Evaluation of Hand Held Infrared Cameras for Bridge Deck Inspection

Final Report

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<tr><td colspan="6">16 Abstract
This project evaluates the practicalities of deploying handheld thermal imaging cameras to survey bridge decks for delaminations. The evaluation includes cost effectiveness, accuracy of detection and level of detail. Substructure units were also examined with this equipment. Traditional methods for identifying internal delaminations in bridge decks have relied on hand sounding with hammers and chain drags. This requires traffic restrictions to allow worker access and relies on worker interpretation of sound to identify delaminations. It is also time consuming. Research into alternative methods for identifying internal defects in concrete has shown promise for the use of infrared thermography based on theoretical and controlled environment evaluations. The abilities of thermal imaging cameras have increased over recent years, accompanied by an increase in the availability of moderately priced equipment. Limitations were found to outweigh benefits for bridge deck evaluations, however promise was seen in evaluation of substructure units. Three bridges were evaluated.</td></tr>
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Handheld infrared camera evaluation
Iowa DOT SPR Project RB15-012

Background
There is a need to identify internal delaminations in bridge decks in order to assess the condition and identify work needs. Traditional methods have relied on hand sounding with hammers or chain drags. This requires traffic restrictions to allow workers access to the deck. Also it relies on the worker's interpretation of sound to identify delaminations and is time consuming. Research into alternative methods for identifying internal defects in concrete has shown promise for the use of infrared thermography. Based on theoretical and controlled environment evaluations, thermal imaging cameras can identify delaminations in concrete. The cameras detect and quantify the amount of infrared radiation emitted by an object. In concrete, the delaminated areas will heat and cool at different rates than the surrounding solid concrete, and thereby emit different levels of infrared radiation. This difference can be identified by the cameras.

The abilities of thermal imaging cameras have increased over recent years, accompanied by an increase in the availability of moderately priced equipment. This has led to the availability of handheld cameras that can provide the level of detail needed to identify delaminations at a price point that makes field use by bridge inspectors a possibility. This project reviewed the practicalities of deploying handheld thermal imaging cameras to survey bridge decks for delaminations.

Equipment
The equipment purchased for this investigation was a FLIR model T620 camera with the standard 24.6mm lens, a 13.1mm wide angle lens and a 41.3mm telephoto lens, see Figure 1. The camera is designed for handheld or tripod mounted use. The lens pivots to allow clear view of the rear display. The camera captures infrared images in one of several color palettes along with visual light images.

Figure 1 - Camera and lenses

Evaluation methods

Hand sounding of concrete is a standard and well accepted method to identify delaminations. To evaluate the camera, surveys were made of decks that had been hand sounded. A comparison was made of the results to determine the level of correlation. In order to be considered a valid alternative to hand sounding, there needed to be a strong correlation between the two methods. The hand sounding surveys were completed by experienced bridge inspectors to assure high quality results.

Bridge evaluations

The following described the finding on selected bridges where comparison surveys were made.

<u>Bridge 7716.1L028 carrying Iowa 28 over the Raccoon River</u>

Conditions:

The field test was performed from 9:00 am to 11:30 am on May 23, 2012. The sky was overcast in the early morning, clearing as the morning progressed. Sunrise was at 5:48 am. The bridge is oriented north-south with the passing lane on the east side. A dense concrete overlay was placed on the bridge deck in 1986. The passing lane was closed during the inspection due to other inspection work taking place on the bridge. Air temperatures and relative humidity for the area during the inspection are listed in table 1. The deck was dry during the inspection.

Time	Air temperature	Relative humidity
8:30	67 °F	53 %
9:00	70 °F	51 %
9:30	71 °F	49 %
10:00	74 °F	44 %
10:30	77 °F	41 %
11:00	78 °F	39 %
11:30	80 °F	36 %

Table 1

Assessment:

During the inspection, Inspection Team 4 was performing a routine inspection of the bridge including sounding the deck surface using traditional sounding methods. Comparisons were made between the locations identified by traditional methods and using the infrared camera. This was also the initial field use of the infrared camera.

During the initial inspection time, the camera did not identify temperature discrepancies at the locations identified as hollow by manual sounding. As the deck temperature increased, temperature variations were identified at the hollow areas and there was some correlation between the two methods. However, the infrared image variation between the wheel path and the rest of the deck obscured the temperature variation at hollow areas. The following photographs show the infrared image and corresponding visual image of hollow locations. The paint outline identifies the extent of hollow areas as determined by manual sounding. The chalk outline identifies the hollow areas identified with the infrared camera. Hollow locations in the shadow of the barrier rail were not identified with the infrared camera.

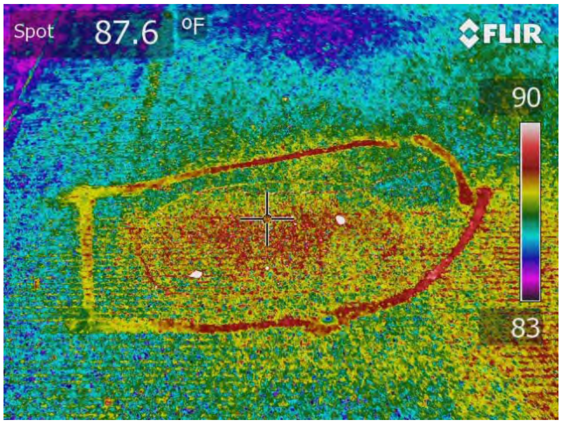

Figure 2 delamination IR image

Figure 2a delamination visual image

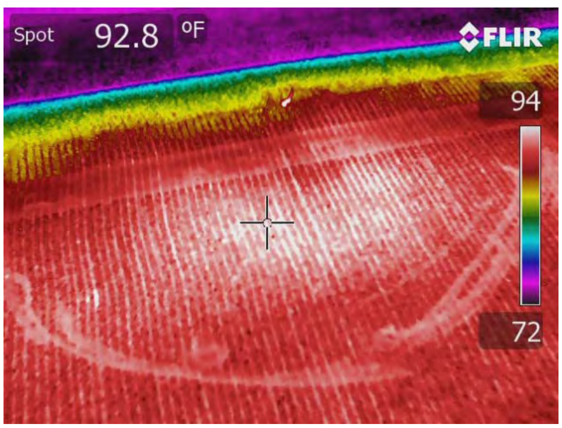

Figure 3 delamination IR image

Figure 3a delamination visual image

Two lenses were used during the inspection, a 24.6mm standard angle and a 13.1mm wide angle lenses were used. Due to the close proximity of the deck, the wide angle lens was more effective. The battery life was sufficient that one battery could be used for the entire inspection.

<u>Bridge 3120.1S020 carrying US 20 over the Mississippi River</u>

The bridge was surveyed July 7, 2012. This bridge is a tied arch truss. The superstructure shadows prevented evaluation of the deck. This is shown in figures 4 and 4a. Portions of the substructure were also reviewed with the infrared camera. Delaminations were clearly identified in the IR image although confirmation by hand sounding was not performed due to access limitations. Examples of the substructure findings are shown in figures 5, 5a, 6 and 6a.

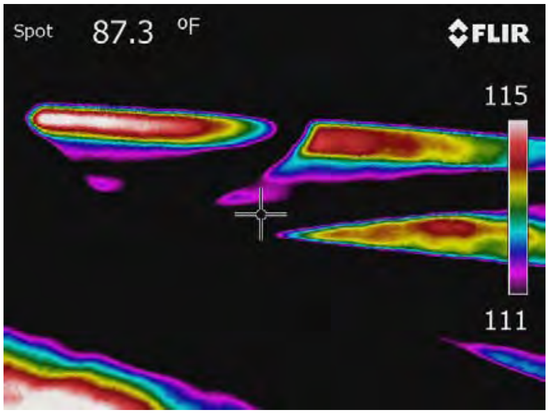

Figure 4 deck IR image

Figure 4a deck visual image

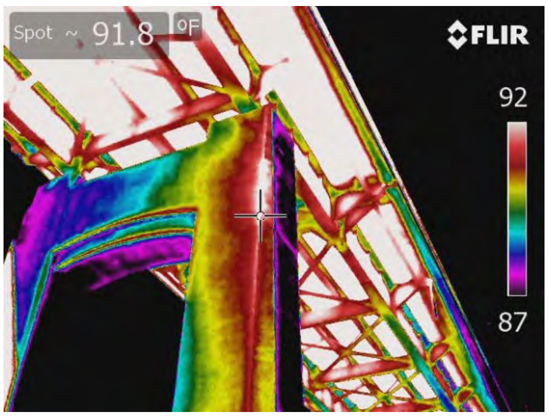

Figure 5 substructure IR image

Figure 5a substructure visual image

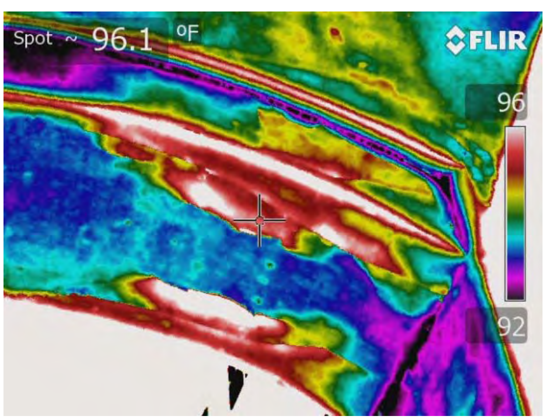

Figure 6 substructure IR image

Figure 6a substructure visual image

<u>Bridge 8684.0S021 carrying Iowa 21 over Wolf Creek</u>

This bridge was surveyed on September 21 and September 26, 2012. Numerous delaminations were identified using hand sounding techniques. Most of the delaminations could not be identified with the infrared cameras. Of those that could, it is doubtful that they would have been located without the prior hand sounding. Figures 7 and 7a show a typical delamination.

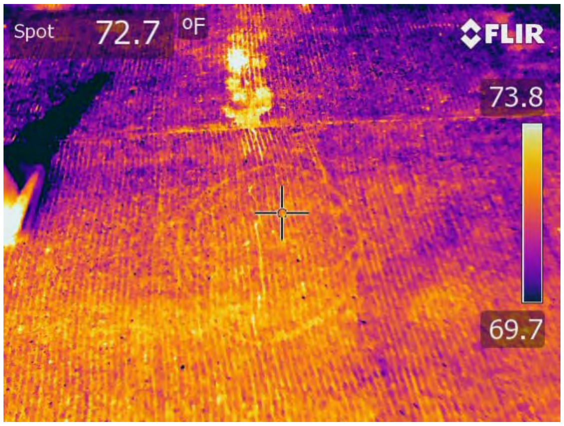

Figure 7 deck IR image


Figure 7a deck visual image

The bridge was visited on multiple days under ideal theoretical conditions. The road tar, epoxy and polishing of exposed aggregates made scanning difficult. A step ladder was used to take pictures at a higher angle of incident in attempt to reduce the effects of reflected solar radiation but did not make a significant difference.

Additionally this deck was surveyed by a private company offering bridge deck evaluation services using infrared thermography. The areas identified by the private company had little to no correlation to the locations identified by hand sounding.

Cores were taken at selected locations. The delaminations were found to be over two inches deep and were beyond the capabilities of the thermal imaging camera to detect.

Overall evaluation

There are several factors limiting the effectiveness of thermography for the evaluations of bridge decks. Surface conditions including polishing of the concrete from tire wear, exposed aggregates and surface contaminants such as road tar can cause a significant hindrance to the evaluation of the bridge decks by changing the emissivity of the surface. The angle of the sun and the angle of the camera can significantly affect the results by reflecting radiation that masks the radiation emitted by the surface. The solar warming and cooling effects appear to be more significant in evaluating the deck and limits the time when a deck can be accurately surveyed. Additionally, corrosion of the reinforcing steel in bridge decks often develops delaminations deeper than can be detected by the infrared cameras. These limitations resulted in false negative results in identifying deterioration in bridge decks. As a result of these findings and the difficulties in assuring good results, the evaluation of bridge decks using infrared cameras does not appear to be a good alternative to the hand sounding techniques.

Originally, there were thoughts that the infrared cameras could be used to identify bridge deck delaminations from a shoulder, curb or sidewalk, thereby reducing traffic control and improving worker safety. Taking images from the side of the road proved difficult due to the angle of exposure. Considerations were made to mounting the camera on a vehicle and utilizing a slow moving operation to evaluate the decks. Due to the performance of the camera handheld in similar conditions, vehicle mounted evaluations were not pursued.

The evaluations on the substructure units does show some promise. As the reinforcing steel on substructure units has less cover than the top mat of reinforcing in a bridge deck, the delaminations are often shallower and easier to detect. Additional evaluations and use of this equipment in evaluating substructure units is expected. This could prove to be a time and cost saving alternative to traditional sounding techniques in substructure inspection applications.