

Note: This performance specification is for repair and strengthening of piles and columns using PileMedic® and QuakeWrap® products. However, the specification is written in a generic “non-proprietary” format for your use. Please review the various sections and eliminate those sections that do not relate to your project. In some cases, more than one option has been presented and you only need to include the one that you plan to use in your project.

PART 1 – GENERAL

1.1 SUMMARY

- A. This Section specifies the minimum requirements for restoring deteriorated piles using Fiber-Reinforced Polymer (FRP) Laminate encasement or jacket (these terms are interchangeable). The work shall consist of using a fiber-reinforced laminate to create a jacket around the pile to be restored, and filling the annulus between the jacket and the pile with fill material, see Section 2.3.
- B. Contractor shall provide all labor, materials, tools, and equipment required for the completion of the Work, as shown on the Contract Documents and specified herein:
 - 1. Prepare existing areas, as defined by these specifications and related Contract Drawings, designated to receive pile restoration
 - 2. Design, furnish, fabricate, and install all jackets, shores, and bracing
 - 3. Prepare installation and placement shop drawings
 - 4. Prepare design drawings for shores, and bracing if required
 - 5. Furnish all submittals required by this Section of the Specifications
 - 6. Coordinate all work with other trades on site.

1.2 REFERENCES

- A. The latest edition and addenda of the following publications in effect on the date of Contract Award are part of this Specification and, where referred to by title or basic designation only, are applicable to the extent indicated by the specific reference:
 - 1. SSPC SP-2, Hand Tool Cleaning
 - 2. SSPC-SP 6/NACE No. 3, Commercial Blast Cleaning
 - 3. SSPC SP-12 WJ-2 Surface Preparation and Cleaning of Metals by Water Jetting
 - 4. SSPC-SP 13/NACE No. 6, “Surface Preparation of Concrete”
 - 5. SSPC-SP 15 Commercial Grade Power Tool Cleaning
 - 6. ASTM F-2207 Standard Specification for Cured-in-Place Pipe Lining System for Rehabilitation of Metallic Gas Pipe; used to establish the confinement capacity of the FRP.

1.3 SUBMITTALS

- A. Comply with pertinent provisions of the Master Project Specification, Submittals.

1. Product Data:

1. Fiber-Reinforced Laminate product data sheets showing material properties and strength.
2. Fill resin product data sheets showing material properties and strength.
3. Adhesive resin product data sheets showing material properties and strength.
4. Fill and Adhesive Resin MSDS sheets.
5. Miscellaneous fasteners, anchors, straps, spacers, etc. product data sheets showing material properties.

B. Design and Shop Drawings:

The following information must be provided and sealed by a professional civil engineer:

1. Calculations showing the confining pressure provided by the jacket being used.
2. Details shall be carried out in accordance with the local building codes, and as shown on plans.
3. Shop drawings showing the FRP jacket installation steps, spacer sizes, overlap details, and the filler material to be placed in the annular space.

C. Certifications

1. ASTM F-2207 test report showing the jacket provides a minimum confining pressure given in Section 2.1.C, below.
2. Summary of full-scale structural test reports for strengthening steel, concrete and timber piles. List of and results of full-scale tests.
3. Product approval by the US Army Corps of Engineers and FEMA
4. Material certification for FRP laminates to show date of fabrication.
5. Material certification for fill and adhesive resin to show date of manufacture.

D. Quality Assurance Documents

1. Daily installation reports showing air and water temperatures
2. Daily installation reports showing lot numbers of FRP laminates and resins used on each pile

PART 2 – PRODUCTS

2.1 FIBER-REINFORCED POLYMER (FRP) LAMINATES

- A. The laminate shall be a high-strength Fiber Reinforced Polymer (FRP) laminate constructed with bidirectional carbon or glass fabrics that provides strength in both longitudinal and transverse directions.

B. The FRP laminates shall have the minimum properties listed in the table below.

| FRP Laminate Properties | | | |
|-------------------------------|------------|-------|--------|
| Property | Standard | Glass | Carbon |
| Longitudinal Direction | | | |
| Tensile Strength, ksi | ASTM D3039 | 62 | 101 |
| Modulus of Elasticity, ksi | ASTM D3039 | 3,500 | 7,150 |
| Ultimate Elongation, % | ASTM D3039 | 1.31 | 0.85 |
| Transverse Direction | | | |
| Tensile Strength, ksi | ASTM D3039 | 60 | 64 |
| Modulus of Elasticity, ksi | ASTM D3039 | 3,650 | 2,940 |
| Ultimate Elongation, % | ASTM D3039 | 1.06 | 1.42 |
| Other Properties | | | |
| Barcol Hardness | ASTM D2583 | 50 | 45 |
| Max. Water Absorption, % | ASTM D 570 | 0.8 | 0.7 |
| Laminate Thickness, in. | | 0.026 | 0.026 |

C. The FRP Laminate must provide the nominal structural values listed in the table below.

| Pile Jacket Dia. (in.) | Glass FRP | | Carbon FRP | |
|---------------------------|---------------------------------|---|---------------------------------|---|
| | Confining Pressure* (psi) | Long. Steel Equivalent spacing, in.** | Confining Pressure* (psi) | Long. Steel Equivalent spacing, in.** |
| 10 | 645 | #4 Gr. 60 at 3in | 1050 | #4 Gr. 60 at 3in |
| 12 | 535 | #4 Gr. 60 at 3in | 875 | #4 Gr. 60 at 3in |
| 15 | 430 | #4 Gr. 60 at 3in | 700 | #4 Gr. 60 at 3in |
| 18 | 355 | #6 Gr. 60 at 7in | 580 | #6 Gr. 60 at 7in |
| 24 | 265 | #6 Gr. 60 at 7in | 435 | #6 Gr. 60 at 7in |
| 36 | 180 | #8 Gr. 60 at 11in | 290 | #8 Gr. 60 at 11in |
| 48 | 130 | #8 Gr. 60 at 11in | 220 | #8 Gr. 60 at 11in |
| 60 | 107 | #8 Gr. 60 at 11in | 175 | #8 Gr. 60 at 11in |

*Assuming a 2-ply jacket

** Off center spacing of Gr. 60 longitudinal steel reinforcement bars distributed around the perimeter of the pile

2.2 ADHESIVE RESIN

- A. The adhesive resin shall be a two-component high-strength structural epoxy designed for underwater applications. It shall have an immediate high tack consistency both in air and water and shall trowel easily.
- B. The adhesive resin shall be a 100% solids formulation with low toxicity and low odor during cure.
- C. The adhesive resin must be NSF-61 Certified for potable water application.
- D. The adhesive resin shall meet the properties listed in the table below.

| Adhesive Resin Properties | | |
|----------------------------|------------|--------|
| Property | Standard | Value |
| Tensile Strength, psi | ASTM D-638 | 4,360 |
| Compressive Strength, psi | ASTM D-695 | 11,700 |
| Flexural Strength, psi | ASTM D-790 | 8,900 |
| Tensile Elongation, Max. % | - - - | 5% |

2.3 FILL MATERIAL

Note: We offer three options for fill materials, depending on the project requirements, the shape of piles and the width of the annular space to be filled. QuakeBond™ 320LV Low viscosity resin is used on circular piles when the annular space can be kept to smaller than 1/4 inch and the pile is cracked or decayed, allowing the resin to penetrate all the voids in the pile. This resin also bonds the PileMedic® jacket and any additional longitudinal reinforcement placed within the annular space to the pile for increased flexural strength. When the annular space is larger (1/4 - 1 inch), PileMedic® UW epoxy grout can be used. This epoxy grout includes approximately 180-225 pounds of silica aggregate per 5 gallon of epoxy for a more economical fill material. Epoxy grout offers the same structural benefits as low viscosity resin. For larger annular space (larger than 1.5 inch), PileMedic® UW underwater grout must be used. The bond strength of this grout to PileMedic® jacket and thus the contribution of PileMedic® jacket to the flexural strength of the pile is conservatively ignored. The fill material has to flow to completely fill the annular space and to completely surround longitudinal reinforcing, thus there is not a definite dimension in the annular space that differentiates the demarcation between epoxy grout and underwater grout. Please select the appropriate filler material from the following 3 options:

- A. LOW VISCOSITY RESIN (See Section 3.2.D for Application Instructions)
 - 1. The fill resin shall be a two-component, high-strength, low-viscosity structural epoxy. The resin shall cure underwater and shall provide excellent durability and chemical resistance. The resin shall be a 100% solids formulation with low toxicity and low odor during cure. Low Viscosity Resin (recommended for round timber, concrete or steel piles where the annular space is minimal (smaller than 1/4 inch) and it is desired to fill the cracks and voids with resin in timber and concrete piles)
 - 2. The fill resin must have a low viscosity of 780 cps at 77 F to ensure that it will fill small cracks and voids in the pile.

3. The resin must be heavier than water, with a density greater than 1.10 to flow to the bottom of the annular space and displace the water.
4. The fill resin must be so that its color would show through the glass laminate.
5. The fill resins shall meet the properties listed in the table below.

| Fill Resin Properties | | |
|------------------------------|-----------------|--------------|
| Property | Standard | Value |
| Viscosity @ T=77° F, cps | ASTM D-1290 | 780 |
| Tensile Strength, psi | ASTM D-638 | 7,900 |
| Compressive Strength, psi | ASTM D-695 | 11,200 |
| Density | - - - | 1.10 |
| Tensile Elongation, Max. % | ASTM D-638 | 5% |
| Hardness, Min. Shore D | ASTM D-2240 | 86 |

B. EPOXY GROUT (See Section 3.2.E for Application Instructions)

1. The epoxy grout shall be a two-component 100% solids epoxy grout specifically designed for underwater concrete and masonry applications.
2. The epoxy grout resin must have a mixed viscosity of 750-1250 cps at 77 F to ensure easy flow.
3. The epoxy grout resin shall meet the properties listed in the table below.
4. The epoxy grout must be so that its color would show through the glass laminate.
5. Epoxy grout will require placement by incorporating ports in the jacket at 180 degree alternating positions and filling the resin from bottom until it comes out of the next top one; then sealing the first port and connecting to the next top one and continuing thus.

| Epoxy Grout Resin Properties | | |
|-------------------------------------|-----------------|--------------|
| Property | Standard | Value |
| Viscosity @ T=77° F, cps | ASTM D-1290 | 750-1250 |
| Tensile Strength, psi | ASTM D-638 | 5,100 |
| Compressive Strength, psi | ASTM D-695 | 8,500 |
| Tensile Elongation, Max. % | ASTM D-638 | 4-8% |
| Hardness, Min. Shore D | ASTM D-2240 | 85-90 |

C. UNDERWATER GROUT (See Section 3.2.E for Application Instructions)

1. The fill material shall be a pumpable underwater cement-based non-shrink grout.

2. The grout shall meet the US Army Corps of Engineers CRD-C-621 specifications for plastic/flowable conditions.
3. The grout shall have minimum compressive strength of 2500 psi (1 day), 8050 psi (7 days) and 9100 psi (28 days).
4. Underwater grout will require placement by incorporating ports in the jacket at 180 degree alternating positions and filling the resin from bottom until it comes out of the next top one; then sealing the first port and connecting to the next top one and continuing thus.

2.4 SPACERS

Spacers used to create an annulus around the pile shall be of the non-reactive type.

2.5 REINFORING MATERIAL

Note: In cases when additional strengthening of the pile for flexural or axial capacity is needed, supplemental reinforcement can be positioned in the annular space. Reinforcing elements can either be one of two types. The first is QuakeWrap® GU50C unidirectional carbon laminate; these strips are 4 inch wide x 0.05 inch thick and have a smooth surface; they can only be used with Low Viscosity Resin (Option A in Section 2.3) is used as Fill Material. The second is epoxy-coated steel reinforcing bars; these are used with larger annular spaces and are suitable when either Epoxy Grout or Underwater Grout (Options B, and C, respectively in Section 2.3) are used. Please select the appropriate reinforcing material from the following 2 options:

A. Carbon FRP Strips

1. The reinforcing material shall be a non-reactive and fully cured carbon FRP strips with a thickness of 0.47 inch and width of 4 inches.
2. The laminate shall have a tensile strength of 400 ksi and a tensile modulus of elasticity of 24,000 ksi.

B. Reinforcing Steel

1. The reinforcing material shall be Grade 60 steel conforming to ASTM A615.
2. The reinforcing steel shall be epoxy coated and conform to ASTM A775.
3. Prior to installation in the field, all reinforcing steel shall be inspected to ensure the epoxy coating is free of any damage. Epoxy coat the ends of rebar that has been cut in the field.

2.6 ALTERNATIVE MATERIALS

Any alternative materials proposed as a substitute for the materials specified in this specification shall be submitted for review and approval to the Project Engineer at least 15 days prior to the bid date.

PART 3 – EXECUTION

3.1 PREPARATION

A. Timber Piles

1. All timber piles scheduled to receive FRP encasements shall be cleaned using high pressure water jetting with rating of 5000 psi. Contractor shall take precautions in order not to remove intact timber section from the existing timber piles during preparation activities. The purpose of this preparation is to remove all marine growth and any soft surface layer that may have accumulated on the piles. Severely deteriorated timber may be removed with water blast.
2. The elapsed time between the cleaning of a timber pile and the installation of the encasement on that timber pile shall not exceed 72 hours. If this time frame is exceeded contractor shall re-clean the pile prior to encasement.
3. Irrespective of paragraph 3.1.A.2, above, Contractor shall remove any marine growth that has accumulated on the pile prior to the installation of the FRP jacket.

B. Concrete Piles

1. All loose and deteriorated concrete shall be removed using hydraulic or pneumatic hand tools.
2. Contractor shall take precautions not to damage non-spalled or cracked concrete at location of scheduled repair.
3. After loose concrete is chipped away, all concrete surfaces scheduled to receive encasements shall be cleaned using high pressure water-jetting with rating of 5000 psi. The purpose of this preparation is to remove all marine growth and any soft surface layer that may have accumulated on the piles.
4. The elapsed time between the cleaning of the concrete surface and the installation of the FRP encasement shall not exceed 72 hours. If this time frame is exceeded contractor shall re-clean the pile prior to encasement.
5. Irrespective of paragraph 3.1.B.4, above, Contractor shall remove any marine growth that has accumulated on the concrete surface prior to encasement.

C. Steel Piles

1. All steel piles scheduled to receive FRP encasements shall be cleaned using high pressure water jetting per SSPC SP-12. The purpose of this preparation is to remove all marine growth and any soft surface layer that may have accumulated on the piles.
2. The elapsed time between the cleaning of a steel pile and the installation of the encasement on that steel pile shall not exceed 72 hours. If this time frame is exceeded contractor shall re-clean the pile prior to encasement.
3. Irrespective of paragraph 3.1.C.2, above, Contractor shall remove any marine growth that has accumulated on the pile prior to the installation of the FRP jacket.

3.2 APPLICATION

A. Epoxy Paste

1. The epoxy paste shall be appropriate for underwater installations or for dry installations, as applicable. Adhere strictly to Manufacturer's Recommendations.
2. The epoxy shall be mixed in small batches at the point of installation.
3. Great care shall be given to application of the epoxy paste to the laminate. Thoroughly clean the laminate surface per manufacturer's recommendation prior to the application of the epoxy paste. Air, water and laminate surface temperature shall be between 45 and 90 degrees F.
4. Do not begin application if air, water or laminate surface temperature is below 45 or expected to fall below 45 F within 12 hours of application.
5. Do not begin application if the dew point is within 5 F of the temperature.
6. All epoxy components shall be conditioned to a temperature between 65 and 85 F prior to the time of mixing.

B. FRP Laminate Jacket (Encasement)

1. Cut the required length of the 4-ft (1200-mm) wide laminate jacket in the field. Note that the jacket must wrap a minimum of twice around the pile (720 degrees) plus an 8-inch (200-mm) overlap.
2. Thoroughly mix the epoxy paste.
3. Apply a 30-mil thick film of the epoxy paste to the overlapping portion of the laminate. A notched trowel can be used to ensure uniform epoxy thickness.
4. Tubes or Spacers and Ports.
 - a. Tubes are used with Low Viscosity Resin; see Section 2.3.A. Secure a minimum of three injection tubes at 120 degrees apart along the height of the pile to be repaired. Grooves may be cut into the pile to place the tubes flush with the face of the pile.
 - b. Spacers are used with Fill Material; see Section 2.3.B and 2.3.C. Install two injection ports in the laminate jacket, one near the bottom of the jacket and the second near the top of the jacket and 180 degrees opposite to the lower jacket. Install the Spacers around the perimeter of the pile at the same elevation to form a "ring". Install one "ring" of Spacers near the bottom of the laminate jacket and install a second "ring" near the top of the laminate jacket.
5. Wrap the laminate around the pile ensuring the second layer is in full contact with the first layer. Adjust the diameter of the jacket as necessary.
6. Use ratchet straps or shrink wrap as temporary means to keep the FRP diameter in the desired size.
7. When necessary, additional 4-ft (1200-mm) sections of laminate can be installed similarly. Apply epoxy paste over the overlapping portion of the first laminate to create a longer jacket.
8. At the contractor's discretion Steps 3 through 7 can be performed on a portion of the pile above water and the assembly lowered below the waterline.
9. Seal the bottom of the annular space.

C. Fill Resin Placement Equipment

1. Contact the FRP Manufacturer for recommended mixing equipment.
2. For small projects the resin may be proportioned and mixed separately before placing the mixed resin in a dispensing pump.
3. For larger projects, an automatic measuring, mixing and dispensing pump must be used.

D. Mixing and Placing Low Viscosity Resin Described in Section 2.3.A above

1. Mix the resin at the point of installation. Adhere strictly to Manufacturer's Recommendations.
2. Minimum application temperature shall be 45 F.
3. All epoxy components shall be conditioned to a temperature between 65 and 85 F prior to the time of mixing.
4. Introduce resin at the bottom of the annular space using tubes of the appropriate size. At a minimum, use 3 tubes located at 120 degrees.
5. Fill the lower 6 inch (150 mm) of the annular space with resin. Allow sufficient time for this resin to set and penetrate into the pile, creating a horizontal seal layer at the bottom of the FRP jacket.
6. Fill the remaining height of the annular space with resin. Fill resin placement shall begin from the bottom of the laminate jacket until it reaches the top of the jacket. The density of the fill resin is heavier than water and will push the water to the top of the annular space.
7. Allow fill resin to overtop the jacket until all water has been removed from the inside of the jacket.

E. Placing of the Fill Material Described in Sections 2.3.B and 2.3.C above

1. Fill the lower 6 inch (150 mm) of the annular space with fill material. Allow sufficient time for this material to set, creating a horizontal seal layer at the bottom of the FRP jacket.
2. Fill material placement shall begin from the bottom of the laminate jacket using pre-installed ports that are positioned at alternating 180 degrees. Start filling the annular space from bottom until the fill material comes out of the next top port; then seal the first port and connect hose to the next top port and continue thus.
3. Allow the fill material to overtop the jacket until all water and any debris has been removed from the inside of the jacket.
4. Seal the top ½ inch height of the annular space with low viscosity resin.

3.3 INSPECTION

A. The Work to be provided in accordance with this Section of the Specification shall be subject to inspection by Owner at any time(s) during the progress of the Work. Contractor shall provide access and any labor, materials, tools, and equipment required by Owner to complete inspection of the Work as specified herein.

B. Completed installations shall be visually inspected to confirm the integrity of the laminate encasement and the resin fill. Any deficiencies shall be corrected at the Contractor's expense. The Contractor shall propose a repair method and submit it to the Engineer for approval prior to implementing said repair.

C. Acceptance of structure shall be contingent on the Work meeting all of the requirements of the Contract Documents as indicated by the results of all testing, inspection, and other quality assurance procedures required by Owner.

END OF SECTION