

NONMETALLIC ACCESSORY MATERIALS FOR CONCRETE PAVEMENT AND CONCRETE STRUCTURES.

(REV10-2-15)

SECTION 932 is expanded by the following new Article:

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

932-3.1 General: Use only solid round thermoset pultruded glass fiber reinforced polymer (GFRP) or carbon fiber reinforced polymer (CFRP) reinforcing bars. All FRP reinforcing bars shall meet the requirements of ACI 440.6 following the test methods from ACI 440.3. Use only GFRP bars manufactured using glass fibers classified as E-CR or R that meet the requirements of ASTM D578. Meet the additional requirements of this Section following the sampling frequency and number of specimens required by ACI 440.6.

932-3.2 Additional Requirements for Bar Size and Strength: The nominal diameter of FRP bars shall be in one-eighth inch increments as described in Table 3-1.

The measured cross-sectional area of FRP bars, including deformations, lugs, sand coating or any bond enhancing surface treatment shall be measured according to ASTM D7205 via the Archimedes method.

The minimum bar diameter, derived from the actual cross sectional area and calculated based on a circular cross section including any surface treatment, shall be equal to or greater than the nominal bar diameter given in Table 3-1.

The maximum bar diameter, derived from the actual cross sectional area and calculated based on a circular cross section including any surface treatment, shall be less than or equal to the maximum bar diameter derived from the maximum cross section area given in Table 3-1.

The nominal diameter and nominal cross-sectional area of an FRP bar shall be used as the bar size designation and for reinforced concrete design calculations and minimum mechanical properties.

Bar Size Designation	Nominal Bar Diameter (in)	Nominal Cross Sectional Area (in ²)	Maximum Cross Sectional Area (in ²)	f [*] _{fu} , Guaranteed Ultimate Tensile Strength (ksi)	
				GFRP Bars	CFRP Bars
2	¼	0.049	0.058	125	210
3	⅜	0.110	0.132	120	190
4	½	0.196	0.234	110	170
5	⅝	0.307	0.367	95	160
6	¾	0.442	0.529	92.5	160
7	⅞	0.601	0.721	90	N/A
8	1	0.785	0.942	85	N/A
9	1⅛	0.994	1.192	82.5	N/A
10	1¼	1.227	1.472	80	N/A

932-3.3 Additional Requirements for Strength of Bar Bends: Meet the requirements of ACI 440.6, Section 10.2 except substitute Sections 10.2.2.1 and 10.2.2 with the following:

Extract straight portions from bent bars of sufficient length to be tested according to ASTM D7205. The tensile strength and tensile modulus of each specimen shall not be less than the guaranteed strength reported by the producer for a bar of that diameter, with minimum values as shown in Table 3-1.

When the bent shape does not allow for the tensile testing of one of its straight portions, a test specimen produced at the same time, during the same production lot, but of sufficient length to perform the required testing, may be used.

932-3.4 General Additional Requirements: Meet the applicable requirements of the Materials Manual and the additional requirements of Table 3-2 for qualification of producers of FRP reinforcing bars seeking approval to be placed on the Department's Production Facility Listing. Producers seeking evaluation of a product in accordance with this Specification must submit test reports conducted by an independent laboratory, qualified by an ISO 17025 accreditation agency, using personnel with actual experience running the test methods for FRP reinforcing bars. Submit the test reports to the State Materials Office.

Property	Test Method	Requirement
Fiber Content	ASTM D2584 Or ASTM D3171	> 55% - volume > 70% - weight
Moisture absorption	ASTM D570	≤ 0.75% (long term immersion to full saturation) at 122°F
Resin's Glass transition temperature (T_g)	ASTM E1640 - DMA Or ASTM E1356 - DSC	≥ 230°F ≥ 212°F
Total enthalpy of polymerization (resin)	ASTM E2160	Report value for each resin system used
Minimum Mean Tensile Modulus of Elasticity	ASTM D7205	≥ 6,500ksi GFRP ≥ 18,000 ksi CFRP
Alkali resistance <i>without</i> load	ASTM D7705	Tensile capacity retention ≥ 80% of ultimate tensile stress (UTS) after 90 days
Alkali resistance <i>with</i> load	ASTM D7705; set sustained tensile stress to induce tensile strain of 3000 micro-strain	Tensile capacity retention ≥ 70% of ultimate tensile stress (UTS) after 90 days
Strength of bent portion of a bar	ACI 440.3 Method B.5	> 60% of straight portion of bar
Transverse Shear Strength	ASTM D7617	> 22 ksi
Bond Strength	Block pull-out by ACI 440.3R Method B.3	> 1.1 ksi

Certification: Meet the testing requirements of Table 3-3 for product acceptance on the project. The Contractor shall provide the Engineer with certification from the producer of the FRP bars, confirming that the requirements of this Section are met. The certification shall conform to the requirements of Section 6. Submit one certification per LOT of FRP reinforcing bars. The Contractor shall ensure that the test results meet the requirements of Table 3-3 using an independent ISO 17025 accredited laboratory with actual experience running the test methods for FRP reinforcing bars.

Sampling: A minimum of six samples of reinforcing bars per LOT will be selected by the Engineer. The minimum sample length is seven feet. A LOT will be sampled only after the entire LOT is delivered to the project site or in an offsite storage facility. FRP reinforcing bars shall be available for sampling a minimum of three weeks prior to their installation.

Property	Test Method	Requirement
Degree of cure	ASTM E2160	≥ 95% of total polymerization enthalpy
Fiber content	GFRP - ASTM D2584 or ASTM D3171 CFRP - ASTM D3171	GFRP - Glass fiber weight fraction ≥ 70% when ASTM D2584 is used GFRP & CFRP - Volume fraction ≥ 55%
Void content	ASTM D2734	≤ 1%
Moisture absorption	ASTM D570	≤ 0.25% in 24 hours at 122°F
Bar Size - Actual Cross Sectional Area	ASTM D7205	See Table 3-1
Minimum & Maximum Bar Diameter	Calculated from Actual Cross Sectional Area	See Table 3-1
Guaranteed Ultimate Tensile Strength (f^*_{fu})	ASTM D7205	See Table 3-1
Minimum Mean Tensile Modulus of Elasticity	ASTM D7205	≥ 6,500 ksi GFRP ≥ 18,000 ksi CFRP