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VDOT EXPERIENCE WITH GROUTED TENDONS IN VARINA-ENON PRECAST SEGMENTAL POST-TENSIONED BRIDGE

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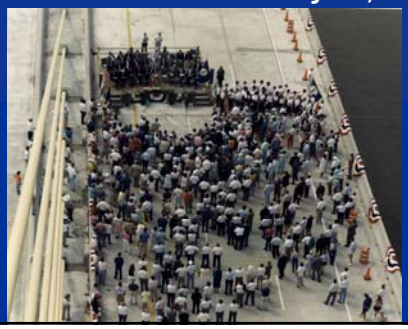
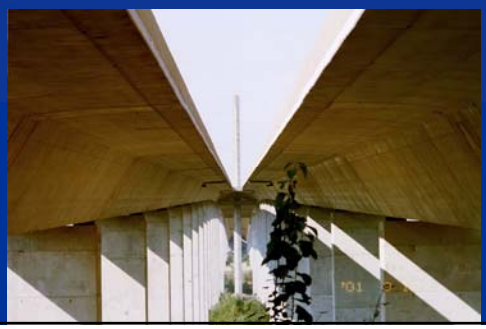
Bridge Construction and Typical Segment

Dedication Ceremony July 18, 1990



I- 295 Varina-Enon Bridge 28 spans



2001 Varina-Enon Inspection: hole in duct; rust on strand & void in duct; rust was confined to vicinity of hole


Expansion Joint - 2001


Expansion Joint - 2001


Tendons at Exp. Joints


Where is the “Beef” (i.e., GROUT)?
10/17/2001

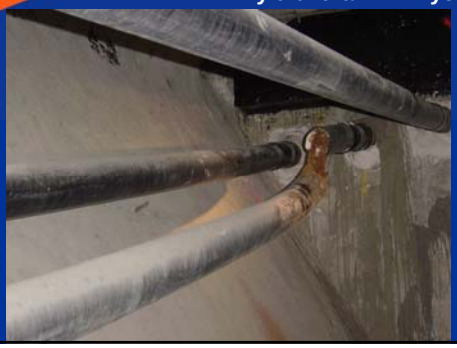

Where is the “Grout”
Vertical Post-Tensioned Anchors

I 295 Failed Tendon (5-30-2007) Why did it fail in 17 years?

Concerns?

- Long Term Performance of Structure
- Preventive Maintenance Requirements to Extend Service Life
- Future Rehabilitation Costs
- In-Depth Inspection Requirements
  - What Techniques?
  - How Frequently?
- Health Monitoring Requirements
  - Short Term Monitoring
  - Long Term Monitoring

I 295 Failed Tendon (5-30-2007) Why did it fail in 17 years?



Why did tendon fail in 17 years?

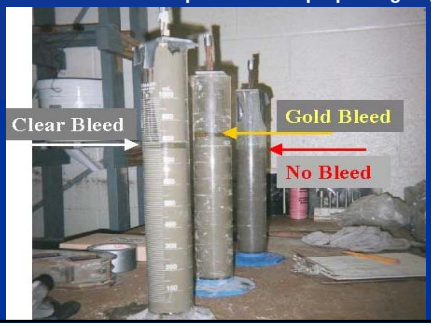
- Original grout (water, cement, admixture)
- Vacuum grout (high performance)
- Original grout and vacuum grout
- Chloride ions (none found)
- Carbonation of grout (original grout at failure)
- Moisture (grout has high moisture content)
- Oxygen (voids in tendons, unsealed vent tubes and inspection holes)
- Combination of factors

Concerns About Grouts in Tendons

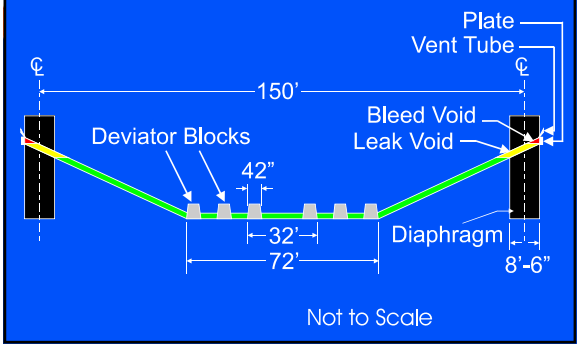
- Voids due to bleeding and segregation (Bleeding in grouts used prior to 2000 was approximately 4 percent. In a 150 ft long tendon, 4 percent bleeding can cause 6 ft of void at the high points in the tendon)
- Voids due to incomplete grouting and leaks

Wick Induced Bleed Test

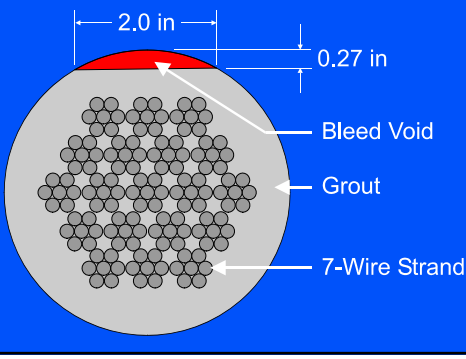
cement and water, aluminum powder, high performance prepackaged grout



Tendon in Typical Span



Tendon Section



Tendon Inspection and Repair

- Inspected tendons for voids in grout, flaws in ducts, and corrosion of strands and anchors (visual, wire probes, sounding, and bore scope) (2001 and 2002)
- Vacuum grouted some voids (2003 and 2004)
- Sealed some tendons (2003 and 2004)
- Replaced 2 tendons (1 failed, 1 with 3 broken wires) (2007)
- Evaluated condition of tendons using Magnetic Flux (approximately 80 % of each duct) (2007)
- Twenty tendons selected for detailed evaluation by removal of a 2-ft section of duct (18 because of corrosion in bore scope pictures, 1 because of Magnetic Flux measurements by Dr Al Ghorbanpoor and 1 because of his visual inspections) (2007)
- Plan to monitor tendons representing 6 conditions (2008)

2001 Varina-Enon Inspection: plugged drain; water submerges tendon; situation of 2nd tendon replaced which had 3 broken wires

Horizontal Tendon Vent (10-12-2001) grout on wall suggests duct was filled

Horizontal Tendon Void (10-12-2001): PT bearing plate, strands, grout and void, no corrosion of strands; typical of voids vacuum grouted in 2003 and 2004

I 295 Failed Tendon (5-22-2007)

Failed Tendon

Failed Tendon

Failed Tendon

Slices of Failed Tendon in Lab at VTRC

Failed Section

Failed Section

8 Ft Downstream of Failed Section

Grouted Section

Magnetic Flux Testing

Section Loss Identified by MF

Grout Moisture Content

Tendon	Broken wires	Section loss	color	Moisture content, %	Absorption, %
NP13T10	2	7 wires 5.3 %	Gray	32.8	35.5
SP12T9	1	4.8 wires 3.6 %	Gray (bottom)	36.6	39.5
SP12T9	1	4.8 wires 3.6 %	White (top)	21.6	36.5

Monitoring 6 Tendon Conditions

1. Voids, no vacuum grout (45 per cent of tendons)
2. Voids, incomplete vacuum grout
3. Drying shrinkage cracks in grout
4. Small section with minor pitting corrosion
5. Pitting corrosion and several broken wires
6. Vacuum grouted tendon with broken wires

Voids, no vacuum grout

Voids, incomplete vacuum grout

Shrinkage Cracks

Broken Wires, NP13T10

Vacuum Grouted Broken Wire, SP12T9

Tentative Conclusions

- Tendons have voids
- Approximately 55 % of tendons were vacuum grouted
- Grout typically has high pH and high moisture content
- Corrosion typically associated with access to oxygen and absence of grout

Recommendations

- Vacuum grout tendons with accessible voids
- Repair ducts and vacuum grout tendons subjected to detailed inspections
- Monitor tendons representing 6 tendon conditions using visual inspections through transparent duct repairs, half cell and rate of corrosion measurements and acoustic emission sensors.

Recommendations

- Consider Other Health Monitoring Technologies Based on Failure Analysis
- Determine Future In-Depth Inspection Requirements
- Perform Additional Repairs As Recommended from On-going Evaluation of Bridge

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U.S. Department of Transportation Federal Highway Administration

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