Study on Preparation and Performance of Liquid Grinding Aid

Yu Jiang[1*], Lei Deng[1], Wenhong Chen[1] and Bo Zhang[1]

[1]KZJ New Materials Group Guizhou Co., Ltd. Longli, Guizhou, China

*Corresponding author's e-mail: owen@xmabr-kzj.com

Abstract. At present, cement grinding aids are mostly made of Triethanolamine, Diethanolamine and other materials. The effect of grinding aids is poor, the energy consumption of cement production is not significantly reduced, and the strength is increased less. In view of this phenomenon, In the article, dihydroxyethyl isopropanolamine, dimethylglycerol, trimethyl aluminate, molasses, sodium thiocyanate, and water are used as raw materials to prepare liquid grinding aid. The experiment shows that adding 0.03% grinding aid in cement grinding can reduce the power consumption of cement production, increase the fineness of cement, increase cement production capacity, and also increase the compressive strength of cement mortar by 4~6 MPa in 3d and 4~10 MPa in 28d, achieving industrial application.

Keywords: dihydroxyethyl isopropanolamine, dimethylglycerol, trimethyl aluminate, liquid grinding aid.

1 Introduction

Cement is an indispensable building engineering material in modern society[1]. With the proposal of the national goals of "carbon peak" and "carbon neutrality", it is of great significance to research, develop and adopt more technical means to achieve energy conservation and carbon reduction in the cement industry and promote the sustainable development of the cement industry[2]. However, the raw materials for cement production are getting worse and worse, especially limestone, volcanic ash, and other particles with larger particle sizes and heavy mud content, which increases the power consumption during cement grinding, wastes energy, increases the wear and tear of grinding equipment, and reduces cement strength, resulting in a decrease in cement production and quality, and affecting project quality.

Additives are widely used by foreign cement enterprises, and China now generally recognizes and accepts cement additives. In cement production, the research and application of grinding aids are receiving more and more attention. Most cement enterprises in China use ball mills to mill clinker. Each ton of cement needs to mill about 3 tons of various materials, accounting for 60%~70% of the total energy consumption, and the utilization rate is quite low. Less than 10% of the energy is used for grinding

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cement material particles [3]. In order to improve the cement performance, adding cement grinding aids in the cement production process has now become an effective way for the cement industry to improve the grinding efficiency[4].Cement grinding aid is a chemical additive that improves the grinding effect and performance of cement. It can increase cement production, reduce grinding power consumption, and enhance the strength of cement at various ages. It can also improve the distribution of cement particles, reduce the proportion of clinker used, and reduce the production cost of cement slurry [5-8]. In the 1930s, the UK and the US respectively invented resin and lignin as grinding aids[9-10]. At present, alcohol amine grinding aids are mainly used in China. In this experiment, trimethyl aluminate was introduced into alcohol amine grinding aids to further improve grinding efficiency, shorten grinding time, and greatly reduce cement production costs.

2 Experiment

2.1 Experimental raw materials and instruments

The detailed information of the raw materials used in this experiment is shown main instruments used in the experiment are displayed in Table 1, respectively.

Table 1. Experimental raw materials

	Raw materials	Specifications	Factory
synthetics	Dihydroxyethyl isopropanolamine	Main content: 99.5%	Shandong Yousuo Chemical Co., Ltd
	Dimeric glycerol	Main content: 99%	Jinan Luying Chemical Technology Co., Ltd
	Trimethyl aluminate	Main content: 85%	Shandong Yousuo Chemical Co., Ltd
	molasses	Industrial grade	Jiangsu Keye Chemical Co., Ltd
	Sodium thiocyanate	Industrial grade	Jiahua Chemical (Shanghai) Co., Ltd
testing materials	Clinker	Particle size(mm): 6 ~ 10	Guizhou Conch Cement Co., Ltd
	Desulfurization gypsum	Containing water(%): 3 ~ 5	Guizhou Conch Cement Co., Ltd
	limestone	Particle size(mm): 4 ~ 8	Guizhou Conch Cement Co., Ltd
	Coal-fired slag	Particle size(mm): 0.5 ~ 3	Guizhou Conch Cement Co., Ltd
	Standard sand	Fineness modulus: 2.8	Xiamen Aisiou Standard Sand Co., Ltd
	Water	tap-water	Self-control
	ZMJ	Main content: 60%	Commercially available grinding aids

The detailed information of the main instruments used in this experiment is shown in Table 2.

Table 2. Main instruments

Laboratory apparatus	Type	Main technical parameters
Digital display thermostatic water bath	HH-2	capacity:3000ml
Electric mixer	JJ-1	Rotary speed:2500r/min
Cement mortar mixer	JJ-5	Automatic control program time: 240±3s
Experimental grinding	r:500*500	Grinding drum speed:48r/min
Digital pressure testing machine	YES-300	Maximum load:300KN
Cement mortar compaction table	ZS-15	Vibration frequency:60r/60s

2.2 Sample synthesis

Start the stirring slurry, add sodium thiocyanate (200g) and molasses (200g) respectively, raise the temperature to 45 ℃, stir for 20 minutes, add dihydroxyethylisopropanolamine (2000g), dimeric glycerol (300g), and trimethyl aluminate (480g), stir for 1 hour, and prepare a dark reddish brown liquid grinding aid, code G200, with a solid content of 60%.

2.3 Performance test method

(1) Compressive strength of cement mortar: Refer to GB/T 17671-2021 "Testing Method for Strength of Cement Mortar" for testing, and the mix ratio of cement mortar is shown in Table 3.

Table 3. Cement Mortar Mix Ratio g

cement	sand	water
450	1350	225

(2) The mix ratio of P. O42.5 cement grinding aid in small grinding experiments is shown in Table 4.

Table 4. Grinding Mix Proportion of Cement Mixtures Kg/m^3

Clinker	Desulfurization Gypsum	limestone	Coal-fired slag
780	50	39	131

3 Results and Analysis

3.1 The Effect of Grinding Aids on Cement Grinding Performance

Effect of Different Dosages of Grinding Aids on Cement Sieve Residue and Specific Surface Area.

G200 was added to the cement mixture at a dosage of 0.01%, 0.02%, 0.03%, and 0.04% for grinding. The grinding time was 3 hours, and the cement residue and specific surface area after grinding are shown in Table 5.

Table 5. Cement Sieve Residue and Specific Surface Area

Dosage(%)	sieve residue(%)	Specific surface area(m^2/kg)
blank	15.1	333
0.01	14.2	346
0.02	11.2	376
0.03	9.5	390
0.04	9.4	393

From Table 5, it can be seen that the cement sieve residue without grinding aids is 15.1%. After adding 0.01% G200, the cement sieve residue is 14.2%, and the sieve residue decreases by 0.9%. When the dosage increases to 0.02%, the cement sieve residue is 11.2%, with a significant decrease. When the dosage is 0.03%, the cement sieve residue is 9.5%, and when the dosage is 0.04%, the cement sieve residue is 9.4%. This indicates that as the dosage increases, the cement sieve residue after grinding gradually decreases, but when the dosage is 0.03%, the decrease is small. According to the specific surface area, the specific surface area of cement without grinding aids is 333 m^2/kg. After adding 0.01% G200, the specific surface area of cement is 346 m^2/kg. After adding 0.02% G200, the specific surface area of cement increases to 376 m2/kg. After adding 0.03% G200, the specific surface area of cement is 390 m^2/kg. After adding 0.04% G200, the specific surface area of cement is 393 m^2/kg. Similarly, when adding a small amount of G200, the grinding effect is poor. When the G200 dosage increases, The specific surface area of cement increases, but when the G200 dosage reaches 0.03%, the increase in specific surface area is relatively small. Based on the comprehensive cost-effectiveness, it can be seen that a G200 dosage of 0.03% has a good promoting effect on the impact of cement sieve residue and specific surface area.

Effect of different grinding aids on cement sieve residue and specific surface area.

Add G200 and ZMJ to the cement mixture for grinding, with a grinding time of 3 hours. After grinding, the cement residue and specific surface area are shown in Table 6.

Table 6. Cement Sieve Residue and Specific Surface Area

grinding aid	Dosage (%)	sieve residue (%)	Specific surface area (m^2/kg)
/	0	15.0	335

G200	0.03	9.5	392
ZMJ	0.03	12	360

From Table 6, it can be seen that the sieve residue of cement without grinding aid is 15%. After adding G200, the sieve residue is 9.5%, reducing by 5.5%. After adding ZMJ, the sieve residue is 12%, reducing by 3%. From the specific surface area, the specific surface area of cement without grinding aid is 335 m^2/kg. After adding G200, the specific surface area increases to 392 m^2/kg, and after adding ZMJ, the surface area is 360 m^2/kg. This indicates that after adding grinding aid to grind cement, the sieve residue of cement decreases and the specific surface area increases, G200 is better than commercially available ZMJ in improving cement performance.

3.2 Compressive strength test of cement mortar

Effect of different amounts of grinding aids on the compressive strength of cement mortar.

First, without adding grinding aids, G200 is added to the cement mixture at a dosage of 0.01%, 0.02%, 0.03%, and 0.04% for grinding. The grinding time is 3 hours. After grinding, the cement is subjected to compressive strength tests for 3d and 28d. The test results are shown in Figure 1:

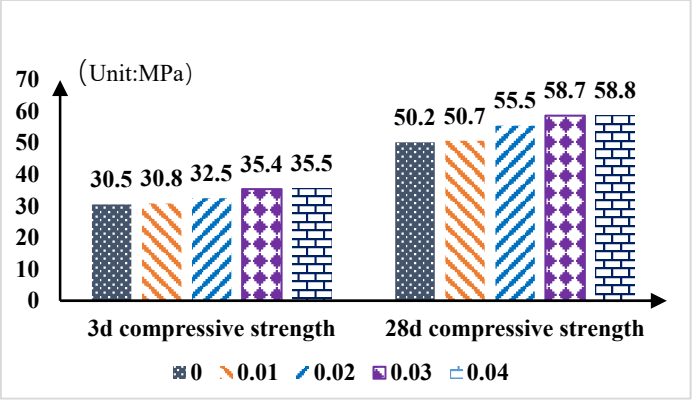

Fig. 1. Compressive strength test of cement mortar

From Figure 1, it can be seen that when grinding cement without adding grinding aids, the compressive strength of cement 3d mortar is 30.5MPa. When adding 0.01% G200 grinding cement, the compressive strength of cement 3d mortar is 30.8MPa, with little increase in strength. When adding 0.02% G200 grinding cement, the compressive strength of cement 3d mortar is 32.5 MPa. When adding 0.03% G200 grinding cement, the compressive strength of cement 3D mortar is 35.4 MPa. When adding 0.04% G200 grinding cement, the compressive strength of cement 3d mortar is 35.4 MPa, The compressive strength of cement 3d mortar is 35.5 MPa, indicating that with the increase of grinding aid dosage, the strength improvement of cement increases. However, when the G200 dosage exceeds 0.03%, the improvement is not significant. According to the compressive strength of cement 28d mortar, when grinding cement without grinding

aids, the compressive strength of cement 28d mortar is 50.2MPa. When adding 0.01% G200 grinding cement, the compressive strength of cement 28d mortar is 50.7MPa. When adding 0.02% G200 grinding cement, the compressive strength of cement 28d mortar is 55.5 MPa. When adding 0.03% G200 grinding cement, the compressive strength of cement 28d mortar is 58.7 MPa. When adding 0.04% G200 grinding cement, the compressive strength of cement 28d mortar is 58.7 MPa, The compressive strength of cement 3d mortar is 58.8 MPa, indicating that the promoting effect of grinding aids on the compressive strength of cement 28d mortar is similar to that of cement 3d mortar.

Effect of different grinding aids on the compressive strength of cement mortar.

Add self-made grinding aids and commercially available grinding aids to the cement mixture for grinding, with a grinding time of 3 hours. After grinding, conduct compressive strength tests on the cement for 3 and 28 days. The test results are shown in Figure 2:

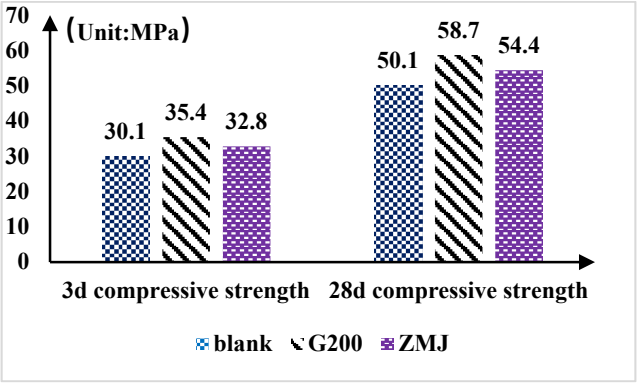

Fig. 2. Compressive strength test of cement mortar

From Figure 2, it can be seen that the compressive strength of the cement 3d mortar without adding grinding aids is 30.1MPa. After adding G200 grinding, the compressive strength of the cement 3d mortar is 35.4MPa, an increase of 5.3MPa. After adding commercial ZMJ grinding, the compressive strength of the cement 3d mortar is 32.8MPa, an increase of 2.7MPa, which can be seen from the 28 day compressive strength; The compressive strength of the 28d cement mortar without adding grinding aids is 50.1MPa. After adding G200 grinding, the compressive strength of the 28d cement mortar is 58.7MPa, an increase of 8.6MPa. After adding commercial ZMJ grinding, the compressive strength of the 28d cement mortar is 54.4MPa, an increase of 4.3MPa. The above experimental results show that after adding grinding aids to grind cement, the compressive strength of the cement mortar at both 3d and 28d is improved, and the compressive strength of the mortar is significantly increased after adding G200 grinding cement.

4 Conclusion

(1) This article uses dihydroxyethylisopropanolamine, dimeric glycerol, trimethyl aluminate, molasses, sodium thiocyanate, and water as raw materials to prepare liquid grinding aid;

(2) After adding grinding aids to grind cement, the cement sieve residue decreases and the specific surface area increases. G200 has a better performance improvement on cement than the commercially available ZMJ;

(3) According to the comprehensive cost-effectiveness, the optimal dosage of grinding aids is 0.03% when grinding cement;

(4) After adding grinding aids to grind cement, the compressive strength of cement mortar at both 3d and 28d was improved, and the compressive strength of mortar increased significantly after adding G200 grinding cement.

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