C_3A량이 상이한 시멘트 경화체의 황산염 팽창 거동에 대한 알카리프리계 급결제의 영향

Influence of Alkali-free based-Accelerator on the Expansion Behaviors of Cement Matrices with Different C_3A Content under Sulfate Attack

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ABSTRACT

Sulfate resistance of mortar specimens with or without alkali-free accelerator exposed to sulfate solutions for 360 days was investigated. Test results confirms a negative effect of alkali-free accelerator on the sulfate deterioration, irrespective of attacking sources. Based on the ASTM C1012 expansion test, the experimental findings demonstrated that higher C_3A content in cement led to the higher expansion, especially in the mortar specimens with alkali-free accelerator.

1. Introduction

Accelerating admixtures comprise chemicals that influence the rate of cement hydration, thereby shortening the setting time and increasing the rate of early strength development. Especially for tunnel structures, accelerator is very important chemical admixture in producing shotcrete. However, special concern needs for durability of concrete using the accelerator. 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.

This study presents the experimental results on the effect of alkali-free accelerator on the sulfate resistance of mortar specimen exposed to sulfate solutions. Additionally, the influence of attacking sources of sulfate attack was experimentally investigated. It is hoped that the finding of this experiment may provide some information in the design of shotcrete in tunnel structures.

2. Materials and sample preparation

2.1 Cements

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The cements used in this study were Type-10 cement(high C_3A, 9.3%) and Type-50(low C_3A, 1.1%) satisfying ASTM C 150 standard specification. The chemical composition, as provided by the cement manufacturer, is presented in Table 1. The minerological compound of the cements is given in Table 2.

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

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I	Insoluble residue	Free CaO
Type-10	19.9	5.0	2.4	63.8	2.5	3.0	2.3	0.8	0
Type-50	23.7	3.0	4.0	64.5	3.0	2.0	0.8	0.3	0.5

Table 1. Minerological compound of the cements (by mass, %)

	C_2S	C_3S	C_3A	C_4AF
Type-10	10.1	62.5	9.3	7.2
Type-50	29.7	50.9	1.1	12.2

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 chemicals used were Na_2SO_4 and $MgSO_4$. The concentrations of sulfate solutions were fixed at 33,800 ppm of SO_4^{2-}. The mortar specimens with or without alkali-free accelerator were exposed to 20 ℃ for 360 days.

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 Sodium sulfate attack

The data on expansion due to sodium sulfate attack of mortar specimens without accelerator is shown in Fig. 1. This indicates more or less higher expansion in mortar specimen with high C_3A content compared to those with low C_3A content in sodium sulfate solution. The ultimate expansion, after 360 days of exposure, of mortar specimen with high C_3A content was 0.234% compared to 0.066% in mortar specimen with low C_3A content. It is thought that this trend is greatly associated with the ettringite formation in proportion to the C_3A content in cement.

For the mortar specimen with alkali-free accelerator, the expansion values are shown in Fig. 2. Comparing the data in Fig. 1, it was observed that the use of accelerator led to the higher expansion in mortar specimens irrespective of C_3A content. It should be noted that the rate of expansion in mortar specimen with high C_3A content was very sharp after 91 days of exposure. The mortar specimen with high C_3A content showed 1.180% in expansion after 360 days of exposure, while expansion of 0.365% was exhibited for the mortar specimen with low C_3A content. These test results are in agreement with the work carried out by Paglia et al.[1].

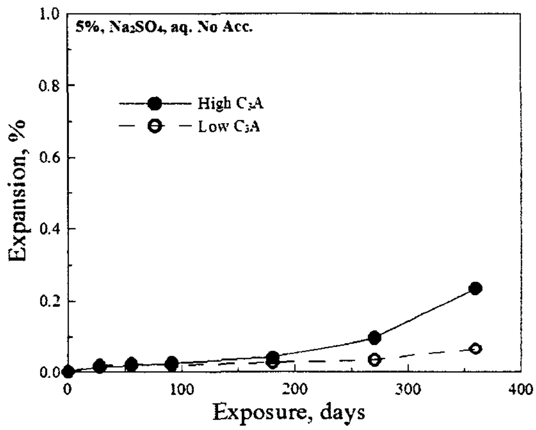

Fig. 1 Expansion of mortar specimens without accelerator by sodium sulfate attack.

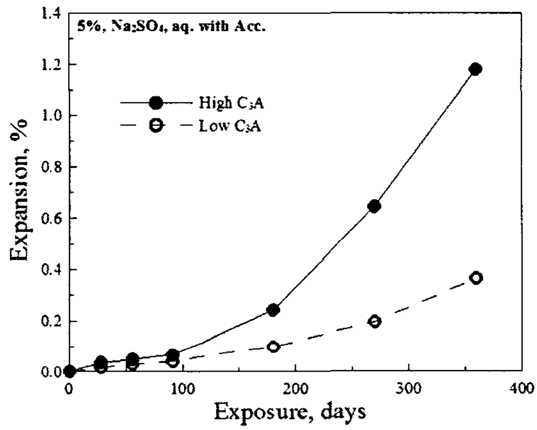

Fig. 2 Expansion of mortar specimens with accelerator by sodium sulfate attack.

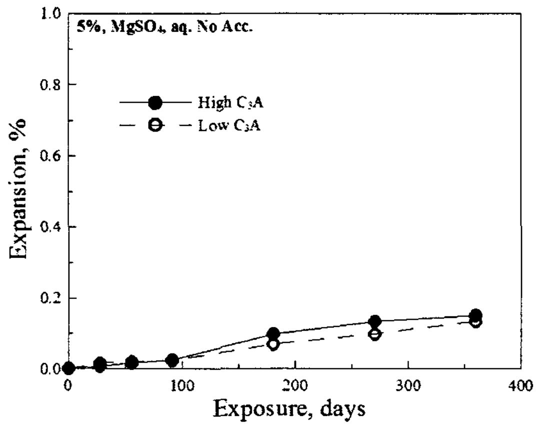

Fig. 3 Expansion of mortar specimens without accelerator by magnesium sulfate attack.

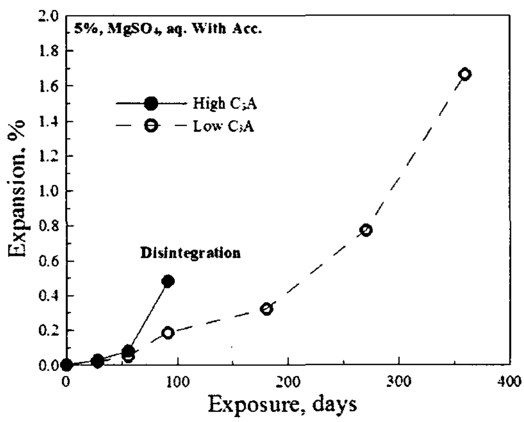

Fig. 4 Expansion of mortar specimens with accelerator by magnesium sulfate attack.

3.2 Magnesium sulfate attack

Fig. 3 presents the expansion results of mortar specimens without alkali-accelerator exposed to magnesium sulfate solutions for 360 days. From the test results, it was found that the data on expansion in mortar specimen with high C_3A content were very similar to those with low C_3A content. Under magnesium sulfate environment, the mortar specimen does not produce expansive reaction, but the integrity of the cement matrix could be significantly reduced by magnesium sulfate attack. Although ettringite succeeds to form during exposure to magnesium sulfate solution, it would be come unstable in the lower alkalinity provided by brucite and will eventually decompose to other sulfate phases(2).

The expansion in mortar specimen with accelerator due to magnesium sulfate attack is shown in Fig. 4. For the mortar specimen with high C_3A content, the expansion was extremely high after 91 days of exposure. The specimens was disintegrated after the exposure period because of an excessive expansion. However, the mortar specimen with low C_3A content showed a relatively lower expansion value of 0.482% after 91 days of exposure. The overall expansion of the mortar specimen was as high as 1.663% with no disintegration after 360 days of exposure.

3.3 Comparison of test results

Form the test results, it was clear that the use of accelerator negatively affects expansion of mortar specimen irrespective of attacking sources. The trend of expansion was also primarily dependent on the used cement types. High C_3A content in cement results in the higher expansion, especially in the case of the mortar specimens made with alkali-free accelerator. More importantly, in case of mortar specimen with accelerator, the expansion results in sodium sulfate solution were different from the those in magnesium sulfate solution. Further study is needed to understand the exact expansion mechanism.

4. Conclusions

1. The expansion of mortar specimens, especially with alkali-free accelerator, was greatly associated with the C_3A content in cement. The mortar specimen with high C_3A content showed a remarkable increase in expansion irrespective of attacking sources.
2. Under magnesium sulfate environment, the expansion of mortar specimens with accelerator displayed extremely high values. This suggests that ettringite formation could not be the primary cause of the expansion in condition of the usage of accelerator in magnesium sulfate solution.

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