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Modeling of Concrete Mixed with Expansive Additives

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Abstract

In this study, the Mechanical properties, volume changes and creep of concrete mixed with expansive additives, which is used as a countermeasure for cracking and shrinkage, were modeled and the model was verified. In addition, the generated stress was estimated using the modeled creep phenomenon to calculate changes in the stress under the restraint condition, thus allowing a comparison with experiment to verify the model's applicability and the validation of the stress prediction technique.

Keywords: Expansive additive, Modeling, Compressive strength, Elastic modulus, Volume change, Creep

1 INTRODUCTION

Cracks of concrete affect the structure's safety, usability, durability, and appearance, it is important to prevent their formation to ensure the longevity and required performance. Given this background, application of expansive additives has been demonstrated to be an effective means of reducing shrinkage and increasing crack resistance; thus, their application to construction projects is gradually becoming popular(1). In this study, we aimed to model the concrete mixed with expansive additives, and to suggest macro prediction of shrikage-reduction behavior, as shown in Fig.1.

2 MODELING

2.1 Mechanical Property(2)

In hardened cement paste with an expansive additives, hydrates are generated owing to hydration between the cement and expansive additives; these hydrates then fill up the pores in the hardened cement. Consequently, a dense, compact structure is formed through the contact between the particles of the expansive additives and cement or that between the cement and particles of the expansive additives, leading to the manifestation of the strength and elastic modulus. Hence, in this study, modeling of the compressive strength and elastic modulus was performed based on the concept of mutual contact area of the particles, taking into consideration the extent of cohesion between the particles and the structure formation by the particles. The compressive strength of the material was modeled by considering the relationship between the porosity and the distributional probability of the weakest points, i.e., points that can lead to fracture, in the continuum. The approach used for modeling the elastic modulus considered the pore structure between the particles that are responsible for transmitting the tensile force and the state of compaction of the hydration products as described by the coefficient of effective radius.

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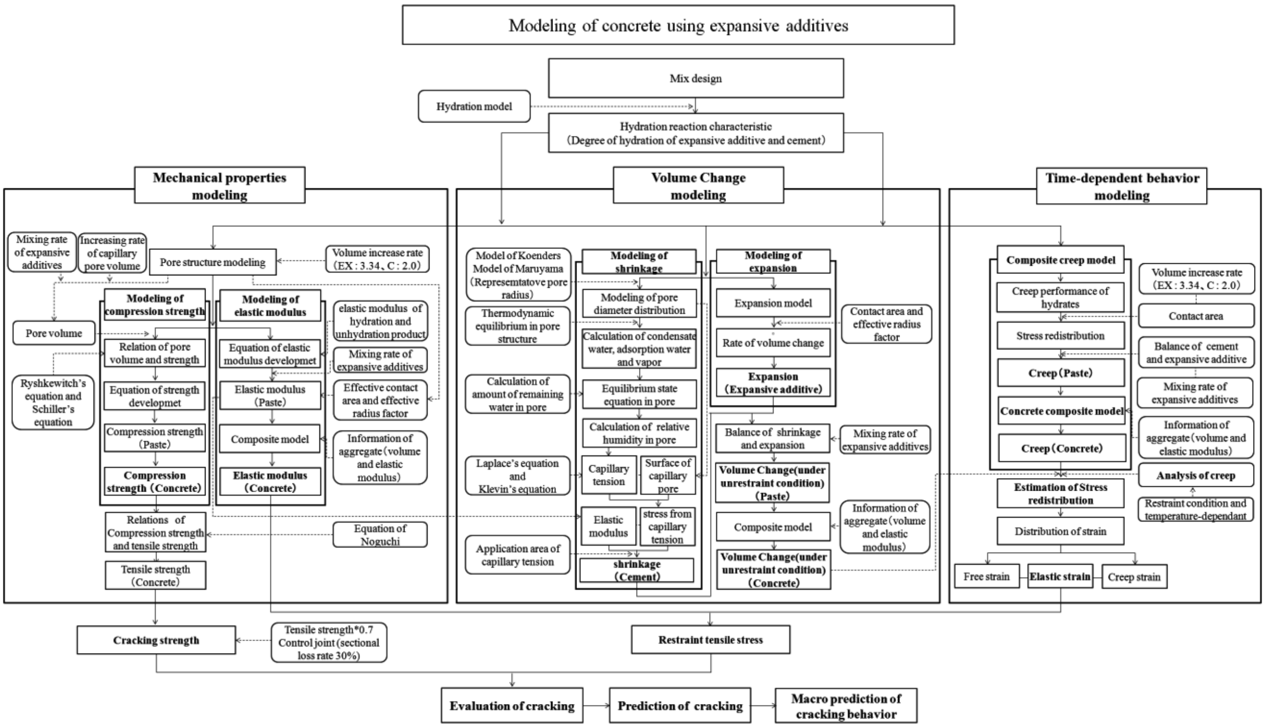

Fig.1 Flow of macro prediction of shrinkage-reduction behavior in concrete using expansive additives

2.2 Volume Change[3]

Volume changes of expansive paste are determined from the balance between the shrinkage of cement and the expansion of the additives. Therefore, volume changes were modeled by applying a balance to the hydrates of cement and the expansive additives. The shrinkage of cement was modeled by assuming that it is caused by capillary tension. This modeling was based on the behavior of the moisture inside the cement's pore structure, by taking into account the pore size distribution and the thermodynamic equilibrium state of the moisture. Using the concept of effective radius factor, the expansion of the expansive additives was modeled by considering the volume expansion of the additive particles caused by an increase in the outermost radius of particles of the hydration products that were formed at an early age.

2.3 Creep[4]

The creep phenomenon of hardened cement mixed with expansive additives was modeled by considering the creep performance of hydration products of cements and expansive additives under the assumption that the characteristics of hydration products of cements and expansive additives are fixed. A new composite model that is appropriate for particle conditions is proposed by considering the balance of the hydration products of cement and expansive additives and the stress redistribution phenomenon of hydration products newly generated by the progress of hydration.

3 VERIFICATION OF MODEL

3.1 Mechanical Properties

To verify Mechanical Properties model, it performed experiment; water-binder ratio is 0.50 with mixed 0, 5 and 10% expansive additives. Fig.2 and 3 shows the compressive strength and elastic modulus estimates found using the model and the values measured in an experiment. The figures also shows Morioka's and Hori's data[5][6]. As shown in the figure, we confirmed that the compressive strength and elastic modulus estimates were positively correlated with the experiment values. For the elastic modulus of the concrete, its aging was confirmed to follow the estimate suggested in Hori's data[6], indicating that the composite model can estimate the elastic modulus of concrete based on the behavior of the paste.

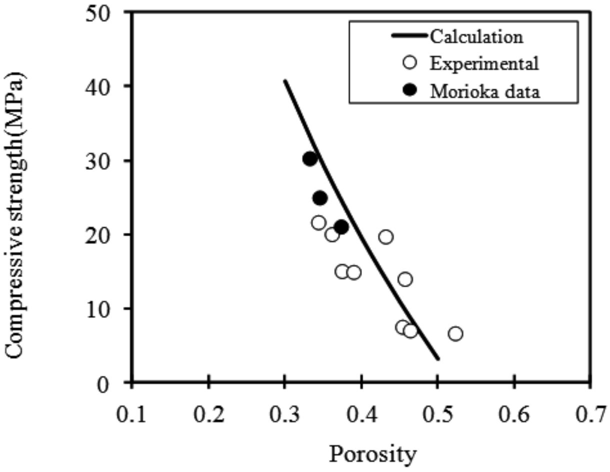

Fig.2 Compressive strength

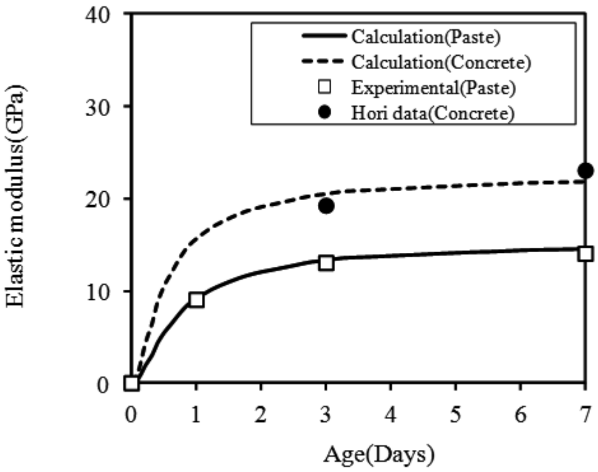

Fig.3 Elastic modulus

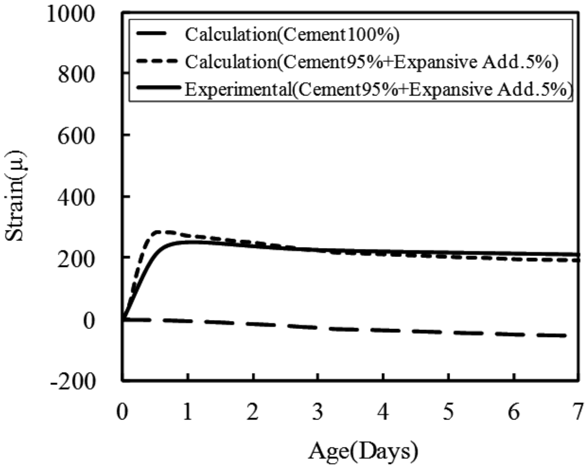

Fig.4 Volume changes

3.2 Volume Changes

Fig.4 shows the prediction results of the volume change of concrete and the results of each of the mixtures formed by mixing cement with 0%, 5% expansive additives at a W/C of 0.50. It also shows the actual measurement value for the mixture of cement with 5% expansive additives. The values predicted by the model were consistent with the measured values, which confirms the model's validity. In addition, the volume changes of concrete were estimated with sufficient accuracy by analyzing the behavior of the paste using a composite model of aggregate and paste.

3.3 Creep

Accumulated creep strain, calculated through the VRTM (variable restraint testing machine) test (quasi-fully restrained test)[(6)], was used to verify the creep model as shown in Fig.5. The experimental work was performed on concrete mixed with a standard amount (20km/m^3) of ettringite-gypsum type expansive additives and normal concrete. Air-entraining and highrange water reducing agents were also used as chemical admixtures.

Fig.6 show the results of the accumulated creep strain obtained from the VRTM test and calculated by the creep model for normal and expansive concretes respectively. As shown in the figures, the model shows good predictability for both types of concrete.

The stress change in concretes at an early age under the restrained condition was estimated. The stress estimation was achieved through the calculation of the stress change by using the modelled creep phenomenon under the restrained condition. The estimated stress was compared and analysed with experimental results under the quasi-fully restrained condition to verify the model validity. The stress measured in the VRTM test and the estimated value of stress from the creep model are shown in Fig.7. As shown in the figures, good prediction of the generated stress can be achieved by analysing the creep phenomenon of free expansion and shrinkage strains under the fully restrained condition in both and expansive concretes.

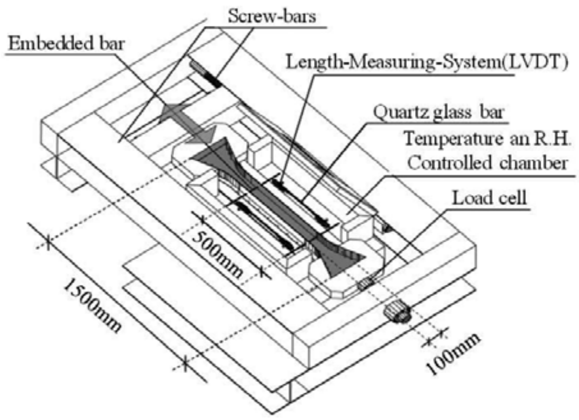

Fig.5 Quasi-fully restraint test (VRTM)(7)

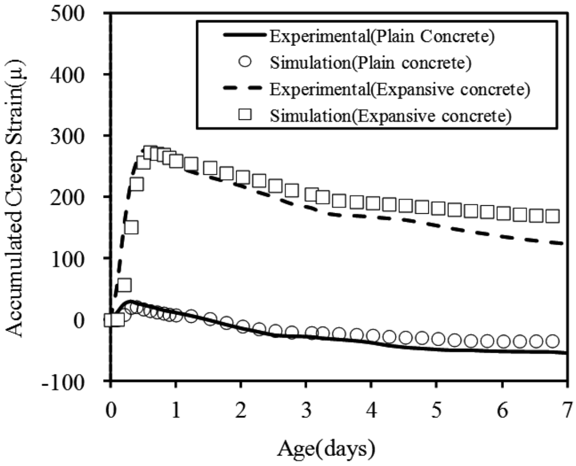

Fig.6 Accumulated creep strain

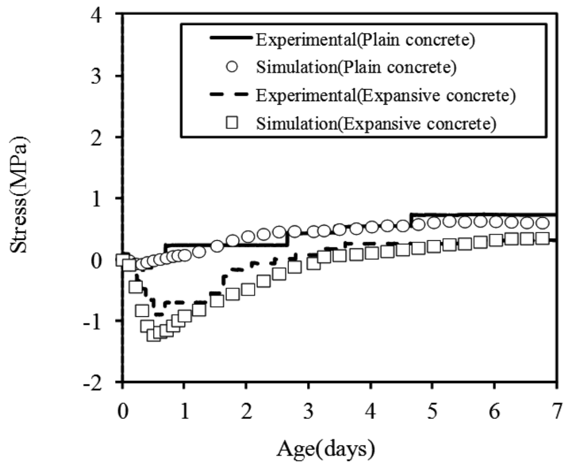

Fig.7 Generated stress

4 CONCLUTIONS

We modeled the mechanical properties, volume changes and creep of concrete mixed with expansive additives. and the model was verified. The values predicted by the model were consistent with the measured values, which confirms the model's validity.

ACKNOWLEDGMENT

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REFERENCES

(1) Choi HG, Tsujino M, Noguchi T, Kitagaki R, Expansion/Contraction Behavior and Cracking Control Effect of Expansive Concrete in Building Structure (in Japanese), Proceedings of the Japan Concrete Institute 34(1), 2012, p. 424-429.
(2) Hyeonggil Choi, Takahumi Noguchi, Modeling of Mechanical Properties of Concrete Mixed with Expansive Additive, International Journal of Concrete Structures and Materials, 9(4), 2015, p. 391-399.
(3) Hyeonggil Choi, Heesup Choi, Myungkwan Lim, Takahumi Noguchi, Ryoma Kitagaki, Modeling of volume changes of concrete mixed with expansive additives, Construction and Building Materials, 75, 2015, p. 266-274.
(4) Hyeonggil Choi, Myungkwan Lim, Heesup Choi, Takahumi Noguchi, Ryoma Kitagaki, Modeling of creep of concrete mixed with expansive additives, Magazine of Concrete Research, 67(7), 2015, p. 335-348.
(5) Morioka M, Hagiwara H, Sakai E and Daimon M, Chemical Shrinkage and Autogenous Volume Change of Cement Paste with Expansive Additive (in Japanese), Proceedings of the Japan Concrete Institute, 21(2), 1999, p. 157-162.
(6) Hori A, Tamaki T and Hagiwara H, Cracking Behavior of Expansive Concrete in Homoaxial Tension (in Japanese), Proceedings of the Japan Concrete Institute, 22(2), 2000, p. 511-516.
(7) Maruyama I, Park SG and Noguchi T, Properties of high performance concrete in early age under quasi-complete restraint condition (in Japanese), Proceedings of the Japan Concrete Institute, 25(1), 2003, p.485–490.