DEPARTMENT OF TRANSPORTATION

Bridge Pile Repair Using Underwater Fiberglass Reinforced Plastic (FRP) Jacket and Steel Reinforced Grout

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February 2025

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Final Report 2024-28

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16. Abstract (Limit: 250 words)

This study explored the feasibility and acceptability of using stay in-place fiberglass reinforced plastic (FRP) jackets and underwater steel reinforced grout for timely bridge piling repairs in Minnesota without dewatering. One of the goals of the project was to determine the current state of practice to this corrosion repair and inspection by researching other projects using similar repairs and to develop a survey to other departments of transportation to gather their experience with this type of repair. Another goal was to document the entire repair process on bridge 9462. Two different products, Five Star PileForm F Jacket and grout system and Denso SeaShield FX-70 and grout system, were installed, and contractor feedback was collected during the installation. This type of repair had a very limited impact to the surrounding area compared to a cofferdam-type repair. In fact, the repair was practically invisible to the drivers on the bridge and boaters were able to pass under the bridge while repairs were taking place. The contractor preferred the Denso product due to the jacket being stiffer, which made the jacket want to shut, since visibility in the water was zero. The jacket's seam was easier to line up. Both products had identical installation steps, and both seemed to be a viable alternative to bridge pile repairs based on the performances from other projects found during the research.

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BRIDGE PILE REPAIR USING UNDERWATER FIBERGLASS REINFORCED PLASTIC (FRP) SLEEVE AND UNDEWATER GROUT

FINAL REPORT

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EXECUTIVE SUMMARY

The objective of this research project was to assess the feasibility and acceptability of using stay in-place fiberglass reinforced plastic (FRP) jackets and underwater steel reinforced grout for timely bridge piling repairs in Minnesota without dewatering. The project aimed to explore the current state of practice of corrosion repair and inspection, record on-site observation, and document the repair process using two different products, gather lessons learned, and provide inspection recommendations.

Minnesota bridge 9462, which is near Saint Cloud, Minnesota, on U.S. Highway 10, was selected for bridge pile repairs. Bridge 9462 is a 3-span continuous slab span supported by cast-in-place (CIP) steel piles. The bridge was widened in 1992, and the original CIP piles from 1962 were found to have 40% to 70% section loss in a 2019 inspection. The pile repair design and plans were completed in-house at the Minnesota Department of Transportation (MnDOT).

To determine the current state of practice of corrosion repair and inspection, a survey was sent to other departments of transportation (DOT) to learn about their experiences and guidelines. The survey results helped evaluate whether there were more available products, how the corrosion repair performed, and if common issues exist to look for during inspection. To further aid in determining the current state-of-corrosion repair, research was conducted on other projects completing similar-type repairs. The research looked for which products were specified and installed and performance of the products.

The research project documented step-by-step the installation of two different products, Denso Seashield FX-70 and grout system and Five Star Pileform F jacket and grout system, which were installed on the two piers of bridge 9462. The installation steps for both products were nearly identical. The contractor's feedback and lessons learned were gathered on the experience of installing the two different products.

Both Denso and Five Star were contacted to determine their recommendations for inspection. The results from the DOT survey also helped formulate inspection recommendations. AECOM recommends inspecting the FRP jacket one year and two years after installation by a MnDOT bridge safety inspector team leader, or under the direct supervision of a MnDOT bridge safety inspector team leader, to determine how the repair is performing. After two years, the inspection of the FRP jacket should occur on the next cycle of underwater inspection for the bridge if the FRP jackets are performing well. Inspection should look for cracks in the FRP jacket caused by impact or ice damage. If the jackets are not performing well and defects are found in the repairs, the issue should be addressed immediately. This could involve repairing or replacing the damaged section. The service life of the jacket typically spans between 5 and 30 years.

The divers from Nordic Group, who completed the repairs to bridge 9462, preferred the Denso FRP jackets over the Five Star jackets. The Denso FRP jacket closes on itself because the jacket is stiffer than Five Star jackets, which benefits the diver in water with poor visibility like the water at bridge 9462. Nordic Group also recommends doing a dive inspection to get field measurements and field conditions for the repair plans to reduce costs by reducing leftover materials. AECOM believes this research project

has shown that using stay in-place fiberglass reinforced plastic jackets and underwater steel reinforced grout is a feasible and acceptable method for timely bridge piling repairs in Minnesota.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE AND SCOPE

In September 2019, the Minnesota Department of Transportation (MnDOT) performed a pile inspection on bridge 9462 carrying southbound traffic on U.S. Highway (US-10) over Little Rock Lake. Bridge 9462 was originally constructed in 1962 and widened with a new superstructure in 1992. The bridge is a three-span concrete continuous slab system. The abutments are supported by cast-in-place piling. The piers are open pile bents piers supported on cast-in-place piling 16-inch diameter with 0.25-inch thick steel pipe pile shell.

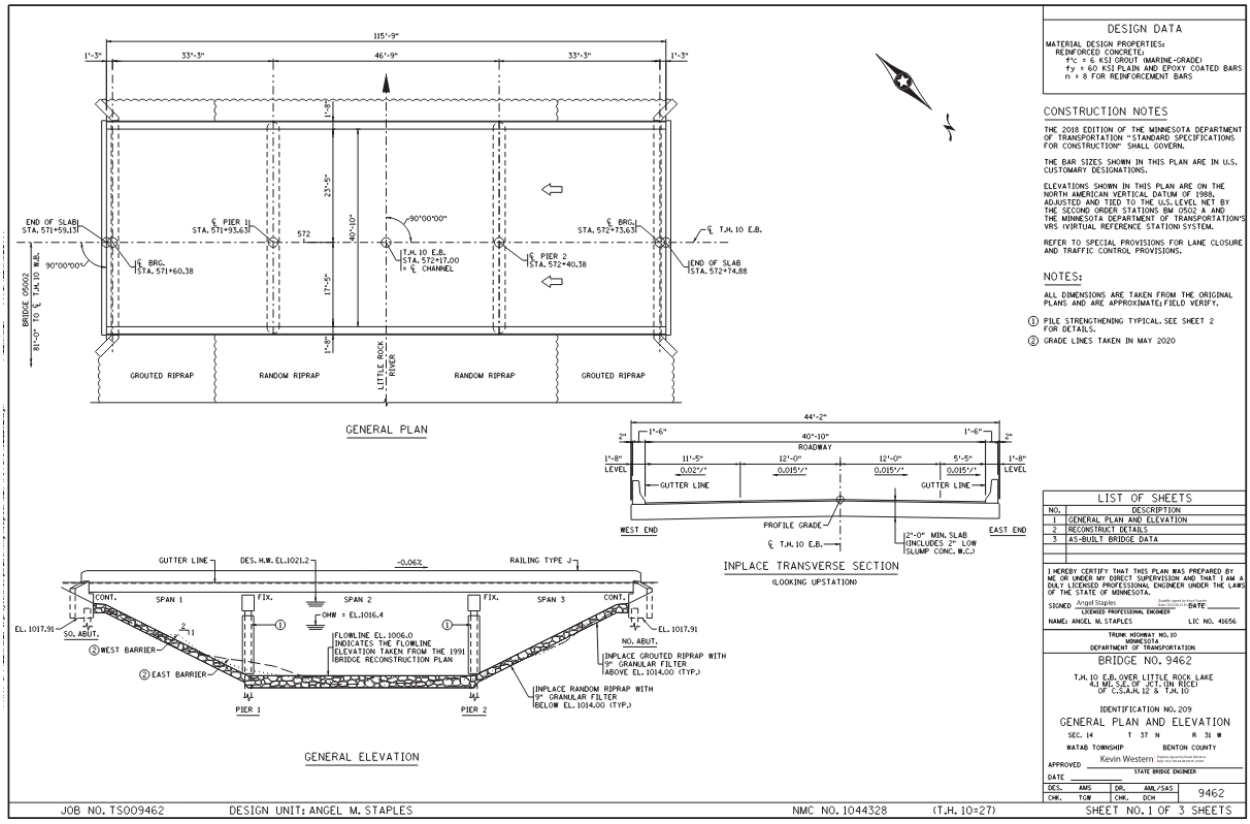

Figure 1.1: Bridge 9462 Plan and Elevation

At the time of inspection in 2019, the water level was lower than normal due to work by the Department of Natural Resources (DNR) downstream on the Mississippi River. The inspectors found dime sized areas in the steel pipe piles where the infill concrete could be observed. MnDOT had the Bridge Office Fracture Critical Inspection team conduct an inspection with a D-meter and discovered severe pitting on all the original piles installed in 1962. The percent of section loss on the piling ranged from 40% to 70% in an area about five to six feet below the concrete pile cap.

The pile repair design and plans were completed in-house by MnDOT in June 2021. The pile repair required pile strengthening due to the section loss. The reinforcement consisted of #4 hoop bars or spiral reinforcement placed around the pile with vertical #6 reinforcement placed inside the perimeter of the hoop bars. The marine-grade grout was to be placed in a six-inch annular space created by the stay in-place form, which is a fiber-reinforced plastic pile jacket, and the bridge pile.

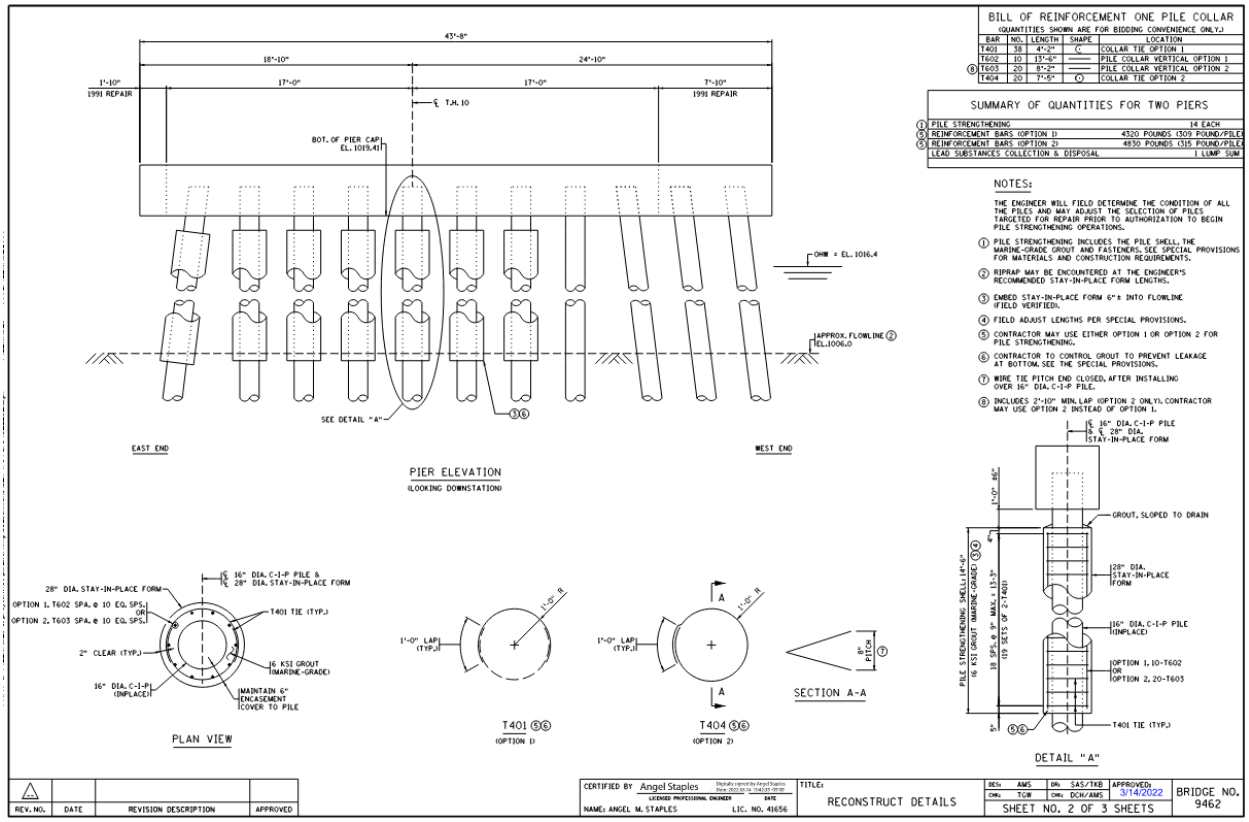

Figure 1.2: Repair Details

The traditional repair of a bridge pile in a waterway or lake would require the construction of a cofferdam to cast a concrete collar around the pile. This type of repair can be expensive due to the cost of the cofferdam construction and keeping the work area dry by continually running water pumps. Traffic would have disruptions for hauling heavy equipment and lane closures during the sheet pile installation. The cofferdam in this area would need to be installed outside the bridge limits and parallel to the bridge, which would disrupt boat traffic traveling under the bridge. Attempting to construct a cofferdam under the bridge would be difficult due to limited clearance under the bridge. Blocking off water passage under the bridge would have an environmental impact on the natural flow of water and aquatic life that uses the passage under the bridge or the habitat around the bridge. Another potential environmental impact would be an accidental chemical spill while refueling pumps or equipment that could lead to water pollution. The construction of the cofferdam could have an impact on local businesses and homeowners with the heavy machinery and sheet pile driving by causing noise disturbance and vibration potentially causing damage. This type of repair can be disruptive, expensive,

and time consuming and have significant environmental impact with the cofferdam sheeting installation, pumping, and removal.

This project explores bridge pile repair, which requires no dewatering or cofferdams, using stay in-place underwater FRP pile jackets and grout systems. In addition to being a stay in-place form, the FRP jacket properties make the jacket non-corrosive, one will not rust or deteriorate over time, which makes for a preferred choice for repairing bridge piles in marine or corrosive environments. FRP jackets can be installed without major disruptions to traffic or other activities on the bridge. The structure can generally remain in service during repairs and the repair process is practically invisible to the drivers on the bridge. Because the FRP is lightweight and easy to handle, the pile jackets require less heavy equipment and can be installed more quickly than steel jackets. The repair cost is lower due to not having the associated costs needed for cofferdam construction.

The special provisions required the installation of a pile strengthening system on 16-inch diameter CIP piles with corroded areas below the waterline. The work involved providing and installing the qualified products, Five Star PileForm F Jacket and grout system and Denso SeaShield FX-70 and grout system, in accordance with the manufacturers' application procedures. The contractor was required to provide documentation from the manufacturers that it was formally trained to install their products, and all workers installing the product had to have received installation training. The work included collection of samples, supplemental underwater pictures or video, if possible, removal of the pile jacket system, if required, and participation in interviews with the research team. All work needed to be performed without dewatering. The work needed to comply with specific requirements for surface preparation, excavation, and containment.

CHAPTER 2: RESEARCH OF CURRENT STATE OF PRACTICE

2.1 REVIEW OF SIMILAR PROJECTS

The projects found below were found by numerous Google searches with varying keywords. The results vary from articles about the projects or project documents like plans or specifications.

2.1.1 Glynn County, Georgia

In 2017, Glynn County Public Works Department proposed to use Five Star Product Pile Jacket Epoxy Grout Low Viscosity (LV) for pile repair on two bridges. One bridge was the Burnett Creek Bridge which had circular timber piles, and the other bridge was the Fancy Bluff Creek Bridge which had rectangular concrete piles (Glynn County). There is no data available on current performance of the repair.

2.1.2 Maryland Department of Transportation

The Maryland Department of Transportation has standard details for fiberglass protective pile jacket for existing piles. The details call for a circular pile jacket for existing piles that are square and circular. The standard details were developed in June of 2017 (MDOT SHA).

2.1.3 Clear Lake, Texas

In 2003, a bridge near Clear Lake, Texas supporting Interstate 45 was repaired using the SeaShield Series 500 system from Denso. Thirty-six square concrete piles were repaired. An inspection in 2020 revealed the Denso system is performing as designed. The repairs have withstood tidal surges and impact from floating debris from Hurricane Rita and Hurricane Ike in 2005 and 2008, respectively (Materials Performance).

2.1.4 Wisconsin Department of Transportation – Yahara River

In 2016, the Wisconsin Department of Transportation released plans to rehabilitate two bridges over the Yahara River, bridge B-13-0315 & bridge B-13-0316. The piles were 14-inch diameter pipe piles. The specifications allowed the use of one product out of this list: Denso Seashield 2000HD, Denso SeaShield Series 500, Simpson Strong-Tie FX-70 System (since acquired by Denso), Five Star PileForm F FRP Jacket and Epoxy Grout System and Stopaq Composite System (WisDOT).

2.1.5 New York Department of Transportation – Bridge 1055040

In 2018, the New York Department of Transportation released plans proposing to install SeaShield Series 500 on 12-inch diameter steel pipe piles. The repairs also called for petrolatum-based tape for anti-corrosion membrane and a tough outer cover that surrounds the tape to protect against weathering and mechanical damage (NYDOT).

2.1.6 Ontario – Holland River Bridge

In 2013, the Holland River Bridge, north of Toronto in Ontario, Canada had the timber piles repaired with Denso SeaShield Series 500 system. The work was completed in fall of 2013. In the winter of 2013, Ontario experienced tremendous snow and ice, and the Denso product protected the piles from any damage. The piles were inspected in the spring and found no damage. As of 2019, the Denso system continues to provide protection of the bridge piles (Frasers).

2.1.7 Duluth-Superior Harbor

In 2008, AMI Consulting Engineers (AMI) and Wisconsin Sea Grant Institute teamed up to study jacketed pile and cathodic protective systems on steel structures. For the jacketed pile portion, AMI installed Denso SeaShield Series 2000 FD jacket and Denso SeaShield Series 500 H-Jacket in the Duluth-Superior harbor. The report documents the installation procedure for the two jackets. AMI did not run into any major issues with the installation and noted "a benefit of installing a large number of pile jackets at one time would include improvement in installation time by a contractor." (Scott, 2008).

2.1.8 Battery Park City Authority – New York, New York

In 2015, the Battery Park City Authority contracted a pile remediation project to place square pile jackets around 20-inch by 20-inch prestressed concrete piles. The specifications mentioned products that may be incorporated by Sika Corporation, Fox Industries, Five Star Marine, and Denso. In the memo for Phase 5 & 6 Pile Remediation, "Battery Park City Authority has chosen the grout filled fiberglass jackets as a method to extend the life of the piles for 40-50 years." (Battery Park City Authority).

2.2 RAC SURVEY REVIEW

In August of 2023, Minnesota Department of Transportation conducted a survey on pile strengthening among bridge owners across the United States. The bridge owners that participated in the survey are part of the Bridge Preservation Working Group affiliated with the National Center of Pavement (NCPP). The objective of this survey was to gather information on the experience of other Departments of Transportation that have used stay-in-place fiberglass reinforced plastic (FRP) jackets and underwater steel reinforced grout for pile repairs. The survey contained fourteen questions on the techniques used, types of inspections, guidelines, and various aspects of pile repair. The survey results are available in Appendix B. There was a total of thirty-three DOTs (Departments of Transportation) who took part in this survey.

The techniques applied to pile strengthening/pile repair vary across different states. According to the result from the pile survey, the top techniques seen or used by DOTs across the states are fiber wrapping, FRP jackets, welding, and the encasement of piles in concrete. Furthermore, for pile repairs under existing structures, dewatering is considered, especially in areas with large water channels. Based on the responses from the survey, the most common technique used for dewatering under an existing

structure is the use of cofferdams, stream diversion, and placement of barriers. Due to the challenges and expenses that occur with pile repairs under existing structures, especially considering dewatering, different pile repair methods are being explored. One of these repair methods utilizes stay-in-place forms with grout in-fill (unreinforced or reinforced) without dewatering which 75% of the survey participants have used or are familiar with. The stay-in-place form with grout in-fill has been used mainly to mitigate deterioration such as section loss and corrosion in steel piles, wide cracks, spalling in concrete piles, and decay/deterioration in timber piles. The below table lists the advantages and disadvantages of using stay-in-place forms with grout in-fill provided in the pile survey.

Table 2.1: Advantages and Disadvantages using stay in-place fiberglass reinforced plastic (FRP) jackets and underwater steel reinforced grout.

Advantages	Disadvantages
Dewatering not needed	Hidden defects (e.g., honeycombing)
Easy to implement	Difficulty inspecting the repair
Economical/Cost effective	Difficulty working in water
Durability	Accessibility of contractor performing repairs
Added rigidity to the deteriorated pile	Difficulty estimating the grout quantity
Less negative impact for environment	
Jacket can be customized	
Less intrusive	

The time interval used for in-service inspections of this method of repair has been observed to be 24 months by most DOTs; however, there are a few that used a 12-month or 48-month time interval for their inspection. In addition, most DOTs use multiple types of in-service inspections for this repair method. The type of in-service inspection selected included the use of Binoculars, inspection from a Boat/Snooper, and underwater inspection. For the use of fiberglass sleeves, one of the guidelines referenced by most of the participants was visual inspection, although if there was evidence of potential defects further inspection procedures are recommended such as point sounding. Additionally, most DOTs follow the construction inspection criteria set by their respective state and manufacturers.

DOTs tend to use varied brands of fiberglass and grout depending on the suppliers available and the location. The list below contains the brands mentioned in the pile survey results:

- Five Star
- Fyfe
- Denso SeaShield
- Simpson Strong Tie
- Pile Medic
- Fox Industries (Denso FX-70 Product)
- Sika Product

- Aquawrap
- Quakewrap
- Euclid Chemical
- Quikrete Companies
- SpecChem
- Kwik Bond Polymers

Among the participants only one DOT has had an issue with a particular brand known as, Aquawrap.

The expected service life added to the structure using the stay-in-place form and grout in-fill repair method ranges from 5 years to 30 years; however, the service life of the structure varies depending on the extent of deterioration and the condition of the bridge. There are a few DOTs that have experienced failure in their bridge pile repair. Some of these failures were due to debris impact and insufficient insight on the extent of the pile deterioration and in other cases it was due to the installation process for the repair such as the jacket coming loose, and inadequate amount of grout fill.

2.3 AVAILABLE PRODUCTS

There appear to be different types of corrosion control systems like a system using petrolatum tape and an outer cover for protection, FRP jacket with epoxy grout, and FRP jacket with underwater grout. The following FRP products can be used as stay in place forms with an underwater grout.

2.3.1 Denso Seashield Series FX-70

The SeaShield FX-70 is a fiber-reinforced plastic composite that is corrosion-resistant and acts as a stay in-place form in marine environments. The FX-70 system was developed by Fox Industries in 1970, later came a part of Simpson Strong-Tie (Simpson Strong Tie Co.). Denso, a subsidiary of Winn & Coates International, acquired the Simpson Strong-Tie FX-70 System from Simpson Strong-Tie in November of 2021, and is continuing to market the FX-70 designation as SeaShield FX-70 (Denso). The system can be used to repair concrete, steel, or timber piles without dewatering and in most cases keeping the structure in service. The system can use either SeaShield FX-225 non-shrink underwater grout or SeaShield FX-70-6MP multi-purpose marine epoxy grout. The non-shrink grout is generally used when pile strengthening is required, and the epoxy grout is generally used when pile strengthening isn't required but a corrosion prevention system is needed.

2.3.2 Five Star PileForm F Jacket

The Five Star PileForm F jacket is a fiberglass reinforced plastic jacket used in hostile marine environments where exposure to ice, floating debris, chemical pollution, oils, acids, salt water, and tidal action may occur. The jacket is also a stay in-place form to be placed around concrete, steel, or timber piles. Five Star also has an underwater non-shrink grout and underwater epoxy grout depending on if pile strengthening is required or not.

2.3.3 Molded Fiber Glass (MFG) Construction and Water Products

MFG Construction and Water Products (MFG CWP) have fiberglass pile jackets to repair structural piles due corrosion or other environmental factors. Their fiberglass pile jackets are resistant to acids, alkalies and most solvents and deliver long-lasting corrosion free protection. Their jackets have been used on Department of Transportation projects in New York, New Jersey, North Carolina, South Carolina, and Louisiana. They do not have underwater grout or epoxy grout so that would have to come from another manufacturer.

2.3.4 Comtech Manufacturing

Comtech Manufacturing appears to only supply the plastic jacket. Their installation process recommends the use of Sika products for epoxy adhesive and sealing compounds. Their repair guide uses Silpro or epoxy grout to fill the annular space. It is worth noting their website homepage says, “We have currently put a hold on all manufacturing, however they have an inventory of 14”, 16” and 18” round pile jackets 12 feet long readily available.”

2.3.5 Pile Medic

The Pile Medic system uses fiber-reinforced polymer laminates to create a jacket around the pile. The wrap must wrap a minimum of twice around the pile plus 8-inches to create the jacket. The annular space can be filled with the provided low viscosity resin, epoxy grout, or underwater grout. The U.S. Army Corps of Engineers, California DOT, and Texas DOT have performed tests on Pile Medic and the use for pile repairs.

2.4 IN-SERVICE INSPECTION RECOMMENDATIONS

2.4.1 Five Star Marine Recommendations

Five Star Marine recommendations for inspection are to inspect the pile jackets for cracks and impact damage. The inspection usually happens once every three years. Freeze-thaw and impact damage are the two reasons for cracking in the installed jackets. A crack in the fiberglass jacket does not mean the system is compromised. The crack would need to go all the way through the fill material. If small cracks are found in the fiberglass jacket, the cracks can be repaired with Five Star Splash Zone, 100% solids two-component epoxy putty, which is the product often used to seal the top of the fiberglass jackets. If the jackets are properly installed using Splash Zone to prevent penetration of water into the system, then only impact damage would cause cracks.

2.4.2 Denso Recommendations

Denso recommends inspecting the jackets for cracks within the fiberglass jacket and ensure the grout is still holding up. Denso mentioned sounding with a hammer is a common method for checking for delamination in the grout. Any damage would be from mechanical damage like ice or impact. Repair

recommendation would depend on the severity of damage and would be a case-by-case situation. There are instances when epoxy grout can be injected into voids if they form within the grout.

2.4.3 Recommendations to MnDOT

AECOM recommends the following procedures for the inspection and maintenance of the pile repair:

- **Visual Inspection**: Start with a thorough visual inspection of the FRP pile shields. Look for any visible signs of damage, wear, cracking, or delamination on the surface. Pay attention to areas where the FRP material is exposed or appears compromised.
- **Material Integrity**: Check for any indications of material degradation or loss of strength. FRP pile shields are designed to be durable, but exposure to harsh environments or mechanical stress can impact their integrity over time.
- **Adhesion and Bonding**: Assess the adhesion of the FRP pile shields to the underlying structure. Ensure that the bonding between the FRP material and the pile is secure and without any detachment or lifting.
- **Corrosion Protection**: While FRP materials are inherently corrosion-resistant, they might still be used in conjunction with other materials, coatings, or systems for additional protection. Verify the condition of any supplementary corrosion protection measures.
- **Surface Contaminants**: Check for any foreign substances or contaminants that could compromise the FRP's performance. Dirt, oil, or chemical exposure could affect the material's properties over time.
- **Structural Soundness**: FRP pile shields are often used for structural reinforcement. Inspect the piles to ensure that the FRP material is effectively enhancing their load-bearing capacity and stability.
- **Environmental Factors**: Consider the environmental conditions the FRP pile shields are exposed to. UV radiation, extreme temperatures, moisture, and chemicals can affect the material's performance and appearance.
- **Documentation**: Keep accurate records of inspection dates, findings, and any maintenance or repairs conducted. This documentation helps track the condition of the FRP pile shields and supports informed decision-making.
- **Ultrasonic Testing**: Ultrasonic testing can be employed to assess the integrity of the FRP pile shield's bonding and any potential defects within the material. This non-destructive technique provides insights into the internal condition of the shields.
- **Expert Consultation**: For comprehensive inspections, involve experts such as structural engineers or product manufactures. They can provide insights into the FRP material's condition and recommend suitable actions based on their expertise.
- **Preventive Maintenance**: Regular inspections should be part of a preventive maintenance strategy. Alongside inspections, ensure that proper installation, compatible coatings, and other protective measures are in place to maximize the longevity of the FRP pile shields.

- **Repairs and Replacements**: If issues are detected, address them promptly. This might involve repairing or replacing damaged sections of the FRP material or taking actions to prevent further deterioration.

2.5 CONSTRUCTION CONSIDERATIONS

With the help of Nordic group, AECOM's first consideration would be to determine what corrosion protection system needs to be installed. The corrosion protection system with grout in the annular space between the pile jacket and bridge pile typically is for pile strengthening and to provide corrosion protection. The systems that use an epoxy grout in the annular space between the pile jacket and bridge pile helps to restore piles and prevent further corrosion to the pile. This decision should ultimately be decided by the structural engineer. The Simpson Strong-Tie literature for the FX-70 mentioned their epoxy grout system is ideal with structures with less than 25% section loss and the underwater grout for repairs with greater than 25% section loss (Simpson Strong Tie Co.). The next consideration would be determining the shape of the fiberglass pile jacket. Round piles would typically have round pile jackets. H-piles can either have a round or square pile jacket placed around them if reinforcement is needed or have a pile jacket in the shape of the H-pile.

Both Denso and Five Star recommend the surface of the existing piles whether the piles are concrete, steel or wood should be thoroughly cleaned and prepared to ensure good adhesion between the existing pile and the fiberglass pile jacket. Any loose rust or materials and marine growth should be removed. Denso and Five Star both recommend cleaning the existing piles with a high-pressure water blast or other mechanical means. Five Star recommends using a minimum of 4,000 pounds per square inch (psi), see Appendix D. Denso recommends to prepare the surface to meet either ICRI Guideline 310.2R CSP 3-6 for concrete, SSPC-SP12/ NACE 5 WJ-4 for steel or to achieve sound surface for wood by using a high-pressure water-blasting or other mechanical (Denso). The fiberglass pile jacket surfaces should also be sound, clean, and free of all contaminates that could prevent proper adhesion.

Denso recommends the underwater placements of the fiberglass jackets should be attempted by experienced certified divers. The installation of the fiberglass jacket should follow the recommendation given by the manufacture. Install proper bracing or spacers if required. Complete a mandatory bottom seal pour, typically 6" to 12" thick, and allow for proper cure time before completely filling the pile. The jacket can be placed in the mudline to help with the bottom seal or if the jacket doesn't extend to the mudline, Five Star mentions the bottom seal "may be closed foam, oakum, and expanding resin or other appropriate material.", see Appendix D. Place the grout or epoxy grout in the manufactures recommended temperatures. Denso recommends having the surface temperature prior to application to be at least 40°F to 95°F (4°C to 35°C) for their FX-70 system (Denso). Five Star recommends having the surface temperatures between 40°F to 90°F (4°C to 32°C) at the time of placement for their underwater grout, see Appendix E. Both Denso and Five Star recommend not to exceed the water content as stated on grout bags to prevent segregation or separation. Do not over fill the pile jacket.

Tasks that MnDOT may want to consider for inspectors during installation are:

1. Verify the piles are cleaned using a minimum of 4,000 psi of marine growth, rust, and other contaminants. A dive inspector may be required for this if the piles can not be inspected while standing in the water.
2. Verify the reinforcement placement like proper overlaps and proper distance from the pile to meet the reinforcement cover.
3. Verify the pile jackets are clean of contaminants. Although not used in this project but verify pump ports are secured to the jacket if the pump ports are being used. If standoffs or internal spacers are, confirm they are secured to the jacket.
4. Confirm the length of pile jacket and verify the pile jacket is placed at the desired elevation. This would include excavation at the river or lake bottom. This step may also require a dive inspector.
5. Confirm the jacket is properly secured around the pile. Verify epoxy has been placed in the vertical tongue and groove joint, screws placed approximately every 6" and ratch straps placed approximately every 12 to 18 inches. Confirm the annular opening around the pile matches the plan and verify the reinforcement is met.
6. Confirm 6 to 12 inches of material has been placed for the bottom seal pour.
7. During the grouting operations:
    a. Note the name of grout being used.
    b. Take grout samples at the beginning of every shift and every five cubic yards installed.
    c. Record pumping rate and how the grout is being pumped, pumping ports, tremie or pouring from the top of the jacket.
    d. Calculate volume of grout installed.
8. Confirm the annular opening around the pile to ensure the pile didn't shift during the pumping operation.
9. Confirm the top of the pile jacket is sealed properly and per plans detail. Note the product being used to seal the top of the pile jacket.

The divers installing the jackets may have helmet cameras to assist on verifying work is being completed in accordance with the manufacture instructions. However, the water needs to be clear to record the installation and Nordic Group mentioned most of the places they work have murky water.

CHAPTER 3: SITE OBSERVATION AND DOCUMENTATION

3.1 GENERAL SITE OBSERVATION

Nordic Group was the contractor who installed the fiberglass jackets. The group had experience installing jackets from Denso and H-pile jackets from Five Star Marine. The divers wore an underwater helmet mounted video camera, but the water visibility was zero possibly due to the algae. The divers mentioned most of the time when they dive the visibility is poor. Nordic Group did an exploratory dive before they started installing jackets and found the bottom of the channel was mostly muck or mud, and the depth was noticeably shallower than noted on the plans. The work started on pier 2, which received the Denso jackets, at the end of August 2022 and was completed at the end of September 2022. The approximate number of working days was 23 days.

Figure 3.1: Water Condition

3.2 JACKET INSTALLATION STEPS

The steps to install the jackets for both Five Star and Denso were nearly identical. The following steps were taken:

1. Surface Preparation: Piles were thoroughly cleaned by using high-pressure (3500 psi to 4000 psi) water-blasting to remove marine growth, rust, and other contaminants. An orange netting with an opening of a quarter of an inch that was folded over onto itself to create two layers was placed onto the pile to catch any lead paint chips flaking off from the cleaning.

Figure 3.2: Diver underwater cleaning pile with netting wrapped around pile

2. Site Preparation: The bottom around the piles were cleared of riprap or other objects preventing placement of the reinforcement cage or jacket. The divers encountered what they thought was overspilled concrete preventing placement of reinforcement cages and jackets. The divers used a pneumatic jackhammer to easily break up the concrete.

Figure 3.3: Diver prepping to start dive with jackhammer

3. Reinforcement Cage Placement: In order to install the reinforcement cages, the contractor placed a ratchet strap around each pile right under the pile cap. Quick Link D Shape Chains were attached to the ratchet strap with a piece of rope hanging from the Quick Link. The contractor pre-tied the reinforcement cages into two pieces on land. When half of the reinforcement cage was placed, the rope was tied to the top hoop of the cage to hang the reinforcement from the ratchet strap. The other half of the reinforcement cage was placed in a similar manner. The overlap of the hoop bars was to be 1'-0" per the plans. The reinforcement cage was adjusted with the ropes to get the hoop bars to align and to be tied.

Figure 3.4: Pier 2 (North) reinforcement cages

4. FRP Jacket Placement: Place jacket around pile. Diver was assisted by his team in the boat to get the fiberglass jacket placed around the pile. Prior to placing the Five Star jackets, the contractor had installed skirts on the bottom of the pile jackets. The skirts were made from a tarp. The tarp was attached around the bottom of the jacket using the same epoxy as used in the tongue-and-groove, see next step.

Figure 3.5: Pier 2 (North) Diver opening jacket at the bottom

5. FRP Jacket Joint Preparation: Once the fiberglass jacket was placed then the epoxy was applied using a manual dispensing tool into the female portion of the tongue-and-groove joint the whole length of the vertical joint, above and below the waterline. Denso has their own tongue and groove epoxy adhesive called SeaShield 525 TG Epoxy. The contractor used Dayton Superior ProAnchor Elite in the tongue and groove joint on the Five Star jackets. According to the manufacturer's data sheets, the Denso epoxy adhesive has a set time of 80 minutes at 77°F (25°C) or 50 minutes at 97°F (36°C), and the Dayton Superior ProAnchor Elite has a working time of 16 minutes at 75°F (24°C).

Figure 3.6: Worker in boat applying epoxy to tongue-and-grove joint above water

6. Closing FRP Jacket: The fiberglass jacket was forced shut by engaging the tongue-and-groove joint then strapping ratchet straps around the jacket to force to tongue-and-groove joint together to get a good seal on the joint. The ratchet straps were placed about every 18-inches from top to bottom.

Figure 3.7: Placing ratchet straps around jacket

7. Securing FRP Jacket Joint: Once ratchet straps are placed, the tongue-and-groove joint is secured by placing self-tapping stainless screws in the center of the joint every six inches. The length of the stainless-steel screws were one quarter of an inch.

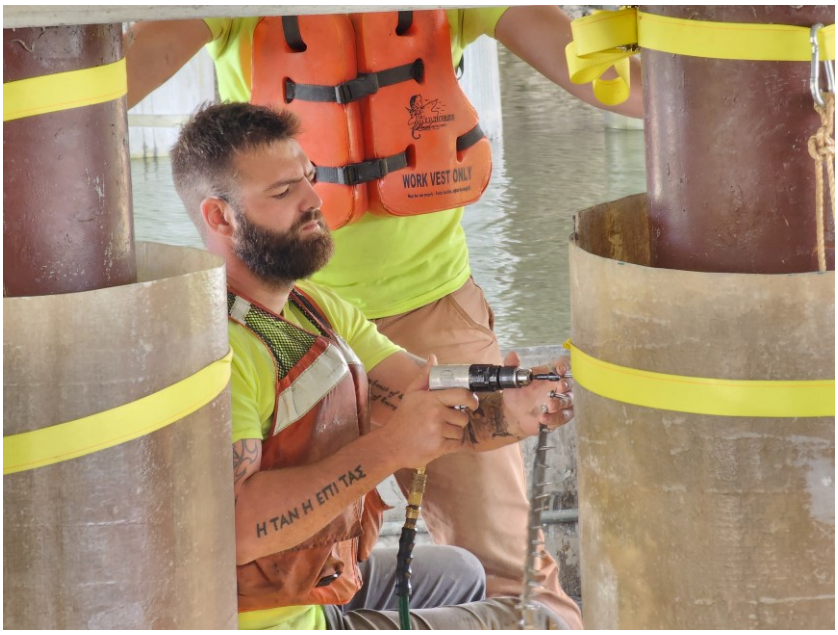

Figure 3.8: Worker securing tongue-and-groove joint with screws

8. Setting FRP Jacket: The bottom of the fiberglass jacket was placed into the mudline by rotating the jacket back and forth. The plans specified seating the pile jacket plus or minus six inches into the flowline. If needed, the divers could have used their pressure washer to assist in placing the fiberglass jacket by jetting the mudline. The mud inside the jacket was not removed once the jacket was placed into the mudline.

9. Installing Spacers: Wood spacers were placed at the top of the fiberglass jacket to help center the jacket around the pile. The wood spacers were approximately six inches wide.

Figure 3.9: Wood spacers at top of jacket

10. Bottom Sealing Pour: After the fiberglass jacket is secured, a six-inch bottom seal is poured using the manufacturer's specified grout. The skirts on the Five Star jackets were to help keep grout from leaking out of the bottom of the jacket during the bottom seal pour. On the Denso jackets, the contractor placed sand in the six-inch annular space before pumping grout to keep grout from leaking out at the bottom of the pile jacket.

Figure 3.10: Five Star jacket with skirt on the bottom

11. Grouting Operation: The day after the bottom seal was placed, the rest of the grouting continued. The pile jackets were not dewatered during the bottom seal pour or for the rest of the grouting operation. The six-inch wood blockings were removed prior to pumping grout. The grout bags and water were placed into the mixing tank then pumped into the jacket. The grout was pumped into the jacket from the top. There were no pump ports installed on the jackets. The barge stayed in place while the boat moved from one jacket to another. The grout was placed in one pile until the water got to the top of the jacket. The water appeared to be foamy so the contractor would start on the adjacent jacket to let the water in the first jacket settle. Once the second jacket had water at the top, they switched back to the first jacket to finish pumping grout to the top, then repeated the process. The ropes tied to the reinforcement were cut as the fiberglass jacket was receiving grout.

Figure 3.11: Grouting operation on the barge

Figure 3.12: Pumping grout into jacket

12. FRP Jacket Trimming: After the grout has cured, the ratchet straps around the jacket are removed, and the top of the jackets are trimmed down flush to the grout with a reciprocating saw. The trimming happened as early as two days after grouting on the Five Star jackets and as late as thirteen days after grouting on the Denso jackets.

Figure 3.13: Trimming top of jacket

13. Sealing Top of FRP Jacket: After the top of the jackets are trimmed down, epoxy was hand mixed and spread out on top of the jacket and grout to seal the system. Both manufactures had a product called Splash Zone for the top of the system. The plans called out for the sealing at the top of the FRP to slope to drain shown in Figure 1.2: Repair Details.

Figure 3.14: Epoxy ball on top of grout before being spread out

Figure 3.15: Finished jacket with Splash Zone epoxy at the top

3.3 FIELD OBSERVATIONS

One notable observation is the concern for the placement of rebar. The reinforcement was suspended at the top of the pile and had no mechanical support, such as rebar chairs, to prevent it from swinging or leaning to one side. Although the rebar cage could have been adjusted during the six-inch bottom seal pour, the cage might not have met the required two-inch cover on the bottom, especially if the top of the cage was leaning to one side. This issue is particularly concerning for the Denso jackets, which appeared to be off centered compared to the Five Star jackets due to the installation of six-inch wood spacers on the Five Star jackets. Another reinforcement concern is on the battered piles. The cage was hanging vertical so the bottom of the cage may be touching the pile due to the batter of the pile.

Figure 3.16: Denso Jacket (Left) & Five Star Jacket (Right)

Another notable observation was the removal of the tremie pipe during the grouting operation and coming back to the pile jacket to finish pumping. MnDOT's 2020 "SB" Bridge Special Provisions on Drilled Shaft Construction specifies "Place concrete continuously to the top of the shaft once placement has begun." (MnDOT 2020 "SB" Bridge Special Provisions). Similar language should be considered for future projects. This will help improve the grout integrity eliminating any cold joints or weak spots and ensure a better-quality product.

The Denso jacket was observed to be more difficult to place around the piles due to the jacket's tendency to close on itself. The diver needed assistance from the team in boat to hold open the top of the jacket during placement.

The Five Star jacket was observed to be more easily placed around the piles due to the jacket being more flexible. The jacket needed to be forced closed with ratchet straps which came with some issues. While forcing the tongue and groove joint together, some instances the diver needed a flat head screwdriver to get the tongue into the groove joint all the way down the joint of the jacket. This may have contributed to having a less than ideal seal on the joint. While pumping grout into the jacket, water was leaking out through the seam. If water can get out of the seam, water may get into the seam and

work the seam loose through freeze thaw cycle. The seam does have epoxy and screws to help hold the jacket together, but future inspections will help determine if a leaky seam during installation reduces the jackets life span.

Figure 3.17: Diver using screwdriver on Five Star joint

Before the contractor secured the tongue and groove joint with screws, they took a strip of duct tape, folded it with the sticky sides together, and proceeded to insert screws through the tape. This allowed the diver to easily install the screws instead of handling one screw at a time or losing a handful of screws underwater. Once the screw was driven to the surface of the fiberglass jacket then the diver would pull on the duct tape to rip the tape free leaving the screw behind.

Figure 3.18: Duct tape with screws

Both the Denso and Five Star products had minimal issues during grout pumping. Some minor issues were observed including the grout clogging the screen between the mixer and pump for the Denso grout. The screen needed to be removed and cleaned. The other issue was the grout line came apart at the hose connection. Both of these instances were rare occurrences, and neither was cause by the products.

Figure 3.19: Grout line connection came apart

3.4 GROUT SAMPLE TESTING RESULTS

Per the special provisions, grout samples were to be collected in accordance with ASTM C109 and tested at 7- and 28-day intervals by MnDOT. The tested grout samples met the technical data for each product.

Table 3.1: Compressive Concrete Strength - Denso SeaShield 510 Underwater Grout

Day	Manufacture's Anticipated f'c (psi)	Sample 1 f'c Test Result (psi)	Sample 2 f'c Test Result (psi)
1	2,500	7,550	4,730
7	7,500	8,900	9,280
28	9,000	9,380	11,290

Table 3.2: Compressive Concrete Strength – Five Star Underwater Grout

Day	Manufacture's Anticipated f'c (psi)	Sample 1 f'c Test Result (psi)
1	3,500	-
7	8,000	8,450
28	8,500	9,870

CHAPTER 4: CONCLUSIONS AND LESSONS LEARNED

4.1 PRE-CONSTRUCTION

The timely discovery of structural problems or deficiencies is crucial to solving them. MnDOT District 3 was fortunate that its inspectors caught the pile deteriorations when they did. The inspectors' observation, combined with the temporary lowering of the lake, played a key role in determining the required work. Underwater inspections are critical for this type of structure in determining the maintenance of a bridge. Some crucial procedures in the underwater inspection are gathering accurate field measurements and evaluating the channel. Nordic Group recommended evaluating the channel for riprap removal and making preparations for unanticipated events such as a floating log lodge at the bottom of the piles during inspections. In addition, a common deterioration for piles is section loss; therefore, inspectors should be aware of this during inspection.

A practice that could be introduced into MnDOT inspection procedures could be to have inspectors collect data to assist in scoping for bridges that are repair candidates. The inspection data could include stream bed conditions, underwater visibility, extent of deterioration, flow rate, and the length of the pile to be repaired. The inspection condition data can be evaluated with the structural capacity of the bridge to determine if pile repairs are required.

The mudline and streambed of a pile should be inspected for corrosion and section loss. Although, deterioration below the mudline is not common, it is possible due to microbial-induced corrosion (MIC). During underwater inspection, if deterioration is noticed around the mudline, jetting can be used but this has to be done by certified MnDOT bridge inspectors. No section loss was observed at the mudlines for the piles on bridge 9462, therefore jetting was not done. Over a foot of streambed material can be removed if section loss is observed along the streambed.

For any construction project to begin, permits are required, and these permits vary depending on the location and laws applicable to the region. Additionally, an environmental review has to be performed to ensure the project does not negatively impact the environment or public health. This project was assessed by different federal and state departments to ensure the repairs were within guidelines. The list and information below contains the permits required and environmental reviews needed for this project (provided by MnDOT):

- United States Army Corps of Engineers
  This project falls under "Category 1: Minor Maintenance – Linear Transportation of the Corps Permit" due to the repair changes on the bridge piles. The statement below contains a detailed description of what cases falls under Category 1: Minor Maintenance:

  > *Minor deviations in a culvert or bridge configuration or filled area due to changes in materials, construction techniques, requirements of other regulatory agencies, or current construction codes, site conditions, or safety standards, including and limited to: the repair of a culvert aprons or bridge piles; lining or cleaning of pipes, culverts or bridges;*

extension of culverts without slope or shoulder widening; upsizing of culverts or flumes; maintenance of existing stream bank protection (not to expand original footprint); resetting or re-tying of aprons and culverts; and apron placements; including the use of temporary discharges necessary to conduct those activities

- MN Department of Natural Resources (DNR)
  A Public Water Work General Permit Authorization is required from the DNR for a Public Water Work Permit. In addition, due to the project being located in a *Designated Infested Water* by the DNR, a *"Best Practices Preventing the Spread of Aquatic Invasive Species"* had to be included in the contract.

- Office of Environment Stewardship
  The office of Environmental Stewardship performed environmental reviews on different aspects of the project:

    - MnDOT Cultural Resources Unit (CRU)
      The project met guidelines for state-funded projects exempted from CRU review. CRU had to send a letter stating that the project did not have the potential to cause effects to properties listed in the State or National Register of Historic Places, assuming such historic properties were present; therefore, no review under the Minnesota Historic Sites Act was needed. Our unit has additionally determined that no review under the Field Archaeology Act or Private Cemeteries Act was needed as project work was limited to previously disturbed areas. This review covered MnDOT's obligations under state statutes but did not constitute a Section 106 review.

    - Protected Species
      They had to do a review of the bridge to make sure that there are no records of federal or state threatened or endangered species being present within the project area that could be affected by the project.

    - Chief Toxicologist
      Reviewed all the Five Star and Denso products that were required for the project, making sure there would be no environmental impacts or impacts to aquatic life.

    - Regulated Materials
      This was required because of lead being present on the in-place piling. In the contract, we had to inform the contractor that lead was present, since the contract required the contractor to disturb the lead due to cleaning the in-place pile. The contractor was to develop a plan to contain the removed paint material as it performed its work. It also had to dispose of the removed paint in accordance with state and federal regulations.

This contract was bid on a lump sum basis; however, moving forward, MnDOT may use a linear foot quantity. This would allow for the quantities to be adjusted. Nordic Group estimated its cost on a per pile basis so there was no itemized cost breakdown for the project. Additionally, access to the piles should be factored in as this could drive up the cost of the repair. If a crane were to be required, it would greatly drive up the cost for the project. Another factor worth considering is the clear height under the bridge and whether riprap is present. If there isn't enough clear height for an excavator on the barge, then the cost could increase as divers would have to move the riprap manually.

Risk analysis is an important aspect in a project, and failure to assess the potential risks can drive up the cost. One of the potential risks that could affect the progress of this repair project would be the flow of the channel. If a channel were to have rapid flow, above four knots (high current), it would be difficult to install the FRP jackets. In a case where there is rapid flow of a channel, two divers would be required to perform the repairs. To avoid the risk of rapid flow, scheduling the repairs to be done during low flow would be beneficial.

4.2 CONSTRUCTION

Nordic Group provided a potential cost-saving suggestion to conduct a dive inspection to get actual field measurements and conditions for the repair plans. Nordic Group estimated the cost for a dive inspection would be about $4,000 for this bridge. The plans specified a jacket height of 14'-6", but upon an exploratory dive on the first day of work, it was determined the jackets would need to be trimmed. The Denso jackets required a reduction of 3'-0" and the Five Star jackets needed 5'-6" removed. As a result, excess reinforcement and grout were left over as well. Information provided from a detailed dive inspection prior to bidding would reduce the possibility of this occurring. The plans also called out riprap, assuming the riprap would need to be moved. This was factored into the cost estimation, but Nordic Group found that only minimal jack hammering was necessary to remove the riprap because the bottom of the waterway was mud. In the case of debris obstruction during the repair, "debris removal" can be considered under a change order for the project.

Figure 4.1: Scrap Pile Jackets (Left) & Left Over Five Star Grout (Right)

In addition to its expertise in this project, Nordic Group has experience with other Denso and Five Star products. It mentioned that where pile strengthening does not require reinforcing steel, it has installed similar corrosion prevention systems using marine epoxy grout instead of underwater grout to fill the annular space. The annular space is typically much smaller for the epoxy grout than the underwater grout. Table 4 contains data on the differential cost on epoxy grout system and underwater grout for both Denso and Five Star. Nordic Group mentioned if the adjacent bridge, bridge 05002, is starting to show signs of corrosion, then the FRP jacket with epoxy grout would be a good application. It also mentioned it installed the Denso petrolatum tape system as a corrosion prevention system. Nordic Group advised to not install the petrolatum tape in locations where ice could build up around the piles and risk tearing the tape.

Table 4.1: Cost difference per LF between Epoxy Grout system and Underwater Grout

	Denso (Per LF)	Five Star (Per LF)
Epoxy Grout System	$ 150.00	$ 106.00
Underwater Grout	$ 305.00	$ 183.00

An overview of the project site can be seen in Figure 4.3. The Little Rock Lake Boat Launch provided a big area for loading and unloading sections of the barge and delivery of materials. The boat launch parking provided a large area for delivery, drop off and pickup. The greatest number of pickup trucks and boat trailers at one time was around three. A small section of trees was cleared for the JLG Telehandler to move the materials from the boat launch parking to the first staging area. The JLG was stored in the first staging area but needed to be able to get to the boat launch to place the pallets of grout on the barge and rearrange the grout pump and water container on the barge. The first stage area could be accessed by either parking in the boat launch parking area or by the ATV trail in the ditch. The second staging area could also be accessed by the ATV trails in the ditch. The dive trailer, an enclosed trailer, and generator was moved from the first staging area to the second staging area. The small boat was used to retrieve the reinforcement cages and pile jackets during the south pier repairs.

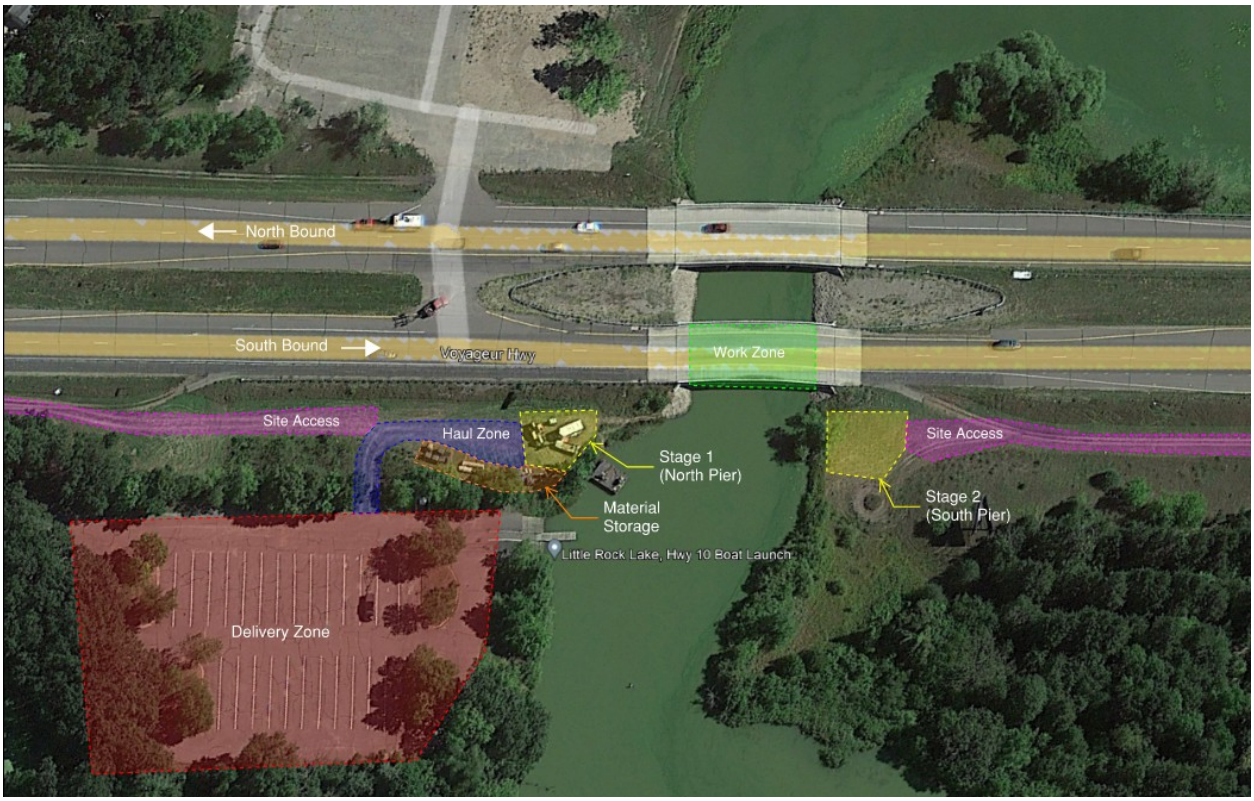

Figure 4.2: Project Site Overview

Figure 4.3: View of Stage 1 without the dive trailer from Stage 2

4.3 POST-CONSTRUCTION

MnDOT has a strong commitment to minimizing social, economic, and environmental impacts associated with any maintenance or construction project. Initially, the repair plan involved blocking traffic to allow for machinery set-up, driving sheet piles to create cofferdams, pumping out water, constructing catwalks for workers, and commencing with normal work. This approach would have blocked boating traffic from the north side of the lake and required a shoulder and lane closure, causing significant traffic disruptions. Moreover, the loud noises and machinery would have also negatively impacted local residents and businesses. However, Nordic Group's work proved to have minimal impact to the surroundings. It was able to complete all the work from a barge situated under the bridge using a small grout mixer and pump. The use of a tender boat to move the barge around and complete the work in such a way that it was invisible to drivers passing over the bridge and allowed boats to pass underneath during construction was highly valued by MnDOT.

MnDOT Maintenance forces may be able to perform these repairs in locations where divers are not required. This would require additional training and possible equipment rental (grout mixer and pump).

Nordic Group preferred the Denso product after the installation was completed. The Denso jacket's unique feature of closing on itself was highly appreciated, as it benefited the diver during installation, especially when water visibility was poor. The Denso product was described as visually better as one of the Five Star jackets had a screw on the inside wall of the groove joint.

Figure 4.4 Five Star Jacket with screw in joint

Nordic Group mentioned an apparatus could be made to assist with the placement with the Denso jackets. The apparatus was described as two vertical wood boards spaced a couple feet apart and attached to two horizontal wood boards with notches in the end. The notches act as a guide for two

ratchet straps to be placed and hooked to the opening of the jacket, so the strap holds the jacket open while it is being placed around the pile.

The maintenance and inspection of a pile repair is critical/important for the service life of the pile. Due to the high strength and resistance to corrosion, FRP jackets need minimum maintenance. However, a key component to the durability of FRP jackets is the installation process. Failure to install the jackets properly could lead to them to coming loose or falling off. During the installation of the FRP pile jackets for bridge 9462, water was leaking through the seam while grout was being pumped into the jacket. To determine the possible effects of the leaky seam, future inspection will be needed. A valuable/good starting point for the maintenance and inspection process would be to provide an as-built diagram/sketch for the FRP pile jackets, which would assist with calling out sections that need repairs. Another beneficial practice to include in the inspection guidelines would be to inspect the pile repairs after major storms to check for debris impact or flood occurrence damages.

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APPENDIX A: PHOTO LOG

Figure A.1: Pier 2 North Pier

Figure A.2: Barge and Boat

Figure A.3: Dive Trailer with Radio and Video Equipment

Figure A.4: Close-up of Hanging Rebar

Figure A.5: Placing Rebar Cage

Figure A.6: Tying Reinforcement

Figure A.7: Reinforcement Hanging from Piles

Figure A.10: Placing Straps Around Jacket

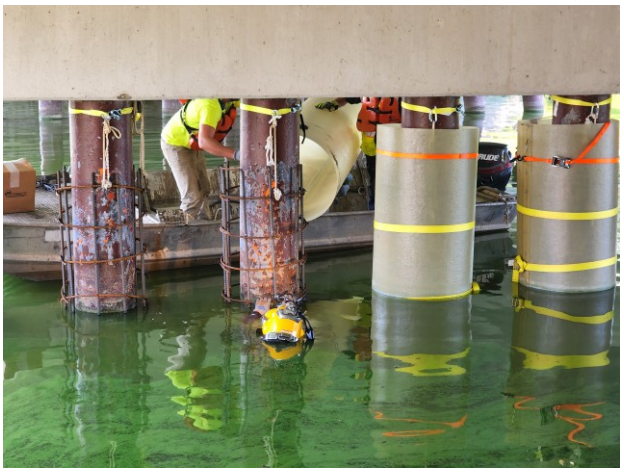

Figure A.8: Placing Pile Jacket

Figure A.11: Installing Screws

Figure A.9: Apply Epoxy to Joint

Figure A.12: Installed Jacket Close-up

Figure A.13: Tools Used to Jacket to Correct Height

Figure A.16: Grouting Operation on Barge

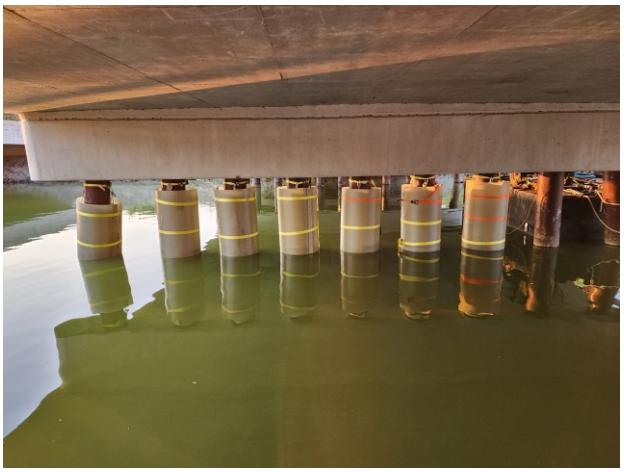

Figure A.14: North Pier Pile Jackets Ready for Grout

Figure A.17: Water Level Rising in Jacket During Grouting Operation

Figure A.15: Moving Barge with Boat

Figure A.18: South Pier with Reinforcement Hanging

Figure A.19: Applying Epoxy to Joint

Figure A.20: Placing Straps on Five Star Jacket

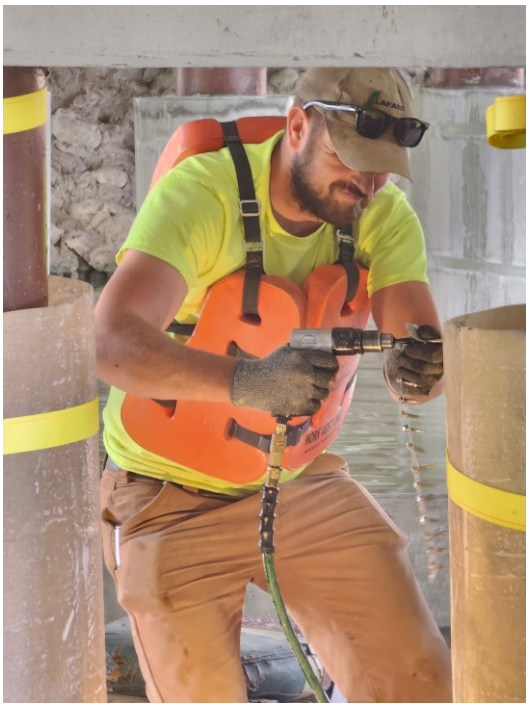

Figure A.21: Installing Screws in Joint

Figure A.22: South Pier Pile Jackets Ready for Grout

Figure A.23: Grouting on South Pier

Figure A.24: Finished North Pier

Figure A.25: North Pier Eastern Most Pile -Final

Figure A.26: North Pier 2nd Pile From the East – Final

Figure A.27: North Pier 3rd Pile From the East –Final

Figure A.28: North Pier 4th Pile From the East –Final

Figure A.29: North Pier 5th Pile From the East –Final

Figure A.30: North Pier 6th Pile From the East –Final

Figure A.31: North Pier 7th Pile From the East –Final

Figure A.32: South Pier without Splash Zone

Figure A.33: South Pier Eastern Most Pile Without Splash Zone

Figure A.34: South Pier 2nd Pile From the East Without Splash Zone

Figure A.35: South Pier 3rd Pile From the East Without Splash Zone

Figure A.38: South Pier 6th Pile From the East Without Splash Zone

Figure A.36: South Pier 4th Pile From the East Without Splash Zone

Figure A.39: South Pier 7th Pile From the East Without Splash Zone

Figure A.37: South Pier 5th Pile From the East Without Splash Zone

APPENDIX B: RAC SURVEY RESULTS

MnDOT Pile Strengthening Survey

In August 2023, a survey using Formstack was distributed by to bridge owners who participate in Bridge Preservation Working Groups associated with the National Center for Pavement Preservation (NCPP). The following questions were presented:

1) What techniques have you seen or used for repair of pile corrosion in a body of water (i.e. river or channel) that doesn't require dewatering?
2) What techniques have you seen or used dewater under existing structures?
3) Has your DOT performed bridge pile repairs using stay-in-place forms (e.g. fiberglass sleeves) with grout in-fill (unreinforced or reinforced) without dewatering?
4) What types of deterioration have you used this solution on?
5) What advantages have been observed with this type of repair?
6) What disadvantages have been observed with this type of repair?
7) What are the time intervals you have used for in-service inspection of this type of repair?
8) What type of in-service inspections does your DOT perform?
9) What guidelines are used to inspect repairs with fiberglass sleeves?
10) What product brands of fiberglass sleeve and/or grout have you used?
11) Have you had any issues with a particular brand?
12) Do you have any construction inspection criteria beyond what the manufacturer recommends?
13) What was the expected service life added to the structure?
14) Has this repair failed on any of your bridge piles? If so, please elaborate on condition, time frame, etc.

33 responses were received from a variety of bridge owners throughout the United States. This document summarizes the results collected.

1) What techniques have you seen or used for repair of pile corrosion in a body of water (i.e. river or channel) that doesn't require dewatering?

OWNER:	1) What techniques have you seen or used for repair of pile corrosion in a body of water (i.e. river or channel) that doesn't require dewatering?
Response type	*Textbox*
Ohio Department of Transportation	Forming and encasing pier piles in concrete.
SDDOT - Office of Bridge Design	I don't recall having to do any repairs of steel pile due to corrosion. We have very, very few steel piles in that type of environment for this reason.
Iowa DOT	We've never repaired corroded pile underwater. We have encased pile underwater with concrete.
State Bridge Maintenance Engineer	Pile Jacketing with FRP.
Oklahoma DOT	- Welding of additional section to the pile - Fiber wrapping - Encasement in concrete
Alabama DOT	Placement of form around pile. It is then pumped full of concrete from the bottom up.
New Mexico Department of Transportation	none
Hennepin County	I have not seen or used this type of repair.
NCDOT	- Reinforced concrete collars - Pile jackets or encapsulation (corrosion of reinforcing or prestressing strand in concrete piles) - FRP wrapping (corrosion of reinforcing or prestressing strand in concrete piles)
City of Houston	Helical Pilling reinforcement, underwater pilling reinforcement, wrapping and repairing damaged piles with concrete material, creating and using technics for timber pilling repair and reinforcement.
New York State Department of Transportation	Fiberglass pile forms, then pump grout underwater.
Virginia Department of Transportation	The most frequent pile repair is in splash zones, but these require dewatering. We occasionally repair steel and timber piles without dewatering. Here we used standard splice techniques.
MassDOT - Highway Division	None. Attempting to install form & pour concrete around deteriorating timber piles as a stop-gap measure, but plan & procedure are still in development.
Texas Department of Transportation	TxDOT has working drawings for reinforced concrete encasement for corroded steel piles. In the concrete mix, corrosion inhibitor is used . Concrete strength to be 3,000 psi in 24 hours. Underwater placement needs pre-approval with proper mix design and anti-washout admixtures. We have seen districts and local govt. entities to weld steel channels to the flanges of the H piles in the dry seasons to strengthen the corroded steel piles as well.
Oregon Department of Transportation	I haven't seen or used any techniques for repair of pile corrosion. My experience is mainly with timber pile repair.

OWNER:	1) What techniques have you seen or used for repair of pile corrosion in a body of water (i.e. river or channel) that doesn't require dewatering?
Montana Department of Transportation (MDT)	Using in-House MDT Maintenance personnel, we perform on average 1 or 2 timber pile repairs per year due to the urgency. These may or may not be in a stream or other body of water. Generally, the same repair process is used in wet or dry. Generally dewatering is not done, so wet conditions require additional access considerations and environmental permits. The repairs are typically done to timber piles on our typical 70- to 90-year-old timber structures. They are intended to be a short to medium term repairs. The process involves using a Corrugated Steel Culvert (~~24"-30" diameter) to jacket the deteriorated length of pile. The steel jacket is placed around the pile, socketed into the streambed to seal the bottom and then the annual space is filled with concrete using a small diameter tremie. We also let a Statewide Job Order Contract (JOC) in 2018 (4 year contract) that ultimately repaired 168 CS4 timber piles on 72 State Owned timber bridges. I estimate that 25% to 30% were in a "wet" location. No de-watering was done at any of the locations by the contractor. The process involved using FRP jackets placed around the piles with the annular space filled with low viscosity epoxy resin. The bottom of the jacket was usually socketed into the streambed, but was always sealed with an oakum fiber "rope" regardless of whether the bottom of the jacket extended below the bottom of the streambed or not. No piles were repaired in water that required diving operations (generally water was 2 feet deep or less at repair locations). Repair of corroded steel piles has not been necessary in Montana due to the rarity of their use as primary, exposed, elements on our structures. Our exposed pile repairs have been limited to timber, and those are generally in dry or shallow water conditions.
Washington State DOT	Fiberglass and steel jackets with grout placed in void.
NJDOT	- Removal of wrought iron jackets and installation of PVC Vector Galvashield DAS Jacket system (including cathodic protection), pile filled using SeaShield 510 UW Grout and 3/8" aggregate. - Stainless steel bars & hoops anchored to the pile cap with stainless steel dowels. Pile wrapped with fiberglass jacket and pile cavity filled with Sea shield Denso 510 grout at 9,000 psi extended with 3/8th inch pea gravel.
Texas Department of Transportation	Reinforced concrete encasement, Anti washout admixture in concrete mix design.
Missouri Department of Transportation	FRP jackets with marine grouting to encapsulate pile deterioration.
MaineDOT	wrapping the pile in FRP, encapsulate the pile in reinforced concrete (small dewatering within the shell)
Missouri Department of Transportation	-FRP shells with high strength grout for strengthening -Add an additional bent in front of existing bent using h-piles driven through holes cut in the deck.
Florida Department of Transportation	- FDOT employees both galvanic jackets and impressed current jackets. Typical construction practice for these has a seal at the bottom and water is displaced as the annular space is filled with fresh grout. - FDOT can provide a Technical Special Provision #457 for further information if desired.
Kentucky Transportation Cabinet (KYTC)	KTC (Kentucky Transportation Center) through the University of Kentucky developed CATSTRONG panels to wrap around piling. UK students produced the CatStrong Biaxial Hemp Wrap (BHW) in the laboratory by applying a two-part epoxy resin to the fabric. KTC's Structures group assisted the District 12 Bridge Crew with a retrofit solution that deployed an experimental hemp fabric to apply to the damaged timber. I'm not sure if the pile was underwater or not. We're also working on a project with deteriorated timber piling. We intend to drive steel piles next to the existing pier- on either side, and then build a concrete pier cap that'll encase the existing pier. And make the timber piles obsolete.

OWNER:	1) What techniques have you seen or used for repair of pile corrosion in a body of water (i.e. river or channel) that doesn't require dewatering?
DelDOT	We have used various types of jacketing, however our most common jackets are fiberglass that we pump full of epoxy grout.
NYCDOT- Division of Bridges	1) Use divers to install fiberglass tubing wrapping or Pearson Piles
State of New Hampshire Dept of Transportation	Underwater blast cleaning of H-Pile to WJ-3, pressure grouting inside fiberglass jackets with marine grade cementitious material.
Wyoming DOT	We don't have any experience to report on this topic.
FDOT	Our pile jackets typically extend a couple of feet below the low water line for cathodic protection (CP) jackets. The pile jackets are filled with the low port at or below the water line and the water is expelled during filling. We have not used de-watering.
Colorado Department of Transportation	none
Wisconsin Department of Transportation	WisDOT has installed jacketing on steel piling using SeaShield Series 2000HD on various bridges throughout the state. This does not repair the existing pile corrosion but slows down future corrosion by limiting the oxygen to the steel.
MassDOT	In one of our bridge maintenance contracts we used fiberglass jackets with underwater grout to perform pile repairs.
Idaho Transportation Department	Petrolatum tape wrap covered by a neoprene jacket.

2) What techniques have you seen or used dewater under existing structures?

OWNER:	2) What techniques have you seen or used dewater under existing structures?
Response type	*Textbox*
Ohio Department of Transportation	Bolted plates on steel piles with section loss.
SDDOT - Office of Bridge Design	NA
Iowa DOT	A cofferdam is the only method I have ever seen.
State Bridge Maintenance Engineer	Concrete Pile Encasement.
Oklahoma DOT	- Cofferdam - Stream diversion
Alabama DOT	Diverting the water with a berm of riprap and filter fabric. Using trash pumps to aid in the control of water. This can only be done in shallow water below 1' in depth.
New Mexico Department of Transportation	I have seen pier caps temporarily shored so that corroded portions could be removed/replaced or externally strengthened. I have also seen new deep foundations built on both ends of the pier with the good portions of the existing piles encased in a new reinforced concrete beam intended to transfer load to the new foundations.
Hennepin County	I have not seen or used this type of repair.
NCDOT	- coferdam - coordination with dam authority to lower water level (smaller bodies of water)
City of Houston	Pumping or diverging water under the existing bridges for repair of piles.
New York State Department of Transportation	I don't have specific experience; however, cofferdams could be used.
Virginia Department of Transportation	We place pile jackets at the tops of precast concrete piles in the in the splash zone where corrosion is most likely. This generally requires some kind of cofferdam. The pile jackets include sacrificial anodes and are generally placed inside carbon fiber forms. We use low permeability concrete after removing damaged areas.
MassDOT - Highway Division	Cofferdams & pumps, temporary river bypass (barrier & pipe).
Texas Department of Transportation	We have dewatered only a couple of times using pump. It was a small creek with shallow waters and we had to repair all the steel piles. So we did a total dewatering instead making a caisson for local dewatering.
Oregon Department of Transportation	Redirecting water with large bags and dewatering with pumps.
Montana Department of Transportation (MDT)	The rare times we have dewatered during In-House Maintenance operations, it was to dry out small scour holes on intermittent prairie streams during the dry season when there were no inflows. The dewatering was done using a 4" trash pump after receiving necessary environmental permits.

OWNER:	2) What techniques have you seen or used dewater under existing structures?
Washington State DOT	steel or fiberglass shell with grouted void, formed reinforced concrete outer shell, Aquawrap (fiberglass wrap), and spliced pile replacement of deteriorated section.
NJDOT	Removal of wrought iron jackets and installation of PVC Vector Galvashield DAS Jacket system (including cathodic protection), pile filled using SeaShield 510 UW Grout and 3/8" aggregate.
Texas Department of Transportation	Sand bags and temporary dams around the piles and pumping the water out.
Missouri Department of Transportation	Aqua dam: https://www.aquadam.net/
MaineDOT	NA
Missouri Department of Transportation	water pumps / damming partial channel width at a time
Florida Department of Transportation	- The only time we dewater is for repairs on drilled shafts. We use cofferdams for this. - We may do this when performing larger repairs of footers, or groups of drilled shafts that require large spalls to be excavated and section replaced.
Kentucky Transportation Cabinet (KYTC)	Just typical techniques.
DelDOT	We haven't dewatered for any jacket installation recently, but when we do dewater for other jobs we will use sandbags, steel sheet piles or construct temporary walls and then pump out the water.
NYCDOT- Division of Bridges	Not applicable on my operation
State of New Hampshire Dept of Transportation	If the structure is high enough, steel sheet piles. If not, IBC sand bags. But for the H-Pile repairs we have done, we did not deploy cofferdams.
Wyoming DOT	
FDOT	Sealed Stay-in-place forms, Coffer Dam
Colorado Department of Transportation	CDOT used splice technique to repair section loss on the existing steel piling on a CDOT bridge.
Wisconsin Department of Transportation	BOS Maintenance has not seen or used dewatering under existing structures.
MassDOT	Cofferdams
Idaho Transportation Department	I have no experience with this.

3) Has your DOT performed bridge pile repairs using stay-in-place forms (e.g. fiberglass sleeves) with grout in-fill (unreinforced or reinforced) without dewatering?

OWNER:	3) Has your DOT performed bridge pile repairs using stay-in-place forms (e.g. fiberglass sleeves) with grout in-fill (unreinforced or reinforced) without dewatering?
Response type	*Radio Button: _ Yes _ No*
Ohio Department of Transportation	Yes
SDDOT - Office of Bridge Design	No
Iowa DOT	No
State Bridge Maintenance Engineer	Yes
Oklahoma DOT	Yes
Alabama DOT	Yes
New Mexico Department of Transportation	No
Hennepin County	No
NCDOT	Yes
City of Houston	Yes
New York State Department of Transportation	Yes
Virginia Department of Transportation	Yes
MassDOT - Highway Division	No
Texas Department of Transportation	Yes
Oregon Department of Transportation	Yes
Montana Department of Transportation (MDT)	Yes
Washington State DOT	Yes
NJDOT	Yes

OWNER:	3) Has your DOT performed bridge pile repairs using stay-in-place forms (e.g. fiberglass sleeves) with grout in-fill (unreinforced or reinforced) without dewatering?
Texas Department of Transportation	Yes
Missouri Department of Transportation	Yes
MaineDOT	Yes
Missouri Department of Transportation	Yes
Florida Department of Transportation	Yes
Kentucky Transportation Cabinet (KYTC)	No
DelDOT	Yes
NYCDOT- Division of Bridges	Yes
State of New Hampshire Dept of Transportation	Yes
Wyoming DOT	
FDOT	Yes
Colorado Department of Transportation	No
Wisconsin Department of Transportation	Yes
MassDOT	Yes
Idaho Transportation Department	No

4) What types of deterioration have you used this solution on?

OWNER:	4) What types of deterioration have you used this solution on?
Response type	*Textbox*
Ohio Department of Transportation	Steel H-piles with section loss at the water level.
SDDOT - Office of Bridge Design	NA
Iowa DOT	We have encased pile that had section loss in shallow water. We've used 55 gallon drums as forms and left them in place.
State Bridge Maintenance Engineer	Precast pile with minor cracks, no sign or minor sign of corrosion of the steel member.
Oklahoma DOT	Timber piles
Alabama DOT	Corrosion of steel piles. Extending existing pile encasements that have been undermined.
New Mexico Department of Transportation	Piles with timber decay, deteriorated concrete, and corroded steel but all repairs were performed in dry conditions.
Hennepin County	We have not used it.
NCDOT	- loss of section on steel piles - corrosion of prestressing strand or reinforcing steel and resulting spalling of concrete piles or columns - necking down of concrete piles due to abrasion or other deterioration
City of Houston	segregation of concrete material from bridge pile
New York State Department of Transportation	The deterioration has been on steel H-piles. They were installed with a protective coating, but it was found to be highly ineffective at the welded splice locations. The H-piles needed to be spliced prior to the installation of the jackets.
Virginia Department of Transportation	Mostly the tops of precast/prestressed concrete piles in splash zones where there is high salinity in the water.
MassDOT - Highway Division	Not applicable. Very curious to see/hear your results.
Texas Department of Transportation	Severe section loss to steel pile.
Oregon Department of Transportation	Timber pile defects such as splitting.
Montana Department of Transportation (MDT)	Only on rotten or otherwise compromised timber piles.
Washington State DOT	ASR and corroded reinforcement in precast concrete piling. timber pile with rot.

OWNER:	4) What types of deterioration have you used this solution on?
NJDOT	- Wide and hairline cracks in the concrete piles - Exposed rebar - Concrete corrosion
Texas Department of Transportation	Corrosion induced section loss.
Missouri Department of Transportation	steel H-pile section loss in stream channels.
MaineDOT	steel piles, timber piles
Missouri Department of Transportation	for h-piles with 25% section loss up to moderate holes in web
Florida Department of Transportation	Spalls, cracking and broken rebar.
Kentucky Transportation Cabinet (KYTC)	Mostly timber piles.
DelDOT	We have used this on steel fluted piles that are concrete filled and have corrosion and section loss of the steel. We have also used this on concrete piles that have scale or spalling.
NYCDOT- Division of Bridges	Steel H pile web deterioration
State of New Hampshire Dept of Transportation	H-Pile section loss within the tidal zone. Our bridges were on the Atlantic coast.
Wyoming DOT	
FDOT	Concret pile repairs in both salt (corrosion) and fresh water (scale damage).
Colorado Department of Transportation	CDOT does not have experience of bridge pile repairs using stay-in-place forms for piling section loss.
Wisconsin Department of Transportation	Spalling/deterioration on existing CIP Concrete Piling, and timber rotting/deterioration.
MassDOT	Minor to severe, even on some concrete piles with 100% section lost.
Idaho Transportation Department	I'm not aware of any.

5) What advantages have been observed with this type of repair?

OWNER:	5) What advantages have been observed with this type of repair?
Response type	*Textbox*
Ohio Department of Transportation	Protects the steel pile well after placed.
SDDOT - Office of Bridge Design	NA
Iowa DOT	It's simple for our local forces to use.
State Bridge Maintenance Engineer	Prevention of steel members from further deterioration, hence extending the life of the piles.
Oklahoma DOT	The forms stay in-place and add additional rigidity to the deteriorated pile
Alabama DOT	Avoiding have to drive new pile and incorporate into the load path.
New Mexico Department of Transportation	It's supplementing a deteriorated pile instead of removing the bad portion and replacing, which would require temporary shoring. It's less intrusive, easier to implement, and faster.
Hennepin County	N/A
NCDOT	repairs of piles without having to dewater
City of Houston	It is more cost effective than removing or replacing the bridge pile.
New York State Department of Transportation	This was the smallest footprint for underwater work due to environmental concerns.
Virginia Department of Transportation	They work well if they are detailed properly.
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	Economic and durable, increase the condition rating of the steel piles in the following inspection.
Oregon Department of Transportation	Still under investigation.
Montana Department of Transportation (MDT)	Quick and relatively cheap (approximately $12,000 per pile in 2018 dollars). Only 2 to 4 days spent at a bridge, depending on access, wet or dry conditions, ambient temperatures, number of piles per bridge, etc... JOC was MUCH cheaper that emergency bridge replacement due to failed pile(s). We have currently 430 State owned timber structures (just over 1/2 are On-System that are between 60 and 98 years old) with timber piles being the primary cause of failure or closure on our timber bridges. The intent was to prevent these continued failures and closures and extend the life of the structures until they can be replaced (likely a 20-to-30-year process, if they are aggressively programmed). No issues with the (previously CS4) FRP jacketed timber piles have been observed, so they have been successful up to this point.

OWNER:	5) What advantages have been observed with this type of repair?
Washington State DOT	No coffer cells.
NJDOT	- Galvanic anodes inside jackets mitigate any current and future corrosion caused by chlorides present in the concrete. - Jacket itself prevents further ingress of chloride into the piles. - Cementitious grout is used to fill the jacket and encapsulate the galvanic anodes. - Service life extension of 30 years may be achieved. - Monitoring box installation on outside of jacket to notify inspectors of functionality of anode jacket.
Texas Department of Transportation	It is quick and can be performed by our maintenance crews inhouse.
Missouri Department of Transportation	speed of repair, save on dewatering, long term protection from advanced or continued deterioration.
MaineDOT	quick, cost-effective, smaller impact to stream bed
Missouri Department of Transportation	- no dewatering needed - no shoring needed - in muddy channel bottoms easy to embed FRP shell - able to keep traffic using bridge on top
Florida Department of Transportation	Short downtime and fast repair. No intrusion on traffic flow.
Kentucky Transportation Cabinet (KYTC)	The timber piles are usually deteriorated in one location, and the sleeve with grout corrects the location. And allows the bridge to be opened again.
DelDOT	It is a significantly faster install than dewatering and the jackets can be custom made to fit any pile configuration. For example we had square shaped piles and round piles that were placed directly against a concrete wall. We had square jackets and U-shaped jackets custom made for these applications.
NYCDOT- Division of Bridges	Not much at all just expensive process using divers plus concrete Tremie
State of New Hampshire Dept of Transportation	- Complete isolation of H-Pile steel from salt water. - Fiberglass jackets have durability against salt water deterioration. - Hoping for repair longevity. We're about 13 years at this point.
Wyoming DOT	
FDOT	This is our primary repair system. In salt water, 100% of pile jackets contain a zinc mesh for cathodic protection. If the existing pile reinforcement is corroded, a larger jacket is used to accommodate additional steel reinforcment bars. In fresh water in Florida, the main concrete pile deterioration is scale damage. The repair for scale damage is a fiberglass jacket filled with cementitious grout with no CP added.
Colorado Department of Transportation	I guess the benefit of using stay-in-place forms for additional corrosion protection for piling.
Wisconsin Department of Transportation	Was done on timber pile, no air is getting to the pile to prevent more rot.
MassDOT	It can be completed quickly and during off-peak seasons. It also limited the amount of permits that we needed to obtain prior to construction.

OWNER:	5) What advantages have been observed with this type of repair?
Idaho Transportation Department	I haven't observed this type of repair.

6) What disadvantages have been observed with this type of repair?

OWNER:	6) What disadvantages have been observed with this type of repair?
Response type	*Textbox*
Ohio Department of Transportation	Can be hard to gain access and does not necessarily add structural capacity back to the steel pile.
SDDOT - Office of Bridge Design	NA
Iowa DOT	You don't know how well the concrete is consolidated or if it is deteriorating inside.
State Bridge Maintenance Engineer	Unable to inspection the repair portion of the pile.
Oklahoma DOT	Purchase and/or fabrication of jacket (Typically we use a CGMP rather than a FRP product).
Alabama DOT	Having to work in the water slows down the actual work process and possibly quality when compared to the dry.
New Mexico Department of Transportation	The encasement may not bring the pile back to original design strength. Enlarging the pile by encasing may increase scour potential. The pile and encasement may be more difficult to visually inspect.
Hennepin County	N/A
NCDOT	- relatively higher costs for having to use divers for installation of in-water systems - longer time for installation of in-water systems - durability of systems not installed properly
City of Houston	It may not last for a long time
New York State Department of Transportation	It is very costly and takes time to complete the work. Constuction inspection of work performed by the contractor was difficult as we didn't have CI divers. They were inspecting work via underwater camera.
Virginia Department of Transportation	If detailed improperly (for example, if permeable concrete is used or there is not cathodic protection), then the pile jackets may have a limited service life (15 to 20 years). We have seen that with the early iterations of the details.
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	Sometimes corrugated metal forms are used which is subject to corrosion. Also honeycombing of concrete may be an issue.
Oregon Department of Transportation	First application on timber piles is still under investigation. FRP tore and grout crumbled on some piles.
Montana Department of Transportation (MDT)	Relative to the alternative of Do-Nothing or replacement of the structure, no disadvantages if the repairs were targeted to CS4 (and sometimes CS3) timber piles to keep costs down.
Washington State DOT	inspection for evaluation of capacity next to impossible.
NJDOT	- Accessibility for contractor performing repairs - Working in tidal waters

OWNER:	6) What disadvantages have been observed with this type of repair?
Texas Department of Transportation	Hidden defects may be present, such as honeycombing.
Missouri Department of Transportation	load capacity restoration (if any has been loss) is not well defined or known.
MaineDOT	challenges getting the frp shell in the same shape as the h-pile.
Missouri Department of Transportation	- not feasible to repair section loss of h-pile at beam cap interface - high strength grout material is expensive
Florida Department of Transportation	Quality of installation is the largest factor here especially surface prep and cleanliness of the rebar when they are done. The better this is the longer the repair will last.
Kentucky Transportation Cabinet (KYTC)	I don't think I've seen it done without dewatering. I could be mistaken though.
DelDOT	you are limited with how far below the mudline you can get the jacket. You are also limited on how clean you can get the pile surface below the water since divers are doing this work by feeling and tooling the area.
NYCDOT- Division of Bridges	Again very costly working under water repair especially dealing with the river tides & currents
State of New Hampshire Dept of Transportation	As an inspector, I had to make all observations through the divers' video feeds. I had to rely on the divers' verbal communications as underwater visibility was not always stellar.
Wyoming DOT	
FDOT	N/A
Colorado Department of Transportation	Dewatering is required if ground water exists.
Wisconsin Department of Transportation	Not able to observe the existing pile after the repairs.
MassDOT	It can be difficult to estimate the grout quantity which could lead to contract overruns.
Idaho Transportation Department	I haven't observed this type of repair.

7) What are the time intervals you have used for in-service inspection of this type of repair?

OWNER:	7) What are the time intervals you have used for in-service inspection of this type of repair?
Response type	*Radio Button: _ 12-month _ 24-month _ 48-month _ Other: Textbox*
Ohio Department of Transportation	12- Month
SDDOT - Office of Bridge Design	Other: NA
Iowa DOT	24 -Month
State Bridge Maintenance Engineer	24 -Month
Oklahoma DOT	24 -Month
Alabama DOT	Other: It would be a 24 month cycle for a state structure and a 48 month cycle for a local structure.
New Mexico Department of Transportation	Other: If serviceability was reduced even after repair, then the inspection interval would be no more than 12 months.
Hennepin County	Other: N/A
NCDOT	24 -Month
City of Houston	24 -Month
New York State Department of Transportation	Other: Our diving inspection intervals are 60 months. Once the repairs are completed, the next dive will be 5 years.
Virginia Department of Transportation	24 -Month
MassDOT - Highway Division	Other: Not applicable
Texas Department of Transportation	Other: We use our routine 24 month inspection to filter for bridges with repair needs. Once repair is made, we perform follow up inspection within few weeks with repair photos and any updated condition ratings .
Oregon Department of Transportation	Other: NA
Montana Department of Transportation (MDT)	24 -Month
Washington State DOT	24 -Month
NJDOT	24 -Month

OWNER:	7) What are the time intervals you have used for in-service inspection of this type of repair?
Texas Department of Transportation	24 -Month
Missouri Department of Transportation	24 -Month
MaineDOT	Other: they are pretty rugged and is estimated to last years
Missouri Department of Transportation	24 -Month
Florida Department of Transportation	24 -Month
Kentucky Transportation Cabinet (KYTC)	24 -Month
DelDOT	24 -Month
NYCDOT- Division of Bridges	Other: Various on Bridge locations and type of repairs to perform
State of New Hampshire Dept of Transportation	24 -Month
Wyoming DOT	
FDOT	Other: Assuming properly installed they return to 48-month inspection intervals unless otherwise noted.
Colorado Department of Transportation	Other: CDOT has no experience of this type of repair.
Wisconsin Department of Transportation	24 -Month
MassDOT	12- Month
Idaho Transportation Department	Other: We haven't done this type of repair that I'm aware of.

8) What type of in-service inspections does your DOT perform?

OWNER:	8) What type of in-service inspections does your DOT perform?
Response type	*Checkbox: _ Binocular _ From Boat/Snooper _ Underwater _ Other: Textbox*
Ohio Department of Transportation	From Boat/Snooper Underwater
SDDOT - Office of Bridge Design	Other: NA for this type of repair.
Iowa DOT	From Boat/Snooper
State Bridge Maintenance Engineer	Binocular From Boat/Snooper Underwater
Oklahoma DOT	Other: Typically a routine inspection from ground. We do not have this type of repair on major stream crossings or lakes.
Alabama DOT	From Boat/Snooper Underwater
New Mexico Department of Transportation	Binocular From Boat/Snooper Underwater Other: NMDOT performs a wide variety of in-service inspections both internally and by outsourcing to consultants.
Hennepin County	From Boat/Snooper
NCDOT	Binocular From Boat/Snooper Underwater
City of Houston	Binocular From Boat/Snooper Other: visual
New York State Department of Transportation	Underwater
Virginia Department of Transportation	From Boat/Snooper Underwater
MassDOT - Highway Division	From Boat/Snooper Underwater
Texas Department of Transportation	From Boat/Snooper Underwater
Oregon Department of Transportation	Underwater

OWNER:	8) What type of in-service inspections does your DOT perform?
Montana Department of Transportation (MDT)	Other: They jacketed timber piles are inspected in the same manner as all other timber piles at the same bridge, typically accessed by hand-on by foot. An Agency Defined Element was created for "jacketed Timber Piles" and a specific guidance memo for inspection was issued.
Washington State DOT	Underwater
NJDOT	Binocular From Boat/Snooper Underwater
Texas Department of Transportation	From Boat/Snooper Underwater
Missouri Department of Transportation	Binocular From Boat/Snooper Underwater Other: Visual from bank or waders
MaineDOT	From Boat/Snooper Underwater
Missouri Department of Transportation	Binocular From Boat/Snooper Underwater
Florida Department of Transportation	Binocular From Boat/Snooper Underwater Other: Electrical continuity, resistance, voltage and current. Reference cell potentials.
Kentucky Transportation Cabinet (KYTC)	Binocular From Boat/Snooper Other: Pretty much everything except for underwater inspections that require diving. Those are contracted out.
DelDOT	From Boat/Snooper Underwater
NYCDOT- Division of Bridges	Underwater Other: Diving inspection & scan sonars
State of New Hampshire Dept of Transportation	From Boat/Snooper
Wyoming DOT	
FDOT	From Boat/Snooper Underwater
Colorado Department of Transportation	Other: CDOT has underwater inspection occasionally.

OWNER:	8) What type of in-service inspections does your DOT perform?
Wisconsin Department of Transportation	Binocular From Boat/Snooper Underwater Other: Have the ability to remove the jackets installed to verify the steel piling has not corroded anymore since installation. This has not yet been completed on any WisDOT bridge.
MassDOT	Binocular From Boat/Snooper Underwater
Idaho Transportation Department	From Boat/Snooper Underwater

9) What guidelines are used to inspect repairs with fiberglass sleeves?

OWNER:	9) What guidelines are used to inspect repairs with fiberglass sleeves?
Response type	*Textbox*
Ohio Department of Transportation	None.
SDDOT - Office of Bridge Design	NA
Iowa DOT	Fiberglass sleeves have not been used.
State Bridge Maintenance Engineer	No specific guidelines. Visual mostly.
Oklahoma DOT	N/A
Alabama DOT	It is really based off feel as visibility underwater is typically limited. This can be difficult as well due to growth of organisms on the form.
New Mexico Department of Transportation	I don't believe we have any repairs that incorporated fiberglass sleeves. We have done repairs with externally bonded fiber materials (carbon fiber, boron fiber...).
Hennepin County	N/A
NCDOT	- Ensure length of fiberglass sleeves extends above an below the mean water level, as specified. - Ensure reinforcing, CP anodes are properly in place and that spacing/ clear cover/ positioning of the fiberglass sleeves meet project specifications. - Ensure concrete/ grout and placement are as specified and in accordance with good construction practice.
City of Houston	Have not used fiberglass sleeves
New York State Department of Transportation	- Construction inspection would follow the specification. Bridge inspection would follow our Bridge Inspection Manual. - For the fiberglass sleeve, the inspection tends to be visual so the sleeve isn't damaged.
Virginia Department of Transportation	Biennial visual inspection as part of the bridge safety inspection.
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	N/A. Fiberglass sleeves has not been used so far as per our knowledge.
Oregon Department of Transportation	No experience yet.
Montana Department of Transportation (MDT)	An ADE was created and a specific inspection guidance memo was issued. Guidance to look for debonding, deterioration, abrasion, impact damage, issues at the interface of the jacket system and timber pile, etc...
Washington State DOT	visual inspection with divers or ROV

OWNER:	9) What guidelines are used to inspect repairs with fiberglass sleeves?
NJDOT	Monitoring box installation on outside of jacket to notify inspectors of functionality of anode jacket.
Texas Department of Transportation	We have not used fiberglass sleeves yet.
Missouri Department of Transportation	Visual
MaineDOT	sounding to check for hollow pockets, visual inspection looking for shell defects or broken fibers
Missouri Department of Transportation	visual observations of deformities, cracks, bubbles, etc.
Florida Department of Transportation	We have a spreadsheet that follows the federally mandated guidelines for inspection of these jackets. This can be shared upon request.
Kentucky Transportation Cabinet (KYTC)	Typical- bulging, cracking, etc.
DelDOT	Visual inspection mainly, looking for any cracks in the fiberglass, lose or missing fasteners, grout spalling at the top or missing collars.
NYCDOT- Division of Bridges	Need adhere to engineer design details and specs
State of New Hampshire Dept of Transportation	- All elements of the bridge are rated on a scale of 0-10. - Visual inspection of jackets performed every two years by boat or snooper. Frequency is increased if rating goes below 4. - Inspection by divers performed every five years. - Jackets are checked for cracking or other damage (perhaps by impact).
Wyoming DOT	
FDOT	Visual inspection unless there is evidence of potential delamination at which point sounding is performed to find the extents of the delam.
Colorado Department of Transportation	none
Wisconsin Department of Transportation	Not Applicable.
MassDOT	Unsure
Idaho Transportation Department	I'm not aware of the use of fiberglass sleeves in our state.

10) What product brands of fiberglass sleeve and/or grout have you used?

OWNER:	10) What product brands of fiberglass sleeve and/or grout have you used?
Response type	*Textbox*
Ohio Department of Transportation	No specific brands. Have taken corrugated piping (both metal and plastic and used them as forms for the encasement.
SDDOT - Office of Bridge Design	NA
Iowa DOT	Don't have this information.
State Bridge Maintenance Engineer	Fivestar and Fyfe
Oklahoma DOT	N/A
Alabama DOT	Do not know.
New Mexico Department of Transportation	I don't believe we have performed any repairs using fiberglass sleeves.
Hennepin County	N/A
NCDOT	No information
City of Houston	Fast and high strength grouts
New York State Department of Transportation	I have seen installation of the five star brand.
Virginia Department of Transportation	several
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	N/A
Oregon Department of Transportation	Not involved with first application.
Montana Department of Transportation (MDT)	Pile Medic
Washington State DOT	varies
NJDOT	PVC Vector Galvashield DAS Jacket system (including cathodic protection), pile filled using SeaShield 510 UW Grout and 3/8” aggregate.

OWNER:	10) What product brands of fiberglass sleeve and/or grout have you used?
Texas Department of Transportation	N/A
Missouri Department of Transportation	Denso sea shield, simpson strong tie, Five Star
MaineDOT	local manufacturer makes them
Missouri Department of Transportation	Kwik Bond Polymers quakewrap; 5 star
Florida Department of Transportation	FDOT Spec Class IV concrete or grout for the fill. The sleeve depends on the manufacturer (Vector, Structural Technologies, Denso).
Kentucky Transportation Cabinet (KYTC)	Not sure, we went with whatever KTC recommended
DelDOT	Our main product used has been Denso.
NYCDOT- Division of Bridges	Seagrout, Sika products, Quakewrap grouts, speedcrete blue line
State of New Hampshire Dept of Transportation	Fox Industries - Fox FX-70 Translucent Fiberglass Jackets and Fox 225 Grout
Wyoming DOT	
FDOT	Brand according to our Approved Products List
Colorado Department of Transportation	Below products in CDOT Pre-approve list - US Mix Co. [Concrete] US Mix Co. [Concrete] US SPEC Euclid Chemical Company [Concrete] Euclid Chemical Company [Concrete] Quikrete Companies Quikrete Companies Mapei Corp. US Mix Co. [Concrete] SpecChem Region Approved Plant Mix Grout
Wisconsin Department of Transportation	Not Applicable.
MassDOT	Simpson strong tie and Five Star Underwater Grout
Idaho Transportation Department	None.

11) Have you had any issues with a particular brand?

OWNER:	11) Have you had any issues with a particular brand?
Response type	*Textbox*
Ohio Department of Transportation	No.
SDDOT - Office of Bridge Design	NA
Iowa DOT	No.
State Bridge Maintenance Engineer	No
Oklahoma DOT	N/A
Alabama DOT	Do not know.
New Mexico Department of Transportation	n/a - We have not used fiberglass sleeves to my knowledge.
Hennepin County	N/A
NCDOT	No information
City of Houston	No
New York State Department of Transportation	No.
Virginia Department of Transportation	Not that we are aware
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	N/A
Oregon Department of Transportation	Not involved with first application.
Montana Department of Transportation (MDT)	No
Washington State DOT	Aquawrap
NJDOT	Not thus far

OWNER:	11) Have you had any issues with a particular brand?
Texas Department of Transportation	N/A
Missouri Department of Transportation	No
MaineDOT	no
Missouri Department of Transportation	no
Florida Department of Transportation	Can't really answer this. Until very recently we've only been using one brand and performance has met our needs.
Kentucky Transportation Cabinet (KYTC)	Not that I'm aware of
DelDOT	it has been very good.
NYCDOT- Division of Bridges	Not much at all!
State of New Hampshire Dept of Transportation	The Fox Industries products performed well. Of great importance is grouting from ports installed on opposite sides of the jacket as it is filled. This minimizes pressure on the standoffs inside and gives a more uniform final product.
Wyoming DOT	
FDOT	N/A
Colorado Department of Transportation	none
Wisconsin Department of Transportation	Not Applicable.
MassDOT	None that I'm aware of.
Idaho Transportation Department	N/A

12) Do you have any construction inspection criteria beyond what the manufacturer recommends?

OWNER:	12) Do you have any construction inspection criteria beyond what the manufacturer recommends?
Response type	*Textbox*
Ohio Department of Transportation	No.
SDDOT - Office of Bridge Design	NA
Iowa DOT	No.
State Bridge Maintenance Engineer	None
Oklahoma DOT	Typically this type of repair is effected by the District bridge crew.
Alabama DOT	No
New Mexico Department of Transportation	n/a - I do not believe we have performed any repairs using fiberglass sleeves.
Hennepin County	N/A
NCDOT	No
City of Houston	No
New York State Department of Transportation	No.
Virginia Department of Transportation	No
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	N/A
Oregon Department of Transportation	Not yet.
Montana Department of Transportation (MDT)	No
Washington State DOT	Visual inspection with divers and ROV.
NJDOT	Every 2 years or after severe storms/hurricanes.

OWNER:	12) Do you have any construction inspection criteria beyond what the manufacturer recommends?
Texas Department of Transportation	N/A
Missouri Department of Transportation	MoDOT has JSPs (contact bridge division for examples) in addition to standard pile repair drawings and policy guidelines https://epg.modot.org/index.php/751.40_LFD_Widening_and_Repair#751.40.1.2_Steel_HP_Pile_Maintenance_and_Repair
MaineDOT	no. we did train the inspector on FRP fabrication.
Missouri Department of Transportation	make sure proper spacing around perimeter of steel pile
Florida Department of Transportation	Yes, all housed within our TSP 457.
Kentucky Transportation Cabinet (KYTC)	Not that I'm aware of
DelDOT	No
NYCDOT- Division of Bridges	Follow up with diving inspection for final results
State of New Hampshire Dept of Transportation	No, not really. We constructed 2" epoxy washes on the tops of all finished jackets to eliminate potential for standing water.
Wyoming DOT	
FDOT	Any activity performed that falls under Standard Spec language would have to adhere to that language.
Colorado Department of Transportation	Any products meet CDOT project requirements will be considered.
Wisconsin Department of Transportation	Not Applicable.
MassDOT	No.
Idaho Transportation Department	N/A

13) What was the expected service life added to the structure?

OWNER:	13) What was the expected service life added to the structure?
Response type	*Textbox*
Ohio Department of Transportation	Varies based on amount of deterioration and conditions of other components of the substructure.
SDDOT - Office of Bridge Design	NA
Iowa DOT	Usually only 5 to 10 years. The bridges are usually a candidate for replacement so a long term repair isn't needed.
State Bridge Maintenance Engineer	15-25 years
Oklahoma DOT	The repairs stay in-place until replacement, which varies.
Alabama DOT	20 Years
New Mexico Department of Transportation	n/a - I do not believe we have done any repairs using fiberglass sleeves.
Hennepin County	N/A
NCDOT	15-20 years
City of Houston	10TO 20 years
New York State Department of Transportation	I am not aware of a specific service life. For our project, I would expect the repairs to last the remaining life of the bridge, 30-50 years.
Virginia Department of Transportation	30 years for later versions of the detail. 15 years or so for earlier versions
MassDOT - Highway Division	Not applicable.
Texas Department of Transportation	N/A
Oregon Department of Transportation	Not involved in the first application.
Montana Department of Transportation (MDT)	We are expecting at least 10 to 20 years. We assume that, due to the age of the bridges (60-98 years old) that were repaired, other piles will likely drive a failure, closure, structure replacement, or drive down the substructure rating before the repaired piles do.
Washington State DOT	Typically used to get an extra 4 to 6 years.
NJDOT	~30 years

OWNER:	13) What was the expected service life added to the structure?
Texas Department of Transportation	30 years for reinforced concrete encasement.
Missouri Department of Transportation	not expecting added service life. Intent is to preserve/maintain existing service life.
MaineDOT	25+ years
Missouri Department of Transportation	maintain as existing condition until bridge replaced in 5 years with regular concrete instead of high strength grout; extend life of pile with high strength grout for 25+ years
Florida Department of Transportation	20 years. We are averaging about 13 years before maintenance is required.
Kentucky Transportation Cabinet (KYTC)	10-15 years
DelDOT	our goal is to get 15 to 20 years
NYCDOT- Division of Bridges	Hopefully 10 years plus
State of New Hampshire Dept of Transportation	Not known. Hopefully a long time.
Wyoming DOT	
FDOT	~25 years from what we have experienced from a properly completed repair.
Colorado Department of Transportation	Mostly, CDOT follows the manufacturer's recommendation if their products are considered.
Wisconsin Department of Transportation	minimum 5 - 10 years, and hopefully 20 years.
MassDOT	Approx. 10 years.
Idaho Transportation Department	30 years for our petrolatum tape wraps.

14) Has this repair failed on any of your bridge piles? If so, please elaborate on condition, time frame, etc.

OWNER:	14) Has this repair failed on any of your bridge piles? If so, please elaborate on condition, time frame, etc.
Response type	*Radio Button: _ Yes _ No _ Other: Textbox*
Ohio Department of Transportation	No
SDDOT - Office of Bridge Design	NA
Iowa DOT	Blank
State Bridge Maintenance Engineer	No
Oklahoma DOT	No
Alabama DOT	No
New Mexico Department of Transportation	
Hennepin County	
NCDOT	Other: Installation was not done in accordance with the project specifications or extent of damage or the conditions of the pile deterioration were worse than understood at the time of the repair.
City of Houston	Other: Flood occurrence damages
New York State Department of Transportation	Other: I am not aware of any failures.
Virginia Department of Transportation	Other: Corrosion continues in pile caps.
MassDOT - Highway Division	
Texas Department of Transportation	No
Oregon Department of Transportation	Other: Application was on timber piles. Failures still under investigation.
Montana Department of Transportation (MDT)	Yes
Washington State DOT	Other: Grout fill incomplete. deterioration of fiberglass shell with 4 years.
NJDOT	No

OWNER:	14) Has this repair failed on any of your bridge piles? If so, please elaborate on condition, time frame, etc.
Texas Department of Transportation	No
Missouri Department of Transportation	No
MaineDOT	No
Missouri Department of Transportation	No
Florida Department of Transportation	Other: Around the 13 year mark is when we start to need to service these jackets.
Kentucky Transportation Cabinet (KYTC)	
DelDOT	Other: Some of the first ones we have done had issues with the jackets coming lose or falling off. Debris impaction or boat damage also broke some of them.
NYCDOT- Division of Bridges	No
State of New Hampshire Dept of Transportation	No
Wyoming DOT	
FDOT	Other: Many of these repairs are in the 25 year range and are still performing adequately.
Colorado Department of Transportation	75 service years for all major structures - bridges, CBC and walls
Wisconsin Department of Transportation	No
MassDOT	No
Idaho Transportation Department	

APPENDIX C: GROUT CYLINDER BREAKS TEST RESULTS

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0210

Print Date: 9/9/2022

Project Number: NMC 1044328
Billing Agency:
Project Eng.: BALFANZ, CHAD
Inspector: BALFANZ, CHAD
Bridge No.: 9462
Part of Structure: Pile Repair
Date Received: 9/9/2022

Source: Denso Sea Shield 510 Grout
Mix Number: Grout

Cylinder Information

Field ID:	1
Date Made:	9/8/2022
Days Cured in Field:	1
Ticket Number:	
Air Content:	
Slump:	
Air Temperature:	
Concrete Temperature:	(50 to 90 Degrees Req'd)

Cylinder ID:	**1.1**				
Date Tested:	9/9/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	94900
Age:	1	**Area (sq. in.)**	12.6	**Strength (PSI)**	**7550**
Fracture Type:	Short Shear	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	2500
1 day Strength Test (psi):	7550

Comments:

Charge: 1-1072
Copies to
davconst@wiktel.com

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Nick Fischer
9/9/2022
10:39:02 AM
Nick Fischer

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0211

Print Date: 9/15/2022

Project Number: NMC 1044328
Billing Agency:
Project Eng.: BALFANZ, CHAD
Inspector: BALFANZ, CHAD
Bridge No.: 9462
Part of Structure: Pile Repair
Date Received: 9/9/2022

Source: Denso Sea Shield 510 Grout
Mix Number: Grout

Cylinder Information

Field ID:	1A	
Date Made:	9/8/2022	
Days Cured in Field:	1	
Ticket Number:		
Air Content:		(5.0% to 8.5% Req'd)
Slump:		(2 to 5 in. Req'd)
Air Temperature:		
Concrete Temperature:		(50 to 90 Degrees Req'd)

Cylinder ID:	**1A.1**				
Date Tested:	9/15/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	111870
Age:	7	**Area (sq. in.)**	12.6	**Strength (PSI)**	**8900**
Fracture Type:	Cone	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	7500
7 day Strength Test (psi):	8900

Comments:

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Nick Fischer
9/15/2022
6:58:42 AM
Nick Fischer

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0212

Print Date: 10/6/2022

Project Number: NMC 1044328
Billing Agency:
Project Eng.: BALFANZ, CHAD
Inspector: BALFANZ, CHAD
Bridge No.: 9462
Part of Structure: Pile Repair
Date Received: 9/9/2022

Source: Denso Sea Shield 510 Grout
Mix Number: Grout

Cylinder Information

Field ID:	1B	
Date Made:	9/8/2022	
Days Cured in Field:	1	
Ticket Number:		
Air Content:		(5.0% to 8.5% Req'd)
Slump:		(2 to 5 in. Req'd)
Air Temperature:		
Concrete Temperature:		(50 to 90 Degrees Req'd)

Cylinder ID:	**1B.1**				
Date Tested:	10/6/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	117850
Age:	28	**Area (sq. in.)**	12.6	**Strength (PSI)**	**9380**
Fracture Type:	Cone	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	9000
28 day Strength Test (psi):	9380

Comments:

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Joshua J. Schulz
10/6/2022
8:30:04 AM

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0228

Print Date: 9/13/2022

Project Number: NMC 1044328
Billing Agency:
Project Eng.: BALFANZ, CHAD
Inspector: BALFANZ, C.
Bridge No.: 9462
Part of Structure: Pile Repair
Date Received: 9/13/2022

Source: Denso Sea Shield 510 Grout
Mix Number: GROUT

Cylinder Information

Field ID:	2
Date Made:	9/12/2022
Days Cured in Field:	1
Ticket Number:	
Air Content:	
Slump:	
Air Temperature:	
Concrete Temperature:	(50 to 90 Degrees Req'd)

Cylinder ID:	**2.1**				
Date Tested:	9/13/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	54880
Age:	1	**Area (sq. in.)**	12.6	**Strength (PSI)**	**4370**
Fracture Type:	Cone and Shear	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	2500
1 day Strength Test (psi):	4370

Comments:

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Nick Fischer
9/13/2022
11:54:14 AM
Nick Fischer

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0229

Print Date: 9/19/2022

Project Number:	NMC 1044328
Billing Agency:	
Project Eng.:	BALFANZ, CHAD
Inspector:	BALFANZ, C.
Bridge No.:	9462
Part of Structure:	Pile Repair
Date Received:	9/13/2022
Source:	Denso Sea Shield 510 Grout
Mix Number:	GROUT

Cylinder Information

Field ID:	2A	
Date Made:	9/12/2022	
Days Cured in Field:	1	
Ticket Number:		
Air Content:		(5.0% to 8.5% Req'd)
Slump:		(2 to 5 in. Req'd)
Air Temperature:		
Concrete Temperature:		(50 to 90 Degrees Req'd)

Cylinder ID:	**2A.1**				
Date Tested:	9/19/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	116620
Age:	7	**Area (sq. in.)**	12.6	**Strength (PSI)**	**9280**
Fracture Type:	Cone	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	7500
7 day Strength Test (psi):	9280

Comments:

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Nick Fischer

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0230

Print Date: 10/10/2022

Project Number:	NMC 1044328
Billing Agency:	
Project Eng.:	BALFANZ, CHAD
Inspector:	BALFANZ, C.
Bridge No.:	9462
Part of Structure:	Pile Repair
Date Received:	9/13/2022
Source:	Denso Sea Shield 510 Grout
Mix Number:	GROUT

Cylinder Information

Field ID:	2B	
Date Made:	9/12/2022	
Days Cured in Field:	1	
Ticket Number:		
Air Content:		(5.0% to 8.5% Req'd)
Slump:		(2 to 5 in. Req'd)
Air Temperature:		
Concrete Temperature:		(50 to 90 Degrees Req'd)

Cylinder ID:	**2B.1**				
Date Tested:	10/10/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	141816
Age:	28	**Area (sq. in.)**	12.6	**Strength (PSI)**	**11290**
Fracture Type:	Cone	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	9000
28 day Strength Test (psi):	11290

Comments:

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Joshua J. Schulz
10/10/2022
1:37:31 PM

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0266

Print Date: 9/27/2022

Project Number:	NMC 1044328
Billing Agency:	
Project Eng.:	BALFANZ, CHAD
Inspector:	BALFANZ, C.
Bridge No.:	9462
Part of Structure:	Pile
Date Received:	9/23/2022
Source:	FiveStar Underwater High Strength
Mix Number:	GROUT

Cylinder Information

Field ID:	3A
Date Made:	9/20/2022
Days Cured in Field:	3
Ticket Number:	
Air Content:	
Slump:	
Air Temperature:	
Concrete Temperature:	(50 to 90 Degrees Req'd)

Cylinder ID:	**3A.1**				
Date Tested:	9/27/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	106200
Age:	7	**Area (sq. in.)**	12.6	**Strength (PSI)**	**8450**
Fracture Type:	Cone and Shear	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	8000
7 day Strength Test (psi):	8450

Comments:

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7:23:53 AM
Nick Fischer

DEPARTMENT OF TRANSPORTATION

Concrete Cylinders Strength Test Report (ASTM C39)

District 3B Materials Lab
3725 12th Street North
St. Cloud, MN 56303

3B-CY22- 0267

Print Date: 10/18/2022

Project Number:	NMC 1044328
Billing Agency:	
Project Eng.:	BALFANZ, CHAD
Inspector:	BALFANZ, C.
Bridge No.:	9462
Part of Structure:	Pile
Date Received:	9/23/2022
Source:	FiveStar Underwater High Strength
Mix Number:	GROUT

Cylinder Information

Field ID:	3B	
Date Made:	9/20/2022	
Days Cured in Field:	3	
Ticket Number:		
Air Content:		(5.0% to 8.5% Req'd)
Slump:		(2 to 5 in. Req'd)
Air Temperature:		
Concrete Temperature:		(50 to 90 Degrees Req'd)

Cylinder ID:	**3B.1**				
Date Tested:	10/18/2022	**Avg. Dia. (in.)**	4.00	**Load (lbs)**	124040
Age:	28	**Area (sq. in.)**	12.6	**Strength (PSI)**	**9870**
Fracture Type:	Cone and Shear	**Defects:**			
Comment:					

Cylinder Strength Summary

Req'd Strength Specification (psi):	8500
28 day Strength Test (psi):	9870

Comments:

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10/18/2022
7:06:02 AM
Nick Fischer

APPENDIX D: FIVE STAR MARINE PILEFORM F INSTALLATION GUIDE

Technical documents for the Five Star recommendations referenced in this report can be found on the manufacturer's website.

The linked document provides a description of Five Star® PileForm™ F – fiberglass reinforced plastic (FRP) bridge and marine protection and rehabilitation jackets. Technical information includes Uses, Advantages, and Sizing & Configuration for the product. Installation guidelines provide details on surface preparation and placement of the jackets.

FRP Bridge and Marine Protection and Rehabilitation Jackets

APPENDIX E: FIVE STAR MARINE TECHNICAL DATA SHEET CEMENTITIOUS UNDERWATER HIGH-STRENGTH GROUT

Technical documents for the Five Star recommendations referenced in this report can be found on the manufacturer's website.

The linked document provides a description of Five Star® Cementitious Underwater High-Strength Grout. Technical information includes Uses, Advantages, Packaging and Yield, and Shelf Life. Application information provides detail on surface preparation, mixing, placement, post placement, and clean-up.

Cementitious Pile Jacket Grout