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（要　旨）

“Nonlinear Ultrasonic and Acoustic Emission Investigation of Concrete Damage”

Structural health monitoring is very important in today’s modern world. Infrastructures experiences man-made and natural disasters that needs more precise and accurate assessment during post event. Material that is commonly used in structures is concrete. Concrete can be assessed in many different ways where factors to be considered in the test are cost, time, and the idle period during assessment. One way of having a better and economical test is the use of non-destructive test. In this dissertation, ultrasonic test and acoustic emission test are applied to evaluate the integrity of concrete specimens. The thesis comprises of two main concrete materials considered for testing, the unreinforced concrete and the reinforced concrete. The unreinforced concrete was designed having a specimen size of 150mm x 150mm x 150mm cube. The method of testing was uniaxial compression load. On the other hand, the reinforced concrete was designed having specimen size of 100mm x 100mm x 400mm beam. The method of testing was four-point loading test.

The first investigation dealt with plain concrete. It used cube specimens where nonlinear ultrasonic test and acoustic emission (AE) test were done simultaneously with the uniaxial compression load test. It focused first on investigating the sensitivity of higher harmonics when different load patterns were applied. These load patterns were single loading pattern and loading/unloading pattern. After knowing the most sensitive higher harmonics generated with single and loading/unloading pattern, different aggregate sizes were casted and tested to investigate the behavior of the most sensitive higher harmonic generation with the aggregate sizes used in the concrete. It was found out that Second Harmonic Amplitude (A2) and strain was the most sensitive among the parameters Ultrasonic Pulse Velocity (UPV), Peak to Peak Amplitude (PPA), Strain, Fundamental Frequency (F1), Second Harmonic Frequency (F2), Third Harmonic Frequency (F3), Fundamental Amplitude (A1), Second Harmonic Amplitude (A2), and Third Harmonic Amplitude (A3). Additionally, acoustic emission test data was used to determine AE location sources. These AE location sources were then used together with convex hull computational geometry to establish a volume connecting all exterior convex points in space. The volume generated by the convex hull was then related to the damage progression of the concrete.

The second investigation dealt with reinforced concrete beams. This was explored due to its complex characteristics where bending occurs having tensile and compressive zones in the beam structure when four-point loading test was done. The variation of reinforcing bars in concrete was designed and made suitable

for the equipment available. Focusing on the ultrasonic test, contact and non-contact ultrasonic test was done when four-point loading test was conducted simultaneously. The non-contact ultrasonic test which was using air-coupled ultrasonic transducers focused on the tension side of the beam where crack opening will be evident, while contact ultrasonic test through direct transmission was set up across the 400mm length of the beam. Then, the acoustic emission test data was used to determine AE location sources. These AE location sources were then used together with convex hull computational geometry to establish a volume connecting all exterior convex points in space in the compression zone of the reinforced concrete beam. The volume generated by the convex hull was then related to the damage progression of the concrete.

Lastly, nonlinear ultrasonic test data were used to generalize and simulate behavior of concrete according to the sensitive parameters. Feed-forward backpropagation Artificial Neural Network (ANN) was used to estimate the stress level experienced by the concrete. Input parameters for the network were taken from the received ultrasonic waves considering time domain and frequency domain. The phenomenon of harmonic generation of the non-linear ultrasonic testing was utilized in modelling the network. All the experimental data were taken from the 150 x 150 x 150 mm cubic concrete specimens and 100 x 100 x 400 mm reinforced concrete beam specimens. A parametric study was conducted using the produced model to predict non-linear relationship of the parameters presented to determine the stress in concrete. The resulting model of this study highlights the non-destructive evaluation capabilities and sensitivities of non-linear ultrasonic test. Furthermore, use of artificial neural network model was done to formulate sensitivity measurements of parameters according to insensitive, short range sensitivity (less than 20% damage) or long range sensitivity (more than 20% damage). It was found out that A2 and neutral axis was the most sensitive among the parameters PPA, Neutral Axis (NA), A1, A2, and A3 in reinforced concrete beams.