Thermal Integrity Profiling for Detecting Flaws in Drilled Shafts

Research Objective

- Evaluate the effectiveness of Thermal Integrity Profiling and its potential to serve as an alternative to Crosshole Sonic Logging

Research Benefits

- Determined Thermal Integrity Profiling is suitable to replace or complement Crosshole Sonic Logging, depending on project considerations
- Provided guidance for improving Thermal Integrity Profiling accuracy and data-driven quality assurance

Principal Investigator

Andrew Boeckmann
University of Missouri
boeckmanna@missouri.edu

Project Manager

Andrew Zimmer
WisDOT
andrew.zimmer@dot.wi.gov

Background

Thermal Integrity Profiling (TIP) measures the temperature of concrete along the length of drilled-shaft reinforcing cages to identify potential defects. The heat generated from hydration of cement within the drilled shaft is captured by wired sensors affixed to the cage and recorded by small data loggers at the ground surface. Areas of lower temperature indicate potential concrete defects within the drilled shaft.

TIP's sensitivity to defects outside the reinforcing cage make it an appealing alternative to Crosshole Sonic Logging (CSL), whose geophysical measurements only capture defects within the cage and often return false positives. This research was conducted to evaluate the effectiveness of TIP and its potential to serve as an alternative to CSL.

Methodology

Three drilled shafts, each measuring four feet in diameter and 30 feet long, were constructed to evaluate the ability of TIP and CSL methods to detect 10 intentionally fabricated defects. Nine defects were simulated by affixing 70-pound sandbags to various parts of the cage. Four were included to evaluate the effect of defect location within the cross-section, particularly how the sensitivity of TIP compares for defects outside the reinforcing cage and defects inside the reinforcing cage; two to evaluate sensitivity to soft bottom conditions; two to evaluate zones of weak concrete; and one to evaluate tremie breach. The final defect, debonding of the access tubes, was simulated by applying wheel bearing grease over the tubes. Debonding of access tubes can lead to false-positive CSL anomalies. Both TIP and CSL were performed on all three shafts.

Reinforcing cages prepped with sensors and sandbags

"This research provides better insight for WisDOT engineers on how to interpret and make use of the results of TIP testing."

– Andrew Zimmer, WisDOT

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Final report is available at: [WisDOT Research website]

Results

TIP measurements produced temperature decreases greater than five degrees Fahrenheit for four defects, decreases between three degrees and five degrees Fahrenheit for two defects, and no discernable temperature decrease for the other three defects. The greatest decreases were observed for weak-concrete defects and defects outside the reinforcing cage, while limited temperature decreases were observed for inclusions within the reinforcing cage and the tremie breach defect. No temperature decrease was observed for the soft bottom defects or the smaller inside-cage inclusion. Defects are significantly more detectable with TIP methods when the evaluation temperatures are taken near the halfway time to peak temperature development, rather than at the peak time.

CSL measurements indicated arrival time increases of at least ten percent and relative energy decreases of at least five decibels for five of the intentional defects, with no discernable increase in arrival time or decrease in relative energy for the other four defects. Successfully identified defects were within the reinforcing cage, including a soft bottom defect and the tremie breach defect. CSL measurements did not produce significant indications for defects outside the reinforcing cage or for weak concrete. The tendency for false positive CSL results due to tube debonding was demonstrated with significantly delayed arrival times and decreased relative energy for CSL measurements. Evaluation of relative energy for CSL test results can be used to identify defects that are not apparent in CSL arrival time results for the same shaft.

Recommendations for Implementation

TIP and CSL each excel in detecting certain defects and fail to adequately detect others; when used complementarily, the tests are well suited to detect all significant defects. The research team recommends allowing TIP as an alternative or, when warranted, as a complement to CSL, depending on project considerations, such as predominant loading type. Both test methods should be used for technique shafts, shafts installed prior to the installation of production shafts to evaluate a contractor's proposed means and methods.

TIP testing should be performed using sacrificial wires, rather than probes, as wires' continuous time records greatly improve the likelihood of detecting defects. Interpretation should include evaluation of temperature versus time plots and be based on raw temperature measurements only, not analyses of effective radius. Any significant temperature deviations should be identified in a TIP report and trigger evaluation by the design engineer of the shaft, who should then determine whether the deviation is permissible or requires further investigation or remediation.

This brief summarizes Project 0092-16-07,
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