SECTION 973
FIBER REINFORCED POLYMER (FRP) COMPOSITE STRUCTURAL SHAPES

973-1 Description.

This Section covers material and fabrication requirements for fiber reinforced polymer (FRP) composite structural shapes.

973-2 Product Acceptance.

Obtain FRP composites from a producer that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

973-3 Thermoset Pultruded Structural Shapes.

Thermoset pultruded structural shapes must meet the requirements in the materials section of the ASCE, Pre-Standard for Load & Resistance Factor Design (LRFD) of Pultruded Fiber Reinforced Polymer (FRP) Structures.

Manufactured components shall be inspected according to ASTM D3917 for dimensional tolerances and ASTM D4385 for visual defects.

Pultruded profiles located on bridge and overhead sign structures shall meet a flame spread index of Class B in accordance with ASTM E84 and meet the requirements of UL94 with a rating of V-1.

973-4 Vacuum Infusion Processed (VIP) Structural Shapes:

973-4.1 Materials:

973-4.1.1 Fibers: Use commercial grade glass fibers that conform to ASTM D578. Glass fibers may be in any form such as rovings, woven fabrics, braided fabrics, stitched fabrics, continuous fiber mats, continuous strand mats, continuous filament mats (CFM), and chopped strand mats (CSM) of any size or weight.

Each structural element shall contain a minimum of 40% (by weight) of glass fibers oriented in a minimum of two directions in accordance with the manufacturer's requirements.

Tensile strength of glass fiber strands, yarns and rovings shall not be less than 290 ksi in accordance with ASTM D7290, determined by a tension test in accordance with ASTM D2343.

973-4.1.2 Resin: Use a commercial grade thermoset resin for fabricating shapes.

973-4.1.3 Additives: Additives such as fillers, promoters, accelerators, inhibitors, UV agents, and pigments, used in the processing or curing shall be compatible with the fiber and resin.

973-4.2 Physical and Mechanical Properties: The physical properties of VIP FRP products shall conform to the requirements of Table 4-1. The characteristic mechanical properties of VIP FRP composite structural members, determined in accordance with ASTM D7290, shall equal or exceed the minimum requirements in Table 4-2 for shapes and Table 4-3 for plates.

Table 4-1
Required Physical Properties - VIP FRP

Table 4-1 Required Physical Properties - VIP FRP		
Physical Property	Requirement	Test Method
Barcol Hardness	> 40	ASTM D2583
Glass Transition Temperature	> 180 F	ASTM D4065
Coefficient of Thermal Expansion	< 7.5 x 10^{-6} in/in/ F (longitudinal)	ASTM D696
Moisture Equilibrium Content	< 2%	ASTM D570, Section 7.4

Table 4-2 Required Mechanical Properties - VIP FRP Shapes		
Property	Minimum Requirement	Test Method
Longitudinal Tensile Strength	30,000 psi	ASTM D3039
Transverse Tensile Strength	7,000 psi	
Longitudinal Tensile Modulus	3 x 10^6 psi	
Transverse Tensile Modulus	0.8 x 10^6 psi	
Longitudinal Compressive Strength	30,000 psi	ASTM D6641
Longitudinal Compressive Modulus	3 x 10^6 psi	
Transverse Compressive Modulus	1 x 10^6 psi	
In-Plane Shear Strength	8,000 psi	ASTM D5379
In-Plane Shear Modulus	0.4 x 10^6 psi	ASTM D5379
Interlaminar Shear Strength	3,500 psi	ASTM D2344

Table 4-3 Required Mechanical Properties -VIP FRP Plates		
Property	Minimum Requirement	Test Method
Longitudinal Tensile Strength	20,000 psi	ASTM D3039
Transverse Tensile Strength	7,000 psi	
Longitudinal Tensile Modulus	1.8 x 10^6 psi	
Transverse Tensile Modulus	0.7 x 10^6 psi	
Longitudinal Compressive Strength	24,000 psi	ASTM D6641
Transverse Compressive Strength	15,500 psi	
Longitudinal Compressive Modulus	1.8 x 10^6 psi	
Transverse Compressive Modulus	1 x 10^6 psi	
Longitudinal Flexural Strength	30,000 psi	ASTM D790
Transverse Flexural Strength	13,000 psi	
Longitudinal Flexural Modulus	1.6 x 10^6 psi	
Transverse Flexural Modulus	0.9 x 10^6 psi	
In-Plane Shear Strength	6,000 psi	ASTM D5379
In-Plane Shear Modulus	0.4 x 10^6 psi	
Interlaminar Shear Strength	3,500 psi	ASTM D2344

973-4.3 Fire, Smoke and Toxicity: VIP profiles located on bridge and overhead sign structures shall meet a flame spread index of Class B in accordance with ASTM E84 and meet the requirements of UL94 with a rating of V-1.

973-4.4 Impact Tolerance: Where impact resistance is stipulated, impact resistance shall be determined in accordance with ASTM D7136.

973-5 Thermoplastic Structural Shapes.

973-5.1 General: For the purpose of this specification, use the following definitions:

a. Thermoplastic Structural Shapes (TSS) includes a thermoplastic matrix reinforced with chopped fiberglass filaments.

b. Reinforced Thermoplastic Structural Shapes (RTSS) includes a thermoplastic matrix reinforced with chopped fiberglass filaments and continuous FRP reinforcing bars meeting the requirements of this Section. Steel reinforcing bars are not permitted.

973-5.2 Materials: Use polyethylene made from recycled post consumer or post industrial thermoplastics. Mix the polyethylene with appropriate colorants, UV inhibitors, hindered amine light stabilizers, antioxidants, and chopped fiberglass reinforcement so that the resulting product meets the requirements specified in Table 5-1 for RTSS and Table 5-2 for TSS. Use a minimum of 15% (by weight) chopped fiberglass reinforcement for both TSS and RTSS. The thermoplastic matrix must not corrode, rot, warp, splinter or crack.

For RTSS members, the use of separate materials for skin and core is at the discretion of each manufacturer; however, both materials must meet the requirements in Table 5-1. The material surrounding the rebar within 1 inch from the rebar surface shall not contain voids greater than 3/4 inch diameter and extend no further than 2 inches along the length of the member. The cross section of the product shall not contain voids exceeding 1-1/4 inches in diameter and the sum of all voids greater than 3/8 inches in diameter shall not exceed 5% of the cross sectional area.

Extrude final product as one continuous piece with no joints or splices to the dimensions and tolerances in accordance with Table 5-3.

Reject any sections containing cracks or splits.

Table 5-1
RTSS Matrix

Property	Test Method	Requirement
Density	ASTM D792	48–63 pcf
Water Absorption	ASTMD570	2 hrs: <1.0% weight increase 24 hrs: <3.0% weight increase
Brittleness	ASTM D746	Brittleness temperature < minus 40°C
Impact Resistance	ASTM D256, Method A (Izod)	>0.55 ft-lbs/in
Hardness	ASTM D2240	44-75 (Shore D)
Ultraviolet	ASTM D4329 UVA	500 hours <10% change in Shore D Durometer Hardness
Abrasion	ASTM D 4060	Weight Loss: <0.02 oz Cycles = 10,000

Table 5-1 RTSS Matrix		
		Wheel = CS17 Load = 2.2 lb
Chemical Resistance	ASTM D543	Sea Water: <1.5% weight increase Gasoline: <9.5% weight increase No. 2 Diesel: <6.0% weight increase
Tensile Properties	ASTM D638	2,200 psi at break min.
Compressive Modulus	ASTM D695	40 ksi min.
Static Coefficient of Friction	ASTM D1894	0.25, wet max.
Screw Withdrawal	ASTM D6117	400 lb (screw) min.

Table 5-2 TSS Matrix		
Property	Test Method	Requirement
Density	ASTM D792	50-65 pcf
Impact Resistance	ASTM D256 Method A (Izod)	> 2.0 ft-lbs/in
Hardness	ASTM D2240	44-75 (Shore D)
Ultraviolet	ASTM D4329 (UVA)	500 hours <10% change in Shore D Durometer Hardness
Chemical Resistance	ASTM D756 or ASTM D543	Sea Water: <1.5% weight increase Gasoline: <7.5% weight increase No. 2 Diesel: <6.0% weight increase
Tensile Properties	ASTM D638	3,000 psi at break min.
Static Coeffecient of Friction	ASTM D2394	0.25, wet or dry min.
Nail Withdrawal or Screw Withdrawal	ASTM D6117	250 lb (nail) min. 400 lb (screw) min.
Secant Modulus at 1% Strain	ASTM D6109	150,000 psi min.
Flexural Strength	ASTM D6109	2,500 psi min.
Compressive Strength	ASTM D6108	2,200 psi min.
Compressive Strength Perpendicular to grain	ASTM D6108	700 psi min.

Table 5-3 Tolerances	
Dimension	Tolerance
Length	0/+6 inch
Width – RTSS	±1/2 inch

Table 5-3 Tolerances	
Width – TSS	±1/4 inch
Height – RTSS Width – TSS	±1/2 inch ±1/4 inch
Clear cover from outer surface to rebar elements (RTSS)	≥3/4 inch (wales) ±1/2 inch (other)
Straightness (while lying on a flat surface)	<1-1/2 inches per 10 feet