CENTER FOR TRANSPORTATION INFRASTRUCTURE AND SAFETY

Field Evaluation of Thermographic Bridge Concrete Inspection Techniques

by

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A National University Transportation Center
at Missouri University of Science and Technology

Disclaimer

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16. Abstract

The goal of this research is to develop new technologies for the condition assessment of concrete to help ensure bridge safety and improve the effectiveness of maintenance and repair.

The objectives of the research are to:

- Quantify the capability and reliability of thermal imaging technology in the field
- Field test and validate inspection guidelines for the application of thermal imaging for bridge inspection
- Identify and overcome implementation barriers

The project will provide hand-held infrared cameras to participating state Departments of Transportation (project partners), train individuals from these states in camera use, and conduct field test of the technology. The reliability of the technology will be assessed and previously developed guidelines for field use will be evaluated through systematic field testing. Project partners will be provided training and hardware for testing within their existing bridge evaluation programs, to identify implementation challenges, evaluate the effectiveness of guidelines, and assess the utility of the technology for bridge condition assessment. A series of field tests that include field verification of results will be conducted by the project partners in cooperation with the research team. These field tests will seek to quantitatively evaluate and verify the capabilities and reliability of the technology under field conditions. These data will be used to validate and improve the guidelines and support practical implementations of the technology. The outcome of the research will be a new tool for improving bridge safety and identifying repair and maintenance needs.

This report addresses the training phase of the project, during which states participating in the pooled fund were training in the underlying theories and procedures for implementing infrared thermography for the condition assessment of bridges. The primary technology developed under this portion of the study was the training modules and slides, which are included herein as an appendix to the report.

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NUTC project 00037366 "Field Evaluation of Thermographic Bridge Concrete Inspection Techniques"

Project No.TPF-5(247)
Field Testing Hand-Held Thermographic Inspection Technologies, Phase II

Report on the Training Phase of the Project

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February 1, 2013

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Disclaimer

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The opinions, findings and conclusions expressed in this publication are not necessarily those of the MO, TX, and NY Departments of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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EXECUTIVE SUMMARY

The training phase of Transportation Pooled Fund project 5(247) Field Testing Hand-Held ThermographicTechnologies, Phase II, consisted of procuring and delivering hand held infrared imaging cameras to each participating state department of transportation and providing training to them in the use of the cameras. From March through October 2012 a camera and training was delivered to the nine participating states at their offices. The cameras provided were FLIR T620s. The training consisted of twelve hours of classroom and field instruction. The classroom instruction covered the basic theory of heat transfer and infrared radiation, the experimental results to date of using infrared images to find subsurface voids in concrete, guidelines for making good infrared images, and the use of the FLIR T620. The field instruction allowed participants to practice making infrared images in afternoon and morning conditions at an in-service concrete deck highway bridge. The participants were then shown how to upload and interpret the infrared images they had made. A total of 82 individuals were trained. The feedback from all participants was positive.

1 PROJECT DESCRIPTION

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The objectives of the research are to:

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- Field test and validate inspection guidelines for the application of thermal imaging for bridge inspection
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This report addresses the training phase of the project, during which states participating in the pooled fund were training in the underlying theories and procedures for implementing infrared thermography for the condition assessment of bridges. The primary technology developed under this portion of the study was the training modules and slides, which are included herein as an appendix to the report.

2 PROJECT BACKGROUND

Thermal imaging can be used to detect and image subsurface voids in concrete. The technology can be applied to determine areas where repairs are needed in concrete bridge decks, soffits of overpass bridges (where there is potentialfor spalling concrete to fall into traffic below) and in FRP overlays. A primary advantage of the technology is that it is non-contact and can be utilized from a distance, such that arms-length bridge access and traffic control are typically not required. The primary disadvantage of the technology is its dependence on certain environmental conditions necessary for the technology to be effective.

During phase I of the research program, guidelines were developed for utilizing the technology on concrete exposed to direct sunlight (such as a bridge deck) and for areas not exposed to direct sunlight (soffits, for example), for which no previous guidelines or procedures existed. These guidelines are available at reference 2. These guidelines will be assessed and modified, if necessary, based on the results of phase II testing. Field test results collected during phase I of the research showed numerous potential applications for the technology, including bridge soffits, composite materials, and concrete decks. Further applications for the technology are expected to be developed through the state-level testing conducted as part of phase II. Additionally, the testing during phase I identified certain conditions that diminished the capability of thermal imaging to easily and quickly assess subsurface damage in concrete, in particular the presence of moisture in the concrete due to saturation. These conditions will be evaluated during phase II through limited laboratory study.

3 THE TRAINING PHASE STATEMENT OF WORK

During this phase, thermal cameras and associated training will be delivered to each participating state. The project deliverable for this phase is**:** Completed training in each partner state and delivery of project equipment.

4 DESIGN OF THE TRAINING

This training is designed to familiarize state Department of Transportation bridge inspectors with thermal imaging. The course is conducted at state Department of Transportation training facilities and at nearby in-service bridges. All the training materials,Powerpoint slides and an eight page camera user's guidebook, have been made available to participating states on the project's internet site. Training materials were developed by the research team during the period January 2, 2012 through March 21, 2012. The classroom presentation was divided into five modules:

Module 1, an introduction to thermography

Module 2, the theoretical background of heat transfer

Module 3, the environmental factors affecting infrared imaging

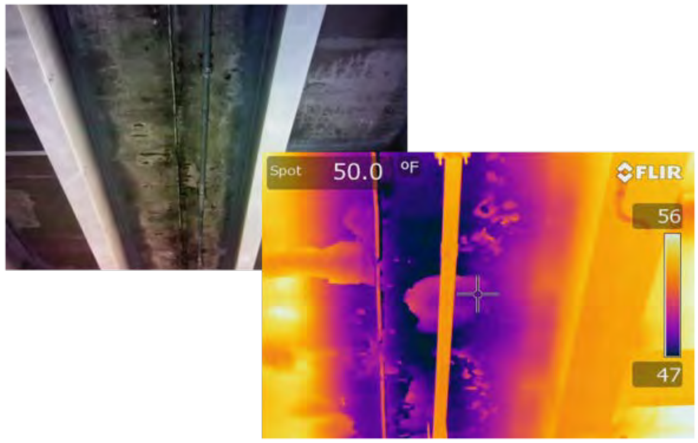
Module 4, making a good infrared image

Module 5, using the infrared camera

All five modules are presented and discussed in the first four hour classroom session. After lunch, the instructors and participants go to an in-service bridge suspected of having subsurface delaminations in the concrete and participants practice imaging suspect areas with the infrared camera in afternoon thermal conditions.

In the classroom the following morning, images from the preceding day's practice are examined and discussed. Each student then has an opportunity to practice interpreting the infrared images. Any errors in imaging are identified and corrective action described. Then the students return to the same bridge and practice taking infrared images in morning conditions (which will differ from the afternoon conditions encountered in the previous session.)

Visible light and infrared images of structures typically imaged in training sessions



5 SELECTION AND DELIVERY OF INFRARED CAMERAS

In the fall of 2011 the research team performed a comparative analysis of available hand-held infrared imaging cameras. TheFLIR T620 was selected as the best camera for the project. In December 2011, an initial order for 5 camera sets was placed. Each camera set consisted of a camera, a 25 degree and a 45 degree angle lens, a spare battery, a battery charger, software for uploading and managing images, and a carrying case. Five camera sets were delivered at the end of December 2011, Five more camera sets were delivered in June 2012. By August 2012 Michigan and Wisconsin had joined the project so two additional cameras were ordered, bringing the total number of camera sets ordered to eleven. Ten of them were transferred to state DOTs at the time of their training session; one camera was retained by the MU research team. The research team delivered one infrared camera to each participating DOT (see table below) except for New York State DOT which received two cameras.

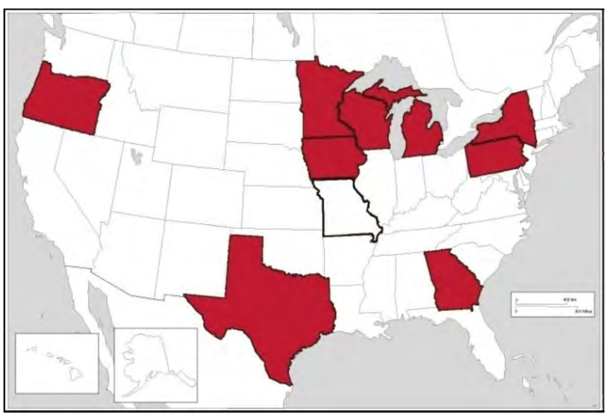
Table 1. Infrared Cameras

Serial number	Date transferred	Receiving organization	Receiving individual
55901214	27 Mar 2012	TX DOT	Leon Flournoy
55901237	23 Apr 2012	MN DOT	Eric Evens
55900995	5 Jun 2012	IA DOT	Mike Todsen
55901032	30 Dec 2011	Univ Missouri	Glenn Washer

55901191	21 May 2012	OR DOT	Bruce Johnson
		PA DOT	
55902092	18 Jul 2012	NYS DOT	Jim Flynn
55902047	18 Jul 2012	NYS DOT	Jim Flynn
55902052	14 Aug 2012	MI DOT	Matt Chynoweth
55902045	17 Sep 2012	GA DOT	Clayton Bennett
55902512	22 Oct 2012	WI DOT	Travis McDaniel

6 DELIVERING THE ON-SITE TRAINING SESSIONS

Training sessions were held in each of the nine participating states during the period March 26 through October 23, 2012.



Texas	March 26-27, 2012
Minnesota	April 23-24, 2012
Oregon	May 21-23, 2012
Iowa	June 4-6. 2012
Pennsylvania	July 16-17, 2012
New York	July 18-19, 2012
Michigan	August 14-15, 2012
Georgia	September 17-18, 2012
Wisconsin	October 22-23, 2012

A total of 82 people received training.Each participant in the training was provided a workbook which included all the training slides used in the instruction and a copy of the infrared camera use guidelines developed by the research team in August 2009 as part of Phase I of this project. Each participant received a certificate for 1.2 continuing education units from the University of Missouri.

7 EVALUATING PARTICIPANTS'SATISFACTION WITH THE ON-SITE TRAINING

At the conclusion of each training session, each participant was asked to complete an evaluation of the training which consisted of 17 questions covering three areas: satisfaction with the training (a higher percentage indicates greater satisfaction), which module of the training was most/least useful, and the participant's expectation of the ease of using infrared cameras in future bridge inspections (a higher percentage indicates the respondent expects camera use to be relatively easy). No training evaluation was done after the TX DOT session.

Table 2. Training Evaluation/Camera Use Ease

State DOT	Satisfaction with training	Most/Least useful module	Will IR camera use be easy?	Number of trainees	Number of evaluations received
MN	75/100	4/1	75/100	8	4
OR	89/100	4/1	82/100	10	10
IA	66/100	4/1	69/100	6	6
PA	88/100	4/1	81/100	10	4
NYS	75/100	4/1	72/100	8	8
MI	84/100	4/1	76/100	22	16
GA	75/100	4/1	83/100	5	5
WI	77/100	4/1	75/100	9	8
TX				7	0

Participants rated each question 1 (best) through 5 (worst.) The Expectation of IR camera use ease was based on 5 questions each of which also had 1 through 5 worst to best rating scale.

8 CONCLUSION

The training phase of the project was successfully executed on time and budget. A total of 82 employees of nine state Departments of Transportation were instructed in the background of thermal imaging and trained in the use of an infrared camera. A FLIR T620 camera was provided to each participating state DOT and that camera was used to image suspected subsurface flaws in concrete bridge decks at a bridge managed by the state DOT. State DOT personnel reviewed images made at the practice session at that bridge successfully practiced identifying and uploading images to the project shared-data site.

Results of participant surveys conducted during the training indicated that the training met the needs and expectations of the states involved in the research. The training slides for each module of the training are included herein as Appendix A.

NUTC project 00037366 "Field Evaluation of Thermographic Bridge Concrete Inspection Techniques"

Project No.TPF-5(247)
Field Testing Hand-Held Thermographic Inspection Technologies, Phase II

Appendix A

Training Modules

Thermography
Module 1, Introduction

Iowa Department of TRANSPORTATION

OREGON.gov

Oregon Department of Transportation

Wisconsin Department of Transportation

Texas Department of Transportation

Minnesota Department of Transportation

MDOT

New York State Department of Transportation

Missouri Department of Transportation

Overview of Training

- Day 1
  - 8-11 classroom discussion
  - 11-12 lunch
  - 12-2 travel to bridge site
  - 2-4 use IR camera to image in PM conditions
  - 4-5 return
- Day 2
  - 8-10 discussion of yesterday's imaging
  - 10-11 travel to same bridge site
  - 11-12 use IR camera to image in AM
  - 12-1 return

The Objectives of this project:

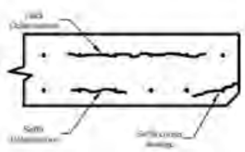
- Using new cameras, test operational parameters with DOT personnel on actual bridge inspections
  - Collect data and upload results to a database
  - Conduct periodic interviews to determine improvements / modifications in use procedures to optimize value
  - Disseminate findings among participating states on an on-going basis
- In parallel with field operations, conduct verification testing, modify the guidelines and conduct lab investigations
- Analyze field data, integrate lab data, and develop a recommended practice that instructs DOT personnel on how to best apply the cameras in the field

Desired results of this project

- Provide maintenance and inspection personnel with a tool for condition assessment of concrete bridges
  - Does not require access
  - Does not disrupt traffic
- Improve their ability to identify defects and deterioration
- Improve the ability to identify the extent of damage to decks w/o interrupting traffic

Background

- Corrosion of embedded reinforcing steel leads to delaminations and spalling of concrete
  - When steel converts to iron-oxides, the corrosion product has greater volume than the steel
  - Tensile stresses resulting from the expansion, which is confined in the concrete, leads to cracking of the concrete
  - Cracks join to form delaminations; grow to surface and cause spalling



Example Bridge Deck Delamination

Detecting Delaminations in Concrete

- **Hammer sounding is the standard for detecting spalling concrete, but**
  - requires hands-on access to the surface of the structure which usually requires traffic control
  - Results are relatively subjective
  - Time consuming
- **Infrared cameras**
  - can image areas without hands-on access and at greater distances
  - can quickly determine the extent of delamination
  - images can be viewed and interpreted in the field <u>and</u> transmitted and archived at the office
  - Results document in digital file
  - More objective (?)

7

IR Challenges

- IR is capable of detecting delaminated concrete
  - Environmental factors limit the reliability and capability of the technology
- These factors include
  - Wind speed, solar radiation, diurnal temperature variations, shade, observation angle, reflections from environment, color variations, precipitation
  - Depth of delamination, type of overlay, etc.

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How does it work?

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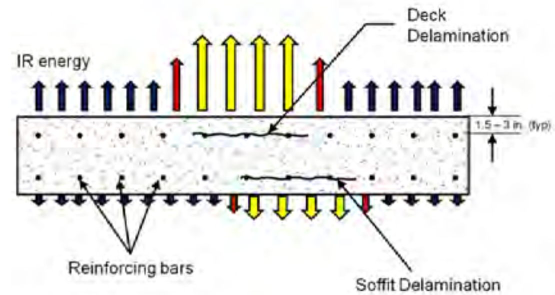
IR Emitted From Concrete Bridge Decks



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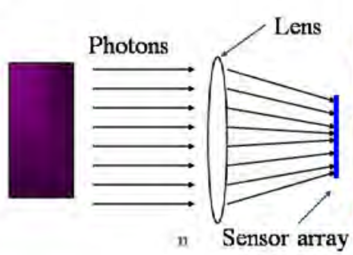
IR cameras are similar to ordinary digital cameras

- Infrared cameras and digital cameras both use charged couple devices (semiconductors) to measure the number of photons impinging on the target array inside the camera
- The target semiconductor is tuned to the appropriate wavelength



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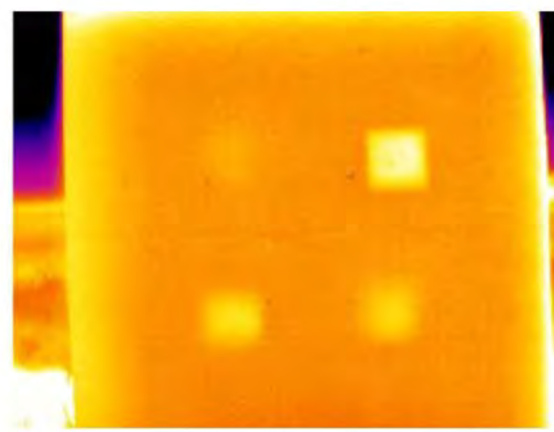
Phase I Research Background



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Experimental Background

- Field
  - Thermal contrast was measured in a test block at different void depths, with and without solar loading, and at a variety of temperature, wind, and humidity conditions to determine the parameters for good thermal imaging. Those findings are the 'Guidelines'
- Lab
  - COMSOL software was then used to create a data model, (calibrated against field data)

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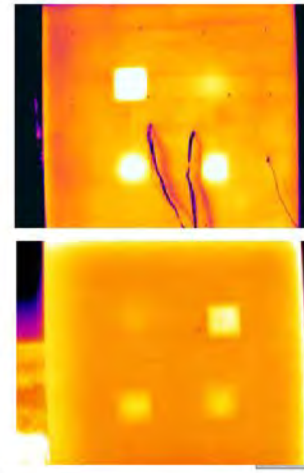
Test Block



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As part of the experimental background to this project, draft use guidelines were developed


Development of Hand-held Thermographic Inspection Technologies

Appendix A: Guidelines for Thermographic Inspection Of Concrete Bridges

August 19, 2008

R06-038

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Phase II: Implementing

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Training Objectives

- Theoretical background of thermography
- Experimental background of this project
- How to make a good IR image
- Using the FLIR T620 camera and software

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During today's training…

- Discuss the your thermography experience to date
- Discuss the theoretical and experimental foundations of this project
- Familiarize you with the FLIR T620 camera
- Familiarize you with good IR imaging practices
- Discuss IR image interpretation and data management
- Deliver FLIR camera for your use

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FLIR T620 Thermal Camera

- Hardened for field use
- Good digital camera
- Higher resolution imager
- Good battery life
- Also looked into Jenoptik and Fluke IR cameras
  - good systems but FLIR offered better features for field use

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Thermography

Module 2, Theoretical Background: heat transfer

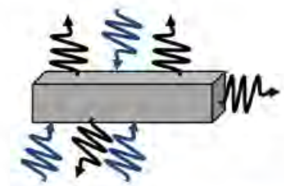
Iowa Department of Transportation
Minnesota Department of Transportation
MDOT Department of Transportation
New York State Department of Transportation
MoDOT Missouri Department of Transportation
pennsylvania
Wisconsin Department of Transportation
OREGON.gov
Oregon Department of Transportation
Texas Department of Transportation
GDOT Georgia Department of Transportation

This module's agenda

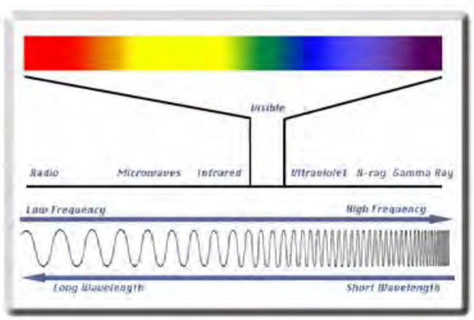
- What is infrared thermography?
- Heat Transfer
  - Convection, Radiation, Conduction
- Factors affecting IR cameras
  - Thermal emissivity
  - Object shape and corner effects
  - Surface (texture, water, asphalt, etc.)
- Review

IR Radiation

- Materials/Objects
  - Emit radiation into the environment
  - Absorb radiation from the environment
  - At thermal equilibrium, emit and absorb at the same rate



What is Infrared Radiation?



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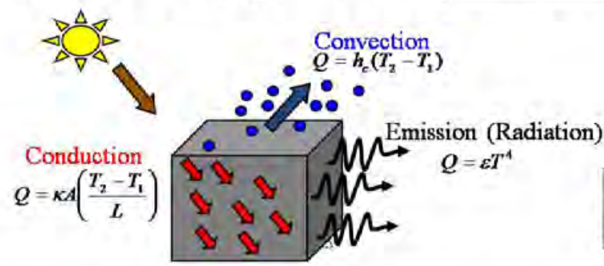
Thermal measurements

- Heat flows (transfers) from hot to cold
- Thermography measures IR radiation emitted from an object, and creates an image in which different colors represent different temperatures
- Reflections, an object's shape and its internal features affect the amount of IR radiation it emits
- Amount of emitted radiation proportional to T^4

3 fundamental methods of heat transfer

- Wind over hot concrete cools it by *convection*
- Direct sunshine on concrete heats it by *radiation*
- Heat flows through concrete by *conduction*



Convection

- Examples of heat transfer by convection
  - Wind blowing over a concrete bridge deck
  - Fan blowing air over a concrete test block
- If concrete is warmer than environment (solar), wind is detrimental
- If concrete is cooler, wind can be helpful

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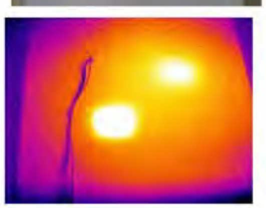
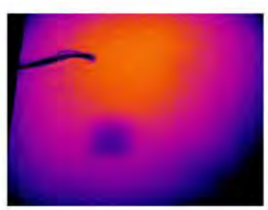
Convective cooling reduces thermal contrast

- Air blowing over a heated block of concrete cools it by convection





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Conduction

- Heat transfer by contact
- Internal heat transfer in solids
- Affected by:
  - Thermal conductivity of material
  - Distance (Time)
  - Temperature gradient

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Conduction

- The sun heats one side of the bridge
- The heat flows through the steel
- But this flow takes time, providing a temporary temperature difference (thermal gradient)

$$Q = \kappa A\left(\frac{T_2 - T_1}{L}\right)$$

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Radiation

- Radiation is the transfer of heat by electromagnetic waves
- Radiation from the sun heats things on earth
  - Direct radiant heating on decks
  - Objects radiate IR energy
    - Detected by camera

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Thermal Inertia

- Thermal inertia is a measure of a material's ability to conduct and store heat
- Is a function of: k = thermal conductivity, ρ = density, C = specific heat
- Materials tend to:
  - Retain previous temperatures
  - React slowly to thermal changes

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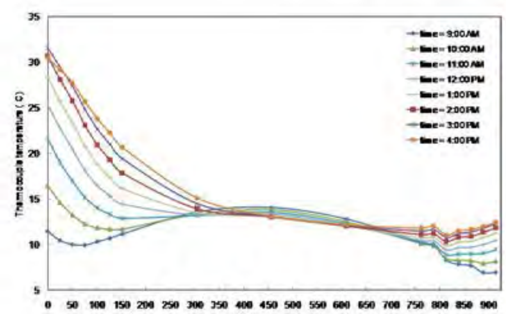
Test Block



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Thermal images are affected by

- Edge Effects
  - Edges and corners heat first
- Moisture
  - Wet spots have different thermal inertia and may have different emissivity
- Internal Features
  - Internal features such as diaphragms, voids, etc. show through in thermal images

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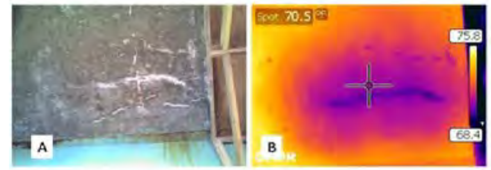
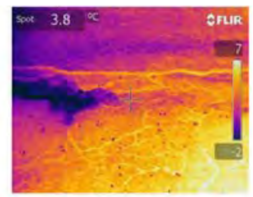
Examples



Saturated



Surface Cracks

Internal Diaphragms

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Examples

Corner Effect

Emissivity Difference

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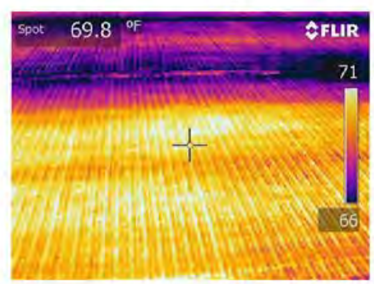
The angle of observation affects the apparent amount of thermal emission

- More energy is emitted at normal angles



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Summary

- 3 types of heat transfer
  - Convection, Conduction, Radiation
  - IR cameras image surface temp
- Thermal Inertia
- Infrared Radiation
- Factors affecting images
  - Edge effects
  - Angle
  - Surface cracks

Thermography

Module 3, Environmental Factors affecting IR images

This module will describe:

- Environmental effects on image quality
- Experimental findings from phase I
- Examples of good and bad conditions for capturing thermal images based on:
  - Ambient temperature
  - Solar loading
  - Wind speed
- example thermal images of delaminations with and without solar loading

Experimental Findings

- For solar exposed surfaces:
  - Late afternoon provides optimum thermal contrast, so imaging is best and deepest voids can be detected
  - Low wind speed improve thermal imaging
- For non-solar exposed surfaces
  - The part of the day in which ambient temperature is increasing is best for imaging
  - Moderate wind improve thermal imaging due to convection heating or cooling

Experimental Setup

- A concrete test block with embedded Styrofoam blocks and thermocouples was constructed to simulated a concrete bridge with voids
- An on-site mini-weather station was assembled to monitor:
  - Ambient Temperature
  - Solar loading
  - Wind Speed
  - Humidity
- Data was logged every 10 minutes, 24 hours a day

Simulated subsurface Defects

Test Block Construction

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Test Block – Data House

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Test Block, Weather Station, and Monitoring Equipment

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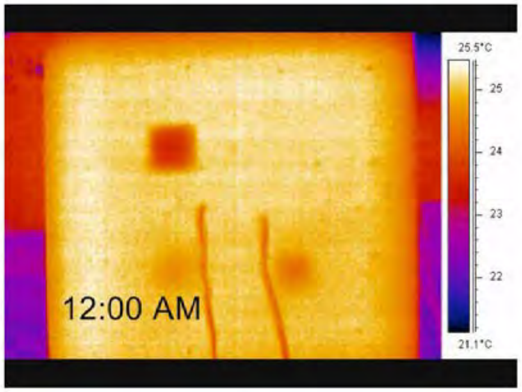
24 hour Test Block Video



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Other Effects

- Time delay from application of heat to detection of damage

$$t \sim \frac{z^2}{\alpha}$$

t = observation time (s)
z = depth of the target (m)
α = thermal diffusivity of the material
K = Thermal Conductivity
C = Specific Heat

$$\alpha = \frac{K}{\rho C}$$

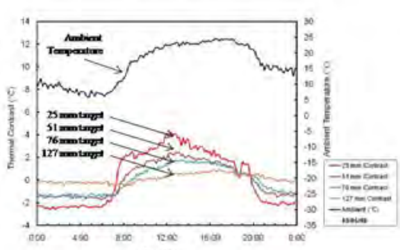
- Contrast loss is a function of defect depth

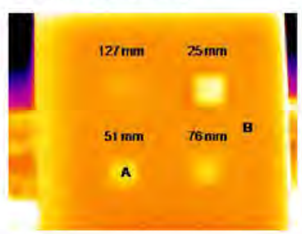
$$c \sim \frac{1}{z^3}$$

c = thermal contrast loss due to defect depth
z = depth of the target (m)

Data Reduction with application

- Graph on left has 2 (y) axis
  - On LHS, the thermal contrast between a pixel over a target and a pixel in acreage
  - On RHS, environmental variable is shown
    - Ambient temperature, solar loading, wind speed, or humidity





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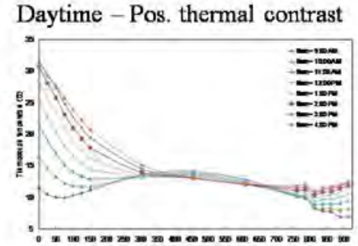
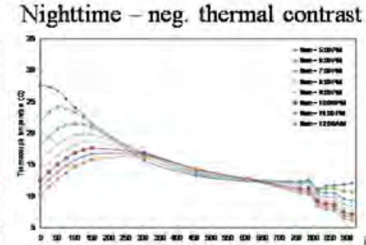
Thermal Gradient in Test Block

Daytime – Pos. thermal contrast

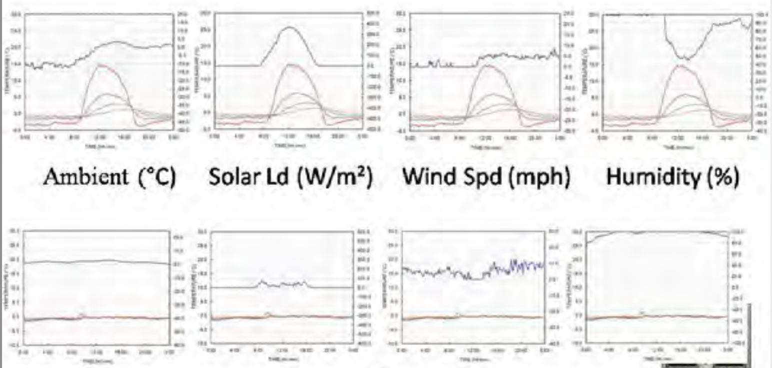


Nighttime – neg. thermal contrast



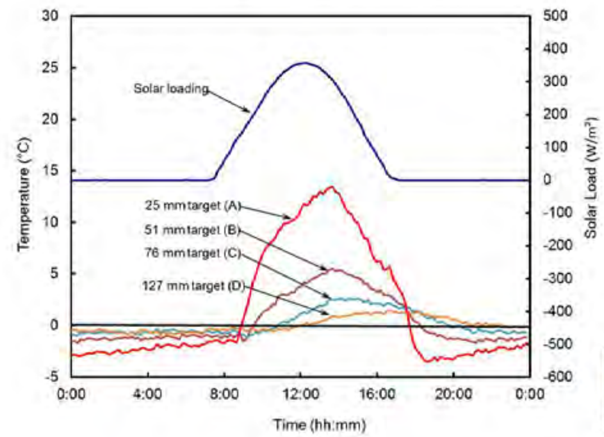
48

Ambient temperature vs. thermal contrast: good conditions for thermal imaging (12/17/07) and poor conditions for thermal imaging (1/10/08)



12

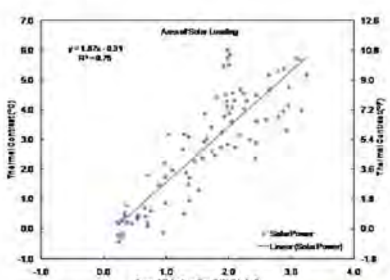
Solar Loaded



Results – South Side

Effect of Solar Loaded

Area of Solar loading:
Intensity of sun x time
-For 1 °C contrast, 0.7 kW-hr/m²
Min.



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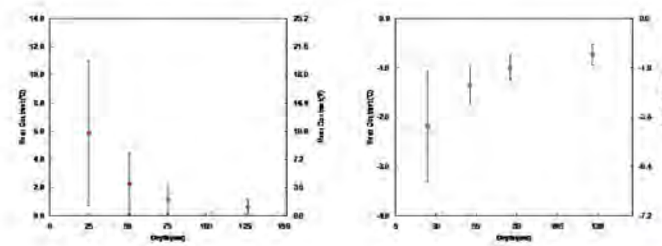
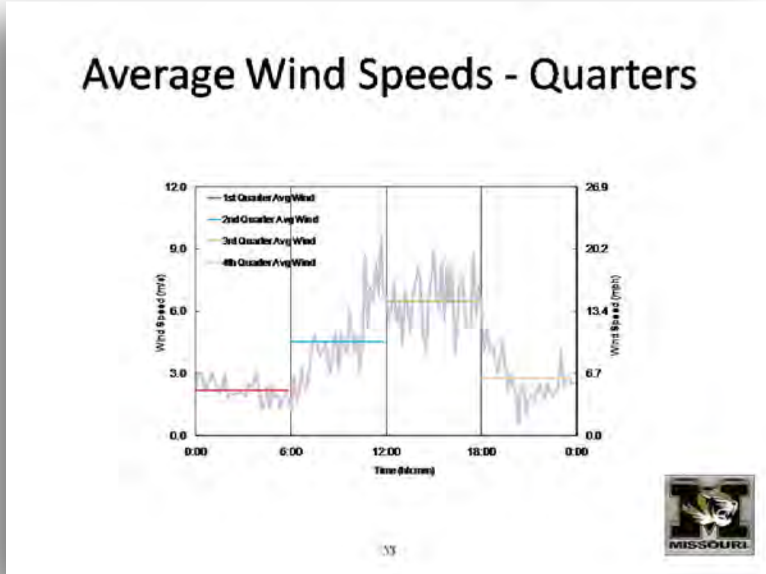
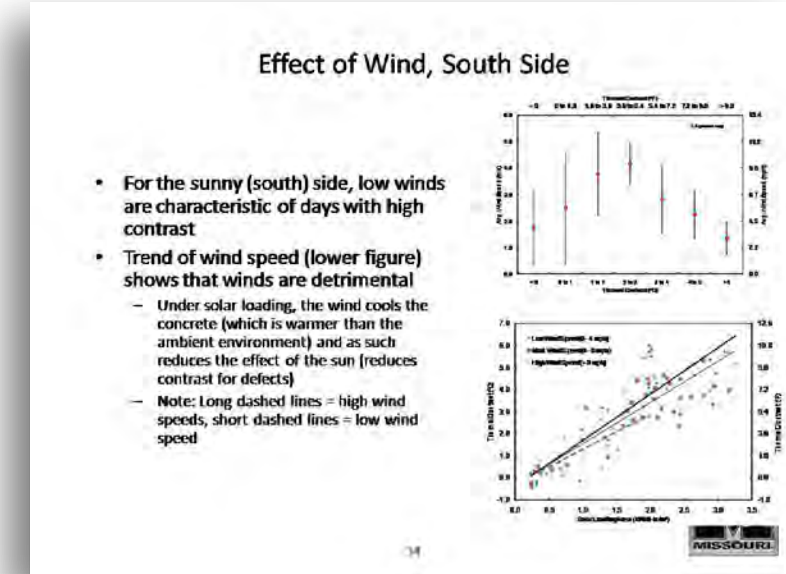
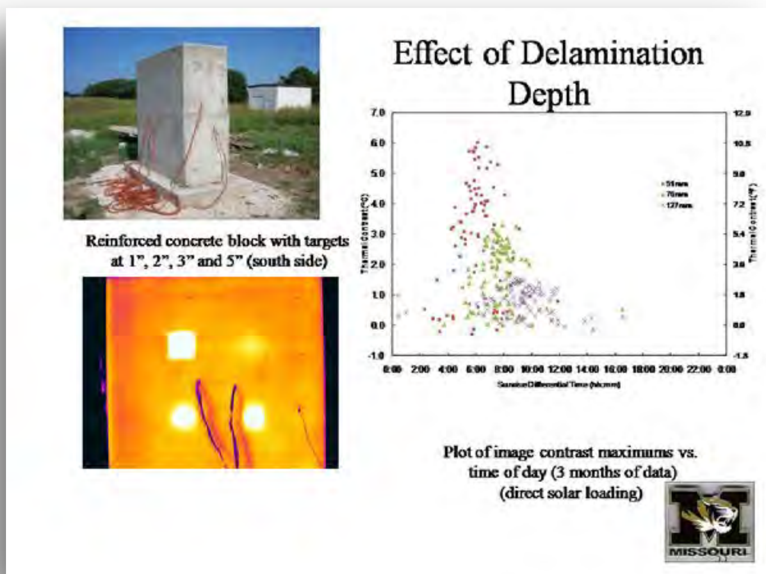
Effect of Depth of Target

- Month of November, South Side



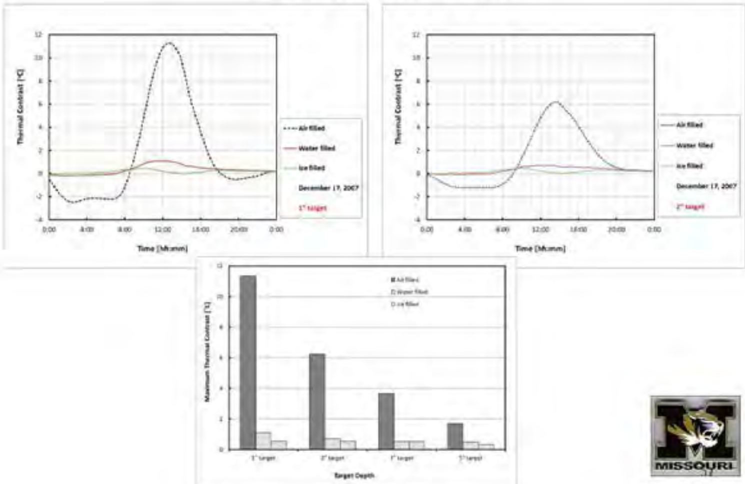

Average Wind Speeds - Quarters
1st Quarter Avg Wind
2nd Quarter Avg Wind
3rd Quarter Avg Wind
4th Quarter Avg Wind
Wind Speed (m/s)
Wind Speed (mph)
Time (hh:mm)
33


Effect of Wind, South Side
• For the sunny (south) side, low winds are characteristic of days with high contrast
• Trend of wind speed (lower figure) shows that winds are detrimental
– Under solar loading, the wind cools the concrete (which is warmer than the ambient environment) and as such reduces the effect of the sun (reduces contrast for defects)
– Note: Long dashed lines = high wind speeds, short dashed lines = low wind speed
34

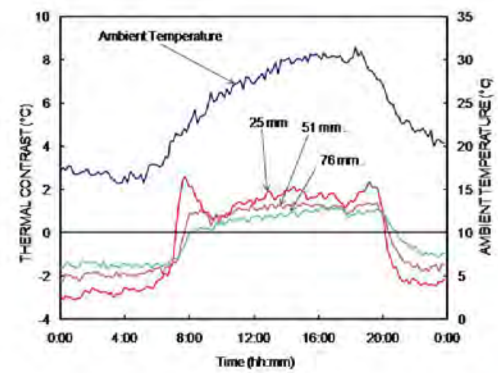

Effect of Delamination Depth
Reinforced concrete block with targets at 1", 2", 3" and 5" (south side)
Plot of image contrast maximums vs. time of day (3 months of data) (direct solar loading)


Inspection Periods – South Side
Sunrise
Sunset
Sunrise
Target Depth (mm)
Inspection Period (hh:mm)
36

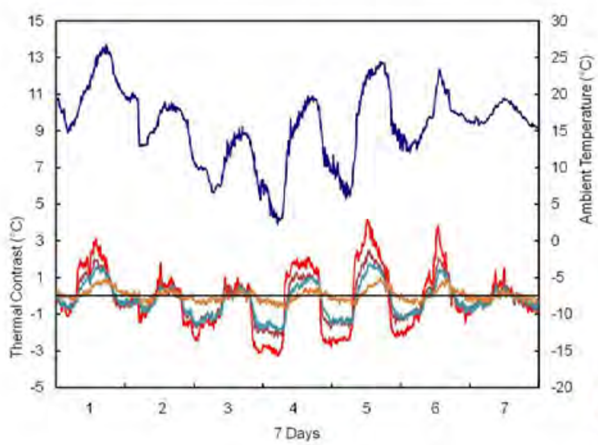
Filled Defects



Shady Conditions

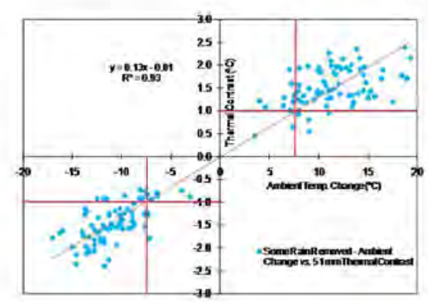


Ambient Temperature vs. Thermal Contrast (North side)



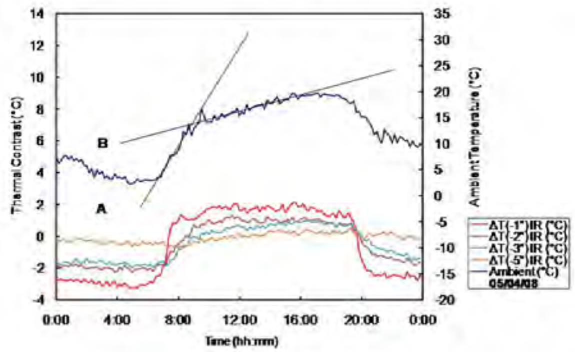
Ambient Temperature Change vs. Thermal Contrast

- On average, 1.4 ºC of contrast either positive (day) or negative (night)



60

Rate of Change Analysis (ROC)



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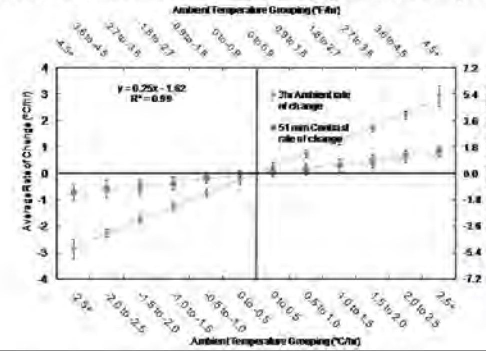
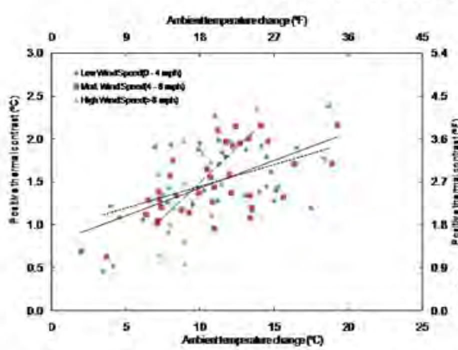
Ambient ROC, 2 in. Deep Target

- It was found that contrast is diminishing when ROC < 0.5 deg C/hr
  - During times of constant temperature, contrast is diminishing, avoid inspections during this time for 2 in. deep defects
  - Inspection should be done during changing ambient temperature

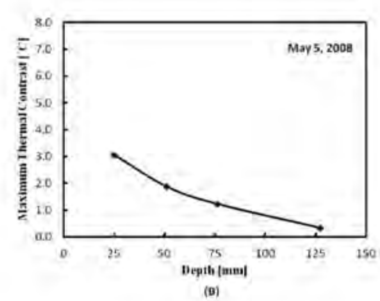


Effect of Wind
North Side

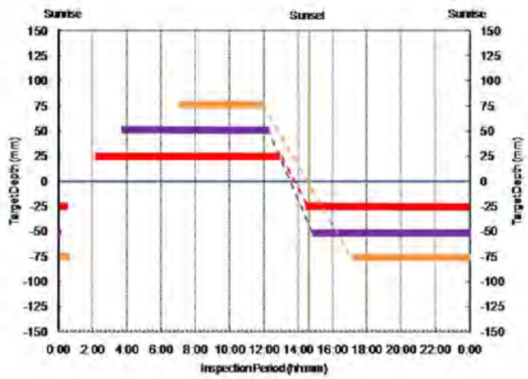


Long dash line = high wind
Short dash line = low wind

Effect of Depth
North Side



Inspection Period – North Side



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Guidelines Overview

- For solar exposed surface
  - 4 hrs. after sunrise (2 in. deep). For 3" deep defect, 5-6 hrs. after sunrise, will last about 5 hrs.
  - Less than average 8 mph winds
- Shaded side
  - Temperature difference of 15° F
  - 10 degrees in first 6 hours after sunrise
  - When temp. decreases, contrast begins to decrease
  - At least 4 hrs. after sunrise for 2 in., about 7 hrs. for 3 in. deep flaws
  - Wind speed less than average 10 mph (?)
    - Wind not necessarily bad

Review

- Experimental set up
- Good vs. bad days for making thermal images
- Delaminations with and without solar loading
  - For solar exposed surfaces
    - Low wind speed and low humidity
    - Late afternoon provides optimum thermal contrast
  - For non-solar exposed surfaces
    - Moderate wind improve IR imaging (?)
    - Part of the day when the ambient temperature is increasing
      - Morning

Thermography
Module 4, Making a Good Image

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pennsylvania

Wisconsin Department of Transportation

Texas Department of Transportation

Minnesota Department of Transportation

MDOT

New York State Department of Transportation

Missouri Department of Transportation

68

This module's agenda

- Capturing a good image
  - Level and Span
  - Image Parameters
    - Focus
    - Range
    - Composition
- Thermal Tuning
- Lens selection

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Level and Span

- The *level* is the temperature at the center of the *span*
- The *span* is the temperature range over which the color palette is applied
  - *Palettes can be altered*
  - *Temperature ranges outside the span are shown as the limit color in the span*

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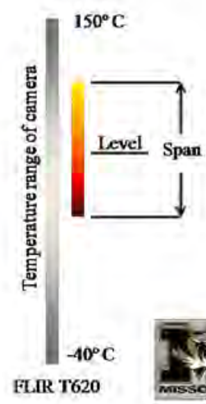
Level and Span

- The span moves with the level across the cameras range
- Span enhances the contrast in the image



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Level and Span

- For concrete structures, typical span settings are in the range of 2 to 8 degrees C.
- The span level setting is critical to allowing for contrast in the image

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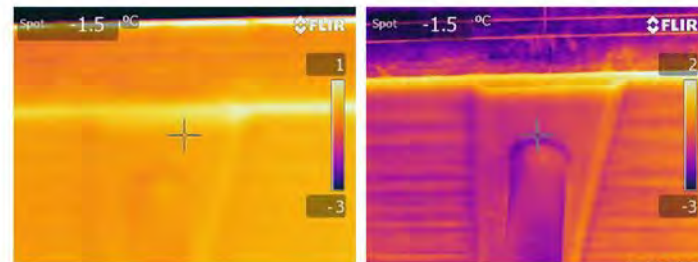
Focus

- Thermal cameras focus is much the same way as any other camera
- Focus cannot be adjusted once an image has been saved on the camera
- The focus varies according to range, and may need to be adjusted frequently if the range to the object under inspection varies
- Use an edge, tool or coin to enable focus
  - Some defined edges in the thermal image

Focus importance for object clarification

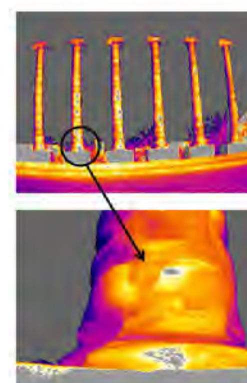


Composition

- Images are created by a focal plane array in the thermal camera
- Each pixel corresponds to a physical size
  - The greater the range to the target, the larger the physical space imaged by each pixel in the camera
- At large distances, small features are lost
  - Zoom in camera is digital (pixels just become larger)

Composition

- From large distances, area of thermal contrast may consist of only a few pixels
- Imaging with the correct composition allow for the boundaries to be defined



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Thermal Tuning

- Adjusting image to enhance the contrast
- Level adjustment
  - Bring middle of span to an average temperature for the structure being observed
- Span Adjustment
  - Create the contrast needed to identify thermal anomalies

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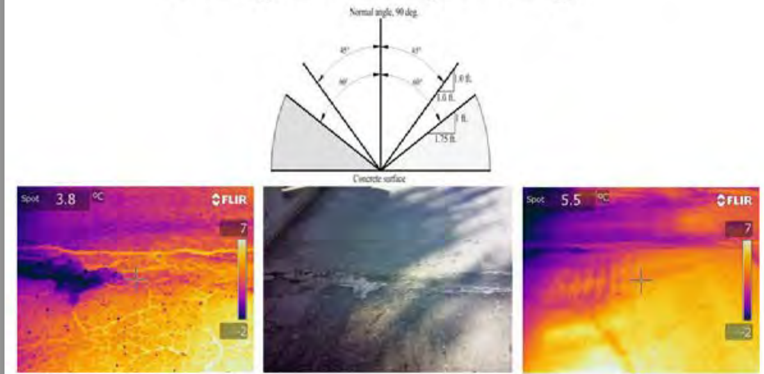
Using the Proper Angle



Good Angle

Bad Angle

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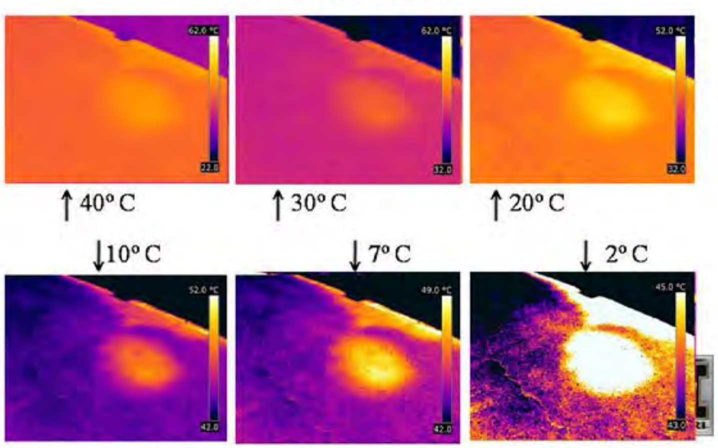
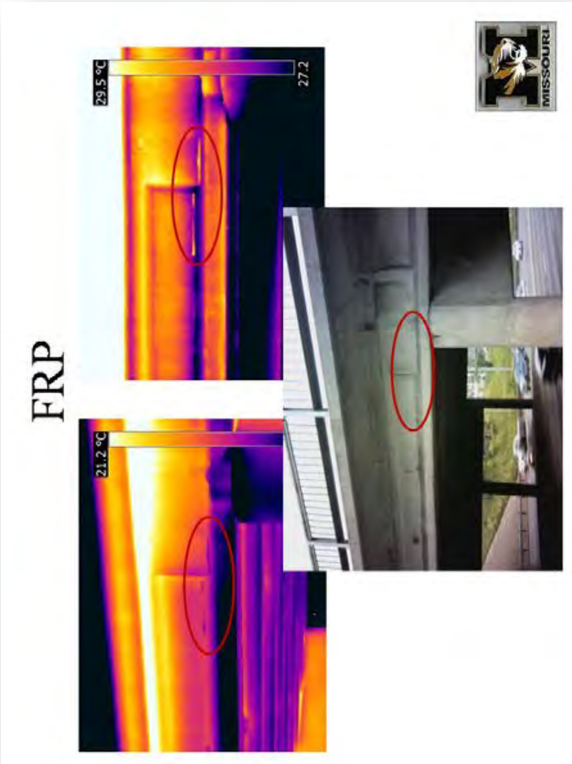
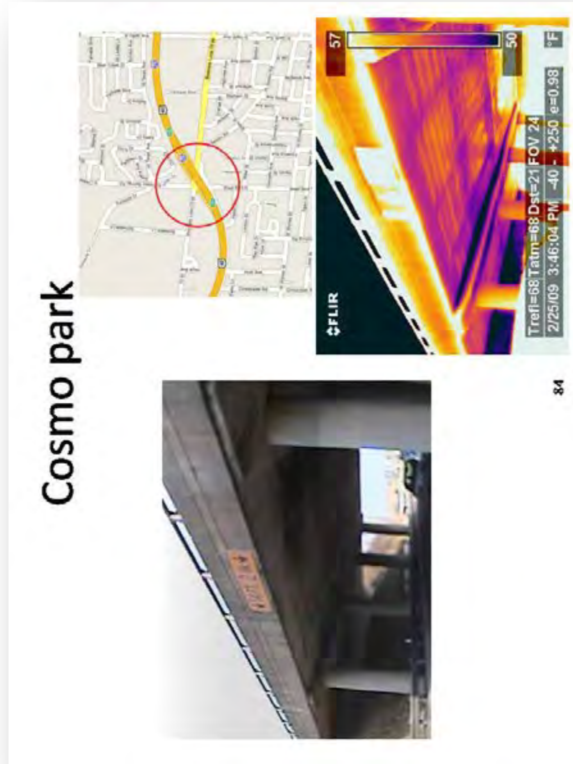
Perfecting the Manual Span/Level Adjustment

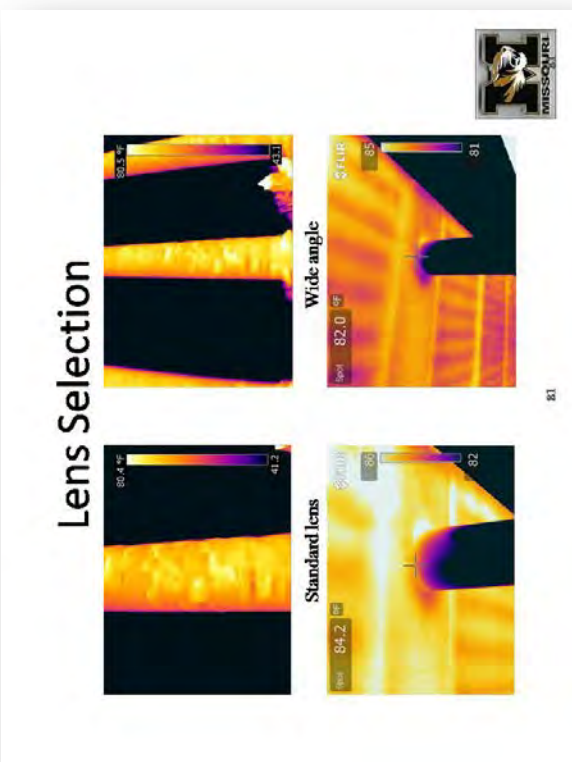


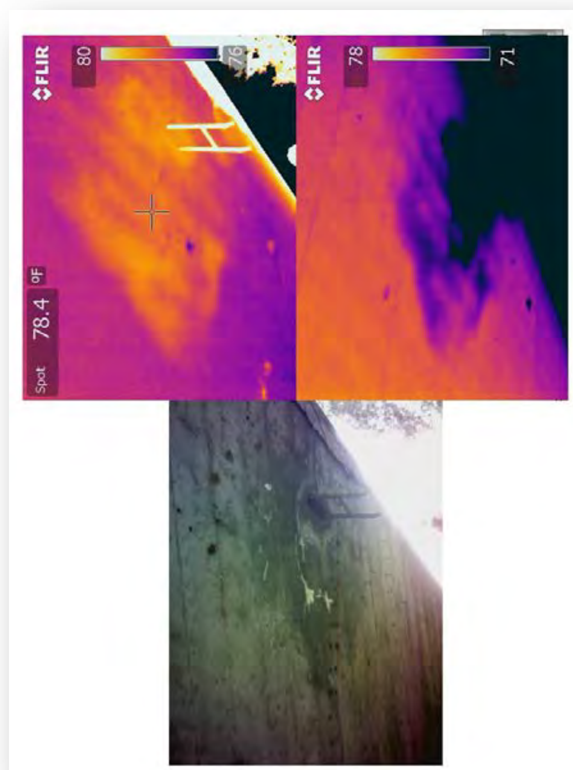
Lens Selection

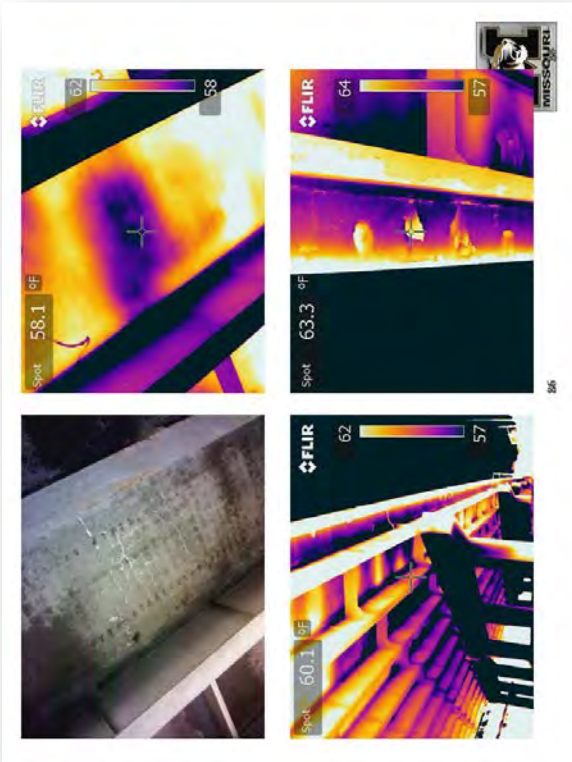
- Camera has two lenses –
  - 25 º
  - and wide-angle, 45 º
- To compose an effective picture, adequate image content is required to detect areas of thermal variation
  - If close to a bridge, thermal variations may not appear if larger than imaging space

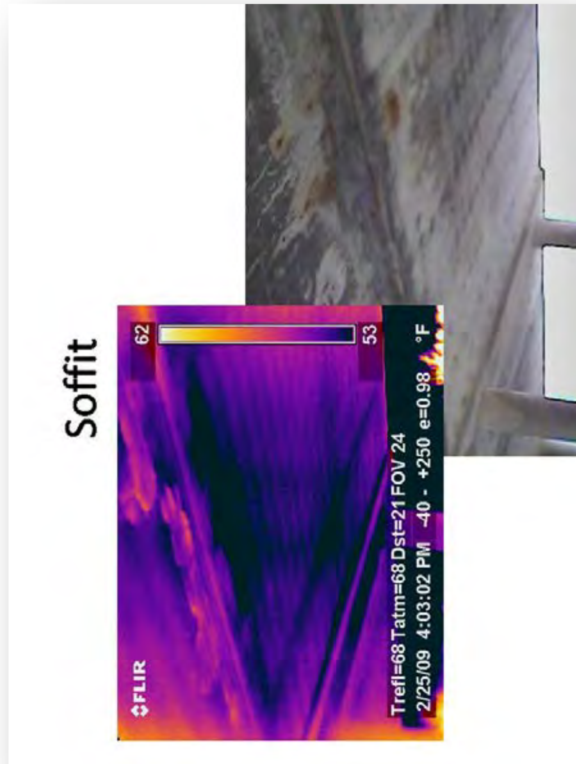

FRP
29.5 °C
27.2
21.2 °C

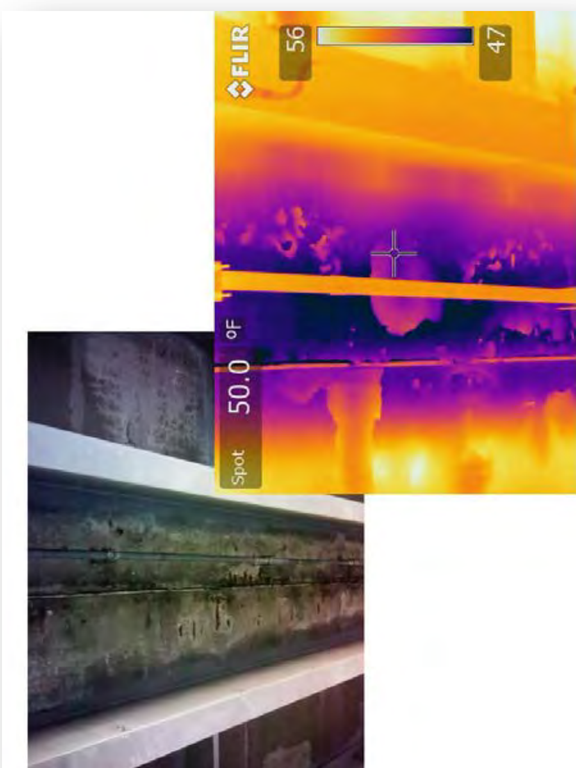

Cosmo park
57
50
°F
FLIR
84

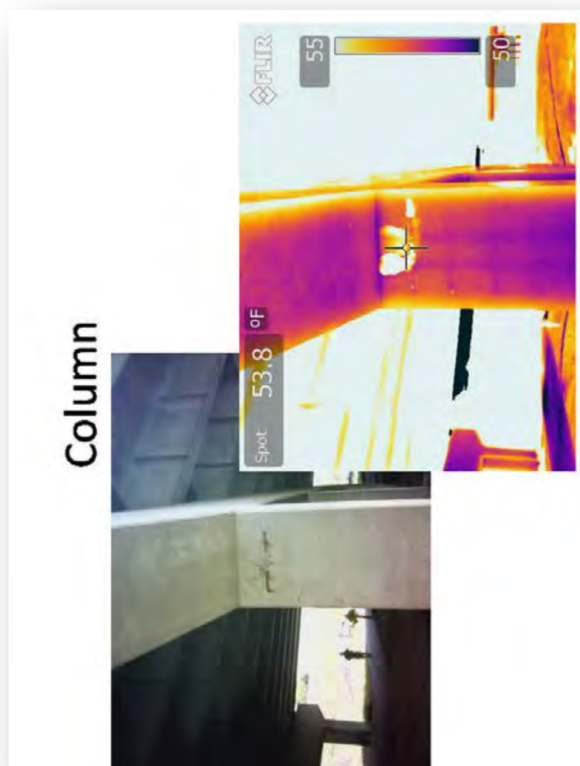

Lens Selection
Standard lens
Wide angle
84.2
82.0
81
MISSOURI


FLIR
80
76
Spot
78.4
°F
78
71




Soffit
Trefl=68 Tatm=68 Dst=21 FOV 24
2/25/09 4:03:02 PM -40 - +250 e=0.98 °F

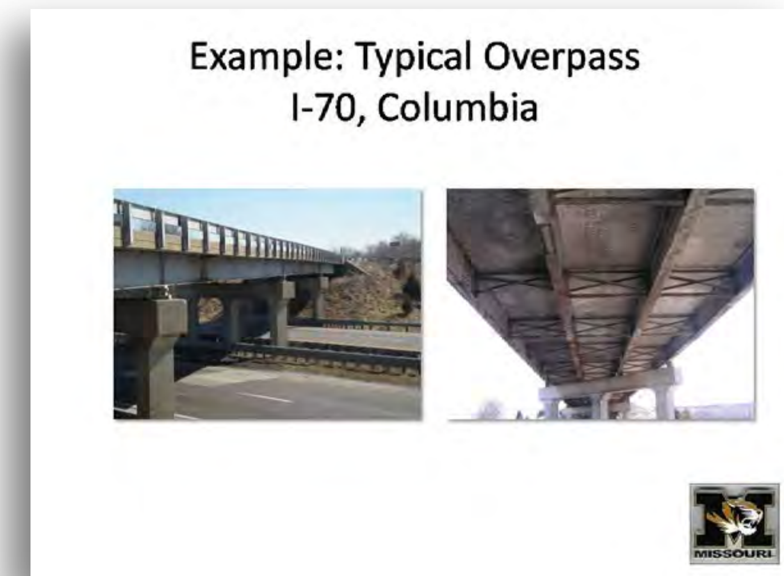


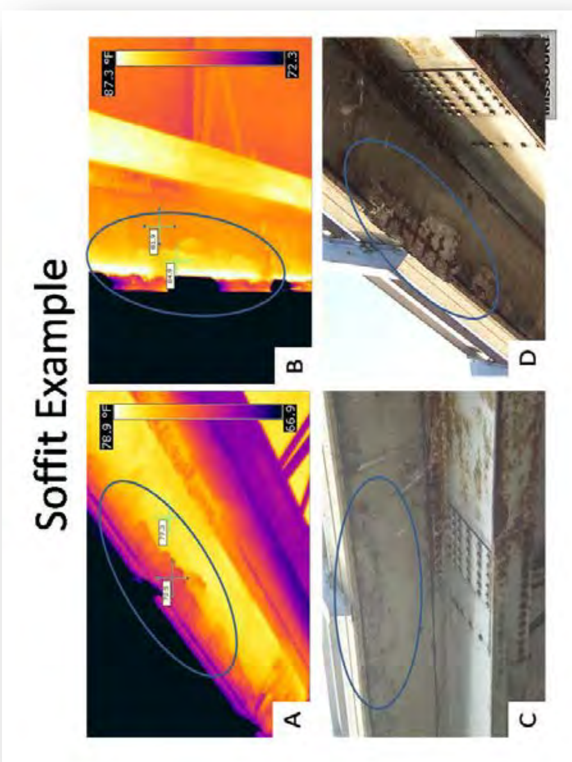

Column


Reflections
FLIR
68
64
89

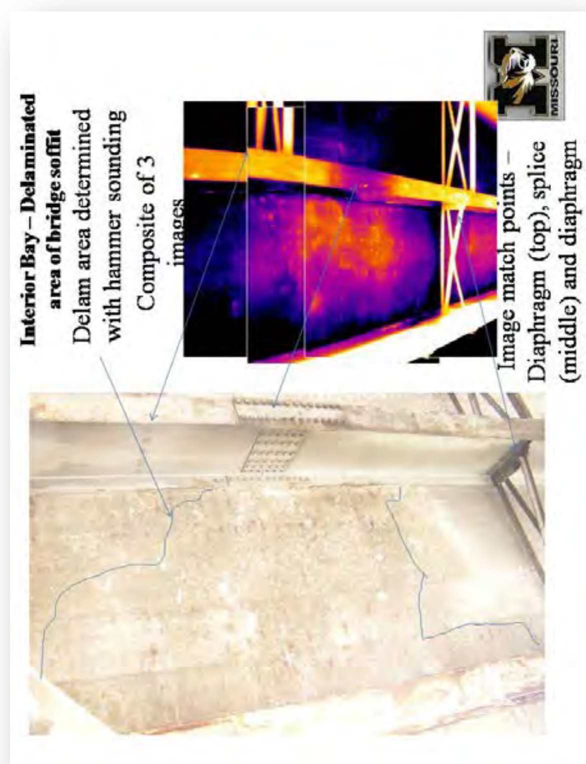

FLIR
81
49

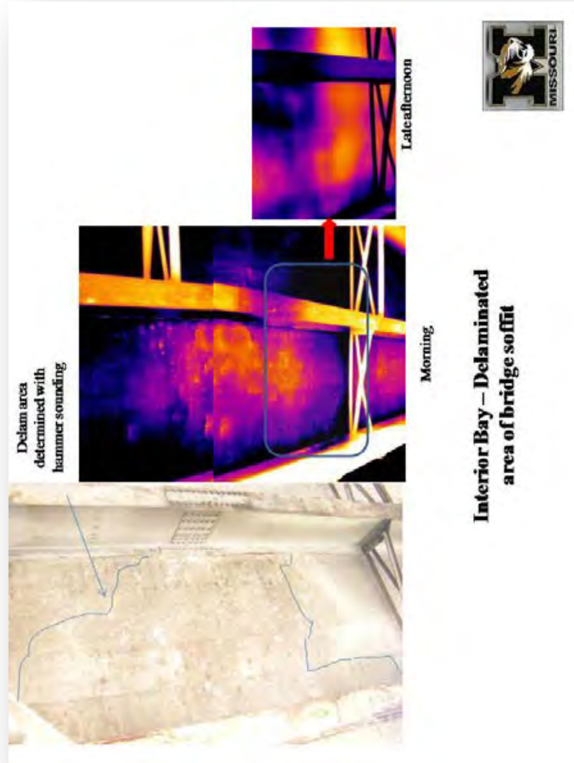

51.7
24.1
FLIR
Before
2 months later
91
MISSOURI

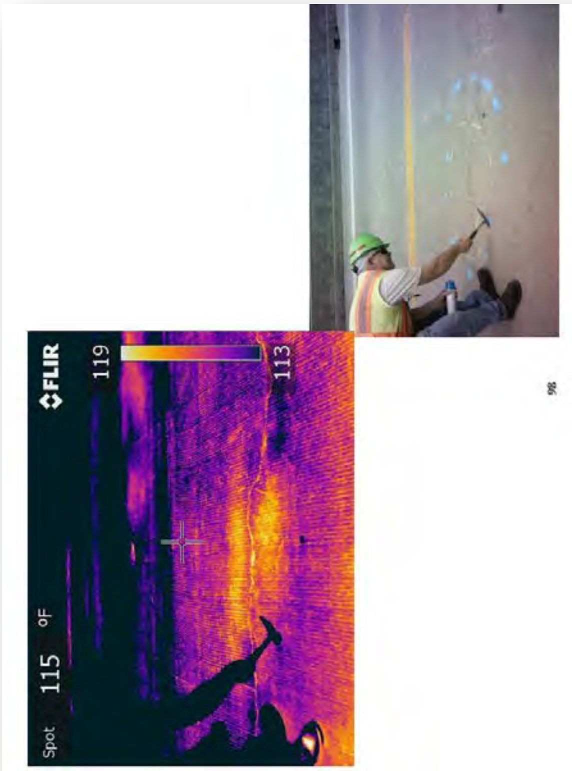

Example: Typical Overpass
I-70, Columbia
MISSOURI

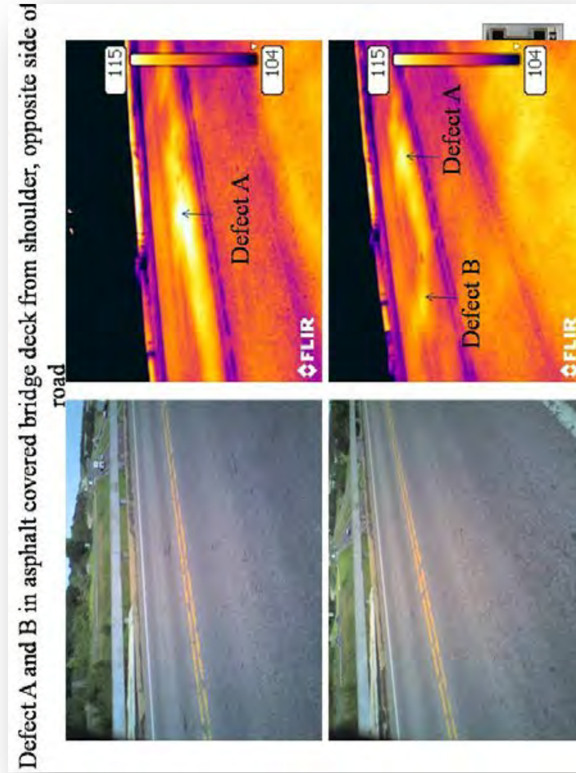

Soffit Example
A
B
C
D
76.9 °F
65.9
87.3 °F
72.3

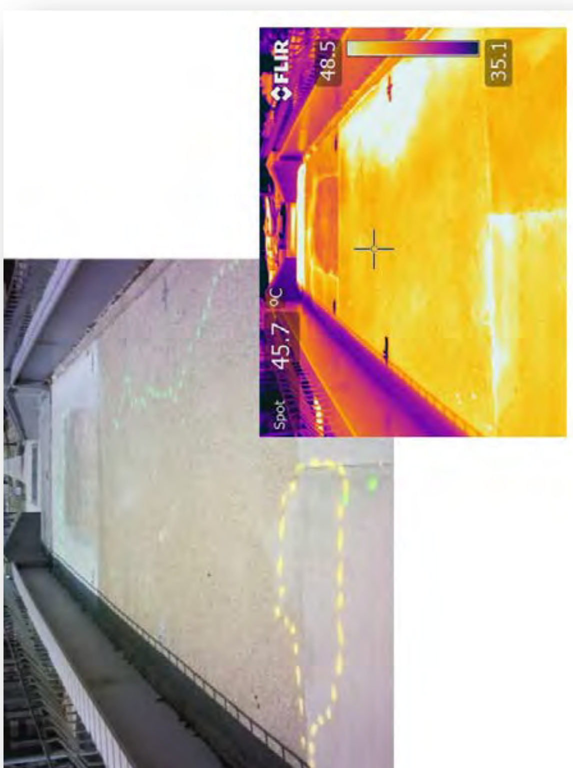

Video of IR Inspection
Before
78.5 °F
66.5

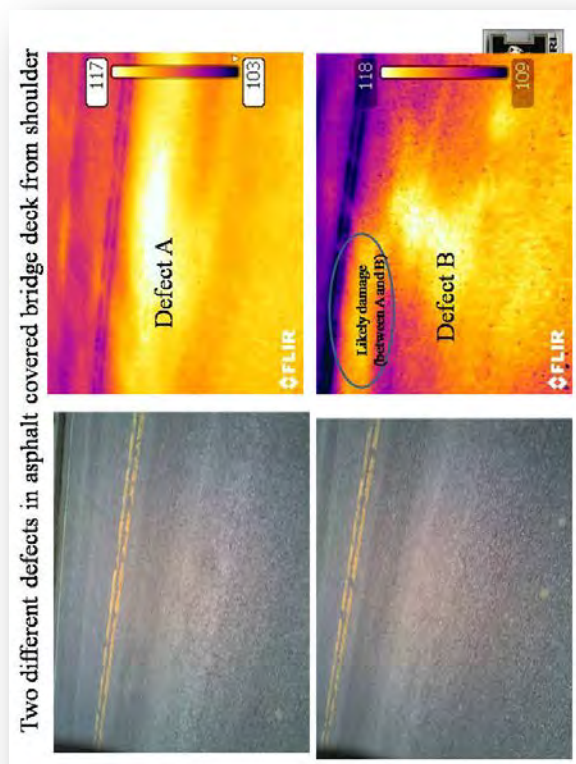

Interior Bay – Delaminated area of bridge soffit
Delam area determined with hammer sounding
Composite of 3 images
Image match points – Diaphragm (top), splice (middle) and diaphragm


Delam area determined with hammer sounding
Morning
Late afternoon
Interior Bay – Delaminated area of bridge soffit


Spot
115 °F
119
113
FLIR
98


Defect A and B in asphalt covered bridge deck from shoulder, opposite side of road
115
104
Defect A
FLIR
115
104
Defect A
Defect B
FLIR


Spot
45.7 °C
48.5
35.1
FLIR


Two different defects in asphalt covered bridge deck from shoulder
117
103
Defect A
FLIR
118
109
Likely damage (between A and B)
Defect B
FLIR

Defect under live traffic Field data (top), scale adjusted in office (bottom)

Review

- Capturing a good image requires
  - Correct Level and Span
  - Setting Image Parameters
    - Focus
    - Range
    - Composition
- Thermal Tuning
- Lens selection

Thermography Module 5, Using the camera

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Minnesota Department of Transportation

MDOT Department of Transportation

New York State Department of Transportation

MoDOT Missouri Department of Transportation

MIZZOU.

Using camera and software

- Using the camera is relatively easy
- Using the software is not difficult but requires some consideration of certain protocols

MIZZOU.

The FLIR T620 with 45 degree lens and professional software

3

The FLIR T620

4

The FLIR T620

5

The Basics of the T620

- **Zooming:** To manually zoom, move the zoom button left/right. For Auto Focus push and release the center of the focus button.
- **Focusing the Camera:** To manually focus, turn the focus ring on the infrared lens left/right. For Auto Focus push and release the save button
- **Auto-Adjusting the image:** To automatically adjust the level and span of the image, push the A/M button and select Auto. Default setting for the camera is auto adjust.
- **Manual-Adjusting the image:** To adjust it manually push the A/M button and select Manual. Push the joystick left/right to adjust the span and up/down to adjust the level.
- **Switching between infrared and digital views:** press the camera button to switch between the two camera views, infrared and digital.
- **Saving an Image:** To save an image press and hold the save button until the picture is taken.
- **Opening an Image:** Push the archive button to open the most recently saved image. Images will appear as thumbnails, use the joystick to scroll through the images. To view a selected image, push the joystick down and the image will appear larger on the screen.
- **Closing a menu:** To close a menu press the Menu/Back button. Note: While a menu is open you will not be able to take any pictures.
- **Choosing Palette:** To change the color palette and the object temperature range, push the Menu button and use the joystick to select Palette. In the palette tab, select the desired palette.
- **Video:** To take a video, press the Menu button and use the joystick to scroll down to Mode. Select Mode by pressing down on the joystick. Under the mode tab select Video using the joystick.

The Basics of the T620

- **Changing Temperature Scale Level:** The camera should display a live infrared image which can achieved by selecting the Camera mode using mode button and joystick. The camera should be in Manual adjustment mode. To change the temperature scale level press the A/M button and select manual, then move the joystick up/down.
- **Changing Temperature Scale Span:** The camera should display a live infrared image which can achieved by selecting the Camera mode using mode button and joystick. The camera should be in Manual adjustment mode. To change the temperature scale span press the A/M button and select manual, then move the joystick left/right.
- **Zooming in/out:** To zoom in or out on a picture press the zoom button left/right to adjust the zoom.
- **Taking Different Measurements:** To take different measurements press the measure button and scroll through the different options using the joystick.
- **Adding/Removing information to a picture:** To add/remove information on a picture, press the programmable button.
- **Recommended values:** If you are unsure about the values, the following are recommended:

Atmospheric Temperature	+20° C
Emissivity	0.95
Object distance	1 m (3.3ft.)
Reflected apparent temperature	+20° C
Relative Humidity	50%

Performing Basic Functions on the T620

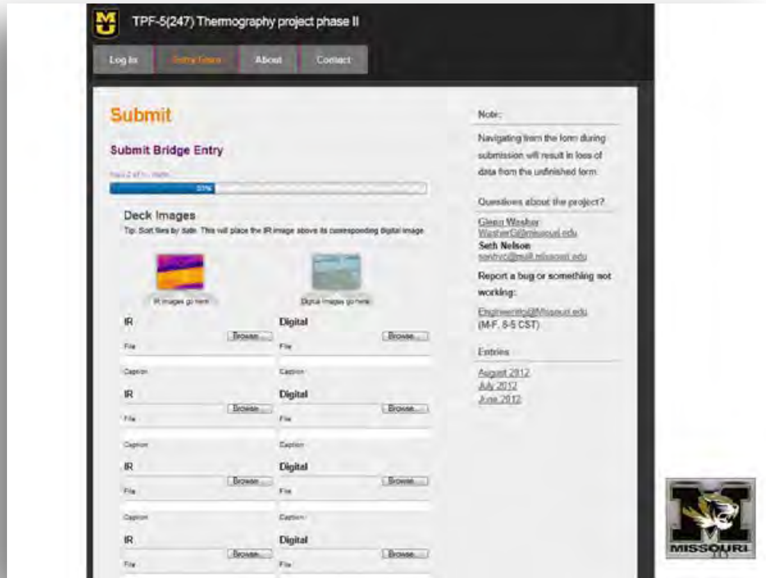
- **Taking pictures**
  - Turn on the camera by pressing the on/off button and remove the lens cap.
  - Press the camera button and select what type of photo is preferred by using the joystick
  - Use the LCD screen to find a desired target.
  - Press and release the save button to auto-focus the picture. Note: when doing this hold the camera as still as possible.
  - Press and hold the save button to save the image on the LCD screen.
- **Downloading pictures to a PC**
  - Plug in the USB cord into the computer and bottom of the camera. Note: make sure the camera is turned on.
  - Click ok and follow the directions on the computer to save the pictures in an appropriate folder.
  - After downloading the pictures use the safely remove hardware function on your computer before unplugging the camera to avoid problems. Note: this is usually found in the bottom right hand corner of the PC screen.
- **Reviewing Pictures**
  - Once a picture or pictures has been saved, press the Archive button.
  - Use the joystick to scroll through the picture saved on the camera
  - Push down on the joystick to get a larger view of each picture. Press the back button to return to the previous view.
- **Add temperature spots/Areas**
  - Press the Menu button.
  - Use the joystick to scroll up to the tools tab.
  - Press the joystick to select the type of measurement desired.
- **Change °F/ ° C**
  - Press the Menu button.
  - Use the joystick to scroll over to the Mode tab.
  - Use the joystick to scroll down to Settings.
  - Use the joystick to scroll over to the Regional tab.
  - Use the joystick to scroll down to Temperature unit and press down on the joystick.
  - Use the joystick to select the desired temperature unit.

8

Image management

- Using Quick Report software
- Using Professional Reporter software
- Uploading .jpg images to MU's online database at thermo.missouri.edu

thermo.missouri.edu



Verification

- Field verification of IR findings
  - hammer sounding, coring, impact echo
- Identify bridge(s)
  - 1-2 bridges in your state with possible defects
    - Ready for demolition?