

# Strengthening of Piles and Seawalls with FRP Products

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*President, QuakeWrap, Inc., and  
Centennial Emeritus Professor of Civil Engineering, U. of Arizona*

**Presented at Docks Expo, Nashville TN  
Wednesday Dec. 7, 2022**



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## Presentation Outline

- Introduction to FRP
- PileMedic® for Repair of Piles & Columns
- Sheet Pile Repair (SPiRe®) for Seawalls & Bulkheads
- Form-A-Tube® for Repair of Piles



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- Professor Mo Ehsani, PhD, PE, SE
  - University of Arizona 1982-20010
  - President & CEO of QuakeWrap Inc. 1994-Present
  - 20 Patents on cost-saving repair & strengthening solutions
  - Google my name to learn more 😊
- Watch videos of over 140 projects at:
  - [www.YouTube.com/QuakeWrapInc/videos](http://www.YouTube.com/QuakeWrapInc/videos)



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## How it all started ...

- 1980s: Studying repair of corroded beams and columns
- 1987: Use nonmetallic Carbon or Glass FRP
- But the materials were used by the military & expensive
- 1989: Fall of Berlin Wall & drop in carbon prices
- 1989: Loma Prieta EQ in California & collapse of columns (mag = 6.7)
- Wrap columns with carbon FRP ..... Thus the name QuakeWrap®



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# History of FRP in Different Industries



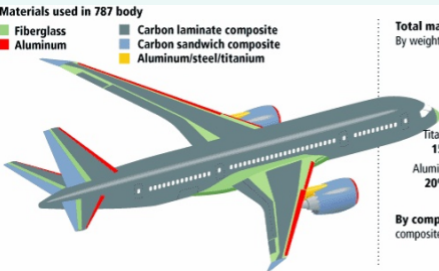
Corvette C1 - 1953



100% FRP Hull

Materials used in 787 body


- Fiberglass
- Aluminum
- Carbon laminate composite
- Carbon sandwich composite
- Aluminum/steel/titanium



Total materials used By weight

Material	Percentage
Composites	50%
Aluminum	20%
Titanium	15%
Steel	10%
Other	5%

By comparison, the 777 uses 12 percent composites and 50 percent aluminum.



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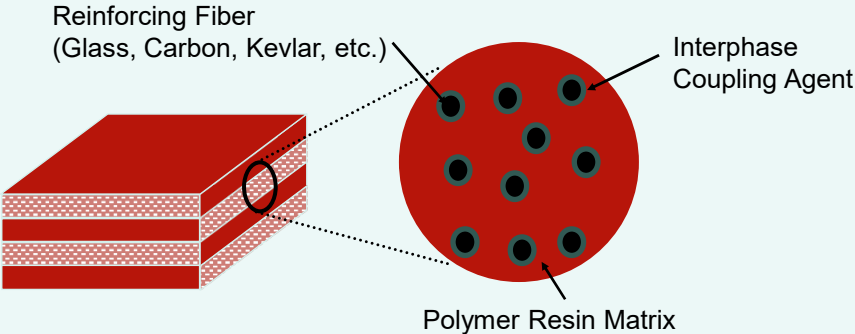
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# Fiber Reinforced Polymer (FRP)

Why is it called FRP?

It is a Polymer (i.e. epoxy, vinyl ester, etc.) that has been reinforced with a Fiber (e.g. carbon, glass, etc.)


FRP does not have the same strength in all directions; these types of materials are called *anisotropic*



Reinforcing Fiber (Glass, Carbon, Kevlar, etc.)

Interphase Coupling Agent

Polymer Resin Matrix



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## FRP Products (1<sup>ST</sup> Generation)

**Fabric**

**Saturating Resin**

**Tack Coat**

**Strips**



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
## Original Concept Demonstration

### *Carbon FRP instead of reinforcing steel*

Video Link: [www.TinyURL.com/Brick-Beam](http://www.TinyURL.com/Brick-Beam)

Watch this video to see how the original concept proposed in 1987 by Prof. Ehsani works.

**DO NOT DISCARD THIS**



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## Blast Protection

Watch Video: [www.tinyurl.com/QW-Blast](http://www.tinyurl.com/QW-Blast)

Watch this video to see how these products can even provide protection against blast loads on buildings!



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## Design with FRP (Steel Equivalency)

- ACI Committee 440
- Steel: No. 7 Gr. 60  
 $T = (0.60)(60) = 36 \text{ kips}$
- Carbon FRP:  
6 inch-wide strip  
 $T = (6'')(6 \text{ k}'') = 36 \text{ kips}$
- One layer of this fabric  $\approx$  No. 7 Gr. 60 placed at 6 in. o.c.
- Note: Little change in weight or thickness
- Much easier to install



Carbon Fabric

Thickness: 0.05 in. (1.3 mm)  
Weight: 0.38 lb/ft<sup>2</sup> (1.83 kg/m<sup>2</sup>)  
 $T = 6000 \text{ lb/in. (1050 N/mm)}$



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## A Unique Organization & Delivery System

QuakeWrap® has developed over 20 patented systems; provides engineering design in all states and field installation by its construction arm (FRP Construction, LLC).

```
graph TD; A[Idea for Product] --> B[Engineering Design]; B --> C[Manufacture In-House]; C --> D[Test: External & In-House]; D --> E[Field Installation]; E --> A;
```



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# PileMedic+®

By QuakeWrap, Inc.



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## What FRP Fabric Cannot Do

- Fabrics are good for flat concrete surfaces.
- What if the column or pile:
  - Has a damaged rough surface
  - Is submerged
  - Has a missing segment
  - Is a Steel H pile

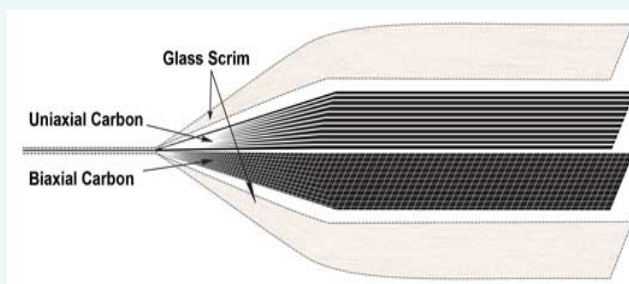


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## Multi-Layered SuperLaminate™ (Multiple US Patents)



- Multi-Axial Reinforcement
- Thickness  $\approx$  0.01 - 0.025 inch
- Tensile Strength  $\approx$  up to 155,000 psi
- Infinite combinations of strength & stiffness can be produced



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## PileMedic® for Encapsulation of Underwater Piles

Watch video: [www.TinyURL.com/PLM-Miami](http://www.TinyURL.com/PLM-Miami)

Watch this video of the first installation of PileMedic® in FL. Note that no coffer dams are needed since the special epoxy cures underwater!





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## PileMedic® Installation videos

These two videos provide great instructions on how PileMedic® is installed.



[www.TinyUrl.com/PLM-Man](http://www.TinyUrl.com/PLM-Man)

[www.TinyUrl.com/PLM-Man2](http://www.TinyUrl.com/PLM-Man2)



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### Elements of PileMedic®

Vertical: #4 @ 3.2 in.  
12 mm @80 mm

Ties: #4 @ 2.8 in.  
12 mm @70 mm

PileMedic® eliminates the need for reinforcement ties.

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### PileMedic® Extensively Tested by

- Texas DOT (Steel H Piles)
- Caltrans (Concrete Piles)
- Nebraska DOR (Timber Piles)
- USACE (Concrete & Timber Piles)
- TEP (Timber Utility Poles)

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# US ACE – Pearl Harbor


Video Link: <https://goo.gl/AUhcJy>

Watch the video of the US Navy testing and training with PileMedic® in various water conditions in Hawaii.



90 piles in Pearl Harbor Feb 2017






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# PileMedic® Kit for the US Military


Following 3 Years of Testing by the USACE



Kit includes:

- 80 ft x 4 ft laminate
- Spacers
- Zip-Ties
- Epoxy cartridges
- Drill mixer
- Disposable supplies
- Installation Manual
- etc.





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Variable Name/Current Value(s):

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003	0.000000
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658,000 Pounds (2930 kN)

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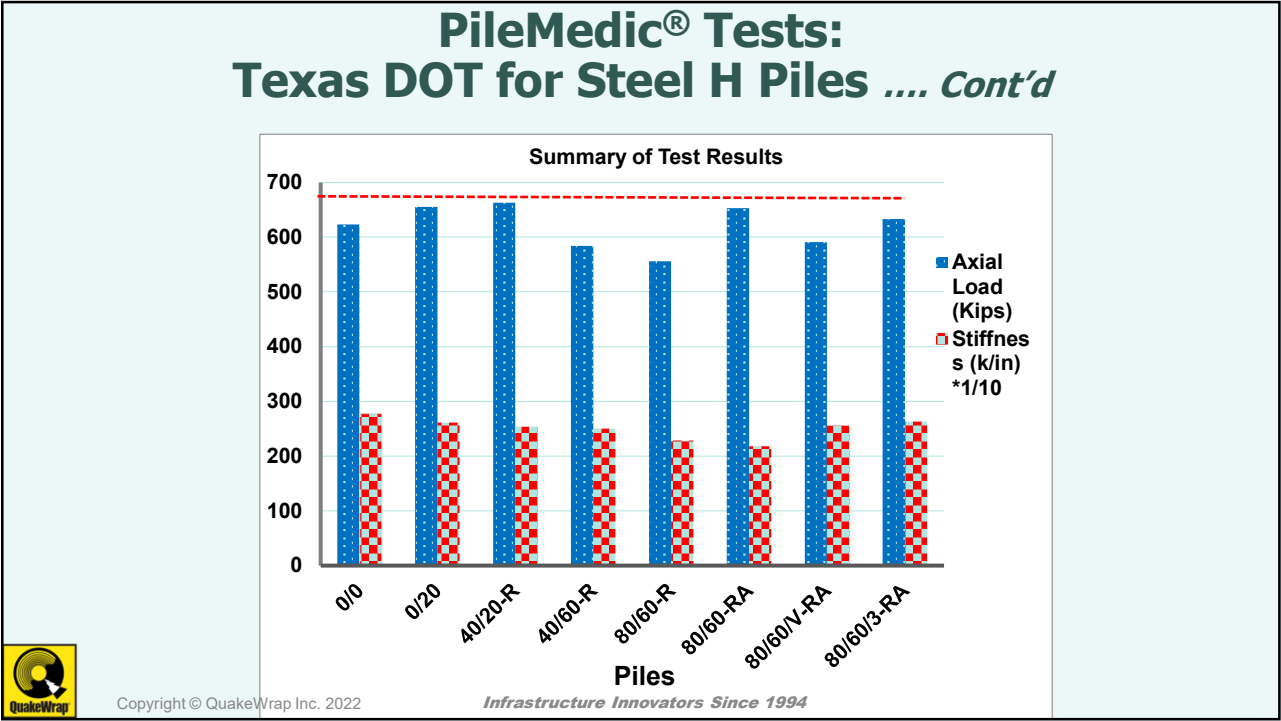
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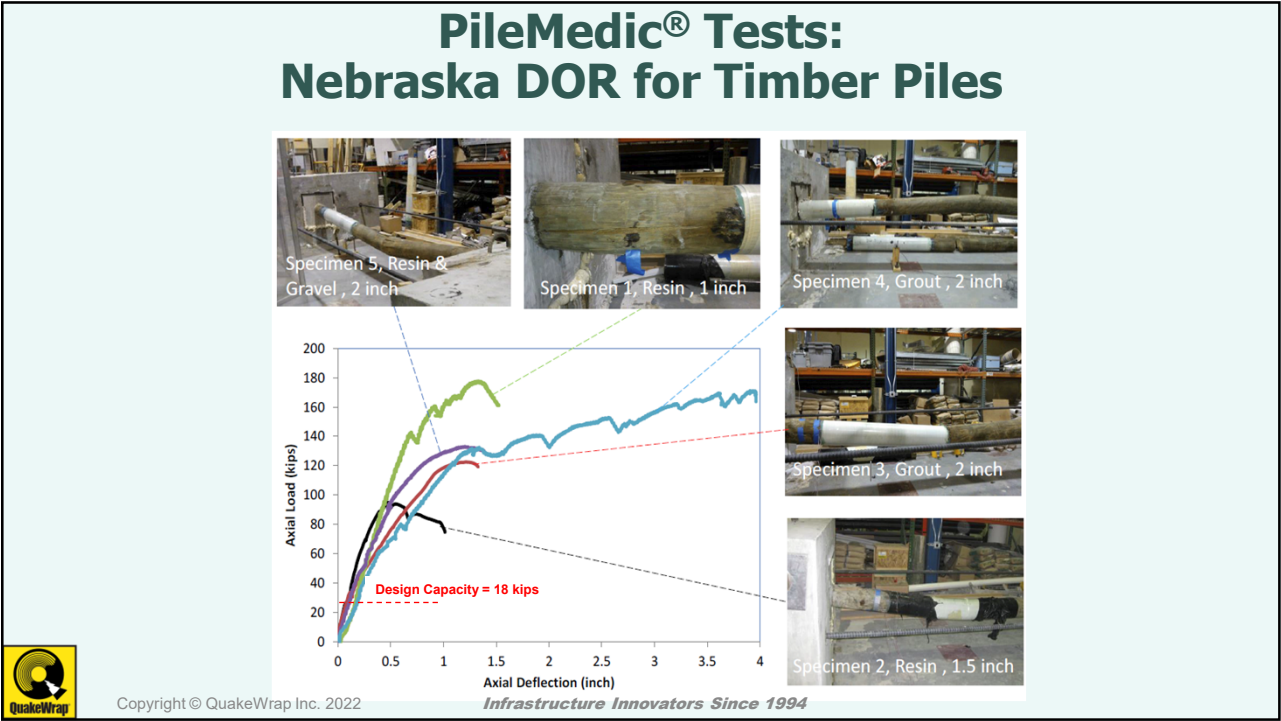
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**658,000  
Pounds  
(2930 kN)**

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## Testing of Timber Utility Pole Repairs

*Tucson Electric Power Tests (2013)*  
watch video: [www.tinyurl.com/T-Pole-Test](http://www.tinyurl.com/T-Pole-Test)



Strengthening of Timber Utility Poles with PileMedic - TEP Tests







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## PileMedic® Tests: US Army Corps of Engineers Laboratories

- Rapid Repair
- Easy for Soldiers
- Fit All Shapes & Sizes
- Restore Strength



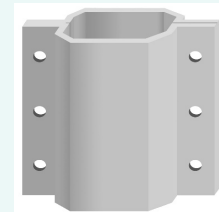


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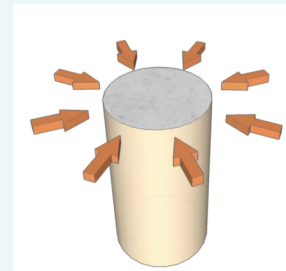
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## Advantages of PileMedic®

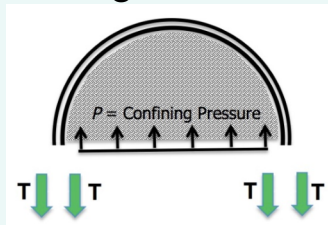
- One size fits all shapes & sizes
- Easy shipment & storage
- Seamless shell stops moisture ingress
- Design to provide any confining pressure (much higher than 300 psi)



Conventional



PileMedic®



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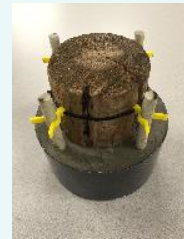
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## PileMedic® Installation Steps

watch videos: [www.tinyurl.com/PLM-Man](http://www.tinyurl.com/PLM-Man)  
and [www.tinyurl.com/PLM-Man1](http://www.tinyurl.com/PLM-Man1)

1. Install spacers to define the annular space
2. Cut the laminate to desired length (Min. 2 wraps + 8 inch)
3. Apply tack coat to second half of laminate
4. Wrap laminate around pile to create a shell of desired diameter
5. Lower the shell into water
6. Repeat steps 3, 4, & 5
7. Seal the bottom
8. Fill the annular space with grout



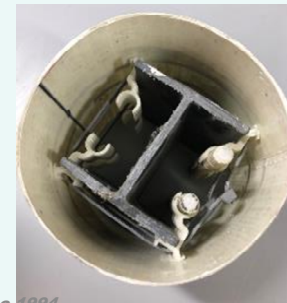
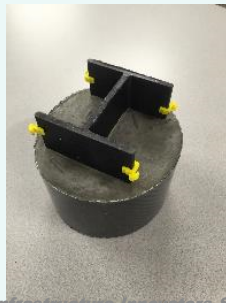
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## Spacers for PileMedic®



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## Sample Pile Repair Project Videos

Watch videos of many completed projects on our YouTube channel:

- 550 Timber Piles (Perdue): [www.tinyurl.com/PLM-Perdue](http://www.tinyurl.com/PLM-Perdue)
- 40 Concrete Piles affected by ASR in Australia: [www.tinyurl.com/ASR-Pile](http://www.tinyurl.com/ASR-Pile)
- Concrete Piles damaged by ship impact in Vietnam: [www.tinyurl.com/Viet-Pile](http://www.tinyurl.com/Viet-Pile)



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### Repair of Pipe Support Piles (SE Asia)

- Piles supporting oil and gas pipes are severely corroded
- Strength can be fully restored with PipeMedic® and ShearWrap



9 Apr 2020 17:03:46  
Jalan Raya Cirebon - Indramayu  
Karangreja  
Suranenggala  
Cirebon  
Jawa Barat



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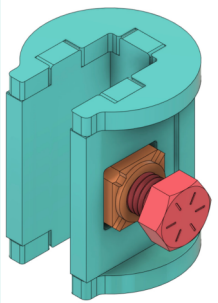
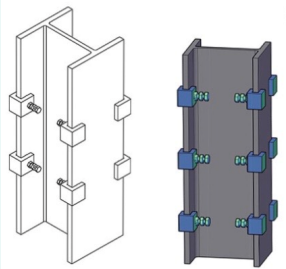
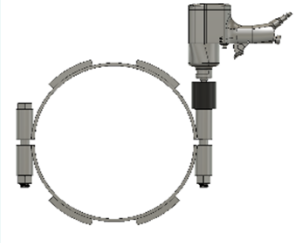

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### ShearWrap™ & ShearClamp™ for Steel Piles

**US Patent #11,286,632**

Watch this video of how steel piles can be repaired using the patented ShearWrap and ShearClamp:


[www.tinyurl.com/ShearWrap](http://www.tinyurl.com/ShearWrap)



Proprietary ShearWrap™

ShearClamp

ShearClamp



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## Other Applications of PileMedic®

- Corroded columns in industrial plants & mines
- Cell phone towers









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## Port Rail Bridge, Adelaide (Australia)

- 9 piers x 16 piles = 144 piles
- Corrosion damage
- Strengthen for seismic load + new rail loadings
- PileMedic® jackets
- Sensitive dolphin sanctuary





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Port Rail Bridge, Adelaide





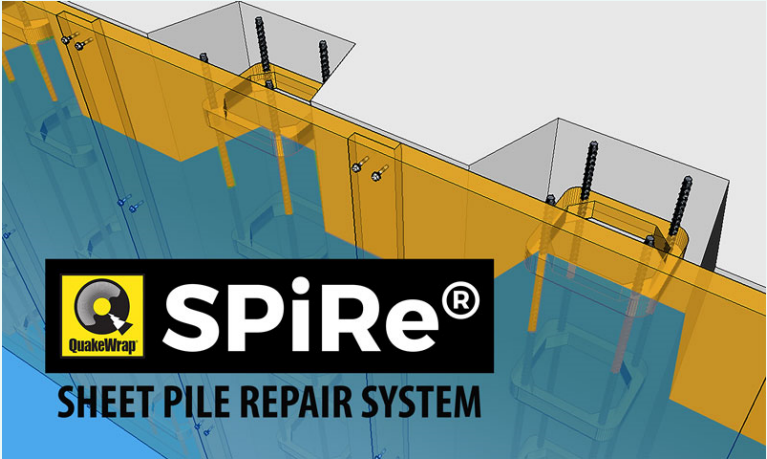
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Bulkhead and Sheet Pile Repair





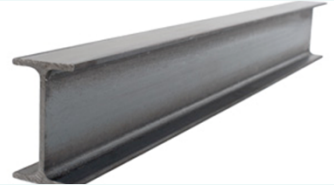


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## Composite Sandwich Concept



**Steel I-beam**

			
RELATIVE STIFFNESS	1	7	37
WEIGHT (Pounds/ft²)	0.910	0.978	0.994



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## Repair of Sheet Piles with SPiRe®

**West Rock, Chesapeake VA**  
**Length = 926-ft    Height =4-14 ft**  
Watch Video at <https://tinyurl.com/SPiRe-WestRock>





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## Repair of Sheet Piles with SPiRe®

### West Rock, Chesapeake VA






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## Repair of Sheet Piles with SPiRe®

### West Rock, Chesapeake VA




1. J Bolts





2. FRP Reinforcing Bars

3. SPiRe® Panels



4. Strong backs before grouting





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## Repair of Sheet Piles with SPiRe®

### West Rock, Chesapeake VA





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## Repair of Sheet Piles with SPiRe®

### West Rock, Chesapeake VA

Watch Video at <https://tinyurl.com/SPiRe-WestRock>





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## Repair of Sheet Piles with SPiRe®

### West Rock, Chesapeake VA





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## Repair of Sheet Piles with SPiRe®

### West Rock, Chesapeake VA





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# Repair of Sheet Piles with SPiRe®

## Port of West Saint Mary, LA

Watch video: [www.tinyurl.com/SPiRe-StMary](http://www.tinyurl.com/SPiRe-StMary)



REPAIRS TO A BULKHEAD  
EXPERIENCING CORROSION



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# Repair of Sheet Piles with SPiRe®

## US Coast Guard, Tongue Point, Astoria OR

Watch video: [www.tinyurl.com/tinyurl.com/SPiRe-USCG](http://www.tinyurl.com/tinyurl.com/SPiRe-USCG)



REPAIRS AND REHABS CORRODED  
STEEL SHEET PILES AND BULKHEADS



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## Repair of Sheet Piles with SPiRe®

*Bair Island, Redwood City, CA*

**Panels can be customized to match the existing sheet pile profile!**





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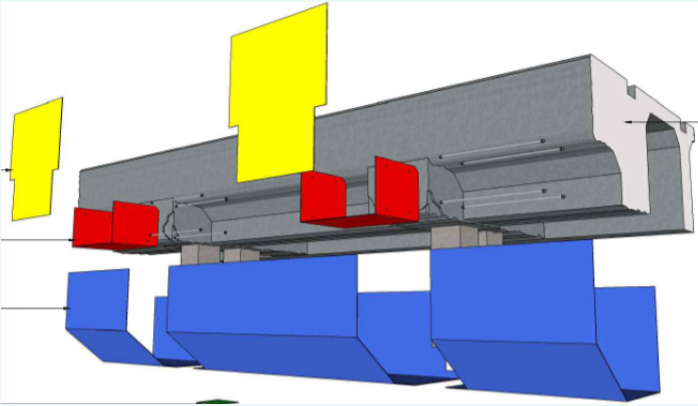
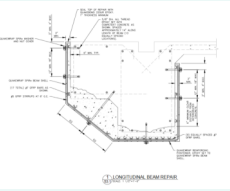


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## Deck Beam & Pier Repairs using SPiRe®

*Port of Galveston, TX 2022*

**video: [www.tinyurl.com/SPiRe-Pier](http://www.tinyurl.com/SPiRe-Pier)**








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# Burnett River Rail Bridge

## Queensland Rail, Bundaberg, QLD May 2019





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# Burnett River Rail Bridge

## Queensland Rail, Bundaberg, QLD May 2019





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Form-A-Tube™

Every strips adds 2-inch to diameter



This pallet of 3000 ft can make  
62 tubes 12" dia X 8' tall or  
42 tubes 18" dia X 8' tall



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**OR**



2. Ribbed surface inside for one-time use as stay-in-place form for repair of piles and columns



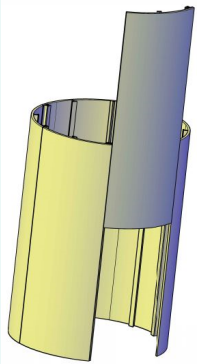
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# Form-A-Tube®

- Make jackets of any shape (even non-circular) on the spot.
- No advanced measurement is needed!



Form-A-Tube™





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# Form-A-Tube®

## Watch video of Pile Repair in Houma, LA:

[www.tinyurl.com/FAT-LA1](http://www.tinyurl.com/FAT-LA1)





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# MoTubes™

Watch video at: [www.tinyurl.com/MoTubes](http://www.tinyurl.com/MoTubes)

- Laminates are 9-ft wide x 500 ft long
- Very strong
- Can build a tube of any shape and size
- Smooth surface (no spiral marks)
- Reusable many times
- For new construction or repair





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# Thank you for your Attention!


Questions?

Email: [Mo@QuakeWrap.com](mailto:Mo@QuakeWrap.com)


Mobile: (520)250-7020

Watch over 140 videos of our projects on:


[www.YouTube.com/QuakeWrapInc/videos](http://www.YouTube.com/QuakeWrapInc/videos)




QuakeWrap.com



PileMedic.com



PipeMedic.com



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