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Technical Corner

New Advances in Repair of Submerged Piles

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Most structural engineers frequently encounter the design of buildings and bridges in their careers. However, a relatively small fraction get involved with the design of marine infrastructure such as submerged piles, see walls or sheet piles. This paper summarizes the structural enhancements and improved constructability offered by a new system developed by the author; full details of the system are available in two recent webinars that have been recorded and area available for download at www.PileMedic.com/webinars.html

PileMedic® is based on a new type of Fiber Reinforced Polymer (FRP) SupperLaminate developed a decade ago (Ehsani 2010). These laminates are made in a special process where one or more layers of reinforcing fabric are saturated with resin and subjected to heat and pressure to produce a very thin laminate. The laminates are typically supplied in rolls that are 4 feet wide by hundreds of feet long. The main advantages of the laminate are described below:

Fig. 1. Laminate being cut to size and coated with epoxy on a barge; divers wrapping the laminate around a pile after the reinforcing bars have been secured in the spacers

a. Size & Shape – The small thickness of the laminates, which is typically less than 0.05 inches, makes them flexible enough to be wrapped around piles of any shape and size. Standard detail requires wrapping the laminate twice (i.e. 720 degrees), plus an 8-inch extension around the pile. Once the right length of laminate is cut from the roll in the field, the second half of the laminate is coated with an epoxy paste, and it is wrapped around the pile and bonded to the first layer, creating a two-ply structural shell around the pile (Fig. 1). This eliminates the need for custom ordering the jackets, saving significant time, and shipping and storage costs. The annular space between the jacket and the pile will be filled with grout, concrete or epoxy grout later.

b. Confinement – Depending on the type of fiber that is used, carbon or glass, the laminates have tensile strength ranging between 28,000 and 150,000 psi. Furthermore, by selecting the orientation of the fibers within the fabrics, the strength of the laminate in the longitudinal and transverse directions can be adjusted to meet the specific project requirements. The jacket creates a uniform confining pressure (i.e. 360 degrees) around the pile, and it eliminates the need for hoop reinforcement. This allows divers to install the vertical reinforcing bars individually (when needed). The elimination of handling of assembled reinforcing cages that requires two divers results in significant savings for the project.

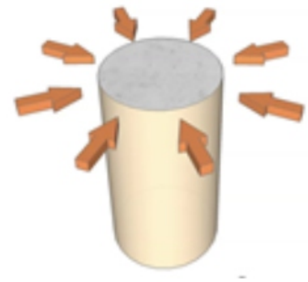

Fig. 2 Jackets provide uniform confinement around the pile.

As part of the development of this repair system for use by the U.S. military and other clients, several accessories have been produced that significantly enhance the quality of construction and result in more accurate engineering design. These are described below:

Fig. 3. Sample spacers and skirt pin.

a. Spacers – These plastic parts are available in a variety of shapes and sizes and serve multiple purposes (Fig. 3). Divers can pass a zip tie through several spacers and fasten them around the pile. The longitudinal reinforcing bars (typically made of glass FRP) can be snapped into place (Fig. 1). This allows the engineer to know the precise location of each bar. The overall length of the spacers defines the annular space between the jacket and the pile that will be filled with grout or concrete. A variation of these spacers can be custom made to attach to the flanges of H-piles for placement of the longitudinal bars. In some cases, the repair portion of the pile extends into the mud line, and the soil provides a seal at the bottom of the jacket for placement of the grout. However, there are many applications where the length of the repair is limited to the splash zone, requiring the creation of a seal at a point along with the height of the pile where the bottom of the jacket will be positioned. The skirt pin is shown in the foreground of Fig. 3 allows the creation of that seal.

b. Shear Transfer – In repaired piles, a load path must exist for the forces in the newly-formed reinforced concrete shell to bypass the damaged zone of the pile. When the pile is made of timber or concrete, the rough surface of the host pile usually provides sufficient load transfer through bond. However, when the host pile is made from steel, a mechanism such as welded shear studs can be used. Underwater welding is costly and difficult, and as was the case on one of our recent projects, the flammable materials present on the site did not allow any welding. Two newly developed products assist with this shear transfer. One is called ShearWrap™ for use on circular steel piles. Each band is about 3-4 inches wide, 0.2 inches thick, and is comprised of two half circles. The divers place the band around the pile (usually above water) and loosely connect the bolts. The band is then free to slide along the height of the pile to its final position. At that point, the divers tighten the two bolts to the specified torque. In some cases, wings can be welded to the steel bands to increase the bearing capacity of the unit. Similarly, for steel H-piles, ShearClamp™ can be used. These individual clamps include a bolt that can be tightened against the flange of the pile. The capacity of each unit can be determined based on its resistance through friction and bearing.

Fig. 4. ShearClamp™ used on H-piles and ShearWrap™ steel bands that are torqued around circular steel piles.

Tests:

The PileMedic® system described above has been tested by several government agencies. Caltrans conducted tests of concrete bridge piling, which were severely damaged in an earthquake. It was shown that even when the longitudinal reinforcing steel in these columns was fractured, the full capacity of the column could be restored in 48 hours without the need for replacing the broken reinforcing steel. Texas DOT conducted a study of corroded steel H-piles at the University of Houston. Even sections with up to 80% section loss gained their full strength after being repaired with this system. Nebraska Department of Roads studied repair of timber piles.

More recently, the U.S. Army Corps of Engineers (ACE) conducted a major investigation of solutions for the exigent repair of piles. Based on full-scale tests, ACE has selected PileMedic® as the only solution for the U.S. military worldwide to repair timber, concrete, and steel piles. As a part of this evaluation, 90 concrete piles were repaired at Pearl Harbor, Hawaii. The installations also considered various conditions, such as poor visibility in the water and water current. As noted by some of the diving team members, the new system reduces the repair time to as little as 1/3 of the previously used pile jackets. Considering that the labor/diving fees account for some 75% of the total repair costs, the new system could result in significant time and cost savings in pile repair projects.

Field Installation:

The system described here has been installed in many projects worldwide. Among these are over 500 timber piles at Perdue Agrobusiness in Chesapeake, VA, 90 concrete piles for the Port of Seattle, 95 steel piles in Houston, 265 steel piles for Indiana DoT, 100 piles in a jetty belonging to the Nigerian National Petroleum Corporation, numerous bridges in Australia, etc. A related application of this system is for the repair of cell phone towers. As the communication companies need to add more equipment to existing towers, these towers that are often placed in congested areas must be strengthened. Some 100 such towers have been retrofitted in California alone with this proprietary technique.

Videos showing the highlights of many of these projects are available on our YouTube channel and can be viewed at this link: https://tinyurl.com/y8mvdhs9