



DIVISION 3 – CONCRETE

Section - 030130 – FRP STRENGTHENING OF CONCRETE

PART 1 - GENERAL

1.1 SUMMARY

- A. This specification is intended to define the minimum requirements of structural strengthening using externally bonded fiber reinforced polymer (FRP) composite systems.
- B. The work includes the furnishing of all materials, labor, equipment and services for the supply, installation and finish of all structural strengthening using externally bonded FRP systems.
- C. The general contractor or subcontractor shall furnish all materials, tools, equipment, transportation, necessary storage, access, labor and supervision required for the proper installation of the externally bonded FRP systems.

1.2 REFERENCED STANDARDS

- A. The publications listed below form a part of this specification to the extent referenced. Where a date is given for referenced standards, the edition of that date shall be used. Where no date is given for reference standards, the latest edition available on the date of the Notice of Invitation to Bid shall be used.
- B. International Code Council (ICC)
 - 1. ICC AC125, Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber Reinforced Polymer (FRP) Composite Systems.
 - 2. ICC AC178, Interim Criteria for Inspection and Verification of Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber Reinforced (FRP) Composite Systems.
- C. American Standard for Testing and Materials (ASTM)
 - 1. ASTM D7565, Standard Test Method for Determining Tensile Properties of Fiber Reinforced Polymer Matrix Composites Used for Strengthening of Civil Structures.
 - 2. ASTM D3039, Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials.
 - 3. ASTM D7522, Standard Test Method for Pull-Off Strength for FRP Bonded to Concrete Substrate.
 - 4. ASTM D4541, Standard Test Method for Pull-off Strength of Coating Using Portable Adhesive-Testers.

5. Fire Protection: ASTM E84 (regarding flame spread and smoke development requirement) and ASTM E119 (regarding hourly fire-rated requirement).

D. American Concrete Institute (ACI)

1. ACI 440.2R-08, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures.

E. International Concrete Repair Institute (ICRI)

1. ICRI Technical Guideline No. 310.2-1997 (formerly No. 03732), Guideline for Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays.

1.3 MATERIAL QUALIFICATIONS

1. Materials for the FRP system have been pre-qualified and shall be supplied by the following manufacturers:
 - a. Surtreat Solutions, Inc. (437 Grant St # 1210, Pittsburgh, PA 15219. Tel: (412) 281-1202.)
 - b. Alternate FRP system manufacturers must provide all items listed in Section 1.5 of this specification prior to the bid date; otherwise, such system shall be considered non-compliant.

1.4 ACTION SUBMITTALS

- A. Structural calculations and shop drawings performed by a Structural Engineer. Design shall follow criteria in Section 1.7 of this specification and be based on the clearly written performance criteria defined on the structural drawings.
- B. Working drawings shall detail the type, locations, dimensions, numbers of layers, and orientation of all FRP materials and coatings to be installed.

1.5 INFORMATIONAL SUBMITTALS

- A. Provide a current ICC Evaluation Service Report, compliant with the 2009 IBC, for the proposed products.
- B. If fire protection is required, provide approved U.L. rated assembly data for any required fireresistant finish (2 or 4 hour rated assembly per ASTM E119 or Class A Building, Flame Spread & Smoke Development per ASTM E84) as proposed with the FRP system. Note: Due to the temperature sensitive nature of FRP systems, no fire resistance system shall be allowed without the aforementioned U.L. rated assembly testing verification.

- C. Manufacturer's product data sheets indicating physical, mechanical and chemical characteristics of all materials used in the FRP system. Data sheets to also include properties of the cured FRP laminates as determined by laboratory testing in accordance with ASTM D7565 and/or ASTM D3039 (ultimate and design tensile modulus, stress and strain).
- D. Manufacturer's Material Safety Data Sheets (MSDS) for all materials to be used.
- E. Certification by the manufacturer that supplied products comply with local regulations controlling use of volatile organic compounds (VOC's). Products that require the use of respirators do not comply with local regulations controlling use of VOC's and shall not be allowed.

1.6 QUALITY ASSURANCE SUBMITTALS

- A. Submit manufacturer's specified QA/QC manual indicating product standards, physical and chemical characteristics, technical specifications, limitations, installation instructions, maintenance instructions and general recommendations regarding each individual material.
 - 1. Only epoxy resins will be accepted for construction of FRP systems referenced in this specification. Other resins, such as polyesters/vinyl esters, are not allowed as substitutes. The manufacturer shall clearly define the epoxy resin working time. Any batch that exceeds the batch life shall not be used.
- B. Durability Requirements: The proposed FRP systems shall be compliant with all testing requirements as per ICC AC125 and a current ICC Evaluation Service Report compliant with the 2009 International Building Code (IBC) shall be provided for all proposed products.
- C. Submit a list of completed surface bonded FRP composite strengthening projects completed with the manufacturer's FRP system in the past 3 years. The list should include at a minimum 25 projects with proposed FRP system, the dates of work, description and amount of work performed.
- D. All FRP composite systems shall be installed by certified applicator with written consent from manufacturer that the contractor has been trained. The certified applicator shall prove a minimum of 5 years experience in performing retrofits using FRP systems and submit a list of no fewer than 15 successful installations.
 - 1. The Engineer of Record may suspend the work if the Contractor substitutes an unapproved FRP system or unapproved personnel during construction.
- E. Identify a manufacturer approved testing laboratory that can perform the required ASTM D7565 and/or ASTM D3039 tests as per Section 3.4C of this specification, if required.
- F. Preinstallation Conference: Conduct conference at Project site.

1.7 PERFORMANCE

- A. Design the composite system to achieve the structural performance shown on the structural drawings and shall be submitted for approval by the Engineer of Record, and shall be performed by a Structural Engineer.
- B. Calculations shall conform to the requirements set forth in ACI 440.2R-08, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures and be based on the design modulus and associated area of the cured laminate for the FRP system to be installed. FRP laminate design values must be lower than the calculated mean determined from the test results of the ASTM D7565 and/or ASTM D3039 field test specimens.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS & COMPOSITE STRENGTHENING SYSTEM

A. Approved FRP system: FRP System and other products to be supplied by Surtreat Solutions Inc. Products include:

- 1. Composite fabric: SCH fiber – primary carbon fiber, unidirectional. SEH fiber – primary glass fiber, unidirectional.
Alternate primary carbon or glass fiber systems available upon request.
- 2. Surtreat TPS System (TPS II, TPS XII, Repel)
- 3. Surcoat AR
- 4. SurcoPrimer Layer I/II
- 5. FRP Anchors
- 6. Crack Injections

2.2 CERTIFIED APPLICATORS

- A. Installations of FRP Systems shall be performed by certified applicators only. Certified applicators shall have the minimum experience and written consent by the FRP manufacturer (See Section 1.6D of this specification).
- B. The certified applicator regarding the installation of all applications and systems described in drawings is Coordinated Systems Consulting, Inc.

PART 3 - EXECUTION

3.1 PRODUCT DELIVERY, HANDLING AND STORAGE

- A. Deliver epoxy materials in factory-sealed containers with the manufacturer's labels intact and legible with verification of date of manufacture and shelf life.



- B. Store materials in a protected area at a temperature between 40°F and 100°F.
- C. Products shall be stored according to the manufacturer's requirements and shall avoid contact with soil and moisture. Products shall be stored to avoid UV exposure.

3.2 SURFACE PREPARATION

- A. Slab Applications.
 - 1. Surtreat TPS System applied to all areas of deterioration and planned prolonging life sections as described in the drawings.
 - 2. Remove any loose material after Surtreat effective timing span has elapsed.

3.3 INSTALLATION

- A. Preparation work for project: Visit site to ensure that all patch work is complete and cured. Review project specifications in detail.
- B. Verify ambient and concrete temperatures. No work shall proceed if the temperature of the concrete surface is less than 40°F or greater than 100°F or as specified on the epoxy component labels. The ambient temperature and temperature of the components shall be between 40°F and 100°F, unless provisions have been made to ensure components' temperature is maintained within this range or the range specified by the manufacturer.
- C. Prepare the epoxy matrix by combining components at a weight (or volume) ratio specified by the manufacturer. The components of epoxy resin shall be mixed with a mechanical mixer until uniformly mixed, typically 5 minutes at 400-600 rpm.
- D. Components that have exceeded their shelf life shall not be used.
- E. Saturation of the fabric shall be performed and monitored according to the manufacturer's specified fiber-epoxy resin ratio. Fabric shall be completely saturated prior to application to contact surface in order to ensure complete impregnation. Saturation shall be supervised and checked by the certified installer. Both the epoxy resin and fabric shall be measured accurately, combined, and applied uniformly at the rates shown on the approved working drawings and per manufacturer's recommendations.
- F. All cutting of fabrics, mixing of epoxy and combination thereof shall take place in a protected area away from critical structure functions and any electrical equipment. G. Prepare surfaces as required, including corner preparation.
- H. Remove dust and debris by hand or with compressed air as per specification.
- I. Clean up and protect area adjacent to element where FRP system is being applied.

- J. Using a roller or trowel, apply one prime coat of epoxy resin to the substrate (2 mil min.). Allow primer to become tacky to the touch.
- K. Fill any uneven surfaces or recesses with thickened epoxy.
- L. Apply saturated fabric to substrate surface by hand lay-up, using methods that produce a uniform, constant tensile force that is distributed across the entire width of the fabric, and ensure proper orientation of the fabric. Under certain application conditions, the system may be placed entirely by hand methods assuring a uniform, even final appearance. Gaps between composite bands may not exceed 0.5" width in the fabric's transverse joint unless otherwise noted on project drawings. A lap length of at least 6" is required at all necessary overlaps in the primary fiber direction of the fabric.
- M. Apply subsequent layers, continuously or spliced, until designed number of layers is achieved, per project drawings.
- N. Using a roller or hand pressure, release or roll out entrapped air, and ensure that each individual layer is firmly embedded and adhered to the preceding layer or substrate.
- O. Detail all fabric edges, including termination points and edges, with thickened epoxy.
- P. Finish: All edges and seams must be feathered. Finish as specified between 24 and 72 hours after final application of epoxy. If finish is provided beyond 72 hours of the application of the epoxy, the surface must be roughened by hand sanding or brush blasting, prior to finishing.
- Q. System may incorporate structural fasteners but limitations and detailing must be verified with FRP system manufacturer.

3.4 INSPECTION AND TESTING

- A. Field Inspection
 - 1. The contractor shall monitor the mixing of all epoxy components for proper ratio and adherence to manufacturer's recommendations. Record batch numbers for fabric and epoxy used each day, and note locations of installation. Measure square footage of fabric and volume of epoxy used each day. Complete report and submit to Owner, engineer-of-record and FRP composite system manufacturer.
 - 2. If a Certified Special Inspector is required, the Certified Special Inspector shall periodically observe all aspects of preparation, mixing, and application. All FRP composite applied areas shall be inspected, in accordance with the manufacturer's specifications for voids, bubbles, and delaminations. All defective areas shall be repaired as per Section 3.5 in this specification.
- B. Direct Tension Adhesion Tests
 - 1. Direct tension adhesion testing shall be conducted using the method described by ASTM

D7522 and/or ASTM D4541. A minimum of one such test shall be performed for each 1,000 ft² (93m²) of surface area to be covered by the FRP application. Pull-off tests shall be performed on a representative adjacent area to the area being strengthened whenever possible. Tests shall be performed on each type of substrate or for each surface preparation technique used.

2. The epoxy bonded to the prepared surface shall be allowed to cure as per manufacturer's requirements before execution of the direct tension pull-off test. The locations of the pull-off tests shall be representative and on flat surfaces. If no adjacent areas exist, the tests shall be conducted on areas of the installed FRP system subjected to relatively low stress during service.
3. The minimum acceptable value for any pull-off test is 175 psi. The average of the tests shall not be less than 200 psi. Additional tests may be performed to qualify the work at each identified area. Each pull-off test is to exhibit a failure mode in the substrate and not the epoxy-to-substrate bond plane.
4. Test locations shall be filled with thickened epoxy after the values have been recorded and verified by the special inspector and the test dollies have been removed.

C. Laboratory Testing

1. Sampling
 - a. Record lot number of fabric and epoxy resin used, and location of installation. Measure square footage of fabric and volume of epoxy used each day. Label each sample from each day's production.
 - b. A "sample batch" shall consist of two 12" by 12" samples of cured composite (note: one 12" by 12" sample creates 5 coupons for ASTM D7565 and/or ASTM D3039 Tension Tests, see 3.4.C.3 of this specification). A minimum of one "sample batch" shall be made daily. Each sample of the "sample batch" will be taken at appropriate times during the day as to ensure the maximum material deviance in the components of the FRP composite.
2. Preparation of Samples
 - a. Prepare sample on a smooth, flat, level surface covered with polyethylene sheeting, or 16 mil plastic film, prime with epoxy resin. Then place one layer of saturated fabric and apply additional topping of epoxy. Cover with plastic film and squeegee out all bubbles.
 - b. Samples shall be stored in a sample box and not moved for a minimum 48 hours after casting. The prepared, identified samples shall be given to a pre-approved and experienced testing laboratory. The laboratory shall then precondition samples for 48 hours at 140°F before testing.
3. Material Tension Tests
 - a. 15 percent of all 12"x12" sample panels shall be tested. Testing specimens shall be cut from samples and tested for ultimate tensile strength, tensile modulus and percentage elongation as per ASTM D7565 and/or ASTM D3039 in the longitudinal fiber direction.



- b. Tensile properties must meet or exceed FRP composite system properties as defined in project specifications. If one coupon does not achieve the design properties, additional coupons from the same sample shall be tested. If these coupons fail (on average), coupons from the other 12-inch-by-12-inch sample, from the same batch for that day, shall be tested. If all tested samples of the sample batch do not meet the conditions of acceptance, it is recommended that 25 percent of all samples be tested.

D. Acceptance Criteria

- 1. FRP design values must be lower than the calculated mean determined from the test results received from the ASTM D7565 and/or ASTM D3039 field test specimens. Acceptable minimum values for ultimate tensile strength, tensile modulus, and elongation shall not be below the submitted design values unless calculations are performed using the tested values that exhibit an acceptable capacity as per the original design demands and concept.

3.5 REQUIRED REMEDIATION

- A. As shown on drawings.

3.6 CLEAN UP

- A. Remove all surplus material, equipment, and debris from the site on completion of the work. Leave the site clean.

END OF SECTION 030130