Appendix E – BridgeGuard Maryland Avenue Delamination Report

Bridge Delamination Report

Grand Rapids, Michigan

Maryland Ave. over I-96

BridgeGuard, Inc.

07/09/2014

Introduction

Bridge delaminations, or anomalies, can be detected within the thermal imagery captured during both daytime and overnight hours as a result of the natural thermal transition within a structure due to normal diurnal environmental exposure.

Delaminations within the concrete interrupt the flow of thermal energy to the inner core and, consequently, those areas will show higher/lower surface temperatures than the surrounding area. The BridgeGuard program exploits this situation by applying an IR camera as a thermal fault detection device. Care was taken to optimize the natural diurnal contrast between potential delaminations and the otherwise homogeneous material to include imaging at the proper time of the day and in appropriate environmental/weather conditions.

This report is presented to document the findings of a thermal infrared image analysis carried out on the bridge identified within this report along with the data specific to that bridge. The defects in this report are a close approximation of actual size and location. The system is a thermal infrared sensor suite that applies computer software tools designed to acquire appropriate information from the collected data, and maintain that data to ensure its availability for further analysis or distribution.

Bridge:	Maryland Ave
Client Name:	MTU
Proposal Number:	N/A
Report Date:	07/09/2014

Lead Field Technician: X____________________
Ben Ruohonen

Data Analysis Technician: X____________________
Chad Therrian

QA/QC Technician X____________________
Dave Torola

Bridge Information

Client: MDOT

NBI Structure No.: Maryland Ave

Number of Lanes: 2

Bridge Width: 2-12’ center scans

Bridge Length: 230’

Year Built: N/A

State Name: Michigan

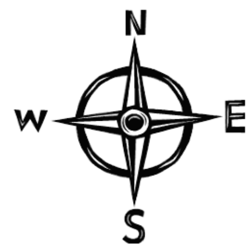
Location: Grand Rapids, MI

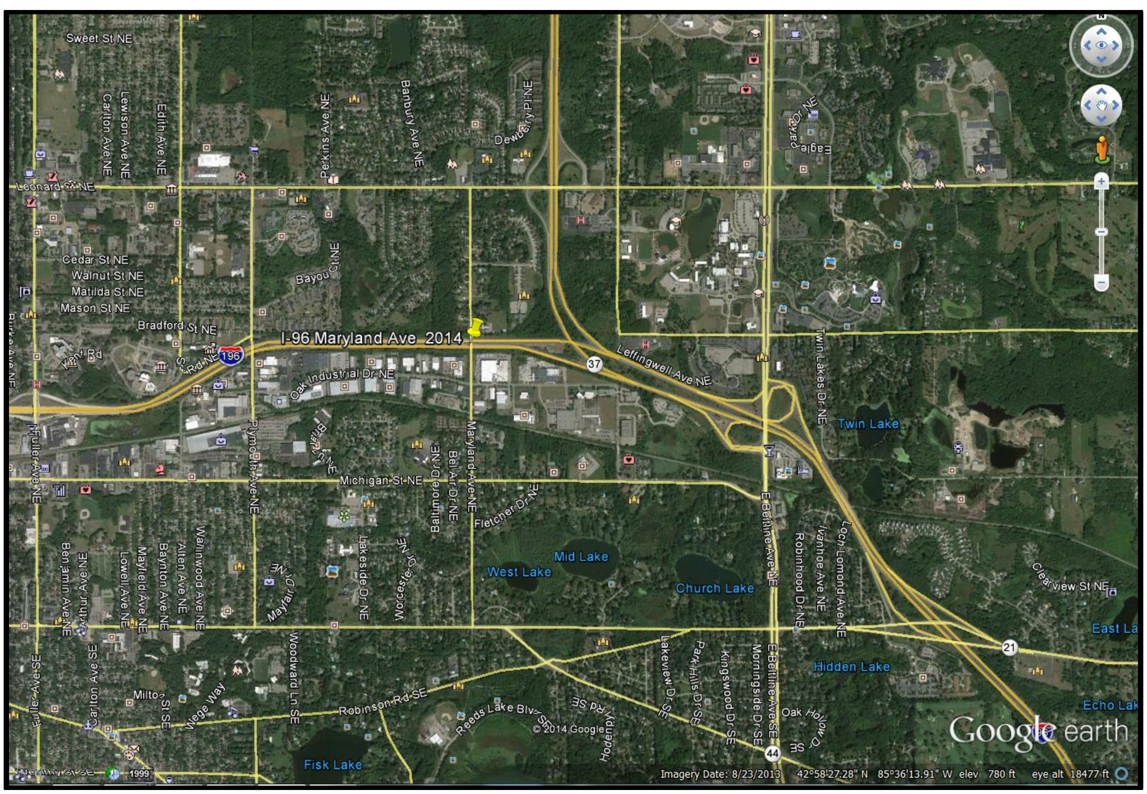
County: Kent

Facility Carried: Maryland Ave

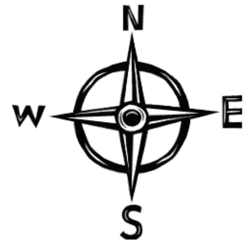
Feature Intersect: Interstate 96

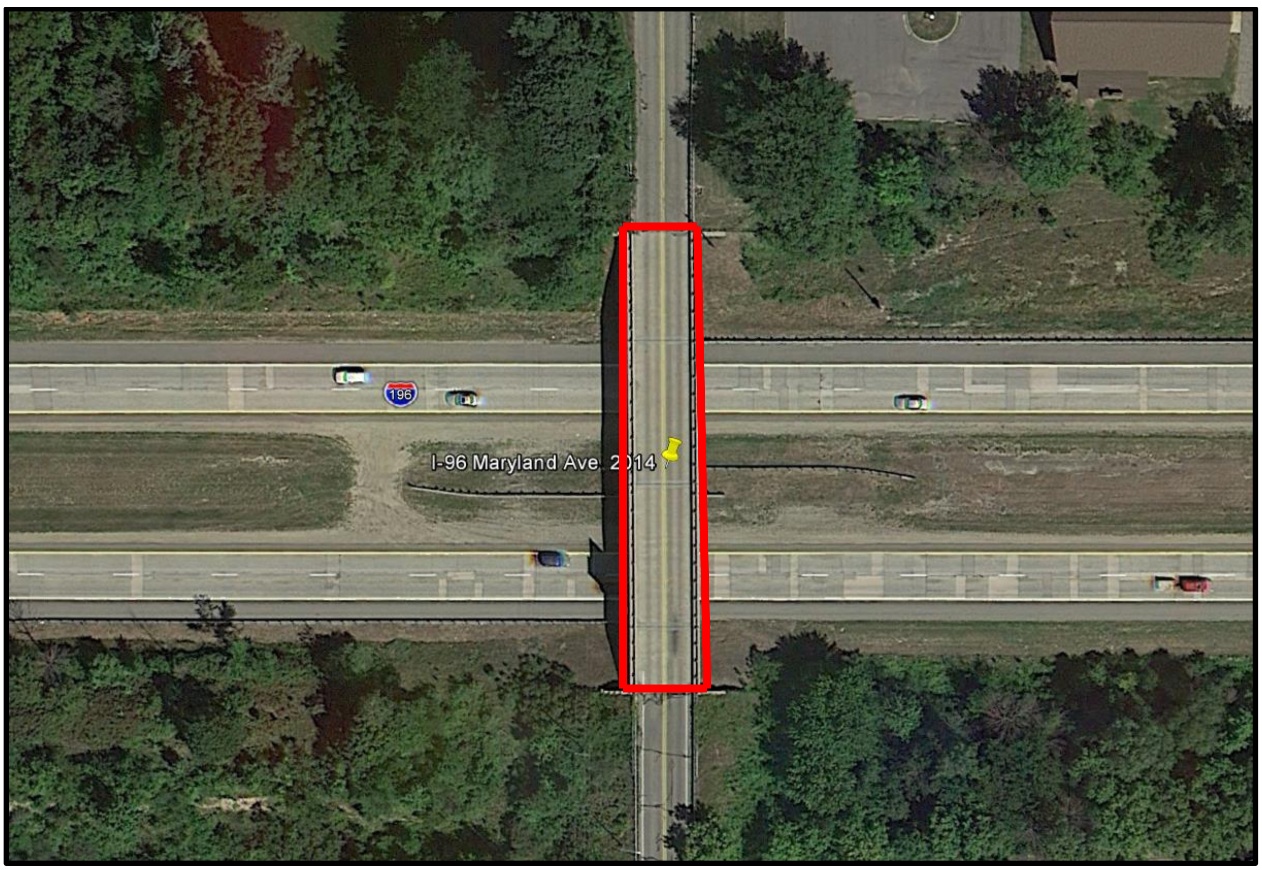
Number of Spans: 4





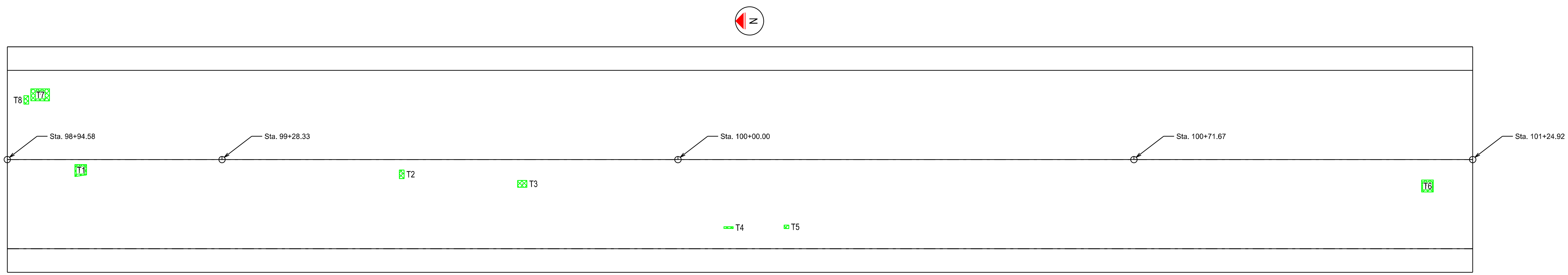
Bridge Layout
(Top View)





NOTES:

1. STATION REFERENCE DRAWING 41027-S24.



KEY

T#	TOP DECK DELAMINATION
TP#	TOP DECK PATCH
MC#	MAP CRACK
S#	TOP DECK SPALL
TC#	TOP DECK CRACK

SCALE 1"=16'6"

DEFECTS SHOWN ARE ONLY A CLOSE APPROXIMATION OF ACTUAL SIZE AND LOCATION.

BRIDGE NUMBER	-
BRIDGE OWNER	MDOT
CONTRACT ISSUED BY	MTU
CONTRACT NUMBER	-
DRAWN BY	J. STOUT
DATE	7-09-2014

BRIDGEGUARD
www.bridgeguard.net
A DIVISION OF TALON RESEARCH INC.
401 QUINCY ST.
HANCOCK, MI 49930

TITLE: MARYLAND AVE

SIZE	DRAWING NUMBER		
B	41027-S24-01		
SCALE	CAGE CODE	SHEET	REV
-	-	1 of 1	-

Defect T #	Length	Width	Area (SF)	Station Final	Offset	Notes
1	1.87	1.82	3.4	99+05.95	R1.6	
2	1.34	0.72	2.06	99+56.60	R2.2	
3	1.07	1.46	1.56	99+75.55	R3.8	
4	0.26	1.46	0.38	100+07.98	R10.6	
5	0.53	0.73	0.38	100+17.09	R10.6	
6	1.87	1.82	3.4	101+17.69	R4.0	
7	1.87	2.92	5.46	98+99.76	L10.3	
8	1.34	0.73	0.97	98+97.57	L9.5	
Total			17.61			

Components	# of Delaminations	Total Element Area (SF)	Delaminated Area (SF)	% Delaminated
Deck Top	8	5,520	17.6	0.32%
TOTALS =	**8**	**5,520**	**17.6**	**0.3%**

*Note: One 12' scan in each direction, no safety lanes were scanned.

Appendix F – BridgeGuard Freer Road Delamination Report

Bridge Delamination Report

Ann Arbor, Michigan

Freer Road over I-94

BridgeGuard, Inc.

07/24/2014

Introduction

Bridge delaminations, or anomalies, can be detected within the thermal imagery captured during both daytime and overnight hours as a result of the natural thermal transition within a structure due to normal diurnal environmental exposure.

Delaminations within the concrete interrupt the flow of thermal energy to the inner core and, consequently, those areas will show higher/lower surface temperatures than the surrounding area. The BridgeGuard program exploits this situation by applying an IR camera as a thermal fault detection device. Care was taken to optimize the natural diurnal contrast between potential delaminations and the otherwise homogeneous material to include imaging at the proper time of the day and in appropriate environmental/weather conditions.

This report is presented to document the findings of a thermal infrared image analysis carried out on the bridge identified within this report along with the data specific to that bridge. The defects in this report are a close approximation of actual size and location. The system is a thermal infrared sensor suite that applies computer software tools designed to acquire appropriate information from the collected data, and maintain that data to ensure its availability for further analysis or distribution.

Bridge:	Freer Road
Client Name:	MTU
Proposal Number:	N/A
Report Date:	07/24/2014

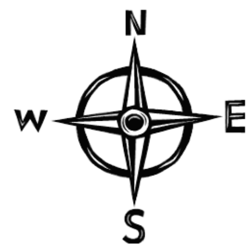
Lead Field Technician: X____________________
Ben Ruohonen

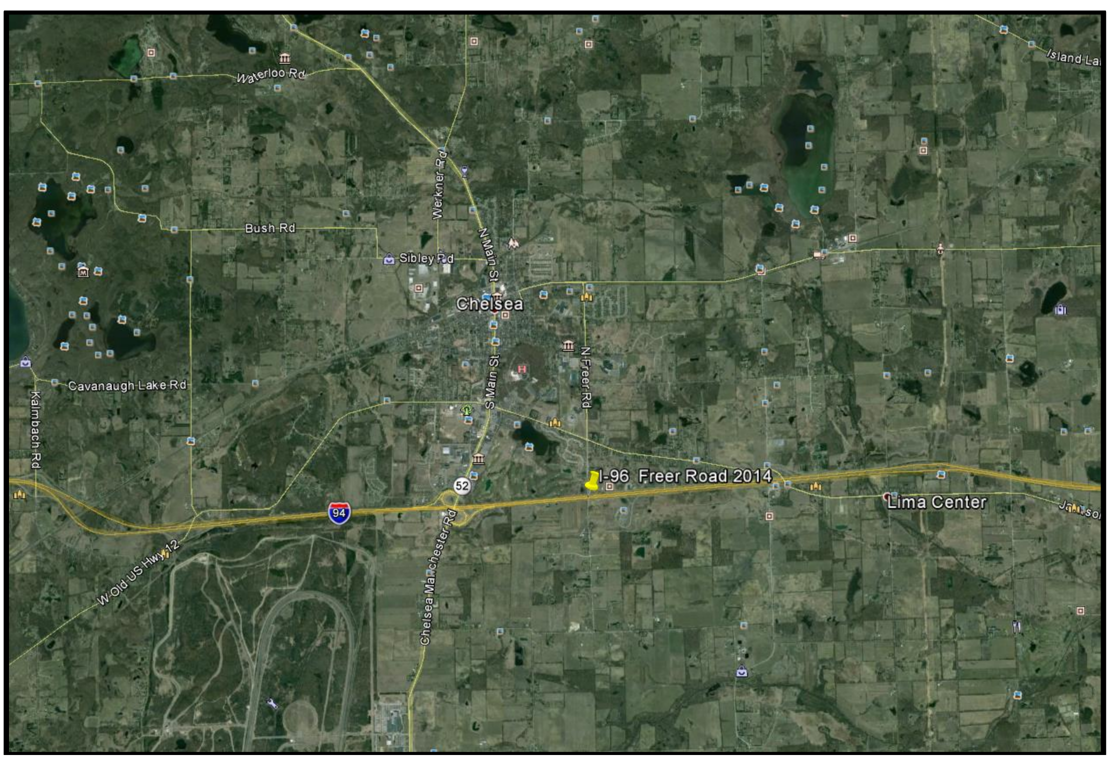
Data Analysis Technician: X____________________
Chad Therrian

QA/QC Technician X____________________
Dave Torola

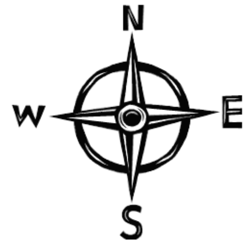
Bridge Information

Client:	MDOT
NBI Structure No.:	Freer Road
Number of Lanes:	2
Bridge Width:	24’
Bridge Length:	213’
Year Built:	N/A
State Name:	Michigan
Location:	Ann Arbor, MI
County:	Jackson
Facility Carried:	Freer Road
Feature Intersect:	Interstate 94
Number of Spans:	4



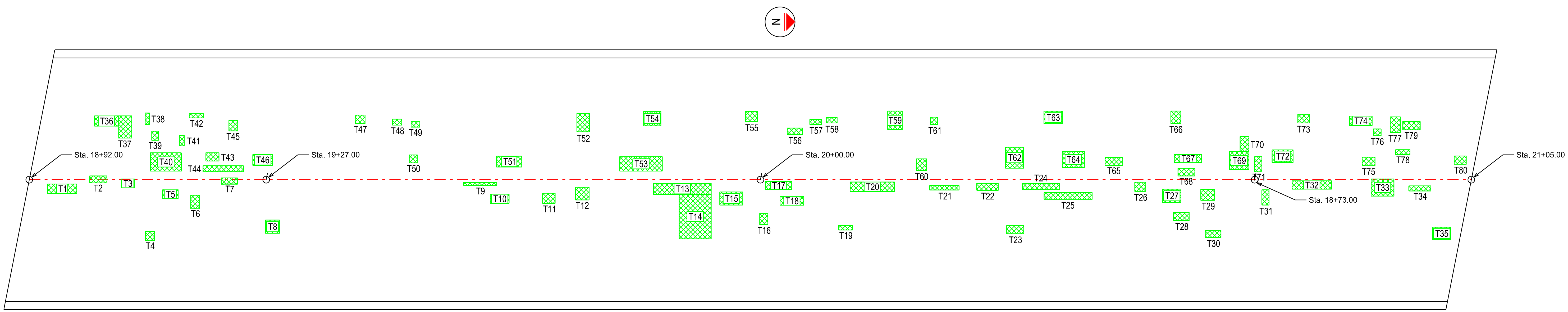


Bridge Layout
(Top View)



NOTES:

1. STATION REFERENCE DRAWING 81105.



DEFECTS SHOWN ARE ONLY A CLOSE APPROXIMATION OF ACTUAL SIZE AND LOCATION.

SCALE 1"=15'0"

BRIDGE NUMBER	-
BRIDGE OWNER	MDOT
CONTRACT ISSUED BY	MDOT
CONTRACT NUMBER	-
DRAWN BY	C. STUROS
DATE	07/24/2014

BRIDGEGUARD www.bridgeguard.net

A DIVISION OF TALON RESEARCH INC. 401 QUINCY ST. HANCOCK, MI 49930

TITLE: FREER RD

SIZE	DRAWING NUMBER		
B	41027-S24-02		
SCALE	CAGE CODE	SHEET	REV
-	-	1 of 1	-

Defect T #	Length	Width	Area (SF)	Station Final	Offset	Notes
1	4.3	1.4	6.0	18+96.85	R1.3	
2	2.6	1.0	2.6	19+02.42	R0.0	
3	1.9	1.3	2.5	19+06.65	R0.6	
4	1.4	1.4	2.0	19+09.82	R8.3	
5	2.3	1.3	3.0	19+12.76	R2.0	
6	1.3	2.0	2.6	19+16.48	R3.3	
7	2.4	0.9	2.2	19+21.66	R0.2	
8	2.1	1.9	4.0	19+27.89	R7.0	
9	4.9	0.5	2.5	19+58.65	R0.7	
10	2.8	1.4	3.9	19+61.46	R2.8	
11	1.8	1.5	2.7	19+68.65	R2.6	
12	2.0	1.9	3.8	19+73.65	R2.0	
13	8.5	1.6	13.6	19+88.54	R1.3	
14	4.7	6.6	31.0	19+90.26	R5.5	
15	3.4	1.9	6.5	19+95.61	R2.7	
16	1.2	1.7	2.0	20+00.55	R5.9	
17	3.9	1.2	4.7	20+02.69	R0.9	
18	3.5	1.3	4.6	20+04.86	R3.1	
19	2.1	0.7	1.5	20+12.75	R7.1	
20	6.5	1.4	9.1	20+16.64	R1.0	
21	4.3	0.6	2.6	20+27.33	R1.2	
22	3.2	1.0	3.2	20+33.62	R1.1	
23	2.5	1.2	3.0	20+37.70	R7.5	
24	5.5	0.9	5.0	20+41.52	R1.0	
25	7.1	1.0	7.1	20+45.38	R2.5	
26	1.6	1.3	2.1	20+56.11	R1.0	
27	2.8	2.0	5.6	20+60.81	R2.5	
28	2.3	1.2	2.8	20+62.05	R5.5	
29	2.0	1.6	3.2	20+66.14	R2.3	
30	2.3	1.1	2.5	20+66.90	R8.1	
31	1.1	2.2	2.4	20+74.82	R2.6	
32	5.8	1.2	7.0	20+81.53	R0.8	
33	3.4	2.5	8.5	20+92.03	R1.2	
34	3.2	0.7	2.2	20+97.31	R1.3	
35	2.6	1.8	4.7	21+00.65	R8.0	
36	3.5	1.5	5.3	19+03.51	L8.6	
37	2.0	3.3	6.6	19+06.12	L7.6	
38	0.7	1.7	1.2	19+09.48	L9.0	
39	1.0	1.4	1.4	19+10.60	L6.6	
40	4.6	2.7	12.4	19+12.20	L2.6	
41	0.7	1.6	1.1	19+14.54	L5.7	
42	2.1	0.6	1.3	19+16.75	L9.5	
43	1.9	1.2	2.3	19+19.17	L3.3	
44	6.0	0.9	5.4	19+20.54	L1.7	

Freer Road Defect Table

Defect T #	Length	Width	Area (SF)	Station Final	Offset	Notes
45	1.3	1.6	2.1	19+22.19	L7.9	
46	3.0	1.6	4.8	19+26.51	L2.9	
47	1.5	1.3	2.0	19+40.94	L8.9	
48	1.4	0.9	1.3	19+46.50	L8.5	
49	1.3	0.8	1.0	19+49.25	L8.3	
50	1.2	1.2	1.4	19+48.67	L3.0	
51	3.7	1.6	5.9	19+62.86	L2.7	
52	1.8	2.7	4.9	19+73.84	L8.5	
53	6.3	2.1	13.2	19+82.57	L2.4	
54	2.5	2.1	5.3	19+84.04	L9.0	
55	1.8	1.5	2.7	19+98.69	L9.2	
56	2.3	1.0	2.3	20+05.07	L7.1	
57	1.7	0.7	1.2	20+08.06	L8.5	
58	1.6	0.8	1.3	20+10.60	L8.7	
59	2.2	2.7	5.9	20+19.83	L8.9	
60	1.5	1.7	2.6	20+23.86	L2.3	
61	1.1	1.1	1.2	20+25.67	L8.7	
62	2.7	3.1	8.4	20+37.64	L3.2	
63	2.7	1.8	4.9	20+43.25	L9.3	
64	3.3	2.4	7.9	20+46.20	L3.0	
65	2.6	1.2	3.1	20+52.36	L2.7	
66	1.5	1.8	2.7	20+61.49	L9.3	
67	4.1	1.2	4.9	20+63.21	L3.0	
68	2.5	1.1	2.8	20+62.99	L1.0	
69	2.9	2.7	7.8	20+70.80	L2.9	
70	1.3	2.2	2.9	20+71.56	L5.1	
71	1.1	2.2	2.4	20+73.55	L2.3	
72	3.1	1.8	5.6	20+77.10	L3.6	
73	1.7	1.3	2.2	20+80.41	L9.0	
74	3.3	1.4	4.6	20+88.84	L8.7	
75	1.9	1.3	2.5	20+90.03	L2.7	
76	1.1	1.0	1.1	20+91.31	L6.9	
77	1.5	2.3	3.5	20+93.82	L8.0	
78	2.1	0.7	1.5	20+95.05	L4.1	
79	2.6	1.2	3.1	20+96.13	L8.1	
80	1.8	1.2	2.2	21+03.37	L2.9	
Total			**342.3**			

Components	# of Delaminations	Total Element Area (SF)	Delaminated Area (SF)	% Delaminated
Deck Top	80	5,112	343.0	6.71%
TOTALS =	**80**	**5,112**	**343.0**	**6.7%**

*Note: One 12' scan in each direction, no safety lanes were scanned.

Total Bridge Area	7667
Scanned Bridge Area	5016

Appendix G – MDOT General Training Session, October 16, 2014

Evaluation of Bridge Decks using NDE at Near Highway Speeds for Effective Asset Management

NDE Training and Implementation Session

Thursday, Oct. 16, 2014

Lansing, MI

Today's Outline

- Meet our team
- Overview of NDE technologies for Bridge Condition Assessment
- Field Demonstrations, Data Output, Processing, and Interpretation
- Integration of NDE with MDOT Sounding
- Equipment Demonstration
- Implementation Discussion
- Q & A

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Project Objectives

1. Investigate NDE techniques that can be deployed at- or near-highway speeds augmenting bridge deck inspection programs (by detecting and quantifying delaminations, cracks, and spalls) for the top surface of the bridge deck.

2. Investigate the condition of deck bottom surfaces and fascia beams in a hands-off manner using NDE technologies.

3. Provide MDOT with training to deploy acceptable technologies.

Review of NDE Technologies (remote sensing)

- BVRCS – Bridge Viewer Remote Camera System
- 3DOBS – 3D Optical Bridge-evaluation System
- Passive IR Thermography (BridgeGuard)
- Active IR Thermography

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BVRCS

- GoPro HERO3
- 12 Megapixel photo capability
- Lightweight, camera: 74g (2.6 oz) and camera with housing: 136g 4.8 oz)
- Up to 12 frames per second at 8.8 MP
- $400

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3DOBS Highway Speed Spall Detection

- Red-EPIC camera system
- 13.8 MP up to 60 frames per second
- Higher frame rate available at lower resolutions
  - 100 fps with compression
- $30,000

3DOBS High-Resolution Crack Detection

- Nikon D800 – full-sized (FX) sensor, 36.3 Mp, 4 fps
- Weight prime lens, weights ~1.5 kg
- max 10 mph speed
- $2,800 ($480 Lens)

Body type	
Body type	Mid-size SLR
Body material	Magnesium alloy
Sensor	
Max resolution (px)	7360 x 4912
Effective pixels	36.3 megapixels
Sensor photo detectors	36.8 megapixels
Other resolutions	6144 x 4912, 6144 x 4080, 5520 x 3680, 4800 x 3200, 4608 x 3680, 4608 x 3056, 3680 x 2456, 3600 x 2400, 3072 x 2456, 3072 x 2040, 2400 x 1600
Image ratio w:h	5:4, 3:2
Sensor size	Full frame (35.9 x 24 mm)
Sensor type	CMOS
Processor	Expeed 3
Color space	sRGB, Adobe RGB
Color filter array	Primary Color Filter
Image	
ISO	100 - 6400 in 1, 1/2 or 1/3 EV steps (50 - 25600 with boost)
White balance presets	12
Custom white balance	Yes (5)
Image stabilization	No
Uncompressed format	.NEF (RAW)
JPEG quality levels	Fine, Normal, Basic
File format	• NEF (RAW): 12 or 14 bit, lossless compressed, compressed or uncompressed • TIFF (RGB) • JPEG
Optics & Focus	
Autofocus	• Phase Detect • Multi-area • Selective single-point • Tracking • Single • Continuous • Face Detection • Live View

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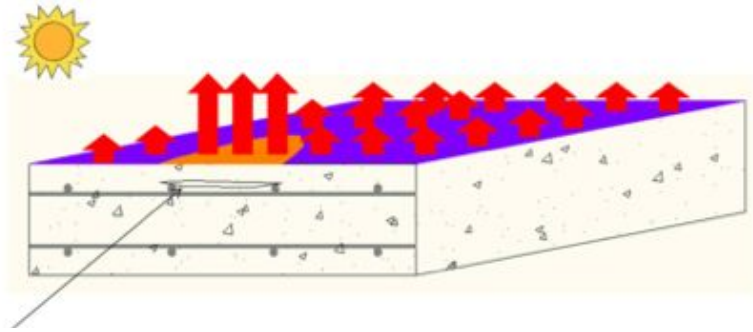
Passive IR Thermography (BridgeGuard)

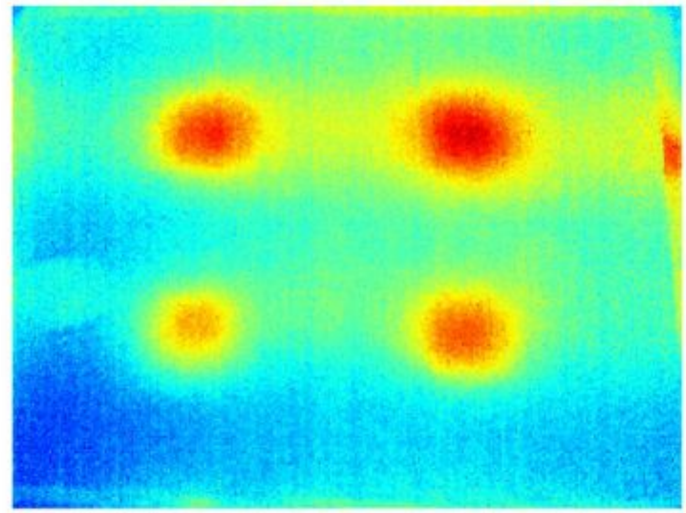


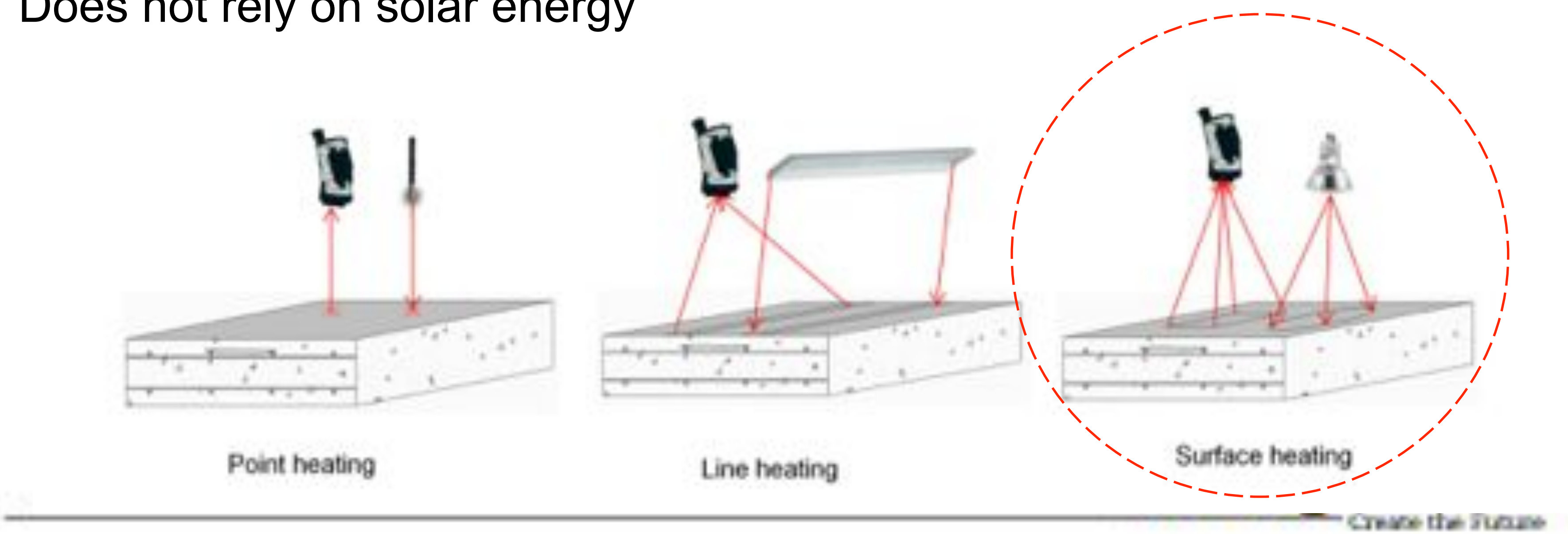
Delamination

- Sun provides thermal impulse
- Heat transfers from surface to concrete interior
- Delaminations restrict heat transfer and appear as hot spots on thermal images during daytime hours
- Maximum contrast occurs during specific testing time window

Active Infrared Thermography

- Infrared heater provides thermal impulse
- Heat transfer restricted by delaminations which appear as hot spots
- Surface heating method allows for larger inspection areas and reduced inspection time
- Not limited to testing time windows
- Does not rely on solar energy





Active Infrared Thermography Equipment

FLIR SC640
- 640 x 480 pixels
- High temperature resolution of 0.1 ^{o}F
- Graphical user interface
- Real time thermal images and temperature output
- $15,000 (used) - $50,000 (new)

FLIR Tau 2
- 336 x 256 pixels
- 1.75 in. x 1.75 in. x 1.2 in.
- Records data to external memory
- Digital number output requiring manual calibrations
- $3500 - $4000

1500 Watt Electric Infrared Heater
- Single tube element
- 7.5 lbs
- 9 in. x 16 in. x 16 in.
- $300-$400

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BVRCS and 3DOBS

- Objectives: To collect a photo inventory of the bridge as well as high resolution imagery for distress detection.

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BVRCS

- Low cost (<$1,000) deployable system that provides visual analysis of bridge deck conditions at the time of data collection.
- Consists of two GoPro Hero3 cameras that can be mounted to any vehicle and used at multiple sites without any additional costs.
- Images are processed and geotagged through GeoJot+ Core
- Hyperlinks are set up using both ArcMap and GeoJot+ Core capabilities allowing for visualization of the condition of the bridge deck at defined locations

3DOBS High-Res Crack Detection

- 20-Mile (#1279) & 24-Mile (#1282) over I-94
  - Standard MDOT inspection; collected 3DOBS High-Res data,
- US-131 NB (#5003) & US-131 SB (#5002) (over White Creek Ave)
  - MDOT detailed scoping inspection; Sept. 10, 2013, 3DOBS High-Res data
- Maryland Ave. (#4795)
  - MDOT detailed scoping inspection; May 28, 2014, 3DOBS High-Res
- Freer Rd. (#10940)
  - No MDOT inspection; 3DOBS High-Res

3DOBS High-Res Data Output

- High resolution imagery produced from 3DOBS-High Res (slower 36 mp version)
- On the left, is high resolution imagery of crack detection.
- Right is high resolution imagery of spall detection.
- DEM

3DOBS High-Res Results

- With imagery resolution of 0.5 mm, cracks down to 1 mm (just over 1/32nd inch) can be mapped.
- Maryland Ave cracks:
  - 35 Cracks were digitized
  - Total crack length – 386.6 in

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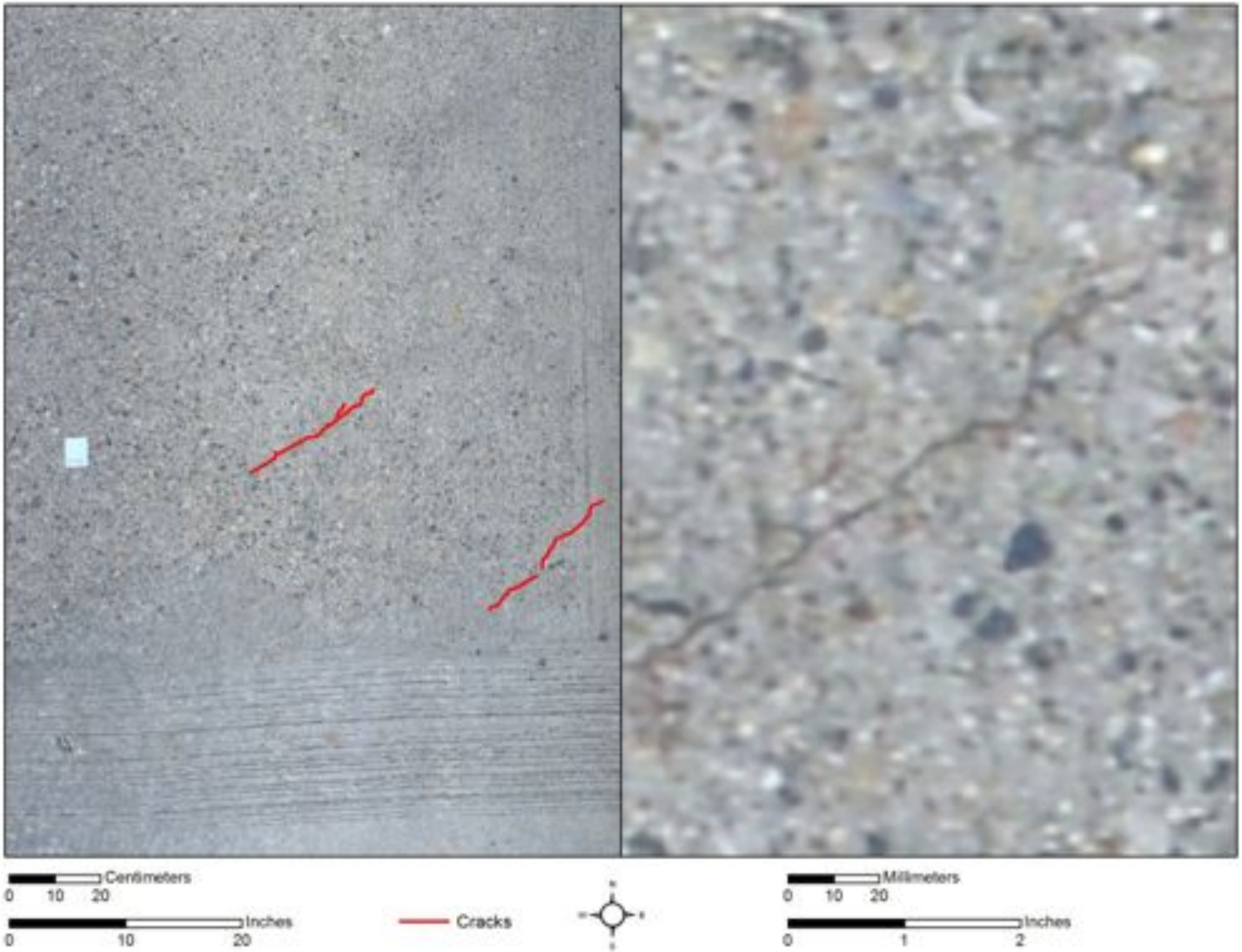
Detail of a 1 mm Crack



Crack detection requirements

- From new Bridge Element inspection manual – 2nd edition from D.Juntunen
- Categories: Good = <.012 inch; Fair = .012-.05”; Poor >.05”
  - Spacing requirements too
- Assessing 3DOBS High-Res capability to identify and categorize

AASHTO Bridge Element Inspection Manual 2nd ed /2013 DRAFT

Element #: 12 — Reinforced Concrete Deck

Description: This element defines all reinforced concrete bridge decks regardless of the wearing surface or protection systems used.

Classification: NBE - National Bridge Element **Units of Measurement:** sq.ft.

Quantity Calculation: The quantity for this element includes the area of the deck from edge to edge including any median areas and accounting for any flares or ramps present.

Condition State Definitions

Defects	Condition States			
	1	2	3	4
	GOOD	FAIR	POOR	SEVERE
Delamination/Spall/Patched Area (1080)	None	Delaminated. Spall 1 in. or less deep or 6 in. or less in diameter. Patched area that is sound.	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.
Exposed Rebar (1090)	None	Present without measurable section loss.	Present with measurable section loss, but does not warrant structural review.	
Efflorescence/Rust Staining (1120)	None	Surface white without build-up or leaching without rust staining.	Heavy build-up with rust staining.	
Cracking (RC and Other) (1130)	Width less than 0.012 in. or spacing greater than 3.0 ft.	Width 0.012–0.05 in. or spacing of 1.0–3.0 ft.	Width greater than 0.05 in. or spacing of less than 1 ft.	
Abrasion/Wear (PSC/RC) (1190)	No abrasion or wearing	Abrasion or wearing has exposed coarse aggregate but the aggregate remains secure in the concrete.	Coarse aggregate is loose or has popped out of the concrete matrix due to abrasion or wear.	
Damage (7000)	Not applicable	The element has impact damage. The specific damage caused by the impact has been captured in condition state 2 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in condition state 3 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in condition state 4 under the appropriate material defect entry.

Element Commentary

The deck evaluation is three dimensional in nature with the defects observed on the top surface, bottom surface, edges or all, and being captured using the defined condition states. Deck top or bottom surfaces that are not visible for inspection shall be assessed based on the available visible surface. If both top and bottom surfaces are not visible, the condition shall be assessed based on destructive and nondestructive testing or indicators in the materials covering the surfaces.

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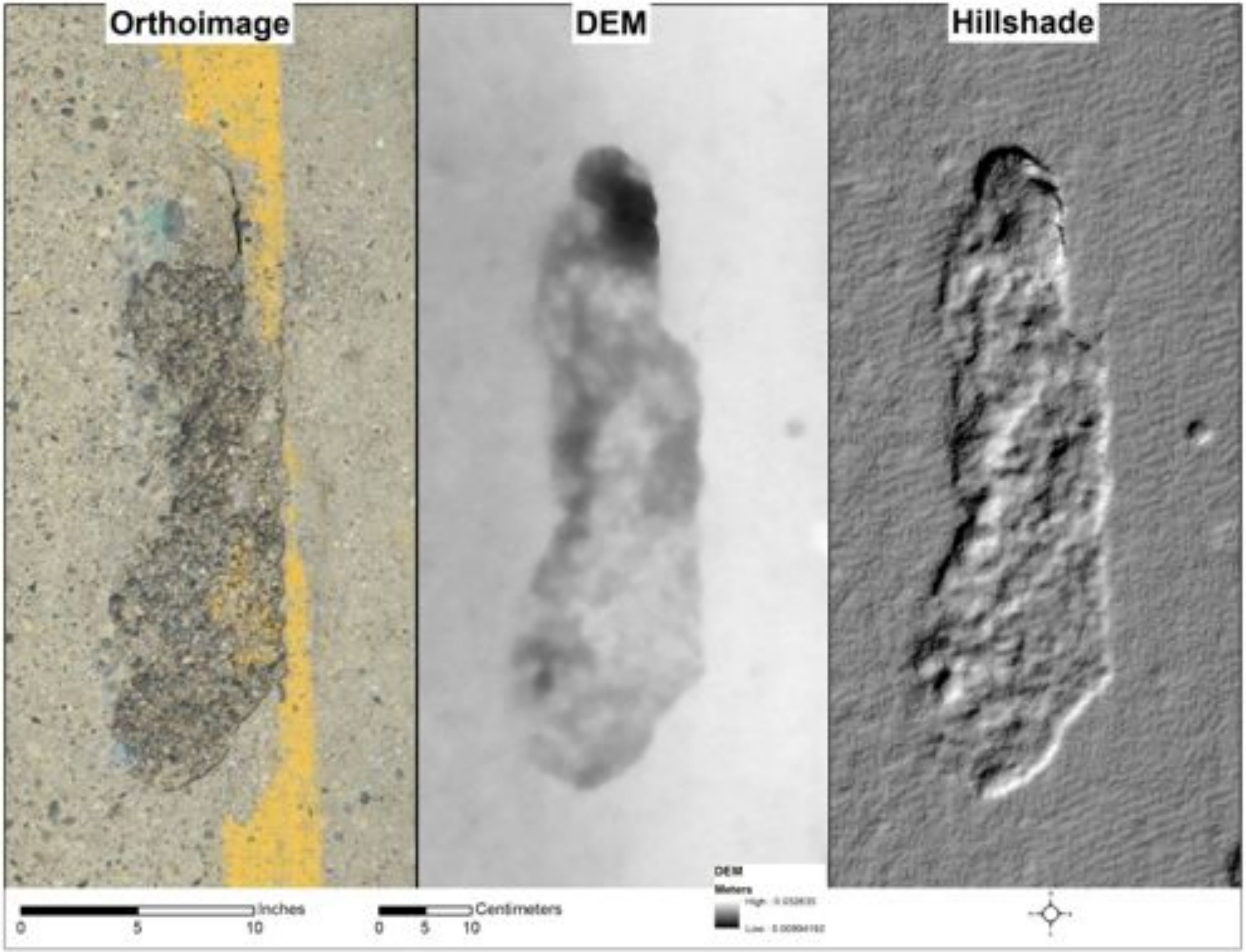
3DOBS Near Highway-Speed Spall Detection

- Maryland Ave. (#4795)
  - MDOT detailed scoping inspection; May 28, 2014, 3DOBS High-Speed

- Freer Rd. (#10940)
  - No MDOT inspection; 3DOBS High-Speed

3DOBS Near Highway-Speed Data



Spall Detection Algorithm

- Able to locate and characterize spalls by area and volume.
- Able to limit the minimum size of spalls detected.
- US-131 NB spall detection results
  - 9.9 ft^2 spalled
  - 1 % of bridge spalled

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Create the Future

Passive IR Thermography

- Objective: To detect bridge deck delaminations using thermal imagery and the natural thermal transition within the structure due to normal diurnal environmental exposure.

20 Mile over I-94

- Tested 8/9/13 at 11:45 am

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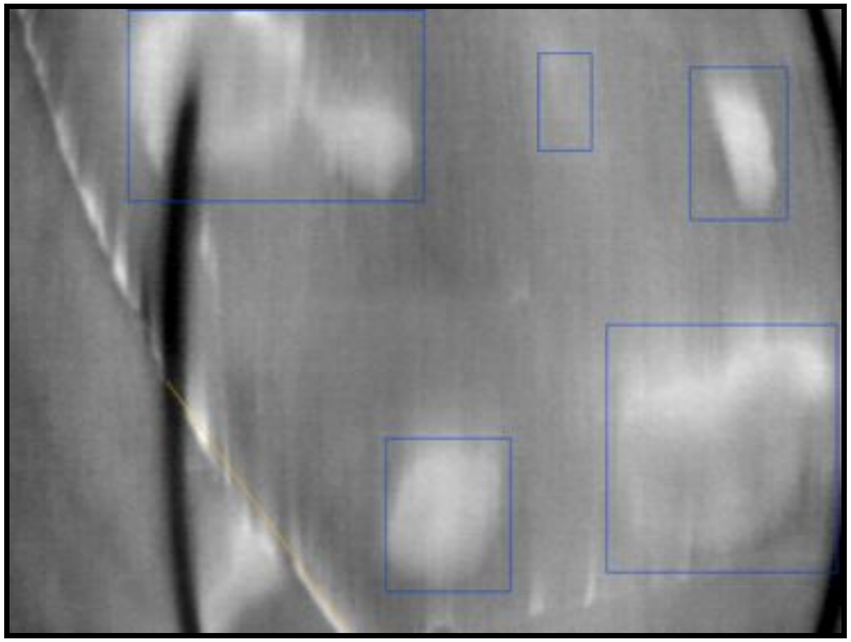
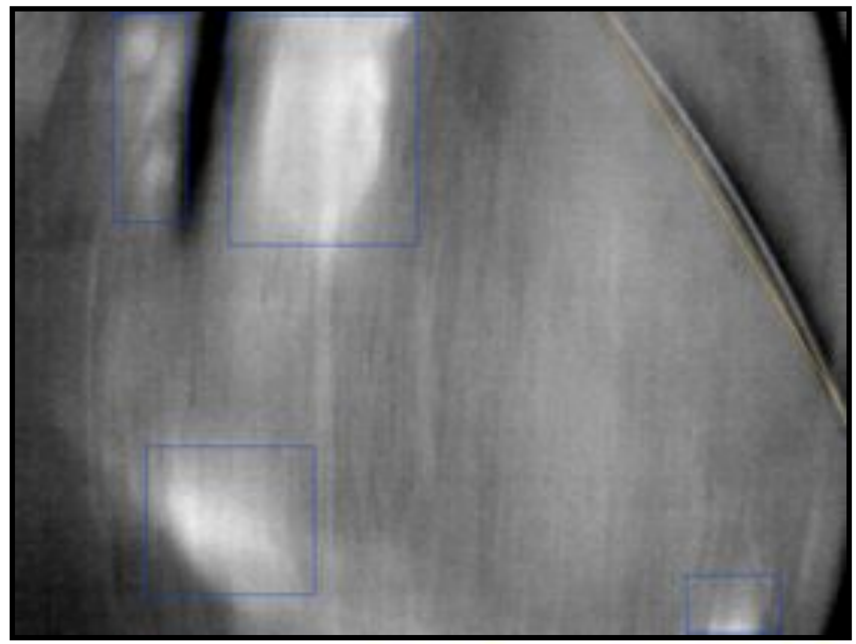
24 Mile over I-94

- Tested 8/9/13 at 12:15 pm

US131 NB over White Creek Ave

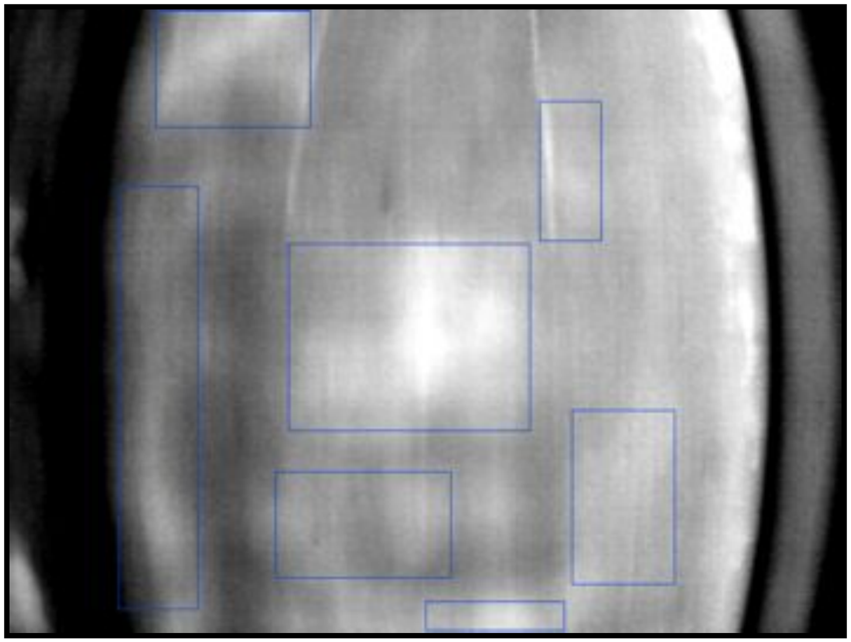
- Tested 8/9/13 at 3:45 pm

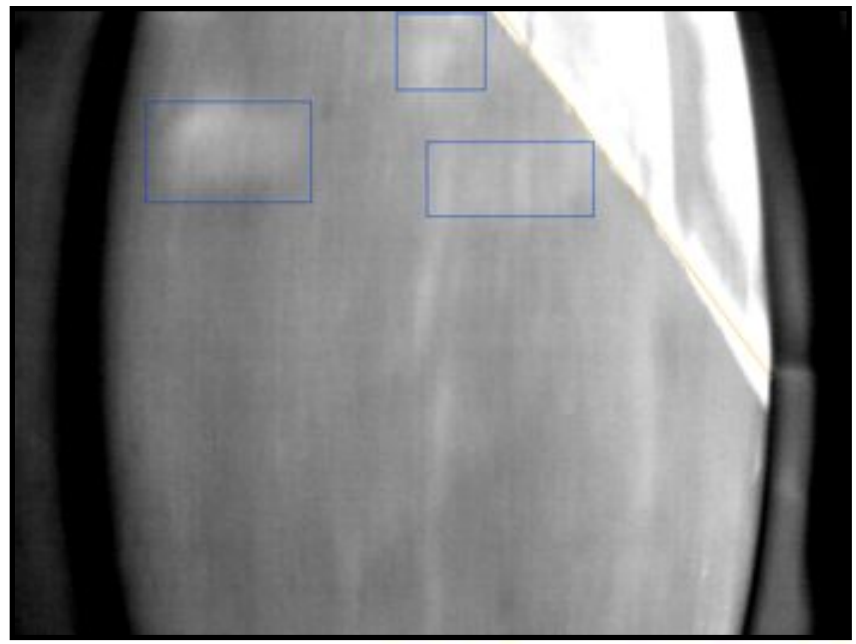




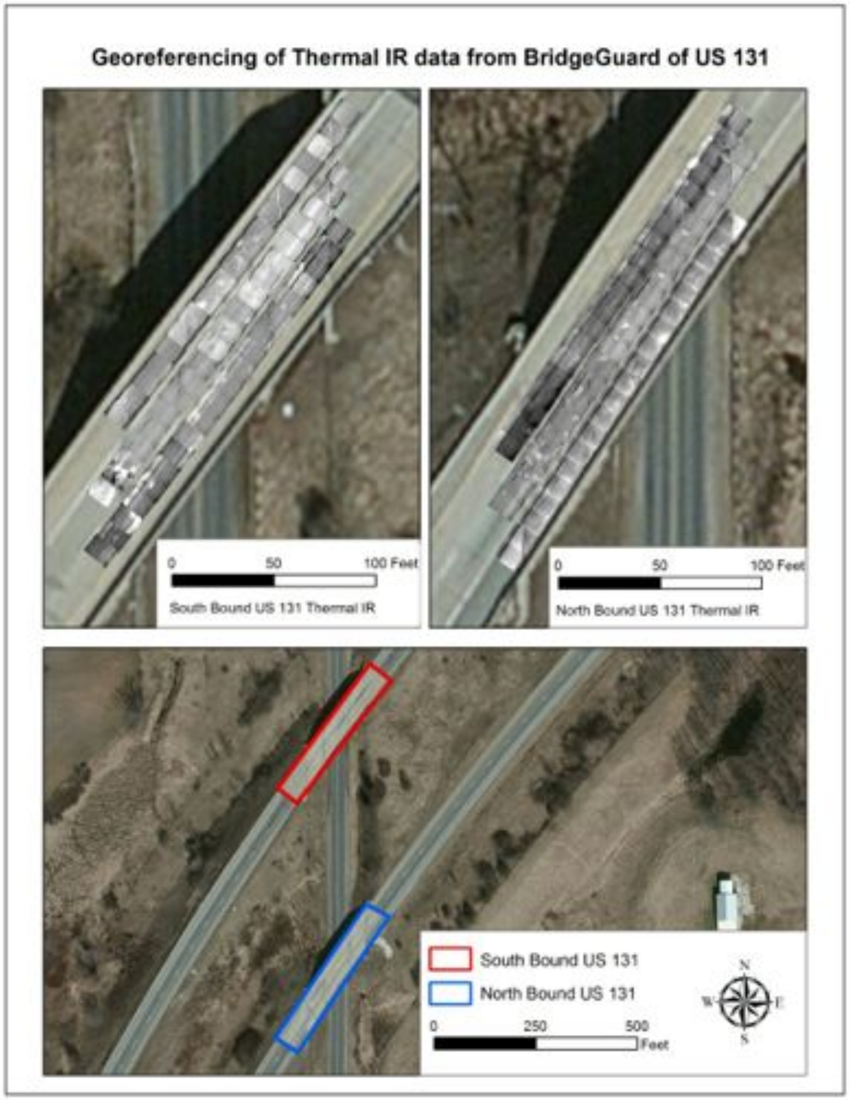
US131 SB over White Creek Ave

- Tested 8/9/13 at 3:45 pm





Passive IR Thermal into GIS



- Thermal Infrared data provided by BridgeGuard
- Using ArcGIS software, MTRI georeferenced and mosaiced these data.
- These data can now be combined with other geospatial datasets (spall detection from 3DOBS).
- Data collected for north and south bound US-131 shown to the left.

Maryland Ave. Thermal Layer

- Mosaiced thermal layer of Maryland Ave.

NDE Technology Integration for Top of Bridge Deck

- All collected data and results are either GIS rasters or shapefiles and can be easily displayed and overlaid in a GIS.
- Data and Results Output:
  - Orthoimage
  - DEM
  - Hillshade
  - Thermal Image Mosaic
  - Detected Spalls Layer
  - Detected Delaminations Layer

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Maryland Ave. Datasets

Orthoimage

DEM

Hillshade

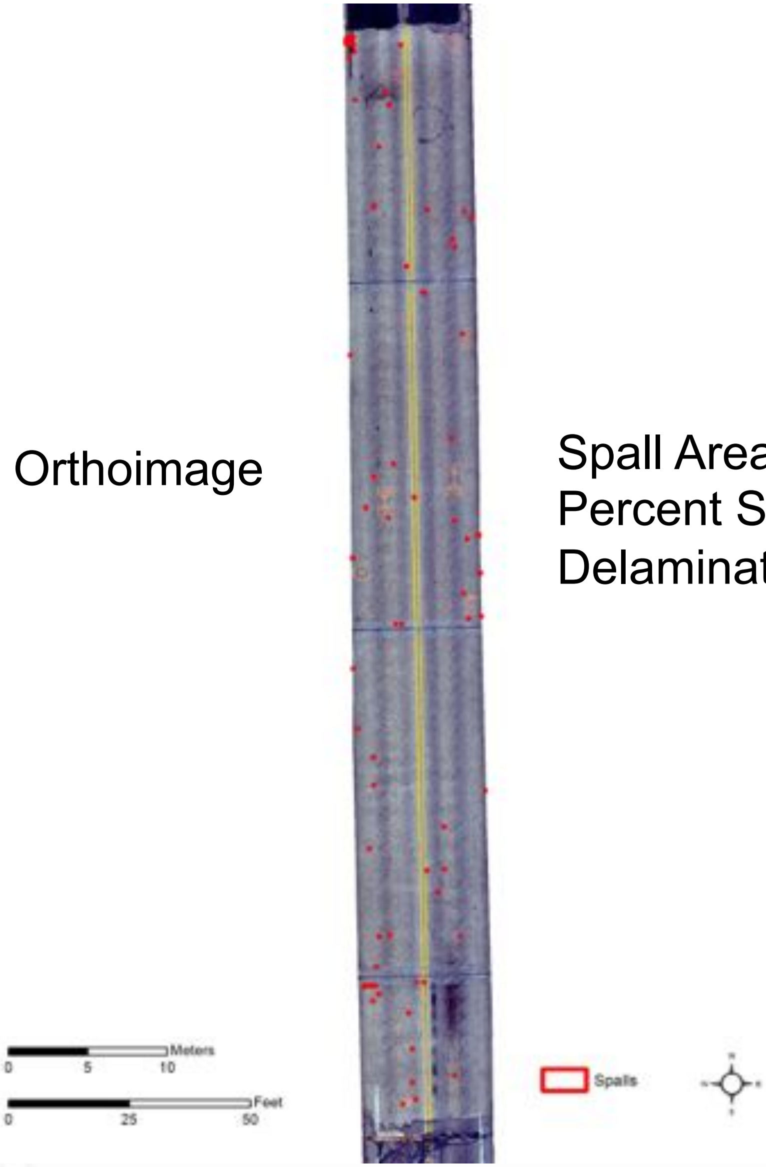
Thermal

Spalls

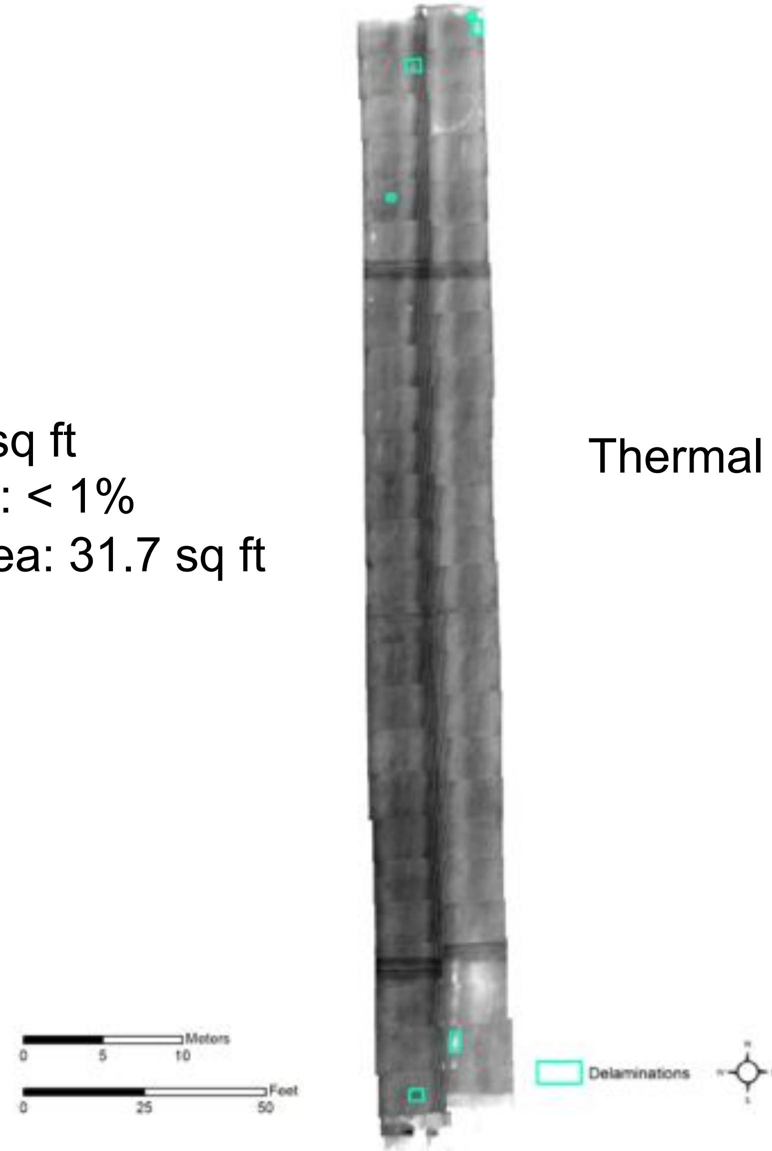
Delaminations

Maryland Ave. Datasets

Orthoimage

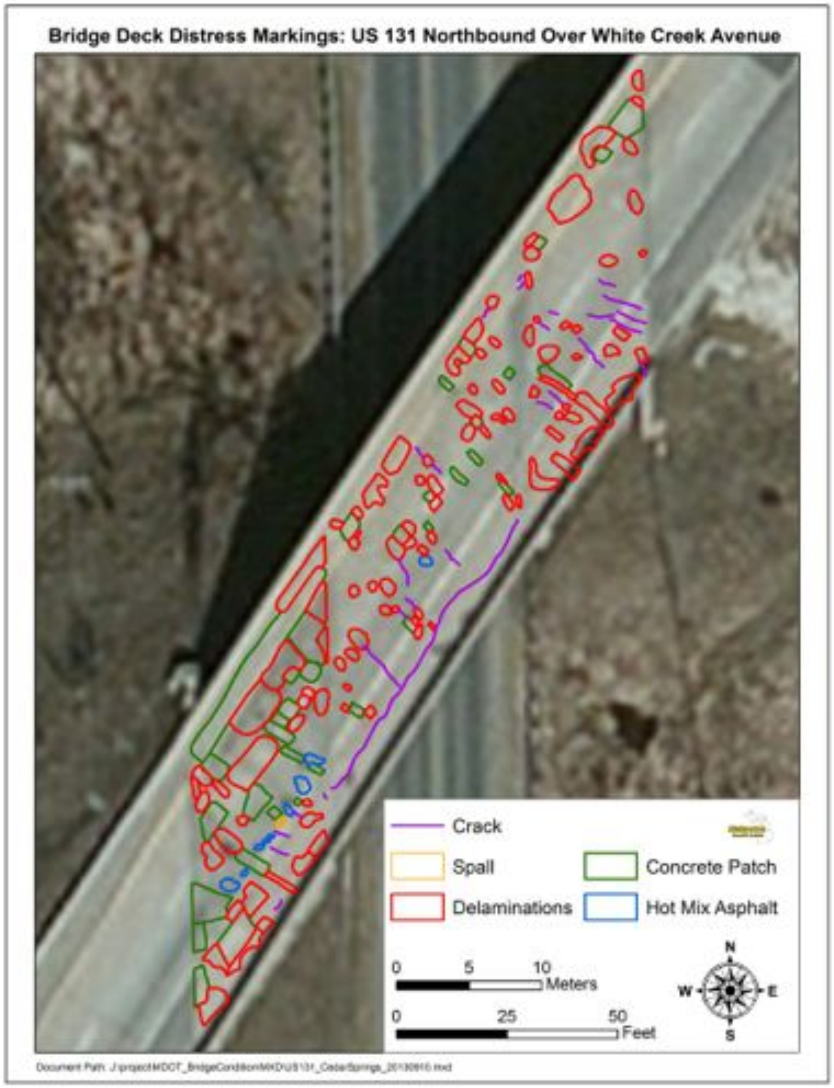


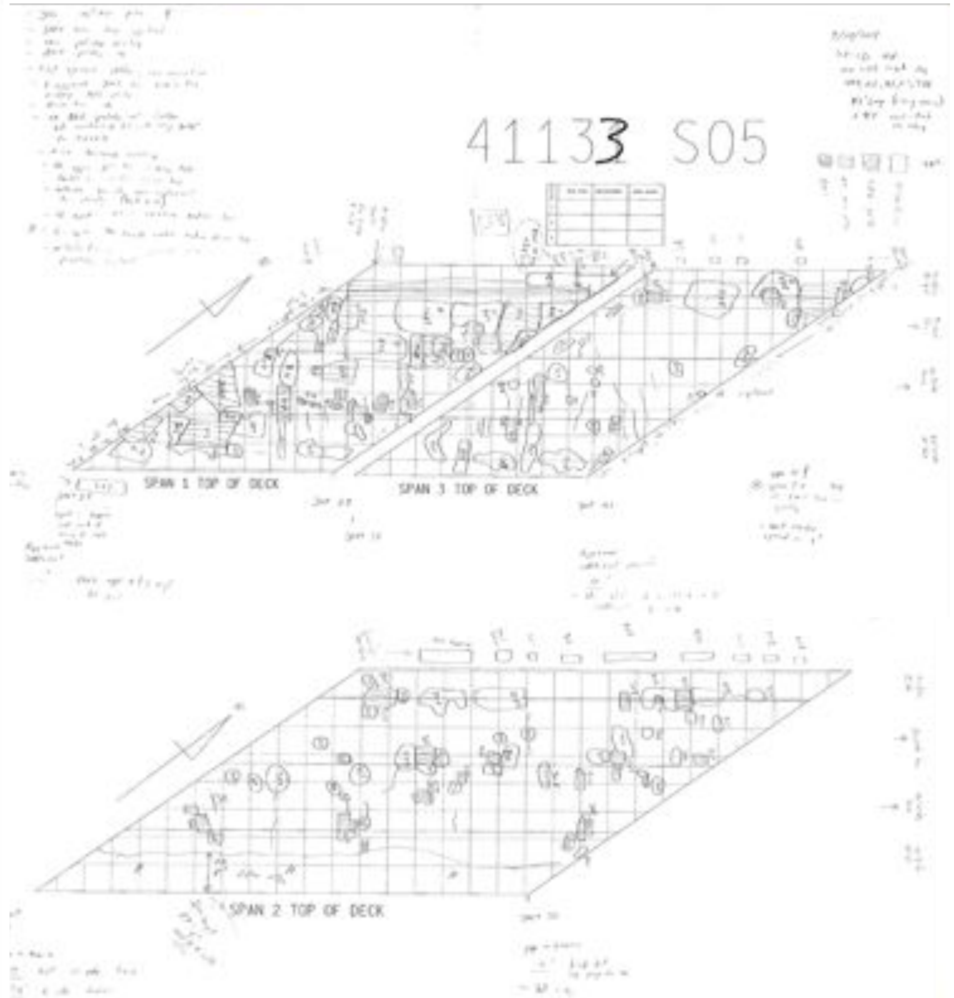
Spall Area: 1.5 sq ft
Percent Spalled: < 1%
Delaminated Area: 31.7 sq ft



Thermal

US-131 NB (5003), Cedar Springs, Michigan





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GIS Layer Generation from MDOT Field Sketches

- MDOT field sketches were imported into ArcMap and georeferenced to basemap imagery
- Based on the MDOT sketches, distress features were digitized according to the type of distress.
- Delaminated area and percentages were calculated for each bridge and compared to MDOT reports.

MDOT Measurements (based on hand sketches)

Bridge Name	Bridge Area (sq. ft)	Delam Area (sq. ft)	% Delam
US131 - SB	7445.00	759.39	10.20
US131 - NB	7843.50	2072.00	26.41
20 Mile	5400.00	1308.00	24.22
24 Mile	5400.00	761.00	14.09

MTRI Measurements (based on GIS Analysis)

Bridge Name	Bridge Area (sq. ft)	Delam Area (sq. ft)	% Delam
US131 - SB	6367.14	542.11	8.51
US131 - NB	7928.12	1786.85	22.54
20 Mile	5343.31	1321.31	24.72
24 Mile	5569.37	780.44	14.01

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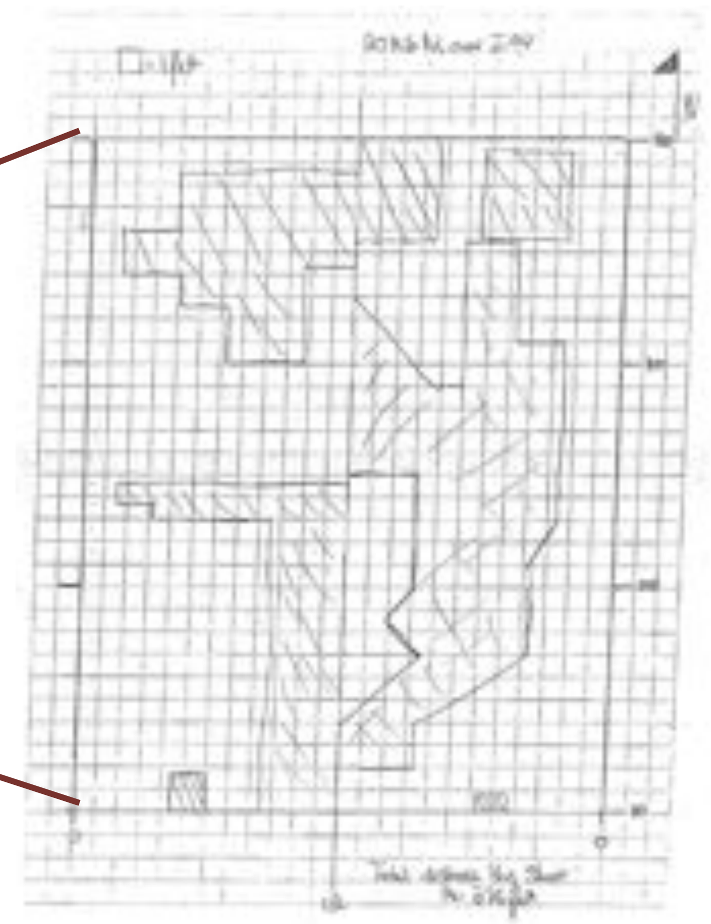
20 Mile Rd (1279), Marshall, Michigan



Active IR Thermography

- Objective: Investigate feasibility of using Active IR on bridge deck underside and fascia beams

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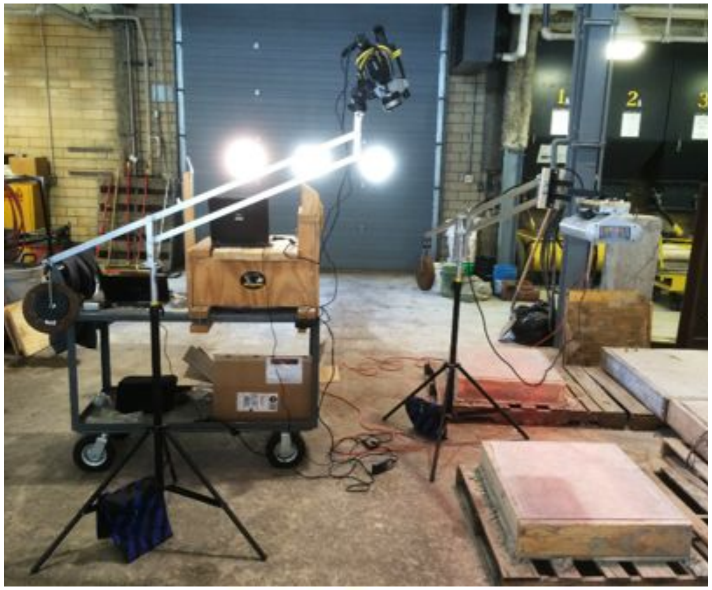
Active IR Lab Studies

- **Test set-up, methods and analysis procedures developed in lab**
  - Test slabs constructed containing simulated delaminations at various depths
  - Tripod mounted camera and heater
  - Heater Distance = 3.5 ft
  - Camera Distance = 6 ft
  - Heat Time = 15 min
- **Width-to-Depth Investigation:**
  - Delaminations detectable if:
    - Width-to-depth ratio ≥ 2
    - Delamination depth ≤ 2 in.
- **Parametric Study:**
  - Investigations of:
    - Heat time
    - Heater distance
    - Thermal concentrations



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Active IR Field Demo Site

Franklin Ave. over US-131 NB & SB (# 4947) conducted on 6/24/2014

- MDOT hammer sounding inspection
- Collected active IR thermal data in 3 test locations:
  - 2 areas on bridge deck underside
  - Side of pier cap
- Data from 15 min and 5 min heat times

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Active IR Field Demo Set-up and Access

- Underside of deck and side of fascia/ pier cap
- FLIR Tau 2 used in comparison with FLIR SC640
- Lift platform truck allowed access to underside of bridge





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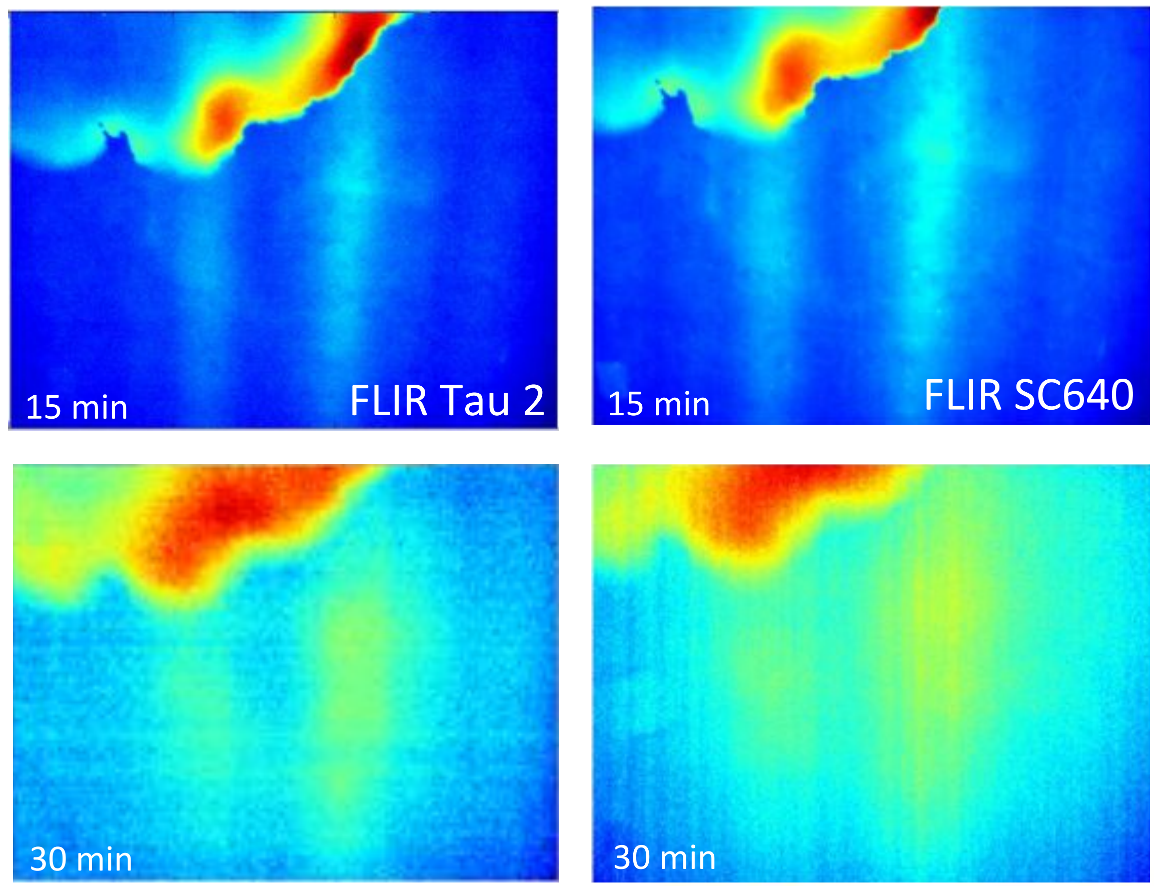
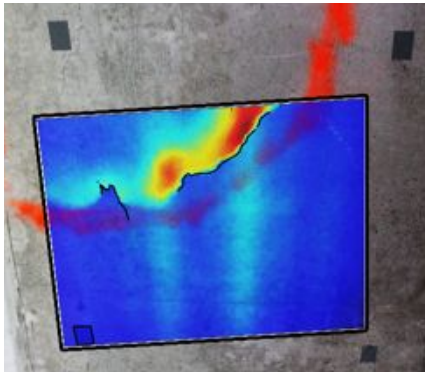
Active IR Data Output

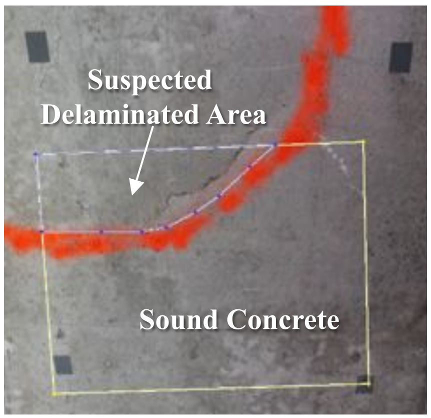
- Cameras provide temporal sequence of numerical matrices
  - FLIR SC640 – actual temperature
  - FLIR Tau 2 – digital numbers
- Matrices can be converted to .xlsx, .mat, .tif, .txt or other common formats
- False color map provides image for visual analysis

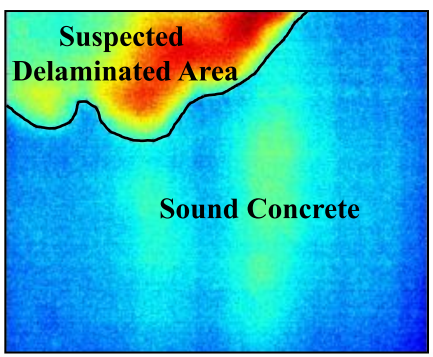
Bridge Deck Underside (Location 2)



Active IR Data Processing and Interpretation







All Processing was conducted using MATLAB

% Area – Compare to Hammer Sounding

1) Align thermal image and optical image using surface defects (cracks) or markers

2) Define total area of optical image using thermal image boundary

3) Draw boundary polygon around delam in optical image and thermal image

4) Calculate % area of delam

5) Convert to sq. ft

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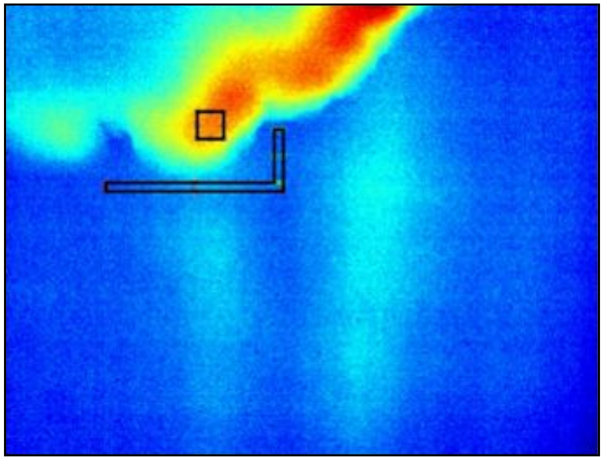
Active IR Data Processing and Interpretation

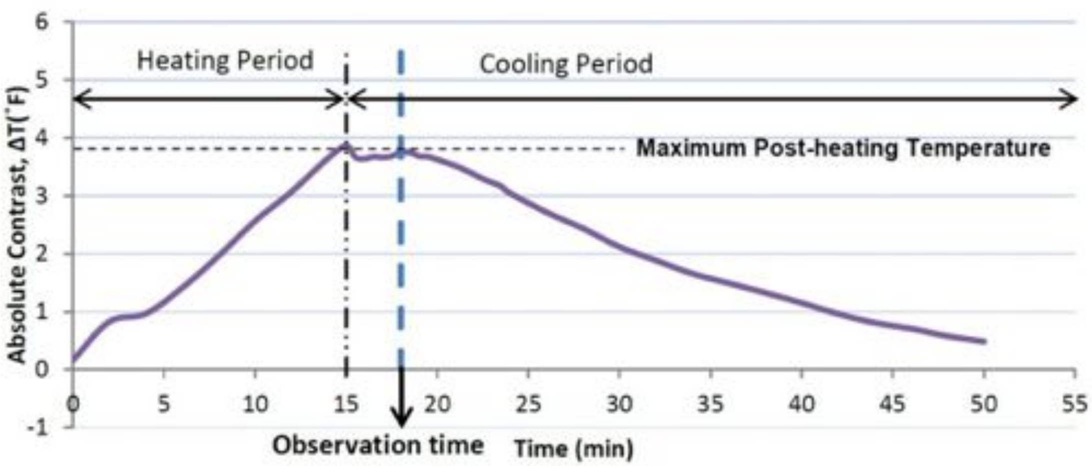


Depth Analysis

1) Construct reference areas for delam and sound concrete
   - L-shape accounts for non-uniform heat patterns

2) Plot contrast between selected areas

3) Determine observation time



- For w/d ≥ 2 and depth ≤ 2 in.
  - Depth is a function of observation time and thermal diffusivity

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Active IR Thermography Findings

- Active IR thermography is feasible for detecting delaminations on the underside of bridge decks and pier caps
- May be applicable to fascia beams (more weather dependent)
- The FLIR Tau 2 is adequate for % delam calculation although a "live feed" is preferred to ensure proper field of view

Test A1: 5 min Heat Time			
Camera	*MDOT Delam %*	*Max Thermal Delam %*	*% of Ground Truth*
FLIR SC640	13.21	10.91	82.55
FLIR Tau 2	-	-	-

Test A2: 15 min Heat Time			
Camera	*MDOT Delam %*	*Max Thermal Delam %*	*% of Ground Truth*
FLIR SC640	14.37	9.71	67.61
FLIR Tau 2	18.45	7.92	42.56

Test B1: 15 min Heat Time			
Camera	*MDOT Delam %*	*Max Thermal Delam %*	*% of Ground Truth*
FLIR SC640	19.28	12.67	65.69
FLIR Tau 2	28.56	19.02	66.58

Test C1 (Pier Cap): 15 min Heat Time			
Camera	*MDOT Delam %*	*Max Thermal Delam %*	*% of Ground Truth*
FLIR SC640	23.70	8.08	34.11
FLIR Tau 2	40.30	23.47	58.23

- MDOT hammer sounding is a conservative method for detecting delaminations

Conclusions

- The RED Epic enabled 3DOBS Near Highway Speed to be driven along side the BridgeGuard thermal camera at vehicle speeds of 45 mph.
- 3DOBS High-Res allows for visualizing cracking down to roughly 1/32nd inch.
- Higher resolution cameras due to be released
  - Nikon DSLR to be released in by end of the year with 40+ MP resolution
- Automated Crack detection algorithm could be developed.

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Conclusions

- A vehicle mount was built that allows for both optical and thermal data to be collected simultaneously.
- Both datasets and results are referenced on top of each other in a GIS to allow for a more complete understanding of surface and subsurface conditions.
- Active thermal IR is a feasible option for detecting delaminations on the underside of bridge decks and pier caps.

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Equipment Demonstration

- BVRCS
- 3DOBS
- Active Thermal IR

Implementation Action Plan Discussion

- What do you see as the next steps?
- How can this best be used by you?
- Where is this value added for you or others at MDOT?
- Other ideas

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Other Questions or Concerns?

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