

# Study on the effect of EPS particles and glass fiber on the properties of phosphogypsum

Kunpeng Deng\*, Changbing Chen

Institute of Urban construction and transportation, Hefei University, Hefei 230601, China

\* Corresponding Author Email: 1596280430@qq.com

**Abstract.** Polystyrene (EPS) particles have the properties of light weight, low cost, smooth and small density. The presence of glass fiber (GF) can significantly improve the toughness and fracture resistance of the material. By adding EPS particles and glass fiber into phosphogypsum, the influence of EPS particle content and glass fiber content on the properties of phosphogypsum was studied, and the phosphogypsum composite with light weight and strong toughness was prepared.

**Keywords:** phosphogypsum, glass fibre, Flexural Strength, compressive strength.

## 1. Introduction

Phosphogypsum is an industrial byproduct formed during the production of wet phosphoric acid, Its production is 4-6 times that of phosphoric acid<sup>[1]</sup>, and its main component is calcium sulfate dihydrate (CaSO<sub>4</sub>·2H<sub>2</sub>O), There is still a lot of dirt. Including water-soluble phosphorus Water insoluble phosphorus, Eutectic phosphorus, Water soluble fluorine, Insoluble fluorine and organic impurities<sup>[2-3]</sup>. At present, the accumulation of phosphogypsum in China is extremely large, and there is a lack of effective recycling and utilization technology. Due to the long-term pollution of phosphogypsum, not only a large amount of soil has been seriously eroded, but also the local ecosystem has been seriously damaged, which has brought great harm to human health and life<sup>[4]</sup>. Therefore, it is important to improve the integrated use of phosphogypsum. At present, the main field of comprehensive utilization of phosphogypsum in China is the building materials industry, which is mainly used to produce cement retarder and building phosphogypsum<sup>[5]</sup>.

The lightweight of gypsum can be achieved by adding light EPS particles into the calcined phosphogypsum<sup>[6]</sup>. Combining lightweight EPS particles with phosphogypsum can develop lighter building materials<sup>[7-8]</sup>. Therefore, the incorporation of GF in phosphogypsum slurry can inhibit the floating of EPS particles, and improve the pressure resistance and crack resistance of gypsum board.

## 2. Test section

### 2.1. Raw materials

Phosphogypsum is an industrial by-product of Hefei Sifang Environmental Protection New Material Co., Ltd. The EPS particles are purchased from the HSBC foam particle factory store. The particle diameter is 3-5mm, the density is 0.012g / cm<sup>3</sup>, and the flexibility is light and elastic. Glass fiber is a product produced by Hefei Xinke Glass Fiber Products Co. Ltd. Its main components are silica, alumina, etc. with high tensile strength and good elasticity coefficient. The physical properties are shown in Table 1.

**Table 1.** Physical properties of glass fiber

length (mm)	fiber diameter ( $\mu$ m)	elastic modulus (MPa)	density (g/cm <sup>3</sup> )	tensile strength (MPa)
15	6-24	4286	2.4-2.7	1000-2000

### 2.2. Material mixture ratio

The effects of EPS particle content and GF content on the properties of EPS particle / phosphogypsum composites were studied by designing EPS particle content and GF content with different mix ratios.

**Table 2.** Test Design Table

experimental group number	1	2	3	4	5	6
EPS particle content	0.0%	0.2%	0.4%	0.6%	0.8%	1.0%

**Table 3.** Test Design Table

experimental group number	1	2	3	4	5	6	7	8
proportion of glass fiber	0.2%	0.4%	0.6%	0.8%	1.0%	1.2%	1.4%	1.6%

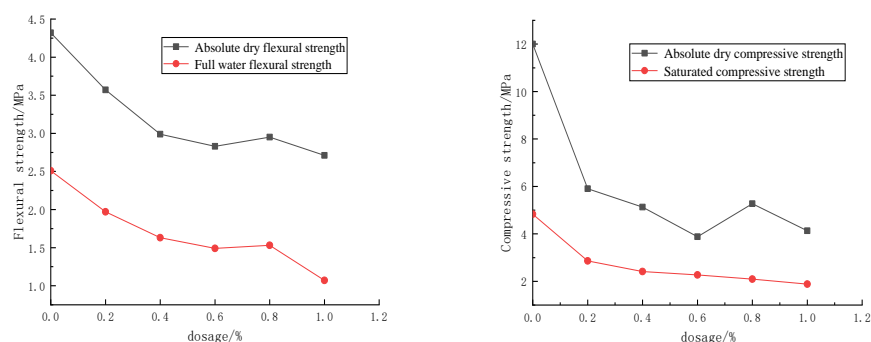
### 2.3. Experimental test

Samples were placed in a drying oven at 120°C, kept at a constant temperature for 7 days, and weighed after the quality of the samples stabilized. After weighing, use the formula to calculate the apparent density of the sample and take the average value. Then tests were carried out for flexural strength and compressive strength, as well as flexural strength and dry compressive strength. Take 3 samples from each group and place them in water so that the water depth on the surface of the samples is at least 5 mm. After absorbing water for 4 hours, completely absorb the moisture of the sample, and then wipe the moisture from the surface of the sample with a damp cloth.

## 3. Results and Analysis

### 3.1. The effect of EPS particle content on the performance of phosphogypsum

The effect of EPS content on the strength and performance of phosphogypsum specimen is shown in the figure below.

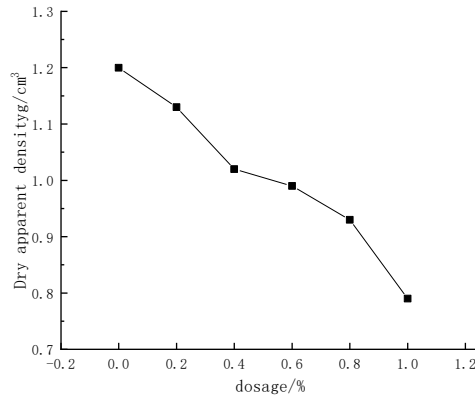


(a) Effect of EPS on flexural strength      (b) Effect of EPS on compressive strength

**Fig. 1** Effect of EPS content on flexural strength and compressive strength of phosphogypsum specimens

It can be seen from Fig.1 ( a ) and ( b ) that when the amount of EPS particles added increases, the strength of the composite material will be significantly weakened. With the increase of the proportion of EPS particles to 0.6 %, the flexural strength of the composite material has a slight increase, which is 1.81 MPa and 4.43 MPa respectively when the content is 0.2 %. When the content is 0.8 %, the dry compressive strength and saturated compressive strength are 5.63 MPa and 2.17 MPa, respectively. However, with the increase of EPS particle content, the gypsum slurry wrapped around it will

decrease. EPS particles are light in weight and low in strength, mainly filling in gypsum slurry. Therefore, the more EPS particles in the composite, the lower the strength. Therefore, with the increase of EPS particles, the strength of the specimen will decrease accordingly. When the content of EPS particles is 0.8 %, the shell structure of EPS particles is better protected, so that the strength of the composite material is improved.

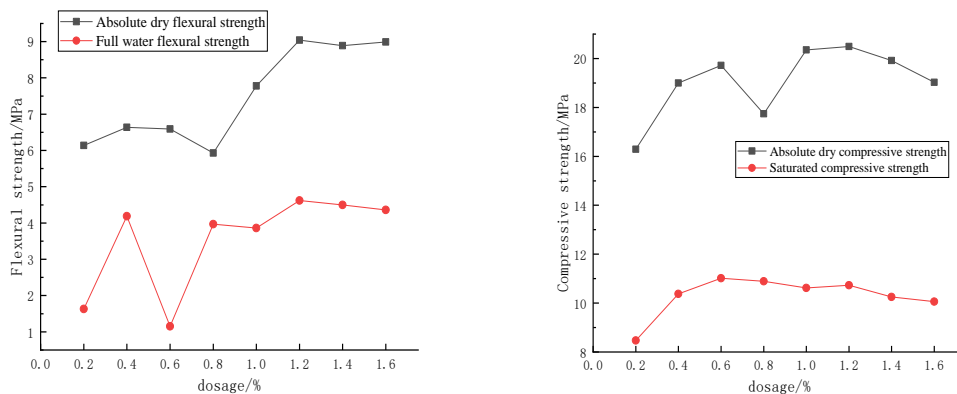


**Fig. 2** Effect of EPS content on dry apparent density of phosphogypsum specimens

It can be seen from Fig.2 that the incorporation of EPS particles will significantly change the dry apparent density of the composites. As shown in the above figure, the amount of EPS particles is inversely proportional to the dry apparent density. Because the density of EPS particles is lower than that of gypsum, when the content increases, the gypsum slurry wrapped by them decreases significantly. Therefore, the more the number of EPS particles, the less the number of gypsum slurry. When the incorporation of EPS particles reached 1.0 %, the dry apparent density of the composites reached a minimum of 0.763 g/cm<sup>3</sup>, which decreased by 36.9% compared with EPS particles. When the addition amount reaches 0.8 %, the dry apparent density of the composite is reduced to 0.947 g/cm<sup>3</sup>, which is 21.7 % lower than that of a small amount of EPS particles. After comparison, When EPS particles were 0.8%, the strength of the composites increased significantly, while the dry apparent density decreased by 36.9 %. Therefore, considering the strength and dry apparent density of the composites, the optimum incorporation ratio should be 0.8 %.

**3.2. Effect of GF content on the performance of phosphogypsum**

The effect of GF content on the strength performance of phosphogypsum specimens is shown in Figure 3.

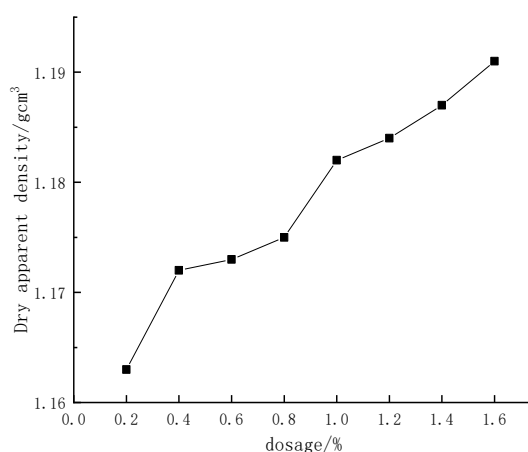


(a) Effect of GF on flexural strength      (b) Effect of GF on compressive strength

**Fig. 3** Effect of GF content on flexural strength and compressive strength of phosphogypsum specimens

It can be seen from Fig.3 that with the increase of GF content, the flexural strength and compressive strength of EPS particles / phosphogypsum composites will increase, and this trend shows a fluctuating characteristic. When the content of GF is 1.2 %, the strength performance of the composite material reaches the highest. If the content is 0.6%, the saturated compressive strength is 11.37 MPa, which is 35.06 % higher than that when the content is 0.2 %. When the content of GF is 0.8 %, the strength of the composite material increases significantly, and there are obvious changes. In addition, when glass fiber is mixed with EPS particles / phosphogypsum composites, on the one hand, it can inhibit the floating of EPS particles by wrapping them, so that they can be better dispersed in phosphogypsum suspension and improve the comprehensive performance of the composites. On the other hand, it can pull the phosphogypsum suspension and EPS particles together to form a fiber-EPS particle-phosphogypsum skeleton. When the composite material is stressed, it can prevent the formation of cracks. However, if the glass fiber content is too much, the fibers are easy to gather together, resulting in uneven stress of the composite material, thereby reducing the strength.

Due to the weak water absorption of GF, the incorporation of GF will reduce the water content of the phosphogypsum slurry, thereby reducing its fluidity. With the increase of GF incorporation, its fluidity will be further reduced, and finally the strength of the composite material will be greatly reduced. If the addition amount of GF is less than 0.8 %, although the fluidity of phosphogypsum slurry is very good, the adhesion between GF and slurry becomes weak due to its large amount of water, which will have a negative impact on the strength of the composite and reduce its strength. If the content of GF exceeds 0.8 %, the poor fluidity of phosphogypsum slurry will have a negative effect on the overall strength, but this negative effect is not as good as the positive effect brought by the fiber itself, so the strength of the composite material will still increase. Mixing GF with EPS particles /phosphogypsum can significantly improve the mechanical properties of the composites. It can also effectively prevent the floating of EPS particles, so as to better mix EPS particles in phosphogypsum slurry and improve the overall performance of the composite material.



**Fig. 4** Effect of GF content on dry apparent density of phosphogypsum specimens

From Fig. 4 it can be seen that the dry apparent density is proportional to the increase of GF content. That is, with the increase of GF content, the dry apparent density will always increase. The density of GF is greater than that of phosphogypsum, and its bundle monofilament structure can effectively fill the gap of phosphogypsum slurry, thus, it is possible to increase the dry apparent density of the composite to obtain superior structural performance. With the increasing amount of GF added, the fluctuation trend of the curve is also gradually rising. When the content of GF reaches 1.2 %, The bending strength, compression strength and dry apparent density of the composites reach optimum condition. At this time, the overall performance is excellent and can be identified as the optimal content.

## 4. Conclusions

1. When the EPS content is 0.8 %, A significant improvement in the strength of the composite, and a 36.9% reduction in the dry apparent density. Therefore, considering the strength and dry apparent density of the composites, the optimum incorporation ratio should be 0.8 %.

2. The addition of glass fiber into EPS particles / phosphogypsum composites can increase the strength and toughness of the material, and can inhibit the floating of EPS particles, and the optimal content is 1.2 %.

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