Abstract

The thesis develops a framework for nondestructive evaluation of concrete and FRP-concrete composites using infrared thermography. An enhanced algorithm based on the correlation function of thermal contrast is proposed to obtain a full field map of the entrapped void distribution in concrete resulting from improper compaction. The obtained void distribution is validated numerically using finite element simulations and experimentally using micro X-Ray CT scans. The reconstructed void map is used to determine a composite statistic to characterize the void distribution. The composite statistic can capture the effect of total void volume, mean void size, and clustering. It is also shown to be strongly correlated to the degree of compaction. Numerical simulations and experiments on cube and prism specimens with various levels of compaction show that the proposed statistic is more sensitive to void clustering than the Powers' spacing factor and the mean air-void spacing factor, two commonly used metrics for characterizing the void distribution in concrete. The proposed statistic also exhibits a strong, negative correlation with compressive and flexural strength. It can thus serve as a global measure of compaction for concrete structural components. It can also be used as a local measure of compaction to help identify poorly compacted zones within a component.

A fully non-contact IRT-based methodology is developed for monitoring corrosion in reinforced concrete. A series of postprocessing algorithms that increase the signal-to-noise ratio of the raw thermograms and an automated thresholding scheme based on the bimodality of the temperature distribution are used to highlight corroded regions along a rebar. The algorithms employed for void detection are leveraged to obtain a map of the debonded regions along the rebar. This unification of capabilities results in an effective tool that can successfully identify all segments along a rebar where the mass loss due to corrosion exceeds 2% of the original mass of the segment.

Finally, an IRT based framework is developed to detect and characterize delaminations in FRP-concrete composites. The framework can be used to detect delaminations within concrete, at the FRP–concrete interface, and within the FRP laminate. Short heat pulses are used for efficient detection and depth estimation of near-surface defects, while longer heat pulses are used for delaminations deeper in the substrate. The effective thermal diffusivity of field specimens is obtained by solving a constrained one-dimensional inverse heat-transfer problem. This enables defect depths to be accurately predicted without the need of elaborate material testing. The predicted area and depth of the defects are seen to closely agree with destructive measurements for a wide range of defect areas and depths.

Keywords: thermography, air voids, defect detection, degree of compaction, reinforcement detection, corrosion, delamination, depth estimation