NSM-CFRP for Bridge Strengthening in Oregon

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AGENDA

Applications
Construction
Specification
Design
Necanicum River Bridge (Built 1939, Rehab 2013)
**GIRDER - CROSSBEAM**

**ELEVATION - INTERIOR GIRDERS**
Scale 1/4"=1'-0"

**ELEVATION - EXTERIOR GIRDERS**
Scale 1/4"=1'-0"

**SECTION A-A**
Scale 1"=1'-0"

**SECTION B-B**
Scale 1"=1'-0"

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**DETAIL B**

*Note*
All KSM-CFRP strips to be installed in grooves according to manufacturer's instructions. Omission grooves according to "Detail B" unless shown otherwise.

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**Girder**

*3 - E300H/177 per interior girder.*

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**Bottom of Girder**

*8" Typi*

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**KSM-CFRP Strips**

*7" - E300H/177 per interior girder. Deacon grooves as required along girder line to drain 1" ground depth of moisture.
GIRDER - CROSSBEAM
GIRDER - CROSSBEAM

PART ELEVATION - INTERIOR GIRDERS
Scale 1/4"=1'-0"

SECTION C-C
Scale 1/4"=1'-0"

SECTION D-D
Scale 1/4"=1'-0"

DETAIL A
Not to Scale

DESCRIPTION:

1. Layout and mark proposed anchor locations.
2. Verify that there are no cracks greater than 0.015 inches wide on the girder being strengthened within the limits of the proposed anchor locations.
3. Lengths extending reinforcement. Adjust the hole location up to 3 inches above the top of the girder to avoid reinforcement. Drill hole to required depth.
4. Clean and polish the hole with a high-pressure water system that has a rotating steel brush.
5. Vacuum the hole and insert the drilled hole for shotcrete. After curing and opening, fill with new concrete in the hole. Insert anchor rod into the top of the anchor rod. Insert the anchor rod and twist it at least 360 degrees during the insertion process.
6. Read the manufacturer's recommended time to reach 3500 psi compressive strength and cure the PCI grouting material as recommended by the manufacturer before opening the section to traffic.
GIRDER - CROSSBEAM

Aslan 500 + Concresive Paste LPL
Umpqua River Bridge (Built 1936, Rehab 2016)

BRIDGE DECK

Bridges are essential components of transportation networks, providing critical infrastructure for transportation and economic development. The Umpqua River Bridge, built in 1936 and rehabilitated in 2016, is one such example. The rehabilitation project cost $552,000, with an estimated total project cost of $5,500,000. The bridge deck was a key aspect of the rehabilitation efforts, ensuring the structural integrity and functionality of the bridge. The project involved significant enhancements and improvements to meet modern transportation needs and standards. The details of the rehabilitation work are critical for understanding the advancements made in bridge engineering and maintenance.
BRIDGE DECK

Photo by Mike Goff
BRIDGE DECK

SECTION AD-AD
Scale 1" = 1'-0"

EXP. Joint
(11) Panels @ 1'-6" = 15'-0"

Floor Beam C
150 Pcs.

C-CFRP Strengthening Tapes
between Foot Beer Rebars

18" x 30" arch strut

Arch Spans

NOTES:
- Strengthening material is carbon fiber reinforced polymer (CFRP).
- Provide CFRP Tape
- Insulate joint with FRP, equivalent to #4 @ 15° u.c. radius.

ARCH SPAN PLAN
Endview of Deck
Scale 1" = 1'-0"
BRIDGE DECK
DECK OVERHANG

Thomas Creek
Oak Avenue
OR42
DECK OVERHANG

Thomas Creek Bridge (Built 1961, Rehab 2016)
DECK OVERHANG

Photo by Mike Goff
DECK OVERHANG – THOMAS CREEK
DECK OVERHANG – OAK AVENUE
DECK OVERHANG – OAK AVENUE
Modified pedestrian roll, see details dwg. 9531E.

Remove existing rails, grate, and drain pipe. Plug drain.

Existing utilities, protect in place.

TYPICAL DECK SECTION

Provide as KSM CFRP that meets the following properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>6.3 mm</td>
</tr>
<tr>
<td>Area</td>
<td>0.177 m²</td>
</tr>
<tr>
<td>Tensile Strength (MPa)</td>
<td>2350</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>18000</td>
</tr>
</tbody>
</table>

KSM CFRP Notes:
- Strain at failure of 20% ± 5%.
- Ultimate tensile force of 4.5 ± 0.2 kN.
- Use KSM 605/65 for details.

Design the KSM CFRP using a Reference Factor of 0.9 and an Environmental Reduction Factor of 0.65.

Remove existing bridge rail. Construct modified combination bridge rail, see details dwg. 95309.

Remove existing bridge rail reinforcing to 2-inches below deck grade and patch with a PCC repair material from the ODOT GPL.

1.5 kN/pa for repair

Remove armored joint and cast repair with PCC repair material.

Replace Joint Sealant Hilti

Provide KSM 605/65 plates in joints.
-Putfast welding in accordance to AWS D1.1

0.177 m² x 0.177 m² (pa) with resin bonded anchor rods

Place outside anchor rods

SECTION A-A
DECK OVERHANG – OAK AVENUE
DECK OVERHANG – OAK AVENUE
DECK OVERHANG – OAK AVENUE
CONSTRUCTION ISSUES & SOLUTIONS

- Centering device
- Certified applicator
- Application advisor’s qualification
- Surface preparation
- Overfilled epoxy
CONSTRUCTION SPECIFICATIONS

Wet-layup-CFRP 1998
NSM-CFRP 2006

Construction issue  Improved specs language

Material testing for ODOT QC

Specific epoxy resin for NSM
CONSTRUCTION SPECIFICATIONS

Wet-layup-CFRP 1998
NSM-CFRP 2006

Construction issue → Improved specs language

Material testing for ODOT QC

Specific epoxy resin for NSM
CONSTRUCTION SPECIFICATIONS

ASTM D7205
Pipe length
Sand-blasted surface
Epoxy anchor
CONSTRUCTION SPECIFICATIONS

Wet-layup-CFRP 1998
NSM-CFRP 2006

Construction issue ➔ Improved specs language

Material testing for ODOT QC
Specific epoxy resin for NSM
CONSTRUCTION SPECIFICATIONS

ASTM A944 – Beam-End Test
DESIGN

Conceptual design
Existing capacity
Required additional capacity
CFRP-NSM engineer
15.4—Flexural strengthening of an interior reinforced concrete beam with NSM FRP bars

An existing reinforced concrete beam (Fig. 15.2) is to be strengthened using the loads given in Table 15.3 and the NSM FRP system described in Table 15.5. Specifically, three No. 3 CFRP bars are to be used at a distance 23.7 in. (602.1 mm) from the extreme top fiber of the beam.

![Diagram of beam with FRP bars](image)

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**Table 15.5—Manufacturer’s reported NSM FRP system properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area per No. 3 bar</td>
<td>0.10 in.²</td>
<td>64.5 mm²</td>
</tr>
<tr>
<td>Ultimate tensile strength $f_{pu}$</td>
<td>250 ksi</td>
<td>1725 N/mm²</td>
</tr>
<tr>
<td>Rupture strain $f_{pu}$</td>
<td>0.013 in./in.</td>
<td>0.013 mm/mm</td>
</tr>
<tr>
<td>Modulus of elasticity of FRP laminates $E_f$</td>
<td>19,230 ksi</td>
<td>132,700 N/mm²</td>
</tr>
</tbody>
</table>

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Fig. 15.2—Schematic of the idealized simply supported beam with FRP external reinforcement.
# Desgın

Necanicum River Bridge

<table>
<thead>
<tr>
<th>Location</th>
<th>Force Effect</th>
<th>Additional Factored Resistance</th>
<th>DWG. Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bent 1 Crossbeam</td>
<td>+M</td>
<td>200 FT-K</td>
<td>92484</td>
</tr>
<tr>
<td>Bent 5 Crossbeam</td>
<td>+M</td>
<td>250 FT-K</td>
<td>92484</td>
</tr>
<tr>
<td>Span 1 Interior Girder</td>
<td>+M</td>
<td>175 FT-K</td>
<td>92481</td>
</tr>
<tr>
<td>Span 1 Exterior Girder</td>
<td>+M</td>
<td>125 FT-K</td>
<td>92481</td>
</tr>
<tr>
<td>Span 3 Interior Girder</td>
<td>+M</td>
<td>175 FT-K</td>
<td>92482</td>
</tr>
<tr>
<td>Span 3 Exterior Girder</td>
<td>+M</td>
<td>125 FT-K</td>
<td>92483</td>
</tr>
<tr>
<td>Interior Girder over Bents 3 &amp; 4</td>
<td>-M</td>
<td>500 FT-K</td>
<td>92482</td>
</tr>
</tbody>
</table>

Notes:
All NSM-CRF to manufacture to "Detail B-B".

2 ~ 63"NSM177 per interior girder. Deepen groove as required along girder line to attain 1" groove depth at midspan.

Section B-B
Scales 1" = 1'-0"
**Umpqua River Bridge**

**REFERENCE**

As constructed drawings:

- Bridge structure (1933) dwgs. 4788 thru 1987
- Existing Material Properties:
  - Shaft, Columns, Beams, and all parts (except footing and pier base)
    - $f'_c = 2400$ psi (Class A, built 1933)
  - Deck slab, sidewalk, and handrail
    - $f'_c = 2700$ psi (Class D, built 1933)
    - $f'_y = 33000$ psi (unknown, built 1933)
- Core samples taken on Deck slab and Beams 1 and H at Spans 1 and 29
- Average $f'_c = 7152$ psi Deck slab (Field testing May 2015)
- Average $f'_c = 5438$ psi Beams 1 and H
- For Resin Bonded Anchor design $f'_c = 4000$ psi.

**NOTE:**

- Strengthening materials include:
  - Carbon fiber reinforced polymer (CFRP).

**DETAIL T**

- Provide CFRP Tape
- Near surface mount (NSM) equivalent to $4 @ 15''$ o.c. rebar

**Paint laminate material with a paint mixture containing a #8 sand mix to provide bonding for class 2 surface finish.**

**Provide CFRP Laminate equivalent to (1) #11 rebar.**

**Span locations:** 1, 3, 4, 6, 7, 9, 16, 18, 19, 21, 23, 25, & 29

- (2) Interior girders per span

**Scale: $\frac{1}{16}'' = 1'-0''$**
DESIGN

Typical Details

Provide an NSM CFRP that meets the following properties:

<table>
<thead>
<tr>
<th>Width</th>
<th>Thickness</th>
<th>Area</th>
<th>Tensile Strength</th>
<th>Tensile Modulus of Elasticity</th>
<th>Ultimate Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
<td>in²</td>
<td>ksf</td>
<td>kcal/ in²</td>
<td>%</td>
</tr>
<tr>
<td>0.63</td>
<td>0.177</td>
<td>0.11</td>
<td>225</td>
<td>15000</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**NSM CFRP Note:**
Strengthen the ex.g. deck overhang to resist an ultimate moment of 17.3 kip-ft/ft and an ultimate tension force of 5.6 kip/ft from the combined resistance of the NSM CFRP and the existing deck reinforcement.

Design the NSM CFRP using a Resistance Factor of 0.9 and an Environmental Reduction Factor of 0.05.

See Special Provision 00565 for details.
DESIGN

Typical Details

Design Section

<table>
<thead>
<tr>
<th>Width</th>
<th>Thickness</th>
<th>Area</th>
<th>Tensile Strength</th>
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<tbody>
<tr>
<td>in.</td>
<td>in</td>
<td>in²</td>
<td>ksf</td>
<td>ksf</td>
<td>%</td>
</tr>
<tr>
<td>0.63</td>
<td>0.177</td>
<td>0.11</td>
<td>285</td>
<td>18000</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Provide on NSM CFRP that meets the following properties:

NSM CFRP Note:
- Strengthen the exisiting overhang to resist an ultimate moment of 17.3 kip-ft/f and an ultimate tension force of 5.6 kip/ft from the combined resistance of the NSM CFRP and the existing deck reinforcement.
- Design the NSM CFRP using a Resistance Factor of 0.9 and an Environmental Reduction Factor of 0.05.
- See Special Provision 00565 for details.

**Ext. @ 5½" (fy=40 ksi)

Assumed f′o=4.0 ksi

**Spacing of NSM CFRP strips, as determined by manufacturer's engineer.

See NSM CFRP Note.

See Special Provision 00565 for details.