Crack Propagation Monitoring in a Single Edge Notched Smart Cement Beam Using the Ultrasonic Method

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Abstract: A single edge notched ultrafine smart cement was tested under three point bending. During the test the crack mouth opening displacement (CMOD) and pulse velocity were monitored to determine the crack propagation. The CMOD was related to the time changes for the ultrasonic waves to pass through the cracked beam using a hyperbolic relationship.

1. Introduction

Ultrasonic visualization has been used for decades as a non-destructive method for different applications. In this investigation, the crack propagation has been monitored using ultrasonic method.

2. Objectives

The objective of the study is to investigate the sensitivity of the ultrasonic wave during crack growth in single edge notched beam.

3. Materials and Methods

Ultrafine smart cement has been used to prepare beam which has been cured for 28 days under relative humidity of 90% condition. The notch to depth ratio of 0.5 has been made in the beam. The ultrasonic device with the frequency of 150 kHz has been used for monitoring the crack propagation during the test. A Crack mouth Opening Displacement (CMOD) gauge was used to measure the CMOD

In order to calculate the crack depth in the beam, the following equation was used:

$$\left(\frac{L}{2}\right)^2 + a^2 = X^2 \qquad X = \frac{V_p T_c}{2} \qquad a = \sqrt{\left(\frac{V_p T_c}{2}\right)^2 - \left(\frac{L}{2}\right)^2} \qquad (1)$$

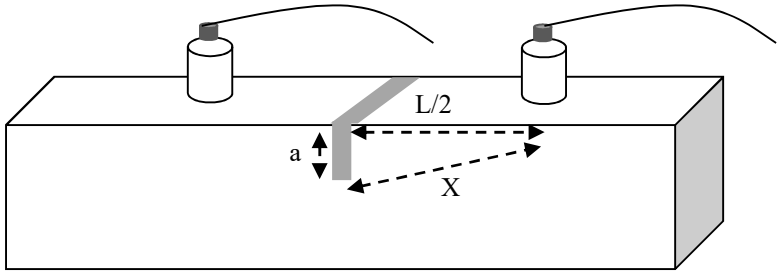

Figure 1. Schematic view of single edge notched beam and location of ultrasonic transducers

In which a is Depth of crack, V_p is Bulk pulse velocity of the sample, T_c is the total Travel time around the crack and L is the distance between two transducers. During the cyclic loading of the beam, ultrasound propagation time was measured by device. Using Eqn (1); the crack propagation has been calculated.

4. Result and Discussion

As we can see in Fig.1. the mouth opening of the beam has reached 0.003 mm at failure, while at the same time, the changes in the ultrasonic propagation time was 35%, Fig.2. We can correlate CMOD and

change in ultrasonic propagation time using hyperbolic model, Fig.4.

$$\frac{\Delta Tc}{Tc_0} = \frac{CMOD}{A+B\times CMOD} = \frac{CMOD}{2.19\times10^{-5}+0.0225\times CMOD} \qquad (R^2 = 0.99) \qquad (2)$$

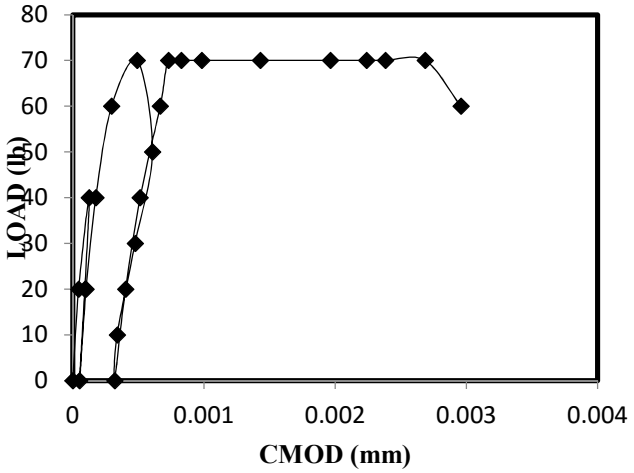

Figure 2. Crack mouth opening displacement vs. load

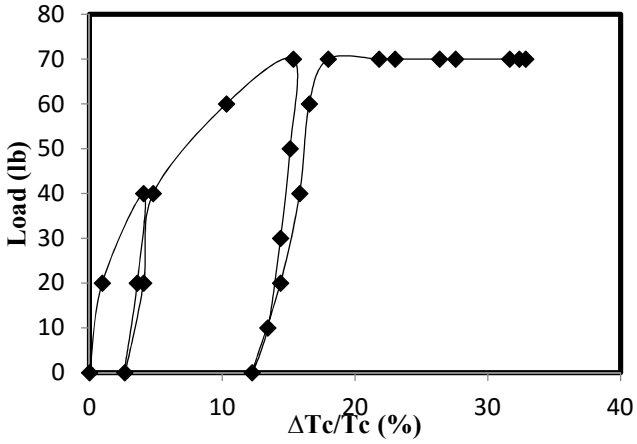

Figure 3. Changes in the ultrasonic propagation time vs. load

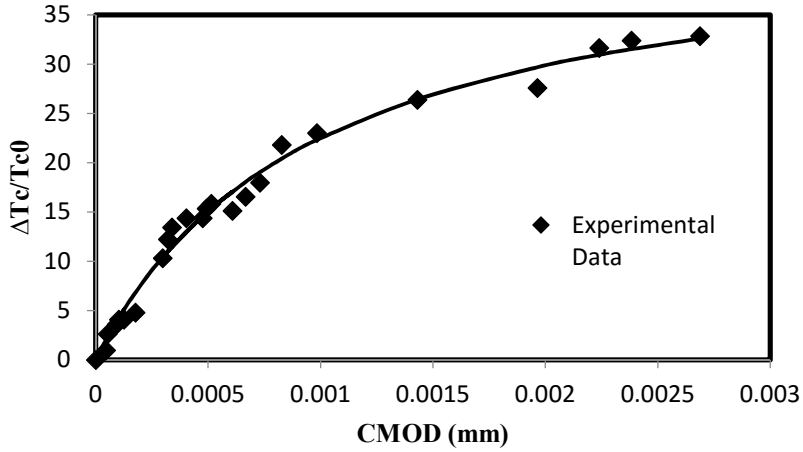

Figure 4. Crack mouth opening displacement vs. changes in the ultrasonic propagation time

5. Conclusion

Ultrasonic is an accurate method of monitoring crack propagation during the cyclic three point bending test with maximum change of 35%. There is a hyperbolic correlation between CMOD and the changes in the ultrasonic propagation time so that with using ultrasonic method, we are able to calculate the Crack mouth Opening Displacement during the cyclic loading.

6. Acknowledgement

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7. References

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