Measuring Size and Distribution of Air Voids in Concrete Using Ultrasonic Waves

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ABSTRACT

During the winter months, water gets into concrete on streets and expands as it freezes. As the temperature increases, this water begins to thaw and contract. This “freeze-thaw” process, when occurring multiple times over the course of the winter, can cause severe premature damage to the concrete in the form of cracks and imperfections. Resurfacing concrete on streets and highways has the potential to cost the government millions of dollars. By inputting small air bubbles into the concrete mix, water can expand into these air pockets and decrease the damage done to the concrete. The purpose of this research was to use high frequency ultrasonic transducers to measure the p-wave velocity of sound waves through concrete specimens in an attempt to accurately measure the necessary size and distribution of these air voids. To accomplish this, test specimens of concrete were prepared and placed in a test rig. A pair of ultrasonic transducers was connected to the two opposite sides of the rig. The p-wave velocity of the ultrasound waves was measured as they pass through the prepared concrete sample. Air voids decrease the velocity of ultrasonic waves through concrete, therefore finding slower velocities with respect to the velocity without air bubbles will give an indication of the amount of air bubbles in a sample. This will provide a non-destructive method of measuring air void content in fresh concrete before concrete has solidified, saving both time and money.

BACKGROUND

- As water seeps into concrete roads and sidewalks, it expands as it freezes and contracts as it thaws. This process wears out the concrete and manifests itself as premature cracking and splitting. Repairing damaged roads is an extremely costly procedure for the state, which results in higher taxes for taxpayers.

- By intentionally adding small air voids, approximately 0.1 mm in diameter, into concrete mixture, water can expand into these “air pockets” and thus increase the concrete’s strength.

- Current methods of measuring air voids involve breaking concrete and optically measuring air content after concrete has hardened and set.

- Passing high frequency Ultrasonic waves through concrete samples, then measuring the output velocity potentially provides a new, non-destructive method of measuring size and distribution of the air voids.

METHODS

- After assembling the test rig with a high-frequency transducer on two opposing sides, we went to the Indiana Department of Transportation lab facilities to prepare concrete samples according to ASTM procedure.

- The test rig was filled with the prepared concrete sample, attached the pair of ultrasonic transducers to a pulser/receiver where its output was connected to an oscilloscope. By measuring the time delay for the ultrasound pulses, the p-wave velocity of the ultrasound can be determined. The velocity was monitored over a span of 24 hours.

RESULTS

- Due to the highly-attenuating “viscoelastic” nature of the concrete in the early formative hours, the early pulse signals were unclear and completely ineffectual. An onset time for the signal was still evident, however.

- However, a much clearer pulse signal was evinced as the concrete began to solidify.

- A marked difference in the velocities of samples with air entrainment added and samples without air entrainment added was discovered.

- Although the output velocity signal is clear for both situations, no perceptible signal can be found until roughly five hours after concrete is mixed due to low signal-to-noise ratio.

CONCLUSIONS

- The results shown above demonstrate that there is a discernible difference in the velocity of Ultrasonic waves passing through concrete samples containing entrained air voids and those of samples without entrained air.

- This supports the proposal that a relationship between the difference in these two velocities and the size and distribution of air voids in concrete can be discovered.

FUTURE DIRECTION

- In the future, a better way of improving the signal-to-noise ratio will be developed within the first hour of making the sample. This way, the amount of air voids in fresh concrete can be measured using non-destructive, ultrasonic waves. The improvement of signal-to-noise ratio could possibly be attained by using lower-frequency, higher powered transducers.

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