Feasibility Study of In-situ Characterization of Size Distribution of Air Voids in Concrete Pavements

Introduction

The air-void system is known to improve the frost resistance of hardened concrete in a region with a cold climate. Extensive laboratory experiments and long-term field trials have confirmed that concrete containing properly entrained air has a better resistance to damage arising from freezing and thawing due to internal distress and salt scaling. To achieve the targeted result, a large number of smaller size bubbles are needed in these air-void systems. It is, therefore, important to control the geometrical characteristics of the bubbles and, in particular, the bubble size distribution. Although the air entrainment mechanism is well known and the procedures for introducing air-entraining admixtures in highway concrete are well established, developing consistent air-void systems in concrete is still a challenging task.

The current measurement technique does not provide timely results that can be used for preventing marginal air-void systems in concrete materials from being placed in the field. In many cases, by the time the air-void system results were known, it was too late to take remedial actions such as the remove-and-replace option, which have presented disadvantages to INDOT and its contractors in terms of both time and money. A feasibility study was proposed to investigate the use of a non-invasive method to accurately determine the spacing factor, distribution of air voids, and how the air-void system of fresh concrete changes over time. In particular, a possible use of ultrasound as a non-invasive means was used to tackle this major challenge in the concrete industry.

Findings

- The ultimate goal of this feasibility study was to identify whether fresh concrete specimens can be characterized within the first hour after the concrete is mixed. Based on the results obtained from the available instrumentation, the largest sample thickness for signal transmission is of the order of 0.6". For fresh mortar specimens, this sample thickness may be acceptable. However, this thickness is not acceptable for a fresh concrete specimen. This is because the minimum sample thickness needs to be several times larger than the characteristic length scale of the aggregate to obtain a representative sampling.
- The latest experimental setup demonstrated the feasibility of using a step-up transformer and a set of tuned transducers to significantly increase the time-domain signal amplitude at minimal additional costs. To overcome the signal quality issues encountered, larger active area transducers with higher amplitude outputs might be sourced. Although the desired sample thickness of 4" was not achieved during the first two hours of hydration, this sample thickness constraint may be relaxed.
by switching to a larger active area transducer. The effective result would be sampling a comparable volume of the test specimen, but at a lower sample thickness.

- Another goal of the project was the development of image processing techniques for air-void systems in hardened concrete during the refinement process in the design of the experimental test fixture. No conclusive time-domain results were obtained within the first few hours of cement hydration. On the other hand, more reliable data were recorded beyond this time window.

- Based on the numerical results obtained from the developed computer program, expanded capabilities can be addressed by processing the entire high-resolution image. These capabilities may reduce the time and effort needed to prepare each specimen for air-void analysis. In turn, more specimens can be analyzed to generate statistically representative predictions. Preliminary results show promise that a coarse aggregate in hardened concrete identification filter based on high sensitivity edge detection combined with color image enhancement techniques would yield a semi-automatic classification system. The image processing algorithms can also be applied to other optical characterization projects for the estimation of other pertinent parameters of cementitious materials.

Implementation

This report concerns a feasibility study on the use of a non-destructive and non-invasive method to determine the size distribution of air voids in fresh concrete, which will be used for placing and acceptance of concrete pavement. A preliminary review of different techniques suggested that the measurement of the p-wave velocity of ultrasound pulses transmitted through a fresh concrete specimen offers the most straightforward approach. This report describes an experimental study to address the design of an experimental test rig, the selection of appropriate equipment, and the determination of the p-wave velocity in fresh cementitious materials. The ultrasound characterization of fresh cement and mortars are discussed. Then, the feasibility of using the ultrasound method to determine the air-void content in a fresh concrete specimen with a minimum thickness of 4” is examined. In addition to the discussions of the ultrasound characterization of fresh cementitious materials, this study also explores the development of a suite of computer programs to characterize the air-void systems of hardened cementitious materials. The approach is based on image processing techniques used to analyze digital images of polished specimens collected with a flatbed scanner. The results will provide pertinent information on the air-void systems in hardened cementitious materials. The state-of-the-art image processing technique has been applied to examine digital images of polished specimens collected with a flatbed scanner. Implementation of the software program and the coloring technique in the hardened concrete is very suitable for fast air-void system investigation of hardened concrete.

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