

SECTION 973
FIBER REINFORCED POLYMER (FRP) COMPOSITE STRUCTURAL
PLASTIC SHAPES

973-1 Description.

This ~~work~~ *Section* covers ~~structural plastic material and fabrication requirements for fiber reinforced polymer (FRP) composite structural shapes~~ *components including fiberglass structurally reinforced composite lumber (SCL) and dimensional fiberglass fiber reinforced composite lumber (FFRCL).*

973-2 Product Acceptance.

~~Use structural plastics listed on the Department's Qualified Products List (QPL). Manufacturers seeking evaluation of products for listing on the QPL must submit an application in accordance with Section 6 and include independently certified test reports, and manufacturer's certification that the material meets the requirements of this Section.~~

~~Structural plastic components used in Contractor developed custom designs may be used in place of QPL listed products. For Contractor developed custom designs, meet the product acceptance criteria in Section 471~~ *Obtain FRP composites from a producer that is currently on the list of Producers with Accepted Quality Control Programs for Fiber Reinforced Polymer. Producers seeking inclusion on the list shall meet the requirements of 105-3.*

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.

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

| <i>Table 4-2 Required Mechanical Properties - VIP FRP Shapes</i> | | |
|----------------------------------------------------------------------|---------------------------------|--------------------|
| <i>Property</i> | <i>Minimum Requirement</i> | <i>Test Method</i> |
| <i>Longitudinal Tensile Strength</i> | <i>30,000 psi</i> | <i>ASTM D3039</i> |
| <i>Transverse Tensile Strength</i> | <i>7,000 psi</i> | |
| <i>Longitudinal Tensile Modulus</i> | <i>3 x 10⁶ psi</i> | |
| <i>Transverse Tensile Modulus</i> | <i>0.8 x 10⁶ psi</i> | |
| <i>Longitudinal Compressive Strength</i> | <i>30,000 psi</i> | <i>ASTM D6641</i> |
| <i>Longitudinal Compressive Modulus</i> | <i>3 x 10⁶ psi</i> | |
| <i>Transverse Compressive Modulus</i> | <i>1 x 10⁶ psi</i> | |
| <i>In-Plane Shear Strength</i> | <i>8,000 psi</i> | <i>ASTM D5379</i> |
| <i>In-Plane Shear Modulus</i> | <i>0.4 x 10⁶ psi</i> | <i>ASTM D5379</i> |
| <i>Interlaminar Shear Strength</i> | <i>3,500 psi</i> | <i>ASTM D2344</i> |

| <i>Table 4-3 Required Mechanical Properties -VP FRP Plates</i> | | |
|--------------------------------------------------------------------|---------------------------------|--------------------|
| <i>Property</i> | <i>Minimum Requirement</i> | <i>Test Method</i> |
| <i>Longitudinal Tensile Strength</i> | <i>20,000 psi</i> | <i>ASTM D3039</i> |
| <i>Transverse Tensile Strength</i> | <i>7,000 psi</i> | |
| <i>Longitudinal Tensile Modulus</i> | <i>1.8 x 10⁶ psi</i> | |
| <i>Transverse Tensile Modulus</i> | <i>0.7 x 10⁶ psi</i> | |
| <i>Longitudinal Compressive Strength</i> | <i>24,000 psi</i> | <i>ASTM D6641</i> |
| <i>Transverse Compressive Strength</i> | <i>15,500 psi</i> | |
| <i>Longitudinal Compressive Modulus</i> | <i>1.8 x 10⁶ psi</i> | |
| <i>Transverse Compressive Modulus</i> | <i>1 x 10⁶ psi</i> | |
| <i>Longitudinal Flexural Strength</i> | <i>30,000 psi</i> | <i>ASTM D790</i> |
| <i>Transverse Flexural Strength</i> | <i>13,000 psi</i> | |

| <i>Table 4-3 Required Mechanical Properties -VP FRP Plates</i> | | |
|--------------------------------------------------------------------|---------------------------------|--------------------|
| <i>Property</i> | <i>Minimum Requirement</i> | <i>Test Method</i> |
| <i>Longitudinal Flexural Modulus</i> | <i>1.6 x 10⁶ psi</i> | |
| <i>Transverse Flexural Modulus</i> | <i>0.9 x 10⁶ psi</i> | |
| <i>In-Plane Shear Strength</i> | <i>6,000 psi</i> | <i>ASTM D5379</i> |
| <i>In-Plane Shear Modulus</i> | <i>0.4 x 10⁶ psi</i> | |
| <i>Interlaminar Shear Strength</i> | <i>3,500 psi</i> | <i>ASTM D2344</i> |

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 ~~plastic~~ polyethylene with appropriate colorants, UV inhibitors, hindered amine light stabilizers, ~~and~~ antioxidants, ~~and chopped fiberglass reinforcement~~ so that the resulting product meets the ~~material property~~ requirements specified in Tables 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 ~~Structural plastic-thermoplastic matrix~~ must not corrode, rot, warp, splinter or crack. ~~The skin must be smooth and black in color unless otherwise specified in the Contract Documents. Skin is the surface material exposed to the atmosphere. Core is the material that surrounds and bonds to the fiberglass reinforcing rods.~~

~~For RTSS members, T~~he use of separate materials for skin and core is at the discretion of each manufacturer; however, ~~if a single material is used, that~~ both materials must meet the requirements ~~for both skin and core 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.~~

~~Manufacture structural plastic~~ Extrude final product as one continuous piece with no joints or splices to the dimensions and tolerances in accordance with Table 5-3. ~~Interior voids shall not exceed 3/4 inches in diameter. Structural plastic members shall be free of twist and curvature.~~

~~Reinforce square fiberglass structurally reinforced composite lumber with a minimum of four fiberglass reinforcing rods placed in the corners of the section.~~

Reinforcing rods must be continuous and offer a minimum flexural strength of 70.0 ksi when tested in accordance with ASTM D4476 and a minimum compressive strength of 40.0 ksi when tested in accordance with ASTM D695. Steel reinforcing rods are not permitted.

Reject any sections of structural plastic containing cracks or splits. Also, inspect the ends of the reinforcing rods and reject any sections containing reinforcing rods with voids or cracks.

Add a minimum of 15% (by weight) chopped fiberglass reinforcement to the polyethylene used for fiberglass structurally reinforced composite lumber and a minimum of 15% (by weight) chopped fiberglass reinforcement for smaller dimensional fiberglass fiber reinforced composite lumber. The fiberglass reinforcement may be reduced when other means of controlling cracking are specified with test results which show long term cracking is nonexistent.

Fiberglass structurally reinforced composite lumber must meet the minimum structural properties listed in Table 4.

Dimensional fiberglass fiber reinforced composite lumber must meet the minimum physical properties listed in Table 5.

| Table 1 Plastic Material Properties—SCL | | | |
|--------------------------------------------|------------------------------|----------------------------------------------------|-------------------------------------------------------------------------|
| Density | ASTM D792 | Skin | 55-63 pcf |
| Density | ASTM D792 | Core | 48-63 pcf |
| Water Absorption | ASTM D570 | Skin | 2 hrs:<1.0% weight increase 24 hrs:<3.0% weight increase |
| Brittleness | ASTM D746 | Skin | Brittleness temperature to be less than -40°C |
| Impact Resistance | ASTM D256 Method A (Izod) | Skin | Greater than 0.55 ft lbs/in |
| Hardness | ASTM D2240 | Skin | 44-75 (Shore D) |
| Ultraviolet | ASTM D4329 UVA | Skin | 500 hours<10% change in Shore D Durometer Hardness |
| Abrasion | ASTM D 4060 | Skin | Weight Loss: <0.02 oz Cycles=10,000 Wheel=CS17 Load=2.2 lb |
| Chemical Resistance | ASTM D543 | Skin/Core Sea Water Gasoline No. 2 Diesel | <1.5% weight increase <9.5% weight increase <6.0% weight increase |
| Tensile Properties | ASTM D638 | Core | 2200 psi at break min. |
| Compressive Modulus | ASTM D695 | Core | 40 ksi min. |
| Static Coefficient of Friction | ASTM D1894 | Skin | 0.25, wet max. |
| Nail Withdrawal or Screw Withdrawal | ASTM D6117 | Skin/Core | 60 lb (nail) min. 400 lb (screw) min. |
| <i>Table 5-1 RTSS Matrix</i> | | | |
| <i>Property</i> | <i>Test Method</i> | <i>Requirement</i> | |

| | | |
|---------------------------------------|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| <i>Density</i> | <i>ASTM D792</i> | <i>48–63 pcf</i> |
| <i>Water Absorption</i> | <i>ASTMD570</i> | <i>2 hrs: <1.0% weight increase 24 hrs: <3.0% weight increase</i> |
| <i>Brittleness</i> | <i>ASTM D746</i> | <i>Brittleness temperature < minus 40°C</i> |
| <i>Impact Resistance</i> | <i>ASTM D256, Method A (Izod)</i> | <i>>0.55 ft-lbs/in</i> |
| <i>Hardness</i> | <i>ASTM D2240</i> | <i>44-75 (Shore D)</i> |
| <i>Ultraviolet</i> | <i>ASTM D4329 UVA</i> | <i>500 hours <10% change in Shore D Durometer Hardness</i> |
| <i>Abrasion</i> | <i>ASTM D 4060</i> | <i>Weight Loss: <0.02 oz Cycles = 10,000 Wheel = CS17 Load = 2.2 lb</i> |
| <i>Chemical Resistance</i> | <i>ASTM D543</i> | <i>Sea Water: <1.5% weight increase Gasoline: <9.5% weight increase No. 2 Diesel: <6.0% weight increase</i> |
| <i>Tensile Properties</i> | <i>ASTM D638</i> | <i>2,200 psi at break min.</i> |
| <i>Compressive Modulus</i> | <i>ASTM D695</i> | <i>40 ksi min.</i> |
| <i>Static Coefficient of Friction</i> | <i>ASTM D1894</i> | <i>0.25, wet max.</i> |
| <i>Screw Withdrawal</i> | <i>ASTM D6117</i> | <i>400 lb (screw) min.</i> |

| Table 5-2 <i>Plastic Material Properties—FFRCLTSS Matrix</i> | | |
|-----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| <i>Property</i> | <i>Test Method</i> | <i>Requirement</i> |
| Density | ASTM- D792 | 50-65- pcf |
| Impact Resistance | ASTM- D256 Method A (Izod) | Greater than > 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 Gasoline No. 2 Diesel | <i>Sea Water: <1.5% weight increase Gasoline: <7.5% weight increase No. 2 Diesel: <6.0% weight increase</i> |
| Tensile Properties | ASTM- D638 | 3,000 psi at break min. |
| Static Coefficient 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. |
| <i>Scant Modulus at 1% Strain</i> | <i>ASTM D6109</i> | <i>150,000 psi min.</i> |
| <i>Flexural Strength</i> | <i>ASTM D6109</i> | <i>2,500 psi min.</i> |

Table 5-2
Plastic Material Properties—FFRCLTSS Matrix

| | | |
|----------------------------------------------------|-------------------|-----------------------|
| <i>Compressive Strength</i> | <i>ASTM D6108</i> | <i>2,200 psi min.</i> |
| <i>Compressive Strength Perpendicular to grain</i> | <i>ASTM D6108</i> | <i>700 psi min.</i> |

Table 3
Dimensions and Tolerances

| Structural Plastic | Dimension | Tolerance |
|-------------------------------------------------------------------------|----------------------------------|-------------------------------------|
| Length | Per order (80 ft Maximum) | 0/+6 inch |
| Width—SCL | See Contract Plans | ±1/2 inch |
| Width—FFRCL | | ±1/4 inch |
| Height—SCL | See Contract Plans | ±1/2 inch |
| Width—FFRCL | | ±1/4 inch |
| Skin Thickness | 3/16 inch minimum | n/a |
| Distance from outer surface to center rebar elements (SCL) | 2 inches | ±1/2 inch |
| Straightness (gap, bend or inside while lying on a flat surface) | | <1-1/2 inches per 10 feet |

Table 4
Structural Properties for SCL

| | | |
|--------------------------------|-------------------|------------------------------------------|
| Member Size | | 10 inches x 10 inches min. |
| Modulus of Elasticity | ASTM D6109 | 521 ksi min. |
| Stiffness, E.I. | ASTM D6109 | 4.05E+08 lb-inch² min. |
| Yield Stress in Bending | ASTM D6109 | 5.3 ksi min. |
| Weight | | 30-37 lb/ft |

Table 5
Minimum Properties for FFRCL

| | | |
|----------------------------------------------------|-------------------|--------------------|
| Modulus of Elasticity | ASTM D6109 | 300,000 psi |
| Flexural Strength | ASTM D6109 | 2,500 psi |
| Compressive Strength | ASTM D6108 | 2,200 psi |
| Compressive Strength Perpendicular to grain | ASTM D6108 | 700 psi |

Table 5-3
Tolerances

| Dimension | Tolerance |
|---------------------|------------------|
| Length | 0/+6 inch |
| Width – RTSS | ±1/2 inch |
| Width – TSS | ±1/4 inch |

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