PileMedic™ for Repair and Strengthening of Columns & Underwater Piles

Mo Ehsani, Ph.D., P.E., S.E.
President, QuakeWrap, Inc., and Professor Emeritus of Civil Engineering, Univ. of Arizona

November 2010

How can we fix these piers in a day while maintaining traffic?

Why Repair/Strengthen?
- Carry larger loads
- Correct construction errors/omissions
- Replace deteriorated materials (steel, concrete, etc.)
- Accidental damage (e.g. truck hitting a girder)
- Comply with new code requirements (e.g. ties for confining R/C columns)
- Blast Protection

History & Background of FRP

FRP Products

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
FRP Version 1.0  Introduced March 1990

History of FRP in Repair & Retrofit

- 1988-89  Beams
- 1990     Columns
- 1993-94  Masonry Walls
- 1997-98  PCCP (Large Dia. Pipes)
- 2004-05  Blast Mitigation
- 2009-10  SuperLaminate

Original Concept Demonstration

Blast Protection

Fort Bragg, N.C.

Wet Layup Process: Saturation of Fabric
Sample QuakeWrap® Projects

Advantages of FRP

- High Tensile Strength (3-5 times stronger than Steel)
- Low Weight (no foundation adjustments required)
- Anisotropic (strength depends on fiber orientation)
- Corrosion Resistance & Acid Protection
- Waterproof
- Excellent Fatigue Behavior
- Speed of Construction
- Versatility
- Odorless & Non-Toxic (QuakeWrap Products)
- Low Cost

Applications of FRP

- Tension Reinforcement -- recall that shear is resisted as diagonal tension
- Confinement
- Water & Chemical Resistance Barrier
- Corrosion Protection through Closure Against Oxygen Penetration – recall that \(O_2\) is the fuel for corrosion process

R/C Columns

Failure of R/C Columns

Concrete Confined with QuakeWrap™
Retrofit of R/C Columns with Steel Jackets

Southern California

Retrofit of Columns with QuakeWrap™

Flexural Reinforcement
Shear/Confinement Reinforcement

Testing of Control Column Specimen

Control Specimen Repaired & Re-Tested

Testing of Retrofitted Companion Specimen

Comparison of Column Specimens

Control: Repaired & Re-Tested
Retrofitted Companion
Corroded Bridge Column
Indiana Project B-28198

Oklahoma City Project IM-40-4(354)151
3-ft Diameter x 35-ft Columns

Corroded Bridge Column
Indiana Project B-28198

Oklahoma City Project IM-40-4(354)151
3-ft Diameter x 35-ft Columns

History of FRP in Repair & Retrofit

- 1988-89 Beams
- 1990 Columns
- 1993-94 Masonry Walls
- 1997-98 PCCP (Large Dia. Pipes)
- 2004-05 Blast Mitigation
- 2009-10 SuperLaminate

Sandwich Construction of PipeMedic™
Laminates (Patent Pending)

- Multi-Axial Reinforcement
- Thickness ≈ 0.01 - 0.025 inch
- Tensile Strength ≈ up to 155,000 psi
- Infinite combinations of strength & stiffness can be produced
- ISO 9000 Certified
Rewriting the story 20 years later

FRP Version 2.0

Fiber Composite Plates Can Strengthen Beams

Advantages of SuperLaminates

- Laminates manufactured in plant
- Significantly reduces construction time
- Improves quality; stronger than wet layup
- Material properties known in advance
- Less dependent on experience of field crew
- Local contractors can be easily trained/certified
- Offers solutions which are impossible with wet layup

Confinement of Square Columns with SuperLaminates™

- Structural Shell
- No Finished Surface Required
- Circular or Square Columns

Retrofit of Steel Columns in existing frame

- Wrap laminate in a cylindrical shape around column
- Secure the top end
- Fill annular space with concrete or grout
- Can construct a composite steel-concrete column
- Increase axial & buckling load for column

Concrete Confined with PileMedic™

- Unconfined or cast in a jacket with seams
- Confined in PileMedic™

Effect of Confining Pressure on Concrete Strength

Assume:
- concrete cylinder with 100 in² of area
- Compressive strength of concrete ($f'_c$) = 5000 psi
- Strength of cylinder = 5000 x 100 = 500,000 pounds (or 500 kips)

Now assume cylinder is confined with PileMedic™:
- Confining pressure = 800 psi
- $f''_c = 5000 + (4.1 \times 800) = 8280$ psi
- Strength of cylinder = 8280 x 100 = 828 kips

The 328 kips gain in strength is due to confinement effect!
Repair of Corrosion-Damaged Steel Columns

Repair of Corroded Bridge Piles

Current Pile Repair System

PileMedic™ for Encapsulation of Underwater Piles … The Jacket that Fits All!

Conventional vs. PileMedic™ Jacket

Pile Jacket Systems Available to Date
Comparison of Tensile Strength with Conventional Jackets

Design Example

Advantages of Repair Using PileMedic™

- 3-4 times stronger than steel
- No weak seams along the sides
- Provides structural confinement
- Increases axial capacity beyond original strength
- Does not corrode
- No metallic bolts or straps
- Grout can be pressurized to fill all voids and cracks
- No custom manufacturing – one size fits all
- Wraps directly on pile > Small annular space
- Available in carbon or glass
- Aesthetically pleasing
- Limited use or no need for costly divers

Repair of Underwater Piles

Utility Pole Repair

Pressurized Injection of Resin into Wooden Utility Pole

The resin fills all crevices & cracks!!
Advantages of Repair of Utility Poles with PileMedic™

- Fills all voids & crevices in wood
- Strengthens pole beyond original capacity
- Maintains the shape of pole
- Prevents against future decay of wood
- Easily installed by utility company crew
- Ideal for strengthening or emergency repairs
- Green Technology

Back to the bridge piers....

Green Sustainable Technology

- Trenchless (No excavation)
  - A 24-inch (600 mm) access is sufficient
- Non-Toxic & No VOC Chemicals
- Light-Weight Materials > Easy Shipping
- Fast Construction w/ Small Crew

Thank you for your Attention!

Questions?

www.QuakeWrap.com

Email: Mo@QuakeWrap.com
Toll Free: (866) QuakeWrap[782-5397]