Basic Creep Model by Considering Autogenous Shrinkage

Lee, Yun* Kim, Jin Keun** Kim, Min Su*

ABSTRACT

Basic creep of concrete during very early ages is an important factor on the behavior of young concrete and a great deal of research has been executed. However, in recent studies, it was revealed that the basic creep measured by sealed concrete was inaccurate, especially for high strength concrete because of autogenous shrinkage at early age.

This paper presents the results from experimental study that investigate to explore the effect of autogenous shrinkage in basic creep. More specifically, four different mix proportions were casted and the primary variables were water-cement ratios.

Through this research, it was found that the differences between apparent specific creep and real specific creep were remarkable in low water-cement ratio at early age. Therefore, it is recommended to modify existing creep model by considering autogenous shrinkage

1. Introduction

Autogenous shrinkage of concrete is a phenomenon that concrete contracts itself without change of weight and temperature of concrete. Although this phenomenon was first discovered by C.G. Lyman in 1940's, researches on autogenous shrinkage have been seldom performed for several decades. This phenomenon is basically due to volume change of cement paste by hydration, that is, volume of cement paste before hydration is larger than cement hydrates produced by chemical reaction. At early age after casting, almost all amount of autogenous shrinkage evolution occurs, and for high strength concrete magnitude of autogenous shrinkage becomes larger. However, it seems that in ordinary concrete having normal concrete strength autogenous shrikage hardly occurs and is not an important matter. Deveolping high perfomance admixture such as super-plasticizer, silica-fume, and fly-ash make it easy to exploit high strength concrete in practice and thus from early in 1990's importance of autogenous shrinkage have arisen

These days, a lot of studies on autogenous shrinkage have been perfomed by many reseachers in several countries. Creep of concrete can be divided in terms of drying shrinkage and basic creep. In case of basic creep test, in which specimens are sealed to prohibit moisture movement to the atmosphere and then sustained load is applied to specimens, strains with time are measured under sustained load. However, recently Altoubat et al.[(1)-(3)] revealed that pure basic creep strains

* Dept. of Civil and Environmental Engineering at KAIST, Ph.D Candidate
** Dept. of Civil and Environmental Engineering at KAIST, Professor

could not be measured due to influence of autogenous shrinkage from sealed specimens, and to obtain pure basic creep compensation of moisture loss by hydration is needed for restraining autogenous shrinkage. Fig. 1 shows schematic relation of pure basic creep and autogenous shrinkage. In this figure, real basic creep can be estimated by substracting autogenous shrinkage strains from apparent basic creep strains. In this study, autogenous shrinkage and basic creep tests were perfomed and real basic creep was obtained from excluding autogenous shrinkage in basic creep.

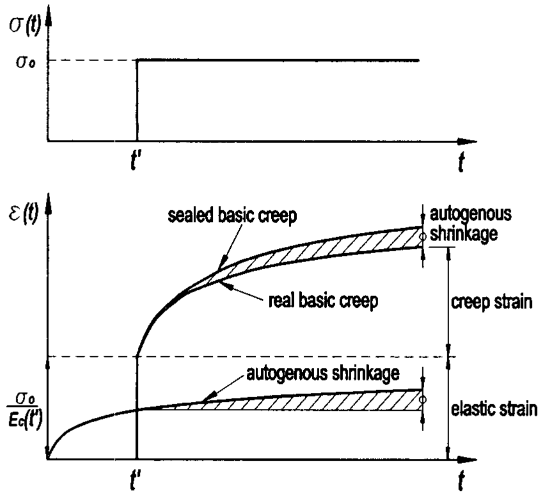

Fig.1 Time dependent deformation of concrete under sustained load

2. Test program

2.1 Test specimen

Table 1 shows concrete mixture proportions for four different water cement ratios. For each concrete mix 2-100×100×400 mm (for autogenous shrinkage) specimens , 12-ϕ150×300 mm (for basic creep) cylindrical specimens, and 12-ϕ100×200 mm (for compressive strength) cylindrical specimens were manufactured. All test cylinders were removed from the mold after 24 hours and were wet-cured in a curing room with 100 percent relative humidity at 20℃ until the testing date. Specimens for autogenous shrinkage were immediately tested after casting.

Table 1 Concrete mixture proportions

W/C	unit weight (kgf/m^2)					Ad
(%)	W	C	S	G	S/a	
30	175	583	591	999	37%	1.0%
40	175	438	687	1031	40%	0.6%
50	175	350	752	1031	42%	0.3%
60	175	292	849	1030	45%	0.1%

2.2 Test method

2.2.1 Autogenous shrinkage

Autogenous shrinkage was measured from 100×100×400 mm specimen as shown in Fig. 2 immediately after casting. For reducing the friction between the formwork and test specimen PTFE(Polytetrafluoroethylene) plate having low friction coefficient was placed, and before the casting a polyester film was fixed to prevent sticking between concrete and PTFE plate. Deformation before the hardening was measured from LVDT(Linear Variable Displacement Transducer), and deformation after the hardening was measured from embedment gage.

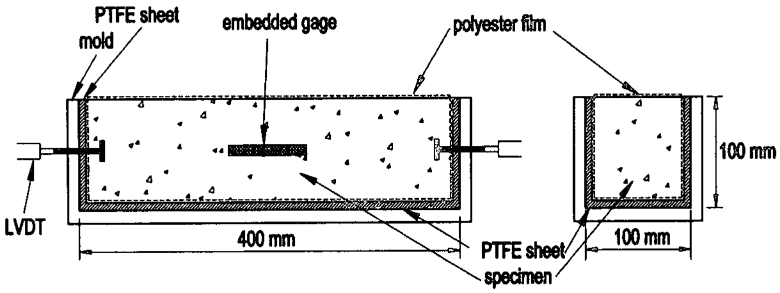

Fig. 2 Test specimen and test method for measuring autogenous shrinkage

2.2.2 Basic creep

Basic creep test was performed at 1, 3, 7, and 28 day ages with 3-ϕ150×300 mm cylindrical specimens in a curing room with 20℃ temperature, and test specimens were sealed by a polyester film to prohibit moisture migration to atmosphere. Creep strain was measured by embedment gage in center of specimen.

3. Test result and analysis

Autogenous shrinkage with respect to water-cement ratio is shown in Fig. 3. As we can see from this figure, autogenous shrinkage is produced mostly at early ages, and there are little increases after one month. Additionally we can see that autogenous shrinkage increases as water-cement ratio decreases. Especially in case of water-cement ratio 30 percent, the result shows that autogenous shirinkage is the biggest of other water-cement ratio mixes. After 50 days, autogenous shrinkage was measured to 60, 80, 110, and 270×10^{-6} respectively.

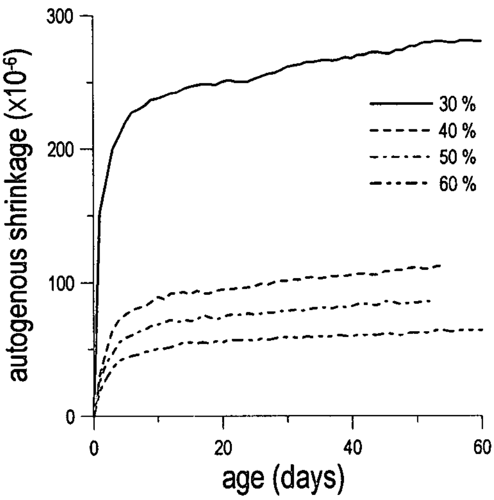

Fig. 3 Measured autogenous shrinkage

Total strain measured during the test of basic creep can be expressed as Eq. (1).

$$\varepsilon_{tot}(t, t') = \varepsilon_{elast}(t') + \varepsilon_{creep}(t, t') + \varepsilon_{auto}(t, t') \quad (1)$$

where, $\varepsilon_{tot}(t, t')$: total strain, $\varepsilon_{elast}(t')$: initial elastic strain, $\varepsilon_{creep}(t, t')$: creep strain and $\varepsilon_{auto}(t, t')$: autogenous shrinkage at time t after loading time t'.

Creep compliance which is the total strain relative to unit stress can be defined as Eq. (2). In this study this is defined as apparent creep compliance as shown in Eq. (2).

$$J_{apparent}(t, t') = \frac{\varepsilon_{tot}(t, t')}{\sigma(t')} \tag{2}$$

While $\varepsilon_{elast}(t')$ and $\varepsilon_{creep}(t, t')$ in Eq. (1) are dependent on applied stress, $\varepsilon_{auto}(t, t')$ is material property which is independent on applied stress. Thus apparent creep compliance cannot be the pure strain induced by unit stress. In this study, real creep compliance is defined as Eq. (3) omitting autogenous shrinkage independent on stress from Eq. (2).

$$J_{real}(t, t') = \frac{\varepsilon_{tot}(t, t') - \varepsilon_{auto}(t, t')}{\sigma(t')} \tag{3}$$

Fig. 4 shows real and apparent creep compliances with respect to four mixes. The differences between real and apparent creep compliance are obvious at loading age 1 and 3 days, but after 7 days there is no definite differences. From these results it can be seen that the effect of autogenous shirinkage, which is not considered in present basic creep model, should be developed.

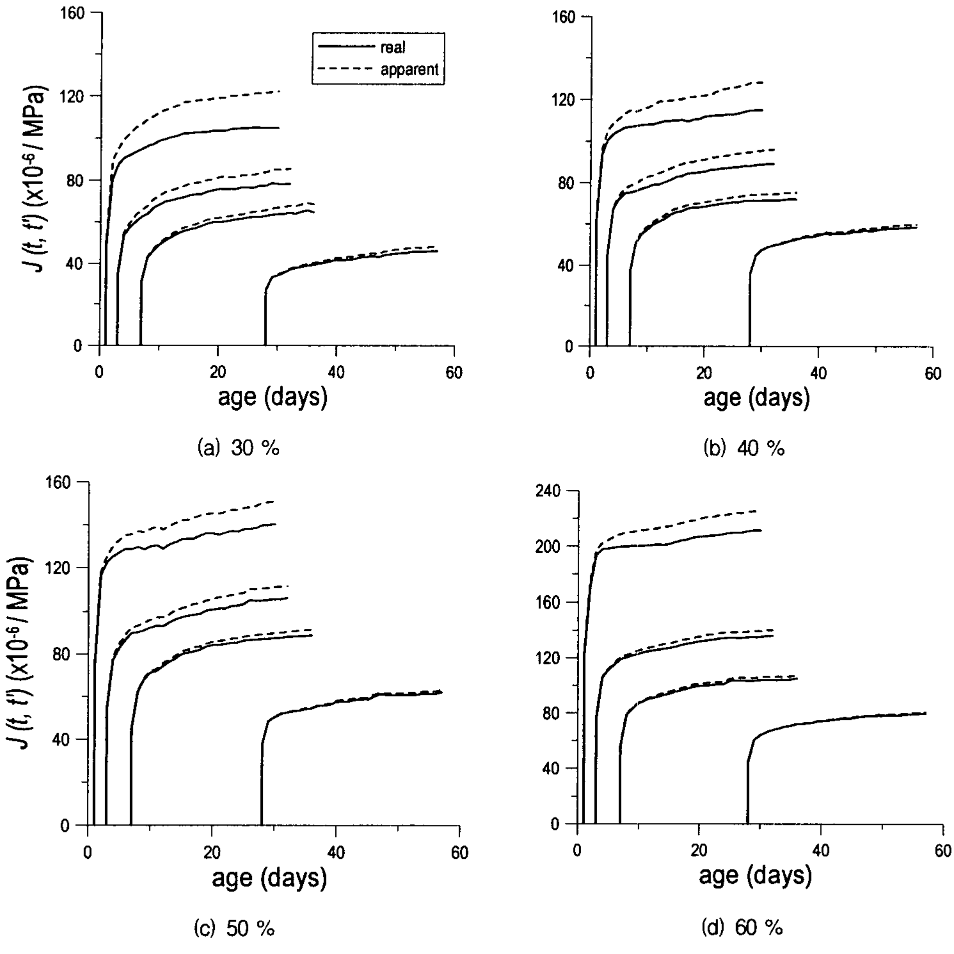

Fig. 4 Apparent and real creep compliance with respect to water cement ratio

Adapting solidification theory[4] to creep behavior Bazant proposed B3 model[5] in which creep deformation is devided in terms of viscoelastic deformation and viscous deformation.
Basic creep model of B3 model is expressed as Eq. (4).

$$J(t, t') = q_1 + q_2 Q(t, t') + q_3 \ln[1 + (t - t')^{0.1}] + q_4 \ln(t/t') \qquad (4)$$

where, q_1 : elastic compliance according to asymptotic modulus($= 1/E_o = 0.6/E_c(t')$),

q_2, q_3, q_4 : emprical coefficients, q_2 : ageing viscoelastic compliance,

q_3 : non-ageing viscoelastic compliance, and q_4 : viscous compliance.

In Eq. (4), function $Q(t, t')$ is like as Eq. (5).

$$Q(t, t') = Q_f(t')\left[1 + \left(\frac{Q_f(t')}{Z(t, t')}\right)^r\right]^{-1/r} \qquad (5)$$

In Eq. (5) $Q_f(t')$, $Z(t, t')$, and r are as follows.

$$Q_f(t') = [0.086(t')^{2/9} + 1.21(t')4/9]^{-1}$$
$$Z(t, t') = (t')^{-1/2} \ln[1 + (t - t')^{0.1}]$$
$$r = 1.7(t')^{0.12} + 8 \qquad (6)$$

Fig. 5 shows the result of regression analysis adapting Eqs.(4), (5) and (6), and basic creep model excluding autogenous shrinkage in B3 model was proposed.

4. Conclusions

Conclusions from the experiments of autogenous shrinkage and basic creep are as follows.

(1) Autogenous shrinkage was produced mostly at early ages, and at water cement ratio 30 percent autogenous shrinkage was definite.

(2) At early ages there are obvious differences between apparent creep compliance and real creep compliance, which is obtained from excluding autogenous shrinkage from apparent creep compliance, and these differences are clear in low water cement ratio mixes.

(3) It is necessary to consider autogenous shrinkage independent on applied stress in present basic creep model.

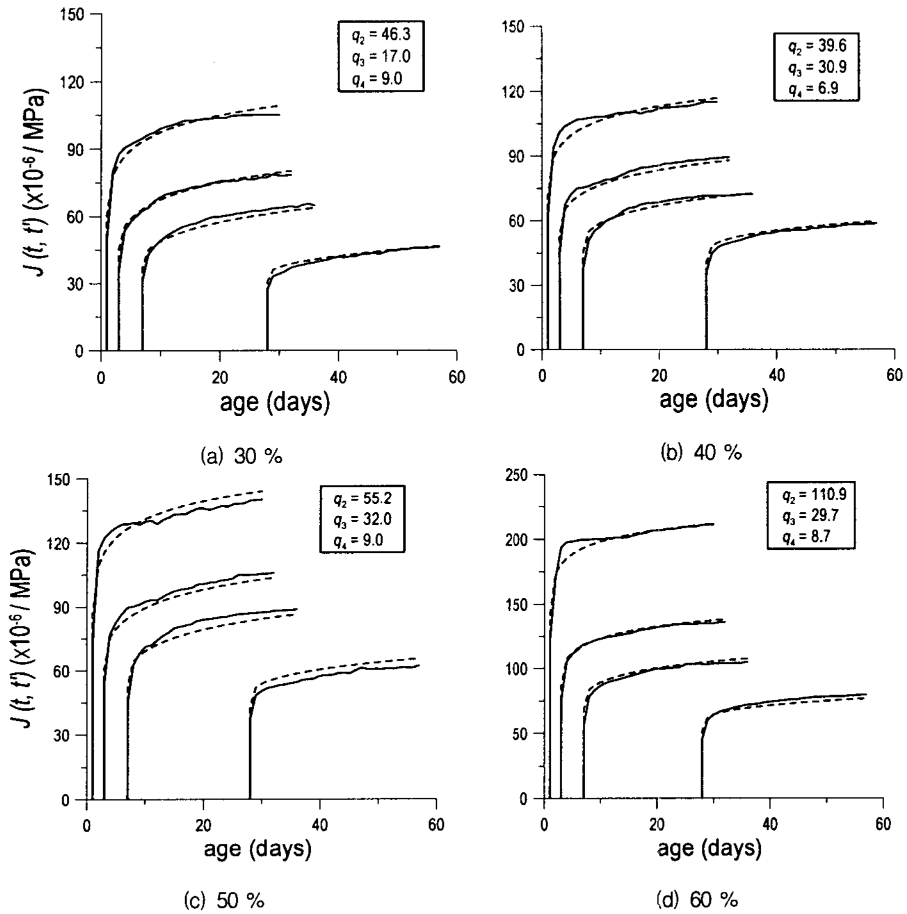

Fig. 5 Apparent creep compliance and regression results of B3 model

Acknowledgements

This research was supported by the National Research Laboratory program from the Ministry of Science and Technology of Korea for the development of cracking control technique of concrete structure. This support is deeply appreciated.

References

1. Altoubat, S. A. and Lange, D. A., "The Pickett Effect at Early Age and Experimental Separating Its Mechanisms in Tension", Materials and Structures, Vol.35, May, 2002, pp.211~218.
2. Altoubat, S. A. and Lange, D. A., "Tensile Basic Creep : Measurements and Behavior at Early Age", ACI Materials Journal, , Vol.98, No. 5, 2001, pp.386~393.
3. Altoubat, S. A., "Early Age Stresses and Creep-Shrinkage Interaction of Restrained Concrete", Ph. D thesis in the Department of Civil Engineering at the Univ. of Illinois at Urbana-Champaign, 2000.
4. Bazant, Z. P. and Prasannan, S., "Solidification Theory for Concrete Creep. I : Formulation",
5. Bazant, Z. P. and Baweja, S., "Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structures-Model B3", Materials and Structures, Vol.28, 1995, pp.357~365.