DIAGNOSING DEFICIENCIES IN POST TENSIONED BRIDGES
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THE “RULES” OF BRIDGE INSPECTION

- What is a bridge: Structure with a total opening of 20 feet or greater. (NBIS/FHWA)

- Routine Inspections - Inspect each bridge at regular intervals not to exceed twenty-four months. (NBIS/FHWA)

- In Ohio - All bridges greater than or equal to 10-feet clear span shall receive an annual inspection with no inspection outside of 18-months.

- FHWA - Fracture critical member (FCM). A steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse.

- Fracture Critical Bridges Inspection - hands-on, arms length inspection of the Fracture Critical Members not to exceed (NTE) 24 months.
FRACTURE CRITICAL BRIDGES

- Non-Redundant, Steel Members, in Tension.
- Generally considered to be trusses, two-girder bridges, steel pier caps, and arguably steel tub girders.
POST-TENSIONED BRIDGES

- What are the rules for Post-Tensioned Bridges?

- Some post-tensioned bridges are not redundant externally.
- Some post-tensioned bridges may have only a few load paths (tendons) internally.
- We can’t see most critical part.
KNOWN ISSUES WITH POST TENSIONING

- **Soft Grout** - Top layer of segregated grout that can form at high points and is corrosive to the tendon.
  - Usually caused by high grout pumping speeds creating bleed water at front of grout head
  - Additives that were included in the grout, mostly pre 2003 bridges.
  - Water/cement ratios exceeding 0.45.

- **High Chloride Grout**
  - Some batches of bagged grout between 2002 and 2010 were found to have high levels of chloride which can be corrosive in the presence of air and water.
  - Longitudinal Tendons in Webs can be inches from the deck surface, cracks can allow Chlorides to enter into voids at high points.

- **High Sulfate Grout** - Should be less than 3\% of weight of grout. High Chlorides and Sulfates in combination can cause corrosion at a lower threshold than otherwise individual thresholds.

- **Voids** - Caused by substandard materials and grouting techniques of the past. Potential Problems:
  - Tendons at highpoints can be only inches from cracks in the deck surface
  - Grout is the last layer of defense for the tendons, bridge concrete cracks over time, tomorrows problems?????
  - Most pre-2001 PT bridges use galvanized coiled steel that is crimped together, not impervious to water
DISTRICT 8 POST-TENSIONED BRIDGES

BUT-129-1425 over Great Miami River

- Constructed 2004 to 2006
- Variable Depth Splice Girder
- Used grout from plant with high chlorides
DISTRICT 8 POST TENSIONED BRIDGES

BUT-75-0376 Cinci-Dayton over I-75

- Constructed 2001
- PS & PT Dog-Legged I-beams
- PT strands continuous entire length.
DISTRICT 8 POST TENSIONED BRIDGES

WAR-71-1514 I-71 over Little Miami River
- Constructed 2011 to 2017
- CIP PT Balanced Cantilever

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HAM-71-0056 over Plum St
Walkway
- Constructed 1999
- PT CIP Slab
HAM-71-0111L over 3rd St & Broadway

- 1998-2000
- Curved Steel Girder with Integral PT Concrete Piercap
- Cracks formed soon after completion of construction.
HAM-71-0110 I-71 over Broadway

- Constructed Circa 2000
- Single cell CIP PT Tub Girder
- Cast on formwork, curved, continuous PT
HAM-50-2138R over Broadway

- Constructed Circa 2000
- Double cell and single cell CIP PT Tub Girder
- Cast on formwork, curved, continuous PT
CRACKING OF TUBS & INTEGRAL PIER CAP

EXISTING CONDITIONS OF CONCERN

Cracking of Diaphragms

Cracking of Webs

Cracking of Deck

Cracking of Integral Pier Cap
TUB GIRDER CRACK TRACKING

- Initially tracked cracks every few months. Crack propagation began to slow.
- UC performed in-situ load test. Deflections found to be acceptable.
- Independent inspection and analysis confirmed design was adequate.
- Cracks were tracked yearly for 5 years. Cracking has mostly stopped.
DISTRICT 8 POST-TENSIONED BRIDGES

WHY OPEN SOME PT DUCTS?
- Observed Cracking - Though stopped, still allows moisture to infiltrate.
- Some Bridges Constructed with older 2002 grouting Spec
  - Variable grout content (not pre-packaged)
  - May or may not have been vented
  - Potential for Soft Grout
- Past potential for Chlorides in pre-packaged grout.
- A PT tendon is composed of many small wires which are individually susceptible to corrosion.
- Owner - Increased confidence when signing the inspection report each year.

CONSULTANT INSPECTION SCOPE
1. Perform in-depth visual inspection and research construction methods. Determine risk/priority for further invasive borescope testing.
2. Perform borescope test and develop scope for repair.
3. Prepare rehabilitation plans.
Team Work Experience

- 50+ PT bridges
  - Segmental box girders
  - Cast in place box girders
  - Straddle bents
  - Pier caps
  - Cable stay

- Worked together as a team for the past 13 years
Timeline of PT Issues

- 1997: Common Grout
- 2000: Mid Bay Bridge - Corrosion due to grout quality
- 2001: FL New Directions for PT Bridges - Prebag Grout
- 2002: Select Acceptance of New PT Standards
- 2002-2010: Sika Grout with high Cl
- 2003: Soft Grout
- 2011-Present: Grout with Sulfates

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Scope of Services

- **Phase 1**
  - Visual inspection, 10 post-tensioned system (PTS) bridges utilizing “New Directions for Florida PT Bridges, Volume 9”
  - Contract documents review
  - Select bridges whose PTS were at a high risk of deficiencies

- **Phase 2**
  - Determine type of NDT and/or IT of tendons and locations
  - Perform NDT and IT of tendons using a statistical approach

- **Phase 3**
  - Generation of Rehabilitation Documents
Three Bridges were Selected for NDT and IT

HAM-71-0111L over 3rd St & Broadway PTS Pier Cap 2

HAM-50-2138R over Broadway 5 Span

HAM-71-0110 I-71 over Broadway 3 Span
Elevation View of Spans 1 and 2 of 5 Span PTS Bridge

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GPR Layout and Borescope Testing

- GPR located reinforcement steel
- GPR located tendon duct
- Drilling borescope test location
Borescope Testing Procedures

- Driving screwdriver into top of duct
- Inserting borescope camera line into test location
Borescope Test Locations

Looking into borescope test location at duct full of grout.

Looking into borescope test location, void at top of duct.
PTS Interiors of Duct Voids-3 Span

Light corrosion

Note grout at top of duct

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Repair of Borescope Test Locations

- Repairing borescope test location where duct is full of grout
- 1/2 inch PVC pipe and valve for void locations
- Borescope test location repair
Corrosion Rate and Grout Sampling

Chipping concrete to access tendon duct in web wall

Exposed tendon strand bundle for corrosion rate testing and grout sampling
Corrosion Rate and Grout Sampling

Typical corrosion rate set up, connecting directly to the tendon bundle.

Typical grout sampling from the exposed tendon duct. Note void at top of duct.
Repair of Corrosion Rate Test Locations

Repair of corrosion rate test location. Duct has been epoxied back into original location.

Finished repair of corrosion rate test location.

Form in place for corrosion rate test location repair pour back.
PTS Interiors of Duct Voids-5 Span

Void at highpoint with exposed tendon strands

Void at highpoint with moisture corroding the duct interior
PTS Interiors of Duct Voids-5 Span

Light corrosion of strand wire at void, indicates moisture in void

Maximum height level during pumping operation

Current grout level

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Water draining from 3 separate locations along Tendon 3
Worried that your PT bridge ducts may contain more than just grout and tendons...
Summary of Conditions and Testing of 3 Span PTS Bridge

- Initial cracks/lower strength concrete
- Chloride content 0.013%, sulfate content less than 3%.
- Grout high pH, moisture below 25%, low grout corrosion rates.
- 20 of 36 (56%) locations had voids. Void depths ranged from 0.25” to 2.0”.
- Voids; Strands above grout/light corrosion steel strands-duct interiors/moisture entering voids.
- Highpoint voids are only a few inches below the top of deck
- Advantageous conditions of bridge
  - Structure is 18 years old/ corrosion has just initiated.
  - Existing grout is of good quality, should protect the embedded steel strands.
Five span bridge summary is similar to the 3 span bridge except for the following:

- 16/78 (20%) locations had voids. Void depths ranged from 0.125 inches to 4.0 inches.
- One void had 5 gallons of water. Concrete cracks/additional moisture?
Recommendations are Similar for the 3 Span and 5 Span Structures

- Concrete bridges crack with age/to prevent corrosion of the PTS we recommend:
  - Most water comes from the deck, interval application of flood coat will help.
  - Remedial grouting of voids per current ASBI and PTI specifications.
  - No further borescope testing required if remedial grouting is performed.
  - Perform corrosion rate analysis and grout analysis every 10 years to check for carbonation reaction.
  - Web shear cracks should be monitored for growth.
  - Perform baseline survey to check for future sags and deflections of the box girders.
HAM-71-0111L over 3rd St & Broadway PTS Pier Cap 2

East side, north half, note cracks up to 0.036 inches wide

West side, north half, note cracks

Blockout at south end of PTS Pier Cap 2. Note rough patch and shrinkage cracks
HAM-71-0111L over 3rd St & Broadway PTS Pier Cap 2-Elevation View

Pier Cap 2 Detail Drawing

**NOTES:**

1. ½" void with exposed and moderately corroded strand hedges and tails. Top ½ of anchor head was soft grout, grout vent pipe is empty.

2. ½" void through grout port, unable to reach tendon duct. Anchor plate exhibits moisture and corrosion.

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HAM-71-0111L over 3rd St & Broadway PTS Pier Cap 2-Elevation View-Typical Elevation View of Blockout and Anchor Assembly

Pier Cap 2 Detail Drawing

TENDON ANCHORAGE DETAIL

- Tendon Duct
- Grout
- Void Area
- Grout Tube
- Base Plate
- Anchor Blockout Area
- Wedges (not shown, typ.)
- Strand Tails (typ.)
- Wedge Plate
- Steel Strands (typ.)
- Trumpet
North End-Tendon 8 Anchor Head Assembly Exposed

Blockout at north end of pier cap

Chipping operation exposing Tendon 8 anchor assembly

Completely exposed Tendon 8 exterior anchor assembly
South End-Tendon 1 Anchor Head Assembly Exposed

- Exposed anchor assembly, empty grout vent and moisture
- Exposed anchor assembly, note corrosion
- Chipping operation to the anchor assembly, note moisture
South End-Tendon 4 Anchor Head Assembly Exposed

Note moisture at interior of blockout

Note corrosion of anchor assembly, empty grout tube and moisture
South End-Tendon 1 Anchor Head Assembly
Empty Grout Vent

Entrance to empty grout vent and corrosion at vent interior

1/4 inch void between trumpet and grout vent

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South End-Tendon 4 Anchor Head Assembly
Empty Grout Vent

Entrance to empty grout vent and corrosion at vent interior

1/8 inch void between trumpet and grout vent
Summary of Conditions and Testing of PTS Pier Cap 2

- Regular concrete was used in block outs creating shrinkage cracks/water enters the anchor assemblies
- 2 of 4 anchor assemblies exhibited moderate to heavy corrosion.
- 2 of 4 grout vents were empty/vents exhibited heavy corrosion/voids in the trumpet areas.
- Moisture may be accessing into the anchor trumpet and tendon strands.
- 4 of 16 locations were tested/failure rate of 50%. 8 locations potentially at risk of corrosion.
- Pier Cap 3 and Pier Cap 4 of HAM-50-2142R/may have corrosive conditions.
- Cracks at the north end of P2 have not grown since being created around construction.
- Grout quality was good/similar to 3 span and 5 span bridges
Recommendations for PTS Pier Caps 2 & 3 of HAM-71-0111L and PTS Pier Cap 4 of HAM-50-2142R

- Pier Caps 2, 3 and 4/replace concrete block outs with non-shrink and urethane clearcoat.
- Clean all corrosion on the anchor assemblies.
- Fill all vent and trumpet voids with an approved grout.
- All anchor head assemblies/block outs should be repaired to ASBI and PTI specifications.
- Cracks in Pier Cap 2 should be epoxy injected to protect the PTS.
Most of the PTS bridges built before 2003, inspected and tested by our team have been well constructed but were lacking in the quality of grouting of the tendon ducts. This is important since the grout surrounding the steel tendons is usually it’s last line of defense against moisture and contaminates.

Since 2003 ASBI, PTI and other stakeholders have made vast improvements in the requirements of grouting materials and grout installation procedures.

Moving forward from 2003, any PTS bridge built with these requirements should perform satisfactory with minimal maintenance for decades.
Questions?

Ohio
Department of Transportation

Thank you!