ITEM 582.08 16 FIBER REINFORCED POLYMER REPAIR OF STRUCTURES (PRECURED AND WET LAY-UP) SM

ITEM 582.09 16 FIBER REINFORCED POLYMER REPAIR OF STRUCTURES (NEAR-SURFACE-MOUNTED) M

ITEM 582.10 16 CONCRETE REPAIR FOR FIBER REINFORCED POLYMER SM

DESCRIPTION

Furnish and install fiber reinforced polymer (FRP) composite materials for bonded repair and retrofit of concrete structures in accordance with the Contract Documents. The Contractor's attention is directed to Source of Supply and Quality Requirements, with regard to advising Departmental Representatives of the sources of the proposed FRP composite materials for use in highway bridges.

MATERIALS

FRP composite materials using isophthalic polyester, vinylester, and epoxy resins, and glass or carbon fibers are covered by this specification. FRP composite materials are classified based on resin type, fiber type, and fiber architecture.

Use an FRP system from the Department's Approved List of Materials and Equipment. Submit manufacturer's certifications for all delivered and stored FRP components before starting the project.

Furnish Samples of precured or near-surface-mounted (NSM) FRP or witness panels of wet lay-ups to the Engineer. Any material that does not meet the requirements of the Contract Documents will be rejected. Additional witness panels may be taken during the installation process.

Follow the tolerances recommended by the manufacturer, unless more stringent requirements are specified in this Specification or in the Contract Documents.

Provide all necessary equipment, in sufficient quantities and in clean and operating conditions, for continuous uninterrupted FRP installation.

Meet the requirements of the following subsections of §700 - Materials:

Grout §701-05
Mortar §701-08

CONSTRUCTION

A. SITE CONSIDERATIONS

Provide necessary pathways, scaffolding, and other means of access to the general project site and to the specific repair area for the personnel, equipment, and materials. Remove all obstructions such as pipes, conduits, and wiring, after making records for subsequent reinstallation at the completion of the project. Remove vegetation, fences, and other obstructions that prevent access for repair, and upon approval of the Engineer, reinstall or dispose of.

B. SAFETY

Include this work in the Health and Safety Plan in accordance with §107-05.

C. STORAGE, HANDLING, AND DISPOSAL

1. Storage

Deliver and store all components of the FRP system in the original factory-sealed, unopened packaging or containers with proper labels identifying the manufacturer, brand name, system identification number, and date. Store catalysts and initiators separately. Protect all components from dust, moisture, chemicals, direct sunlight, physical damage, fire, and temperatures outside the range specified in the system data sheets.

2. Handling

Handle all components of the FRP system, especially fiber sheets, according to the manufacturer's recommendations. Protect them from damage and avoid misalignment or breakage of the fibers by

pulling, separating, or wrinkling them or by folding the sheets. After cutting, stack sheets dry or with separators, or rolled gently at a radius no tighter than 300 mm, or as recommended by the manufacturer.

3. Disposal

Dispose of any component of the FRP system that has exceeded its shelf life or pot life, that has not been properly stored, and any unused or excess material that is deemed waste.

D. SUBMITTALS

Submit the following documents to the Engineer prior to installing the FRP system. In addition, when a Professional Engineer (PE) designs the FRP system, the PE must sign and stamp all design documents, including Working Drawings, and submit two copies for approval to the Deputy Chief Engineer (Structures). Allow three (3) weeks for review after complete calculations, drawings, and any supplemental data are received by the D.C.E.S.

1. Qualifications of Contractor/ Applicator

Document a minimum of 3 years of experience or 15 similar field applications with acceptable reference letters from respective Owners and provide a certificate of completed training from the Manufacturer/Supplier for at least one field representative who will be present on site throughout the project.

2. Design Details and Working Drawings

a. Design details

When only the required loads and capacities of FRP system are shown in the Contract Documents, engage the services of a Professional Engineer (PE) to design the FRP repair. Design the FRP in accordance with the American Concrete Institute (ACI) 440, "Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures." Use appropriate strength reduction factors for a minimum life span of 20 years.

b. Working drawings

Prepare and submit Working (Shop) Drawings in accordance with the New York State Steel Construction Manual for shop drawings. Include the type of FRP system, work locations, relevant dimensions of the system, and the work plan on the working drawings, including the necessary preparations of the existing structure in the case of repair. Include the time schedule for various steps in the work and clearly identify the environmental conditions that may affect the application and curing of the FRP system.

3. Quality control

Provide a quality control plan for approval by the Engineer. Include specific procedures for tracking and inspection of all FRP components prior to installation, inspection of all prepared surfaces prior to FRP application, inspection of the work in progress to assure conformity with specifications, obtaining quality assurance samples, inspection of all completed work, performing tests for approval, and repair of any defective work. Repair or remove and replace any part of the work that fails to comply with the requirements.

4. Other documents

1. The Manufacturer's Safety Data Sheet (MSDS). Make the MSDS for each FRP component available to all at the work site.

2. The manufacturer's system information sheet which identifies the mechanical, physical, and chemical properties of all components of the FRP system.

3. The application guide that contains the installation and maintenance procedures.

E. CONCRETE REPAIR

Repair the concrete, if necessary, according to Section 582 of NYSDOT Standard Specifications, and clean and prepare all concrete surfaces prior to installing the FRP system.

1. Repair of Defective Reinforcement

Repair all defective steel reinforcement. Do not apply FRP systems to concrete suspected of containing corroded reinforcement. Clean and prepare corroded or otherwise defective reinforcement by abrasive cleaning to near white appearance. Cut damaged reinforcement that needs to be replaced at sufficient length to ensure full section and sound material in the remaining portion. Provide sufficient length for splices for ruptured or cut reinforcing or prestressing steel.

Place mechanical anchorage for the repair material if specified in the Contract Documents. Secure anchors in place by tying to other secured bars, and do not permit anchors to protrude outside concrete surface. If necessary, build up the concrete surface to cover the protrusions.

2. Restoration of Concrete Cross Section

Fill the area of removed concrete, and any void larger than 13 mm diameter and 3 mm depth, with repair material that conforms to NYSDOT Standard Specifications. Use a repair material that has a compressive strength equal to or greater than 31 MPa and 38 MPa at 7 days and 28 days, respectively. Submit the design mix for all repair materials to the Engineer for approval. Use a repair material that has a minimum bond strength to the existing concrete of 1.4 MPa in the pull-off test meeting ASTM D4541. Restore the section to concrete and exposed steel which is clean, sound, and free of surface moisture and frost. Apply water continuously to concrete for 12 hours before placement of patching materials. Fill all cracks and cuts in the concrete wider than 0.25 mm by pressure injection of epoxy according to NYSDOT Standard Specifications. If water is leaking through cracks or concrete joints, provide water protection and a water conveyance and weep holes before restoring the section. Cure the repair material a minimum of 7 days before installing the FRP system, unless the curing and strength are verified by tests.

F. SURFACE PREPARATION

Prepare the surface after the Engineer approves the repair and restoration of the concrete section. Contact-critical applications are treated the same as bond-critical applications. Provide an adhesive bond with adequate strength between FRP and concrete. Promote continuous contact between FRP and concrete by providing a clean, smooth, and flat or convex surface.

1. Surface grinding

Grind all irregularities, unevenness, and sharp protrusions in the surface profile to a smooth surface with less than 1 mm deviation. Use a disk grinder or other similar device to remove stains, paint, or any other surface substance that may affect the bond.

2. Chamfering corners

Chamfer or round to a minimum radius of 13 mm all inside and outside corners and sharp edges. Grind ridges, form lines, and sharp or roughened edges greater than 6 mm. Remove obstructions and embedded objects before installing the FRP system.

3. Grooves for near-surface-mounted FRP

Make a properly dimensioned groove in the concrete, where the FRP bar or strip is to be placed. Take care to avoid local fracture of the concrete surrounding the groove. Free the groove of loose, unsound, or bond-inhibiting materials such as oil, efflorescence, or moisture. Remove all obstructions and embedded objects from the groove area.

4. Surface profiling

Fill and smooth over any remaining voids or depressions with diameters larger than 13 mm or depths greater than 3 mm, when measured from a 300 mm straight edge placed on the surface, using putty made of epoxy-resin mortar or polymer-cement mortar with strength equal to or greater than 28 MPa. Cure the patching material a minimum of 7 days before installing the FRP system, unless the curing and strength are verified by tests.

5. Surface cleaning

Remove any dust, laitance, grease, oil, curing compounds, wax, impregnations, stains, paint coatings, surface lubricants, foreign particles, weathered layers, or any other bond-inhibiting material. If power wash is used, allow the surface to dry thoroughly before installing the FRP system. Protect the cleaned surface against redeposit of any bond-inhibiting materials. Cover with a water-based epoxy any newly repaired or patched surfaces that have not cured a minimum of 7 days.

G. INSTALLATION OF FRP SYSTEM

1. Shoring

Shore repaired members temporarily with conventional methods, if specified in Contract Documents, or required by the Engineer for safety. Do not remove until the FRP system has fully cured and gained its design strength.

2. Environmental Conditions

Examine environmental conditions before and during installation of the FRP system to ensure conformity to the Working Drawings. Do not apply primers, putty, saturating resins, or adhesives on cold, frozen, damp, or wet surfaces. Apply only when ambient and concrete surface temperatures are between 10°C and 32 °C , or as specified by the manufacturer. Install the FRP system when the moisture level on all contact surfaces is less than 4.3%, as evaluated according to ACI 503R-93. Moisture restrictions are waived for resins that have been formulated for wet applications.

a. Moisture vapor transmission

Do not continue application of bonded FRP systems when moisture vapor transmission is present. Inject any bubble that develops from moisture vapor transmission with the same adhesive material used for the FRP system.

b. Applications in inclement weather

Auxiliary measures may be employed to correct the conditions when inclement weather does not allow installation of the FRP system. An auxiliary heat source may be used in cold weather to raise the ambient and concrete surface temperatures to acceptable levels, as recommended by the manufacturer, but to no more than the glass transition temperature (Glass Transition Temperature (Tg) -the approximate midpoint of the temperature range over which a transition in material response from elastic to viscoelastic takes place). Pressurized oil-free air may be used to dry the surface dampness.

3. Application of Wet Lay-Up FRP Systems

a. Mixing of resin components

Mix all resin components, including main agent and hardener, at the proper temperature, using the appropriate weight ratio and for a duration specified by the manufacturer, until thorough mixing with uniform color and consistency is achieved. Do not dilute resins with any organic solvents such as thinner. Manual stirring and small electrically powered mixing blades are allowed. Mix resin in quantities sufficiently small to ensure that it can be used within its pot life. Dispose of mixed resin that begins to generate heat or show signs of increased viscosity.

b. Primer and putty

A primer coat is generally required in all available FRP systems. Apply one or two coats of primer on the concrete surface to penetrate its open pores as per manufacturer's requirements. Apply the putty as soon as the primer becomes tack-free. If the putty is not applied within 7 days after the primer application, roughen the surface with sandpaper or a similar tool. Clean the resulting surface before applying the putty. Apply a thin coat of putty in one or two layers, and smooth over the surface to fill in any small voids, cracks, or uneven areas. After applying the putty, correct any swelling on the surface to meet the required surface profile. Protect the surfaces of primer and putty from dust, moisture, and other contaminants before applying the FRP.

c. Saturant

Uniformly apply the first coat of saturating resin as an undercoat on all concrete surfaces where the FRP system is to be installed. Use saturant with sufficiently low viscosity to ensure full impregnation of the fiber sheets prior to curing.

d. Applying fiber sheet and saturant

Install the fiber sheet in place and gently press onto the wet saturant. Release any entrapped air between the fiber sheet and concrete surface by rolling across the sheet in the direction parallel to the fibers, while allowing the resin to impregnate the fibers to the concrete. Rolling perpendicular to the fiber direction is not allowed. In bidirectional fabrics, roll initially in the fill direction end to end, and then in the warp direction. Apply sufficient saturant on top of the fiber sheet, as an overcoat, to ensure full saturation of the fibers. Apply undercoat, fiber sheets, and overcoat with no interruption.

e. Multiple fiber plies

In multi-ply installations, repeat the sequence above for each additional fiber sheet. The amount of resin overcoat for intermediate plies is approximately 15% greater than a single-ply installation, because the saturant serves as overcoat for the applied ply and undercoat for the next ply. Follow the Contract Documents for the fiber orientation and ply stacking sequence. Apply each ply before the onset of complete gelation of the previous layer. Determine the number of plies that can be applied in a single day based on the manufacturer's recommendation. Multiple plies can also be applied in several days. When previous layers are cured, interlayer surface preparation, such as light sanding and filling with putty may be required.

f. Overlapping

Construct a lap joint when an interruption occurs in the direction of the fibers. The minimum lap splice is 152 mm. Stagger lap splices on multiple plies and adjacent strips. No lap joint is necessary in the transverse direction.

g. Alignment of FRP materials

Deviation in the alignment more than 5° (approximately 85 mm/m) is not acceptable. Install the fibers free of kinks, folds, and waviness.

h. Anchoring of FRP sheets

Anchor the FRP sheets to the concrete following the method specified Working Drawings. Take care to avoid damage to the FRP system and to the concrete when using mechanical clamps and fasteners. Take precautions when steel fasteners are used for carbon FRP to avoid galvanic corrosion. Embed FRP anchors sufficiently into the concrete.

4. Application of PreCured FRP Systems

Follow the procedure for Wet Lay-Up Systems except as directed below. Prepare the surface with an open roughened texture.

a. Application of adhesive

Apply adhesive evenly to all concrete surfaces where the precured FRP system is to be installed. Follow the manufacturer's recommendation for the thickness and viscosity of the adhesive layer.

b. Placement of precured system

Clean and cut the precured FRP system to the required length, then place it into the wet adhesive. Release entrapped air between the laminate and concrete and remove excess adhesive. Do not disturb the applied FRP system before the adhesive fully cures.

c. Grouting of precured shells

Grout precured shells around concrete columns no less than 24 hours after installation following the procedure on the Working Drawings.

5. Application of Near-Surface-Mounted FRP Systems

NSM FRP systems are an alternative to externally bonded FRP systems. In this system, a bar or strip is inserted and anchored into a precut groove. Do not install the NSM FRP system when surface moisture is present on the concrete or when rainfall or condensation is anticipated.

a. Application of embedding paste

Mix the components of the embedding paste to the ratio specified by the manufacturer until thorough mixing with uniform color and consistency is achieved. Half-fill all the grooves with paste.

b. Placing FRP reinforcement

Clean the round FRP bar or rectangular FRP strip, cut it to the proper length, and place it at the middepth of the groove. Lightly press it so as to force the paste to flow around it and completely fill the space between FRP and the sides of the groove. Then fully fill the groove with additional paste and level the surface.

6. Curing

Follow the approved curing procedure. Elevated temperatures, not modified chemistry, may be used to achieve a rapid cure. Installed plies must be cured before placing subsequent plies. Do not apply the full load until curing is complete.

7. Protective Coating and Finishing

Apply the protective coating on the surface of the FRP system. Use a nonvapor-barrier, flexible waterproofing compatible with the FRP system. The coating may be a polymer-modified Portland cement coating or a polymer-based latex coating. Use methods for vertical or overhead work. Match the color and texture of the adjacent concrete. Do not use solvent wipes to clean the FRP surface, unless approved by the FRP manufacturer. If abrasive cleaning is necessary, limit air pressure to avoid damage

to the fibers. Do not apply the coating when surface moisture is present or when rain or condensation is anticipated.

8. Temporary Protection

Install temporary protection after the resin has fully cured.

H. INSPECTION AND QUALITY ASSURANCE

After 24 hours of initial cure:

1. Inspection for Debonding

The Engineer will perform a visual inspection of the surface for any swelling, bubbles, voids, or delaminations. If an air pocket is suspected, a hard object will be used to tap the FRP to identify delaminated areas by sound, with at least one strike per 0.1 m^2. Defects smaller than 6 mm diameter will require no corrective action, unless they occur next to edges or there are more than five such defects in an area of 0.9 m^2. Repair defects larger than 6 mm in diameter.

2. Inspection for Adhesion

Before applying the protective coating, perform a direct pull-off test in the presence of the Engineer and following ASTM D4541 to verify the tensile bond between the FRP system and the concrete. At a minimum, perform three pull-off tests with at least one test per span or one test per 93 m^2 of the FRP system. A failure at the bond line with a tensile stress below 1.4 MPa is unacceptable. If one or more of the pull-off tests is found unacceptable, the work will be rejected and repaired.

3. Inspection for Cured Thickness

Take 13 mm diameter core samples in the presence of the Engineer to inspect the cured laminate thickness and number of plies. The sampling frequency is the same as Inspection for Adhesion. Repair cored areas. The FRP system is not acceptable if the number of plies is less than that specified in the Contract Documents, or if the cured thickness of the FRP system is less than that specified in the approved design calculations by more than 0.8 mm. Repair the entire area of FRP system that is marked unacceptable.

4. Auxiliary Tests

If witness panels are required, the FRP System is not acceptable when the average tensile strength or the lowest tensile strength is more than 5% and 10%, respectively, below that specified in the Contract Documents, as determined by ASTM D3039.

I. REPAIR OF DEFECTIVE WORK

Submit a proposed repair procedure to the Engineer for approval for repairs for any condition not addressed in this Specification or in the Contract Documents.

1. Repair of Protective Coating

Defects in protective coatings can be of three types: small hairline cracks, blistering, and/or peeling. Apply a new coating to concrete with moisture content below 0.05%. Prior to any repair of protective coating, examine the FRP system, visually or otherwise, to ensure that no defect exists within or on the surface of the FRP. Repair defects in the FRP. If a protective coating appears to show small areas with cracks, lightly sand the local surface. Apply a new coating with the appropriate primer based on the manufacturer's recommendations. At the minimum, apply the coating over an area extending 25 mm on either side of the defect. If the protective coating shows signs of blistering, carefully scrape clean the

entire area of blisters as well as the surrounding area to a distance of at least 300 mm. Completely remove the existing coating of a blistered surface before recoating. Wipe the area clean and then dry thoroughly. Once dry, the area can be recoated after application of the primer coat, if required by the manufacturer. If the surface shows signs of excessive peeling, scrape off the entire coating, and lightly sand, wipe clean, and thoroughly dry before applying a new coat.

2. Epoxy Injection of Small Defects

Small voids or surface discontinuities no greater than 6 mm diameter are not defects, and require no corrective action, unless they occur next to edges or when there are more than five such defects in an area of 0.9 m^2. Repair small defects between 6 mm and 32 mm diameter using low-pressure epoxy injection, as long as the defect is local and does not extend through the complete thickness of the laminate, in the case of multi-ply FRP systems. If any delamination growth is suspected between the FRP plies due to injection, halt the procedure and repair according to Patching of Minor Defects.

3. Patching of Minor Defects

Minor defects are those with diameters between 30 mm and 150 mm, and frequency of less than five per any unit surface area of 3 m length or width. Remove the area surrounding the defects to an extent of at least 25 mm on all sides. Wipe the area clean and thoroughly dry. Patch the area by adding an FRP patch of the same type of the original laminate and extending at least 25 mm on all sides of the removed area. Repair can also be conducted using the procedure in Replacement of Large Defects.

4. Replacement of Large Defects

Mark defects larger than 150 mm diameter and scarify out to at least 25 mm on all sides. For multi-ply FRP systems, scarify progressively through the layers until past the defective area. If the defect extends to the first FRP ply adjacent to the concrete, remove the entire thickness of FRP and primer. Prepare the concrete and apply the primer after ensuring that the surface and FRP are clean and dry. Follow procedures for a new system when applying in the scarified area, except add an additional layer extending a minimum of 150 mm on all sides of the scarified area as a patch. After curing, apply the protective coating over the entire area.

METHOD OF MEASUREMENT

The various types of composite repairs and strengthening will be measured by the linear meter to the nearest 0.1 meter of each bar or strip for near-surface-mounted FRP systems and by the square meter to the nearest 0.1 square meter for precured and wet lay-up systems. The quantity to be paid for is the area of the existing concrete covered with FRP composite material or the length of the FRP bars and strips as incorporated into the work.

Concrete repair will be measured by the square meter to the nearest 0.1 square meter. The quantity to be paid for is the area of concrete repaired to receive the FRP composite material.

BASIS OF PAYMENT

The unit price bid per linear meter or square meter for FRP repair and strengthening of concrete substructures includes the cost of all materials, labor, equipment, testing, and other services necessary to satisfactorily complete the work in accordance with these specifications and the directions of the Engineer. Concrete repairs made to prepare for installation of the FRP will be paid for under a separate item. Include the cost of all repairs or replacement of the FRP resulting from failed test data in the unit price bid.