CFRP CONCRETE PROTECTION AND STRENGTHENING

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TxDOT Bridge Construction & Maintenance Section
TxDOT’s Use of Carbon Fiber Reinforced Polymer Wraps

- Until now, used primarily for confinement of concrete members
- Moving forward, will also use CFRP for strengthening of concrete members
  - Increasing capacity
  - Restoring capacity
- Based on ACI’s guidelines and recent research from The University of Texas at Austin
- Don’t have any plan to use on steel rehabilitation
Where We are Now

- 2014 Standard Specifications
  - Special Specification 4191 becomes Standard Spec Item 786, “Carbon Fiber Reinforced Polymer (CFRP)”
  - Minimum training requirements for installers
  - Detailed surface prep, installation, and testing requirements

- Two categories
  - Protection (also confinement)
  - Strengthening
    - TxDOT provides minimum additional shear and/or moment capacity
    - Contractor must submit signed and sealed calculations

- Preapproved materials only
Preapproved List

- List maintained by Bridge Division
- Additional suppliers recently added:
  - DowAksa
  - Simpson Strongtie

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<table>
<thead>
<tr>
<th>2004 Specifications</th>
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SPECIAL PROVISION

TO

SPECIAL SPECIFICATION

4191–001

Carbon Fiber Reinforced Polymer (CFRP) for Strengthening Concrete Structural Members

For this project, Special Specification Item 4191, “Carbon Fiber Reinforced Polymer (CFRP) for Strengthening Concrete Structural Members,” is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

Article 4191.2 Materials. Table 2, “Approved CFRP Systems” is voided and replaced by the following:

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Approved CFRP Systems</th>
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<tbody>
<tr>
<td>Product Name</td>
<td>Producer</td>
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<tr>
<td>SikaWrap Hex 117C</td>
<td>Sika Corporation</td>
</tr>
<tr>
<td>Tyfo SCH-11UP</td>
<td>Fyfe Corporation, LLC</td>
</tr>
<tr>
<td>MBrace CP130</td>
<td>BASF Construction Chemicals</td>
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</tbody>
</table>
Preapproved List

- DMS-4700 completed and ready for distribution
- Construction Division will maintain Material Producer List
- Protection and strengthening
- For now, independent lab results will be accepted
Repairing Vehicular Impact Damage

- CFRP can make up for lost strands
  - Ultimate strength only
  - Does not carry dead load
  - No effect on cracking moment
- Increases ductility
- Sacrificial reinforcing in lateral direction
The Finished Product
Prestressed Concrete Impact Damage Repair

Recent repair performed by TxDOT maintenance crew
Substructure Impact Damage Repair
FRP helps absorb and distribute load during subsequent impacts.

Distributing Impact Loads and Stresses
Current CFRP Use – Lake OH Ivie Column Confinement

- Concrete expanding and cracking due to alkali-silica reaction (ASR)
- Checkerboard pattern installed in 2004 ineffective
- 100% CFRP coverage in 2012
Lake OH Ivie Column Confinement – Before the Work
Lake OH Ivie Column Confinement - Installation
Lake OH Ivie Column Confinement - Installation
Repairing Fire-Damaged Concrete
Repairing Fire-Damaged Concrete

- CFRP for beam: shear strengthening
- CFRP for columns: confinement
- Concrete encasement for bent cap
Substrate:
- Concrete-only for now
- No plans to use on structural steel

Different types of FRP
- Carbon fiber is stronger
- In the past glass fiber was more economical; the cost difference is currently negligible compared to overall cost of work
Significant cost and historic benefit if using to strengthen as alternative to replacement (complicate shapes and significant shoring requirements)

Significant aesthetic improvement:
- CFRP finish is uniform and can match concrete when coating is allowed
- Concrete patch material seldom matches surrounding material and results in patchwork appearance

Potential disadvantage is that future damage under CFRP not visible
Patchwork Appearance – Conventional Patching
Concealed Problems
CFRP on Historic Bridge – Maybe not the Best Example
Applications on Historic Structures

- Increasing capacity for vehicular loading
- Restoring capacity to account for damage or deterioration
- Multiple coating options to help retain existing aesthetic features
  - Paint
  - Silicone resins high performance paints that match concrete appearance
- Potential to maintain a cleaner structure by washing an impermeable surface
- Long lasting – Don’t have the history but the concept should prove out
Texas Historic Commission

- Met with some resistance or differing opinions in the past
- Recently took part in panel discussion
- THC appears to be receptive to the idea of utilizing CFRP on historic bridges
  - Preference is still to leave existing surfaces exposed
  - CFRP is preferable to large scale removal and replacement
- Coated CFRP can more closely resemble surrounding concrete than patching
Strengthening in the Past
Historic Bridge Application

- TxDOT’s first application – Arroyo Burro Bridge in South Texas
  - Increasing shear capacity on concrete arches
  - Anchored CFRP
Planned Strengthening - Arroyo Burro Bridge
Variable Depth Concrete Girder Unit

26"

24"

3'
Variable Depth Concrete Girder Unit
Variable Depth Concrete Girder Unit
Variable Depth Concrete Girder Unit

Positive Moment Section
Arroyo Burro Bridge

**TABLE OF ESTIMATED QUANTITIES**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>QUANTITY</th>
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<tbody>
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<td>5061 2060</td>
<td>Concrete Span Finish</td>
<td>SF</td>
<td>50.0</td>
</tr>
<tr>
<td>5070 2060</td>
<td>Carbon Fiber Overlay</td>
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(1) Includes CFRP Anchor

**PROCEDURES:**

1. **Epoxy:** Pour into mixing with form 794. **Epoxy Resin** and 2040. **Epoxy Thickner** to mix 1:1 ratio. Place a measured amount of epoxy in the area to be treated. Use a trowel to spread the epoxy to ensure a uniform thickness.

2. **CFRP:** Mix in accordance with the Specifications.

3. **Steel Rods:** Use #11, Carbon Fiber Reinforced Polymer (CFRP).

4. **Placement:** Place the CFRP in the areas as specified in the plans. Place the CFRP in the areas as specified in the plans. Follow the reinforcement procedures to assure proper bond. Place the CFRP in the areas as specified in the plans. Follow the reinforcement procedures to assure proper bond.

5. **Paint:** Apply a top coat of paint as specified in the plans. Follow the reinforcement procedures to assure proper bond.

**NOTICE:**

1. Submit proposed materials and work procedures to Engineer for approval.

2. Submit proposed materials and work procedures to Engineer for approval.

3. Submit proposed materials and work procedures to Engineer for approval.

4. Submit proposed materials and work procedures to Engineer for approval.

5. Submit proposed materials and work procedures to Engineer for approval.

6. Submit proposed materials and work procedures to Engineer for approval.

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**ARROYO BURRO BRIDGE REPAIR**

195.00' GIRDER UNIT (SOUTH UNIT)

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Effective Date 3/12/2014

01/22/2014

Texas Department of Transportation

2014 TTI Short Course
Arroyo Burro Bridge
CFRP Strengthening per ACI

- **ACI 440.2R-08**
  - *Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures*

- Minimum capacity without FRP
  - \( \Phi R_n \geq 1.1S_{DL} + 0.75S_{LL} \) (Eq. 9-1)
  - Accounts for damaged FRP (especially fire)

- Increasing flexural strength (Chapter 10)
  - Increases of up to 160% documented (*just because you can doesn’t mean you should*)
  - 40% is more reasonable

- Increasing shear strength (Chapter 11)
Anchored CFRP

- Center for Transportation Research (CTR) at The University of Texas at Austin (Report 0-6306)
- Substantially increases bond strength
- Improved ductility through redistribution of load
- New equations for shear strengthening (moment, too)
Anchored CFRP

- 125x125mm CFRP Patches over anchor neck—horiz. and vert. plies
- Hole area = 1.4 x anchor area
- 13mm Typ.
- 60°
- Anchor into concrete
- Hole chamfer 13mm Radius
- Anchor Fan
- Corner Chamfer 13mm radius
Anchored CFRP

CFRP Un-Anchored for Shear Test

CFRP Anchored for Shear Test
QUESTIONS?
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