Evaluation of Fineness Levels on the Sulfate Resistance of Cement Matrix with GGBS

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ABSTRACT

This paper describes the sulfate resistance of cement pastes and mortar with or without ground granulated blast furnace slag (GGBS). Sulfate attack was performed on the cement pastes and mortar, which had been prepared by using a water-binder ratio of 0.45. Variables were the fineness levels of GGBS and the concentrations of two sulfate solution.

In this present study, compressive strength and length change were carried out to evaluate the sulfate resistance of GGBS with various fineness levels.

From the test results, it can be concluded that the deterioration modes of cement matrix with GGBS were dependent on the exposure solutions.

Moreover, the influence of fineness levels of GGBS on the sulfate resistance was somewhat little because of a relative short exposure period.

1. Introduction

Recently, there has been a growing trend for use of supplementary cementitious materials, whether natural, waste, or by-products, in the production of composite cements because of ecological, economical, and diversified products quality reasons.

GGBS, a by-product of the transformation of iron ore into pig-iron in a blast furnace, has been increasingly used for additive material in concrete. GGBS has relatively constant chemical composition compared to fly ash, silica fume, pozzolanas, etc. Besides, it has advantages like low heat of hydration, high sulfate and acid resistance, better workability, higher ultimate strength, etc.

In particular, sulfate attack on concrete is complex process as was reported by Cohen and Mather. Many factors, such as cement type, sulfate cation type, sulfate concentration and exposure period, may affect the sulfate resistance. However, not much research has been conducted to evaluate the effect of sulfate concentration on the performance of plain and blended cements.

In the present paper, Immersion tests with two sulfate solution were carried out investigates the resistance to sulfate attack of cement matrix with or without the fineness levels of GGBS.

2. Materials and Test procedures

2.1 Materials

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2.1.1 Cement and mineral admixture

The mortar specimens were produced at two different cements, ordinary portland cement (OPC), ordinary portland cement + 50% ground granulated blast furnace slag (GGBS). GGBS with three different nominal fineness levels of 4,000 (SG4), 6,000 (SG6) and 8,000 (SG8) cm^2/g was adopted, respectively. The mixture proportion of all mortars is binder : sand = 1:2. Mortar and paste specimens were made at water-binder ratio (w/b) of 0.45.

The mixing procedure of mortar followed a method based on KS L 5105. The chemical composition and physical properties of OPC and GGBS used in this experiment are also detailed in Table 1.

2.1.2 Aggregate

River sand, which is a fine aggregate immune to most chemical agents and has little organic compounds, is employed for manufacturing mortar specimens. The fine aggregate were entirely passed from the sieve of 5mm. The specific gravity, absorption and fineness modulus of fine aggregate are 2.60, 0.80% and 2.80, respectively. During testing, it is assumed that no chemical influence by fine aggregate are excluded.

Table 1. Chemical composition and physical properties of OPC and GGBS

Symbol	Chemical composition (%)							Physical properties	
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Ig. loss	Specific gravity	Specific surface area (cm^2/g)
OPC	20.2	5.8	3.0	63.3	3.4	2.1	1.2	3.13	3,120
SG4	31.7	14.5	0.7	41.7	5.4	2.1	2.6	2.92	4,450
SG6	32.2	14.6	0.4	44.0	5.6	1.1	1.2	2.92	6,000
SG8	32.3	14.6	0.4	44.0	5.6	1.1	1.2	2.92	8,000

2.2 Test procedures

ASTM C 1012 "Test Method for Length Change of Hydraulic Cement Mortars Exposed to a sulfate solution" was used as a basis for the mortar sulfate resistance test. All specimens were cured in a chamber for 180 days. The mortar specimens were immersed in two solutions (a) 5% of sodium sulfate solution (NS solution) and (b) 5% magnesium sulfate solution (MS solution). Compressive strength test were performed on the each mixture at 0, 28, 91 and 180 days of immersion. At each interval, the compressive strength of three mortar specimens drawn from water and test solutions were measured and then their values were averaged.

The length change was measured at each immersion period. All length change values were compared with the initial length of prism mortar specimens (after 7 days of curing in water). The length change is calculated by the following equation.

$$\Delta Li = (Li - Lo) / Lo \times 100(\%)$$

Where, ΔLi = length change at (i) immersion period (%), Li = length of prism mortar specimen measured at (i) immersion period, and Lo = initial length of prism mortar, which is measured before mortar specimen is exposed to attacking solution.

3. Results and discussion

3.1 Compressive strength

The test results of the compressive strength of OPC mortar specimens made with a w/b ratio of 0.45 immersed in water, NS and MS solutions are shown in Fig. 1. This figure shows the compressive strength development of OPC mortar specimens with a 0.45 w/b and indicates that mortar immersed in NS and MS solutions begin to reduce the compressive strength after 91 days of exposure. While mortar specimen immersed in water didn't decrease in compressive strength even up to 180 days of exposure. After 180 days of exposure, the compressive strength of mortar specimens immersed in MS and NS solution was about 42MPa and 47MPa, respectively.

On the other hand, Fig. 2 illustrates compressive strength of GGBS mortar specimens with different fineness levels subject to sulfate attack at 180 days. The compressive strength of mortar specimens immersed in NS and MS solutions were significantly lower than that of mortar specimens immersed in water. In the mortar specimens with three fineness GGBS immersed in NS solution, the compressive strengths were 52MPa, 50MPa and 58MPa, respectively. For the mortar specimens immersed in MS solution, the compressive strength was 48MPa, 46MPa and 50MPa, respectively. The compressive strength for mortar specimens with a higher fineness GGBS was better than those for mortar specimens with a lower fineness GGBS. In particular, the compressive reduction was higher in MS solution than in NS solution.

Therefore, the deterioration modes of cement matrix with GGBS were dependent on the exposure solutions.

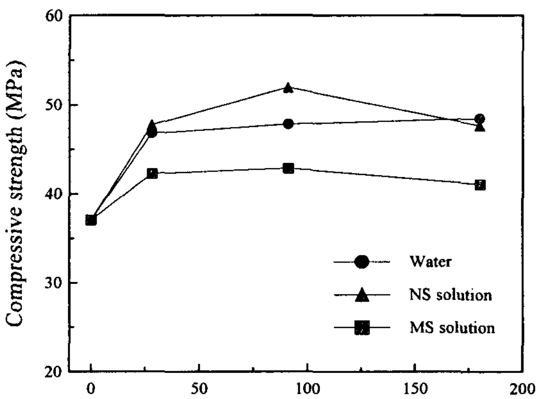

Fig. 1 Compressive strength of OPC mortar specimens immersed in water and sulfate solutions

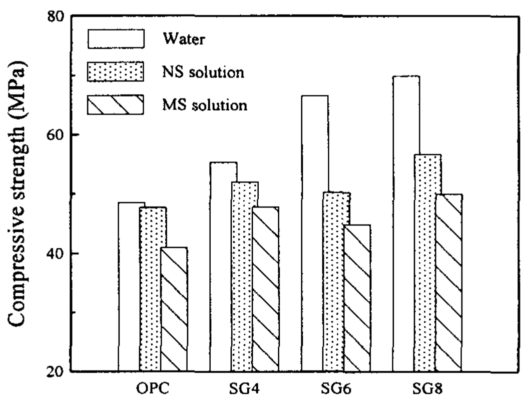

Fig. 2 Compressive strength of mortar specimens with different fineness levels of GGBS (180 days)

3.2 Length change

The length change of mortar specimens with different fineness levels immersed in NS and MS solution are presented in Fig. 3 and Fig. 4 for 180 days immersed period, respectively. The average length change values at 180 days of exposure to NS solution were about 0.087%, while for SG4, SG6 and SG8 mortar specimens it was 0.039%, 0.028% and 0.027%, respectively. In case of OPC mortar specimens, the length change was higher than GGBS about 40%.

The length changes of OPC mortar specimens in both NS and MS solution were similar to each other up to 56 days of immersion. However, after 91 days, OPC mortar specimens exposed to NS solution experienced much larger length change the MS solution. It can be explained that the ettringite causing expansion in cement matrix would become unstable in the lower alkalinity provided be brucite.

Meanwhile, the average length change in OPC mortar specimens immersed in MS solution was 0.055%. In case of specimens immersed in MS solution, the length change values of SG4, SG6 and SG8 were 0.045%, 0.033% and 0.030%, respectively.

Therefore, in the OPC mortar specimens immersed in NS solution, the length change had some increase in comparison with MS solution. The length change of GGBS mortar specimens of various fineness indicates similar a trend immersed two sulfate solutions. Thus, the influence of fineness levels of GGBS on the sulfate resistance was somewhat little because of a relative short exposure period.

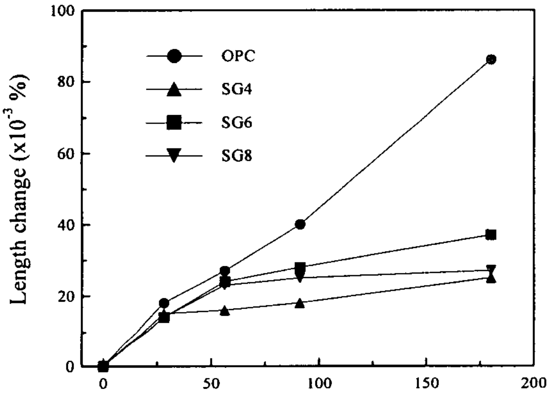

Fig. 3 Length change of mortar specimens with different fineness levels of GGBS (NS solution)

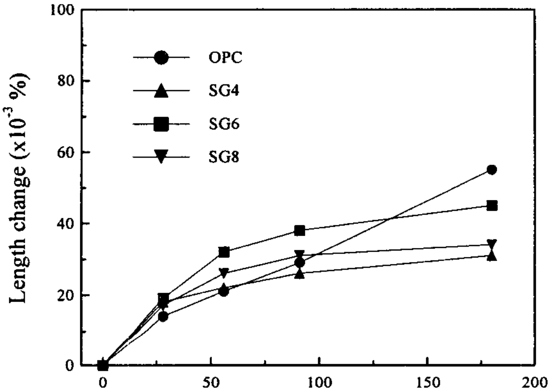

Fig. 4 Length change of mortar specimens with different fineness levels of GGBS (MS solution)

4. Conclusion

(1) The compressive strengths of OPC mortar specimens immersed in NS and MS solutions is decreased after 91 days in comparison with those in water. In case of length change, NS solution is much higher than that of MS solution.

(2) The results of length change of GGBS mortar specimens immersed in NS and MS solutions were similar at all the various fineness. In the NS solution, a drastic length change of OPC mortar specimen was observed.

(3) In the absence or presence of GGBS, the deterioration modes of cement matrix were dependent on the exposure solutions.

(4) The influence of fineness levels of GGBS on the sulfate resistance was somewhat little because of a relative short exposure period.