Corrosion Evaluation and Mitigation of Bonded Post-Tensioning

Presented by:

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Outline

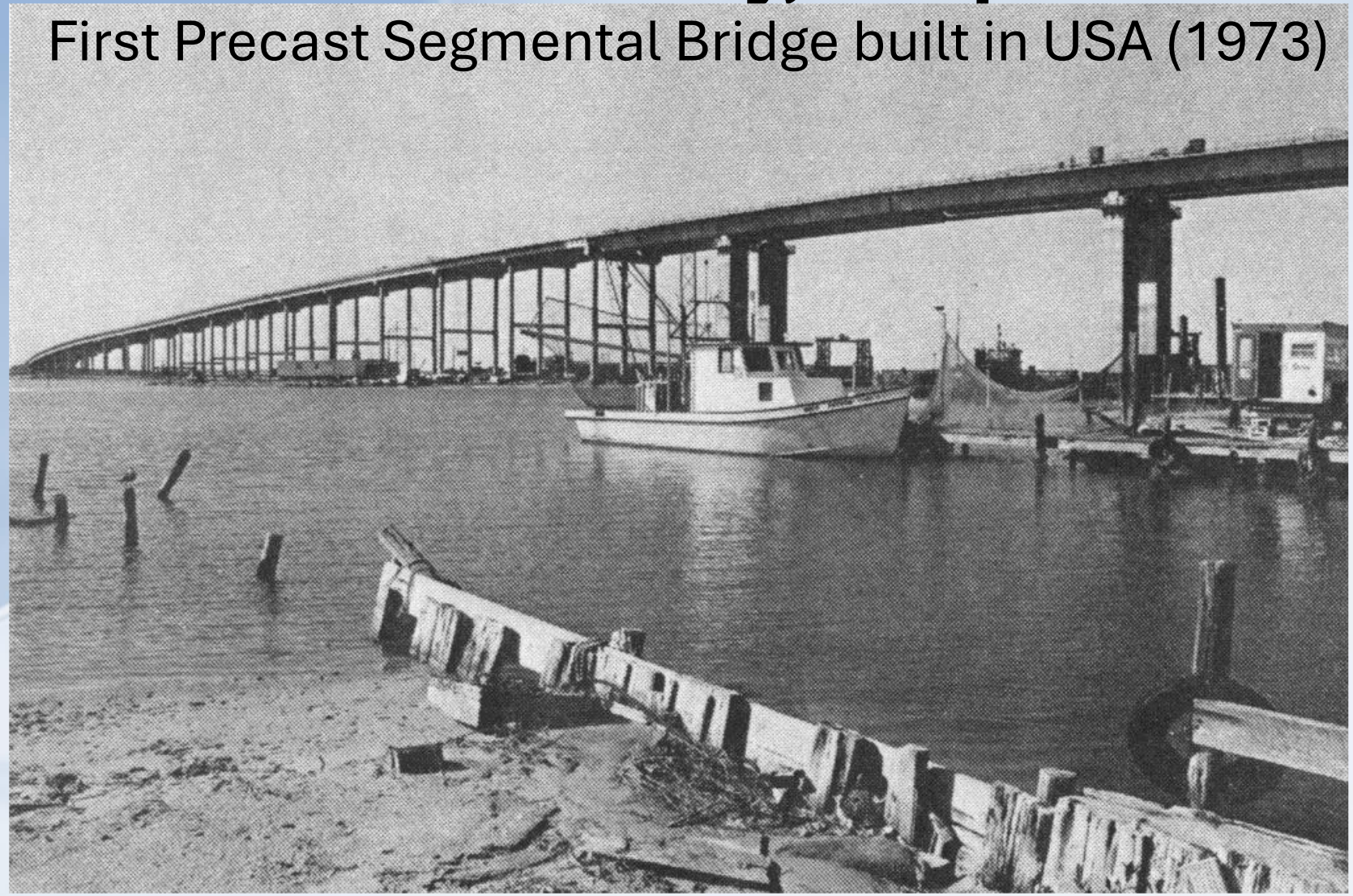
- Post–tensioning Background
- Common problems found in post-tensioning
- How to detect the problems – Testing methods
- How to rehabilitate and mitigate the problems

History

- Eugene Freyssinet proposed the use of Post-tensioned concrete in 1928
- First PT bridge built in France in 1941
- Post-tensioning gains popularity in Europe due to steel shortage: 1946
- First PT bridge in US: 1949 - 1951
- Structurally efficient, long span bridges

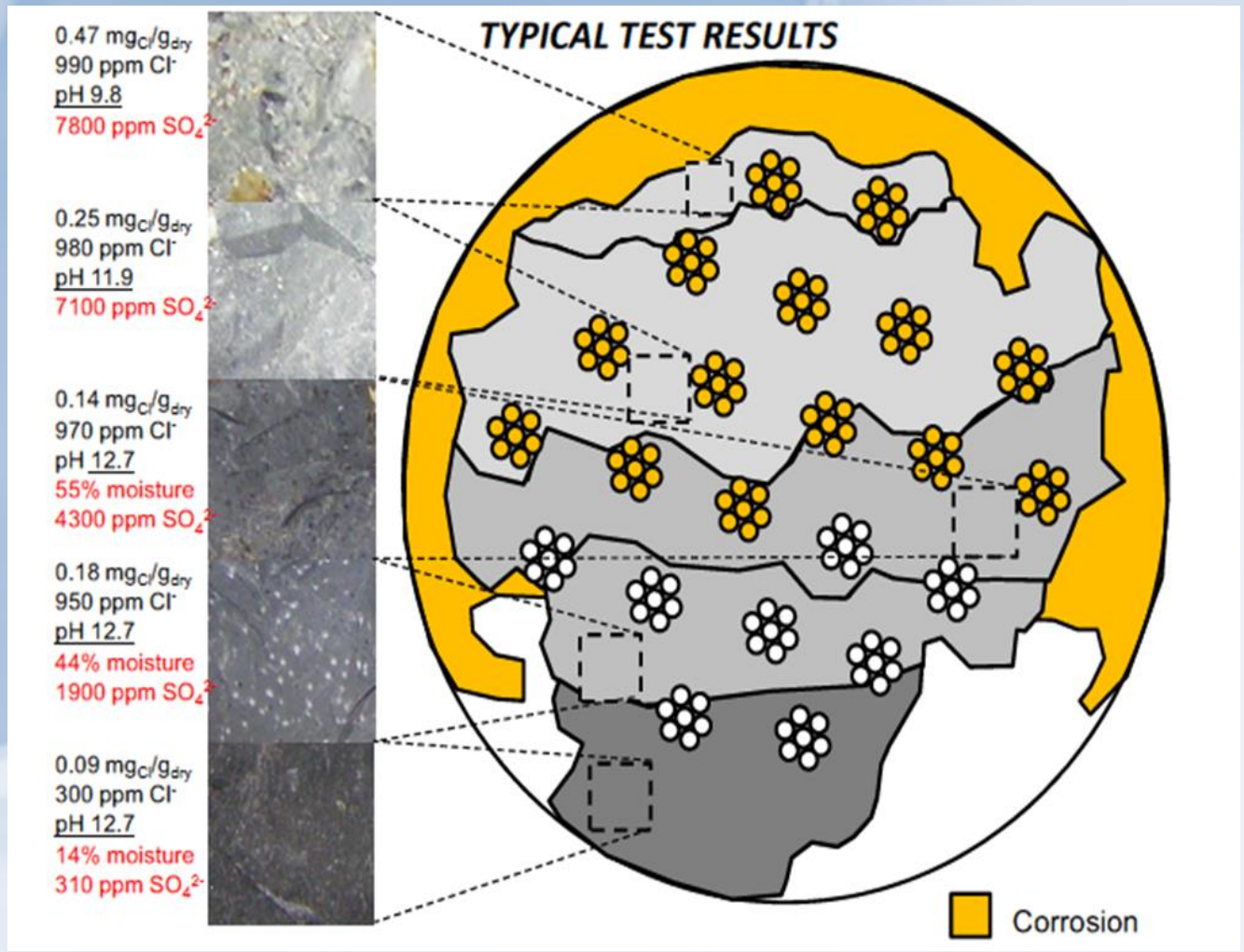
JFK Memorial Causeway, Corpus Christi, Texas

First Precast Segmental Bridge built in USA (1973)



What are the common problems?

Defective Grout (Segregation)



Grout Voids -Unprotected Strands

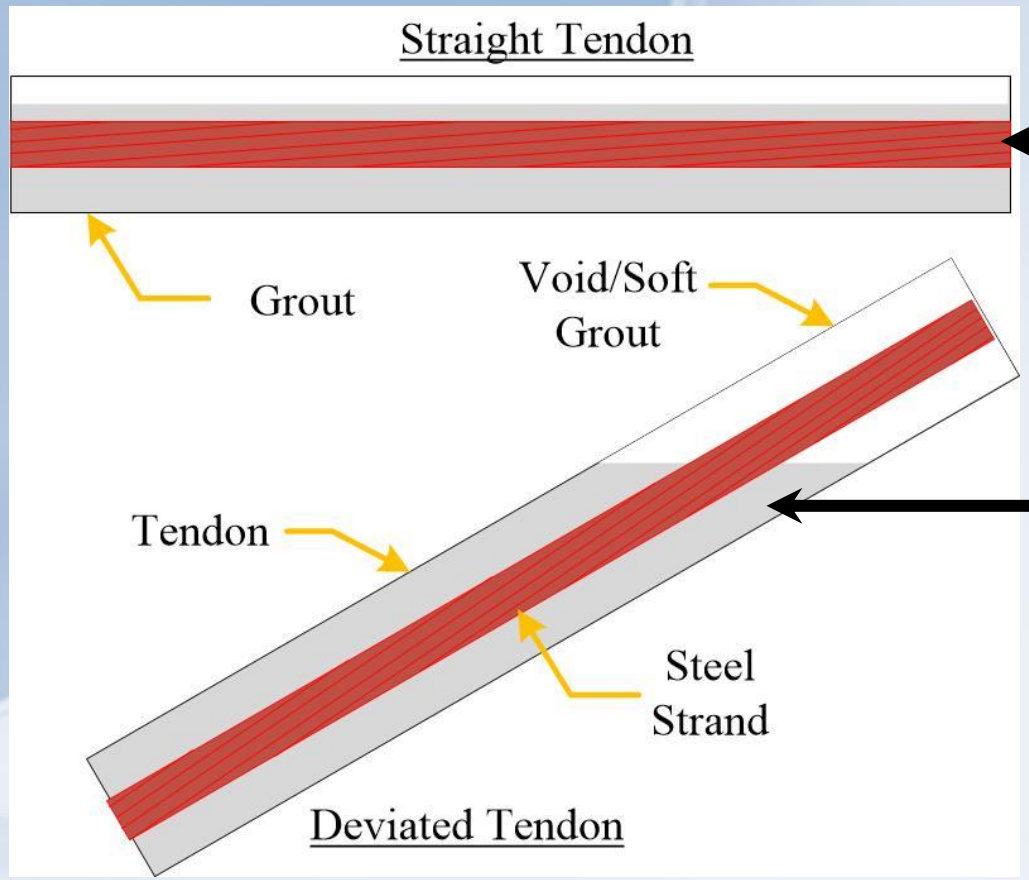
Corrosion

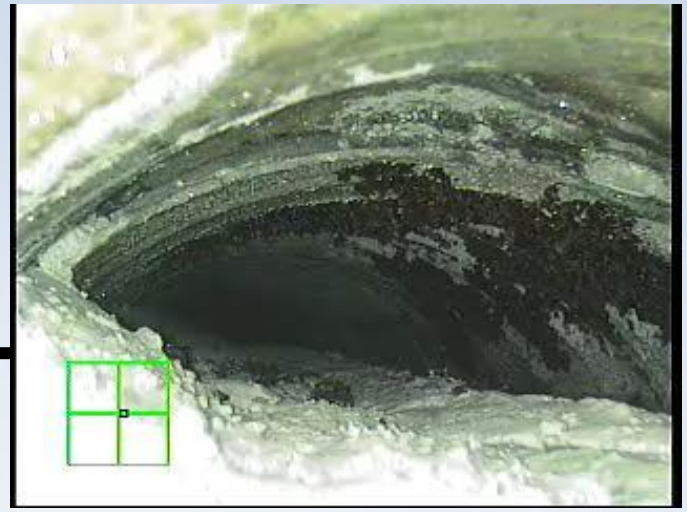
Bleed Test

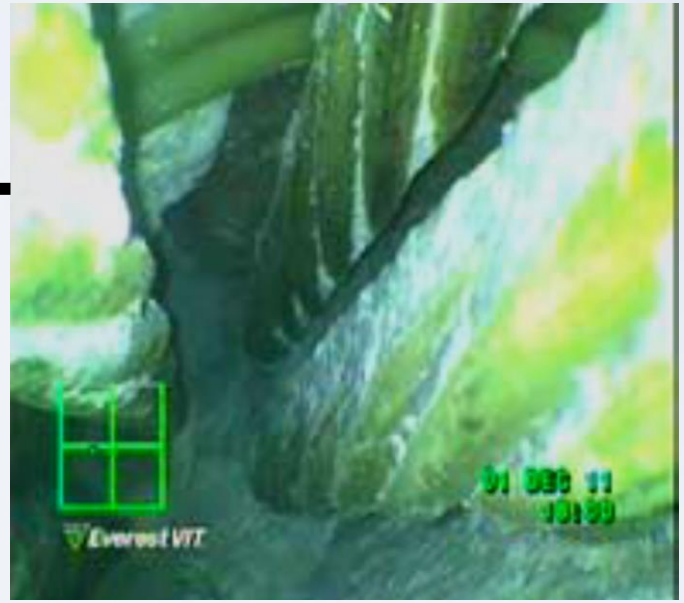
Wick-induced bleed test by American Segmental Bridge Institute (April 2012)

Portland cement grout ~ 4% bleeding after 24 hours of grout operation.

Straight vs Deviated Tendon

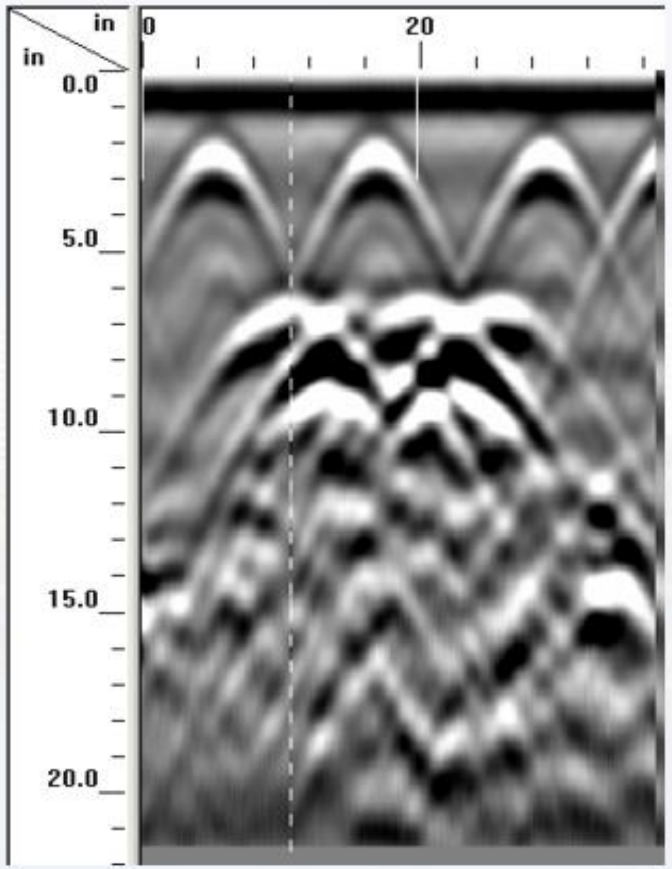


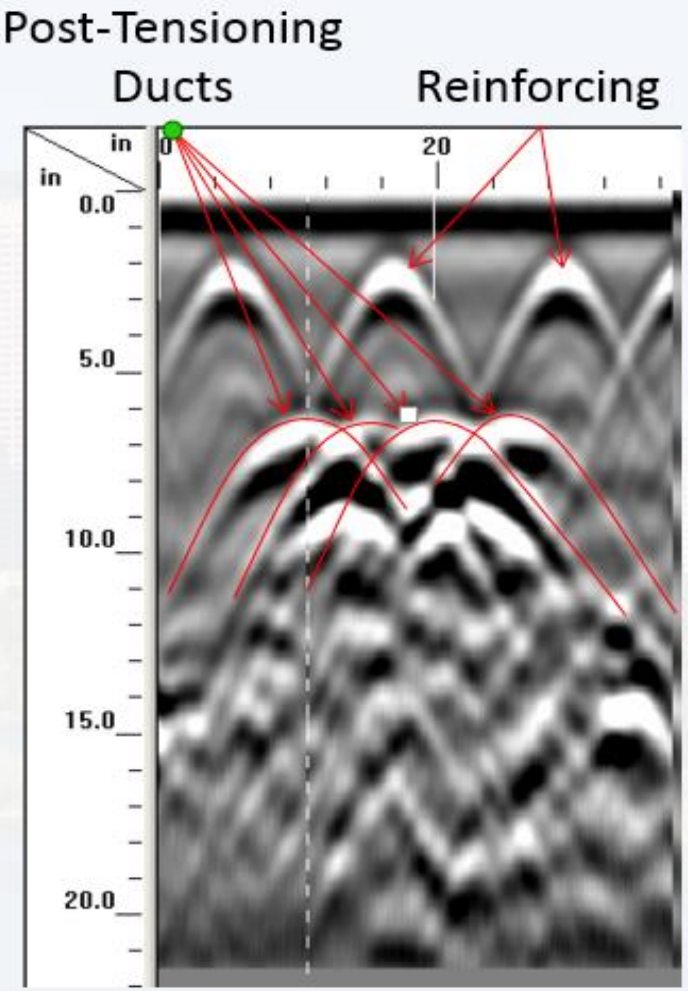




How do we find these problems?

Ground Penetrating Radar

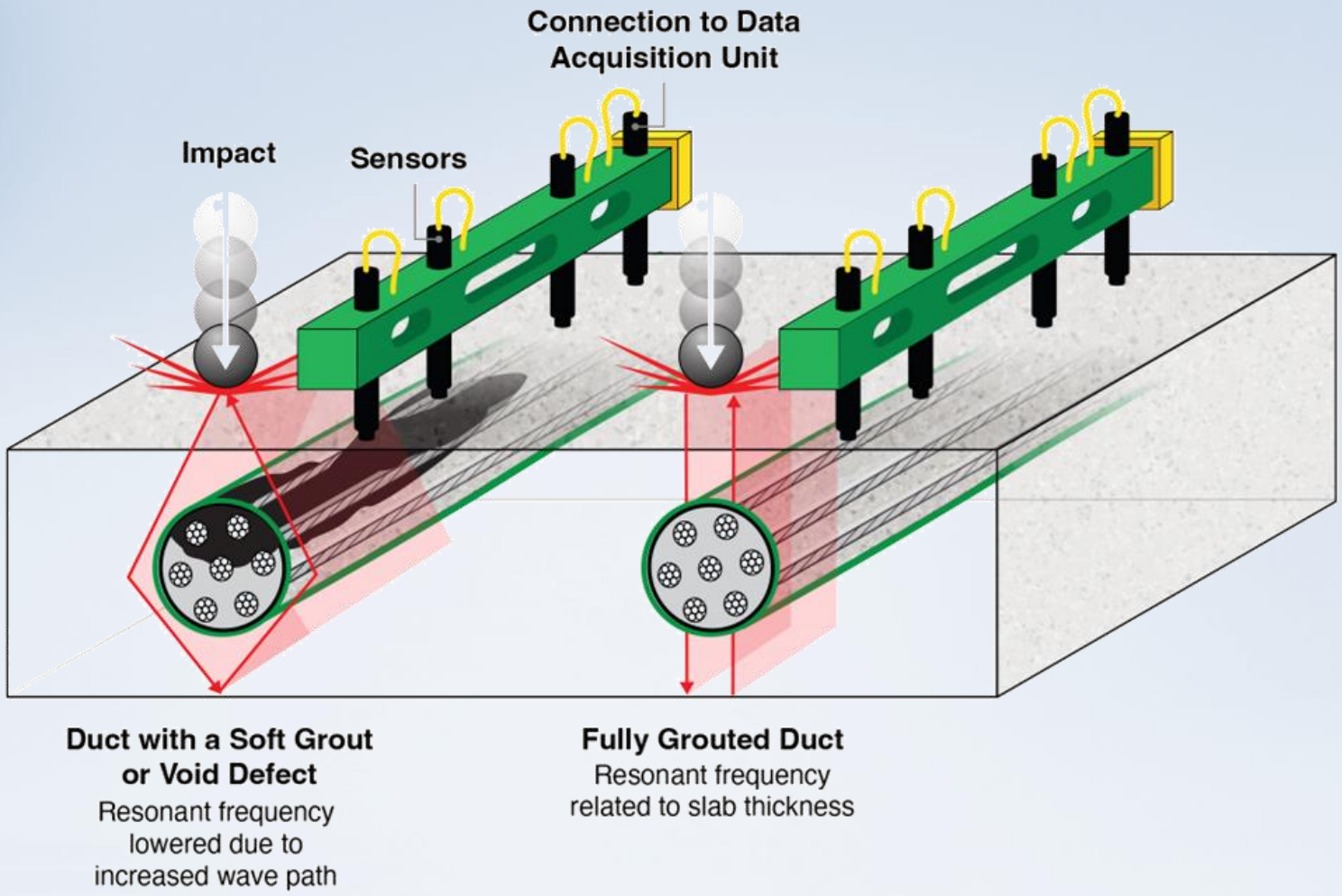




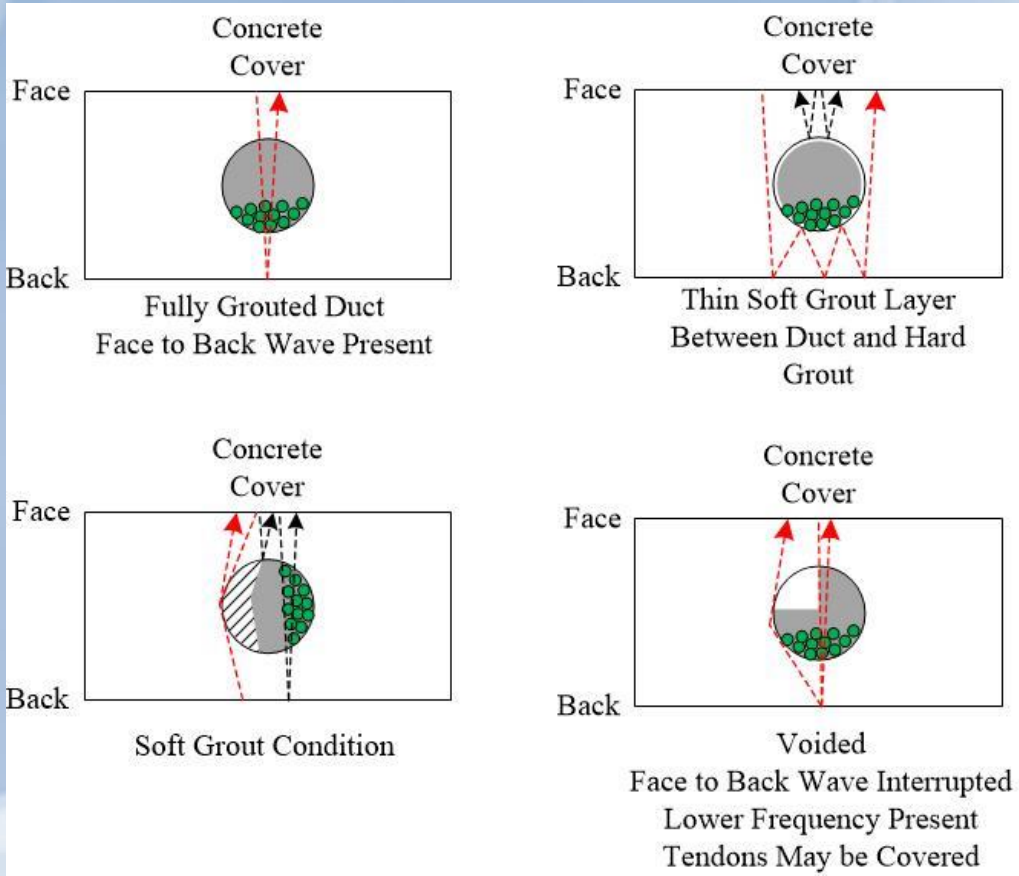
Locating Ducts

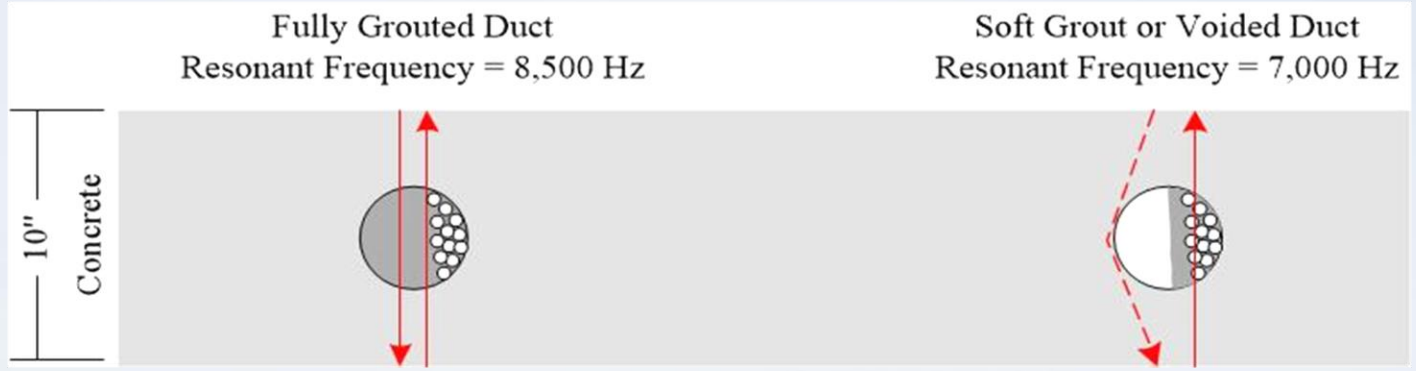
Mark the tendon path every 1 ft.

Impact Echo

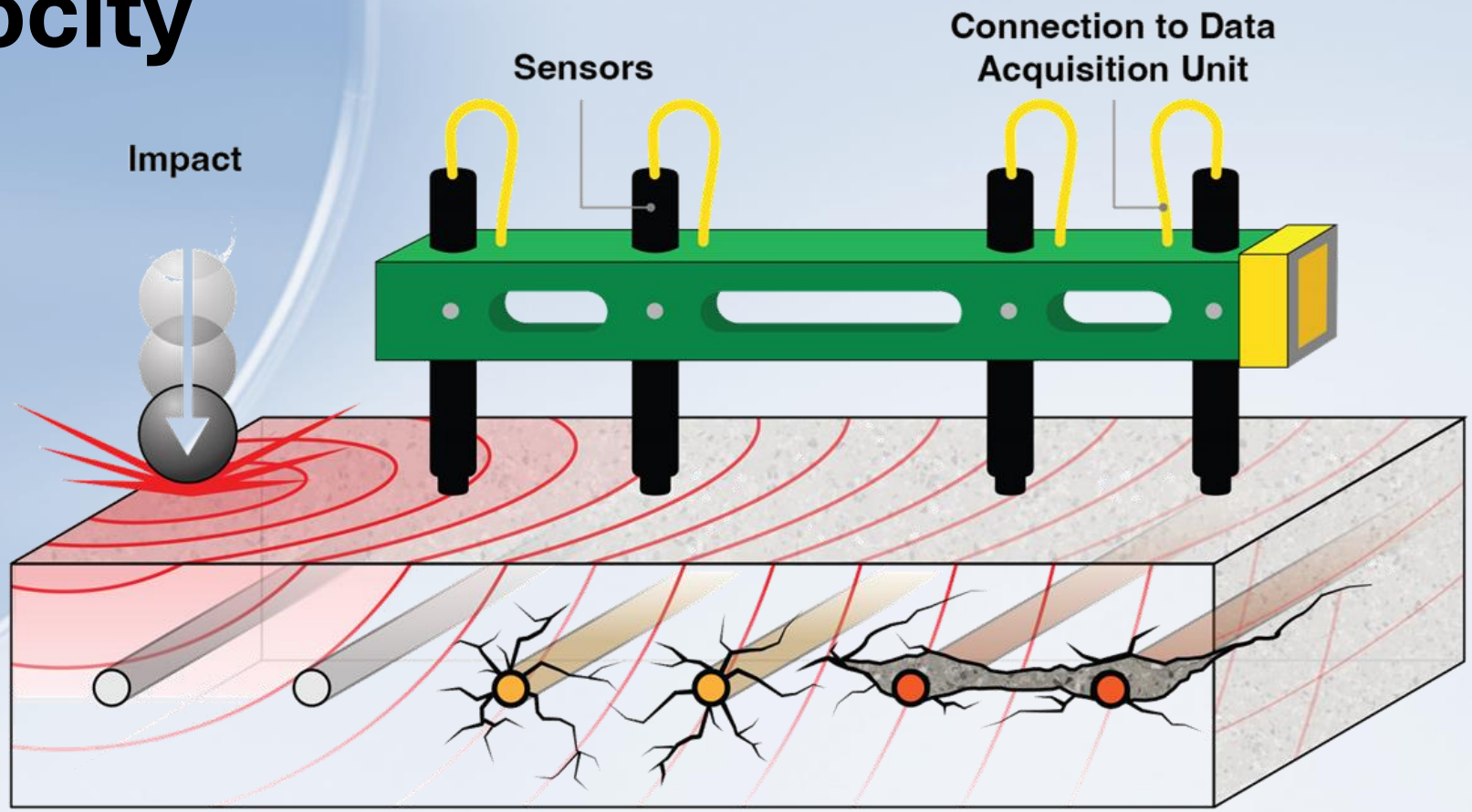

Connection to Data Acquisition Unit
Impact
Sensors
Duct with a Soft Grout or Void Defect
Resonant frequency lowered due to increased wave path
Fully Grouted Duct
Resonant frequency related to slab thickness

Impact Echo


Concrete
Cover
Face
Back
Fully Grouted Duct
Face to Back Wave Present
Concrete
Cover
Face
Back
Thin Soft Grout Layer
Between Duct and Hard
Grout
Concrete
Cover
Face
Back
Soft Grout Condition
Concrete
Cover
Face
Back
Voided
Face to Back Wave Interrupted
Lower Frequency Present
Tendons May be Covered


Fully Grouted Duct
Resonant Frequency = 8,500 Hz
Soft Grout or Voided Duct
Resonant Frequency = 7,000 Hz
10"
Concrete

Pulse Velocity



Sound Concrete

Normal Compressional and Shear Wave Velocity

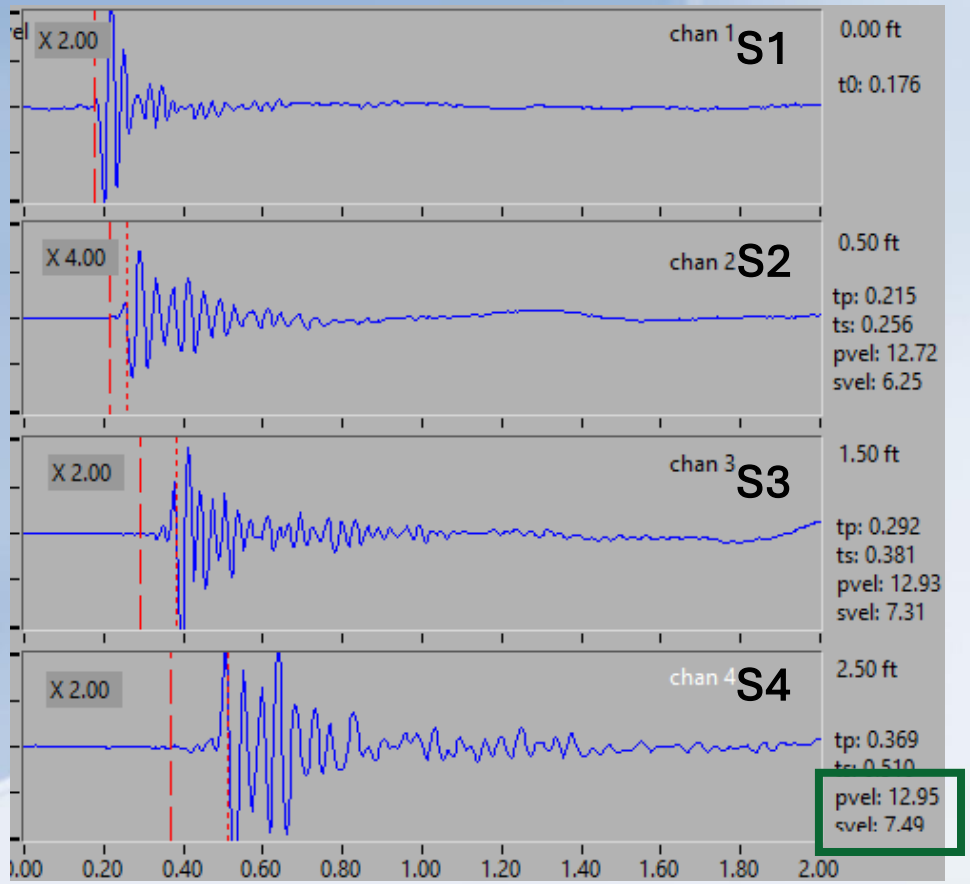
Micro-Cracking

Low Compressional Velocity and Lower or Loss of Shear Velocity

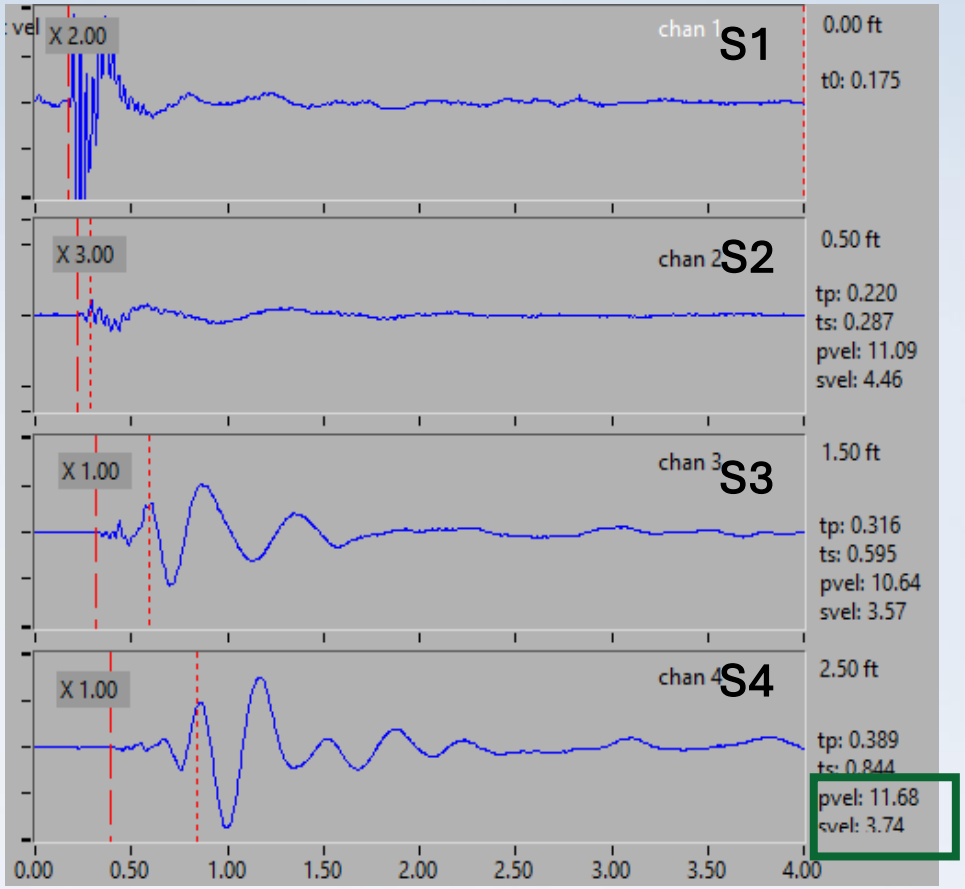
Delamination

Varying Compressional and Shear Wave Velocity

Testing Speed



No Defect in PT Tendon

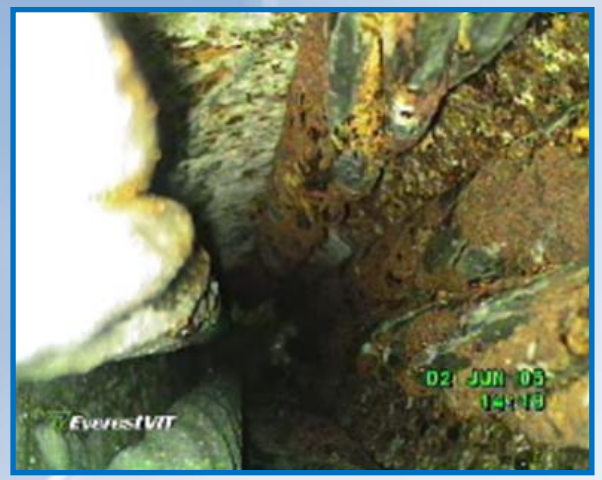


Possible Grouting Defect

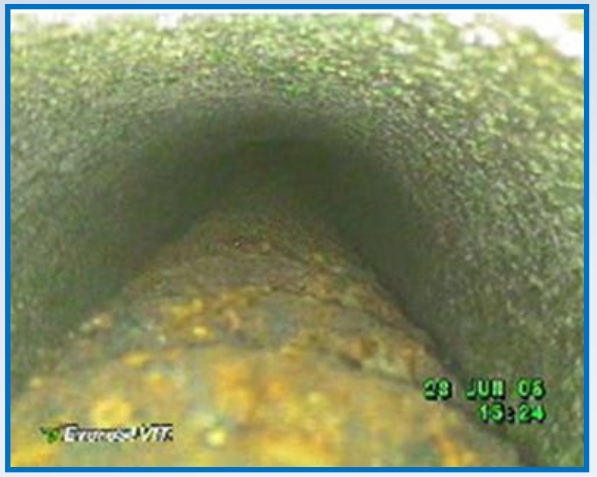
Borescope Inspection

Typical Defects

Void Bottom Corrosion on Duct & Tendons



Corrosion on Duct & Tendon



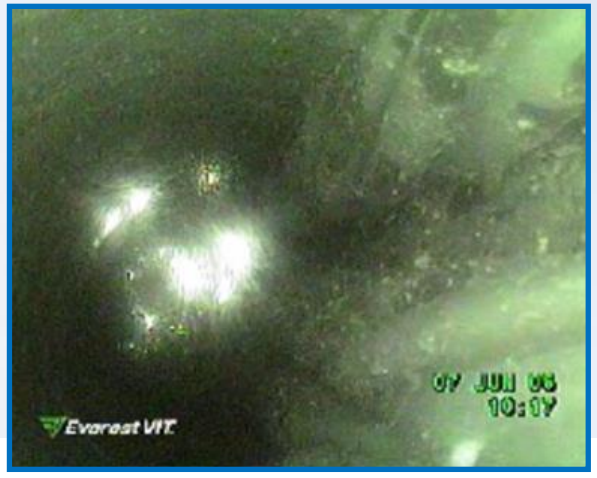
Void in Pier With Dywidag Bar Instead of Tendons

Corrosion on Duct

Void With Tendon Corrosion

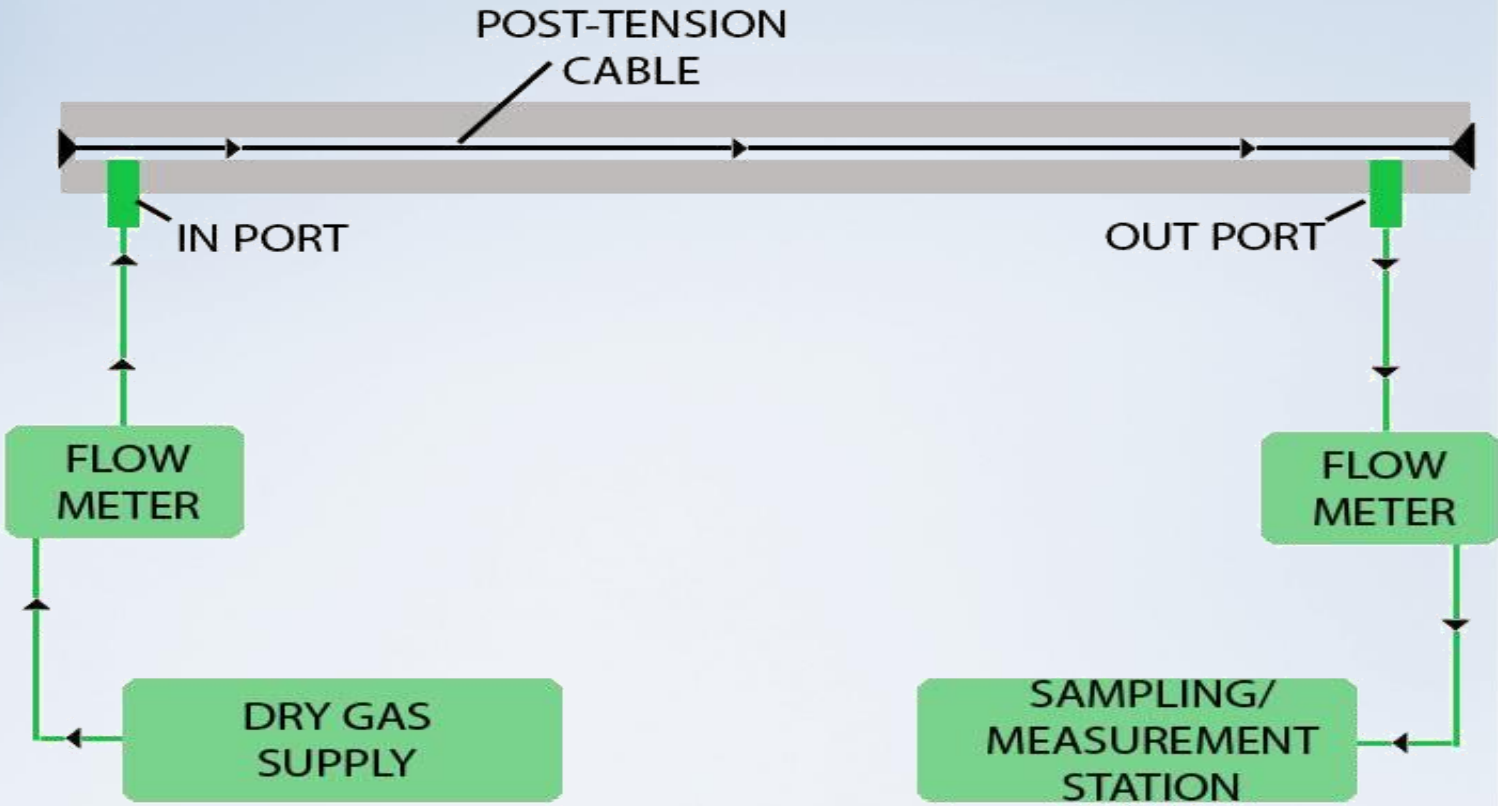
Anchor Plate, Tendons & Duct are Grout Coated

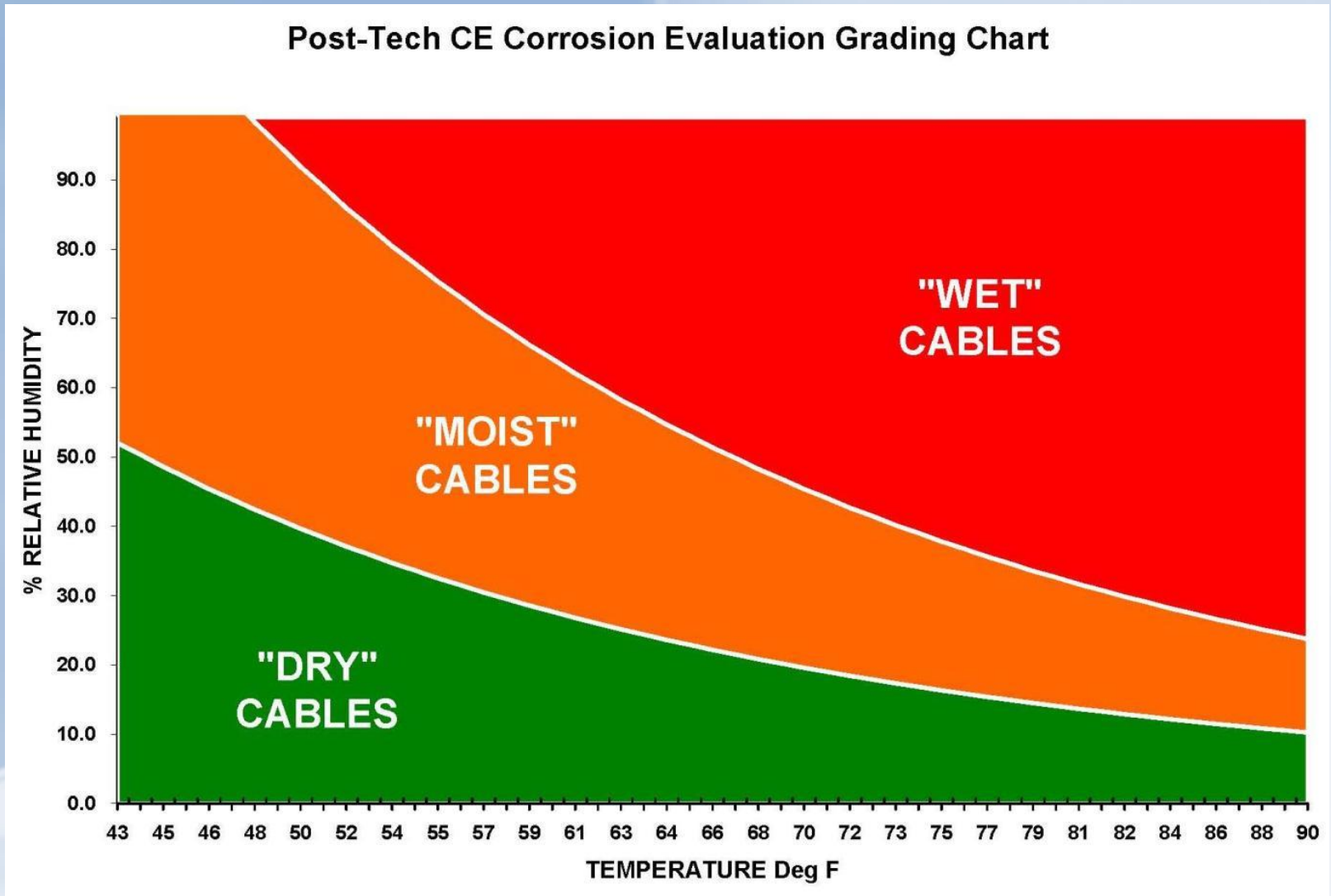
Anchor Close-Up, Top of Tendons Show Corrosion



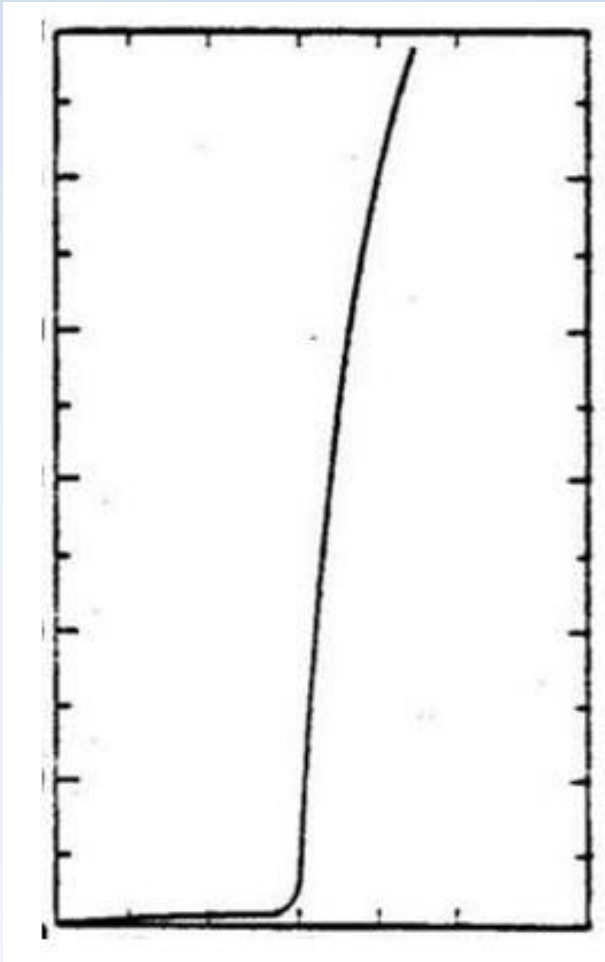
Tendon Found with Standing Water Inside

Moisture Testing





Corrosion Rate



Moisture (RH)

Case History of 3 Bridge PT Evaluation

Bridges Inspected

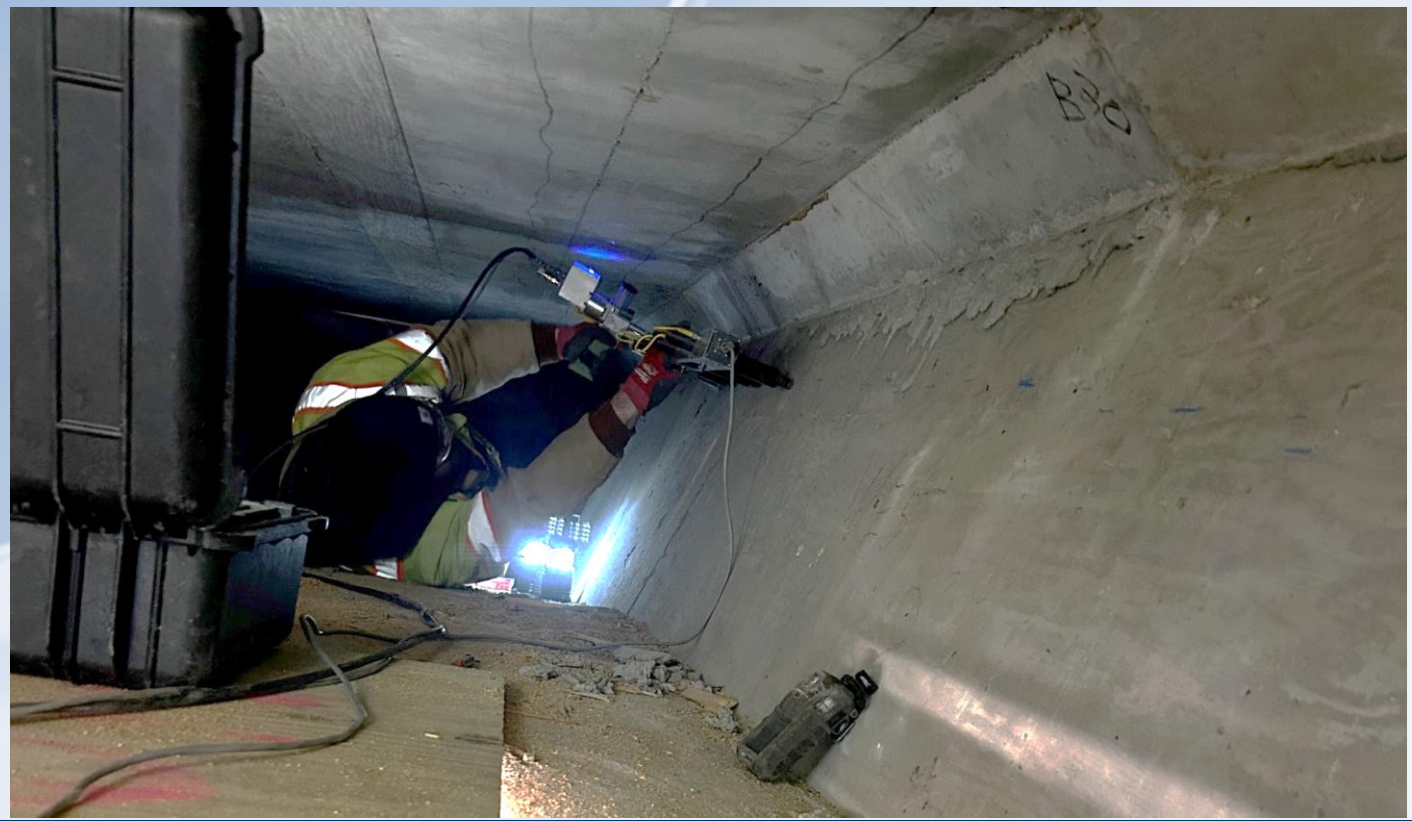
- Pedestrian Bridge
  - Cracking along exterior of PT girders
    - Leaking efflorescence
  - Pedestrian bridge with 2 PT spans crossing a state highway
  - Single box spans with 2 tendons per span
- Twin Eastbound/ Westbound bridges
  - WB- 4 span bridge carrying the highway as an overpass
  - EB - 3 span bridge carrying the highway as an overpass
  - Three cell box girders with 3 tendons in each web (12 tendons/span)

Inspection Technique

- Testing 100% of the PT - $$$
- VCS performed targeted testing focused 15 feet along PT tendons
  - 15 feet from **anchor locations**
  - 15 feet in both directions from **high points** at piers
- Impact echo/pulse velocity (IE/PV) located potential defects
  - Confirmed by drilling and borescope inspection
  - Suspect locations were drilled and documented (borescope)

Pedestrian Bridge

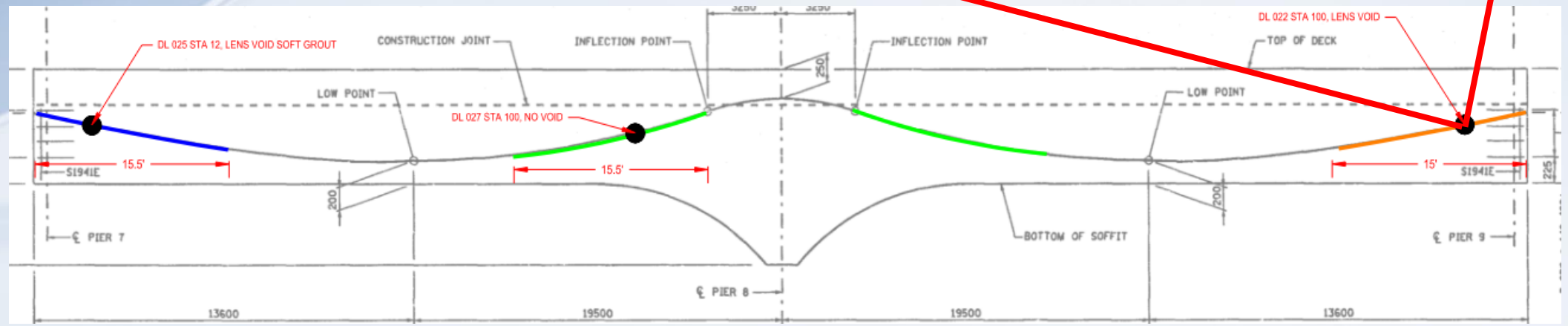
- IE/PV identified the presence of lens voids and soft grout in one tendon



Pedestrian Bridge

- Defects identified in west girder

LEGEND	
	VOID
	NO VOID
	LENS VOID
	SOFT GROUT

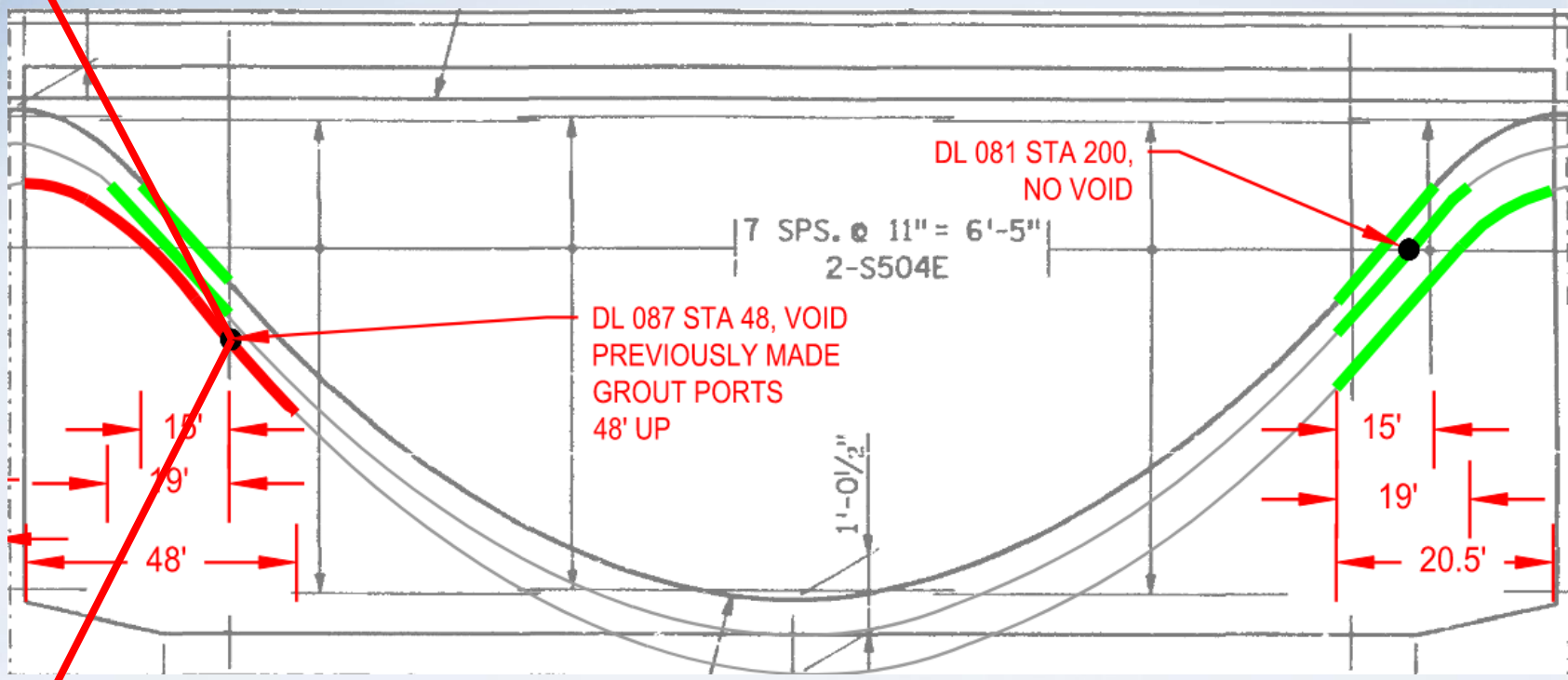


WB Bridge

- Previous inspections employed drilling in random locations to identify voided tendon ducts.
  - Some remedial grouting repairs
- VCS identified a large void that was approximately **48 feet** long

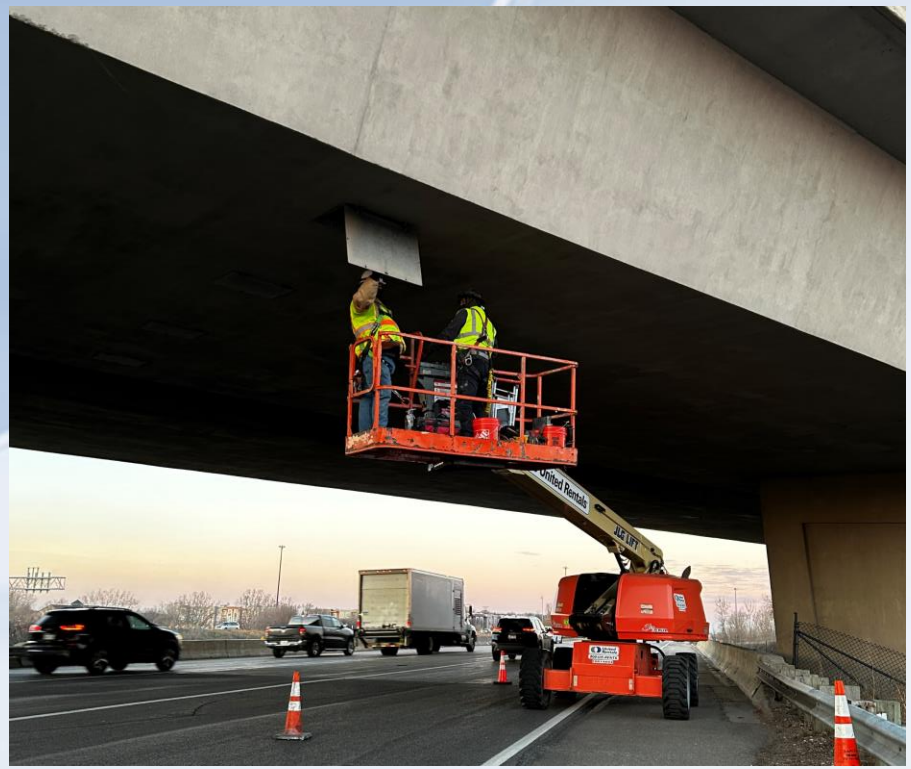
WB Bridge

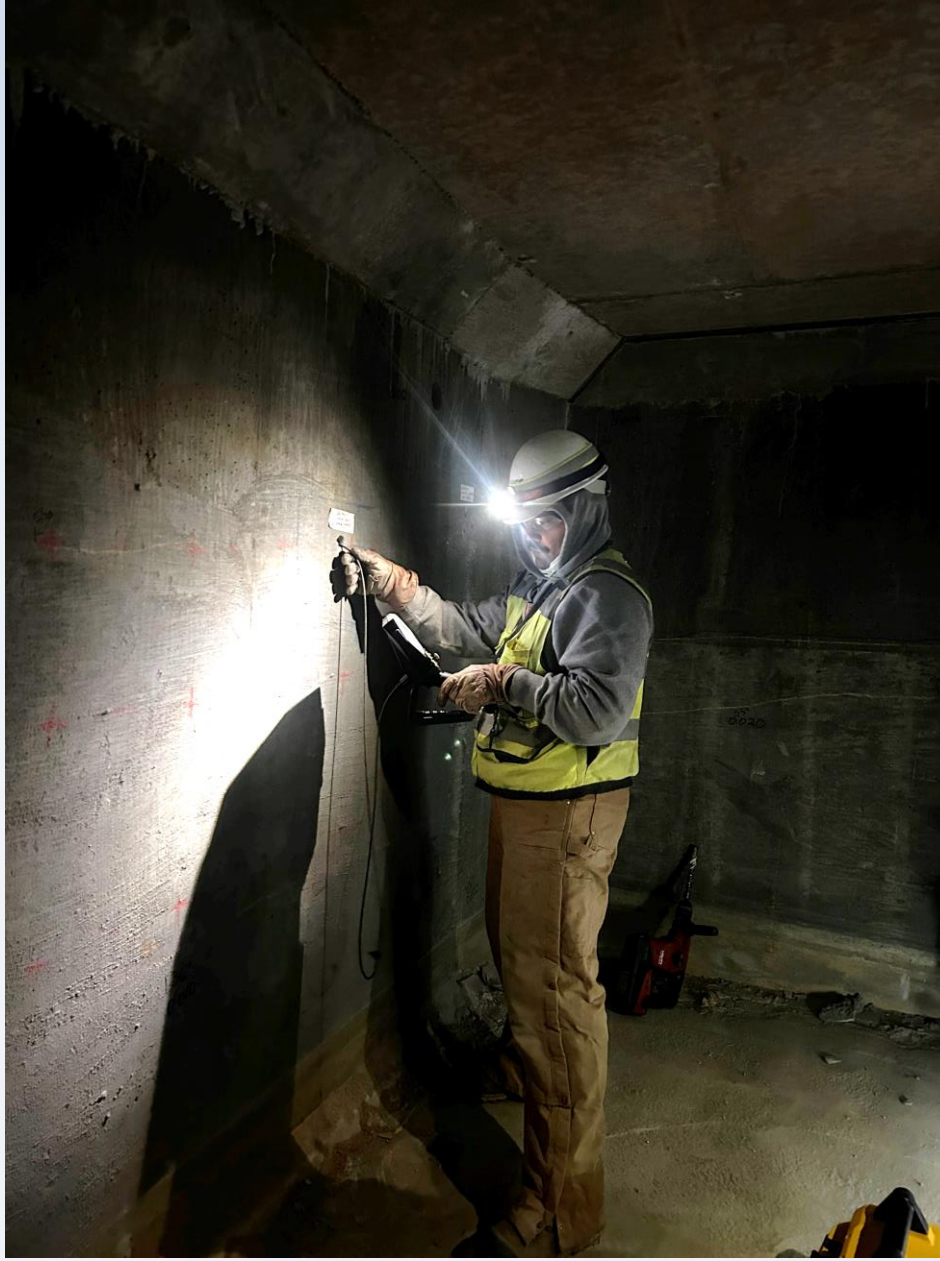
- Largest identified void of 48 feet



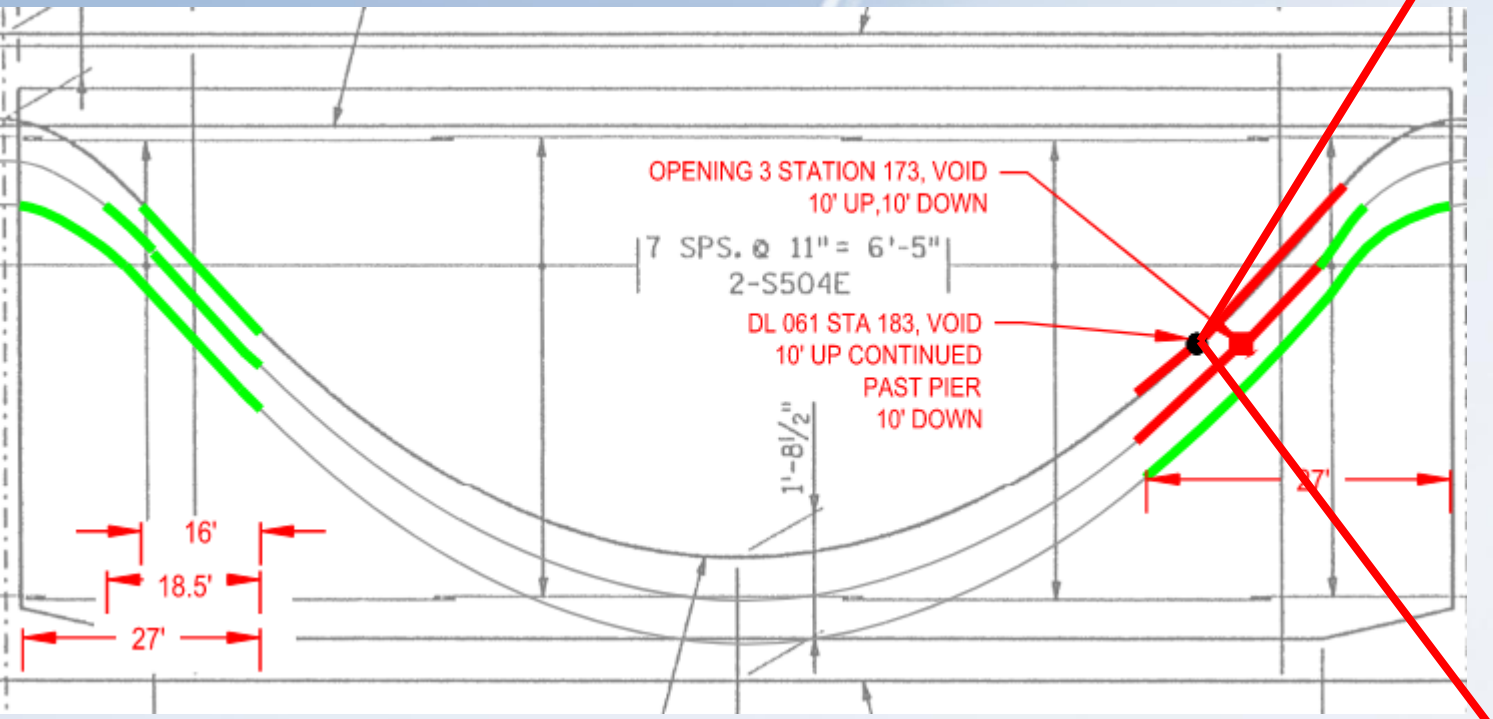
EB Bridge

- Previous inspections by random drilling
  - No remedial grouting in the past
- Largest void identified over **20 feet** long





EB Bridge


OPENING 3 STATION 173, VOID
10' UP,10' DOWN
7 SPS. @ 11" = 6'-5"
2-S504E
DL 061 STA 183, VOID
10' UP CONTINUED
PAST PIER
10' DOWN
1'-8 1/2"
27'
16'
18.5'
27'

Investigation Summary

- Few defects identified in Pedestrian Bridge
- Large voids found in WB and EB Bridges
- Strands are generally in good condition
  - Corrosion ranging from mild to moderate
  - No broken strands or wires identified

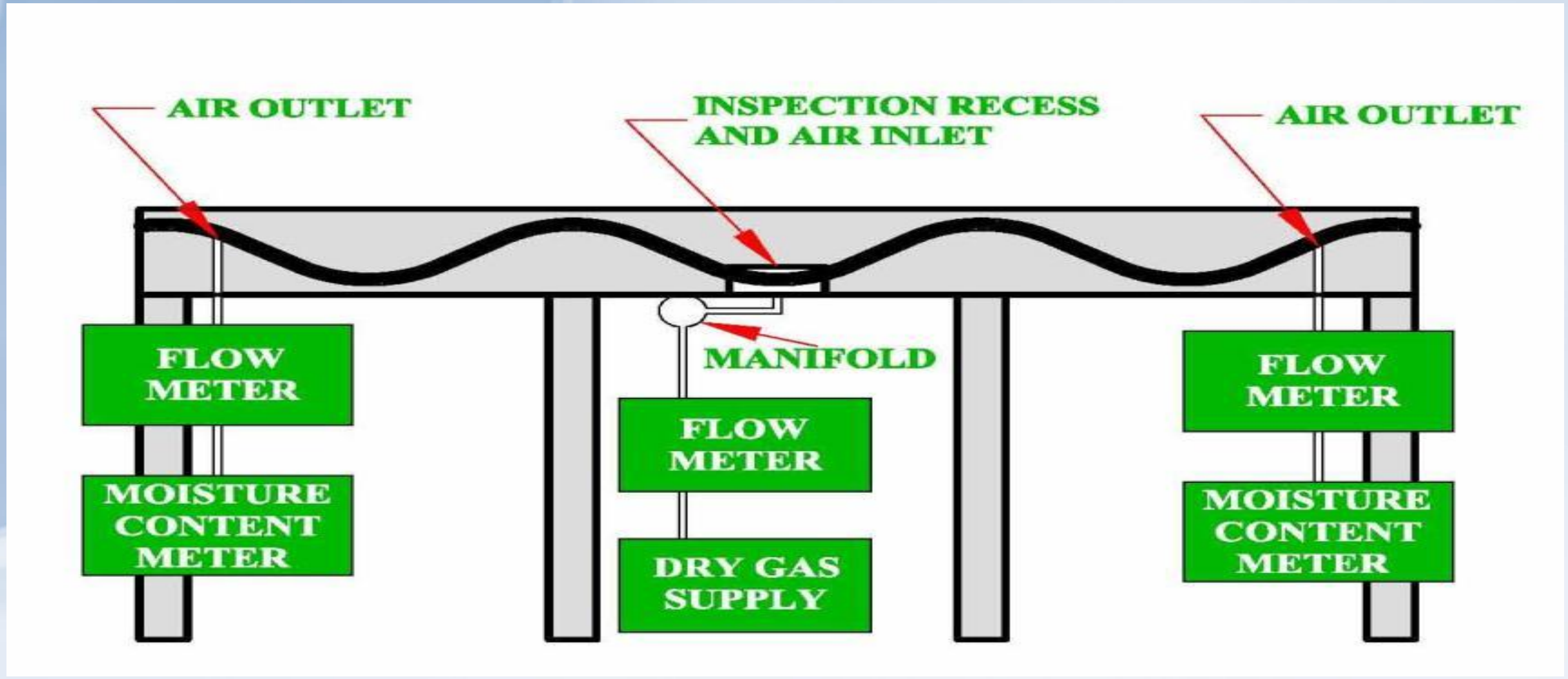
Rehabilitation
and
Mitigation Strategies of PT

Rehabilitation

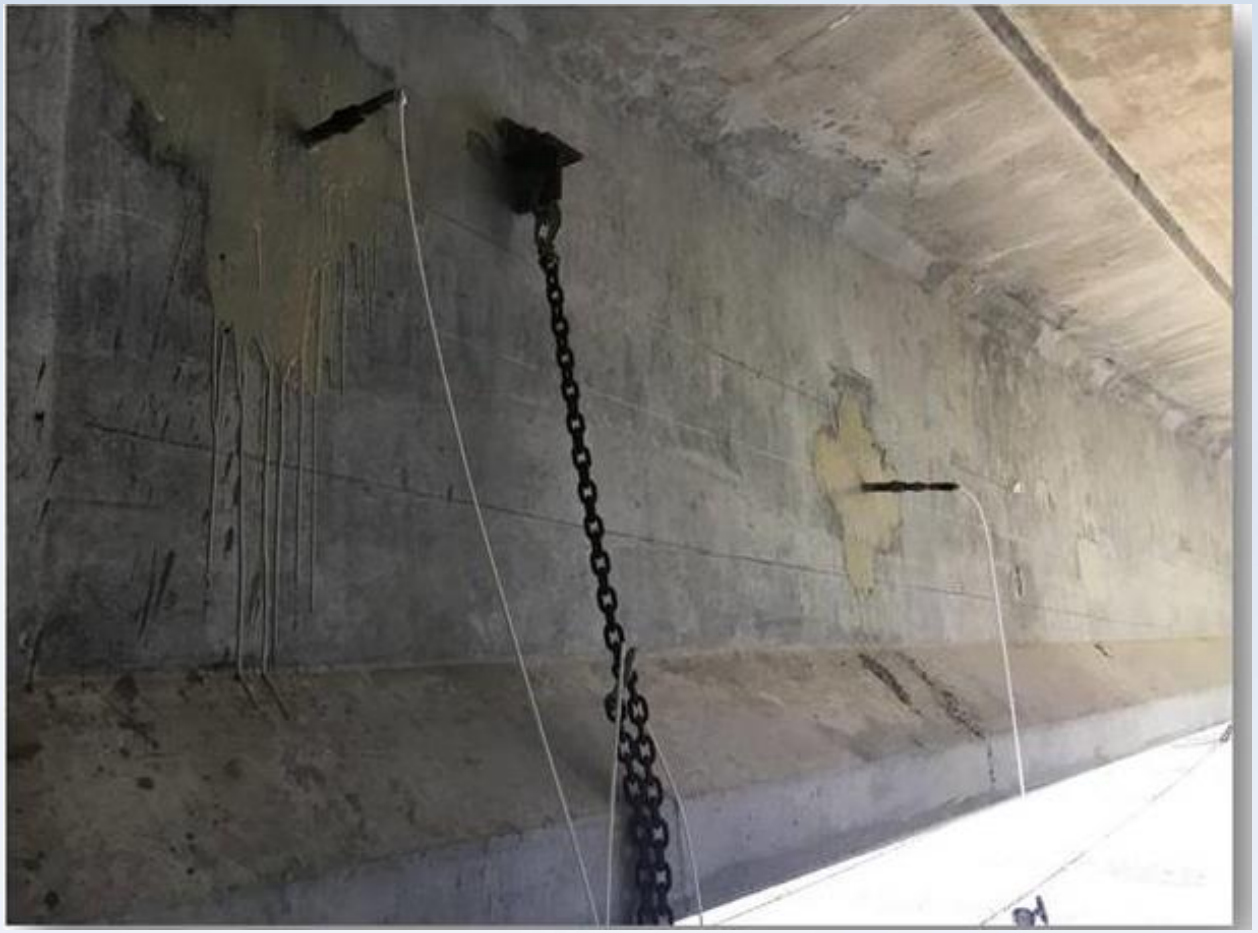
- Challenges
  - How can we stop or prevent deterioration of tendons?
    - Especially when we know grout defects exist
  - Access along length extremely difficult
    - Particularly with Embedded ducts

- Rehab Options
  - Drying
    - If there is moisture along the tendon
  - PT Impregnation material
    - Coats steel to prevent corrosion
    - Displaces water
    - Permeates into voids and concrete
  - Regrouting
    - Severely Voided

PT Drying

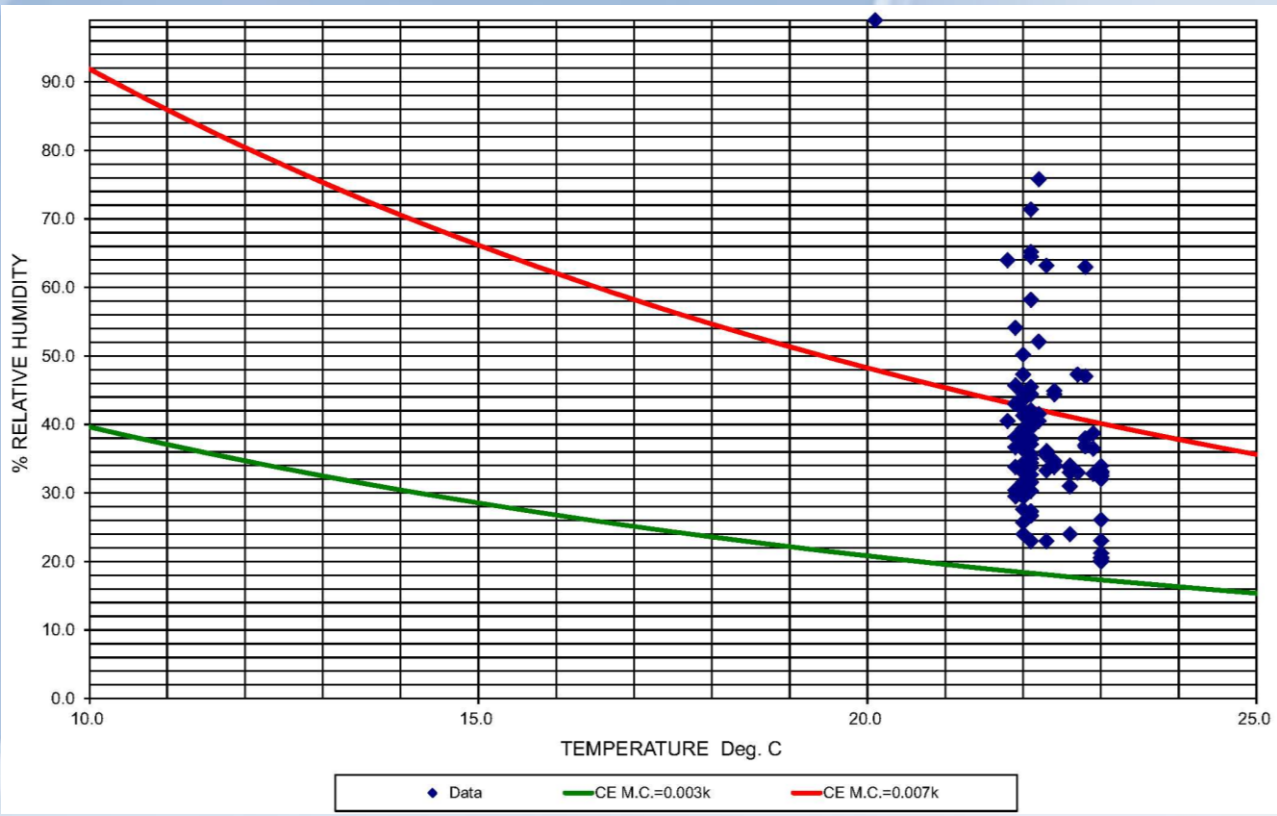

AIR OUTLET
INSPECTION RECESS AND AIR INLET
AIR OUTLET
FLOW METER
MANIFOLD
FLOW METER
MOISTURE CONTENT METER
DRY GAS SUPPLY
FLOW METER
MOISTURE CONTENT METER

PT Drying

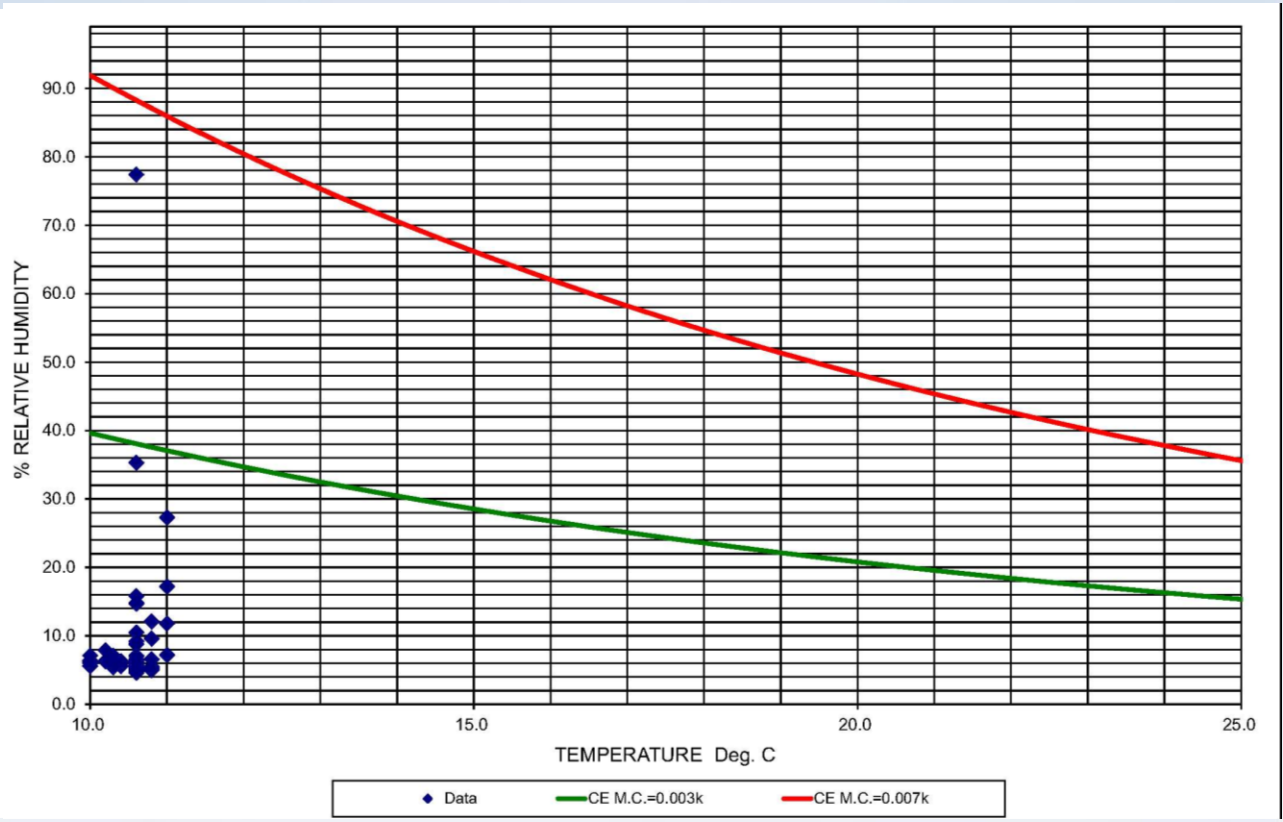


Monitoring of Drying Process

PT Drying- Performance



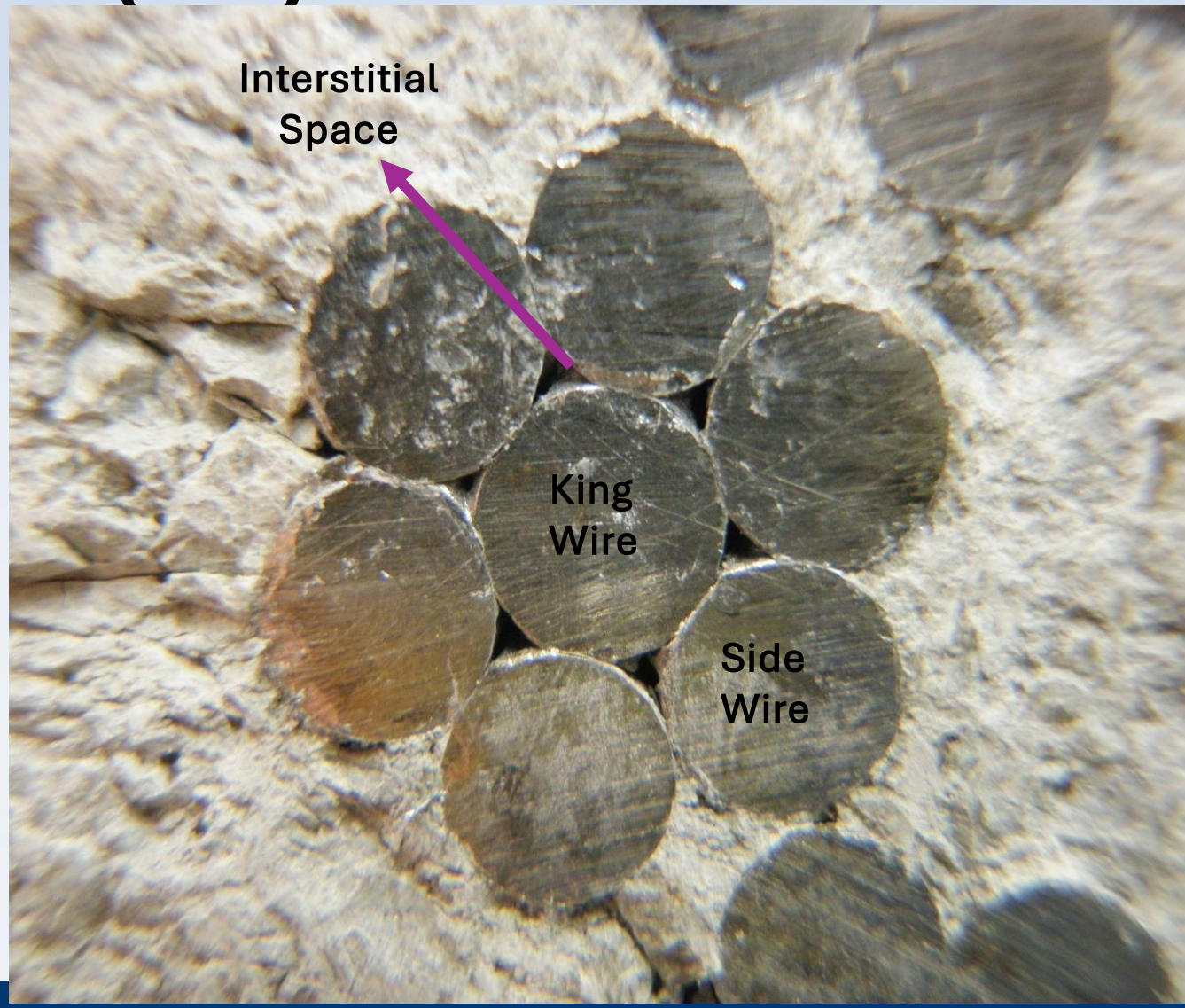
PTCE Before Drying Process



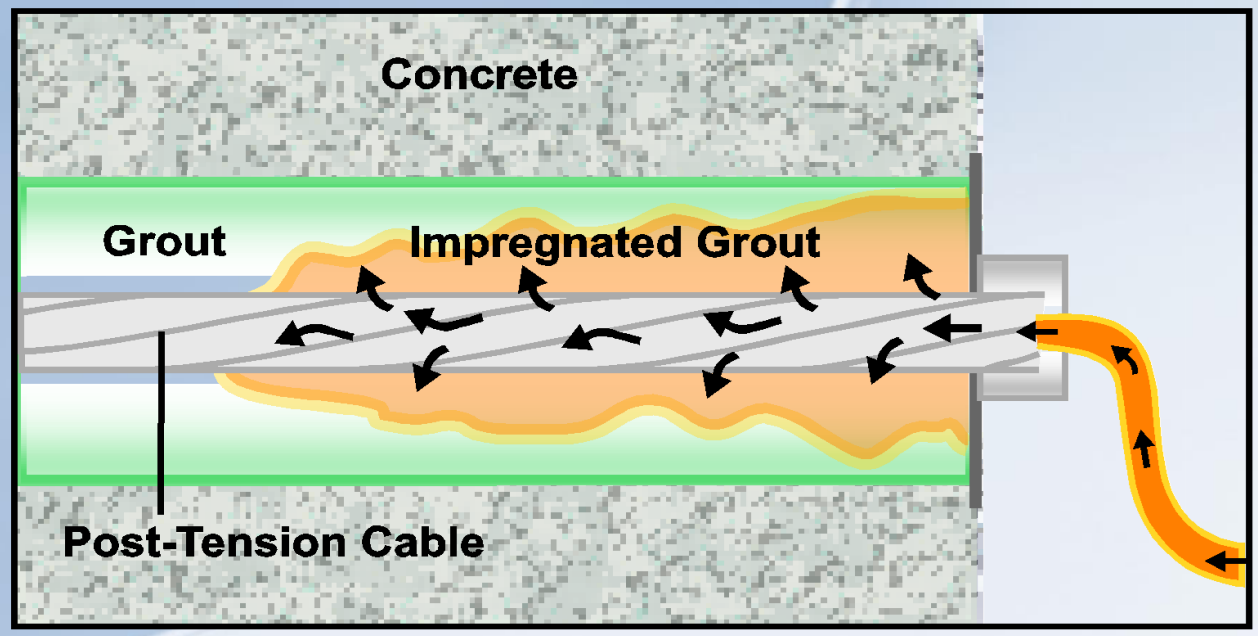
PTCE After Drying Process

Post Tension Impregnation (PTI) Process

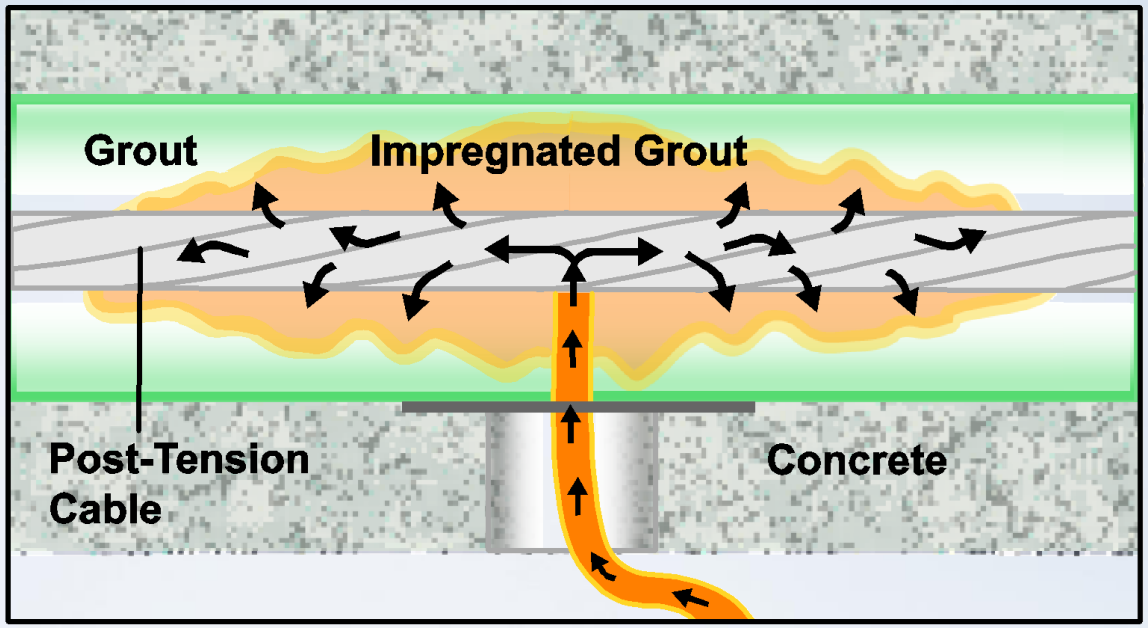
- Corrosion protection process for grouted PT tendons with voids or defective grout
- Impregnation material transported inside strands full length of tendon
- Impregnation material reduces corrosion by:
  - Coating exposed steel in voids
  - Improving corrosion resistance of grout



Access



End Port



Intermediate Access Port

Anchor Cap Removal

Original Anchor Cap

Grout

Exposed Strands
after Grout Removal

IMPREGNATION

Impregnation at Tendon End

Impregnation Material Appear at Far End

VERIFICATION

Impregnation nearing completion

Inspection opening and removal of grout to verify presence of impregnation material

Impregnation material visible along all PT strands

Performance Validation

Interim Report:

Evaluation of a Silicon Based Polymer Corrosion Inhibitor for Post-Tensioned Tendons

K. Bergum
T. Risher
State Materials Office
Corrosion/Durability Laboratory
March 1, 2017

Summary

- PT tendons are susceptible to corrosion
- Evaluation techniques are available to determine the cause, extent and location of problems
- Corrosion mitigation techniques are available to protect and extend the service life of PT tendons in existing structures

Thank you

Questions?

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