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THERMAL INTEGRITY TESTING OF DRILLED SHAFTS

BACKGROUND

Drilled shafts are large-diameter, cast-in-place concrete structures that can develop enormous axial and lateral capacity and, consequently, are the foundation of choice for many large bridges subject to extreme event loads such as vessel collisions. Many drilled shafts are constructed in the State of Florida using the slurry method as a means to stabilize the excavation (i.e., slurry is pumped into the shaft immediately following excavation to retain wall integrity and removed only when the concrete is placed). This means that both excavation and concreting are blind processes which increase the chance of unwittingly producing defects in the shaft.

One method to assess the presence of defects and formation of anomalies makes use of the heat of hydration of curing concrete and temperature measurements within the shaft from access tubes. Prior to this method, this heat was considered an undesired side effect long recognized for its potentially harmful consequences. In fact, massive concrete structures that may be seriously compromised by detrimental extremes in the internal temperature

A new, easy-to-use method of assuring shaft integrity via infrared thermal detection methods is available. It can assess the presence or absence of intact concrete both outside and inside a drilled shaft reinforcement cage. The system utilizes the crosshole sonic logging tubes typically installed in production shafts (steel or PVC) and a down-hole temperature probe.

OBJECTIVES

The primary objective of this study was to assess the capability of thermal integrity testing as a viable means to provide quality assurance for drilled shafts. To this end, the project tasks were threefold:

- review data collection and sensor systems capable of making the required measurements and develop a robust down-hole device
- review existing temperature prediction software that deals with concrete hydration and develop a 3-D thermal analysis package expressly for verifying thermal scans of drilled shafts
- collect temperature data from full-scale shaft pours, both production and experimental, to assure equipment capabilities and provide calibration data for the 3-D thermal package.

A secondary objective was to identify when drilled shafts should be considered as mass concrete.

FINDINGS AND CONCLUSIONS

Mass concrete predictions are presently based on geometric parameters as well as concrete mix design constituents. In this study, researchers investigated both forward and inverse models for predicting the size and location of anomalies. However, the focus was on forward models rather than on inverse models, which are inherently more difficult. The research showed that thermal integrity testing promises a viable alternative to conventional methods for detecting anomalies. The developed approach detects anomalies in drilled shafts by identifying irregularities in temperature profiles; simple signal matching methods with the 3-D thermal/concrete model accurately reproduce the conditions and, therefore, the resultant temperature fields.

The study showed that thermal modeling of mass concrete elements is a more effective approach to assessing when and to what extent differential and peak temperature values have been exceeded. The ability to determine the exact temperature throughout the mass element also can be inputted into a stress evaluation package that combines concrete strength maturation information with the temperature gradients experienced. This information can provide a clearer indication of when/where concrete cracking is likely to occur. The present temperature differential criterion does not take into consideration the temperature gradient with regard to the distance over which the differential exists. The thermal modeling of these conditions combined with stress evaluation will enable the State to produce a more thorough differential temperature criterion.

Field data collected suggested that mass concrete conditions can occur, in special cases, in shafts as small as 2 ft in diameter and, more commonly, in 4 ft diameter shafts. Both modeling and collected data confirm that mix design, shaft geometry, and site conditions should be considered when reviewing shafts as mass concrete.

Finally, researchers developed a concept involving large diameter drilled shafts whereby the central-most concrete is intentionally omitted. Inquiries with local contractors have indicated that constructing a 9ft diameter shaft with a 4ft central void is possible. Numerical modeling of this concept shows great promise. Such an approach has the dual purpose of reducing temperature and decreasing concrete volume and the associated fresh concrete properties requirements.

BENEFITS

Prior to this study, no one state-of-the-art integrity method was capable of assessing an entire shaft. Available methods were useful only for certain regions. Thermal integrity testing, on the other hand, has the potential to be a method applicable to the entire shaft. Moreover, it can scan the shaft concrete both inside and outside the reinforcing cage and return the test results within 1 – 2 days after the shaft is poured, making remedial efforts, if necessary, easier to carry out. As the temperature profiles obtained from logging tubes are matched to 3-D thermal modeling, information regarding the internal/core temperature and differential temperatures can be mapped throughout. Therefore, this method provides a single, time- and cost-effective testing method that can enhance production. Implementation of the shaft concept with the central void would provide additional cost savings and potentially enhance shaft integrity.

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