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Performance Analysis of Polypropylene Material on Thermal Insulation Effect of Cement External Wall

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In order to solve the shortcomings of the traditional organic thermal insulation material, the ordinary portland cement is modified firstly. Although organic insulation material is lighter in texture and better in thermal insulation, it is very flammable. In addition, the insulation property of inorganic insulation material is insufficient. When the content of high alumina cement is 20 parts and the content of Li_2CO_3 is 3 parts, the initial setting time of the high alumina cement – ordinary portland cement composite system is the shortest. The time is 12min and 22min, which is close to the gas-bubble stabilization time. Then the effect of polypropylene addition on the properties of composite cement is studied. The results show that the optimum performance of the cement foam insulation material is best when the polypropylene fiber content is 2%. The compressive strength is 0.619MPa, the bulk density is 285kg/m3, the water absorption is 15.4%, and the thermal conductivity is 0.079w/mk. In conclusion, this kind of material belongs to grade A non-combustible material.

1. Introduction

Annual building energy consumption will cause a large amount of energy waste, and thermal insulation material plays a pivotal role in building energy efficiency. Although the traditional organic insulation material is light and has good thermal insulation performance, there are very serious flammable defects. It is difficult to meet the requirements of building energy-saving materials because of the lack of thermal insulation performance of inorganic insulation materials (Zhang et al., 2016). Organic / inorganic composite thermal insulation material combines the advantages of organic and inorganic insulation materials, and is expected to overcome their shortcomings (Majid et al., 2017), so as to achieve both insulation and energy saving, and fire safety.

Cement-based composite foaming material is a kind of lightweight porous material (Soon et al., 2014), which is made of cement as the main body and produces a large number of bubbles in the slurry system by physical or chemical methods. Cement-based composite foam material is one of the hot spots in recent years due to its characteristics of heat preservation, heat insulation, light weight, sound insulation and moisture resistance (Prinya et al., 2017). It is difficult to control the porosity of cement foaming material prepared by physical foaming. Therefore, in recent years, the chemical foaming method (Antonio et al., 2016) is used in the production of cement foaming material. Foaming agent is one of the main factors affecting the material performance. It affects the number, structure and distribution (Flores et al., 2014) of the pores in the material. In addition, admixtures, such as early strength agent, water reducer, reinforcing agent, process conditions, foaming-molded temperature (Hamed et al., 2015), also affect the performance of cement foaming material to a great extent. In this paper, a kind of cement based composite foaming material is prepared, and the effect of polypropylene addition on its properties is studied.

2. Method

2.1 Raw materials and equipment

The experiment materials: Ordinary portland cement (PO42.5), Ordinary high alumina cement (CA70-E), water reducer (JCBH), Li_2CO_3 (chemically pure), Na_2SO_4 (chemically pure), $CaCl_2$ (chemically pure), polypropylene fiber (staple fiber), Al powder (chemically pure), NaOH (chemically pure).

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The experiment materials: magnetic stirring apparatus, numerical control ultrasonic cleaner, electric constant temperature drying oven, scanning electron microscopy, micro control electronic universal testing machine, plane table thermo-conductivity meter.

2.2 Experimental procedure

According to the ratio shown in Table 1, the cement, water and water reducer agent in different systems are stirred evenly, and the initial setting time is determined.

Table 1: Ratio of modified cement

Test No.	Ordinary Cement	High Aluminum Cement	$CaCl_2$	Na_2SO_4	Li_2CO_3
1	100	0	0	0	0
2	95	5	0	0	0
3	90	10	0	0	0
4	85	15	0	0	0
5	80	20	0	0	0
6	75	25	0	0	0
7	80	20	1	0	0
8	80	20	2	0	0
9	80	20	3	0	0
10	80	20	4	0	0
11	80	20	5	0	0
12	80	20	0	1	0
13	80	20	0	2	0
14	80	20	0	3	0
15	80	20	0	4	0
16	80	20	0	5	0

Then, the selected modified cement is mixed with a certain amount of polypropylene fiber and foaming agent, then it is placed in a certain mold, and the foam is stopped at a certain temperature. The addition amount of polypropylene fiber is 0%, 1%, 2%, 3%, and foaming agent is 15%. The foaming temperature is 65℃ (Chen et al., 2015).

3. Result analysis of cement modification experiment

3.1 Effect of high alumina cement on initial setting time of portland cement

Ordinary portland cement and high alumina cement all have normal initial setting time when they are used alone. But when the mixture is used, the setting time of the mixing system is not the combination of the two cement setting times. Table 2 lists the influence of different content of high alumina cement on the initial setting time of portland cement.

Table 2: The effect of alumina cement on the setting time of initial and final for ordinary portland cement

Test No.	Ordinary Cement	High Aluminum Cement	Initial setting time	Final setting time
1	100	0	110	216
2	95	5	106	183
3	90	10	85	175
4	85	15	42	76
5	80	20	29	52
6	75	25	36	58

It can be seen from Table 2 that the addition of high alumina cement will shorten the initial setting time of portland cement. With the increase of the amount of high alumina cement, the initial setting time of composite cement system is shortened. When the amount of high alumina cement is less than 10 parts, the setting time of the system is not sensitive to change. When the addition amount is 10 parts, the final setting time of the composite system is 177min, which is shortened by 17.3%. When the addition amount is 15 parts, the initial setting time of the system decreases greatly. The initial setting time is 43Min, which is reduced by 60.9%. The

final setting time is 76min, which is reduced by 64.5%. When the content of high alumina cement is 20 parts, the initial setting time of composite system is the shortest. With the increase of its amount, the setting time has almost no change. Therefore, the amount of high alumina cement selected in the experiment is 20 parts.
Reason of rapid solidification of composite cement slurry system: The basicity of high alumina cement is lower than ordinary portland cement (Vahid and Togay, 2015). When the two cements are mixed together, the hydration reaction of cement will change, resulting in the acceleration or shortening of the initial setting time of the cement (Olgun, 2013). The addition of high alumina cement will reduce the alkalinity of ordinary portland cement and increase the content of CA in the composite system. Therefore, the hydration of cement is accelerated, so that the initial and final setting time of composite system is shortened (Navid et al., 2016).

3.2 Effect of content of early strength agent on initial setting time of cement composite system

As shown in Figure 1 and Figure 2, after adding the early strength agent CaCl2, Na2SO4 and Li2CO3, the initial setting time of ordinary portland cement-high alumina cement composite system has been reduced to varying degrees.

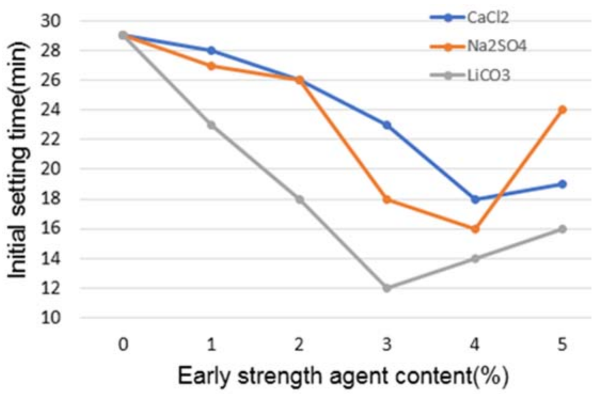

Figure 1: The effect of early strength agent content on the initial setting time for different cement composite system

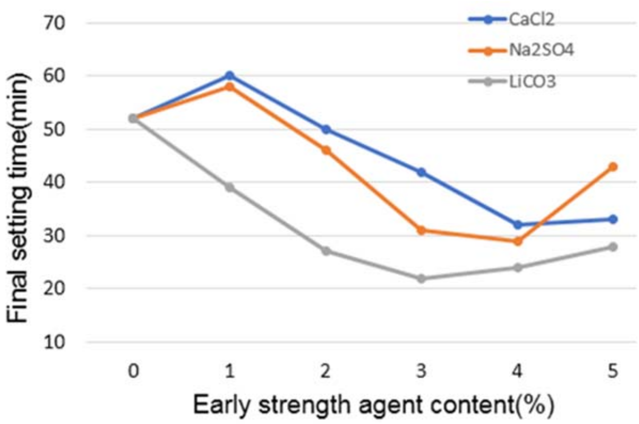

Figure 2: The effect of early strength agent content on the final setting time for different cement composite system

As shown in the figure, the addition of Li2CO3 has a great influence on the initial setting time of the composite system. When adding 3 parts of Li2CO3, the initial setting time of the system is the shortest, respectively: 12min, 22min, which is close to the gas-bubble stabilization time. The reason why Li2CO3 accelerates the coagulation process of composite cement system is that Li2CO3 can react with Ca(OH)2 produced by hydration of composite cement and form LiOH, which improves the alkalinity of cement hydration environment (Ehsan et al., 2016). OH- ions can replace the water molecules produced by hydrolysis of Al3+ in high alumina cement and accelerate its hydrolysis process, thus reducing the critical dimension of the free energy and crystal nucleus of [Al(OH)6]3- octahedron nucleation, and promoting the crystal nucleus growth (Navid et al., 2015). At the same time, the Li＋ and OH- produced by strong base LiOH ionization can form four coordinated structure, and this structure will promote the polymerization of [Al(OH)6]3- octahedron. Therefore, the addition of Li2CO3 accelerates the early hydration and condensation of the composite system (Ramezanianpour et al., 2013).

4. Effect of polypropylene fiber dosage on cement foaming material

4.1 Effect of polypropylene fiber dosage on properties of cement foaming material

As shown in the Figure 3, Figure 4 and Figure 5, the compressive strength, bulk density and water absorption of cement foaming material have a certain change trend with the addition of polypropylene fiber. Before adding polypropylene fiber, the compressive strength of the material is the lowest, only 0.055MPa. The bulk density is the largest, reaching 229.9kg/m3. The water absorption rate reaches 32%. With the addition of polypropylene fiber, the compressive strength of the material increases gradually, and the bulk density and water absorption decrease gradually. When the dosage is 2%, the maximum compressive strength of the material is 0.807MPa, which is 0.752MPa higher than that without fiber. The smallest bulk density is lowest, only 190.6kg/m3. The water absorption rate is only 16%, which is 50% lower than that without fiber. This is mainly related to the size, distribution and uniformity of bubbles inside the material (Mao et al., 2015). Polypropylene fiber will affect the foaming of the system, and further verify the great influence of polypropylene fiber on the macro properties of cement foaming material. When the dosage is more than 2%, the compressive strength of the material begins to decrease gradually, and the bulk density and water absorption increase gradually (Osman et al., 2016). Therefore, the optimum content of polypropylene fiber for cement foaming material is 2%.

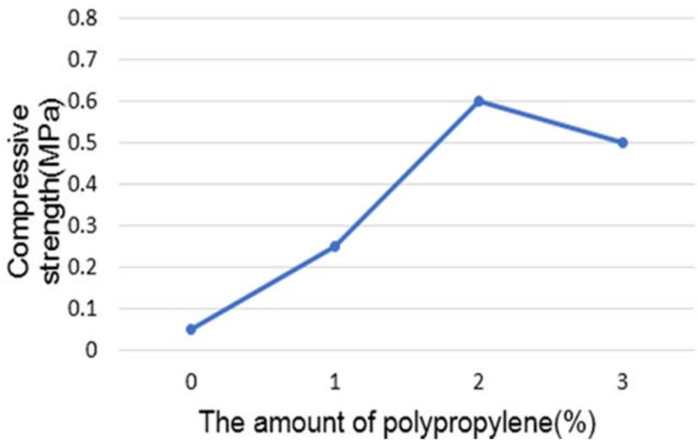

Figure 3: The effect of polypropylene content on the compressive strength of material

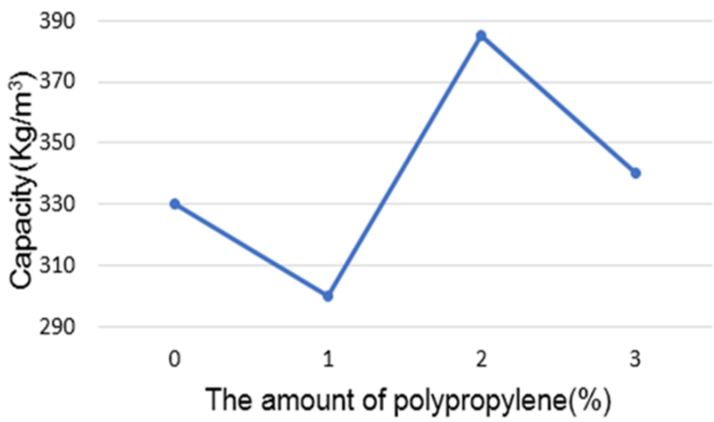

Figure 4: The effect of polypropylene content on the capacity of material

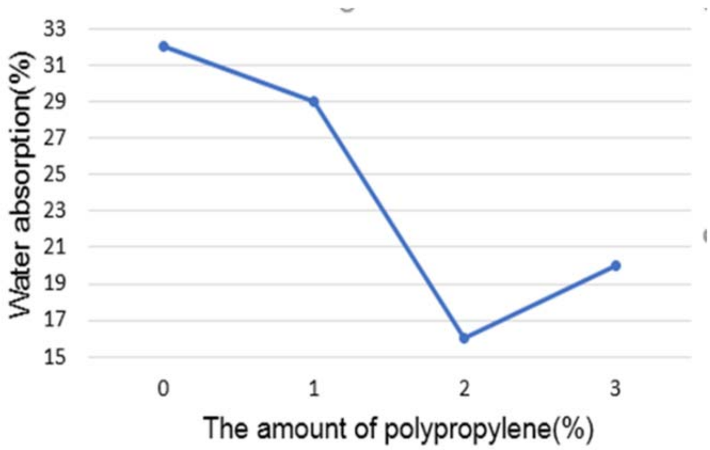

Figure 5: The effect of polypropylene content on the water absorption of material

According to the above experiment, the cement foaming material is prepared at 65°C, and its thermal conductivity and fire resistance are measured. The comprehensive properties of cement foaming material are as follows: 0.619MPa compressive strength, 285kg/m3 bulk density, 15.4% water absorption, 0.079w/m·K thermal conductivity. In conclusion, the material belongs to grade A non-combustible material.

4.2 Mechanism analysis of effect of polypropylene fiber on cement foaming property

Before adding polypropylene fiber, the foaming capacity of the cement foaming system is large, and there are a lot of open pores in the surface and interior of the solidified material. Some pores are interconnected, which makes the pores larger and unevenly distributed. Therefore, the compressive strength of the material is low, and the bulk density and water absorption rate are larger (Osman et al., 2014). With the increase of the content, the pores on the surface and inside of the material decrease gradually, and the size of the material gradually decreases. Because of the increase of fiber content, the resistance of composite cement system to foaming gas is enhanced, and the internal porosity is reduced (Saeid et al., 2016). When polypropylene fiber is added, the pore size of the surface and interior of the material is small, and some pores are closed pores, and the distribution is uniform. Therefore, the compressive strength of the material is larger, and the bulk density and water absorption rate are the lowest (Peng et al., 2013). This explains the best reason of macro physical properties of polypropylene fiber in micro aspect. However, when the amount of the additive is too large, the dispersion of polypropylene fiber in the composite foaming cement system begins to become uneven. The size of the pores on the surface and inside of the material is different, which leads to the decrease of the macroscopic physical properties of the cement foaming material (Kutalmış et al., 2015).

5. Conclusion

In this paper, the preparation of cement foaming material based on ordinary portland cement-high alumina cement composite system has been studied systematically. The conclusions are as follows: The proportion of high alumina cement is 20 parts in the modified cement part. When the content of Li_2CO_3 is 3 parts, the initial setting time of composite cement slurry is the shortest. When the content of polypropylene fiber is 2%, the surface and internal pore size of cement foaming material is smaller. Some pores are closed and the distribution is uniform. The compressive strength of the material is large, and the bulk density and water absorption rate are the lowest. The comprehensive properties of the cement foaming material are as follow: 0.619MPa compressive strength, 285kg/m3 bulk density, 15.4% water absorption.

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