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USACE / NAVFAC / AFCEC / NASA **UFGS-04 01 21 (October 2007)**

Preparing Activity: USACE **Superseding UFGS-04 01 21 (April 2006)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2014
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DIVISION 04 - MASONRY

SECTION 04 01 21

REHABILITATION OF REINFORCED AND UNREINFORCED MASONRY WALLS USING SURFACE APPLIED FRP COMPOSITES

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SECTION 04 01 21

REHABILITATION OF REINFORCED AND UNREINFORCED MASONRY WALLS USING SURFACE APPLIED FRP COMPOSITES
10/07

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NOTE: This guide specification covers the requirements for rehabilitation of masonry walls and is intended for use in defining those requirements for procurement of structural strengthening using fiber reinforced polymer (FRP) composite systems.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
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PART 1 GENERAL

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NOTE: In general, reinforced masonry is defined as masonry construction containing vertical bar reinforcement, horizontal bar or joint reinforcement, mortar, and grout combined so that the component materials will act together to resist the design loading conditions.

Masonry not meeting the above definition but bonded together with mortar and containing, if necessary, the minimum amount of reinforcement for crack control and vertical stiffeners, is classified as non-reinforced or unreinforced masonry (URM).

The project drawings should show all necessary details, architectural and structural, including wall sections, masonry bond and pattern, control joint locations, joint dimensions, reinforcement locations, anchors, bond beam and special units, masonry dimensions, and FRP composite details to complement this section.

Work covered by this specification will include the installation of near surface embedded fiber reinforced polymer (FRP) composite systems as structural repointing applied to masonry members. The work will include:

a. Inspection of the structural members specified on the contract drawings to be reinforced with FRP. The inspection must check the location for cracks and existing conditions of the masonry substrate.

b. Furnishing of materials, labor, equipment and all items necessary for rehabilitation of existing masonry members by application of externally bonded FRP composite systems as specified on the contract drawings and specifications.

c. Cooperation and coordination with all other trades in executing the work described in the overall contract.

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1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN CONCRETE INSTITUTE INTERNATIONAL (ACI)

ACI 440.2R	(2008; Errata 2009; Errata 2010) Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures
ACI 440.3R	(2012) Guide Test Methods for Fiber-Reinforced Polymer (FRP) for Reinforcing or Strengthening Concrete Structures
ACI 503.1-503.4	(1992, R 2003) Four Epoxy Specifications

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

ACGIH 0112	(2011) TLVs and BEIs

ASTM INTERNATIONAL (ASTM)

ASTM C581	(2003; E 2008; R 2008) Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures, Intended for Liquid Service
ASTM D2240	(2005; R 2010) Standard Test Method for Rubber Property - Durometer Hardness
ASTM D2563	(2008) Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts
ASTM D3039/D3039M	(2008) Tensile Properties of Polymer Matrix Composite Materials
ASTM D3045	(1992; R 2010) Practice for Heat Aging of Plastics Without Load
ASTM D3171	(2011) Standard Test Method for Constituent Content of Composite Materials
ASTM D4541	(2009; E 2010) Pull-Off Strength of Coatings Using Portable Adhesion Testers
ASTM E84	(2014) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM G154	(2012a) Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

ICC EVALUATION SERVICE, INC. (ICC-ES)

ICC ES AC125	(2007; R 2009; R 2010; R 2012) Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Fiber-Reinforced Polymer (FRP) Composite Systems

ICC ES AC178	(2003; R 2008) Acceptance Criteria for Inspection and Verification of Concrete and Reinforced and Unreinforced Masonry Strengthening Using Fiber-Reinforced Polymer (FRP) Composite Systems

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.1200	Hazard Communication

1.2 SYSTEM DESCRIPTION

1.2.1 Design Requirements

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NOTE: The resin system used in the FRP composite system seals up the surface of the wall where it is applied and can impede air and moisture migration through a wall. If the wall should not be sealed tight, full coverage of the wall with the FRP system should be avoided thus allowing normal air and water vapor transmission.
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The design of the FRP composite system shall conform to ACI 440.2R and shall provide [seismic] [wind] [and] [blast] strengthening for [clay] [and] [concrete] masonry walls. The strengthening design requires that walls with the FRP system applied fail by cracking through the masonry units and mortar prior to any delamination or rupture of the FRP composite system. Submit complete shop drawings for each installation of the composite system showing details of fiber architecture, fiber type, dimensions, number and thickness of layers, direction of fiber layers, sequence of layer applications, lap splices, joint and end details, anchorage of the FRP composite system, proposed connections to diaphragms and adjacent walls, and locations to be applied as specified. Submit Design Calculations for the FRP composite system for approval to the Contracting Officer, prepared by or on behalf of the Contractor to determine the layout of the FRP materials to be installed, stamped by a registered professional civil or structural engineer and conforming to requirements set forth in the ICC ES AC125 Acceptance Criteria based on tension force and strain limits. Provide an FRP system that does not adversely affect air and moisture permeation through the masonry walls.

1.2.2 Performance Requirements

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NOTE: Provide the parameters of strength or force that must be provided by the rehab. The following variables must be considered in determining the enhanced performance requirements: the load on the wall, the size of the wall, the wall aspect ratio, wall openings, etc.
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Provide the FRP composite system with [seismic] [wind] [and] [blast] strengthening for [clay] [concrete] masonry walls by [[_____]percent] [the quantity indicated on the shop drawings]. The system shall transfer [seismic] [wind] [and] [blast] loading in concert with the existing masonry

to the building foundation.

1.2.3 Submittal Requirements

The following shall be submitted:

a. System environmental durability test results conducted and reported by an independent testing facility; the report shall provide the following information:

(1) FRP System nomenclature
(2) Testing facility name
(3) Testing facility address
(4) Testing facility telephone number
(5) Testing facility point of contact
(6) Freeze-thaw test results
(7) UV test results
(8) Fire resistance test results

b. Test results by an independent testing facility on walls which are representative of the actual configuration and loading conditions for this contract, showing the following information:

(1) FRP System nomenclature
(2) Primer/filler system nomenclature
(3) Coating/finishing system nomenclature
(4) Testing facility name
(5) Testing facility address
(6) Testing facility telephone number
(7) Testing facility point of contact
(8) Test wall substrate material
(9) Test wall aspect ratio
(10) FRP fiber orientation and fiber density
(11) FRP composite application process
(12) Cyclic in-plane test results in accordance with ICC ES AC125 to include the following:

(a) Description of test setup.
(b) Rate and method of loading.
(c) Deformation and strain measurements.
(d) Modes of failure.

c. Manufacturer's printed installation instructions to include the following:

(1) Brand name

(2) Catalog numbers

(3) Names of manufacturers for each material to be used. Include with instructions the estimated quantity of each material to be used on the job.

(4) Detailed mixing and application instructions to include:

(a) Mixing instructions
(b) Curing times between coats or layers
(c) Application procedures for surface coatings
(d) Cold weather installation to include the minimum application

temperature recommended by the FRP system manufacturer or 4 degrees C 40 degrees F whichever is higher. Application at temperatures below 4 degrees C 40 degrees F shall be approved by the Contracting Officer and the minimum Shore hardness for the lower temperatures shall be provided.
(e) Hot weather installation to include the maximum application temperature recommended by the FRP system manufacturer or 38 degrees C 100 degrees F whichever is lower. Application at temperatures above 38 degrees C 100 degrees F shall be approved by the Contracting Officer and the minimum Shore hardness for the higher temperatures shall be provided.
(e) Inclement weather installations
(f) Application procedures of top coating material

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Quality Control[; G][; G, [_____]]

SD-02 Shop Drawings

FRP Composite System[; G][; G, [_____]]

SD-03 Product Data

Materials
Tensile Properties
Material Safety Data Sheets (MSDS)

SD-04 Samples

Materials[; G][; G, [_____]]
Anchors

SD-05 Design Data

Design Calculations[; G][; G, [_____]]

SD-06 Test Reports

Field Testing
Laboratory Testing
Wall Tests[; G][; G, [_____]]
Hardness Test

SD-07 Certificates

Materials[; G][; G, [_____]]
Regulatory Requirements
System Manufacturer[; G][; G, [_____]]
Contractor[; G][; G, [_____]]
Field Representative[; G][; G, [_____]]
Applicators[; G][; G, [_____]]

SD-08 Manufacturer's Instructions

FRP Composite System; G, [____]

SD-10 Operation and Maintenance Data

Record Retention; G, [____]

1.4 QUALITY ASSURANCE

Inform workers having access to the work area of the contents of the applicable material safety data sheets (MSDS) and of potential health and safety hazards and protective controls associated with materials used on the project. Submit data sheets for all materials to be used at the job site in accordance with OSHA and 29 CFR 1910.1200. The work area is one that may receive mists and odors from the rehab application and curing operations. Train workers in the safe handling and application of FRP materials and the exposure limit for each material that the worker will use or otherwise be exposed to during the course of the project. Instruct personnel having a need to use respirators and masks in the use and maintenance of such equipment.

1.4.1 System Manufacturer

The FRP composite system manufacturer shall have used the proposed materials system on a minimum of ten completed strengthening projects completed with the manufacturer's composite system. Submit certification including: the dates of work, type, description and amount of work performed, as well as a point of contact for the Contractor doing the work, and an owner representative to include name, address and telephone number.

1.4.2 Contractor

Completed a minimum of five FRP composite strengthening projects on vertical flat surfaces and a minimum of three of those jobs using the manufacturer's composite system. Submit the dates of work, type, description and amount of work performed, the FRP system installed for each project, and the name and telephone number of a contact person or owner for which the work was completed.. Submit the name and qualifications for its Field Representative who will perform the actual work supervision, the date certification course completed, and a list of a minimum of ten completed FRP composite strengthening projects of similar applications using the manufacturer's composite system. Include the dates of work, type, description and amount of work performed, and the name and telephone number of a contact person or owner for which the work was completed.

1.4.3 Applicators

1.4.3.1 Training

Submit certification that the FRP composite applicators have completed, as a minimum, a certification course provided by the FRP manufacturer, which includes hands-on application of FRP systems to masonry substrates. A field representative who has completed the course of instruction and has completed a minimum of ten FRP composite strengthening projects, three (3) using the manufacturer's composite system, shall be present onsite during all installation of the FRP system.

1.4.3.2 Experience

Only qualified applicators meeting these requirements and those having prior experience in the specified surface preparation and coating applications shall be assigned to perform the work described herein. Submit a syllabus of the certification course, as well as listing of past application projects completed by the applicators. Include the dates of work, type, description and amount of work performed, and the name and telephone number of a contact person or owner for which the work was completed.

1.4.4 Regulatory Requirements

Insure that the composite system used does not release volatile organic compounds (VOC) into the air in excess of the most restrictive of NIOSH RELs, OSHA PELs or ACGIH TLVs for worker or occupant exposure during installation and/or over the useful life of the structure. If VOCs exceed any of these exposure limits during installation or use, provide additional ventilation for the duration of the excess outgassing. Ensure that at no time will they exceed STEL, even if additional ventilation or air supply is provided. Provide the necessary equipment to comply with these requirements. Once cured, insure the FRP composite system does not exhibit any detectable odor at a distance of 300 mm one foot from the FRP surface.

Submit certification that resins proposed for use meet Federal VOC regulations and those of the local Air Pollution Control Districts having jurisdiction over the geographical area in which the project is located.

1.4.5 Pre-installation Meetings

Prior to commencement of any work, arrange and conduct a meeting between the Contracting Officer, Contractor, and the independent special inspector to discuss the project requirements. Review the requirements of the Specification and overall project requirements. Review and discuss all aspects of the project including containment, environmental control, surface preparation, strengthening system application, quality assurance, schedule requirements, and safety. Request clarification of any ambiguities, and advise the Contracting Officer of any potential conflicts and/or any technical requirements that appear improper or inappropriate.

1.5 DELIVERY, STORAGE, AND HANDLING

1.5.1 Labeling

Deliver polymer resin materials in original factory-sealed containers with the manufacturer's labels intact and legible with verification of product nomenclature, manufacturer's name, product identification and batch number, date of manufacture and shelf life or expiration date. Do not use polymer resin materials that have exceeded the shelf life.

1.5.2 Storage

Store materials in a covered, well-ventilated area protected from exposure to any detrimental conditions including: airborne contaminants, dirt, dust, sunlight, temperatures lower than 4 or greater than 38 degrees C 40 or greater than 100 degrees F, rainfall, sparks or flame and in accordance with the manufacturer's requirements. Store polymer resins separate from their hardeners.

1.6 PROJECT/SITE CONDITIONS

1.6.1 Environmental Requirements

1.6.1.1 Application Temperature

a. Do not apply primers, saturating resins and adhesives to cold or frozen surfaces. When the surface temperature of the masonry surface falls below a minimum level, as specified by the FRP system manufacturer, the work will cease until both the air and masonry temperature rise above the specified minimum. Supplemental sources of heat shall not be used to raise the air or masonry surface temperature unless approved by the FRP composite system manufacturer.

b. When the surface temperature of the masonry and/or the air temperature rise above the maximum level as specified by the FRP system manufacturer, the work will cease until both the air temperature masonry temperature cool below the specified maximum.

1.6.1.2 Wet or Damp Surfaces

Unless they have been formulated for such applications, do not apply resins and adhesives to damp or wet surfaces.

1.6.1.3 Breathable Wall Surfaces

Do not completely cover masonry surfaces that are designed to allow air and vapor transmission with FRP systems.

1.6.2 Existing Conditions

As-built drawings of the structure [are attached] [can be accessed at [_____]].

1.6.3 Work Coordination

Coordinate work to minimize exposure of building occupants, other Contractor personnel, and visitors to dust, mists, and odors from preparation, FRP system application and clean-up operations.

1.7 WARRANTY

Furnish a warranty (either by the manufacturer or Contractor) for FRP composite system installation. Insure the warranty covers the FRP composite system [design,] installation, bond to the substrate, and interlaminar bond, as well as mechanical property retention, and fabric-resin compatibility. The warranty shall run directly to the Government and shall cover a period of not less than 5 years from the date of Government's acceptance.

PART 2 PRODUCTS

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NOTE: FRP system forms can be categorized based on how they are delivered to the work site and installed. Externally applied FRP composite systems come in a variety of forms including wet lay-up systems, prepreg systems, and precured systems.

Wet lay-up FRP systems consist of dry unidirectional or multi-directional fiber sheets or fabrics that are impregnated onsite with a saturating resin. The saturating resin is used to bond the sheets to the masonry surface. Wet lay-up systems are saturated with resin and cured in place and in this sense are analogous to cast-in-place concrete. For dry lay-up systems, the fabric is placed on the wall and then saturated in-place with resin and cured in place.

Prepreg FRP systems consist of unidirectional or multidirectional fiber sheets or fabrics that are preimpregnated with a saturating resin in the supplier's facility. Prepreg systems are bonded to the concrete surface with or without an additional resin application, depending upon specific system requirements. Prepreg systems are saturated offsite and, like wet lay-up systems, are cured in place. Prepreg systems usually require heat for cure.

Precured FRP systems consist of composite shapes (plates, strips, ribbons, and bars configured as an open mesh grid or solid laminate) manufactured in the system supplier's facility and shipped to the

job site. Typically, an adhesive is used to bond the precured shapes to the masonry surface.

It is important that only one system manufacturer supply all materials system components (reinforcements, resins and adhesives) for a specific job. The arbitrary selection of a fiber reinforcement and a resin/matrix material can lead to failure of the FRP composites system due to matrix-reinforcement incompatibilities and are, therefore, not allowed.

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2.1 MATERIALS

Do no substitute the submitted reinforced FRP composite system or any of its components during the course of the project. Submit manufacturer's product data sheets indicating physical, mechanical, and chemical characteristics of all materials used in the FRP system application and certification from the system manufacturer of the guaranteed material and section properties for the supplied material. As a sample, also submit an FRP plate 300 x 300 mm 12 x 12 inches or plate of equivalent area when one of the fiber reinforcing dimensions is less than 300 mm 12 inches.

2.2 MANUFACTURED PRODUCTS

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NOTE: The values listed in the following table should be provided by the design engineer and be based on the values and assumptions that were used in developing the rehab design. The items in Table 1 below will be the minimum acceptable property values for the FRP system to be installed and potential FRP systems submitted which do not meet these minimums should be rejected.

Submittals must demonstrate that the proposed materials will match the intent of the engineering design using the properties listed above. Proposed FRP systems must utilize the same primary fiber reinforcement type (e.g., carbon fiber, aramid fiber, or E-glass fiber) as the system listed above.

Proposals for material systems must include, at a minimum, documented evidence that the Manufacturer of the proposed system meets the requirements of Table 1, and demonstrate the structural equivalency of the proposed system to the system(s) specified.

****

Table 1 lists the minimum allowable gross laminate properties for the cured [glass] [carbon] [aramid] [hybrid] reinforced FRP composite system. Submit values for the Tensile Properties of the composite material as determined by tensile testing in accordance with ASTM D3039/D3039M, elastic modulus determined by the strength and rupture strain values and ultimate tensile strength and rupture strain values determined by subtracting three (3) standard deviations from the average values of twenty (20) or more tensile tests.

TABLE 1		
	FRP COMPOSITE REQUIREMENT	TEST METHOD
Elongation: max.	[_____] percent	ASTM D3039/D3039M
Guaranteed Tensile Strength, min., in primary fiber direction	[_____] kPa psi	ASTM D3039/D3039M
Ult. Breaking Load, min., in primary fiber direction width	[_____] kg/mm lb/in	ASTM D3039/D3039M
Modulus of Elasticity, min. based on cross sectional area of primary fibers	[_____] kPa psi	ASTM D3039/D3039M
Percent Tensile Strength Retained after: 7 days exposure at 100 percent humidity	[_____] percent	ASTM G154
2,000 hours exposure to UV	[_____] percent	ASTM G154
3,000 hours exposure to ozone	[_____] percent	ASTM C581
3,000 hours exposure to alkali	[_____] percent	ASTM C581
3,000 hours exposure to salt water	[_____] percent	ASTM C581
3,000 hours exposure at 60 C 140 F	[_____] percent	ASTM D3045
Guaranteed Tensile Strength at 90 degrees to primary fibers, min.	[_____] kPa psi	ASTM D3039/D3039M
Ultimate Tensile Strength of Lap Splices in Primary Fiber Direction	[_____] kPa psi	ASTM D3039/D3039M
Ply Thickness	[_____] mm inch	ASTM D3039/D3039M
Fiber Volume Fraction	[_____] percent	ASTM D3171
Visual Defects	Acceptance Level [_____]	ASTM D2563

2.3 COMPONENTS

2.3.1 FRP Composite System

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NOTE: Select the appropriate system from the three

choices below and delete the others.
****

2.3.1.1 Wet Lay-up System

A wet lay-up FRP system consists of [glass] [carbon] [aramid] fiber in [an epoxy] [a polyester] [a polyurethane] resin.

2.3.1.2 Prepreg System

A prepreg FRP system consists of [glass] [carbon] [aramid] fiber in an uncured polymer resin.

2.3.1.3 Precured System

A precured FRP system consists of [glass] [carbon] [aramid] fiber, fabricated as [strips] [plates] [ribbons] [bars] in [an open mesh grid] [a solid laminate] configuration with a resin matrix of [vinyl ester] [polyester] [epoxy] [polyurethane] [specialty resin] applied to the surface of the masonry wall using [a polyurethane] [an epoxy] structural adhesive.

2.3.2 Use of Primer/Filler

The primer/filler used for the protective seal coat and for filling voids consists of a thickened [epoxy] [polyester].

2.3.3 Finish and Coating

Perform final finish and apply architectural coatings as prescribed in architectural specifications and drawings [_____].

2.4 ACCESSORIES

2.4.1 Anchors

Install anchors for the FRP system as prescribed by the FRP system manufacturer and designated in the Shop Drawings. Submit two of each type of anchor to be used.

2.4.2 Miscellaneous

Provide other materials as needed for the proper installation of the complete composite system as specified.

2.5 MIXES

Mix [Resins] [Adhesive] in accordance with the FRP system manufacturer's recommended procedure. Assure that all [resin] [adhesive] components are at a proper temperature and are mixed in the correct ratio until there is a complete mixing of components and a uniform color. Mix each batch of [resin] [adhesive] in quantities sufficiently small to ensure that all mixed [resin] [adhesive] can be used within the [resin] [adhesive] pot life. Do not use mixed [resin] [adhesive] that exceeds its pot life as defined by the system manufacturer.

[2.6 FLAME SPREAD/FIRE PROTECTION

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NOTE: Unless stated otherwise by the local fire

building code, this paragraph may be deleted if the FRP materials are installed on the exterior of a structure or if a flame barrier is installed between living space and the FRP materials system.

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Meet requirements for Class 1 fire rating in accordance with ASTM E84 and meet or exceed local building code requirements for flame spread and smoke generation.

]PART 3 EXECUTION

3.1 SUBSTRATE, TEMPERATURE, AND ENVIRONMENT

3.1.1 Examination

Examine existing conditions to assess the quality of the masonry substrate, identify potential obstructions, and verify dimensions/geometries shown on shop drawings.

3.1.2 Environmental Temperature

Should the potential for adverse temperatures occur during installation, stop the application of FRP until temperatures return to within the range specified in the Manufacturer's Instructions. Obtain approval from the FRP manufacturer and the Contracting Officer before using supplemental heating or cooling sources.

3.1.3 Other Environmental Factors

Should the potential for direct contact by rain, dust or dirt, excessive sunlight, high humidity, or vandalism occur during installation, temporary protection may be required until the resins have cured. Provide and install tents and/or plastic screens as required to protect the FRP system as it cures. Assure resins are cured before removal of temporary shoring or allowing the structure to be exposed to new loads. In the event of suspected damage to the FRP system during installation, notify the Contracting Officer. Repair any damage caused by installer negligence at no additional cost to the Government.

3.2 PREPARATION

3.2.1 Materials Testing

Assure that delivered FRP materials meet the specified requirements prior to starting the project. This may require laboratory testing. Reject all materials that do not meet the minimum requirements, as specified in Table 1 and by the Contracting Officer. In addition, determine the gel time, pot life, and curing hardness of the resins.

3.2.2 Worksite Ventilation

Ventilate work areas during FRP application so that worker exposure to chemical substances does not exceed limits established by ACGIH 0112, or required by a more stringent applicable local regulation. Ventilate interior work zones having a volume of 280 cubic m 10,000 cubic ft or less at a minimum of 2 air exchanges per hour. Maintain ventilation in larger work zones by means of mechanical exhaust. Exhaust solvent vapors outdoors, away from air intakes and workers. Temporarily seal return air

inlets in the work zone before start of work until the polymer resin has cured.

3.2.3 Substrate Repair

3.2.3.1 Surface

[The area to receive FRP composite is relatively sound structurally.] [There are known problems associated with the condition of the original masonry and the masonry substrate that can compromise the integrity of the FRP system.] [Fill surface cracks greater than 1.6 mm 1/16-inch to a minimum depth of 25 mm 1 inch.] [Remove areas of loose or spalling masonry material.]

3.2.3.2 Sub-Surface

Do not apply externally bonded FRP systems to masonry substrates containing corroding reinforcing-steel. Note and report evidence of localized cracking and/or spalling at grouted cells or of rust stains to the Contracting Officer. Do not proceed with work until the cause(s) of the corrosion is addressed and the corrosion-related deterioration repaired.

3.2.4 Surface Preparation

3.2.4.1 Surface Cleaning

Remove all loose or unsound materials and other conditions that would inhibit bond such as laitance, dust, dirt, oil, curing compound, existing paint or coatings, efflorescence, and any other matter that could interfere with the bond of the FRP system from the masonry or repaired surfaces to which the FRP system is to be applied.

3.2.4.2 New Masonry Preparation

Unspoiled new masonry only requires wire brushing to remove loose surface particles.

3.2.4.3 Old Clay Masonry Preparation

Prepare surface of older clay masonry using hand tools, power tools or water blasting techniques. Do not use abrasive blasting.

3.2.4.4 Old Concrete Masonry Preparation

Concrete masonry may be blasted using a light blast abrasive or cleaned using hand tools, power tools or water blasting techniques.

3.2.4.5 Cleaned Surface Protection

After the cleaning operations are complete, protect the surface prior to FRP installation so that no materials that may interfere with bond are redeposited on the surface. Apply the FRP composite system to the prepared wall within 72 hours of performing the surface preparation.

3.2.5 Surface Plane Variation Tolerance

3.2.5.1 Tooled Mortar Joints

Fill all tooled mortar joints with putty or another epoxy-based paste with

adequate bonding properties to the masonry substrate to make them flush with the adjacent clay masonry unit or concrete block. Ensure that localized out-of-plane variations between masonry units do not exceed 1.6 mm 1/16-inch or the tolerances recommended by the FRP system manufacturer, whichever is less. Smooth localized out-of-plane variations in the masonry units using putty as needed. It is not necessary to screed filler onto the surface to fill all bug holes. Fill larger holes greater than 6 mm 1/4 inch in diameter and other voids with putty.

3.2.5.2 Untooled Mortar Joints

Grind or chisel untooled mortar joints that protrude beyond the masonry surface or other protuberances or irregularities flush with the surface.

3.2.6 Obstructions, Corners and Non-Planar Surfaces

Obstructions, re-entrant corners, concave surfaces and embedded objects can affect the performance of the FRP system. Modify as necessary. Movable obstructions and embedded objects may need to be removed prior to installing the FRP system. [Give special care to re-entrant corner detailing and concave surface detailing to ensure that the bond of the FRP system to the substrate is maintained.]

3.2.7 Surface Moisture

Ensure that all surfaces to receive the strengthening system are as dry as recommended by the FRP system manufacturer. Evaluate moisture content in accordance with the requirements of ACI 503.1-503.4 standard specification applicable to the application.

3.3 FRP INSTALLATION

Do not install the FRP composite if the ambient air temperature or substrate surface temperature exceeds that recommended by the system manufacturer. Do not install the FRP composite when surface moisture is present on the substrate or when rainfall or condensation is anticipated in the work areas.

3.3.1 Primer

****

NOTE: Wet lay-up systems typically require a primer to saturate and penetrate the masonry surface and enhance the bond strength of the FRP system. Adhesives used with pre-cured systems, depending upon its chemistry, may not require use of a primer.

Delete this paragraph if not required in the project.

****

a. Mix primers according to the FRP system manufacturer's installation instructions. Assure resin components are at a proper temperature and mixed in the Manufacturer's prescribed mix ratio for its prescribed mixing time until there is a uniform and complete mixing of components.

b. Apply primers to areas on the masonry surface where the FRP system is to be placed. Place primer uniformly on the prepared surface at the manufacturer's specified rate of coverage. Allow primer to cure to the degree specified by the FRP manufacturer before applying subsequent

materials.

3.3.2 Putty/Filler

Assure putty/filler used is compatible with the FRP strengthening system and complies with the FRP system manufacturer's specifications. Use putty or another epoxy-based paste with adequate bonding properties to masonry only to fill voids and smooth surface discontinuities prior to application of other materials. Allow putty to cure to the degree specified by the FRP manufacturer before applying subsequent materials. Grind rough edges or trowel lines of cured putty smooth prior to continuing the installation.

3.3.3 Wet Lay-Up and Prepreg Systems

Install the FRP system in strict accordance with the FRP system manufacturer's recommendations. Apply sufficient saturating resin to achieve full saturation of the fibers in accordance with the manufacturer's specifications. Release or roll out entrapped air between layers before the resin sets. Place successive layers of saturating resin and fiber materials before complete cure of the previous layer of resin. Handle sheet and fabric materials in a manner to maintain the fiber straightness and orientation. Remove and repair fabric kinks, folds, or other forms of severe waviness.

3.3.4 Precured Systems

Install the FRP system in strict accordance with the FRP system manufacturer's recommendations. Uniformly apply adhesives to the prepared surfaces where pre-cured systems are to be placed. Apply adhesives at a rate recommended by the FRP manufacturer to ensure full bonding of successive layers. Release or roll out entrapped air between layers before the adhesive sets.

3.3.5 Lap Splices

[Stagger lap splices unless noted otherwise in the Shop Drawings and by the Contracting Officer.] [Lap splices are not permitted except as shown in the Shop Drawings.]

3.3.6 Curing of Resins

Inspect the primer and FRP resin to ensure proper cure according to the manufacturer's recommendation. Field modification of resin chemistry is not permitted.

3.3.7 Surface Finish - Coating Application

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NOTE: Only those surfaces exposed to direct sunlight and weather require surface finish coating. There may also be applications where it is desired for architectural reasons or aesthetics.
****

3.3.7.1 Preparation

Apply paints and coatings prior to final resin cure for best results. After the FRP resin has cured, the coating can be applied by performing a light dust blast of 30-mesh silica sand (or equivalent method) to break the

gloss finish in preparation of a finish coating. Remove dust and residue from all surfaces by flushing with clean water before applying the coating. Assure all surfaces are dry before applying the surface finish coating.

3.3.7.2 Multiple Coats

Use coatings compatible with the FRP strengthening system and applied in accordance with the manufacturer's recommendations. Apply two finish layers of coating according to the coating manufacturer's instructions prior to full cure of the FRP system.

3.3.8 Installation Procedure Modification

Installation procedures may be modified to achieve maximum results, subject to approval by the Contracting Officer. Procedural modifications approved by the Contracting Officer prior to implementation are allowed.

3.3.9 System Placement Tolerances

Follow FRP ply orientation and ply stacking sequence in accordance with that shown in the Shop Drawings. Assure variations in angle from the intended direction of fiber alignment prescribed in the Shop Drawings are less than 5 degrees.

3.4 WALL FEATURE COMPATIBILITY

3.4.1 Weep Holes

Maintain all weep holes. Ensure that no resin enters existing weep holes. Do not cover existing weep holes with the FRP composite.

3.4.2 Construction Joints

[3.4.2.1 Control Joints

Maintain all CMU control joints. Ensure that the FRP composite does not bridge existing control joints.

][3.4.2.2 Expansion Joints

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NOTE: Design loads must be evaluated to determine whether or not to maintain existing expansion joints.

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[Maintain all clay masonry expansion joints.] [Those expansion joints indicated on the shop drawings shall be maintained.] Ensure that the FRP composite does not bridge existing expansion joints.

][3.4.3 Diaphragms

Anchor the FRP system into the floor and ceiling diaphragms in accordance with the Shop Drawings. Ensure anchorage does not create local stresses that may locally fracture the walls when deflection occurs due to out-of-plane loading.

]3.5 QUALITY CONTROL

Maintain quality assurance and quality control (QA/QC) programs and criteria. Provide full inspection of the surface preparation and composite systems applications to ensure full compliance with the specified requirements. Submit a quality assurance plan for installation and curing of all FRP materials to include personnel safety issues, installer certification, application and inspection of the FRP system, location and placement of splices, curing provisions, means to assure dry surfaces, quality assurance samples and cleanup. The plan will indicate the testing that will be performed and identify the party or parties responsible for this testing.

3.5.1 Independent Special Inspector

Provide a special inspector, trained and certified by the FRP system manufacturer and approved by the Contracting Officer. The Special Inspector shall not be an employee of the Contractor or be financially associated with the Contractor beyond the inspection contract. The Special Inspector shall perform inspections in accordance with this specification and ICC ES AC178.

3.5.2 Laboratory Qualification

The testing laboratory shall be one approved by the Engineer of Record, the Contracting Officer and the Contractor. The laboratory shall have experience in testing FRP materials and have performed ASTM D3039/D3039M wall tests for at least three (3) different Contractors prior to this contract. Submit the results of the wall tests.

3.6 LABORATORY TESTING

3.6.1 Witness Panels

3.6.1.1 Wet Lay-up and Prepreg

Fabricate witness panels onsite using installation procedures identical to the method used to install the FRP system to the masonry surfaces. Fabricate two witness panels for each day of production or one for each 46 square m 500 square ft of production whichever is more. From a standard polymer resin mix, saturate a 300 x 300 mm 12 x 12 inch piece of fabric according to specified fiber-resin ratio. On a smooth, flat, level surface covered with polyethylene sheeting or 0.4 mm 16-mil plastic film, prime the surface with polymer resin and then prepare the witness panel by placing two layers of saturated fabric oriented in the same direction on the flat surface. Apply an additional topping of polymer resin and cover the completed sample with plastic film and squeegee out all bubbles. Store samples in a sample box at the work site and do not move them for a minimum 48 hours after casting. Mark the panels with the date of fabrication, location of application, number of plies and primary fiber direction. Ship the samples within two weeks of fabrication to the pre-approved testing laboratory for evaluation.

3.6.1.2 Precured

Witness panel samples for precured sheet and strip material are the width of the procured sheet and a length sufficient to achieve 92,900 square mm 144 square inches in total area taken randomly from the material received at the job site.

3.6.2 Panel Testing

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NOTE: Due to the sensitivity of ASTM D3039/D3039M, not all testing laboratories are capable of performing this test. The testing laboratory used shall have a history of performing ASTM D3039/D3039M tests prior to the contract.
****

Determine lap splice strength, tension strength, and elastic modulus of FRP materials. Test not fewer than two (2) coupons from each witness panel in the laboratory in accordance with ASTM D3039/D3039M. If one coupon from a witness panel fails to meet the minimum strength specified in Table 1, test five (5) additional coupons from the witness panel with the failed coupon. If a second one fails, test five (5) coupons from all panels for that day of production. Take appropriate remedial measures to ensure integrity of the FRP system applied for the day the failed witness panels were prepared. In addition, test a minimum of five (5) coupons from each witness panel for the remainder of the job or until ten successive witness panels are tested with no coupon failures. Then two (2) coupon tests per witness panel may be resumed. The Contracting Officer may waive or alter the frequency of testing.

3.6.3 Report

The laboratory shall report the mechanical properties of the witness panels in accordance with ASTM D3039/D3039M. Submit a copy of the report to the Contracting Officer and Special Inspector for review.

3.7 FIELD TESTING

3.7.1 Mixed Resin Hardness

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NOTE: The term "resins" include primers, saturating resins, binders, and adhesive components.

The required resin samples are a minimum of 1/4-inch (6.4 mm) in thickness, whereas FRP placed on a wall is much thinner, typically 1/8-inch (3.2 mm) or less. During initial stages of curing, thicker cross sections tend to be softer than thin ones. There is, therefore a variation in the required hardness to account for this phenomenon.
****

Prepare two samples of each mixed resin, primers, binders, saturants, and adhesives, per day from two, separate, nonconsecutive batches of each. The resin samples should be a minimum of 3.2 mm 1/8-inch thick and 50 mm 2 inches in diameter. Retain the mixed resin samples for testing to evaluate curing progress.

3.7.1.1 Testing

Evaluate relative curing progress of the resin on the job site by measuring the hardness of the resin sample at 24 hours and 48 hours of cure in accordance with provisions of ASTM D2240. Ensure the polymer resin exceeds

the Shore hardness reported by the manufacturer evaluated at the lowest air temperature for the curing time period. Take measurements at a minimum of three different points distributed over the resin specimen's surface at least 6.4 mm 1/4-inch apart from each other.

3.7.1.2 Report

Report the mean hardness value obtained, resin identification and manufacturer, resin batch number, resin mixing date and time, test date and time, air temperature when the resin was mixed, air temperature when the testing was performed, the minimum air temperature for the curing period, and the type and serial number of durometer used. Submit test reports as specified.

3.7.1.3 Remedial Measures

In the event that measured hardness is less than the manufacturer's reported hardness for the temperature range, take remedial measures as specified.

3.7.2 In-Place FRP Hardness

3.7.2.1 Testing

Evaluate relative curing progress of the in-place FRP resin at 24 hours and at 48 hours using the Shore Durometer hardness test in ten-degree intervals between 4 and 38 degrees C 40 and 100 degrees F for both neat resin and for FRP laminate on masonry substrate.as described in ASTM D2240. Perform a minimum of five tests on each 9.3 square m 100 square ft of wall or portion thereof with FRP composite applied to it. Ensure the Shore hardness exceeds the manufacturer's values for the time period measured and the lowest air temperature during that time period. Submit minimum Shore hardness values for fully cured resin and fully cured FRP laminate on masonry substrate.

3.7.2.2 Report

Report both the individual and mean hardness values obtained, the locations where each hardness test was performed, the FRP application date, test date and time, air temperature when the FRP was applied, air temperature when testing performed, and the type and serial number of durometer used.

3.7.2.3 Remedial Measures

In the event that hardness is less than the manufacturer's reported hardness for the temperature range, take remedial measures as specified. For any structural member where testing indicates that the installed composite system does not meet the minimum specified hardness values, immediately halt the FRP installation and notify the Contracting Officer. Remove the affected, installed FRP composite at no expense to the Government and replaced with FRP composite meeting or exceeding the minimum hardness values.

3.7.3 Adhesion Strength

3.7.3.1 Testing

a. Using the method described by ACI 440.3R or ASTM D4541 conduct direct tension adhesion testing of cored samples. Perform a minimum of three

tests for each day of production or for each 46 square m 500 square ft of FRP application, whichever is less. Perform pull-off tests on each area of fiber sheet installed on a single day. Perform tests on each type of masonry substrate or for each surface preparation technique used.

b. Allow the FRP system to cure a minimum of 24 hours before execution of the direct tension pull-off test. The locations of the pull-off tests shall be representative and on flat surfaces. If possible, conduct the tests on areas of the FRP system subjected to relatively low stress during service. The minimum acceptable value for any single tension test is 1.2 MPa 175 psi. The average adhesion strength of the three tests at each location shall not be less than 1.38 MPa 200 psi. The tension adhesion tests shall exhibit failure of the masonry substrate indicated by a layer of masonry on at least 80 percent of the underside of the test puck following the test.

3.7.3.2 Report

Report the adhesive strength values for each test and the average strength for each day's production. Report the type of failure for each. Report No adhesion of the masonry to the FRP surface adhered to the test puck to the Contracting Officer.

3.7.3.3 Remedial Measures

In the event that the adhesive strength does not meet the minimum allowable strength, take remedial measures. Halt FRP installation and notify the Contracting Officer. Remove affected, installed FRP composite at no expense to the Government. Clean the substrate surface and apply FRP composite that meets or exceeds the minimum specified values.

3.7.3.4 Test Repair

After testing, fill the hole in the FRP composite with putty and smooth it. Apply a 4-inch (100 mm) or more overlapping sheet patch of equivalent plies over the location where the sample was taken.

3.7.4 Laminate Thickness and Number of Plies

Measure the cured laminate thickness and count the number of plies. Avoid taking samples from high stress areas or splice areas. Where laminate is too thin or not having sufficient plies, add additional plies to meet design specifications.

3.8 QC/QA INSPECTION

3.8.1 Special Inspector Duties

Inspect the FRP composite overlay during and immediately following application of the composite. Inspect FRP systems and all associated work as required by the applicable codes and as described in the QA/QC plan. Observe all aspects of onsite preparation and material application including surface preparation, resin component mixing, application of primer, application of resin and fiber sheet, curing of composite, and the application of protective coatings. The special inspector shall require compliance with the design drawings and specifications.

3.8.2 Daily Inspection Records

Include in daily inspection records:

a. Date and time of installation;
b. Ambient temperature, relative humidity, and general weather observations;
c. Surface temperature of the masonry receiving the FRP composite system;
d. Surface dryness;
e. Surface preparation methods;
f. Surface cleanliness;
g. Type of auxiliary heat source, if applicable;
h. Fiber or pre-cured laminate batch number(s) and location in structure;
i. Batch numbers, mix ratios, mixing times, and mixed color of all resins, including primers, putties, saturants, adhesives, and coatings mixed for the day;
j. Observations of progress of cure of resins;
k. Conformance with installation procedures;
l. Pull-off test results: bond strength, failure mode, and location;
m. FRP system properties from witness panel tests, if required;
n. Location and size of any delaminations or air voids;
o. General progress of work.

Submit daily inspection and progress reports to the Contracting Officer.

3.8.3 Void Detection

After allowing at least 24 hours for initial resin cure to occur, perform a visual and acoustic tap test inspection of the layered surface. Other methods for detecting voids may be employed; all parties concerned shall agree upon these methods prior to the submission of bids or proposals. Mark voids requiring corrective action in accordance with the specified FRP maintenance and repair procedure.

3.8.4 Delaminations

Evaluate the cured FRP system for delaminations or air voids between multiple plies or between the FRP system and the masonry. Use inspection methods capable of detecting delaminations of 1300 square mm 2 square inches or greater. Submit all delaminations or other anomalies to the Engineer of Record for evaluation.

3.8.4.1 Wet lay-up and Prepreg Systems

****
NOTE: Determine and correct the cause of delamination prior to application of the patch.
****

a. Small delaminations or air voids less than 1300 square mm 2 square inches each are permissible, so long as the delaminated area is less than 5 percent of the total laminate area and there are no more than 10 such delaminations or air voids per 0.93 square m 10 square ft.

b. Repair large delaminations or air voids, greater than 16,000 square mm 25 square inches by selectively cutting away the affected sheet and applying a sheet patch of equivalent plies overlapping the undisturbed FRP sheet by a minimum of 100 mm 4 inches on all sides. Use anchors in reticent corners where overlapping is not possible. The number and

locations of the anchors require approval by the Engineer of record.

c. Delaminations or air voids less than 16,000 square mm 25 square inches may be repaired by resin injection or ply replacement, depending upon the size and number of delaminations and their locations. Consult the Contracting Officer on which repair method will be used.

3.8.4.2 Pre-cured Systems

For pre-cured FRP systems, evaluate each delamination or air void and repair in accordance with the Contracting Officer's direction.

3.8.5 Fiber Orientation

Evaluate fiber or pre-cured laminate orientation by visual inspection. Evaluate for fiber waviness, a localized appearance of fibers that deviate from the general straight-fiber line in the form of kinks or waves. Report fiber or pre-cured laminate misalignment of more than 5 degrees from that specified on the design drawings (approximately 80 mm/m 1 in/ft) to the Contracting Officer for evaluation and acceptance.

3.8.6 Record Retention

Retain the records of inspection and witness panels throughout the warranty period. Retain samples of mixed resin and maintain a record of the placement of each batch. Upon completion of repairs, re-inspect the laminate to verify that the repair was properly accomplished. Evaluate the FRP systems and accept/reject based on conformance or nonconformance with the design drawings and specifications. Include FRP system material properties, as-built fiber orientation, presence of delaminations, cure of resins, and adhesion to substrate in the evaluation. Submit procedures to properly maintain the installed FRP system as well as written manufacturer recommended repair procedures for damage to the in-place FRP system.

3.9 REPAIRS

3.9.1 Application Defects

Repair all defects spanning more than 5 percent of the surface area according to the FRP maintenance and repair procedure. There are two types of repairs: resin injection or removal and reapplication of the FRP system.

3.9.2 Tears in the Reinforcing Fibers

Repair tears in the reinforcing fibers that cross fiber tows greater than 50 mm 2 inches in length by adding additional plies of FRP material.

3.9.3 Remedial Measures for Defects

In locations where the FRP adhesion does not meet the minimum adhesion requirements, remove the laminate from the wall surface and apply new laminate. Review and get approval of the revised anchor details by the Contracting Officer prior to installation. Should the Contracting Officer determine that anchors are inappropriate, remove the FRP composite and replace with new composite meeting the minimum adhesion requirements.

3.10 WORK AREA CLEAN UP

Upon completion of the work, remove staging, scaffolding, and containers

from the work site or destroy them in an approved manner. Remove FRP composite, resin, and other deposits on adjacent surfaces and leave the entire job cleaned to equal or better condition to that prior to the start of the job. Place cloths, cotton waste and other debris, that might constitute a fire hazard, in closed metal containers removed at the end of each day. Dispose of all resins and adhesives properly as indicated on the MSDS sheets. Store and transport all resins and adhesives as indicated in MSDS directions. Contain and dispose of spent abrasive blast media properly as required by local authorities. Contain all material to be discarded at the site until properly disposed of.

-- End of Section --