Use of Thermography for Bridge Inspection

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Agenda

• Goals and Objectives
• Background
• Research
• Field examples
• Conclusions
Goals and Objective
Pooled fund TPF-5(152) (Phase 1)

- Goal: Improve technology and methods for the condition assessment of civil infrastructure
- Objectives: Develop thermal imaging technology for detecting subsurface damage in concrete
  - Provide a practical tool for routine inspection and maintenance

*Pooled – fund research allows state Departments of Transportation to pool research funding to work on common problems*
TPF-5(247) States
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
Motivations for Using IR Camera
Motivation
Risk of Soffit Damage

OKLAHOMA CITY (AP) - In 2004, a football-sized piece of concrete fell from a bridge and crashed through Yvonna Osborn’s windshield while she was driving home on Interstate 35.

Falling concrete hits car on I-70
Darla McFarland
the Examiner

A Kansas City man narrowly escaped serious injury Wednesday when a 20-pound chunk of concrete dropped from the Noland Road bridge on to Interstate 70 and smashed through his windshield.

Concrete chunk falls off bridge and smashes a car

Concrete from bridge falls onto Chicago st

Saturday, January 23, 2010

All Headlines
A chunk falls off bridge over 35E, striking two cars — but bridge deemed sound
By Mark H. Gotfrid
mgottfried@pioneerpress.com
Article Last Updated: 07/27/2008 12:18:02 AM CDT

A hard rain and then some on Second St.
Concrete falls off bridge, but woman says concern fell on deaf ears

Concrete falls from I-77 bridge

RICK STILLION/The Daily Jeffersonian
December 18, 2009

State inspectors to examine bridge where concrete fell
Posted: 02/01/2010 11:50 AM
IR Thermography Instruments

- Shorter wavelengths
  - High frequency
- Longer wavelengths
  - Low frequency

**Typical components of an IR thermography**

1. IR Radiation emitted by atmosphere
2. IR Radiation emitted by "subject"
3. UV and Visible
4. Germanium Lens
5. Spectral Filter
6. Microbolometer Focal Plane Array
7. Resulting Thermal Image
Basic Principles of IR Thermography

- Subsurface delaminations create perturbation in heat transfer through the concrete

Thermal response of delaminations in concrete: (A) day time condition; (B) night time condition; (C) surface temperature and thermal contrast as a function of time

\[ q_{rad} = \varepsilon \sigma T^4 \]
Research

• The detection of the subsurface delaminations depends on the environmental conditions at the bridge
  – Effects:
    • Ambient Temperature Changes: Temperature variations during the day
      – Warming in the daytime, cooling at night
    • Wind speed: Convective heat transfer from the environment
    • Depth of defect
    • Solar exposure
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

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

\[
Q = h_c (T_2 - T_1)
\]

\[
Q = \varepsilon T^4
\]
Thermal Contrast

• Comparison of solar exposure vs. shade

![Graph showing thermal contrast and solar loading comparison between shady/soffit and sunny/deck areas.](image)
Shady Conditions – 48 hrs
Phase I: Guidelines

### Phase I: Guidelines

The following are suggested guidelines for the thermographic inspection of highway bridges, based on the results of the research:

1. **Target Depth (mm)**
   - Sunrise: 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 0.00
   - Sunset: 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 0.00

2. **Inspection Period (hh:mm)**
   - Sunrise: 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 0.00
   - Sunset: 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 0.00

3. **Sunrise to Sunset**
   - Target Depth (mm)
   - Inspection Period (hh:mm)

4. **Guidelines**
   - **Temperature Change**
     - Ambient temperature change should be monitored during the inspection period.
   - **Wind Speed**
     - Average wind speeds should be measured during the inspection period.
   - **Imperfections**
     - Visible imperfections should be noted during the inspection period.

5. **Note**
   - Inspections should be conducted during the inspection period.

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### 4.3 Angle of Observation

- Observing surfaces at a low angle can increase ambient reflections and reduce the effective resolution of the inspection.
- Inspections should be conducted as close as possible to normal angles (0°) as practical.

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### 4.4 Schematic Diagram of Observation Angles

- Normal angle: 0°
- Viewing angle: 90°
The maximum thermal contrast decreased exponentially by a constant multiple of 0.98 as the void depth increased.

The maximum thermal contrast increased nonlinearly (as a logarithm function) with increasing thickness of the void.
Different Materials in Void

![Graph showing thermal contrast over time for different materials filling a void. The graph compares Air-filled void, Styrofoam-filled void, Water-filled void, Epoxy adhesive-filled void, and Ice-filled void for a 51 mm deep void. The x-axis represents time in hours and minutes, while the y-axis represents thermal contrast in °C.]
Examples from Field Testing with States
Soffit Example
Bridge Soffit Example

A

B

C

D

Image capture time (Figure A)

Image capture time (Figure C)
FRP
Stephen’s Pedestrian Bridge
Stephen’s Pedestrian Bridge
Under Bridge Domicile- PA
Hybrid Beams
Conclusions

• Main Advantage
  – Extend the reach of the inspector
    • Observe damage without accessing surface
  – Relatively easy to use, real-time results

• Main Disadvantages
  – Uneven performance due to
    • Environmental conditions
    • Variations in damage
    • Best for <=~2 in., more limited for ~3-4 in., limit ~5 in.

• Best Uses
  – A tool for the inspectors toolbox that greatly improves capability, with known limitations
  – Detect loose concrete that could fall into roadway
  – Rapid deck, abutment, soffit assessments
Questions