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Mechanism and Effect of Activating Agent on Mechanical Performance of Steel Slag Composite Materials

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Abstract: This study investigates the effect of three kinds of activating agent on the mechanical performance of steel slag composite materials. Hydration products of the pastes at different ages are investigated by XRD. The results show that compared with the calcium hydroxide, gypsum and sodium sulfate can excite the activation of steel slag more effectively. When amount of gypsum is 1.5%, the 3d strength increases to 1.2MPa, 7d strength increases to 3.3MPa, 28d strength increases to 5.0MPa. Ca^{2+} and SO_4^{2-} are provided by gypsum, SiO_2, Fe_2O_3 and Al_2O_3 in steel slag act with $Ca(OH)_2$, hydration products such as hydrated calcium silicate, are generated in the paste. Enhancement of early strength may be attributed to rapidly consumption of Al_2O_3 in steel slag and $Ca(OH)_2$. When amount of Na_2SO_4 is 1.5%, the 3d strength increases to 5.1MPa, 7d strength increases to 6.5MPa, 28d strength increases to 15.5MPa. XRD patterns show that the main products are consist of hydrated calcium silicate, Aft and calcium hydroxide. These products are bonded together, fill the void of paste, so the density increased, and higher strength are obtained.

Keywords: Activator, mechanical property, steel slag.

1. INTRODUCTION

Steel slag is a kind of by-product in the process of steel making [1]. It has become an important industrial wastes in China. Only 10% of steel slag is currently used again in China [2], storage of large amount of steel slag will occupy land resources, cause water pollution, environmental pollution and soil pollution. So more concern has been paid to reuse steel slag [3].

It shows that C_2S, C_3S, C_4AF and other minerals exist in the steel slag, which provide the gelling properties of steel slag, but "dead burned" is formed during melting at high temperature, hydration activity of C_3S must be activated in a very long time, C_2S only contributes to the later strength, so hydration performance of steel slag is very poor. The improvement of steel slag's cementitious activity has become one of the important ways to promote the widely used of steel slag in architecture [4~6]. At present, active activation of steel slag are studied by domestic and foreign researchers, and some achievements have been made [7~11]. The chemical compositions of steel slag vary greatly with preparation materials and production technology, the effect of different activator on the hydration process and mechanical performance of steel slag is different. In this paper, the effect of calcium hydroxide and gypsum, sodium sulfate on mechanical performance of steel slag are studied, hydration products is analyzed by XRD.

2. MATERIALS AND EXPERIMENTS

2.1. Materials

The steel slag adopted in this experiment is produced by a steel plant in Qianan, with grain size of less than 5mm. It was dried, crushed and ground in a ball mill, until the specific surface area less than 450m^2/kg. Calcium hydroxide, gypsum and sodium sulfate are used as activators.

2.2. Specimen Molding

Adjust the consistency of the plastic paste to 28±2 mm. Samples of 20×20×20 mm were prepared. After molding, the samples were cured at 20±1°C(95% R.H.) for 1 d, then samples were demolded, put in natural water for different ages.

2.3. Testing

The compression strength of specimen was measured by compression-testing machine (NYL-60). Phase analysis of material was identified by X-ray diffraction (Cu kα radiation, λ=0.15418μm).

3. RESULTS AND DISCUSSIONS

3.1. Effect of Calcium Hydroxide on Mechanical Performance of Steel Slag

The effect of calcium hydroxide on compression strength of 3d, 7d and 28d is shown in Fig. (**1**). As shown in the figure, the compression strength of the samples is increased,

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when the content of $Ca(OH)_2$ is increased, and decreased when the amount of $Ca(OH)_2$ exceeds 1.5%. As the amount of $Ca(OH)_2$ is 1.5%, strength of 3d increased about 100%, 28d strength increased about 69.2%. As the content of $Ca(OH)_2$ is 1.0%, the the strength of 7d increased about300%.

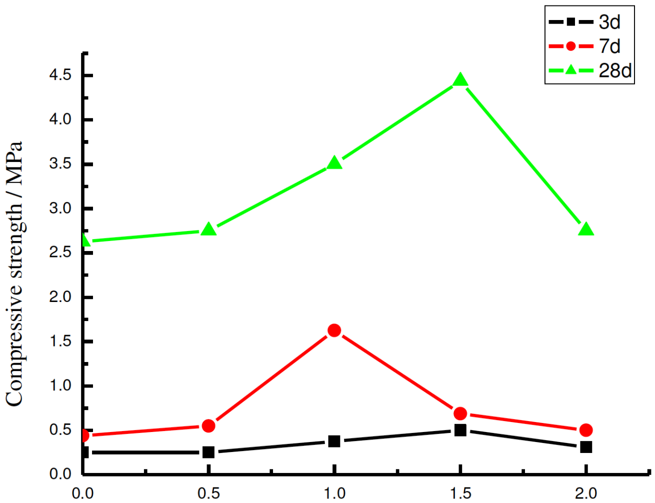

Fig. (1). Effect of $Ca(OH)_2$ on compressive strength.

When $Ca(OH)_2$ is used as activator, vitreous silica structure dissociated rapidly under the excitation function of Ca2+, OH- and other ions, ionic group of Si-O and Al-O dissolve out and act with ions released by steel slag to form C-S-H-Al gel. During hydration of steel slag, the products fill or connection in the network structure, the structure of steel slag becomes compacting gradually, the macro performance is the enhancement of strength. When amount of $Ca(OH)_2$ is higher, Ca^{2+} increased, system has a relatively high ratio of Ca to Si, double electronic layer is formed on the surface of particles, hydration of steel slag is limited, which result in poor strength.

3.2. Effect of Gypsum on Mechanical Performance of Steel Slag

Influence of gypsum on compression strength of 3d, 7d and 28d is shown in Fig. (**2**). As shown in this figure, the compression strength of samples increased with the content of gypsum. As content of gypsum is 1.5%, compression strength of 3d increased to 1.2MPa, the strength of 7d increased to 3.3MPa, the strength of 28d increased to 5.0MPa.

It reveals that, gypsum can enhance hydration of steel slag in paste. Ca^{2+} and SO_4^{2-} are provided by gypsum, SiO_2, Fe_2O_3 and Al_2O_3 in steel slag act with $Ca(OH)_2$, hydration products such as calcium silicate hydrates, are generated in the paste. Enhancement of early strength may be attributed to rapidly consumption of Al_2O_3 in steel slag and $Ca(OH)_2$. With time going on, nuclear of liquid phase increase, small size crystals generate and contact each other. With the increase of hydration products, the crystal structures continue to be filled, the strength of paste can be improved.

3.3. Influence of Sodium Sulfate on Mechanical Performance of Steel Slag

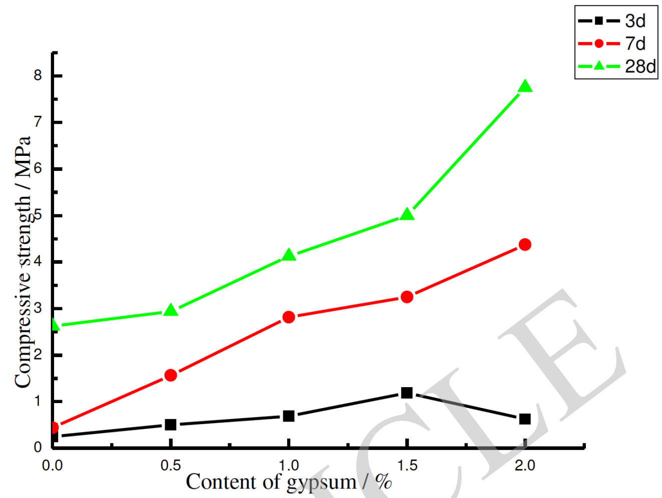

Fig. (2). Influence of gypsum on compression strength.

The influence of sodium sulfate on compression strength of 3d, 7d and 28d is shown in Fig. (**3**). It can be seen that, the compression strength of samples are improved with the increasing content of sodium sulfate, decreases slowly as the amount is higher than 1.5%. As the content of sodium sulfate is 1.5%, the strength of 3d has increased from 0.3MPa to 5.1MPa, the strength of 7d has increased to 6.5MPa, the strength of 28d has increased to 15.5MPa.

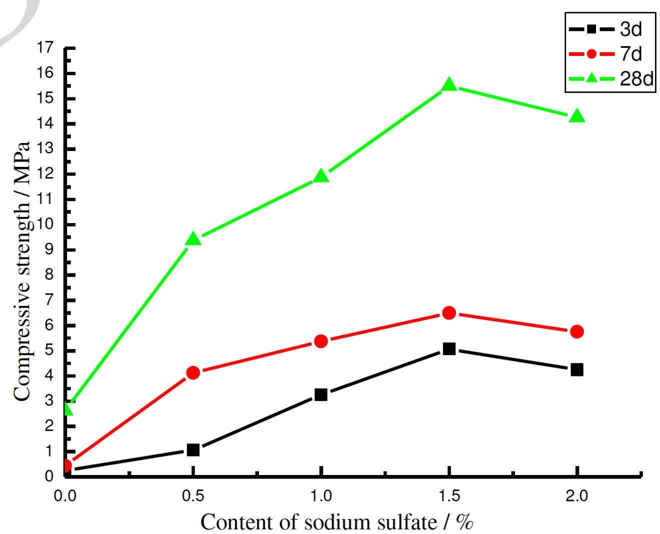

Fig. (3). Influence of Na_2SO_4 on compression strength.

It reveals that, Na_2SO_4 can take dramatic effect on hydration of steel slag. Vitreous network structure of steel slag can be destructed more thoroughly, more hydration products can be formed in early stage [10]. XRD patterns show that the main products are consist of calcium silicate hydrates, calcium hydroxide and Aft. These hydrate products are bonded together, fill in the voids of paste, the density increase, and lead to higher strength. But when the content of sodium sulfate is more than 2.0%, PH value is changed,

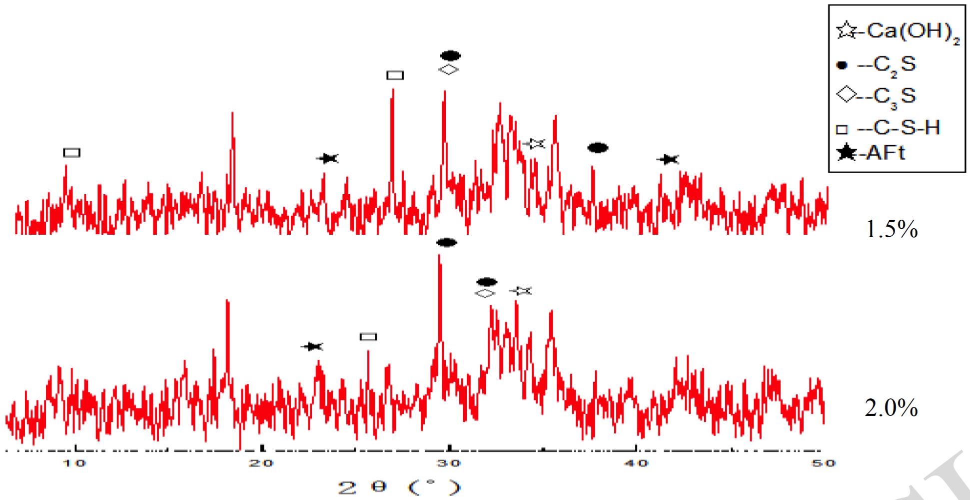

Fig. (4). XRD of samples with 1.5% and 2.0% sodium sulfate at 28d.

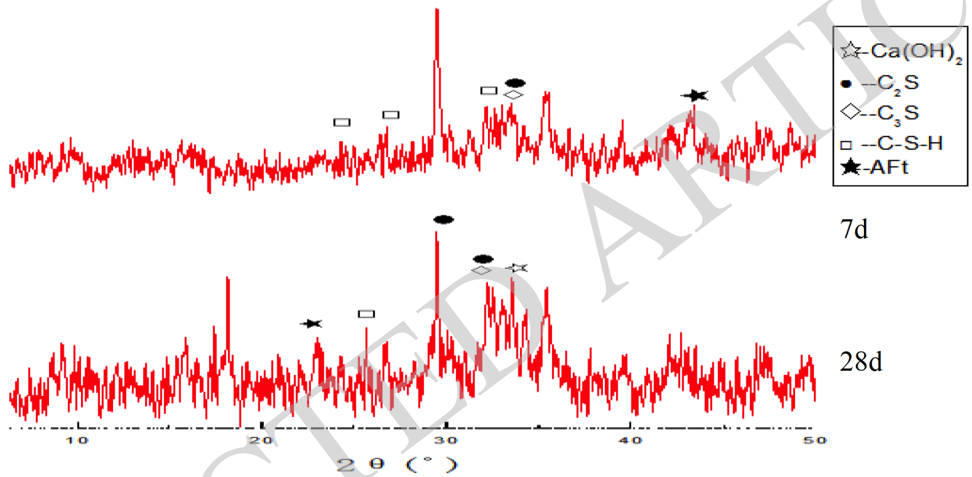

Fig. (5). XRD of samples with 2.0% sodium sulfate at 7d and 28d.

formation of Aft is affected, which result in poor strength and floating hoarfrost on surface of specimen.

3.4. XRD Analysis

XRD patterns of various samples with 1.5% and 2.0% sodium sulfate at 28d are shown in Fig. (**4**). It can be seen that, the main products are consist of calcium silicate hydrates, calcium hydroxide and Aft. The amount of hydrates is various with the different content of sodium sulfate. When the content of sodium sulfate is 1.5%, more peaks appeared in XRD patterns, more Aft are formed in paste, higher strength is obtained.

XRD patterns of the hardened specimen with 2.0% sodium sulfate at 7d and 28d are shown in Fig. (**5**). It can be seen that, with time going on, hydration products have a better growth and a higher degree of crystallinity, formation of gels and Aft are improved, the strength of paste can be enhanced.

CONCLUSION

Different kind of activators can effectively enhance hydration of steel slag to varying degrees. More hydration products can be formed during the hydration process. Mechanical properties both in early and later stage could be enhanced.

When the content of gypsum is 1.5%, the 3d strength increases to 1.2MPa, 7d strength increases to 3.3MPa, 28d strength increases to 5.0MPa. gypsum can enhance hydration of steel slag in paste. Ca^{2+} and SO_4^{2-} are provided by gypsum, SiO_2, Fe_2O_3 and Al_2O_3 in steel slag act with $Ca(OH)_2$, hydrates such as calcium silicate hydrates, are generated in the paste. Enhancement of early strength may be attributed to rapidly consumption of Al_2O_3 in steel slag and $Ca(OH)_2$. With time going on, nuclear of liquid phase increase, small size crystals generate and contact each other.

As the content of Na_2SO_4 is 1.5%, the 3d strength increases to 5.1MPa, 7d strength increases to 6.5MPa, 28d strength increases to 15.5MPa. XRD patterns show that the main products are consist of calcium silicate hydrates, calcium hydroxide and Aft. These hydrates are bonded together, fill in the void of paste, the density increase, and lead to higher strength. But when the content of sodium sulfate is more than 2.0%, PH value is changed, formation of Aft is affected, which result in poor strength and floating hoarfrost on surface of specimen.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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DISCLOSURE

"Part of this article has been previously published in Journal of Chemical and Pharmaceutical Research, 2014, 6(10):458-462 ".

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