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The Compressive Strength of Cement–Slag–Calcium Sulphoaluminate Ternary System

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ABSTRACT

At present, there is an increasing interest on the use of calcium sulphoaluminate ($C_4A_3\$$) in cement. In this paper, pure mineral of sulphoaluminate ($C_4A_3\$$) was prepared in laboratory. Different dosages of steel slag and $C_4A_3\$$ were blended into cement. The aim of this paper is to investigate the compressive strength of this ternary system. The test results show that the addition of $C_4A_3\$$ can improve the strength of cement. Larger $C_4A_3\$$ dosage (7%) may reduce the 28 days strength. The optimal $C_4A_3\$$ dosage is 5%. In ternary system, $C_4A_3\$$ has no obvious improvement, while 5% dosage could improve the strength a little.

1. INTRODUCTION

Under the presence of water, calcium sulphoaluminate reacts with gypsum, and forms to ettringite increasing the early strength of cement (Wang, Su, & Zhang, 1999; Zhang & Glasser, 2002).

The $C_4A_3\$$–OPC binary system has made great social and economic benefits in improving the mechanical properties of cement and reducing consumption of cement. As we known, steel slag is the by-products during steelmaking process, accounts for about 15–20% of steel production. With the development of steel manufacture, the amounts of steel slag increase dramatically. The rational use of slag has become a critical problem with the promoting of the sustainable development. Steel slag contains some minerals such as cement clinker. It is a kind of cementitious material.

In this study, the optimal dosage of $C_4A_3\$$ blended into cement is discussed. After that, the influence of $C_4A_3\$$ and slag on the compressive strength of cement–slag–$C_4A_3\$$ ternary system is investigated.

2. EXPERIMENTS

2.1 Raw Materials

Chemicals: Al_2O_3 (AR), $CaSO_4 \cdot 2H_2O$ (AR) $CaCO_3$ (AR); steel slag: after crushing and ball milling, slag powder can go through 0.08 mm square mesh sieve. The specific surface area of slag is 330 m^2/kg. Cements: PII 525 (Gangnam – Onoda Cement Co., Ltd.)

2.2 Experiments

$C_4A_3\$$ mineral preparation: with a molar ratio of 3:3:1, $CaCO_3$, Al_2O_3, and $CaSO_4 \cdot 2H_2O$ are mixed with water. The mixtures are then briquetted to box shape and dried in oven (45°C). The samples are burned for 135 min at 1350°C and maintained the same temperature for 2 h. After cooling, the samples are ground through 0.08 mm square mesh sieve.

Mixture compositions: different dosages of $C_4A_3\$$ and slag are blended into Portland cement. The variation of gypsum dosage in the ternary system is also considered. The mixture compositions are summarized in Table 1.

Table 1. Mixture compositions used in this study.

$C_4A_3\$$ (%)	Steel slag (%)	OPC (%)	$CaSO_4 \cdot 2H_2O$ (%)
0	0	100	0
	5	95	
	10	90	
	15	85	
3	0	95.3	1.7
	5	90.3	
	10	85.3	
	15	80.3	
5	0	92.2	2.8
	5	87.2	
	10	82.2	
	15	77.2	
7	0	88.9	4.1

Test methods: according to GB/T1346-2001, the water requirement of normal consistency of cement is determined. According to GB/T 17671-1999, the compressive strength of mortar is measured.

3. RESULTS AND DISCUSSIONS

3.1 Mechanical properties

Table 2 shows the measured water requirement of normal consistency for different mixtures. It can be seen that the addition of $C_4A_3\$$ improves the water requirement of normal consistency obviously. With the same dosage of $C_4A_3\$$, the water requirement of normal consistency of the ternary system decreases slightly with the increase of the amount of slag.

Table 2. Water requirement of normal consistency and strength of different mixtures.

$C_4A_3\$$ (%)	Steel slag (%)	Water	Compressive strength (Mpa)		
			1 days	3 days	28 days
0	0	–	18.9	36.9	58.2
	5	25.8	17.8	33.8	57.2
	10	25.6	15.2	29.9	54.1
	15	25.4	12.9	27.3	48.8
3	0	27.3	17.9	38.4	58.2
	5	27.1	14.8	33.0	54.1
	10	26.8	13.3	30.3	48.9
	15	26.3	10.1	27.8	49.2
5	0	29.7	18.0	39.2	59.1
	5	28.7	15.3	33.9	55.2
	10	28.2	13.6	30.6	52.5
	15	28.2	10.9	28.1	50.5
7	0	29.8	18.4	36.3	54.1

The compressive strength of different mixtures is also shown in Table 2. In the later sections, the effects of $C_4A_3\$$ and coupled with slag on the compressive strength of cement are illustrated, respectively. Figure 1 shows the effect of $C_4A_3\$$ on the compressive strength of cement. From this figure, it can be seen that 3 and 5% $C_4A_3\$$ improves the compressive strength of cement obviously, especially at 3 and 28 days. Instead, the mixture blended with 7% $C_4A_3\$$ has a lower compressive strength than pure Portland cement. Figures 2, 3, and 4 show the effect of $C_4A_3\$$ coupled with different dosages of slag (5, 10, and 15%) on the compressive strength of mortar. For 5 and 10% slag, the addition of $C_4A_3\$$ reduces the strength of the ternary mixtures (0–5 MP) (see Figures 2 and 3). In addition, it can be seen that 5% dosage $C_4A_3\$$ has weak effect on the reduction of the compressive strength of ternary mixtures. For higher slag dosage mixtures (15%), the addition of $C_4A_3\$$ can increase the compressive strength of mortar at 3 and 28 days.

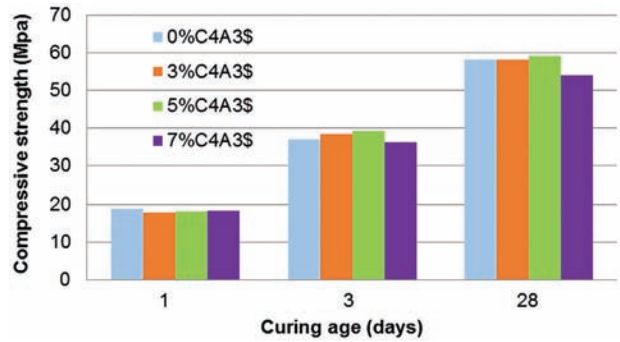

Figure 1. The effect of $C_4A_3\$$ on the compressive strength of mortar.

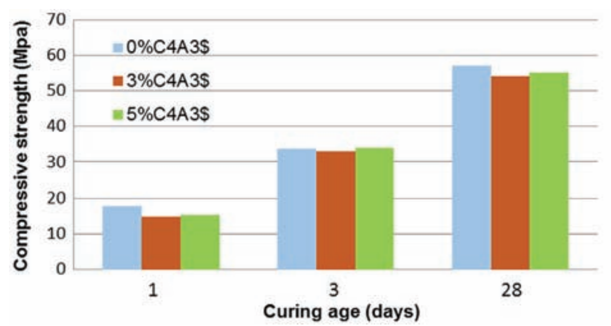

Figure 2. The effect of $C_4A_3\$$ coupled with 5% slag on the compressive strength of mortar.

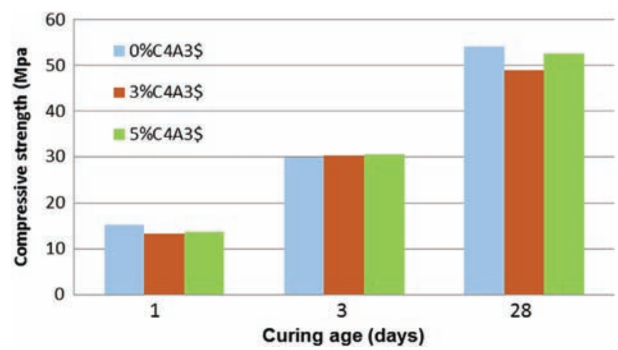

Figure 3. The effect of $C_4A_3\$$ coupled with 10% slag on the compressive strength of mortar.

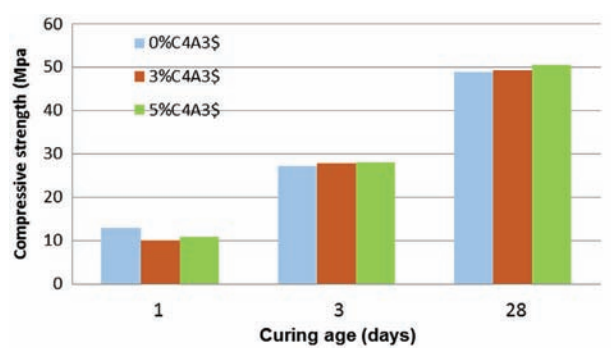

Figure 4. The effect of $C_4A_3\$$ coupled with 15% slag on the compressive strength of mortar.

3. CONCLUSION

(1) The addition of $C_4A_3\$$ can improve the strength of cement. Mortar strength increased 2–3 MPa, and the optimal C4A3$ dosage is 5%.

(2) Small $C_4A_3\$$ dosage (3%) has no obvious improvement on the strength of mortar, but larger $C_4A_3\$$ dosage (7%) may reduce the 28 days strength.

(3) In ternary system, $C_4A_3\$$ has no obvious improvement, while 5% dosage could improve the strength a little.

(4) In this study, 5% $C_4A_3\$$ dosage (the dosage of cement is 77.2%) is favourable for energy conservation and emission reduction for cement applications.

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