FDOT TRANSPORTATION SYMPOSIUM 2019

Wonderwood Connector Bridge Post-Tensioning Tendons Investigations and Phase 1 Repair

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Learning Objectives

- Understanding the processes of post-tensioned bridges durability investigations
- Learning the application of Non-Destructive Evaluation (NDE) Method
- Developing structural evaluations prior to repair strategy
- Implementing repair concept to repair plans
- Learning how to repair soft grout
- Learning new technology (drying and impregnation of corrosion inhibitor) through strands interstitials spaces in protecting strands corrosion

Presentation Outline

1. Background
2. PT Tendons Investigations
3. Repair Strategy
4. Phase 1 Repair Construction
5. Closing

Background

Bridge Description

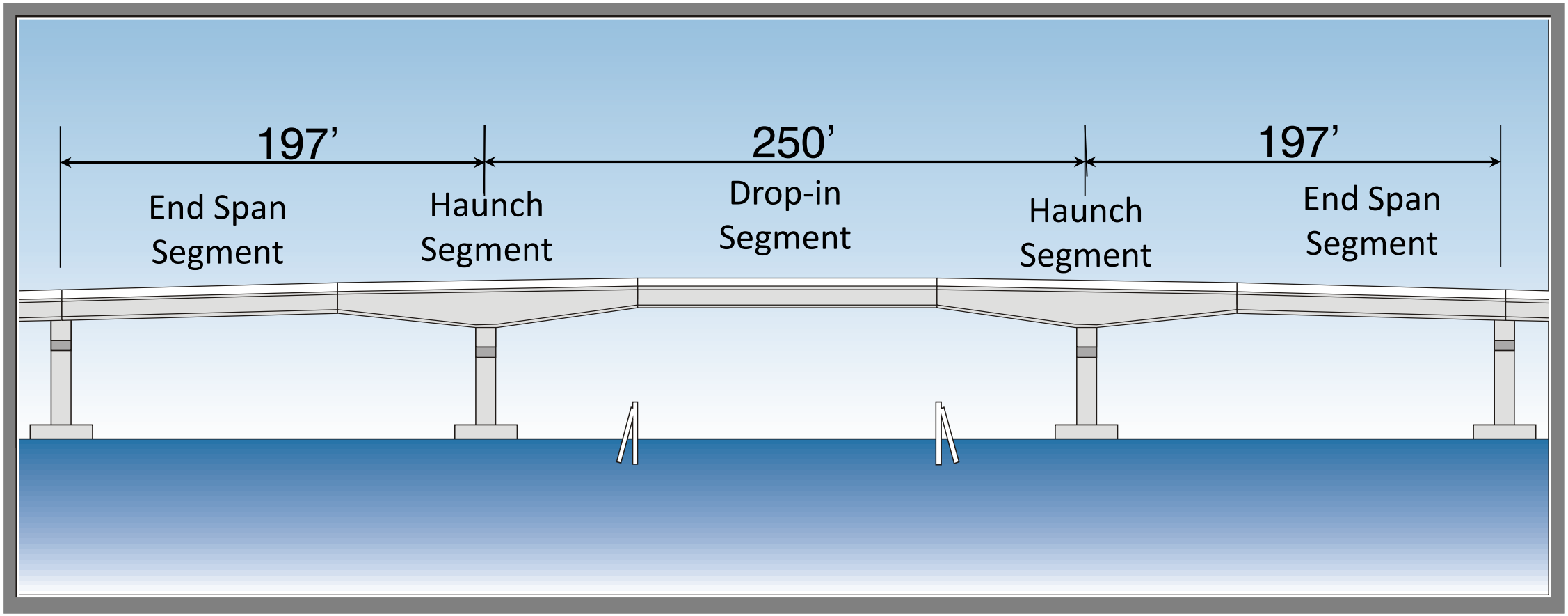
- Bridge No. 720677
- Wonderwood Connector Bridge is located over the Inter-coastal Waterway on SR 166, north east of Jacksonville, FL
- The total bridge length is 3584’ and 90’-9” wide deck consisted of 8 lines of prestressed concrete I girders.
- The focus of this presentation is the three-span continuous Post-tensioned spliced girder main span bridge of 197’-250’-197’ (total length of 644’)

Background (cont.)

Construction Information

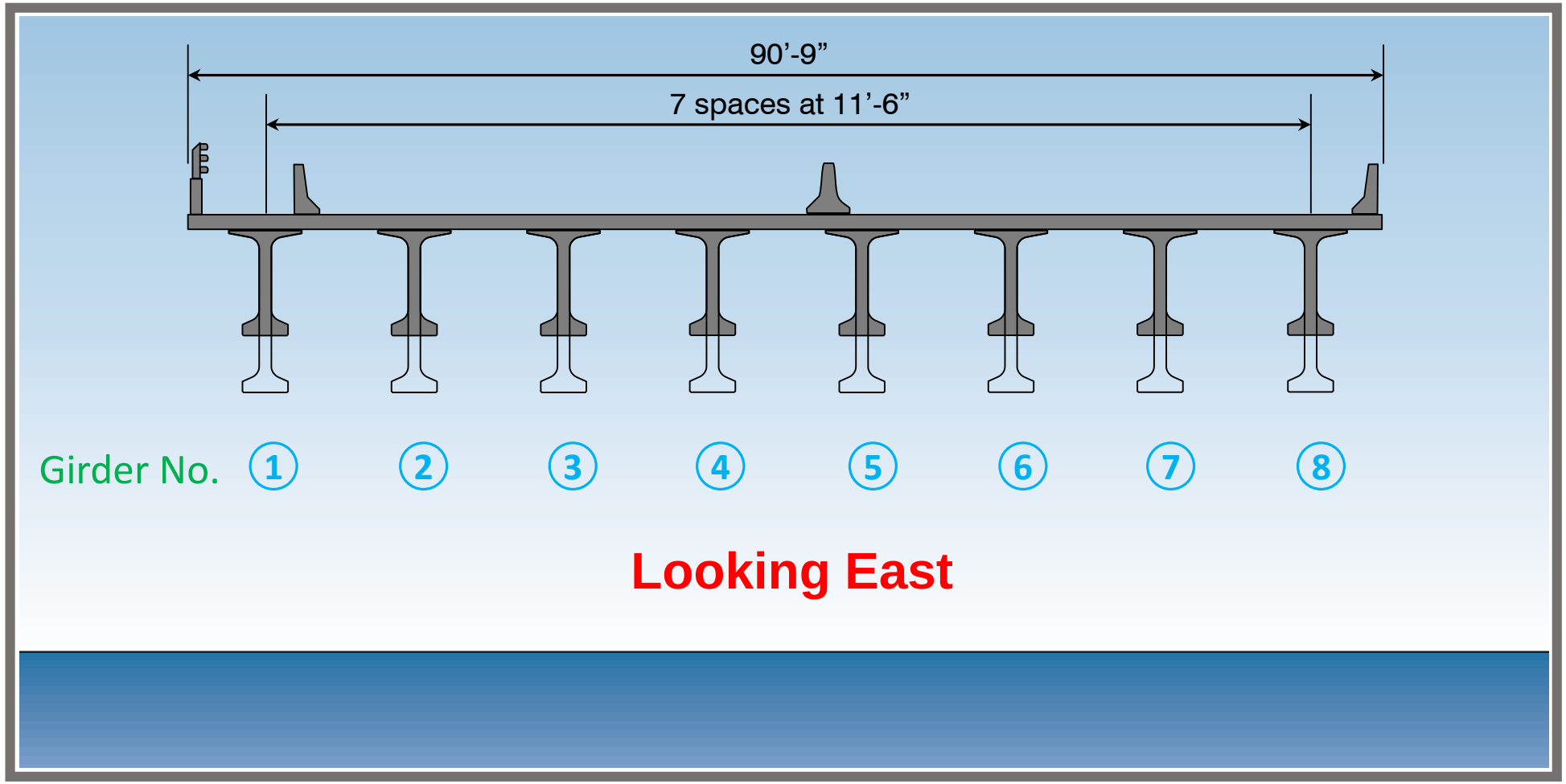
- Construction date: 2002 - 2004
- PT system: VSL (old system)
- PT duct: Galvanized corrugated metal duct
- Grout: Sika Cable Grout

Background (cont.)



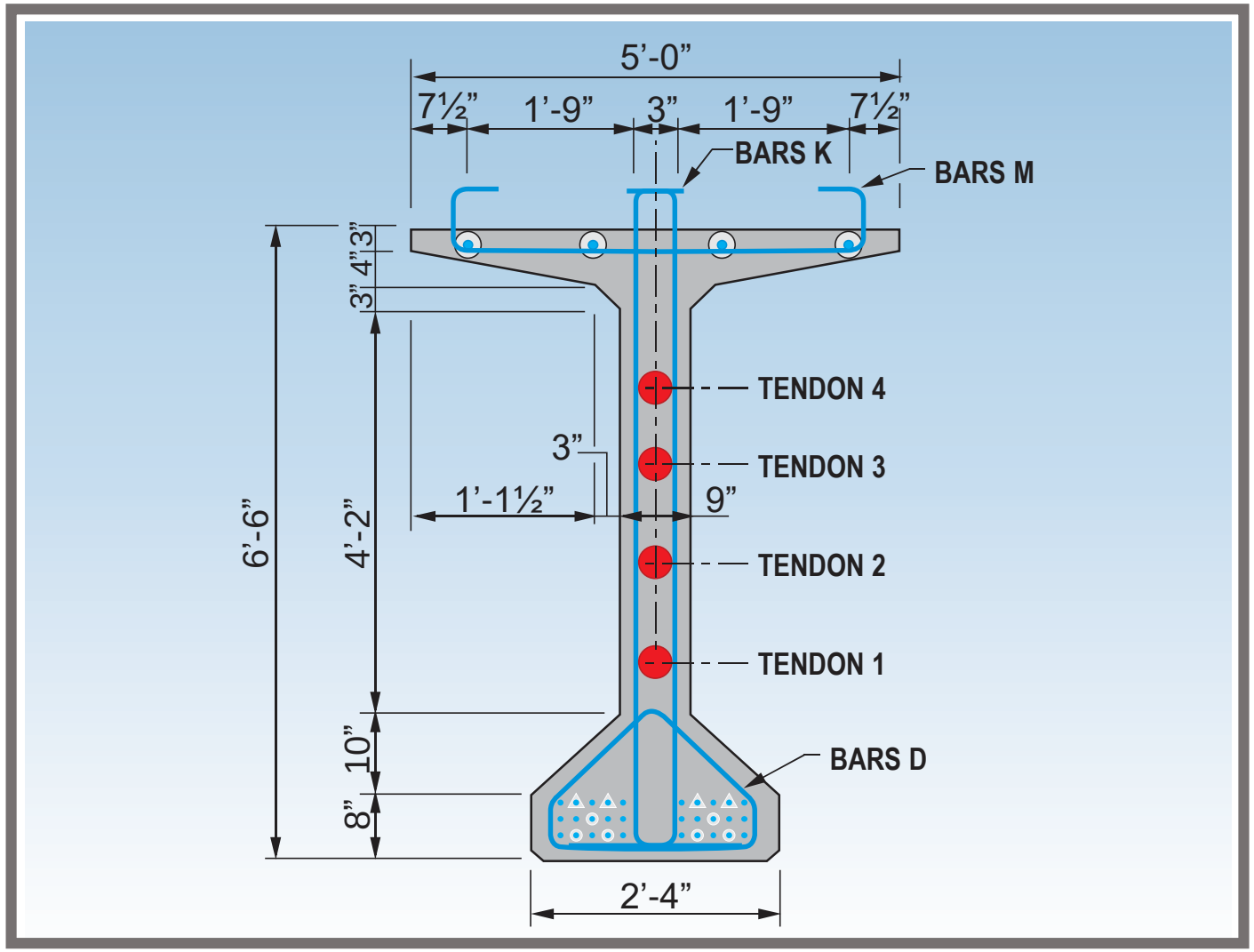
Main Spliced Girder Unit Elevation View

Background (cont.)



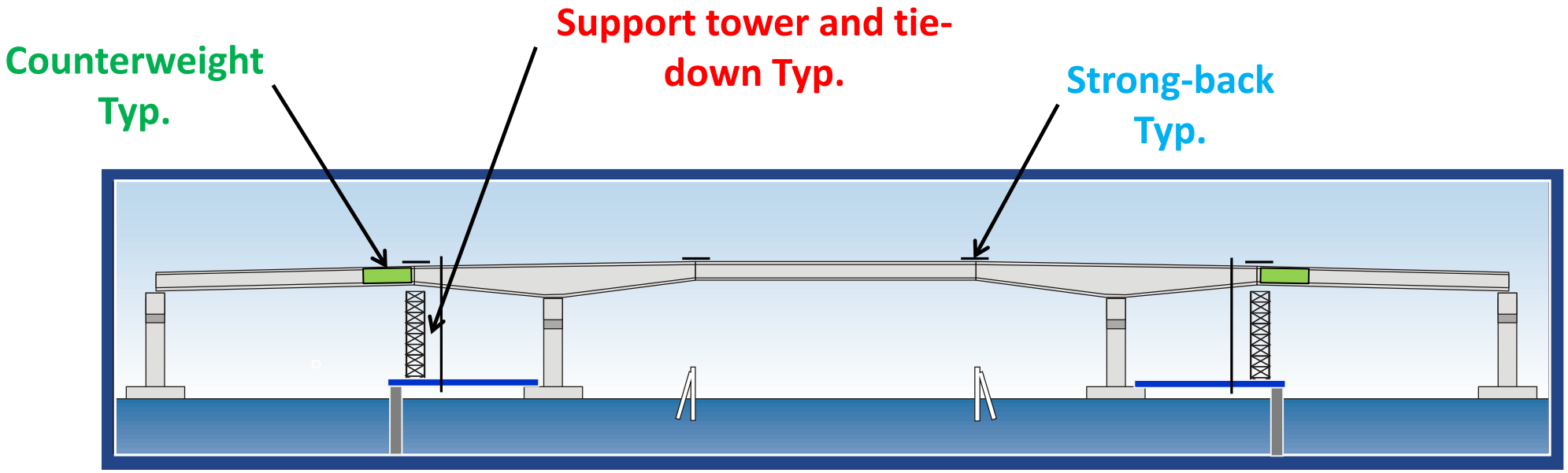
Typical Cross Section

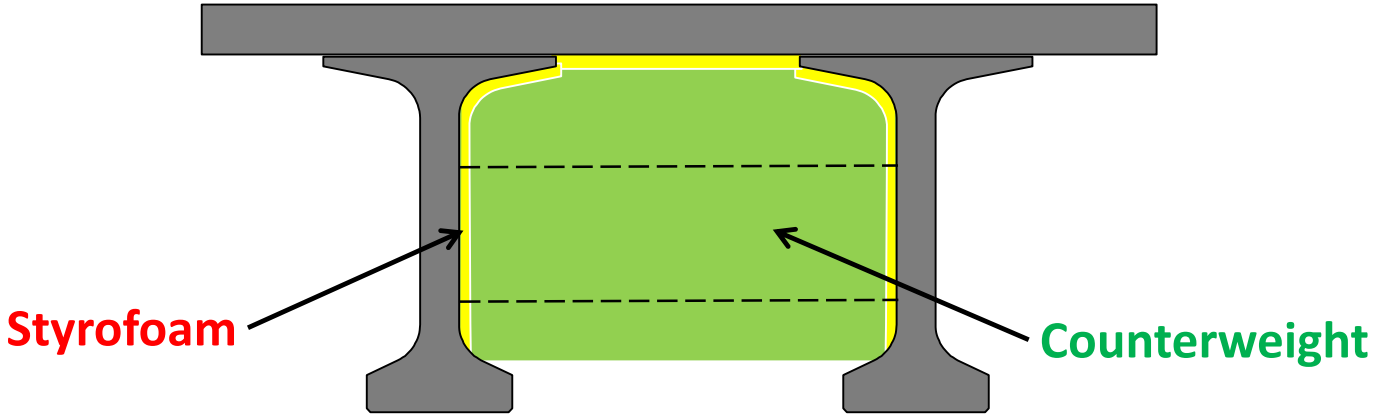
Background (cont.)



Typical Section

Background (cont.)





Notes: Due to geometry control issues that arose during construction, counterweights were added in the side spans.

Background (cont.)

Beam	Tendon 1	Tendon 2	Tendon 3	Tendon 4	Total
1	15	15	19	18	67
2	15	15	19	18	67
3	15	15	19	19	68
4	15	15	19	16	65
5	15	15	19	18	67
6	15	15	19	19	68
7	15	15	18	18	66
8	15	15	19	18	67

Note: Tendon sizes range from 15-0.6” to 19-0.6” strands

PT Tendons Investigations

Initial PT Investigations

Scope: To obtain some grout samples for chloride test

1st inspection : April 16, 2012 to May 4, 2012

2nd inspection : July 16, 2012 to August 10, 2012

Report Findings

1. Metal duct corrosion
2. Strands corroded (no failed strands found)
3. Putty-like grout (5 samples from girders), high moisture
4. Soft, chalky grout (6 samples from girders)
5. Chloride contents : 0.01 to 0.04% by weight of cement. [limit 0.08%]
6. Moisture Content: 50% to 75%

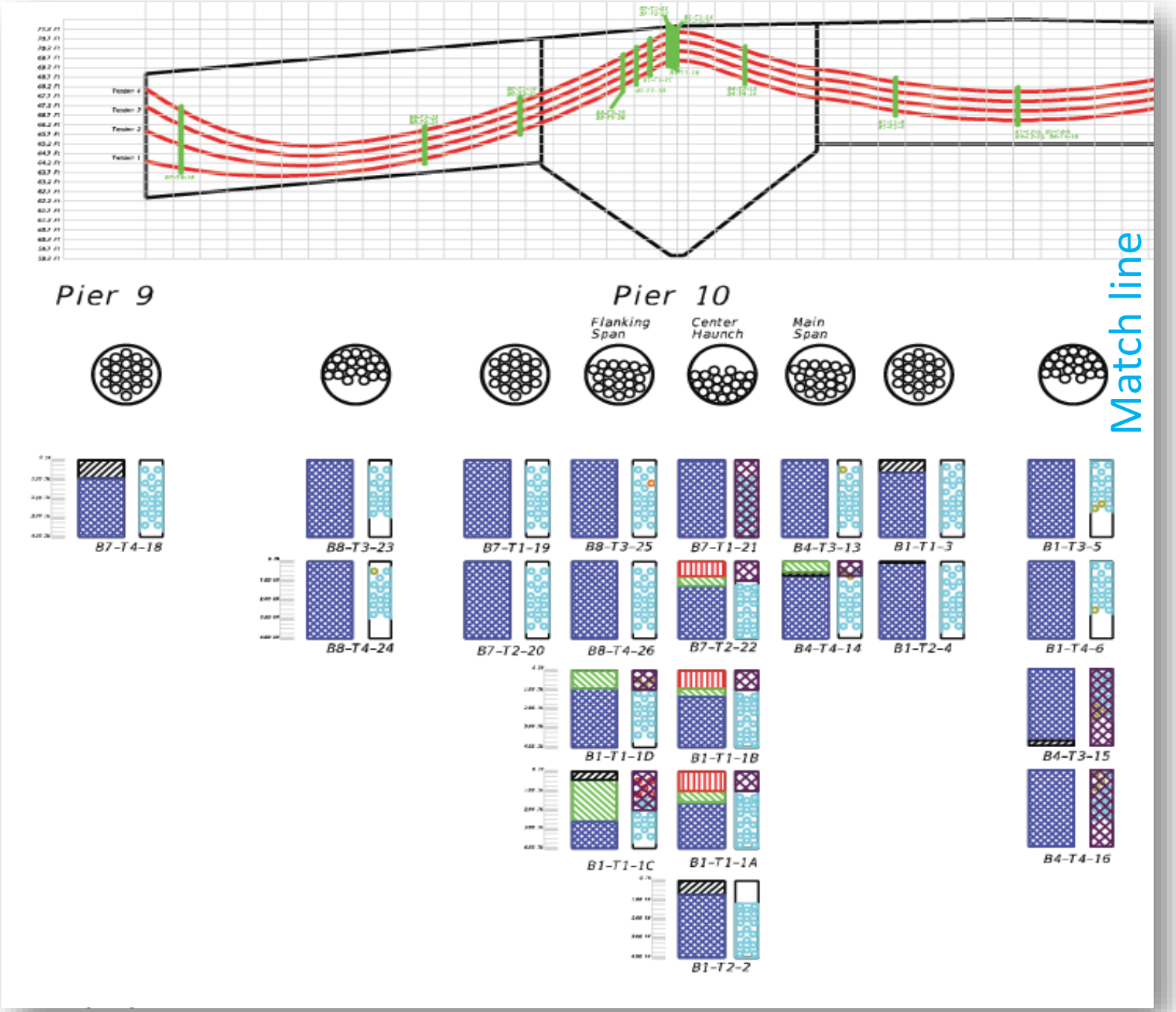
PT Tendons Investigations

Grouting Problems during Construction

- Beam 1 – T3: Cap and hose blew out
- Beam 1 – T4: Grout leaked at closure, anchor head cracked, stopped grouting at I port, grout set (incomplete grouting), pumped grout from the other end.
- Beam 4 – T3: While grouting T3, found leakage at upstream closure @ P10 haunch and grout crossed over to T4,Tube broke off at I port, flushed out T3, LE was empty. T4 was blocked.
- Beam 4 -T4: blockage found in the center part of mid-span; water found from pier 9 to 10; closure pour spall from top flange into the web; grouting was done from both ends.

Note: Missing grouting data of all beams T1 and T2.

PT Tendons Investigations



Legend

- Putty Grout
- Thick Black Material
- Soft and Chalky Grout
- Hard Grout
- Ducts
- Corroded Ducts
- Location of Strands
- Severe Strand Corrosion
- Moderate Strand Corrosion
- Minor Surface Corrosion

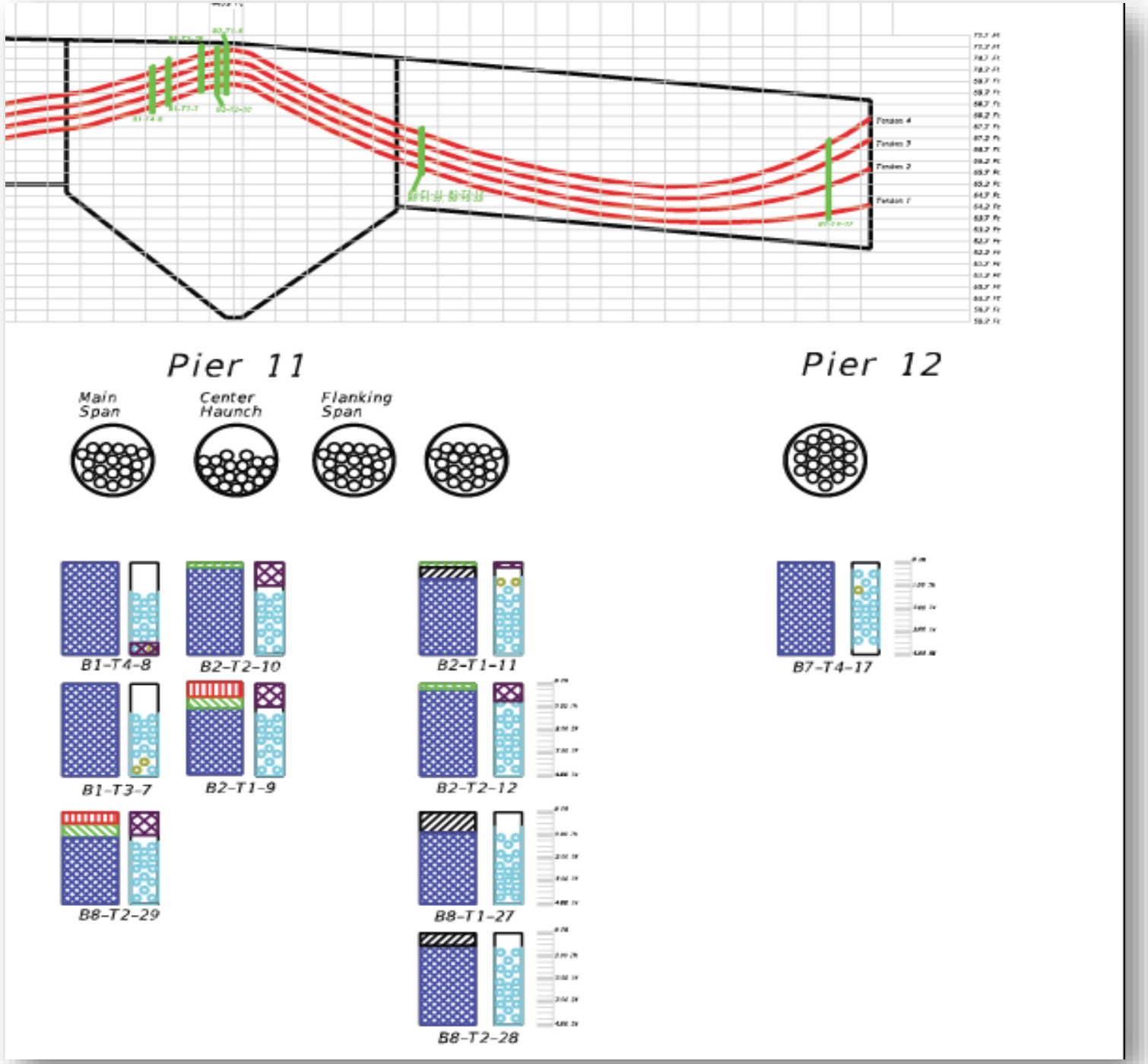
Findings in graphical form

Courtesy of D2 DSMO

FDOT TRANSPORTATION SYMPOSIUM

PT Tendons Investigations

Match line



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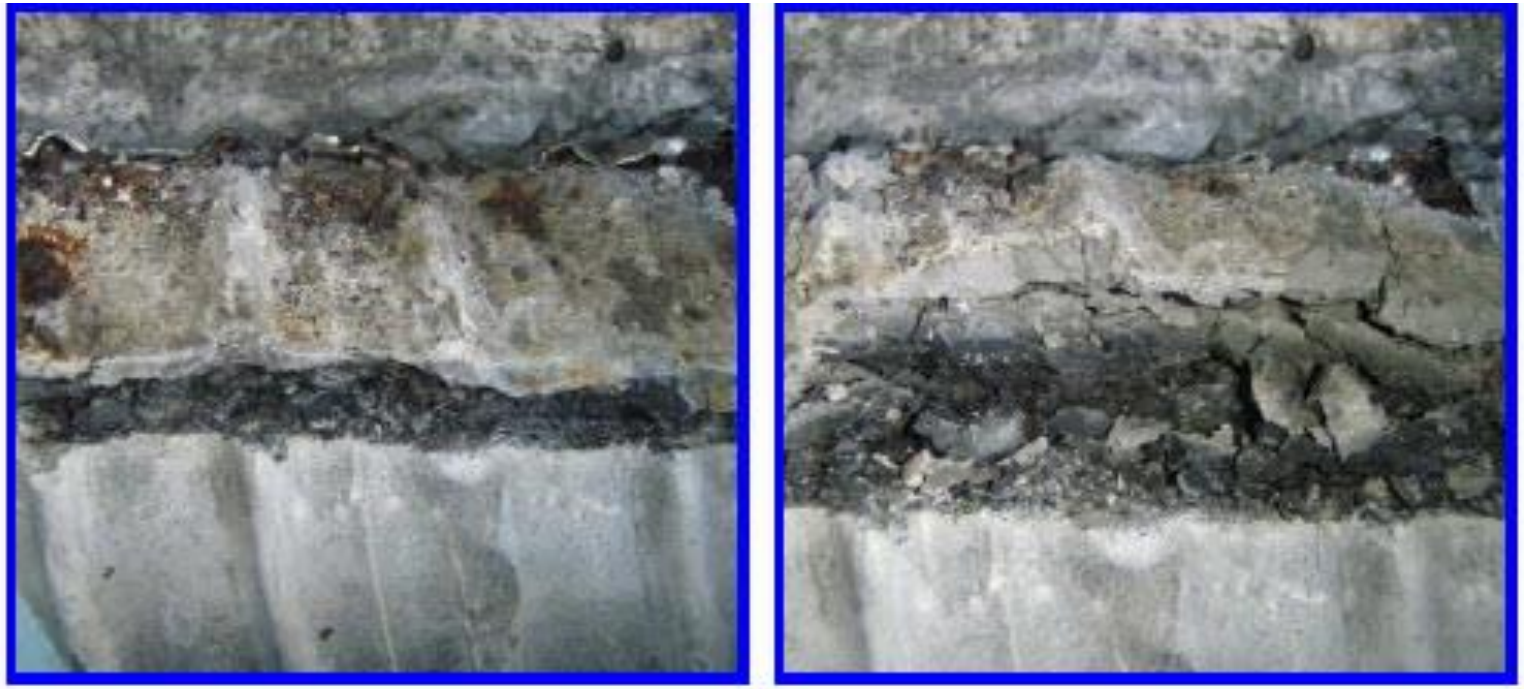
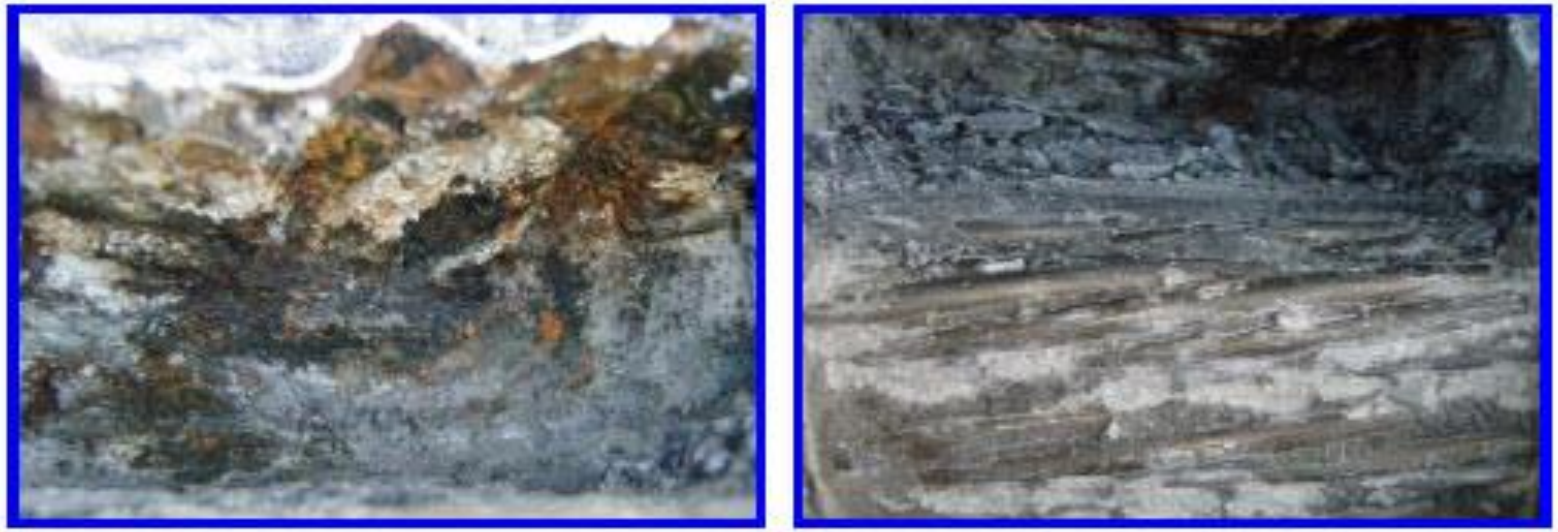
FDOT TRANSPORTATION SYMPOSIUM

PT Tendons Investigations



Conditions while grout samples were being collected (note black material under the putty like grout).



Corrosion on the inside surface of the duct that was in contact with putty like grout (left photograph) and no corrosion on wires that were in good grout.

Tendon 2 in Girder 8 at Pier 11

PT Tendons Investigations

PT Tendons Investigations

Strands with moderate corrosion and severe corrosion (before and after cleaning off corrosion products with a wire brush)

PT Tendons Investigations

Failed corroded strand

Notes: The failed corroded strand was discovered during the repair when the contractor was trying to obtain grout sample for moisture test.

PT Tendons Investigations

Follow-up Investigation (3rd Investigation)

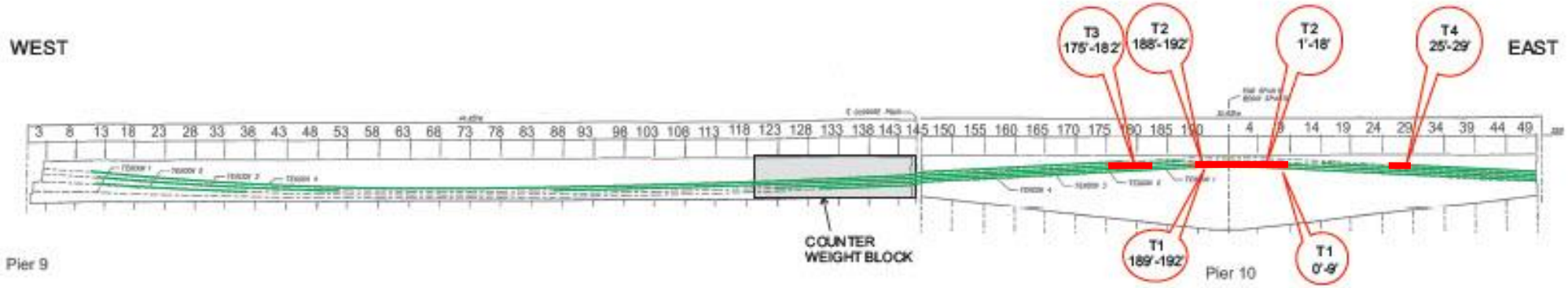
Time frame: September 22, 2014 to October 14, 2014
Method: Sonic / Ultrasonic Impact Echo NDE and Ground Penetrating Radar (GPR) was used to locate the tendon locations.
Primary goal: To map areas of soft grout and voids for all tendons for repair plans.

PT Tendons Investigations

Report Findings

- Confirmed the previous findings from the 1st and 2nd investigations.
- Discovered voids of 20 ft. long duct filled with water (Girder 8, Span 11, Tendon 3). The water could be from run-off from the deck through pour-back over the pier based on pressure test. or bleed water. The PH levels of test result showed indicative of bleed water.
- 3% (400 ft.) of approximately 13,555 feet tendon length subjected to impact echo, indicated the presence of soft grout and / or voids.
- 30% filled with hard grout.
- 67% have a thin rim of soft grout surrounding hard grout (1/16” to ¼ “ thick; ¾” thick in localized areas).
- The thin rim of soft grout consisted of thin rim of brittle grout surrounding hard grout, powder grout surrounding hard grout, putty grout sounding hard grout and duct corrosion.
- 87 locations of small holes in the duct were drilled for inspection verifications and borescope.

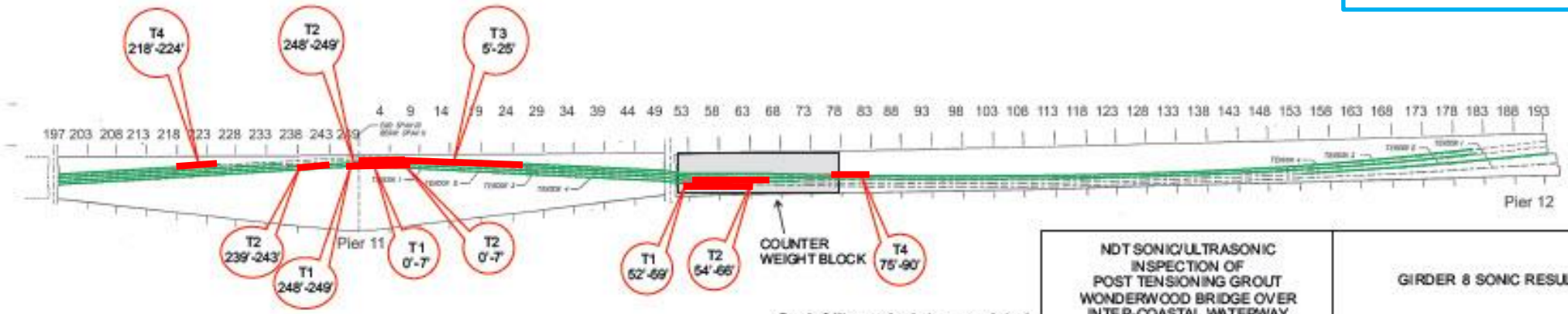
PT Tendons Investigations



Legend

Red: soft grout / voids

Green: Impact Echo coverage



Sonic/Ultrasonic data associated with voids or soft grout

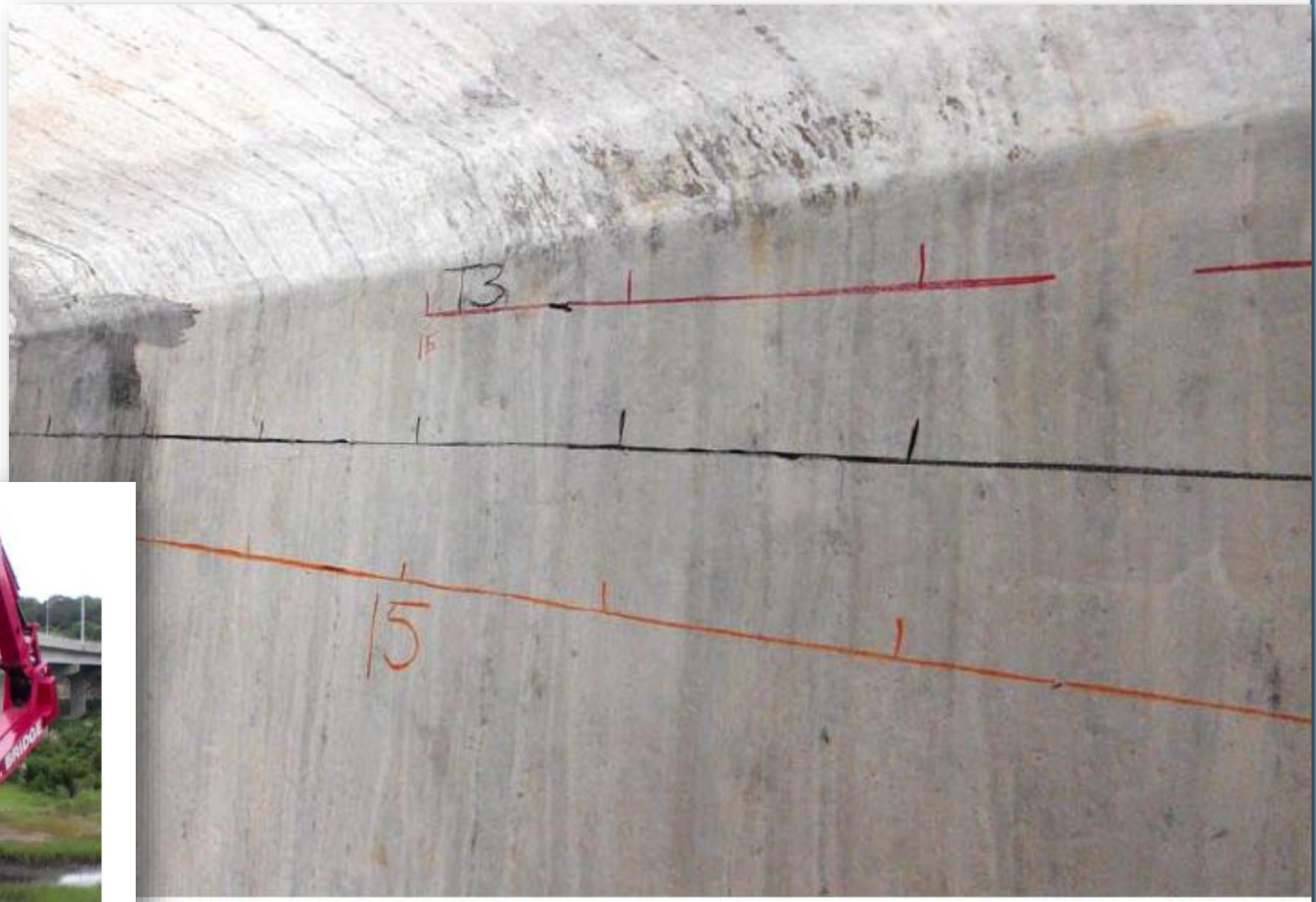
Sonic/Ultrasonic coverage

NDT SONIC/ULTRASONIC INSPECTION OF POST TENSIONING GROUT WONDERWOOD BRIDGE OVER INTER-COASTAL WATERWAY JACKSONVILLE, FLORIDA PREPARED FOR PARSONS BRINCKERHOFF BY NDT CORPORATION	GIRDER 8 SONIC RESULTS	
	NOVEMBER, 2014	FIGURE 14

Typical soft grout / voids mapping

PT Tendons Investigations

PHOTOGRAPH 1: Passing a radar antenna over a web tendon



PHOTOGRAPH 2: Marks of tendon profiles

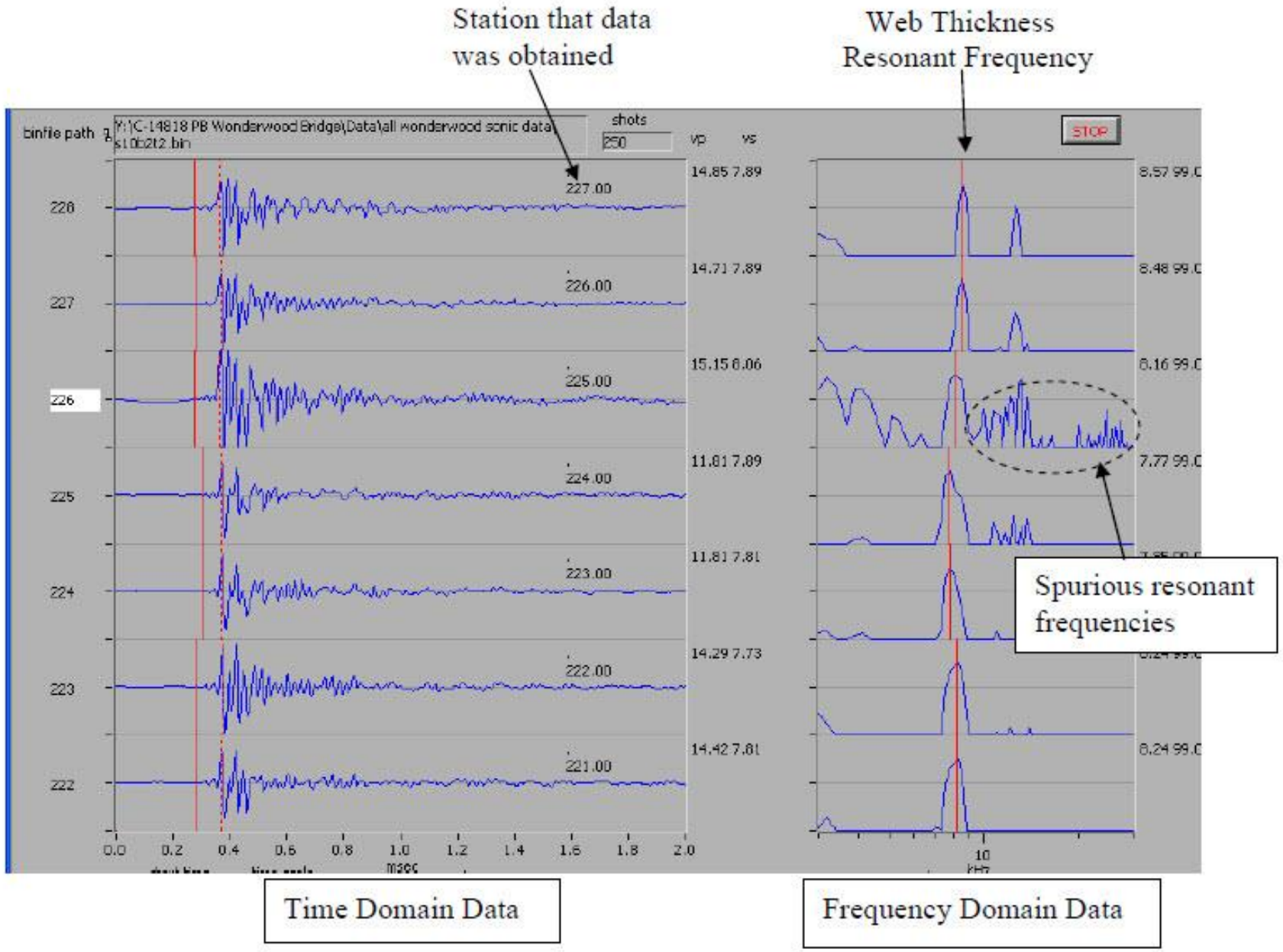


Figure 5: Samples of Time Domain and Frequency Domain data

Photo shows application a projectile impact energy source over web tendon

PT Tendons Investigations

PT Tendons Investigations

Figure 5A. Collection of a water sample at the drilled hole at NDT Station No. 19.

PT Tendons Investigations

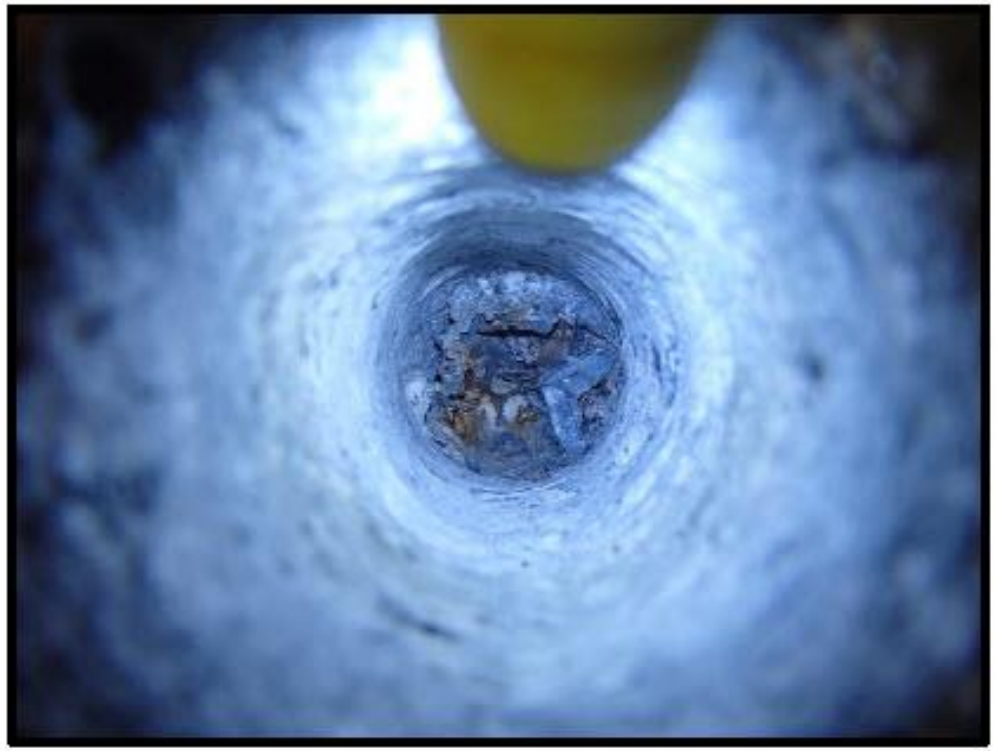
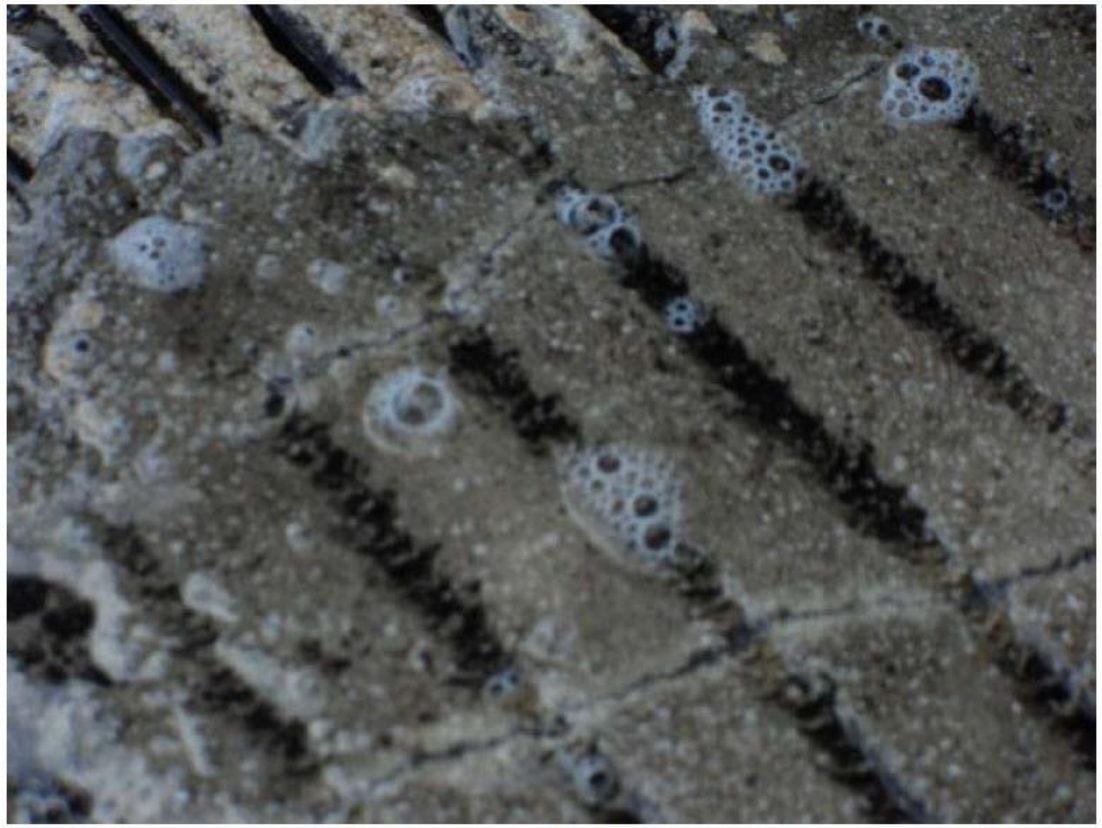


Figure 15B. Photograph inside the drilled hole at NDT Station No. 193 (S11-G4-T2).

PHOTOGRAPH 6: Temporary protection plug

PT Tendons Investigations

PHOTOGRAPH 7: Soapy water bubbles around patch in the deck



PHOTOGRAPH 8: Soapy water bubbles around cracks in the deck

Repair Strategy

Based on the three investigation reports, FDOT D2 DSMO Tasked Parsons Brinckerhoff (WSP) to study a repair strategy for Wonderwood Connector bridge.

Objective:

Evaluate the structural behavior and capacity of the main span unit in case of tendon deficiency.

Scope:

- Review existing plans, inspection reports, and construction documentation.
- Compute loads and time-dependent effects to determine service and ultimate load combinations. Check stresses and ultimate capacity assuming no structural deficiencies.
- Evaluate four tendon failure scenarios and determine impact on service and ultimate limit states.

Repair Strategy

Initial Phase I Repair Recommendations

Repair the existing tendons with deficiencies, such as grout voids, duct with water and soft-grout.

- ❑ *Remove soft grout
- ❑ Fill voids with vacuum grouting
- ❑ Apply Vector's Impregnation repair method for tendons with soft grout, including drying of the grout

Foot Notes:

- * Soft grout removal mock-up was not successful during Lab Testing, and later changed to drying of the soft grout
- The Vector's Impregnation method was Lab tested to improve process
- Technical Special Provisions were developed for both grout vacuum injection and Drying plus Impregnation

Repair Strategy / Lab Testing

Soft grout removal mock-up test at FDOT Structural Laboratory in Tallahassee

Repair Strategy / Lab Testing

Soft grout removal mock-up test at FDOT Structural Laboratory in Tallahassee

Repair Strategy / Lab Testing

Mock-up Test for Soft Grout removal

Conclusion: Unsuccessful

Results - Loose grout clogged outlet port

Mock Up- 5 Soft Grout Recipe Scenarios

Results - Soft grout remained and water migration to hard grout locations

Rotation Nozzle Hydro-blasting

Hydro-blasting

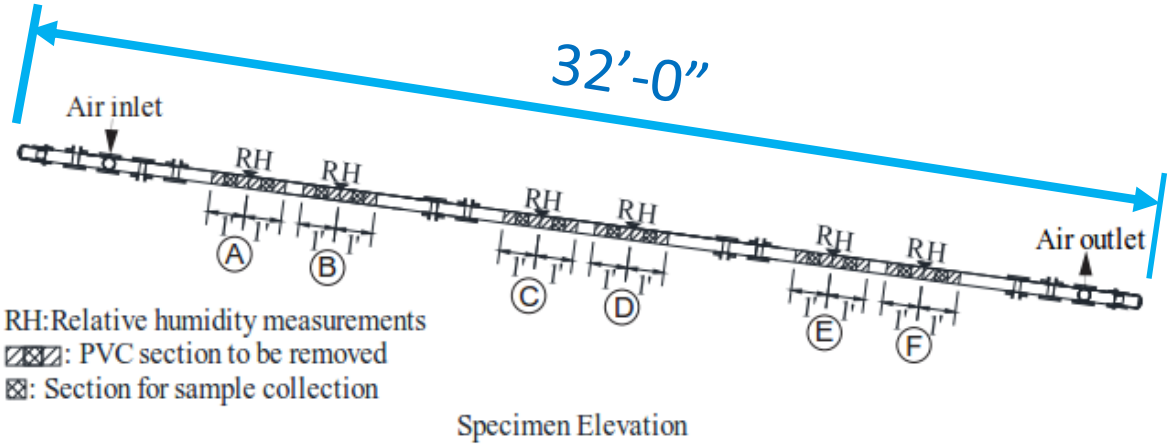
Vacuum assisted hydro-blasting

Repair Strategy

Soft grout dehumidification / drying mock-up test at FDOT Structural Laboratory in Tallahassee

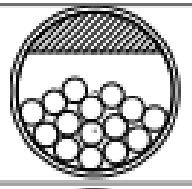
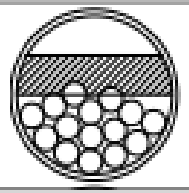
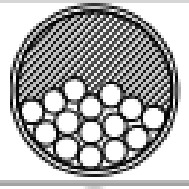
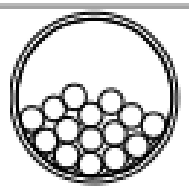
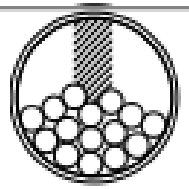
Repair Strategy Lab Testing

Mock-up testing for drying soft grout



Two – 32 ft. tubes with humidity sensors continuously dried for 90 days

Table 1 Sample location

	Top
	Bottom
	Top + Bottom
	Below the strands
	Near probe holes

Courtesy of FDOT

Repair Strategy Lab Testing

Results

- Drying decreased moisture content
- Vacuum assisted drying shortened drying time
- A continuous power source is needed
- Humidity probes are unreliable after exposure to water

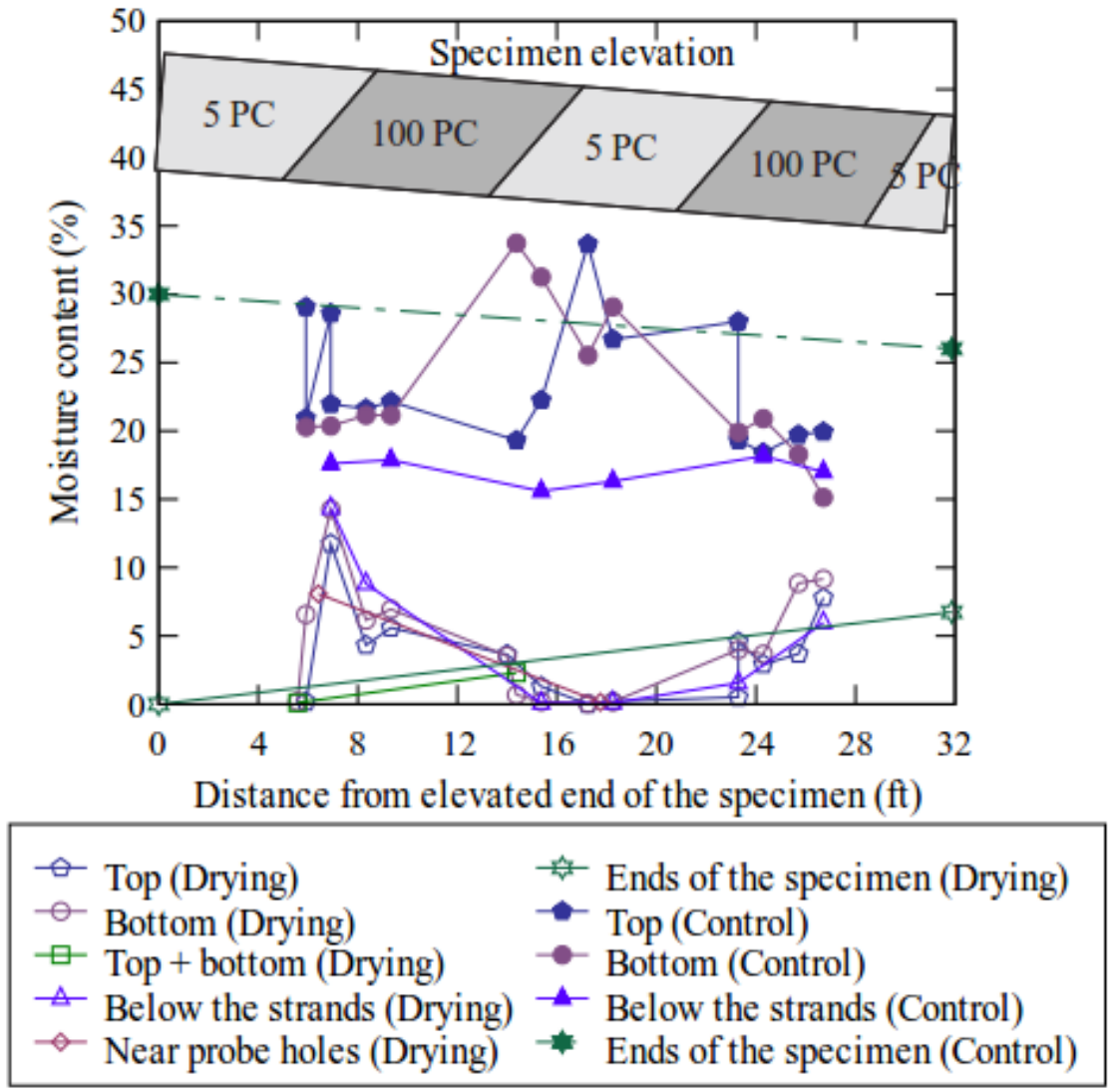


Figure 6 Comparison of moisture content for drying and control specimens 2

Final Phase 1 Repair Strategy After Lab Testing

Final Phase 1 Procedure

Step 1: Fill grout voids using vacuum grouting / vacuum assist grouting

Step 2: Drying process by blowing clean dry air to the tendons with soft grout. The drying is perform for the length of the t[illegible].

Drying is considered acceptable, provided m[illegible] one or both of following requirements:

a. The average relative hu[illegible] air from outlet ports has reached 20% or less.

b. The soft grout [illegible] maximum of 40% moisture (required grout samples t[illegible]ture level)

Status: Almost Complete

Step 3: Impregn[illegible]ocess can only begin after tendon drying is accepted. The impregnation pro[illegible]ct is a Vector's proprietary product. The liquid injected is called Hydrocarbon and Silicon Polymer Inhibiting Impregnation Material. The corrosion inhibiting material is impregnated through the interstitial spaces between wires of a strand and the material travels from end to end of the tendon.

Repair Strategy

Phase 2 Repair Recommendations

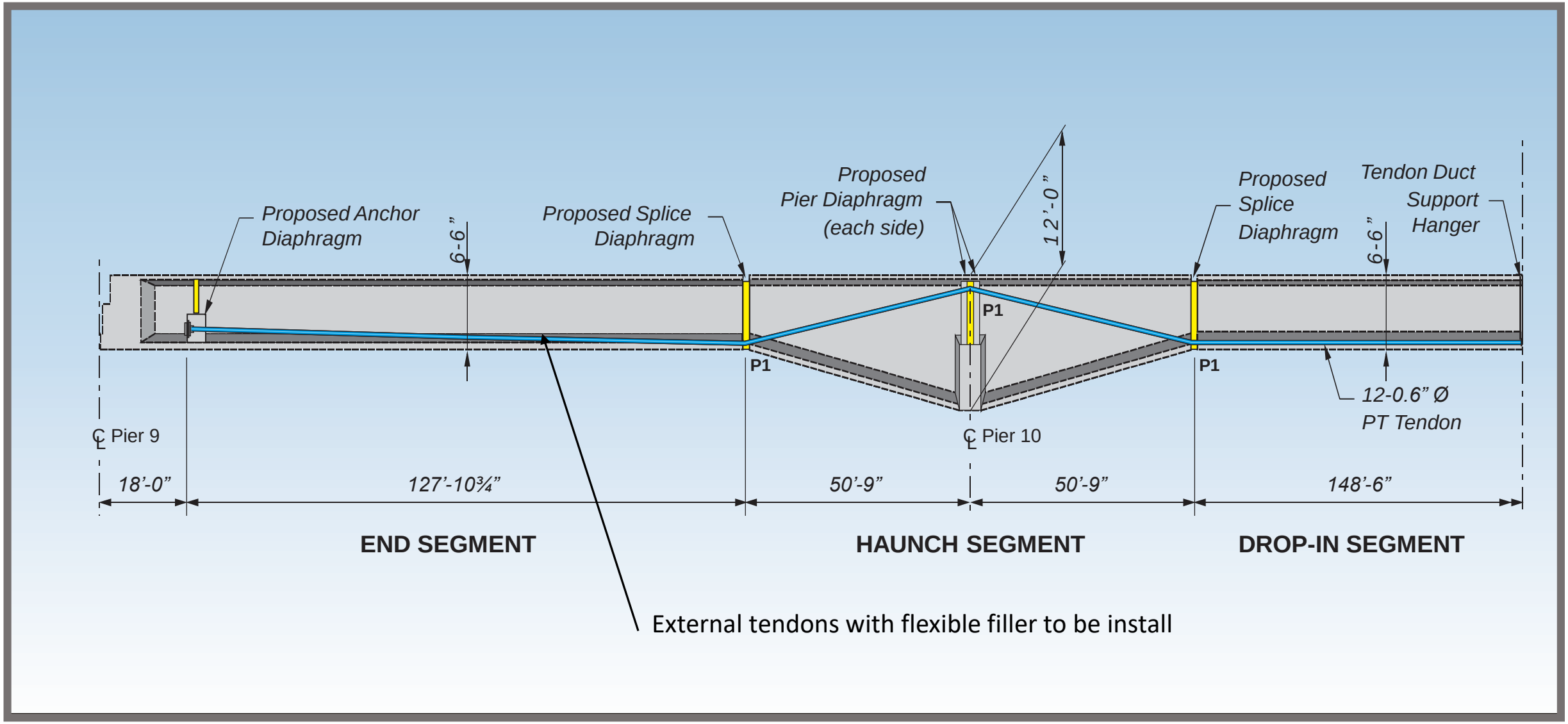
Add belt and suspenders: External tendons

Status: On going

Start: Summer 2019

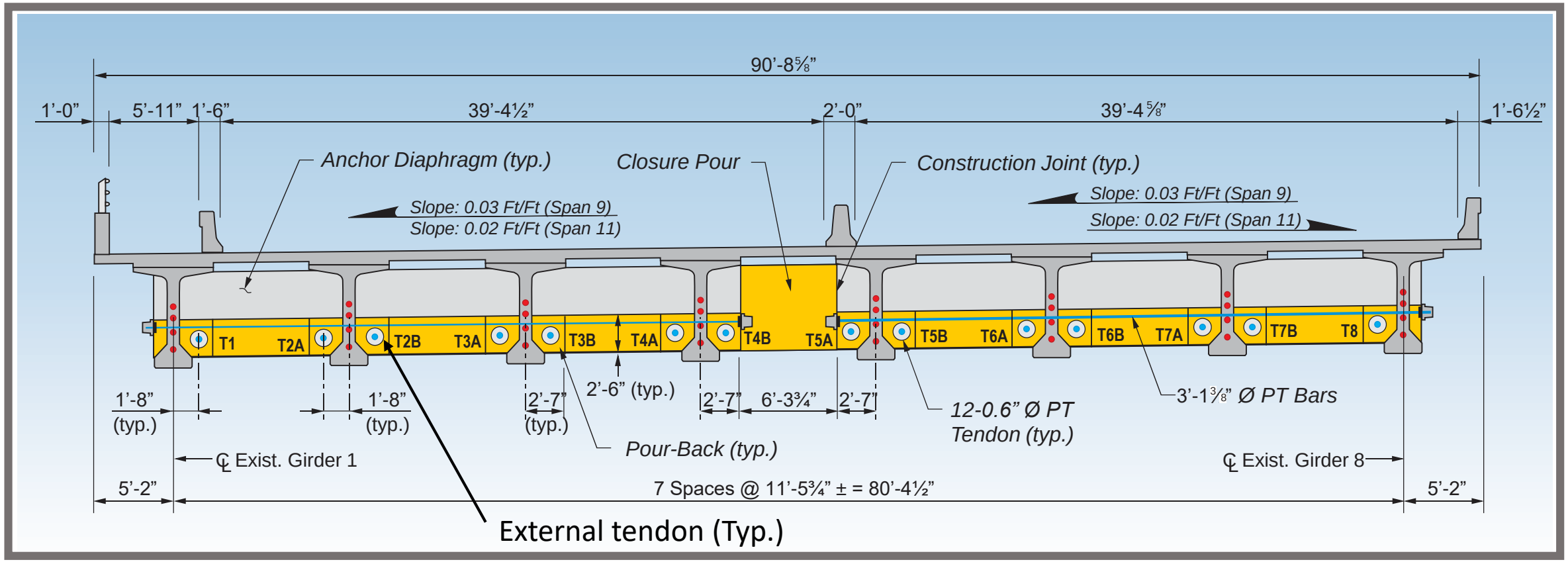
We plan to present the Phase 2 Repair in 2020 Symposium

Repair Strategy



Elevation View - Phase 2 Repair Strategy - External Tendons

Repair Strategy



Typical Sections – - Phase 2 Repair Strategy - External Tendons

Phase 1 Repair Construction

Tendon Mock-up

Grout Voids Injection

Phase 1 Repair Construction

Tendon Impregnation Process – Contractor's Mock-up

Phase 1 Repair Construction

Tendon Inspection and Dissection

Grout cap

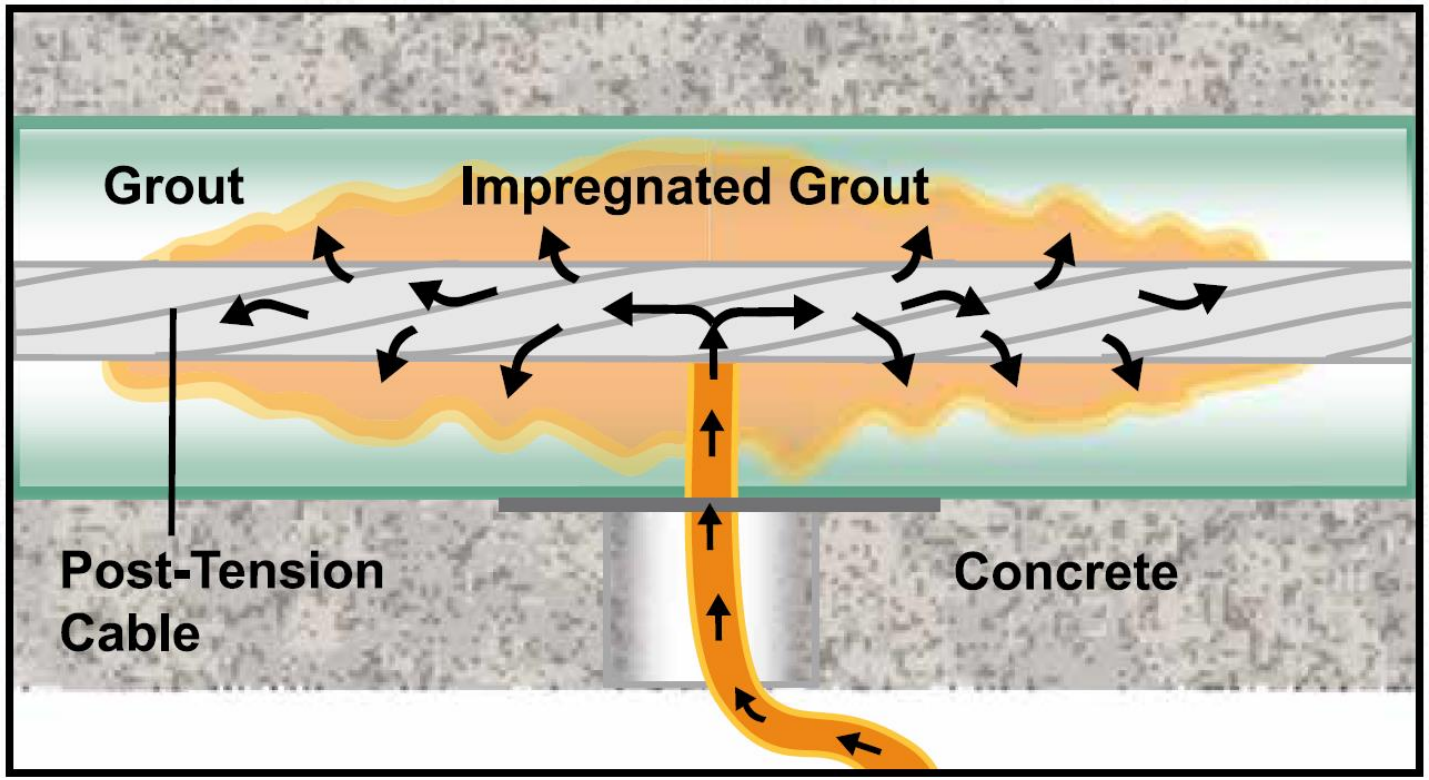
Contractor's Mock-up

Phase 1 Repair Construction

Salt spray testing on steel plate with untreated (left) and Post-Tech PTI treated section (right)

Salt spray testing on untreated (left) and Post-Tech PTI treated strand (right)

Phase 1 Repair Construction



Tendon Impregnation

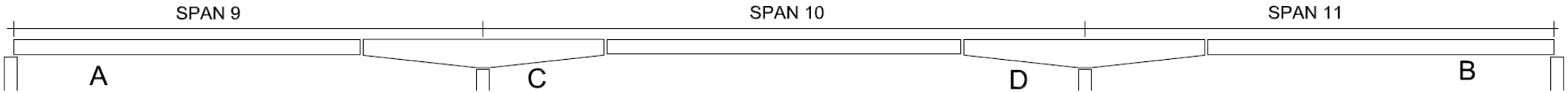
Post-Tech PTI flows along interstitial spaces in strands

Phase 1 Repair Construction

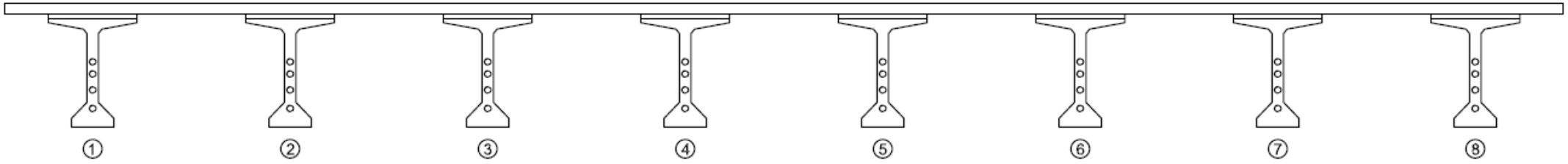
Work platform under the bridge set up

Phase 1 Repair Construction

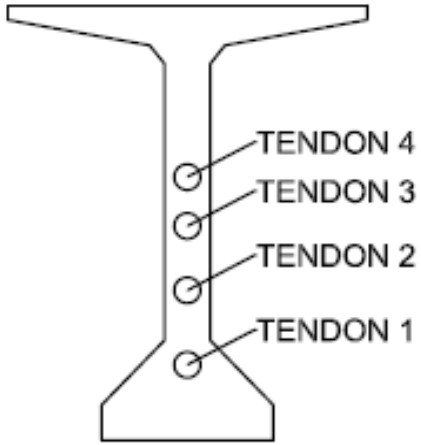
Work platform under the bridge



ELEVATION - SPANS 9, 10 & 11



GIRDER NUMBERS



TENDON NUMBERS

TENDON REPAIR SCHEDULE

GIRDER 1 - TENDONS 1 & 2
GIRDER 2 - TENDONS 1 & 2
GIRDER 3 - TENDON 1
GIRDER 4 - TENDONS 3 & 4
GIRDER 7 - TENDONS 2 & 4
GIRDER 8 - TENDONS 1, 2 & 3

Phase 1 Repair Construction

Phase 1 Repair Construction

Ground Penetrating Radar (GPR) for locating tendon

Phase 1 Repair Construction

Phase 1 Repair Construction

Time to seal the clamp!! ……How hard could it be?!

1. Silicone + Clamp
2. Butyl tape + Clamp

Phase 1 Repair Construction

Alright why is this not working…..

3. Weather Stripping (WS) + Clamp
4. Epoxy + Clamp
5. Epoxy + Clamp + Epoxy

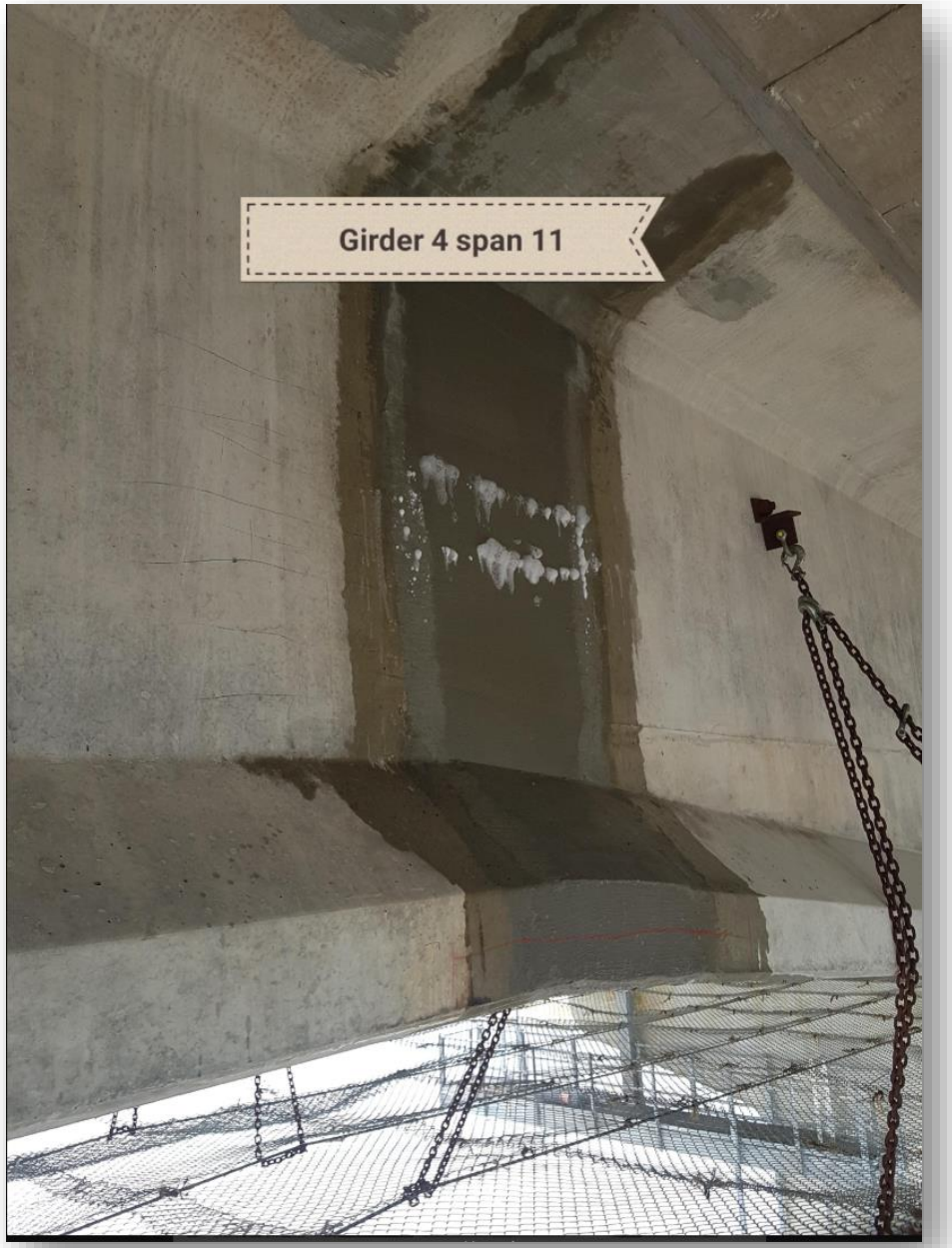
Phase 1 Repair Construction

6. Epoxy + WS + Clamp +Epoxy + Cure time + Bonding Agent + Concrete ☺

Phase 1 Repair Construction

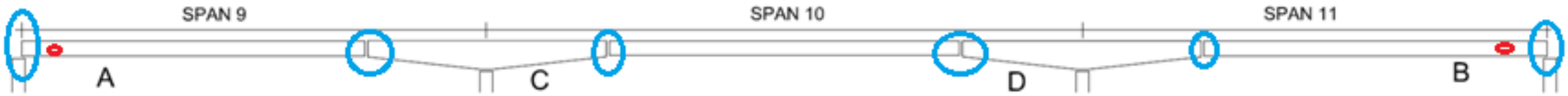
Drying process

Phase 1 Repair Construction



Phase 1 Repair Construction

Major Leak Zones



ELEVATION - SPANS 9, 10 & 11

Phase 1 Repair Construction

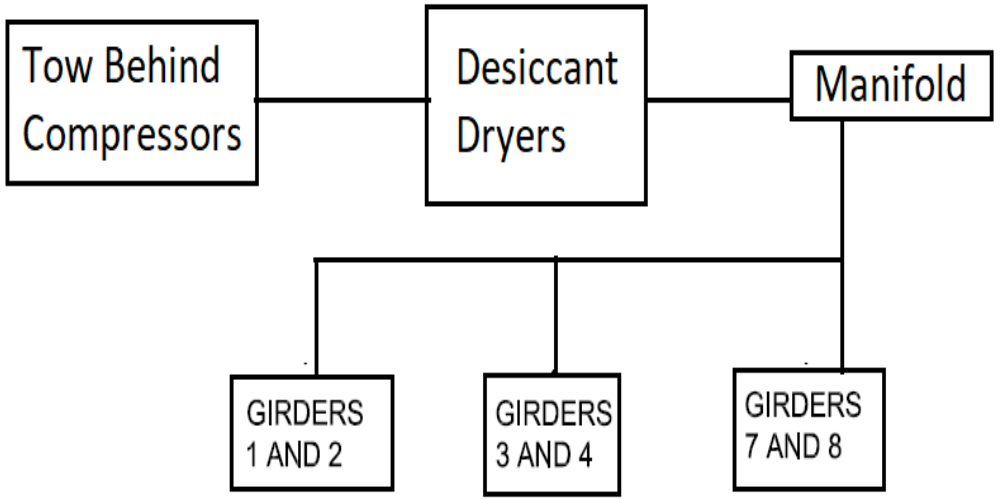
-Air flow rate
-Air temperature
-Relative humidity

Phase 1 Repair Construction

Air Sensors and Remote Monitoring Units (RMU'S)

Phase 1 Repair Construction

Drying Layout Original Plan



Tendon ID	Flow (LPM)
G1T1	7
G1T2	1
G2T1	0.7
G2T2	0.3
G3T1	3
G4T3	2
G4T4	0.3
G7T2	0.5
G7T4	2.5
G8T1	0.3
G8T2	0.3
G8T3	2

ELEVATION - SPANS 9, 10 & 11

Phase 1 Repair Construction

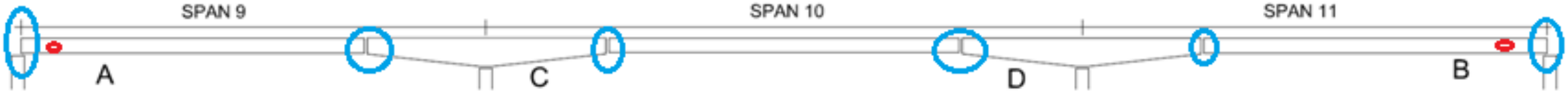
off to verify air is flowing continuously from the injection end, prior to using the vacuum pump. Pressurized air injection shall have a maximum relative humidity of 10%. The contractor is required to check the pressurized air injection flow rate and vacuum pump outlet relative humidity of air at least weekly or as directed by the Engineer. The drying of soft grout is considered acceptable if one or both of the following are met:

1. The average relative humidity of the air from the outlet ports has reached 20% or less.
2. The soft grout has a maximum moisture content of 40 % as approved by the Engineer from samples taken at locations along the length of the tendons as directed by the Engineer.
3. Clean and install the impregnation port(s) on the tendon location(s) determined in the field

process shall include a vacuum pump during all drying operations, to enhance the drying airflow and decrease drying time. Dry each tendon section using pressurized air injection at one end and vacuum assistance at the opposite end. Install pressure gages and regulators at each air inlet with a required minimum pressure of 20 psi. Flow valves shall be installed at the vacuum outlet, and a required minimum air flow of 10 L/minute shall be maintained. Check air flow with vacuum pump assistance

Phase 1 Repair Construction

But Wait….What About Those Leaks?

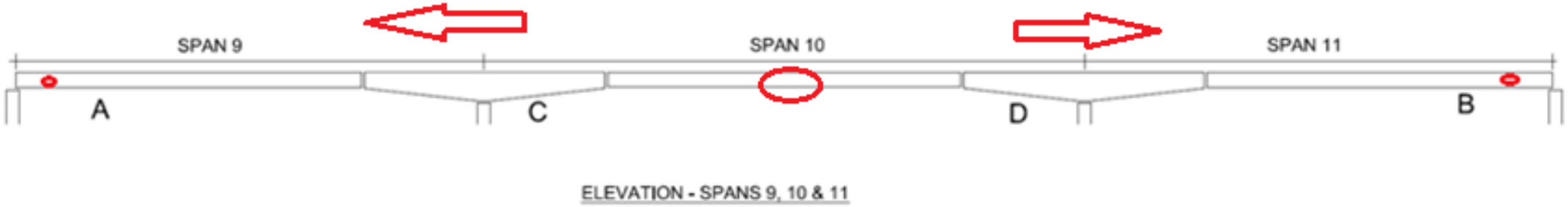


ELEVATION - SPANS 9, 10 & 11

Phase 1 Repair Construction

Drying Layout Plan A

Drying Layout Plan B



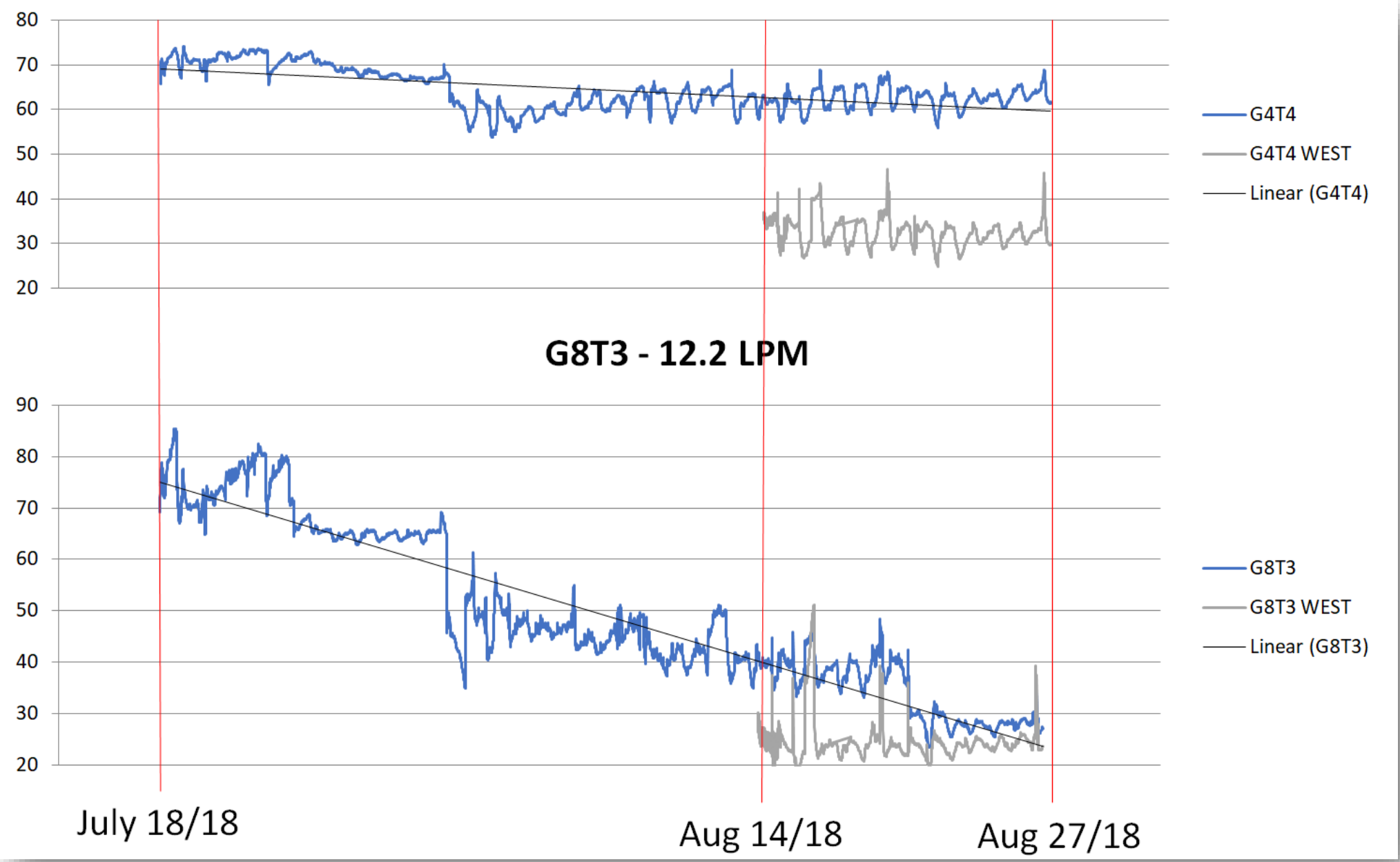
Phase 1 Repair Construction

Tendon ID	Flow (LPM)
G1T1	7
G1T2	1
G2T1	0.7
G2T2	0.3
G3T1	3
G4T3	2
G4T4	0.3
G7T2	0.5
G7T4	2.5
G8T1	0.3
G8T2	0.3
G8T3	2

Sample ID	Avg Air Flow LPM
G1T1-11	3.75
G1T1-9	4.5
G1T2-11	4.7
G1T2-9	3.5
G2T1-11	2.3
G2T1-9	4
G2T2-11	2
G2T2-9	1.8
G3T1-11	6
G3T1-9	2
G4T3-11	2
G4T3-9	13
G4T4-11	3
G4T4-9	11
G7T2-9	22
G7T2-11	4.5
G7T4-9	12
G7T4-11	13
G8T1-9	13
G8T1-11B	5
G8T2-9	6
G8T2-11	7
G8T3-9	11
G8T3-11	12.5

Flow rate comparison End-to-end vs Center-out

Phase 1 Repair Construction

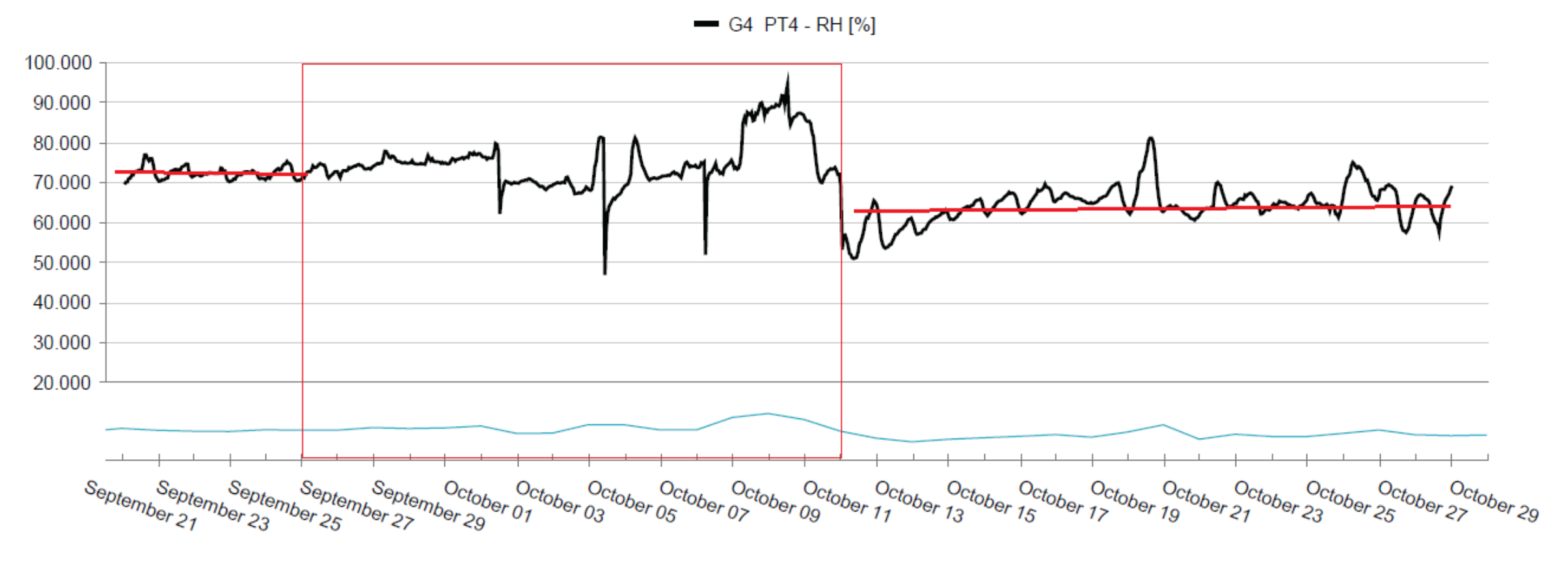


Outlet Humidity Change Over Time

FDOT TRANSPORTATION SYMPOSIUM

Phase 1 Repair Construction

Vacuum Pump Trial



Phase 1 Repair Construction

Sample ID	Start Date 2018		Sept. 2018		Oct. 2018		Nov. 2018		Dec. 2018		Mid Jan		
	Mid July 2018 - East Drying Port Average RH%	Mid August 2018 West Drying Port Average RH%	East Drying Port Average RH%	West Drying Port Average RH%	East Drying Port Average RH%	West Drying Port Average RH%	East Drying Port Average RH%	West Drying Port Average RH%	East Drying Port Average RH%	West Drying Port Average RH%	East Drying Port Average RH%	West Drying Port Average RH%	Total Change
G1T1-11	66.00%		54.00%		51.00%		60.00%		37.00%		36.00%		30%
G1T1-9		63.00%		62.00%		65.00%		57.00%		54.00%		53.00%	10%
G1T2-11	68.00%		61.00%		61.00%		63.00%		59.00%		45.00%		23%
G1T2-9		57.00%		62.00%		62.00%		55.00%		54.00%		52.00%	5%
G2T1-11	75.00%		81.00%		71.00%		64.00%		54.00%		44.00%		31%
G2T1-9		55.00%		58.00%		58.00%		54.00%		49.00%		44.00%	11%
G2T2-11	76.00%		68.00%		70.00%		70.00%		65.00%		60.00%		16%
G2T2-9		57.00%		61.00%		62.00%		61.00%		53.00%		53.00%	4%
G3T1-11	41.00%		50.00%		54.00%		56.00%		49.00%		39.00%		2%
G3T1-9		48.00%		60.00%		57.00%		52.00%		51.00%		39.00%	9%
G4T3-11	53.00%		53.00%		47.00%		44.00%		45.00%		36.00%		17%
G4T3-9		27.00%		28.00%		25.00%		25.00%		23.00%		19.00%	8%
G4T4-11	69.00%		72.00%		72.00%		72.00%		67.00%		56.00%		13%
G4T4-9		34.00%		36.00%		32.00%		28.00%		28.00%		32.00%	2%
G7T2-9		31.00%		28.00%		22.00%		24.00%		24.00%		30.00%	1%
G7T2-11	80.00%		77.00%		82.00%		76.00%		80.00%		80.00%		0%
G7T4-9		21.00%		27.00%		24.00%		29.00%		27.00%		19.00%	2%
G7T4-11	62.00%		42.00%		49.00%		64.00%		33.00%		28.00%		34%
G8T1-9		41.00%		38.00%		37.00%		24.00%		23.00%		21.00%	20%
G8T1-11B	81.00%		94.00%		99.00%		62.00%		95.00%		90.00%		-9%
G8T2-9		57.00%		55.00%		54.00%		50.00%		60.00%		57.00%	0%
G8T2-11	68.00%		75.00%		79.00%		81.00%		85.00%		80.00%		-12%
G8T3-9		26.00%		35.00%		20.00%		?		19.00%		Injecting	7%
G8T3-11	74.00%		34.00%		34.00%		41.00%		29.00%		Injecting		45%

Phase 1 Repair Construction

Grout Sample
Moisture Content

ELEVATION - SPANS 9, 10 & 11

Phase 1 Repair Construction

Air RH – 35%, Grout Sample – 10.8% wt

*RH – Relative humidity of outflow air
Sample – Measured in % of water by weight (Moisture content)

Phase 1 Repair Construction

Air RH – 35%, Grout Sample – 10.8% wt
Air RH – 90%, Grout Sample – 7.9% wt

*RH – Relative humidity of outflow air
Sample – Measured in % of water by weight (Moisture content)

Phase 1 Repair Construction

Air RH – 35%, Grout Sample – 10.8% wt
Air RH – 90%, Grout Sample – 7.9% wt
Air RH – 50%, Grout Sample – 42.3% wt

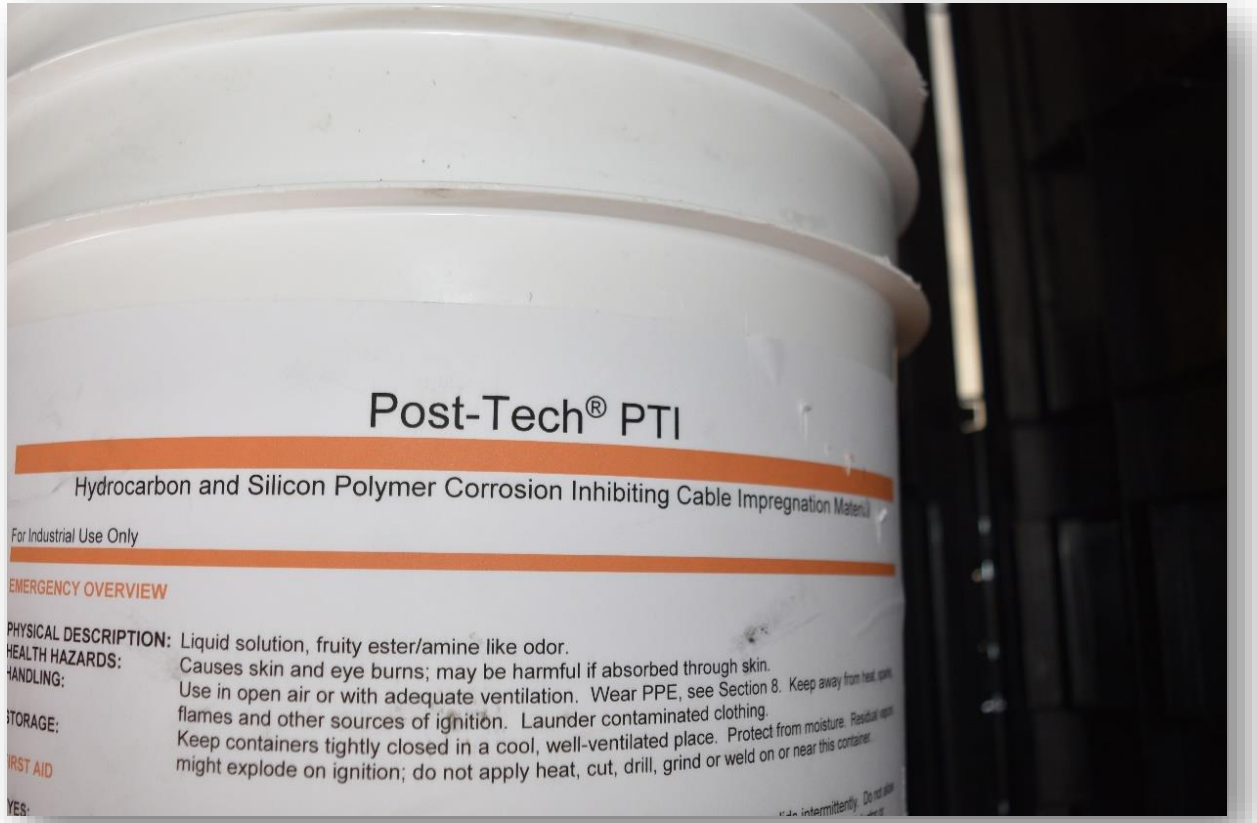
*RH – Relative humidity of outflow air
Sample – Measured in % of water by weight (Moisture content)

Phase 1 Repair Construction

PTI Resin Injection Pump

Phase 1 Repair Construction

Impregnation Set-up



Phase 1 Repair Construction

Field Injection Records

PARSONS

M. Byington
1-21-19

Contract: E2V62 Wonderwood Bridge Tendon Impregnation Record

Avg Air flow LPM: 5

Tendon: G4-T3

Inlet Locations: Span #10 sta# 114

Outlet Locations: Span #9 sta# 182
Span #11 sta# 19

Note: Inches of depth are measured in the pre-packaged container. 1" of depth equals 1.57 liters of material.

Date	Start	Stop	Time	Inches	Liters	PSI	Notes
1-21-19	9:10			9.5			Cont. bucket #2 Vac pumps each outlet
			9:40	9.25	0.39		
			10:13	9.0	0.39		
			10:45	8.75	0.39		
			11:15	8.625	0.2		
			11:45	8.375	0.39		
			12:15	8.25	0.2		
			12:45	8.0	0.39		
			1:15	7.75	0.39	110	
			1:45	7.25	0.79		
			2:15	7.25	0		
1-21-19		2:53		6.875	0.59		Stop
		1-21-19 =	5.72 hrs		4.12L		0.72 L/hr pumping rate
			Totals				

5.72 hrs

West End Anchorage Treatment

East End Anchorage Treatment

FDOT TRANSPORTATION SYMPOSIUM

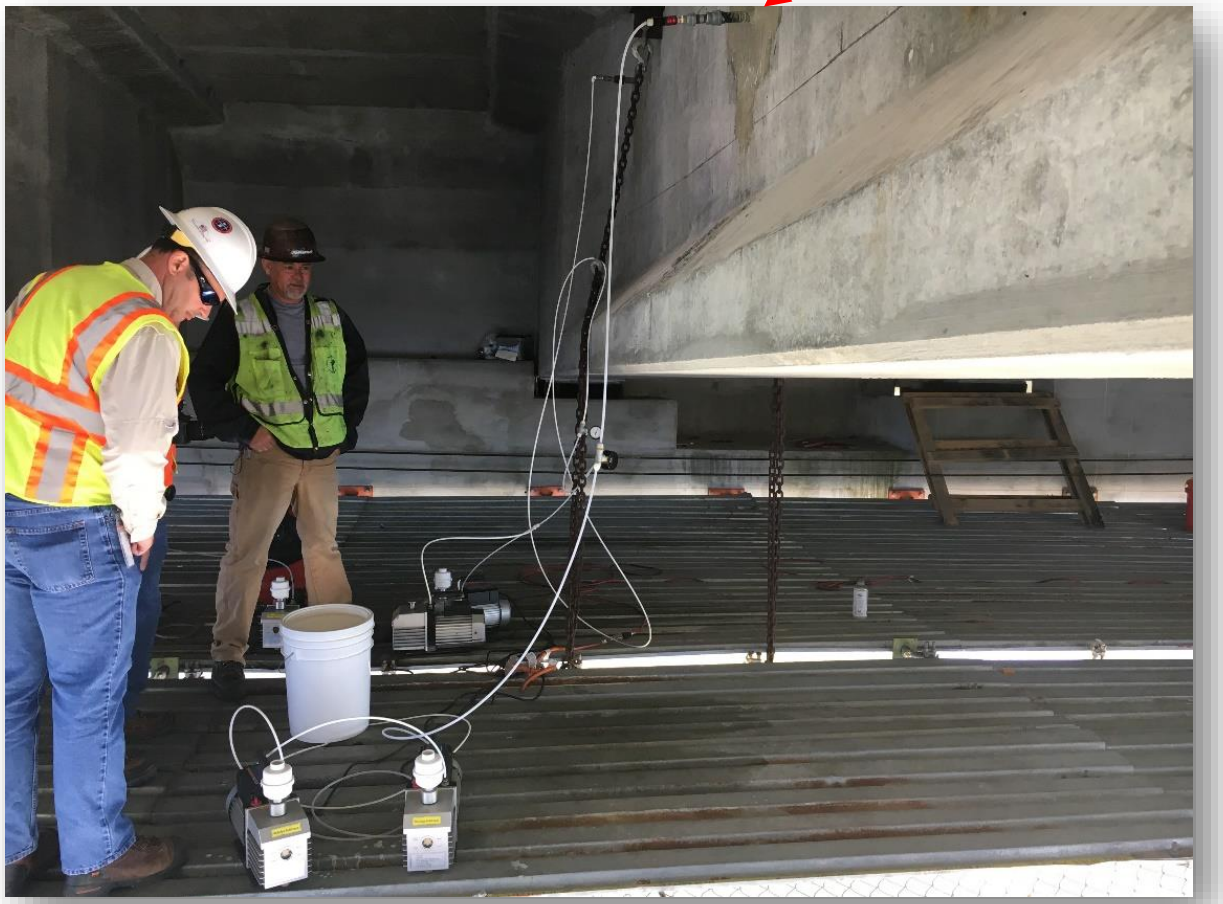
Phase 1 Repair Construction

Vacuum Pump Assistance for Injection

Phase 1 Repair Construction

Impregnation process

Outlet port



Inlet port

Phase 1 Repair Construction

- 4 Cables Injected
- 8 cables In progress (Repairing leak locations)

Project Credits

Phase 1 Repair Construction

Owner: FDOT District 2 (supported by SMO, SDO, D2 DSMO and D2 Construction)
CE&I: Parsons
Contractor: M&J Construction
Sub-contractor for tendons repair: Vector Corrosion Technologies
Engineer of Record: Parsons Brinckerhoff (WSP)

Investigations Phase

FDOT D2 / SMO
TranSystems
Concorr Florida
Parsons Brinckerhoff (WSP)
NDT Corporation (now part of Vector Corrosion Technologies)