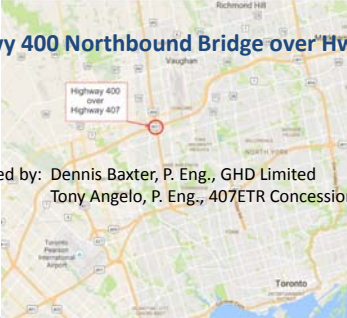



## Post-Tensioning System Evaluation

### Hwy 400 Northbound Bridge over Hwy 407




Presented by: Dennis Baxter, P. Eng., GHD Limited  
Tony Angelo, P. Eng., 407ETR Concession Company Ltd.


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## Post-Tensioning Grout Problems

- Voids
  - Incomplete filling of ducts or grout leakage prior to hardening
  - Typically, caused by grout bleed where excess water floats to the top of the grout resulting in a pocket of water or a void if the water later evaporates.




Wick-induced bleed test by American Segmental Bridge Institute in April 2012 showing portland cement grout with about 4% bleeding after 24 hours of grouting operation.

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## Post-Tensioning Grout Problems

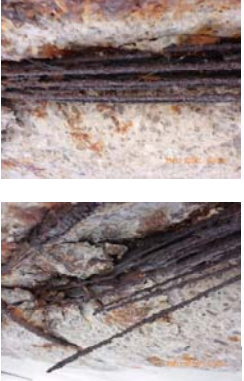
- Variations in Grout Properties
  - Grout is intended to provide a uniform, protective environment around post-tensioning strands
  - Variations in grout properties create variations in corrosion potentials which can initiate and sustain corrosion.
  - Excess water used with prepackaged grouts can result in segregation and the creation of a layer of porous and / or soft grout with a different chemical composition compared to good quality grout


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## Post-Tensioning Grout Problems

- Chloride Contaminated Grout
  - Exposure to chlorides in the environment
  - Chloride contamination of the grout





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### Typical Corrosion Damage Identified in 2000



- Mostly corrosion of tendons within the anchor limits
- Most prevalent on external tendons

**DUCTS AND ANCHORS FILLED WITH GROUT FOR PROTECTION**

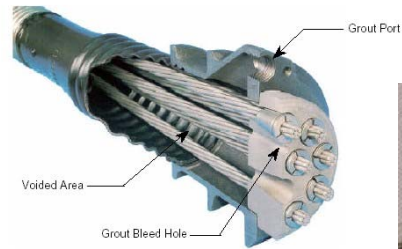


Source: FDOT



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### Corrosion of Tendons in Anchors (2000)



**- Severe corrosion was present inside the anchors**

Source: FDOT



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### Corrosion of Tendons in Anchors (2011)



**CORROSION INDUCED TENDON FAILURES DISCOVERED ON ONE BRIDGE**

Source: FDOT



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### Hwy 400 over Hwy 407 Bridge Construction Details

- Constructed in 1990
- 4 span post-tensioned rectangular box girder; 203.6 m long



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### Evaluation Process

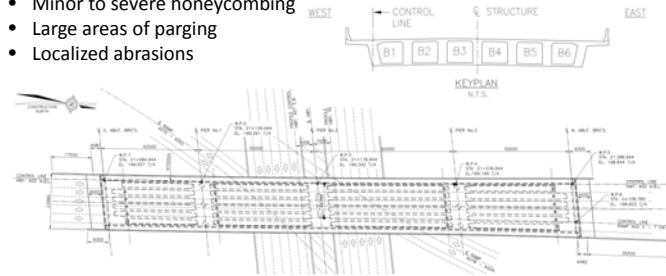
- Visual and delamination survey
- Ground penetrating radar
- Sonic/ultrasonic impact-echo testing on tendons
- Openings to verify echo results and collect samples
- 8 dust samples for chlorides
- 1 sample for petrography
- 11 samples for carbonation
- Inspect 1 stressing head
- 2 air tests along PT tendons



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### Visual and Delamination Survey

- Narrow cracking along post-tensioning particularly in exterior girder
- Localized delaminations not associated with post-tensioning
- Minor to severe honeycombing
- Large areas of parging
- Localized abrasions



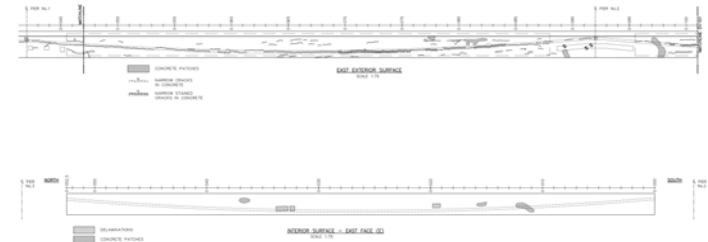
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### Visual and Delamination Survey



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### Visual and Delamination Survey



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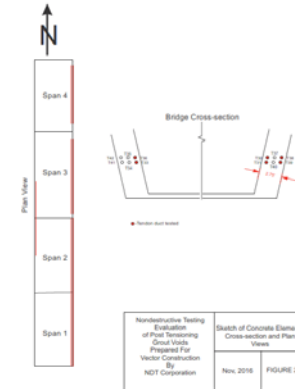
### Locating PT tendons

- Locate tendons with ground penetrating radar
- Determine the average depth of concrete covering the PT tendon



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### Locating PT tendons



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### Impact-Echo Testing

- Check for voids in grouted ducts

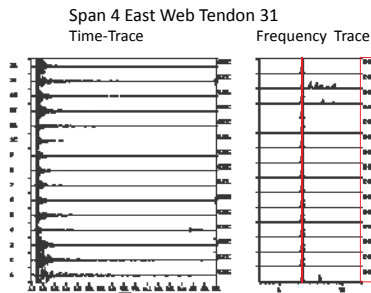


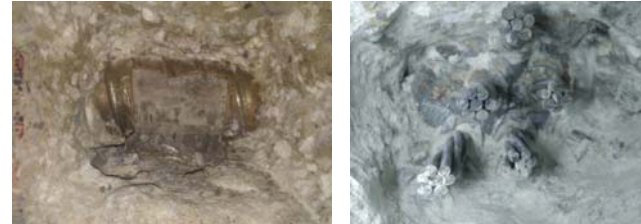
Photo-1 Sensor Array and Projectile Energy Source



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### Sampling

- Cut openings to verify findings and collect samples



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### Sampling

CONCRETE OPENING LOCATIONS

ONLY LABELED TENDON DUCTS WERE INCLUDED IN THE INSPECTION

WEST EAST

TENDON DUCTS

BRIDGE CROSS SECTION

Location	Duct No.	Test Performed at Each Inspection Location			
		Chloride Test	Carbonation Test	Penetration Test	air Test
1	30	Yes	Yes	Yes	Yes
2	42	Yes	Yes	/	/
3	41	/	Yes	/	/
4	33	Yes	Yes	/	/
5	31	Yes	Yes	/	Yes
6	31	/	Yes	/	Yes
7	39	Yes	Yes	/	/
8	30	Yes	Yes	/	/
9	38	Yes	Yes	/	/
10	30	Yes	Yes	/	Yes
11	30	/	Yes	/	Yes

/ Specific examination criteria was not performed at this opening location.  
Yes - Specific examination criteria was performed at this opening location.

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### Types of Chloride Testing

- Acid Soluble
- Water Soluble
- Soxhlet Method

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### Chloride Thresholds

- 0.2% by weight of cement (ACI)
- 0.031% by weight of concrete
- 1.2 lb Cl-/yd<sup>3</sup> of concrete (0.71 kg/m<sup>3</sup>)
- These code guidelines are rather simplistic
- Different concrete conditions have different thresholds: wet or dry concrete, pre-stressed, etc.
- In reality corrosion activity is progressive and based on the Chloride / Hydroxyl Ratio (Cl-/OH-)

	Acid Sol.	Water Sol.	Water Sol.
Test Method	ASTM C1152	ASTM C1218	Soxhlet
Prestressed	0.08	0.06	0.06
Reinforced Wet	0.10	0.08	0.08
Reinforced Dry	0.20	0.15	0.15% by weight Cement

Section 1

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### Carbonation Testing

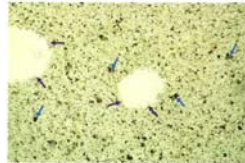
- Mainly to determine amount of carbonation
  - Can also be used to determine some types of chemical contamination
- 1% phenolphthalein in alcohol or 50/50 mixture of distilled water and alcohol
- Generally perceived to indicate pH of > 9.5

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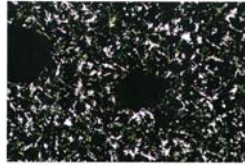
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### Petrographic Examination

- Good quality
- No inherent defects
- Water-cement ratio 0.35 to 0.45
- Well-hydrated
- Abundant Calcium Hydroxide
- 2-3% air content



3a. Plane-polarized light. Blue arrows indicate representative residual/reticulated portland cement clinker particles, which appear fairly well-hydrated. Purple arrows show elongated lightly leaching voids.



3b. Cross-polarized light. Calcium hydroxide crystals (white crystalline material in paste matrix) are abundant.

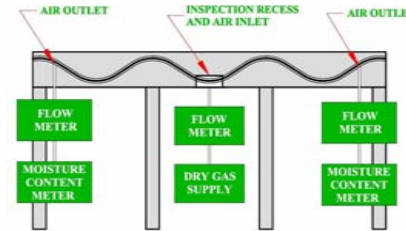
Fig. 3 Thin section photomicrographs of PG Sample 1, illustrating features of the paste. Both images show the same field of view but under different lighting. Field of view, from left to right is approximately 6.78 mm (0.27 in.).



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### Air Flow Test

- Testing for voids along tendons
- Interstitial spaces in tendons seldom filled with grout and often contain air voids where water and chlorides can collect
- Tendons tested did not show any sign of air flow



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### Questions

- Thanks to:
  - Vector Corrosion Technologies
  - NDT Corporation
  - Petro Laboratories Inc.
  - CTL Group



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