OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
FIBER-REINFORCED POLYMER MATERIAL

These Special Provisions revise, amend, and where in conflict, supersede applicable sections of the 2009 Standard Specifications for Highway Construction, English and Metric.

(*Add the following:*)

524.01 DESCRIPTION

This work consists of structural strengthening using fiber-reinforced polymer (FRP) composite wrap. Fiber may be either Carbon (CFRP) or E-Glass (EGFRP). Use carbon fiber (CFRP) unless otherwise specified on the plans.

Reference is made to AASHTO publication, "Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements," and American Concrete Institute publication ACI 440.2R-02, "Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures."

524.02 MATERIALS

A. Material Properties

Provide a unidirectional, high-strength fiber fabric fully saturated with compatible epoxy resin. Use epoxy resin and FRP laminae in accordance with ACI 440.8-13, "Specification for Carbon and Glass Fiber-Reinforced Polymer (FRP) Materials Made by Wet Layup for External Strengthening of Concrete and Masonry Structures." Provide FRP dry properties which meet or exceed the requirement of ACI 440.8, except that the minimum weight for CFRP shall be 9 oz/yd^2 [300 g/m^2], and the minimum weight for EGFRP shall be 27 oz/yd^2 [900 g/m^2].

Provide flexible, waterproofing, non-vapor barrier protective top coating compatible with the FRP manufacturer's recommendations to protect the FRP from ultraviolet radiation and mild abrasion. Match the color and texture of the protective top coating to adjacent concrete.

B. Product Data

Provide to the Engineer a copy of the Manufacturer's Safety Data Sheets (MSDS) for all materials to be used on site and certification that the materials conform to local, state, and federal environmental and worker safety laws and regulations. Include mechanical, physical, and chemical properties, and material specifications for the proposed primer, putty, resin, saturant, fiber, and protective top coating. Provide to the Engineer the manufacturer's maintenance recommendations for the protective top coating and the complete FRP system.

524.03 EQUIPMENT

Furnish all materials, tools, equipment, transportation, necessary storage, access, labor and supervision required for the proper application of the composite system.

524.04 CONSTRUCTION METHODS

Provide a technical representative from the composite system manufacturer at the start of work. Use a contractor certified by the manufacturer by means of written verification to install the composite system. In addition, provide the names of the applicator's key personnel (superintendent and assistant) who will perform the actual work with the written verification from the manufacturer. The Engineer may suspend the work if an unauthorized composite system is substituted for an authorized composite system, or if unauthorized personnel is substituted for authorized personnel during construction.

A. Shop Drawings

Provide complete shop drawings for each installation of the composite system. Show details of the widths of strips, number and thickness of layers, orientation of the layers, joint and end details, and locations to be applied in accordance with the plans and specifications. When required on the plans, include anchorage systems providing location and material properties for spikes, ties, or other anchors required for FRP system. Show locations of all gaps and laps.

B. Calculations

When plans show a minimum and/or maximum required strength for shear or flexure, provide complete calculations to the Bridge Engineer for approval. Design the composite system in accordance with the AASHTO guide specification " Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements" to achieve the structural performance shown on the structural drawings for required factored tensile, shear, torsion, axial forces and strain limits. Provide calculations stamped by a Professional Engineer, registered in the state of Oklahoma.

C. Delivery and Storage

Deliver epoxy materials in factory-sealed containers. Verify that the manufacturer's labels are intact and legible (including brand, system identification number, and batch number) with verification of date of manufacture and shelf life. Store materials in a protected area at a temperature between 35°F [2°C] and 100°F [38°C]. Store products according to the manufacturer's requirements and avoid contact with moisture. Do not use components that have exceeded their shelf life.

D. Concrete Repairs

Epoxy inject all cracks in the concrete surface wider than 0.01 in. [0.3 mm] in accordance with Section 520, "Structural Concrete Repair by Sealing and Injection." Allow epoxy used for crack sealing to cure in accordance with the manufacturer's recommendations. Apply pneumatically placed mortar to the dimensions shown on the plans, or as specified by the Engineer in accordance with Section 521. Ensure that pneumatically applied mortar is cured as specified in Subsection 521.04.D.(4).

E. Surface Preparation

Once all concrete repairs are made and cured, prepare concrete substrate surfaces to promote continuous intimate contact between the FRP and the concrete by providing a clean, smooth, and flat or convex surface. Grind away all irregularities, unevenness, and sharp protrusions to provide less than 1/16 in [2 mm] surface profile deviation. Fill all voids or depressions of diameters larger than ½ in [13 mm] or depths greater than ⅛ in [3 mm] with a type G epoxy in accordance with Subsection 701.13.B.(7), or as approved by the fiber-reinforced polymer (FRP) manufacturer. At a minimum, allow all patching materials to cure a minimum of 2 days and reach a minimum of 3,000 psi [21 MPa] compressive strength prior to installation of the FRP wraps. Round or chamfer all inside and outside corners and sharp edges to a minimum radius of ½ in [13 mm]. Remove all laitance, dust, dirt, oil, foreign particles, disintegrated materials, and any other matter that could interfere with the bond of the concrete to the FRP using abrasive or water blasting techniques. Apply corrosion inhibitor in accordance with Special Provision 535-1, "Surface Applied Penetrating Corrosion Inhibitors." Ensure that the inhibitor product will not interfere with the bond of the fiber-reinforced polymer material using techniques recommended by the inhibitor manufacturer.

F. Application of Composite Fabric

Ensure that all patch work is complete and cured. Verify ambient and concrete temperatures are between 35°F [2°C] and 100°F [38°C]. Maintain epoxy curing temperatures in the temperature range designated for the formulation used. Temperature cure ranges and times to be determined by manufacturer. Protect the composite system from contact by moisture for a minimum of 24 hours. Prepare the epoxy matrix by combining components at a weight (or volume) ratio specified on the manufacturer's labeled units, with an allowable tolerance of ± 10%. Mix the components of epoxy resin with a mechanical mixer until uniformly mixed, typically 5 minutes at 400 to 600 rpm. Saturate and monitor the fabric according to manufacturer's specified fiber-resin ratio. A previously calibrated saturator can be used to achieve the specified ratio. Completely saturate fabric prior to application of contact surfaces in order to assure complete impregnation of fabric. Have a properly trained supervisor verify that saturation is correct. Measure and combine the epoxy resin and fabric and deposit uniformly at the rates shown on the approved working drawings and per manufacturer's recommendations. Completely saturate all fibers of the composite system with epoxy resin per proper ratio.

G. Installation

Unless otherwise provided by the manufacturer, install the FRP fabric as follows:

- Broom clean surfaces to receive the FRP.
- Using a roller or trowel, apply one prime coat of thickened epoxy resin to the concrete surface [2 mil minimum [50 µm]]. Allow primer to become tacky to the touch.
- Ensure the FRP fibers are oriented as noted on the plans. Saturate fabric with epoxy matrix through calibrated saturator, or according to manufacturer's specified fiber-resin ratio.
- Apply saturated fabric to concrete surface by hand lay-up, using methods that produce a uniform, constant tensile force that is distributed across the entire width of fabric. Under certain application conditions the system may be placed entirely by hand methods assuring a uniform,

even final appearance. Provide gaps when the length of member to be wrapped exceeds 5 ft [1.5 m]. Use 2 in [50 mm] gaps spaced at 2 ft [0.6 m] centers. The gaps should only occur parallel to the primary fiber direction (the material would need to be continuous in the primary fiber direction). In cases where the primary direction of the fibers are placed both horizontally and vertically, provide a 2 in [50 mm] square gap every 2 ft [0.6 m] in both directions. Ensure that the gaps are completely free of all epoxy resin products used to bond FRP. Provide a lap length of at least 6 in [150 mm] at all necessary over-laps in the longitudinal direction of the fabric.

- Apply subsequent layers, continuously or spliced, until designed number of layers is achieved, per project drawings.

- Using a roller or hand pressure, ensure proper orientation of fibers, release or roll out entrapped air, and ensure that each individual layer is firmly bedded and adhered to the preceding layer or substrate.

- Apply a final coat of thickened epoxy. Detail all fabric edges, including butt splice, termination points, and jacket edges, with epoxy.

- Apply fire coating (if required) per manufacturer's published installation procedures in accordance with UL and Warnock Hersey testing and per ICBO ES Evaluation Report.

- Apply top coat of paint as specified between 24 and 72 hours after final application of epoxy. Use paints that allow vapor transmission at gaps. Remove dust and residue prior to application of paint coats. If after 72 hours the epoxy is cured, the surface must be roughened by sanding or brush blasting.

- Ensure that anchorage systems are fastened in accordance with the FRP manufacturer's recommendations.

- Record batch numbers for fabric and epoxy used each day, and note locations of installation. Measure square footage [square meters] of fabric and volume of epoxy used each day.

H. Testing

After the initial resin has cured at least 24 hours, perform the following test:

- Visually inspect for any defects in the FRP wrap.

- Tap or sound any areas suspected to contain air pockets.

- Perform two direct pull-off tests for every 300 square feet [28 square meters] wrapped in accordance with ASTM D 7522. Ensure when testing prestress beams not to score the substrate more than ¼ in [6 mm]. Accept pull-off tests which fail in the concrete substrate (failure mode G) and not at the interface between the FRP and the concrete. At the discretion of the Engineer, pull-off tests may be performed at locations of similar substrate near the FRP installation area. Prepare test samples using identical application procedures at the same time that the project FRP is installed. Repair the damaged FRP and concrete at test areas after testing is complete.

I. Repairs

Repair all defects (including bubbles, delaminations, and fabric tears) spanning more than 5% of the surface area as directed by the Engineer. Perform repairs as follows:

- Inject or back-fill small defects (on the order of 6 in [150mm] diameter) with epoxy.
- Inject bubbles less than 12 in [300 mm] in diameter with epoxy by drilling two small holes into the bubble. The holes will allow injection of the epoxy and escape of entrapped air.
- Repair bubbles and delaminations greater than 12 in [300 mm] in diameter by removing and re-applying the required number of layers of the composite and the required finish coatings. Small entrapped air pockets and voids naturally occur in mixed resin systems and do not require repair or treatment.

524.05 METHOD OF MEASUREMENT

Measure fiber-reinforced polymer by the square foot [square meter] applied for the specified thickness or number of layer as indicated on the plans.

524.06 BASIS OF PAYMENT

The Department will pay for each pay item at the contract unit price per the specified pay unit as follows:

Pay Item:	Pay Unit:
CARBON FIBER-REINFORCED POLYMER	Square Feet [Square Meter]
E-GLASS FIBER-REINFORCED POLYMER	Square Feet [Square Meter]

The Department will consider the cost of all materials, equipment, labor, and incidentals necessary for proportioning, mixing, delivery, storage, handling, surface preparation, installation, sampling, testing, repairs and curing of the fiber-reinforced epoxy composite system to be included in the unit price bid for fiber-reinforced polymer.

Payment for epoxy injection will be in accordance with Subsection 520.06.

Payment for *Pneumatically Placed Mortar* will be in accordance with Subsection 521.06.

Payment for corrosion inhibitor will be in accordance with Special Provision 535-1, “Surface Applied Penetrating Corrosion Inhibitors.”

Payment for type G epoxy to be included in the price bid for fiber-reinforced polymer.