

SPECIAL PROVISION

PROJECT #
PIN #

SECTION 03938S

FIBER REINFORCED POLYMER (FRP) SYSTEM

Delete Section 03938 in its entirety and replace with the following:

PART 1 GENERAL

1.1 SECTION INCLUDES

- A. Externally bonded Fiber Reinforced Polymer (FRP) system used for protection of columns, bent caps, girders and as shown.

1.2 RELATED SECTIONS

- A. Section 02741: Asphalt Mix
- B. Section 02776: Concrete Flatwork
- C. Section 03924: Structural Concrete Repair
- D. Section 03932: Concrete Slope Protection Repair

1.3 REFERENCES

- A. ASTM D 3039: Tensile Properties of Polymer Matrix Composite Materials
- B. ASTM D 7522: Pull-Off Strength for FRP Laminate Systems Bonded to Concrete or Masonry Substrates
- C. ASTM D 7565: Determining Tensile Properties of Fiber Reinforced Polymer Matrix Composites Used for Strengthening of Civil Structures
- D. International Code Council Evaluation Service (ICC-ES)

1.4 DEFINITIONS

- A. Provider – The manufacturer furnishing the FRP system

- B. Installer – The Contractor or subcontractor preparing the concrete substrate surfaces and installing the FRP system

1.5 SUBMITTALS

- A. Quality Assurance submittals for review before ordering materials
 - 1. Provider Qualifications. Include at least the following:
 - a. The company name
 - b. The name, phone number, and documented experience of the Provider's technical support representative.
 - 1) List related FRP System project experience, including project size, location, owner, engineer or architect, and contact information.
 - c. List of FRP System Provider's experience completing externally bonded FRP system application projects using the recommended system
 - 1) Include at least three projects within the last five years.
 - 2. Installer Qualifications. Include at least the following:
 - a. List of at least three projects completed applying FRP systems in the last five years
 - 1) Include the project size, location, engineer or architect and two owner or agent references responsible for oversight or inspection on the project with their contact information (phone and email).
 - b. The names and documented experience of the Installer's superintendent and applicator
 - c. Certification from the Provider that the Installer has been trained and has sufficient experience to install the system being used
- B. FRP system information. Include at least the following:
 - 1. Manufacturer's product data sheets for all system components including primer, resin, and carbon fiber reinforcing for review
 - a. Include a letter of compatibility under the FRP system manufacturer's letterhead if the manufacturer's product data sheets do not state that the primer is a compatible component of the FRP system.
 - 2. A current ICC-ES Evaluation Report evaluating the proposed FRP system to be used on this project for review
 - 3. Material Safety Data Sheets (MSDS) and installation instructions for information for all system components including primer, resin, and carbon fiber reinforcing.

- C. FRP system working drawings for review.
 - 1. Details for surface preparation
 - 2. Complete system details including at least the primer, FRP reinforcement, resin, and protective coating
 - 3. Details for the types, locations, number of layers, splice details, materials and orientation of FRP materials and coatings to be installed
 - 4. Limits of FRP reinforcing
 - 5. Installation procedures and recommendations
 - 6. Details for protecting elements from direct sunlight during installation and curing of the FRP system.
 - a. Refer to this Section, Paragraph 3.3 A1 for sun protection requirements.
- D. FRP System Repair Procedure for review
 - 1. Describe the method to repair delaminations up to 2 in².
 - 2. Describe the method to repair delaminations larger than 2 in².
 - 3. Describe the process for full removal and reapplication of delaminated material.
 - 4. Describe the process to repair areas damaged by pull-off test. Include at least the following:
 - a. Concrete patching material according to Section 03924
 - b. Method to repair damaged FRP
- E. Documentation for information
 - 1. Copies of purchase order and packaging slips showing quantities and dates of primer and resin purchased
 - 2. Test results of the pull-off tests noting location, quantity bond strength, failure location, and who performed the tests
 - 3. Contractor's daily Construction Logs. Include at least the following information:
 - a. Weather and temperature at application times
 - b. Amount of product used and square footage/linear footage of substrate covered
 - c. Batch numbers of all products used
 - d. Names of crew members and technical representative

1.6 QUALITY ASSURANCE

- A. Provider service requirements
 - 1. The Provider's technical support representative must:
 - a. Have at least three years of relevant experience in the installation of the proposed FRP system on at least three different projects, and with guiding and assisting Installers in the FRP system installation

- b. Provide technical support and training to the Installer and the Department regarding handling, storage, production, and placement
- c. Attend the preconstruction meeting
- d. Instruct the Installer, Contractor, and Engineer of anything that could adversely affect the performance of the FRP system
- e. Be present during the installation of the FRP system for the project
 - 1) The Engineer may waive the requirement for the Provider's technical support representative to be onsite after completion of the first complete installation of FRP to each member type (for example: column or bent cap).
 - a) Complete installation includes surface preparation, layer application, testing, repair and coating.
 - b) The Provider's technical support representative must be available for consultation throughout the duration of the application.
 - c) The Department reserves the right to require the Provider's technical support representative to be onsite if at any time the Engineer is concerned with the product installation quality.

B. Delaminations

- 1. Small entrapped air pockets and voids on the order of $\frac{1}{16}$ inch to $\frac{1}{8}$ inch diameter do not require repair or treatment.
- 2. Delaminations of less than 2 in² are permissible except at the edges or boundaries.
 - a. No more than ten delaminations of this size are allowed per 10 ft² of the laminated area.
- 3. Delaminations larger than 2 in² require repair.
 - a. Delaminations larger than 25 in² require repair by removing the delaminated material and reapplying the FRP system.

C. Bond strength

- 1. Areas of insufficient bond strength, as determined by a pull-off test, are considered to be indication of delamination and require full removal and reapplication of the delaminated FRP system as determined by additional pull-off tests. Refer to this Section, Article 3.5.

1.7 DELIVERY, STORAGE AND HANDLING

- A. Deliver materials in factory sealed containers with the manufacturer's labels intact and legible.
- B. Store and handle materials according to the manufacturer's recommendations.
 - 1. Protect material from dirt, chemicals, moisture, extreme temperatures, and physical damage.

PART 2 PRODUCTS

2.1 FRP SYSTEM

- A. Use an FRP system that meets or exceeds the minimum values listed in Table 1.
 - 1. Use a primer compatible with the resin and reinforcement.
 - 2. Use Carbon FRP reinforcement.
 - 3. Provide two or more plies of FRP reinforcement.
 - 4. Use a high solids UV resistant polymer or acrylic based protective coating that matches existing concrete color unless otherwise shown.

Table 1

Minimum Physical Properties of the Composite FRP System in the primary direction		
Property	Value	Method
Laminate Tensile Strength	100 ksi	ASTM D 3039
Laminate Tensile Strength per Ply	1.7 kips/inch/ply ¹	ASTM D 7565
Laminate Elongation at Break	0.9%	ASTM D 3039 or ASTM D 7565
Laminate Tensile Modulus of Elasticity	9,500 ksi	ASTM D 3039
Laminate Tensile Modulus of Elasticity per Ply	160 kips/inch/ply ¹	ASTM D 7565

1. When not provided, this value can be computed by multiplying the Tensile Strength or Modulus of Elasticity according to ASTM D 3039 by the nominal thickness of a single ply.

PART 3 EXECUTION

3.1 EXPOSE SURFACES FOR PREPARATION

- A. Remove asphalt pavement, concrete flatwork, and concrete slope protection as necessary to perform FRP system installation and as shown.
- B. Excavate as necessary to expose surfaces to be prepared.

3.2 SURFACE PREPARATION

- A. Prepare concrete surfaces according to the Provider's recommendations.
- B. Remove sharp edges and other deformations to provide a smooth, even surface.
 - 1. Round the edges of corners, including chamfered corners, where FRP is wrapped around the corner to at least a ½ inch radius to prevent stress concentrations and voids between the FRP and the concrete.
- C. Sandblast clean the entire concrete surface that will receive the FRP system.
 - 1. Remove materials that may be detrimental to the bonding and curing of the FRP system.
- D. Cure concrete repairs for at least the time required by the Provider before installing the FRP system.
- E. Lightly abrade the surface of the previously applied and cured resin layer by hand, using a medium-grit sandpaper (100 grit), before applying subsequent layers or the protective coating unless application occurs within 48 hours of the application of the previous layer.

3.3 LIMITATIONS

- A. Do not install FRP unless the substrate temperature is expected to remain between 50 degrees and 90 degrees during installation and curing of the FRP system.
 - 1. Provide sun protection during installation and curing of the FRP system for elements that will be subject to direct sunlight for more than 1 hour per day while ambient air temperature is 70 degrees F or higher.

- B. Verify the moisture content in the concrete substrate does not exceed 4.0 percent when measured by an electronic meter.
 - 1. Do not apply the FRP system if measurements exceed 4.0 percent.

3.4 FRP INSTALLATION

- A. Install the FRP according to the Provider's recommendations.
- B. Orient primary fiber in the direction shown.

3.5 PULL-OFF TESTS

- A. Perform pull-off tests at the locations determined by the Engineer to determine the bond strength between the bonded FRP and the concrete substrate. Refer to ASTM D 7522.
 - 1. Perform at least two tests on one bent cap for each bridge when FRP system is installed on bent caps.
 - a. Take one test from the side face of the bent cap and one test from the underside, where applicable.
 - 2. Perform at least two tests on one column for each bridge when FRP system is installed on columns.
 - a. Take one test within the lower 10 ft of the column, and one test from a location above 10 ft, where applicable.
 - 1) Only one test, at a location determined by the Engineer, is required for columns 3 ft in diameter or smaller.
 - 3. Perform at least two tests on one representative concrete element for each bridge when FRP system is installed on girders.
 - a. Do not perform test on the girder itself.
 - b. The representative concrete element may be a nearby part of the project or a concrete element used solely for the purpose of testing.
 - 1) Completed tests on concrete elements nearby require repair. Refer to this Section, Article 3.6.
 - c. Apply the FRP to the representative concrete element in the same work shift and with the same personnel as the application of FRP to a girder.

- B. Minimum specimen bond strength is 200 psi.
 - 1. Perform additional pull-off tests if a pull-off test results in a bond strength less than the minimum specified to determine the extent of the low bond strength on the element.
 - a. Perform an additional pull-off test on each element of the same type at the bridge to determine the extent of the low bond strength.
 - 1) A column with low bond strength initiates tests on all columns at the bridge, for example.
 - 2. Additional testing may be required as determined by the Engineer.

3.6 FRP SYSTEM REPAIR

- A. Follow the authorized FRP System Repair procedure for the repair of delaminated areas, areas of insufficient bond strength, and areas damaged by pull-off tests.

3.7 PROTECTIVE COATING APPLICATION

- A. Extend the protective coating beyond the edges of FRP.

3.8 REPLACE REMOVED ELEMENTS

- A. Return soil and embankment to original grade.
- B. Replace elements removed as part of this work.
 - 1. Refer to Section 02741 for asphalt pavement.
 - 2. Refer to Section 02776 for concrete flatwork.
 - 3. Refer to Section 03932 for concrete slope protection.

END OF SECTION