석회석슬래그 시멘트의 강도향상 및 미세분석 : 황산알루미늄의 역할

Strength improvement and micro analysis of limestone-slag cement : role of aluminum sulfate

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Abstract : Limestone slag cement is a green and sustainable building material with huge market potential. However, its shortcoming of low early compressive strength needs to be improved. A method of using aluminum sulfate to improve the early strength of ternary mixed mortar was proposed, and its effect and optimal dosage were tested. Macroscopic properties such as mechanical properties and surface electrical resistivity were measured at different dosages (0%, 1%, 2%, 3%). The microstructure and products of the mixtures were tested in detail, including by scanning electron microscopy, thermogravimetric analysis, and X-ray diffraction. The results show aluminum sulfate enhances mechanical properties and significantly increases surface electrical resistivity. The 1% and 2% doses had no adverse effects on the 28-day mechanical properties, while the 3% dose reduced the 28-day strength. Considering the changes in mechanical properties and surface electrical resistivity, 1% aluminum sulfate is the optimal dosage.

키워드 : 황산알루미늄, 에트링가이트, 초기 강도, 삼원 혼합물, 수화
Keywords : aluminum sulfate, ettringite, early strength, ternary mixture, hydration

1. Introduction

1.1 purpose of the research

Limestone-slag cement usually has low early strength, which may affect construction progress and limit its application in engineering. Therefore, there is an urgent need to improve its early strength. Aluminum sulfate is a commonly used chemical additive often used to improve the early strength of shotcrete slurry. It is expected to become an effective tool to enhance the early strength of limestone slag cement. In this study, we conducted a series of tests on ternary mixtures containing different aluminum sulfate contents (1%, 2%, and 3%), including compressive strength testing, microstructure observation, and XRD analysis.The effect of micron-sized ettringite on the physical properties of the mixture was analyzed.

2. Materials and methods

2.1 Materials

The ternary cement in this study was manufactured using type I cement, limestone, and blast furnace slag, with a material ratio of 50:15:30. The average particle sizes of the materials are 10.65μm, 4.79μm and 9.27μm respectively. Laboratory-grade aluminum sulfate has a purity of 99.9%. Aluminum sulfate replaced 1wt%, 2wt%, and 3wt% in the ternary mixture. The water-binder ratio is 0.5. The sand-binder ratio is 2.5.

2.2 Methods

In this study, compressive strength and surface resistivity tests were performed according to standards ASTM C109 and AASHTO T 358. The accumulated heat of hydration was monitored using an isothermal calorimeter (TAM-Air). The powders were subjected to XRD analysis for mineralogical analysis. Scans were performed over a 2θ range of 5-45° at a 2θ /s scan rate of 0.05° to determine the intensity of crystalline diffraction peaks in the material. The microstructure of the hydration products was observed using an SEM (JSM-7900 F, JEOL Ltd., Japan) with an operating voltage of 15 kV.

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3. Results

Table 1. Strength, electrical resistivity and cumulative hydration heat of ternary mixtures.

Specimens	12h cumulative hydration heat (J/g)	1D compressive strength (MPa)	1D Surface electrical resistivity(KΩ/cm)
Contral	47.77	2.9	2.3
1%	63.43	3.32	2.5
2%	72.62	3.46	2.5
3%	92.64	3.8	4.28

Table 1 summarizes the results of changes in cumulative hydration heat, strength, and resistivity with increasing aluminum sulfate content. The cumulative heat of hydration in 12 h increases with the increase in the substitution degree of aluminum sulfate. This reflects that adding aluminum sulfate promotes the hydration of the paste.

The main reason for the increase in compressive strength is due to the increased content of hydration products due to the promotion of hydration. This leads to the enhancement of the paste microstructure. In other words, an increase in hydration products may result in a denser microstructure of the mixture. Therefore, this is also responsible for the slight increase in the resistivity of the mixture.

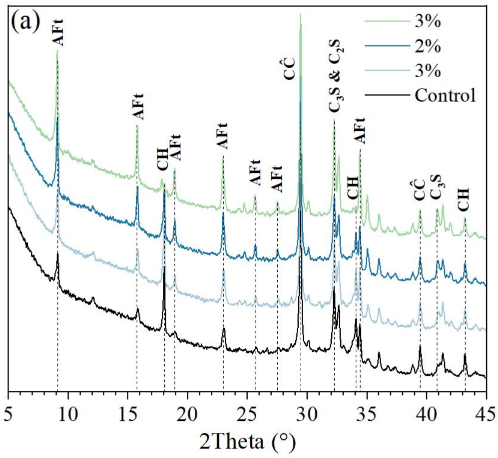
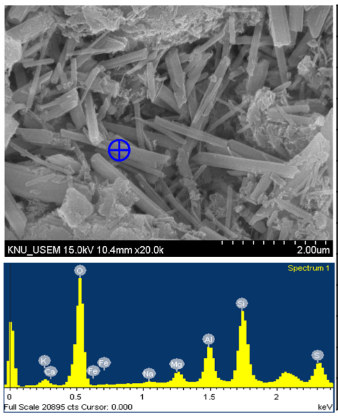


Figure 1. X-ray diffractogram of the samples at 1 days.



Element	Weight %	Atomic %
O K	53.74	71.43
Na K	0.23	0.22
Mg K	1.37	1.20
Al K	4.12	3.25
Si K	8.88	6.72
S K	3.60	2.39
K K	0.66	0.36
Ca K	26.75	14.19
Fe K	0.64	0.25
Totals	100.00	

Figure 2. SEM of the 3% samples at 1 days.

Figure 1 shows the XRD diffraction pattern of ternary mixtures after curing for 1 days The content of ettringite in the samples increased with the increase of aluminum sulfate. As shown in Figure 2, the ettringite in the 3% samples matrix increased significantly at 1 days. This helps fill the pores of the matrix, thereby increasing early strength.

The effect of AS in the system is (1) increasing the concentration of sulfate ions and aluminum ions in the initial solution promotes the formation of AFt. (2) Promote the formation of Hc. Hc can refine the pores to improve corrosion resistance.

4. Conclusions

This study describes the early engineering performance of the ternary mixture promoted by the addition of aluminum sulfate. Based on the above results, it was concluded that the early strength and surface resistivity increased with the increase of aluminum sulfate content. The cumulative heat of hydration changed significantly.

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