Development of Non-Destructive Damage Inspection for in-Service Concrete Structure

- (1) Visualization and Quantification of Cracking Damage in-Service Concrete by X-ray CT Method -

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1. Introduction

The limiting states of structures are the result of a gradual accumulation of microdefects during in-service period, which leads to the initiation and development of macroscopic cracks, loss of performance and destruction. Therefore, there is a necessity to monitor the condition of the development of damage in the structure's body. By the author, the damage estimation method for in-service concrete by Acoustic Emission (AE) and related non-destructive inspection method is developed[1)-3)]. In this study, detection of cracking damage in-service concrete by X-ray CT method and post treatment of 2D/3DX-ray images.

2. Experimental and Analytical procedure

2.1. Experimental procedure

The cylindrical samples of 10 cm in diameter and about 15-20 cm in height were taken from the damaged RC head works in Shinkawa drainage station, which was constructed after about 50 years in Niigata, Japan. The sampling structure was extremely developed of the cracking system on the concrete surface.

The selected core samples were inspected with a helical CT scan. The output images are visualized in gray scale with setting threshold calculated by Otsu and Maximum Entropy methods[4)-5)]. After X-ray CT measurement, an ultrasonic test and a resonant frequency test were performed. The following formulas calculated the Dynamic modulus of elasticity from both parameters:

$$E_d = V_p{}^2 \rho \frac{(1-v)(1+v)}{(1-v)} \quad (1)$$

$$E_D = 4 * 10^{-3} \frac{f^2 L}{A} \quad (2)$$

where V_p is pulse velocity, ρ is the density of concrete, v is Poisson's ratio, f is resonant frequency, L is the length of sample, A is an area of sample.

2.2 Analytical procedure

To describe the distribution of concrete particles, a binary image is generated from the 8-bit longitudinal-sectional images. To conduct a more accurate analysis, manual operations are carried out. After it, geometric properties are calculated by Image J software.

3. Results and discussion

Fig. 1 depicts the relationship between non-destructive and geometric parameters of testing concrete. The accumulation of damage in tested samples is positively correlated with an increasing trend of the total perimeter of cracks to aggregates. In damaged conditions, the high value of its ratio is demonstrated under low V_p.

Pearson's correlation coefficient R of V_p is -0.58 (*p-value* is 0.047), -0.62 (*p-value* is 0.033) of E_d. The Pearson's correlation coefficient R of E_D is -0.18 (*p-value* is 0.57). The exceeding *p-value*

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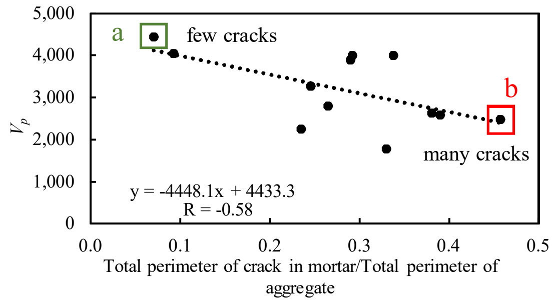
0.05 by this value is interpreted correlation as not statistically significant.

Due to the ultrasonic pulse velocity in concrete being the average of its velocities in concrete components, the dynamic modulus of elasticity E_d based on V_p gives reliable information about the damage condition of structure. Accordingly, it means the successful transmissions of ultrasound through the concrete structure are considered indicative of absence from inner cracks or its little number.

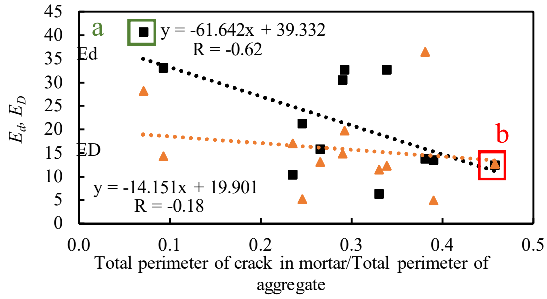
Fig. 2 illustrates samples with different degrees of cracking damage. As can be seen, sample (a) has a small number of inner cracks and a high value of pulse velocity, then sample (b) demonstrates an active cracking system and a low value of pulse velocity.

4. Conclusions

In this study, visualization and quantification of cracking damage in-service concrete are conducted by X-ray CT and dynamic Young's modulus. It is qualitatively demonstrated that testing concrete is damaged based on a comparison of X-ray CT parameter and the dynamic Young's modulus. Reasonable agreement with the spatial distribution of cracks in concrete is confirmed by the results of elastic wave characteristics in core test.

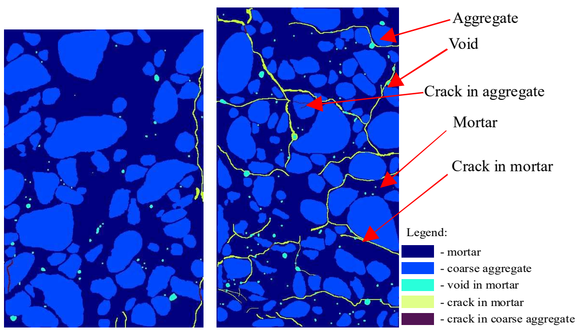


(a) Results of V_p



(b) Results of E_d and E_D

Fig. 1 Relationship between non-destructive testing parameters and geometric parameters.



(a) Few cracking sample (b) High cracking sample

Fig. 2 Component's scheme of damaged samples.

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