Effect of semi-adiabatic curing on autogenous shrinkage of high performance concrete

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1. Introduction

In high performance concrete (HPC) mixture, due to its low water to cement ratio, thermal deformation and autogenous shrinkage occur simultaneously. If they are confined internally or externally, they may cause crack in HPC structures. When HPC is exposed to different curing condition at early ages, hydration of cement is changed. This may lead to different behaviors of volume change in HPC.

In this study, effects of semi-adiabatic curing and the resultant temperature rises on autogenous shrinkage of HPC were investigated experimentally.

2. Experimental

2.1. Materials and mixture proportion of concrete

Ordinary Portland cement with a specific gravity of 3.10 g/cm^3 was used. The coarse aggregate used was crushed stone with the maximum size of 16 mm. The fine aggregate was natural sand with a fineness modulus of 2.5. A superplasticizer of 0.56-2.1% by weight of cement was used to obtain workable mixtures of concrete. The mixture proportions and slump of the concretes are given in Table 1.

2.2. Experimental procedures

(1) Semi-adiabatic temperature history test

Two identical 100mm×100mm×400mm prism specimens were cast in an insulation box. A thermocouple was placed at the center of each specimen to record semi-adiabatic temperature history (Fig.1).

(2) Autogenous shrinkage test

In order to measure autogenous shrinkage at the same semi-adiabatic temperature history as that obtained by the test mentioned above, a temperature control chamber with a built-in computer program was used. The environment of the chamber can follow the prescribed semi-adiabatic temperature history and maintain a humidity of 60±10%.

Four identical 100mm×100mm×400mm prism specimens were cast and divided into two groups. Specimens of group 1 were placed in the temperature control chamber under the semi-adiabatic temperature condition, while ones of group 2 were placed in a room at ambient temperature of 20℃.The specimens of Group 1 were demolded at 7d and those of group 2 were demolded at 3d. Deformations of all the specimens were measured immediately after casting using non-contact shrinkage measuring instrument (Fig.2). After demolding, strain gauges were put on two parallel sides of all the specimens, and then sealed by using a layer of grease and a polyester film. The entire test data was recorded automatically by a logger.

Using the following equation, autogenous shrinkage $\varepsilon_{ag}(t)$ was calculated:

$$\varepsilon_{\mathrm{ag}}(t) = \varepsilon_{\mathrm{total}}(t) - \alpha(t) \bullet [T(t) - T_{\mathrm{initial}}] \qquad (1)$$

Where $\varepsilon_{\mathrm{ag}}(t)$ is the total measured deformation, $\alpha(t)$ is the coefficient of thermal expansion (CTE) (here $\alpha(t)$ = 10×10^{-6}/℃ was assumed), $T(t)$ is the concrete temperature, and T_{initial} is the initial temperature.

3. Results and discussion

Changes in temperature of concretes are shown in Fig.3. There is no significant difference between the specimens

Table 1 Mixture composition of concretes

Mixes	W/C	Slump (mm)	Unit Content (kg/m^3) C	W	S	G	SP
OPC-1	0.2	240	700	140	600	900	12.60
OPC-2	0.3	255	600	180	600	900	9.00
OPC-3	0.4	250	500	200	600	900	4.50

Fig.1 The insulation box containing concrete specimens

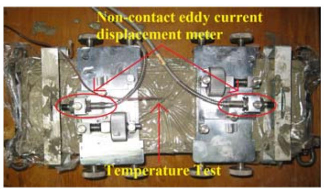


Fig.2 Non-contact shrinkage measuring instrument

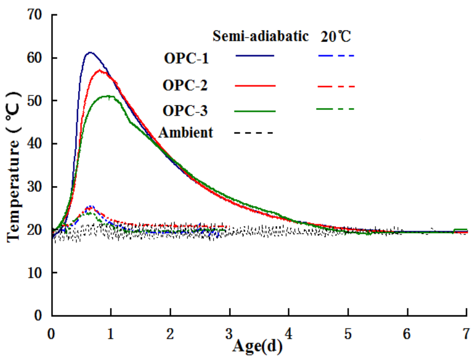


Fig.3 Temperature rises for concretes

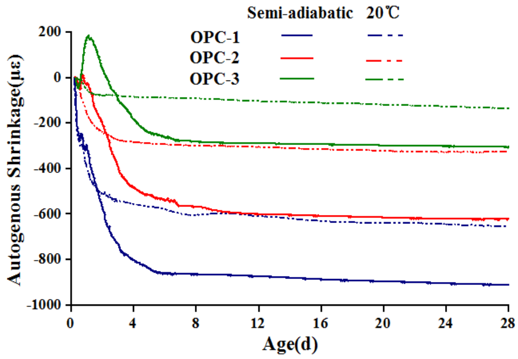
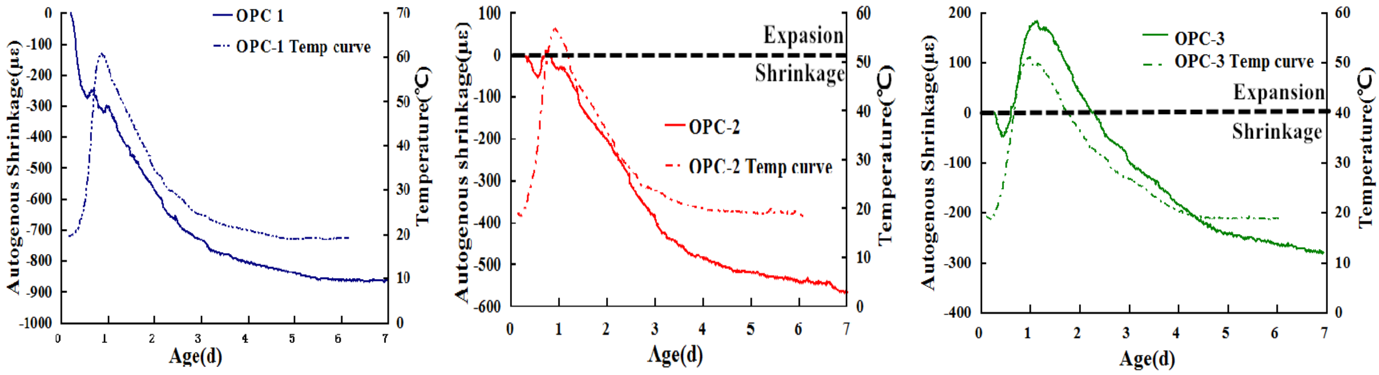


Fig.4 Autogenous shrinkage of concretes



(a) w/c=0.2 (b) w/c=0.3 (c) w/c=0.4

Fig.5 Correspondence between autogenous shrinkage and temperature of concretes cured at semi-adiabatic condition

cured at 20℃. However, for the specimens cured in the semi-adiabatic condition, these temperatures increased steeply. The peak temperatures were decreased and the times to attain the peaks were delayed with increase in w/c.

Autogenous shrinkage of concretes is shown in Fig.4. Autogenous shrinkage greatly depended on the temperature. Furthermore, it is also found that the semi-adiabatic condition increased the rate of autogenous shrinkage in concrete. This is due to the temperature dependence of both cement hydration and self-desiccation. In view of differences in autogenous shrinkages between two curing condition, effect of temperature is more prominent at low w/c than high w/c. However, relative shrinkage of the semi-adiabatic condition to the ambient temperature is greater at high w/c than low w/c. The sensitivity to temperature was reduced by active hydration of cement at low w/c, while it was greatly enhanced by semi-adiabatic high temperature at high w/c. Then the hydration in concrete with high w/c is accelerated, leading to relatively large autogenous shrinkage.

It should be also noted that the specimens cured at the semi-adiabatic temperatures exhibited markedly different behaviors between setting time and 3d (Fig.5). While the specimen with w/c of 0.2 showed a plateau in the evolution of autogenous shrinkage, the specimens with w/c of 0.3 and especially 0.4 exhibited an expansion in different degrees. The times when the expansion was observed were approximately the same as those of reaching the peak temperature. This expansion can be attributed to the increase of CTE after setting time under the semi-adiabatic curing temperature. The thermal deformation increases and even exceeds self- desiccation around the time of the peak temperature. Then the effect of self-desiccation is less reflected to autogenous shrinkage.

4. Conclusions

(1) Not only the magnitude but also the rate of autogenous shrinkage exposed to the semi-adiabatic condition were higher than those at ambient temperature of 20℃. This effect was more prominent at higher w/c. The strong time-dependence of early-age CTE resulted in expansion in HPC with high w/c.

(2) The peak temperature value and its corresponding age varied with w/c of HPC. The lower the w/c, the higher the peak value, and the earlier the age to reach it.

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