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ABSTRACT

Mechanical material properties of concrete specimen are evaluated locally and non-destructively using an ultrasonic C-scan system. The time of flight of the sound wave between front surface and back surface for test samples was measured. Local Young's modulus at scanning point and average Young's modulus of entire specimen are calculated. Testing techniques are developed by calibrating the transducer not only to compensate for the time delay but also to control the measurement of properties of interest, such as true density and local thickness. In order to obtain additional mechanical property, such as Poisson's ratio, the transverse velocities of the wave through the specimen need to be measured. This non-destructive evaluation technique is an important alternative material property measurement method to replace the traditional testing methods that destroy specimens after testing. Advantage of high accuracy and time saving is also expected from this study.

INTRODUCTION

It has not been easy to obtain material properties of concrete, a composite material of cement and matrix, whereas metal has been tested by many conventional methods. Engineers demand accurate and effective way to find out characteristic of concrete for quality assurance and reliability. There are many Non-destructive testing techniques for tough testing environment. The Ultrasonic testing technique is one of the most accurate nondestructive testing methods. The aim of the ultrasonic c-scan implementation is to include satisfaction of no change material properties because other testing methods may inevitably change properties of specimen in physical.

In this study, the concrete block and disc samples have been measured to find their modulus of elasticity using the ultrasonic testing method. The testing system is pulse echo scan, which is one of major type of scans. The scheme was set up to read the peaks of the front wall echo (FWE) and the back wall echo (BWE). Both amplitude of the signal and the time of flight were recorded for each experiment. Then collected data transferred into MATLAB calculation to have local and average Young's modulus for each sample. Currently, thick sample, more than one inch thickness, is not possible to have BWE because of improper transducer. While performing experiment, enhanced system will be developed to have expansion of larger range to specimen. After all, obtaining Young's modulus from non destructive testing technique will be advantage in terms of accuracy and effortless.

When using ultrasonic to test material properties, there are two main types of scans that are used. These are the through transmission scan and the pulse echo scan. The through transmission scan is generally used for mapping inhomogeneity in the material. Lower frequencies, between 0.5-5 MHz, tend to be used for this. Two transducers are needed for this type of scan and are aligned perpendicularly to the material. The pulsing sensor sends a sound wave through the sample to the receiver, which sends the signal back to the computer.
The pulse echo scan is generally used for mapping surface defects of the material. A higher frequency (10-25 MHz) is often used for this purpose. The pulse echo scan utilizes only one transducer, which acts as both the emitter and the receiver. A signal is sent into the sample and the sound wave reflects off of the sample and back up to the transducer.

THEORETICAL BACKGROUND

Equations for the longitudinal velocity, Poisson's Ratio, Young's modulus and modulus of rupture were found for ultrasonic testing. The longitudinal velocity of the wave through the material was calculated using the following equation:

$$c_l = \frac{l}{0.5t_1} \qquad (1)$$

where l is thickness of the concrete block or disk, t_1 is the time lapse between the front wall echo and the back wall echo and c_l gives the longitudinal speed of sound through the material.

The calculation for Poisson's ratio requires both the longitudinal velocity and the transverse velocity. The current testing system is not capable to measure a transverse velocity while collecting a longitudinal velocity because only one probe was used. Instead, the transverse velocity was looked up and found to be 0.135 in/µs considered as average transverse velocity for concrete from reference. The following equation was used to calculate Poisson's ratio for the concrete cylinders.

$$\nu = \frac{0.5\left(\frac{c_l}{c_t}\right)^2 - 1}{\left(\frac{c_l}{c_t}\right)^2 - 1} \qquad (2)$$

where ν is Poisson's ratio and *ct* gives the transverse speed of the ultrasonic through the material.
The calculation for Young's modulus and an approximation are as follows:

$$E = c_l^{\,2} \cdot \rho \frac{(1+\nu)(1-2\nu)}{(1-\nu)} \qquad (3)$$

And approximated to

$$E = c_l^{\,2} \cdot \rho \qquad (4)$$

Here ρ is the density of the concrete block. The following is the expression for the Modulus of Rupture.

$$G = c_t^2 \cdot \rho \qquad (5)$$

There is a possible way to enhance accuracy if a local thickness is measured. The speed of wave in water is known. If difference between FWE and bottom surface wall echo is detected, local thickness will be calculated using modified equation one. However, this will be only valid when back of specimen is flat surface.

$$l = 0.5 \cdot c_w \cdot (t_1 - t_2) \qquad (6)$$

Where: c_w is the speed of wave in water and t_1 and t_2 are the time lapse from probe to FEW and bottom surface, respectively.

EXPERIMENTAL SETUP

As shown in figure 1, the ultrasonic testing system is equipped with one probe and a computer for data acquisition. Figure 2 shows testing specimen which is half inch thick and 4 inch diameter. In whole tests, One MHz transducer has been used and Poisson's ratio of concrete is taken as 0.2 from reference since transverse velocity of wave of sample is not available. Due to the difficulties of measuring local thickness and Poisson’s ratio, average volume of samples and reference Poisson’s ratio were used for recent experiments. Therefore, presented results are based on the assumption that the specimen has relatively small thickness change.

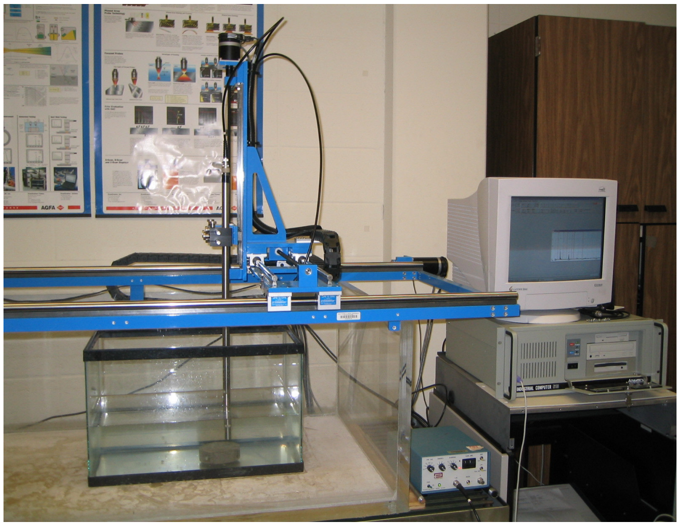


Figure 1: Ultrasonic C-Scan Testing System Apparatus

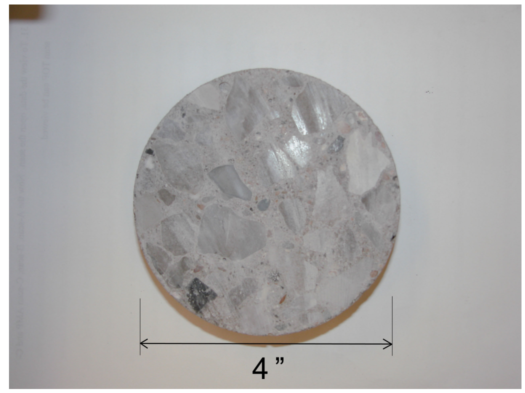
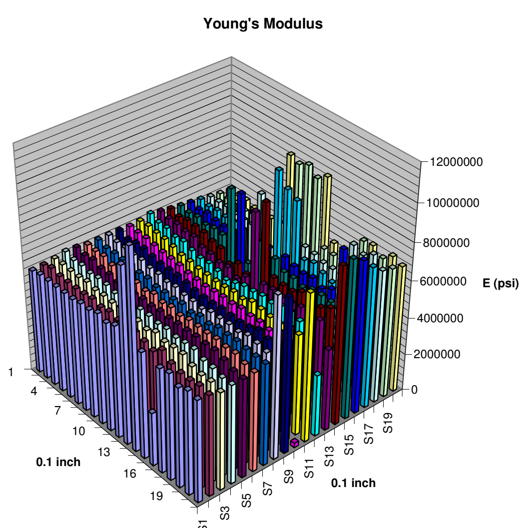


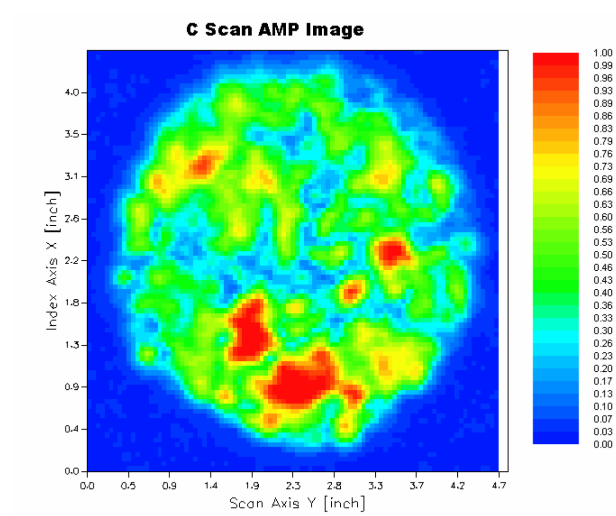
Figure 2: Concrete Specimen

RESULTS

Experimental Young’s Modulus is obtained between 5 and 9X10^6 psi. Young’s modulus of concrete is known as 4.35×10^6 psi approximately. It was difficult to get BWE from testing 1 inch thick samples so that results are not presented. The distribution of local elastic modulus from one of specimens is presented as figure 3 shown. Figure depicts representative elastic modulus by accumulating and averaging local values.



(a) MATLAB



(b) Data Acquisition System

Figure 3: Graphical Presentation of Local Young’s Modulus

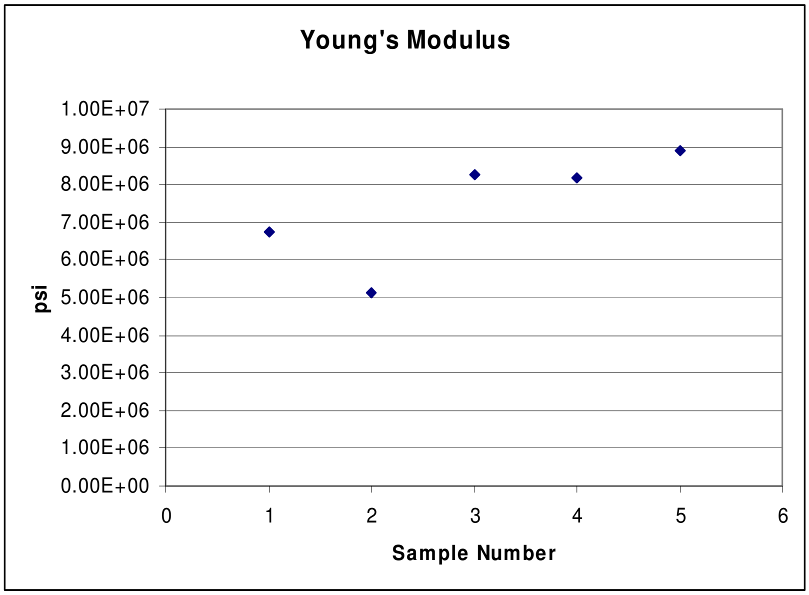


Figure 4: Average Young's Modulus of Concrete Specimens

CONCLUDING REMARKS

Ultrasonic C-scan method was used to measure local elastic modulus on concrete specimen with the assumption that the thickness change is relatively small. The current results are restricted by the capability of the Ultrasonic testing system. However this attempt is valuable to determine material properties of concrete in tough testing environment. The concrete specimen was immersed in water during the tests but no noticeable mechanical changes were observed.

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