Early age expansion in mortars cured internally with a superabsorbent polymer

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1. Introduction

With the advent of high strength concretes with low water to cement ratios, occurrence of autogenous shrinkage has been of great interest. As a new multipurpose chemical admixture for concrete, superabsorbent polymers (SAP) have been introduced to mitigate autogenous shrinkage. It is well known that SAP sometimes results in large expansion of the mortars at early ages. The expansion would be advantageous to reduction in shrinkage. However, it should be noted that the expansion is often followed by considerable shrinkage.

In this study, the evolution of microstructure in mortars with SAP was evaluated by electrical resistivity measurement and the rheology test. Those results are related to the autogenous deformation behaviors at very early ages.

2. Experimental

2.1. Materials and mixture proportion

Ordinary Portland cement was used. A commercial product of silica fume was used. The fine aggregate was siliceous sand. A polycarboxylic acid type superplasticizer was used. The SAP used was produced by inverse suspension polymerization. The SAP was sieved to obtain two particle size distributions (SAP-L: 300~600μm, SAP-S: 150~300μm). Its absorption capacity is 13.3g/g of dry mass. Mixture proportion of mortars is given in Table 1.

Table 1 Mixture proportion of mortars (mass fraction)

Mixes	w/b	C	SF	S	SP	SAP
Control	0.28	1	0.094	1.89	0.017	-
SAP	0.28	1	0.094	1.78	0.017	0.003

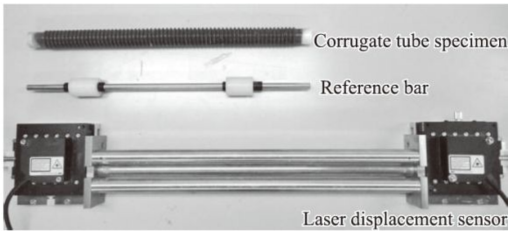

Fig. 1 Measuring instruments for length change test

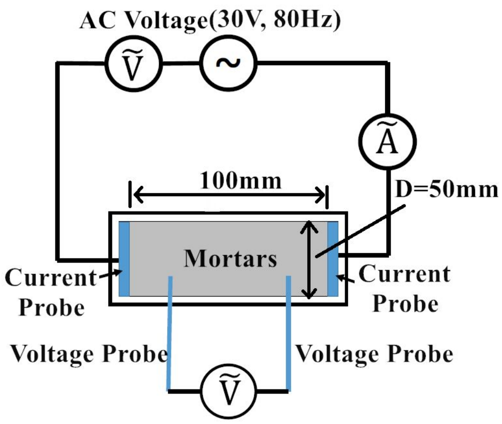

Fig. 2 Schematic diagram of an apparatus to measure electrical resistivity

2.2. Experimental procedures

(1) Length change test

Length change of mortars was measured in accordance with ASTMC1698-09 (Fig. 1). In a preliminary test, the initial setting time was determined using a cement paste with the same w/b as the mortar. The initial setting time was used as the origin of length change.

(2) Electrical resistivity test

The electrical resistivity was measured by the four electrodes method in accordance with JSCE-K 562-2008. Mortars were directly placed into a cylindrical mold shown in Fig. 2. Changes in the resistivity were continuously recorded up to twelve hours.

(3) Rheological test

Plastic viscosity of mortars was measured with a commercial rheometer. Measurement was made at prescribed time intervals up to a few hours after the addition of water.

3. Results and discussion

Autogenous deformation of mortars is shown in Fig. 3. The addition of the SAP greatly reduced shrinkage. The large particles of SAP-L provide a considerable benefit in shrinkage mitigation at longer time scales. While the rate of shrinkage was greatly changed shortly after setting in the control mixture, followed by monotonic shrinkage, the SAP mixture exhibited an expansion. Furthermore, the mortars with large SAP exhibited greater initial expansion than those with the small SAP. Periods of the expansion continued longer when the large SAP were used. The magnitude of the expansion and the extent of shrinkage reduction depend on the size of SAPs. The impact of the expansion in mitigating autogenous shrinkage was considerable. Differences in the initial expansion were reflected to subsequent differences in shrinkage at longer ages. A large part of the reduction in

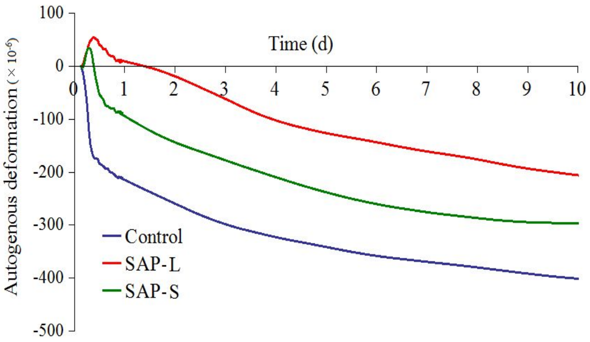

Fig. 3 Autogenous deformation of mortars

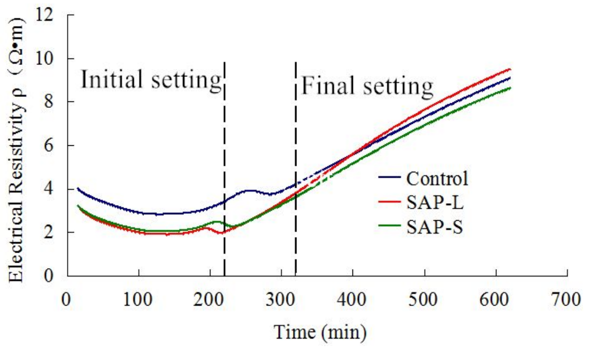

Fig. 4 Development of electrical resistivity

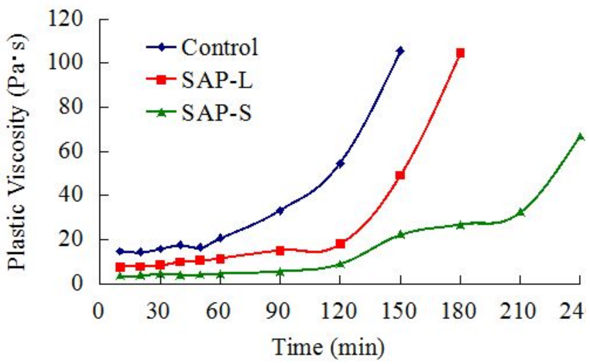

Fig. 5 Development of plastic viscosity

autogenous shrinkage resulted from the expansion.

The electrical resistivities of mortars are shown in Fig. 4. The three mixtures exhibit a similar tendency in electrical resistivity with time. The electrical resistivity drops to the minimum point and then gradually increases with time. The times when the resistivity began to increase in the SAP mortars were about 50 min earlier than the control mortar. Setting times are also shown in Fig. 4. The initial setting time for all the mixtures is about 220 min, and the finial setting time is around 320 min. The times when the resistivity of the SAP mixtures started increasing are almost the same as the initial setting time, while it is between the initial and final setting for control mixtures. Therefore, the electrical resistivity development reflects the hydration process and evolution of capillary pores networks in mortars. Internal relative humidity is kept high by internal curing water, which is released from SAP. This accelerates the hydration of cement so that internal solid skeleton has formed earlier in the SAP system. From Figs. 3 and 4, the periods of notable autogeous deformation are almost the same as the ones when a continuous phase of capillary pores was rapidly divided. Then the control experienced self-desiccation so that it exhibited autogenous shrinkage. On the other hand, two SAP mixtures have the same amount of internal water. If the hydration of cement is assumed to proceed similarly in the two SAP mixtures, it is difficult to explain difference in the autogenous deformation simply from self-desiccation. In other words, differences in the expansion behavior and subsequent rates of shrinkage in the two mixtures may be related to microstructure at very early ages before the setting of cement.

Fig. 5 shows plastic viscosity of mortars. No obvious change in plastic viscosity was observed in all the mixture before 60 min. When SAP was used, the time at which plastic viscosity started increasing was delayed. The mortars with SAP-L showed a pronounced increase in plastic viscosity. In contrast to this, gradual increase was observed for the mortars with SAP-S. It is clearly found from Fig. 5 that there must be significant differences in the microstructure between two SAP mixtures ever if it is in the dormant period in the hydration of cement. Those differences should be related to releasing water from SAP, which depends on particle sizes of SAPs. Expansion could be caused by re-absorption of the released water. Then the initial evolution of internal structure before setting plays a significant role in determining the moisture distribution, which dominates expansion at early ages.

4. Conclusions

Transition periods of autogenous deformation from expansion to shrinkage depend on sizes of SAPs. As internal water reserviors, SAP may affect the evolution of microstructure even before the initial setting time. This results in the difference in the subsequent expensive behavior.

References

1) Gaurav S, Barbara L, Patrick J, Gwenn L S, Jason W, Karen S, The origin of early age expansions induced in cementitious materials containing shrinkage reducing admixtures, Cement and Concrete Research, 41(3)(2011)218-229.

Acknowledgments

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