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Research Article

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Mechanism and effect of accelerating agent on mechanical properties of steel slag-slag powder cementitious materials

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ABSTRACT

The effect of triethanolamine, $CaCl_2$ and complex accelerator on the mechanical properties of steel slag-slag powder is studied. Hydration products of the pastes are investigated by XRD. Compared with triethanolamine and $CaCl_2$, complex accelerator can dramatically affect hydration of steel slag and slag powder. The strength of specimen increases with the content of sodium sulfate in complex accelerator increasing, decreases when the content is more than 1.5%. When the content of sodium sulfate is 1.5%, the 3d strength increases to 7.6MPa, 7d strength increases to 7.9MPa, 28d strength increases to 19.5MPa, the vitreous network structure of steel slag can be destructed more thoroughly, more hydration products can be formed. These hydration products are bonded together and fill the void of paste, the density increase, and lead to higher strength. But when the content of sodium sulfate is more than 1.5%, PH value is changed, formation of AFt, hydration of C_3S and C_2S in later stage is affected, which result in poor strength. The results show that compared with the calcium hydroxide, gypsum and sodium sulfate can stimulate the activity of steel slag more effective. XRD analysis shows that the amount of hydration products is different when the content of sodium sulfate is different. When the content of sodium sulfate is 0.5%, the main products are consist of C-S-H , $Ca(OH)_2$, C_2S, C_3S and AFt; When the content of sodium sulfate is 1.5%, the main products are consist of C-S-H and AFt, formation of AFt, hydration of C_3S and C_2S in later stage result in higher strength of paste

Key words: Accelerating agent; Mechanical property; Steel slag; Slag powder

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INTRODUCTION

Steel slag is the waste generated during the process of steel making. With the rapid development of China's iron and steel industry, quantity of steel slag increases year by year [1]. In 2010, China's crude steel production exceeded 6 million tons, which generated about 1 million tons of steel slag [2], and still has an annual growth in the number of 30 hundred thousand tons. However, utilization of steel slag rate is very low, the comprehensive utilization rate is of 50% ~ 60% [3], if these steel slag cannot be used effectively; they will occupy more and more land, pollute the environment and result in waste of resource.

Chemical composition of 70% steel slag in China is similar to that of Portland cement clinker; they have potential gelation performance [4]. In order to make full use of steel slag, researches on activation, hydration products and mechanism of steel slag composites can be found at home and abroad [5~10]. Wang Qiang [11] investigated the cementitious properties of basic oxygen furnace steel slag and its role in the hydration and hardening process of cement-steel slag complex binder, results show that the hydration process of steel slag is very similar with that of cement, but its hydration rate is much low, raising the fineness of particles, alkaline condition and elevated curing temperature can all promote the hydration of steel slag at early age.Li Zhaofeng et al. [12] investigated the pro perties of the clinker-poor steel slag cement, with a composition of steel slag 40%, blast furnace slag 40%, clinker 15%, gypsum 5% and composite alkali activators 2. 5%, results show that it can measure up the stands of grade 42.5 ordinary Portland cement, the hydration process of the cement includes activators hydration, clinkers, hydration,

steel slag dissociation and hydration, the normal setting and hardening of the cement depend on the components of the composite activators and the first hydration products of clinker.

However, due to the unstable chemical composition of steel slag, the effect of different activator on the hydration process of steel slag-slag powder is different, and mechanism on activity should yet to be studied. In this paper, the effect of triethanolamine, $CaCl_2$ and complex accelerating agent on mechanical properties of steel slag-slag powder are studied; the mechanism is analyzed by XRD

EXPERIMENTAL SECTION

1. Materials

The steel slag provided by a steel plant in Qian'an, with the grain size of less than 5mm. It can be used in test After grinding in a ball mill, until the specific surface area less than 450m^2/kg. Triethanolamine, $CaCl_2$ and complex accelerator are used as accelerating agents.

2. Specimen preparation

The standard plastic consistency of s=28±2 mm (the sign s denotes the dropping depth of the testing needle of Vickle's meter passing through the pastes) was adopted to control the water amount required. The size of the paste specimens was 20×20×20 mm. After molding and curing at 20±1℃ and 95% R.H. for 1 d, the specimens were demolded and cured in natural water fo3d,7d and 28d.

3. Testing and characterization**.**

The compressive strength is tested by NYL-60 compression-testing machine.

The microstructure of specimens were determined by X-ray diffraction(XRD, X′ Pert MPD) with Cu kα radiation.(λ=0.15418μm)

RESULTS AND DISCUSSION

1. Effect of triethanolamine on mechanical properties of steel slag-slag powder

Fig.1 shows the effect of triethanolamine on compressive strength of 3d, 7d and 28d. The compressive strength of the specimen increases with the content of triethanolamine increasing, and decreases as the content is more than 1.0%. When the content of triethanolamine is 1.0%, the 3d strength increases about 366%, the 7d cement strength increases about 350%, 28d strength increases about 104%.

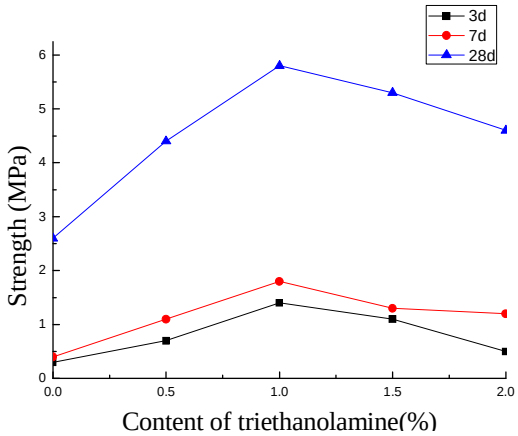


Fig.1 Effect of triethanolamine on compressive strength of steel slag-slag powder

It reveals that, unshared electron pair of N atom in trieehanolamine is easy to form a covalent bond with metal ions, complexation reaction occurred. Complex compound is easily soluble in water, soluble region point is generated on the surface of the clinker particles, dissolution rate of C_3A and C_4AF increase, reaction of gypsum accelerates, more calcium sulfoaluminate occurred, the strength is enhanced. When the content of trieehanolamine is more than 1%, formation of more complex compound can restrain hydration of C_3S and C_2S, the strength is poor.

2. Effect of CaCl2 on mechanical properties of steel slag-slag powder

Fig.2 shows the effect of $CaCl_2$ on compressive strength of 3d, 7d and 28d. The strength of specimen increases with

the content of $CaCl_2$ increasing. When the content of $CaCl_2$ is 1.5%, the 3d strength increases to 2.4MPa, 7d strength increases to 8.0MPa, 28d strength increases to 16.8MPa.

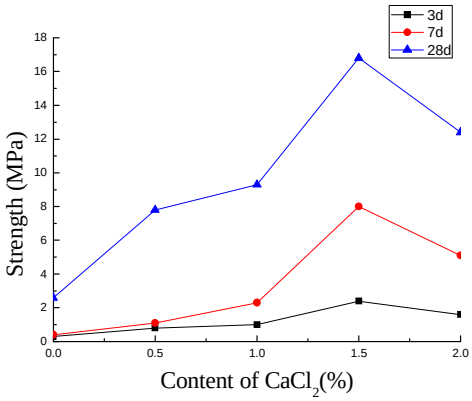


Fig.2 Effect of $CaCl_2$ on compressive strength of steel slag-slag powder

It reveals that, $CaCl_2$ can enhance hydration of steel slag and slag powder in paste, the reactions are as follows:

$CaCl_2+3CaO\cdot Al_2O_3+H_2O=3CaO\cdot Al_2O_3\cdot 3CaCl_2\cdot 10H_2O$

$CaCl_2+Ca(OH)_2+H_2O=CaCl_2\cdot 3Ca(OH)_2\cdot 12H_2O$

With the increase of $Ca(OH)_2$, hydrated calcium silicate and hydrated calcium aluminate are formed, the crystal structures continue to be filled, the strength of paste can be improved.

3. Effect of complex accelerator on mechanical properties of steel slag-slag powder

Trieehanolamine-sodium sulfate complex accelerator is used in the experiments. Content of trieehanolamine is 0.05%, content of sodium sulfate is variable. Fig.3 shows the effect of complex accelerator on compressive strength of 3d, 7d and 28d. The strength of specimen increases with the content of sodium sulfate increasing, decreases when the content is more than 1.5%. When the content of sodium sulfate is 1.5%, the 3d strength increases to 7.6MPa, 7d strength increases to 7.9MPa, 28d strength increases to 19.5MPa.

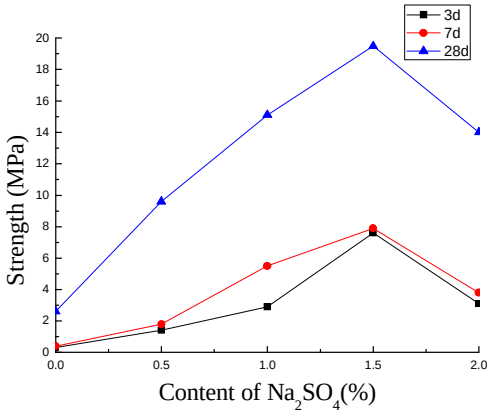


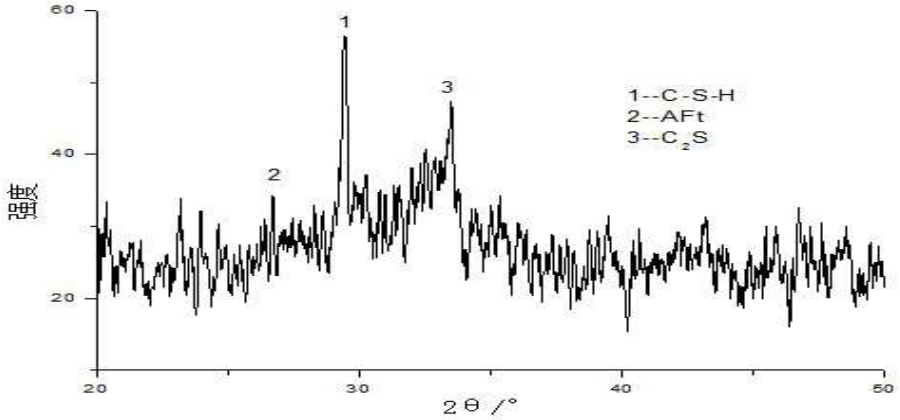
Fig.3 Effect of sodium sulfate on compressive strength of steel slag-slag powder

It reveals that, complex accelerator can dramatically affect hydration of steel slag and slag powder. The vitreous network structure of steel slag can be destructed more thoroughly; more hydration products can be formed. These hydration products are bonded together and fill the void of paste, the density increase, and lead to higher strength. But when the content of sodium sulfate is more than 1.5%, PH value is changed, formation of AFt, hydration of C_3S and C_2S in later stage is affected, which result in poor strength.

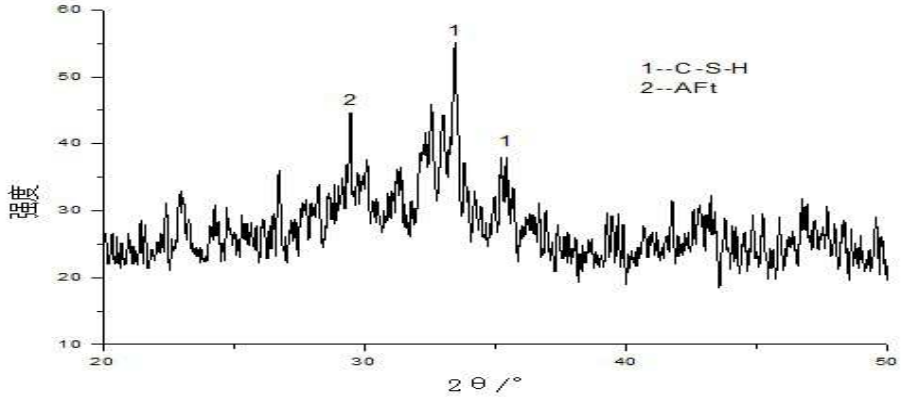
4. XRD analysis

Fig.4 shows the XRD patterns of the hardened specimen with 1.5% sodium sulfate of complex accelerator at 7d and 28d. It can be seen that, the main products are consist of C-S-H and AFt. The amount of hydration products is different when the age is different. Little C_2S can be finding in the pattern of 28d, hydration of C_2S lead to higher

strength in later stage.



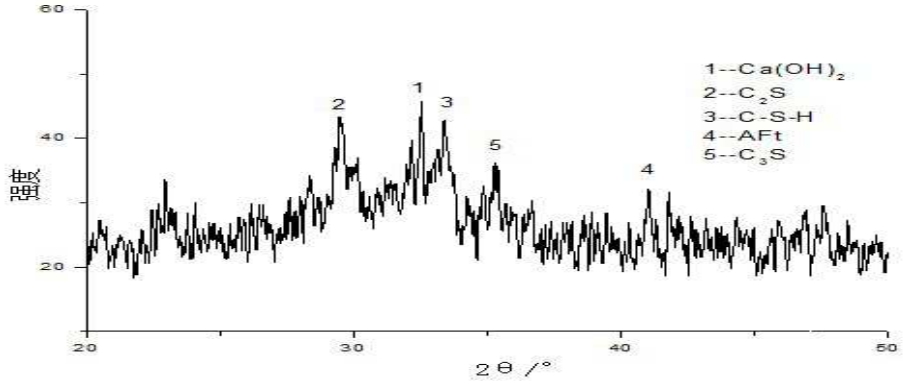
(1)7d



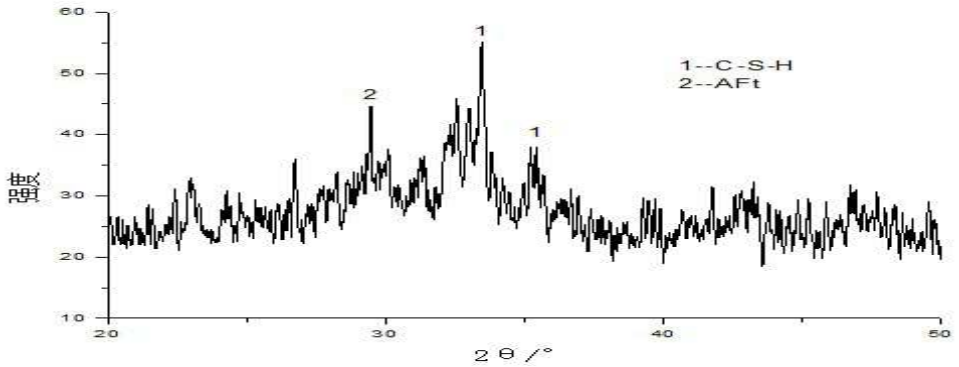
(2)28d

Fig.4 XRD patterns of specimen with 1.5% sodium sulfate of complex accelerator at 7d and 28d

Fig.5 shows the XRD patterns of the hardened specimen with 0.5% and 1.5% sodium sulfate of complex accelerator at 28d. It can be seen that, the main products are consist of C-S-H and AFt. The amount of hydration products is different when the content of sodium sulfate is different. When the content of sodium sulfate is 0.5%, the main products are consist of C-S-H , $Ca(OH)_2$, C_2S, C_3S and AFt; When the content of sodium sulfate is 1.5%, the main products are consist of C-S-H and AFt, formation of AFt, hydration of C_3S and C_2S in later stage result in higher strength of paste.



(1)0.5% sodium sulfate of complex accelerator



(2)1.5% sodium sulfate of complex accelerator

Fig.5 XRD patterns of specimen with 0.5% and 1.5% sodium sulfate of complex accelerator at 28d

CONCLUSION

When the content of triethanolamine is 1.0%, the 3d strength increases about 366%, the 7d cement strength increases about 350%, 28d strength increases about 104%. Trieehanolamine is easy to form a covalent bond with metal ions, complexation reaction occurred. Complex compound is easily soluble in water, soluble region point is generated on the surface of the clinker particles, dissolution rate of C_3A and C_4AF increase, reaction of gypsum accelerates, and more calcium sulfoaluminate occurred, the strength is enhanced.

The strength of specimen increases with the content of $CaCl_2$ increasing. When the content of $CaCl_2$ is 1.5%, the 3d strength increases to 2.4MPa, 7d strength increases to 8.0MPa, 28d strength increases to 16.8MPa. With the increase of $CaCl_2$, hydrated calcium silicate and hydrated calcium aluminate are formed, the crystal structures continue to be filled, and the strength of paste can be improved.

Complex accelerator can dramatically affect hydration of steel slag and slag powder. The vitreous network structure of steel slag can be destructed more thoroughly; more hydration products can be formed. These hydration products are bonded together and fill the void of paste, the density increase, and lead to higher strength. But when the content of sodium sulfate is more than 1.5%, PH value is changed, formation of AFt, hydration of C_3S and C_2S in later stage is affected, which result in poor strength

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