CFR Polymer is Perfect Rehab for Ohio Levee System Culvert

Tomas T. Jimenez, P.E.
Business Development Manager
(858) 342-8951
tjimenez@aegion.com
Presentation Outline

- Introduction to FRP
- Project Background
- Installation
- Inspection
- Conclusion
Fiber-Reinforced Polymer (FRP)

The Tyfo® fiber-reinforced polymer (FRP) system are designed to increase the structural performance of existing PCCP, RC and steel pipes. Fibrwrap® Construction, an Aegion company, is the exclusive installer of the Tyfo® FRP pipeline repair system for pipelines.
CFRP Rehabilitation Capabilities

Diameter range
Medium – Large pipe
30” to 252” (internal)

Pressure range
Up to 400+ psi
Vacuum pressure
(to 14.7 psi)
Glass Fiber Systems

- Glass Fibers
  - Tyfo® SEH-51A
  - Tyfo® WEB
  - Tyfo® BC

- Epoxies
  - Tyfo® S Epoxy
  - Tyfo® SW1S Epoxy
  - Tyfo® S-T Epoxy
  - Thickened Tyfo® S and Tyfo® S-T Epoxies
Tyfo® SCH Systems – Carbon Fiber Systems

- Carbon Fibers
  - Tyfo® SCH-41
  - Tyfo® SCH-41-2X
  - Tyfo® SCH-Mark V
  - Tyfo® SCH-11UP
  - Tyfo® UC Strips

- Epoxies
  - Tyfo® S Epoxy
  - Tyfo® SW1S Epoxy
  - Tyfo® S-T Epoxy
  - Thickened Tyfo® S and Tyfo® S-T Epoxies
Carbon Fiber Reinforced Polymer (CFRP): Properties are based on the fiber and durability is based on the polymer.
Stress-Strain Behavior Illustrates Critical Design Principals
Typical CFRP Design Approach

- Consider degradation level of host pipe
- Stand-alone (fully structural design) versus composite design (with inner core)
- Use Load resistance factor design/AWWA C305 (LRFD)

### Circumferential Design

<table>
<thead>
<tr>
<th>Limit State</th>
<th>Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFRP Rupture (2)</td>
<td>1-Internal pressure</td>
</tr>
<tr>
<td></td>
<td>2-Internal pres. + External Loads</td>
</tr>
<tr>
<td>Buckling</td>
<td>External loads: Groundwater + Vacuum</td>
</tr>
<tr>
<td>Debonding</td>
<td>Empty pipe under external loads</td>
</tr>
</tbody>
</table>

### Longitudinal Design

<table>
<thead>
<tr>
<th>Limit State</th>
<th>Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFRP Rupture</td>
<td>Internal pressure (Thrust, Poisson) +</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td>Debonding</td>
<td>Internal pressure (Thrust, Poisson) +</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td>Buckling</td>
<td>Temperature</td>
</tr>
</tbody>
</table>
## FRP Codes-Reports-Design Guidelines

<table>
<thead>
<tr>
<th>Code/ Report</th>
<th>Code Title</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWWA C305</td>
<td>CFRP Renewal and Strengthening of PCCP</td>
<td>Dec-18</td>
</tr>
<tr>
<td>AWWA C304-04</td>
<td>Prestressed Concrete Pressure Pipe, Steel Cylinder Type</td>
<td>Dec-07</td>
</tr>
<tr>
<td>AWWA M11</td>
<td>Steel Water Pipe - A Guide for Design and Installation</td>
<td>Jul-04</td>
</tr>
<tr>
<td>ASME PCC-2</td>
<td>Repair of Pressure Equipment and Piping</td>
<td>Apr-11</td>
</tr>
<tr>
<td>ASME B31.1</td>
<td>Power Piping (ASME Code for Pressure Piping, B31)</td>
<td>Jun-12</td>
</tr>
</tbody>
</table>
Uses of FRP Rehabilitation Systems

• Structural rehabilitation
  • Segmental repairs
  • Full length repairs
  • Fully structural rehabilitation
  • Single criteria requirement – pressure, transient, broken back, joint rehab
• Joint rehabilitation
  • Leak remediation
  • Structural strengthening
• Reinforced coating application
  • Durable coating
  • Nominal strength
FRP Installation Method
STEP 1: SURFACE PREPARATION

Sand Blasting Equipment

Finished Surface - Concrete
FRP Installation Method
STEP 2: PRIMER / SATURATION

Surface Primer

Material Transport

CFRP Impregnation
Installation Method

STEP 3: FRP SYSTEM INSTALLATION

Circumferential layer installation
QA/QC Process

- Continuous Inspection conducted by Quality Control Specialist (QCS)
- Selected QA/QC steps documented
  - CFRP material manufactured by an ISO 9001:2015 certified company
  - Verify installation is in accordance with drawings and specifications
  - Condition of host pipe
  - Control of air flow, temperature, and humidity
  - Surface preparation
  - Adhesion tests
  - Material saturation
  - Application (details, timing)
  - Termination details
  - Preparation of witness panels
  - Post-installation inspection
  - Curing (85% cure before service)
  - Thickness measuring device
In-Situ Quality Control Testing
ASTM D4541 – Adhesion Testing

• Minimum (3) 2 ft x 2 ft panels on adjacent non-repair pipes

• Prepared and tested by Installer (ASTM D4541)

• Witnessed by Inspector

• >200 psi required for at least 3 tests per panel

• Failure mode may affect design approach!
Testing of Witness Panels after Construction

- Prepared by the Installer, witnessed by the Inspector, tested by the Independent Testing Agency
- Three panels or one panel per day per work shift, whichever is greater
- One layer of CFRP
- Preparation of panels spread throughout construction
Case Study – Zoar Levee

Unique Project Requirements

- 36” reinforced concrete box culvert rehabilitation
- Operated by US Army Corps of Engineers
- The box culvert structure is critical for dam safety
- Box culver joints were cracked and damaged due to service conditions
- The FRP composite wrap was designed to prevent soil erosion behind the culvert and to maintain dam integrity
- The FRP wrap was used in conjunction with concrete repairs
- The FRP wrap supported watertight requirements and nominal strength requirements
Case Study – Zoar Levee
Ventilation and Dehumidification
Case Study – Zoar Levee
Unique Project Requirements

- Background and E-verify checks
- USACE safety practices
- Confined space entry plan and rescue team
- Cleaning and jetting of culvert
- Pre and Post CCTV
- Ventilation
- Surface preparation
- Inspection and QC testing (ASTM D3039 and D4541)
- Materials contain 0% VOC
- 22 joints repaired
Case Study – Zoar Levee
Unique Project Challenges

- Small site setup footprint
- No truck access was allowed on the levee walls and hence a CIPP crew was not allowed to enter the site
- Hydraulic capacity requirement prevented the loss of cross sectional area
- CIPP liners would reduce the culvert hydraulic capacity
- The USACE required a repair method to prevent sink holes at the dam structure
Case Study – Zoar Levee
Concrete Repairs
Case Study – Zoar Levee
Installed FRP Composite System

CFRP joint repair
Case Study – Zoar Levee
FRP Material Inspection
Conclusions

- Unique box culvert structure was successfully rehabilitated with FRP materials
- Joint rehabilitation or spot repairs for pipes or box culverts can be cost effectively rehabilitated with FRP materials
- The concrete repairs and FRP materials effectively provide the leak prevention and nominal strengthening required by project
- The project team was able to support all required safety, quality control, logistics and structural criteria
- The project team delivered the project on time and on budget
Thank you!

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