

1 GENERAL

1.1 DESCRIPTION OF WORK

1. This specification is intended to define the minimum requirements of structural strengthening using externally bonded fiber reinforced polymer (FRP) composite systems.
2. Work Includes:
 - A. Inspection of all structural members to be reinforced with FRP as per the contract drawings. Inspection shall verify all member locations and document all cracks and the existing conditions of the concrete substrate.
 - B. Furnishing all materials, tools, equipment, transportation, necessary storage, access, labor and supervision required for the proper installation of the externally bonded FRP composite system.
 - C. Coordination with other trades as necessary to complete the work per the contract drawings.

1.2 REFERENCE STANDARDS

General

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.

American Concrete Institute (ACI)

1. ACI 440.2R-17, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures.
2. ACI 562-16, Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary

American Standard for Testing and Materials (ASTM)

3. ASTM D3039, Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials.
4. ASTM D4541, Standard Test Method for Pull-off Strength of Coating Using Portable Adhesive-Testers.
5. ASTM D7522, Standard Test Method for Pull-Off Strength for FRP Bonded to Concrete Substrate.
6. ASTM D7565, Standard Test Method for Determining Tensile Properties of Fiber Reinforced Polymer Matrix Composites Used for Strengthening of Civil Structures.

International Code Council (ICC)

7. ICC AC125, Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber Reinforced Polymer (FRP) Composite Systems.
8. ICC AC178, Interim Criteria for Inspection and Verification of Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber Reinforced (FRP) Composite Systems.
9. ICC ESR-3499, Concrete Strengthening Using the MapeWrap™ FRP Composite Systems.

International Concrete Repair Institute (ICRI)

10. ICRI Technical Guideline No. 310.2R-2013, Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair.
11. ICRI Technical Guideline No. 310.1R-2008, Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion.
12. ICRI Technical Guideline No. 320.2R-2009, Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces.

1.3

SUBMITTALS

Product Information

1. The proposed FRP systems shall be compliant with testing requirements per ICC AC125. Provide a current ICC Evaluation Service Report, compliant with the 2015 International Building Code (IBC).
2. Manufacturer's technical data sheet indicating physical, mechanical and chemical characteristics of all materials used in the FRP system.
3. Independent laboratory testing for the required ASTM D7565 and/or ASTM D3039 test procedures for both the proposed FRP composite system and FRP anchor system (if required). Submit testing of a minimum of 25 specimens for each FRP composite system and FRP anchor system (if required) to verify the design modulus of elasticity as per Section 2.1.1.
4. Installation procedures, maintenance instructions, and general recommendations regarding each material to be used.
5. Manufacturer's Safety Data Sheets (SDS) for all materials to be used.
6. Certification by the manufacturer that supplied products complies with local regulations controlling use of volatile organic compounds (VOC's).

Project Information

7. Working shop drawings prepared and sealed by a licensed professional engineer detailing the type, number of layers, orientation, dimensions, and locations of all FRP materials to be installed.
8. Design calculations for the composite system shall be submitted for approval by the Engineer of Record, and shall be stamped by a licensed professional engineer. The composite system must meet the minimum equivalent stiffness requirement ($E \times A$) as indicated in Section 2.2.3 or equivalent to the $E \times A$ represented by the number of layers of the MapeWrap™ Composite System called out on the contract documents. If required, composite anchors must meet the minimum total weight per length for each size of anchor specified per Section 2.2.9.
9. Submit a quality control plan which indicates the testing to be completed to meet the requirements of section 3.5 of this specification as well as identify the party or parties responsible for performing this testing.

1.4 QUALITY ASSURANCE

Manufacturer / Supplier Qualifications:

1. Submit a list of completed surface bonded FRP composite strengthening projects completed with the manufacturer's FRP composite system in the past 5 years. The list should include at a minimum 50 projects with the proposed FRP system, the dates of work, type, description and amount of work performed.
2. The Manufacturer / Supplier must support a training program which provides instruction to applicators in the proper installation of the specified FRP system.

Applicator Qualifications:

3. Applicator must have written approval from the Manufacturer / Supplier to install the specified FRP system.
4. At least one field representative who has completed the training program provided by the Manufacturer / Supplier for the specified FRP system must be present on site at all times during installation of the FRP system.
5. The Engineer of Record may suspend the work if the Contractor substitutes an unapproved fiber reinforced composite system or unapproved personnel during construction.

1.5 PRODUCT DELIVERY, HANDLING AND STORAGE

1. Deliver materials in original factory-sealed containers with the manufacturer's labels intact and legible with lot number, date of manufacture, and shelf life listed.
2. Store materials in a protected area at a temperature between 50°F and 85°F (10°C and 30°C).

3. Products shall be stored according to the Manufacturer's most current technical data sheets.

1.6 COORDINATE WITH OTHER TRADES

1. Prior to application, the FRP Composite System contractor shall be briefed on any new or unusual construction procedures to ensure that they are aware of special conditions that may have occurred by the EOR and/or other trades on project (e.g. new penetrations, construction anomalies).

2 PRODUCTS

2.1 MANUFACTURER / SUPPLIER MATERIAL QUALIFICATIONS

1. Materials for the FRP system have been pre-qualified and shall be supplied by the following manufacturers:
 - A. MAPEI Corp. 1144 East Newport Center Drive, Deerfield Beach, Florida 33442
Tel: 1-888-876-2734, www.mapei.com/us
 - B. Approved alternate FRP manufacturer. Alternate FRP systems will be considered provided the contractor submits, prior to bidding the work, written notification of the proposed substitution to the Owner's Engineer. The proposed alternate FRP system must be of the same primary fiber type (e.g. carbon or E-glass fibers) and fiber orientation (e.g. uni-ax, bi-ax, quadri-ax) as the specified system(s). The written notification of the proposed substitution must include all of the following:
 - a. Documentation that the Manufacturer / Supplier of the proposed alternate system meets the requirements of sections 1.4.1, 1.4.2 and 2.2 of this specification
 - b. All information and testing required by section 1.3 of this specification
 - c. Calculations demonstrating the structural equivalency of the proposed alternate system based on equivalent stiffness (ExA).
 - d. A current ICC Evaluation Service Report, compliant with the 2015 International Building Code (IBC).

2.2 MATERIALS

FRP Composite System

1. All FRP composite systems must be proprietary systems comprised of all associated fiber reinforcement and polymer adhesives/resins. FRP systems comprised of fiber reinforcement and polymers from more than one Manufacturer are not permitted.

Fiber Reinforcement

2. Approved MapeWrap™ FRP Composite System fiber reinforcement includes:
 - A. MapeWrap™ C Uni-Ax 300
 - a. Uni-axial carbon fiber fabric
 - B. MapeWrap™ C Uni-Ax 600
 - a. Uni-axial carbon fiber fabric
 - C. MapeWrap™ G Uni-Ax 900
 - a. Uni-axial glass fiber fabric
 - D. Alternate primary carbon or glass fiber systems available upon request.
3. Typical design values utilizing FRP composite system with MapeWrap™ 31 epoxy saturant (dry-layup) can be found in table below:

	E (Design Modulus) (ksi)	t (Thickness per Layer) (in)	E x A** (Stiffness) (kip/in)
MapeWrap™ C Uni-Ax 300	12,161*	0.0199	242
MapeWrap™ C Uni-Ax 600	11,875*	0.0397	471
MapeWrap™ G Uni-Ax 900	2,586	0.0701	181

* As listed in ICC ESR-3499

** Cross sectional area based on a 1 in. width x thickness of the fiber

Polymer Components:

4. 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 shelf life shall not be used.
 - A. MapeWrap™ Primer 1
 - a. Epoxy primer used on bare, properly prepared substrate
 - B. MapeWrap™ 11 or MapeWrap™ 12
 - b. Epoxy putties used to level the properly prepared, primed substrate

C. MapeWrap™ 21

- c. Epoxy saturant used for Wet Lay-up applications

D. MapeWrap™ 31

- d. Epoxy saturant used for Dry Lay-up applications

Protective Coatings:

5. The FRP system shall be top coated with a coating approved by the FRP Manufacturer when exposed to UV or for aesthetical purposes as specified by the Engineer of Record.

6. Acrylic Coating

A. Elastocolor® Coat, Paint, or Flex

- a. As manufactured by MAPEI Corp. 1144 E. Newport Center Drive, Deerfield Beach, Florida 33442 Tel: 1-888-876-2734, www.mapei.com/us

7. Aliphatic Polyurethane

A. Mapefloor™ Finish 450

- a. As manufactured by MAPEI Corp. 1144 E. Newport Center Drive, Deerfield Beach, Florida 33442 Tel: 1-888-876-2734, www.mapei.com/us

8. Alternate finishes must be approved by the Owner / Engineer

Composite Anchors

9. Fiber anchors shall be supplied by manufacturer if needed. Anchors shall be prefabricated and shipped directly from the manufacturer. Anchor labels shall have the date of manufacture, the lot number and the minimum weight per unit length for each anchor size.

3 APPLICATION

3.1 CONDITION ASSESSMENT

1. Assess existing conditions to check the quality of the concrete substrate, locate potential obstructions, and verify the dimensions and geometry of the existing member to be strengthened match what is shown on the shop drawings.

3.2 EXPOSURE CONDITIONS

Environmental Conditions

1. The MapeWrap™ FRP system should be installed when the ambient temperature is between 40°F and 90°F (5°C and 32°C). In colder conditions it is permissible to use clean (electric or propane) auxiliary heat sources to raise the ambient temperature to a

suitable level. In warmer conditions, precondition the epoxy materials in ice baths and keep out of direct sunlight to extend the working time of the material.

2. Moisture on the surface of the substrate inhibits the successful adhesion of epoxies to the substrate. Do not install the MapeWrap™ FRP system when moisture is present on the surface of the substrate or when rainfall or condensation is anticipated.
3. Check for water leakage through cracks and concrete joints. Any seepage of water must be addressed prior to installing the MapeWrap™ FRP system.

Site Conditions

4. Maintain a clean work area. Surface preparation will generate much dust and debris, and should be cleaned up at the end of each day so that these loose materials do not inhibit the bond of the MapeWrap™ FRP system.

3.3 SURFACE REPAIRS AND PREPARATIONS

Concrete Repair

1. Unsound areas of the concrete substrate must be removed back to sound concrete. Existing coatings and/or materials with low compressive strength and elastic modulus such as plaster shall be removed from the substrate.
2. Repair all corrosion damage prior to installing the MapeWrap™ FRP system. Deteriorated concrete and corroding reinforcing steel shall be repaired per ICRI Guideline 310.1R-2008. Active corrosion must be addressed prior to applying the MapeWrap™ FRP system.
3. All voids in the concrete must be filled prior to application of the MapeWrap™ FRP system.
 - A. Voids greater than 0.50 inches in depth, considered large voids, shall be filled with an appropriate repair mortar. Select a suitable repair mortar per ICRI Guideline 320.2R-2009. If required per Engineer of Record's specifications, the bond strength of the repair material to the existing substrate may be verified per ASTM D 4541. The minimum direct pull-off strength required is 200 psi. Filling of large voids shall be paid as an extra to the contract work of installing the composite system.
 - B. Voids less than 0.50 inches in depth may be repaired with MapeWrap™ 11 or 12 epoxy putty or a suitable repair material per ICRI Guideline 320.2R-2009.
4. All cracks greater than 0.010 in wide must be pressure injected with epoxy or similar material as specified by the Engineer of Record.

Surface Preparation

5. The surface to receive the composite shall be free from fins, sharp edges and protrusions that will cause voids behind the installed FRP composite System or that, in the opinion of the Engineer of Record, will damage the fibers. These surfaces shall be either ground and smoothed to less than 0.04 in (1 mm) or leveled per section 3.3.3 of this

specification.

6. Where the fiber reinforcement is to be run around outside corners or edges, the corners must be rounded to a minimum radius of 0.75" (19.05 mm). No special detailing is required if the fibers are running parallel to the edge or corner.
7. Bond-critical Applications: When the cross-section of the concrete member is not completely encased by the FRP material, the surface of the concrete must be profiled to a minimum ICRI CSP 3 per ICRI Guideline 310.2R-2013. Surface contaminants such as laitance, surface lubricants, paint coatings, etc. must be removed by abrasive blasting and/or disc grinding. Dust generated from surface preparation operations must be removed from the substrate using suitable methods. Should dust be removed using water the surface must be thoroughly dried prior to commencing installation of the FRP system.
8. Contact-critical Applications: When the cross-section of the concrete member is completely encased by the FRP material, such as when wrapping columns, surface preparation should be such that continuous intimate contact between the concrete substrate and the FRP system. At a minimum, the surface shall be flat or convex to ensure proper load transfer to the FRP system and be free of dirt, dust, laitance, or other contaminants.

Fiber Anchor Applications (if required)

9. Mark locations and pre-drill holes for the fiber composite anchors. Provide beveled edges at entry and exit points as detailed.
10. Remove dust and debris from hole using compressed air, brooms, or vacuum.

3.4 INSTALLATION

1. Preparation work for project: Visit site to ensure that all patching is complete and fully cured. Review project specifications in detail to ensure no new penetrations or changes have been made.
2. Verify ambient and concrete temperatures. No work shall proceed if the temperature of the concrete surface is less than 40°F (5°C) or greater than 100°F (38°C) or as specified on the Manufacturer's technical data sheets for the epoxy. The ambient temperature and temperature of the components shall be between 40°F (5°C) and 100°F (38°C), unless provisions have been made to ensure components' temperature is maintained within this range or the range specified by the Manufacturer.
3. Prepare the epoxy primer, filler, or saturant (dependent on application step) by combining components at a weight (or volume) ratio specified by the manufacturer. Do not mix partial kits. The components of epoxy resin shall be mixed with a mechanical mixer until uniformly mixed, typically 3-5 minutes at 400-600 rpm and until homogenous in color and consistency.
4. Components that have exceeded their shelf life shall not be used.

5. Apply the FRP system primer to all areas of the concrete substrate where the FRP system is to be installed. Place uniformly per the Manufacturer's specified coverage rate and allow to cure per the Manufacturer's published installation instructions prior to proceeding.
6. The putty component of the FRP system is used to fill voids and level surface discontinuities prior to application of the fiber materials. The putty shall be allowed to cure per the Manufacturer's published installation instructions and rough edges and trowel lines of cured putty shall be ground smooth prior to proceeding.
7. The FRP fabric and saturating resin may be installed using either the Dry or Wet Lay-up Methods. In either case, sufficient saturating resin must be utilized to ensure complete encapsulation of the reinforcing fibers. The fibers must be pressed tightly against the substrate, free from any entrapped air. Refer to the Manufacturer's specified coverage rate for application of the saturating resin. The fibers must be pressed tightly against the substrate, free from any entrapped air. If a protective topcoat is to be used, broadcast oven dried silica sand to refusal into the final layer of saturating resin. Size and gradation of sand must be approved by owner and Manufacturer to ensure proper final appearance.
8. After all required layers of the fiber reinforcing have been applied, allow the system to sufficiently cure per the Manufacturer's published installation guidelines prior to applying a topcoat (where required). The topcoat shall be installed per the Manufacturer's recommendations.

3.5 QUALITY CONTROL

Field Documentation

1. A field supervisor that has completed the training program provided by the Manufacturer shall monitor all processes involved in the installation of the FRP system including surface preparation, epoxy component mixing, application of epoxies and fiber sheets, curing of the composite and application of protective coatings.
2. 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 of production and provide report to Engineer of Record and Manufacturer.

Field Inspection for Voids/Delaminations

3. The contractor shall allow a minimum of 24 hours for initial cure of the epoxy components.
4. Following initial cure, the contractor shall perform visual and acoustic tap test inspections of the installed FRP system.
5. Voids requiring repair shall be clearly marked and remediated per section 3.5.11 of this specification.

Bond Testing

6. Bond testing is only required for bond-critical applications, when direct tension pull-off testing shall be completed per ASTM D 4541 at a test frequency specified by the Engineer of Record. Contact-critical applications do not require bond testing.

7. The direct tension pull-off testing shall be completed under the following conditions:

- A. Allow the FRP system to cure for a minimum of 24 hours prior to execution of the direct tension pull-off test
- B. The locations of the pull-off tests shall be representative of typical project conditions. When possible, complete the test on areas of the FRP system subjected to relatively low service stress.

8. Test Frequency

- A. Perform a minimum of one direct tension pull-off test per _____ of installed FRP (surface area)

- B. Recommended Test Frequency

<u>Total Area of FRP to be Installed</u>	<u>Recommended Test Frequency</u>
0 to 1000 ft ² (0 to 100m ²)	1 test per 500 ft ² (50 m ²) of FRP
1000 to 5000 ft ² (100 to 500m ²)	1 test per 1000 ft ² (100 m ²) of FRP
5000 to 10000 ft ² (500 to 1000m ²)	1 test per 2000 ft ² (200 m ²) of FRP
Over 10000 ft ² (1000m ²)	1 test per 3000 ft ² (300 m ²) of FRP

- C. Pull-off tests must be executed on each type of concrete substrate or for each method of surface preparation used if variations in these conditions exist.

9. Criteria for Acceptance

- A. The failure mode of the pull test must be cohesive failure within the concrete substrate.
- B. The tensile bond strength as determined by the pull test must be greater than 200 psi (1.4 MPa)

10. Repair the tested areas per the requirements of section 3.5.11.C

Repair of Damaged or Defective Areas

11. Repair of delaminated areas of installed FRP reinforcement

- A. Small delaminations less than 2 in² each (1300 mm²) do not require corrective action provided the total delaminated area is less than 5% of the total laminate area and there are no more than 10 such delaminations per 10 ft² (1 m²).

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- B. Moderate delaminations less than 25 in² (16,000 mm²) may be repaired by filling the delamination by low-pressure injection of the epoxy saturant or by the following procedure specified for large delaminations.
- C. Large delaminations greater than 25 in² (16,000 mm²) shall be repaired by selectively cutting away the affected sheet, reapplying primer and putty, and applying an overlapping FRP patch of equivalent plies and fiber orientations.

3.6 **CLEAN UP**

- 1. Remove all surplus material, equipment and debris from the site on completion of the work. Leave the site clean and at no cost to the Owner, repair any damage to the new or existing structures, property or services caused by the installation and testing of the FRP composite.

END OF SECTION 03 01 00