National Highways ‘Structures Moonshot’

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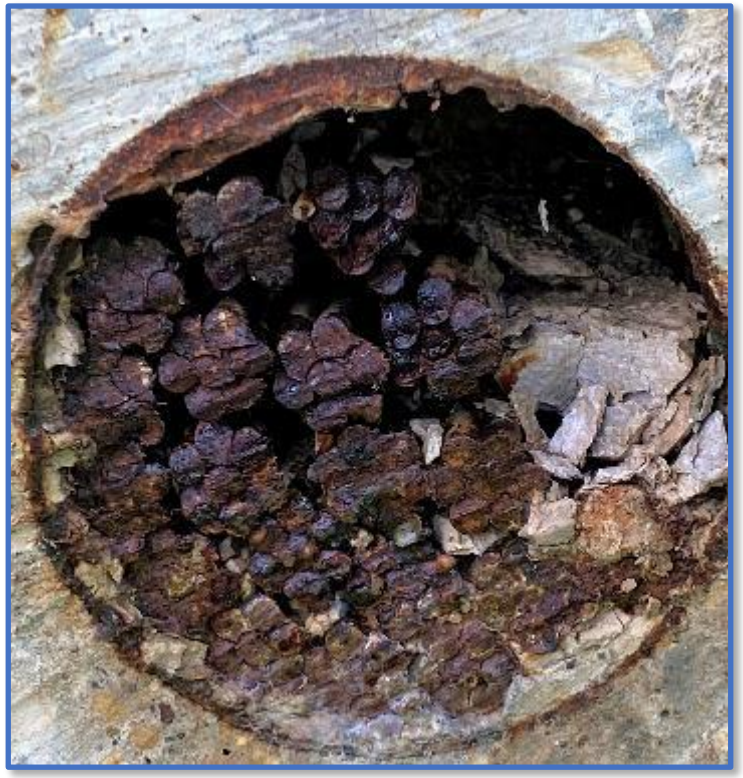
The Challenge:

Initial Focus of Moonshot: Post-tensioned Concrete Bridges (and Half-joints)

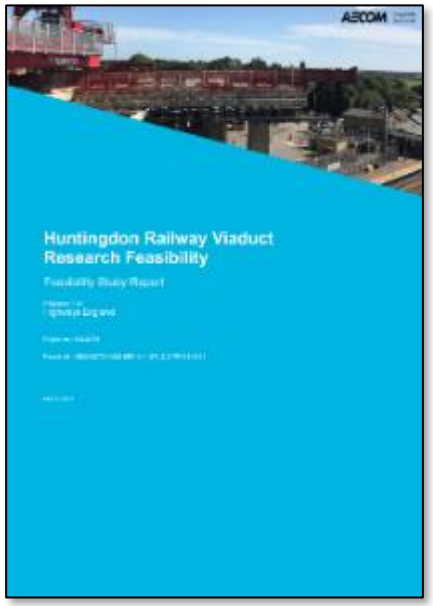
Lack of grout in post-tensioning duct



Corroded strands in a poorly grouted duct

Half-joint

Feasibility Studies



Feasibility Studies Commissioned and Completed

Viaduct Demolition

Recovered Section

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Post Tensioned Structure Investigation – Current state of the art and Problem Statement

Current approach

- Ground penetrating radar – Effective for locating post-tensioning ducts.
- Ultrasonic tomography – Location of voids within ducts.
- Impact echo – Verification of void detection
- Intrusive investigations – Can expose and identify tendon condition, presence of water etc. in a localised area.
- Grout sampling and testing to identify chloride contamination
- Acoustic emission monitoring can identify wire breaks.

Limitations

- Condition away from local intrusive investigations is unknown.
- Intrusive investigations are semi-destructive.
- Extent of wire breaks prior to commencement of acoustic emission monitoring is unknown.
- Therefore, capacity of structure is uncertain.

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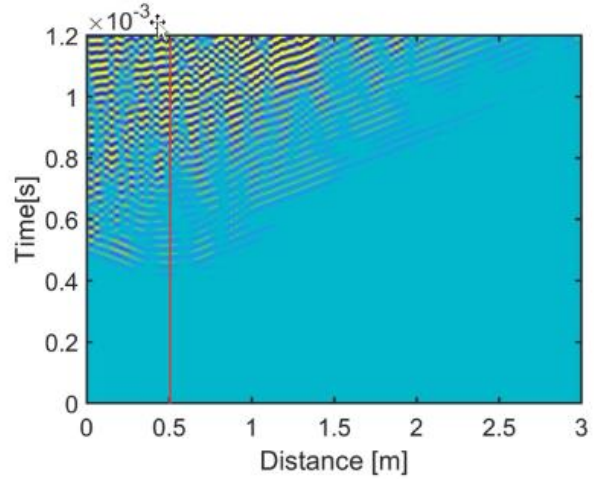
Scope of current phase of the Moonshot project

Development of Innovative Technologies

- We have commissioned work on lower TRL technologies that have potential to support our aspirations.



The Huntingdon Railway Viaduct Trials present two opportunities:

- The ability to verify the conclusions drawn from 20 years of monitoring (e.g. Have wire breaks occurred in the post-tensioning system, and have they occurred where the acoustic emission system indicated?)
- A test bed for established and emerging technologies/methods (relatively high TRL technologies), with direct verification of results possible through careful hydro-demolition.

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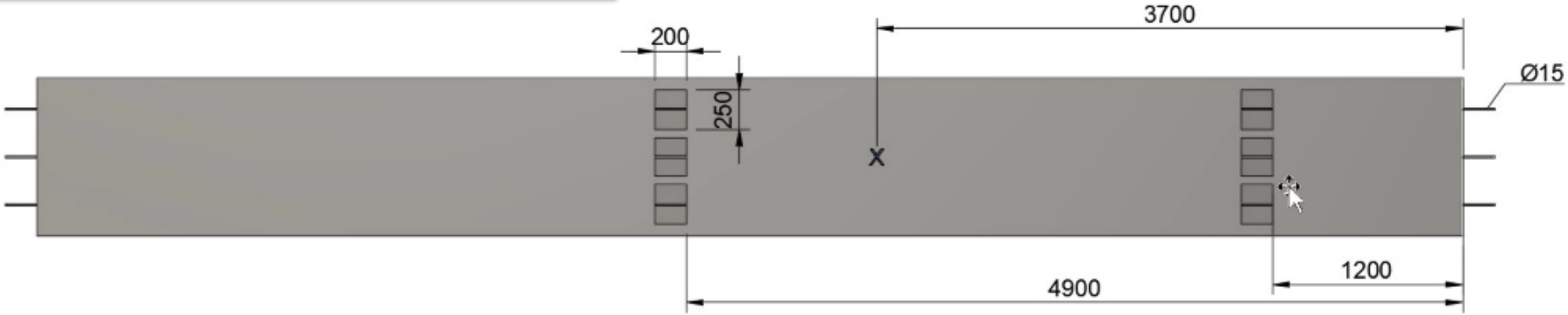
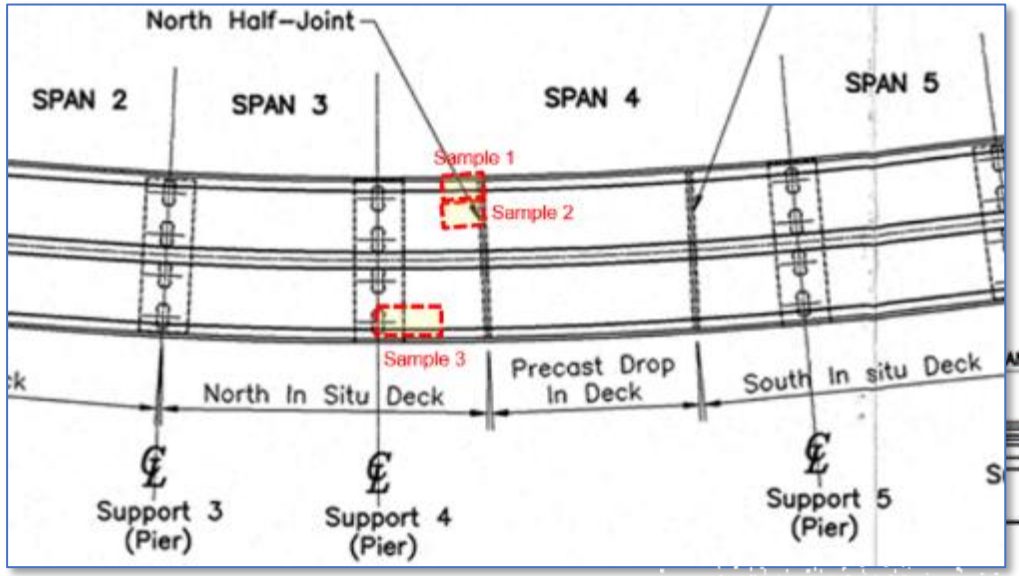
Innovative Technology – Guided Wave

- Numerical modelling undertaken looking at various scenarios.
- Indications were positive, and helped to shape subsequent testing.
- Trials undertaken on 9m long reinforced concrete beam with ‘built-in’ defects.
- Exciter applies guided wave, sensors detect signals from buried defects.
- Some limitations, around signal attenuation, practicalities etc, but a substantial step forward.

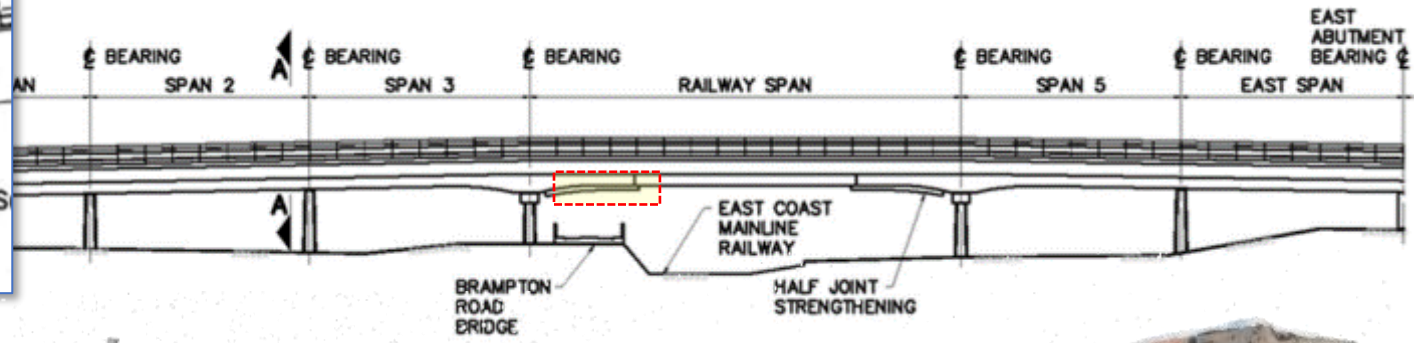


Project Scope – Huntingdon Viaduct



A14 Huntingdon Viaduct Demolished Section Trials

- Testing of beams using current NDT technology available
- Undertake controlled demolition recording actual condition
- Compare NDT technology findings with actual condition



TO321 – Project Scope – Huntingdon Viaduct

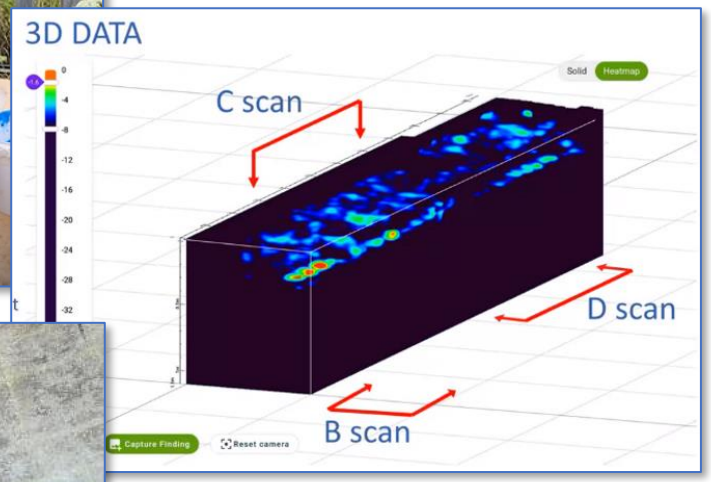
Hierarchy Level	Description	Applicability		Value
1	***Locating and identifying physical properties***	HJ	PT	Increasing Value of Data
1.1	Locate the strands and/or the rebar approximately	✓	✓	
1.2	Identify sizes of strand and/or rebar	✓	✓	
1.3	Identify duct type		✓	
1.5	Map all strands and rebar completely and accurately – position and sizes (stretch target)	✓	✓	
1.6	Identify chemical and physical properties of the materials (e.g. Section 3.7.5 and 3.7.6 of CS 465)	✓	✓	
2	***Conditions for corrosion***			
2.1	Locate any absence of duct grouting		✓	
2.2	Identify areas where the reinforcement is at high risk of corrosion, e.g. loss of concrete passivation or high chlorides	✓	✓	
2.3	Identify areas where the tendons are at high risk of corrosion, e.g. loss of concrete passivation or high chlorides		✓	
3	***Indications of damage***			
3.1	Identify discontinuities in reinforcing and/or prestressing steel that may be indicative of corrosion or breakages	✓	✓	
3.2	Identification of plastic deformations of reinforcement (e.g. necking)	✓		
3.3	Measurement of surface cracking at re-entrant corners (width, length, depth)	✓		
3.4	Measurement of cracking along length of re-entrant corners (width, length, depth)	✓		
4	***Pinpoint location and quantify magnitude of deterioration***			
4.1	Corrosion locations	✓	✓	
4.2	Magnitude and shape of section loss from corrosion at each location	✓	✓	
4.3	Wire break locations		✓	
4.4	Number of wire breaks at each location		✓	
5	***Other behaviour to detect if possible***			
5.1	Bond slip between steel and concrete (should have occurred at least in cutting samples)		✓	
5.2	Re-anchoring of strands (should have occurred at least in cutting samples)		✓	

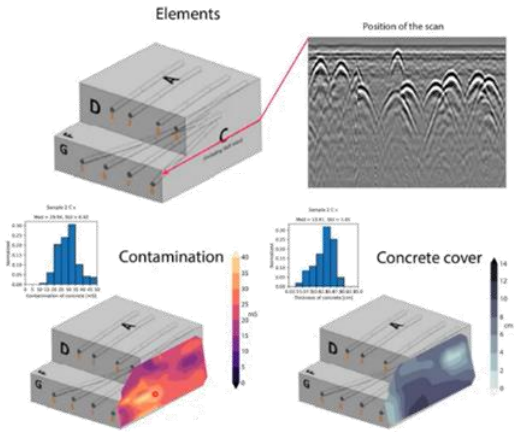
Type of test	Activity/Test Type
Mechanical Wave	Acoustic Emission Monitoring (AEM)
Optical	Initial visual inspection
Electromagnetic	Covermeter survey
Optical	Hyperspectral Imagery
Particle sensors	FTIR hydrogen gas monitoring
Optical	Portable X-Ray (PTX)
Electromagnetic	Chloride mapping
Mechanical Wave	Anchorage guided wave
Mechanical Wave	Advanced Impact Echo
Electromagnetic	Ground Penetrating Radar (GPR)
Optical	Infra-red thermography (IRT)
Electrochemical	Half Cell Potential Survey
Magnetic	Magnetic Flux Leakage (MFL)
Mechanical Wave	Joint fracture evaluation
Mechanical Wave	Advanced ultrasonics (ELOP & Pundit)
Electromagnetic	GSSI StructureScan Mini (GPR)
Core sampling	Chloride core samples
Electrochemical	Electrical resistivity
Optical	DIC (during demolition)
Optical	Demolition & inspection

‘Moonshot’ Testing Undertaken

Test Type	Equipment	Scope	Providor
Dust Sampling (Chloride Reference)	N/A	Original Spec	VSL, Bridgology
Tapping	N/A	Original Spec	CTS
Cover meter Survey	Elcometer 331 Cover Meter	Original Spec	CTS
Electrical Resistivity	Proceq Resipod	Original Spec	CTS
GPR	Proceq GP8000	Original Spec	VSL, Bridgology
GPR	Proceq GP8800	Additional Test	Screening Eagle (via Mistras)
GPR	Proseq GP8000	Additional Test	Screening Eagle (via Mistras)
Joint Fracture Evaluation	Bespoke	Original Spec	Screening Eagle (via Mistras)
Ultrasonic Pulse Echo (Concrete)	Proseq PD8050	Original Spec	Screening Eagle (via Mistras)
Impact Echo	Proseq PI8000	Original Spec	Mistras
Anchorage Guided Wave	Bespoke	Additional Test	Mistras
Acoustic Emissions	Bespoke	Additional Test	Mistras
FTIR Gas Monitoring	Gasmet GT5000 Terra Portable Gas Analyser	Original Spec	RAU
Hyperspectral Imaging	Hyperspectral Camera (400 - 1000nm wavelength)	Original Spec	University of Bristol (via RAU)
Field Spectromatry	Spectral Evolution RS3500 Field Spectrometer (350 - 2500nm wavelength)	Additional Test	Pro-Lite Technology (via RAU)
Raman Spectophacy	Wasatch Photonics 785nm Raman Spectrometer	Additional Test	Pro-Lite Technology (via RAU)
Gamma Ray Spectomatry	ImiTec ARARM Gamma Ray Sensor	Additional Test	RAU
Portable Xray Flourescence (PXRF)	ThermoFisher Niton XL3t GOLDD+ analyser	Original Spec	RAU
Ultrasonics (Concrete)	ELOP	Additional Test	Allied Associates (via Mistras)
GPR	GSSI Flex NT	Original Spec	Allied Associates (via Mistras)
GPR	GSSI Structure Scan Mini XT	Additional Test	Allied Associates (via Mistras)
GPR	Proseq GP8000	Open Invite	Screening Eagle
GPR	Proseq GP8800	Open Invite	Screening Eagle
Half-cell potential survey	Proseq Profometer Corrosion	Open Invite	Screening Eagle
Visual Inspection	Hausbots 1080p/30x optical zoom	Additional Test	HausBots, VTC
Cover meter Survey	Proseq Profometer PM8000	Additional Test	HausBots, VTC
GPR	Proseq GP8000	Additional Test	HausBots, VTC
Half-cell potential survey	Proceq Profometer Corrosion TBC	Additional Test	HausBots, VTC
Magnetic Flux Leakage	Bespoke	Original Spec	IFDB
Muon Tomography	Bespoke	Additional Test	Gscan
Ultrasonic Measurements (Steel Tend	Mistras Proprietry	Additional Test	Mistras
Cover meter Survey	Hilti PS300	Open Invite	Hilti
Cover meter Survey	Hilti PS1000	Open Invite	Hilti
Concrete carbonation tests	N/A	Original Spec	CTS
Half-cell potential survey	Proceq Profometer Corrosion	Original Spec	CTS

NDT SME Data Collection





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haus bots protecting the built environment

Royal Agricultural University

Jacobs

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MISTRAS

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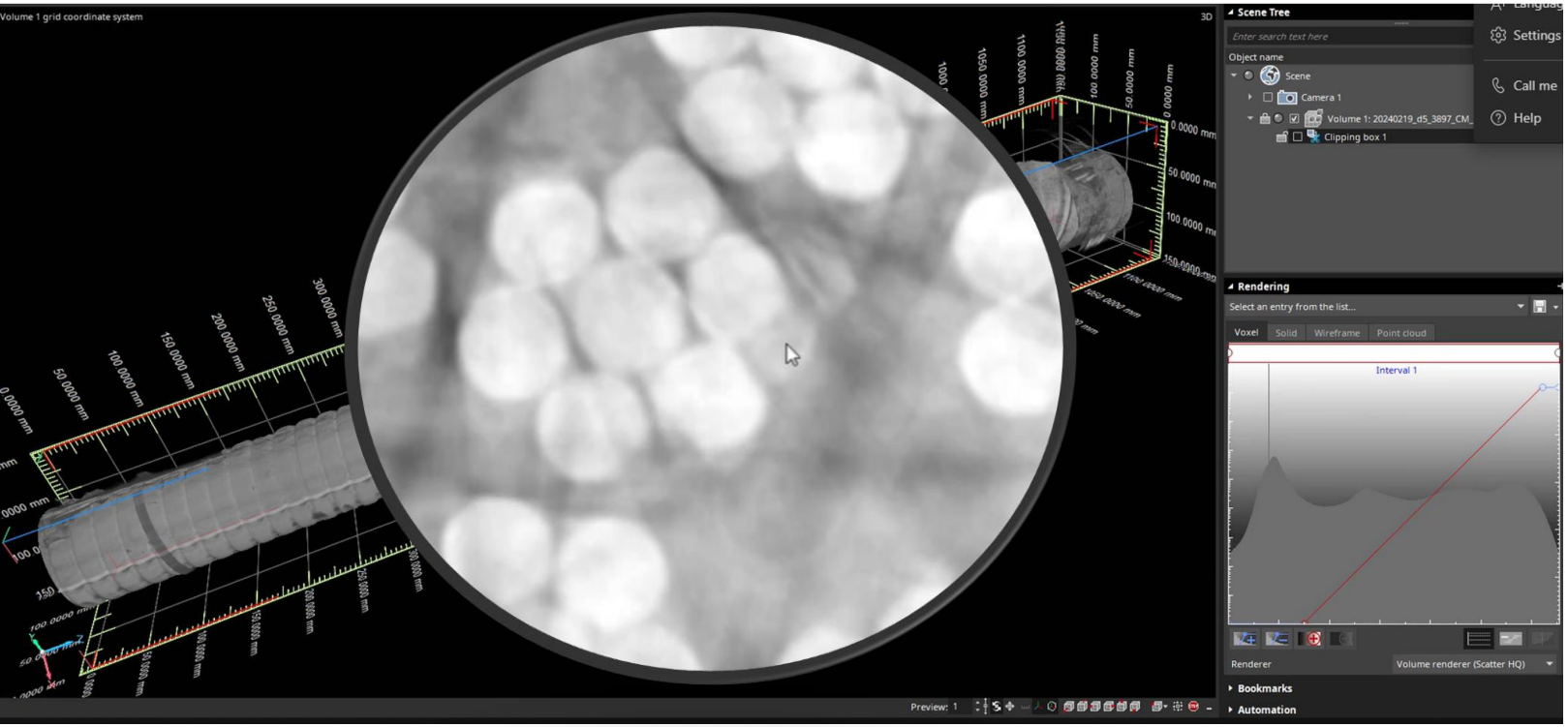
NDT SME Data Collection - XCT



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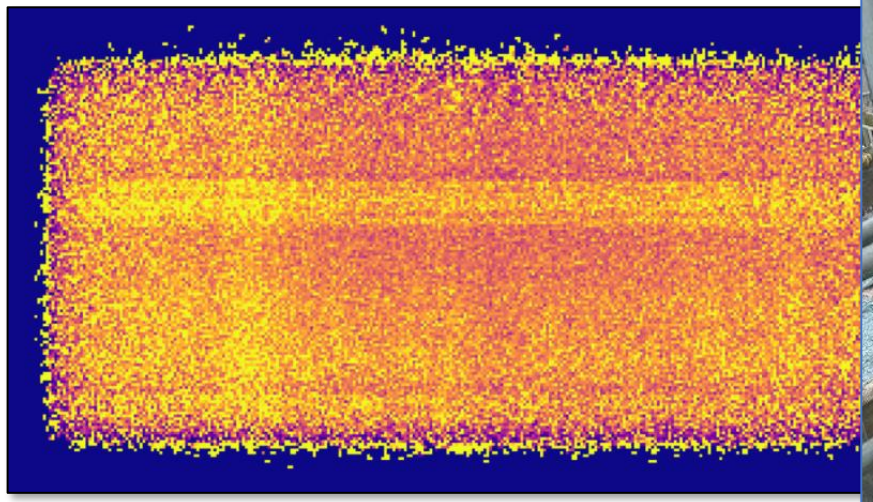
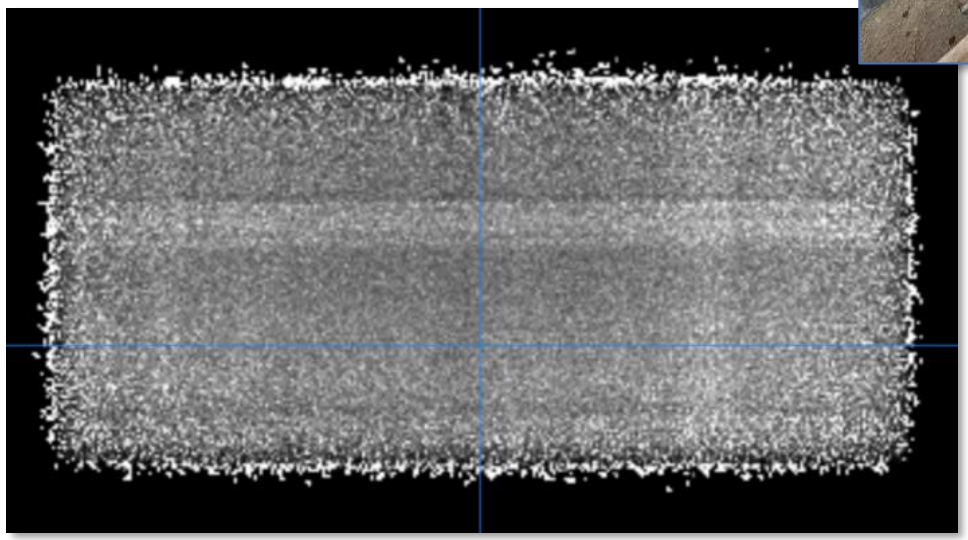
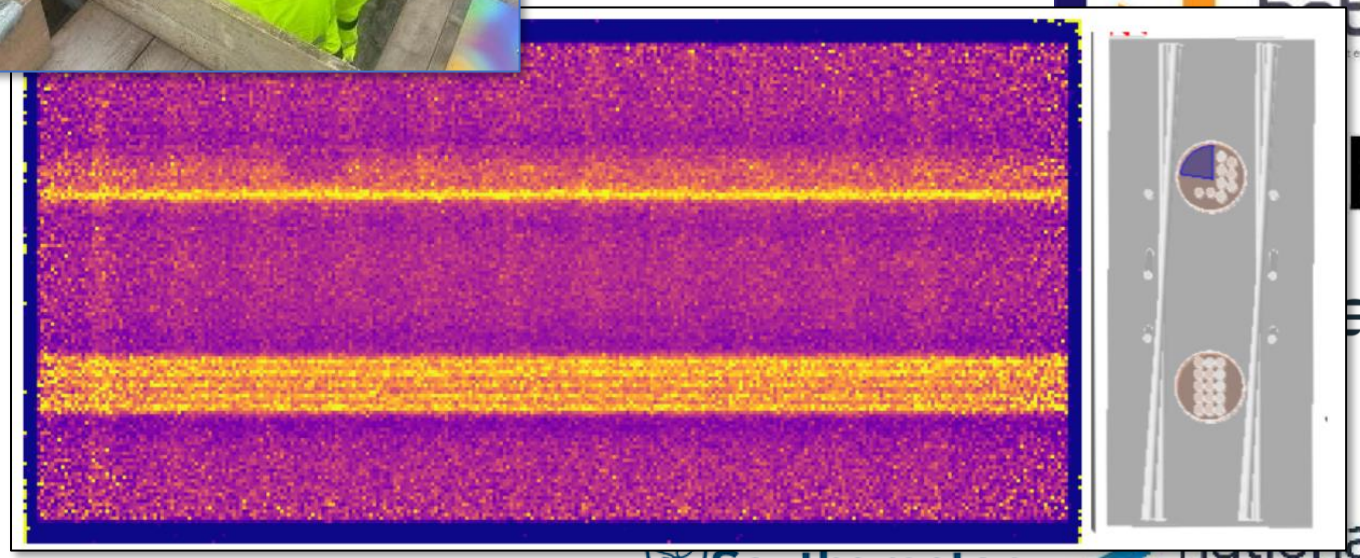
NDT SME Data Collection - GScan







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NDT SME Workshop – November 2023

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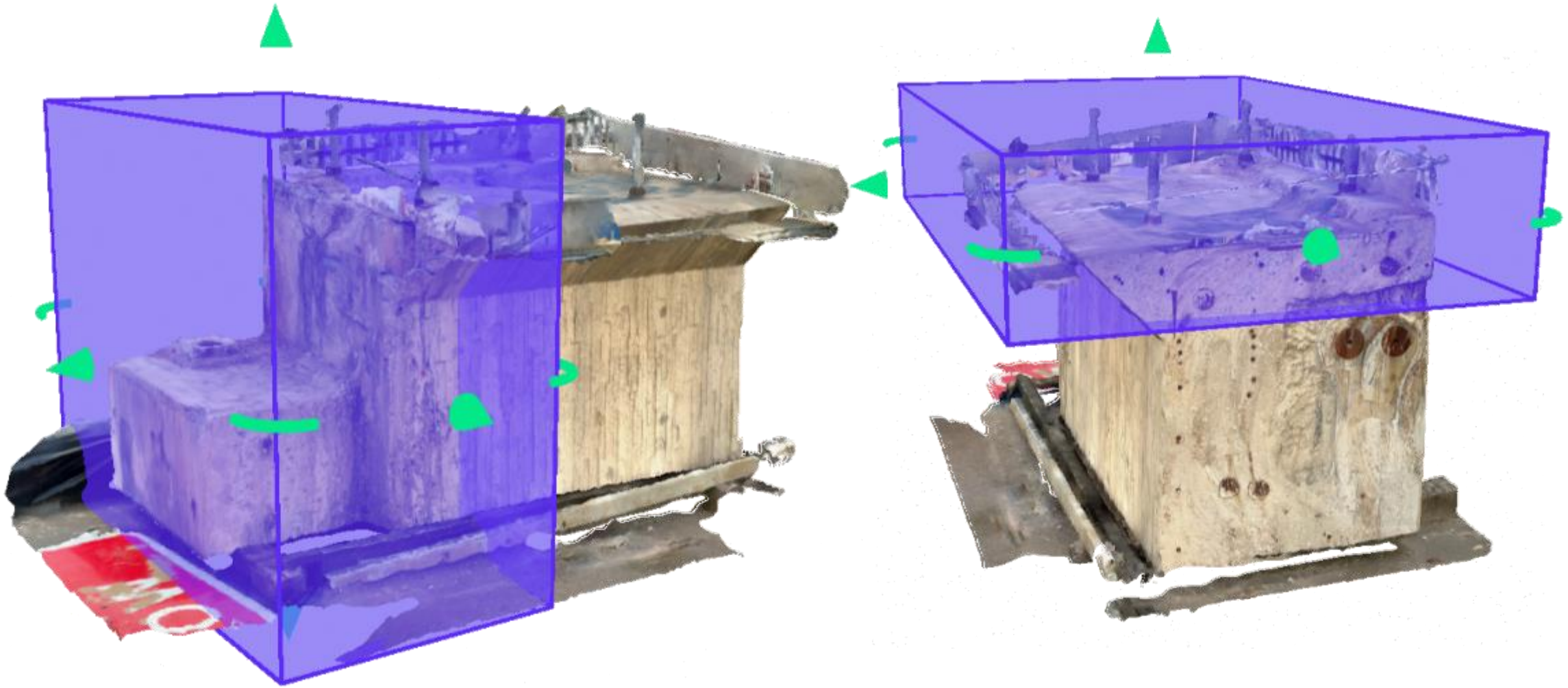
Huntingdon Viaduct Trials:

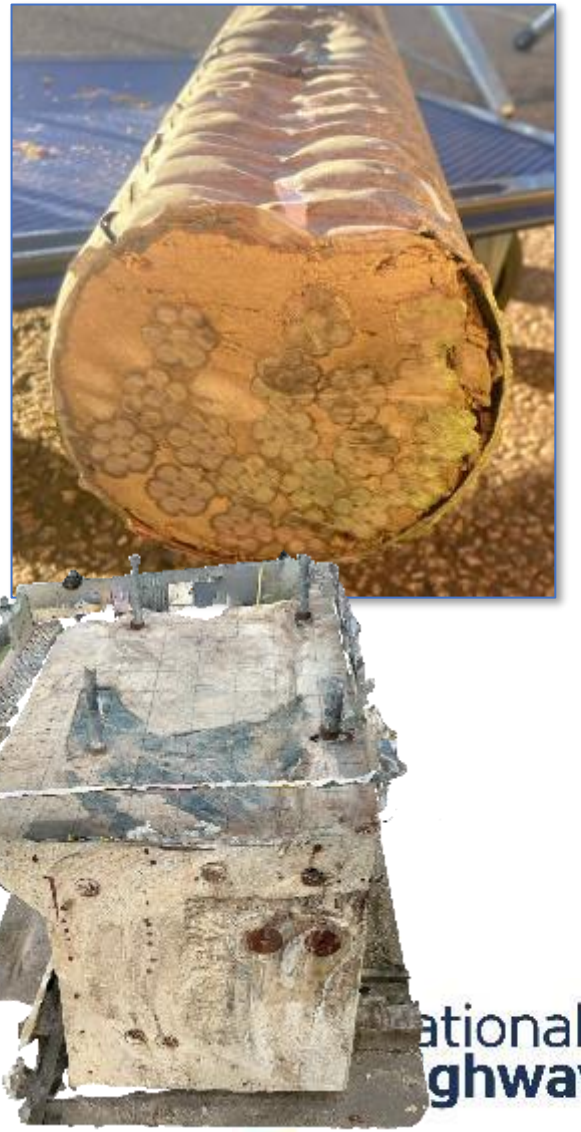
Hydrodemolition and Inspection

Hydrodemolition Proposal – Sample 1



Hydrodemolition Proposal – Sample 3

Hydrodemolition Findings – Sample 1



Hydrodemolition Findings – Sample 3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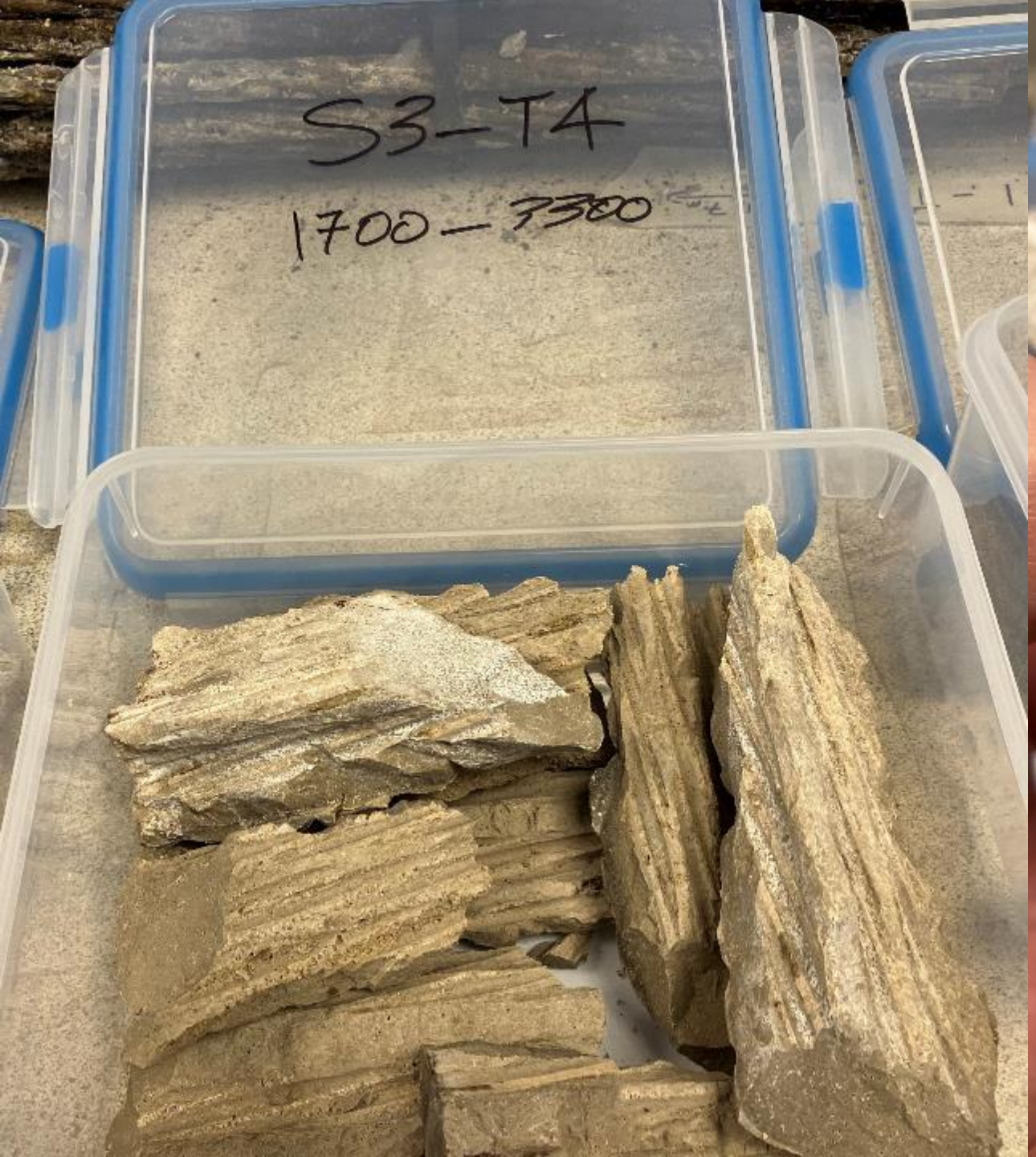
S3 T4



S3-T4
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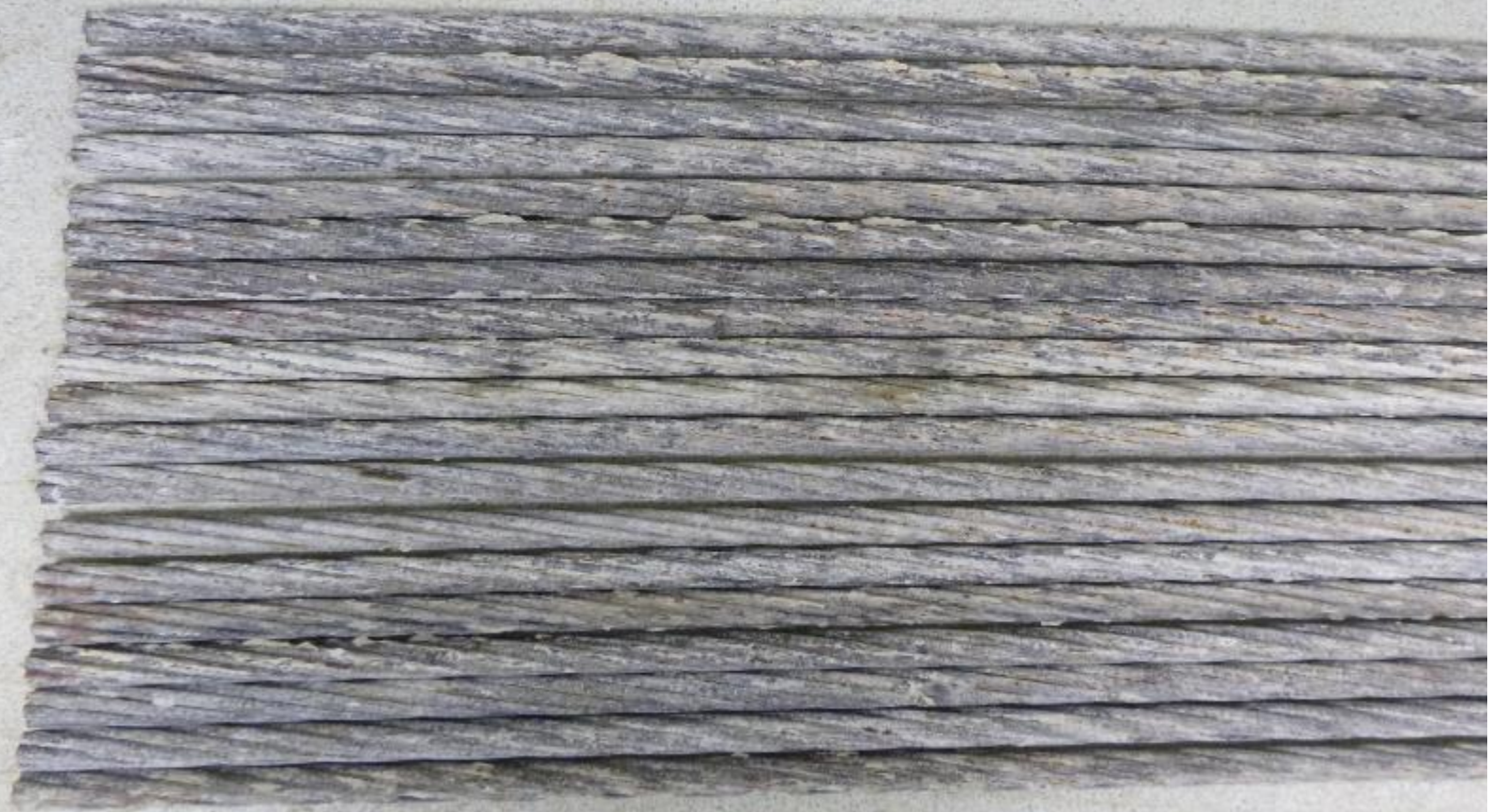


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0.5mm


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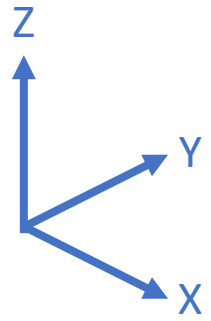
10 20 30 40 50 60 70 80 90 100
0.5mm

Huntingdon Viaduct Trials:

Inspection Findings

Opening Order	Sample	Tendon	Chainage			Date Opened in lab	General Strand / Wire Observations
3	1	1	0	-	1	29/03/2024	Significant voiding of the grout evident, light surface corrosion of wires
	1	1	1	-	1.5	03/04/2024	Grout OK, white / powdery, Light surface corrosion
	1	2	0	-	1	07/04/2024	Grout voiding at 12'O clock position, Strands and wires all in average condition - surface corrosion
	1	3	0	-	1.7	07/04/2024	Tendon in very poor overall condition, strands cut (cored) / corroded wires in evidence
6	3	1	0	-	1.7	24/04/2024	Grout voiding at 12'O clock position, Strands and wires all in average condition - surface corrosion
	3	1	1.7	-	3.2	24/04/2024	Grout voiding at 12'O clock position, Strands and wires all in average condition - surface corrosion
	3	1	3.2	-	4.7	11/04/2024	Grout intact throughout and at ends, Strands and wires all in good condition
	3	1	4.7	-	6.15	11/04/2024	Grout intact throughout and at ends, Strands and wires all in good condition
7	3	2	0	-	1.7	25/04/2024	Grout segregation / bleeding (sands) at 12'O clock position, Strands and wires all in good condition
	3	2	1.7	-	3.4	25/04/2024	Grout segregation / bleeding (sands) at 12'O clock position, Strands and wires all in good condition
	3	2	3.4	-	4.6	17/04/2024	Grout intact @3400 end, loose at 4600 end, Strands and wires all in good condition
	3	2	4.6	-	6.2	17/04/2024	Poor grout, no significant corrosion except local to 6200 end with minor section loss to wires. Aligns with where minor loss of grout also observed
8	3	3	0	-	1.7	26/04/2024	Grout segregation / bleeding (sands) at 12'O clock position, Strands and wires in poor condition (section loss and corrosion)
	3	3	1.7	-	3.4	26/04/2024	Grout segregation / bleeding (sands) at 12'O clock position, Strands and wires in poor condition (section loss and corrosion)
	3	3	3.4	-	4.7	02/05/2024	Grout segregation / bleeding (sands) at 12'O clock position, Strands and wires all in average condition (surface corrosion)
	3	3	4.7	-	6.2	02/05/2024	Grout segregation / bleeding (sands) at 12'O clock position, Strands and wires all in average condition (surface corrosion)
5	3	4	0	-	1.7	04/04/2024	Poor grout, no significant corrosion / pitting to wires observed
	3	4	1.7	-	3.3	07/04/2024	Grout intact throughout and at ends, Strands and wires all in good condition
	3	4	3.3	-	4.8	07/04/2024	Grout intact throughout and at ends, Strands and wires all in good condition
	3	4	4.8	-	6.2	07/04/2024	Grout intact throughout and at ends, Strands and wires all in good condition
2	3	5	0	-	1.7	27/03/2024	Minimal grout, One wire break ST.17
	3	5	1.7	-	3.2	02/04/2024	Minimal grout, some wire pitting
	3	5	3.2	-	4.7	02/04/2024	Grout over half length of duct, duct steel poor, surface corrosion to wires
	3	5	4.7	-	6.25	03/04/2024	Grout intact throughout and at ends, Strands and wires all in good condition
4	3	6	0	-	1.6	03/04/2024	Tendon in very poor overall condition, strands and broken / corroded wires in evidence
1	3	7	0	-	1.6	21/03/2024	Grout largely intact - different materials - minor pitting to wires noted
	3	7	1.6	-	3.2	22/03/2024	Grout largely intact - different materials - minor pitting to wires noted
	3	7	3.2	-	4.8	22/03/2024	Grout largely intact - different materials - surface corrosion to wires noted
	3	7	4.8	-	6.07	27/03/2024	Grout largely intact - different materials - surface corrosion to wires noted

Sample 1

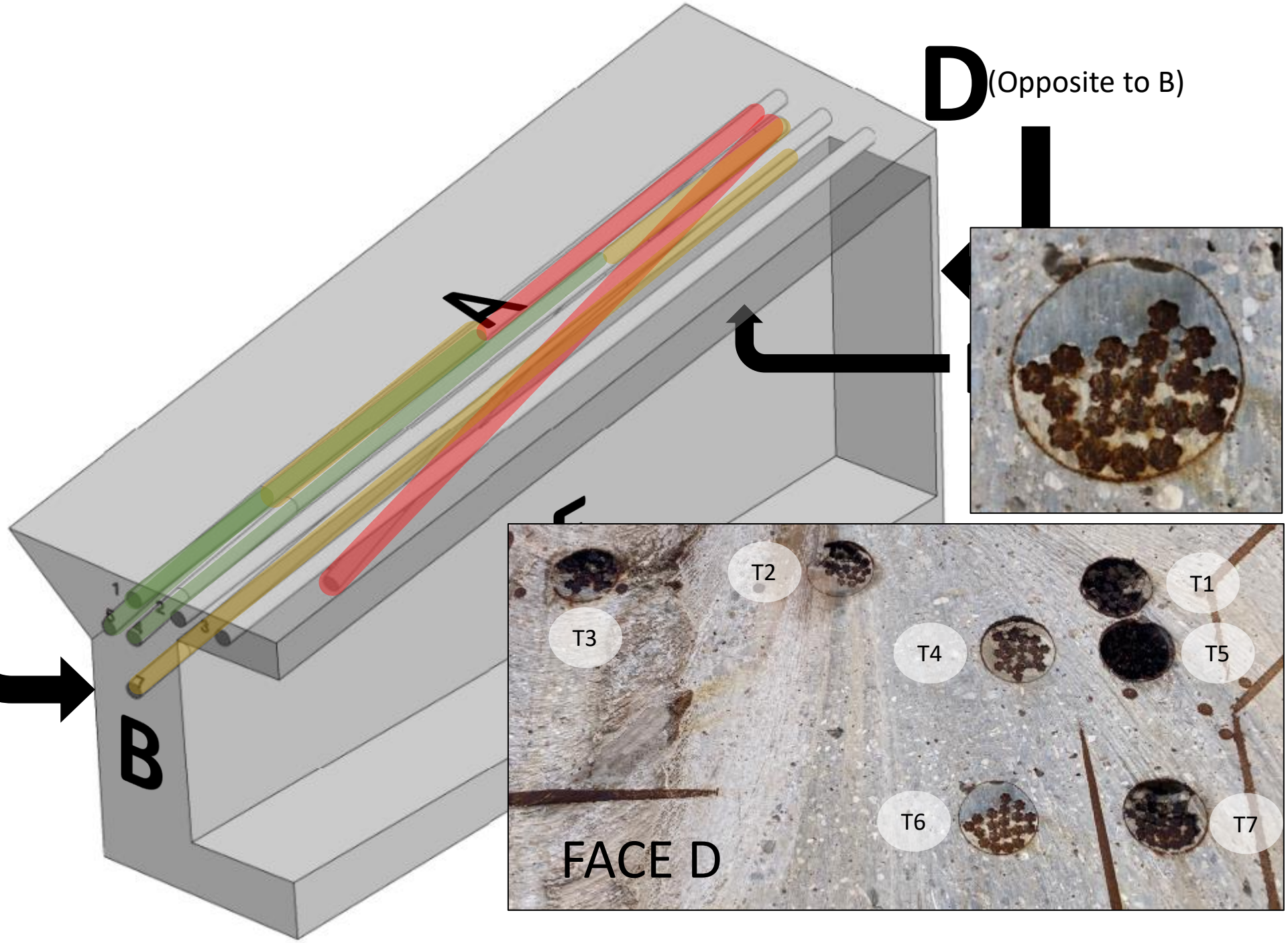


T1

T2

T3

All Tendons


D
(Opposite to B)
A
(External patterned face)
C
B
T1
T2
T3
T4
T5
T6
T7
FACE D

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Huntingdon Viaduct Trials:

Data Assessment and Digital Twin

Test Data Sources

NDT Visual Inspection (VI-NDT)

- **CTS:** Defect images, locations, dimensions
- **HausBots:** Videos

Carbonation Test (CBT)

- **CTS:** Values at specific locations

Cover Meter Survey (CMS)

- **CTS:** Numerical Grid
- **HausBots:** Values at specific locations

Dust Sampling (DS)

- **CTS:** Values at specific locations
- **Bridgology:** Heat Map Overlay

Electrical Resistivity (ER)

- **CTS:** Numerical Grid

Half-cell Potential Survey (HPS)

- **CTS:** Numerical Grid, Contour Plot Overlay
- **HausBots:** Values at specific locations

Ground Penetration Radar (GPR)

- **Bridgology, Hausbots & Hilti:** Heat map overlay
- **Screening Eagle**: Corrosion potential overlay
- **Allied Associates:** 3D Model

Guided Wave (GW)

- None received

Magnetic Flux Leakage (MFL)

- **IFDB:** Scan overlays

Muon Tomography (MUON)

- **GScan:** Scan images?

Field / Raman Spectrometry (FRS)

- **RAU:** 1 graph per sample

FITR Gas Monitoring

- **RAU:** Gas over time graph (face-based)

Portable Xray Fluorescence (PXF)

- **RAU:** Chlorine values at specific locations

Hyperspectral Imaging (HYP)

- **RAU:** Image scan, graphs at specific locations

Acoustic Emission (AE)

- **MISTRAS:** Values at specific tendons?

Impact Echo (IE)

- **MISTRAS:** Numerical grid, graph overlay

Pulse Echo (PE)

- **MISTRAS:** Heat map overlay

Ultrasonic Tomography (UT)

- **MISTRAS:** Heat map overlay

Ultrasonic Wire Inspection (UW)

- **MISTRAS:** Wire Overlays

XCT Scan (XCT)

- **UoS**: .vgl? / .vgp? / .raw?

Hydrodem Visual Inspection (VI-HDM)

- **AtkinsRealis:** LiDAR 3D Overlay

Intrusive Visual Inspection (VI-INT)

- **AtkinsRealis:** Defect images, locations, dimensions

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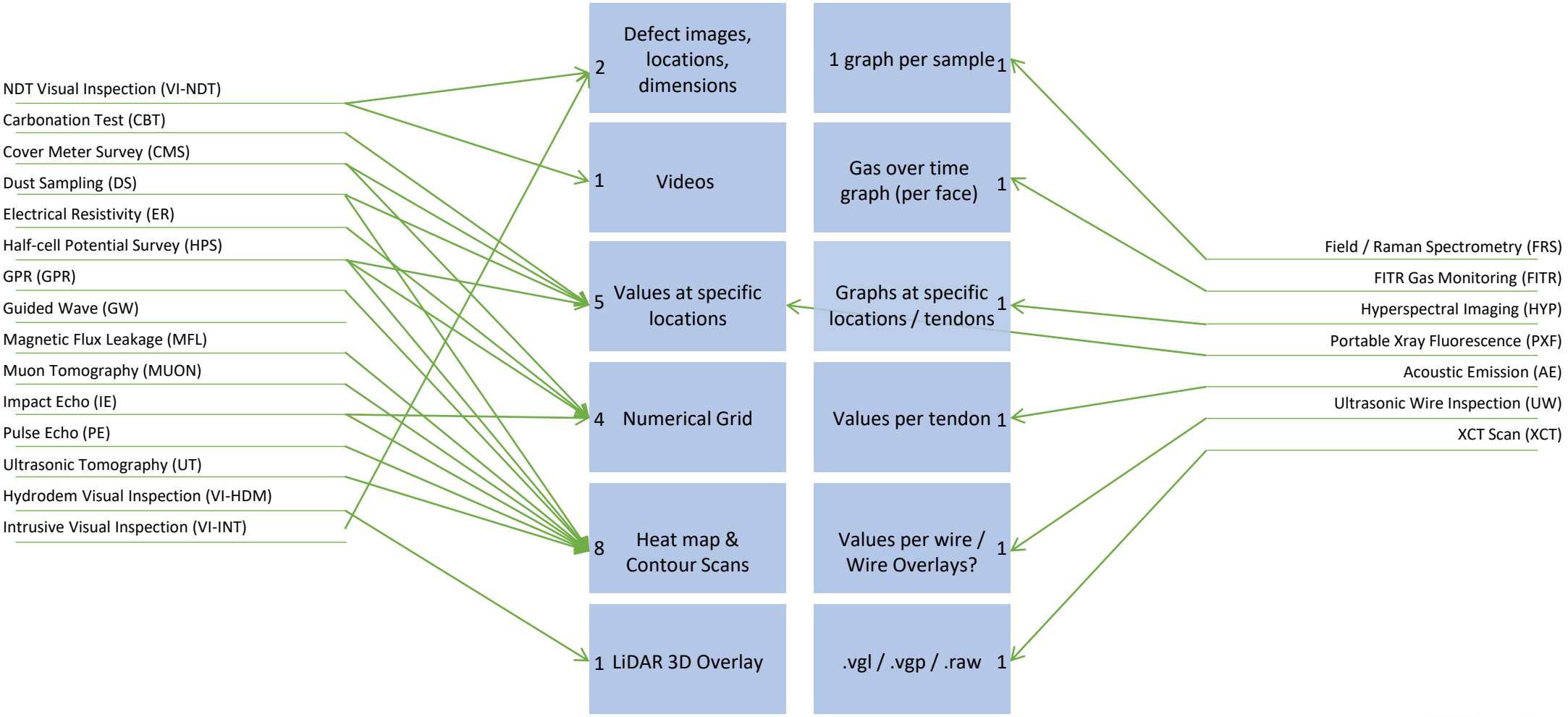
Test -> Data


NDT Visual Inspection (VI-NDT)
Carbonation Test (CBT)
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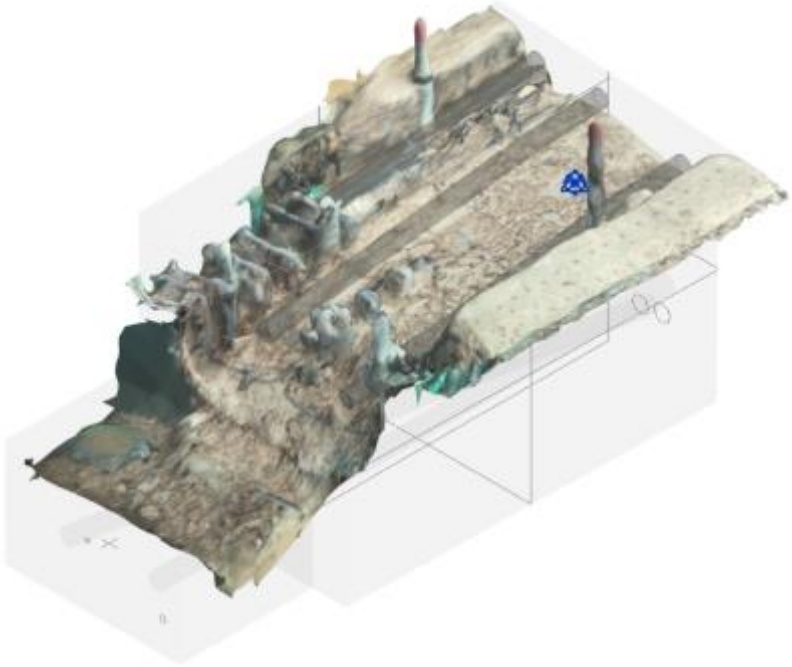
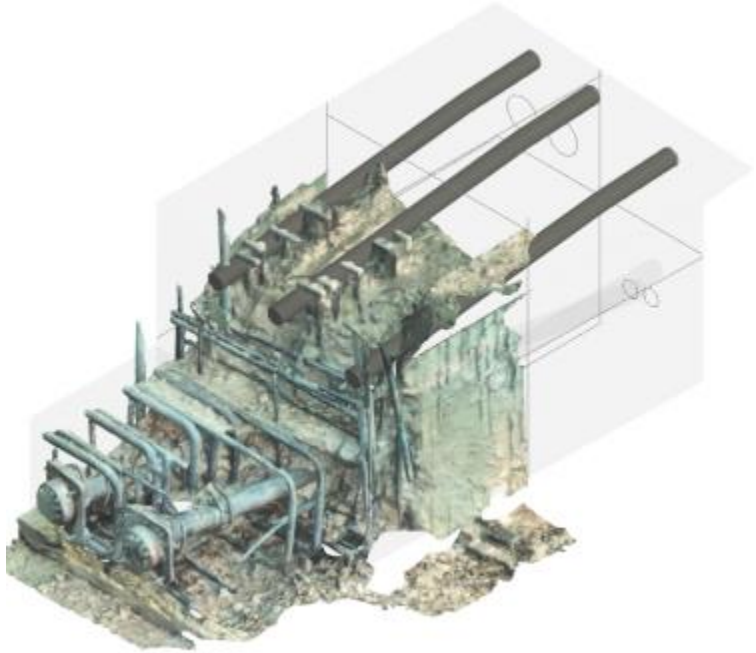
GPR (GPR)
Guided Wave (GW)
Magnetic Flux Leakage (MFL)
Muon Tomography (MUON)
Impact Echo (IE)
Pulse Echo (PE)
Ultrasonic Tomography (UT)
Hydrodem Visual Inspection (VI-HDM)
Intrusive Visual Inspection (VI-INT)
2 Defect images, locations, dimensions
1 Videos
5 Values at specific locations
4 Numerical Grid
8 Heat map & Contour Scans
1 LiDAR 3D Overlay
1 graph per sample 1
Gas over time graph (per face) 1
Graphs at specific locations / tendons 1
Values per tendon 1
Values per wire / Wire Overlays? 1
.vgl / .vgp / .raw 1
Field / Raman Spectrometry (FRS)
FITR Gas Monitoring (FITR)
Hyperspectral Imaging (HYP)
Portable Xray Fluorescence (PXF)
Acoustic Emission (AE)
Ultrasonic Wire Inspection (UW)
XCT Scan (XCT)

Digital Twin

Polycam





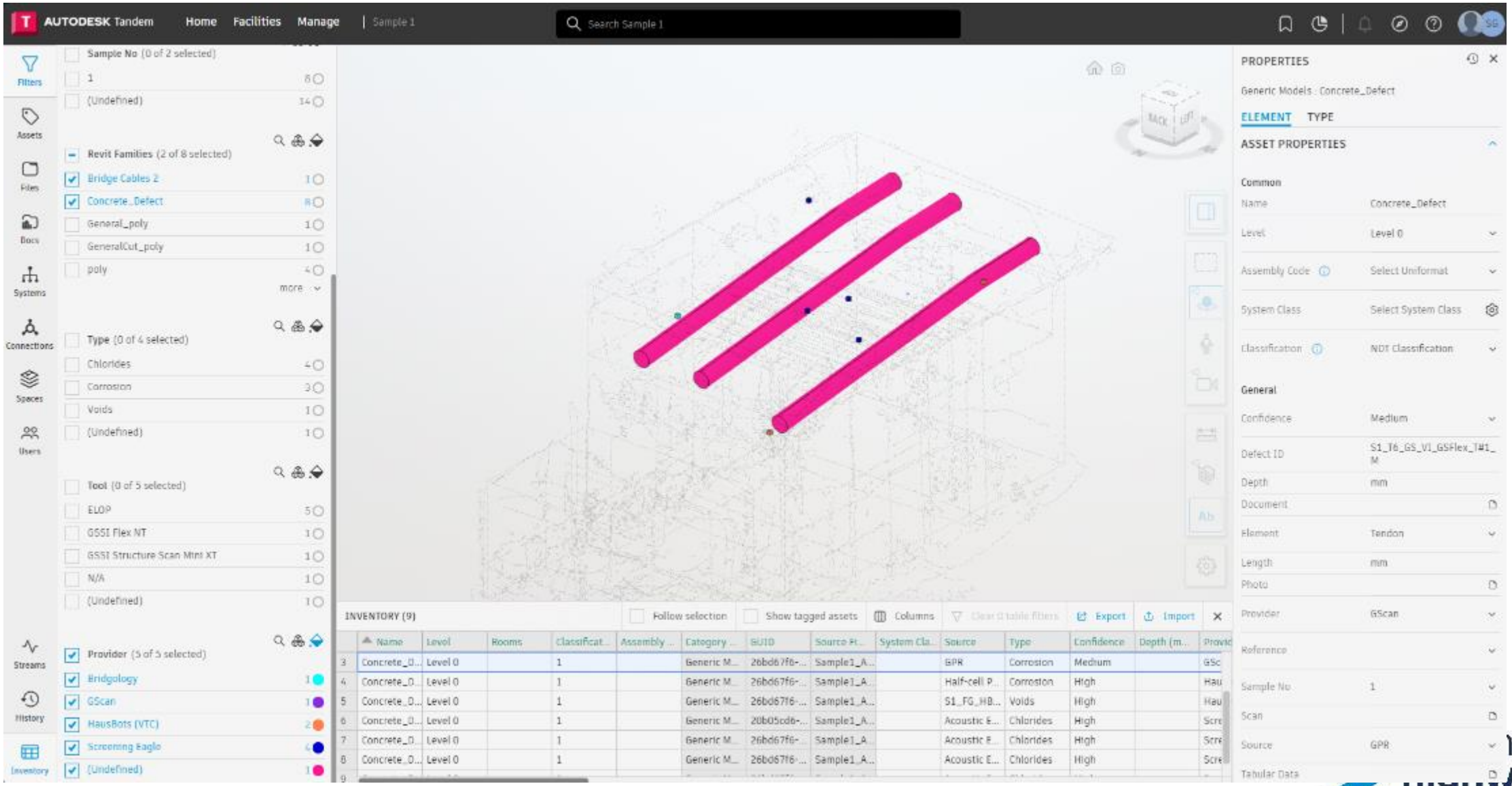
November 22nd

November 27th

November 29th

national highways

Digital Twin – Data Visualisation



Digital Twin – Data Visualisation

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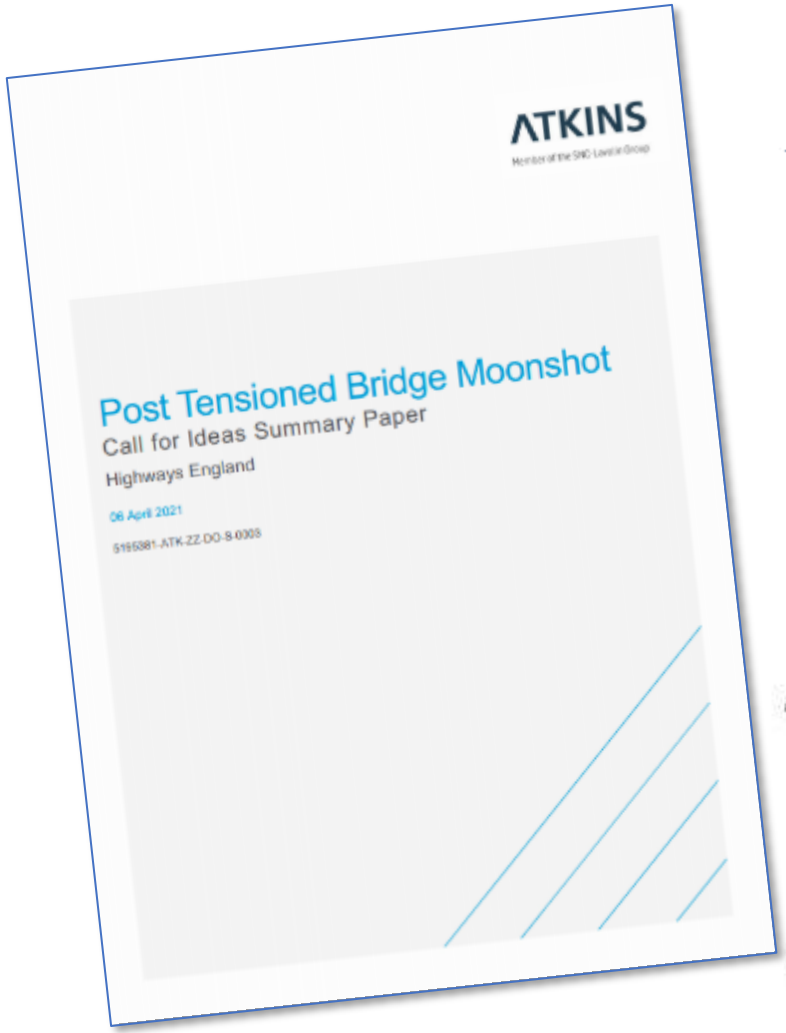
NEXT STEPS AND FINAL THOUGHTS

‘Moonshot’ Collaborators



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Thank you – Questions and Discussion