***Designer Notes: All surface preparation involving concrete removals, patching, and crack injection is to be detailed and paid for separate from this SPV. For components that are not new, include “Concrete Surface Repair” (Standard Spec 509) and “Epoxy Injection Crack Repair” (STSP 509-025) as needed.***

Fiber Wrap Reinforcing Structural, Item SPV.0165.xx.

**A Description**

This special provision describes providing structural strengthening using externally bonded, high-strength, fiber reinforced polymer (FRP) composite/epoxy resin systems field-applied per the details shown on the plans.

**B Materials and Design**

**B.1 Materials**

Furnish a glass or carbon composite fabric that is a continuous unidirectional filament woven fabric with a primary fiber of electrical (E) glass or carbon, respectively.

Use a two-component, solvent-free with 0% Volatile Organic Compound (VOC) epoxy that is supplied by the manufacturer. Polyester resin shall not be allowed as a substitute for epoxy resin. Deliver epoxy materials in factory sealed containers with the manufacturer’s labels intact and legible with verification of the date of manufacture and shelf life.

The protective top coating shall be concrete gray in color and match the color of the adjacent unwrapped concrete. Protective top coating shall be vapor permeable and UV resistant.

The use of more than one FRP system in a project is not permitted. All components, including primer, putty, filler, protective coating, and other materials, shall be compatible with the FRP system.

Store products in a protected area at a temperature between 40°F and 100°F with no moisture contact, no UV exposure, protected from dirt, chemicals, and physical damage, and according to the manufacture’s requirements. Do not use components exceeding their shelf lives.

Provide the following to the engineer:

* The manufacturer’s data sheet indicating physical, mechanical and chemical characteristics of all materials used in the FRP system including the primer, putty, resin, saturant, fibers, and top coating.
* The manufacturer’s Material Safety Data Sheets (MSDS) for all materials used.
* The manufacturer’s instructions for installation and repair, including information on lap details if required.
* The manufacturer’s storage and handling requirements of all materials.

Supplied composite fabric and epoxy resin products must have a minimum of ten installations. Furnish proof of successful installations including date of construction and owner references. Furnish certified test reports including 1000 hour tests for 140°F, water, and salt water.

**B.2** **Design**

It is the responsibility of the contractor to submit, to the Department, a design and supporting documentation as required by this special provision that is compliant with the design specifications. The FRP strengthening shall provide additional structural strength as shown on the structural plans. A copy of the below listed information shall be submitted to the engineer for review and acceptance no later than 60 days from the date of notification to proceed with the project.

The design/shop plans shall be prepared on reproducible sheets, 11” x 17” size, including borders. Each sheet shall have a title block including the project identification number and structure number. Drawings shall specifically identify number of layers, fiber orientation direction, dimensions, and any required laps, including their location and lengths. If anchors are required, drawings shall specifically identify type and properties of anchors, location of anchors, embedment depth, and splay width and length. Design calculations and notes shall be on 8-1/2” x 11” sheets and shall contain the project identification number, date of preparation, initials of the designer and the checker, and a page number at the top of the page. All plans and calculations shall be signed, sealed and dated by a professional engineer licensed in the State of Wisconsin.

The design of the FRP repair shall conform to the latest edition ACI 440.2R *Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures* including all updates and errata, the standard specifications, this special provision, and standard engineering design procedures as determined by the department, with the following exceptions to ACI 440.2R:

* The strengthening limit check in equation 9-1 can be omitted.
* The fire endurance check in equation 9-2 can be omitted.
* The value of d (distance from the extreme compression fiber to the centroid of the tension reinforcement) need not be taken less than 0.8\*h as specified in ACI 318-14 Section 22.5.2.1, where h is the height of the member. The effective depth of the FRP shear reinforcement dfv can also be calculated using this limited d.

FRP laminate design values must be lower than the calculated mean determined from the test results of ASTM D7565 and/or ASTM D3039 field test specimens.

If more than three layers of FRP are required for the design, contact BOS to discuss before proceeding. It is desirable that no more than three layers of FRP be used.

For shear applications, U-wraps or complete (full) wraps must be used; side bonding is not allowed. Provide at least a 2 inch gap between FRP strips.

**C Construction**

**C.1 Certified Applicators**

Installers shall have a minimum of three years of experience performing similar FRP composite strengthening, and be trained and certified by the manufacturer of the supplied FRP composite/epoxy resin system being used. Submit a list of completed surface bonded FRP composite strengthening projects completed with the manufacturer’s FRP composite system in the past three years. The list shall include a minimum of 10 projects with the proposed FRP system, the dates when work was performed, general description of work, quantity of work and owner references. Provide written verification from the FRP composite manufacturer that the applicator has received the required training and is a certified installer by the FRP manufacturer.

**C.2 Surface Preparation**

Remove spalled and loose concrete.

Grind uneven surfaces or protrusions until smooth. Any corners or edges shall be rounded over to a minimum radius of 1/2-inch. This requirement also applies to beveled edges which must be ground smooth to eliminate sharp spots.

Per standard spec 509, treat any areas of active corrosion of the reinforcement and patch the concrete surface so as to restore it to its original dimensions. When patching the concrete substrate, remove defective concrete down to sound concrete; the extents of the area to be removed and patched shall be 1/2-inch beyond the boundary of the distress on all sides. If there is a loss of bond between the reinforcing steel and the concrete, remove the surrounding concrete to a depth equal to the greater of 3/4-inch or the maximum aggregate size plus 1/4-inch. If surface repair is performed, allow patches to cure a minimum of 10 days before FRP application or until the surface moisture is less than 4%. This work to be paid for under separate bid items per the plans.

Epoxy inject cracks in the concrete larger than 0.25 mm in width at least 24 hours prior to FRP installation. Seal cracks smaller than 0.25mm in width in aggressive environments at the direction of the engineer. This work to be paid for under a separate bid item per the plans.

Preserve and utilize the required existing reinforcing steel, and blast clean, realign, and retie as the engineer directs. If additional reinforcement is required, use grade 60 steel conforming to AASHTO M31 and standard spec 505.2. Repair damage to existing, epoxy-coated reinforcement conforming to 509.3.1.

The concrete surface shall be clean, and free of any material that could interfere with bonding, such as dirt, grease, wax, etc. The surface must also be free of moisture with a maximum moisture content of 4%. Immediately prior to bonding all contact surfaces shall receive a final cleaning by hand or oil-free compressed air to remove any residual dust, powder residue or laitance.

On each member to receive FRP, prepare an adjacent area just beyond the limits of the repair using the same surface preparation as the repair area for testing. Test the tensile bond strength of the prepared concrete substrate per ACI 503R at a minimum of 1 location per member. Location(s) will be determined by the engineer. A passing test will have a tensile strength greater than 250 psi, or a failure into the substrate where more than 50% of the core area has failed deeper than 1/4-inch. Patch the hole(s) created by the pull off tests. All tests shall be conducted in the presence of the engineer.

**C.3 Installation**

Place FRP only under the following conditions or per manufacturer’s recommendation:

* Ambient temperature and the temperature of the epoxy resin components shall be between 55°F and 90°F during the entire application process.
* Relative humidity less than 85%.
* Surface temperature more than 5°F above the dew point.
* Moisture level of all contact surfaces, included patched areas, less than 4% unless the resin has been specifically formulated for wet applications.

Unless directed otherwise by the engineer, install the FRP after all dead loads have been applied to the bridge. Do not install FRP while the component being repaired is subjected to live loads.

Apply, per manufacturer’s instructions, a system-compatible putty as required to fill uneven surfaces or recesses. Depending on the manufacturer, the putty may be applied before or after the primer.

Apply the primer coat uniformly to the substrate using a roller or trowel. Primed and puttied surface shall be protected from all contaminants (i.e., dust, moisture, etc.) prior to the application of the fiber wrap.

Mix the components of the epoxy resin with a mechanical mixer and apply the epoxy resin uniformly to the fiber at a rate that ensures complete saturation of the fabric. Apply saturating resin uniformly to the prepared substrate. Begin resin application within one hour after the batch has been mixed. Use all resin within the pot life as specified by the manufacturer.

Apply the fabric as shown on the shop drawings. Fiber orientation shall not deviate from the orientation shown on the shop drawings. Handle fiber wraps in a manner to maintain fiber straightness and prevent fiber damage. Any kinks, folds, or severe waviness will not be accepted. Use rollers or hand pressure to remove any air trapped between the fabric and the concrete, or between fabric plies. Rolling must be parallel to the direction of the fibers to avoid fiber misalignment or damage. Do not use metal serrated rollers because they can damage the FRP fabric.

If anchors are required, install per manufacturer’s instructions. When drilling in anchors, avoid prestressing strands. If needed, request girder shop drawings from the Bureau of Structures to locate strands.

Stagger the joints between layers so that a continuous sheet in one layer will span the joints of the sheets in the layer below. If multiple layers cannot all be placed in one day, defer to the manufacturer to determine the extent of the cure and surface preparation required for the previously placed layers required before proceeding. Laps shall be as shown on the design/shop drawings, with a minimum edge lap of 6 inches and a minimum end lap of 12 inches. Laps should be staggered between layers.

Cover the final layer of fabric with a coat of epoxy that produces a uniform finished surface and detail fabric edges, including terminations points, with thickened epoxy or putty per manufacturer’s instructions.

Cure per manufacturer’s instructions. The FRP system shall be protected from weather, large temperature variations, moisture, sand, dust, and other foreign particles during curing. Do not allow the system to be subjected to live loads until it is completely cured. Defer to manufacturer’s instructions regarding the degree of cure which must be achieved before additional dead loads can be applied to the wrapped member.

An additional protective coating is required to protect the fibers from the elements, specifically UV radiation, and to give the final aesthetic effect. Install protective coating per manufacturer’s instructions after the field inspection described in section C.4.3 has been conducted. To prepare the FRP surface to receive the coating, clean and roughen the exterior surfaces of the composite wrap using a light abrasive after the final epoxy coat is completely polymerized. The abrasive shall be of the appropriate hardness to roughen the surface without damaging the fibers. Remove all dust, dirt, and other bond inhibiting materials and dry all cleaned and roughened surfaces.

For each member to receive FRP, install FRP using the same methods described above on the area adjacent to the repair area that received surface preparation and pull off testing in Section C.2. This area will be used for acceptance testing.

**C.4 Testing and Acceptance**

**C.4.1 Records and Sampling**  
The contractor shall record the following information for each installation:

* Date, time, and specific location of installation.
* Surface preparation methods.
* Widths and lengths of cracks not injected with epoxy.
* Material information including product used, fiber and resin lot/batch numbers, mixture ratios, mixing times, etc.
* Ambient temperature, relative humidity, and general weather observations at the beginning and end of each installation.
* Concrete surface temperature, concrete moisture content, and surface cleanliness.
* Number of FRP layers used and fiber orientation of each layer.
* Square footage of fabric and volume of epoxy used each day.

Prepare a minimum of two sample batches daily for each layup configuration, each consisting of two 12” x 12” samples of cured composite (for a total of at least four samples daily per layup configuration). Collect materials for the sample batches at an appropriate spaced interval during the day to ensure the maximum material deviance in the components of the FRP composite.  
  
Prepare samples on a smooth, level surface covered with polyethylene sheeting or 16 mil plastic film. Prime the sheeting or film surface with epoxy resin. Place layers of saturated fabric to match layup configuration and apply additional topping of epoxy. Cover with plastic film and squeegee out all air bubbles. Store samples flat in a sample box or in a protected area and do not move for a minimum of 48 hours after casting.

**C.4.2 Laboratory Testing and Acceptance**

The prepared, indentified samples shall be tested by an approved, experienced laboratory. Precondition the samples at 140°F for 48 hours before testing. Cut test specimens from samples provided and test for ultimate tensile strength, tensile modulus and percentage elongation per ASTM D7565 and/or ASTM D3039 in the longitudinal fiber direction.

Test a minimum of 15% of all samples per ICC AC178*, Interim Criteria for Inspection and Verification of Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber Reinforced (FRP) Composite Systems.* If one set of coupons fails to meet the design values (on average), then the other 12” x 12” sample from the same sample batch will be tested. If the second sample tested also fails (on average) to meet the design values, the remaining sample batch for that day will be tested and appropriate remediation shall be taken to ensure the integrity of the system at the locations from the failed sample batch.

FRP design values must be lower than the calculated mean determined from the test ASTM D7565 and or ASTM D3039 test results. Acceptable minimum values for the ultimate tensile strength, tensile modulus and elongation shall not be below the submitted design values.

Any test result values (on average) below the manufacturer’s submitted design values are considered a failure and require remediation subject to the approval of the engineer.

Testing must be conducted prior to the subjecting the FRP to live traffic loads. In cases of staged construction, this may necessitate more than one round of testing.

**C.4.3 Field Testing**

After the initial resin has cured, conduct a minimum of two tensile bond tests per 1,000 square feet in accordance with ASTM D7522 in the presence of the engineer and at location(s) specified by the engineer. Drill cores through the FRP and into the existing concrete a minimum of 1/4-inch but no more than 1/2-inch. A passing test will have a tensile strength greater than 200 psi, with a failure into the substrate where more than 50% of the core area has failed deeper than 1/4-inch. Immediately patch test core holes by blowing out with oil-free and moisture-free compressed air, and filling epoxy per manufacturer’s instructions.

In the presence of the engineer, the contractor will conduct a visual and acoustic sounding inspection to test for defects such as voids, delaminations, external cracks, chips, cuts, loose fibers, external abrasions, blemishes, foreign inclusions, depressible raised areas, or fabric wrinkles. Conduct this inspection after placement and cure of the protective coating.

In the presences of the engineer, the contractor will conduct a visual inspection of the protective coating for damage including but not limited to cracking, crazing, blisters, peeling, or external abrasions. Conduct this inspection after placement and cure of protective coating.

If any defects are found, they must be repaired as detailed in C.4.4, or removed and replaced.

**C.4.4 Required Remediation**

Inject or back fill any small voids or bubbles (1-1/2” diameter or less) with epoxy. If five or more such voids are found in an area smaller than 10 square feet, submit a proposed remediation procedure subject to the acceptance of the engineer.

Voids or delaminated areas greater than 3” in diameter or an equivalent rectangular area shall be reported to the engineer. Proposed remediation procedure(s) for addressing these areas are subject to the acceptance of the engineer.

In the event the laboratory testing determines a sample batch possesses material properties (on average) below the material properties assumed for design, remedial measures are required. Any structural member where the installed FRP composite system has tested material properties below the values used for the design must be remediated. Install additional layers or provide other remediation acceptable to the engineer.

Fiber misalignment exceeding 5 degrees (approximately 1” of deviation over 1 foot length) is considered unacceptable. Proposed remediation is subject to the acceptance of the engineer.

**D Measurement**

The department will measure Fiber Wrap Reinforcing Structural by the square foot acceptably completed.

**E** **Payment**

The department will pay for measured quantities at the contract unit price under the following bid item:

|  |  |  |
| --- | --- | --- |
| ITEM NUMBER | DESCRIPTION | UNIT |
| SPV.0165.xx | Fiber Wrap Reinforcing Structural | SF |

Payment for Fiber Wrap Reinforcing Structural is full compensation for supplying a design and shop drawings; preparing required submittals; cleaning the surfaces of elements to be strengthened; furnishing, transporting, handling, and installing the fabric, finish coat of epoxy, the final protective coating system; sampling, sample preparation, and field and laboratory testing; and required remediation. No extra measurement or payment will be made for overlap areas.

Repairing damage to existing reinforcement is incidental to this item.

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