“Bridge-in-a-Backpack”
Inflatable Composite-Concrete Bridges

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University of Maine
Outline

• UMaine Composites Center
• Governor’s Composites Initiative
• Bridge-in-a-Backpack
  – Why and how
  – 8 Years of R&D
  – 2 demonstration projects
• Benefits and next steps
• Video
UMaine Advanced Structures & Composites Center

- 70,000 ft² ISO 17025 Accredited Lab
- 140 personnel
- Analysis & Design + Prototyping + Testing + Code Reports
UMaine Composites Center

• 200+ Clients Globally
• Prototyping/testing up to 230 ft spans
• Nanocomposites
• Global Impact
  – 3 ACMA ACE awards in last 2 years
  – 2009 Champion for Economic Development Award
  – Over 400 publications in last 10 years
Maine’s Composites Initiative

• Governor John Baldacci
• Up to 10% composites for bridges
Composite Bridge Drains
Maine DOT Collaboration

- Hillman Composite Beam
  - Static and fatigue testing
  - 500 ft bridge under contract

- Composite Culvert Lining
  - Composite liner repairs degraded metal culverts
Penobscot Narrows Bridge

- Maine DOT, FHWA, Figg Engineering Group, UMaine
- Steel strands replaced with carbon composite strands
- Long term performance monitoring
“Bridge in a Backpack”

- Developed by UMaine over an 8 year period
- *Advanced Infrastructure Technologies, LLC*

Arch Placement

Decking Installation

Completed Bridge
On-Site Production: Reduce shipping and handling logistics

- Geometries completely customizable for site requirements
- Spans made up to 90’, tube thickness up to ½”
A Faster, More Efficient Cast-in-Place Concrete Bridge

- Inflatable FRP tubes, made on site
- Tube weighs 200 lb for 70’ span versus 50,000 lbs for Prestressed concrete girder
- Hand labor or light equipment

Arch Installation at UMaine

6 Arches Installed by 3 Laborers in 10 Minutes
Three Functions of FRP Tube:

1. Stay-in-place form for concrete

Eliminates need for temporary formwork
Three Functions of FRP Tube:

2. Structural reinforcement for concrete

Three Components of FRP Reinforcement

Confined

Unconfined

Stress-Strain Relationship for Concrete

Eliminates rebars
Three Functions of FRP Tube:

3. Protection for concrete

Protects against corrosion, prolongs life, reduces maintenance

Concrete Corrosion Cycle

Steel rusts, expands

Spalling of concrete further exposes reinforcement
8 Years of Design & Testing at UMaine

Static & fatigue testing of over 40 specimens
Experimental and Predicted Response

Arch Deflected Shape, Experimental and Predicted
(Deflections Magnified 15X)
Experimental and Predicted Response

<table>
<thead>
<tr>
<th></th>
<th>Load (kip)</th>
<th>COV</th>
<th>specimens</th>
<th>Difference</th>
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<tbody>
<tr>
<td><strong>Initial</strong></td>
<td>Experimental</td>
<td>72.0</td>
<td>2.55%</td>
<td>3</td>
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<tr>
<td></td>
<td>Predicted</td>
<td>69.0</td>
<td>-----------</td>
<td>-----------</td>
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<tr>
<td><strong>Secondary</strong></td>
<td>Experimental</td>
<td>57.6</td>
<td>7.75%</td>
<td>3</td>
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<tr>
<td></td>
<td>Predicted</td>
<td>57.0</td>
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**Load-Deflection Response of Concrete-Filled FRP Tubular Arch**

- **Initial hinge at crown**
- **Subsequent hinges at shoulders**
Neal Bridge Replacement – Fall 2008

- First Bridge-in-a-Backpack, 34’ span, 44’ wide
- 23 arches installed in one day
- Arches filled with concrete (1 hour)
- FRP decking
Neal Bridge Replacement – Fall 2008

FRP Headwall
Backfill, Pave, Rail

Sensors monitor performance during backfill and service
Low maintenance, joint-free, buried structure
Neal Bridge Field Load Testing

• Performed April 2009
• 2 fully loaded tandem axle dump trucks (66 kip total weight)
• Loading configurations in parallel and series, quasi-static and dynamic
• Instrumentation:
  – Arches – strain and deflection
  – Soil – vertical and radial soil pressure
• Field measurements indicate structure significantly exceeds AASHTO requirements
• Analytical live load rating of 1.96 X AASHTO HL-93
McGee Bridge Replacement

- *Composite low bid against Steel, Concrete, and Wood*
- August 2009: installation in North Anson, ME

<table>
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<tr>
<th>Bid #</th>
<th>Bridge Type</th>
<th>% Over Low Bid</th>
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<tr>
<td>1</td>
<td><em>Bridge-in-a-Backpack</em></td>
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<tr>
<td>2</td>
<td>Steel on concrete</td>
<td>6.8%</td>
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<td>3</td>
<td>Steel on concrete</td>
<td>18.4%</td>
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<td>4</td>
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<td>23.4%</td>
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<tr>
<td>5</td>
<td>Concrete</td>
<td>23.5%</td>
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<td>6</td>
<td>Timber on concrete</td>
<td>30.0%</td>
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McGee Bridge Replacement: 12 Days

CONSTRUCTION SEQUENCE
1. Demo. existing steel bridge
2. Drill bedrock, form footings
3. Arch installation (3 hrs)
4. Pour concrete footings
5. Install composite decking
6. Fill arches with concrete (1 hr)
7. Install composite headwalls
8. Backfill bridge
9. Grading, guardrails, cleanup
Where we’re going...
2010-2011 Governor’s Composite Bridge Construction

- 5 more Maine bridges in 2 years
- Spans from 24’ – 72’
- Currently in design phase
Continuing R&D Plan

Expand Geometric Capabilities
• Spans up to 90 ft
• Diameters up to 26”
• Rigid frame and girder designs

Expand Manufacturing Capabilities
• Onsite manufacturing
• Versatile resin package
• Large scale production
Bridge-in-a-Backpack Capabilities: Interstate Overpass

INTERSTATE OVERPASS
NORTH AND SOUTH DIRECTIONS
MINIMAL MEDIAN

INTERSTATE OVERPASS
NORTH AND SOUTH DIRECTIONS
40' MEDIAN
Bridge-in-a-Backpack Capabilities: Stream Crossings/Railway Crossings

SINGLE RADIUS ARCH

VARIABLE RADIUS ARCH

SHALLOW STREAM CROSSING

DEEP STREAM CROSSING

SINGLE TRACK RAILWAY CROSSING
Summary and next steps

- Composites can compete on first-cost basis!
- 50% reduction in carbon footprint
- Public interest finding from FHWA for Maine
- TIG Application
- 20% of US bridges candidates
- 15 projects in multiple states, International projects
- Expand geometries and spans (800 ft bridge)
- Recent value bidding by contractors
- Beyond bridges
Thank you!

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