Update on Post-Tensioned Structures in Virginia

Michael Sprinkel, P.E.
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Outline

- Bridges Prior to 2001: water cement grout
  - Varina Enon Bridge
- Bridges Since 2001: prepackaged grout
  - Smart Road Bridge
  - Lord Delaware and Eltham Bridges
  - US 460 Bridge
- Bridges in 2017 and Later: flexible filler
- Tendon Inspection and Replacement Issues
- Conclusions
- Recommendations
Varina Enon (VE) Bridge, I295 over James River

- PT grout was a mixture of water & cement ($w/c \leq 0.42$).
- Completed in 1990; 480 external tendons in superstructure.
5-22-2007: Tendon SP12T15 failed after 17 years. Tendon was vacuum grouted in 2004; value of grouting questioned.
Typical Grouted Condition of Draped Tendons (1)

- Grout bleeds and segregates leaving 2 voids, each approximately 2 per cent of the tendon length.
- For 150-ft tendon two 3-ft voids with unprotected strands at anchors is typical (red in figure).
- **Preservation:** NDE methods can not be used to evaluate the condition of the strands. **Install acoustic emission monitoring system to detect wire breaks.**
VE Bridge Longitudinal Tendon Summary

• One of 480 tendons failed.
• Two tendons replaced.
• Corrosion and wire breaks in 2 tendons.
• 55 per cent of tendons vacuum grouted.
• 4 tendons injected with corrosion inhibitor.
• Acoustic emission monitoring to be installed.
Transverse Tendon Failure May 2017
Transverse Tendon Grout Cover
 Moved Out @ 7 Locations

05.10.2017
VE Bridge Transverse Tendon Summary (2)

- NDT Corporation investigated the condition of transverse deck tendons in 2 cable stay spans using Impact echo and drill holes.
- 98 tendons per span (14 tendons per typical segment, 7 typical segments per span).
- Various frequencies found in 120-130 tendons.
- Drilled into over 20 tendons to confirm the grout condition and many locations are fully grouted but with a weak grout.
- 7 tendons believed to be failed because grout cover had moved were not failed.
Preservation: Four Tendons Injected with Corrosion Inhibitor July 21-28, 2015 (3)

- Hydrocarbon and silicon based material injected
- Many leaks before and during injection, connections sealed with epoxy paste or fiber reinforced polymer
- Inhibitor moves through the interstitial space between strand as well as voids in tendon
- All tendons were successfully impregnated
- Cost: per tendon (mobilization: $3,947; injection: $8,275)
- Post construction treatments: seal tendons, inject corrosion inhibitor and vacuum grouting
Acoustic Emission Monitoring to Detect Wire Breaks

- Acoustic emission monitoring is the most economical technology for identifying corrosion in tendons.
- Tendons can be monitored closely for wire breaks and plans can be made for replacement.
- Un-anticipated lane closures because of tendon failures can be avoided.

AE Events: August 30 and September 9, 2009
Smart Road Bridge 2001
First bridge to be grouted with a prepackaged material
Smart Road Bridge

• NDT Corporation (NDT) and Siva Corrosion Services, Inc. investigated the quality of the grout and the corrosion condition of post-tensioning tendons.
• GRP and Impact-Echo Testing and Drill Hole Verification of selected longitudinal tendons
• Corrosion and Grout Testing
Smart Road Bridge Summary

- 226 longitudinal tendons
- 19 tendons investigated
- Impact echo testing on 16 tendons 5,300 ft.
- Obtained grout samples for 9 tendons.
- Measured half-cell potentials and rate of corrosion on 7 tendons.
Smart Road Bridge Summary

• 4-ounces of water collected from one anchor.
• Thin voids about 1/8-in thick found in two bottom continuity tendons
• Thin voids about 1/3-in thick found in one tendon bottom continuity tendon
• One top cantilever tendon found to have a 33’ long void with no grout and moderate corrosion on surface of strands. Vacuum grouting recommended.
Smart Road Bridge Summary (5)

• Longitudinal cracks were observed running along the underside of the top cantilever tendons. Cracks influenced IE readings.
• The grout and strand condition was very good throughout the bridge.
Lord Delaware and Eltham Bridges 2006
Lord Delaware and Eltham Bridges
Two sets of seven 4-span continuous spliced PT bulb tee girders 880-ft long in each bridge (Four locations and 14 miles of PT tendons)
Problem: Tendons not grouted correctly.
Problems caused by Water in Tendons

Spall in web caused by water freezing in tendon

Water leaking from closure pours

Water, calcium hydroxide, and rust stains from water leaking from tendons
Summary: Lord Delaware and Eltham Bridges

• **Condition:**
  - All 84 tendons in 28 girders likely contain water, soft grout and voids. Elevated iron and sulfate contents in water. Rust stains indicate corrosion.

• **Preservation:**
  - Acoustic emission monitoring to be installed to identify wire breaks.
  - Repair decisions can be based on wire breaks.
  - Developing plans to dry and inject corrosion inhibitor into 3 tendons in 1 girder and drain tendons and repair spalls and delaminations in all 28 girders.
Two US 460 Bridges 2014
First PT project to require a grouting mock up.
ASBI Award in 2017
US 460 Bridge Summary

- NDT Corporation (NDT) and Siva Corrosion Services, Inc. investigated the quality of the grout and the corrosion condition of post-tensioning tendons.
- 188 longitudinal tendons per bridge, 376 total.
- 19 tendons investigated
- Impact echo testing on 12 tendons 4,200 ft.
- Obtained grout samples from 8 tendons.
- Measured half-cell potentials and rate of corrosion on 6 tendons.
US 460 Bridge Summary (6)

• Thin chalky grout at top of bottom continuity tendon.
• Small void at top of grout cap on partially external tendon.
• Very weak sand like grout at top of grout cap on partially external tendon.
• The grout and strand condition was very good throughout the bridge.
• Strands for strength and serviceability:
  - External tendons: strands shall be carbon steel
  - Internal tendons: strands shall be stainless steel
• Strands for erection only shall be carbon steel.
• Ducts:
  - External: smooth high density polyethylene.
  - Internal: galvanized steel.
• Filler material for tendons for strength & serviceability:
  - External tendons: flexible filler, un-bonded design.
  - Internal tendons: grout, bonded design.
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Tendon Inspection and Replacement Issues

• The strands in critical sections in many PT structures can not be evaluated.
• Internal tendons can’t be replaced (external tendons can be added as needed to replace failed internal tendons).
• Strands can’t be replaced.
• Filling tendons with flexible filler rather than grout may allow strand replacement if sufficient access is provided at the anchor ends.
Conclusions

1. Visual inspections do not provide an adequate indication of the condition of the strands in PT structures.
2. The strands in critical sections in many PT structures can not be evaluated.
3. Based on visual inspections the PT bridges in Virginia are performing well with the exception of the 2 bridges at West Point.
4. The bridges at West Point are failing prematurely because the tendons were not grouted in accordance with the specifications.
Recommendations

1. Design PT bridges so the strands can be replaced. Use flexible filler and provide adequate access to the anchor area.

2. Install acoustic emission systems on PT bridges believed to have strand corrosion so the condition of the strands can be monitored.

3. Conduct research on mitigation, repair and preservation strategies for PT structures with incorrectly grouted tendons.
References


Questions?

Michael.Sprinkel@VDOT.Virginia.gov