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

CEAO Bridge Conference and Trade Show

DAN SPRINGER, P.E., PMP & ANGELA TREMBLAY, P.E. – LJB INC.

DAN RENAUD – PRESTRESS SERVICES INDUSTRIES, LLC.

AUGUST 17, 2016

BOTTOM LINE

- Box beam bridges deteriorate and are being replaced 30-40 years after construction

BOTTOM LINE

- 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

- Problem and solutions
- Project goals
- Carbon Fiber Composite Cable (CFCC) box beam and transverse post-tensioning design
- Fabrication
- Cost comparisons and summary

BOX BEAM BRIDGE PROBLEMS

- Common problems with box beam bridges
  - Deterioration of the beam reinforcing and steel strands
    - Non-composite beams with asphalt wearing surface
    - Inadequate waterproofing on the tops of the beams
    - Deterioration of grouted shear keys
    - Leakage through the joints between beams

BOX BEAM BRIDGE PROBLEMS

- Composite box beams with a concrete deck typically outlast non-composite box beams with an asphalt surface

COMMON BEAM DETERIORATION

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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)

TOKYO ROPE MFG. CO., LTD.

- ODOT
  - Office of Structural Engineering
  - District 11
- Prestress Services Industries, LLC

PRESTRESS SERVICES INDUSTRIES, LLC

LJB DESIGN TEAM

- Daniel Springer, P.E., PMP
  - Project manager

- Angela Tremblay, P.E.
  - Lead designer

- Amy Moore, P.E.
  - Lead designer

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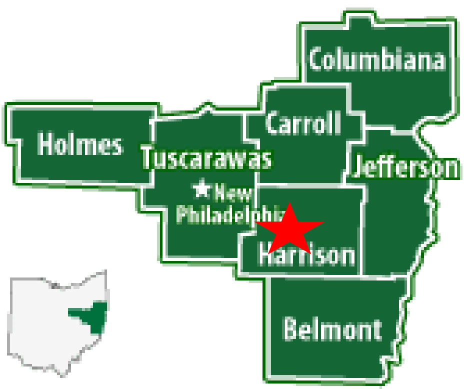
- Project scope
  - Replace two existing box beam bridges over Clendening Lake



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- 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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- Project Challenges
  - Managing and coordinating a large design team
  - First Ohio bridge that utilizes beams that have CFCC prestressing strands
  - Developing two separate sets of project plans (one for beam fabricator and one for general contractor)

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- Final Bridge Designs
  - Combination of different types of foundations due to variability in bedrock (drilled shafts, pile foundations and spread footings)
  - Both bridges are single span composite box beam bridges on reinforced concrete wall type abutments
  - One bridge scoped to be conventional materials while the other bridge scoped to be non-conventional materials

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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

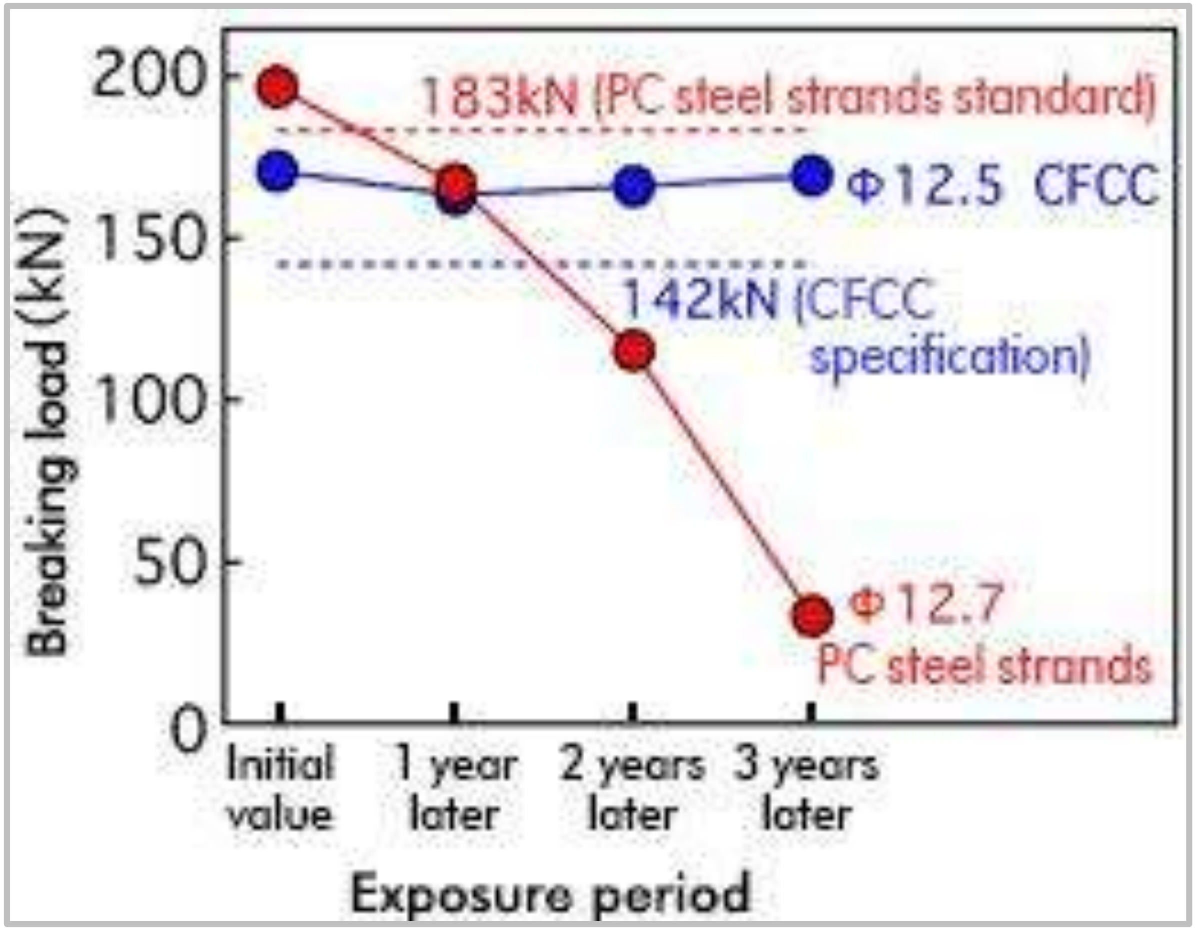
CARBON FIBER COMPOSITE CABLE (CFCC)

- High corrosion resistance
  - > Superior resistance to acid and alkali
    - Oceans
    - Areas using salt for de-icing of roads

Condition of CFCC after exposure

Condition of low relaxation strands after exposure

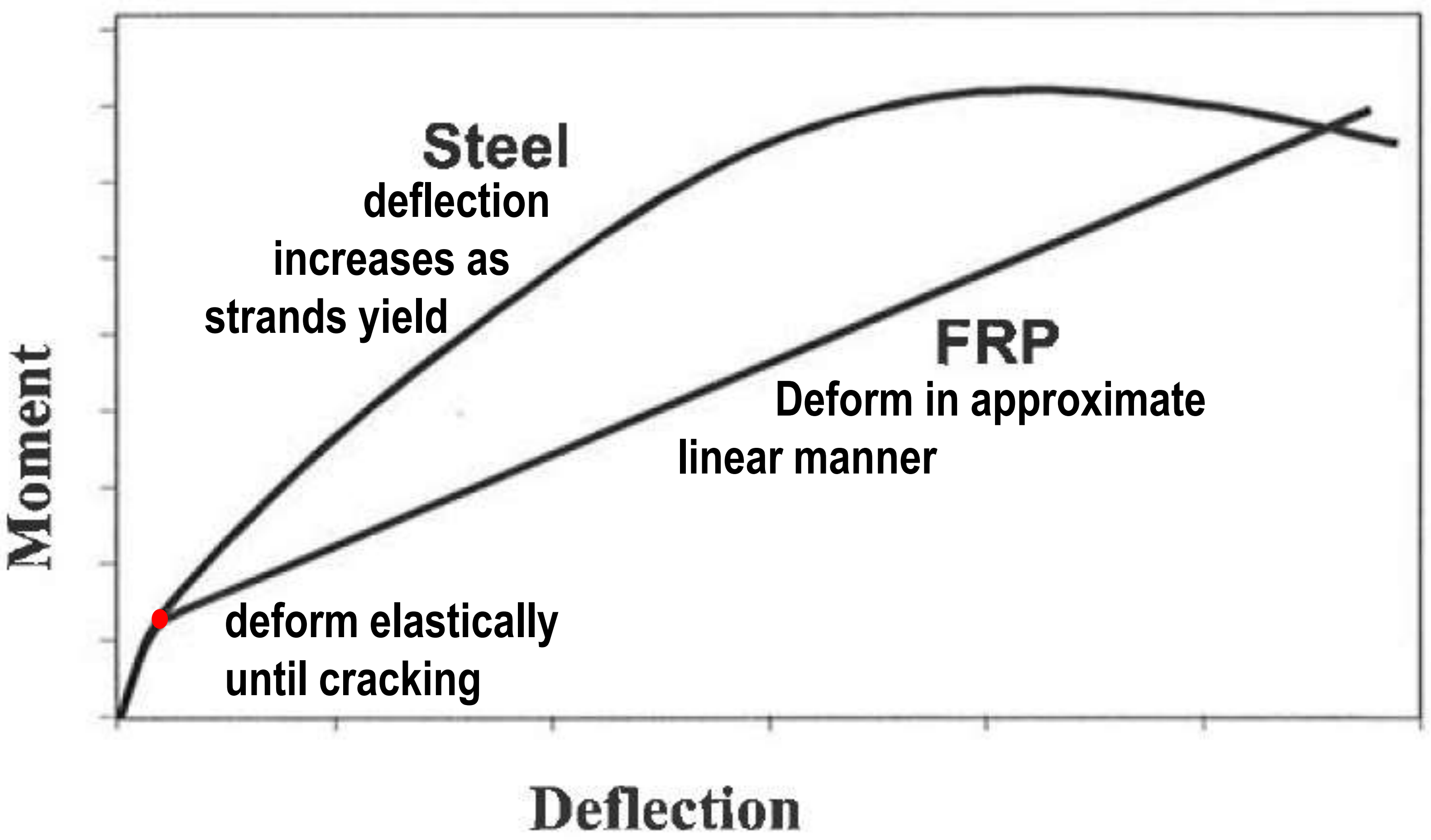
CFCC – HIGH CORROSION RESISTANCE



DESIGN CHALLENGES WITH CFCC

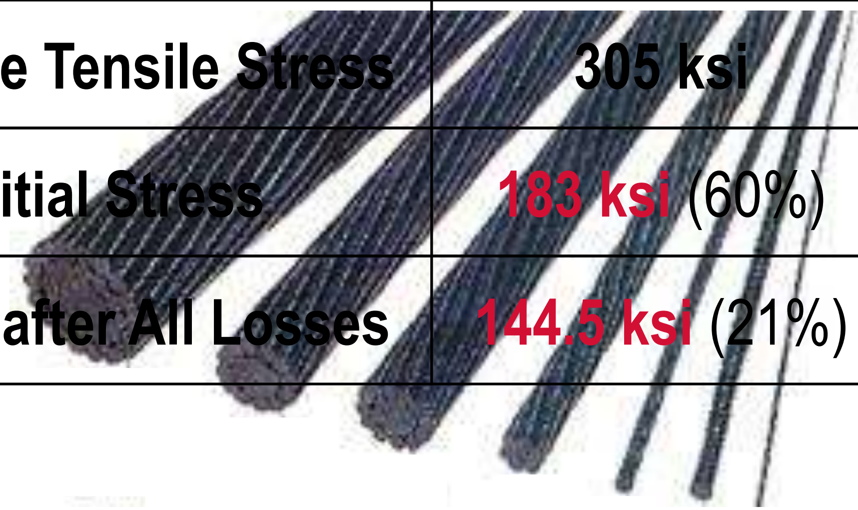
- Designed using ACI-440.4R-04 (Prestressing Concrete Structures with FRP Tendons)
- Tensile stress allowed at service limit state
  - Zero for CFCC design
  - $0.0948\sqrt{f'c}$ = 250 psi for a severe corrosive environment (AASHTO Table 5.9.4.2.2-1)
    - Resulted in more strands to limit concrete tensile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

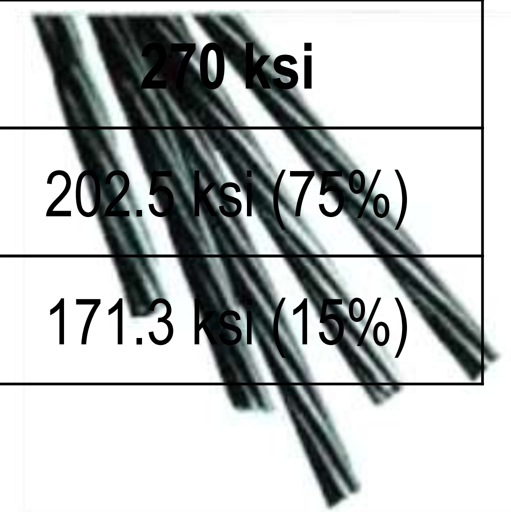
DEFORMATION CHARACTERISTICS



CFCC VS STEEL PRESTRESSING

	CFCC	Low Relaxation
Diameter	0.6 inch	0.5 inch
Area	0.179 sq in	0.167 sq in
Ultimate Tensile Stress	**305 ksi**	**270 ksi**
Initial Stress	**183 ksi** (60%)	202.5 ksi (75%)
Stress after All Losses	**144.5 ksi** (21%)	171.3 ksi (15%)





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

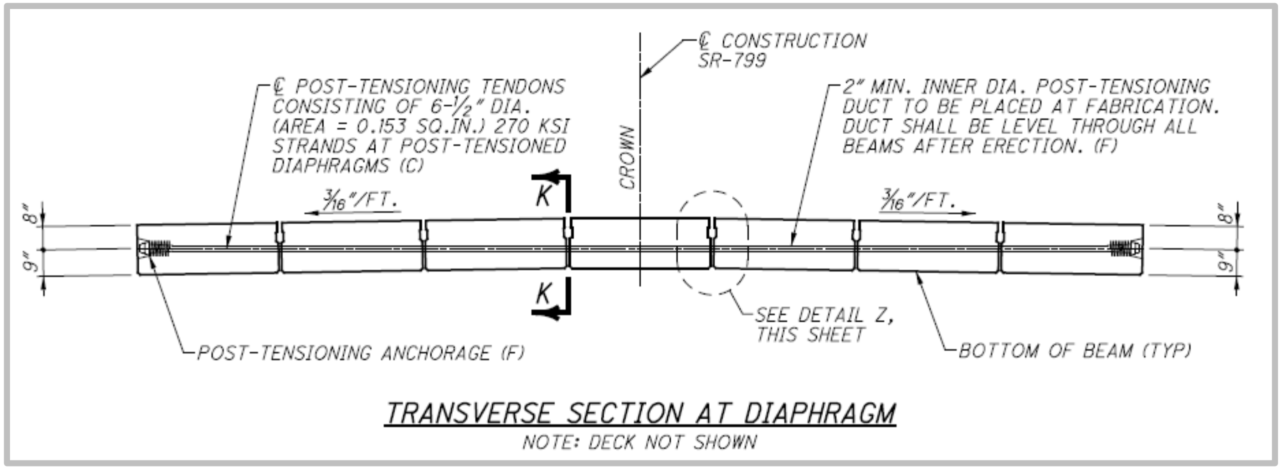
CFCC VS TRADITIONAL BRIDGE

- 7 CB17-48 box beams; 55'-0" span

	HAS-799-0390 CFCC & Stainless	HAS-799-0452 Traditional
Strand	0.6 inch diameter 0.179 sq in	0.5 inch diameter 0.167 sq in
Number of Strands	36 CFCC	28 Low Relax
Release Concrete	6.5 ksi	5.5 ksi
Final Concrete	7 ksi	7 ksi

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



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

PAST PROJECTS AND EXPERIENCE

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

PSI's Second CFCC Project in St. Joseph, MI in 2016.

(59) CFCC Strands

Epoxy Coated Rebar

HN4249 x 107' Long

PRESTRESS SERVICES INDUSTRIES, LLC

PREPLANNING FOR CFCC

1. Bed selection and number of beams per cast.
2. Coupler staggering layout and stressing sequence.

1. Bed Criteria

Based on stressing capacity and making full use of the casting bed length

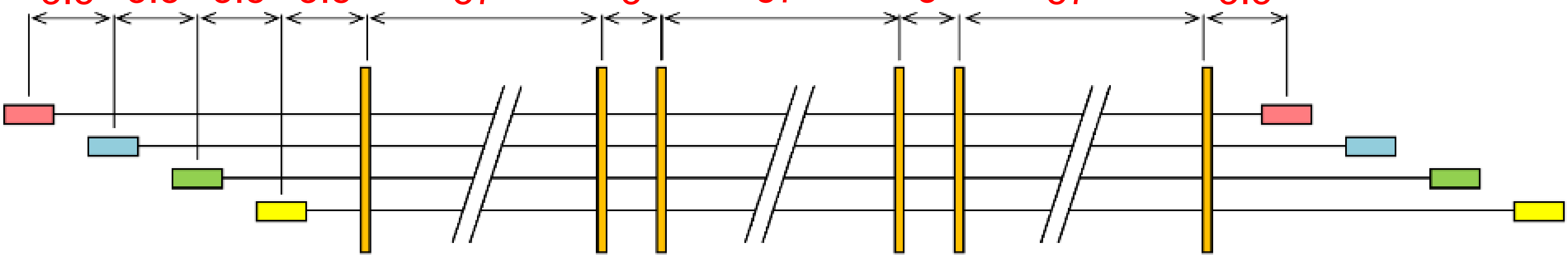
- Harrison County, OH CFCC beams consists of (7) beams 17” x 48” x 57’ long.
- The beams have (36) .6” dia. strands pulled to approximately 33,500 lbs.
- Number of coupler locations were (4) spaces at approximately 4’-0”

2. Sequencing Criteria

Based mainly on the size of the coupler.

PREPLANNING FOR CFCC

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

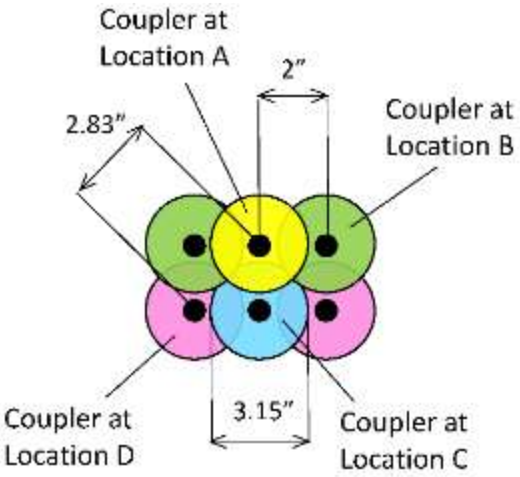


<u>Bed Allowances</u>

- ✓ (3) Beams per cast = 57’ x 3 = 171’-0”
- ✓ (2) Gaps between beams = 3’ x 2 = 6’-0”
- ✓ <u>(4) Locations @ 3’-6” x 2 ends = 28’-0”</u>
- ➢ Total Above = 207’ ➡ Use 210’ Casting Bed

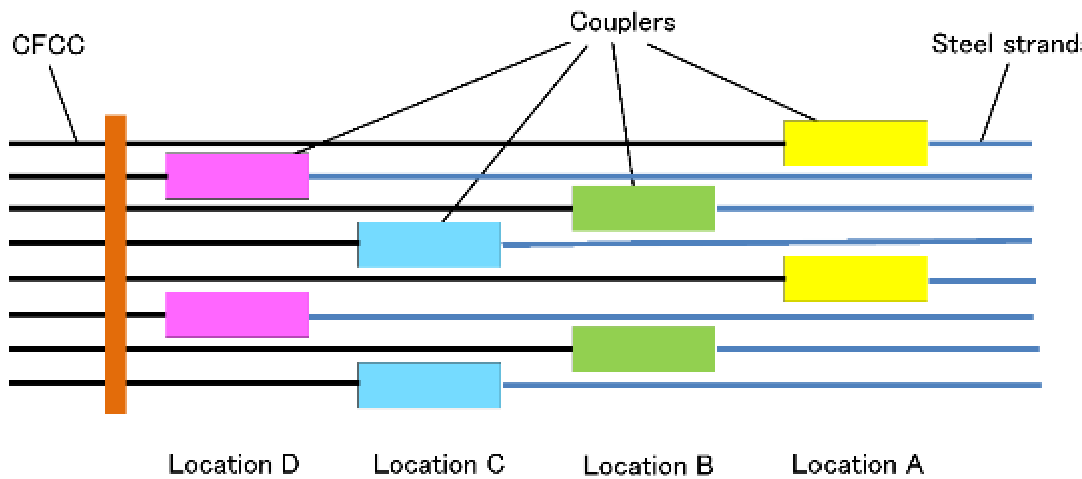
<u>Strand Length based on ‘Chuck to Chuck of 225’</u>

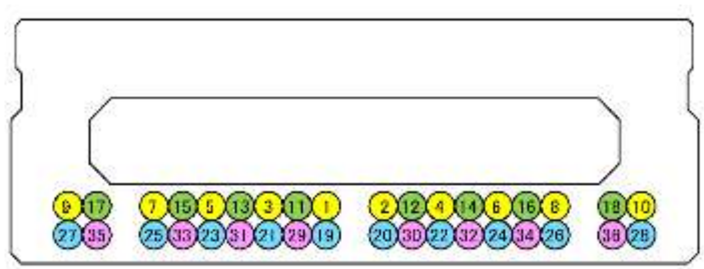
- ➢ CFCC = (3.5’ x 5) + (57’ x 3) + (3 x 2) = 194.5’
- ➢ Steel = 225’ Chuck to Chuck – 194.5 CFCC = 30.5’



PREPLANNING FOR CFCC

Coupler Layout & Stressing Sequence





Elongation is a critical component of the coupler layout and sequencing preplanning

SAFETY AND CFCC STRAND

SAFETY AND CFCC STRAND


Installing


Cutting


Running

HANDLING CFCC

Pushing Machine

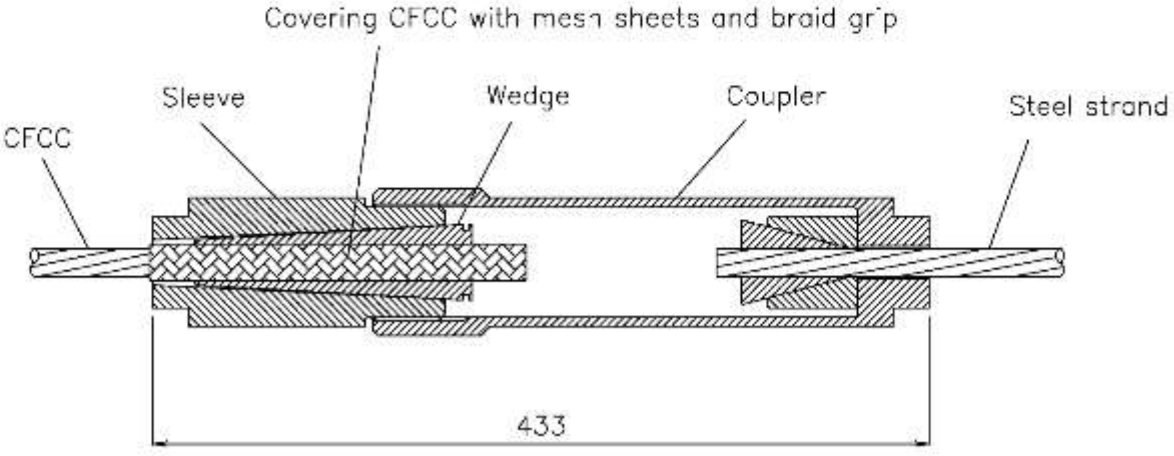
THE COUPLER


Buffer


Braiding


Wedges


Steel


Covering CFCC with mesh sheets and braid grip
Sleeve
Wedge
Coupler
Steel strand
CFCC
433

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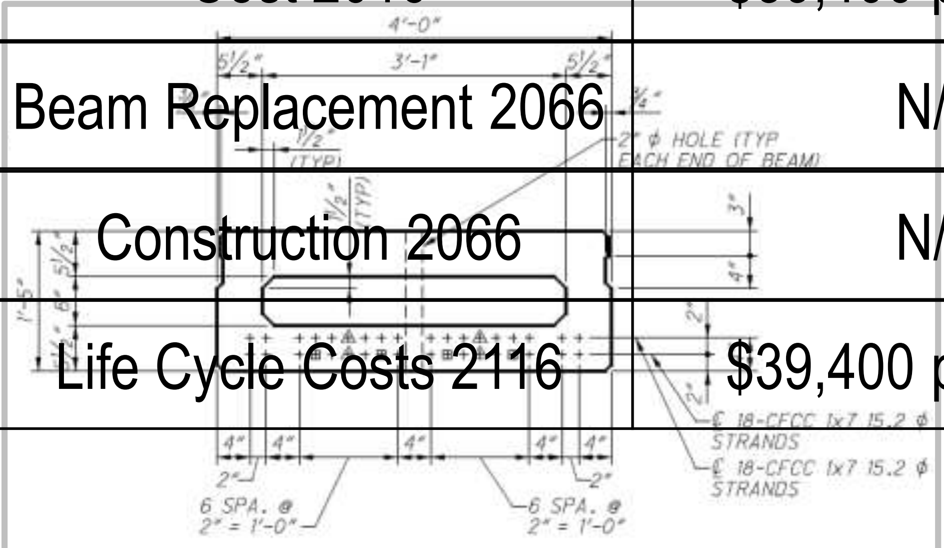
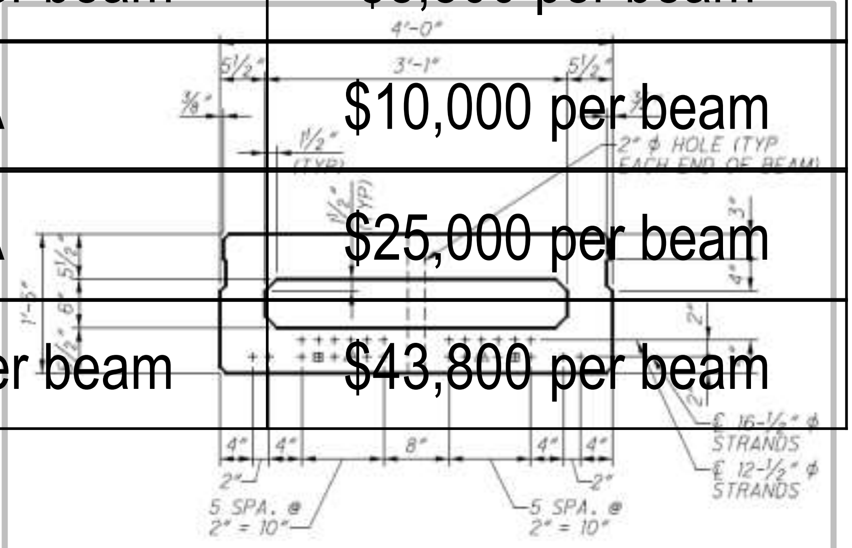
Picture of
Final Product

CFCC VS TRADITIONAL BRIDGE

	HAS-799-0390 CFCC & Stainless	HAS-799-0452 Traditional
Life Span	100+ years	40 - 50 years
Cost 2016	$39,400 per beam	$8,800 per beam
Beam Replacement 2066	N/A	$10,000 per beam
Construction 2066	N/A	$25,000 per beam
Life Cycle Costs 2116	$39,400 per beam	$43,800 per beam



CB17-48 CFCC PATTERN



CB17-48 STRAND PATTERN

SUMMARY

- Unique learning experience
- Increasing the life of box beam bridges
  - Carbon fiber prestressing strands instead of the steel strands
  - Stainless steel reinforcing instead of typical epoxy-coated rebar
  - Transversely post-tensioning
- Contractor sale date: August 11, 2016

THANK YOU & FOR MORE INFORMATION

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