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Abridgment

Bridge Rehabilitation Programming by Using Infrared Techniques

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Techniques used to determine the needs and characteristics of bridge and roadway maintenance are highlighted. The results imply that the use of infrared equipment for inspections is appropriate to accomplish relatively rapid evaluations. However, limitations of the technology are apparent in observing overlaid surfaces because the distinction between delaminated areas versus debonded bituminous overlaid pavement areas was not reliable. Despite the deficiencies associated with performance as a precise testing mechanism, infrared thermography has an application as a tool to collect historical data and provide a basis for programming rehabilitation projects.

Several methods are used to describe the current condition and provide projections of future rehabilitation needs for the bridges on the Illinois tollway system. An annual inspection program that consists of a visual analysis of regular maintenance needs is supplemented with more detailed analysis each three or four years. There are more than 450 bridges (85 percent of which have been in service more than 20 years) that are included in the maintenance and rehabilitation program. Although the substructures are in good condition, there is an increasing need to have a more formalized approach to describe the bridge deck condition.

In 1976 the Illinois State Toll Highway Authority initiated a program to develop a more thorough method of bridge deck inspection, which included Delamtect surveys. Continuation of the program to set priorities for rehabilitation included the detailed evaluation of the application of infrared thermography.

PAST APPLICATIONS

The inspection program focused on bridge deck evaluation methods and isolated several of the available technologies in use to evaluate the deterioration, detection, and rehabilitation needs on the tollway system. The five techniques that have been studied include Delamtect, electric-potential readings, pulse-velocity measurements, swept-frequency radar, and thermal mapping. The study concluded that no single evaluation method was capable of describing the delaminated areas within a level of accuracy required for the preparation of contract documents. The most cost-effective diagnostic method for the short-term needs of the tollway was the Delamtect, even though the research team experienced numerous inconsistencies in the evaluation and plotting of Delamtect results (1).

Delamtect and other acoustical methods have been used to establish the condition of the reinforced-concrete deck slab beneath the asphalt wearing surfaces on bridges that have not required extensive maintenance in the past and have experienced deck deterioration. However, Delamtect requires excessive time for lane closures, and there is considerable variability of the data obtained with different overlays, sealers, and environmental conditions. Due to these problems, the Illinois State Toll Highway Authority was interested in pursuing evaluations from infrared equipment.

METHODOLOGY

The infrared methods employed for scanning the bridge decks in this study varied, as they were based on equipment and technique changes from 1976 to 1982. The earlier inspections included aerial and van-mounted equipment for the survey work. The aerial shots had significant distortions due to atmospheric conditions, reflection from oil drippings, tire and other markings, and sand and debris on the deck. The van-mounted equipment provided simultaneous recordings of the infrared scan and a video of the actual surface appearance. The video record allowed for correlation and subsequent plots of the bridge deck. Despite the highly sophisticated nature of the equipment used for the analysis, the results did not provide the clarity that was desired, nor did they correlate with visual inspection data.

The more recent inspections that have provided sufficient data are from an elevation of 15-20 ft in a bucket truck. The height is required to ensure

Table 1. Conditions for infrared survey.

	Bridge				Roadway
Condition	1	2	3	4	5
Ambient temperature (° F)	63-66.5	77	86	86-93	82
Pavement temperature (° F)	78	86	99	105	100
Wind (mph)	8-12	10-12	10-12	10	10-12
Time of day	10:00 a.m.-1:00 p.m.	9:00 a.m.-1:00 p.m.	1:00-3:00 p.m.	11:00 a.m.-1:30 p.m.	11:30 a.m.-1:00 p.m.
Month	April	May	May	July	July
Spectrum[a] (microns)	2.5-5	2.5-5	2.5-5	3.5-5	3.5-5
Window (° F)	5	5 and 10	10	10	10

[a] Variations occur in the spectrum range as a result of the acquisition of a solar filter. The filter cut off the low end of the spectrum and eliminated shadow distortion problems.

minimum distortions through vertical shots of the deck. Although the setup is quite slow and requires lane closure, there is less distortion than shooting from a van-mounted system, which requires that the camera be at a more acute angle. The delaminations tend to be overstated or understated with that type of setup, depending on the camera position with respect to the pavement surface.

The bridges were surveyed under the conditions detailed in Table 1. Literature sources implied that the ideal conditions for infrared work are at midday when the deck is absorbing the most heat (2-5). However, there is still uncertainty on the best detection time period by the users of infrared [note, data are from conversations with H. Betz, Research Institute, Illinois Institute of Technology (June 30, 1982) and from G. Clemena, Virginia Highway and Transportation Research Council (April 27, 1982)]. The original work in remote-sensing applications implied that it is best to shoot at dusk or dawn when the source is giving off heat. But, since delaminations absorb and give off heat rapidly, scanning at that time is inappropriate. Earlier research suggested that periods from 8:00 a.m. to 2:00 p.m. and from 8:00 p.m. to 4:00 a.m. are the most reliable times for surveying due to the necessity of obtaining data during periods of rapid heating and cooling (5). Our analysis suggests that midday is appropriate. An experimental aerial shot of one bridge in the evening hours showed no discernible detail when attempting to locate cold spots on the cooler deck. The bridges that were analyzed were surveyed at various times between 9:00 a.m. and 3:00 p.m. on clear, sunny days. The temperatures ranged from 66° to 93°F during the testing from April to July.

The average difference between the ambient and pavement temperatures was 13°F with variations from 9° to 17°F. There were no particular problems associated with the wind conditions, although gusting created temporary inaccuracies in the scanning data. Minimum/maximum pavement temperature differences were checked with a digital thermometer in order to calculate the required scanning-window temperature range.

The equipment required a spectrum of 2.5-5 microns initially, but an added high-pass solar filter increased the spectrum to 3.5-5 microns. The roadway glare created significant distortions in the initial tests. The use of the lens increased the emissivity readings from the roadway pavement and clarified the results. The elimination of the shorter wavelengths associated with glare to a shorter range improved the results and decreased the effect of shadows.

Aluminum targets were placed in the center of the lane to correlate conditions shown in the infrared exhibits to the actual site. [Aluminum is used due to its low emissivity (0.05) and high reflective capabilities.] The 3x3-in squares were spaced at 15-ft increments. The targets appear much larger on the cathode-ray tube (CRT) and thermographic prints due to their high reflectivity and glare. The distortions created problems in the interpretation.

INTERPRETATION OF RESULTS

The thermographic data were compared with Delamtect survey data and the resident engineer's plot of the actual partial and full-depth patching requirements to check for accuracy. Three spans are highlighted for this analysis. The bridge is a ramp that carries two lanes of traffic from the north-south (Tri-State) tollway to the northwest tollway in the Chicago area. Spans 8, 9, and 10 are illustrated in Figures 1, 2, and 3, respectively. There are 19 spans on the ramp. There are two 80-ft spans of prestressed-concrete girders and one steel span of 171 ft. The prestressed-concrete girder spans carry a 7.5-in-thick reinforced-concrete deck, while the steel girder spans carry a 9-in-thick deck supported by steel transverse floor beams.

A plot of the sounding survey on the stripped deck shows correlation with the infrared and Delamtect survey plots. The sounding displayed fewer delaminations in the steel span (span 10) than the other survey methods. The actual breakout resulted in quantities that were more extensive than those shown on the survey maps. It should be recognized that breakout quantities tend to exaggerate the extensiveness of delaminations and peripheral cracking and do not allow for a thorough comparison of the exact points of deterioration. (The breakout plot includes the delaminated area plus the contiguous exposed regions, which allow for a clean and squared repair site.)

In summary, the infrared thermographic results contributed in defining the delamination characteristics of the bridges and roadways surveyed but did not provide enough detail to suggest that more reliable quantity estimates will result. The data collected from the survey are most appropriate for providing a historical record of bridge and pavement conditions and in planning for rehabilitation needs. A program of scanning the entire system every other year, with additional testing of specified bridges and roadway segments, is useful for both quality control and budget programming needs.

The additional information that can be provided by using infrared provides details for programming needs, but the technology requires a substantial financial commitment. In a recent paper on the cost-effectiveness of the equipment, Madding (6) suggested that the decision to invest in the equipment rather than hiring a thermographic consultant would require an annual dedication of at least 73 person-days with the equipment.

CONCLUSIONS

This analysis indicates that infrared thermography

Figure 1. Span 8.

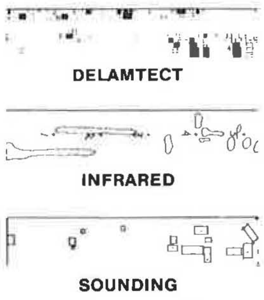


Figure 2. Span 9.

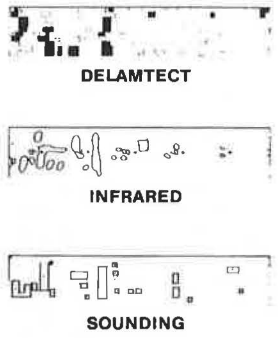
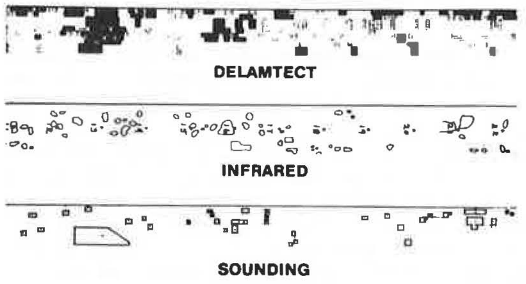


Figure 3. Span 10.



is applicable to the survey of bridge decks and pavement sections for programming and setting priorities for rehabilitation needs. Through historical records of infrared surveys, the program can determine the relative degree of change that occurs during a specified period of time. Other technologies can serve to complement this information by describing the depth and severity of the delamination.

Infrared thermography is not appropriate for use in estimating quantities for contract documents. The test comparisons indicated that the quality of data is not substantially better than that of the Delamtect when comparing mapped infrared and acoustical data with the actual breakout survey. The pavement breakout maps indicate that rehabilitation quantities were up to three times more extensive than those indicated through either the infrared or Delamtect methods.

There were difficulties associated with isolating and identifying hot spots. Bituminous patches, crack sealers, and tire marks were identified as hot spots. The presence of these affected the quality of the interpretation and required that an analyst have appropriate visual records to complete the interpretation.

It was especially difficult to detect with any degree of accuracy the point of debonding or the lateral extent of debonding. There was no means of differentiating delaminations from debonded wearing surfaces without destructive testing. The acoustical methods that have been applied also have similar problems. The testing showed that the use of infrared may have limitations in its applications.

It may not be cost effective to purchase the equipment for the purposes of rehabilitation programming with smaller system demands. However, when van-mounted equipment is used, the cost advantages increase sharply if it is weighed against the safety and time constraints associated with lane closures required when using acoustical mechanisms. In addition, the estimation of budgeting needs for future years and other ancillary advantages may outweigh excessive initial capital requirements.

The data are inconclusive for quantity estimates when using the infrared equipment, although its applicability to general rehabilitation programming is warranted. Further studies that use more refined testing and equipment may provide more detail in detecting deterioration.

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