HAS-799-03.90/04.52:
ODOT’S 1ST PROJECT WITH CARBON FIBER PRESTRESSING STRANDS

Ohio Transportation Engineering Conference (OTECC)

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DAN RENAUD – PRESTRESS SERVICES INDUSTRIES, LLC.

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Box beam bridges deteriorate and are being replaced 30-40 years after construction.
ODOT’s goal is to utilize non-conventional materials to increase the useful life of these bridges to 100 years.

- Carbon Fiber Composite Cable (CFCC)
- Stainless Steel
PRESENTATION OVERVIEW

- Common problems and solutions
- Project goals
- Carbon Fiber Composite Cable (CFCC) box beam and transverse post-tensioning design
- Fabrication
- Cost comparisons and summary
COMMON BEAM DETERIORATION
POSSIBLE BOX BEAM BRIDGE SOLUTIONS

- Conventional solutions to increasing the life of box beam bridges
  - Using a composite concrete deck instead of applying asphalt wearing surface to tops of beams
POSSIBLE BOX BEAM BRIDGE SOLUTIONS

- Non-conventional solutions to increasing the life of box beam bridges
  - Transversely post-tensioning the box beams
  - Carbon fiber prestressing strands instead of the steel strands
  - Stainless steel reinforcing instead of typical epoxy-coated rebar
  - High performance grout or UHPC for shear keys between beams
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- LJB
  - Resource International Inc.
  - Dr. Nabil Grace - Lawrence Tech University
  - Roy Eriksson - Eriksson Technologies, Inc.
  - Tokyo Rope (CFCC provider)

- ODOT
  - Office of Structural Engineering
  - District 11

- Prestress Services Industries, LLC
Project scope

- Replace two existing box beam bridges over Clendening Lake
Project scope

- One bridge scoped to be conventional materials while the other bridge scoped to be non-conventional materials
- Perform research into non-conventional methods and materials
  - Provide ODOT with design criteria and final design
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Non-Conventional Bridge is Unique and Innovative

- First bridge in Ohio to use Carbon Fiber Composite Cable (CFCC) prestressing strands (Tokyo Rope)
- Stainless steel reinforcing bars in the box beams, composite concrete deck slab and approach slabs
- Transversely post-tensioned (both bridges)
CARBON FIBER COMPOSITE CABLE (CFCC)

- Developed by Tokyo Rope Mfg. Co., Ltd.
- Patented in 10 countries
- CFCC® is a registered trade mark of Tokyo Rope
- Fiber-reinforced polymer (FRP)

TOKYO ROPE MFG. CO., LTD.
CARBON FIBER COMPOSITE CABLE (CFCC)

- Composite reinforcing cable utilizing carbon fibers and resins formed into a standard cable shape
- Twisted 7 micrometer diameter carbon fibers with an epoxy resin
- 7 strands braided into 1 cable
CARBON FIBER COMPOSITE CABLE (CFCC)

Advantages:

> Light weight and flexible
  - 15 lbs per 100 feet of CFCC
  - 52 lbs per 100 feet of steel strands
> High tensile strength
> High corrosion resistance
CARBON FIBER COMPOSITE CABLE (CFCC)

- High corrosion resistance
  - Superior resistance to acid and alkali
    - Oceans
    - Areas using salt for de-icing of roads
CFCC – HIGH CORROSION RESISTANCE

![Graph showing the comparison of breaking load between CFCC and PC steel strands over an exposure period of 3 years. The graph indicates that CFCC maintains a higher breaking load compared to PC steel strands, with a specification of 142 kN.]
DESIGN CHALLENGES WITH CFCC

- Designed using ACI-440.4R-04 (Prestressing Concrete Structures with FRP Tendons)
- Tensile stress allowed at service limit state
  - Zero for CFCC design
  - $0.0948 \sqrt{f'_c} = 250$ psi for a severe corrosive environment
    - (AASHTO Table 5.9.4.2.2-1)
      - Resulted in more strands to limit concrete tensile stress
Deformation Characteristics

- Deform elastically until cracking
- Deflection increases as strands yield
- Steel: Deform in approximate linear manner
- FRP: Deform elastically until cracking

Graph showing moment vs. deflection for steel and FRP, illustrating their deformation characteristics.
## CFCC VS STEEL PRESTRESSING

<table>
<thead>
<tr>
<th></th>
<th>CFCC</th>
<th>Low Relaxation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>0.6 inch</td>
<td>0.5 inch</td>
</tr>
<tr>
<td>Area</td>
<td>0.179 sq in</td>
<td>0.167 sq in</td>
</tr>
<tr>
<td>Ultimate Tensile Stress</td>
<td>305 ksi</td>
<td>270 ksi</td>
</tr>
<tr>
<td>Initial Stress</td>
<td>183 ksi (60%)</td>
<td>202.5 ksi (75%)</td>
</tr>
<tr>
<td>Stress after All Losses</td>
<td>144.5 ksi (21%)</td>
<td>171.3 ksi (15%)</td>
</tr>
</tbody>
</table>
STAINLESS STEEL SUPERSTRUCTURE

- Stainless steel using in 6” concrete deck and stirrups
- ODOT didn’t want a corrosive steel material in the box beams with the CFCC strands
STAINLESS STEEL REINFORCING BARS

- Corrosion resistant
- US conventional bar sizes
- Standard bend shapes
- Grade 60 and Grade 75
- Care is required during shipping, handling, fabrication and placement
TRANSVERSE POST-TENSION

- Replace traditional tie rods with post-tension
  - Help prevent leakage between the box beam joints
- Post tensioning at quarter points (both bridges)
  - Six 0.5” diameter low relaxation strands
**CFCC VS TRADITIONAL BRIDGE**

- 7 CB17-48 box beams; 55’-0” span

<table>
<thead>
<tr>
<th></th>
<th>HAS-799-0390 CFCC &amp; Stainless</th>
<th>HAS-799-0452 Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strand</td>
<td>0.6 inch diameter 0.179 sq in</td>
<td>0.5 inch diameter 0.167 sq in</td>
</tr>
<tr>
<td>Number of Strands</td>
<td>36 CFCC</td>
<td>28 Low Relax</td>
</tr>
<tr>
<td>Release Concrete</td>
<td>6.5 ksi</td>
<td>5.5 ksi</td>
</tr>
<tr>
<td>Final Concrete</td>
<td>7 ksi</td>
<td>7 ksi</td>
</tr>
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</table>
## CFCC VS TRADITIONAL BRIDGE

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</tr>
</thead>
<tbody>
<tr>
<td><strong>Life Span</strong></td>
<td>100+ years</td>
<td>40 - 50 years</td>
</tr>
<tr>
<td><strong>Cost 2016</strong></td>
<td>$39,400 per beam</td>
<td>$8,800 per beam</td>
</tr>
<tr>
<td>Beam Replacement 2066</td>
<td>N/A</td>
<td>$10,000 per beam</td>
</tr>
<tr>
<td>Construction 2066</td>
<td>N/A</td>
<td>$25,000 per beam</td>
</tr>
<tr>
<td>Life Cycle Costs 2116</td>
<td>$39,400 per beam</td>
<td>$43,800 per beam</td>
</tr>
</tbody>
</table>
PSI Presentation Overview

1. Past projects and experience with CFCC strand
2. Preplanning for Carbon Fiber Composite Strand
3. Specific Safety Requirements and Material Handling
PSI’s First CFCC Project in Taylor County, KY in 2014.

(29) CFCC Strands  Stainless Steel Rebar  HN4054 x 74’ Long
PAST PROJECTS AND EXPERIENCE


- (59) CFCC Strands
- Epoxy Coated Rebar
- HN4249 x 107’ Long
1. Bed selection and number of beams per cast.
2. Coupler staggering layout and stressing sequence.

<table>
<thead>
<tr>
<th>1. Bed Criteria</th>
<th>2. Sequencing Criteria</th>
</tr>
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<tbody>
<tr>
<td>Based on stressing capacity and making full use of the casting bed length</td>
<td>Based mainly on the size of the coupler.</td>
</tr>
<tr>
<td>➢ Harrison County, OH CFCC beams consists of (7) beams 17” x 48” x 57’ long.</td>
<td></td>
</tr>
<tr>
<td>➢ The beams have (36) .6” dia. strands pulled to approximately 33,500 lbs.</td>
<td></td>
</tr>
<tr>
<td>➢ Number of coupler locations were (4) spaces at approximately 4’-0”</td>
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</tr>
</tbody>
</table>
PREPLANNING FOR CFCC

210’ Casting Bed with a ‘Chuck to Chuck’ of 225’ selected.

Bed Allowances

✓ (3) Beams per cast = 57’ x 3 = 171’-0”
✓ (2) Gaps between beams = 3’ x 2 = 6’-0”
✓ (4) Locations @ 3’-6” x 2 ends = 28’-0”

➢ Total Above = 207’          Use 210’ Casting Bed

Strand Length based on ‘Chuck to Chuck of 225’

➢ CFCC = (3.5’ x 5) + (57’ x 3) + (3 x 2) = 194.5’
➢ Steel = 225’ Chuck to Chuck – 194.5 CFCC = 30.5’
Elongation is a critical component of the coupler layout and sequencing preplanning.
SAFETY AND CFCC STRAND
HANDLING CFCC

Pushing Machine
THE COUPLER

Buffer

Braiding

Wedges

Steel

Covering CFCC with mesh sheets and braid grip

CFCC

Sleeve

Wedge

Coupler

Steel strand

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THANK YOU & FOR MORE INFORMATION

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