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Effect of Diatomite on Thermal Insulation Properties of Straw Fiber Cement-based Composites

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Abstract. This paper mainly studies the effect of Diatomite Content on the thermal insulation performance of straw fiber cement-based composites. The test shows that 30% sulphoaluminate cement is replaced by ordinary Portland cement. XRD test showed that the diffraction peaks of Ca $(OH)_2$ and Ettringite were stronger than those of ordinary Portland cement, and the crystallization effect was better. The compressive strength and flexural strength increased by 7.6% and 20% respectively. With the increase of diatomite content, the dry density and thermal conductivity of the composite decreased. When diatomite content was 25% of the total cementitious material, the dry density of the composite was 1068.37 kg/m^3, and the thermal conductivity could reach 0.1163 W/(m.K). The thermal insulation performance of the composite could be significantly improved by adding diatomite.

1. Introduction

Straw fiber is a renewable green energy. According to statistics, the average annual output of straw in China is about 900 million tons[1], which brings serious social problems and brings great harm to the environment in open-air burning of straw in rural areas. Straw fiber is a typical fibrous thermal insulation material because of its wide specific strength, high specific length and diameter, and good thermal insulation performance. Diatomite is a kind of biosiliceous rock formed by the remains of single-cell algae deposited for hundreds of millions of years. It is a microporous material with good thermal insulation[2]. The diatomite in China has a huge reserves. The surface of the treated diatomite has a large number of nano-scale channels. The micro-porous structure of diatomite has excellent thermal insulation performance. This experiment will study the effect of low-grade diatomite mixed with composite cement on the thermal insulation performance of straw fiber cement-based composite board.

2. Test process

2.1 Test Material

Cement: sulphoaluminate cement with strength grade 52.5 and ordinary Portland cement; water reducing agent: polycarboxylic acid series superplasticizer with water reducing effect of 25%; fly ash: grade II fly ash; silica fume: SiO_2>90%; slag: specific surface area of 1.0373 m^2/g; straw fiber: common annual reed straw of Jilin Province, straw The length of culm fibers was controlled at 5-10 mm and 10-25 mm in two different lengths. Diatomite: The third grade original soil in Linjiang area, Jilin Province, is grinded for 20 minutes and then calcined at 600℃ for 2 hours to be reserved. The related hysical and chemical properties are shown in Table 1.

Table 1. Physicochemical Properties and Component Analysis of Diatomite

Bulk density (g/cm³)	Pore radius (nm)	specific surface area (m²/g)	chemical composition (%)				
			SiO_2	Al_2O_3	Fe_2O_3	CaO	Other
2.4	100-600	20.1376	80.13	5.45	1.23	0.53	12.66

2.2 specimen preparation and testing

Sulphoaluminate cement and ordinary Portland cement were mixed to make composite cementitious materials. Sulphoaluminate cement accounted for 0%~50% of the new cementitious materials and six equivalent gradients were labeled as P_1~P_6, respectively. According to the proportion of cement: quartz sand: water = 1:3:0.5, put into the mortar mixer, mix evenly and then put the mortar into the 40 mm×40 mm×160mm test model. After 24 hours, demoulding was maintained in standard environment for 28 days.

Straw accounted for 30% of the total mass, and diatomite accounted for 0%~25% of the total mass of cementitious materials. Six gradients were labeled C_0~C_5 respectively. Straw, diatomite, fly ash, silica fume, slag and composite cement were mixed evenly according to the mass ratio, and finally the mixture was put into the prepared 300 mm×300 mm×30 mm test model, and the test model was normal. After pressing at temperature for 6 hours, the composite material was demoulded and cured for 28 days at (30±2) ℃, and (60~80)% relative humidity.

The test of cement strength, initial setting time, final setting time, dry density and thermal conductivity refer to GB/T 17671 "Testing method for strength of cement mortar (ISO method)", GB/T 1346 "Testing method for water consumption, setting time and stability of cement standard consistency", GB/T 5486.2 "Testing method for inorganic rigid adiabatic sheeting", GB/T 1029 "Testing and prevention of steady thermal resistance and related properties of adiabatic materials". Relevant standards such as heat shield plate method are tested.

3. Test results and discussion

3.1 Strength and setting time of composite cementitious materials

The composite cementitious material with strength grade 52.5 was prepared by mixing sulphoaluminate cement and Portland cement in different proportions. The 28-day strength test results are shown in Fig. 1 and Fig. 2, and the setting time is shown in Fig. 3.

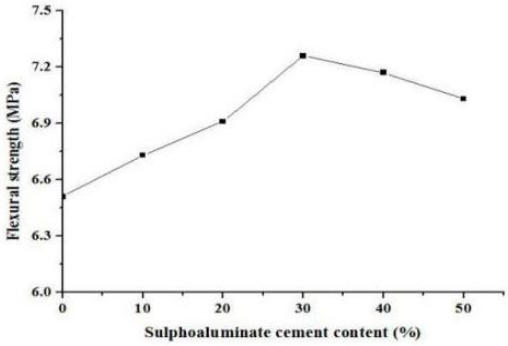

Fig 1.Effect of Sulphoaluminate Cement Content on Flexural Strength of Composite Cementitious Material

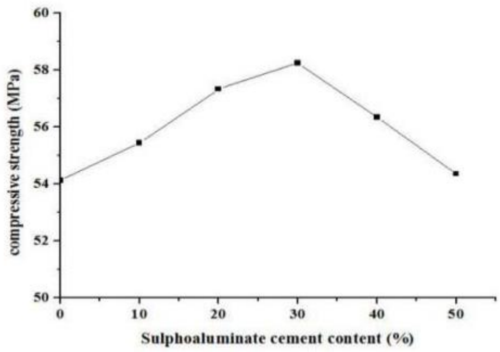

Fig 2.Effect of Sulfoaluminate Cement Content on Compressive Strength of Composite Cementitious Material

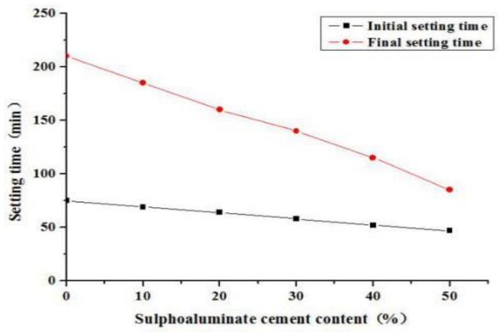

Fig 3.Effect of Sulphoaluminate Cement Content on Setting Time of Composite Cementitious Material

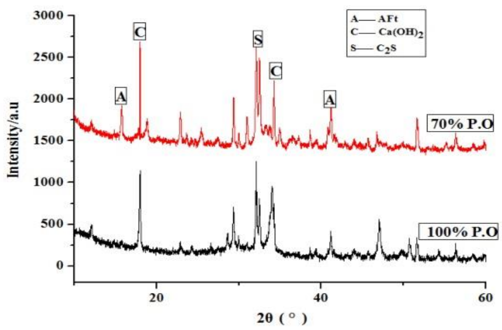

Fig 4. XRD Spectrum of Hydrated Portland Cement and Composite Cementitious Material

Fig. 1 and figure 1 show that the flexural strength and compressive strength of composite cementitious materials increase first and then decrease with the increase of the content of sulphoaluminate cement in composite cementitious materials. When the content of sulphoaluminate cement is 30%, the flexural strength reaches the maximum of 7.26 MPa and the compressive strength reaches the maximum of 58.25 MPa. Compared with ordinary Portland cement, the compressive strength and flexural strength increase by 7.6% and 20%, respectively. % Fig. 3 shows that the addition of sulphoaluminate cement shortens the initial setting time and final setting time of cement, and the time interval between initial setting and final setting decreases with the increase of the content of sulphoaluminate cement.

From the XRD spectra of composite cement cured for 28 days in Fig. 4, it can be seen that the product of adding sulphoaluminate cement to ordinary Portland cement has not changed substantially, nor has there been a new crystal structure[3]. The characteristic peaks of $Ca(OH)_2$ and Ettringite are at 18.007 and 34.101 degrees and 15.784 degrees respectively. The characteristic diffraction peaks of C_2S are about 22 degrees. Comparing the XRD spectra of mixed cement and ordinary Portland cement, it can be seen that the diffraction peaks of $Ca(OH)_2$ and Ettringite are stronger than those of ordinary Portland cement. The strength of C_2S peaks in hydration products without hydration is just the opposite. This shows that sulphoaluminate cement is added to ordinary Portland cement and participates in hydration reaction to produce a large number of ettringite and Ca $(OH)_2$ crystals. At the same time, adding sulphoaluminate cement into ordinary Portland cement to introduce tricalcium aluminate, the high alkalinity of ordinary cement accelerates the hydration of tricalcium aluminate, thus effectively improving the strength of composite cement and accelerating the setting time of composite cement.

3.2 Effect of Diatomite on Thermal Insulation Properties of Straw Fiber Composites

The ratio of sulphoaluminate cement to ordinary Portland cement is 3:7. The proportion of straw fiber in the total mass remains unchanged at 30%. The effects of different Diatomite Content on the dry density and thermal conductivity of cement-based straw fiber composites are investigated. The test results are shown in fig. 5 and fig. 6

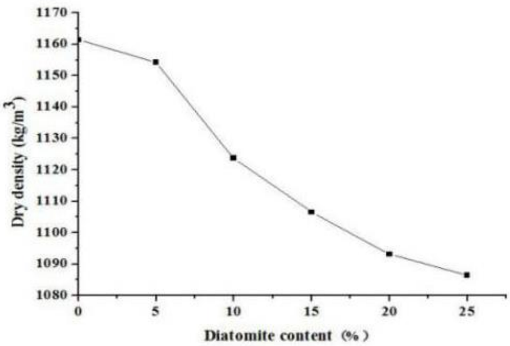

Fig 5.Effect of Diatomite on Dry Density

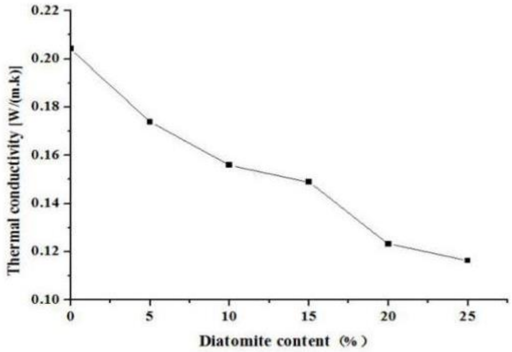

Fig 6.Effect of diatomite content on thermal conductivity

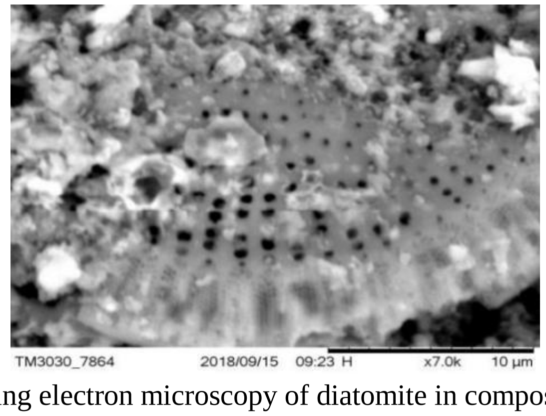

Fig 7.Scanning electron microscopy of diatomite in composite materials

Fig. 5 shows that the dry density of the composite decreases with the increase of diatomite content. Fig. 6 shows that the thermal conductivity of the composite decreases with the increase of diatomite content. When the content of diatomite is 15%, the dry density of the composite decreases by 30.52 kg/m^3. When the content of diatomite is 25%, the thermal conductivity is 0.1163 W/(m.K), which is 48.45% lower than that of the blank group. The scanning electron microscopy (SEM) images show that diatomite is a kind of surface microporous material, and diatomite is mostly nano-porous. When diatomite is added to the composite material, the micro-pore of diatomite is filled with air, while the molecules of static air are inactive at room temperature, and the free path of thermal movement is about 55-65 nanometers[4]. The micro-pore locks the air molecules in the pore and forms a micro-pore[5]. The nano-scale semi-enclosed heat convection field reduces the micro-convective heat transfer between air molecules in the pore, and the thermal conductivity of diatomite with uniform pore distribution is even lower than that of static air. On the other hand, due to the addition of low-density diatomite into the cementitious materials, secondary hydration reaction occurs in the cementitious system, which increases the porosity between the fibers, reduces the interstitial porosity between the straw fibers, and increases the independent porosity in the composite materials. Independent enclosed pore also reduces the thermal radiation conduction of air and effectively reduces the thermal conductivity of materials. Therefore, adding diatomite into the straw fiber cement-based composites can effectively improve the thermal insulation properties of the composites.

4. Conclusion

When 30% sulphoaluminate cement is replaced by 30% sulphoaluminate cement in ordinary Portland cement, the crystallization effect of ettringite and $Ca(OH)_2$ is better after hydration. The flexural strength is 7.26 MPa and the compressive strength is 58.25 MPa. Compared with ordinary Portland cement, not only the compressive strength and flexural strength are increased by 7.6% and 20% respectively, but also the initial setting time and final setting time are shortened. It has good working performance.

When diatomite is added into composite materials, the dry density of composite plates decreases gradually. Air molecule is semi-closed in the micro-pore of diatomite, which effectively reduces the thermal convection effect of air molecule. The thermal conductivity decreases with the increase of diatomite content. When diatomite content is 25%, the thermal conductivity of straw board can reach 0.1163 W/(m.K), which has good thermal insulation performance.

Acknowledgments

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