Preparation and properties of solid waste based lightweight plastering gypsum

Xiaohua Tian¹, Dongji Liu¹ and Fengqing Zhao¹,*
¹Heibei University of Science & Technology, Shijiazhuang, China

*Corresponding author e-mail: zhaofq3366@126.com

Abstract. The lightweight plastering gypsum with excellent heat preservation performance was prepared from β-hemihydrate gypsum obtained by calcining desulfurization gypsum, the polyurethane foam waste modified with water glass, and a composite auxiliary agent composed of ground steel slag and granulated blast-furnace slag. The density of the product is 762.3 kg/m³, the initial setting time is 150 min, the final setting time is 205 min, the flexural strength is 3.1 MPa, the compressive strength is 6.8 MPa, and the thermal conductivity is 0.098 W/(m·K).

1. Introduction

Desulphurization gypsum is a by-product obtained from wet desulphurization of flue gas in thermal power plants⁴. It can be calcined to obtain β-hemihydrate gypsum, and further to produce the products with the advantages of fire and sound insulation, light in weight, heat preservation, humidity control and breathability, which is well known as environment friendly building materials.

However, the setting and hardening of β-hemihydrate gypsum is very fast, the operation time is short, and the water resistance is poor. In practical application, appropriate retarders and other additives are often added to adjust the properties of β-hemihydrate gypsum⁵. Chen Xiongmu⁶ used metallurgical waste to modify β-hemihydrate gypsum. When 5% ground steel slag or manganese slag was used, the setting time of gypsum paste prolong to more than 100 minutes from 5 minutes (blank), which indicated that metallurgical waste slag was excellent as the retarder. Yu Haiyan⁷ compared the effects of mineral powder, fly ash, Portland cement, high alumina cement and mineral powder on the mechanical properties and water resistance of desulfurized gypsum in alkali environment. It was found that both the compressive strength and water resistance of modified desulfurized gypsum were greatly improved with the mass ratio of desulfurized gypsum: mineral powder: CaO: water reducer = 4:1:0.3:0.04, the water-binder ratio was 0.41. Steel slag and granulated blast-furnace slag can not only improve the operability of gypsum, but also improve its water resistance⁷,⁸.

Considering that the volume density of plastering gypsum should not be greater than 1000kg/m³ in practice, the polyurethane foam waste was used as thermal insulation material in this work to reduce the volume density; steel slag, granulated blast-furnace slag and anhydrate were used as additive to solve the problem of short setting time and increase the water resistance of solid based plastering gypsum.
2. Experimental method

2.1. Preparation of Lightweight Plaster

The polyurethane foam waste was crushed and sieved, add some sodium silicate and well mixed. Desulphurized gypsum was calcined at 160~180°C for 1.5 hours to prepare β-hemihydrate gypsum. Then the latter was mixed with additive (mixture of steel slag, mixture of granulated blast-furnace slag and anhydrate), polyurethane foam waste and thixotropic agent to obtain an environment friendly lightweight plastering material.

2.2. Performance Test

The setting time and mechanical strength of β-hemihydrate gypsum were determined according to GB/T 9776-1988. The plastering gypsum slurry was prepared and poured into a 40mm×40mm×160mm mold, then demold after 2 hours, and cure at 55°C for 3 days, dry to constant weight, weigh to calculate the density, and then test the absolute dry bending strength and compressive strength.

3. Results and discussion

3.1. Effect of Additive on Setting Time of Gypsum

Change the above-mentioned additive to investigate the effect on the setting time of β-hemihydrate gypsum. The results are shown in figure 1 and figure 2.

![Figure 1. Effect of additives on the initial setting time of gypsum](image1)

![Figure 2. Effect of additives on the final setting time of gypsum](image2)

It can be seen from figure 1 and figure 2 that the setting time of β-hemihydrate gypsum is prolonged as the amount of the additive is increased. When the additive dosage is 7.87%, the initial setting time reaches 150 min and the final setting time 205 min, indicating that the modifier has a good retarding effect on gypsum and can be used as a retarder for gypsum.

3.2. Effect of Additives on Mechanical Strength of Gypsum

The effects of different additives on the flexural and compressive strength of gypsum were investigated. The results are shown in figure 3 and figure 4.
It shows that the mechanical strength of β-hemihydrate gypsum decreases with the increase in the dosage of additive. When the dosage is 7.8%, the flexural strength is 3.1 MPa and the compressive strength is 6.8 MPa. Compared with the commonly used citrate and phosphate, the mechanical strength loss is smaller and the cost is lower. Besides, large amount of ettringite and calcium silicate hydrate in the hydration process, which improves the water resistance of the material.

3.3. Effect of Polyurethane Foam Waste

The effects of polyurethane foam waste on the thermal conductivity and density of gypsum board was investigated. The results are shown in Table 1.
Table 1. Effect of Waste Polyurethane Foam on Gypsum Performance.

| Content/% | Density/kg·m⁻³ | Thermal conductivity/W·m⁻¹·K⁻¹ | Flexural strength/MPa | Compressive strength/MPa |
|-----------|----------------|--------------------------------|-----------------------|--------------------------|
| 0         | 1100.85        | 0.3300                          | 11.50                 | 24.10                    |
| 8         | 849.02         | 0.1086                          | 6.70                  | 2.40                     |
| 10        | 762.30         | 0.0980                          | 5.30                  | 2.10                     |

It can be seen that the incorporation of polyurethane foam waste has a great influence on the thermal insulation performance and density of gypsum materials. With the increase of the dosage of polyurethane foam waste, the thermal insulation performance is improved, the density is lowered, and the strength is also reduced. The appropriate dosage is 10%, in this case, the performance is superior to the relevant counterpart materials.

3.4. Proportioning and performance of Lightweight Plaster

The proportioning of plastering gypsum is obtained with the mass ratio of Calcined desulfurization gypsum: modified waste polyurethane foam: auxiliary agent= 82.13:10:7.87. The main performance of the lightweight plaster is shown in Table 2.

Table 2. Main performance of plastering gypsum.

| Density/kg·m⁻³ | Thermal conductivity/W·m⁻¹·K⁻¹ | Setting time/min | Dry strength/MPa | Water resistance increase/% |
|----------------|--------------------------------|------------------|------------------|----------------------------|
| 762.30         | 0.0980                          | Initial setting time | final setting time | Flexural strength | Compression strength |
|                |                                 | 150              | 205              | 2.1                       | 5.3                     | 26.47                  |

4. Conclusion

1) Using various industrial solid wastes, a kind of lightweight plastering gypsum material with good thermal insulation, good operability, crack resistance and water resistance was prepared. It can be used as a plastering material for the interior wall of multi-storey and high-rise buildings. The addition of polyurethane foam waste can effectively improve the indoor temperature stability and comfort. With low cost and good benefit, it has good prospects for promotion.

2) Modification of polyurethane foam waste by adding water glass, the problem of mixing evenness of waste polyurethane foam and other materials is solved. After being used to prepare plastering gypsum, the thermal conductivity of the material was reduced, the energy saving effect of the building was improved, and the reasonable disposal of waste polyurethane foam was also achieved.

3) The additive in the formulation plays important role in control the setting time of the plastering gypsum. Besides, in the hydration gypsum, it helps generate a large amount of ettringite and calcium silicate hydrate in the hydration process, which improves the water resistance of the material. Compared with cement-based and ordinary gypsum materials, the performance is excellent.

References

[1] Feng Chunhua, Chen Miaomiao, Li Dongxu. Effect of Retarder on Properties of Flue Gas Desulfurization Calcined Gypsum[J]. Bulletin of the Chinese Ceramic Society, 2014, 33 (05):1231-1235.

[2] Kyung J C, Kyung S Y, Kyong T K. Characteristics of gypsum crystal growth over calcium-based slurry in desulfurization reactions[J]. Materials Research Bulletin, 1997, 32 (2): 197-204.

[3] Cao Xiaomei, Zhai Xiaofang, Qian Zhongqiu, Wu Kaisheng. Research Progress in Building Gypsum Retarder[J]. Materials Reports, 2013, 27(S2): 298-301.

[4] Peng Jiahui, Zhang Jianxin, Chen Mingfen. Effects of Sodium Tripolyphosphate on crystal growth habit and morphology of dihydrate. Journal of the Chinese Ceramic Society, 2006, 32(6): 723-727.
[5] Chen Xiongmu, Li Lingxiao, Zhao Fengqing. Effect of waste metallurgical slags on the retarding characteristics of β-semi-hydrated gypsum and the mechanism[J]. Chemical Industry and Engineering Progress, 2018, 37(12): 4924-4931.

[6] Yu Haiyan, Li Yongqiang, Wang Lei. Effect of modified materials on physical and mechanical properties of desulfurized gypsum and its mechanism[J]. Journal of Henan University of Urban Construction, 2019(04): 45-53.

[7] Chen Yong, Jie Pengyang. Study on Modified Phosphorus Building Plaster Using Ground Steel Slag[J]. Jiangxi Building Materials, 2018(09): 29+32.

[8] Yu Shibin, Chen Yongjin, Pan Wen. Study on Modified Phosphorus Building Plaster Using Ground Steel Slag[J]. Non-Metallic Mines, 2018, 41(05): 48-49.

[9] Ma Baoguo, Sun Zhongda, Su Ying, Jinzhao, Zhulu. Mechanism Research of Phosphor Building Gypsum with Retarder Modified[J]. Bulletin of the Chinese Ceramic Society, 2017, 36(12): 3978-3983+3992.

[10] Li Han, In metope paint the plaster the application of the system. Technology and Market, 2012, 3(19): 3-4.

[11] Chen Mimi, Zhang Mengmeng, Zhao Fengqing. Combined production of gypsum retarder and activated carbon from waste penicillin mycelium. Chinese Journal of Environmental Engineering, 2017, 11(6): 3747-3752.

[12] SINGH M, GARG M. Retarding action of various chemicals on setting and hardening characteristics of gypsum plaster at different pH[J]. Cement and Concrete Research, 1997, 27(6): 947-950.

[13] Fang Xiuhua. New Developments in Polyurethane Foams. Polyurethane industry, 2000(04): 6-10.