Electrically Isolated Tendon (EIT) Pilot Project, SH146 – Kemah, TX

Presented by:
Jordan Sessa, Structural Technologies

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ENGINEERING RCEP REGISTERED CONTINUING EDUCATION PROGRAM

Purpose and Learning Objectives

Purpose

The ASBI Monthly Webinar provides an educational forum to learn new techniques used in successful projects, lessons learned from development projects, and showcases a case study allowing for discussion of the project.

At the end of this presentation you will be able to:

Identify and understand the differences in PL-3 vs. PL-2 Bonded Post Tension Tendons

Agenda

- Advancing PT Practices
- PT Corrosion in Bridges
- What are Electrically Isolated Tendons (EIT)?
- VC Sensor
- How EIT & VC Sensor identify potential corrosion problems
- Where are EIT's used today?
- SH146 Pilot Project – Kemah, TX
- Questions

ADVANCING POST-TENSIONING PRACTICES

Advancing Post-Tensioning Practices

- Improve Infrastructure Service-Life
  - Use of modern guidance
  - Improve Construction Quality
    - Develop well trained workforce
    - Use of modern/innovative equipment
- Improve Infrastructure Resilience
  - Utilize replaceable PT
  - Integrate intelligence – remain operational
- Improve Infrastructure Intelligence
  - Assess tendon encapsulation
  - Assess corrosion onset
  - Assess PT force / stress (direct)

Technology Implementation - Demonstration

EIT

Junction Box

<u>Post-tensioned Bent Cap</u>

V/C Sensor

Vacuum Assist

THE CORROSION ATTACK SCENARIOS

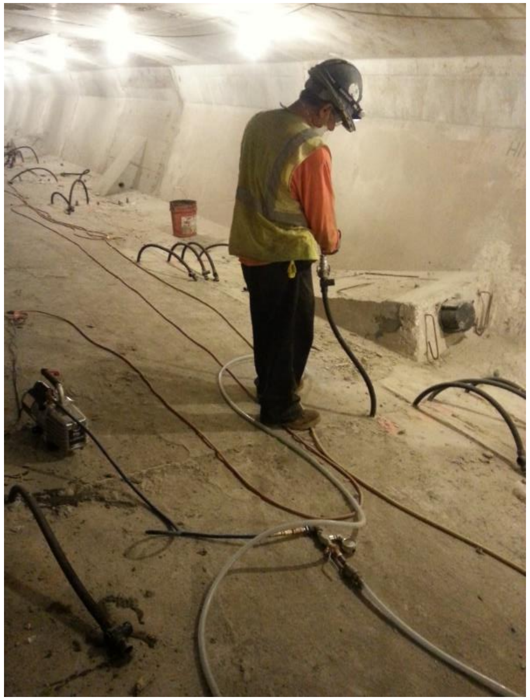
Attack Scenarios

- EXTERNAL attack scenario:
  - Destruction of passivation
  - Stray current
  - Risk for segmental construction

- INTERNAL attack scenario:
  - Macro electric cell at interface of stable and moist non-stable grout
  - Incompletely filled ducts with presence of water and oxygen

Identifying PT Corrosion in Existing Bridges

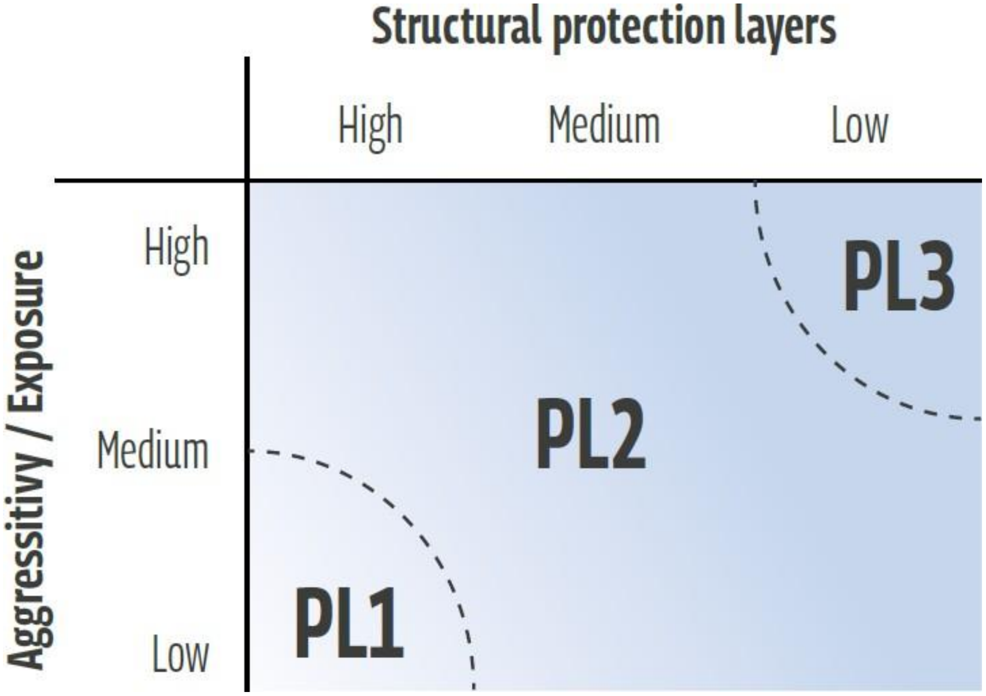
- Usually reactive to signs of failure in the structure such as:
  - Cracks in concrete
  - Complete failure of external PT
- Preemptive measures to identify corrosion often requires destructive testing.
- Can be expensive to identify and correct, usually spanning several years and multiple contracts

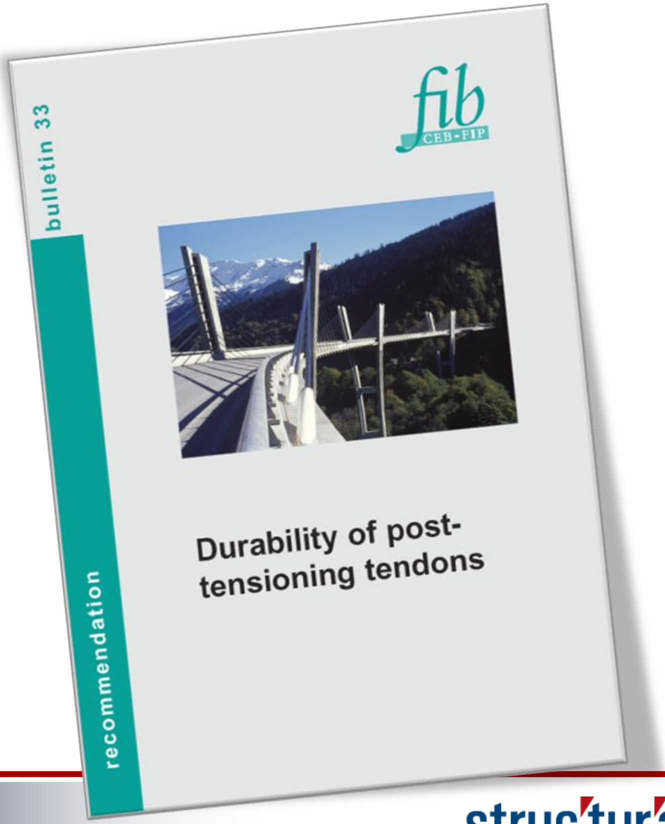


ELECTRICALLY ISOLATED TENDONS (EIT)

PROTECTION OF THE TENDON

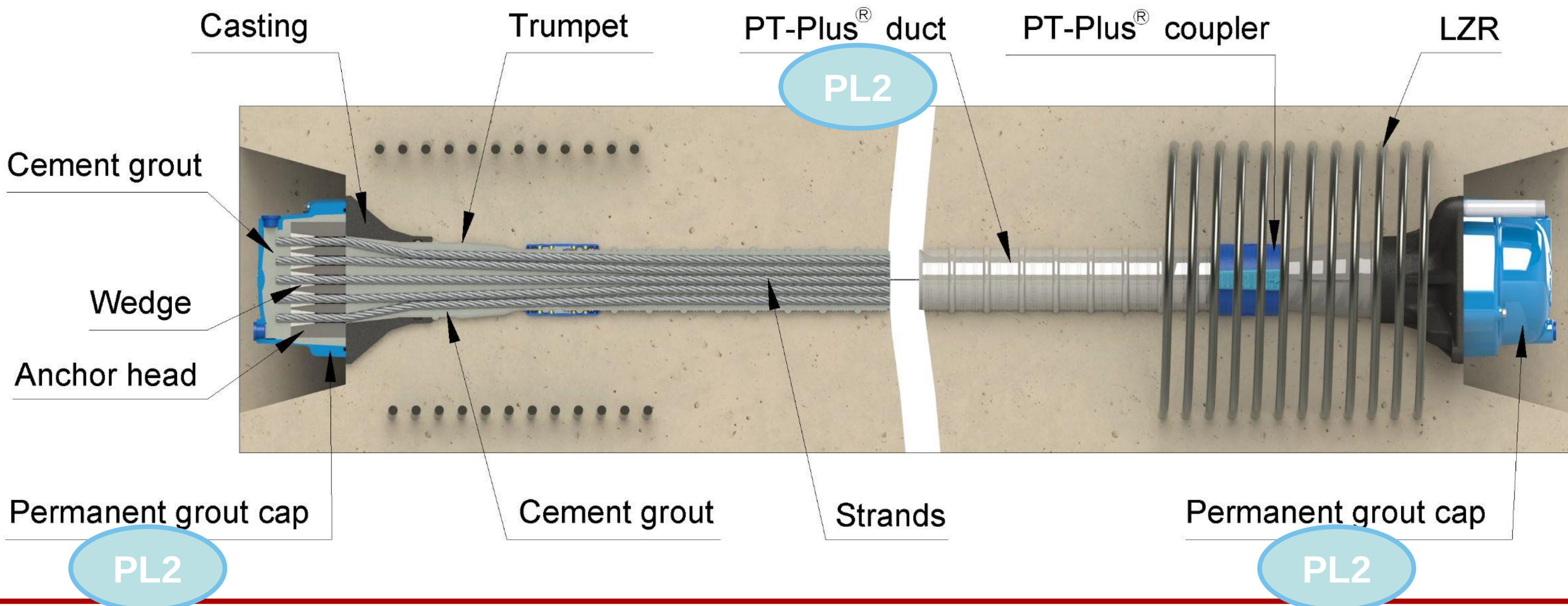
- Leak Tight Encapsulation of the tendon.
- Protection levels: fib bulletin 33, published in 2005.
- Environmental aggressivity/exposure and structural protection.





Protection Level 2

- Plastic enclosing over the tensile element of its full length and providing a permanent leak tight barrier, e.g. tendons fully encapsulated in a robust plastic duct.



Electrically Isolated Tendons (EIT)

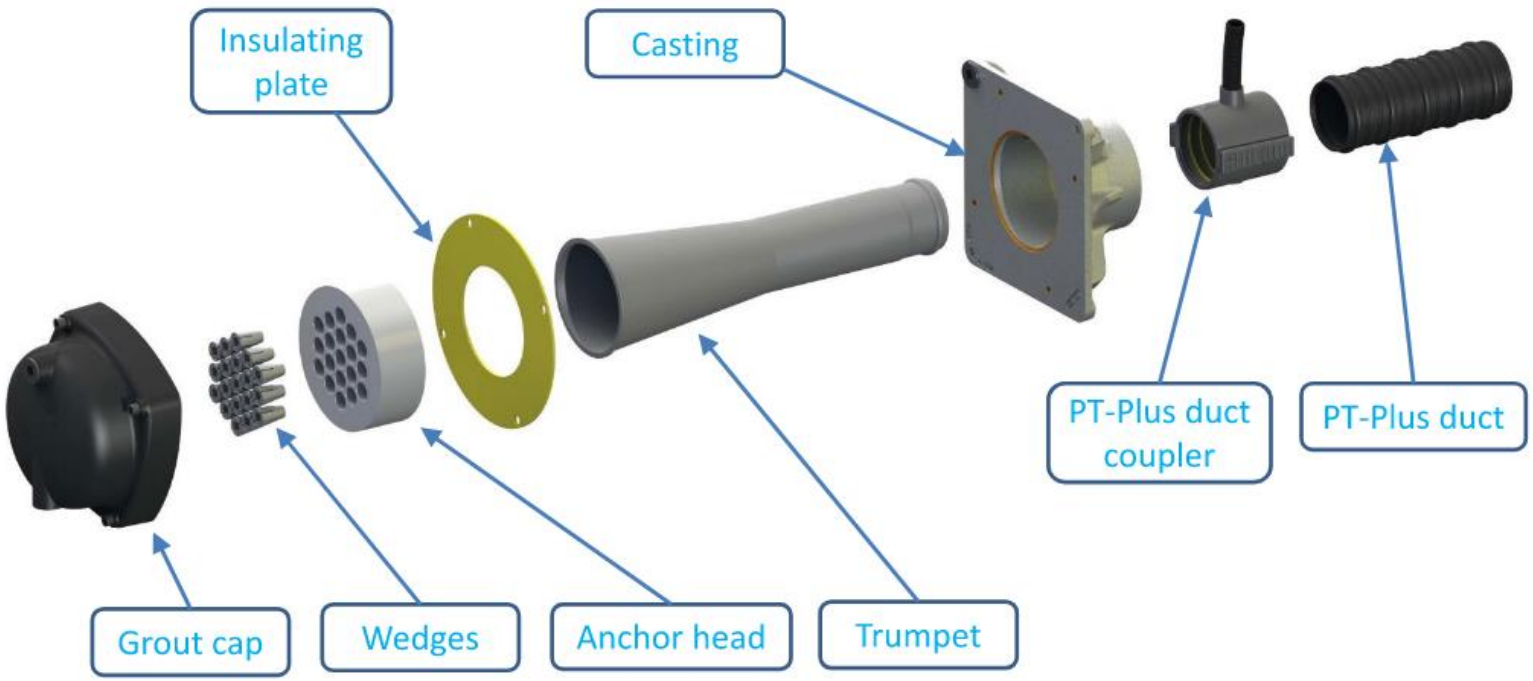
- PTI/ASBI M50.3 Protection Level 3 (PL-3)
- Prestressing strands are electrically isolated from elements outside the tendon envelope
- Monitoring capability to test electrical isolation at anytime
- Electrical isolation proves watertightness and prevention of contaminates throughout lifespan.

Benefits of Electrically Isolated Tendons (EIT)

- Full Encapsulation of the tendon (like PL-2)
  - Increased durability
- Stray current protection (an external attack scenario requiring as mitigation strategy electrical isolation of the PT tendon)
  - Increased durability
- Electrical isolation of the tendon enables the detection of any leaks in the tendon's encapsulation due to faulty workmanship during installation and at service
  - Allows quality assessment of the PT tendon assembly by measurement
  - Taking a single measurement per tendon after concreting at any point of time offers reliable quality control

EIT Details

- Electrical isolation is carried out by isolating the wedge plate (anchor head) and strands from the bearing plate (casting) and surrounding concrete.



EIT Measurements

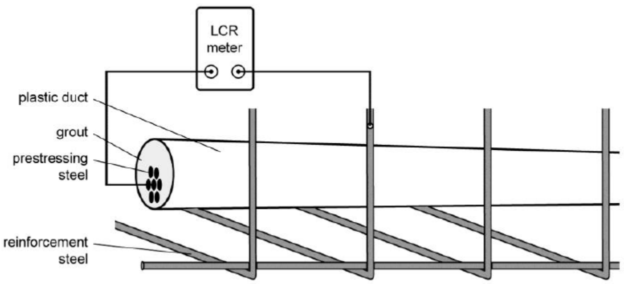


Figure 9. Schematic illustration of measuring the electrical impedance between the pre-stressing steel and the reinforcing steel of EIT.

- Use LCR meter connected between the rebar cage and the strand

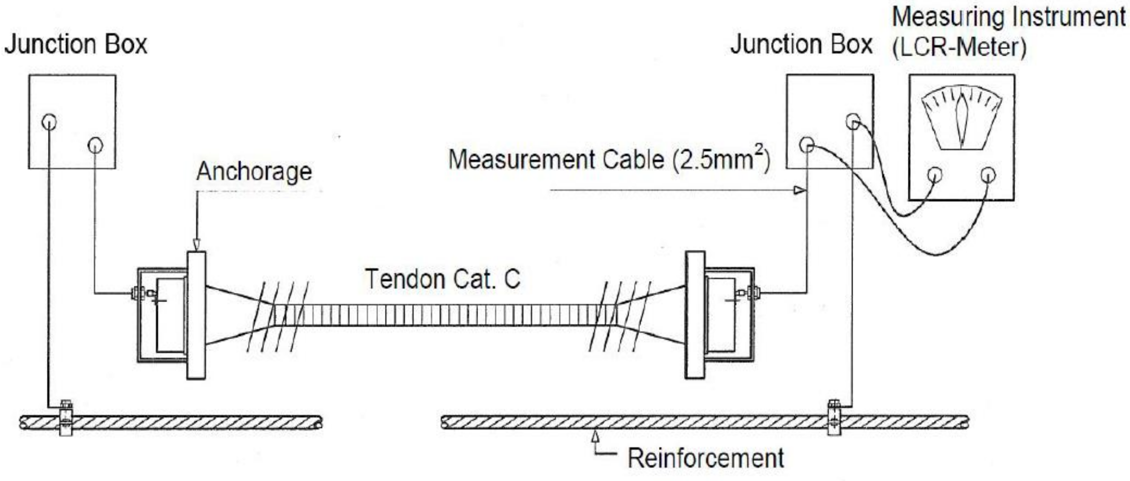


Figure 24. Electrical connections to the tendon at both ends [3, 4]

EIT Measurements

- The measurement of resistance must consider the characteristic of the tendon
- The measure is made at 1Khz in parallel mode

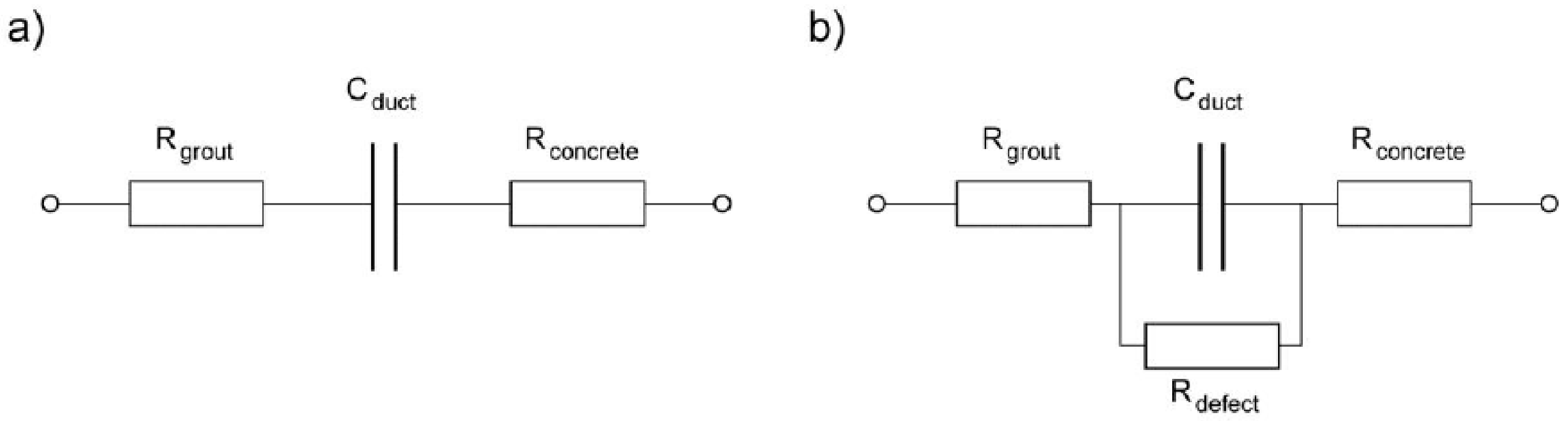
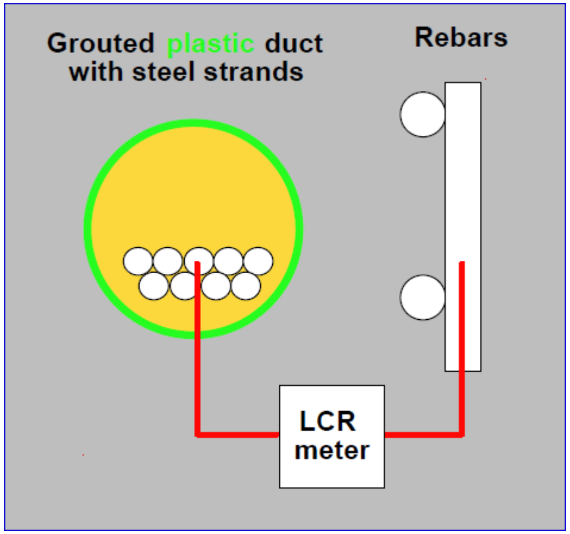


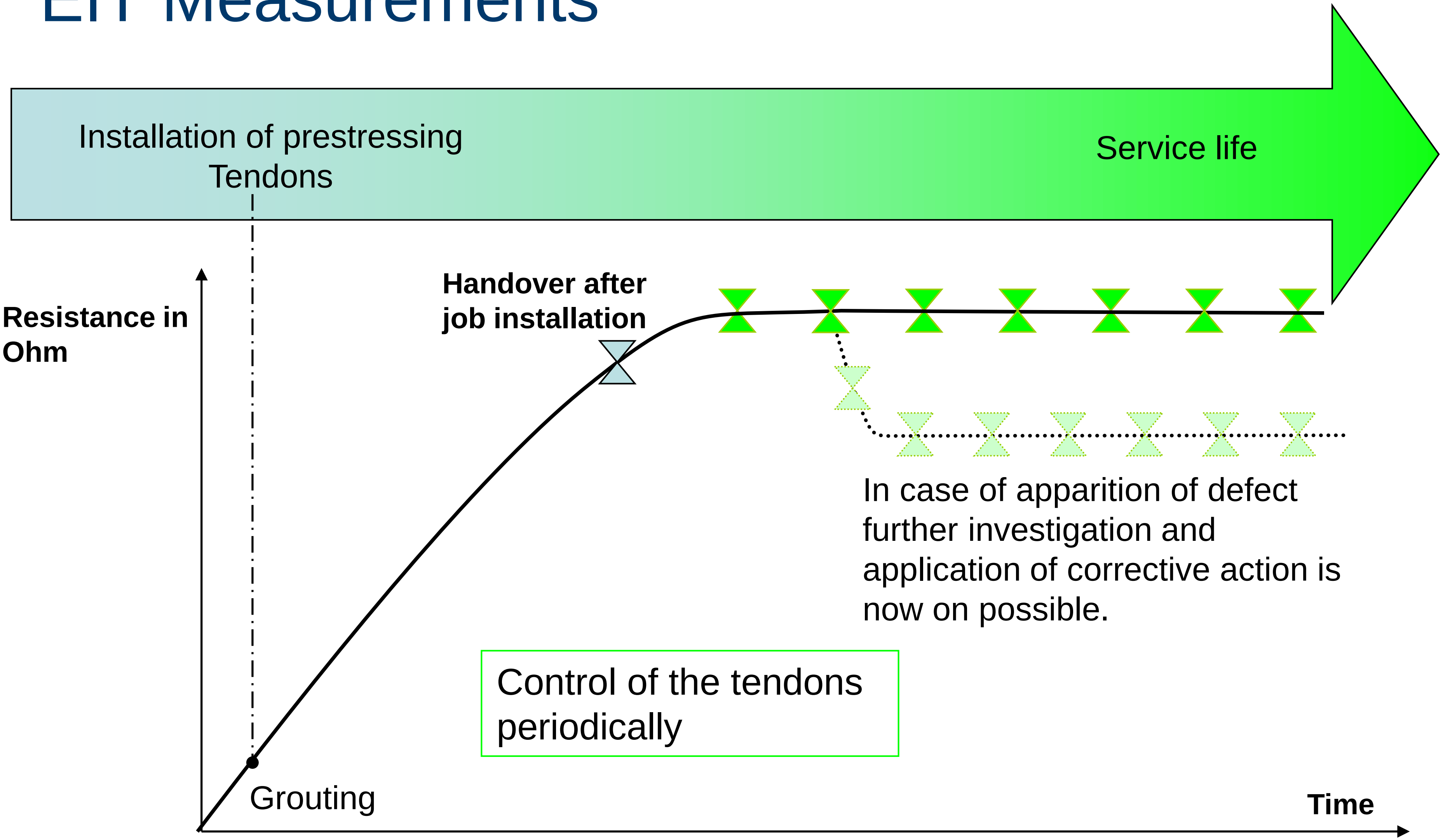
Figure 10. Equivalent electrical circuits for the interpretation of the impedance measurements; a) defect-free plastic duct (with assumed infinitely high ohmic resistance); b) plastic duct with a defect.

EIT Measurements

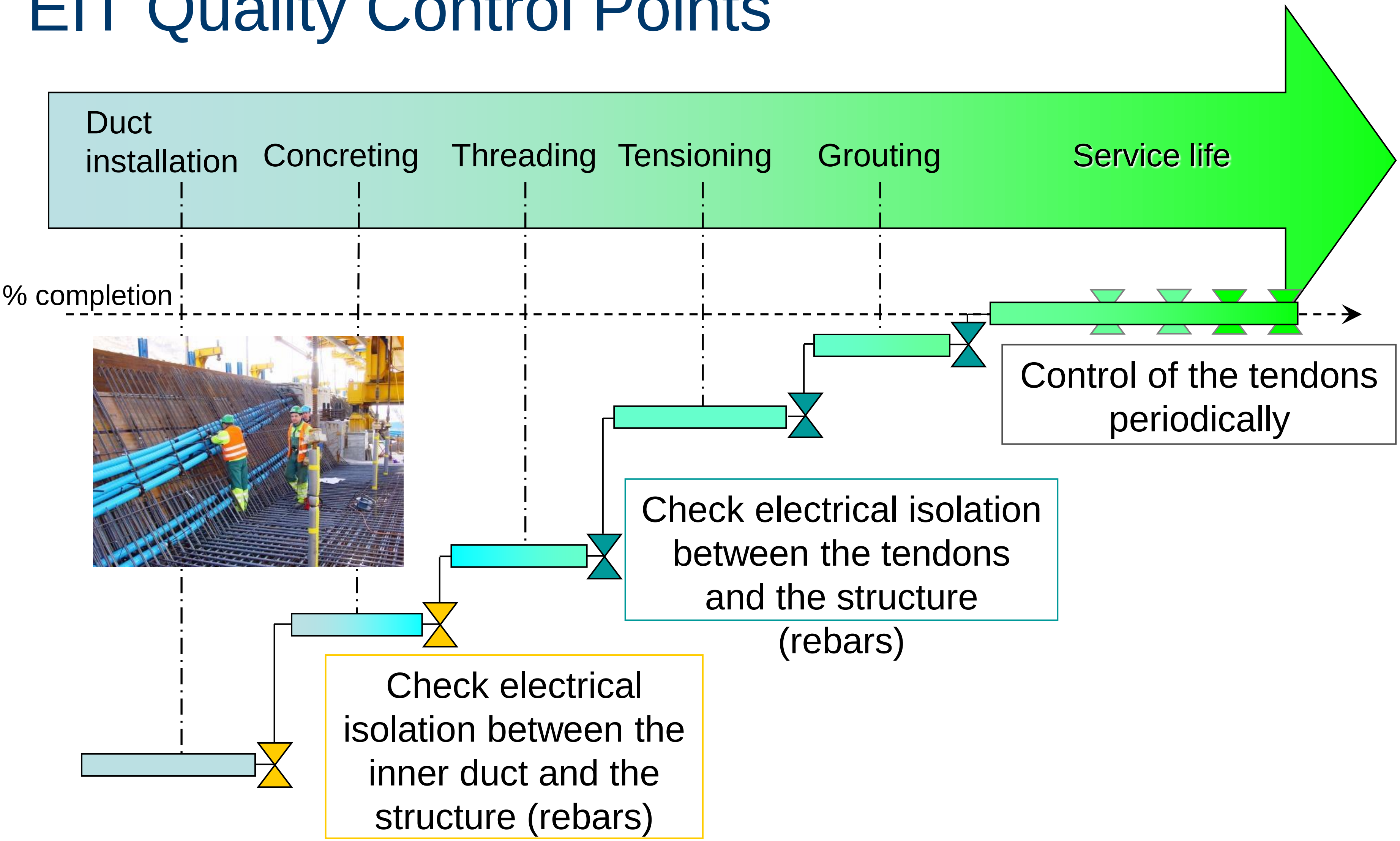
- Tendon electrically isolated by using plastic ducts and insulation plates at anchorages
- Use electrical resistance measurement to check integrity of encapsulation
- During construction and for long term monitoring
- Allows localisation of encapsulation defects



EIT Measurements

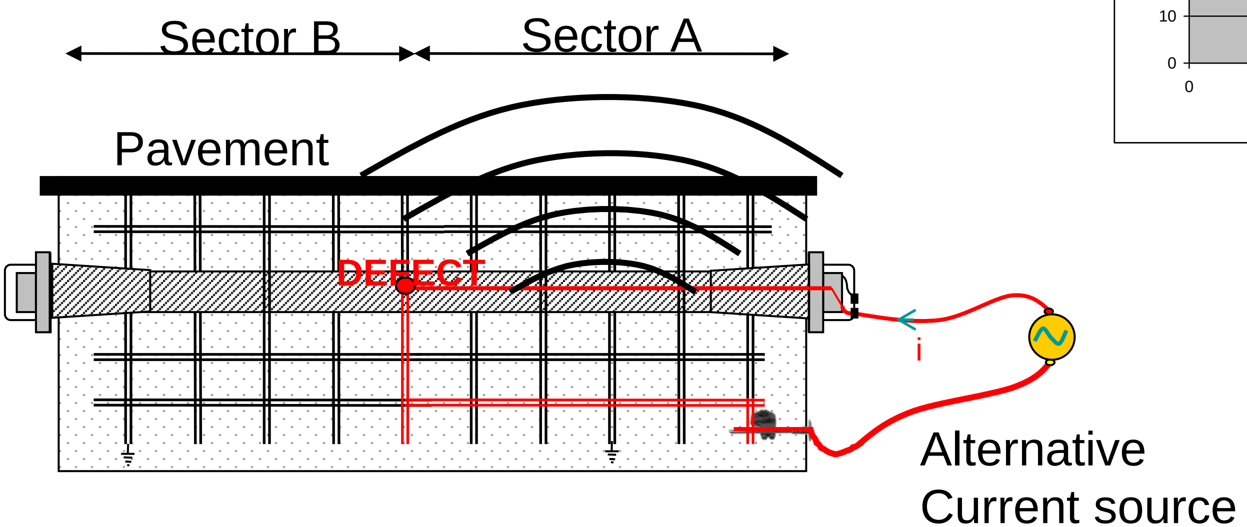


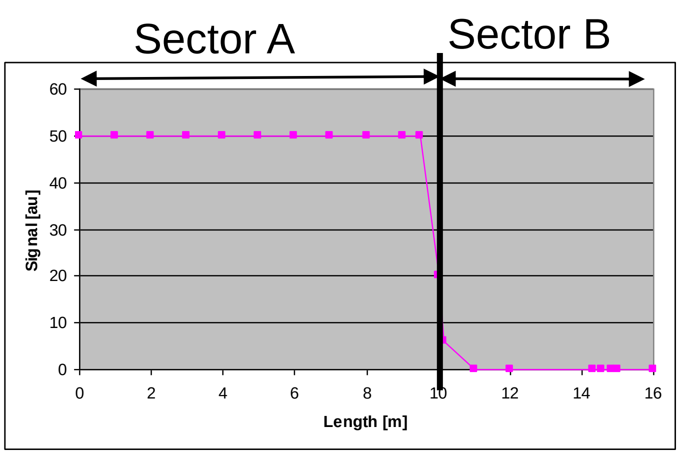
EIT Quality Control Points



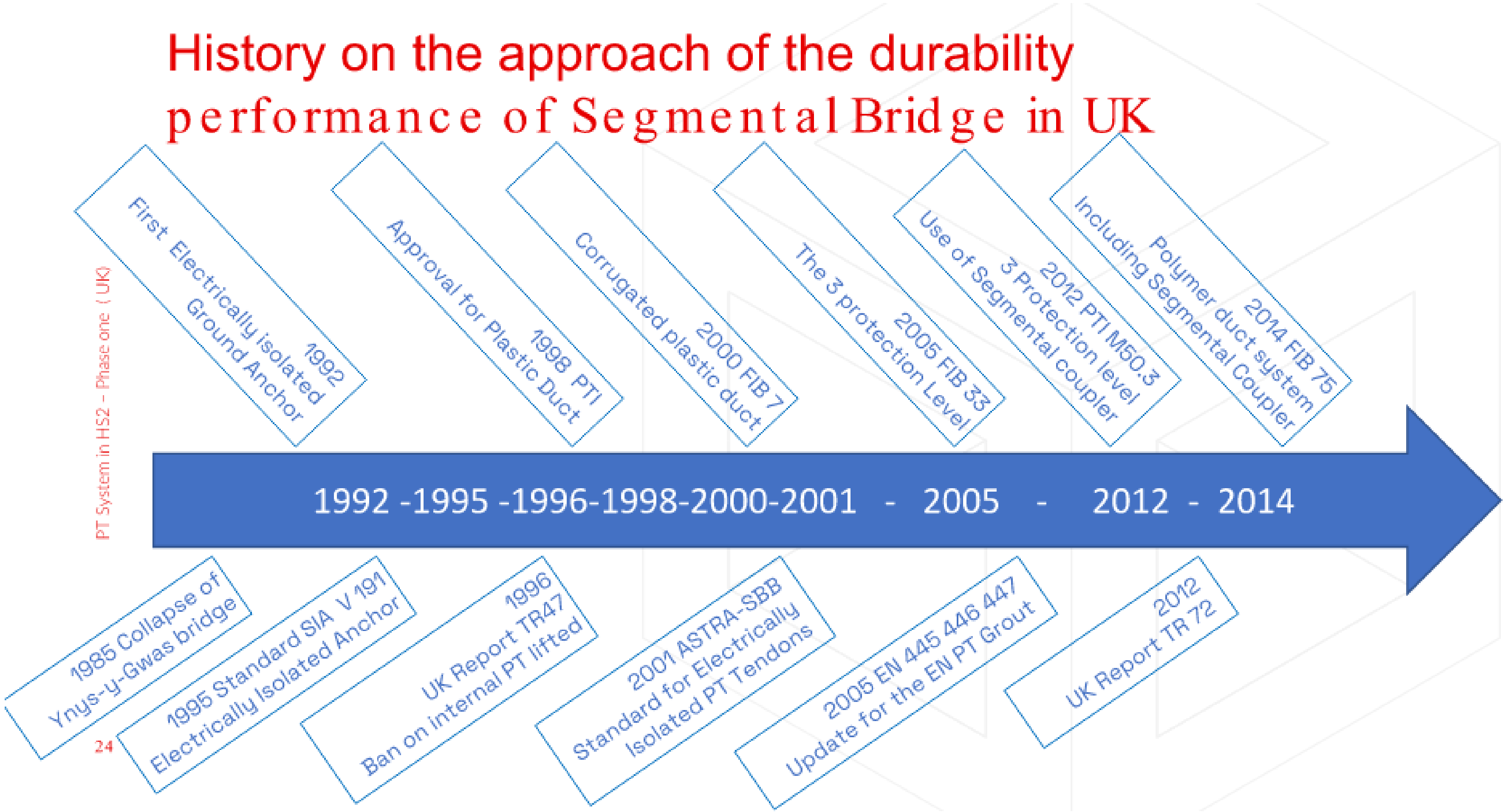
EIT Electrical Leak Location

- Hydration of Concrete and grout allows it to be electrically conductive
- Potential electrical leaks includes:
  - Grout cap connection
  - Trumpet and duct connections
  - Grout vent & drains
  - Penetrations after grouting
- NDT method for finding EIT leakage.





EIT Projects



EIT Projects

United Kingdom - HS2 - Colne Valley Viaduct 2022

Hong Kong - Zhuhai Macau Bridge, Hong Kong - 2017

Troya Bridge, Czech Republic - 2013

Alp Transit Gotthard, Camorino, Switzerland - 2011

Lect Viaduct, Geneva, Switzerland - 2009

Letzigraben Bridge (Durchmesser-linie, Zürich, Switzerland - 2008

Nove Spojeni Bridge, Prague, Czech Republic - 2007

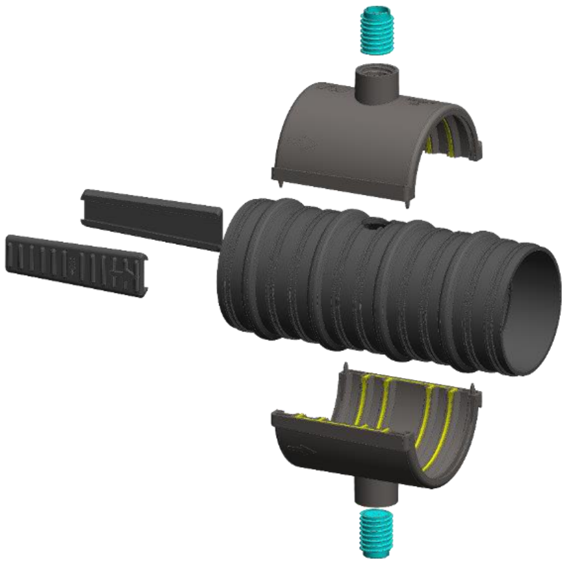
Roeti Bridge, Solothurn, Switzerland - 2006

Rhone Bridges, Leuk, Switzerland - 2003

EIT WITH VOID CORROSION SENSOR

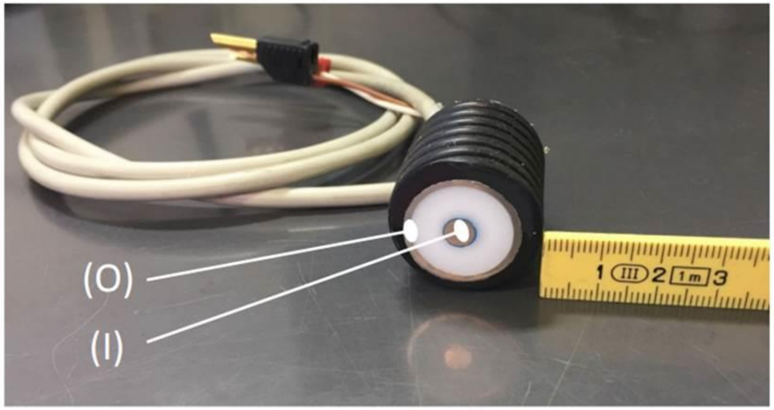
EIT Operation Excellence

- VC Sensor provides the ability to prove the performance of the grout
- Typically placed behind anchor heads, high points, or other critical locations along tendon
- Addresses concerns of “internal” attacks



VSL Void and Corrosion Sensor (VCSensor)

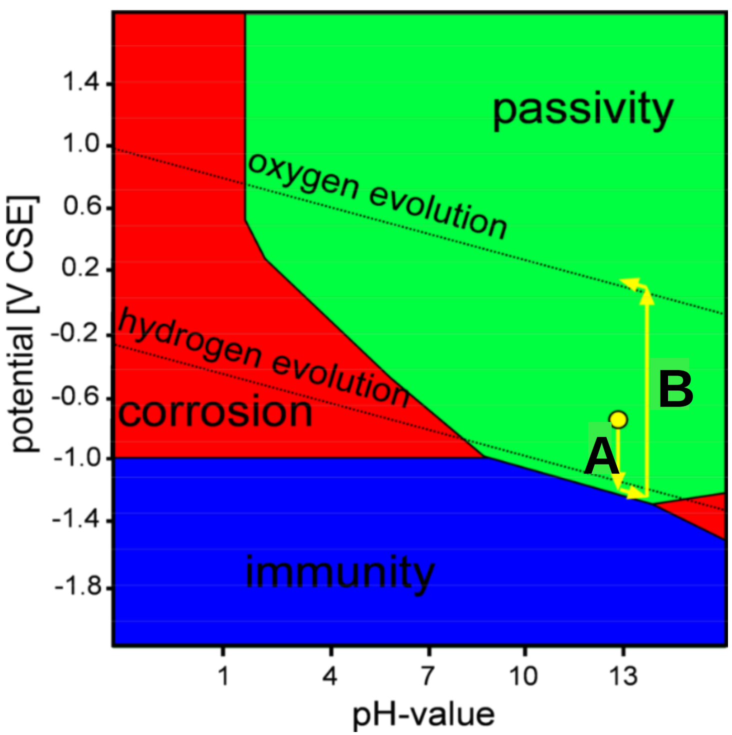
- The main objective is to instrument post-tensioned tendons with sensors to:
  - Control the quality of injections – complete filling of duct and passivation of strands,
  - Detect over time whether corrosion starts.

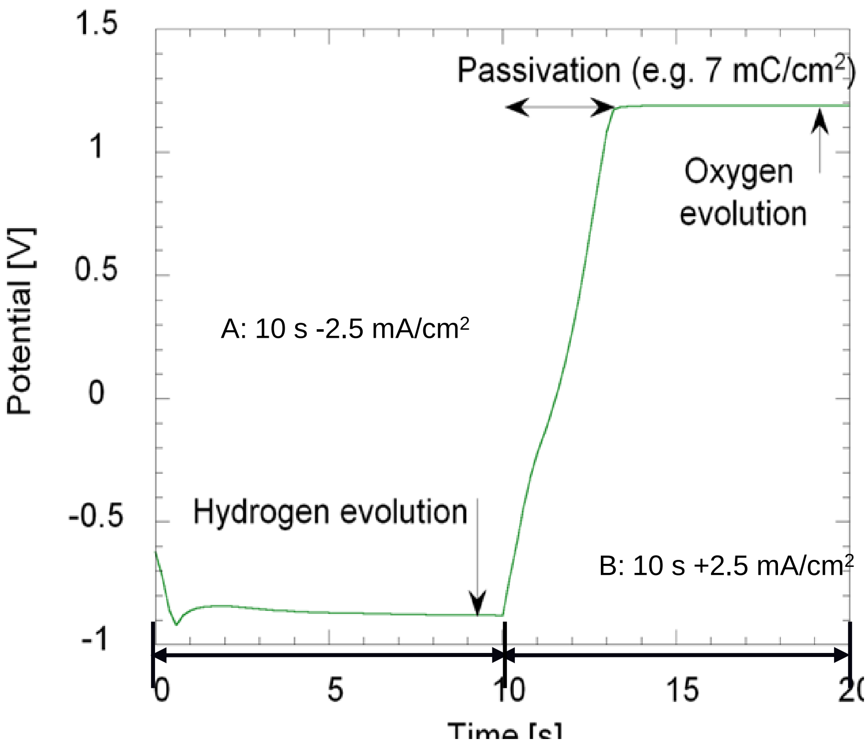


- VSL VCSensor
  - Consisting of Center Electrode (I), Ring Electrode (O) at fixed distance and Insulation
  - Isolated from the tendon system to take Potential measurement between Center and Ring Electrode.

VC Sensor Theory

- The Pourbaix Diagram of the steel
  (Electro Potential / PH material solution)



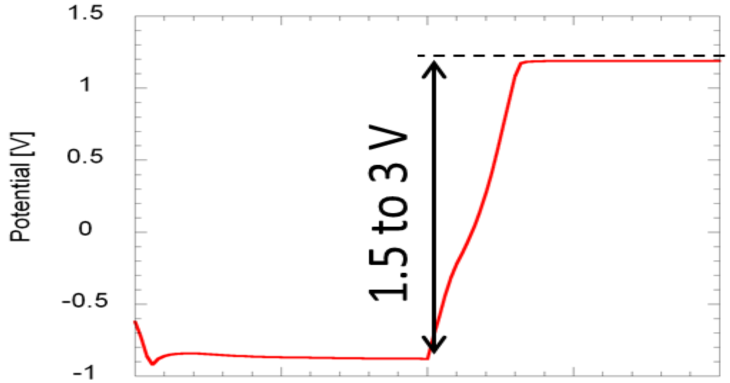


VC Sensor Measurement Interpretation

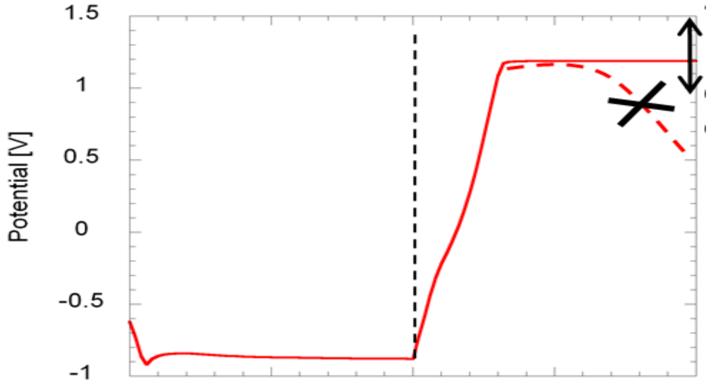
Evaluation of Readings

- Measure C3 – Tendon cross-sectional filling at VC Sensor location. Grout is in contact with the sensor (high point).
  - No voids, low risk of corrosion
  - Strands surrounded by grout, precondition for passivation of strands
- Measure C1/C2 – Passivation of steel electrode = passivation of PT strands
  - Strands are surrounded by a passivating environment, which results in the formation of a passivation layer on the surface of the strands, effective protection of strands against corrosion.

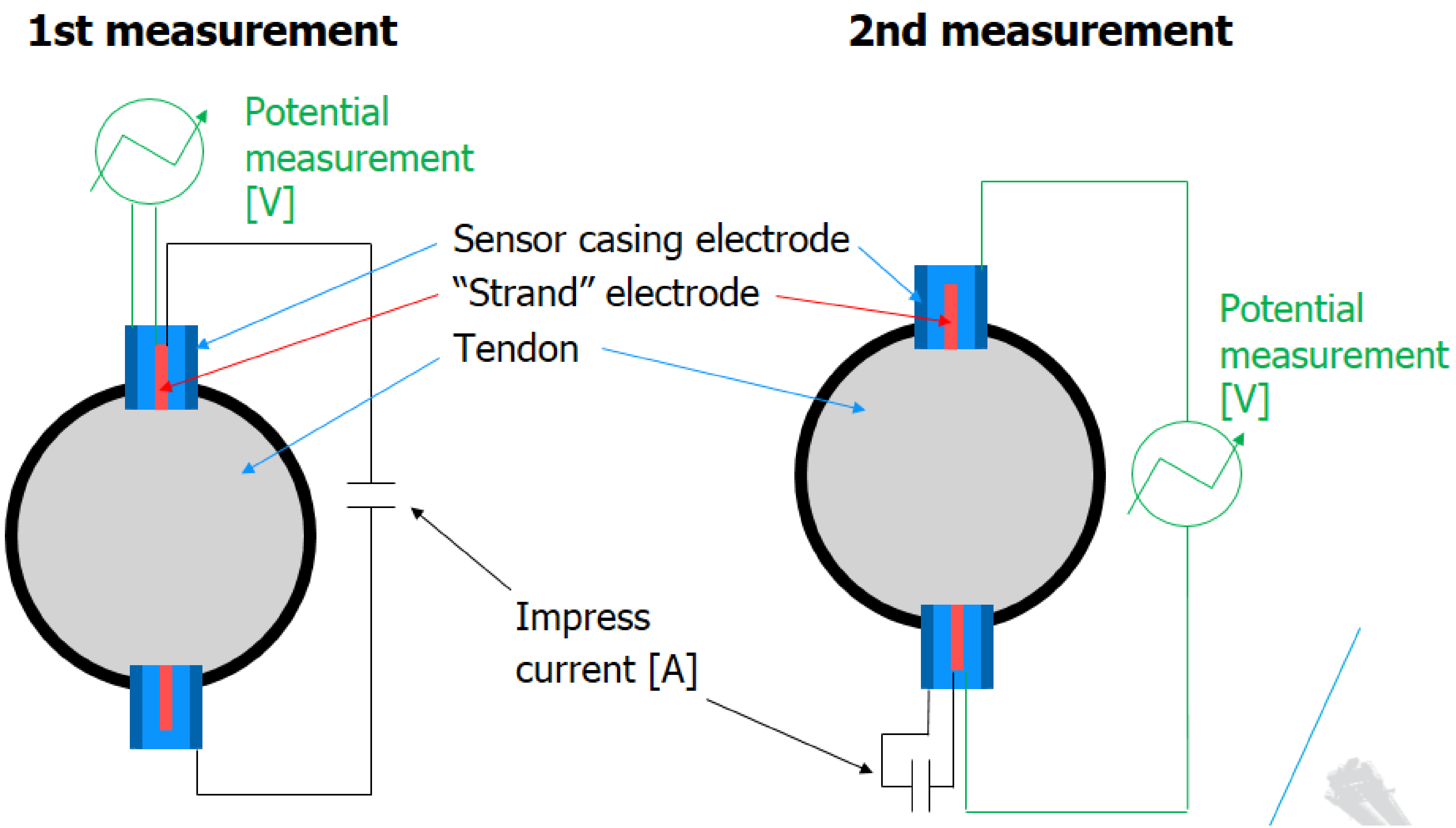
C3 Fully Grouted



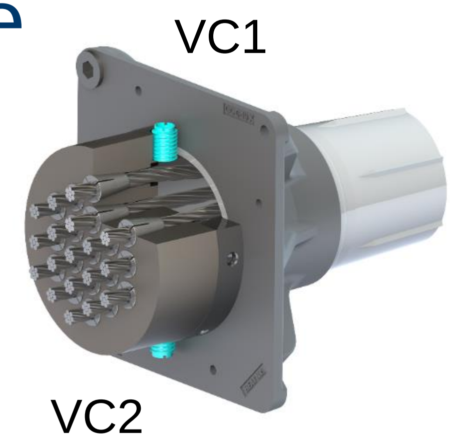
C1-C2 Passivity of Steel



VC Sensor Measurement Procedure



VC Sensor Measurement Procedure

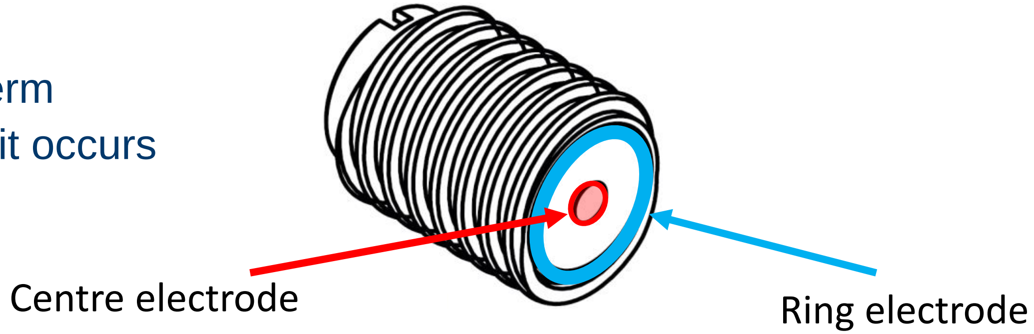


- Measure the electrical Potential (V) or Current Flow (mA) between the VCsensor's Center Electrode and Ring Electrode

Long term potential measurement					
Result Comparison	Grout Level			Passivation of steel and complete setting of grout (no soft grout)	No Corrosion ongoing
VC1	**Full**	**Partial**	**Empty**	**Good**	**Yes**
Similar to VC2	✓			✓	✓
Lower than VC2	✓			Risk of corr.	Risk of corr.
VC1 Open circuit		✓		Risk of corr.	Risk of corr.
VC1 and VC2 Open circuit			✓	Risk of corr.	Risk of corr.

VC Sensor Summary

- VC Sensor provides the ability to check at two stages.
  - Grouting Stage
    - Filling at the time of grouting (30 minutes)
    - Passivation just after grouting (3 hours)
  - Structure Life Cycle
    - Corrosion risk in the long term
    - Corrosion rate when and if it occurs

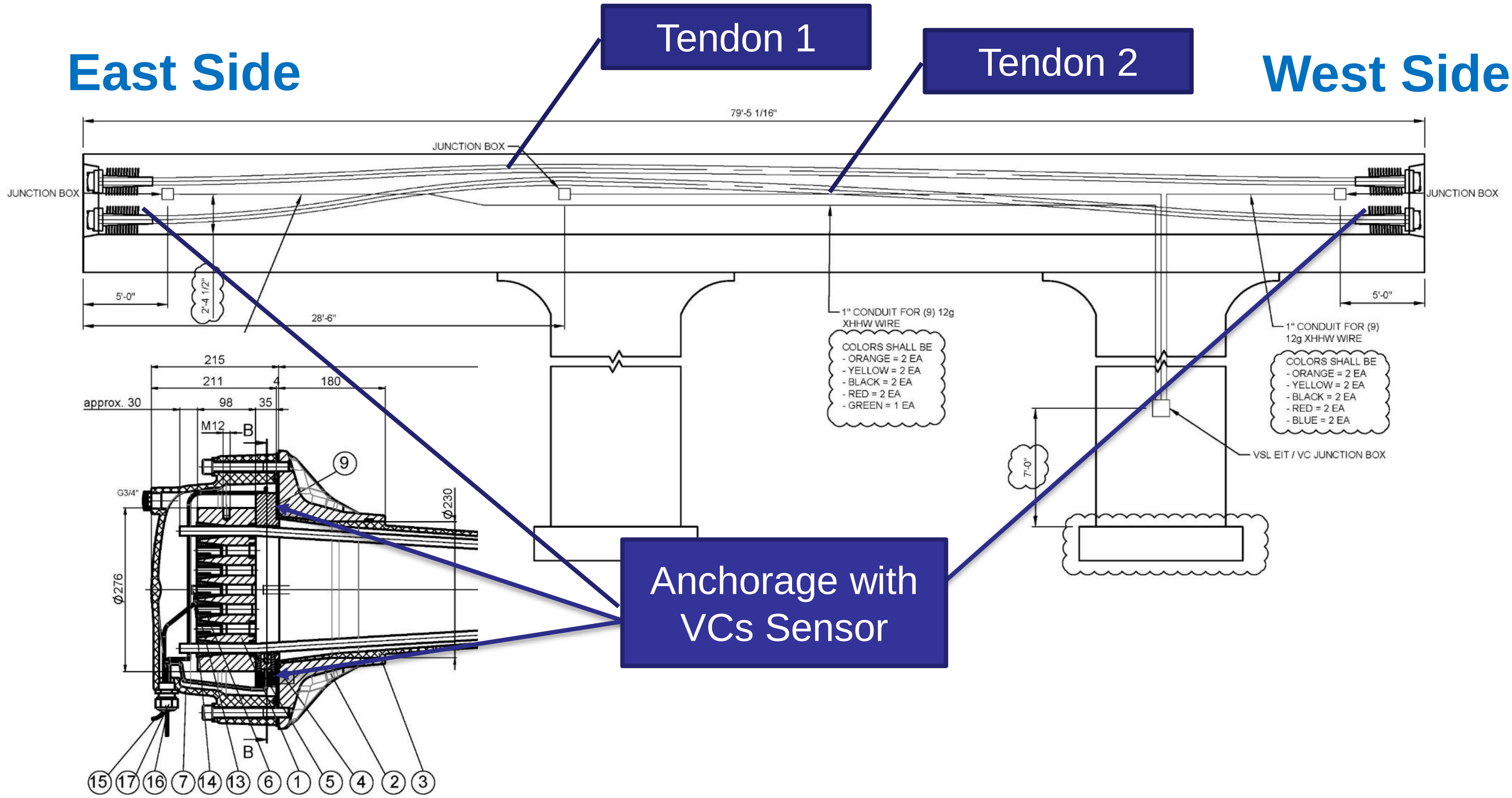


TxDOT SH146 & FHWA EIT PILOT PROJECT

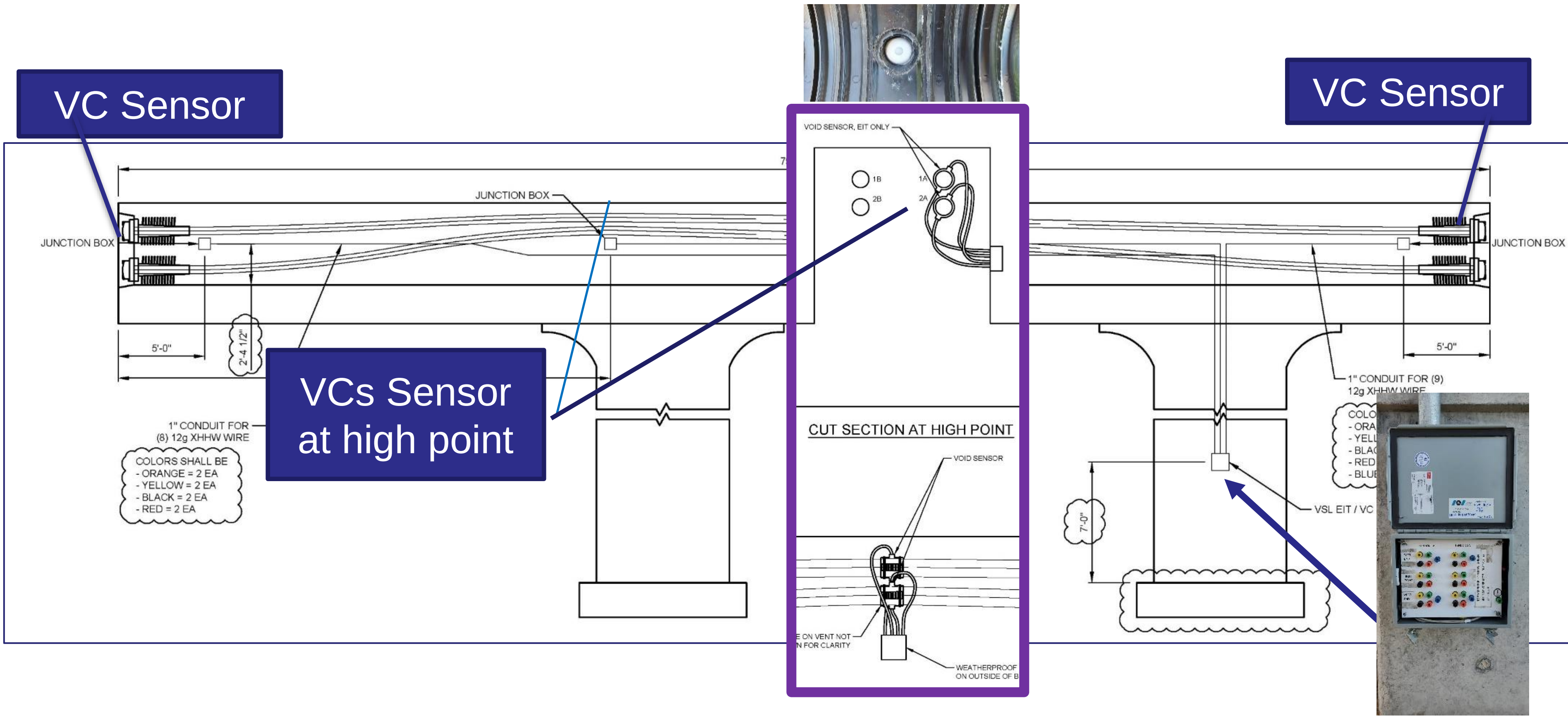
SH146 - EIT Pilot Project

- PT Cantilever inverted-T bent caps
- 20 PT Bent caps across the project
- 0.6x37 strand tendons, 4 tendons per cap
- Two tendons in Bent 107 were converted to PL-3 (EIT)
- Kemah, TX

SH146 - EIT Pilot Project



SH146 - EIT Pilot Project

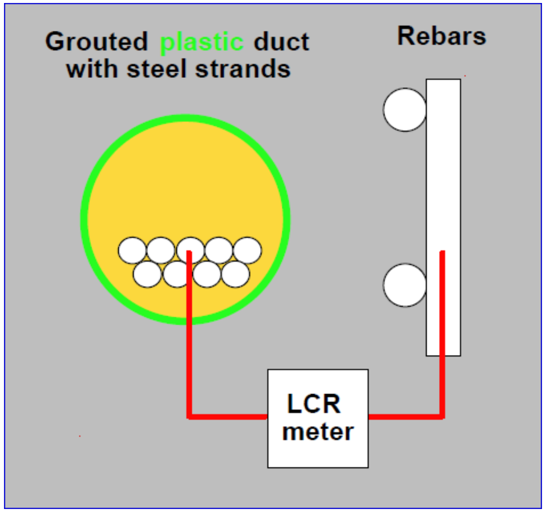


Critical Hold Points

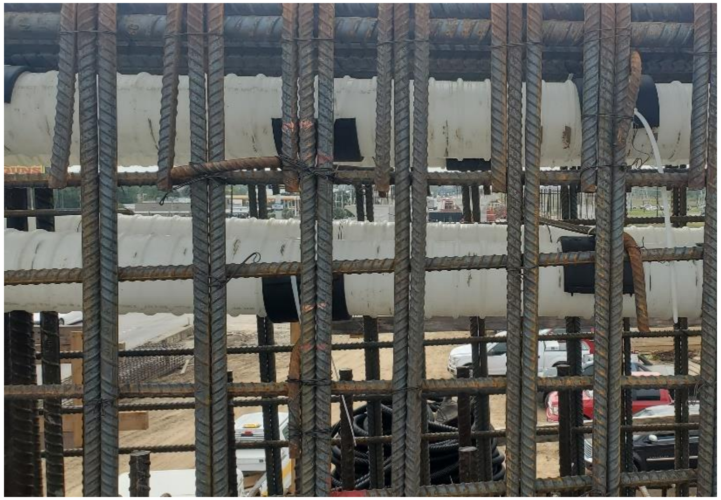
- After duct installation - Pre-pour air test
- Prior to strand installation - Check for contaminate infiltration
- Prior to stressing - Check electrical isolation
- After stressing - Check electrical isolation
- Prior to grouting - Setup for vacuum assist grouting
- After grouting - Check electrical isolation

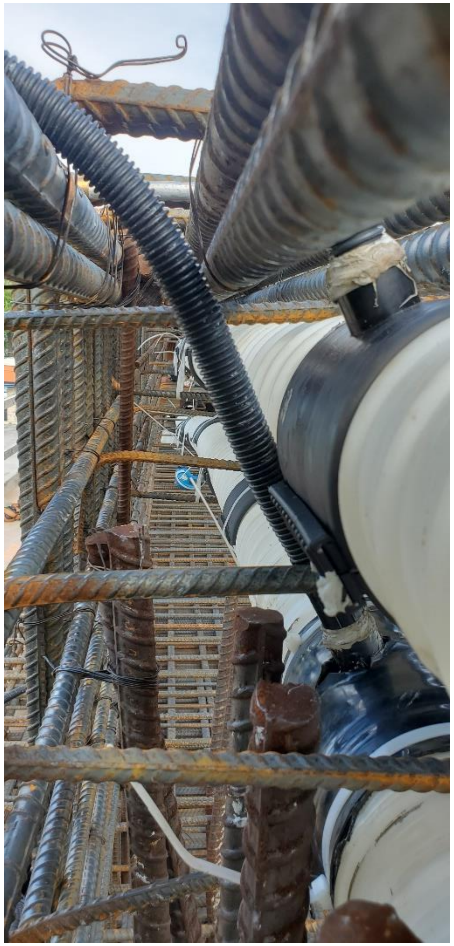
EIT Electrical Leak Location

- Mitigate electrical leaks by:
  - Applying heat shrink over duct couplers
  - Use of protective shell at tight radii curves in tendon profile
  - Make tendon airtight prior to grouting, vacuum assist grouting
  - Minimize number of grout vents
  - Use VC Sensor in lieu of post-grout inspection



SH146 - EIT Pilot Project





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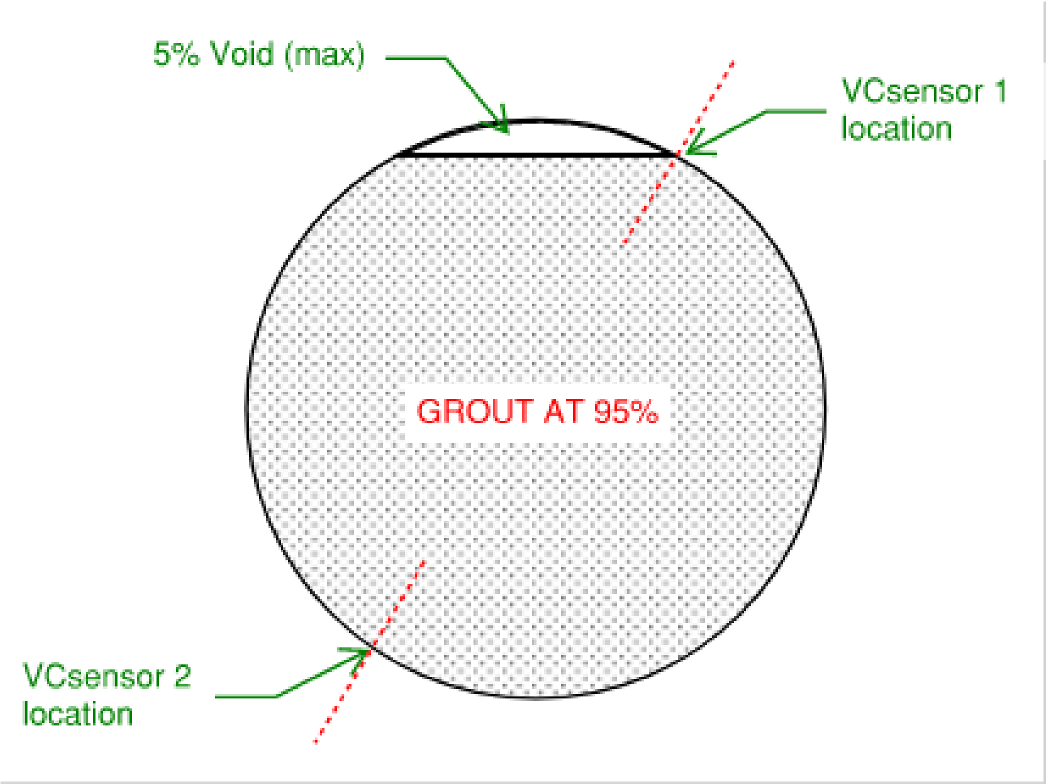

SH146 - EIT Pilot Project

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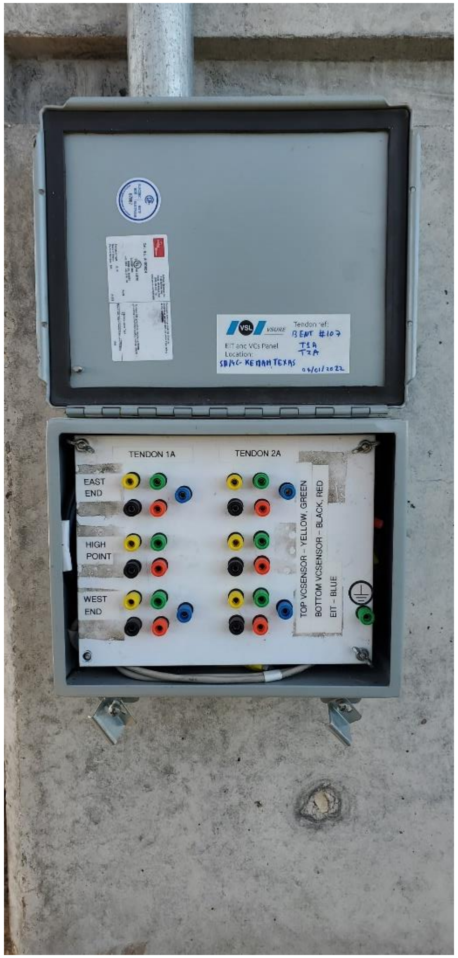
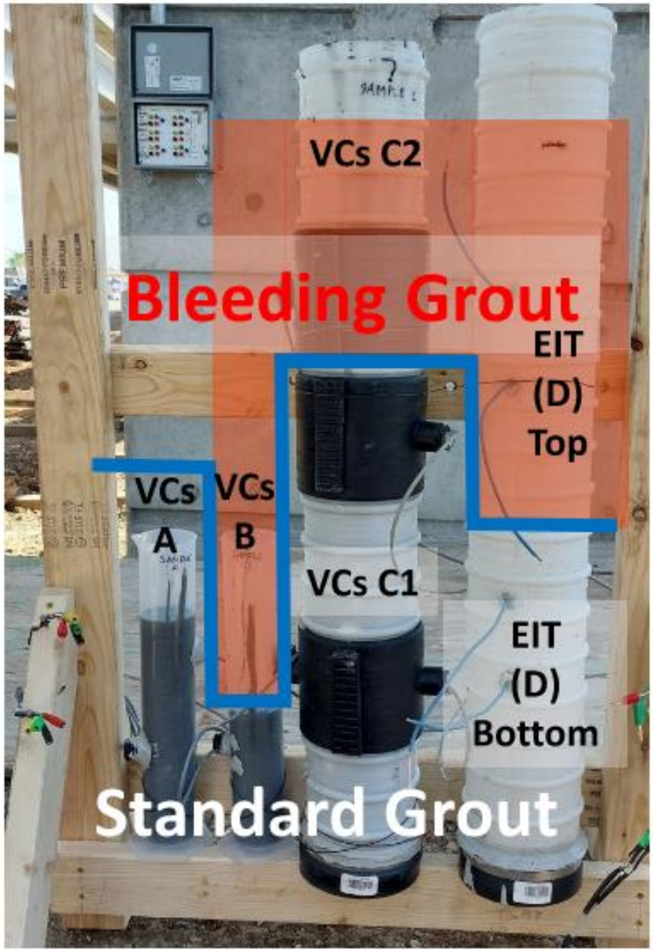


SH146 – EIT Pilot Project

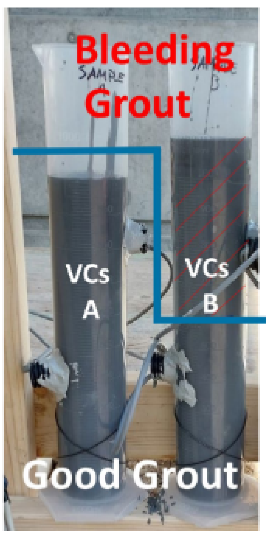
VC Sensor Testing and Calibration

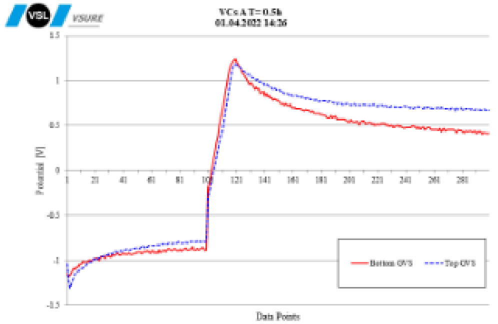


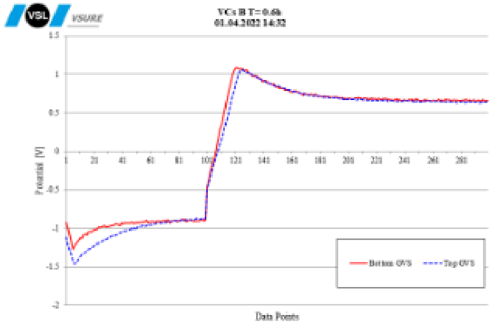
- Correctly mixed grout below the blue line
- Grout with 50% extra water above the blue line to simulate a bleeding grout

VC Sensor Testing and Calibration

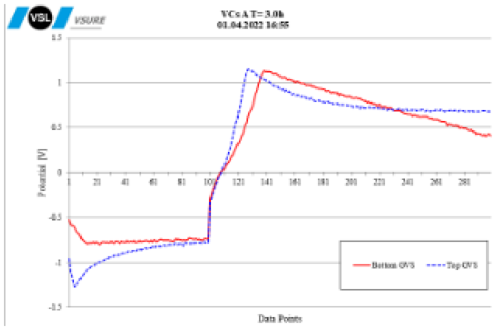
Results on Beaker

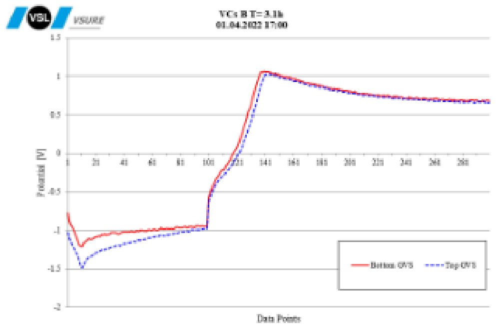




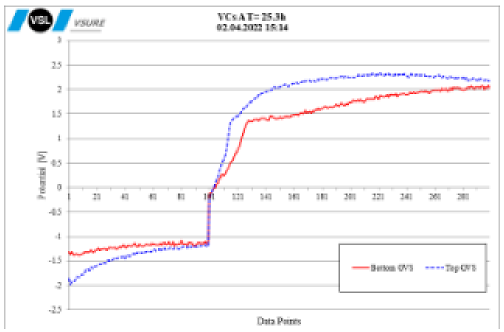


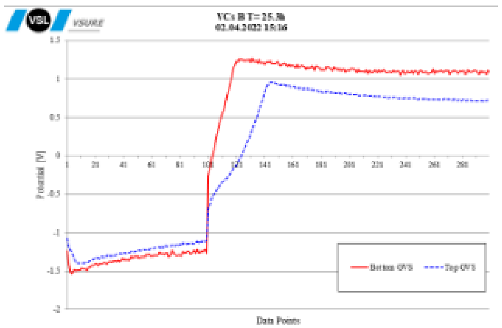
- 0.5 hour





- 3 hour

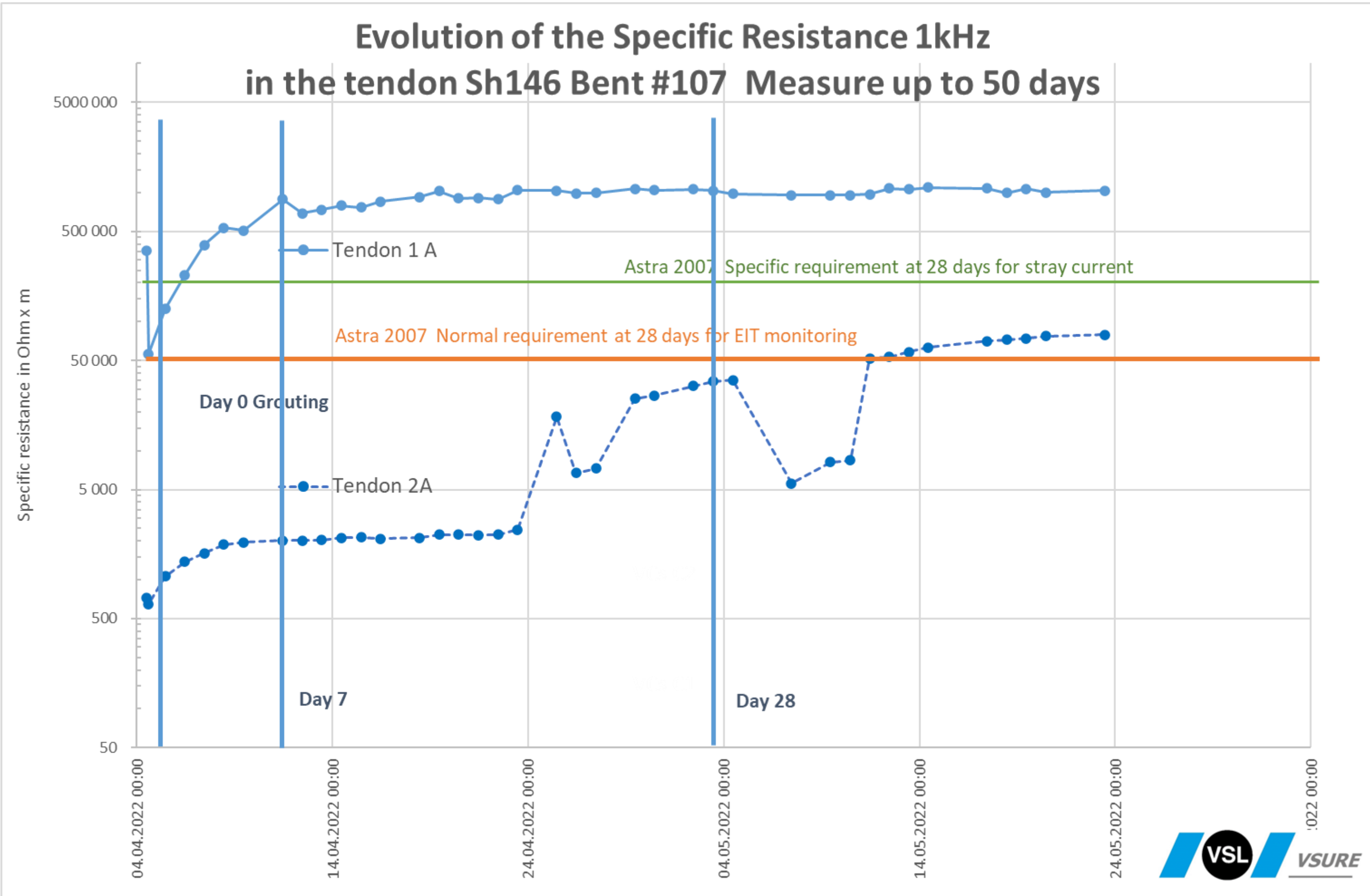




- One day

TxDOT SH146
EIT & VC Sensor Results

EIT Results

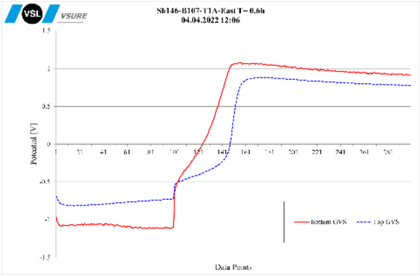


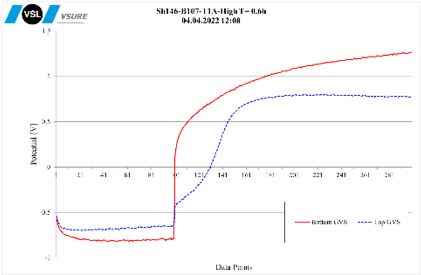
Evolution of the Specific Resistance 1kHz
in the tendon Sh146 Bent #107 Measure up to 50 days
Specific resistance in Ohm x m
5000 000
500 000
50 000
5 000
500
50
Tendon 1 A
Tendon 2A
Astra 2007 Specific requirement at 28 days for stray current
Astra 2007 Normal requirement at 28 days for EIT monitoring
Day 0 Grouting
Day 7
Day 28
04.04.2022 00:00
14.04.2022 00:00
24.04.2022 00:00
04.05.2022 00:00
14.05.2022 00:00
24.05.2022 00:00
VSL
VSURE

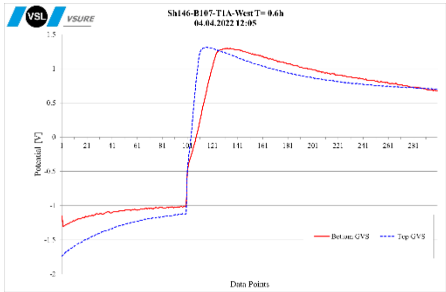
Tendon 1A Results

EAST | HIGH | WEST

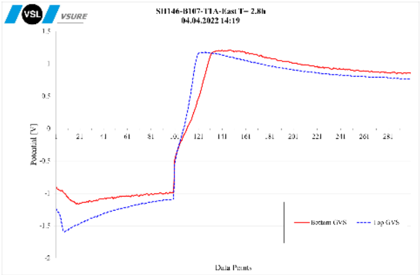
- 0.5 hour

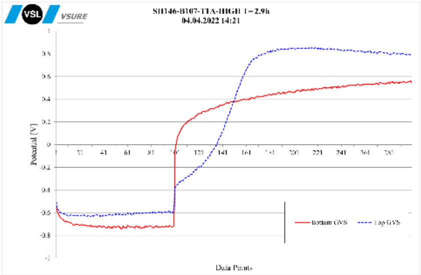


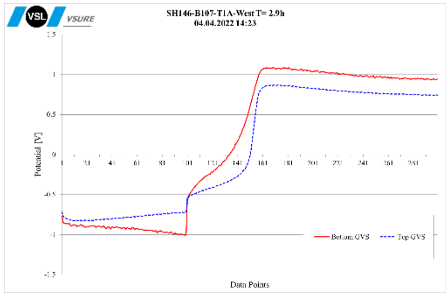




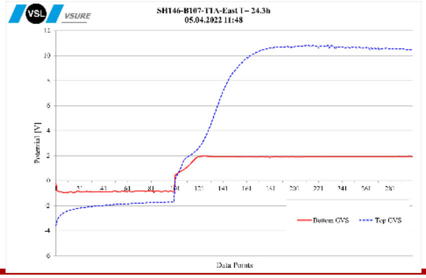
- 3 hour

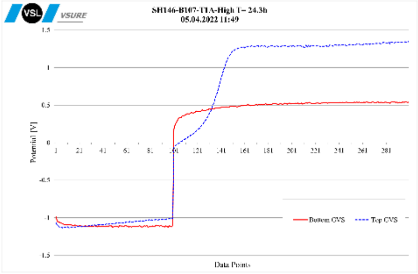


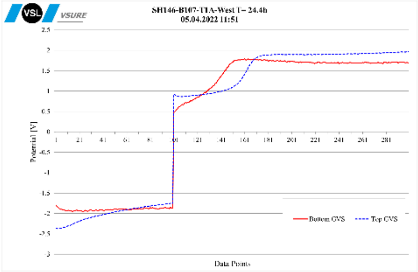




- One day



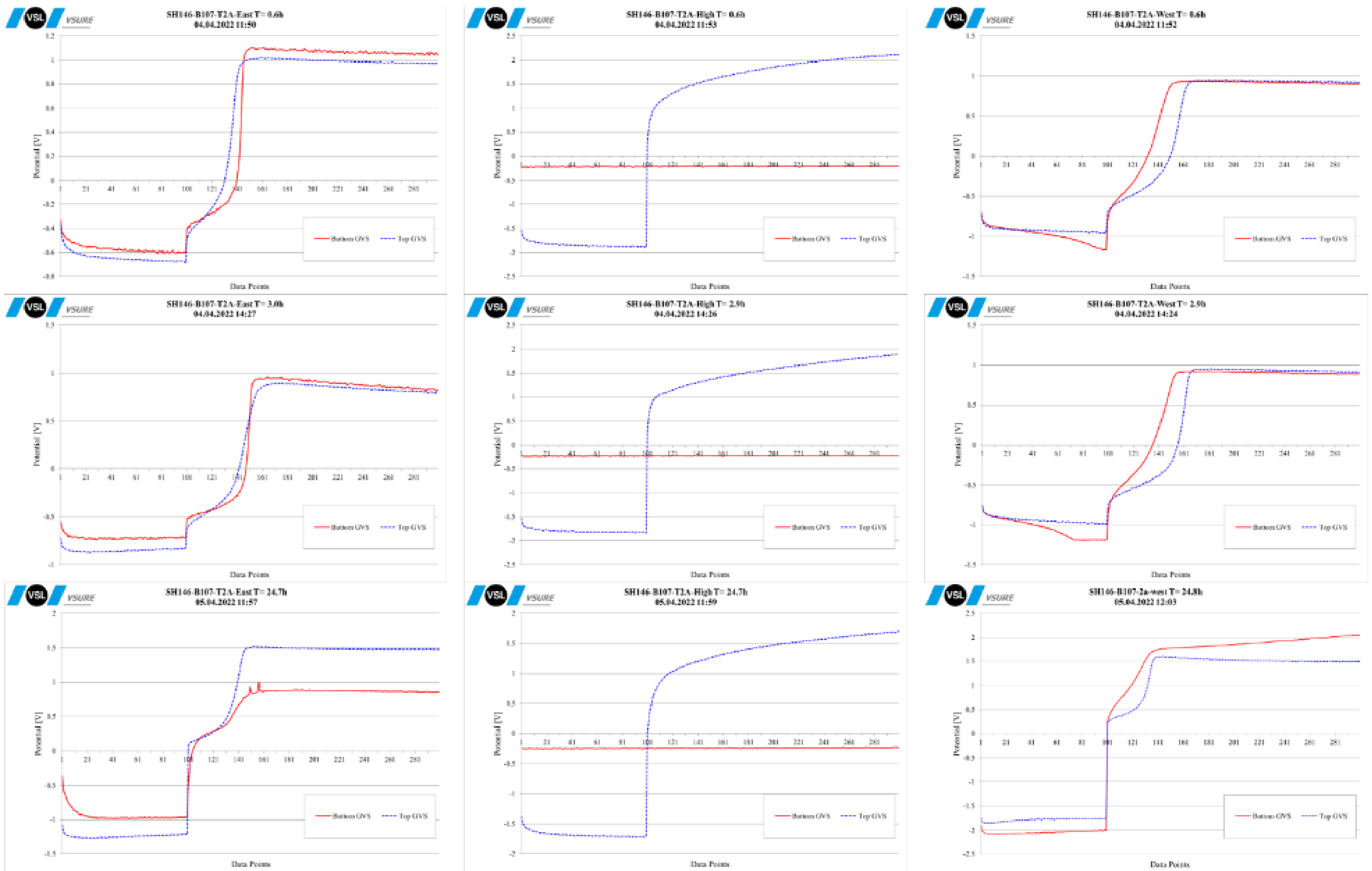




Tendon 2A Results

EAST HIGH WEST

- 0.5 hour
- 3 hour
- One day



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QUESTIONS?

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