NETC 20-3

Investigating Thermal Imaging Technologies and Unmanned Aerial Vehicles to Improve Bridge Inspections

Project Close-Out Webinar
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Agenda

1. Project Team
2. Introduction and Research Objective
3. Field Testing and Data Analysis
4. Guidelines and Protocols for Implementation

Project Team

AECOM Research Team:

- Kevin Ahearn, PE, Principal Investigator
- Brady Seston, PE
- Reed Brockman, PE
- Ed Zhou, PE, PhD
- Zach Magee, EIT
- Tony Tieso

Technical Committee:

- John “Sam” Maxim, Maine Department of Transportation (Technical Committee Chair)
- Vitalij Staroverov, Connecticut Department of Transportation
- Bruce Sylvia, Massachusetts Department of Transportation
- Nicholas Goulas, New Hampshire Department of Transportation
- Colin Franco, Rhode Island Department of Transportation
- Evan Robinson, Vermont Agency of Transportation
- Dale Peabody, Maine Department of Transportation (Advisory Committee Liaison)

Introduction and Research Objective

"Develop UAV-based inspection and analysis protocols using infrared thermal imaging to determine the existence and extent of concrete delamination, with emphasis on the underside of bridge decks"

Introduction and Research Objective

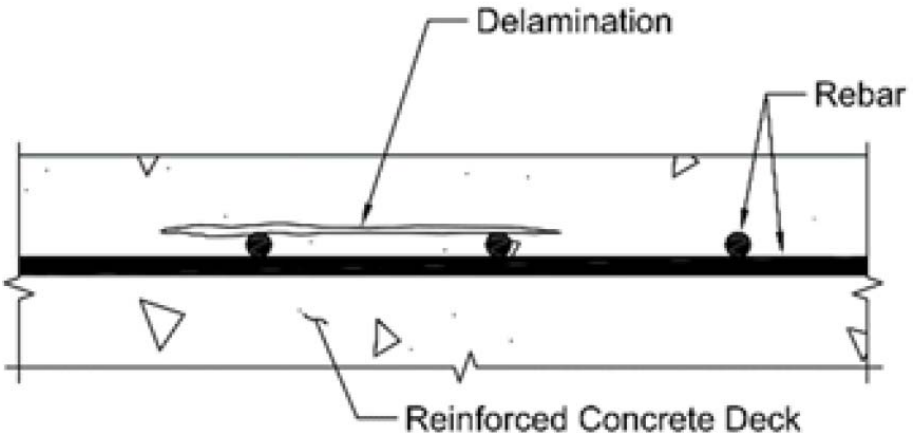
- Concrete delamination caused by expansion of corroding reinforcing steel
- Can be difficult to detect visually
- Presents critical safety hazard
  - Direct impact
  - Distraction of drivers

Introduction and Research Objective

- Traditionally identified with manual methods:
  - Hammer Sounding
  - Chain Drag
  - Rotary Percussion Tool
- Requires hands-on access
- Subjective documentation
- Relies on ability to hear sound that is produced

Introduction and Research Objective

- Thermal imaging is a potential tool for identifying delaminations along the underside of bridge decks
- Delaminations cause voids or air pockets in the deck
- Air acts as an insulator causing the delamination to change temperature faster than the adjacent deck
- Relies on ambient air temperature changes for underside of bridges



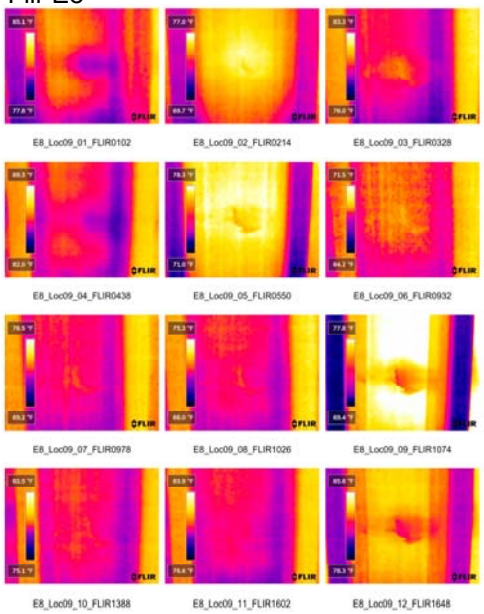
Field Testing and Data Analysis

Two Phases for Field Testing

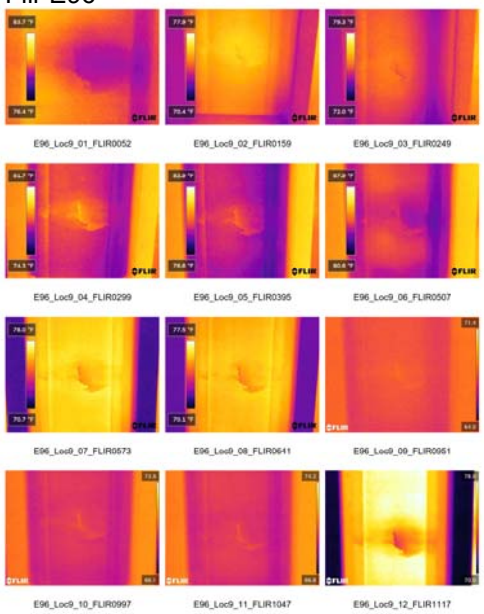
Handheld Thermal Cameras

- Field tested Flir, Fluke, and Seek Shot Pro thermal cameras
- Repeated imagery to determine temperature and weather condition recommendations
- Repeated imagery to compare different thermal resolutions

Flir E8



Flir E96



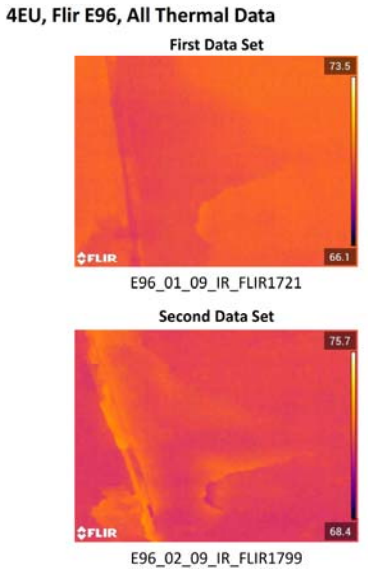
Field Testing and Data Analysis

Two Phases for Field Testing

Handheld Thermal Cameras

- Determine whether traditional inspection findings could be verified
  - Beades Bridge – All delaminations at least partially identified
  - Washington Bridge – 64% at least partially identified

Flir E8



Flir E96

Field Testing and Data Analysis

Two Phases for Field Testing

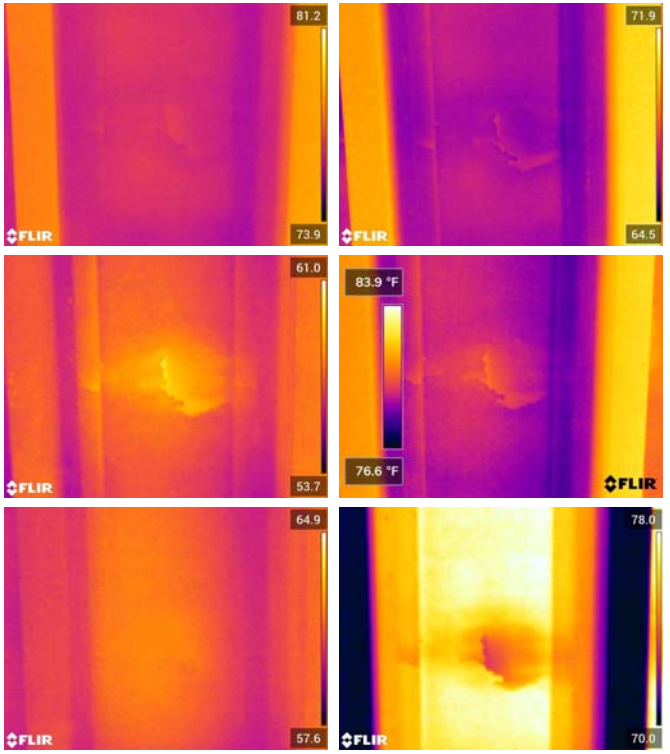
Drone-Mounted Thermal Cameras

- Field tested Zenmuse XT2 mounted on DJI Matrice 210
- Two bridges
- Perform UAV-IR survey to identify delaminations for comparison to traditional rehabilitation level inspection
  - Ramp K – 78% of delaminations at least partially identified
  - Ramp B – 51% of delaminations at least partially identified
  - Both thermal surveys included false positive identifications
  - Both identified more delamination than the previous routine inspection

Field Testing and Data Analysis

Initial Conclusions

- Handheld thermal cameras offer more control of settings
- Increased thermal resolution improves likelihood of detection
- Limits of delamination do not always line up with limits determined by traditional methods and will vary based on temperature changes
- Not all delamination will be detected
- Potential for false positive identification



Inspection and Analysis Protocols

Thermal Imaging

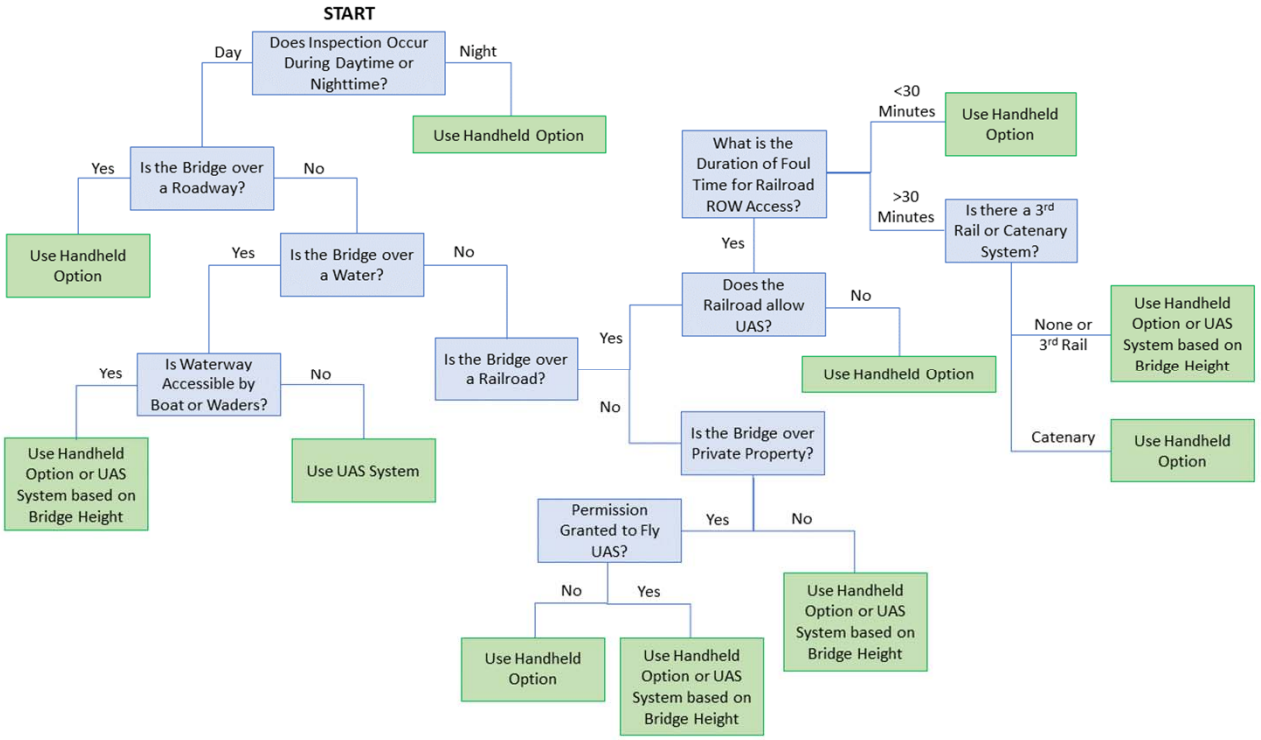
Recommended Weather Conditions for Data Collection

- Temperature change for the preceding 6 hours
  - 10° F for handheld
  - 15° F for drone-mounted
- Wind Speeds
  - < 30 mph for handheld
  - < 20 mph for drone-mounted
- No rain at least 48 hours prior

Inspection and Analysis Protocols

Thermal Imaging

Equipment Selection



Equipment Selection Matrix Based on Bridge Height				
Distance to Bridge Element	Flir E96			Zenmuse XT2 (640x480, 13mm)
	10mm	17mm	29mm	
10'	✓			
15'	✓			
20'	✓			✓
25'	✓			✓
30'	✓	✓		✓
35'	✓	✓		✓
40'		✓	✓	✓
45'		✓	✓	✓
50'		✓	✓	✓
>50'			✓	✓

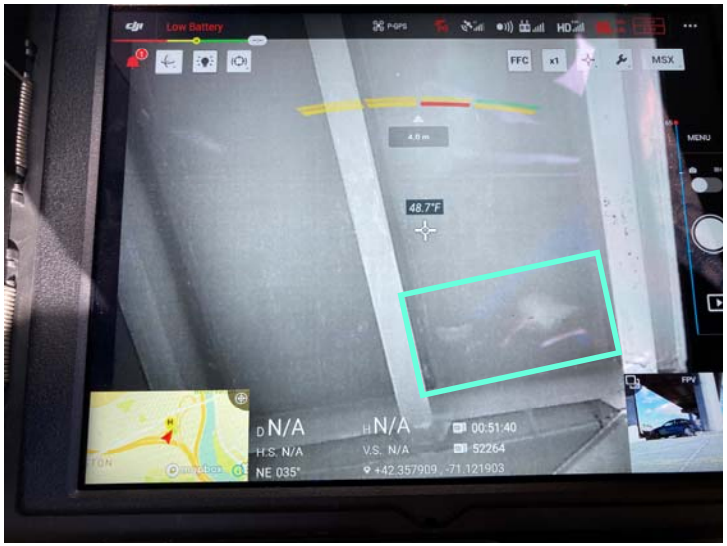
Distance to Bridge Element	Thermal Camera Resolution					
	160 x 120	320 x 240	336 x 256	464 x 348	640 x 480	640 x 512
<10'	✓	✓	✓	✓	✓	✓
10'	✓	✓	✓	✓	✓	✓
15'	✓	✓	✓	✓	✓	✓
20'	✓	✓	✓	✓	✓	✓
25'		✓	✓	✓	✓	✓
30'		✓	✓	✓	✓	✓
35'				✓	✓	✓
40'				✓	✓	✓
45'					✓	✓
50'					✓	✓
>50'					✓	✓

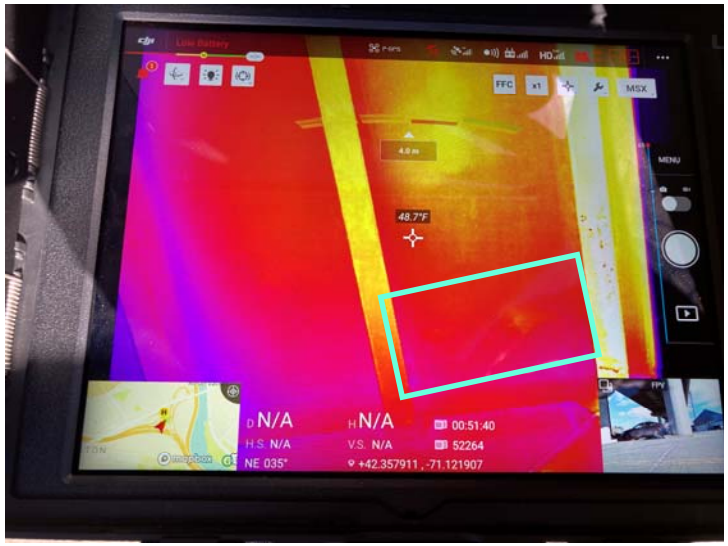
Inspection and Analysis Protocols

Thermal Imaging

Camera Settings

- Radiometric JPEG files
- Thermal and visual image capture
- White hot color palette
- Set temperature limits to be 8° to 10° F apart



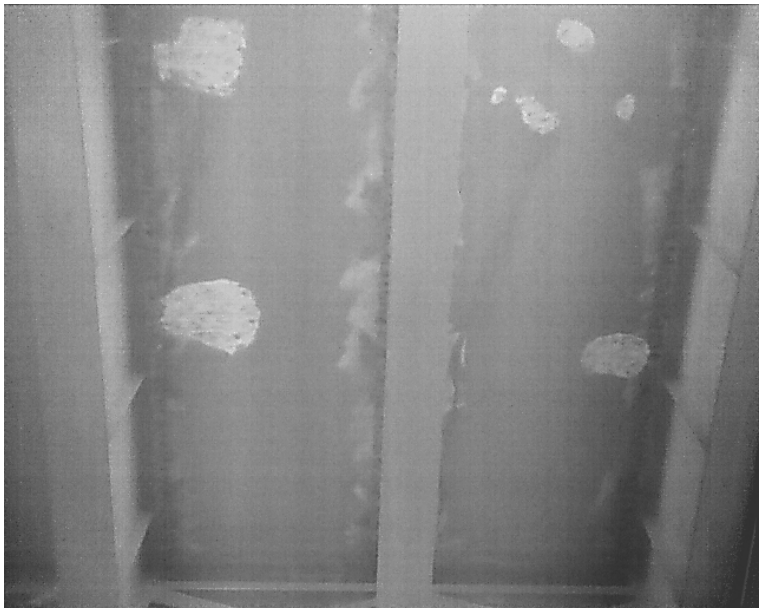


Inspection and Analysis Protocols

Thermal Imaging

Data Interpretation

- False positive identification is possible
- Numerous factors affect temperature readings
- Cross check with visual imagery



Inspection and Analysis Protocols

Drones / UAV / UAS

- Applications depend on numerous factors
- Potential to Improve Efficiency and Safety
  - Another “Tool in the Toolbox” based on **Engineering Judgement**
- Critical to understand capabilities and limitations of equipment

Inspection and Analysis Protocols

Drones / UAV / UAS

General Protocols

- Planning
  - Determine needed authorizations and waivers
  - Identify site hazards
  - Perform risk assessment and hazard mitigation
  - Schedule appropriate flight crew
    - Team Leader required for NBIS inspections
- Operational
  - Safety toolbox meeting
  - Inspect equipment and set up
  - Pre-flight and control checks
  - Perform operation
  - Review data
  - After action review

Inspection and Analysis Protocols

Drones / UAV / UAS

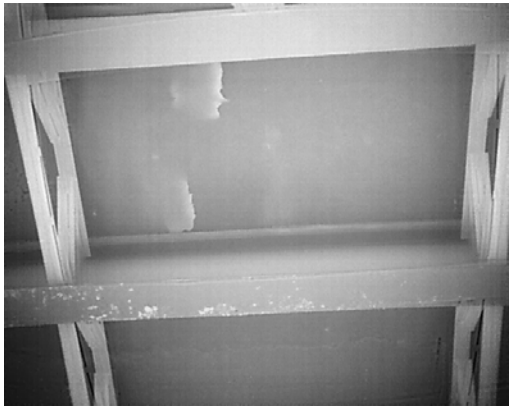
Inspection Applications

- Inventory / Record Photos
- Aerial Imagery
- Visual Screening Tool
- Channel Inspection




Conclusion

- Thermal imaging is able to detect varying degrees of delamination under the right conditions (10°-15° F temperature swing)
- Even under ideal conditions, it is possible that not all delaminations will be detected by thermal imaging
- Limits of delamination do not always line up with limits determined by traditional methods and will vary based on temperature changes
- Proper interpretation of thermal images is essential to accurately identify delaminations and avoid false positive identification



Thank you.

Additional questions or comments can be directed to
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