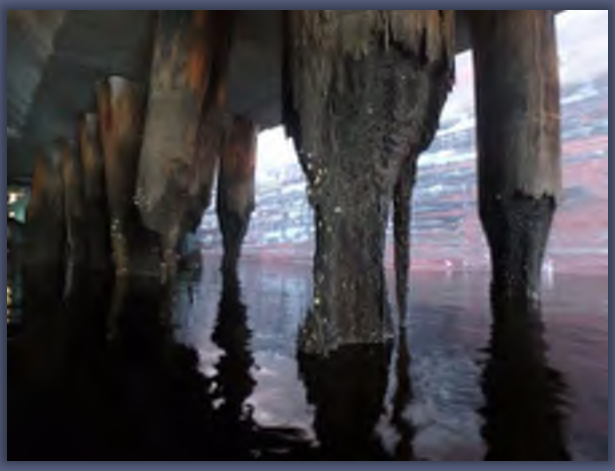
PileMedic+
By QuakeWrap, Inc.

Product Information



QuakeWrap
Stronger Than Steel

Fig. 1. From left to right: carbon and glass PileMedic®laminates and unidirectional carbon strips. Note the flexibility of PileMedic® being bent by hand.

BACKGROUND

PileMedic® is a patented technology that is only offered through QuakeWrap Inc. (QWI). In the late 1980s, Professor Ehsani pioneered the field of repair and retrofit of structures with Fiber Reinforced Polymer (FRP) products. He founded QWI in 1994 focusing on providing engineering design and FRP materials to clients who were seeking such services in the early years of this industry. Numerous awards of excellence from the industry have recognized both QWI and FRPC. In December 2009, Dr. Ehsani left the University of Arizona as a Professor Emeritus of Civil Engineering to fully devote his attention to the growth of QWI.

PRODUCT DESCRIPTION

PileMedic® is a technology developed following 25 years of research and development. These laminates are constructed with specially designed equipment. Sheets of carbon or glass fabric up to 5-feet wide are saturated with resin and passed through a press that applies uniform heat and pressure to produce the laminate (Fig. 1). The laminates offer several advantages compared to other products:

a) Using a combination of unidirectional and/or biaxial fabrics, PileMedic® laminates provide strength in both longitudinal and transverse directions.

b) PileMedic® is very thin; with a thickness as small as 0.01 inch, it is flexible enough to be wrapped around corners of square columns (Fig. 1).

c) PileMedic® laminates are manufactured in plants under high quality control standards; this improves the quality of the finished construction.

d) The repairs can be completed much faster in the field.

e) The strength of the laminates can be tested ***prior*** to installation.

f) The number and pattern of the layers of fabrics in PileMedic® laminates can be changed to produce an endless array of customized products providing different strength values along the height of the pile or in the hoop direction.

g) Additional coatings to the surface of the laminate can be added for abrasion and UV protection.

These unique features of PileMedic® have led the U.S. Army Corps of Engineers and the Federal Emergency Management Administration (FEMA) to single out PileMedic® as the only product for repair of columns and piles that may be damaged in a disaster such as a hurricane, earthquake, terrorism, etc. (Field Operations Guide, 2013 available here http://goo.gl/ANSxql).

UNIQUE FEATURES

From a performance point of view the PileMedic® system has several unique features:

1. **The Strongest Pile Jacket on the Market** -- Tensile strengths of PileMedic® laminates range between 62,000 to 155,000 psi. These strengths are anywhere from 3 to 10 times higher than other pile jacket systems used to date (see comparisons here http://goo.gl/2KuJqW).

2. **One Size Fits All** – There is no need to order the jackets for the right shape and size in advance. A roll of laminate can be cut in the field to fit any shape or size pile.

3. **Seamless Shell** – PileMedic® jackets are coated with a special epoxy paste and wrapped two or more times around the pile to create a multi-ply impervious shell. This process results in a seamless shell around the pile that will keep all moisture and oxygen out. Along the height of the pile, the jacket segments are overlapped a minimum of 4 inches and epoxied together for a watertight joint. Since water and oxygen are the primary source of deterioration in timber piles and corrosion in steel piles, the seamless construction of PileMedic® brings the corrosion rate to a near halt.

4. **Confinement Pressure** – The lack of a vertical seam means that the PileMedic® jacket has the same tensile strength 360 degrees around the pile. This high confining pressure significantly increases the strength of the pile for the same enlargement size. All other pile jackets have a bolted or glued seam which becomes the weak point under loading.

QuakeWrap, Inc. is the only company that holds U.S. Patents on FRP systems that provide confinement of piles by continuous wrapping of the pile. One of our patents (U.S. Patent #8,650,831) includes providing sheets made with any materials around the pile and then continuously wrapping those sheets with FRP for confinement. Our second patent was just approved on May 10th, 2016 (Application # 12/618,358); it is based on using the PileMedic® laminates and the technique described in this document.

A recent study has shown that when concrete columns get damaged by Alkali Silica Reaction (ASR), a minimum confining pressure of 300 psi is needed to prevent further swelling of the concrete. PileMedic® is the only jacket system capable of offering such confinement. By adjusting the number of layers of the wrap, virtually any desired confining pressure can be provided.

5. **Axial and Flexural Strength** – PileMedic® laminates are reinforcing sheets, like a steel plate that can be deigned to provide any level of axial, shear or flexural strength for the pile. Further details are provided in Section C-1.

6. **Ease of Installation** – PileMedic® jackets require little training and equipment for installation. The fact that the jackets can be wrapped around the pile above water and then pushed into water results in significantly less need for divers during the installation.

7. **Quick Repair** -- Conventional jackets must be ordered in advance, manufactured to size and shipped to the job site; this causes considerable delay in repair of the damaged pile. The problem is even more severe following an event such as earthquake or explosion where the size and shape of the piles that get damaged are not known in advance. In such emergency repairs, PileMedic® is the only product where a single flat sheet can be used immediately to repair piles of any shape or size. This is one of the reasons why the Army Corps of Engineers Search and Rescue Program has listed PileMedic® in its Field Operations Guide as the best and fastest solution to restore the strength of a damaged column or pile (goo.gl/ANSxql).

8. **Full Restoration of Pile Capacity** – Within 24 hours of completed installation, the full capacity of the pile is reached or surpassed. An example of this is detailed below in the study conducted by Caltrans and NSF to restore the strength of a concrete bridge pier that was severely damaged in an earthquake (http://goo.gl/HRHzjr).

STRUCTURAL CAPACITY RESTORATION

PileMedic® is truly a structural strengthening system for piles. The laminates contain fibers in two directions (longitudinal and transverse). When wrapped around a pile or column, the jacket creates a seamless shell around the column with tremendous confining pressure on the column. It is well known that the axial capacity of a column is proportional to the degree of confinement. So, the more layers of PileMedic® are wrapped around the pile, the higher the axial capacity of the pile. As an example, a 4000 psi concrete pile may resist axial loads like a 5000 or 6000 psi concrete pile depending on the number of wraps and the confining pressure the jacket places on the pile. In many cases, this increase in capacity is sufficient enough to eliminate the need for enlargement of the pile cross section.

The annular space between the PileMedic® jackets and the pile or column can be filled with a variety of filler materials and reinforcing elements. The pros and cons of each system is described here and summarized in Table 1.

Table 1 - Direct contribution of PileMedic® laminates to load-carrying capacity of piles

Pile Material	Behavior	Material used to fill the annular space		
		Cementitious Grout	**Epoxy Grout**	**Low Viscosity Resin**
CONCRETE	Axial	Yes[1,2]	Yes[1,2,3]	Yes[1,3]
	Shear	Yes[1,2]	Yes[1,2,3]	Yes[1,3]
	Flexure	No[2]	Yes[1,2,3]	Yes[1,3]
TIMBER	Axial	Yes[1,2]	Yes[1,2,3]	Yes[1,3]
	Shear	No[1,2]	Yes[1,2,3]	Yes[1,3]
	Flexure	No[2]	Yes[1,2,3]	Yes[1,3]

1 Additional gain is achieved by means of confinement of pile and filler material
2 Additional gain is achieved by placement of steel or GFRP rebars in the annular space
3 Additional gain is achieved by placement of carbon strips in the annular space

One type of filler material is cementitious or underwater grout. These are the least expensive fillers and are ideal when a large annulus (e.g greater than 1 inch) is to be filled. Grouts can be either pumped through ports installed on the jacket or placed using the tremmie technique. The drawback of cementitious grouts is that the large particle size prevents the grout from penetrating into narrow cracks in concrete piles or filling the voids inside a deteriorated timber pile. Cementitious grouts also have poor bonding capacity to the smooth surface of PileMedic® jackets. Thus, when using a cementitious grout, only the confining benefits of the jacket can be realized; contribution of the jacket to the flexural capacity of the retrofitted pile is conservatively ignored. If necessary, longitudinal reinforcing elements such as steel or GFRP rebars can also be placed in the annular space; these increase both flexural and axial capacity of the retrofitted pile.

Another type of filler material is epoxy grout; these are essentially epoxy resins that are extended with sand and small gravel to make a product with a unit cost between plain resin and cementitious grout. Depending on the particle sizes in epoxy grouts, they usually require

an annular space of 1 inch or wider to ensure the grout flows freely and does not leave any air pockets in the annular space. Epoxy grouts also bond the PileMedic® laminate to the host pile and engage the jacket in resisting axial, shear and flexural loads. Additional longitudinal reinforcing elements such as carbon strips and FRP or steel rebars can also be placed in the annular space when epoxy grouts are used.

Fig. 2. Penetration of low viscosity resin into all cracks and voids

A third type of filler material is a low viscosity epoxy resin. These cost more than cementitious grouts and are best used when a small annular space (less than approx. 1/8 inch) is to be filled. Small diameter injection tubes can be positioned at 90 or 120 degrees apart along the height of the pile, or can be embedded in grooves cut along the pile; the PileMedic® jacket is tightly wrapped around the pile and the injection tubes and low viscosity resin is pumped into the annular space through the injection tubes. QuakeBond™ 320LV, for example, is one such resin that cures under water, eliminating the need for costly coffer dams in such repairs. The resin is also 2-3 times stronger than concrete or wood in compression. As shown in Figure 2, even under a gravity flow condition, the resin fills all internal cracks and voids in a deteriorated timber (or concrete) pile. The thin film of resin that is formed in the annular space around the pile, serves as an impervious layer that encapsulates the pile and further prevents moisture and oxygen ingress (in addition to the same behavior provided by the PileMedic® jacket itself); this will significantly reduce corrosion and deterioration rate.

Moreover, the use of epoxy as a filler material will bond the PileMedic® jacket to the host pile. In this case, the jacket will significantly increase the axial, shear and flexural strength of the pile, with minimal increase in pile diameter! These contributions can be calculated using established procedures such as those recommended by ACI Committee 440. The narrow width of the annular space makes it impractical to add any reinforcing bars. However, if necessary, unidirectional carbon strips that are 0.05 inch thick can be positioned in the annular space. The injection resin bonds these strips, the pile and the PileMedic® jacket together resulting in significant increases in strength of such piles.

It is noted that there is no structural benefit in creating a thick layer of the injection resin around the pile. So, to keep costs down, when a timber pile has major section loss (an hour glass shape), one can build up the missing area with a lower cost cementitious grout before the pile is wrapped in PileMedic® jacket and injected with resin.

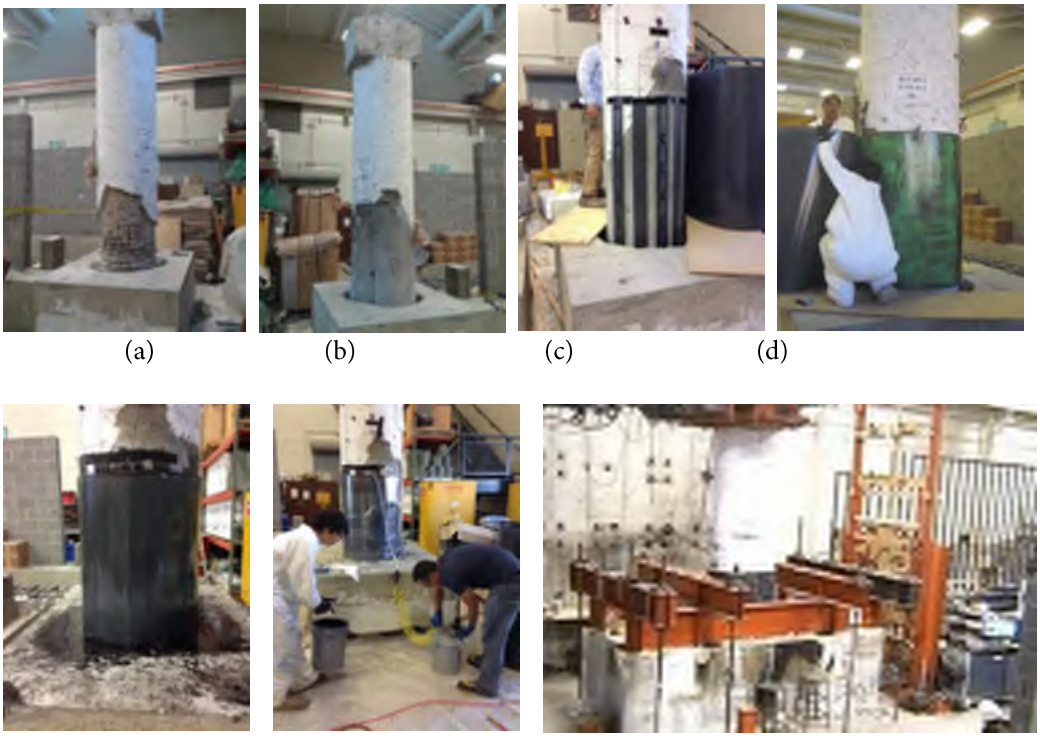
SUMMARY OF STRUCTURAL TESTS PERFORMED

Since the introduction of PileMedic® in 2010, State DOTs that are faced with repair and strengthening of piles and columns have funded their own research on this product to prove its capabilities. Among these are studies funded by the following:

1) California Department of Transportation (Caltrans) and the National Science Foundation (NSF) on restoring the strength of concrete columns that are severely damaged in an earthquake.
2) Nebraska Department of Roads on restoring the strength of decayed timber bridge piles.
3) Texas DOT on repair and strengthening of severely corroded steel H piles in river crossings.
4) United States Army Core of Engineers – in progress (2016)
5) Louisiana Tech University & Louisiana DOT – in progress (2016)

Details of the completed studies are presented below.

Concrete Column – With funding from the NSF and Caltrans researchers from three universities participated in a study to develop a solution for rapid return to service of bridge piers that may get severely damaged in an earthquake. The 24"x36" concrete column was first subjected to simulated earthquake loading, causing the fracture of three No. 8 rebars on each face of the column. The objective of the study was to see if the strength and ductility of the column could be restored without replacing the broken steel bars! The various stages of repair using PileMedic® laminates are shown In Figure 3.



(a) (b) (c) (d)

(e) (f) (g)

Fig. 3. Test of earthquake-damaged bridge pier; a) column with broken steel bars, b) concrete patched, c) carbon strips installed, d) wrapping of PileMedic® carbon laminate, e) filling the base with epoxy, f) injecting epoxy in annular space, and g) re-testing of pier after repair

Timber Piles – In conjunction with the Nebraska Department of Roads (NDR), researchers at Florida International University tested five timber piles. A 16-inch long portion of each pile was shaved and removed in an hourglass shape to depths ranging from 1 to 2 inches to simulate various degrees of damage encountered in the field. All piles were encased in PileMedic® glass laminates that extended 12 inches beyond the damaged area along the length of the pile. The damaged area was filled with pure resin or a mix of resin and gravel. The ends of the piles were cast in a 24-inch concrete cube. The specimens were subjected to a combination of axial and lateral loads. The axial load vs. axial deflection of all five specimens and a photograph of the failed specimens at the conclusion of each test are shown in Figure 5. The design capacity for these piles was calculated to be 18 kips. The specimens showed various degrees of increased axial load capacity and their failure load ranged from 5.3 to 9.9 times the design capacity. The final report is available here (goo.gl/pXeWp5).

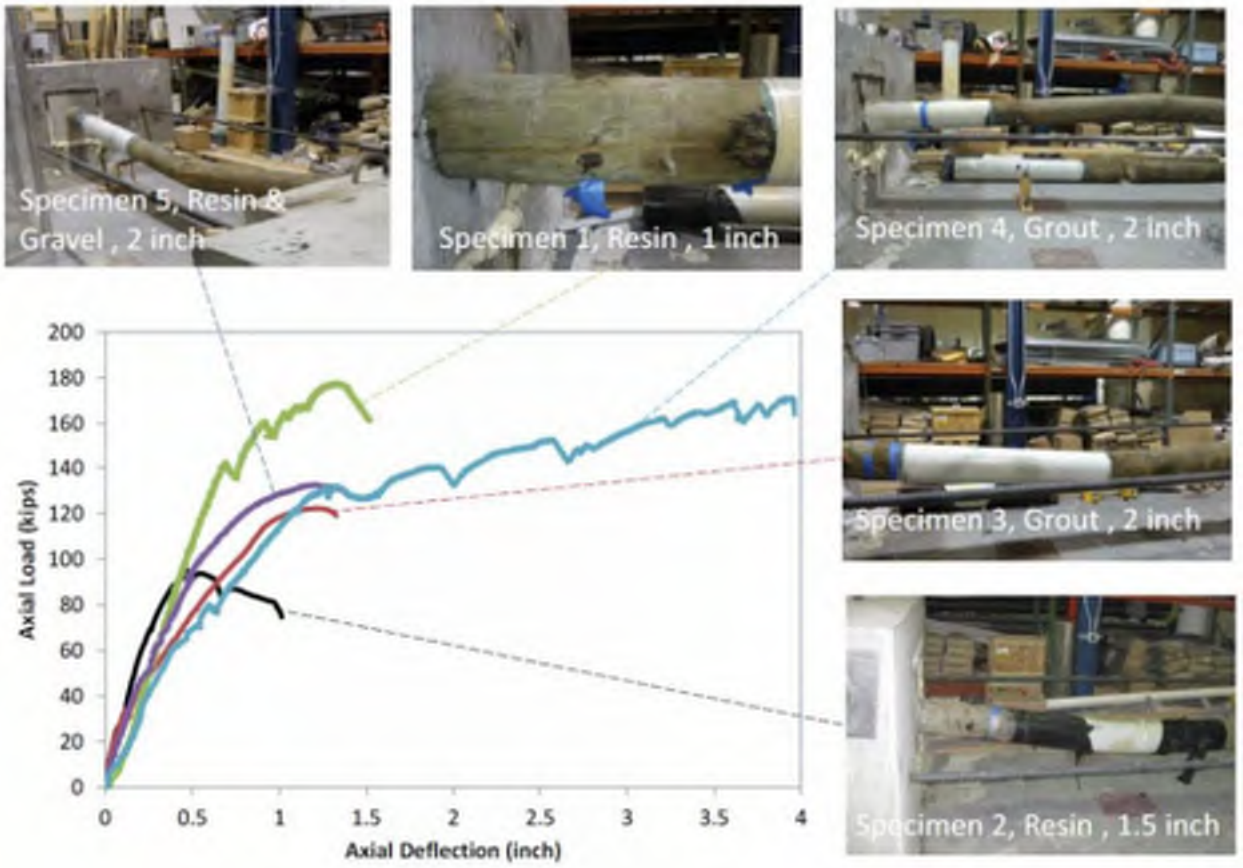
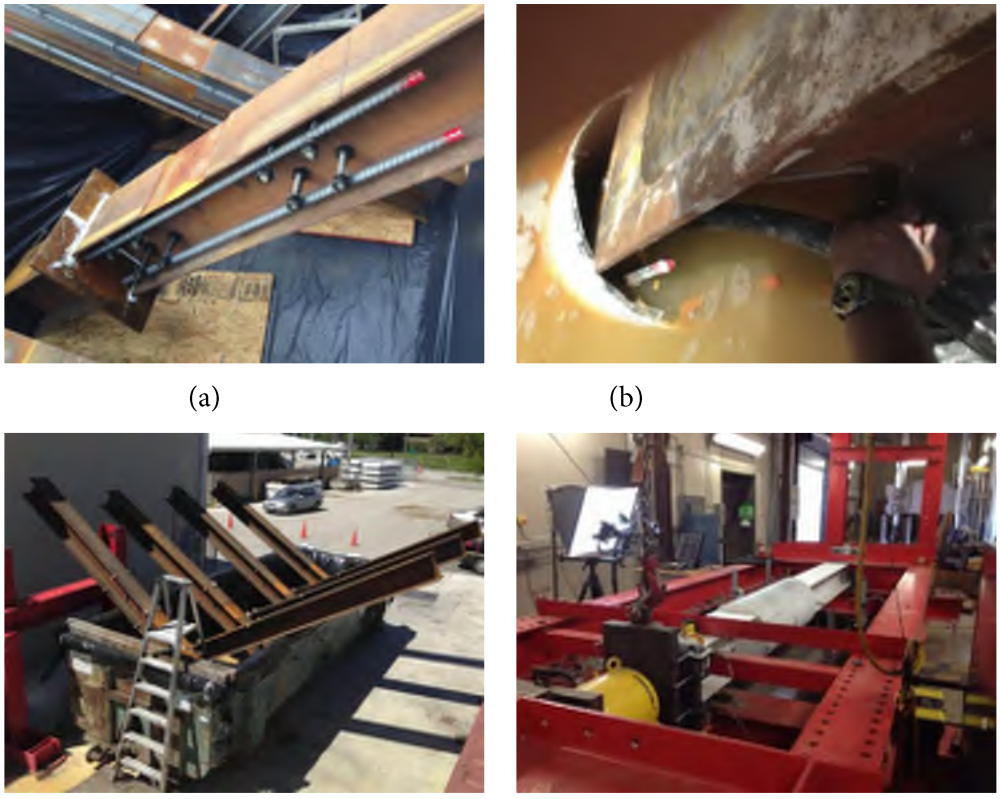


Fig. 5. Load deflection curve and failure mode of specimens (Mohammadi et al. 2014)

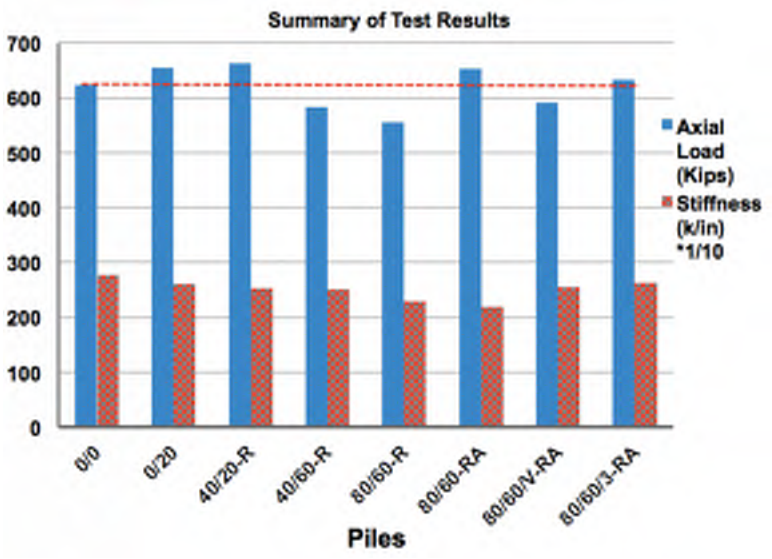
Steel H-Piles - Texas DOT has also completed a major funded project at the University of Houston. In that study, 7 full-scale steel piles were tested under different degrees of corrosion damage and encasement in PileMedic® jackets (Figure 6). As an example, specimen 80/60/V-RA refers to a pile where 80% of the flange section and 60% of the web section were removed to simulate loss due to corrosion. The specimen also included a 2 inch void in the web and it was repaired with the addition of longitudinal rebars and anchor bolts (Fig. 6(a)).



(a) (b)

(c) (d)

Fig 6. Steel H piles tested for Texas DOT at the University of Houston; (a), (b) & (c) repair of specimens in submerged condition, (d) testing of repaired H pile



The specimens were subjected to axial compressive loads and the results are shown in Figure 7. All specimens regained or exceeded their undamaged axial capacity as a result of retrofit with the PileMedic® system. A copy of the draft report is available here (http://goo.gl/yBTHX3)

INSTALLATION

The installation of the PileMedic® system is shown in this video (goo.gl/DX9ItL).

Required Surface Preparation: All piles scheduled to receive PileMedic® jackets shall be cleaned using high pressure water jetting with rating of 5000 psi.

Required Tools and Equipment: Installation of PileMedic® requires few tools. Tape measure, shears to cut laminate, electrical drill for mixing of the epoxy, notched trowel to apply epoxy and ratchet straps to hold laminate in place during cure time.

Required Personnel and Level of Training Experience: One of the key features of PileMedic® is the ease of installation. Any skilled laborer will be able to follow the simple installation steps below. QuakeWrap, Inc. can provide written detailed steps along with video instruction. For larger projects we can provide technical representatives on site to train and oversee installation.

Assuming a 4-foot tall repair on a pile, the contractor will first have to cut the proper length out of the long roll of laminate. Our standard detail calls for a minimum wrap of two turns (i.e. 720 degrees) plus an 8-inch extension. So, assuming a 12-inch diameter pile with a perimeter of approximately 38 inches, the installer must cut a piece 38+38+8= 84 inches long (figure a & b). The first 38 inches that will be installed against the pile surface does not need to get coated with epoxy. The two-component QuakeBond™ 220UR is mixed (fig. c) and the paste-like epoxy is applied with a notched trowel over the remaining 38+8=46 inch of the laminate (fig. d). The epoxy thickness will be about 0.03-0.04 inch. Air, water and laminate surface temperature shall be between 45 and 90 degrees Fahrenheit.

2. Wrap & Strap

Next the crew will pick up the laminate sheet and wrap it around the pile, making sure that the uncoated piece is next to the pile. By continuing to wrap, the second half of the laminate that is coated with epoxy will be placed over the first layer, creating a two-ply jacket around the pile (fig. e). The jacket size can be adjusted at this time until a desired annular space between the jacket and pile is reached. Since the epoxy is not cured at this stage, ratchet straps or shrink-wrap can be wrapped around the laminate to make sure it holds its shape for the next few hours (fig. f). At this stage, the jacket can slide up or down along the pile to the final desired location. It can also be pushed into water from a floating surface (fig. g). QuakeBond™ 220UR epoxy cures underwater so these laminates can be installed by divers underwater as well.

3. Fill Annular Space

The bottom of the annular space between the jacket and the pile is sealed with Oakum rope or expansive grout and the annular space between the jacket and the pile is filled with a grout, an epoxy grout or QuakeBond™ 320LV Low Viscosity Resin (fig. i and j). The QuakeBond™ 320LV Low Viscosity Resin cures under water and will bond the jacket to the pile. It will also fill all the voids and cracks in the timber or concrete pile (fig. k). The resin is about 3 times stronger than most woods, so any hole or void in the timber pile that is filled will be a lot stronger than before. The jacket enhances the axial and bending strength of the pile. If additional bending capacity is desired, strips of QuakeWrap® GU50C carbon strips can be placed in the annular space prior to introduction of the resin.

Please note:
The filling material can be either a low viscosity resin, epoxy grout or a cementitious underwater grout. Grout is useful in enhancing the axial capacity of the pile but it will not transfer the flexural strength of the jacket into the pile due to the smooth inside interface between the jacket and grout. Thus grout is not recommended when the flexural strength of the pile has to be enhanced. Longitudinal rebar can be added before pouring grout if flexural strength is desired.

If the pile is severely damaged, those areas can be first patched with a cementitious material or filled with aggregate to minimize the volume of resin that will have to be injected in the annular space. Such repairs have been tested in the study of timber piles that was carried out by the Nebraska Department of Roads and have shown to be very effective.

For repairs taller than 4-feet, additional 4-foot tall laminates can be wrapped around the pile and overlapped by 4 inches or more to create a continuous long jacket around the pile.

ADAPTABILITY

One of the primary advantages of PileMedic® is its adaptability to fit piles of virtually all sizes and shapes. PileMedic® laminates are currently made 4-foot wide and packaged in 150-ft long rolls in a box. Our current equipment allows for production of laminates that are as wide as 5-foot; the length of the laminates can be much longer but 150-200 feet long rolls seem to be the right size of packaging for most of our clients. The roll in each box can be used to repair a number of piles, depending on the size and shape of the piles and the length being repaired. Unused portion of the laminate can be saved for future repair projects. This unique feature of PileMedic® offers many advantages since it eliminates the need to "special" order the jackets for specific shapes and sizes. In many cases, such ordering could result in delays in the repair time. Furthermore, the jackets may be the wrong size causing further delays in the project.

TECHNICAL DATA

The PileMedic® system consists of glass or carbon laminates and resins. A summary of the products and their uses are described in the table below and their Product Data Sheets are attached to this paper.

Product	Notes
PileMedic® PLG60.60	Biaxial glass laminate to create a shell around the pile
PileMedic® PLC100.60	Biaxial carbon laminate to create a shell around the pile
PileMedic® PLC150.10	Uniaxial carbon laminate to create a shell around the pile
QuakeWrap® GU50C	Carbon strips as flexural reinforcement placed in the annular space
QuakeBond™ 220UR	An epoxy paste applied between layers of PileMedic® that cures underwater
QuakeBond™ 320LV	A low viscosity resin used to fill the annular space between the jacket and the pile and to penetrate and fill all the cracks and voids in the pile; 320LV cures underwater
PileMedic® UW Grout	An underwater grout that is mixed and placed in the annular space between the jacket and the pile

These laminates are wrapped at a minimum 720 degrees (two complete wraps) around the pile with an 8-inch extension past the starting point. As shown in the section on Force Equivalency of the Product Data Sheet, the PLC100.60 jacket is equivalent to No.4 Gr. 40 ties placed at 1.75 inch on center along the pile height; this value contributes to the confining pressure and axial capacity of the pile. At the same time the jacket provides a force equivalent to No. 4 Gr. 40 longitudinal bars placed vertically at 2.5 inch on center around the perimeter of the pile; this value contributes to the axial and bending capacity of the pile. By wrapping the laminate 3 turns instead of the minimum 2 turns, all of these values will be increased by 50%.

Learn more about QuakeWrap, Inc

WHAT IS QUAKEWRAP®?

Introduced in the 1980s, Carbon Fiber Reinforced Polymer (CFRP) is a structural reinforcing material that is applied like wallpaper, reaching 2 to 3 times the strength of steel in 24 hours!

The QuakeWrap® family of products strengthen, repair, and restore deteriorating and aging buildings and infrastructure faster and less expensively than other repair or replacement solutions.

APPLICATIONS

- Beams & Columns
- Blast Protection
- Bridge Pilings
- Chimneys & Smokestacks
- Cooling Towers
- Culverts
- Force Protection
- Foundations
- Historic Preservation
- Manholes/Access Points
- New Pipeline Construction
- Pipe Repair
- Seawalls & Sheet Piles
- Seismic Retrofit
- Silos
- Slabs
- Submerged Piles
- Tanks
- Utility Tunnels, Vaults & Poles
- Walls

ADVANTAGES

- High tensile strength
- Lightweight
- Conforms to all shapes
- Full cure in 24 hours
- Ease of installation
- Non-toxic
- Odorless
- Waterproof

Today, QuakeWrap is a one-stop shop for engineers, architects and Owners seeking economical solutions for repair and retrofit of concrete, masonry, wood and steel structures and pipelines.

QuakeWrap offers "turnkey" services that can be tailor-made to the needs of the particular project/client. Among the services we offer are:

- Supply of complete line of materials (glass or carbon fabrics, carbon plates, resins, and top coatings)
- Assistance with design or complete sealed designs including Auto CAD drawings.
- Installation by our own construction crew for the following project types

- Carbon Fiber Reinforcement (CFRP)
- Fiberglass Reinforcement (FRP)
- Corrosion Protection
- Seismic Retrofit
- Structural Concrete Repair
- Epoxy Crack Injection
- Urethane Chemical Injection
- Gunite
- Shotcrete
- Pile Jacketing
- Abrasive Blasting/Grinding
- Coatings
- Galvanic Anodes
- Shoring
- Post Tension Repairs
- Secondary Containment
- Pipe Repairs
- Column Repairs
- Manhole Repairs
- Blast Walls

Precast Damage

- Expansion Joint Failure
- Grouting
- Beam Repair
- Shear Crack Failure
- Tunnel Repairs
- Non-Slip Surface
- Structural Integrity
- Pipe Support
- Coatings Dock and Wharf Repair
- Bearing Pad Replacement
- Base Plate Grout
- Pump Base Pedestal
- Structural Strengthening
- Balcony Repair
- Clean Room
- Beam Deflection
- Reactor Units
- Pipe Wrap

RECENT AWARDS

- American Society of Civil Engineers (ASCE) Innovation Award for Best Value – Green Engineering, 2016
- Environmental Excellence Award of Merit for Energy and Technology Innovation, Arizona Forward, 2015
- Success in Exporting, Congressional Record, 2014
- Technology Leader of the Year, Arizona Technology Council, 2014
- Excellence in Global Business AZ District Export Council, 2014
- Trenchless Technology's Project of the Year Award, 2011
- Award of Merit in Structural Engineering, Structural Engineers Association of Arizona (SEAOA), 2010, 2015, 2016
- Award of Merit, International Concrete Repair Institute (ICRI), 2010
- Southern Arizona Smart Inspiring Enterprise (SASIE) Awards Finalist, 2009
- Trenchless Technology Project of the Year Award (Honorable Mention), 2009
- Outstanding Concrete Repair Project, PNM PIPE/International Concrete Repair Institute (ICRI), 2008

Bridge Pile Encasement at Barron River Bridge, Cairns, Queensland, Australia

RELEVANT FEATURES

- Repair of submerged columns damaged by ASR
- Marine environment causes continuous dry wet cycles (similar to PVNGS cooling towers)
- Encapsulation of columns with FRP jackets

CONSTRUCTION COST

$220,000

DATE COMPLETED

July, 2015

THE CHALLENGE

Barron River Bridge in Cairns, Australia carries the southbound traffic of Captain Cook Highway. The octagonal shaped concrete piles had experienced Alkali Silica Reaction (ASR) and required remediation. Each of the four piers consisted of 10 piles. The piles varied in height from 4m to 6m. The tides in this region are as high as 3m but only about 300mm of the piles are exposed during low tide, requiring all of the repairs to be performed underwater with limited visibility of less than a foot. The waters at this site in tropical northern Australia is also known for its crocodiles, sharks, jellyfish and the like.

OUR SOLUTION

QuakeWrap designed a solution to arrest the ASR by encasing the piles in a jacket that would eliminate the influx of any water. Conditions for the installation divers required working inside a protective steel cage to protect against predators. This also limited the choice of jackets that could be safely handled.

PileMedic® FRP laminate was used to encase the piles. These thin sheets were wrapped around the piles in 1.2m high segments to create a seamless impervious shell that was subsequently filled with a low viscosity resin. The resin sealed the concrete and filled any voids and cracks in the concrete. The project was successfully completed ahead of schedule with no injuries to the crew or disruption of traffic.

CREDITS

- QuakeWrap Australia: General Contractor
- QuakeWrap, Inc.: Design Engineer

Wood Pile Strengthening for Valvoline, St. Louis, MO

RELEVANT FEATURES

- 45 foot tall columns
- Encapsulation in PileMedic® jackets
- Epoxy injection of entire column

Before

After

CONSTRUCTION COST

$473,500

DATE COMPLETED

2015

CREDITS

- FRP Construction: General Contractor
- QuakeWrap, Inc.: Design Engineer

THE CHALLENGE

Wood piles, 16 inches in diameter by 45 feet high, located on the shore of the Mississippi River had been degraded by the moisture/drying cycle of the river due to the seasonal changes in river height, and by debris impacting the piles during high water, high flow rate periods.

OUR SOLUTION

We strengthened the damaged wood by injecting low viscosity resin followed by wrapping the piles in PileMedic® laminate. This combination of resin filling the voids and the confinement from the laminate increased the strength of the piles; protecting them from debris

Precast Cell Phone Tower Strengthening for Crown Castle, Southern California

RELEVANT FEATURES

- Wet layup FRP applied to the pole surface
- Strengthening of 50-60 foot tall hollow concrete cell phonetowers with FRP
- Anchoring of longitudinal reinforcement intofooting
- Lateral confinement of pole withFRP jackets

Carbon and glass FRP applied to the lower portions of the pole.

Nearly 2/3 of the pole wrapped with PileMedic laminates and filled with grout.

CONSTRUCTION COST

$2 million

DATE COMPLETED

2015-2016

CREDITS

- FRP Construction: General Contractor
- QuakeWrap, Inc.: Design Engineer

THE CHALLENGE

Wireless communication and the amount of information being transmitted has seen exponential growth in recent years, requiring faster networks to handle the heavier traffic. In response, cellular communication companies must provide additional equipment on their towers.

These towers or poles are often in congested areas where installation of new towers is very difficult. Use of systems that require a larger footprint is also undesirable. A cost-effective compact retrofit system that can be implemented without disruption of service is an ideal solution. In addition, there is a growing interest in the western states to seismically upgrade these towers.

In the US, Crown Castle is the largest cell phone tower owner with over 40,000 towers. They maintain the towers and lease the space to service providers.

OUR SOLUTION

Among the options considered, QuakeWrap's patented proposed design to use FRP to strengthen the towers offered the most viable solution. The technique offered the flexibility to easily change the strength of the pole along the height. Tension reinforcement for the pole was provided by bonding unidirectional carbon fabrics to the exterior surface of the pole.

Through a master design/build agreement, QuakeWrap's installation partner, FRP Construction, has strengthened 29 Crown Castle cell phone towers throughout Southern California to date and 10 more are currently under construction.

Strengthening of each tower takes approximately 4 days to complete. The lightweight PileMedic® laminates eliminate the need for any heavy equipment and all work can be accomplished using a manlift. Once the shells are created around the pole, the annular space is filled with a high-strength non-shrink grout. The laminates are coated with a UV-resistant coating. Cables and appurtenances near or attached to the pole are moved slightly to accommodate the FRP and concrete placement then relocated to their original position. The design allowed the pole to remain fully operational during the repair with little change in the appearance and size of the pole.

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Product Data Sheet

PileMedic™ PLG60.60

For Structural Strengthening of Columns and Submerged Piles

DESCRIPTION

PileMedic™ PLG60.60 is a high-strength Fiber Reinforced Polymer (FRP) laminate constructed with bidirectional glass fabrics providing strength in both longitudinal and transverse directions. The laminate is wrapped around the column or pole and the overlapping portions are bonded together using QuakeBond™ 220UR (Underwater Resin) or QuakeBond™ J201TC (Tack Coat) to create a strong shell around the existing structure. PileMedic™ is unique in that it allows construction of a seamless structural shell around an existing column, utility pole or submerged pile. The annular space between PileMedic™ Jacket and the host pile can be filled with QuakeBond™ 320LV Low Viscosity epoxy resin or high-strength non-shrink grout.

USE.

- Repair of underwater piles
- Repair of bridge piers
- Repair & strengthening of corroded steel columns
- Repair & strengthening of timber utility poles & bridge piling
- Applicable to all materials: concrete, steel and timber

ADVANTAGES.

- One flat sheet can be used to construct a shell of *any size in the field*, eliminating the expense and delays of special order jackets.
- The jacket provides significant *lateral confining pressure* (in the hoop direction) that increases the axial compressive capacity of the pile or column.
- Provides *flexural (bending)* enhancement.
- The *seamless shell prevents migration of moisture and oxygen* into the column, significantly reducing future rate of corrosion and deterioration.
- Annular space can be adjusted in the field *to minimize the volume of grout or resin*.
- Eliminates or reduces the need for costly divers in underwater pile repairs
- *Corrosion-resistant* system can withstand various chemicals.
- *Non-toxic, odorless* resins are approved for potable water.
- Strength of the laminates can be verified *prior to installation in the field* (in contrast with wet layup FRP systems).
- Laminates can be installed as single shells with overlapping joints along the column height or as a continuous spiral shell.
- The laminates are manufactured in our plant with the highest quality control.

PACKAGING

Standard rolls are 50 in. X 150 feet (1.27 m X 45.7 m). PileMedic™ laminates can be custom manufactured in widths up to 60 inches (1.52 m).

SHELF LIFE

PileMedic™ laminates have unlimited shelf life when stored properly.

STORAGE CONDITIONS

Store in dry place at 30°-120° F (0°-50° C).

APPLICATION

1) Cut the required length of PileMedic™ considering the number of layers necessary and the overlap length beyond the starting point.
2) Wipe PileMedic™ with appropriate cleaner (e.g. acetone or MEK) using clean cloth.
3) Apply QuakeBond™ 220UR (Underwater Resin) or QuakeBond™ J201TC (Tack Coat) on the over-lapping regions of the laminate sheet.
4) Wrap the laminate around the pile or column to create a multi-layer jacket as required. Spacers may be used to control the size of the annular space between the host pile and the PileMedic™ jacket.
5) Use ratchet straps to temporarily hold the jacket in the desired size.
6) Seal the bottom of the annular space.
7) Before the epoxy cures, fill the annular space with non-shrink grout or resin; the hydrostatic pressure from the weight of the grout will press the PileMedic™ laminate plies against each other for improved bonding. For underwater applications, the grout or resin must be compatible for such applications.
8) For longer piles, repeat the above steps for additional 4-ft wide bands of jacket along the height of the pile; insert the lower portion of the new jacket a minimum of 4 inches inside the previously installed jacket.
9) Leave the installation undisturbed for 24 hours before removing the ratchet straps.
10) Apply appropriate coating on the exterior of the jacket.

Installation of PileMedic™ products must be performed only by specially- trained and approved contractors.

Laminates can be cut to appropriate length using commercial quality heavy duty shears. Care must be taken to support both sides of the laminate during cutting to avoid splintering. Since dull or worn cutting tools can

damage, weaken or fray the fiber, their use should be avoided.

LIMITATIONS
Design calculations must be made and certified by a licensed professional engineer.

CAUTION
PileMedic™ PLG60.60 laminates are non-reactive. They do not require a Material Safety Data Sheet (MSDS). However, caution must be used when handling since a fine carbon dust may be present on the surface. Gloves must therefore be worn to protect against skin irritation. Care must also be taken when cutting the laminates to protect against airborne carbon dust generated by the cutting procedure. Use of an appropriate, properly fitted NIOSH approved respirator is recommended.

PILEMEDIC™ PLG60.60 PROPERTIES			
		US Units	SI Units
Longitudinal (0°) Direction:			
Tensile Strength	(ASTM D3039)	62 ksi	431 MPa
Modulus of Elasticity	(ASTM D3039)	3,500 ksi	24,140 MPa
Ultimate Elongation	(ASTM D3039)	1.31 %	1.31 %
Transverse (90°) Direction:			
Tensile Strength	(ASTM D3039)	60 ksi	418 MPa
Modulus of Elasticity	(ASTM D3039)	3,650 ksi	25,250 MPa
Ultimate Elongation	(ASTM D3039)	1.06%	1.06%
Laminate Properties:			
Ply Thickness		0.026 in.	0.66 mm
Barcol Hardness	(ASTM D 2583)	50 min	50 min
Water Absorption	(ASTM D 570)	0.8% max	0.8% max

Jacket Diameter inches (mm)[1]	Confining pressure psi (MPa)[2]	Gain in strength psi (MPa)[3]
12	535 (3.7)	2145 (14.8)
24	265 (1.9)	1070 (7.4)
36	180 (1.2)	715 (4.9)
48	130 (0.9)	535 (3.7)
60	107 (0.7)	430 (3.0)

(1) Cylindrical jackets constructed with two plies of PileMedic™ PLG60.60 laminate plus an 8-inch (200-mm) overlap beyond the starting point.
(2) Nominal confining pressure for a cylindrical jacket.
(3) Nominal increase in compressive strength of concrete column & grout due to confining pressure of jacket.

FORCE EQUIVALENCY
A double layer of PileMedic™ PLG60.60 provides the following equivalent forces:
No. 4 Gr. 40 stirrup placed at 2.5 inches on center
No. 4 Gr. 40 bars placed vertically at 2.5 inches on center

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Product Data Sheet

QuakeBond™ 220UR Underwater Resin

DESCRIPTION
QuakeBond™ 220UR (Underwater Resin) is a two-component high-strength structural epoxy designed for underwater application. QuakeBond™ 220UR has an immediate high tack consistency both in air and water. QuakeBond™ 220UR trowels easily and has a user friendly 2:1 volumetric mix ratio. QuakeBond™ 220UR is a 100% solids formulation with low toxicity and low odor during cure and features a unique 12-hour turnaround to service without force cure or specialized equipment.

USE
- Adhesive for bonding external reinforcement to concrete, masonry, wood, stone, steel, etc.
- Structural bonding of carbon or glass laminates, e.g. PipeMedic™ or PileMedic™ products.
- Structural bonding of fabrics saturated with QuakeBond™ J300SR resin on vertical and overhead surfaces.

ADVANTAGES
- High strength, high modulus, structural paste adhesive.
- Fully compatible and excellent adhesion to PipeMedic™ or PileMedic™ laminates and fabrics saturated with QuakeBond™ J300SR resin.
- Paste consistency ideal for underwater applications.
- Convenient easy mix ratio, (2 volume parts of component "A" with 1 volume part of component "B").
- 100% solvent free.
- Moisture tolerant.
- 12 hour full cure.
- Tile like high gloss finish easy to clean and decontaminate.
- Environmentally sound.

COVERAGE
Applied at a thickness of 15 mil (0.4 mm) results in 100 square feet per gallon (0.4 liter per square meter). Rough and uneven surfaces result in lower yields.

PACKAGING
Component "A" is supplied in 2-gallon (7.58L) containers and component "B" in 1-gallon (3.79L) containers, resulting in 3-gallon kits. Likewise 15 gallon kits are available. Ships DOT non-regulated.

MIXING
Prior to mixing, components A Resin and B Hardener should be at room temperature (60-75 F/16-24C). Pour Part B Hardener into Part A Resin. Mix for 3 minutes using a Jiffy mixer head and a mechanical drill. To ensure complete mixing, scrape sides and bottom of container and continue mixing for an additional 1 or 2 minutes. Do not mix more material than can be applied within the 30 minutes pot life. DO NOT HAND MIX. Begin application immediately – no induction time.

SHELF LIFE
Shelf life is 12 months from the date of manufacture when stored in unopened containers and under recommended conditions. Material should be stored in a dry area under cover at temperatures between 45-95F/7-35C. It is recommended that the coating components be kept inside at a minimum of 60F/16C for 24 hours prior to start of application. Keep away from heat, flame and ignition sources.

CERTIFICATE OF COMPLIANCE
- Material Safety Data Sheet (MSDS) will be supplied upon request and is included with each shipment.
- Possesses 0% volatile content per EPA Test Method 24.

SURFACE PREPARATION
Steel – *Immersion Service*: SSPC-SP10 Near White Blast Cleaning with 3.0-mil profile
Non-Immersion Service: SSPC-SP6 Commercial Blast Cleaning with 2.0 mil profile
Concrete – Concrete must be properly cured for a minimum of 28 days before application of coating. Surface must be entirely free of oil, grease, dirt, detergent, surface water, laitance, curing compounds, coatings or other contaminants that may interfere with adhesion. The concrete must be abrasive blasted to provide an anchor pattern (similar to 60-80 grit sandpaper min.) for adhesion. Final prepared surface should be clean and rough. Consult SSPC-SP13 – Surface Preparation of Concrete.

APPLICATION
Air and surface temperature should be between 50-90F/10-32C. Do not begin application if air, substrate or material temperature is below 50 F/10C or expected to fall below 50F/10C within 12 hours of application. Do not begin application if dew point is within 5F/3C of the temperature. Variations in temperature can affect pot life and sag properties of this material. Do not exceed 20% by volume of thinner with NSP-T1 Thinner. NSP-T1 Thinner will not clean hoses or equipment adequately. Clean up using Acetone or other Ketone Solvent. For concrete surfaces, a primer coat of either NSP 100, 101 and 110 is strongly recommended.

LIMITATIONS
This product may not cure properly in temperatures below 50 F (10 C). All epoxies will show chalking/yellowing on exterior exposures. Application of epoxy coatings in cool temperatures and high humidity can result in the formation of amine blush. Blush may appear as a milky, white, tacky residue on the surface of the cured coating and must be removed before the application of another coat. Intercoat adhesion problems may occur if blush is not removed.

FIRST AID
In case of skin contact, wash thoroughly with soap and water. For eye contact, flush immediately. For respiratory problems, remove to fresh air. Wash clothing before reuse. Consult MSDS for detailed information.

CLEANUP
Collect with absorbent material, flush with water. Dispose of in accordance with local disposal regulations. Uncured materials can be removed with approved solvent. Cured materials can only be removed mechanically.

EPOXY PROPERTIES	
Color	White, Black, Tile Red, Light Gray
Pot Life at 77° F (25° C)	30 minutes
Full cure time	12 hours
Tensile Strength (ASTM D-638)	4360 psi (38.6 MPa)
Compressive Strength (ASTM D-695)	11700 psi (80.7 MPa)
Flexural Strength (ASTM D-790)	8900 psi (61.4 MPa)
Adhesion to Concrete	Substrate Failure
Adhesion to Steel SSPC-SP10	>1200 psi (8.3 MPa)
Adhesion to Damp Concrete	>350 psi (2.4 MPa) Substrate Failure
Tensile Elongation	5%
Hardness, Shore D	90
Abrasion Resistance	37.7 mg Average Wt. Loss
Flame Spread	Class A
Flammability	Self Extinguishing

KEEP OUT OF REACH OF CHILDREN.
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Product Data Sheet

PileMedic™ UW Grout

DESCRIPTION

Pilemedic™ UW Grout is a pumpable underwater cement-based non-shrink grout for use in underwater repair such as pile restoration. Pilemedic™ UW Grout is designed for underwater use in tidal zones in applications requiring a non-shrink, non-metallic, wash out resistant grout in thicknesses from 1/2" up to several inches. Pilemedic™ UW Grout is specially formulated for minimal wash-out and is salt-water resistant.

USE

Recommended for underwater grouting of bridge columns, concrete pilings, and dam repairs where a "wash- out" resistant, free flowing or pumpable non-shrink grout is required.

FEATURES/BENEFITS

- "Wash-out" resistant thixotropic consistency for dependable Underwater repairs (displaces water)
- Free-flowing or pumpable consistency for easy application
- High early and ultimate strength for fast repair and turn around without chlorides
- Positive expansion for maximum durability and adhesion.

SPECIFICATIONS/COMPLIANCES

Corp of Engineers CRD-C-621 (plastic / flowable conditions)

APPLICATION

Preparation: Substrate must be clean and sound. All loose material must be removed. Substrates which are permanently immersed should be sandblasted or cleaned with a high pressure water jet. Non-immersed or intermittently immersed substrates can also be prepared using these techniques. Depending on the circumstances, scabbling or brush hammering may be appropriate. In view of the flowable nature of Pilemedic™ UW Grout, all form work must be grout-tight. This can be achieved using foam rubber sealing strips at the edges.

Mixing: The quantity of water required to achieve a flowable consistency must be accurately measured for each mix. Start with 7 pints and add additional water to bring the consistency to a flowable or pumpable yet cohesive mix. Do not exceed 8 pints of water. Each 50 lb bag requires approximately 7.5 pints of water. A mechanically powered grout mixer must be used. Ensure that the machine capacity and the number of workers is adequate to enable grouting to be carried out as a continuous operation. Place the specified amount of water in the mixer. Slowly add the contents of the Pilemedic™ UW Grout bag, mixing continuously. When all of the contents have been added, mix continuously for a minimum of 3 minutes, making sure that a smooth, uniform mix is obtained.

Placing: Pilemedic™ UW Grout can be dry packed, poured or pumped into place. Place the grout within 20 minutes of mixing to gain the full benefit of the expansion process. Continuous grout flow is required and the grout should be poured or pumped through a flexible tube, minimum diameter 1/2" to the lowest point in the form. At the start of the operation, the grout flow should be restricted in order to avoid any water entrapment. The bottom of the tube may be raised as necessary to reduce any back pressure, but should not be raised above the level of the grout. A 6" minimum depth is suggested below the grout surface to optimize performance.(tremie method).

Application depth: Pile Jackets may be filled with Pilemedic™ UW Grout in thicknesses up to 4" in one pour when placed above water. When placed under water, the heat sink effect in this environment permits thickness up to 7" be placed. For thicker sections up to 10" above water and 20" under water, it is necessary to extend the Pilemedic™ UW Grout using a clean, rounded and well graded aggregate in the size range 3/8" to 1/2". The quantity of aggregate should not exceed 1 part aggregate to 1 Pilemedic™ UW Grout by weight. For such mixes, a mortar mixer should be used. Unrestrained surface areas should be kept to a minimum. Excessively large volumes should require a thermal analysis to determine any limitations on pour size.

Curing: Curing will not be required in intermittent or totally submerged conditions. However, when cast above water, cover immediately with clean wet rags and keep moist until final set.
After final set, remove rags and apply a ASTM C-309-91 curing compound.

TYPICAL TEST DATA	
Set Time at 70° F (ASTM C-266)	
Initial Set	100 min
Final Set	240 min
Compressive Strength (ASTM C-109)	
1 day	2500 psi
7 days	8050 psi
28 days	9100 psi
Note: the data shown is based on controlled laboratory testing. Reasonable variation from test results shown can be expected. Field and laboratory testing should be controlled on the basis of the desired placing consistency, rather than strictly on water content.	

PACKAGING / YIELD

50 lb. (22.7 kg) multiple plastic lined bag will yield approximately 0.42 cu. ft. in a flowable condition. Also available in 3000lb super stacks. Maximum extension (100% b weight) 50 lbs of 3/8" pea stone with 50 lbs of Pilemedic™ UW Grout will yield approximately 0.70 cu. ft.

SHELF LIFE / STORAGE

Pilemedic™ UW Grout should be stored in a cool, dry interior area. At no time should material be exposed to high moisture, rain or snow conditions. When stored in the original tightly closed container, the shelf life is one year from the date of manufacture.

LIMITATIONS / PRECAUTIONS

Do not exceed the recommended mix water amount. Pilemedic™ UW Grout is a fast setting product, so mixing equipment should be cleaned with water as soon as possible.

Do not allow repairs to freeze until the material has reached a minimum of 1000 psi compressive strength. In adverse temperatures, follow ACI recommendations for hot/cold weather concreting practices. We only use potable water for mixing.
Minimum surface and ambient temperature of 45°F and rising is required at the time of application. For optimum results, condition material to between 65°F and 85°F.

Avoid hazards by following all precautions found in the Material Safety Data Sheet (MSDS) product labels.

KEEP OUT OF REACH OF CHILDREN. FOR INDUSTRIAL USE ONLY. NOT FOR INTERNAL CONSUMPTION.
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The FRP Retrofit Experts

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Product Data Sheet

QuakeBond™ 320LV Low Viscosity Resin

DESCRIPTION
QuakeBond™ 320LV (Low Viscosity Resin) is a two-component, high-strength, low-viscosity structural epoxy. The low viscosity makes this an ideal product for crack injection, gravity feed or patching. It can be used as a liquid binder for sand, aggregate or other mineral fillers to form cost-effective material to fill the annular space around piles when PileMedic™ laminates are used. The resin cures underwater, making it suitable for repair of submerged piles. The high compressive and tensile strength of this epoxy provide structural strength for the pile or pole in repairs using PileMedic™ laminates. QuakeBond™ 320LV can be used in repair of concrete, masonry and wood structures. The resin also provides excellent durability and chemical resistance. The convenient 2:1 volumetric mix ratio is user friendly. QuakeBond™ 320LV is a 100% solids formulation with low toxicity and low odor during cure.

USE
- Filling the annular space created between the PileMedic™ and concrete or timber pile or pole being repaired for both above-water and submerged conditions
- As a binder mixed with sand and small-size aggregates to form a resin-based grout to fill larger annular spaces in repair of piles and poles using PileMedic™
- Filling cracks in concrete by injection or gravity feed
- Crack repairs in masonry, wood and concrete structural members
- A moisture barrier (water-proofing) system in conjunction with PileMedic™ laminates

ADVANTAGES
- High strength, high modulus, low-viscosity structural adhesive.
- Moisture insensitive – it cures under water
- Fully compatible and excellent adhesion to PileMedic™ carbon or glass laminates.
- Convenient easy mix ratio, 2:1 by volume.
- 100% solids, VOC free and Butyl Glycidyl Ether (BGE) free.
- Nearly odor-free.

COVERAGE
Apply as a filler material to fill all cracks and voids in concrete, masonry and timber structures. Application rate varies greatly based on the porosity and the volume of voids present in the structural member being repaired. For wider annular spaces, the epoxy can be mixed with clean silica sand and pea gravel (3/8 inch and under) for improved yield.

PACKAGING
Each of the components is supplied in 5-gallon (19L) containers or 55-gallon (208L) drums, resulting in 15-gallon or 165-gallon kits. Ships DOT non-regulated.

MIXING
Mix 2 parts resin "A" to 1 part hardener "B" by volume into a clean container. Mix thoroughly for 3 minutes using a paddle at low speed (400-600 rpm) to avoid air entrainment. Mix only the quantities that can be used within pot life. REMEMBER -- you will have less working time at higher temperatures. DO NOT THIN; solvents will prevent proper cure. If desired, silica sand and well-graded pea gravel (3/8 inch and under) can be added up to a maximum of 70 pounds sand and gravel per gallon of QuakeBond™ 320LV.

SHELF LIFE
2 years in original, unopened and properly stored containers.

STORAGE CONDITIONS
Store at 55°-100°F (13°-38°C)

CERTIFICATE OF COMPLIANCE
- Material Safety Data Sheet (MSDS) will be supplied upon request and is included with each shipment.
- ASTM C 881 Compliant

APPLICATION
Properly mixed QuakeBond™ 320LV can be used to fill the annular space between PileMedic™ jackets and the pile or pole being repaired. When introduced at the bottom of the annular space, the high density of the resin pushes the entrapped water to the top. The resin can be thickened with clean silica sand and pea gravel (3/8 inch and under) for filling larger annular spaces. All epoxy components shall be preconditioned to a temperature between 65°F (18°C) and 85°F (29°C) prior to the time of mixing.

LIMITATIONS
Minimum application temperature of the epoxy is 45° F (7°C). DO NOT THIN this epoxy with solvents.

CLEANUP
Uncured materials can be removed with approved solvent or warm soapy water. Cured materials can only be removed mechanically.

SAFETY PRECAUTIONS
Avoid breathing of vapors. Forced local exhaust is recommended to effectively minimize exposure. NIOSH approved, organic vapor respirators and forced exhaust are recommended in confined areas, or when conditions may cause high vapor concentrations. Do not weld on, burn or torch any epoxy materials as this will cause release of hazardous vapors. Consult MSDS for detailed information.

EPOXY PROPERTIES:		
Color – Both Parts "A" and "B" are amber liquid		
Viscosity Mixed at 77° F	(ASTM D-2196)	780 cps
Working Time at 77° F (25° C)		20 minutes
Gel Time		30 minutes
Weight (Mixed) lb/gallon		9.21
Density (Mixed) kg/liter		1.11
Tensile Strength	(ASTM D-638)	7,900 psi (54.5 MPa)
Compressive Strength	(ASTM D-695)	11,200 psi (77.2 MPa)
Elongation @ Break	(ASTM D-638)	4.8%
Adhesion to Concrete		>800 psi (5.5 MPa); 100% failure in concrete
Hardness, Shore D	(ASTM D-2240)	86

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