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Evaluation of the thermally damaged concrete using nonlinear ultrasonic

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ABSTRACT

Occurrence of contact-type defect, which is one of the representative damage in thermally damaged concrete, induces the degradation of concrete properties. This study attempts to evaluate the residual mechanical properties of thermally damage concrete using a nonlinear ultrasonic method. Concrete samples were prepared as different mix proportions and various damaged condition. The nonlinearity parameters measured by an impact-modulation method were correlated with the residual mechanical properties, such as compressive strength, elastic modulus, and peak strain, obtained from compressive stress-strain curves. As a result, the regressed relationships of both experimental measurements were proposed to predict the mechanical properties based on the nonlinear ultrasonic method.

1. INTRODUCTION

Conctact-type defect is one of the representative damage at a multi-scale of concrete in thermally damaged concrete (Yim et. al. 2012), which generated defects can be identified by opening and pores of cement-based materials. Previous research reported that measurement of contact-type defects is a meaningful factor indicating thermal damage in concrete. This means that the contact-type defects can be represented by measurement of nonlinearity parameter via nonlinear ultrasonic method. Therefore, these experimental results of nonlinearity parameters can be correlated with the results of residual mechanical properties [Yim et. al. 2013]. The aim of this paper is a summary report about correlation between experimental measurements of thermally damaged concrete using an impact-modulation technique for nonlinearity parameter and compressive testing for mechanical properties, such as compressive strength, elastic modulus, and peak strain corresponding to compressive strength. Correlations

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were performed for different exposure times and mix proportions. As a result, the relationships were developed based on a regression analysis to predict residual mechanical properties of thermally damaged concrete.

2. Samples

Thermally damaged concrete samples were prepared having four different mix proportions as shown in Table 1. The mix proportions are represented as the weight ratio of water, cement, sand, and gravel in sequence. The prepared cylindrical samples (height of 20cm and diameter of 10 cm) were subjected to different high temperatures (200˚C, 300˚C, 400˚C, 500˚C, and 600˚C) with 2 hours exposed times under an electric furnace. Case1 additionally was subjected with 1 and 3 hours exposed times. Further details are described in (Yim et. al. 2013).

Table 1 Mix-proportions of sample (kg/m^3)

Case1	160 : 320 : 744 : 1100
Case2	171 : 285 : 744 : 1100
Case3	160 : 320 : 922 : 922
Case4	171 : 285 : 922 : 922

3. Nonlinearity parameter

Experiments were performed to the thermally damaged concretes based on the set up for impact-modulation method, where detailed set up is represented in (Yim et. al. 2013). The nonlinearity parameters are then measured by a relative ratio of spectral energies as degree of contact-type defects in thermally damaged concrete. Where measured nonlinearity parameters are summarized as different case of thermal damage in Table 2.

Table 2 Nonlinearity parameters as different mix proportion and exposed time

Peak temperature	Case1 (1hour)	Case1 (2hour)	Case1 (3hour)	Case2 (2hour)	Case3 (2hour)	Case4 (2hour)
20˚C	0.0459	0.0459	0.0459	0.0223	0.0296	0.0207
200˚C	0.2492	0.2253	0.8087	0.2403	0.2236	0.1526
300˚C	1.2463	1.7055	2.1849	0.5433	0.8667	0.4288
400˚C	2.3988	4.6448	9.7339	3.0927	2.3296	1.5127
500˚C	4.6156	10.608	15.785	4.9382	8.6143	7.2909
600˚C	9.7301	21.250	38.707	20.536	14.262	16.699

4. Mechanical properties

Compressive tests were also performed according to the ASTM C-39 to measure the stress-strain curve of prepared samples. From these curves, residual mechanical properties can be obtained with different case of thermal damage. The stress-strain curves and residual mechanical properties are described in (Yim et. al. 2013).

5. Correlation

The correlations are investigated between the relative ratios of nonlinearity parameters and residual mechanical properties as different mix proportion and exposure times. The correlated data are depicted in Fig. 1 with increased ratio of nonlinearity parameter according to the decreased ratio of compressive strength, decreased ratio of elastic modulus, and increased ratio of peak strain. As can be seen in Fig. 1, correlated data are not affected by the various exposure times and mix proportions.

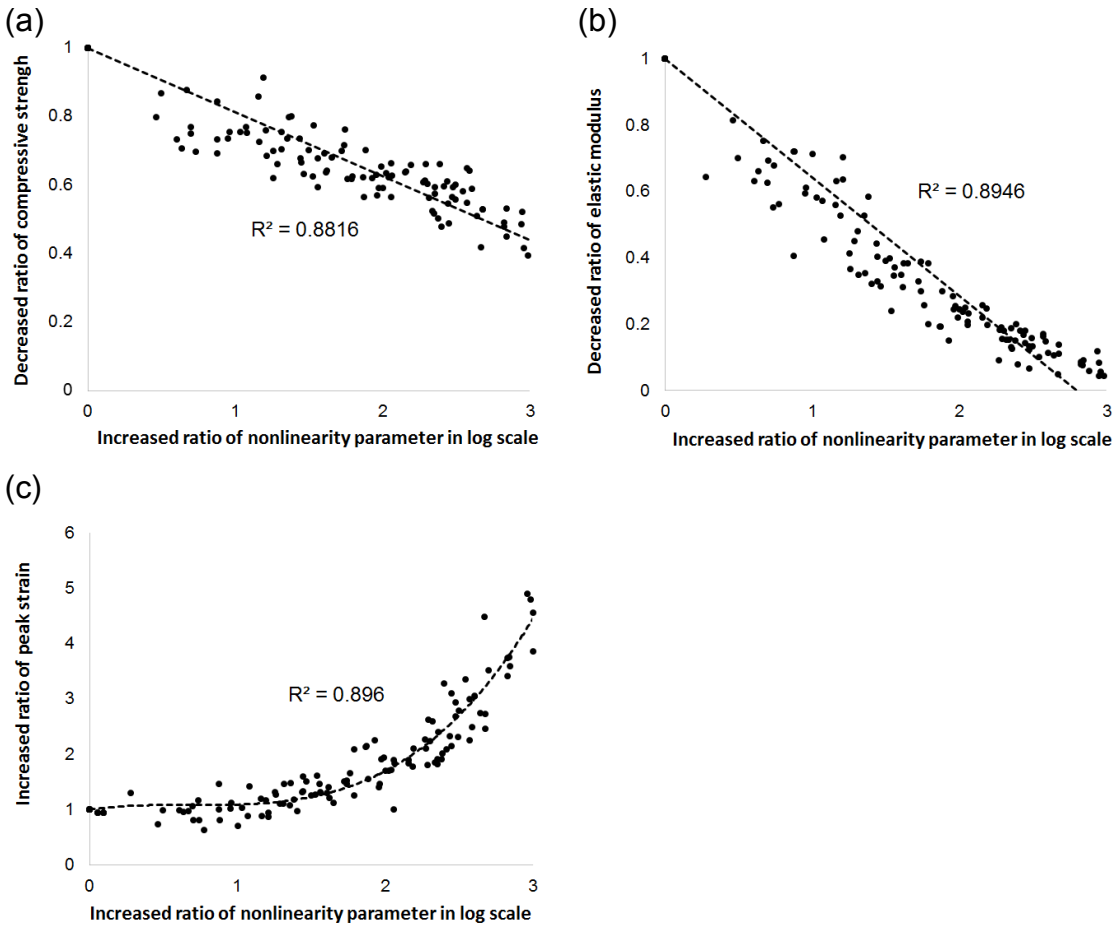

Fig. 1 Relationships between increased ratio of nonlinearity parameter in log scale and: (a) decreased ratio of compressive strength; (b) decreased ratio of elastic modulus; (c) increased ratio of peak strain.

6. Conclusion

Mechanical properties of concrete are degraded from thermal damage. The nonlinearity parameters measured by nonlinear ultrasonic method can represent the thermal damage in concrete induced by contact-type defects. This paper summarized the correlation study between the ratios of nonlinearity parameters and the ratio of mechanical properties (Yim et. al. 2013). Developed correlations can be represented as the relationships, and which can use as a prediction model of residual mechanical properties of thermally damaged concrete.

REFERENCES

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