CEA Transportation Connects Alberta Conference

Counteracting Microbial Induced Corrosion - Reed Narrows Bridge

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Microbiologically Influenced Corrosion (MIC)

- ***Definition:*** "metal deterioration as a result of the metabolic activity of micro- organisms."

- **Sulfate-Reducing Bacteria (SRB)**
  - Micro-organisms break down organic material
    - Properties between algae and fungi
    - Bacteria doesn't consume the steel, it reduces sulphate to hydrogen sulfate which corrodes the steel
  - Sulfate in water and sediment reacts with SRB

$$SO_4 \xrightarrow{SRB} H_2S$$

$$H_2S + Fe \rightarrow FeS + H_2$$

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Reed Narrows Bridge

- 165m, 7-span precast concrete girder bridge
- Constructed in 1973
  - Deck and girders in good condition
  - ~30 years of service life remaining
- Substructure
  - 6 piers (pile bents)
    - 6 unreinforced concrete-filled steel tube piles per pier (36 total)
    - 610 mm outer diameter
    - 12.7 mm design steel wall thickness

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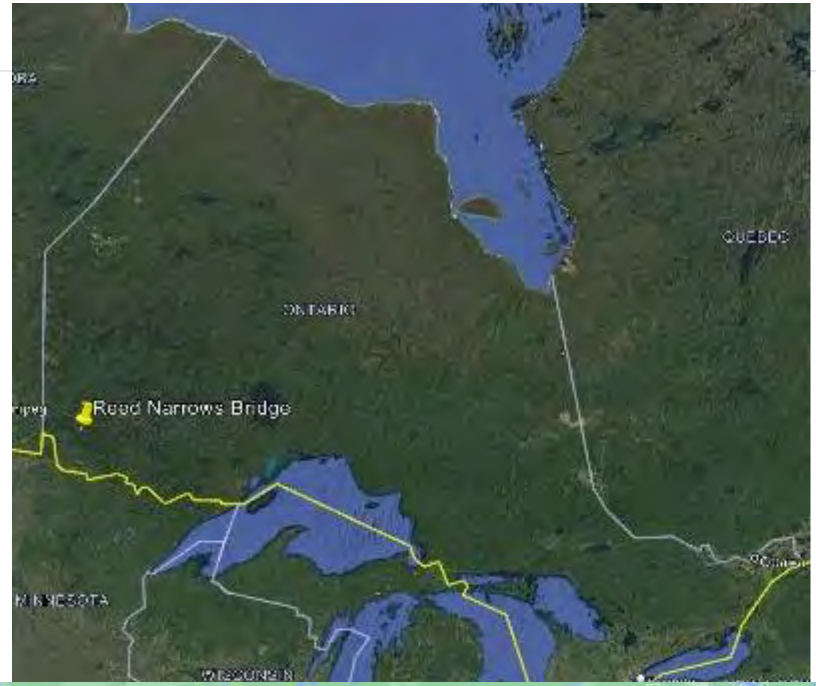
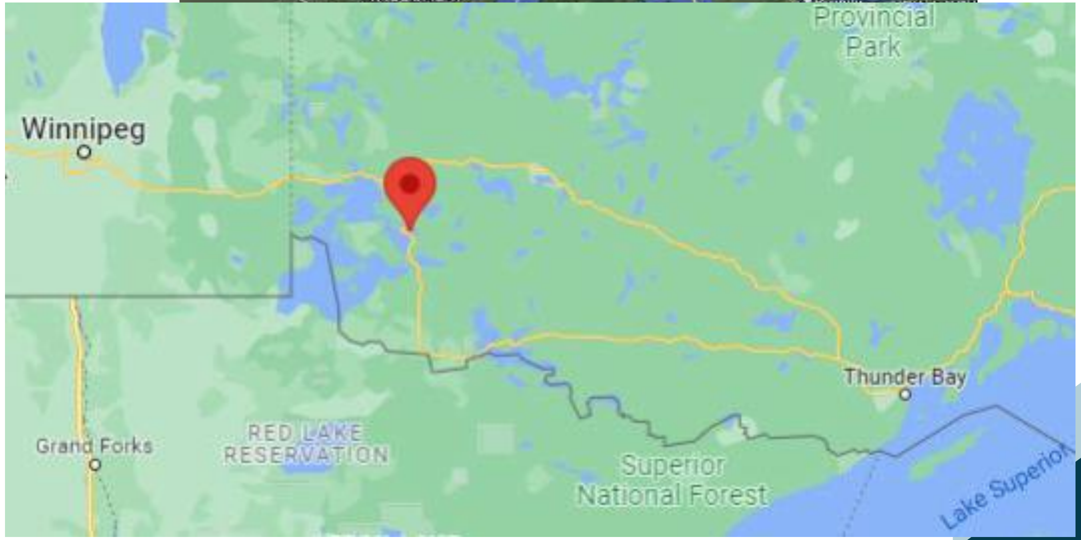
Reed Narrows Bridge

- Lake of the Woods, Ontario
  - Massive fresh-water lake with over 100,000 km of shoreline
- Ontario Ministry of Transportation
  - Highway 71 connects Hwy 11 to Hwy 17
  - Less than 100 km from Manitoba border
- Water depth varied from 0.5 – 2.0m at the piers
- High recreational usage of the watercourse
  - Navigation had to be maintained during construction
- High fish and fish habitat sensitivity (cool water)





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Pipe Pile Condition

- 2018 underwater investigation
  - Pile cleaned of algae below water
  - Ultrasonic testing (UT) and pit gauge utilized
- Severe MIC identified
  - Band of severe pitting located ~0.5-1.0m below waterline on all piers
  - Average 62% section loss (maximum pitting depth was 86%)
  - Shiny steel pile surface under organic scale

Substructure Evaluation

- **Intent was to determine when pile intervention would be required**
- Started with 30% section loss, went up 10% increments (40%, 50%, 60%, 70%) until failure
- *Assumptions*
  - Fixed piers analyzed (largest reactions)
  - Considered only the steel section (no concrete fill)
  - Assumed uniform section loss around pile perimeter
  - Battered piles resist lateral loads; and therefore, lateral deflections were not sufficient to develop passive resistance along the pile shaft. Thus, soil springs were not used in the analysis.
  - As per CHBDC Section 14, ice loading and temperature effects not considered
- *Results*
  - Pile failure at 70% section loss → *compared to 62% avg observed in field*
  - “Do Nothing” approach would result in 100% section loss in 27 years
  - Pile strengthening required for Bents 1-4
  - Bents 5 &6 had less section loss and could be candidates for encapsulation

Life Cycle Cost – Options Considered

1) Pile encapsulation

- Protect from further corrosion; no additional strength
- Maintain current condition for remainder of service life

2) Pile strengthening

- Protect piles from further corrosion <u>*AND*</u> increase load carrying capacity

3) Full bridge replacement

- High cost (detour structure required, new in-water substructure)
- Environmental impacts to fish habitat

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2019 Repair Strategy

- Pile Strengthening of all piles recommended
  - Minimal cost difference between strengthening all vs. select piles
  - True composition of the piles (if concrete filled) is unknown
  - Level of certainty in localized and global section loss

Challenges

- Retrofit completed in wet conditions
  - Cofferdam would be costly due to pile bent configuration
- Qualified divers required for installation
- Equipment sourcing and use
- Short in-water work timing window (July 16th to March 31st)
- Shallow water at end piers

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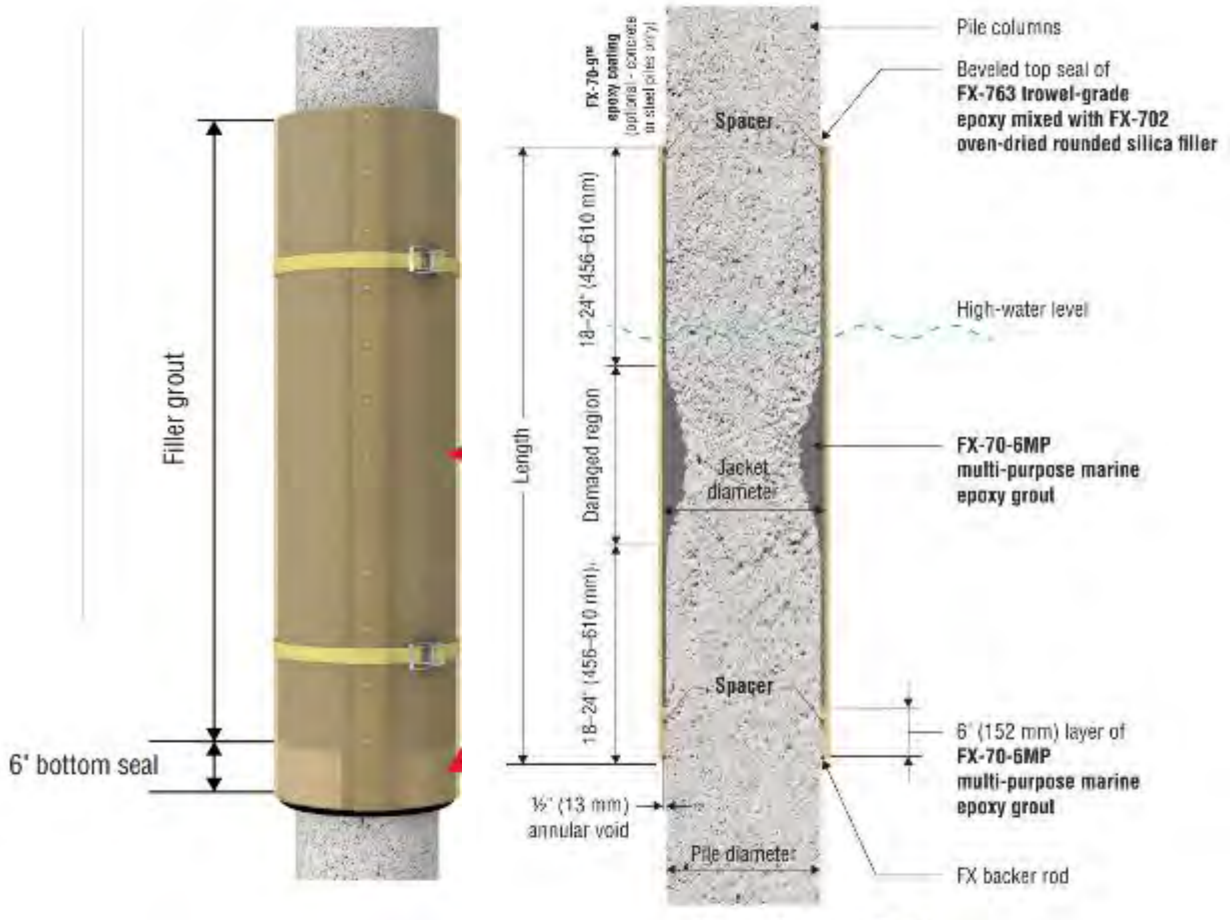
Repair Process



Epoxy Grout Method

- Manually remove organic scale
- Waterblast pile surface to clean
- Hand excavate bottom of repair area
- Install shear connectors
- Install steel cage assemblies
- Water blast encapsulation area
- Blast clean inside surface of translucent FRP jacket
- Install FRP jacket
- Fill voids with epoxy grout

Repair Design

- **Mechanical bond – shear studs**
  - Shear studs installed into solid steel (no section loss)
  - 900 mm attachment zone (top and bottom)
  - 3/8″ diameter studs with a length of 1″ (25 mm)

- **5/8″ diameter threaded bars**
  - 3 reinforcing bars at 8 locations

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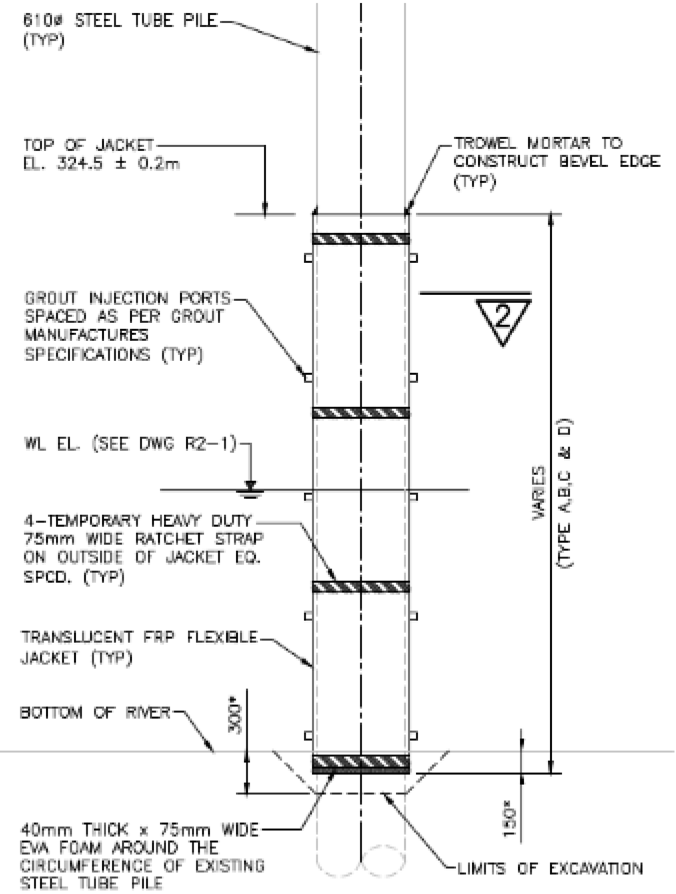
Repair Design

- **Fibre-Reinforced Polymer (FRP) Jacket**
  - 70 MPa (min.) ultimate tensile strength
  - 3 mm (1/8”) thickness, manufactured in 1 piece
  - Extends 150 mm below riverbed for most piles

- **Adhesive Bond – multi-purpose marine epoxy**
  - >60 MPa at 28 days; must be compatible with the FRP

Strengthening Detail



TUBE PILE JACKET
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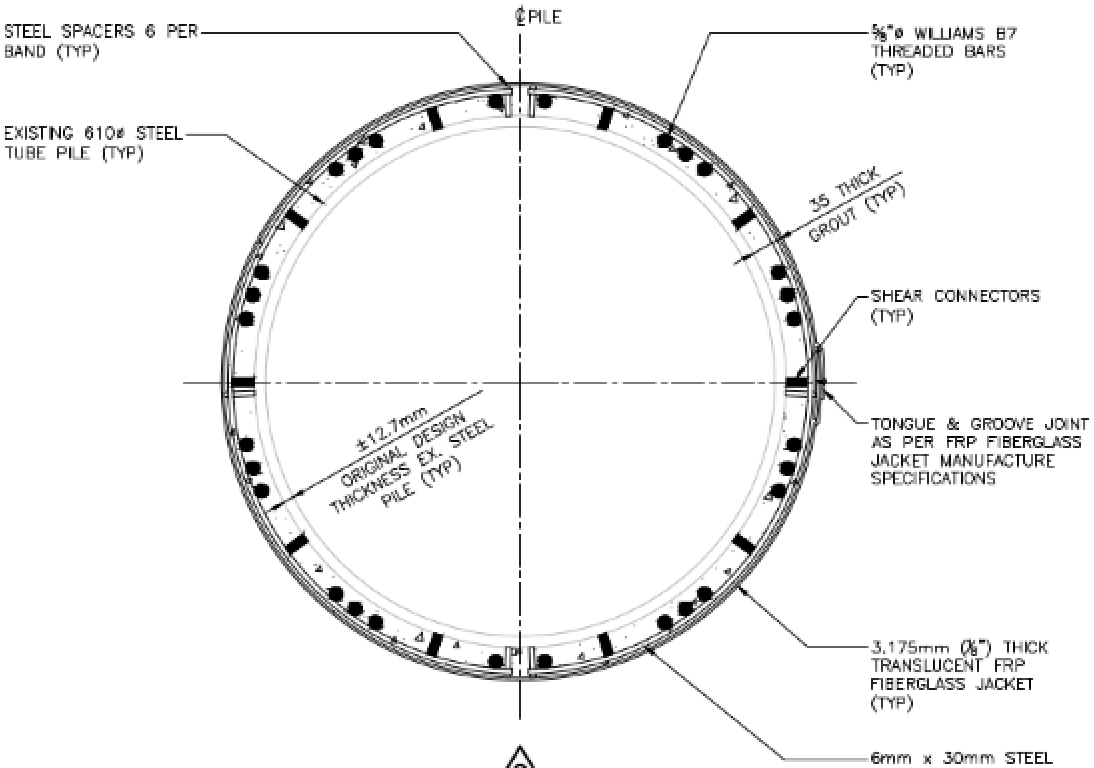
* BOTTOM OF FRP JACKET SHALL BE AT LEAST 150mm BELOW THE RIVERBED. AT PIER BENT 1, PILES 4 & 5 ONLY, BOTTOM OF FRP JACKET SHALL BE ADJUSTED TO BE AT LEAST 400mm



2
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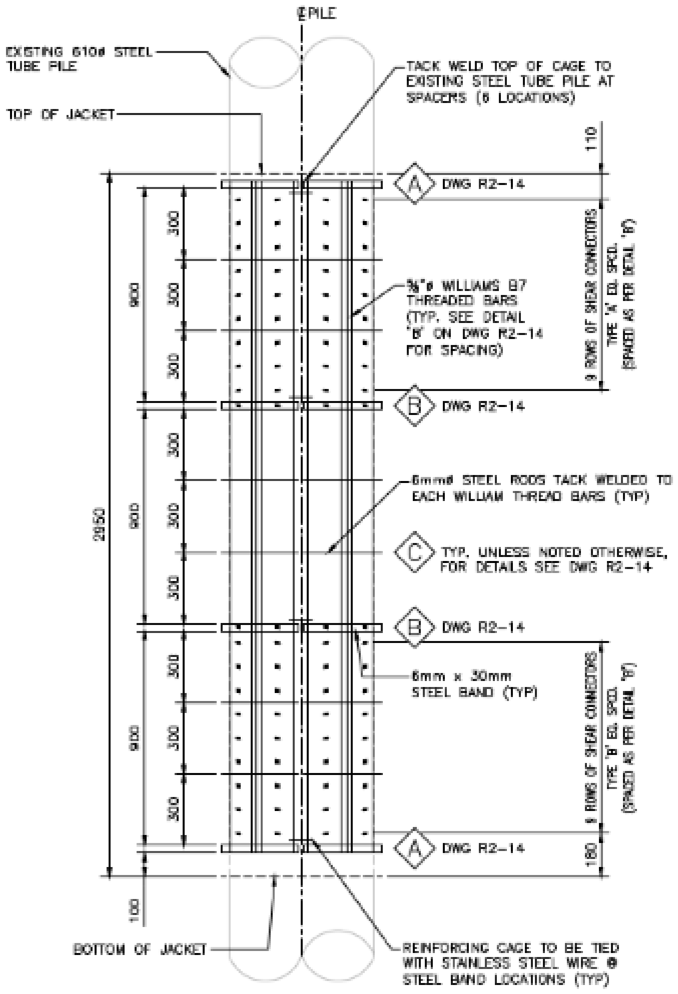

ELEVATION-TYPE C
CAGE ASSEMBLY

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Powder Actuated Tools

- Fasten the shear stud to the pipe pile
    - Stud fully penetrates the steel
    - Metal fuses when the stud enters the steel through the velocity and resulting heat


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Summary

- $6M total rehabilitation cost → $1M for pile repair
- 2 years of construction → pile strengthening completed over 2 weeks in late fall 2019

Future Considerations

- ➢ Difficulty sourcing of the shear stud tool and cartridges

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Dominion Divers

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