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Experimental Study on the Mechanical Properties of Desulfurized Gypsum Foam Concrete

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Abstract

Desulfurized gypsum foamed concrete is one of the hot research and development fields at present, and has broad application prospects in the field of construction engineering and environmental protection. Firstly, the desulfurized gypsum foam concrete uses the waste gypsum resources as the main raw materials, which has the characteristics of environmental protection and sustainable; Secondly, FGD gypsum foamed concrete shows superior compressive strength and bending strength, and has good mechanical properties, which is suitable for structural and non-structural applications. At the same time, desulfurized gypsum foamed concrete also shows excellent thermal insulation, fire resistance and sound insulation properties. The purpose of this study is to evaluate the mechanical properties of desulfurized gypsum foam concrete. The key indexes such as compressive strength, bending strength, deformation characteristics, water absorption and thermal conductivity of FGD gypsum foamed concrete were studied by means of experiments. The experimental results show that FGD gypsum foamed concrete has good mechanical properties and certain durability, which is suitable for construction industry and other applications.

Keywords

Desulfurized Gypsum Foam Concrete; Mechanical Properties; Compressive Strength; Water Absorption; Thermal Conductivity.

1. Introduction

As a new type of building material, desulfurized gypsum foamed concrete has obvious advantages in environmental protection and energy saving. In the past few decades, gypsum foam concrete has been widely studied and applied, but at present, there are few researches on mechanical properties of desulfurized gypsum foam concrete. Therefore, the purpose of this study is to systematically study the mechanical properties of desulfurized gypsum foamed concrete by experimental means, and to provide a certain reference for its practical applica.

2. Experimental Method

Material preparation: desulfurized gypsum, foaming agent (hydrogen peroxide), cement, foam stabilizer, water reducing agent, and admixture (fly ash, polypropylene fiber).

2.1 Desulfurized Gypsum

The desulphurized gypsum used in this study is the desulphurized building gypsum.

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2.2 Fly Ash

He fly ash used in this research is Class II fly ash, which is produced by Zhengzhou Gongyi Longze Material Co., LTD.

2.3 Polypropylene Fiber

The polypropylene fiber used in this study is produced by Changsha Linxiang Building Materials Co., LTD. The length of polypropylene fiber used is 6mm.

2.4 Blowing Agent

The blowing agent used in this study is hydrogen peroxide (H2O2), which is produced by Liyang Dadi New Material Co., LTD.

3. Experimental Design

The sample of desulfurized gypsum foamed houcoagulant was prepared and cured. The compressive strength, bending strength, water absorption and thermal conductivity of the sample were tested and measured respectively, and the deformation characteristics were recorded after the test.

3.1 Compressive Strength

The size of the compressive strength specimen is 100mm×100mm×100mm. According to the current national building materials industry standard "Foam concrete Block" JC/T1062[66], the compressive strength of the desulfurization gypsum foam concrete was measured at 28 days of age under the condition of standard curing (temperature 20±2°C, relative humidity above 95%). When measuring, put the test block into the pressure testing machine to start the machine, start fast, and then slow down the measurement. Finally, when the value on the pressure test machine has been stable in the negative case, the reading result is the compressive strength of the sample. As shown in equation (1):

$$f = \frac{F}{A} \tag{1}$$

Where: f -- compressive strength of the specimen (MPa), the exact value of the result is 0.1MPa;

F -- failure load of specimen (N);

A -- specimen pressure section area (mm2);

Set the loading rate as 0.5MPa/s, and take the average value of each group as the final compressive strength.

3.2 Water Absorption

According to the national building materials industry standard "foam concrete block" JC/T1062, the volume water absorption of desulfurized gypsum foam concrete was measured. Take out the test block after drying and protect the water under standard curing conditions (the water temperature is 20±2°C), take out after curing for 24h, wipe the surface water, weigh it, and calculate the water absorption. As shown in Equation 2:

$$W = \frac{m_b - m_0}{m_0} \times 100\% \tag{2}$$

Where: W -- specimen mass water absorption (%);

m_b -- mass of specimen after saturated water absorption (kg);

m_0 -- mass of the specimen after absolute drying (kg);

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The average value of each group is the final water absorption.

3.3 Thermal Conductivity

The specimen cured for 28d was put into a drying oven for drying at a temperature of 60±5℃, and when it was dried to a constant temperature, it was put into a thermal conductivity meter for measurement. According to the current national standard "Determination of steady-state thermal resistance of thermal insulation materials and related characteristics of protective hot plate method" GB/T10294[68], the average test temperature is 25℃, the temperature of hot plate and cold plate are 35℃ and 15℃ respectively, and the average value of each group is the final thermal conductivity.

4. Sample Preparation

Desulfurized gypsum foamed concrete was prepared by hydrogen peroxide (H2O2) chemical foaming. Firstly, desulfurized gypsum, fly ash, Portland cement, powdered polycarboxylic acid superplasticizer and calcium stearate were weighed and put into a mixer for 2min at a constant speed until the powdered material was uniform. Weigh the retarder, activator and hydrophobic agent, melt them in water at a temperature of about 40℃, and stir the stirred powder material in warm water at a constant speed until uniform, and then pour hydrogen peroxide into the slurry to stir quickly, and quickly put them into the mold; Make concrete foam forming at room temperature, in order to prevent water evaporation, put plastic wrap and wait for 24h; After the specimen solidified, the excess foam concrete from the formed foam concrete was sawed off with a saw and demoulded, wrapped with plastic wrap and placed in a curing box for 7 days and 28 days.

5. Experimental Measurement

A press was used to measure the compressive strength of the sample, a bending tester was used to measure the bending strength of the sample, a water immersion test was used to measure the water absorption performance of the sample, and a thermal conductivity meter was used to measure the thermal conductivity of the sample. The deformation characteristics of concrete were observed after the experiment.

5.1 Compressive Strength

In this test, the content of fixed foaming agent is 0.01g/cm3, the content of water reducing agent is 0.008g/cm3, and the content of foam stabilizing agent is 0.012g/cm3. Liu Tongwei et al. [69] prepared light thermal insulation material based on desulphurized gypsum with a large content of desulphurized gypsum as the matrix. In this experiment, the content of desulphurized gypsum in the single content test was determined through preliminary tests: 95%, 85% and 75% of the remaining parts are supplemented by Portland cement. The compressive strength of 28d is shown in 1, and the compressive line diagram drawn by Origin drawing software is shown in 1.

Table 1. Compressive strength of foamed concrete under different desulfurized gypsum content

Serial number	Desulfurization gypsum content (%)	Compressive strength (Mpa)
1	75	3.57
2	85	3.33
3	95	3.06

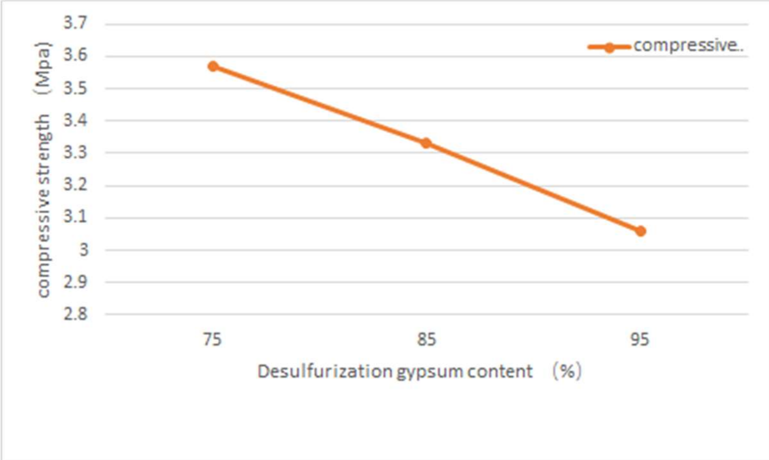

Fig. 1 Effect of desulfurization gypsum content on the compressive strength of foam concrete

5.2 Water Absorption

Desulphurized gypsum, as an air-set inorganic cement-forming material, absorbs water when it exists in a humid environment, resulting in the dissolution of pure desulphurized gypsum system. However, the addition of Portland cement can improve the desulphurized gypsum system, and the combination of cement and desulphurized gypsum can effectively block water molecules and improve the water absorption of desulphurized gypsum. The influence of desulfurized gypsum content on water absorption of foamed concrete is shown in Table 2 and Fig. 2.

Table 2. Water absorption rate of foamed concrete under different desulfurized gypsum content

Serial number	1	2	3
Desulfurization gypsum content, %	65	75	85
Water absorption, %	20.35	23.9	26.15

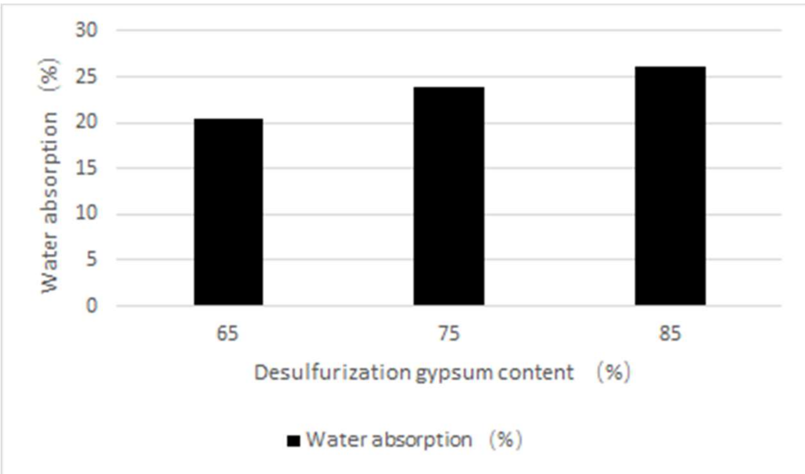

Fig. 2 Influence of desulfurization gypsum content on water absorption of foamed concrete

5.3 Thermal Conductivity

The thermal conductivity test results of desulfurized gypsum foamed concrete are shown in Table 3, and the thermal conductivity range analysis of desulfurized gypsum foamed concrete is shown in Table 3.

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Table 3. Thermal conductivity of desulfurized gypsum foamed concrete

Test number	Experimental factor			Thermal conductivity, W/(m·K) A
	A Desulfurized gypsum, %	B Fly ash, %	C Polypropylene fiber, %	
T1	65	5	0.2	0.144
T2	65	10	0.3	0.142
T3	65	15	0.4	0.137
T4	75	5	0.3	0.140
T5	75	10	0.4	0.141
T6	75	15	0.2	0.139
T7	85	5	0.4	0.149
T8	85	10	0.2	0.137
T9	85	15	0.3	0.152

Table 4. Analysis of thermal conductivity range of desulfurized gypsum foamed concrete

Orthogonal test	factor	K_{1j}	K_{2j}	K_{3j}	Range R	Primary and secondary order	Optimal combination
Thermal conductivity	A	0.141	0.140	0.146	0.006	A >C >B	$A_1B_2C_1$
	B	0.144	0.140	0.143	0.004		
	C	0.140	0.145	0.142	0.005		

It can be seen from Table 4 that the order of the range values of the three different factors on the thermal conductivity is R_A>R_C>R_B, that is, the main influencing factors on the thermal conductivity of desulfurized gypsum foamed concrete are A(desulfurized gypsum), and the secondary factors are C(polypropylene fiber) and B(fly ash). The order among the levels of each factor is ,A_3>A_1>A_2 B_1>B_3>B_2, C_1>C_2>C_3. A2 is the optimal level value in factor A, B2 is the optimal level value in factor B, and C1 is the optimal level value in factor C. Therefore, the best combination of A1B2C1 three factors in water absorption is 75% desulfurization gypsum, 10% fly ash, 0.2% polypropylene fiber. In order to more intuitively analyze the influence of three factors on the thermal conductivity of desulfurized gypsum foamed concrete, a line diagram of the relationship between each factor and water absorption is drawn, as shown in Fig. 3.

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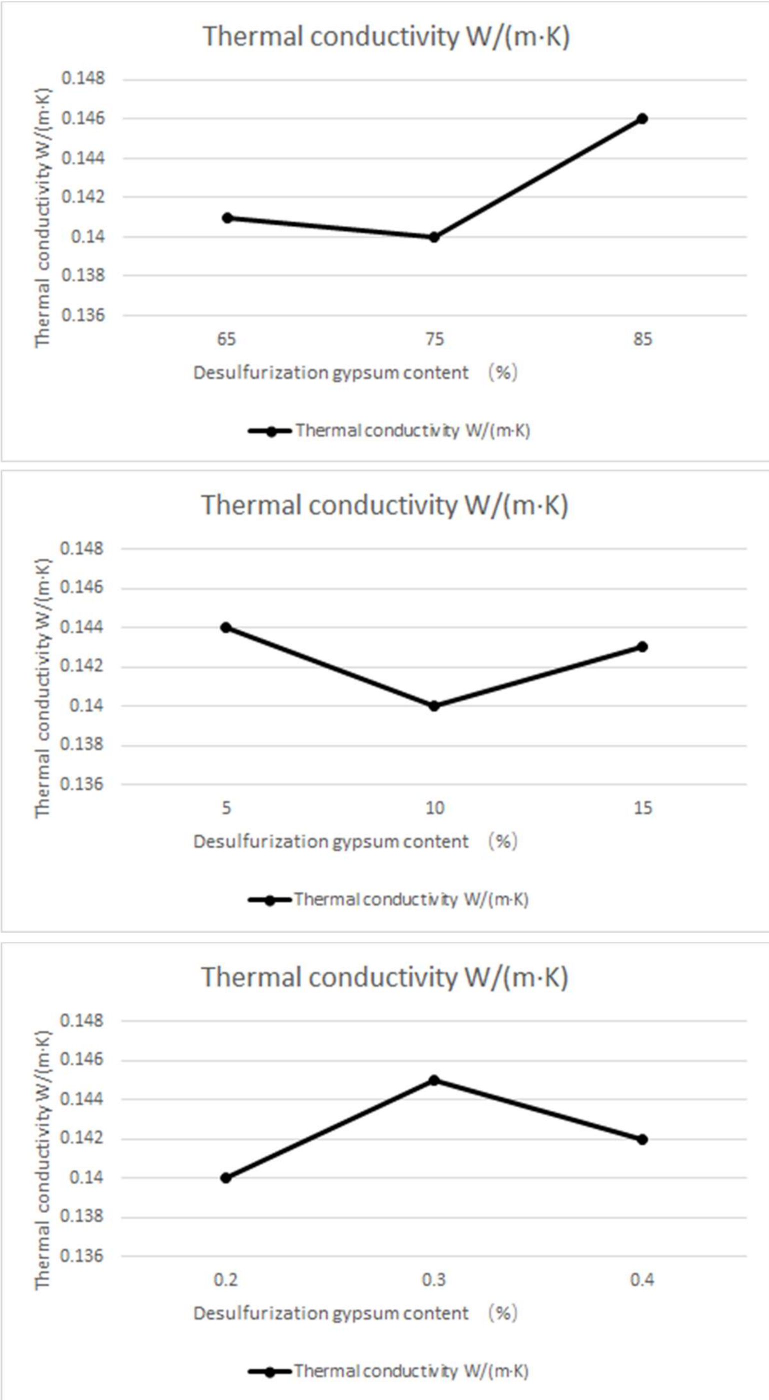

Fig. 3 Influence of desulfurization gypsum content on water absorption of foamed concrete

6. Results and Discussion

6.1 Compressive Strength

With the increase of desulfurized gypsum content, the 28d compressive strength of desulfurized gypsum foamed concrete shows a decreasing trend. When the desulfurized gypsum content is 75%, the maximum compressive strength of desulfurized gypsum foamed concrete is 3.57MPa. When the content of desulfurized gypsum is reduced from 95% to 75%, there is a rising trend of pressure resistance, because there is less cement in the gelling system. The desulfurized gypsum foamed concrete is mainly supported by desulfurized gypsum, and its hydration product is only calcium sulfate dihydrate, with low strength. However, with the increase of Portland cement, cement participates in the hydration reaction, and the hydration products increase, which makes the gelling

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system structure more tight and firm, so it will improve the mechanical properties of desulfurized gypsum foamed concrete.

6.2 Water Absorption

As can be seen from Figure 2, the water absorption rate gradually increases with the increase of desulphurized gypsum. When the content of desulphurized gypsum is 75%, the water absorption rate of desulphurized gypsum foamed concrete reaches the lowest value of 20.35%. It is attributed to the fact that desulphurized gypsum itself is a porous material, which is a material with strong water absorption. When the content of desulphurized gypsum is small, under the hydration reaction with Portland cement, the hydration product ettringite and hydrated calcium silicate gel can fill the pores and play a barrier role. However, with the increase of desulfurization gypsum content, the hydration reaction caused by the reduction of cement also decreases, resulting in the increase of water absorption. With the increase of desulfurization gypsum content, the slurry thickens, resulting in uneven distribution of bubbles, and the existence of large bubbles also leads to the increase of water absorption. Therefore, for the water absorption of foamed concrete with desulfurized gypsum, the optimal content of desulfurized gypsum is 75%.

6.3 Thermal Conductivity

Content of desulphurized gypsum.

It can be seen from Figure 3 that the thermal conductivity decreases first and then increases with the increase of desulphurized gypsum. When the content of desulphurized gypsum is between 65% and 75%, the thermal conductivity gradually decreases and reaches the minimum value of 0.140W/(m·K) when the content of desulphurized gypsum is 75%. Due to the porous nature of desulfurized gypsum itself, a large amount of water evaporates inside the hardened desulfurized gypsum, so that there is a large porosity inside the desulfurized gypsum, and in this section, the fluidity of the slurry is relatively large, the generated bubble distribution is relatively uniform, so that the thermal conductivity of desulfurized gypsum foam concrete is reduced. However, with the increase of desulfurization gypsum content, the consistency of slurry increases, the fluidity decreases, resulting in large and uneven distribution of bubbles, and the decrease of porosity leads to the increase of thermal conductivity. Therefore, the optimum content of desulfurized gypsum is 75%.

Fly ash content.

As can be seen from Figure 3, the thermal conductivity of desulfurized gypsum foamed concrete gradually decreases with the increase of fly ash content, and the thermal conductivity reaches the minimum value of 0.140W/(m·K) when the fly ash content is 10%. Fly ash itself is a glass ball with a smooth appearance and small particle size, which can be well dispersed in the slurry, effectively improving the fluidity of the slurry, making the generated bubbles evenly distributed in the foamed concrete slurry, and increasing its porosity [83]. Therefore, with the increase of fly ash content, the thermal conductivity of desulfurized gypsum foamed concrete gradually decreases. Therefore, the optimum content of fly ash is 10%.

Polypropylene fiber content.

As can be seen from Figure 3, with the increase of polypropylene fiber content, the thermal conductivity decreases first and then increases. When the polypropylene fiber content is 0.3%, the thermal conductivity reaches the minimum value of 0.140W/(m·K), and when the content is 0.2%~0.3%, the appropriate amount of polypropylene fiber will introduce air into the slurry during the mixing process. The presence of bubbles formed by air and blowing agent increases the porosity and decreases the thermal conductivity. When the content exceeds 0.3%, a large amount of fiber will lead to uneven distribution of bubbles inside FGD gypsum foamed concrete, blockage of pores, decrease of heat conduction capacity, and increase of thermal conductivity [84]. Therefore, the optimum content of polypropylene fiber is 0.3% in terms of thermal conductivity.

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7. Conclusion

Through the experimental research, we can draw the following conclusions:

1) Desulfurized gypsum foam concrete has good mechanical properties and shows obvious advantages in compressive strength.

2) The use of admixtures has a certain effect on the mechanical properties of FGD gypsum foamed concrete, and different proportions of admixtures may lead to different performance changes.

3) Desulfurized gypsum foam concrete has low water absorption performance, which is of great significance for the durability of the material and the thermal insulation performance.

4) Thermal conductivity is one of the key indicators to evaluate desulfurization gypsum foamed concrete in building insulation, and the research results show that it has a low thermal conductivity, which is expected to play an important role in energy saving.

8. Suggestions for Further Research

1) On the basis of experimental research, the durability of desulfurized gypsum foamed concrete can be evaluated in more detail, including freeze-thaw cycle test and chemical corrosion test.

2) Refine the influence of different admixture proportions and preparation proportions on the mechanical properties of desulfurized gypsum foamed concrete, and find out the best ratio scheme.

3) Further study the engineering application performance of desulfurized gypsum foamed concrete and explore its wide application in the field of building materials.

4) Establish a numerical model of desulfurized gypsum foamed concrete, predict its mechanical properties, and simulate its strength, stiffness and deformation.

9. Summary

As a new type of building material, FGD gypsum foamed concrete has good mechanical properties, especially in compressive strength, bending strength, water absorption and thermal conductivity. The experimental research provides important scientific basis and technical support for the application of desulfurized gypsum foamed concrete, and also provides beneficial exploration direction for further optimization of material ratio and development of new building materials.

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