Table 932-8
Physical and Mechanical Property Requirements for Bent FRP Reinforcing Bars

Property	Test Method	Requirement	Specimens per LOT
Fiber Mass Fraction – Bent Portion[b]	ASTM D2584 or ASTM D3171	≥70%	5[m]
Short-Term Moisture Absorption – Bent Portion[b]	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	5[m]
Long-Term Moisture Absorption – Bent Portion[b]	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	5[m]
Glass Transition Temperature – Bent Portion[b]	ASTM E1356 (DSC; T_m) /ASTM D3418 (DSC; T_{mg})	≥212°F	3[m]
Degree of Cure – Bent Portion[b]	ASTM E2160	≥95% of Total polymerization enthalpy	3[m]
Measured Cross-Sectional Area – Straight Portion	ASTM D7205	Within the range listed in Table 932-6	5[m]
Guaranteed Tensile Load[a] – Straight Portion		≥ Value listed in Table 932-6	
Tensile Modulus – Straight Portion		≥6,500 ksi for BFRP and GFRP ≥18,000 ksi for C~~R~~FRP (Type I) Bar > 22,400 ksi for CFRP (-Type II) Strand	

Table 932-8 Physical and Mechanical Property Requirements for Bent FRP Reinforcing Bars			
Property	Test Method	Requirement	Specimens per LOT
Alkali Resistance without Load – Straight Portion	ASTM D7705; 3 months test duration, followed by tensile strength per ASTM D7205	≥ 80% Tensile strength retention	5[m]
Strength of 90° Bends	ACI 440.3, Method B.5 or ASTM D7914	> 60% Guaranteed tensile load listed in Table 932-6	5[m]
Transverse Shear Strength – Straight Portion	ASTM D7617	>22 ksi	5[m]
Horizontal Shear Strength[p]	ASTM D4475	>5.5 ksi	5[m]

a – Guaranteed tensile load shall be equal to the average test result from all three lots minus three standard deviations.
b – Bent portion specimens shall be extracted from a central location within a 90° bend.
m – Tests shall be conducted for the smallest, median, and largest bent bar size produced.
p – Only required for BFRP bars.

932-3.4 Material Acceptance: Submit to the Engineer a certificate of analysis for each production LOT from the producer of the FRP reinforcing bars, confirming compliance with the requirements of this Section.

932-3.4.1 Sampling: The Engineer will select a minimum of six straight bars with minimum lengths of 7 feet each and a minimum of five bent bars or spiral bends/revolutions from each shipment, representing a random production LOT, per bar size of FRP reinforcing for testing in accordance with Table 932-9. Testing shall be conducted, at the Contractor's expense, by a Department approved independent laboratory. Each test shall be replicated a minimum of three times per sample. Submit the test results to the Engineer for review and approval prior to installation. Testing will not be required for bars to be used solely as reinforcement for sheet pile bulkheads, but LOT samples will still be selected and retained by the Engineer until final acceptance of the work.

Table 932-9 Testing Requirements for Project Material Acceptance of FRP Reinforcing Bars				
Property	Test Method	Requirement	Test Required for Straight Bar	Test Required for Bent Bar
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	Yes	Yes – bent portion[b]
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	Yes	Yes – bent portion[b]
Glass Transition Temperature	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F	Yes	Yes – bent portion[b]
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	Yes	Yes – bent portion[b]
Measured Cross-sectional Area	ASTM D7205	Within the range listed in Table 932-6	Yes	Yes – straight portion
Guaranteed Tensile Load[a]		≥ Value listed in Table 932-6	Yes	No
Tensile Modulus		≥6,500 ksi for BFRP and GFRP ≥18,000 ksi for CFRP (Type I) Bars ≥22,400 ksi for CFRP (~~-~~ Type II) Strands	Yes	No

a – Guaranteed tensile load shall be equal to the average test result from all three lots minus three standard deviations.
b – Bent portion specimens shall be extracted from a central location within a 90° bend.

932-4 FRP Spirals for Concrete Piling.

FRP Spirals for reinforcing in concrete piling shall be CFRP conforming to the requirements of Section 933 or 932-3 for CFRP (~~Strand~~Type II).

NONMETALLIC ACCESSORY MATERIALS FOR CONCRETE PAVEMENT AND CONCRETE STRUCTURES.

(REV 7-13-21)

ARTICLE 932-3 is deleted and the following substituted:

932-3 Fiber Reinforced Polymer (FRP) Reinforcing Bars.

932-3.1 General: Obtain FRP reinforcing bars from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

Use only solid, round, thermoset basalt fiber reinforced polymer (BFRP), glass fiber reinforced polymer (GFRP) or carbon fiber reinforced polymer (CFRP) reinforcing bars. Single or multi-wire CFRP strands are permitted as spirals for reinforcing in concrete piling where specified in the Contract Documents. Bars shall be manufactured using pultrusion, variations of pultrusion, or other suitable processes noted in the producer's Quality Control Plan, subject to the approval of the State Materials Office (SMO). For BFRP and CFRP bars only vinyl ester or epoxy resin systems are permitted. For GFRP, use only bars manufactured using vinyl ester resin systems and glass fibers classified as E-CR or R that meet the requirements of ASTM D578.

932-3.2 Bar Sizes and Loads: The sizes and loads of FRP reinforcing bars shall meet the requirements in Table 932-6. The measured cross-sectional area, including any bond enhancing surface treatments, shall be determined according to Table 932-7.

Table 932-6
Sizes and Tensile Loads of FRP Reinforcing Bars

Bar Size Designation	Nominal Bar Diameter (in.)	Nominal Cross-Sectional Area (in^2)	Measured Cross-Sectional Area (in^2)		Minimum Guaranteed Tensile Load (kips)		
			Minimum	Maximum	BFRP and GFRP Bars	CFRP (Type II) Single & 7-Wire Strands	CFRP (Type I) Bars
2.1-CFRP	0.21	0.028	0.026	0.042	-	7.1	-
2	0.250	0.049	0.046	0.085	6.1		10.3
2.8-CFRP	0.280	0.051	0.048	0.085	-	13.1	-
3	0.375	0.11	0.104	0.161	13.2		20.9
3.8-CFRP	0.380	0.09	0.087	0.134		23.7	
4	0.500	0.20	0.185	0.263	21.6		33.3
5	0.625	0.31	0.288	0.388	29.1		49.1
6	0.750	0.44	0.415	0.539	40.9		70.7
6.3-CFRP	0.630	0.19	0.184	0.242	-	49.8	
7	0.875	0.60	0.565	0.713	54.1		-
7.7-CFRP	0.770	0.29	0.274	0.355	-	74.8	
8	1.000	0.79	0.738	0.913	66.8		-
9	1.128	1.00	0.934	1.137	82.0		-

Table 932-6 Sizes and Tensile Loads of FRP Reinforcing Bars							
10	1.270	1.27	1.154	1.385	98.2		-

932-3.3 Material Requirements: Producers shall submit to the State Materials Office (SMO), a test report of the physical and mechanical property requirements in Table 932-7 and Table 932-8 as applicable for the types and sizes of FRP reinforcing produced. Qualification testing shall be conducted by an independent laboratory approved by the Department for performing the FRP test methods.

Three production LOTS shall be randomly sampled at the production facility by a designee of the SMO. The minimum number of specimens per production LOT shall be as indicated in Table 932-7 and Table 932-8. The coefficient of variation (COV) for each test result shall be less than 6%. Outliers shall be subject to further investigation per ASTM E178. If the COV exceeds 6%, the number of test specimens per production LOT may be doubled, a maximum of two times, to meet the COV requirement. Otherwise, the results shall be rejected. A production LOT is defined as a LOT of FRP reinforcing produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

Table 932-7 Physical and Mechanical Property Requirements for Straight FRP Reinforcing Bars			
Property	Test Method	Requirement	Specimens per LOT
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	5[n]
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	5[m]
Long-Term Moisture Absorption	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	5[m]
Glass Transition Temperature (Tg)	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F	3[m]
Total Enthalpy of Polymerization (Resin)	ASTM E2160	Identify the resin system used for each bar size and report the average value of three replicates for each system	--
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	3[n]
Measured Cross-Sectional Area	ASTM D7205	Within the range listed in Table 932-6	10[n]
Guaranteed Tensile Load[a]		≥ Value listed in Table 932-6	
Tensile Modulus		≥6,500 ksi for BFRP and GFRP ≥18,000 ksi for CFRP (Type I) Bars ≥ 22,400 ksi for CFRP (Type II) Strands	
Alkali Resistance with Load	ASTM D7705; Procedure B, set sustained load to 30% of value in Table 932-6; 3 months test duration, followed by tensile strength per ASTM D7205	≥ 70% Tensile strength retention for BFRP & GFRP ≥ 95% Tensile strength retention for CFRP	5[m]
Transverse Shear Strength	ASTM D7617	>22 ksi	5[n]
Horizontal Shear Strength[p]	ASTM D4475	>5.5 ksi	5[n]
Bond Strength to Concrete, Block Pull-Out	ACI 440.3R, Method B.3 or ASTM D7913	>1.1 ksi for Bars >0.9 ksi for Strands	5[m]

a – Guaranteed tensile load shall be equal to the average test result from all three lots minus three standard deviations.
n – Tests shall be conducted for all bar sizes produced.
m – Tests shall be conducted for the smallest, median, and largest bar size produced.
p – Only required for BFRP bars.

932-3.3.1 Additional Requirements for Bent FRP Bars: For all bars produced by bending straight solid FRP bars before the resin is fully cured, the minimum inside bend radius shall be at least three times the nominal diameters for bar sizes 2 through 8; and four times the nominal diameters for sizes 9 and 10.

The straight portion of a bent FRP reinforcing bar shall be extracted with sufficient length for tensile testing according to Table 932-8. When the bent shape does not allow for the tensile testing of one of its straight portions, test specimens produced at the same time during the same production LOT shall be used.

Table 932-8
Physical and Mechanical Property Requirements for Bent FRP Reinforcing Bars

Property	Test Method	Requirement	Specimens per LOT
Fiber Mass Fraction – Bent Portion[b]	ASTM D2584 or ASTM D3171	≥70%	5[m]
Short-Term Moisture Absorption – Bent Portion[b]	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	5[m]
Long-Term Moisture Absorption – Bent Portion[b]	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	5[m]
Glass Transition Temperature – Bent Portion[b]	ASTM E1356 (DSC; T_m) /ASTM D3418 (DSC; T_{mg})	≥212°F	3[m]
Degree of Cure – Bent Portion[b]	ASTM E2160	≥95% of Total polymerization enthalpy	3[m]
Measured Cross-Sectional Area – Straight Portion	ASTM D7205	Within the range listed in Table 932-6	5[m]
Guaranteed Tensile Load[a] – Straight Portion		≥ Value listed in Table 932-6	
Tensile Modulus – Straight Portion		≥6,500 ksi for BFRP and GFRP ≥18,000 ksi for CFRP (Type I) Bar ≥ 22,400 ksi for CFRP (Type II) Strand	

Table 932-8 Physical and Mechanical Property Requirements for Bent FRP Reinforcing Bars			
Property	Test Method	Requirement	Specimens per LOT
Alkali Resistance without Load – Straight Portion	ASTM D7705; 3 months test duration, followed by tensile strength per ASTM D7205	≥ 80% Tensile strength retention	5[m]
Strength of 90° Bends	ACI 440.3, Method B.5 or ASTM D7914	> 60% Guaranteed tensile load listed in Table 932-6	5[m]
Transverse Shear Strength – Straight Portion	ASTM D7617	>22 ksi	5[m]
Horizontal Shear Strength[p]	ASTM D4475	>5.5 ksi	5[m]

a – Guaranteed tensile load shall be equal to the average test result from all three lots minus three standard deviations.
b – Bent portion specimens shall be extracted from a central location within a 90° bend.
m – Tests shall be conducted for the smallest, median, and largest bent bar size produced.
p – Only required for BFRP bars.

932-3.4 Material Acceptance: Submit to the Engineer a certificate of analysis for each production LOT from the producer of the FRP reinforcing bars, confirming compliance with the requirements of this Section.

932-3.4.1 Sampling: The Engineer will select a minimum of six straight bars with minimum lengths of 7 feet each and a minimum of five bent bars or spiral bends/revolutions from each shipment, representing a random production LOT, per bar size of FRP reinforcing for testing in accordance with Table 932-9. Testing shall be conducted, at the Contractor's expense, by a Department approved independent laboratory. Each test shall be replicated a minimum of three times per sample. Submit the test results to the Engineer for review and approval prior to installation. Testing will not be required for bars to be used solely as reinforcement for sheet pile bulkheads, but LOT samples will still be selected and retained by the Engineer until final acceptance of the work.

Table 932-9 Testing Requirements for Project Material Acceptance of FRP Reinforcing Bars				
Property	Test Method	Requirement	Test Required for Straight Bar	Test Required for Bent Bar
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	Yes	Yes – bent portion[b]
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	Yes	Yes – bent portion[b]
Glass Transition Temperature	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F	Yes	Yes – bent portion[b]
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	Yes	Yes – bent portion[b]
Measured Cross-sectional Area	ASTM D7205	Within the range listed in Table 932-6	Yes	Yes – straight portion
Guaranteed Tensile Load[a]		≥ Value listed in Table 932-6	Yes	No
Tensile Modulus		≥6,500 ksi for BFRP and GFRP ≥18,000 ksi for CFRP (Type I) Bars ≥22,400 ksi for CFRP (Type II) Strands	Yes	No

a – Guaranteed tensile load shall be equal to the average test result from all three lots minus three standard deviations.
b – Bent portion specimens shall be extracted from a central location within a 90° bend.

932-4 FRP Spirals for Concrete Piling.

FRP Spirals for reinforcing in concrete piling shall be CFRP conforming to the requirements of Section 933 or 932-3 for CFRP (Type II).