황산염환경에 노출된 알카리프리계 급결제 사용 시멘트경화체의 성능저하

Deterioration of Cement Matrix with Alkali-free Accelerator Exposed to Sulfate Media

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ABSTRACT

This paper presents the findings on the sulfate resistance of mortar specimens with or without alkali-free accelerator exposed to sodium sulfate solution for 270 days. Test results confirms a negative effect of alkali-free accelerator on the sulfate deterioration. Additionally, the influences of exposure concentration and temperature of sulfate solution on expansion were investigated. Especially, at a high concentration of solution a significant expansion of mortar specimens with alkali-free accelerator was observed. Further, low temperature also promoted the deterioration of the cement system due to sulfate attack.

1. Introduction

A variety of additives and admixtures have been used for concrete structures. Especially for tunnel structures, accelerator is very important chemical admixture in producing shotcret. The choice of a particular accelerator and its dosage is commonly determined by the setting time required for the shotcrete application. Most of the accelerator used today are based on alkali aluminates due to the rapid setting behavior. However, the use of alkali-free accelerator has been increased with respect to the performance of shotcrete containing it and safety for worker.[1]

This paper describes the effect of alkali-free accelerator on the sulfate resistance of mortar specimen exposed to sodium sulfate solution. Additionally, the influence of exposure concentration and temperature of sulfate solution was experimentally investigated. The finding of this experiment may provide some information in the design of shotcrete in tunnel structures.

2. Materials and sample preparation

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2.1 Cement

The cement used in this study was Type-10 cement (OPC) satisfying ASTM C 150 standard specification. The chemical composition, as provided by the cement manufacturer, are presented in Table 1. The C_3A content in the cement was 9.3%.

Table 1. Chemical composition of the cement (by mass, %)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I	Insoluble residue	Free CaO
19.9	5.0	2.4	63.8	2.5	3.0	2.3	0.8	0

2.2 Fine aggregate

Ottawa standard grade sand, which was produced from Illinois, USA, was selected for making mortar specimens. During testing, it is assumed that no chemical influences by fine aggregate are excluded.

2.3 Accelerator

In this study, accelerator based on alkali-free system was used in mortar mixture. For comparison, control mortar specimens without alkali-free accelerator were also used.

2.4 Exposure conditions

The exposure solution used to provide sulfate attack to the specimens was made by dissolving reagent grade chemical in tap water. The chemical used was Na_2SO_4. Three levels of concentrations of sulfate solution (2.5%, 5% and 10% sodium sulfate solution) were prepared. In order to investigate the effect of solution temperature, mortar specimens with or without alkali-free accelerator were exposed to 4 and 20℃, respectively.

2.5 Sample preparation

The prism bars with a size of 25 × 25 × 285 mm were used for expansion measurement. The mixture proportion of the mortars is cement : sand = 1 : 2.75. Mortar specimens were made at water-cement ratio of 48.5%. The mortar specimens were moved into sulfate solutions after the compressive strength development of 20MPa.

2.6 Expansion measurement

Based on ASTM C1012, expansion was measured at each exposure period. All expansion values were compared with the initial length of prism mortar.

3. Results and discussion

3.1 Effect of exposure concentration

Fig. 1 presents the expansion results of mortar specimens with alkali-accelerator exposed to sodium sulfate solutions for 270 days. From the test results, it was observed that the expansion was greatly associated with the concentration of attacking solution. At a higher concentration of sulfate ions (10% sodium sulfate solution), the ultimate expansion value was as high as about 0.943% after 270 days of exposure, while there is only about 0.081% for a low concentration of sulfate solution (2.5% Na_2SO_4 solution) at the same exposure period. Expansion data on mortar specimens without accelerator were plotted in Fig. 2. As expected, the mortar specimens exposed to 10% sodium sulfate solution had a relative big expansion value compared to those exposed to

2.5% sulfate solution. The sharp increase in expansion for mortar specimens in 10% sulfate solution was observed after 150 days of sulfate exposure, while the expansion of mortar specimens in 2.5% sulfate solution was almost stable during exposure period.

Fig. 3 shows the photos of mortar specimens with alkali-free accelerator exposed to different concentrations of sulfate solutions. This photos clearly explain relationship between the deterioration degree due to sulfate attack with exposure concentration. For the mortar specimen in 10% sulfate solution, a lot of cracks formed by excessive expansion were observed in all faces of the specimen.

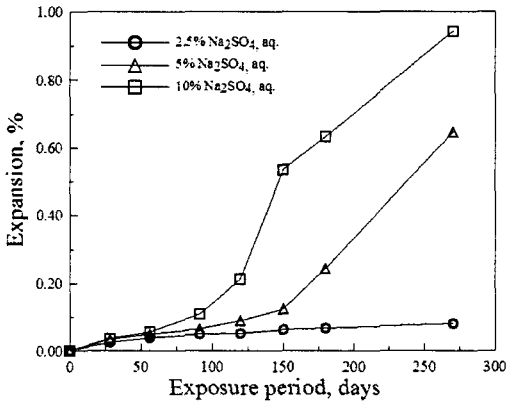

Fig. 1 Expansion of mortar specimens with alkali-free accelerator under different exposure concentration

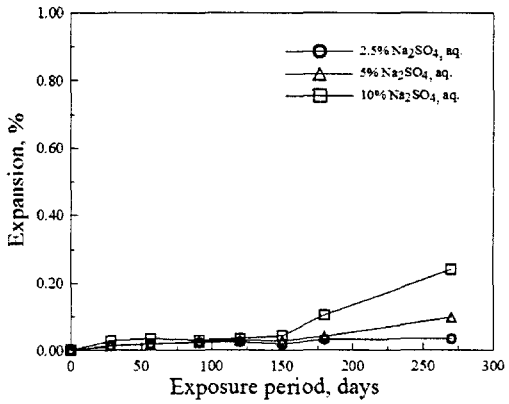

Fig. 2. Expansion of mortar specimens without alkali-free accelerator under different exposure concentration

Fig. 3. Mortar specimens with alkali-free accelerator, (A) 2.5% Na_2SO_4, aq., (B) 5% Na_2SO_4, aq., (C) 10% Na_2SO_4, aq.

3.2 Effect of exposure temperature

Metha[2] reported the effect of solution temperature on the sulfate attack in the literature. At a low temperature, the deterioration mode by sulfate attack is significantly related to the thaumasite formation ($CaCO_3 \cdot CaSO_4 \cdot CaSiO_3 \cdot 15H_2O$). Fig. 4 presents the effect of solution temperature on the expansion of mortar specimens with alkali-free accelerator. The specimens stored in sulfate

solution at a low temperature (4℃) were completely disintegrated after 120 days of exposure. After the exposure time, the expansion value of mortar specimens was about 0.261%, while there was about 0.088% in expansion for mortar specimens exposed to room temperature. However, in case of mortar specimens without accelerator, the difference of expansion values with the increase of solution temperature was not significant. This imply that the effect of solution temperature on the sulfate degradation was much more dominant in mortar specimens with alkali-free accelerator.

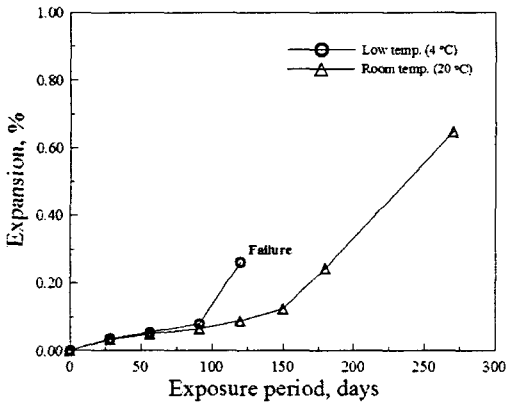

Fig. 4. Expansion of mortar specimens with alkali-free accelerator under different exposure temperature

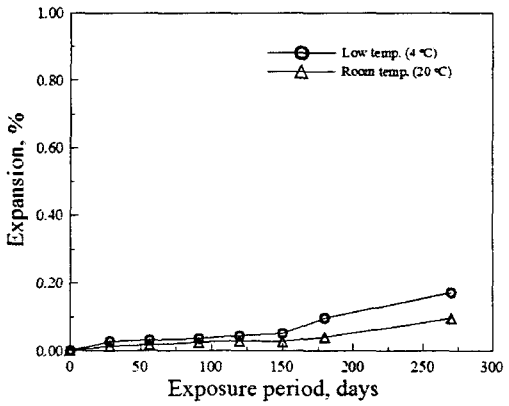

Fig. 5. Expansion of mortar specimens without alkali-free accelerator under different exposure temperature

4. Conclusions

1. The expansion of mortar specimens, especially with alkali-free accelerator, was greatly associated with the exposure concentration of sulfate solution. With an increase of the concentration, there was a remarkable increase in expansion of the mortar specimens.
2. While the effect of exposure temperature on the sulfate deterioration of mortar specimens was less in the cement system without accelerator, the mortar specimens with alkali-free accelerator were deteriorated at a low temperature.

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