SPECIALIZED POST-TENSIONING ASSESSMENT AND REPAIR OF BRIDGES

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SENIOR ASSOCIATE

Outline
- Past projects
- PT history and basics
- Initial and FDOT detailed concerns
- Examples of challenges
- Current durability strategy
- PT protection
- SikaGrout 300PT issues
- FHWA response
- Assessment methods
- Monitoring options
- Remedial Actions
- Looking ahead...

Past Projects
- Varina Enon Bridge, VA – External tendon failure investigation
- Steamboat Hills Bridge, NV – Stressing related web delamination
- Oklahoma Bridges, Statewide – PT assessments
- Hawaii Bridges, HI – PT assessments and trial NDE
- San Antonio, TX – Routine inspection and grout materials testing
- Branch Avenue Bridge, MD – Routine inspection and trial NDE
- Minnesota Bridges, Statewide – Inspection, grout testing, and monitoring
- Oregon Bridges, Statewide – PT assessments
- Florida Bridges, District 5 – PT assessments

PT History

Table 1.1 - Developments in Precast Concrete History

<table>
<thead>
<tr>
<th>Year</th>
<th>Author/Researcher</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>F.# Dikken</td>
<td>Concept of using prestressing to increase concrete strength and durability</td>
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<tr>
<td>1946</td>
<td>M. Sander</td>
<td>Improved concrete by using high-strength steel</td>
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<tr>
<td>1947</td>
<td>V. W. Van Buren</td>
<td>Developed new techniques for manufacturing prestressed concrete beams</td>
</tr>
<tr>
<td>1948</td>
<td>R. E. Holmes</td>
<td>Developed new techniques for manufacturing prestressed concrete beams</td>
</tr>
<tr>
<td>1949</td>
<td>K. Winter</td>
<td>Improved concrete by using high-strength steel</td>
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<tr>
<td>1950</td>
<td>R. E. Holmes</td>
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</tbody>
</table>

PHWA/UT - Conclusions, Recommendations and Design Guidelines for Corrosion Protection of Post-Tensioned Bridges 2004
PT Basics
- Precompression in concrete results in a more durable structure
- History of 60+ years of durable PT bridges (introduced in US in 1960s)
- PT system: bonded or unbonded
- Components: prestressing strands or high strength bars; anchorages and couplers; metal or plastic ducts; and cementitious grout, grease, or wax
- Prior to early 2000's, grout comprised of cement and water which led to bleed water and grout voids
- Newer PT specifications require high performance grout and attention to vents and drains
- On November 23, 2011, FHWA notified the public of 34 bridges with elevated chloride levels; SikaGrout 300PT between 2002-2010 from Marion, Ohio plant

Initial Concerns
- Grout voids, water infiltration, and cracking noted in UK in 1970s; Ynys-Y-Gwas bridge collapsed in 1985; Malle bridge collapsed in 1992
- UK moratorium on PT in September 1992
  - Lifted in 1996 for CIP grouted PT but precast PT moratorium remained in place due to joint detailing
- US problem first noticed in 2002 at the Midbay Bridge and Sunshine Skyway Bridge in Florida
  - Investigation to determine root cause and how wide spread the problem was – grout voids, water infiltration, and chloride intrusion led to corrosion
  - FDOT updated design guidelines and PT specs

PT Basics Internal vs. External Tendons
- Internal PT Tendons
- External PT Tendons

FDOT Detailed Concerns
- Voids associated with accumulation of bleed water at tendon anchorages
- Recharge at tendon anchorages with salt water or surface drainage during construction
- Leakage through end anchorage protection details
- Quality of the grout installation and grout material
- Splitting of polyethylene ducts
- Deficiencies in implementation and inspection of grouting procedures
**Example of Challenges**

**Poor Drainage Details**

- Grout Voids and Corrosion

**Example of Challenges**

**Grout Voids and Corrosion**

- Over pressurized during grouting
- Physical damage during construction
- Different thermal coeff. of expansion
- Mix design with expansive agents

**Example of Challenges**

**Anchor Protection**

- Incomplete and deteriorated pourbacks
- Deck repairs over pourbacks

**Example of Challenges**

**External Tendon Duct Cracking**

- Over pressurized during grouting
- Physical damage during construction
- Different thermal coeff. of expansion
- Mix design with expansive agents
Example of Challenges
Improper Use of Materials

- Duct tape is good but not for permanent HDPE repairs

Example of Challenges
Inadequate Duct Repair

Example of Challenges
Regrouting Materials

- Repair material with gypsum was identified as contributing factor

Durability Strategy

- Enhanced PT Systems
- Anchor Protection
- Increase Redundancy
- Watertight Bridges
- Fully Grouted Tendons

FDOT PT Strategy
PT Protection
- Develop structural bond between concrete and the prestressing steel (bonded system)
- Provide protection to the prestressing steel against corrosion
  - Deck overlay (bridges)
  - Dense, low permeability concrete
  - Robust plastic ducts (or polyethylene pipe)
  - High performance, anti-bleed grout
  - Anchorage protection details
- Modified grouting procedures to limit voiding
- Developed new thixotropic grouts
  - 1st generation had silica sand
  - 2nd generation had calcium carbonate as filler

PT Protection
New Procedures and Grouts
- Modified grouting procedures to limit voiding
- Developed new thixotropic grouts
  - 1st generation had silica sand
  - 2nd generation had calcium carbonate as filler

PT Grout Concerns
- Bridge Zero, Texas, 2010, chloride source was cement
- FHWA chloride limit is 0.08% by weight of cement
- Affected >200 projects including 120 bridges, 39 states
- Resulted in the following:
  - Additional chloride testing during construction
  - Recommended ASTM C1152 be used to limit variable test results
  - Increased threshold to 0.75% weight/cement
  - Industry Organizations, FHWA and other engineers, corrosion investigations leading to new chloride thresholds (up to 1.5% weight of cement)
  - Soft grout led to research related to sulfate content, water content, and time/storage limitations, not tied to grout lot or other variables
  - We need to wait and see what the research and physical performance will be...
FHWA Response

- Determine max. chloride concentration for construction period
- Determine PT protection level (PL 1A to 3)
  - PL 1A – bare strand, filling material stable/nonreactive, galvanized/plastic duct, no grout voids
  - PL 1B – 1A plus engineered grout and permanent grout caps
  - PL 2 – 1B plus enclosure capable of permanent leak-tight barrier
  - PL 3 – 2 plus electrical isolation or encapsulation to be monitorable and inspectable at any time

<table>
<thead>
<tr>
<th>Chloride Concentration % (per et. of cement)</th>
<th>2001 to 2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
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<tbody>
<tr>
<td>0.25%</td>
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Table 1 - Maximum Chloride Concentration by Production Period

FHWA Response

- Determine risk level based above (RL 1 to 4)
- Assess bridge system redundancy and element ductility
  - Ductility - easily detectable cracking before debilitialing strength loss
  - Redundancy - based on the load rating system factors (phi factors)
  - Structure classification - based on ductility and redundancy (S1 to 3)

PT Assessment Methods

- Document review
- Visual inspection and acoustic sounding (cracks, deflection, water stains, efflorescence, ponding water, grout leakage)
- Nondestructive testing
  - GPR / Borescope (typical, other methods less common)
  - Infrared thermography
  - Ultrasonics (MIRA)
  - Magnetic flux leakage (MFL)
  - Relative capacitance
  - Corrosion monitoring (half cell, corrosion rate, other probes)
  - Vibration analysis
  - Gamma radiography
PT Assessment Methods

- High Point and Anchor Inspection
  - 1" dia. drill hole openings
  - Inspection openings

PCI Grading of Strands

- Frothy grout - very high air
- Grout with no unhydrated cement

PT Assessment Methods

Materials Testing

- Scanning Electron Microscopy

PT Assessment Methods

Materials Testing

- Petrography - Chlorides, Sulfates
Monitoring Options

- Corrosion rate and potential measurements
  - Duct openings required to access grout and strands
  - Are we measuring duct or strand corrosion
  - Commercially available probes (C-probes installed for MNDOT project)
    - Sensor installed inside duct
    - Data acquisition system, modems, and power needed
    - Some have sample strand that is used as a reference element
- Other options: Bulk water probes (washing machine parts), relative humidity probes, temperature probes, acoustic monitoring, vibration monitoring, etc.
Common Remedial Actions

- May do nothing if:
  - No grout voids, corrosion, or moisture infiltration noted
  - Grout voids observed but strands are protected by grout
- If corrosion, voids, etc. are noted, perform detailed analysis to determine how many strands or tendons are needed?
- If repairs are needed (client often decides this due to various considerations):
  - Remedial grouting if strands are exposed to air/moisture infiltration
    - Vacuum grouting, vacuum assisted grouting, pressure grouting
  - Tendon replacement or strengthening (typically external)
  - Rehabilitation of PT anchor protection systems (install permanent grout caps and treat pourbacks)
  - HDPE pipe repair (heat shrink sleeves)
- As an alternate, consider periodic assessments/monitoring

Vacuum Assisted Grouting

Looking Ahead...
Agency Perspective

- Numerous post-tensioned bridges in each agency
- Limited inspection/assessment funds
- No specific mechanism to report post-tensioning distress
- Limited existing contracts to perform specialized inspections and remedial work
- Currently we are working with MNDOT and ODOT on this issue
- Specialized bridge inspector training related to post-tensioning distress needed
- Reporting mechanisms, within the confines of existing bridge inspection software, that will allow post-tensioning observations to be sorted and tracked needed
- Development of standard vacuum assisted grouting and other post-tensioning inspection and repair details needed

Looking Ahead...
Agency Perspective

- Development of a tiered assessment and repair system (Presentations to ODOT and FHWA)
  - Tier 1 – Visual inspection by maintenance personnel to locate and document conditions
  - Tier 2 – Perform limited borescope inspection of high points and/or anchors
  - Tier 3 – Perform more detailed inspection
    - Up to 20% high points/anchors
    - More advanced NDE techniques
  - Tier 4 – Perform 100% inspection of high points and anchors
  - Tier 5 – Develop plans and specifications for remedial grouting and bridge rehabilitation
  - Overriding Option – Emergency bridge closure, shoring, in-depth inspection, etc.