

Preparing Activity: USACE MasterFormat™ 2004 - 04 01 20

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 23 June 2005

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DIVISION 04 - MASONRY

SECTION 04910

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06/04

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USACE / NAVFAC / AFCEA / NASA UFGS-04910 (June 2004)

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SECTION 04910

REHABILITATION OF REINFORCED AND UNREINFORCED MASONRY WALLS USING FRP COMPOSITE STRUCTURAL REPOINTING 06/04

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.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

PART 1 GENERAL

NOTE: In general, reinforced masonry is defined as masonry construction that contains 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 shall include:

- a. Inspection of the structural members specified on the contract drawings to be reinforced with FRP. The inspection shall 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 structural repointing using 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.

1.1 REFERENCES

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.

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.

ACI INTERNATIONAL (ACI)

ACI 440.2R

(2002) Design and Construction of
Externally Bonded FRP Systems for

Strengthening Concrete Structures

ACI 503.4 (1992) Standard Specification for
Repairing Concrete with Epoxy Mortars

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

ACGIH Publication 0028 (1998) TLVs and BEIs

ASTM INTERNATIONAL (ASTM)

ASTM D 2240 (2004) Rubber Property - Durometer Hardness

ASTM D 2563 (1994; R 2002e1) Classifying Visual
Defects in Glass-Reinforced Plastic
Laminate Parts

ASTM D 3039/D 3039M (2002e1) Tensile Properties of Polymer
Matrix Composite Materials

ASTM D 3171 (1999; R 2004) Standard Test Method for
Constituent Content of Composite Materials

ASTM D 3916 (2002) Tensile Properties of Pultruded
Glass-Fiber-Reinforced Plastic Rod

ASTM D 4501 (2001) Adhesive Bonds Between Rigid
Substrates by the Block-Shear Method

ASTM D 638 (2003) Tensile Properties of Plastics

ASTM D 882 (2002) Tensile Properties of Thin Plastic
Sheeting

INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS (ICBO)

ICBO ES AC 125 (2001) Acceptance Criteria for Concrete
and Reinforced and Unreinforced Masonry
Strengthening Using Fiber-Reinforced,
Composite System

ICBO ES AC 178 (2001) Acceptance Criteria for Inspection
and Verification of Concrete and
Reinforced and Unreinforced Masonry
Strengthening Using Fiber-Reinforced
Polymer (FRP) Composite Systems

U.S. DEPARTMENT OF DEFENSE (DOD)

EI 042XX (200X) Design of Fiber Reinforced Polymer
Composites Systems for Rehabilitation of
Unreinforced and Lightly Reinforced
Masonry Walls

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

29 CFR 1910.1200 Hazard Communication

1.2 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01330 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" 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.

NOTE: For non-Design-Build type contracts, Shop Drawings and Design Data should be provided by the Government.

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.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

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

A quality assurance plan for the installation and curing of all application materials to include personnel safety issues, installer certification, application and inspection of the FRP system, structural paste/adhesive curing provisions, means to assure clean, dry masonry 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.

SD-02 Shop Drawings

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

Complete shop drawings for each installation of the composite system. The shop drawings shall contain details of the fiber reinforcement type, dimensions, and end details, proposed connections to the diaphragms and adjacent walls, and locations to be applied as specified. Include any calculations prepared by or on behalf of the Contractor to determine the layout of the FRP materials to be installed.

SD-03 Product Data

Materials

Manufacturer's product data sheets indicating physical, mechanical, and chemical characteristics of all materials used in the FRP system application.

Tensile Properties

Delivery Inspections

Values as determined by tensile testing in accordance with ASTM D 3916, for FRP rods or ASTM D 3039/D 3039M, for flat or rectangular shaped FRP reinforcement. Design elastic modulus shall be determined by the strength and rupture strain values. Ultimate tensile strength and rupture strain values shall be determined by subtracting three (3) standard deviations from the average values of twenty (20) or more tensile tests.

Material Safety Data Sheets (MSDS)

Data sheets for all materials to be used at the job site in accordance with OSHA and 29 CFR 1910.1200.

SD-04 Samples

Materials; G, [____]

FRP bar 300 mm 12 inches long. Plate of cured structural paste/adhesive 75 x 75 mm 3 x 3 inches.

SD-05 Design Data

Design Calculations; G, [____]

Design calculations for the FRP composite system stamped by a registered professional civil or structural engineer. Calculations shall conform to requirements set forth in EI 042XX and in the ICBO ES AC 125 Acceptance Criteria and be based on tension force and strain limits.

SD-06 Test Reports

Field Testing

Laboratory Testing

Results of Shore hardness tests at 3 and at 24 hours in ten degree intervals between 4 and 38 degrees C 40 and 100 degrees F for structural pastes/adhesives used. System environmental durability test results conducted and reported by an independent testing facility; the report shall show the following information:

- a. FRP System nomenclature
- b. Testing facility name
- c. Testing facility address
- d. Testing facility telephone number
- e. Testing facility point of contact
- f. Freeze-thaw test results
- g. 2000 hour UV exposure test results
- h. Fire resistance test results
- i. Seven day exposure at 100% humidity test results
- j. 3000 hour test results for ozone exposure, for alkali exposure, for salt water immersion, and for 60 degrees C 140 degrees F exposure

Wall Tests; G, [____]

Test results by an independent testing facility on walls which are representative of the actual configuration and loading conditions for this contract. Currently, no standard tests exist; therefore, the submitted testing shall be approved by the Contracting Officer. The report shall show the following information:

- a. FRP System nomenclature
- b. Testing facility name
- c. Testing facility address
- d. Testing facility telephone number
- e. Testing facility point of contact
- f. Test wall substrate material
- g. Test wall aspect ratio
- h. FRP orientation and frequency/location
- i. FRP composite shape and cross-sectional area
- j. Cyclic in-plane test results in accordance with EI 042XX and ICBO ES AC 125 to include the following:

- (1) Description of test setup.
- (2) Rate and method of loading.
- (3) Deformation and strain measurements.
- (4) Modes of failure.

SD-07 Certificates

Materials; G, [____]

Certification from the system manufacturer of the guaranteed material and section properties for the supplied material.

Regulatory Requirements; G, [____]]

Certification that structural pastes/adhesives 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.

System Manufacturer[; G][; G, [____]]

A list of a minimum five (5) successfully completed FRP composite strengthening projects completed with the manufacturer's composite system. The list shall include at a minimum:

- a. The dates of work
- b. Type, description and amount of work performed
- c. A point of contact for an owner representative to include:
 - (1) Name
 - (2) Address
 - (3) Company/Agency name
 - (4) Telephone number

Contractor; G, [____]

The Contractor shall have completed a minimum of five (5) FRP composite strengthening projects on vertical flat surfaces and a minimum of three (3) of those jobs using the manufacturer's composite system. The list shall include at a minimum:

- a. The dates of work
- b. Type, description and amount of work performed
- c. A point of contact for an owner representative to include:
 - (1) Name
 - (2) Address
 - (3) Company/Agency name
 - (4) Telephone number

Field Representative; G, [____]

The name of the Contractor's field representative who will perform the actual work supervision, the date certification course completed, and a list of a minimum of five (5) FRP composite strengthening projects, three (3) using the manufacturer's composite system. The field representative shall be present on site during installation of the FRP system. The list shall include at a minimum:

- a. The dates of work
- b. Type, description and amount of work performed
- c. A point of contact for an owner representative to include:
 - (1) Name
 - (2) Address
 - (3) Company/Agency name
 - (4) Telephone number

Applicators[; G][; G, [____]]

Certificates of training by the FRP system manufacturer for all FRP applicators as well as listing of past application projects completed by the applicators. A course syllabus for the certification course completed by the FRP composite applicators.

SD-08 Manufacturer's Instructions

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

Submit the manufacturer's printed installation instructions to include the following:

- a. Brand name
- b. Catalog numbers
- c. Names of manufacturers for each material to be used. Include with instructions the estimated quantity of each material to be used on the job.
- d. Detailed mixing and application instructions to include:
 - (1) Mixing instructions
 - (2) Curing times between coats or layers
 - (3) Application procedures for surface coatings
 - (4) 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.
 - (5) 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.
 - (6) Inclement weather installations
 - (7) Application procedures of top coating material

SD-10 Operation and Maintenance Data

Record Maintenance; G, [____]

Procedures to properly maintain the installed FRP system as well as written manufacturer recommended repair procedures for damage to the in-place FRP system.

1.3 FRP COMPOSITE SYSTEM

1.3.1 Design Requirements

The design of the FRP composite system shall conform to ACI 440.2R and shall provide [seismic] [wind] [and] [blast] strengthening for clay brick and concrete masonry walls; the Contractor shall provide design calculations as specified in the Submittals paragraph. Walls with the FRP system shall fail by cracking through the masonry units and mortar prior to any debonding or rupture of the FRP composite system.

1.3.2 Performance Requirements

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.

The FRP composite system shall provide [seismic] [wind] [and] [blast] strengthening for [clay brick] [concrete] masonry walls by [[_____]%) [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.

1.4 QUALIFICATIONS

1.4.1 System Manufacturer

The FRP composite system manufacturer shall have used the proposed materials system on a minimum of five (5) completed projects.

1.4.2 Contractor

The Contractor shall have completed a minimum of five (5) FRP composite strengthening projects on vertical flat surfaces and a minimum of three (3) of those jobs using the manufacturer's composite system. The Contractor shall provide the qualifications for its Field Representative as specified in the Submittals paragraph.

1.4.3 Applicators

1.4.3.1 Training

The FRP composite applicators shall 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 five (5) 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 application preparation shall be assigned to perform the work described herein.

1.5 WORK SITE SAFETY

Workers having access to the work area shall be informed of the contents of the applicable material safety data sheets (MSDS) and of potential health and safety hazard and protective controls associated with materials used on the project. Workers shall be trained in the safe handling and application, and the exposure limit, for each material that the worker will use or otherwise be exposed to during the course of the project. Personnel having a need to use respirators and masks shall be instructed in the use and maintenance of such equipment.

1.6 REGULATORY REQUIREMENTS

The bonding materials used shall 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, additional ventilation shall be

provided for the duration of the excess outgassing. At no time will they exceed STEL, even if additional ventilation or air supply is provided. The Contractor is responsible for providing the necessary equipment to comply with these requirements. Once cured, the FRP composite system shall not exhibit any detectable odor at a distance of 300 mm one foot from the FRP surface.

1.7 PREINSTALLATION CONFERENCE

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

1.8 DELIVERY, STORAGE, AND HANDLING

1.8.1 FRP Reinforcing Bars and Shapes

FRP reinforcing bars are susceptible to surface damage. Puncturing their surface can significantly reduce the strength capacity of the FRP reinforcements. In the case of glass FRP rods, the surface damage can cause a loss of durability due to infiltration of alkalis. The following handling guidelines are recommended to minimize damage to both the FRP bars and workers handling them:

- a. FRP reinforcing bars should be handled with work gloves to avoid personal injuries from either exposed fibers or sharp edges;
- b. Do not store the FRP bars on the ground. Pallets should be placed under the bars to keep them clean and to provide easy handling;
- c. High temperatures, ultraviolet rays, and chemical substances should be avoided because they can damage FRP bars;
- d. Occasionally, bars become contaminated with form releasing agents or other substances. Substances that decrease bond should be removed by wiping the bars with solvents before placing them in the masonry;
- e. It may be necessary to use a spreader bar so that the FRP bars can be hoisted without excessive bending.

1.8.2 Structural Pastes/Adhesives

1.8.2.1 Labeling

Structural pastes/adhesives shall be delivered 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. Adhesive materials that have exceeded the shelf life shall not be used.

1.8.2.2 Storage

All structural paste/adhesive materials shall be stored in a covered, well-ventilated area and protected from exposure to any detrimental conditions including: airborne contaminants, dirt, dust, sunlight, temperatures lower than 4 degrees C 40 degrees F or greater than 38 degrees C 100 degrees F, rainfall, sparks or flame and in accordance with the manufacturer's requirements.

1.9 PROJECT/SITE CONDITIONS

1.9.1 Environmental Requirements

1.9.1.1 Application Temperature

a. Structural pastes/adhesives shall not be applied 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 rises 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.

1.9.1.2 Wet or Damp Surfaces

Unless they have been formulated for such applications, structural pastes/adhesives shall not be applied to damp or wet surfaces.

1.9.2 Existing Conditions

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

1.9.3 Work Coordination

Work shall be coordinated 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.

1.10 WARRANTY

Manufacturer's standard warranty for FRP composite system installation shall be furnished. The warranty shall include the FRP composite system [design,] installation, bond to the substrate, and interlaminar bond, as well as mechanical property retention, and bar-adhesive 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

NOTE: Structural repointing, using precured FRP systems, consists of embedding composite rods and shapes, manufactured in the system supplier's

facility and shipped to the job site, and a structural adhesive required to bond the precured rods and shapes into grooves cut in the masonry surface.

All materials (reinforcements and structural Pastes/adhesives) for a specific job shall be supplied by one system manufacturer only.

Substitution of FRP rods or shapes or substitution of structural pastes/adhesives from those which comprise the manufacturer's FRP system are not allowed. The arbitrary selection of a fiber reinforcement and an adhesive material can lead to failure of the FRP composites system due to possible matrix-reinforcement incompatibilities.

2.1 MATERIALS

NOTE: The values listed in the following tables should be those values and assumptions that were used in developing the rehab/strengthening design. Those items in Table 1 below will be the minimum acceptable property values for the FRP bars and shapes to be installed. Those items in Table 2 will be the minimum acceptable properties for the structural paste/adhesive.

For test methods with two methods listed, the first refers to round shapes like FRP bars and the second pertains to rectangular cross sectional shapes.

Submittals must demonstrate that the proposed materials will match the intent of the engineering design using the properties listed below.

Submittals for material systems must include, at a minimum, documented evidence that the manufacturer of the proposed system meets the requirements of the Tables below, and demonstrate the structural equivalency of the proposed system to the system(s) properties specified.

The FRP [rods] [shapes] shall conform to the material properties listed in Table 1. The structural paste/adhesive shall conform to the material properties listed in Table 2. No substitution of the submitted reinforced FRP composite system or its components will be allowed for the project. The Contractor shall provide values for the Tensile Properties of the composite material as specified in the Submittals paragraph.

TABLE 1: Properties of Pre-formed FRP Rods and Shapes

COMPOSITE PROPERTY	FRP TEST REQUIREMENT	METHOD
-----------------------	----------------------------	--------

COMPOSITE PROPERTY	FRP TEST REQUIREMENT	METHOD
Elongation: max.	[_____] %	ASTM D 3916/ASTM D 3039/D 3039M
Visual Defects	Acceptance Level [_____]	ASTM D 2563
Guaranteed Tensile Strength, min.,	[_____] kPa (psi)	ASTM D 3916/ASTM D 3039/D 3039M
Tensile Modulus of Elasticity, min.	[_____] kPa (psi)	ASTM D 3916/ASTM D 3039/D 3039M
Cross-sectional Area	[_____] mm ² (in ²)	ASTM D 3916/ASTM D 3039/D 3039M
Fiber Volume Fraction	[_____] %	ASTM D 3171

TABLE 2 Structural pastes/adhesives/Polymer Adhesives

COMPOSITE PROPERTY	FRP TEST REQUIREMENT	METHOD
Elongation:	[_____] %	ASTM D 882
Ultimate Tensile Strength, min.,	[_____] kPa (psi)	ASTM D 638
Modulus of Elasticity, min.	[_____] kPa (psi)	ASTM D 638
Bond Strength	[_____] kPa (psi)	ASTM D 4501

2.2 COMPONENTS

The FRP system shall consist of [glass] [carbon] [aramid] [rods] [rectangles] [grids] with a resin matrix of [vinyl ester] [polyester] [epoxy] [urethane] [specialty resin] binder and an [epoxy] [urethane] [_____] structural adhesive. The structural paste/adhesive used as an embedding material shall be formulated to bond masonry and FRP materials and, once cured, protect the FRP shapes from the environment. The structural paste/adhesive shall be suitable for use in both non-load bearing and load bearing applications.

2.3 ACCESSORIES

The Contractor shall provide all other materials as needed for the proper installation of the complete composite system as specified.

2.4 MIXES

Mixing of structural paste/adhesive materials shall be done in accordance with the FRP system manufacturer's recommended procedure. All adhesive components shall be at a proper temperature and shall be mixed in the correct ratio until there is a complete mixing of components and a uniform color. The amount of each batch of adhesive materials mixed shall be in

quantities sufficiently small to ensure that all mixed structural paste/adhesive can be used within its pot life. Mixed structural paste/adhesive that exceeds its pot life as defined by the system manufacturer shall not be used.

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 and geometries shown on shop drawings.

3.1.2 Environmental Temperature

Should the potential for adverse temperatures occur during installation, the application of FRP shall cease until temperatures return to within the range specified in the Manufacturer's Instructions. Any supplemental heating or cooling sources shall be approved by the FRP manufacturer and the Contracting Officer before use.

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 construction pastes/adhesives have cured. The Contractor shall provide and install tents and/or plastic screens as required to protect the paste/adhesive as it cures. The structural paste/adhesive shall be cured before removal of temporary protection or allowing the structure to be exposed to new loads. In the event of suspected damage to the FRP system during installation, the Contracting Officer shall be notified. Should the damage be caused by the Contractor's negligence, the resulting repairs shall be done at no additional cost to the Government.

3.2 PREPARATION

3.2.1 Delivery Inspections

Prior to starting the project, the Contractor and Independent Special Inspector shall assure that delivered FRP materials meet the specified requirements. This will require laboratory testing. The tensile strength, and modulus of elasticity for each batch of FRP bars used shall be determined. Materials that do not meet the minimum requirements, as specified in Tables 1 and 2 and by the Contracting Officer, shall be rejected. In addition, the gel time, pot life, and cured hardness of the structural paste/adhesive shall be determined.

3.2.2 Substrate repair

3.2.2.1 Surface

[The mortar joints to receive FRP composite are 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.] [Remove areas of loose or spalling mortar material.]

3.2.2.2 Sub-Surface

FRP systems shall not be applied to masonry substrates containing corroded reinforcing steel. Evidence of localized cracking and/or spalling at grouted cells or rust stains shall be noted and reported to the Contracting Officer. Work shall not proceed until the cause(s) of the corrosion is addressed and the corrosion-related deterioration repaired.

3.2.3 Work Preparation

3.2.3.1 Substrate Inspection

The applicator shall insure that all other scheduled masonry repairs are complete and cured. The mortar surfaces to which the FRP system is to be applied shall be free of loose or unsound materials and other conditions that would inhibit bond such as oil, efflorescence or moisture.

3.2.3.2 Worksite Ventilation

Depending on the type of structural paste/adhesive used, work areas shall be ventilated during structural paste/adhesive application so that worker exposure to chemical substances shall not exceed limits as established by ACGIH Publication 0028, or as required by a more stringent applicable local regulation. Interior work zones having a volume of 280 cubic meters 10,000 cubic feet or less shall be ventilated at a minimum of 2 air exchanges per hour. Ventilation in larger work zones shall be maintained by means of mechanical exhaust. Solvent vapors shall be exhausted outdoors, away from air intakes and workers. Return air inlets in the work zone shall be temporarily sealed before start of work until the structural paste/adhesive has cured.

3.2.3.3 Obstructions

Obstructions and embedded objects can affect the performance of the FRP system and shall be modified as necessary. If possible, obstructions may need to be removed prior to installing the FRP system.

3.3 FRP INSTALLATION

3.3.1 Temperature and Moisture

3.3.1.1 Substrate

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

3.3.1.2 Structural Paste/Adhesive

The temperature of the polymeric structural paste/adhesive components at the time of mixing shall be as specified by the manufacturer. When the air or substrate temperature is outside the prescribed range, work shall not proceed unless other measures approved by the Contracting Officer are employed.

3.3.2 Embedment Slot Cutting

Lay out embedment slot locations on the wall surface at the specified locations. Prepare containment to catch dust and masonry chips generated during the embedment slot cutting/grinding.

3.3.2.1 Slot Cutting

Using a grinder or saw with a suitable blade, cut slots in the masonry to the width and depth specified in the shop drawings. Special care shall be taken to avoid local fracture of the masonry.

3.3.2.2 Slot Finishing

The masonry slot surfaces to receive FRP composite shall be free from fins, and protrusions that may prevent the FRP [bars] [shapes] from being embedded to the specified depth in the wall. The contact surfaces shall be dried as recommended by the FRP system manufacturer. Moisture content shall be evaluated in accordance with the requirements of Section 2.3.2.5 of ACI 503.4. The contact surfaces shall have no loose particles, paint, oil, dirt, dust, efflorescence, mildew or free moisture on them at the time of application. Solvent or chemical cleaning methods shall not be used to clean surfaces. All contact surfaces shall be cleaned by hand using wire brushes or by using compressed air. [Using masking tape or other suitable adhesive tape, fix a strip at each edge of the slots].

3.3.3 FRP Reinforcing Bar Preparation

3.3.3.1 Handling

The construction activities shall be conducted in such a way that potential damage to the FRP bars and shapes is minimized.

3.3.3.2 Cutting

Cutting of the FRP bars shall be performed with a high-speed grinding cutter or a fine blade saw. FRP bars should never be sheared. The use of a dust mask is recommended when cutting.

3.3.4 FRP Installation

3.3.4.1 Application of Structural Paste/Adhesive

The structural paste/adhesive shall be mixed according to the specifications prescribed by the manufacturer. A layer of structural paste/adhesive shall be placed uniformly in the slots cut in the masonry substrate.

3.3.4.2 FRP Reinforcing Bar Application

Press the FRP reinforcing bar into the slot so that the surface of the [bar] [shape] is below the surface of the wall. Completely fill the slot with the structural paste/adhesive to encapsulate the bar and strike the surface even with the surface of the masonry.

3.3.5 Curing

Structural paste/adhesive curing temperatures shall be maintained within the required temperature range designated by the manufacturer for the

formulation used for the manufacturer specified time. The composite system shall be protected from contact by moisture for a minimum period of 24 hours.

3.3.6 Finish

Once cure is complete, remove any masking tape applied around the edges of the slots taking care not to damage the structural paste/adhesive. [The structural paste/adhesive shall be [stained] [painted] according to the shop drawings in accordance with the manufacturer's instructions.]

3.3.7 Construction Joints

3.3.7.1 Control Joints

All control joints shall be maintained. The FRP composite shall not bridge existing control joints.

3.3.7.2 Expansion Joints

All expansion joints shall be maintained. The FRP composite shall not bridge existing expansion joints.

3.3.8 Installation Procedure Modifications

Modifications of the manufacturers installation procedures and to the design and shop drawings shall not be made without the written approval of the Contracting Officer and Engineer of Record. The Contracting Officer and Engineer of Record shall approve procedural modifications prior to implementation.

3.4 QUALITY CONTROL

3.4.1 General Requirements

Quality assurance and quality control (QA/QC) programs and criteria provided in the pre-construction submittals shall be maintained by the FRP installation contractor, and others associated with the project. The Contractor shall provide full inspection of the surface preparation and composite systems applications to ensure the requirements of this specification are fully complied with.

3.4.2 Independent Special Inspector

A special inspector, trained and certified by the FRP system manufacturer, shall be provided by the Contractor 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 ICBO ES AC 178.

3.5 FIELD TESTING

3.5.1 Mixed Structural paste/adhesive Hardness

During installation, two samples of mixed structural paste/adhesive shall be prepared per shift from two, separate, [nonconsecutive batches] [separate tube sets] of structural paste/adhesive. The structural paste/adhesive samples shall be a minimum of 3 mm 1/8-inch thick and 50 mm

2-inches in diameter. The mixed structural paste/adhesive samples shall be retained for testing to evaluate curing progress.

3.5.1.1 Curing Evaluation

Relative curing progress of the resin shall be evaluated on the job site by measuring the hardness of the resin sample at 3 hours and 24 hours of cure in accordance with provisions of ASTM D 2240. The shore hardness measurements shall exceed the minimum hardness values submitted by the materials manufacturer based on the lowest air temperature during the curing period evaluated. Measurements shall be at a minimum of three different points distributed over the surface of the structural paste/adhesive at least 6 mm 0.25 inch apart from each other.

3.5.1.2 Report

The special inspector shall report the mean hardness value obtained, structural paste/adhesive identification, manufacturer, and batch number, structural paste/adhesive mixing date and time, test date and time minimum air temperature during the curing evaluation time, and the type and serial number of the durometer used.

3.5.1.3 Remedial Measures

In the event that curing does not meet the above criteria, remedial measures shall be taken as specified.

3.5.2 In-Place Structural paste/adhesive Hardness

During installation, a minimum of one test shall be performed on each 152 m 500 linear feet or portion thereof of FRP bar installed at 3 hours after installation and at 24 hours after installation.

3.5.2.1 Curing Evaluation

Relative curing progress of the in-place FRP resin shall be evaluated using the Shore hardness test described in ASTM D 2240. The shore hardness measurements shall exceed the minimum hardness values submitted by the materials manufacturer based on the minimum substrate temperature observed during the evaluation period.

3.5.2.2 Report

The special inspector shall 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 and substrate temperature when the FRP was applied, air and substrate temperature when testing was performed, and the type and serial number of durometer used.

3.5.2.3 Remedial Measures

In the event that curing does not meet the above criteria, remedial measures shall be taken specified.

3.6 LABORATORY TESTING

3.6.1 Witness Panels

NOTE: There are two FRP configurations the witness panels need to emulate: 1) masonry walls where grooves are cut in the outer surface or shell of the unit with the FRP bars laid in the grooves, and 2) structural repointing where grooves are cut only in the mortar joints.

The witness panels consist of two blocks of masonry/mortar joined by the FRP bars to roughly approximate a dog bone. For thin masonry units, those less than 150 mm (six inches) high, i.e. clay masonry, a short prism is required at each end. For larger masonry units such as standard concrete masonry units, only a single masonry unit is required at each end. For structural repointing witness panels, 150 mm (six-inch) high blocks of mortar similar to that in the wall are required.

During installation, witness panels shall be fabricated onsite using installation procedures identical to the method used to install the FRP system into the masonry surfaces. The panels shall be marked with the date of fabrication, and location of application. Two witness panels shall be fabricated for each day of production or one for each 152 m 500 linear feet of production, whichever is more. The witness panels shall be submitted to an approved laboratory within two weeks of fabrication. The Contracting Officer may waive or alter the frequency of testing.

3.6.1.1 Witness Panel Construction

[The witness panel shall consist of two brick prisms, two bricks high, with full mortar bed joints.] [The witness panel shall consist of two standard CMU units, two units high with a face shell mortar bed joints.] A groove shall be cut in opposite surfaces of the prisms centered on each other and FRP bars installed in the same manner as those in the wall allowing sufficient separation between prisms to insert a hydraulic actuator and steel plates to spread the applied loads.

3.6.1.2 Witness Panel Testing

Not fewer than one witness panel from each day's production shall be tested in the laboratory. If one panel fails to meet the minimum strength specified in Table 1, all the witness panels for the day's production shall be tested. If a second one fails, all panels for the project shall be tested until the job is completed. Appropriate remedial measures shall be taken to ensure integrity of the FRP system. The witness panel test is designed to directly measure the shear capacity of the bond between the embedded FRP bars and the masonry units. The test involves pushing apart the two prisms to which the FRP bar is applied.

a. Insert the steel plates between the masonry prisms to provide a means to distribute the load from the hydraulic actuator. A hydraulic actuator is placed between the steel plates, and a load applied at a constant rate until failure. Measure the load applied to the prisms using a pressure transducer or analog pressure gauge.

b. For failures within the cut slot, calculate the bond strength by dividing the maximum load at failure by the slot surface area.

c. For tensile failures of the FRP bars, the bond strength shall be noted as the tensile strength of the bar, the maximum load divided by the bar cross-sectional area.

3.6.1.3 Report

Report the bond strength and the mode of failure. An acceptable failure mode is characterized by either the removal of a layer of masonry bonded to structural paste/adhesive or the tensile rupture of the FRP bar. If the FRP bar fails by shear at the prism edge, the test shall be repeated and the data discarded. If failure is due to loss of bond between the FRP bar and the structural paste/adhesive or within the structural paste/adhesive, remedial measures shall be taken, as specified.

3.6.2 Laboratory Qualification

NOTE: If rectangular FRP shapes are specified to be used, the laboratory should have experience using test method ASTM D 3039/D 3039M. If FRP bars are specified, ASTM D 3916 should be cited.

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 D 3039/D 3039M] [ASTM D 3916] wall tests for at least three (3) different contractors prior to this contract.

3.7 REMEDIAL MEASURES

For all strengthened sections where testing indicates that the installed composite system has material properties below the minimum specified values, the installed FRP composite shall be removed and replaced with FRP composite meeting or exceeding the minimum specified values. None of the cost to remove unacceptable FRP composite, repair damaged masonry as a result of the FRP removal, and install replacement FRP composite shall not be accrued to the government but shall be the responsibility of the Contractor.

3.8 FIELD QUALITY ASSURANCE

3.8.1 Inspection

FRP systems and all associated work shall be inspected as required by the applicable codes and described in this specification. The FRP composite installation shall be completely inspected by the special inspector during and immediately following installation of the FRP composite system. The FRP systems shall be evaluated and accepted or rejected based on conformance or nonconformance with the design drawings and specifications. The special inspector shall require compliance with the design drawings and specifications. The independent special inspector shall observe all aspects of onsite preparation and material application including the following:

- a. Material container labels
- b. Surface Preparation (cutting and/or grinding slots in the wall surface)
- c. Mixing of polymer structural paste/adhesive

- d. Application of structural paste/adhesive to the slots
- e. Placement of bars in the slots
- f. Curing of structural paste/adhesive
- g. Adhesion to substrate
- h. Application of coatings

3.8.2 Daily Inspection Records

Daily inspection records shall include:

- a. Date and installation start and finish times;
- 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. FRP [bar] [shape] batch number(s), linear footage, and locations installed in structure;
- i. Batch numbers, mix ratios, mixing times, total volumes, and mixed color of all polymer resins, including primers, putties, pastes, adhesives, and coatings mixed for the day;
- j. Observations on progress of structural paste/adhesive cure to include measured Shore hardness values;
- k. Conformance with installation procedures;
- l. General progress of work.

3.8.3 Record Maintenance

The independent special inspector shall retain the records of inspection and witness panels throughout the warranty period. The Contractor shall retain samples of mixed structural paste/adhesive and maintain a record of the placement of each batch. Inspection and progress reports shall be submitted daily to the Contracting Officer.

3.9 REPAIRS

All defects shall be repaired according to the FRP maintenance and repair procedure provided by the system manufacturer.

3.10 WORK AREA CLEAN UP

Upon completion of the work, staging, scaffolding, and containers shall be removed from the site or destroyed in an approved manner. FRP composite, structural paste/adhesive, and other deposits on adjacent surfaces shall be removed and the entire job left cleaned to equal or better condition to that prior to the start of the job. Cloths, cotton waste and other debris that might constitute a fire hazard shall be placed in closed metal containers and removed at the end of each day. All adhesives shall be stored, transported, and disposed of properly as indicated on the MSDS sheets. Masonry dust and chips shall be contained and disposed of properly as required by local authorities. All material to be disposed of shall be contained at the site until properly disposed of.

-- End of Section --