

The Latest Innovation in Pipe & Culvert Repair Using Carbon FRP

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Outline

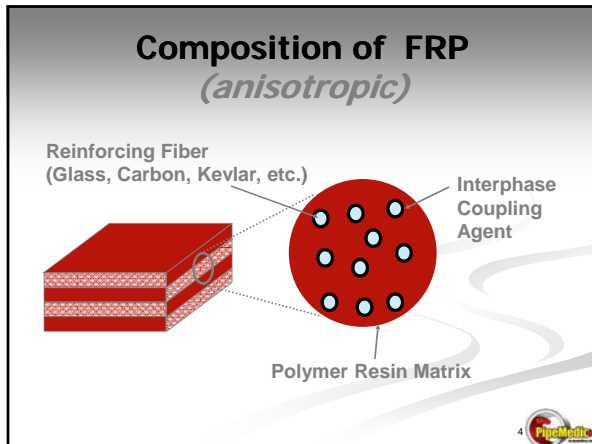
- ❑ What are FRPs?
- ❑ History & Background of FRP
- ❑ Pipe Types & Problems
- ❑ Repair of Pipes with FRP
 - ❑ Large Diameter Pipes
 - Wet Lay-up
 - Pre-Cured Laminates
 - ❑ Repair of Small Diameter Pipes
 - Pre-Cured Laminates
- ❑ Q & A

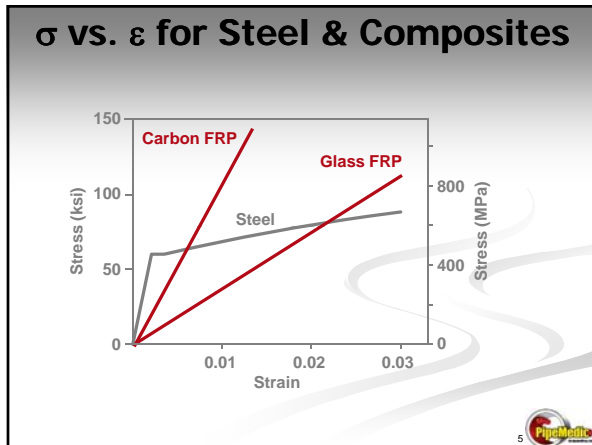


What is Fiber Reinforced Polymer (FRP)



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- ### Advantages of QuakeWrap®
- 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
 - Excellent Fatigue Behavior
 - Speed of Construction
 - Versatility
 - Odorless
 - Non-Toxic
 - Low Cost
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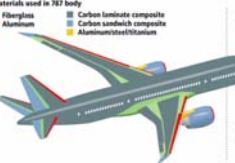
History & Background of FRP



Corvette C1 - 1953



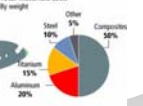
100% FRP Hull




Materials used in 787 body

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

Total materials used by weight



By comparison, the 777 uses 12 percent composites and 52 percent aluminum.



The First Paper on FRP ...



CONCRETE INTERNATIONAL
Design & Construction
March 1990 Vol. 12 No. 3

Repair & Rehabilitation

Epoxy-bonded glass fiber-reinforced plastic plates may provide a corrosion-free solution to increasing the load-carrying capacities of concrete bridges.

Fiber Composite Plates Can Strengthen Beams

By Robert W. Brinson, Ph.D., and Robert W. Brinson, Ph.D.

The addition of stress-bonded steel plates to the tension face of concrete beams has been used to increase their load-carrying capacity. This method is attractive for repair and strengthening of existing concrete beams with steel plates. However, the use of steel plates is limited by the weight and corrosion of the steel. The use of fiber-reinforced plastic (FRP) plates is a promising alternative. FRP plates are lightweight, corrosion-free, and have a high strength-to-weight ratio. This paper discusses the design and construction of FRP plates for the repair and strengthening of concrete beams. The advantages of FRP plates over steel plates are discussed. The design and construction of FRP plates are discussed. The advantages of FRP plates over steel plates are discussed. The design and construction of FRP plates are discussed.



Fig. 1 - Beam cross section

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Blast Test: Specimen Construction

Thickness: 8 inches (200 mm)



Blast Test: Loading & Results

Charge: 200 pounds (91 kg) TNT
Height: 3 feet (0.9 m) above ground
Distance: 30 feet (9 m) away from wall



Blast Pressure: 200 psi (1.4 MPa; 14 kg/cm²)
Midspan Deflection: 9 inches (230 mm)












Fort Bragg, NC



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Sample QuakeWrap® Projects


 Testing + R&D	 Condo, FL	 Chimney, AL
 Bridge, NM	 Museum, CA	 Bldg, PR
 Bridge, IN	 Pipe, Costa Rica	 Bldg, PA

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Pipe Types Suitable for FRP Repair

- Steel
 - Loss of wall thickness due to corrosion
- Ductile Iron
- PVC
- Fiberglass
- Brick
- Clay
- Corrugated Metal Pipe
- Concrete
- Cast In Place
- PCCP

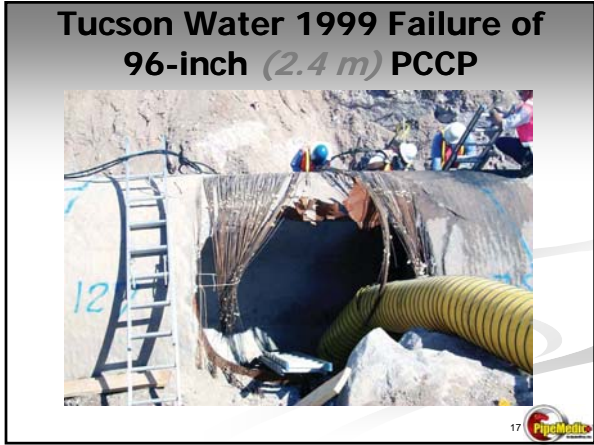


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Prestressed Concrete Cylinder Pipe (PCCP)

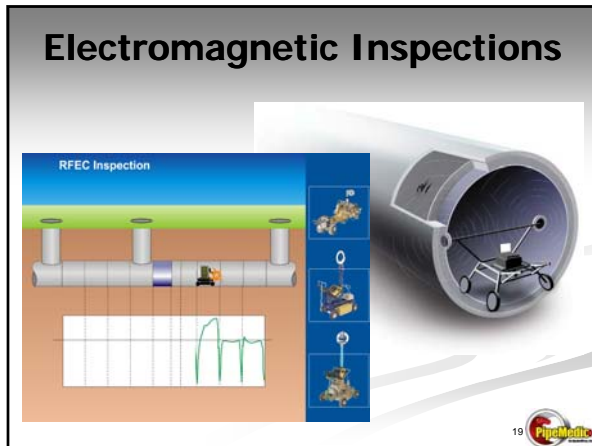


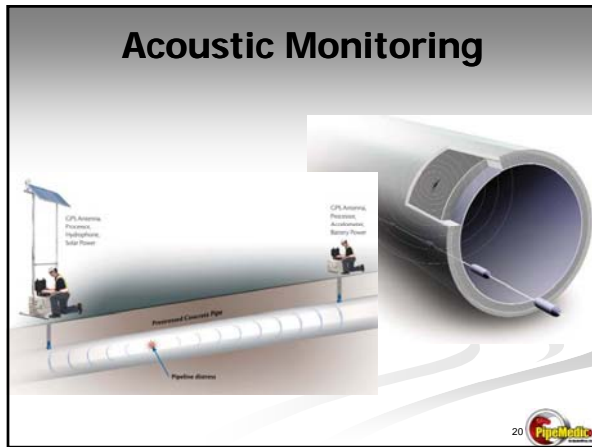
Tucson Water 1999 Failure of 96-inch (2.4 m) PCCP





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Prestressed Concrete Cylinder Pipe(PCCP)

Rank	Pipe #	+STA	Drain Position (ft)	# of B by Region	Total # of B	Pipe Location		Nearest Feature
						#	SP	
1	747	+91	3.3, 5.3, 9.0, 11.0, 18.0	35	41	10	U	HH @ STA 137+03
2	750	+31	2.0, 6.0, 11.0, 14.5, 18.5	60	30	10	U	HH @ STA 137+03
3	751	+58	3.5, 5.5, 9.0, 12.0	30	20	10	U	HH @ STA 137+03
4	748	+91	2.0, 5.5, 9.0, 11.5, 15.5	30	20	9	U	HH @ STA 137+03
5	374	+98	5.5, 9.0, 14.0, 18.0	30	13	13	D	HH @ STA 137+03
6	510	+91	2.0, 4.0, 9.0, 13.0	5	20	20	D	HH @ STA 133+08
7	770	+90	4.5, 11.0, 15.15	25	13	13	D	HH @ STA 137+03
8	751	+71	3.0, 5.0, 11.5, 18.0	5	5	4	U	HH @ STA 137+03
9	579	+02	2.0, 3.0, 5.0, 8.0	5	5	8	D	HH @ STA 137+03
10	564	+94	1.5, 12.0	3, 10	15	23	D	HH @ STA 133+30

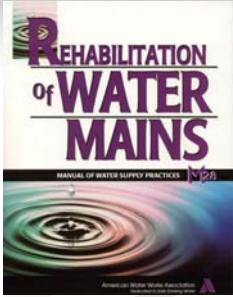
"By assessing the actual condition of a pipeline using RFEC/TC one can gather the information required to start to predict the probability that individual pipe sections might fail given present operating conditions."


The decision can then be made to selective repair or replace pipe segments that are expected to fail. Repair of pipe segments require a structural solution to reinstate the hoop strength capability of the pipe.

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Manual of Water Supply Practices


**AWWA M28
Committee**



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AWWA Liner Classifications

AWWA Classification	Non-structural	Semi-structural		Fully Structural
	Class I	Class II	Class III	Class IV
Trenchless Products	<ul style="list-style-type: none"> Cement mortar lining Epoxy/ PU lining 	<ul style="list-style-type: none"> CIPP Rehabilitation Modified Epoxy lining 	<ul style="list-style-type: none"> Modified sliplining CIPP rehabilitation 	<ul style="list-style-type: none"> Sliplining CIPP rehabilitation Polyester-reinforced polyethylene Fiber Reinforced Polymer (FRP)




Class IV Liner

- Structurally independent of host pipe for internal loading
- Addresses the following:
 - Corrosion
 - Pin holes
 - Gaps
 - Joint leaks
 - Can be designed as a independent new pipeline


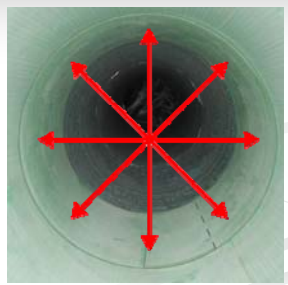


Outline


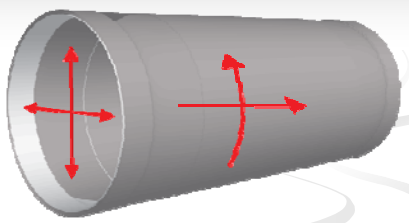
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- Pipe Types & Problems
- **Repair of Pipes with FRP**
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Internal Pressure

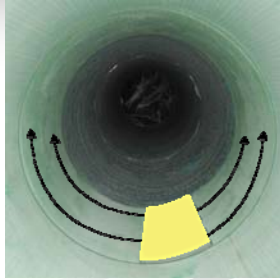


Hoop and Longitudinal Stresses



Overlap in Hoop Direction

- Overlap length is a function of:
- > Epoxy strength
 - > Strength of FRP in hoop direction



Overlap in Longitudinal Direction

- Overlap length is a function of:
- > Epoxy strength
 - > Strength of FRP in longitudinal direction

The result is a one-piece structural pipe inside the host pipe!



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Wet Lay-up

- Saturate Fabric
- Apply Tack Coat
- Install Fabric
- Align Fibers Properly
- Remove Air Bubbles
- Make Samples for Testing



Power Service of New Mexico (PNM)

10-ft diameter PCCP (Oct 2007)



Equipment modified to go through manhole

Scaffolding & saturating inside pipe



Power Service of New Mexico (PNM)

10-ft diameter PCCP (Oct 2007)



Protective glass layer on steel pipe

Tight work space in 48" steel risers



The Latest Innovation in Pipe & Culvert Repair Using Carbon FRP

Power Service of New Mexico (PNM)
10-ft diameter PCCP (Oct 2007)



2008 Award of Excellence from ICRI

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El Encanto Hydropower, Costa Rica
1.1 miles x 7-ft diameter (July 2009)

Sloped Terrain



Water seeping into pipe



Leaks continued after cracks were filled



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El Encanto Hydropower, Costa Rica
1.1 miles x 7-ft diameter (July 2009)

Four 2'x2' access ports



Poor surface conditions required much prep



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The Latest Innovation in Pipe & Culvert Repair Using Carbon FRP

El Encanto Hydropower, Costa Rica




Challenge: Not only strengthen but to leak proof
Successful pressurization tests on July 15, 2009



Production Rate

- ❑ 5742 ft (1750 m) of Pipe
- ❑ 150,000 ft² (14,000 m²) of fabric
- ❑ Surface Prep (7 days)
- ❑ Fabric Installation + Top Coat (15 days)
 - > 4 Stations
 - > 1 Supervisor
 - > 10 laborers
- ❑ Average Production Rate per 8 hour shift
 - > 10,000 ft² (930 m²)
 - > 380 ft (116 m)




NSF-61 Potable Water Certified

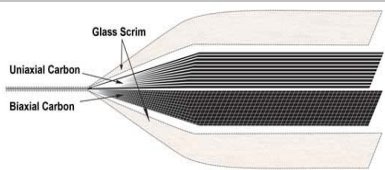


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Sandwich Construction of PipeMedic™ Laminates (Patent Pending)



- Infinite combinations of strength & stiffness can be produced
- ISO 9000 Certified



Obvious why Earlier Attempts by Others Failed!



Overlap in Longitudinal Direction



PipeMedic™ Laminates



Installation Procedure


- ❑ Cut required length of laminate
- ❑ Apply Epoxy to back of laminate (or pipe)
- ❑ Bond laminate to pipe surface in rings with overlap at the end of ring
- ❑ Install next ring with overlap in direction of flow
- ❑ Anchor leading edge
 - > Mechanical (Weko, Link Pipe, Victaulic)
 - > Detail with Fabric



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The Result is ...

- ❑ A Pipe within a Pipe
- ❑ A Structural Pipe (Internal Pressure)
- ❑ Virtually no Loss in Diameter
- ❑ One Size Fits All Pipe Diameters !!!
- ❑ No Annular Space to Grout
- ❑ Ambient Cure; No Temperature or Steam Required
- ❑ Smooth Surface; Low Friction; Better Flow Characteristics




Structural Properties

psi units (MPa units)


	PipeMedic™ PC4	PipeMedic™ PC2.2	PipeMedic™ PG2.2	Insituform RPP™
Tensile Strength	156,000 <i>(1,075)</i>	101,000 <i>(695)</i>	62,000 <i>(430)</i>	6,000 <i>(40)</i>
Tensile Modulus	13,800,000 <i>(95,145)</i>	7,150,000 <i>(49,300)</i>	3,500,000 <i>(24,130)</i>	

1. RPP = Reconstruction of Pressurized Piping
2. While not listed here, carbon laminates are 20%-25% stronger than their wet lay-up counterparts.



PipeMedic™ Example

- ❑ Steel Pipe
- ❑ Diameter: 96 inches *(2.44 m)*
- ❑ Pressure: 150 psi *(10.34 bar)*
- ❑ Retrofit Solution: 2 layers of Unidirectional Carbon Fabric




Applied Like V
Three Times

pa
ending

Wet Lay up	Using PipeMedic™
1 layer of glass	One laminate!
First layer of carbon	
Second layer of carbon	

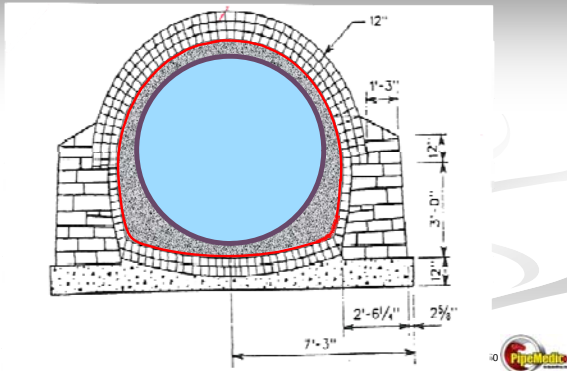
Installation time reduced by 80% !!!



Robot for Installation of Laminates



Pressurizing a Gravity Pipe



Corrugated Metal Pipe (CMP) Culvert

- Advantages:
 - No loss of diameter
 - No Grouting required
 - One-Size Fits all
- Disadvantage:
 - Little Compressive Strength



Wet Layup vs. PipeMedic™	
Wet Layup	PipeMedic™
Truly trenchless	Truly trenchless
Strengthens pipe	Strengthens pipe
Fits all pipe diameters	Fits all pipe diameters
Fabric applied in layers	Single multi-layer laminate
Align fiber orientation	Already aligned
Remove air bubbles	No air bubbles
Saturation inside pipe	No saturation
Samples tested <i>after</i>	Samples tested <i>before</i>
Installation is complete	Installation begins
Longer time required	Reduces time by upto 80%
Experienced crew required	Certified installers

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Spot Repair for Pipes > 8-in (200 mm) in Diameter

Apply epoxy to PipeMedic™ & wrap around packer ...

Hold PipeMedic™ in coiled position with strings ...

Lower assembly into pipe ...

Guide to repair position with CCTV camera ...

Inflate packer and allow epoxy to set (20 min.) ...

Deflate packer & remove!

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Repair of Pipes w/o Street-Level Bypass

Repairs can be done without bypassing the water on the street (no traffic closure)

Can do spot repair or entire pipeline

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Open-End Pipe or Culvert

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Applications

- ❑ Large Repairs: Engineered Solutions
- ❑ Spot Repairs (8 inch diameter & larger):
 - Kits Starting at \$400
 - Certified Installers
 - Low Capital Investment
- ❑ Tanks
- ❑ Installations by us & Certified Installers



Green Sustainable Technology

- ❑ When we speak of trenchless, we mean **ZERO** excavation
 - A 24-inch (600 mm) access is sufficient
- ❑ In most cases, no bypass at street level
- ❑ Non-Toxic & No VOC Chemicals
- ❑ Fast Construction w/ Small Crew



Services Offered

- ❑ Engineering/Construction Firm
 - Design
 - Materials
 - Installation or Supervision
 - Certified Installers



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Thank you for your Attention!

Questions?

www.QuakeWrap.com

www.PipeMedic.com

Reference Papers: www.PipeMedic.com/library
Specification is Available online.

Email: Mo@QuakeWrap.com
Toll Free: (888) 830-PIPE[7473]