Improved Load Rating Procedures for Deteriorated Unstiffened Steel Beam Ends

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massDOT
Massachusetts Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

NEW ENGLAND TRANSPORTATION CONSORTIUM

University of Massachusetts Amherst

Outline

- **Current State of Inspection and Corrosion Topologies**
- **Corrosion Mapping via 3D Scanning**
- **Laboratory Experiments and Capacity Evaluation of Rolled Girders with Corroded Ends**

Current State of Inspection and Corrosion Topologies

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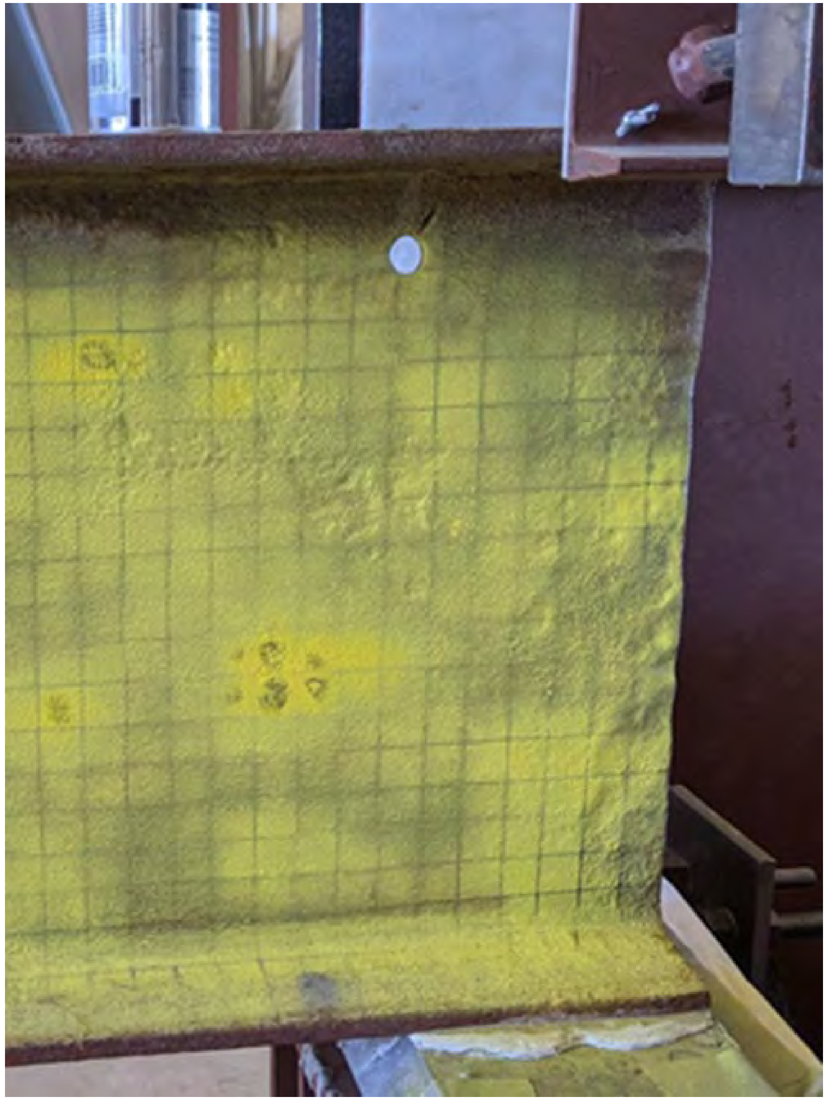
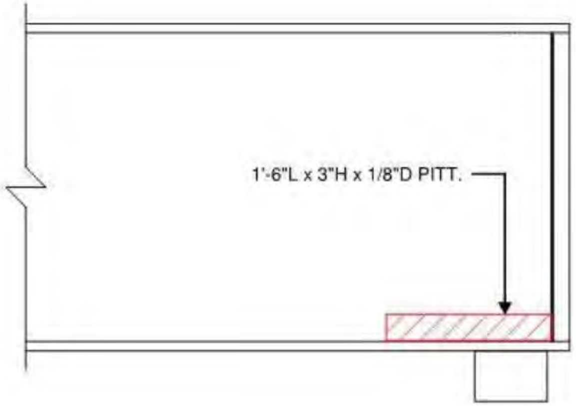
3D Scanning for Bridge Inspection – Current State-of-Practice



Source: GE

Stringers: Rolled Beams | Poor Condition-See Description | **Cover Plates:** N/A

Extensive rust scale with moderate to heavy section loss in the south abutment beam ends, perforations could soon occur.

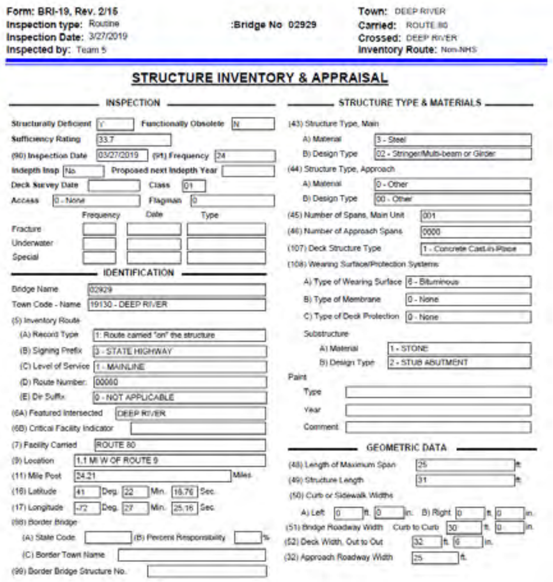


Assume 24 WF 100 (smallest section):
T = 22.45"
tw = .468"
Original Area = T*tw = 10.5 in^2
Lost Area = 3" x (1/8)/2" = .1875 in^2

100(.1875/10.5) = 1.8%

Courtesy: CTDOT and VTrans

Bridge Inspection – Compiled Inspection Reports


Form: BRI-19, Rev. 2/16
Inspection type: Routine
Inspection Date: 3/27/2019
Inspected by: Team 5
Bridge No 02929
Town: DEEP RIVER
Carried: ROUTE 80
Crossed: DEEP RIVER
Inventory Route: Non-NHS

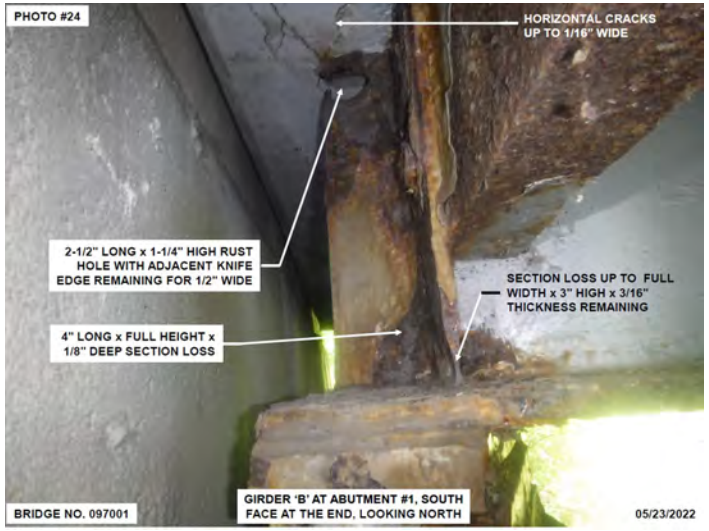
STRUCTURE INVENTORY & APPRAISAL

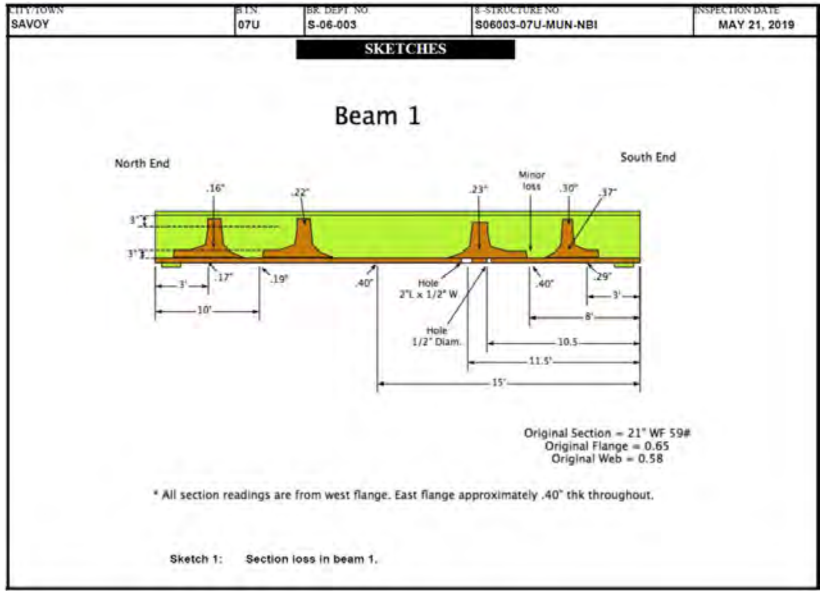
INSPECTION
Structurally Deficient Y
Functionally Obsolete N
Sufficiency Rating 33.7
(90) Inspection Date 03/27/2019
(91) Frequency 24
Indepth Insp No
Proposed next Indepth Year
Deck Survey Date
Class 01
Access 0 - None
Flagman 0
Frequency Date Type
Fracture
Underwater
Special

IDENTIFICATION
Bridge Name 02929
Town Code - Name 19130 - DEEP RIVER
(5) Inventory Route
(A) Record Type 1: Route carried "on" the structure
(B) Signing Prefix 3 - STATE HIGHWAY
(C) Level of Service 1 - MAINLINE
(D) Route Number 00080
(E) Dir Suffix 0 - NOT APPLICABLE
(6A) Featured Intersected DEEP RIVER
(6B) Critical Facility Indicator
(7) Facility Carried ROUTE 80
(9) Location 1.1 MI W OF ROUTE 9
(11) Mile Post 24.21 Miles
(16) Latitude 41 Deg. 22 Min. 15.76 Sec.
(17) Longitude 72 Deg. 27 Min. 25.16 Sec.
(99) Border Bridge
(A) State Code
(B) Percent Responsibility %
(C) Border Town Name
(99) Border Bridge Structure No.

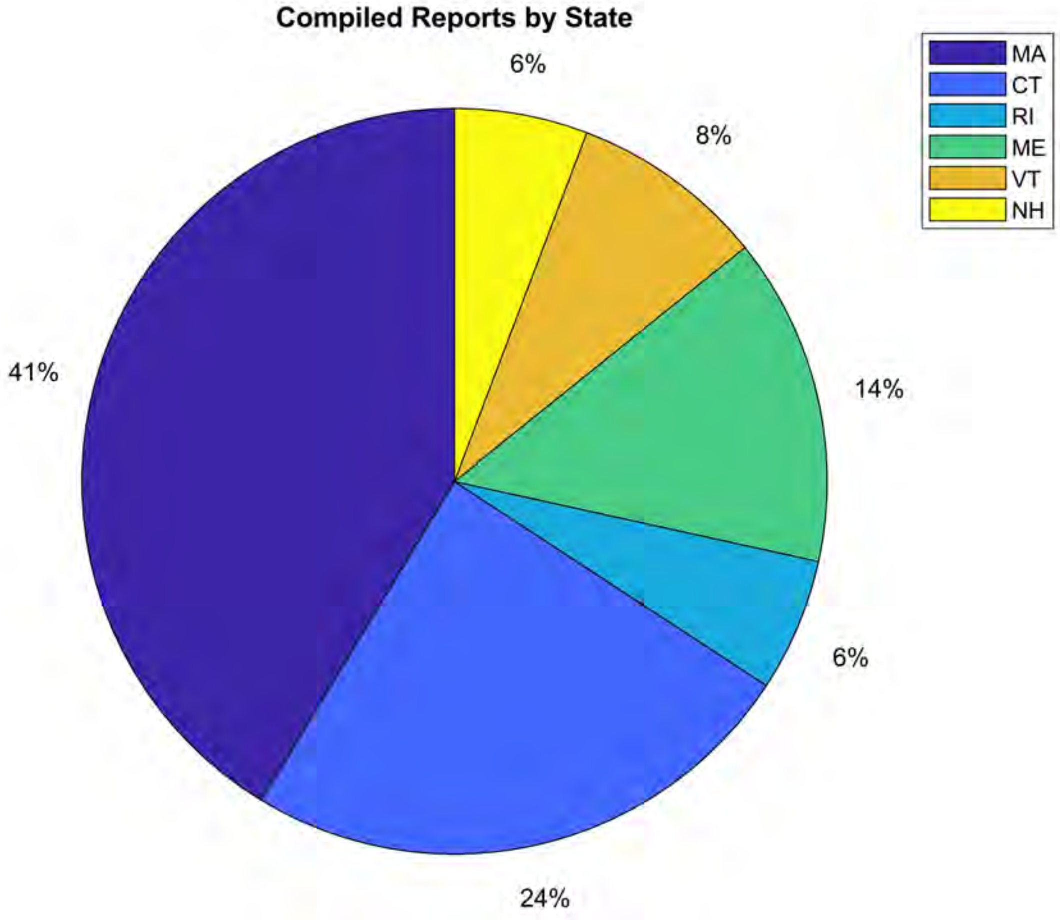
STRUCTURE TYPE & MATERIALS
(43) Structure Type, Main
A) Material 3 - Steel
B) Design Type 02 - Stringer/Multi-beam or Girder
(44) Structure Type, Approach
A) Material 0 - Other
B) Design Type 00 - Other
(45) Number of Spans, Main Unit 001
(46) Number of Approach Spans 0000
(107) Deck Structure Type 1 - Concrete Cast-in-Place
(108) Wearing Surface/Protection Systems
A) Type of Wearing Surface 6 - Bituminous
B) Type of Membrane 0 - None
C) Type of Deck Protection 0 - None
Substructure
A) Material 1 - STONE
B) Design Type 2 - STUB ABUTMENT
Paint
Type
Year
Comment

GEOMETRIC DATA
(48) Length of Maximum Span 25 ft
(49) Structure Length 31 ft
(50) Curb or Sidewalk Widths
A) Left 0 ft 0 in. B) Right 0 ft 0 in.
(51) Bridge Roadway Width Curb to Curb 30 ft 0 in.
(52) Deck Width, Out to Out 32 ft 6 in.
(32) Approach Roadway Width 25 ft





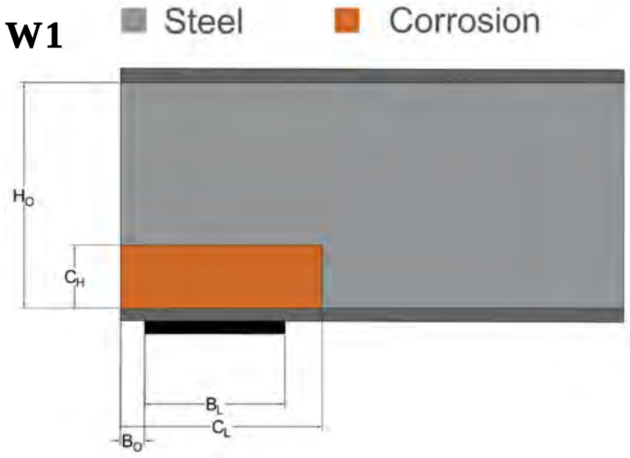

MASSACHUSETTS DEPARTMENT OF TRANSPORTATION
STRUCTURES INSPECTION FIELD REPORT
ROUTINE & SPECIAL MEMBER INSPECTION
PAGE 1 OF 21
BR. DEPT. NO. C-16-028
01 | 0KQ
COLRAIN | C18028-0KQ-DOT-NBI | 080.787 | D:OPEN | JUN 9, 2017
ST112 JCKSNVLLE RD | 1933 | 1938 | 0000
WATER E BR NORTH RIVER | Rural Minor Arterial
402 : Steel Continuous Stringer/Girder | State Highway Agency | State Highway Agency
1 : Concrete Cast-in-Place | Cloudy | 22°C | R. MANCARI
ITEM 58 DECK 6
ITEM 59 SUPERSTRUCTURE 3
ITEM 60 SUBSTRUCTURE 4
1. Abutments
2. Piers or Bents
3. Pile Bents
X=UNKNOWN N=NOT APPLICABLE H=HIDDEN/INACCESSIBLE R=REMOVED



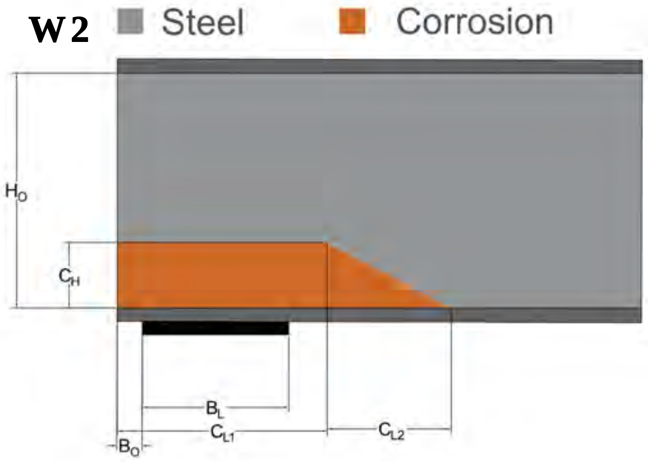
Courtesy: CTDOT, RIDOT, MassDOT

Bridge Inspection – Corrosion Topologies

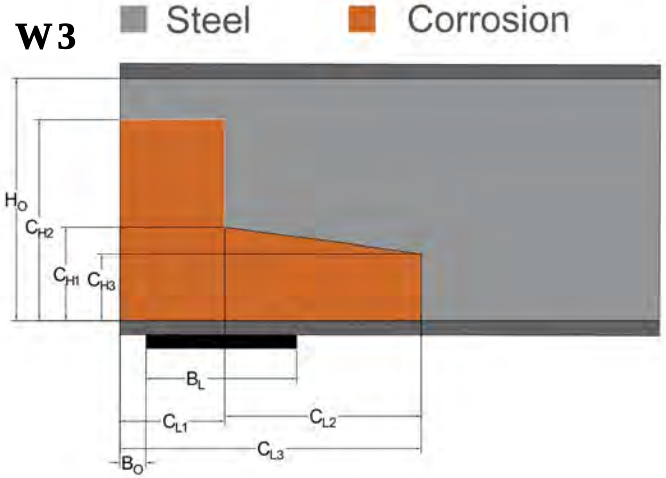
W1



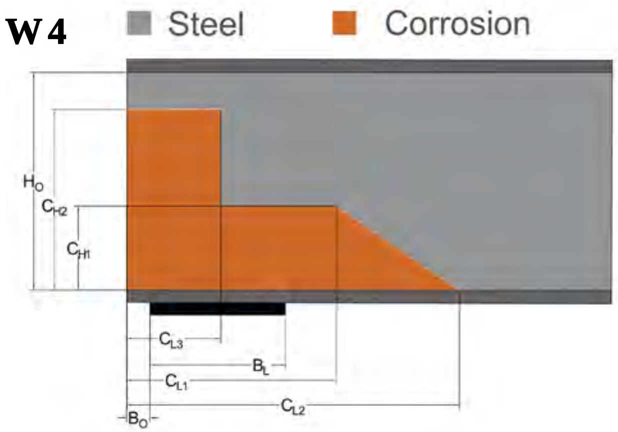
W2



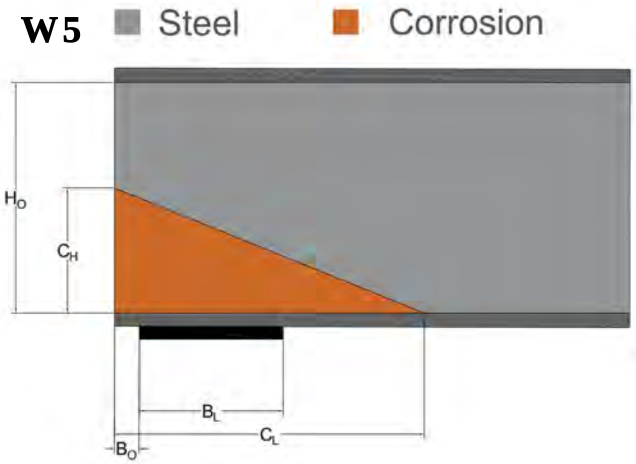
W3



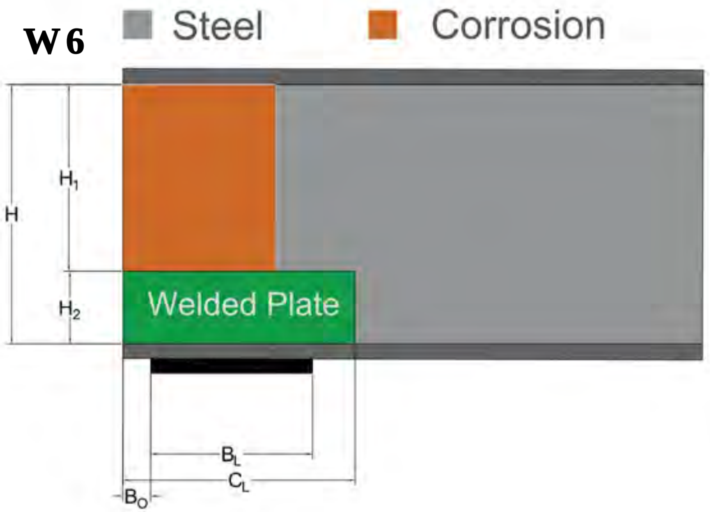
W4



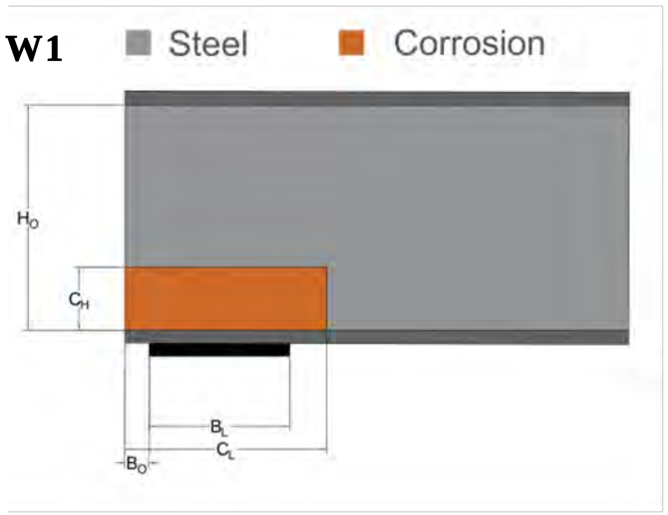
W5

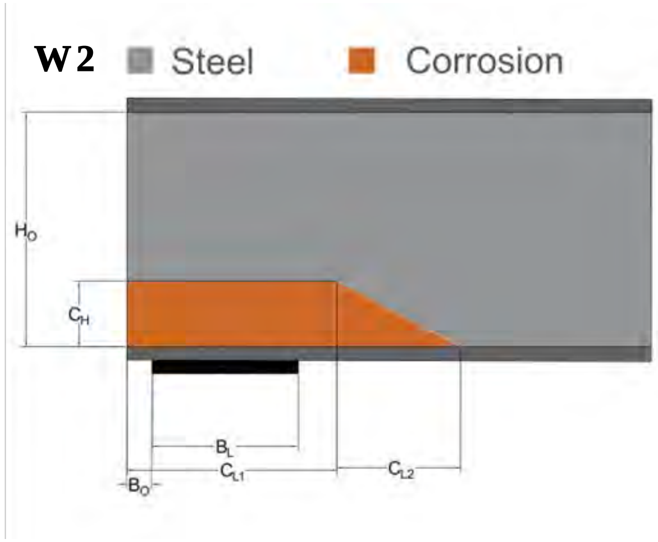


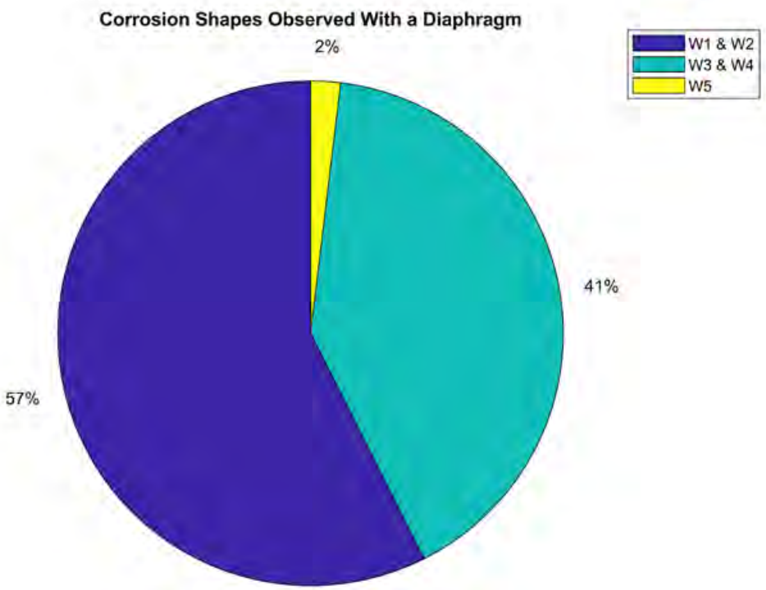
W6

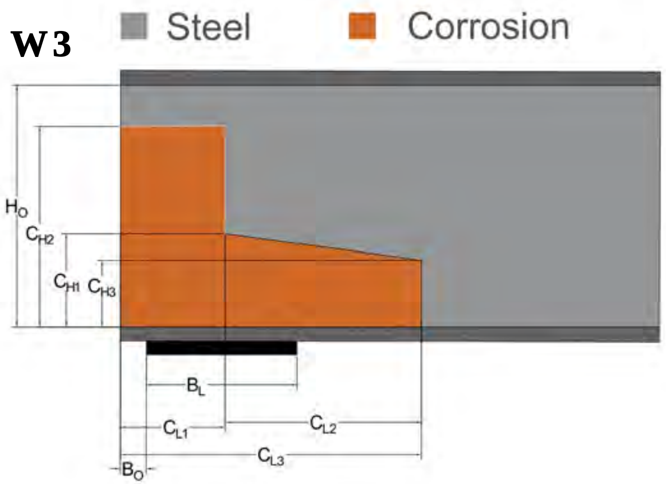


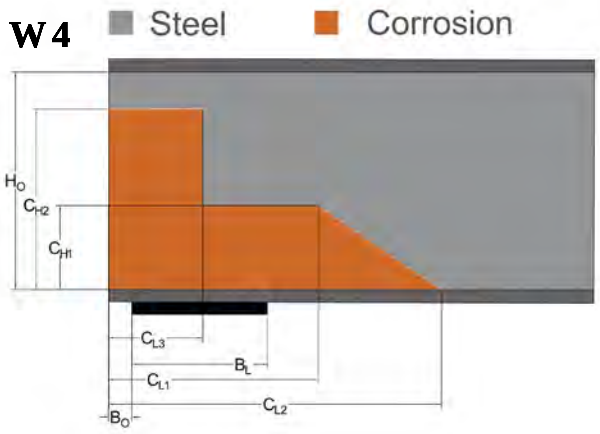
Bridge Inspection – Corrosion Topologies

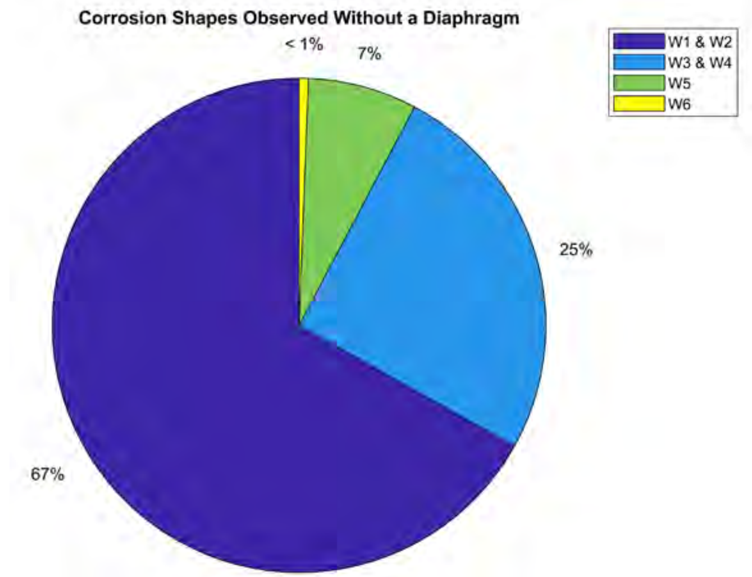




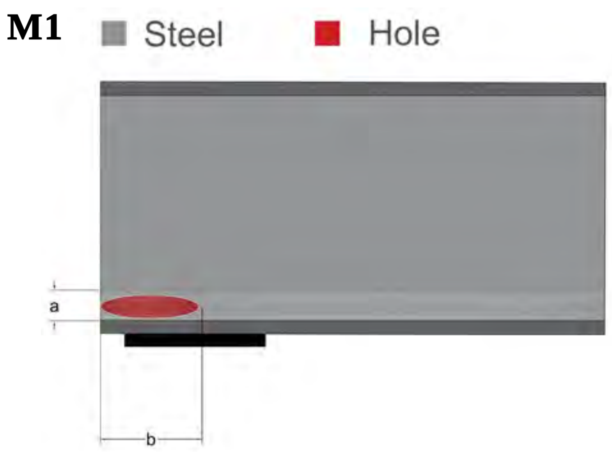


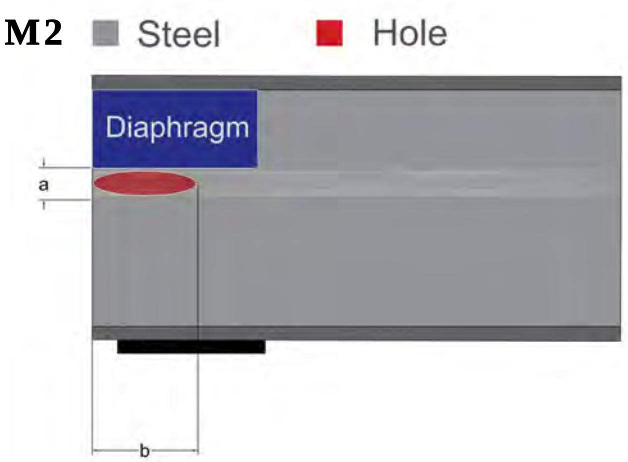


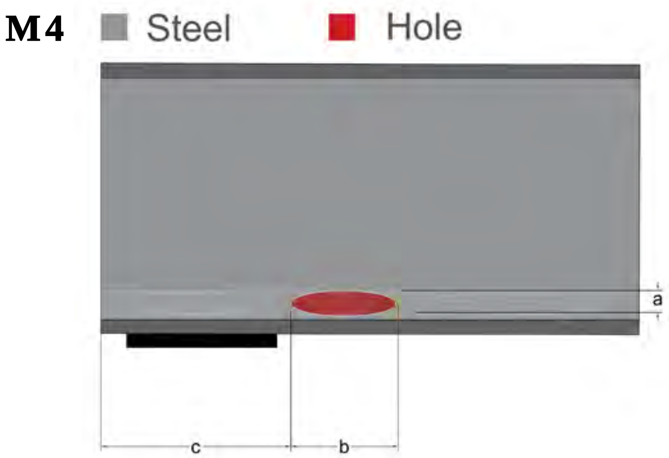


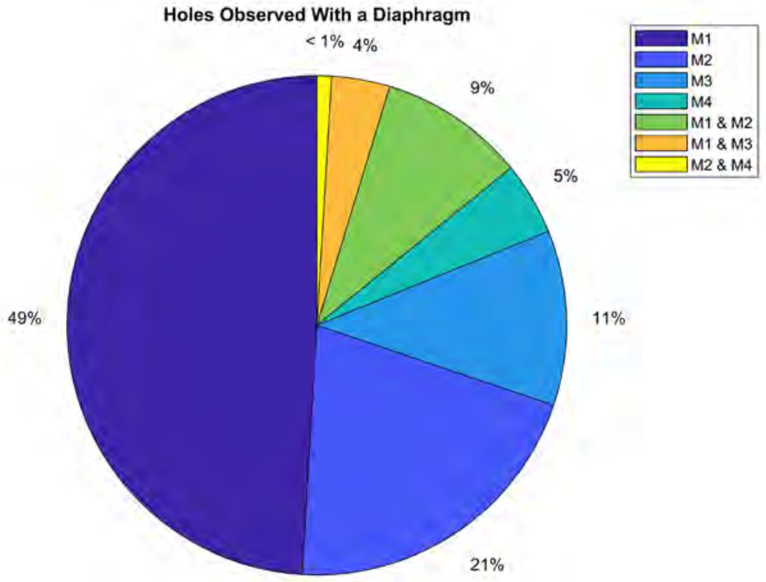


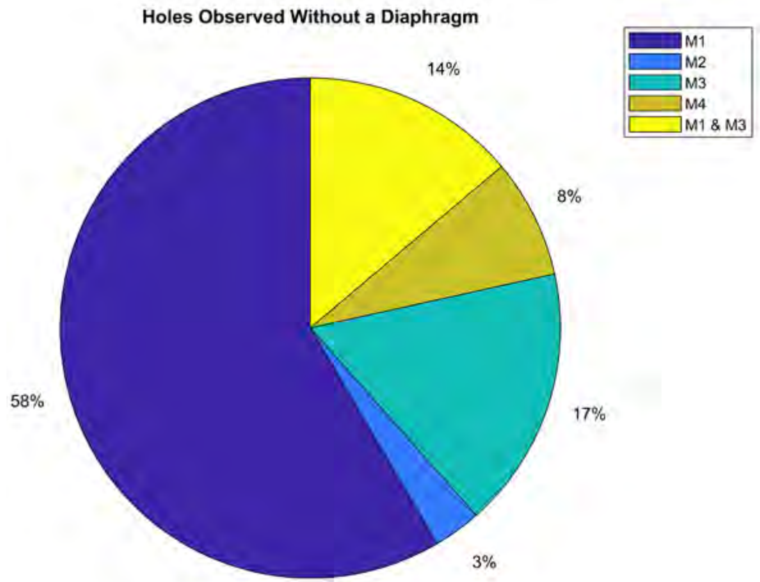
Bridge Inspection – Corrosion Hole Patterns











Corrosion Mapping via 3D Scanning

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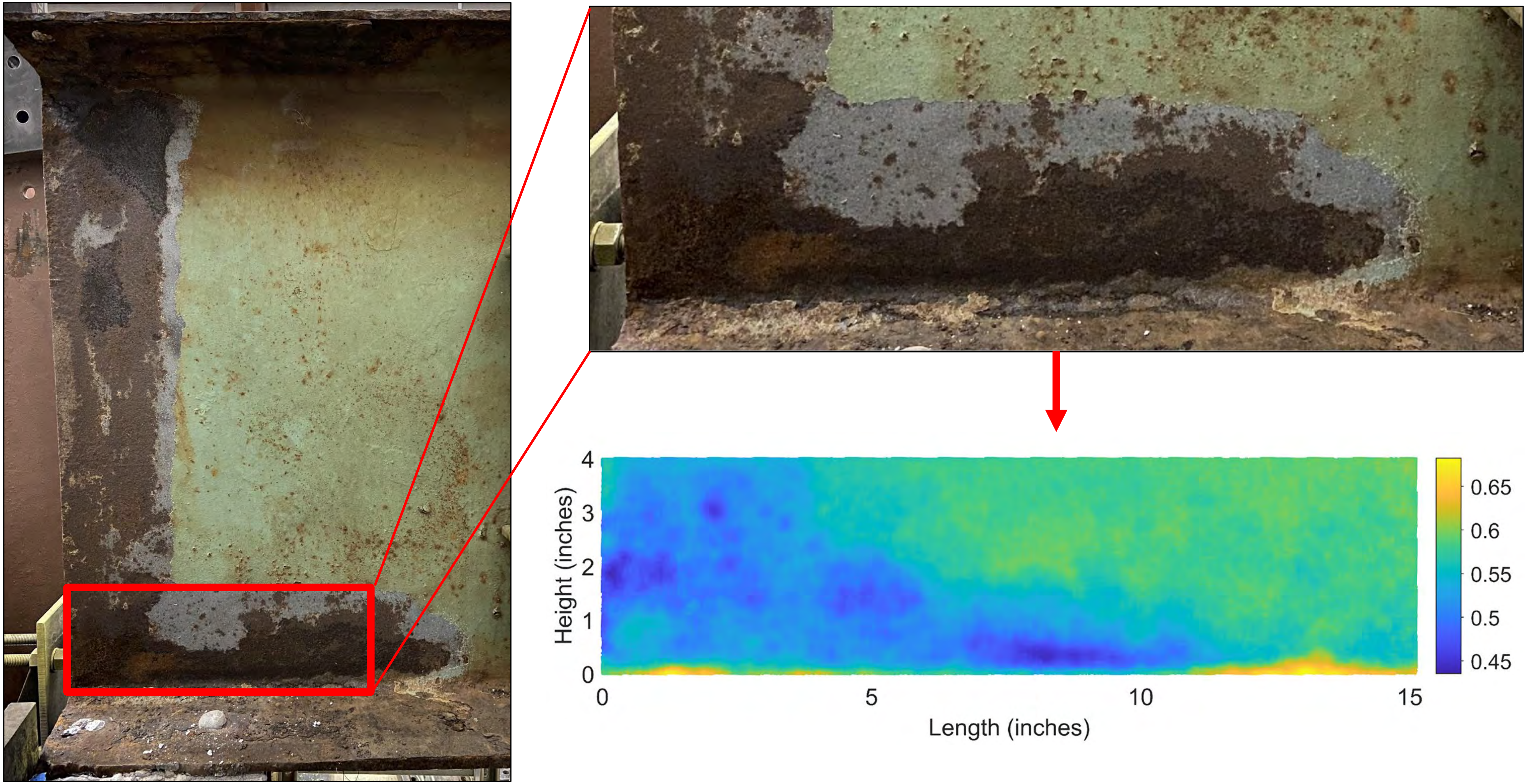
3D Scanning for Bridge Inspection



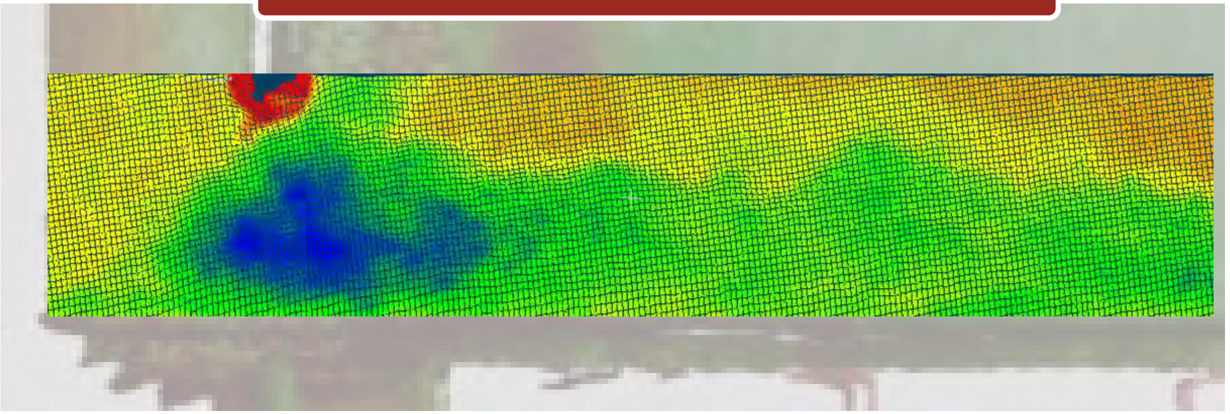
3D Scanning for Bridge Inspection - Process

1. Component Identification

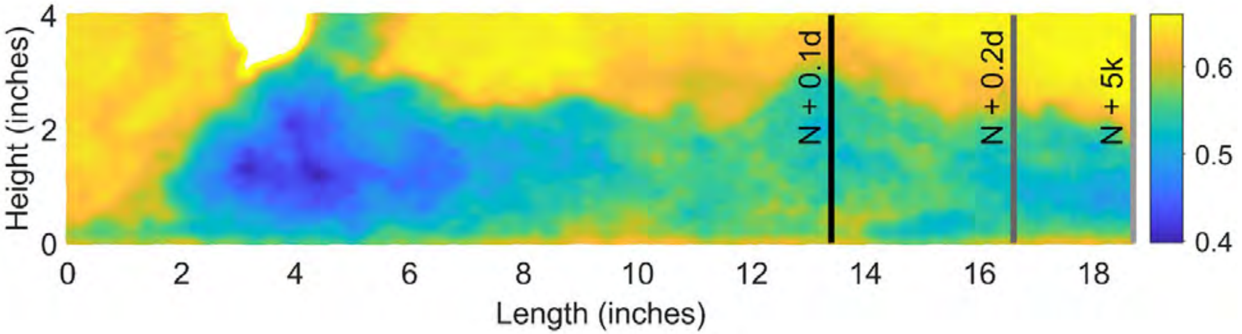
2. Scanning

3. Model Processing

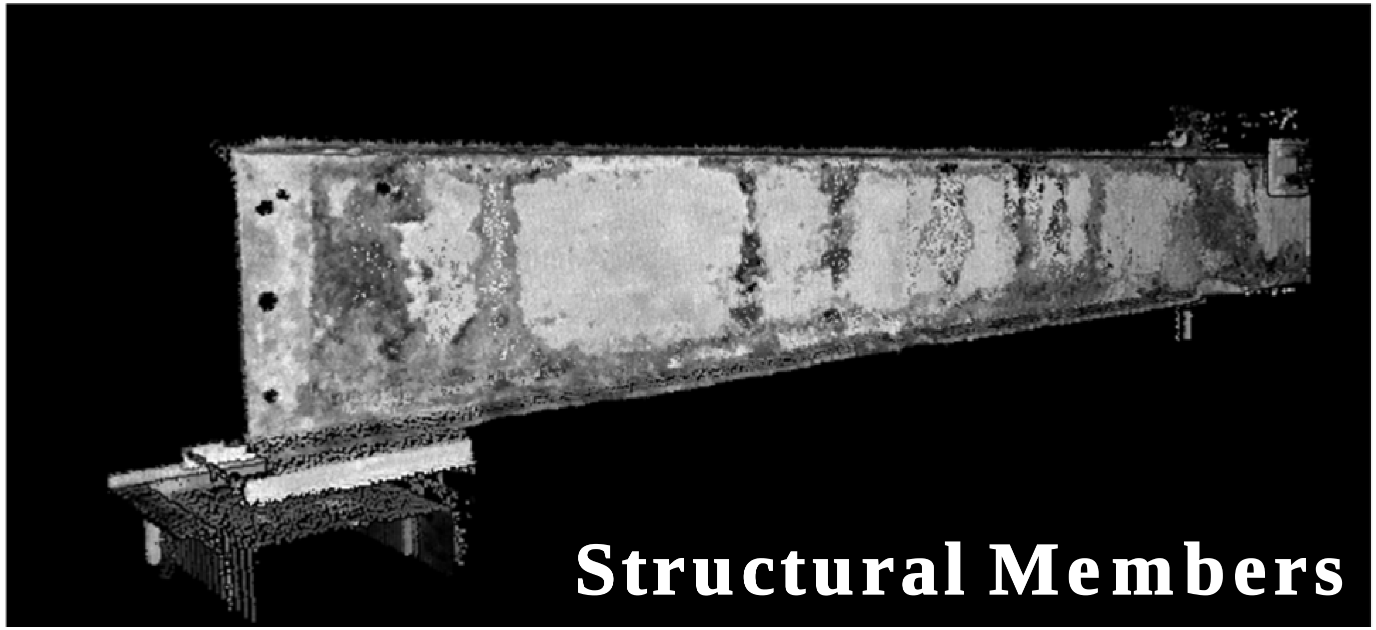
4. Post-Processing



5. Output map generation

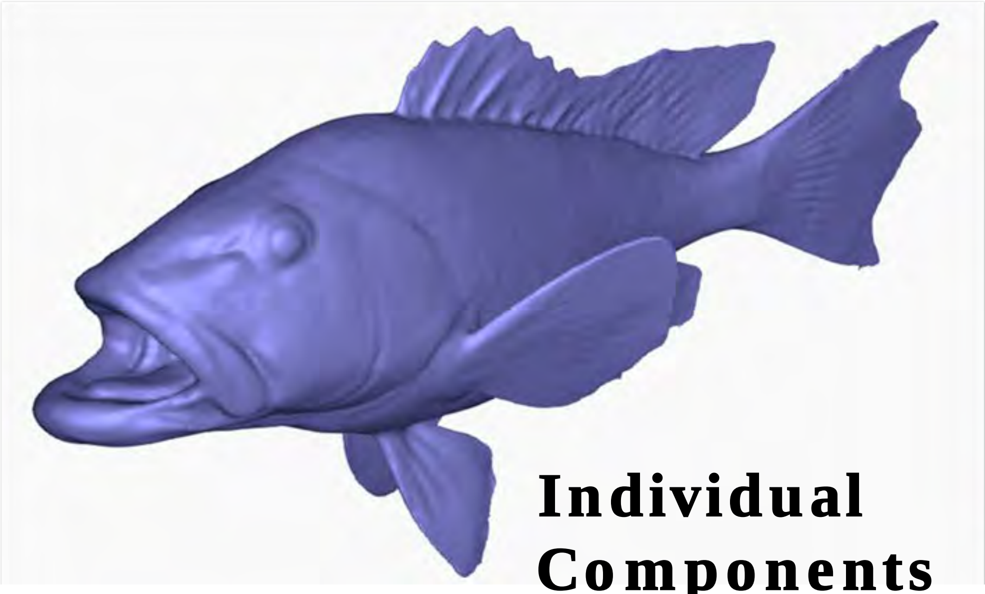


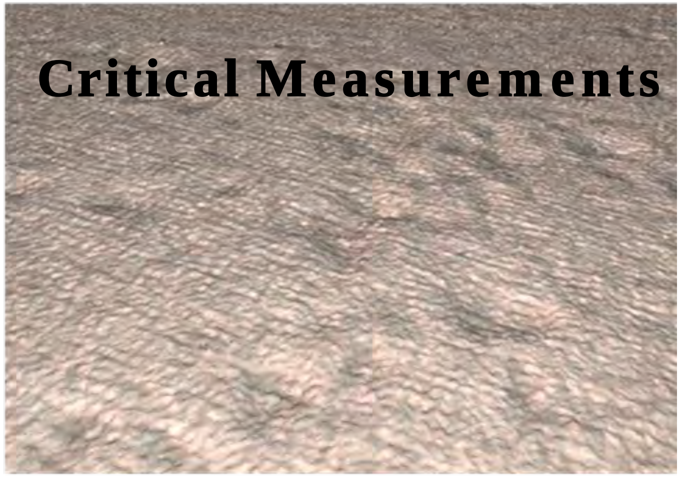
3D Scanning



3D Scanning

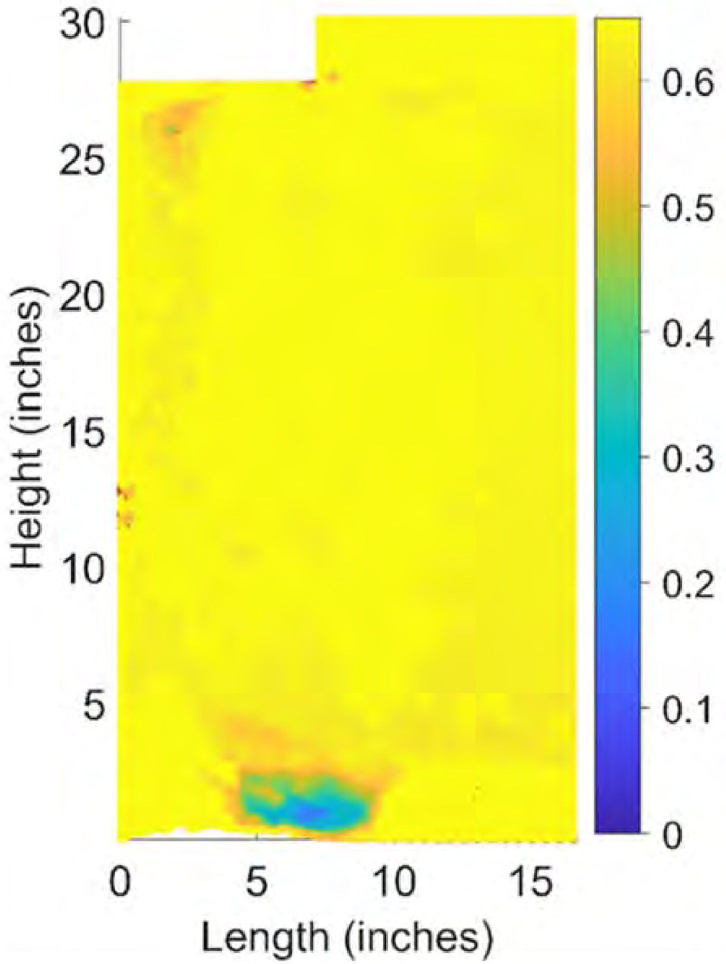

Localized Inspection


Individual
Components


Critical Measurements

Case Study: Corroded End

→



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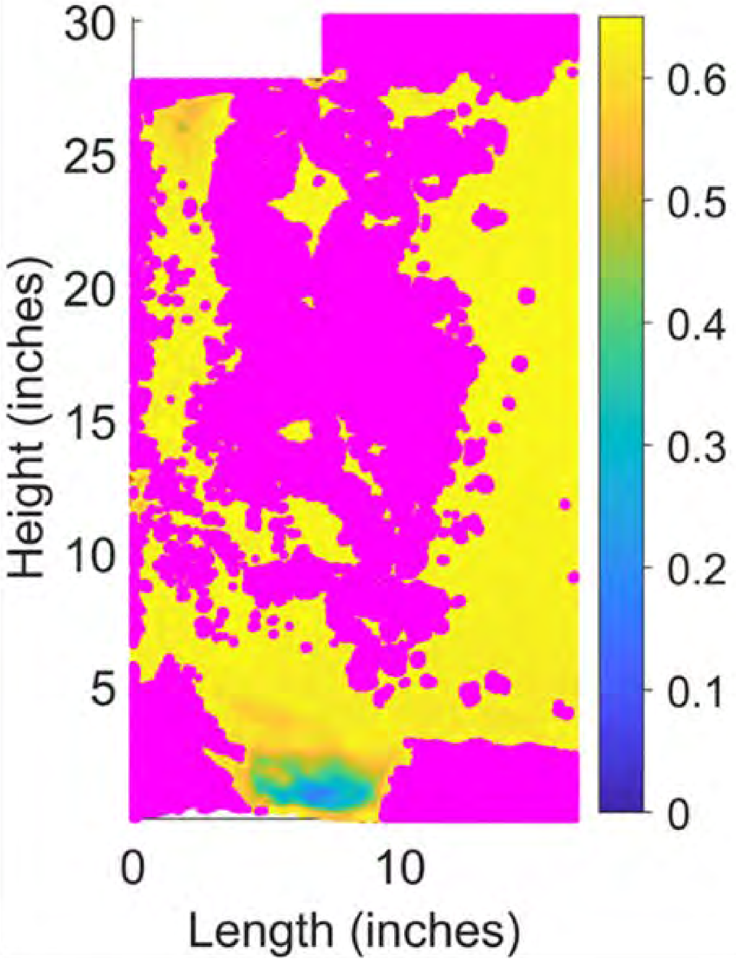
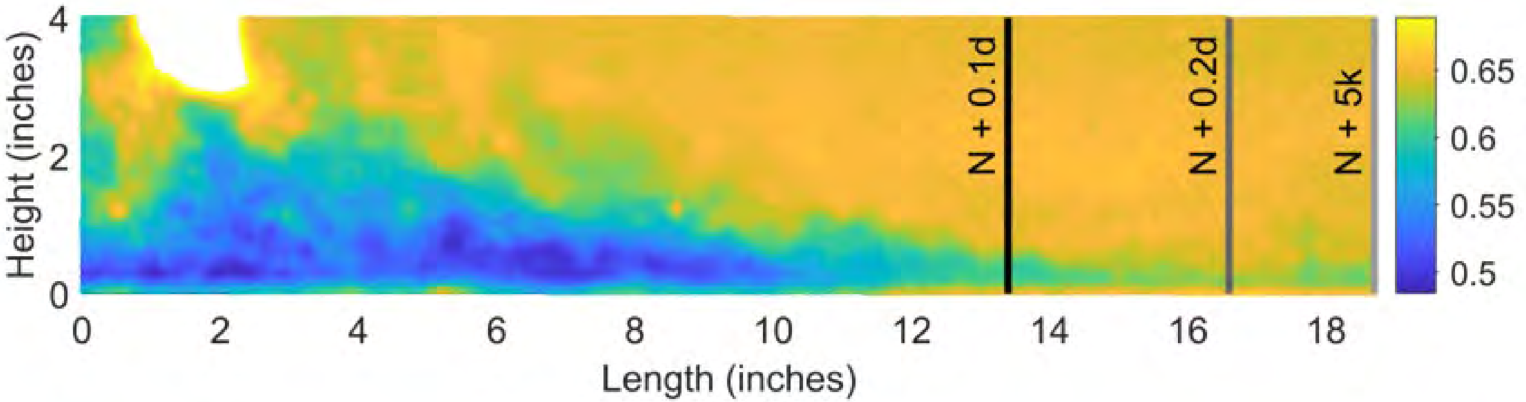


Higher Cloud Density, detail, and accuracy:

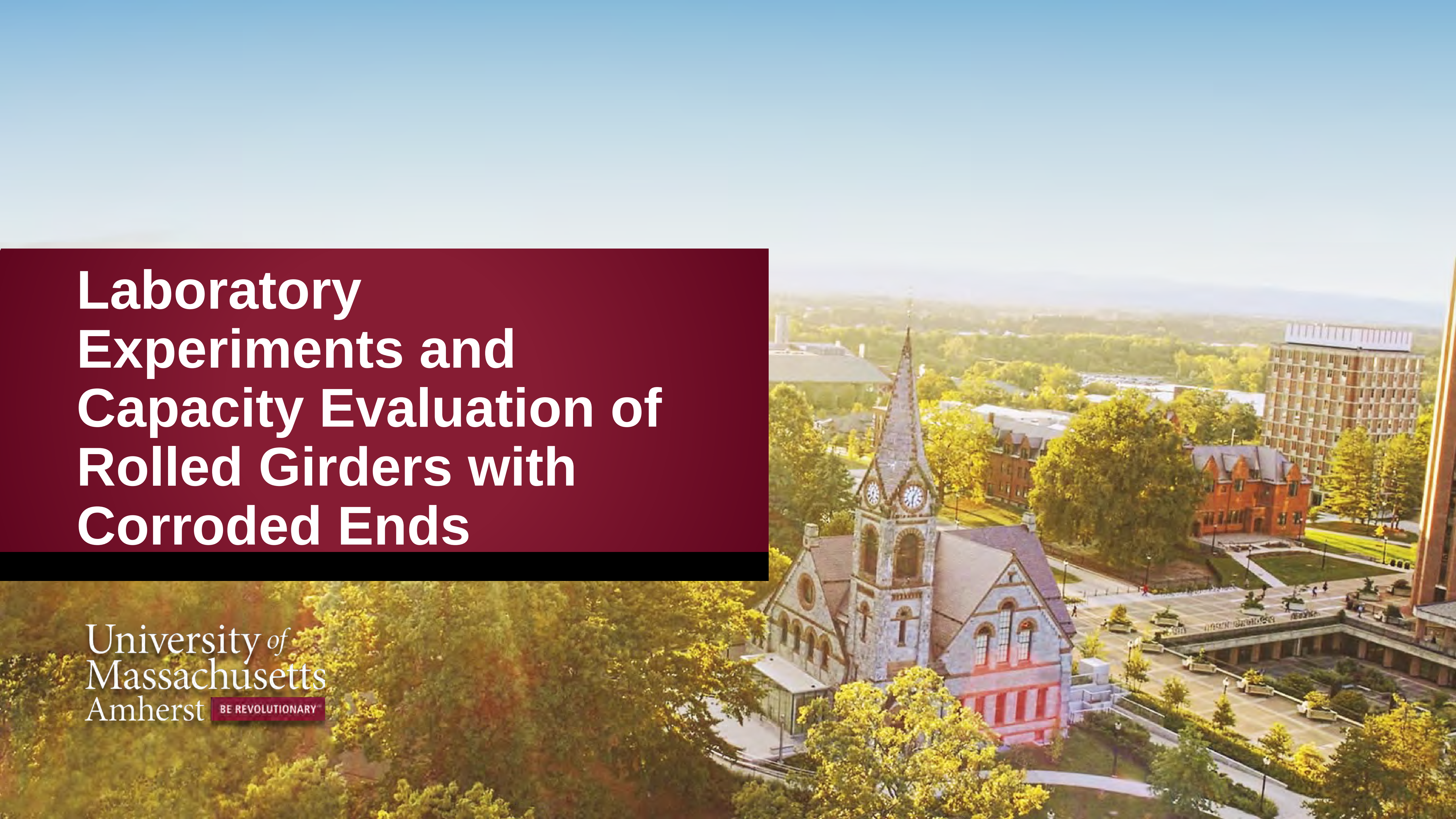
- Around 400,000 points in the selected area to the right and millions of points in the full web height area
- Captures difficult to measure components like pitting and section loss at the edge of the web



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

Laboratory Experiments and Capacity Evaluation of Rolled Girders with Corroded Ends



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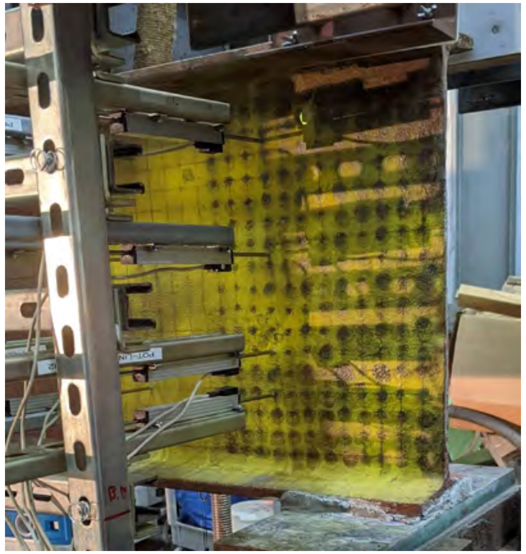
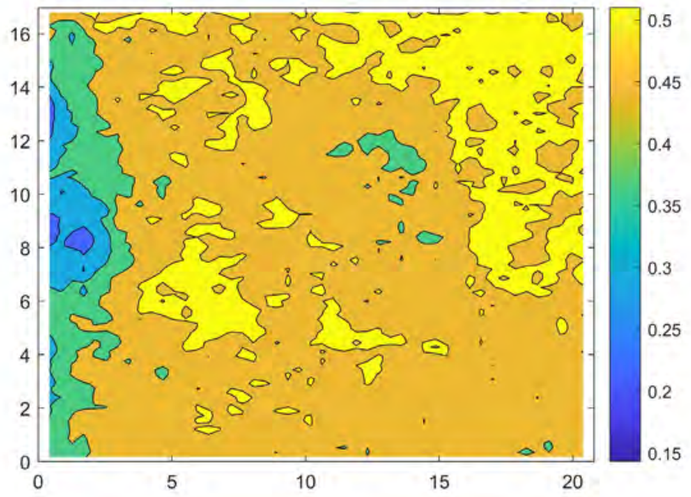
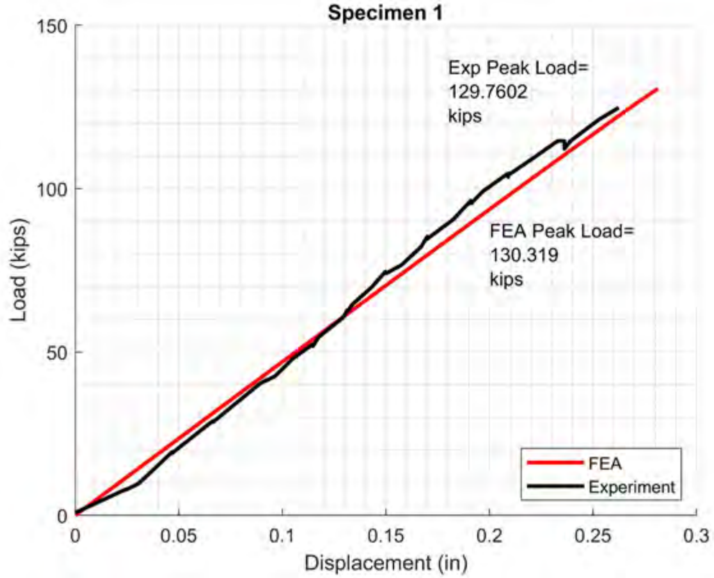
Connecticut 1

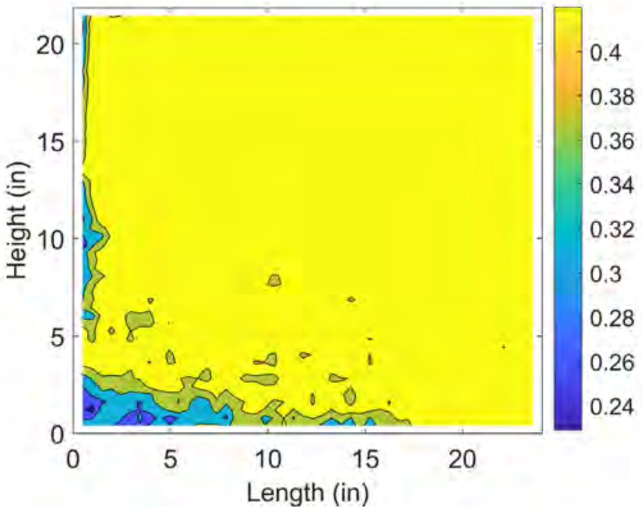


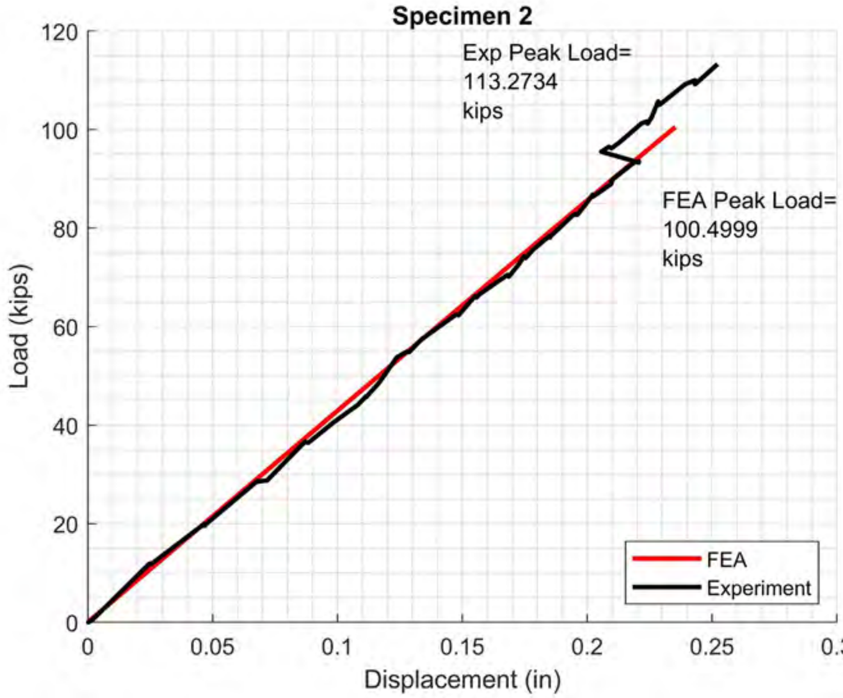




Beam Type: AS 24x65.4 (best match)
Intact Thickness: 0.51 inches
Height: 20 inches

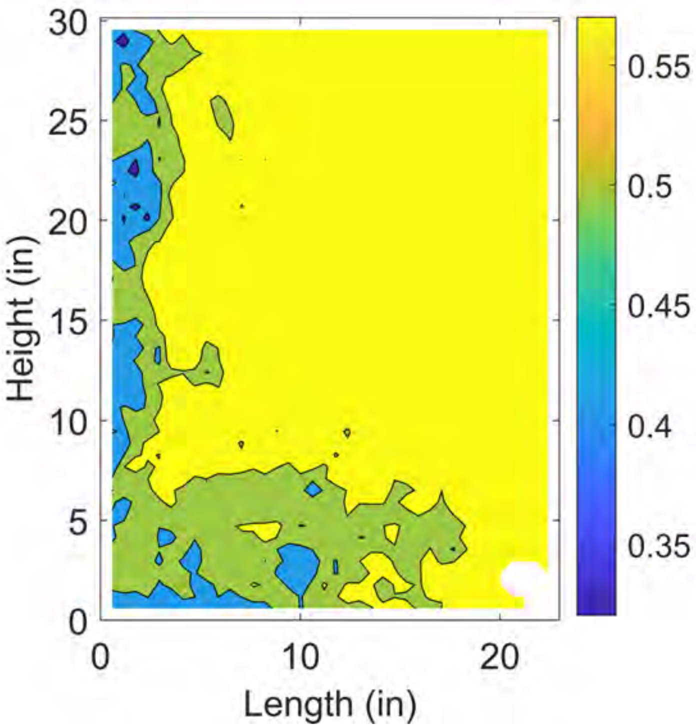
Peak Load:
129.76 kips

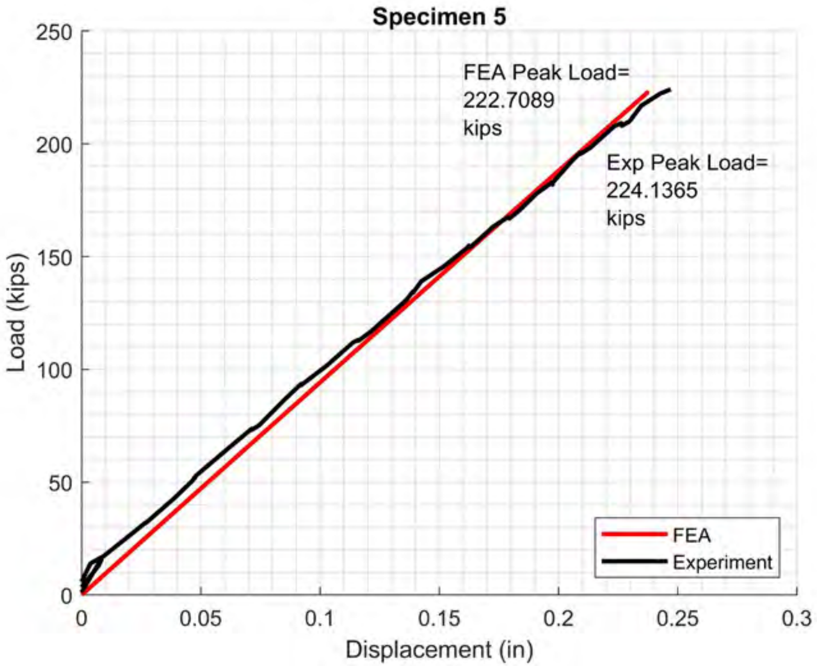




Beam Type: CB 24x8.5 (Best match)
Intact Thickness: 0.42 inches
Height: 24 inches

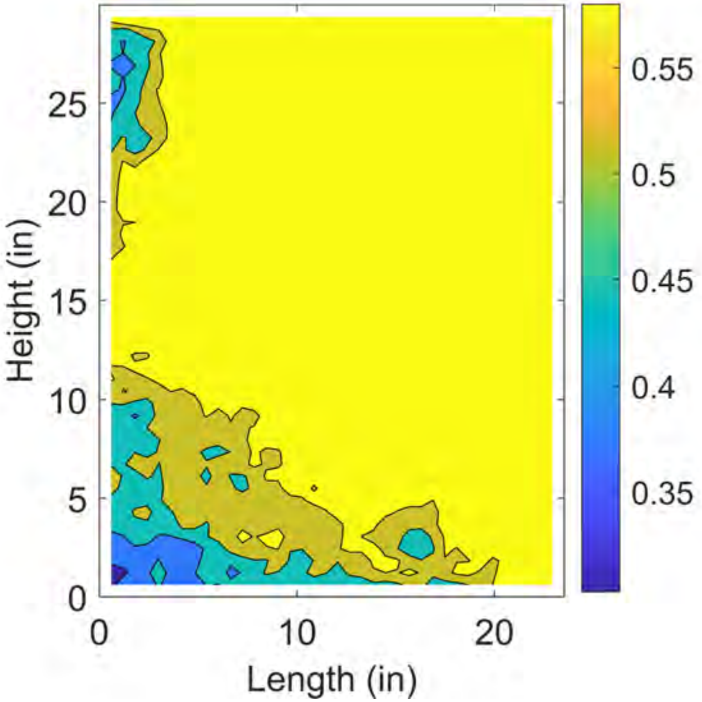
Peak Load:
113.27 kips

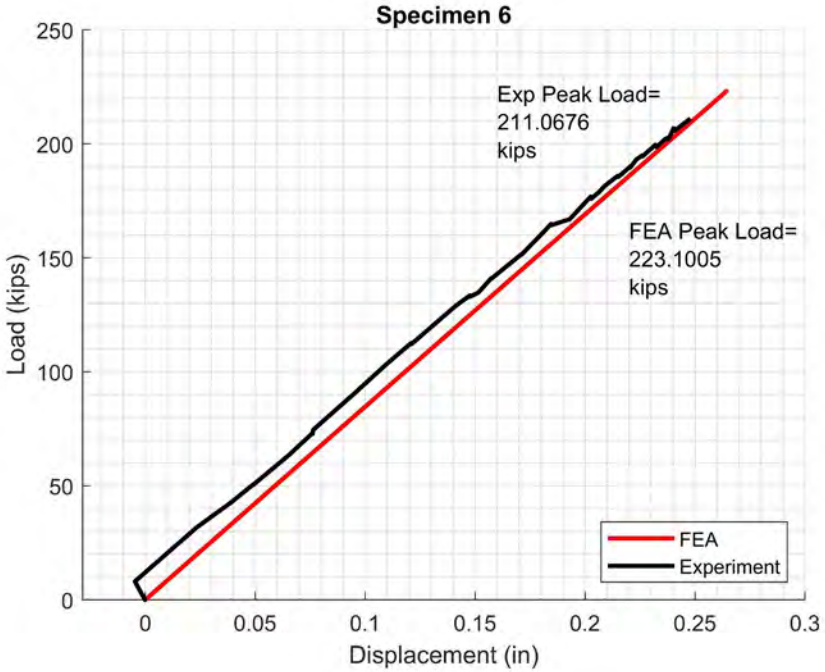




Beam Type: B33x132 Assumed
Intact Thickness: 0.58 inches
Height: 33.150 inches

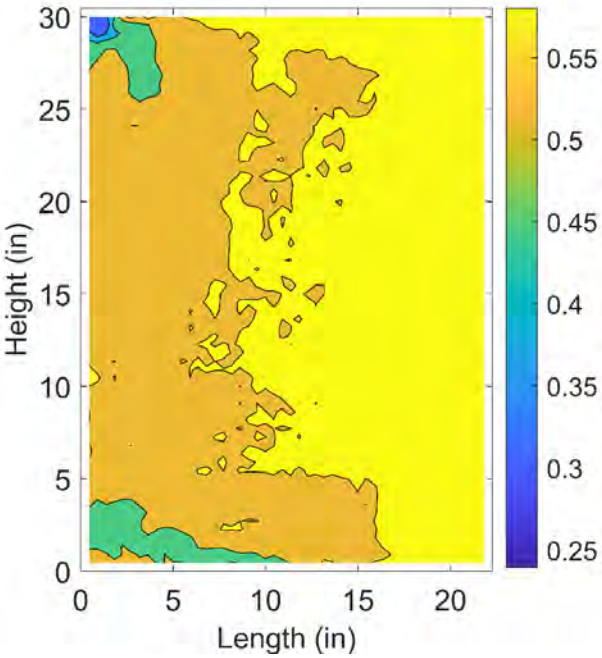
Peak Load:
224.14 kips

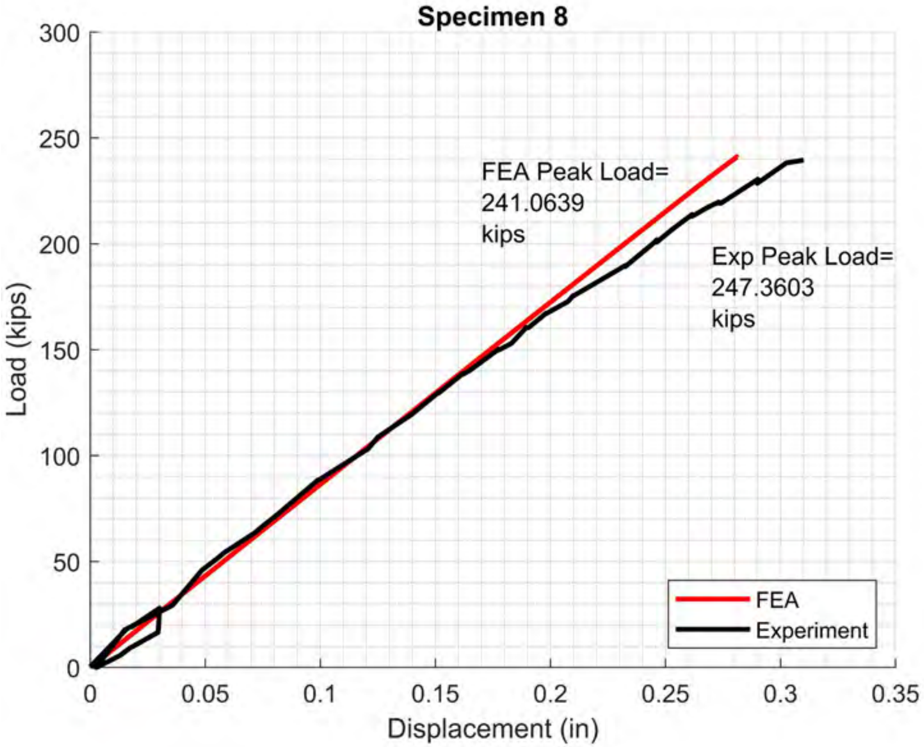




Beam Type: B33x132 Assumed
Intact Thickness: 0.58 inches
Height: 33.150 inches

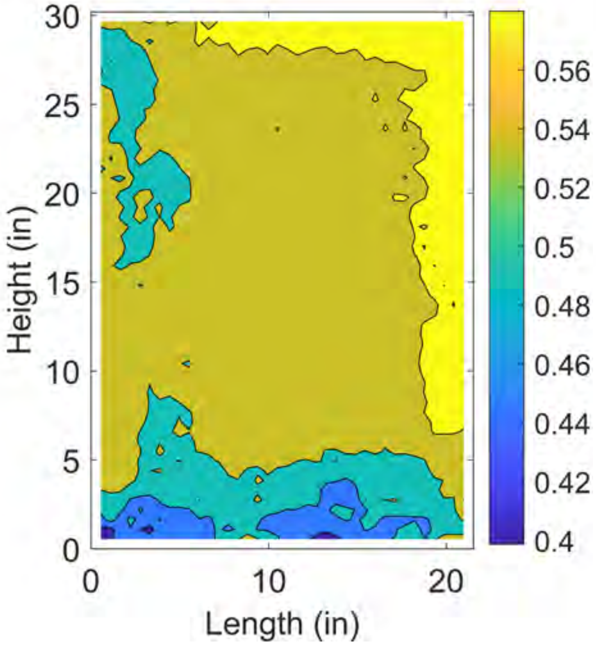
Peak Load:
211.06 kips

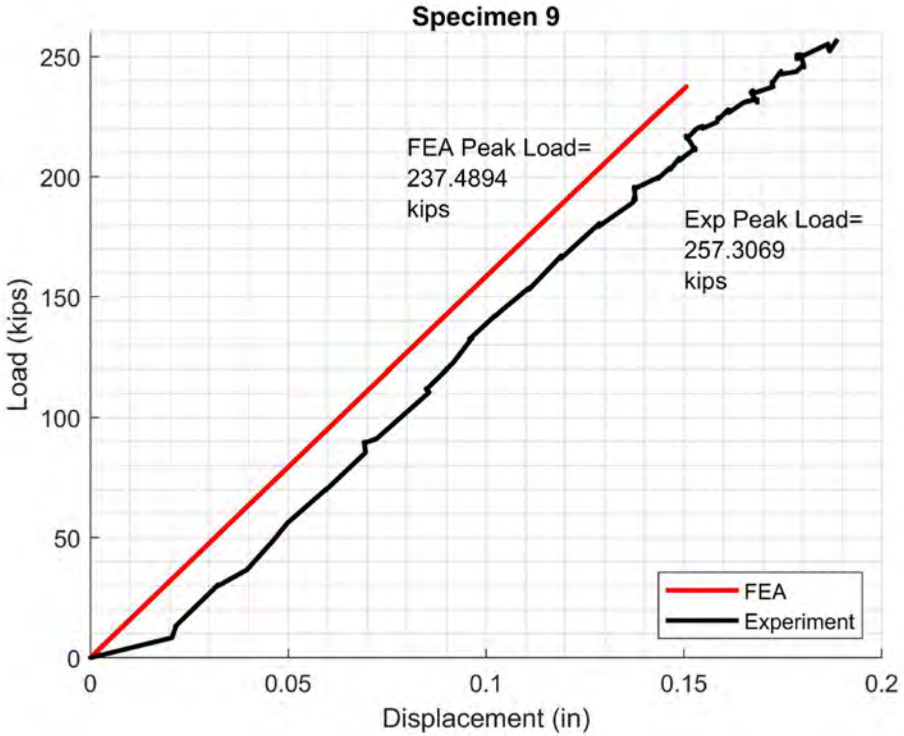




Beam Type: B33x132 Assumed
Intact Thickness: 0.58 inches
Height: 33.150 inches

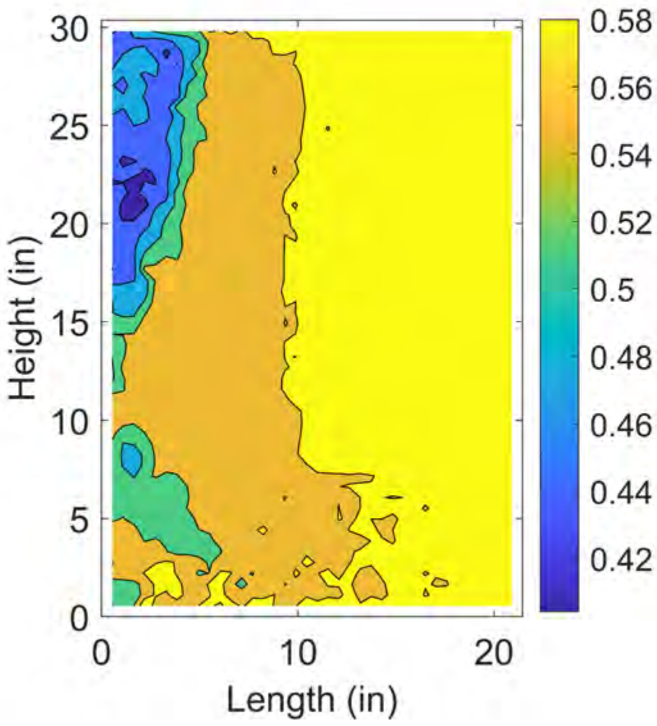
Peak Load:
247.36 kips

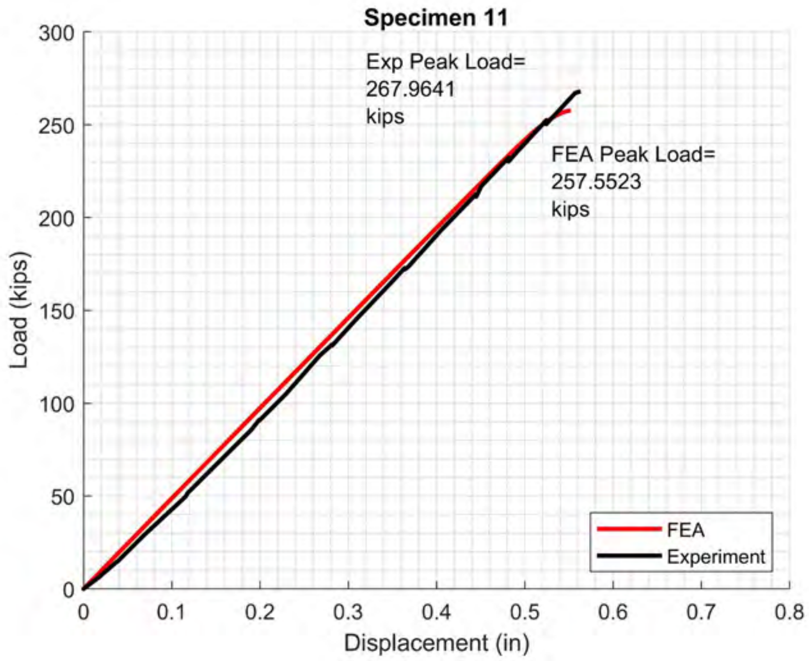




Beam Type: B33x132 Assumed
Intact Thickness: 0.58 inches
Height: 33.150 inches

Peak Load:
257.31 kips

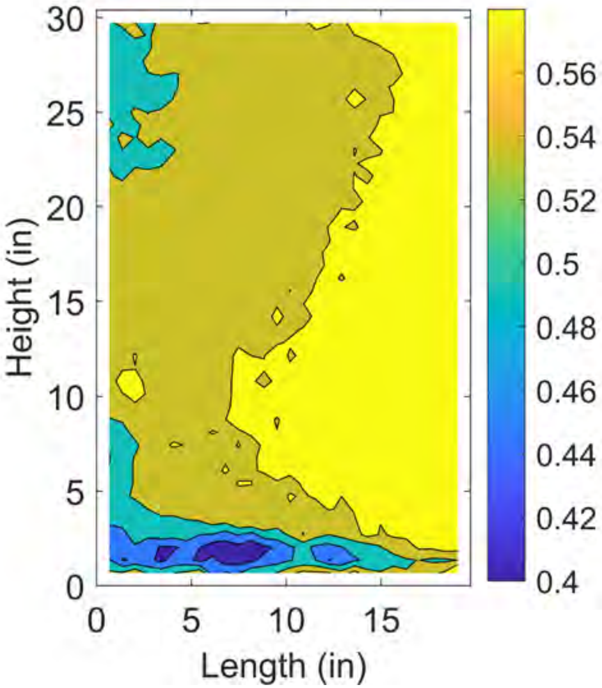


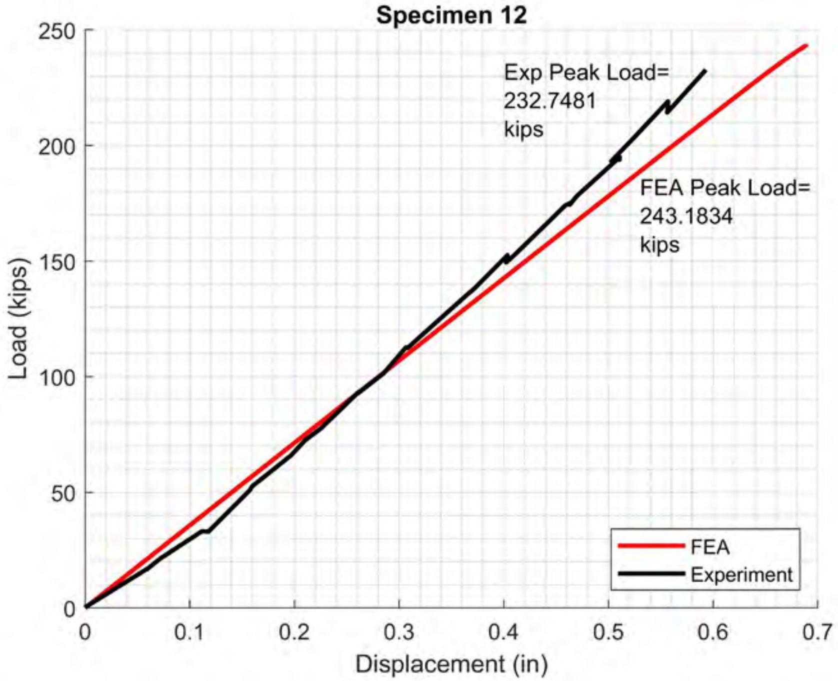


Beam Type: B33x132 Assumed
Intact Thickness: 0.58 inches
Height: 33.150 inches

Peak Load:
267.14 kips

Maine 10

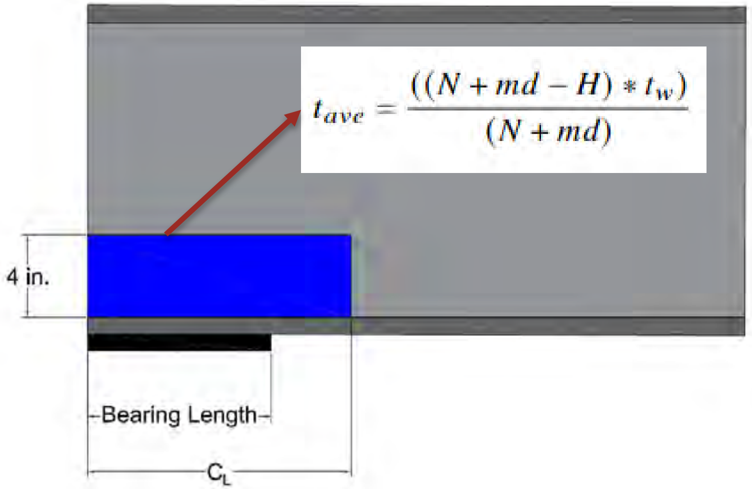




Beam Type: B33x132 Assumed
Intact Thickness: 0.58 inches
Height: 33.150 inches

Peak Load:
232.32 kips

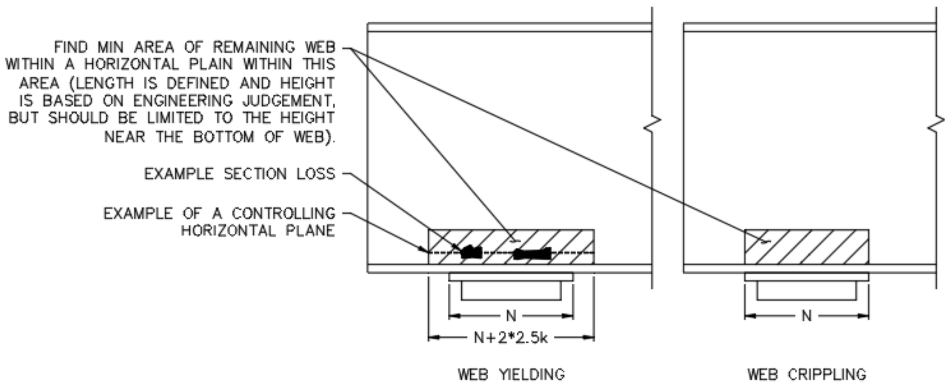
MassDOT



Web Crippling

$$R_n = a * \sqrt{E * F_y * t_f} * t_{ave}^{1.5} + b^{\frac{(0.33*d)}{N}} * (\frac{4(N - H)}{d} - 0.2) * \frac{\sqrt{EF_y t_f}}{t_{ave}^{1.5}} * t_{ave}^{3} * (\frac{CL}{(N + md)})^{0.15}$$

AASHTO LRFD

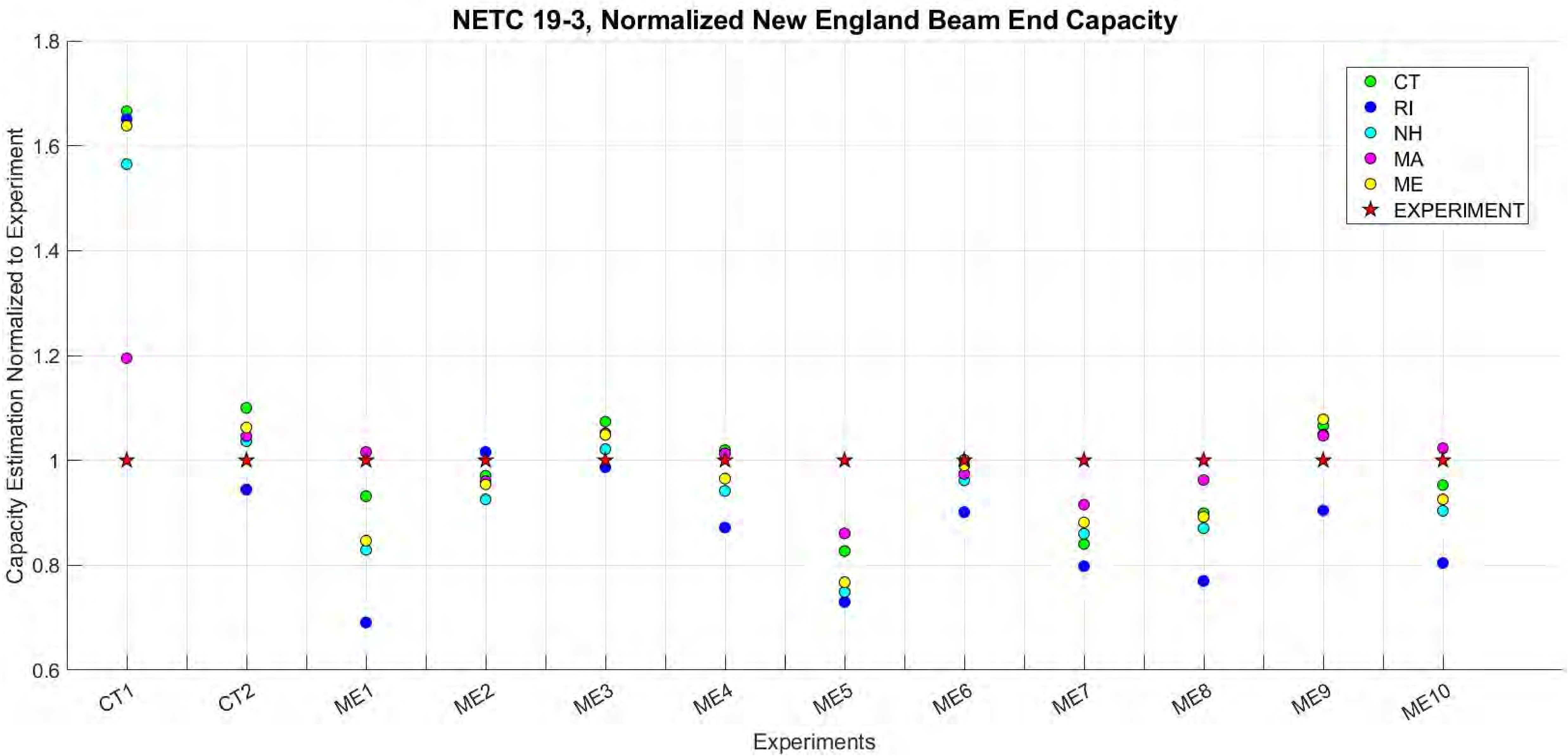


Courtesy: RIDOT

Web Crippling

$$R_n = (0.4 * t_{wcrip}^2 * (1 + (\frac{4N}{d} - 0.2) * (\frac{t_{wcrip}}{t_f})^{1.5}) * \sqrt{\frac{(E_S * F_y * t_f)}{t_{wcrip}}}$$

Comparison of Capacity Estimation



Corrosion Profiles:

- The groupings of **W1/W2 and W3/W4** corrosion profiles were the most prevalent observed throughout the data of bridge inspections provided by the states of New England
- Beams from the same bridge exhibit similar corrosion shapes

Scanning:

- Scanning provides the inspector/user with a comprehensive profile for a corroded end as opposed to just using visual and point measurements
- **Enhanced Inspection:** Easy to use even with limited access
- **High fidelity modelling and measurement reliability:** More data, higher accuracy, higher precision

Experiments and Ratings :

- Each experiment was successful in capturing capacity of the corroded end; failure in the form of **web buckling** was achieved in each experiment
- Overall**, MassDOT's** capacity predictions for corroded beam ends performed with higher accuracy and consistency across all twelve experiments

massDOT Massachusetts Department of Transportation

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U.S. Department of Transportation Federal Highway Administration

More detailed information can be found:

1. Tzortzinis, G., Knickle, B., Bardow, A., Breña, S., Gerasimidis S. “Strength evaluation of deteriorated girder ends. I: Experimental study on naturally corroded I-beams.” *Thin-Walled Structures,* 2021.

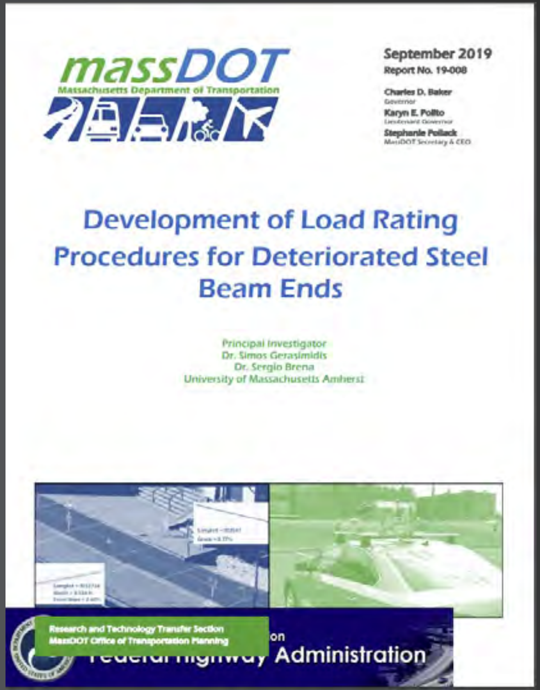
2. Tzortzinis, G., Knickle, B., Bardow, A., Breña, S., Gerasimidis, S. “Strength evaluation of deteriorated girder ends. II: Numerical study on corroded I-beams.” *Thin-Walled Structures, 2021.*

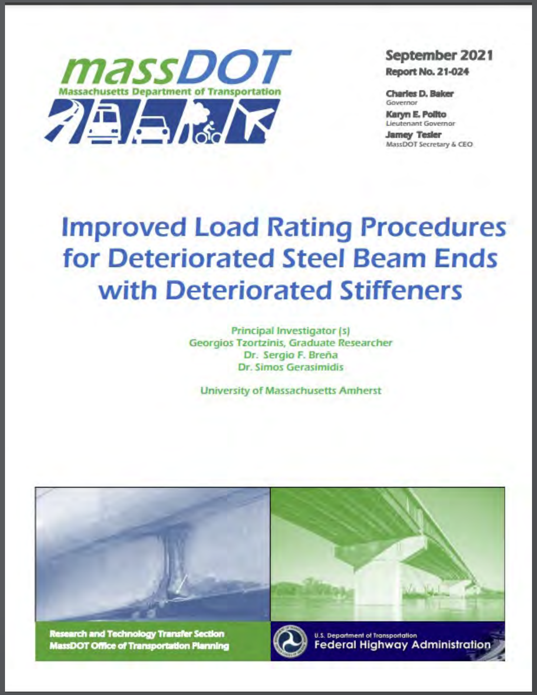
3. Tzortzinis, G., Breña, S., Gerasimidis, S. “Experimental, computational and analytical evaluation of plate girders with corroded ends.” (In Press)

4. Tzortzinis, G., Ai, C., Breña, S., Gerasimidis, S. “Using 3D laser scanning for estimating the capacity of corroded steel girders: Experiments, computations and analytical solutions.” (Under Review)

5. Tzortzinis, G., Gerasimidis, S., and S. Breña. 2021 “Improved load rating procedures for deteriorated steel beam ends with deteriorated stiffeners. *Final Report”. MassDOT Research Rep. 21-024, Massachusetts Department of Transportation, Office of Transportation Planning*, Boston, MA

6. Tzortzinis, G., Gerasimidis, S., Breña, S., and B. Knickle. 2019. “Development of load rating procedures for deteriorated steel beam ends: deliverable 4.” *MassDOT Research Rep. 19-008, Massachusetts Department of Transportation, Office of Transportation Planning*, Boston, MA





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Thank You!

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