Cold-spray Additive Repair of Corroded Steel Bridge Beams

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Superior Carriers
SCHOOL BUS
UNLAWFUL TO PASS WHEN RED LIGHTS ARE FLASHING
ONE WAY
NO TURNS
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Outline

Part 1: UMass Bridge program
2015-present

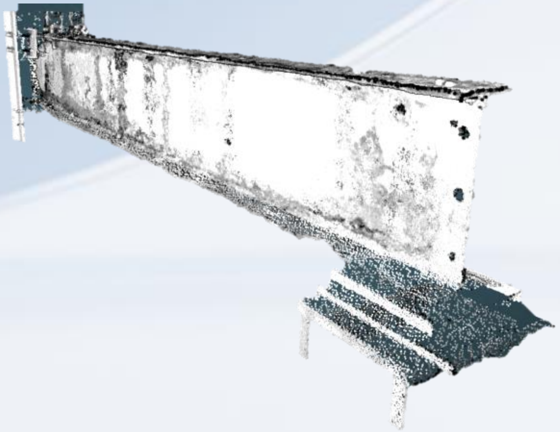
Part 2: 3D scanning for bridge inspection
hardware, data acquisition and processing

Part 3: Corrosion Repair
Cold spray AM

Bridge Experiments

Scanning

Cold-spray AM

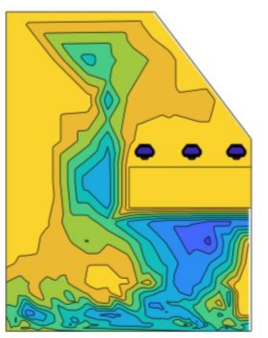


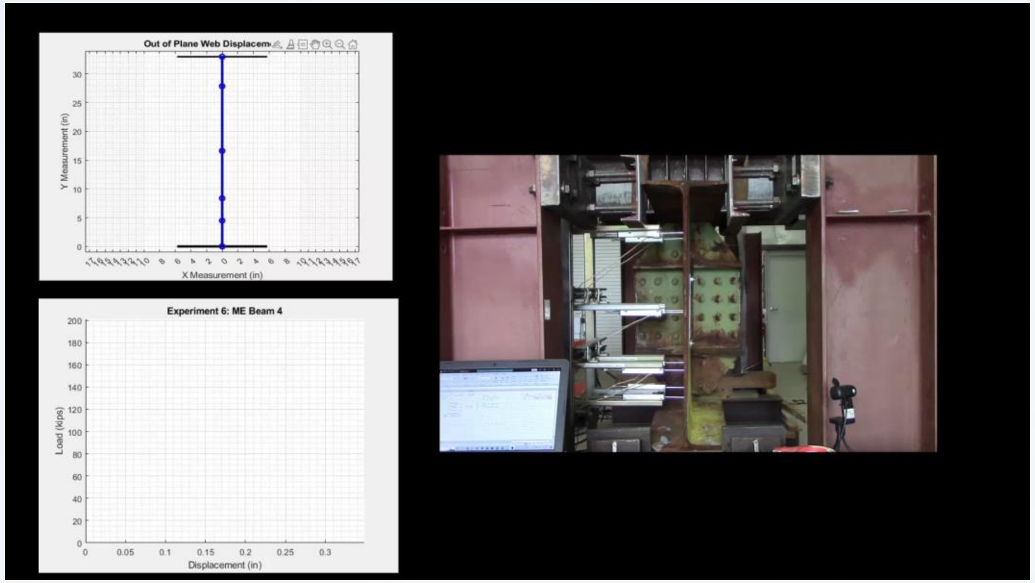
Part I Bridge program

Bridge Program

First research group to our knowledge to pack a bridge and bring it to the lab and test it

Since 2019 we have tested 17 beam ends from New England



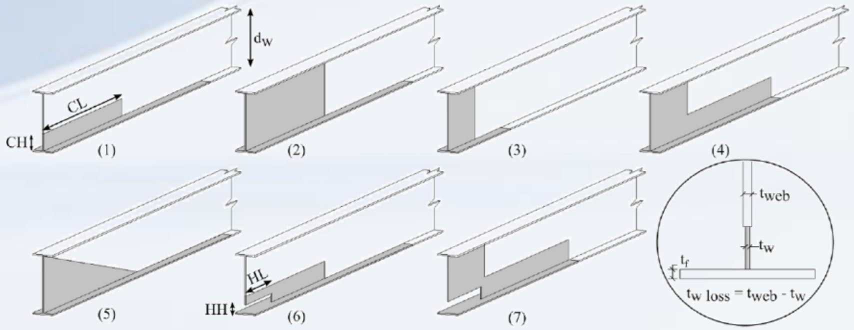


Inspection Reports

Massachusetts
- Reports: 123
- Corroded Ends: 1045

New England
- Reports: 132
- Corroded Ends: 915

Total > 1960



Experimental Work

Massachusetts
- Bridges: 3
- Tested Ends: 9

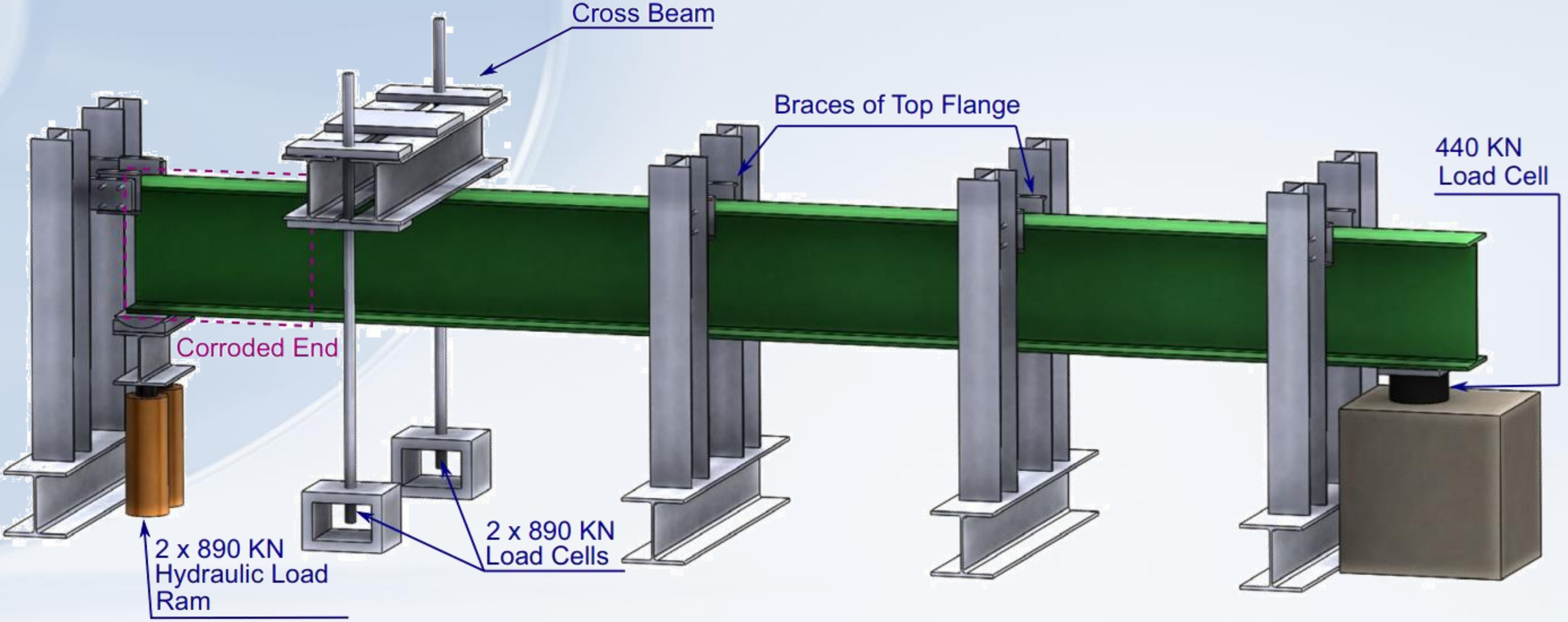
New England
- Bridges: 7
- Corroded Ends: 29

Total: Beams from 10 bridges

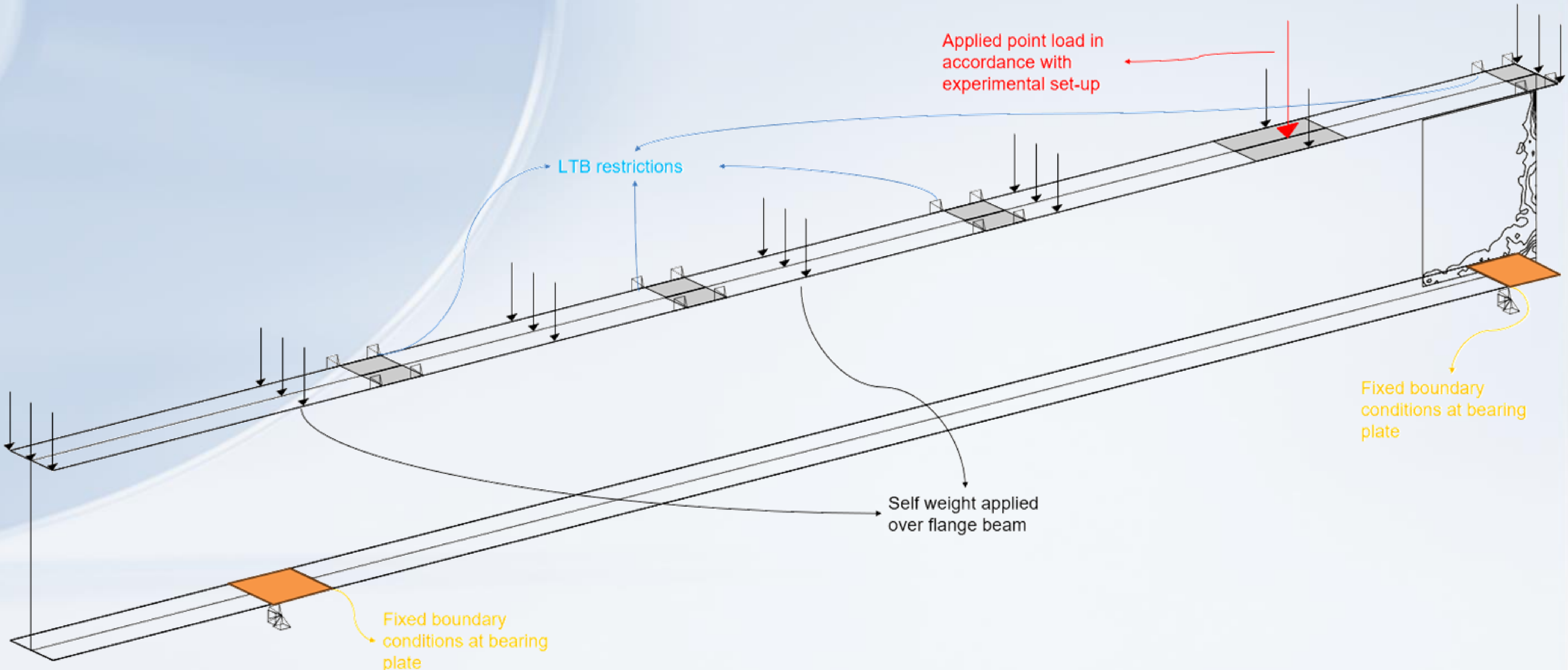
Numerical Work

More than 5000 simulated scenarios (FEM and statistics to produce guidelines)

Experimental study



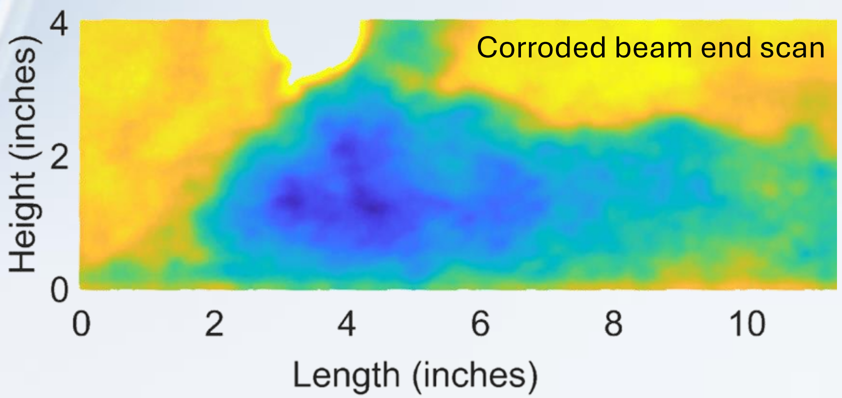
Bridge beam model



Bridge Program

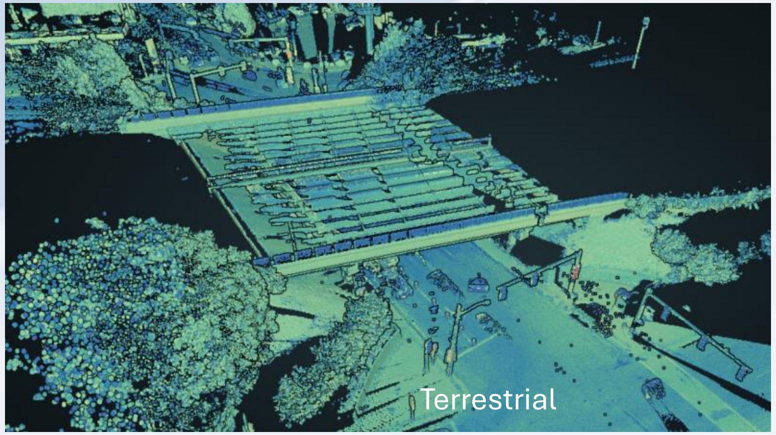
Part II:
3D scanning for bridge inspection

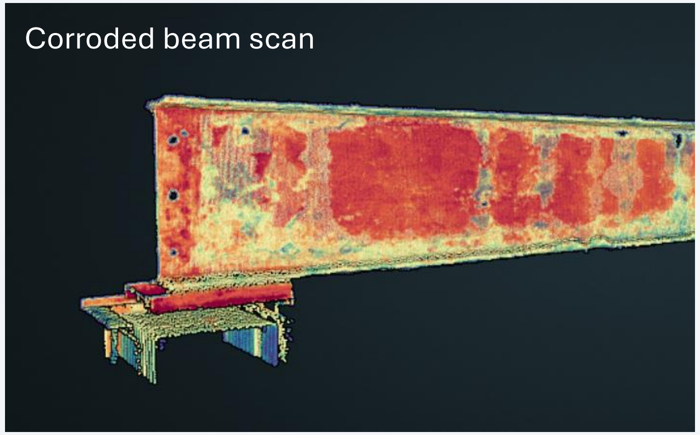

Large scale bridge scan

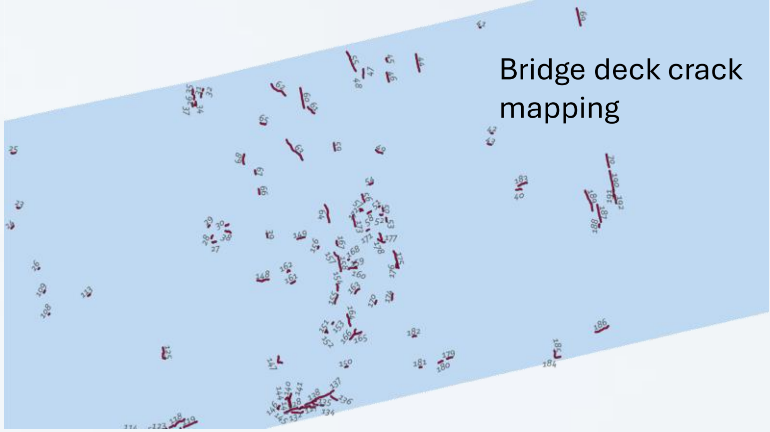


Concrete spalling

Bridge deck slopes


Terrestrial


Corroded beam scan

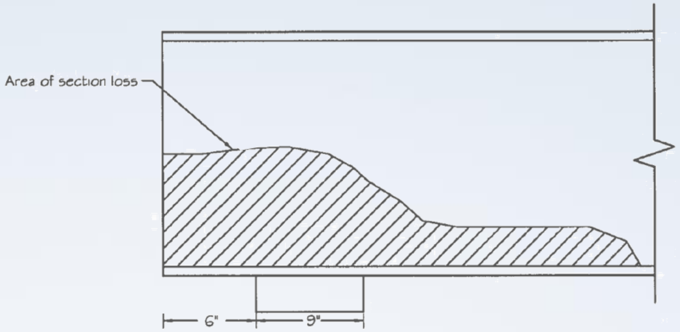

Bridge deck crack mapping

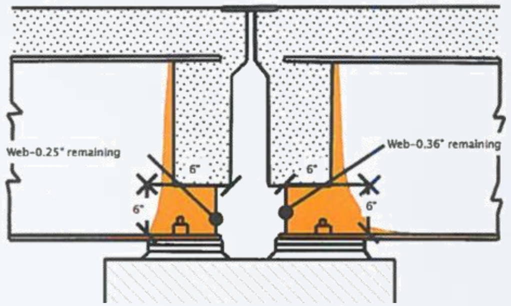
Corroded beam ends – Current State-of-Practice

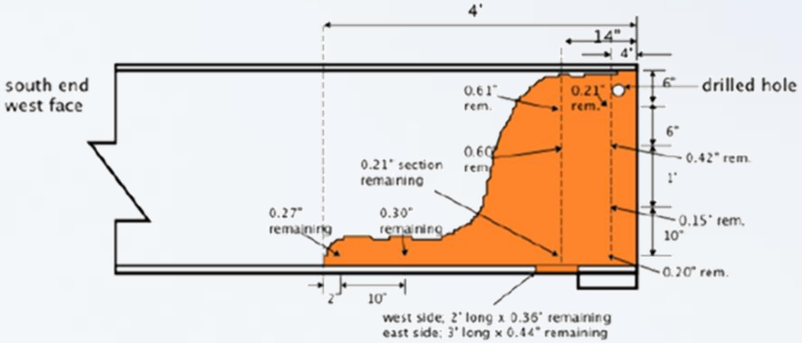
In the field

Taking Measurements

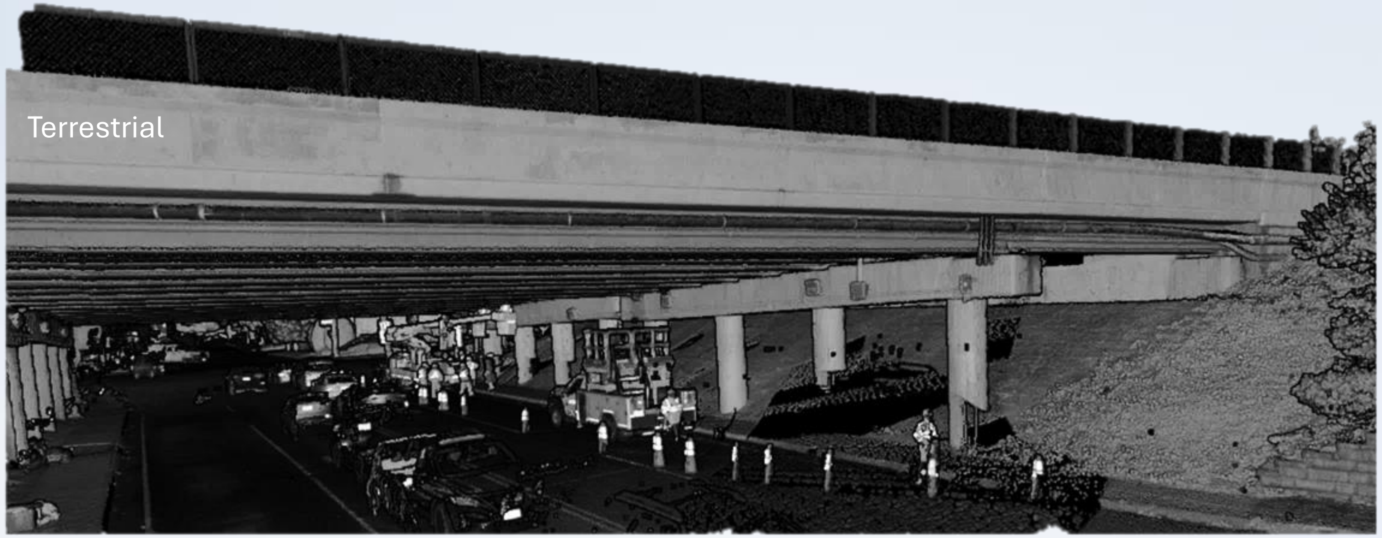
Corrosion Sketches

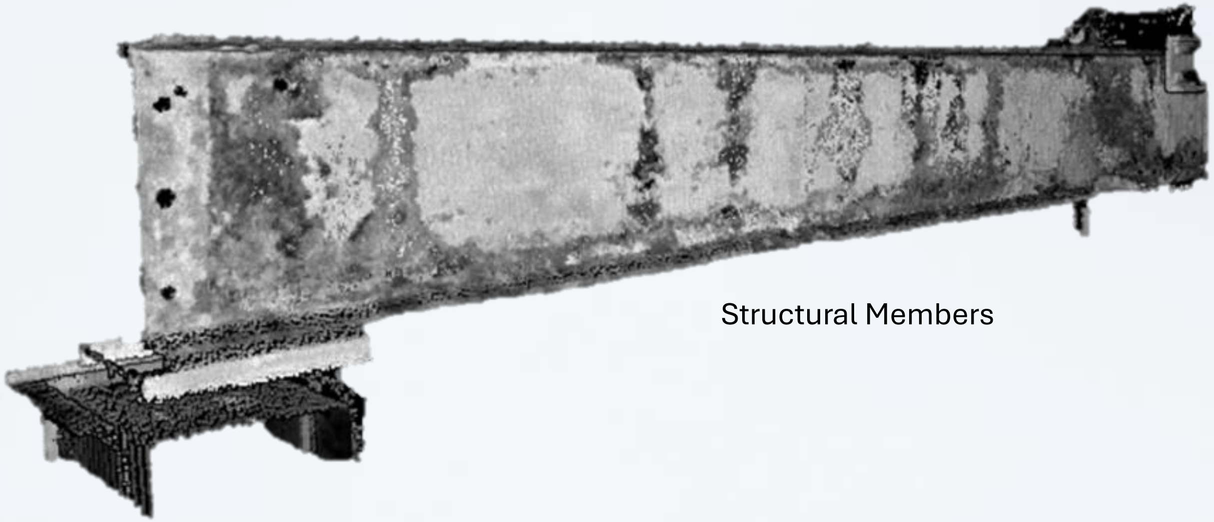






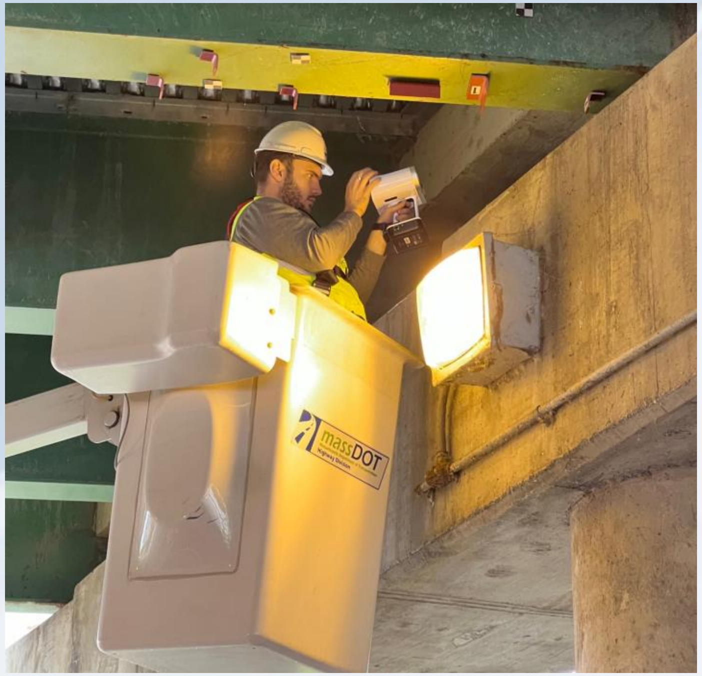
3D Scanning for Bridge Inspection - Terrestrial

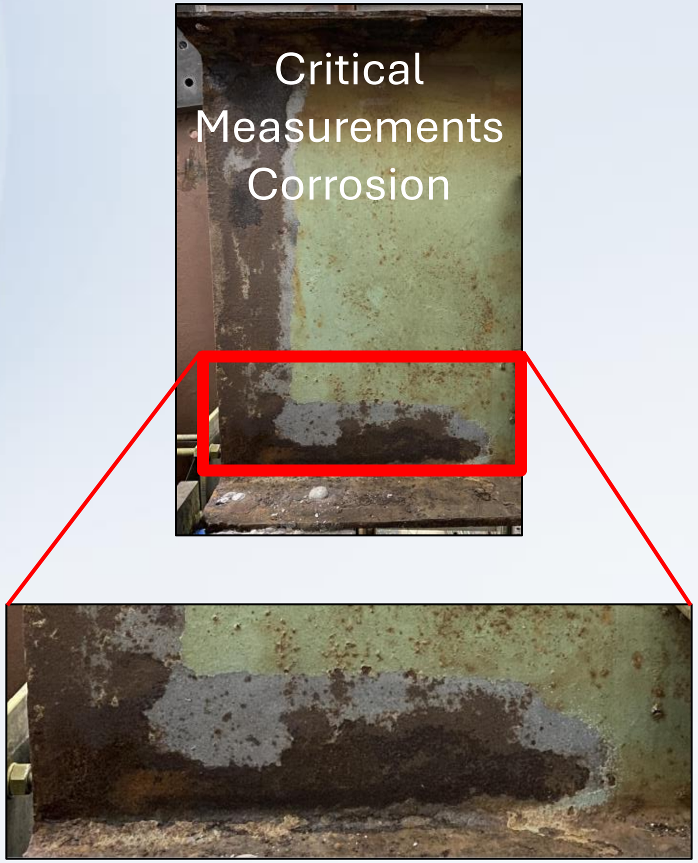


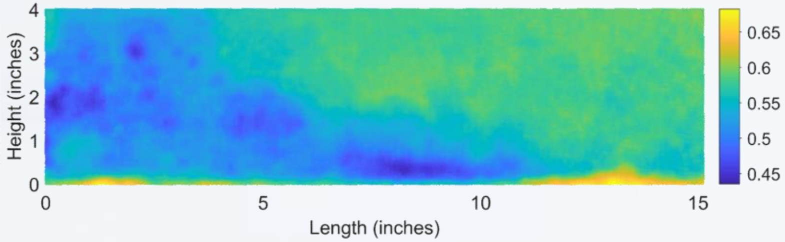


Structural Members

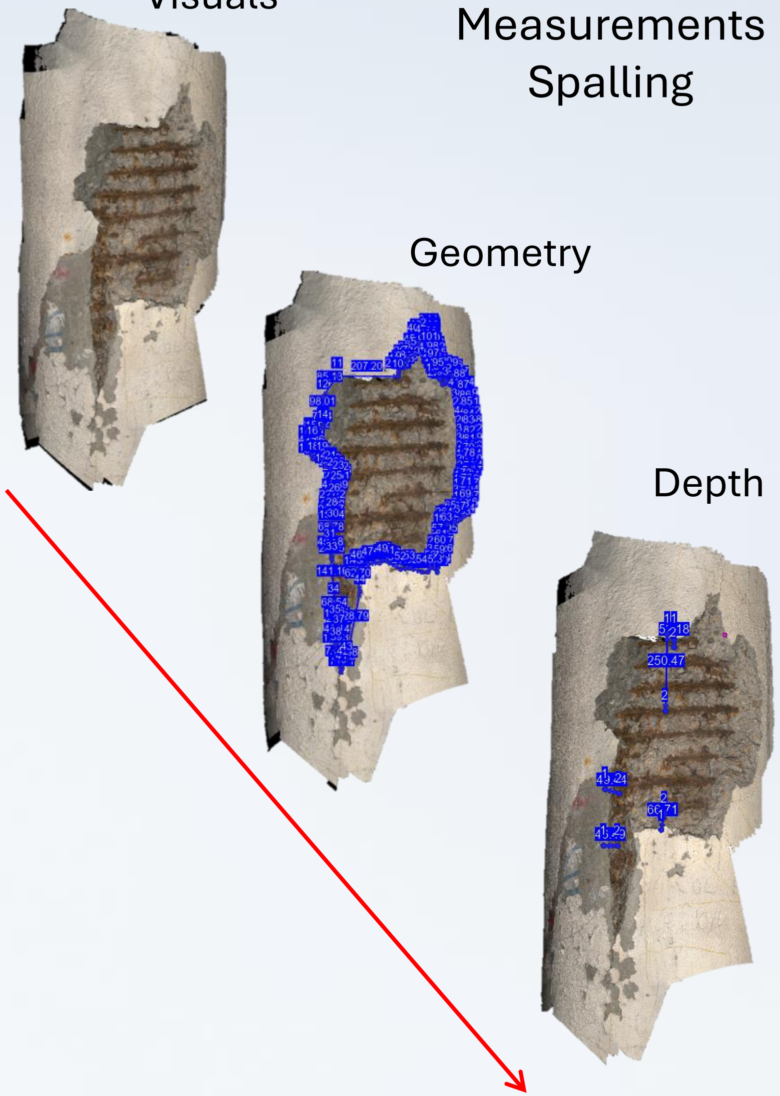
3D Scanning for Bridge Inspection - Local







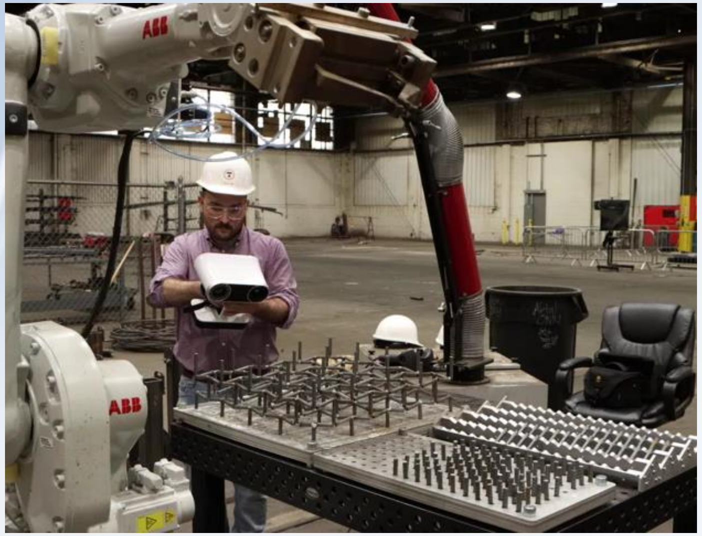
Critical Measurements Spalling



3D Scanning for Bridge Inspection - Process

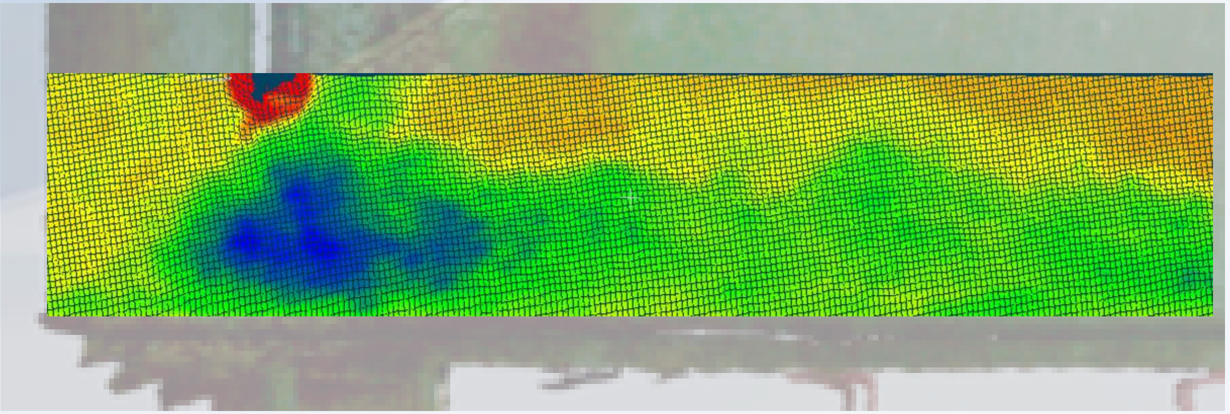
1. Component Identification

2. Scanning

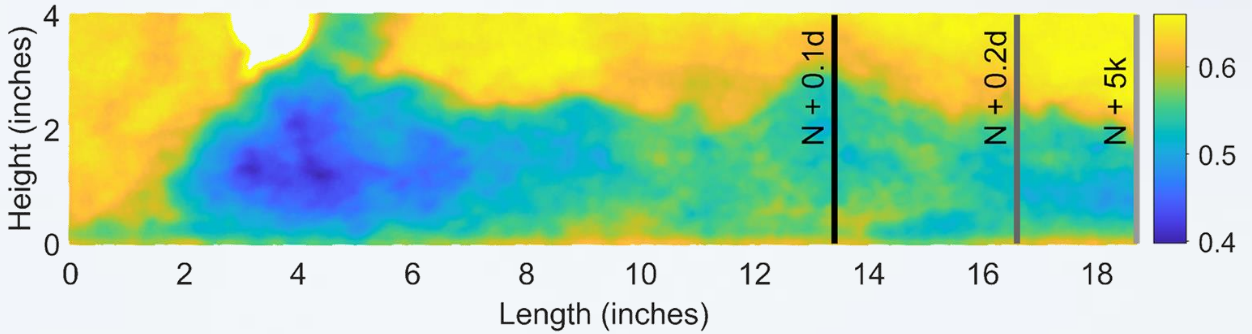


3. Model Processing

4. Post-Processing



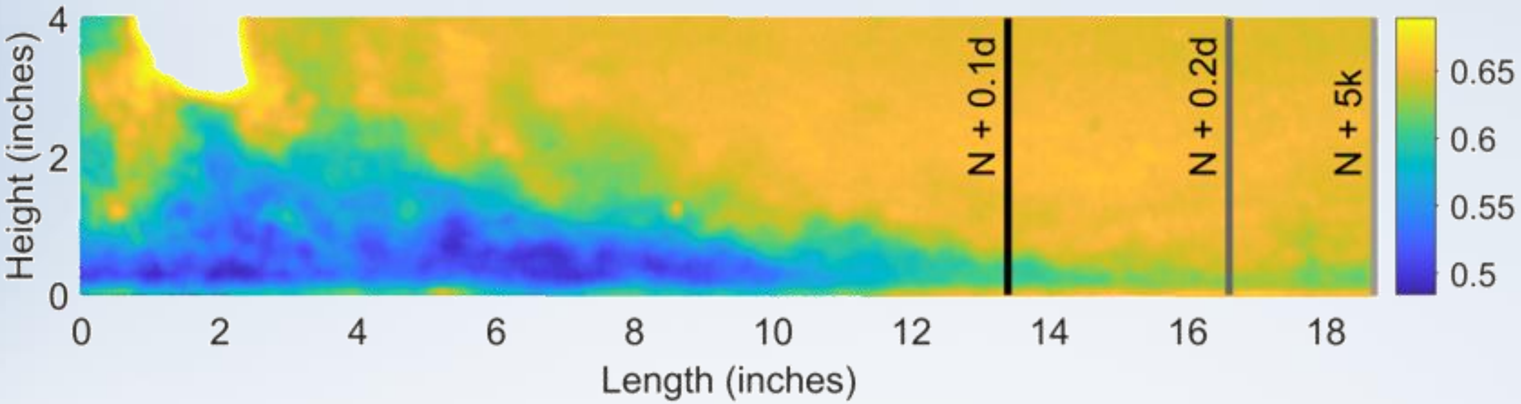
5. Output map generation



3D Scanning for Bridge Inspection - Summary

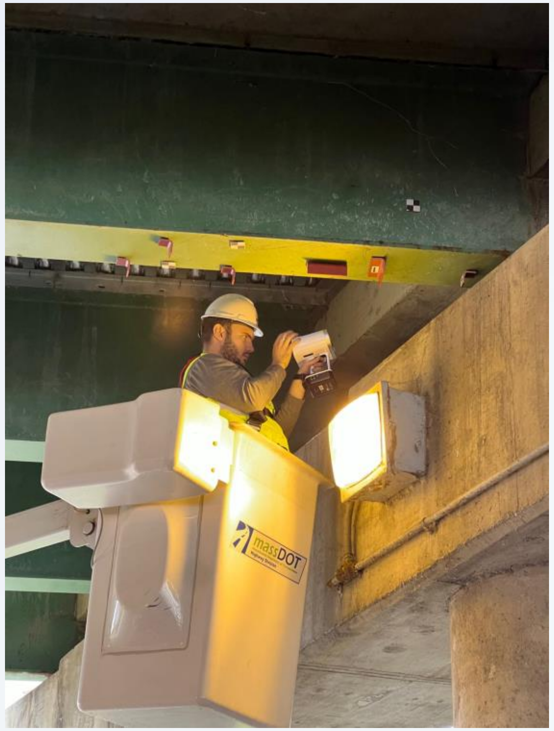
Higher Cloud Density, detail, and accuracy:

- Around 400,000 points in the selected area to the right and millions of points in the full web height area
- Captures difficult to measure components like pitting and section loss at the edge of the web



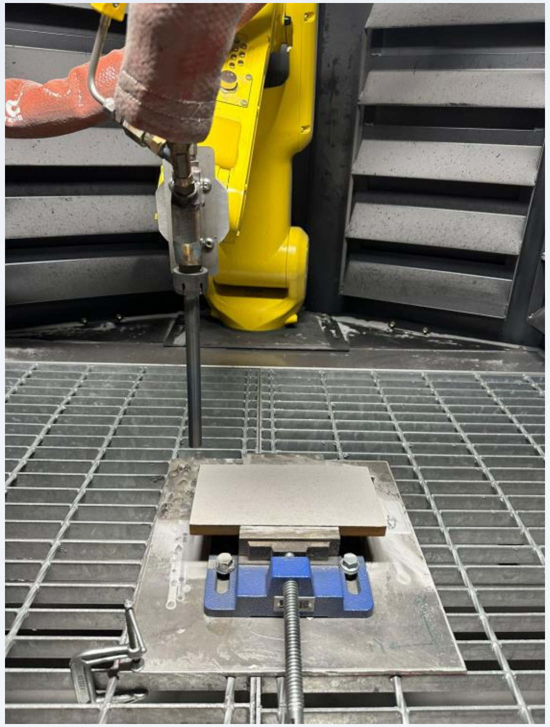
Portability and maneuverability:

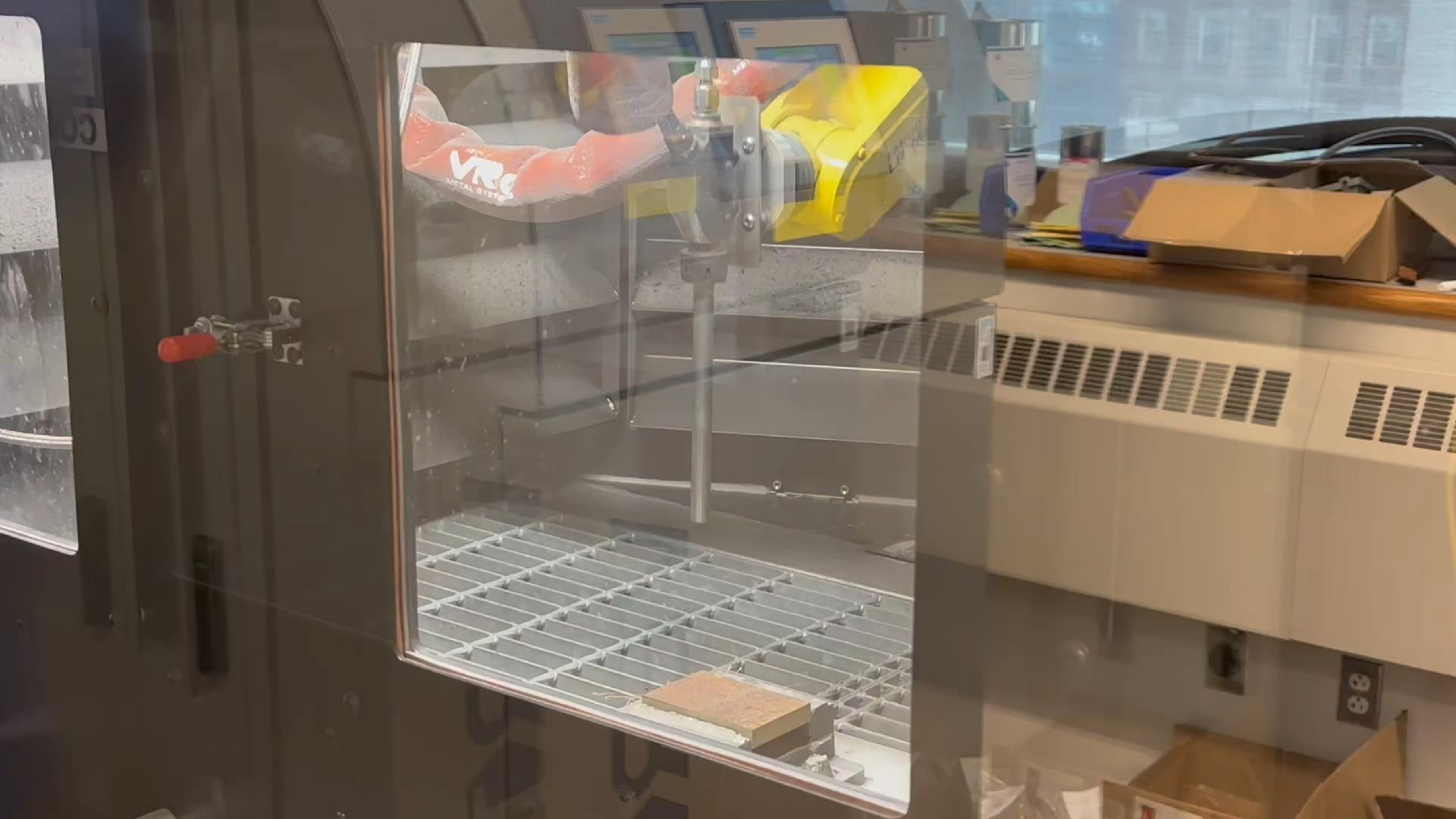
- Roughly 5 minutes per scan
- Easy to train and learn the scanning process
- Handheld and relatively lightweight machinery allows for easy on-site scanning



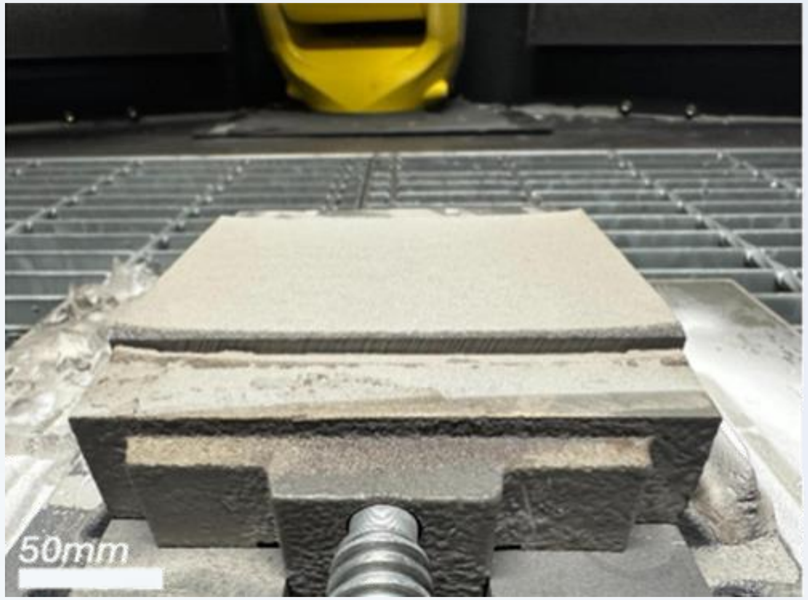
Part III

Cold-spray additive manufacturing



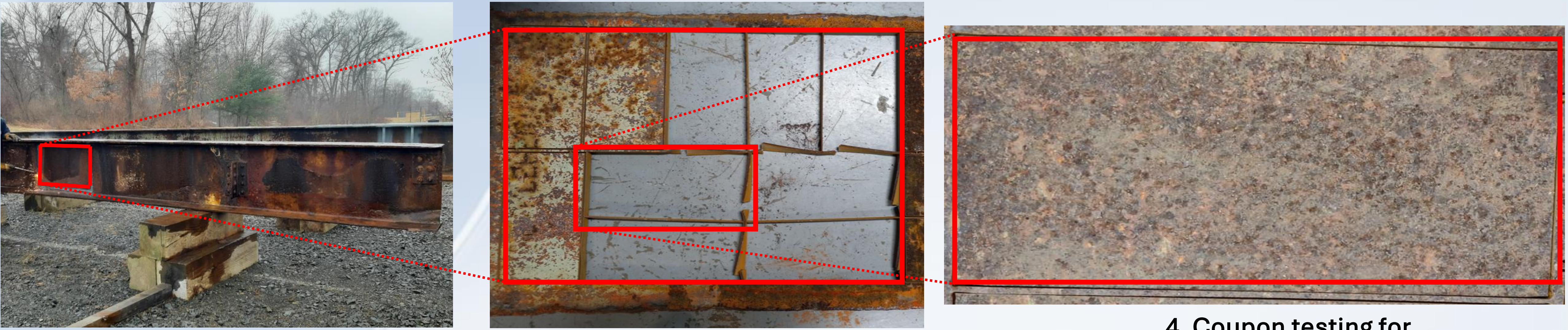

VR

Cold-Spray built up layers

	150 seconds	1200 seconds
		
A36	A36 + intermediate layer	A36 + intermediate layer + built up layers

Methodology

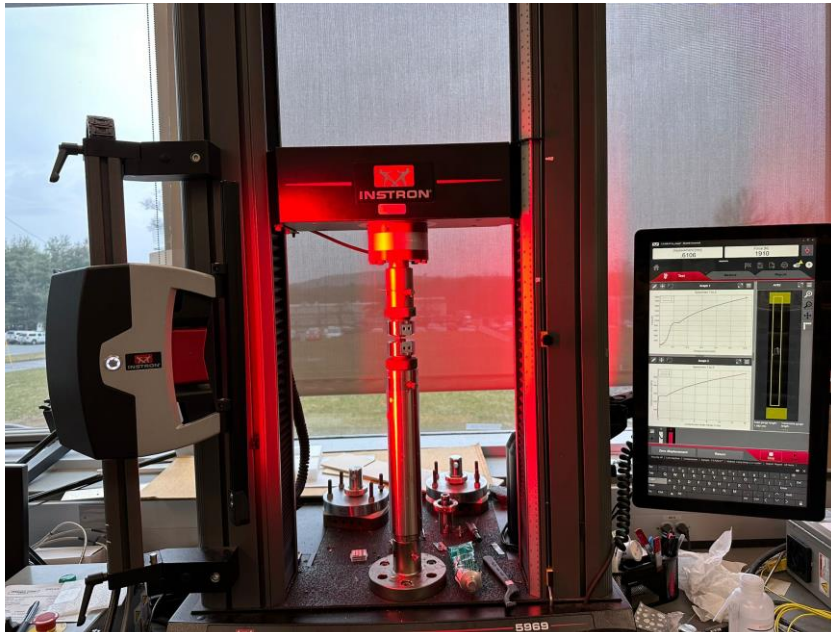
1. Obtain corroded substrates from real naturally-corroded steel beams from bridges in New England



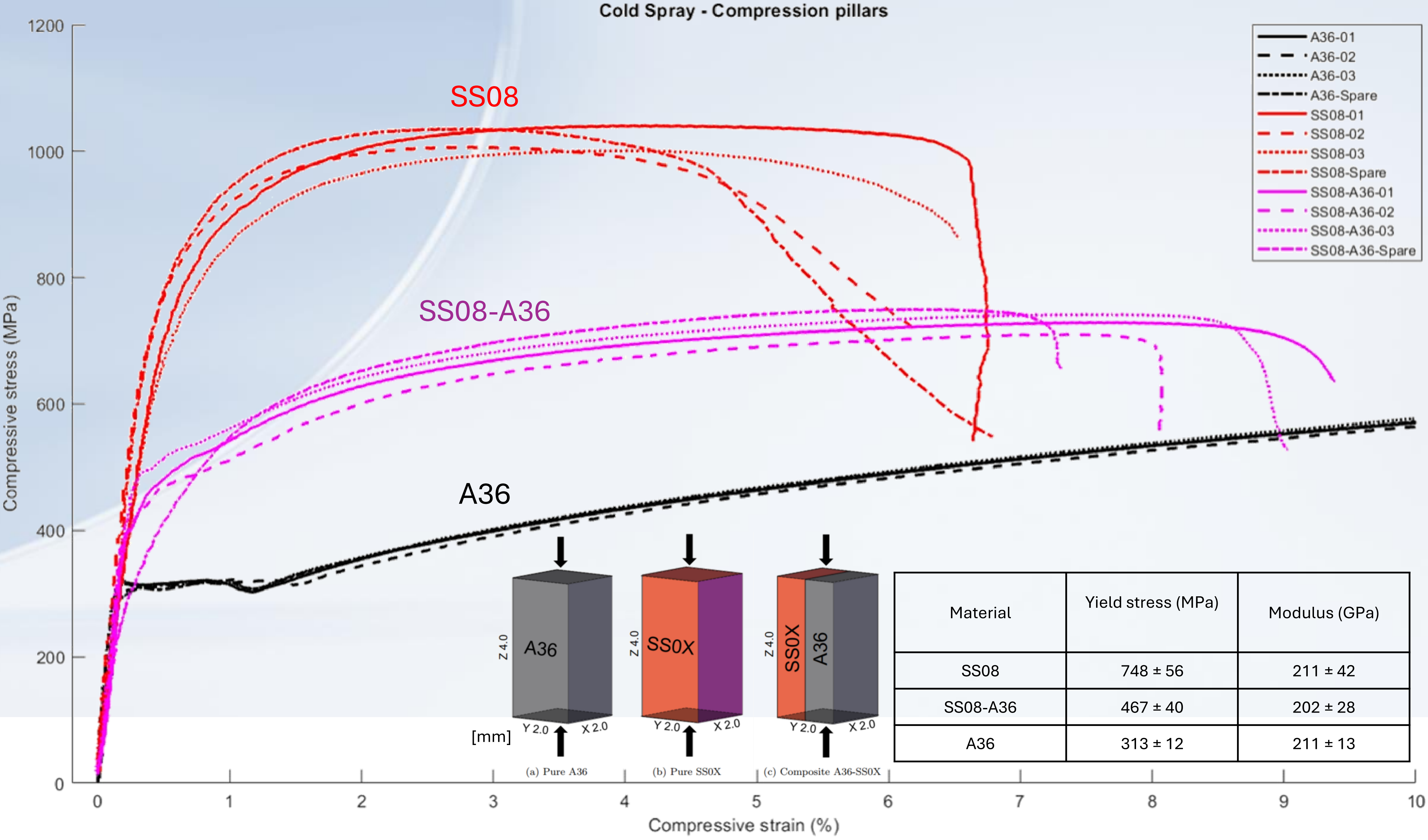
2. Cold Spray AM

3. Coupons of composite steel

4. Coupon testing for mechanical properties

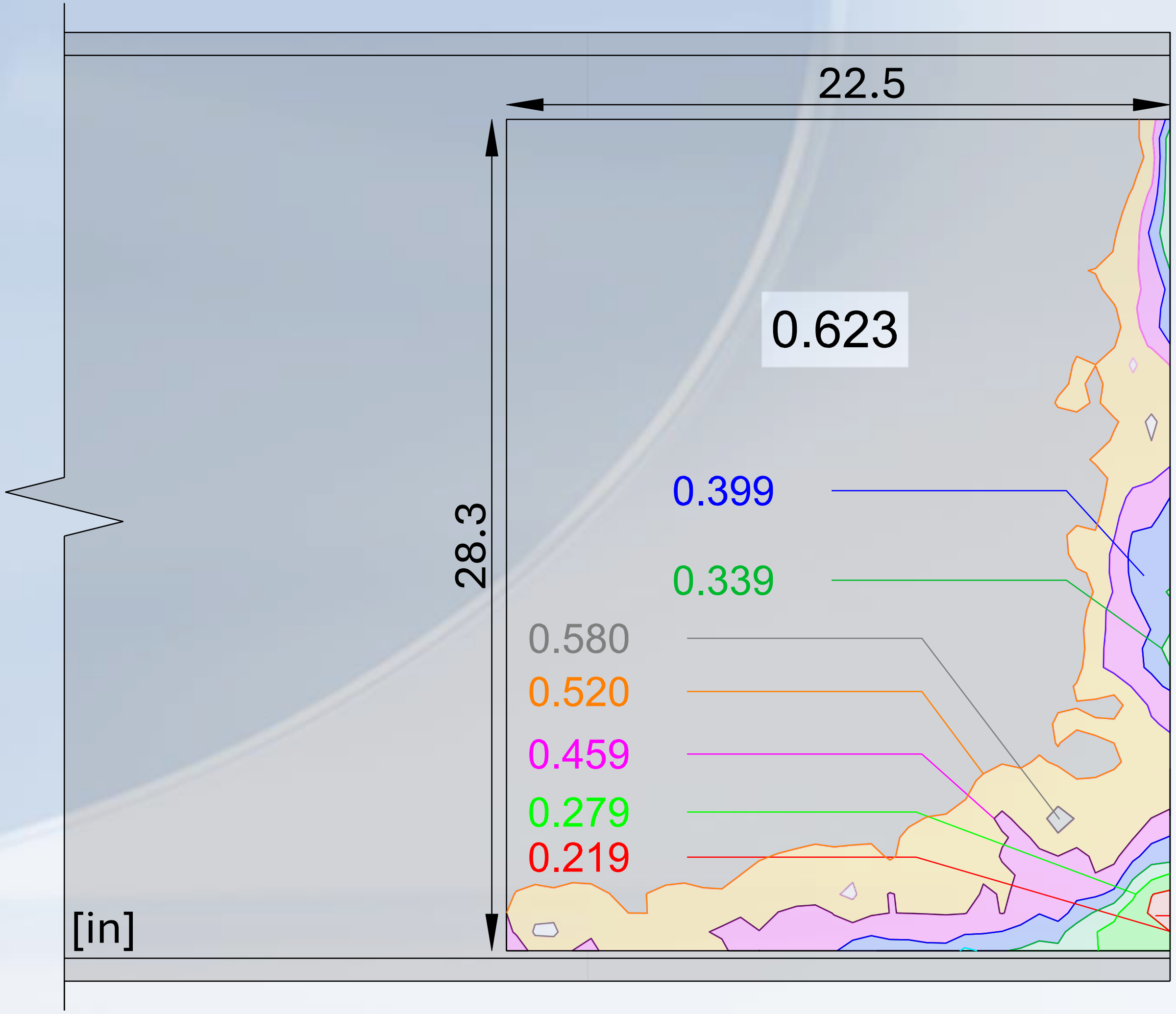


Mechanical properties



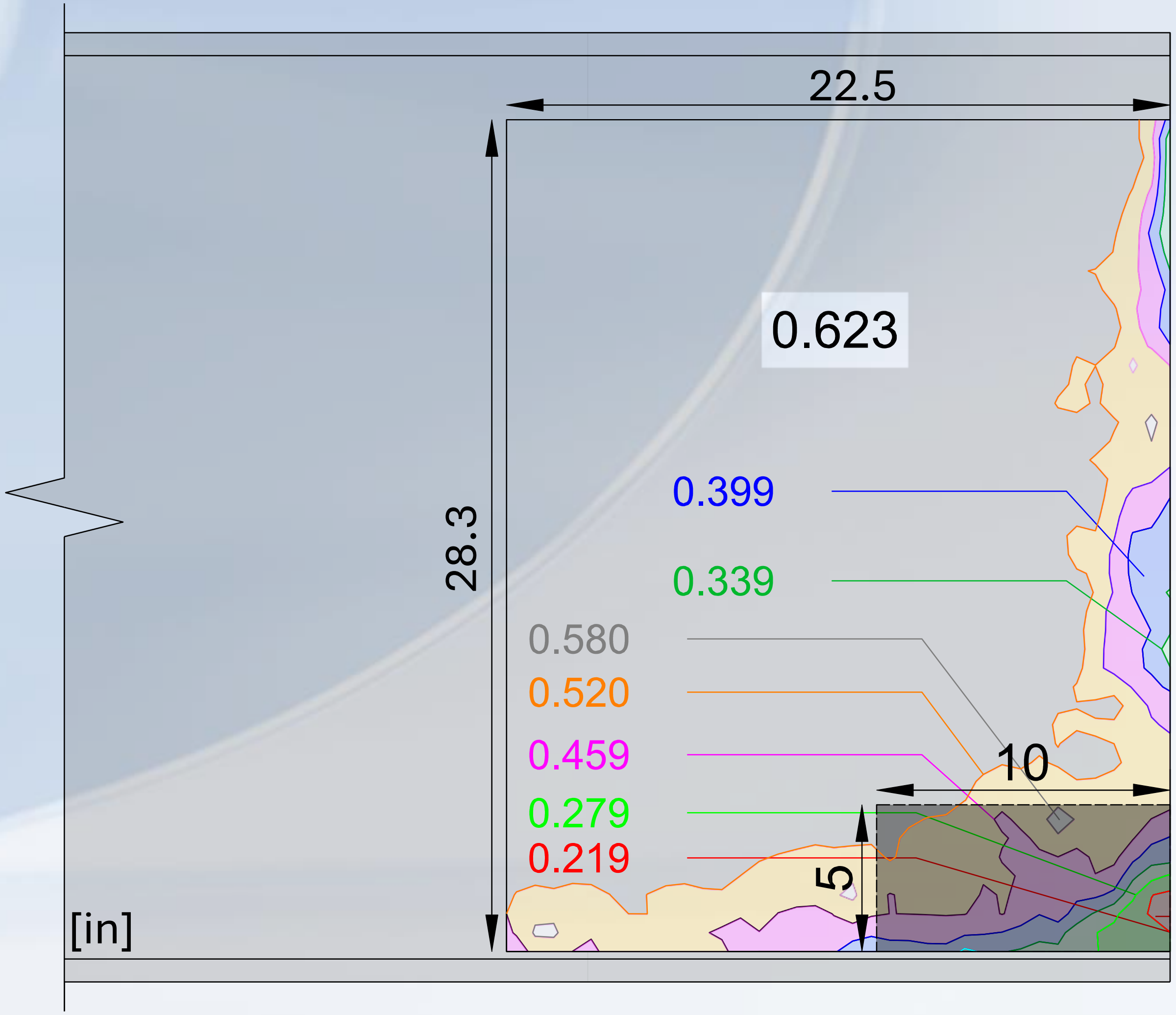
Material	Yield stress (MPa)	Modulus (GPa)
SS08	748 ± 56	211 ± 42
SS08-A36	467 ± 40	202 ± 28
A36	313 ± 12	211 ± 13

Maine Bridge Beam

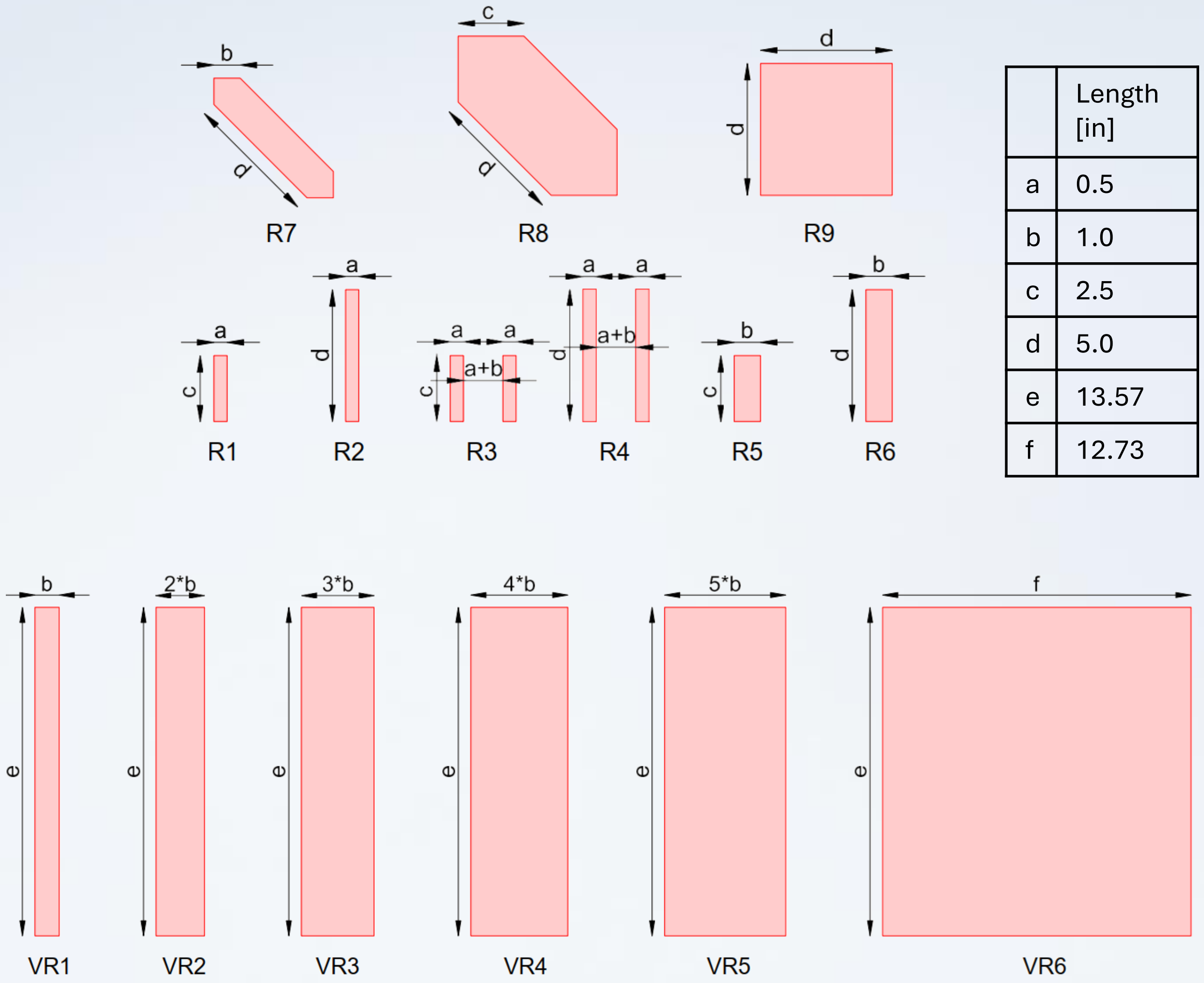


Case Study 1 – Maine Bridge

Thickness repair scenario

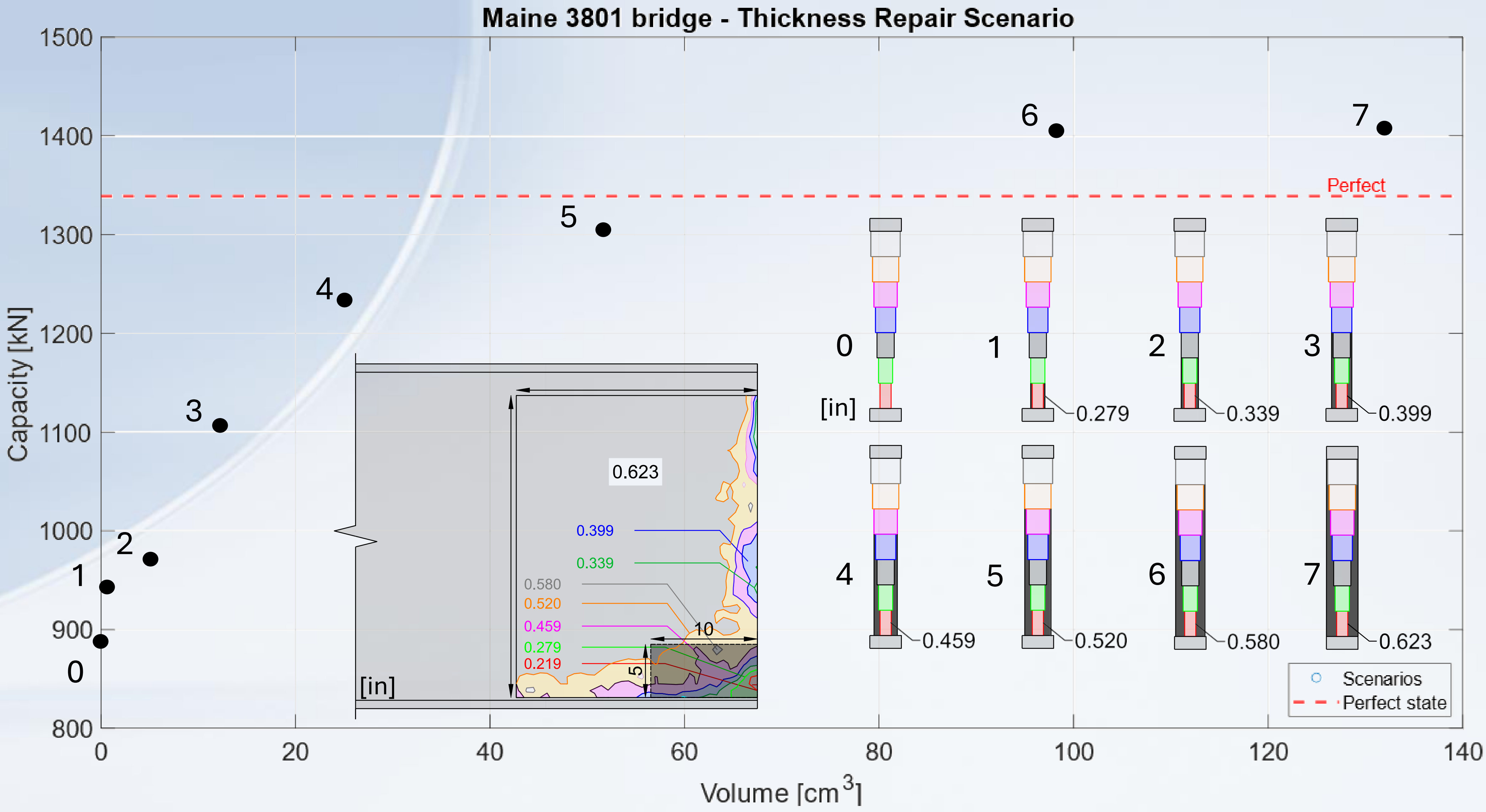


Line repair scenarios

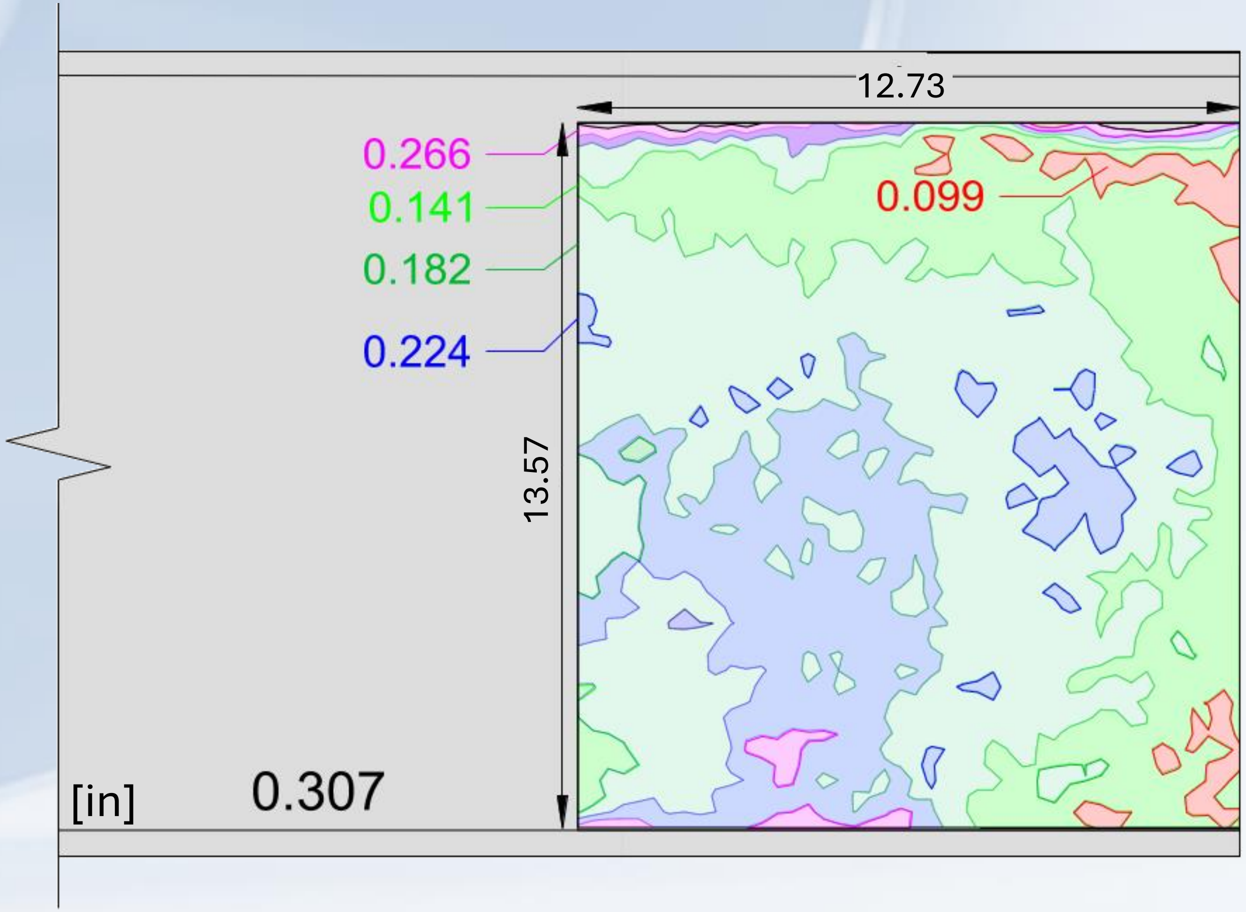


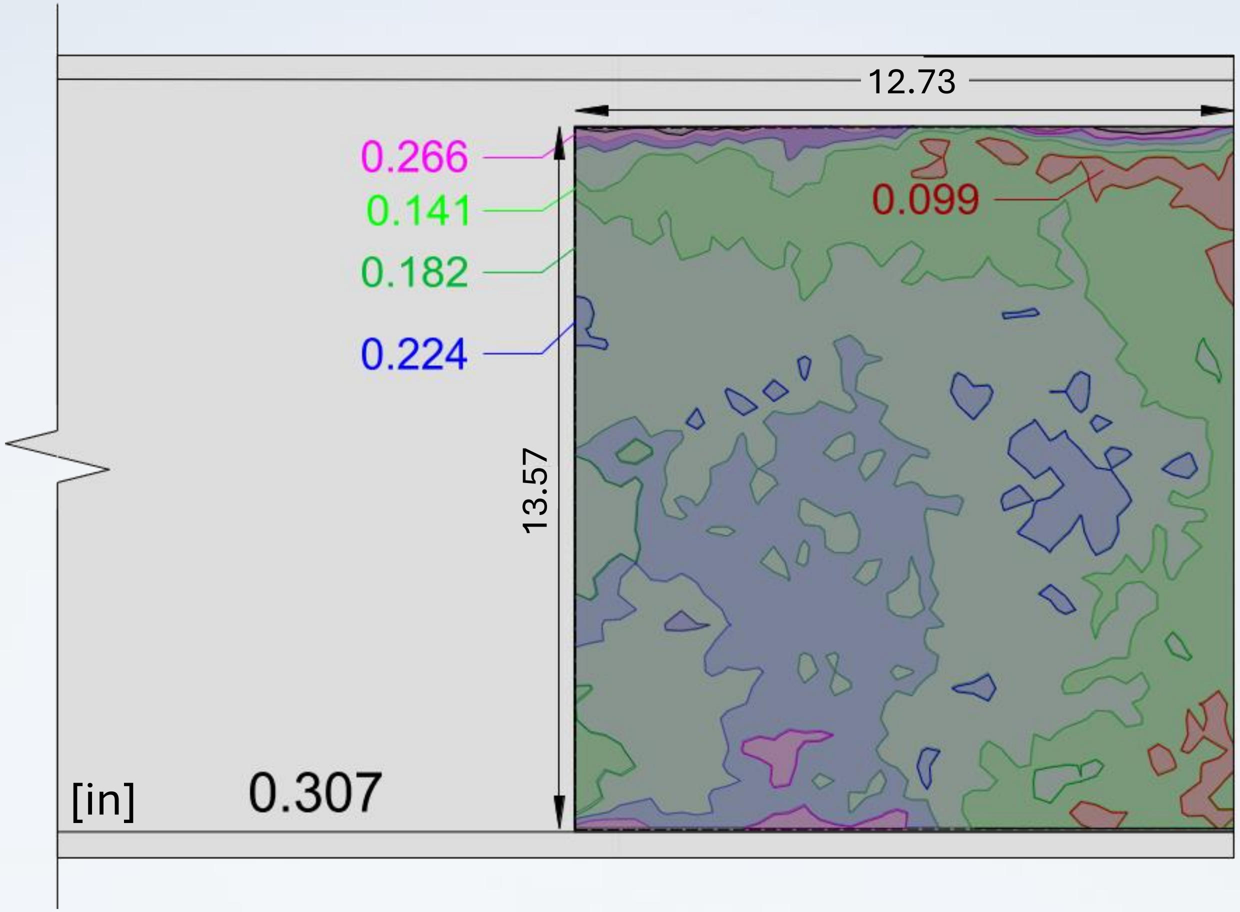
	Length [in]
a	0.5
b	1.0
c	2.5
d	5.0
e	13.57
f	12.73

Case Study 1 – Maine Bridge

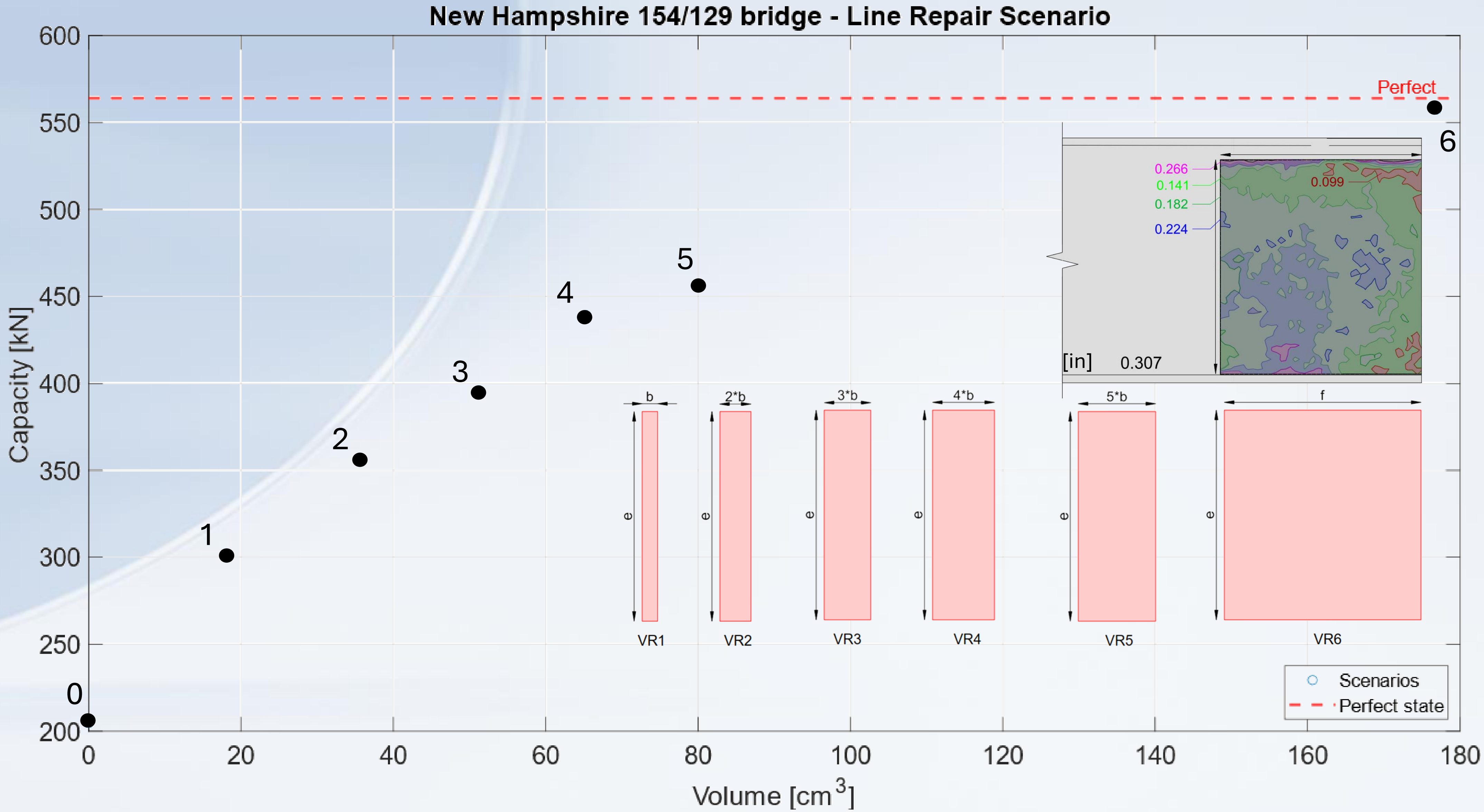


Case Study 2 – New Hampshire bridge



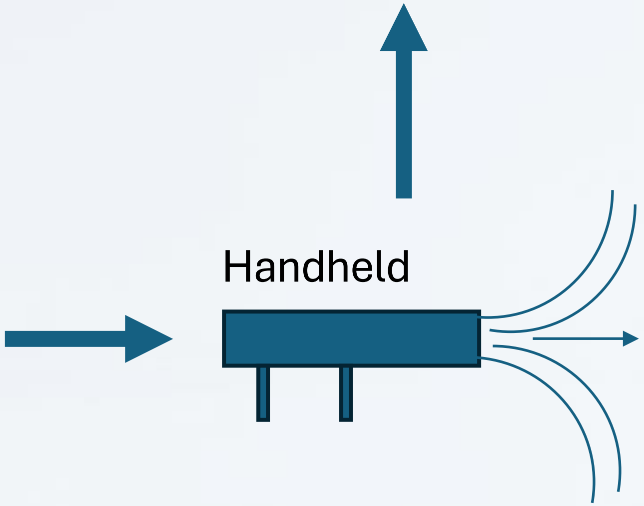


Case Study 2 – New Hampshire bridge



Outlook


VRC Raptor
Cold Spray System


Handheld


Blast removal
Primary deposition
Additional Coating

Costs

This work

Cleaning
- Cleaning & Containment
- Access equipment

Labor
- Design engineer
- Field Engineer
- Inspector
- Scanner

Spraying
- Powder
- Gas
- Fuel
- Labor
- Equipment

Maintenance of Traffic
- Load restrictions
- Partial closures/ Lane restrictions
- Full closures/ Detours
- Traffic control staff
- Equipment

Environmental
- Material
- <<Time
- Preservation

Cleaning → Labor → Spraying → Maintenance of Traffic → Environmental

Total cost per mass of CSAM process < 500 $/lb

Summary

2015	2017	2018	2019	2019	2020	2021	2022	2024	2025
Simos Research Group	Bridge Research Project I	Bridge Research Project II	Bridge Research Project III	Bridge Research Project IV	Research expands to New England	Adoption in MA Bridge Manual	Bridge Research Project V, VI, VII	Acquisition of portable sprayer	FIRST FIELD REPAIR

massDOT
Massachusetts Department of Transportation

New England Transportation Consortium

M2I2
Massachusetts Manufacturing Innovation Initiative

1

2017

1st in the country to test naturally – real - corroded bridges in the lab

2

2021

New Bridge Load rating methods adopted in MA Bridge Manual

AASHTO proposal for national adoption 2025-2026

3

2022

1st in the country to <u>successfully</u> test cold spray repair on real naturally corroded plates from real bridges in the lab

4

2024

Acquisition of portable cold sprayer (UMass)

Thank you!

Questions?

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Massachusetts Institute of Technology

Moving Massachusetts Forward. massDOT Massachusetts Department of Transportation

UMass Amherst College of Engineering