Fiber Reinforced Polymer Upgrades for Large Pipelines

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Agenda

- Inspection Methods evolution
- Repair Options analysis
- Carbon Fiber technical overview
- Project overview: 144-inch PCCP
- Project overview: 36 & 42-inch steel pipeline
- Advancements in surface preparation
- Overcoming operational challenges
- Conclusions
Solutions that integrate products, engineering, and construction

State of the Art Products
Engineering Support Services

Specialty Contracting
- **Products & Systems**
  - Strengthening
  - Force Protection
  - Pipe Repair & Upgrade
  - Corrosion Control
  - Moisture Control
  - Concrete Restoration
  - Equipment Foundations
  - Post Tensioning

- **Engineering Support**
  - Investigative Condition Assessment
  - Engineering
    - Product Customization
    - Design – Assist
    - Specialty Full Design

**State of the Art Products**
**Engineered Solutions**
Pre-Stressed Concrete Cylinder Pipe (PCCP) overview

Key points:

- Certain types of pre-stressing wires susceptible to failure
- Installed in 16-24 foot sections, often referred to as “spools”, which lends well to segmental or targeted repairs
- Current inspection technology and owner behavior, typically repairing suspect segments
- Other concrete - cracking due to surge pressure damage, corroded reinforcement steel, age or soil settlement factors
- Metallic - corrosion of pipeline due to soil chemistry, age or other factors causing section loss (wall thinning) and can lead to leaks
- Polymer based - cracking due to surge pressure damage, age or soil settlement issues
Pipeline Inspection Methods

1. Visual & sounding - Determines severely deteriorated pipe areas
2. In-line acoustics - Determines leaks in the pipe
3. Electromagnetics - Determines pre-stressing wire breaks in PCCP
4. Impact echo - Determines concrete integrity or metallic wall thickness
5. Magnetic flux leakage - Determines metallic pipe wall loss
6. Correlators - Determines leaks in the pipe and average pipe wall thickness
Repair Options Analysis

What are the alternatives?

1. Dig & replace - new pipe
2. Steel slip-lining
3. Protective coatings
4. Structural lining - CFRP
5. External post-tensioning
Carbon Fiber Technical Overview

FRP = Fiber Reinforced Polymer

Carbon Fiber provides structural strength.
Epoxy resin provides durability.
Carbon Fiber Technical Overview

- 36-inches and above diameter for buried pipe, no size limitations for exposed piping
- Fluid type - water and waste water
- Internal pressures - up to 400psi
- External loads - no limit
- Host pipe materials - most any material including PCCP, reinforced concrete, steel, cast iron, ductile iron, and polymer based piping systems
- Temperature limit - 130F
- Schedule - need minimum 4 day construction window
Carbon Fiber Technical Overview

- Durability - ICC compliance
- Testing requirements
  - Resin system
  - Wet lay-up method
  - Minimum field applications
# Carbon Fiber Technical Overview

## ICC AC-125 Durability Matrix

<table>
<thead>
<tr>
<th>ENVIRONMENTAL DURABILITY TEST</th>
<th>RELEVANT SPECIFICATIONS</th>
<th>TEST CONDITIONS</th>
<th>TEST DURATION</th>
<th>MINIMUM PERCENT RETENTION</th>
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</thead>
<tbody>
<tr>
<td>Water resistance</td>
<td>ASTM D 2247, ASTM E 104</td>
<td>100 percent, 100 ± 2°F</td>
<td>1,000, 3,000 and 10,000 hours</td>
<td>90</td>
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<tr>
<td>Saltwater resistance</td>
<td>ASTM D 1141, ASTM C 581</td>
<td>Immersion at 73 ± 2°F</td>
<td>1,000, 3,000 and 10,000 hours</td>
<td>85</td>
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<tr>
<td>Alkali resistance</td>
<td>ASTM C 581</td>
<td>Immersion in Ca (CO₃) at pH = 9.5 &amp; 73 ± 3°F</td>
<td>1,000 and 3,000 hours</td>
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<tr>
<td>Dry heat resistance</td>
<td>ASTM D 3045</td>
<td>140 ± 5°F</td>
<td>1,000 and 3,000 hours</td>
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</tbody>
</table>
Carbon Fiber Technical Overview

Design Considerations Overview

- Internal working pressure
- Internal working-plus-transient pressure
- Weight of pipe and fluid
- Earth load above the pipe
- Live loads at the ground surface
- External pressure due to groundwater above the pipe
- Negative pressure inside the pipe

What is the desired service life?
Carbon Fiber Technical Overview

End connection detailing

- **Existing Pipe Bell End**
- **Existing Pipe Spigot End**
- **Remove existing concrete and replace with thickened epoxy. Provide smooth surface to receive FRP**
- **Remove concrete using straight circumferential cut and fill corner with thickened epoxy. Avoid damage to steel cylinder**
- **Stainless steel expansion ring and 1/4" thick rubber strip expanded against pipe wall to achieve 100 PSI interface pressure**
- **Longitudinal glass FRP**
- **Circumferential carbon FRP**
- **Epoxy mortar**
- **Thickened V-wrap 700 epoxy top coat**
Project Overview: 36 & 42-inch steel pipeline

- Nuclear Facility in United States
- Circulating Water System consists of 36 & 42-inch carbon steel pipelines
- Thinning wall sections and limited thru-wall leaks were detected during inspection
Project Overview: 36 & 42-inch steel pipeline

Project Scope:
- Carbon fiber reinforced polymer (CFRP) composite lining of 255 continuous lineal feet of 36 & 42-inch carbon steel pipe during 2013 outage

Unique Project Challenges:
- Extremely poor condition of substrate
- Sequencing operations activity in small diameter pipeline
- Coordination of weld repairs during operations
- Changes in elevation and slope conditions within scope area
Project Overview: 36 & 42-inch steel pipeline
Advances in Surface Preparation

Before

After

36 & 42-inch steel pipeline project
Project Challenges: 36 & 42-inch steel pipeline

- Project sequencing during installation due to limited access within 36-inch pipe

Primer coat installation

Glass Fiber installation

Carbon Fiber Installation

Final CFRP layer & topcoat
Background - Quality Control Program

Multiple QA/QC Personnel
- 3rd Party inspector
- Full time Quality Assurance Manager
- Multiple Owner Representatives

Documentation for each stage of implementation
- Material verification
- Surface preparation
- Mixing and saturation
- CFRP liner installation
- End details and special detailing
- Top coat
- Final cure
FRP Composite Systems - Next Generation

Installation Overview - Reinforcing Steel
StrongPIPE Hybrid FRP System

Description

Legend
1. 1\textsuperscript{st} Glass FRP Layer (longitudinal)
2. High Str. Steel Wire
3. Polymer Matrix
4. 2\textsuperscript{nd} Glass FRP Layer (longitudinal)
5. Flexible Topcoat
Thank you!

Questions?

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