Performance of Posttensioned Bridges

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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 123 Bridge
  ▪ US 460 Bridge

• Bridges in 2017 and Later: flexible filler

• Tendon Inspection and Replacement Issues

• Conclusions

• Recommendations

3/14/2017
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.
Typical Grouted Condition of Draped prior to 2001 (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).
- **Questions:** Do voids affect service life? Should voids be vacuum grouted? Vacuum grouted with what?
- **Preservation:** NDE methods can not be used to evaluate the condition of the strands. Install acoustic emission monitoring system to detect wire breaks.
5-22-2007: Tendon SP12T15 failed after 17 years. Tendon was vacuum grouted in 2004; value of grouting questioned.
Preservation: Four Tendons Injected with Corrosion Inhibitor July 21-28, 2015 (2)

- 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)
Acoustic Emission Monitoring to Detect Wire Breaks

• Acoustic Emission is considered the most economical technology for identifying corrosion in tendons and providing information for making decisions with respect to tendon replacement.

• Each tendon in the VE bridge has 19 seven wire strands = 133 wires per tendon.

• Tendons can be monitored closely for wire breaks and plans can be made for replacement.

• An estimated installation cost is $720,000 for 2 sensors per span respectively (3).

• Monitoring costs are minimal and depend on how it is done.
Sensors on Walls of Cable Stay Saddle in VE Bridge

AE Event Representing Concrete Crack Rubbing

AE Events for August 30 and September 9 2009

133 wires
Summary: Varina Enon Bridge

• **Condition:**
  - One of 480 tendons failed.
  - Two tendons replaced.
  - Corrosion and wire breaks in 2 tendons.

• **Preservation:**
  - 55 per cent of tendons vacuum grouted.
  - 4 tendons injected with corrosion inhibitor.
  - Acoustic emission monitoring to be installed.
    - Tendons with wire breaks can be replaced.
    - Un-anticipated lane closures can be avoided.
    - Low risk PT design with acoustic emission monitoring.
Smart Road Bridge 2001
First bridge to be grouted with a prepackaged material
Tendon condition to be evaluated
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. Grout segregated into hard grout, soft grout and water.
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
Evaluations of tendons: Impact Echo locates problems; drilled holes provide samples of hard grout, soft grout and water.
Evaluation: Problem with Grouting: extra water in mix or tendon causes grout to segregate into hard grout, soft grout and water

Height Changes from 4x8-in cylinders

Picture: $w/b = 0.65$: Hard grout @ 4.7-in instead of 8-in.
Summary: Lord Delaware and Eltham Bridges

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

• Preservation:
  - Try drying and injection of tendons in 1 girder.
  - Acoustic emission monitoring can be installed to identify wire breaks.
  - Repair decision can be based on wire breaks.
  - Unanticipated lane closures can be avoided.
  - High risk PT design that should be avoided.
US 123 over Occoquan 2006

Three span continuous PT bulb Tee spans (180-ft, 239-ft and 181-ft) with 14 beams with 3 tendons
Summary US 123

- Evaluated the tendons using Ground Penetrating Radar because IE does not work with plastic ducts.
- GPR measurements taken at 79 locations.
- Samples taken at 10 locations believed to have a void or soft grout. No voids or soft grout found.
- Most beams did not have cracks in the web along the tendons. Most cracks in deep beams over piers.
- The bridge is correctly grouted based on the positive GPR readings, the samples and the minimal incident of cracking in the beams.
- Tendons can be grouted correctly using 2 of the prepackaged grouts.
US 460 Bridge 2012
First PT project to require a grouting mock up. Tendon condition to be evaluated.
• 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.
Tendon Inspection and Replacement Issues

• The strands in critical sections in many PT structures can not be evaluated.

• Internal tendons can’t be replaced (provisions can be made for future external tendons by adding diabolos and anchor bulkheads).

• 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 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


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Questions?