

# USING INFRARED THERMOGRAPHY FOR NON- DESTRUCTIVE EVALUATION (NDE) OF BRIDGES

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Bridge Division

## Need Good Bridges

Bridges are a critical and valuable asset; to manage this asset well, we need to know its condition

The deck and often the beams/girders, barrier railing, piers, and abutments are made of reinforced or prestressed concrete

If the steel within the concrete begins to corrode, it causes damage/delamination that may not be visible on the surface

In order to assess the condition, we need to "see" inside the concrete

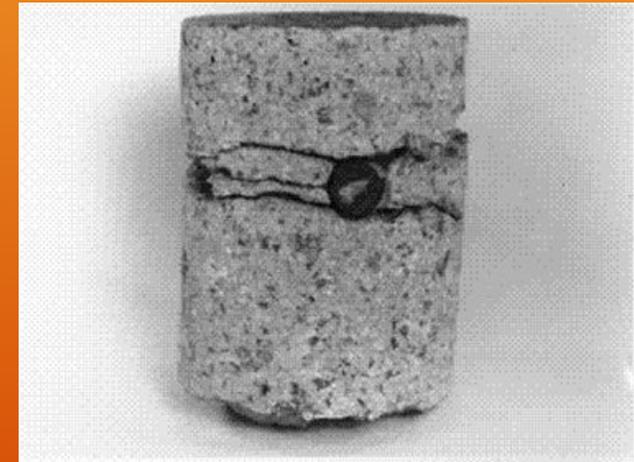
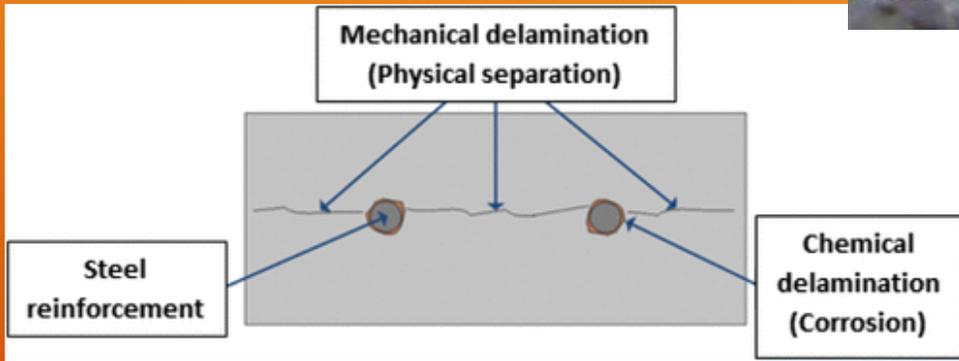
NDE methods provide a way to "see" delamination within the concrete without damaging the bridge

Need Good Bridge Condition information for short and long term planning to Keep our Bridge Good

SAFELY  
MOVE  
PEOPLE  
AND  
GOODS



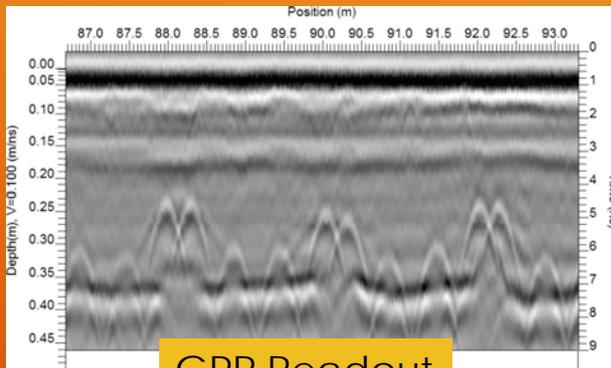
# WHY DO WE NEED NDE FOR BRIDGES?



# CONCRETE DELAMINATION



Impact Echo Apparatus



GPR Readout

NDE methods allow us to detect problems before they become visible on the surface

- Impact Echo \*
- Ultrasonic Pulse Echo
- Ultrasonic Surface Waves
- Impulse Response
- Ground Penetrating Radar (GPR) \*
- Half-Cell Potential
- Galvanostatic Pulse Measurement
- Electrical Resistivity
- IR Thermography \*
- Chain Dragging (Sounding) \*

Most require specialized equipment and/or training to operate and interpret

## NDE METHODS FOR BRIDGE DECKS



# CHAIN DRAGGING

Most commonly used NDE method

Advantages:

- Accurate
- Simple to use
- Delamination is indicated by hollow sound as compared to a clear ringing in sound concrete

Challenges:

- Can be difficult to hear in noisy surroundings – traffic, construction
- Can be dangerous working close to traffic
- Dependent on inspector's hearing ability and experience
- Fairly time-consuming – chain has to touch every part of the deck
- Can only be used on horizontal surfaces

- ▶ Bridge wanted IR camera as a second NDE tool for bridge deck assessment
- ▶ Hand held units available
- ▶ Fairly intuitive interpretation of images
- ▶ Ability to quickly scan a bridge deck
- ▶ Ability to view from edge of bridge
- ▶ Research and Pooled Fund studies confirmed useful tool; reliable results



<https://youtu.be/OWkMUtjSuKE>

## INFRARED (IR) THERMOGRAPHY

All surfaces emit electromagnetic wave radiation relative to their temperature



IR camera detects emitted electromagnetic wave radiation

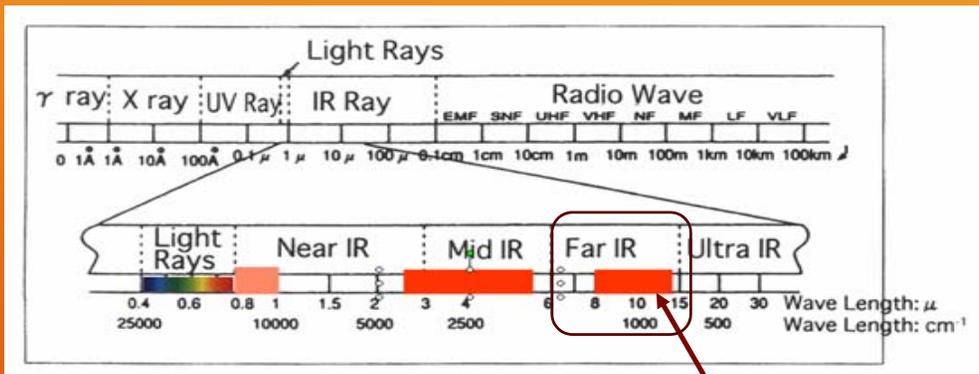
- Wavelengths between 8 and 12  $\mu\text{m}$



Converts electromagnetic waves to electrical signals



Processes signals to create thermal map or Thermogram



Electromagnetic Spectrum



## INFRARED (IR) SCIENCE

- ▶ Strategic Highway Research Program 2 involving TRB, AASHTO and FHWA

- ▶ Purpose - find strategic solutions to challenges of
  - ▶ Saving Lives
  - ▶ Reducing Congestion
  - ▶ Improving Quality of Life (Renewing Roads and Bridges)

- ▶ April 2016 – Applied for \$30,000 User Incentive Grant

- ▶ Using NDE Technologies Bridge Decks



# SHRP2 IMPLEMENTATION ASSISTANCE NONDESTRUCTIVE TESTING TECHNOLOGIES FOR CONCRETE BRIDGE DECKS (R06A)

## SEPTEMBER 2016 NDDOT AWARDED GRANT



- Purchase of Infrared camera
  - Researched and tested several
  - March 2017 – Purchased FLIR T620 (\$21,375)
- SME Training
  - May 2017 – Olson Engineering provided on-site training in Bismarck – 12 NDDOT employees
- Additional training and NDE tools
  - March 2017 – Purchased Delam Tool
  - June 2017 – Infrared Thermography Training
  - Remaining funds will be used for additional Infrared or other NDE tools

[Click this link to see video.](#) This link will take you to YouTube.



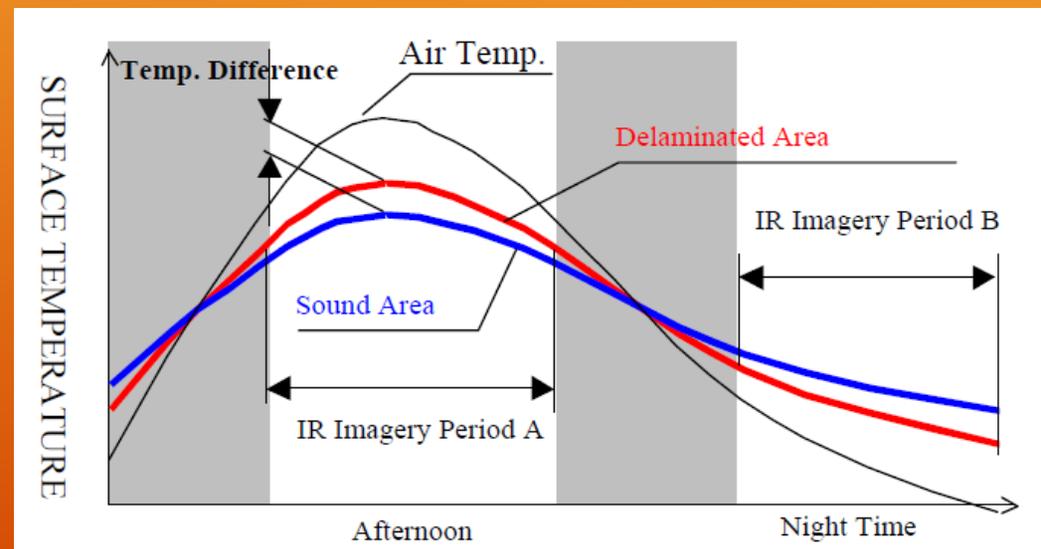
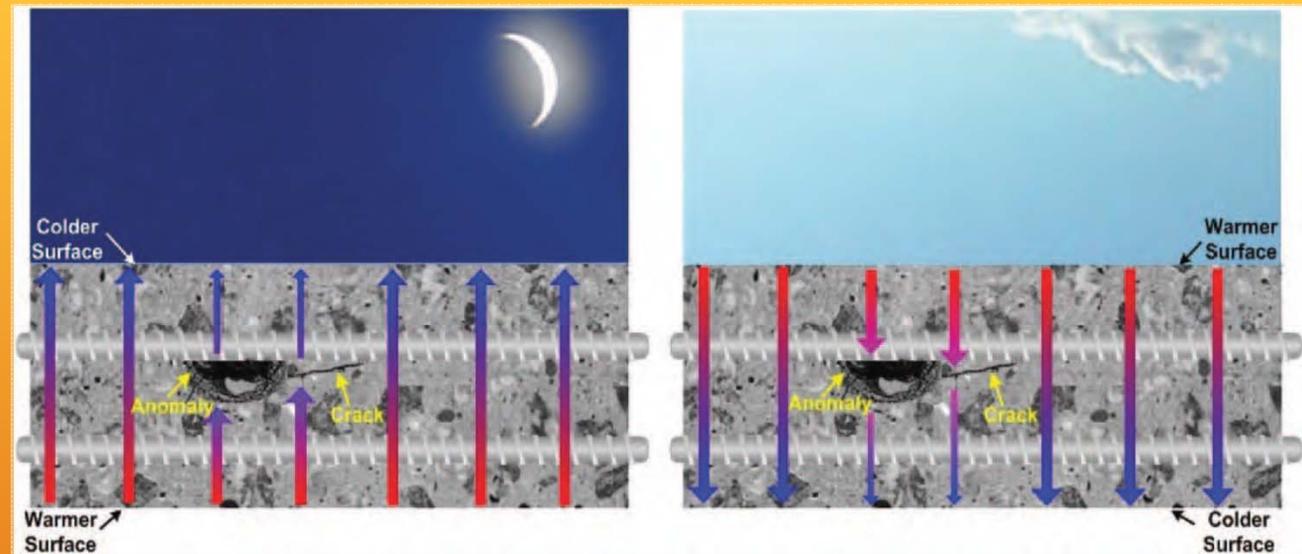
# FLIR T620 THERMAL SENSITIVITY





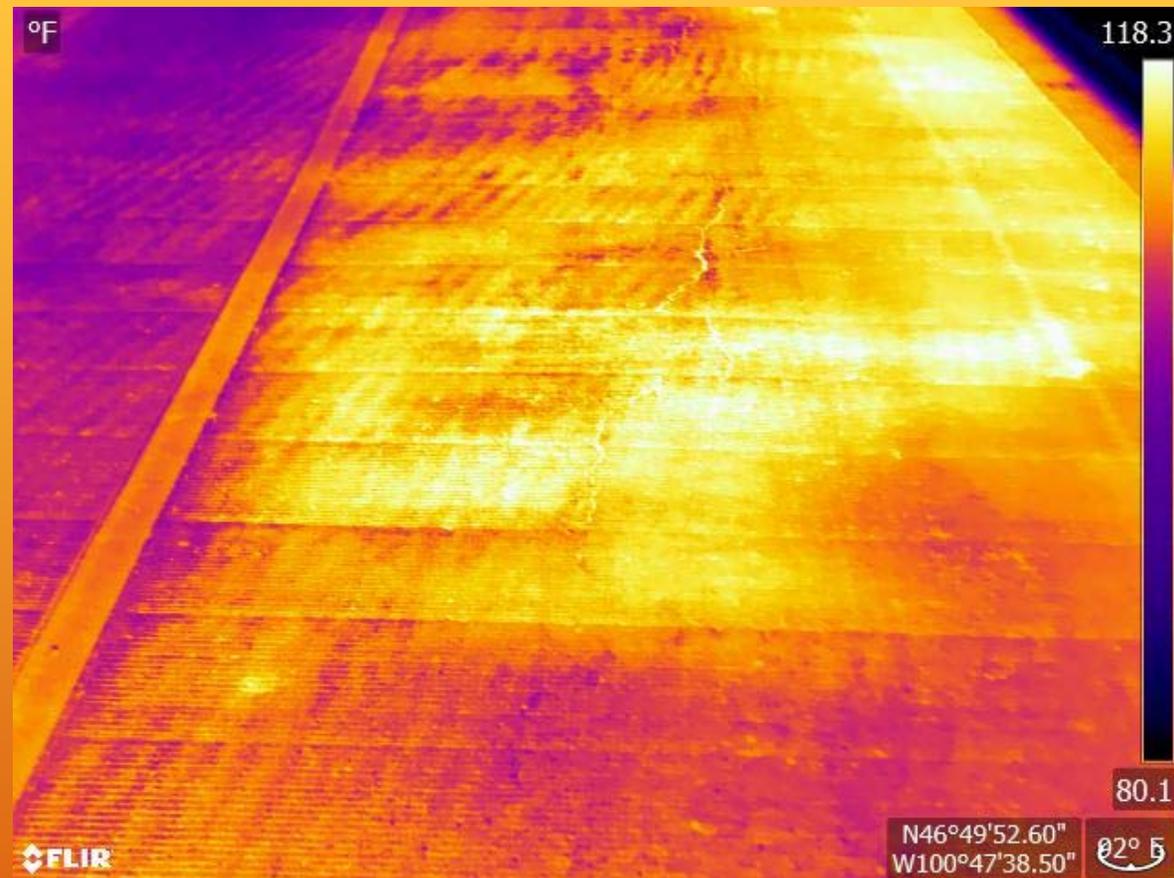
# FLIR T620 THERMAL MSX

- Variations in the surface temperature of the bridge deck indicate areas of discontinuity, typically delamination
- Uniform material of uniform depth (sound concrete) heats and cools relatively uniformly
- Uniform material of differing depths heats and cools non-uniformly

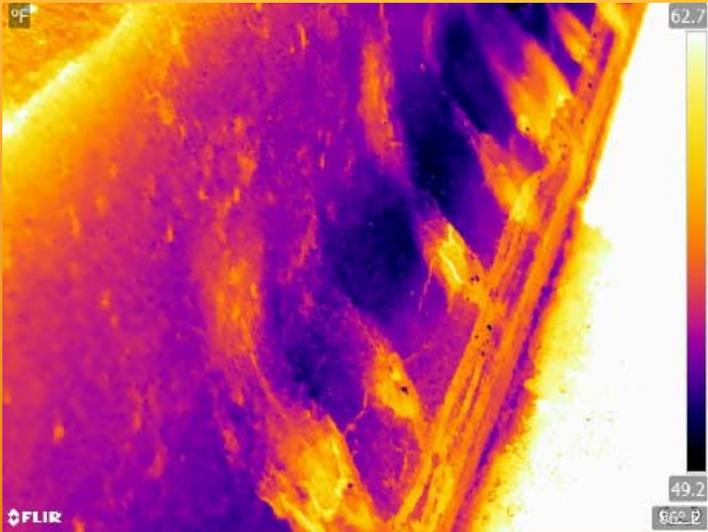


# USING IR NDE FOR BRIDGE DECK ASSESSMENT

- ▶ Areas of a bridge deck with discontinuities will warm and cool more rapidly than the surrounding sound concrete.
- ▶ Using an infrared camera to observe these areas will help identify the presence of:
  - ▶ Delamination
  - ▶ Cracking
  - ▶ Voids/Anomalies



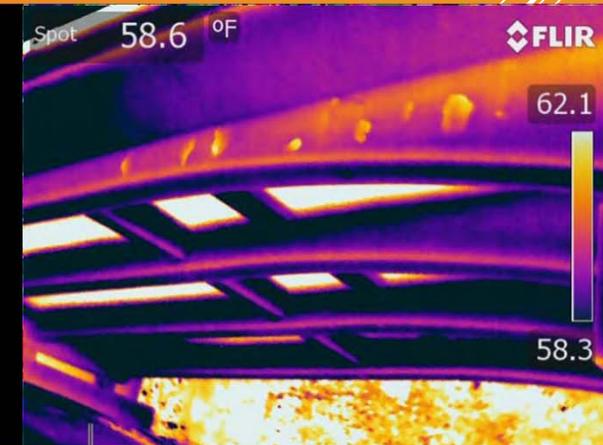
## USING IR NDE FOR BRIDGE DECK ASSESSMENT



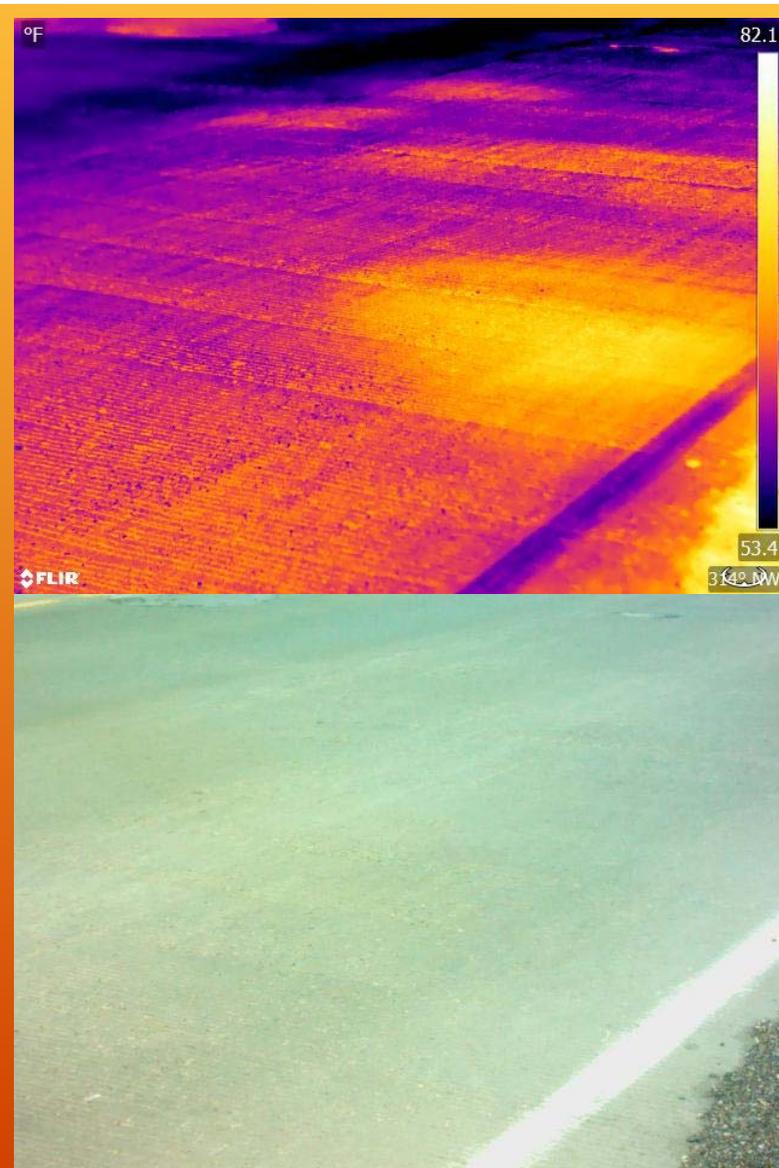
- Direct sun work very well as a heat source.
- Not required though as long as there is a substantial temperature change

Barriers

# USING IR NDE FOR ASSESSMENT OF OTHER BRIDGE ELEMENTS

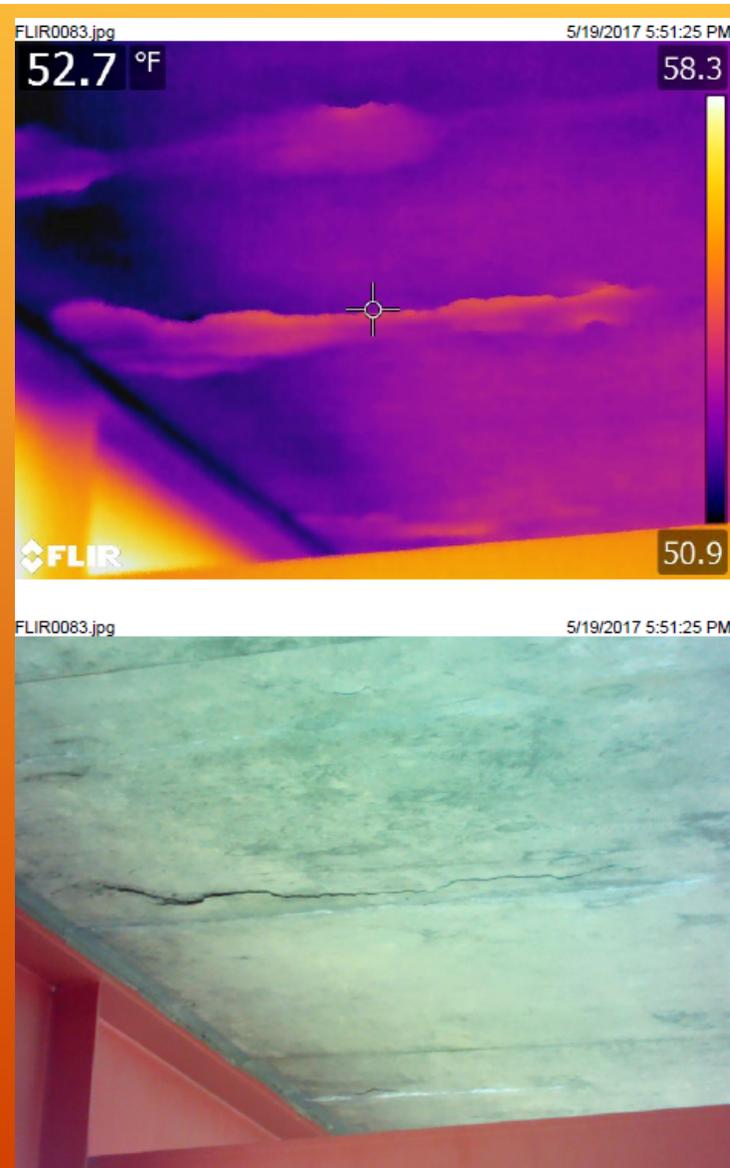


Beams



## ADVANTAGES OF USING IR THERMOGRAPHY

- Non-contact
- Ability to capture images from a distance minimizing traffic disruption and increasing safety
- Not affected by external noise
- Not dependent on inspector's hearing
- Less time consuming than chaining
- Physical image to review
- Images relatively easy to interpret



## ADVANTAGES OF USING IR THERMOGRAPHY

- Can use on vertical surfaces such as barriers, piers, abutments, etc.
- Can be used on underside of deck
- Camera is relatively easy to use

Another tool to help assess our bridge condition

Better understanding of bridge condition – better project planning

Current Conditions	Deck Daytime	Shaded Daytime	Shaded Nighttime
			
Inspection Window	10/26/2017 12:17:00 PM to 10/26/2017 6:17:00 PM	10/26/2017 12:17:00 PM to 10/26/2017 8:17:00 PM	10/26/2017 7:36:00 PM to 10/27/2017 4:36:00 AM
Time until Inspection (hh:mm)	02:15	02:15	05:04
Time left to Inspect (hh:mm)	03:45	05:45	09:00
Temperature Increase/Decrease 6 Hr After/Before Sunrise/Sunset(Degree F)	N/A	-2.0	-2.1
Past 3hr Temperature Change (degree F/Hr)	-0.4	-0.4	-0.4
Temperature Change Maximum (degree F)	N/A	25	-38
3 Hr Windspeed Average (mph)	+26.9	N/A	N/A

# CHALLENGES OF USING IR THERMOGRAPHY

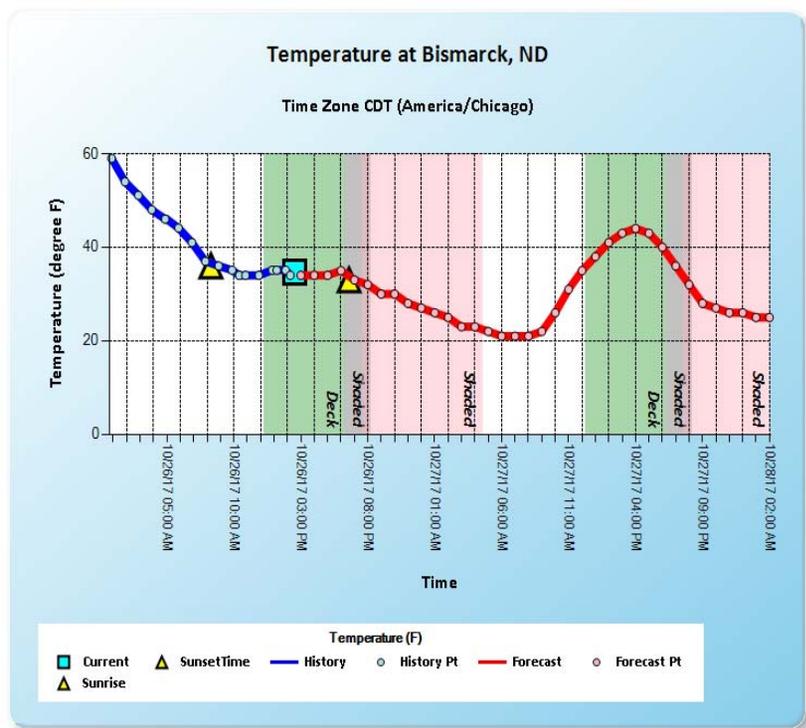


## • Weather

- Optimal weather – Sunshine, low humidity, calm winds, fairly large temperature changes (10° F minimum; 20° F or more is best)
- Due to thermal sensitivity of T620 can operate in less than optimal conditions

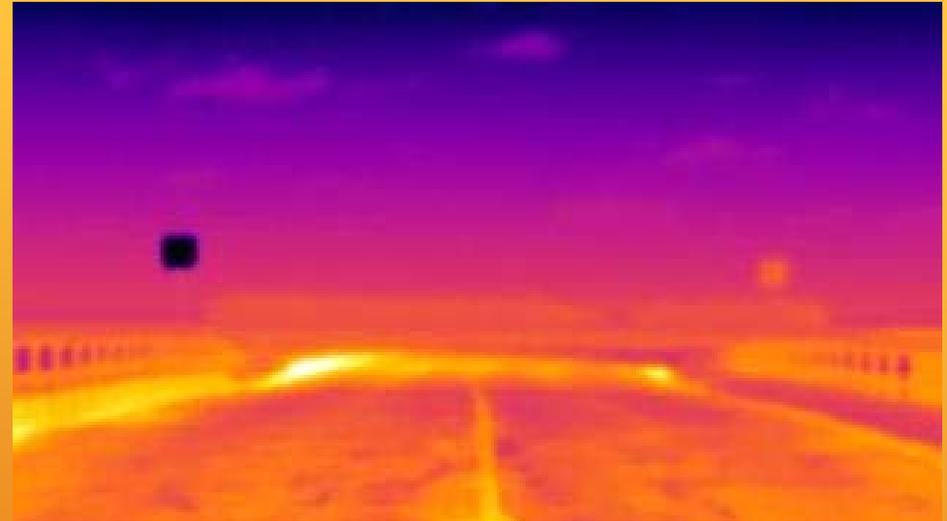
## • Timing

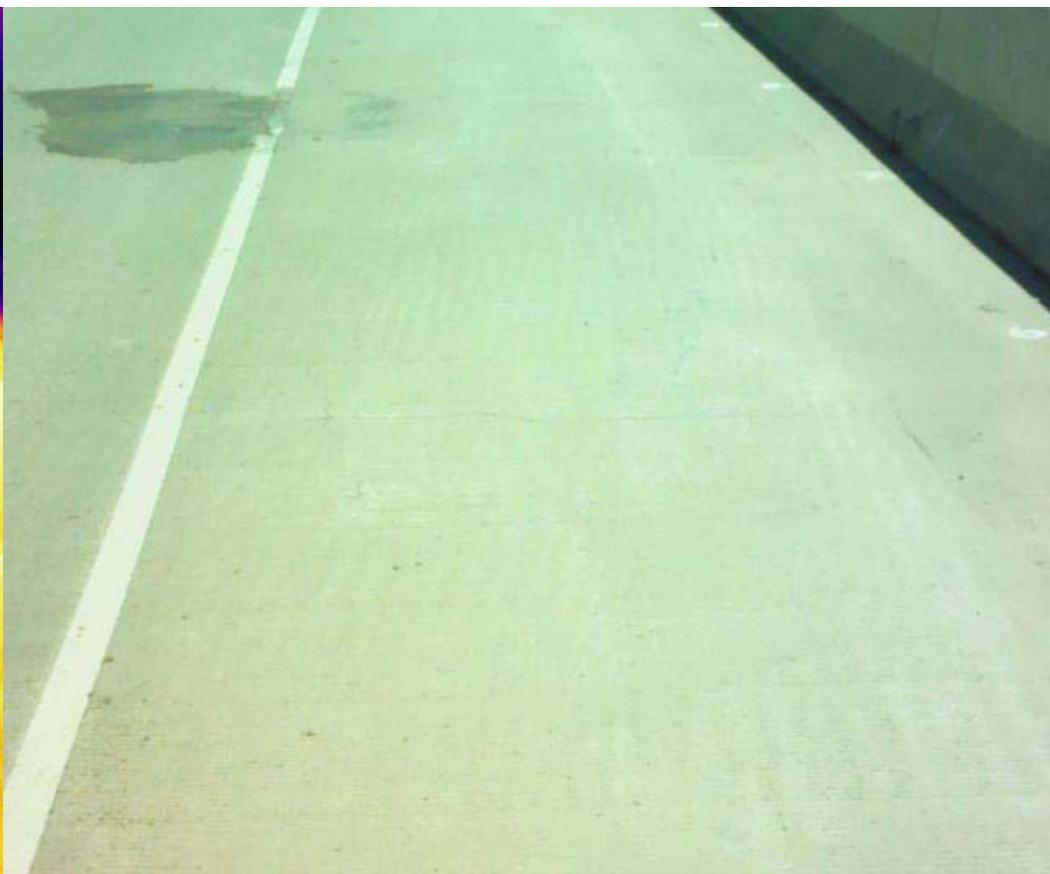
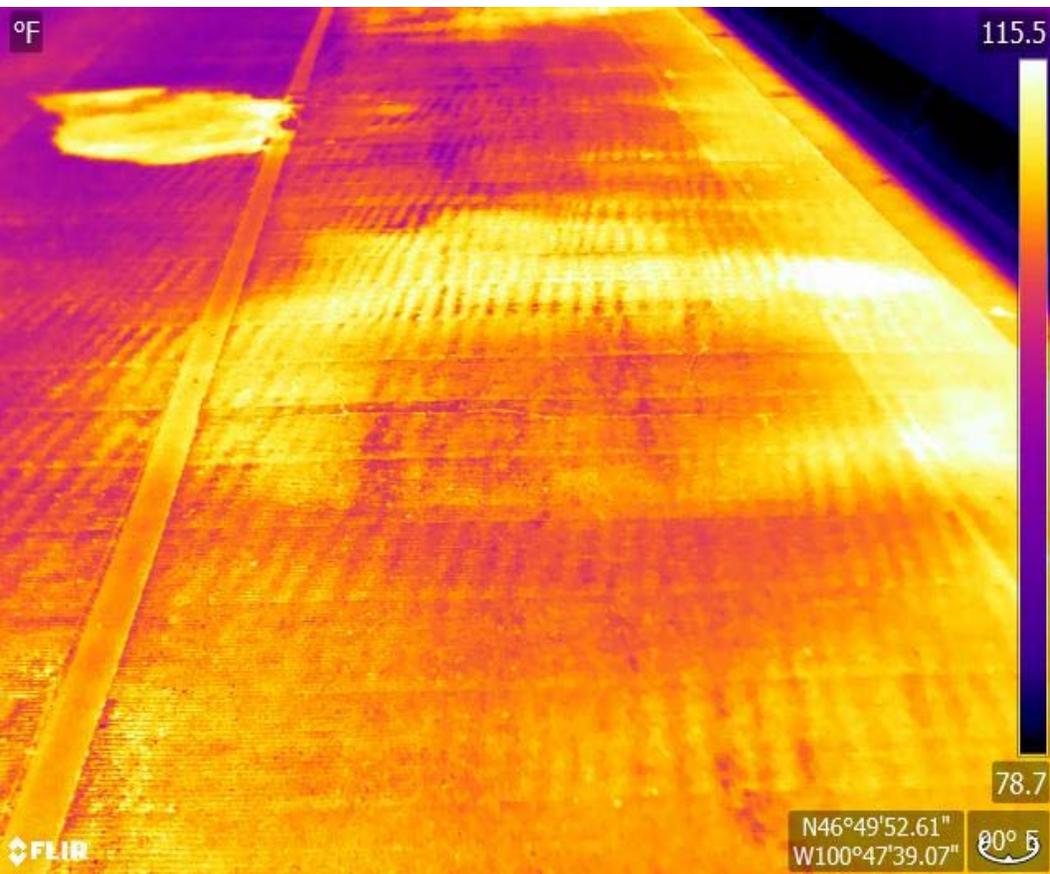
- Typically the daytime “window of opportunity” begins about 4-6 hours after sunrise and continues for about 4-6 hours



- Potential misinterpretation of image
- Different materials have different emissivities
  - Emit differing amounts of “heat”
  - Concrete has a high emissivity – typically appears close to actual temperature
  - Asphalt has a very high emissivity
  - Shiny metals typically have low emissivities – can’t trust apparent temperature
- Need to understand *what* you are seeing and *why* it appears as it does

## CHALLENGES OF USING IR THERMOGRAPHY





## CHALLENGES OF USING IR THERMOGRAPHY

- ▶ Other possible sources of error
  - Shade or shadows
  - Reflected IR radiation
  - Moisture

## Unique opportunity to test locally

- ▶ Coordinated with Materials and Research Division and Bismarck District Construction
- ▶ Measured and marked 10' grid on deck
- ▶ Used IR camera to systematically image deck
- ▶ Bismarck District chained and marked areas of delamination
- ▶ Reimaged deck with IR camera for comparison

Bernie Southam, Tyler Wollmuth, Loren Lee, Travis McCloud,  
Bismarck District;

Seung Baek, and T. J. Murphy, Materials and Research

Brian Raschke, Bridge Division

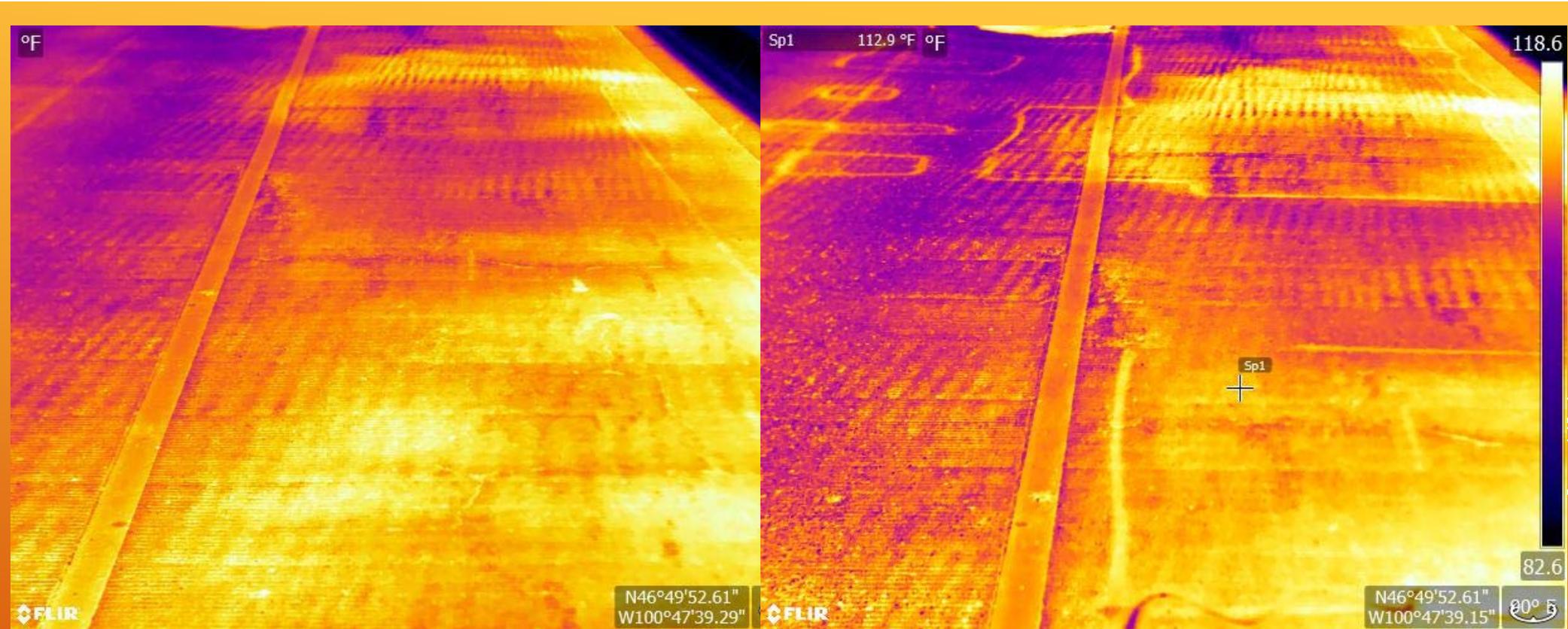


# FIELD TESTING AT NDDOT 194 RECONSTRUCTION, BISMARCK

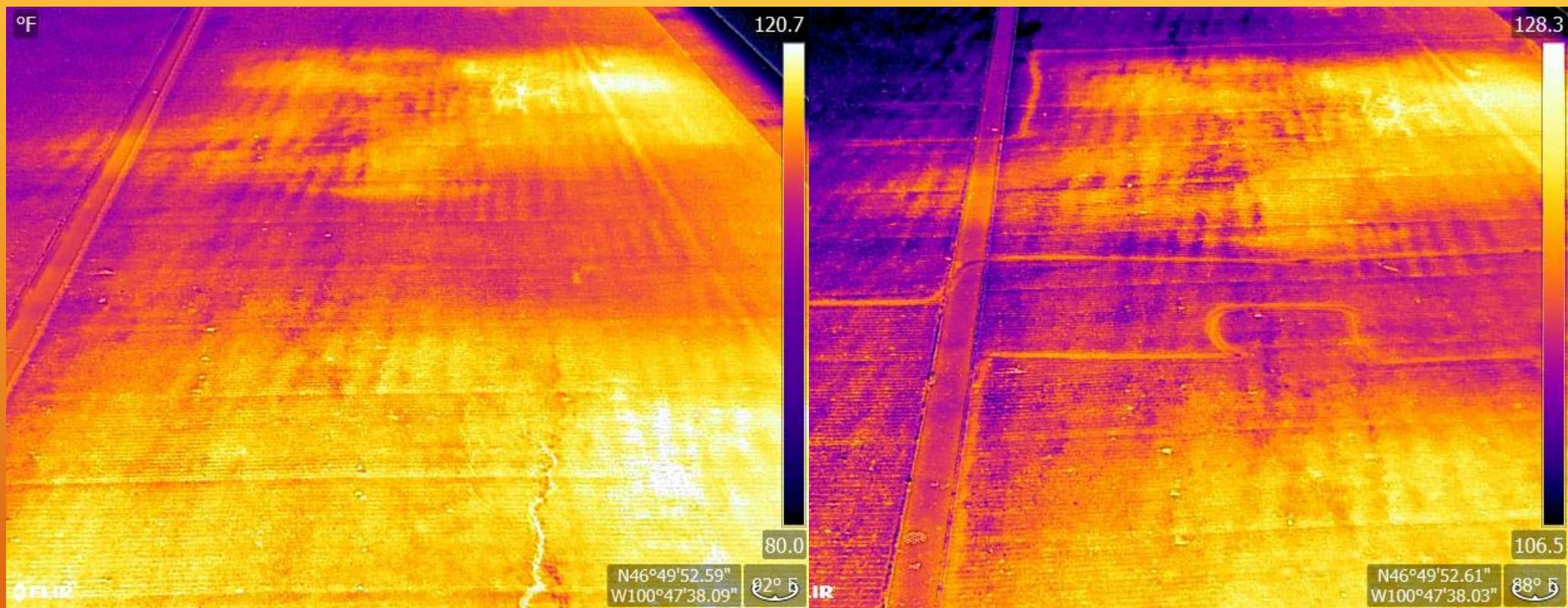
- ▶ Marking and labeling at 10' intervals along right, left, and center of bridge took about 10 minutes
- ▶ Thermal imaging of the deck took about 8 minutes (about 36 images)
  - ▶ 3 passes; 12 images per pass
- ▶ Chaining took about 45 minutes with 3 people working (2 hrs 15 minutes work time)
  - ▶ Included marking delaminated areas



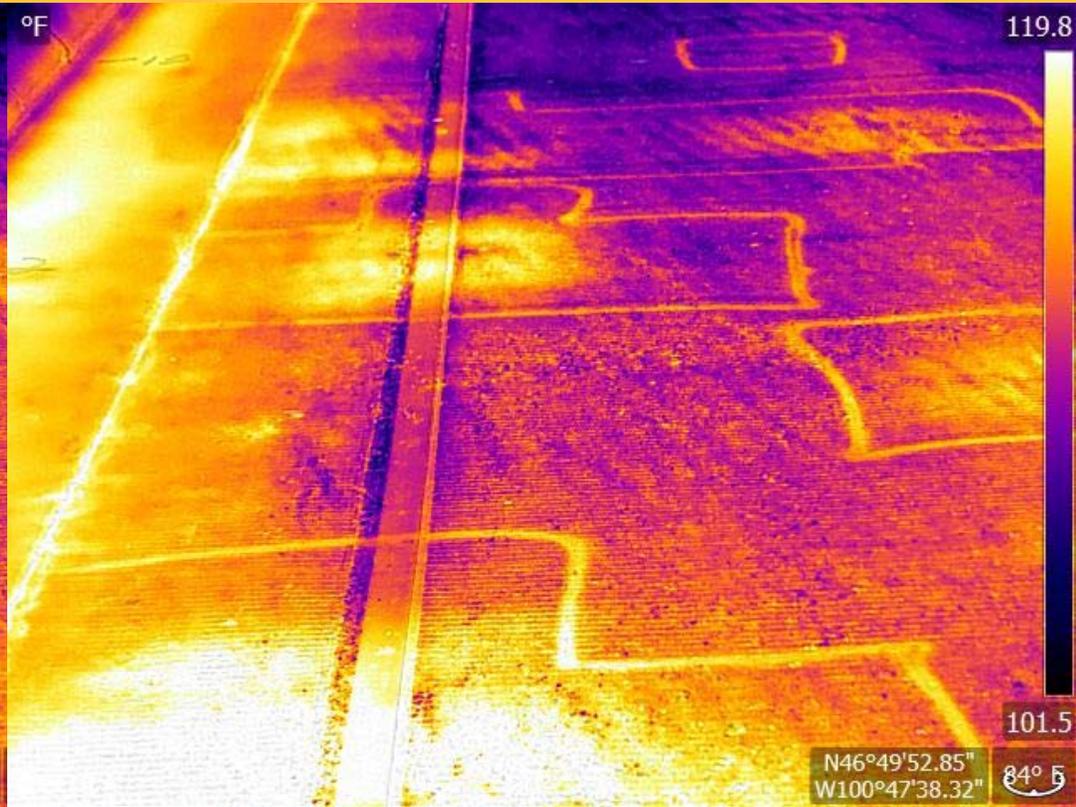
BRIDGE 94-158.425 - WASHINGTON ST



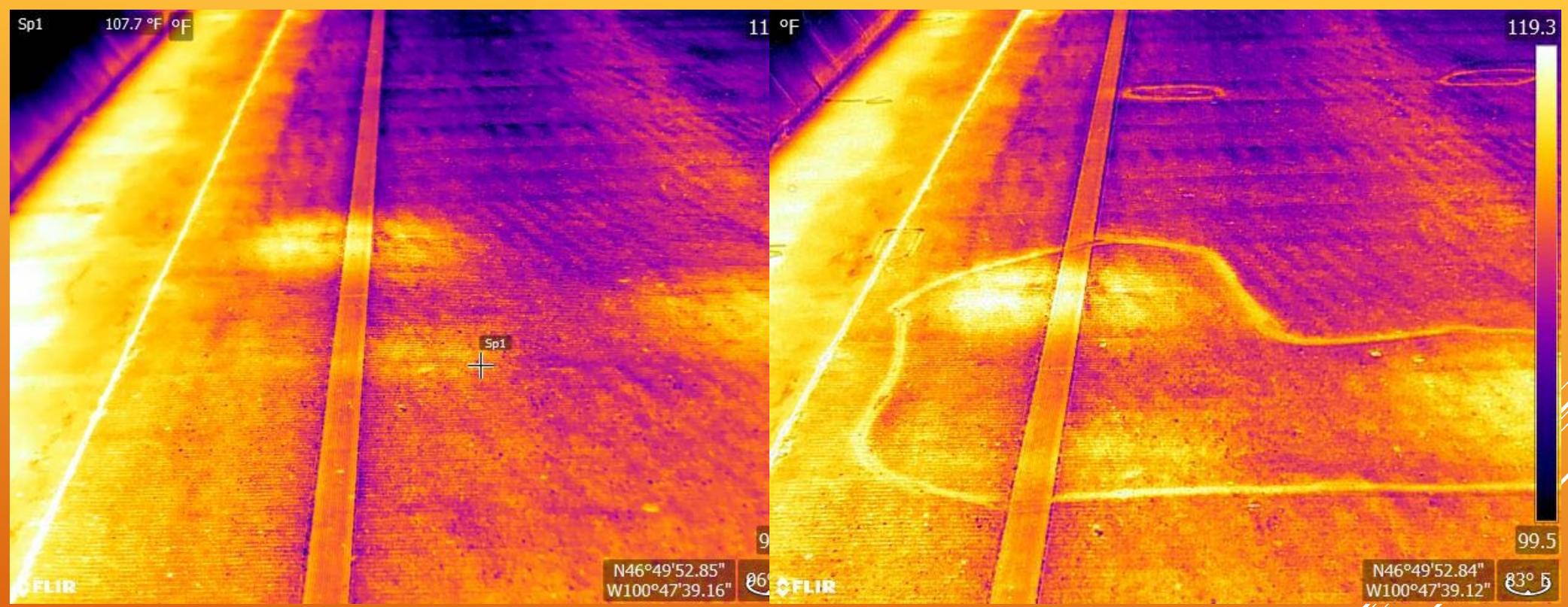
BRIDGE 94-158.425 - WASHINGTON ST



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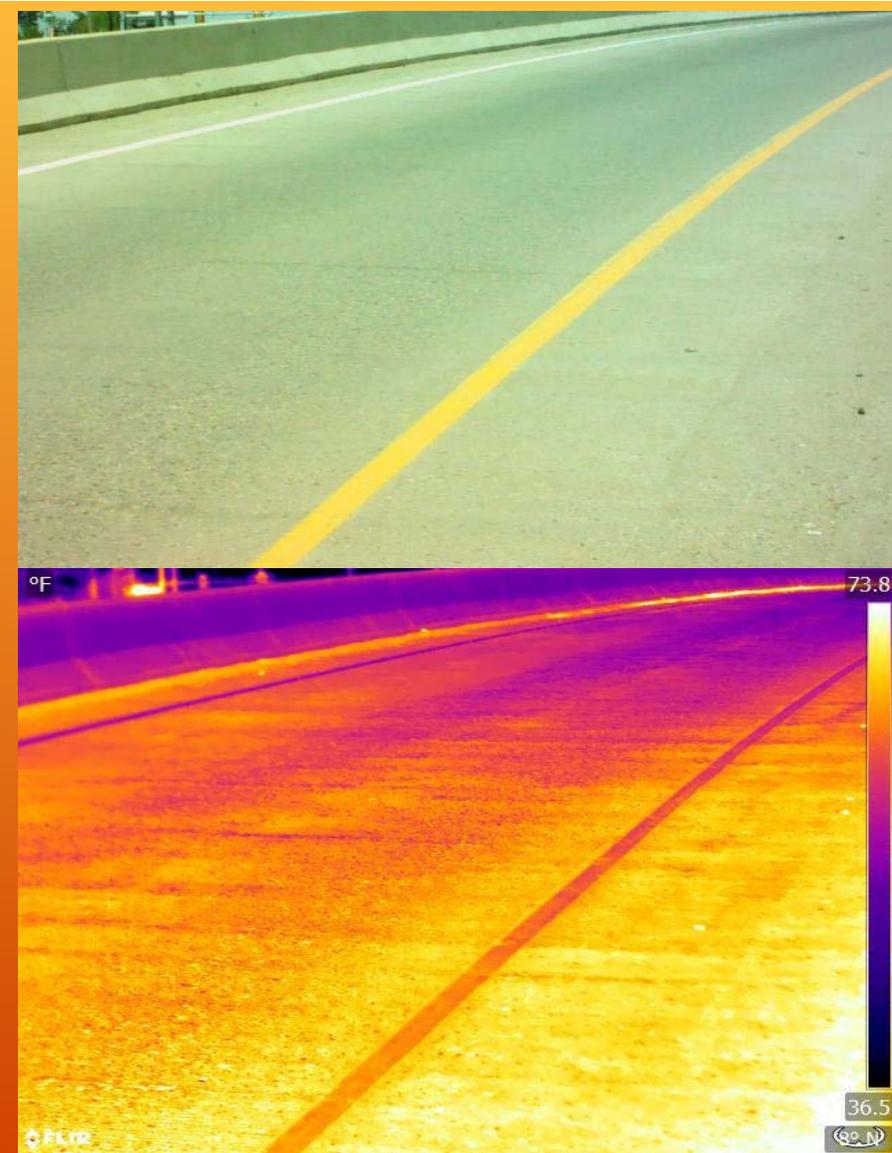
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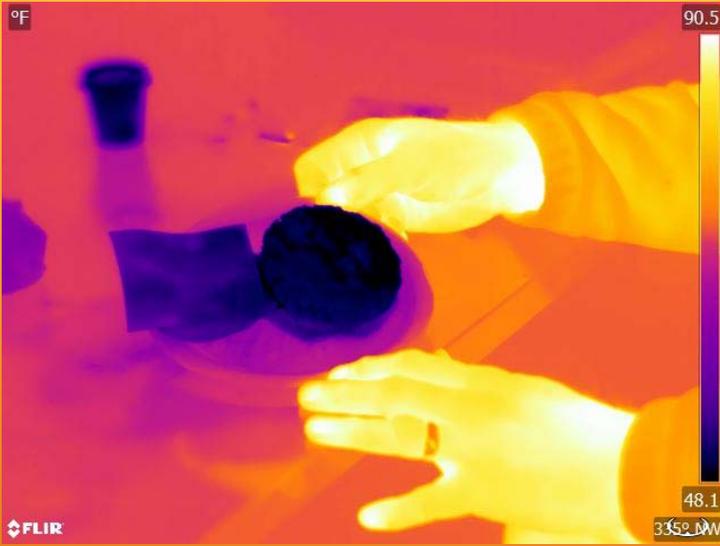


BRIDGE 94-158.425 - WASHINGTON ST

# ADDITIONAL AND FUTURE USES

- Field Reviews to determine scope of work
  - Decks – top and bottom
  - Barriers
  - Other Bridge Elements
- Part of Inspection Program
  - Assist with assessment





THANK YOU!!

DEMO

