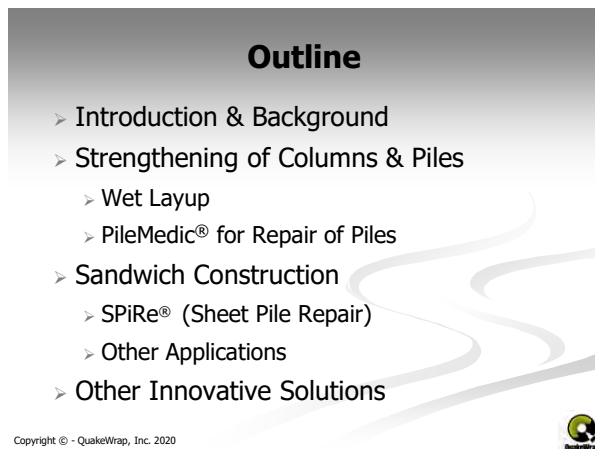




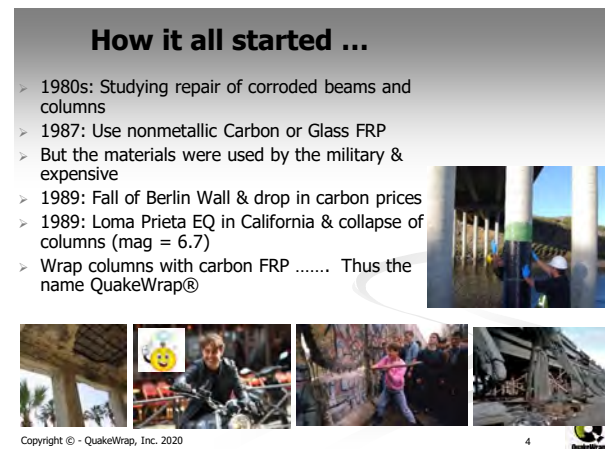
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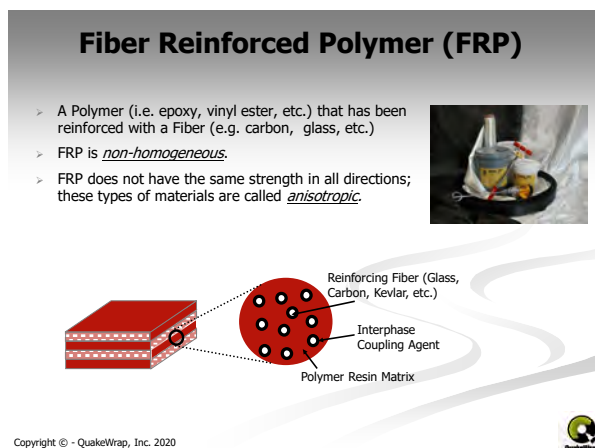
2



3



4



5



6

### Design with FRP

- 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.  
[20mm bar spaced at 120mm]

Note: Little change in weight or thickness  
Much easier to install!

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

Carbon Fabric

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7

### Sample Projects/Applications

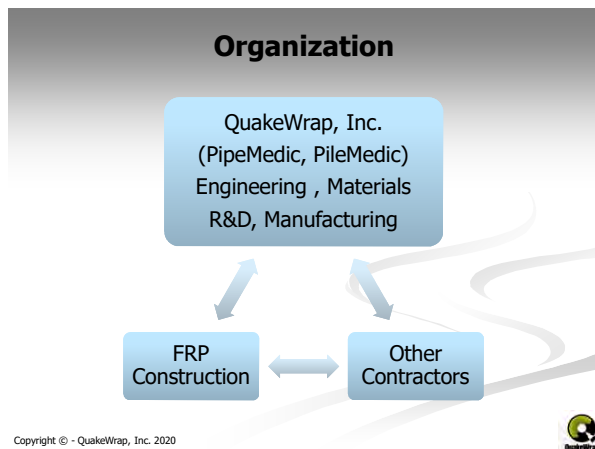
Testing + R&D      Condo, FL      Penstock, Costa Rica

Bridge, NM      Settling Tank, MX      UN Lebanon

High Rise, AK      Culvert, Cairns, Australia      Kazakhstan

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8



9

### Advantages of FRP

- High Tensile Strength (*3-5 times stronger than Steel*)
- Low Weight (*no foundation adjustments required*)
- Corrosion Resistance & Protection
- Chemical Protection
- Waterproof
- Speed of Construction
- Versatility
- Installation requires no major/heavy lifting equipment
- Odorless & Non-Toxic (QuakeWrap Products)
- NSF-61 Certified for pipes  $\geq 8$  inches
- Minimal Investment

NSF  
Notified Certification Body

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10

### Outline

- Introduction & Background
- Strengthening of Columns & Piles
  - Wet Layup
  - PileMedic® for Repair of Piles
- Sandwich Construction
  - SPiRe® (Sheet Pile Repair)
  - Other Applications
- Other Innovative Solutions

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11

### Failure of Pre-1970s Columns

12 in. (300 mm)

Poor Tie Detail

Buckled Bar

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12

## Failure of R/C Columns

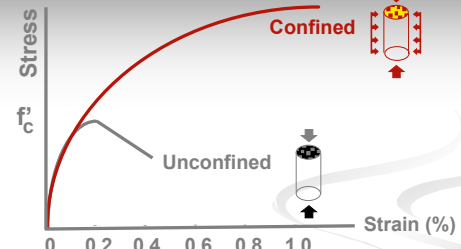


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13

## Concrete Confined with QuakeWrap®



Confinement:  
a. Increases compressive strength  
b. Increases ductility (or strain at failure)

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14

## Retrofit of R/C Columns with Steel Jackets

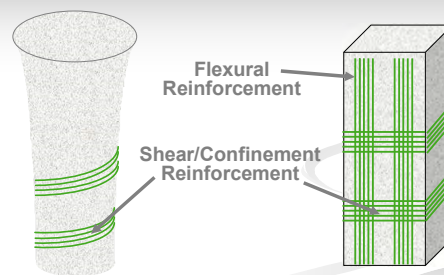


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15

## Retrofit of Columns with FRP



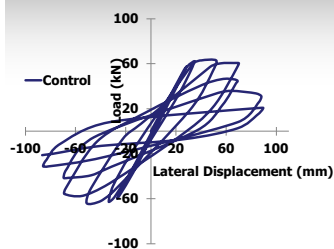
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16

## Control Column Specimen

(US National Science Foundation Project 1992-94)

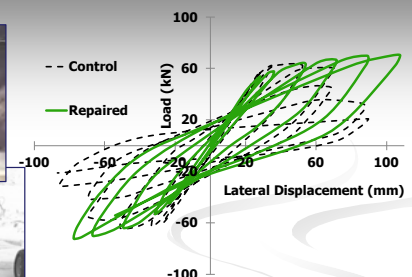


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17

## Control Specimen Repaired & Re-Tested



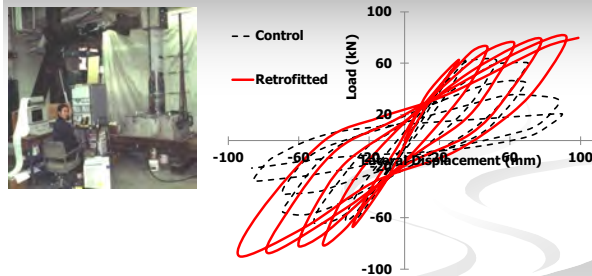
Note how confinement improves the behavior of this column that had already failed!

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18

## Retrofitted Companion Specimen



Confinement also improved the behavior of this undamaged column that was retrofitted before testing.

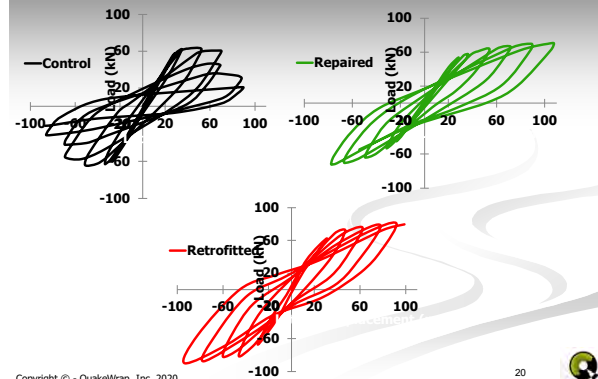
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19

## Comparison of Column Specimens



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20



20

## Limitations of Wet Layup

The wet layup system that we introduced in the early 1990s has several problems:

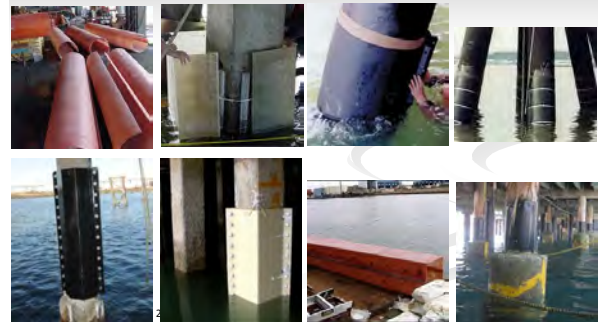
1. Surface of column must be clean and smooth
2. They can only be wrapped on convex surfaces; (not applicable to repair of steel H-piles or timber piles)
3. Can not be wrapped under water

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21

## Pile Jacket Systems Available to Date



22

## Limitations of Conventional Jackets



Problems with Current Technology:

- Special order to desired size; delays & possibility of wrong size
- Bulky to transport & store onsite
- Seam allows moisture to get in & corrosion to continue
- No confining pressure

The shortcomings of these jackets and wet layup FRP led to the invention of PileMedic®

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23

## Outline

- Introduction & Background
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  - PileMedic® for Repair of Piles
- Sandwich Construction
  - SPiRe® (Sheet Pile Repair)
  - Other Applications
- Other Innovative Solutions

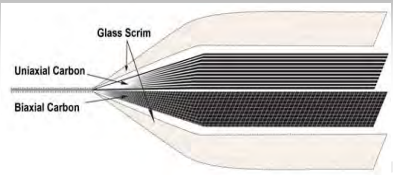

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24



### PileMedic® (3 US Patents)

- Multi-Axial Reinforcement
- Thickness  $\approx 0.01 - 0.025$  inch (0.25-0.67mm)
- Tensile Strength  $\approx$  up to 155,000 psi (1030 MPa)
- Infinite combinations of strength & stiffness can be produced

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25

### PileMedic® for Encapsulation of Underwater Piles



PileMedic®

26

### Advantages of PileMedic®

- The Strongest Pile Jacket On The Market (28 – 155 ksi)
- One Size Fits All
- Seamless Shell Prevents Future Corrosion; *recall that oxygen is the fuel to the corrosion process*
- Eliminates Ties (or Hoop Reinforcement)
- Provides Significant Confinement Pressure
- Enhances Axial, Flexural and Shear Strength
- Non-Corroding
- No Heavy Equipment Required for Installation
- Very Thin and Installs in Tight Spaces
- Fast Repair – Full capacity in 24
- Faster Installation than other Jackets; Saves Dive Time


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27

### Design Example

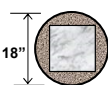
Design Data:

- 12x12 inch pile
- $f'_c = 4,000$  psi
- Ignore reinforcing steel
- $P_n = 0.85 f'_c (12 \times 12) = 490$  kips

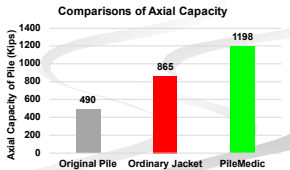


Encapsulated Pile:

- 18 inch diameter
- Fill with 4,000 psi grout



#### Comparisons of Axial Capacity



System	Axial Capacity of Pile (Kips)
Original Pile	490
Ordinary Jacket	865
PileMedic	1198

Same pile encapsulated in PileMedic®,  
 $f'_{cc} = 5,548$  psi >  $P_n = 1198$  kips 38% Increase in Capacity!

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28

### Research on PileMedic®

- *No Pile Jacket system has been evaluated as extensively as PileMedic®*
- Caltrans -- Concrete Piles
- Texas DOT -- Steel H Piles
- Tucson Electric Power -- Timber Utility Poles
- Nebraska DOR -- Timber Piles
- US Army Corps of Engineers -- Timber Piles

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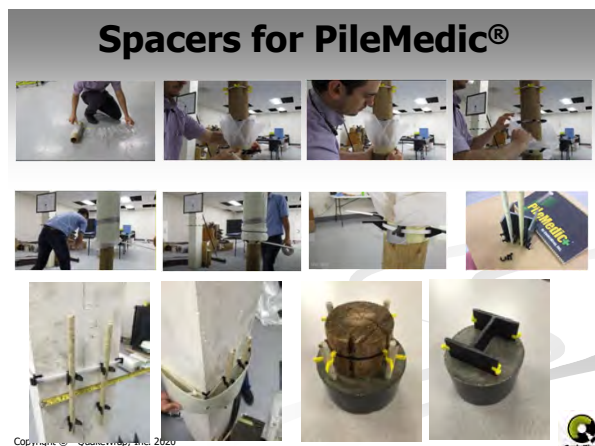
### US Army Corps of Engineers

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

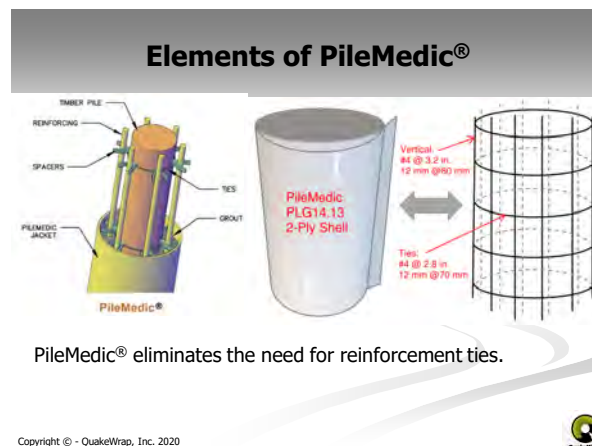


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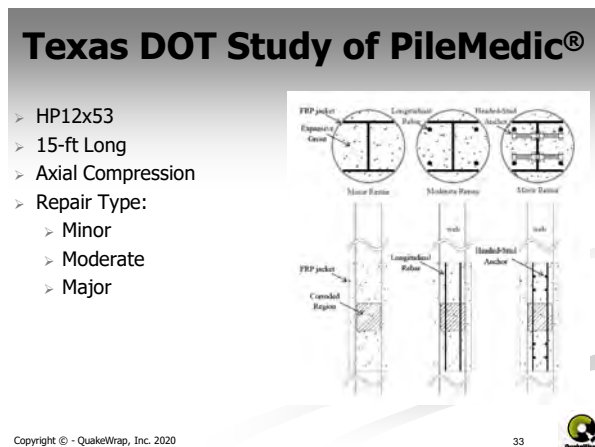
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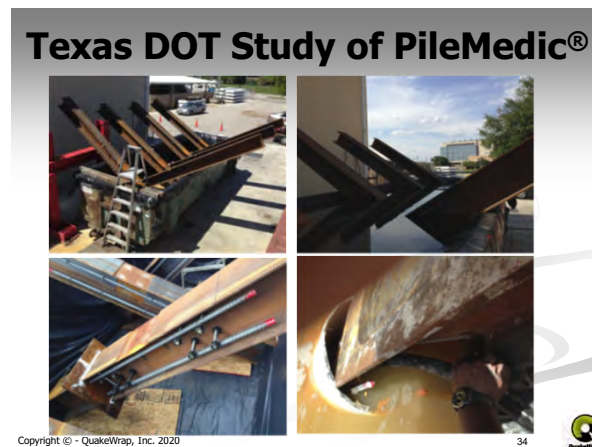
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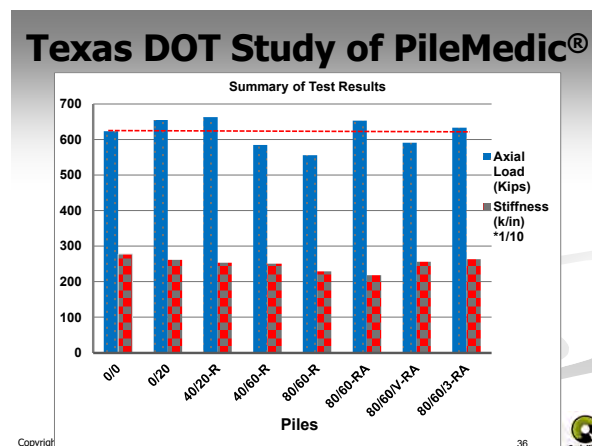
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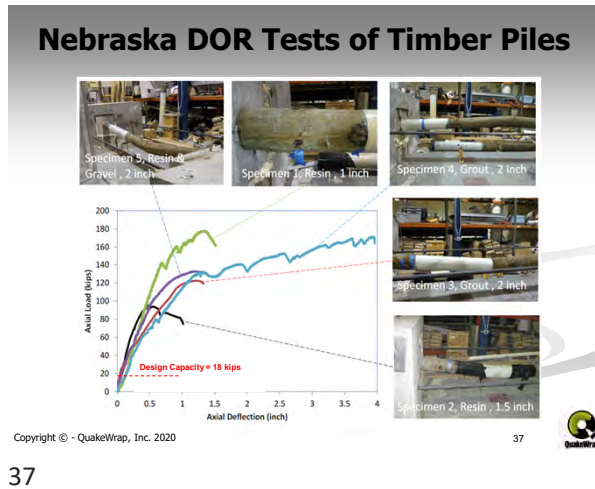
34



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36



37

### Sample Recent Pile Repair Projects

- Perdue Agriculture – 500 Timber Piles
- Pearl Harbor – 90 Concrete Piles
- Port of Seattle – 95 Hexagonal Concrete Piles
- Nigerian Petroleum Corp – 120 Steel Piles
- Odfjell Terminal – 100 Steel Piles
- Indiana DOT Bridge – 256 Steel Piles
- Port of San Francisco – Seismic Retrofit of Concrete Piles (ongoing)

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### Perdue Agriculture

Chesapeake, VA 2016

Creating a new pile even when the original pile is completely gone.

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### Todds Bridge Australia

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### Lawnville Road Bridge Australia

Notice small gap Between wall and column

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### Nigerian National Petroleum Corporation

120 Steel piles  
40 in. (1m) diameter  
40 ft (12 m) tall

Two noteworthy features:

1. Most of the repair was done without divers
2. ....

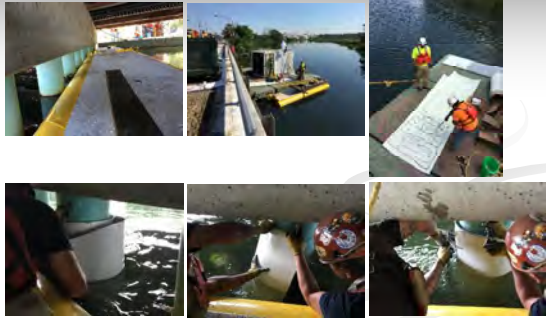
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### Kennedy Ave. Bridge, IN

Watch Video at <https://tinyurl.com/tg3jgrg>



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### Steel Bridge Piling


Watch Video at <https://tinyurl.com/yx84ymz8>



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### Repair of Corroded Bridge Piles (St. Louis, MO)


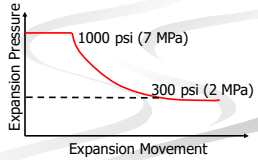


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### Alkali-Silica Reaction (ASR)

- ASR is a swelling reaction that occurs over time in some concretes
- Results in large expansive pressures
- Encapsulation to:
  - Seal Cracks
  - Inhibit Chloride, Water & Oxygen Ingress
  - Resist Internal Pressure by Confinement to Limit ASR

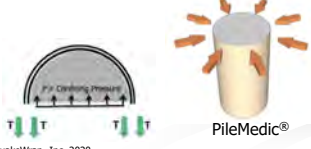





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### Alkali-Silica Reaction (ASR)

- Over 15 years Transport & Main Roads (TMR), QLD tried a couple of promising FRP Jackets
- The jacket failed at the fins
- Project was put on hold
- Successfully repaired in 2016 using PileMedic®

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### Barron River Bridge

Watch Video at <https://tinyurl.com/ryeyc6y>



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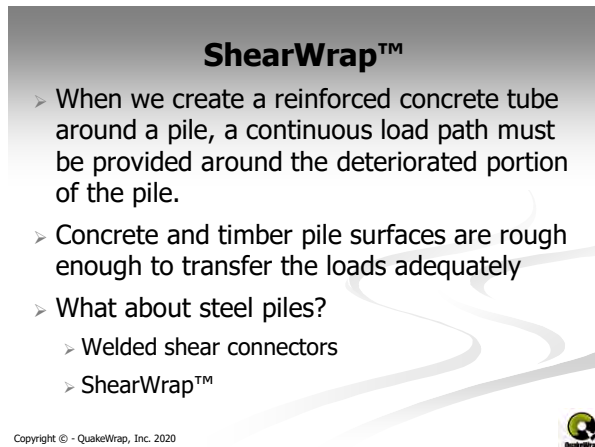




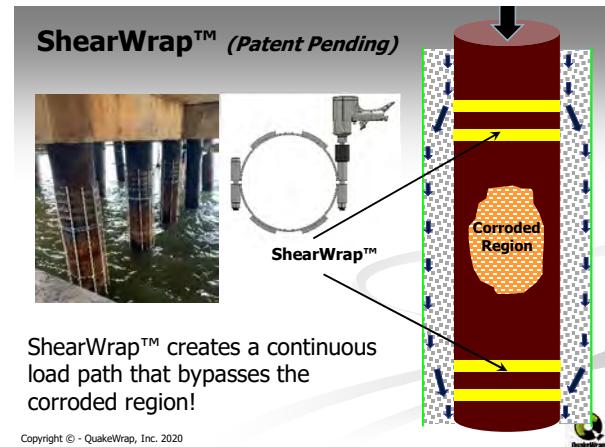
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54

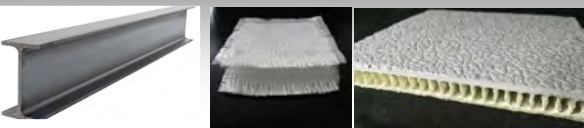
### Outline

- Introduction & Background
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- Other Innovative Solutions

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### Composite Sandwich Concept



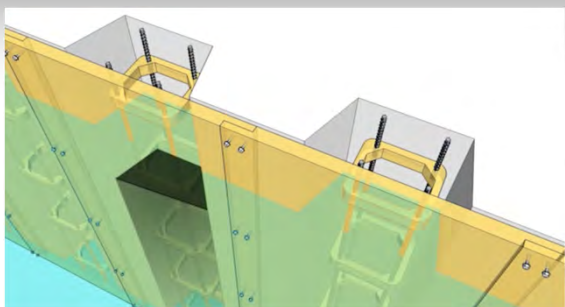
	T	2T	4T
RELATIVE STIFFNESS	1	7	37
WEIGHT (Pounds/ft²)	0.910	0.978	0.994

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### Sheet Pile Repair System (SPiRe®)

Video Link: <https://tinyurl.com/y8kpaz48>



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### Repair of Sheet Piles with SPiRe®

Port of West St. Mary, LA

150-ft long  
7-ft tall




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### Repair of Sheet Piles with SPiRe®

Port of West St. Mary, LA



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### Repair of Sheet Piles with SPiRe®

Port of West St. Mary, LA



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61



62



63



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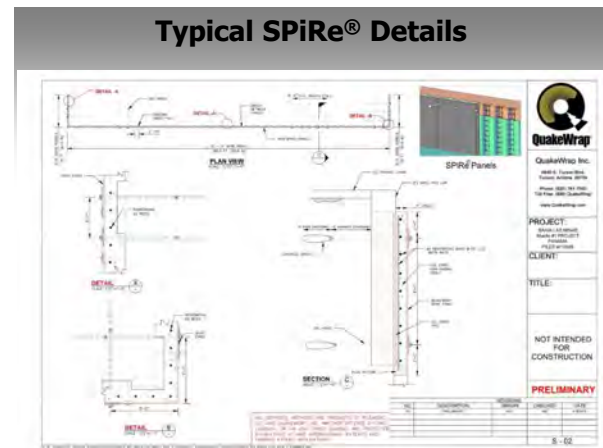
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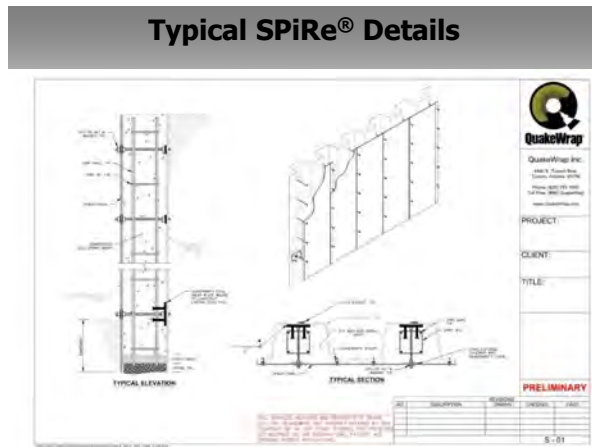
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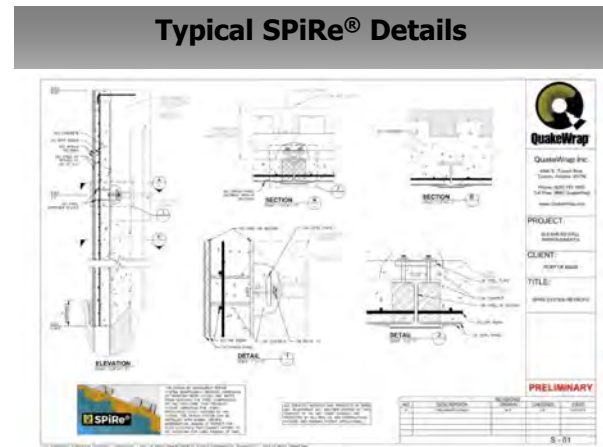
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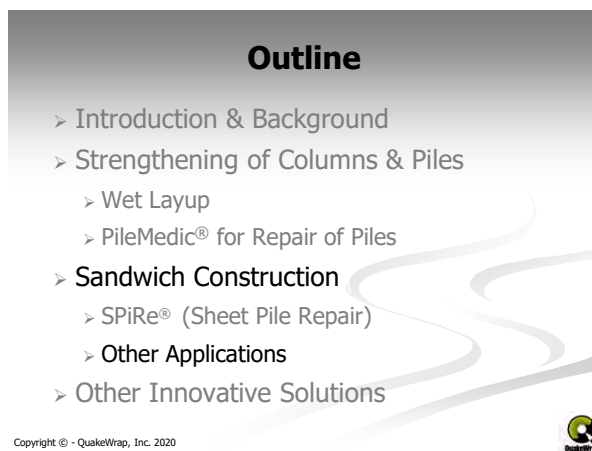
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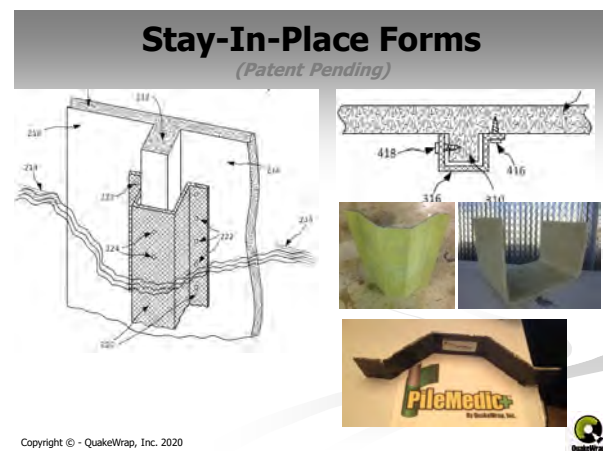
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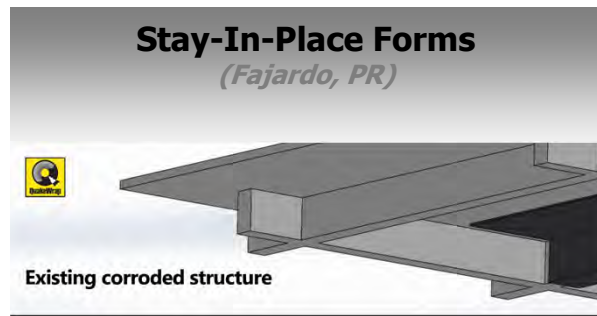
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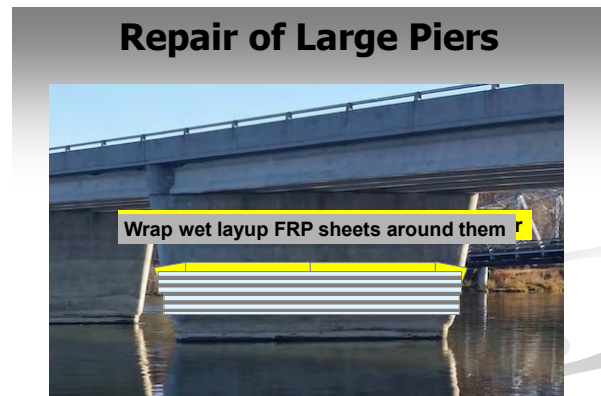


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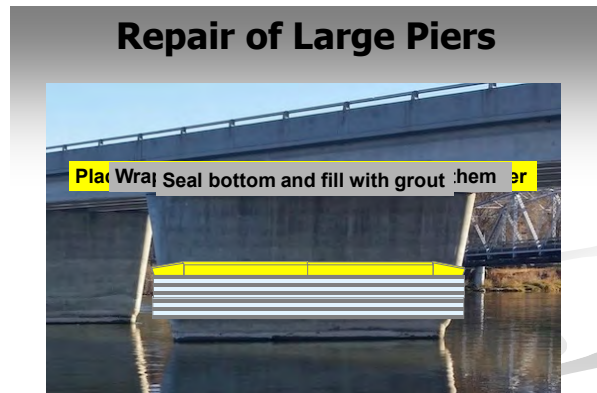
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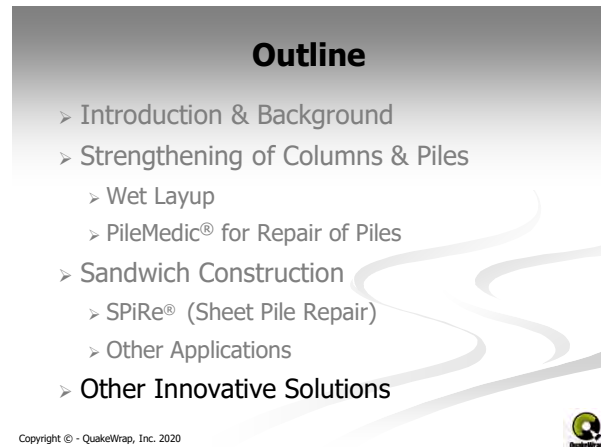
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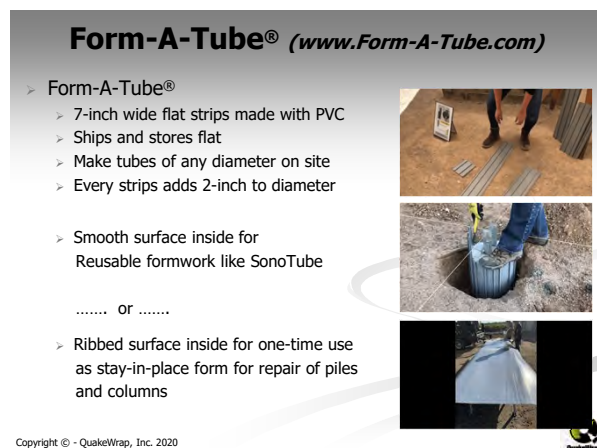
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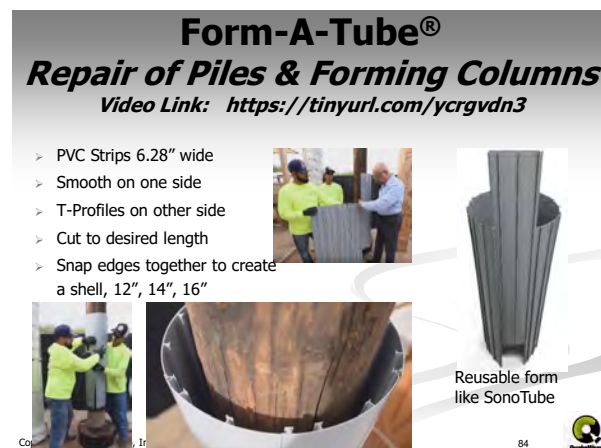
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### Contents of Upcoming Webinar

*(to be offered in the next couple weeks)*

- Material properties
  - Test Data
- Specifications
  - PileMedic
  - SPiRe
  - Grout
- Design Examples
- PileMedic Construction Documents
- SPiRe Construction Documents
- Benefits of each system

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85

### Thank You!

Mo Ehsani  
[mo@quakewrap.com](mailto:mo@quakewrap.com)  
[www.PileMedic.com](http://www.PileMedic.com)

Watch over 120 videos of :  
[YouTube.com/QuakeWrapInc](https://www.youtube.com/QuakeWrapInc)

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86