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EFFECT OF FLY ASH (FA) ON PROPERTIES OF MAGNESIUM SULPHOALUMINATE CEMENT (MSC) BASED FIRE RETARDANT COATINGS FOR STEEL SUBSTRATE

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Magnesium sulphoaluminate (MSA) cement is a new type of inorganic coating for steel substrate with excellent fire retardant performance. In order to make full use of the advantages of MSA cement based coatings, the effect of fly ash on setting time, strength of MSA cement paste coating was studied. The phase compositions of MSA cement hydration products were analyzed by X - ray diffraction (XRD) and scanning electron microscopy (SEM). The results showed that the addition of fly ash prolongs setting time and increases the strength of MSA cement at 1 day (d) significantly. After adding fly ash, no new hydration products were generated, but it can significantly improve morphology of MSA cement with the compact structure of hydration products.

Keywords: magnesium sulphoaluminate cement; fly ash; cement coating; strength; X - ray research

INTRODUCTION

Magnesium sulphoaluminate cement obtained by adding volcanic ash materials to the MgO - $MgSO_4$ - H_2O cementitious system of MOS cement [1 - 3]. MSA cement has advantages of fast setting speed, good adhesion, high temperature retardant and corrosion resistance, which suit for the use of coatings on steel substrate [4 - 6]. As an inorganic material, MSA cement based coatings overcome the disadvantages of organic and metallic coatings such as pollution and poor resistance to high temperatures and weathering. However, further research is still needed of fly ash on the performance of MSA cement based coatings. In this paper, the effects of fly ash on the settingtime, compressive strength and flexural strength of MSA cement based coatings were tested. The phase compositions of MSA cement coating were analyzed by XRD and SEM.

EXPERIMENTAL PROGRAM

Raw materials

The magnesium oxide used in the current study was light - burned MgO powder with a purity of 85 %, from Liaoning Province, China. The chemical compositions of the raw materials in wt.% are presented in Table 1.

The bauxite used in this study was produced by Henan Jiayuan Environmental Protection Materials Co., Ltd. The fly ash used in this study was produced by China Huadian Corporation. The chemical compositions of the bauxite and fly ash in wt. % are presented in Table 2.

Table 1 **Chemical compositions of light burned magnesium oxide / mas. %**

Component	Content
MgO	88,12
SiO_2	3,6
CaO	1,3
Al_2O_3	0,77
Fe_2O_3	0,68
Loss on ignition	1,6
Others	3,93

Table 2 **Chemical compositions of bauxite and FA / mas. %**

Component	Content	
	Bauxite	FA
SiO_2	39,48	47,67
Al_2O_3	53,33	33,79
CaO	0,92	5,58
Na_2O	0,13	0,00
Fe_2O_3	1,75	6,65
MgO	0,35	0,48
SO_3	0,89	2,09
TiO_2	1,80	1,52
K_2O	0,41	1,28

The magnesium oxysulfate ($MgSO_4 \cdot 7H_2O$) employed produced by an environmentally friendly building material manufacturer in Zhengzhou, Henan Province. The citric acid ($C_6H_8O_7 \cdot H_2O$) and aluminum sulfate ($Al_2(SO_4)_3$) selected as modifier additive for MSA cement was a pure analytical reagent grade crystal obtained from Tianjin Biaozhunkeji Ltd., China.

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Targeting the effect of fly ash on the properties of MSA cement coating, paste specimens with 10 %, 20 %, 30 % fly ash were prepared.

Test methods

The test method of cement setting time refers to current Chinese National Standard GB / T 1346 - 2011.

For each mixture, cubic specimens with a size of 40 × 40 × 40 mm and 40 × 40 × 160 mm were cast in steel molds with vibration compaction. The strength development of the mixtures was recorded at 1, 3, 7, 14 and 28 days at temperature of 20 ± 2 °C and relative humidity of 60 ± 5 % curing room. The cement compression resistance test machine (TYE - 300) and a load of 1,5 mm / min were selected.

RESULTS AND DISCUSSION

Effect of fly ash on setting time of MSA cement

The effect of fly ash on the setting time of MSA cement is shown in Figure 1. It can be seen that the setting time of cement slurry is prolonged with the increase of fly ash content. The fly ash incorporation of 10 %, the initial setting time and final setting time are extended by 10 minutes and 19 minutes, and the setting time are extended by 31 minutes and 45 minutes when the fly ash content increases to 30 % respectively.

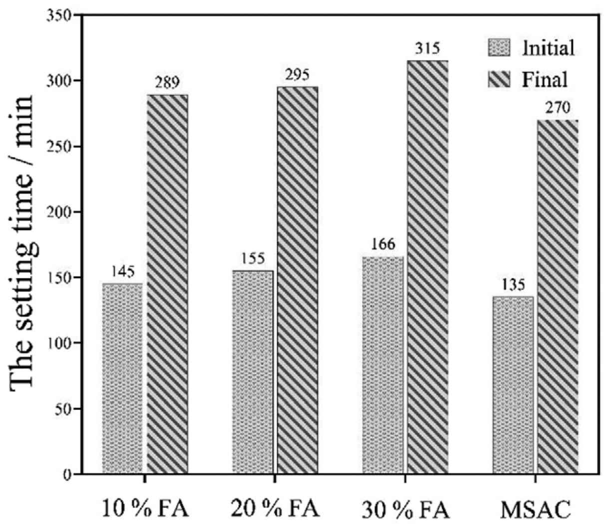


Figure 1 Effect of FA on the setting time of MSA cement sludge

Effect of fly ash on the strength of MSA cement

The compressive strength and flexural strength of MSA cement with 10 %, 20 %, 30 % fly ash at different ages are shown in Figure 2 and Figure 3. From Figure 2, it can be seen that after adding 10 %, 20 % and 30 % fly ash, the compressive strength and flexural strength both are increased with the extension of age. Among them, the strength increase rate is faster before 7 days, and the increase rate is relatively slow after 7 days. At 1 day of age, the compressive strength is increased by 45 %, 55 % and 80 % compared to the control sample, while at 3 days (d), the compressive strength is increased by 17 %, 19 % and 15 % respectively.

It can also be seen from Figure 3 that the addition of fly ash can improve the early flexural strength of MSA cement, and the flexural strength of 1d is 56 %, 51 % and 34 % higher than that of the control sample. At 3 d, 7 d and 28 d, the flexural strength of the test block with 10 % fly ash is still higher than that of the control sample.

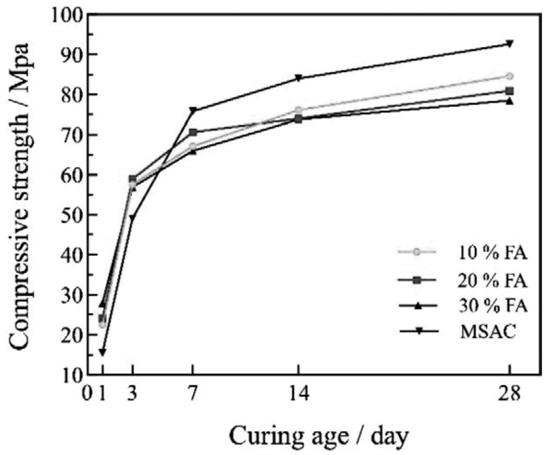


Figure 2 Effect of FA on compressive strength of MSA cement

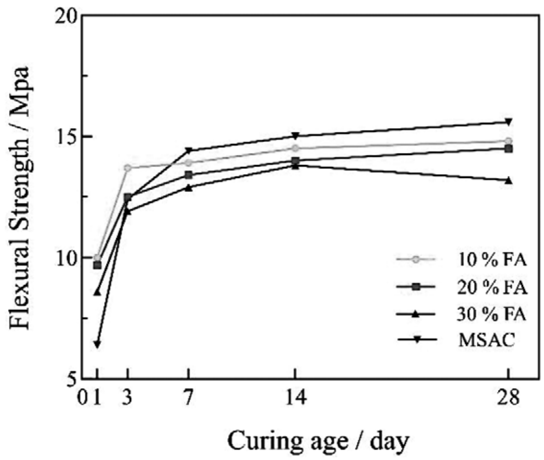


Figure 3 Effect of FA on flexural strength of MSA cement

XRD AND SEM ANALYSIS

The XRD patterns of MSA cement and MSA cement with 30 % fly ash at 1d and 28d are shown in Figure 4 and Figure 5 respectively. It can be seen from the figures that the main hydration products of MSA cement are M - A - $\overline{S}$ - H crystalline phase, as well as flat shape like M - S - H, AH_3, M - A - S - H gel product. In addition, the system contains a small amount of $Mg(OH)_2$, residual MgO and $MgCO_3$ impurities. No new hydration products are generated after the addition of fly ash, indicating that fly ash is not participate in the reaction in this system at room temperature.

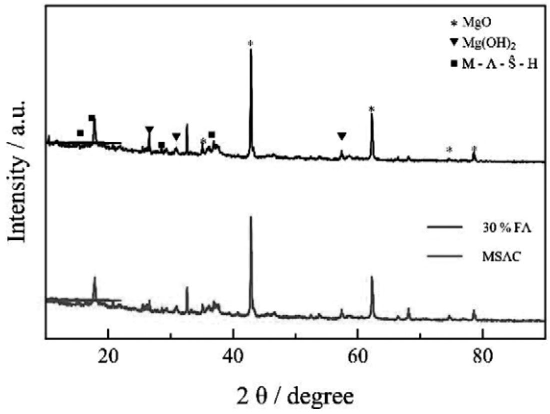


Figure 4 XRD patterns at the curing age of 1 d

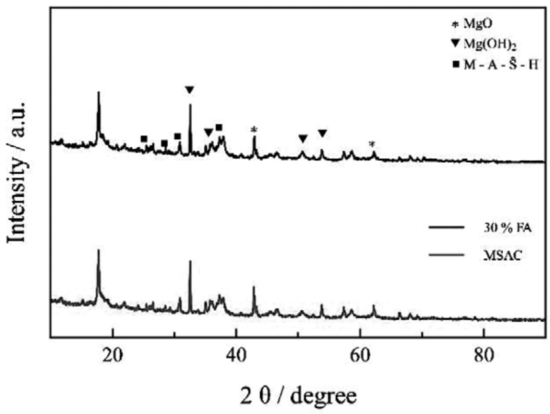
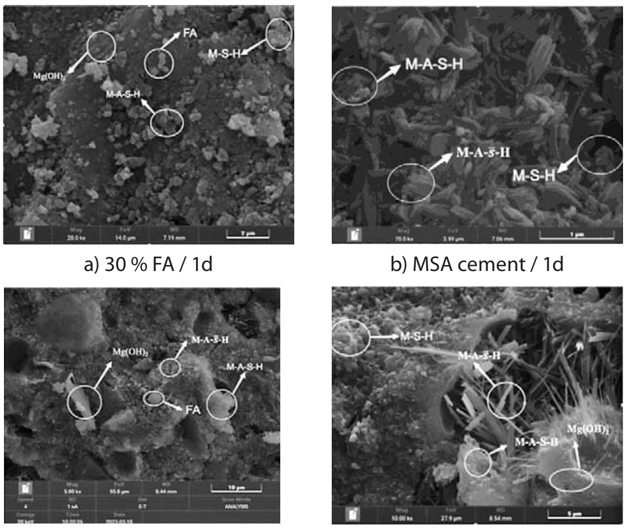


Figure 5 XRD patterns at the curing age of 28 d

The SEM images of MSA cement and MSA cement with 30 % fly ash at 1 d and 28 d are shown in Figure 6. From the figure, it can be seen that the fly ash particles filling the pores and the microstructure of MSA cement is improved, which makes the structure denser than the control sample, thus the early performance of MSA cement is improved.



a) 30 % FA / 1d b) MSA cement / 1d

c) 30 % FA / 28d d) MSA cement / 28d

Figure 6 SEM images of MSA cement

CONCLUSIONS

The initial and final setting times of MSA cement are delayed by fly ash, and the setting time is extended with the increase of fly ash content. The early mechanical strength of MSA cement is improved by fly ash. At 1 day of age, the compressive strength of the 10% fly ash ratio group is increased by 45 % and the flexural strength is increased by 56 % compared to the control sample. Adding fly ash, no new hydration products were generated, but it can significantly improve morphology of MSA cement with the compact structure of hydration products.

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REFERENCE

[1] M. Chen, R.S. Xiong, K.Y. Xi, Sulfur Magnesium Oxychloride Cement and Magnesia Sulphoaluminate Cement [J], China Building Materials Science & Technology, (2013) 05, 19 - 22.

[2] T. Shuang, D.P. Cai. Clinker - free magnesial fly ash cement and its application in production [J], Coal ash, 24 (2012) 06, 4 - 6.

[3] X.X. Chen, J. Xu. Mechanics capability analysis for FRC board and design for material configuration [J], China Building Materials Science & Technology, 21 (2012) 03, 75 - 78.

[4] E.Y. Sun, X.Z. Meng. Study on the effect of metallurgical waste on the cracking resistance of magnesium oxysulfate cement coatings [J], Metalurgija, 63 (2024) 1, 146 - 148.

[5] Z.G. Li, X.S. Zhang, Y.Y. Guo, D.M. Zhang, L.L. Jiang, J. Zhu. Effect of modifier and superfine steel slag powder on properties of magnesium oxysulfate (MOS) cement [J], Metalurgija, 60 (2021) 1 - 2, 27 - 29.

[6] N. Wang, H.F. Yu, W. Bi, "Effects of sodium citrate and citric acid on the properties of magnesium oxysulfate cement", Construction and Building Materials, 169(2018), 697 - 704.

Note: Responsible for the English language is Y. Hu, Xiamen, China