“An Introduction to Hybrid Composite Culvert Rehabilitation”
An Introduction to Hybrid Composite Culvert Rehab (HCCR)

• Origins: Maine Composite Bridge Initiative
• Intro to Kenway & AEWC
• CMP culverts & the need for rehab options
• Hybrid Composite Culvert Rehab System:
  Configuration
  Materials
  Testing & verification
  Installations
  Environmental Considerations
  Performance, Acceptance & Cost
• Other FRP infrastructure Applications

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Hybrid Composite Culvert Rehabilitation (HCCR)

Developed in 2009 by Kenway and the University of Maine’s Advanced Structures and Composites Center (AEWC) with funding provided by the ME DOT under the Maine Composite Bridge Initiative.
Kenway Corporation

- 1947: founded - building wooden boats
- 1950s: transitioned to FRP
- 1960s: segued to FRP for industry
- 1991: new facility in Augusta, ME.
- 2008: back into boats
- 2011: diversified employing eighty
Markets Served by Kenway

- Pulp & Paper
- Power & FGD
- Renewable Energy
- Chemical
- Aquaculture
- Infrastructure
- Transportation
- Semi-Conductor
- Waste Water
- Marine

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Established by NSF in 1996 to be a world leader in wood and non-wood hybrid composites for construction

AEWC Mission
– Education
– Research
– Commercialization

Industry Support
– Product Development
– Testing: coupon to full-scale
– Building Code Reports

An ISO 17025 R&D Laboratory Accredited by International Accreditation Service

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AEWC’s Infrastructure Experience

- Developer of “Bridge in a Backpack”
- Testing facility of the “HCB - Hybrid Composite Beam”
- Cutting Edge Offshore Wind Laboratory

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CMP Failure Mode – Need for Rehab Options

- Corrosion leads to loss of strength and erosion of supporting soil
- Corrosion is more often concentrated in invert
- Replacement is more costly and disruptive than rehabilitation

“We face an epidemic of deteriorating CMP Culverts” - DOT engineer from neighboring state

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Traditional Rehabilitation Method for Large Diameter Culverts w/Failed Inverts

Reinforced Concrete:

- Labor intensive…
- Raises invert elevation considerably…
- Limited durability …
- Reliant on heavy equipment…
- Time consuming…
Design Objectives for HCCR:

Provide value & benefit over existing options:

- provide full structural capacity of CMP
- minimize impact on hydraulic capacity
- sensitive to aquatic organism passage
- rapid installation
- competitive on a “first cost” basis
- extend service life
HCCR’s Design is Based on Manufacturability and Material Properties

- FRP restores strength
- Annular grout / FRP provide stiffness and fill annular gap between corrugated steel and liner
- Powder-actuated fasteners transfer the thrust loads from CMP to the FRP liner
Fiberglass Fabric: Fibers are selectively orientated @ 0°, 90°, +45° and -45° degrees for customizable properties.

Vinyl Ester Resin: durable, tough, fatigue resistant and environmentally stable resin, which “casts” fibers in the desired orientation.
Materials: Resulting Panel

• Resulting panel is strong but flexible, fatigue and impact resistant, durable and light weight
• Pigments and UV inhibitors resist environmental effects
• Granite grit ensures composite action with grout

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Materials: Grout

- Non shrinking
- Portland cement based
- 5,000 psi @ 28 days
- Fine aggregate: Sand
- Slump 8”-10”
Materials: Powder Actuated Fasteners

- Pre-mounted steel washers
- 1¼" long pins
- Galvanized
- No pre-drilling
- Quick to install
- Performance verified by testing
Materials: Structural Adhesive

Plexus MA 560-1 or equal:

- Joins adjacent FRP panels and internal weirs
- Two part (1:1) methyl methacrylate adhesive
- Excellent fatigue and impact resistance
- 55-70 minute working time
- >2,500 psi tensile strength
AEWC Performed Tests to Verify Predictions and Prove the Concept

- Design Loads per AASHTO LRFD Bridge Design Specification
- Material testing to verify tensile, compressive, and flexure strength
- Component testing to verify seam strength, buckling resistance, and overall performance relative to CMP culvert
Baseline Steel CMP & Hybrid CMP Culvert
Six foot Diameter Load Test

Buckling failure of the CMP in both steel & hybrid tests.
Installations
Rt. 9, Amherst, ME

• September 2009
• 8’ diameter
• 130 ft long
• Round CMP pipe
• No internal weirs

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Installations
Rt. 9, Amherst, ME

- October 2009
- 8’ diameter
- 130 ft. long
- Round CMP pipe
- 9 internal weirs
- External fish ladder
Installations
Stinking Brook Bridge
Rt. 11, Ebeemee, ME

- Aug 2010
- 11’-5” span x 7’-3”
- 70 ft. long
- Plate arch
- 4 internal weirs
- External fish ladder
Installations
Rt. 11 over Grant Brook
Indian Township, ME

- Sept 2010
- 10’ diameter
- 80 ft. long
- Round CMP
- 4 internal weirs
- Taylor Construction
Installations
Rt. 11 over Partridge Brook
Penobscot, ME

- October 2010
- 13’span x 8’ rise
- 70 ft. long
- Plate Arch
- 4 Internal weirs
- Taylor Construction

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Manufacturing Process: Vacuum Infusion

- Consistent laminate quality
- High fiber/low void content
- Ultra-low VOC emissions
- Minimal resin or glass waste
- Dimensional stability
- Close tolerances
- Minimal trim losses
- Net shape mold
Rapid Installation Minimizes Brook Impact

Diversion of flow through adjacent culvert for East lining

Pumping of brook flow for West culvert maintenance

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Minimal Preparation Required
Prior to Liner Installation

Pressure washing to remove algae and debris

Sealing holes with MMA adhesive or hydraulic cement

Removal of occasional extra long bolt

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Panels Can be Positioned by Hand

Panels are sized to keep weight under 300 lbs

Wheeled dolly helps move panels along culvert
Efficient Placement and Fastening

Flexible panels accommodate variations in CMP cross-section

Anchoring is quick using Hilti powder actuated fasteners – no pre-drilling required
Seams are Sealed and Grout is Pumped

Approx 300 ft of culvert can be grout filled in a 12 hr day

MMA adhesive is cured in one hour
Very First Field Installation
Completed in One Week

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Internal FRP Weirs Trimmed to Custom Fit

- Templated at each location
- Trimmed on site
- Factory infused
- Bonded in place

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Modular Fish Ladder Reduces Field Time
Technique is Suitable for Overhead Repairs

Kenway is developing a panel that will reinforce 360 degrees of the culvert

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Low Environmental Impact and Confirmed Brook Trout Passage

Before
- Deep scouring from outfall
- Erosion during high flow

After
- Smoother elevation transitions
- Protective rip rap
Design Flexibility....

Easily mates to existing traditional materials if desired

Amherst installation has survived freeze-thaw cycles in Northern Maine without issue

System matches any geometry and changes in shape due to settling/heaving
FRP is Safe for the Environment

FDA regulation 21 CFR 177.2420 which governs materials intended for repeated use in contact with food

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Benefits of HCCR

- **Minimal Reduction of Hydraulic Capacity:** Only about 1” increase in invert elevation

- **Minimal Access Requirements:** Lightweight composite panels can be installed by hand

- **Quick:** Minimizes traffic impact and in-stream time

- **Critter friendly:** Minimal invert elevation change and no impact on stream pH or leaching of chemicals

- **Economical:** Approximately $450/ft installed

- **Durable:** Highly corrosion, abrasion, and impact resistant; service life projected >75 yrs

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HCCR Success

• Only 1” increase in invert elevation very well received by biologists – surface profiles easily incorporated in FRP liner

• ME DOT has accepted HCCR as a standard specified option vs. cast-in-place and shotcrete

• VT, NH, and CT DOTs are all planning demonstration projects

“In, Out and Stay Out”... HCCR satisfies FHWA objectives of “Highways for Life” & “Accelerated Bridge Construction”
Composite Bridge Drain Development
(AEWC, ME DOT & Kenway Collaboration)

FRP Bridge Drain Prototypes Tested by AEWC

Composite Solution to Corrosion Problems

Cost-competitive Alternative to Galvanized Drains

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Composite Piles & Stay-In-Place (SIP) Forms

Kenway Provided Composite Forms to Modern Continental on “Big Dig” Project

Pre-Manufactured SIP Forms for a Variety of Marine & Infrastructure Applications

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Composite Repairs & Reinforcement

Degradation of wood & concrete piles in marine & infrastructure…

…repaired and strengthened with composite wraps and overlays.

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Awards & Recognition

• 2009: Kenway Corporation received the American Composites Manufacturer’s Assoc. “Award for Technical Innovation”

• 2009: “Large Company Business Leader of the Year” award from MaineBiz

• 2008: The Maine Manufacturing Extension Partnership’s “Manufacturer of the Year”

• Letters of recognition from State and National politicians including U.S. Senator Olympia Snowe, U.S. Senator Susan Collins and Governor Baldacci

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Questions?
Learning Assessment Question 1 of 3:

What material properties suit fiberglass to the application of strengthening CMP culverts?

• Strong but flexible, prior to grouting.
• Tough with good fatigue resistance.
• Durability.
• Light weight for quick installation.
Learning Assessment Question 2 of 3:

What advantages does the Hybrid Composite Culvert Rehabilitation System offer over traditional reinforced concrete repair?

• Minimal increase in invert elevation
• Minimal loss of hydraulic capacity
• Speed of installation
• Durability
• Economy
Do the Hybrid Composite Culvert Rehabilitation System FRP panels expose the job site environment to hazardous chemicals?

• No. The FRP panels are factory cured and are totally inert when delivered to the job site.

• Seams and joints are sealed with a two part adhesive, that is commonly used on job sites. Because it is quick reacting and is of a viscous, putty consistency, and is dispensed from a pneumatic gun. It is extremely unlikely that it would contaminate the job-site environment.