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Thermal Insulation Properties of Fly Ash and Waste Polystyrene Mixed Block Building Materials

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In order to make effective use of fly ash and waste polystyrene to develop new energy-saving wall construction materials, we take lime and gypsum as fly ash activator, use waste polystyrene (EPS) as the insulation component to prepare block materials, study the block material distribution optimization ratio, and analyse the hydration mechanism and insulation of block materials. The results show that the lime ratio is 10%, gypsum ratio is 5%, and the amount of fly ash is 20% ~ 25%. When the modified EPS is 2.5%, the thermal conductivity coefficient of block materials is 0.505W/ (m.K), excellent in insulation.

1. Introduction

With the improvement of people's living standard, and more and more serious energy problems, people's requirements on the housing insulation increase, the research and development of thermal insulation materials has become a hot topic in the field of building materials, and the use of wastes to develop new insulation materials is a top priority among hot topics. Fly ash and waste polystyrene (EPS) are the two largest killers of the environment. How to reasonable use it and develop the wastes to valuable things is the new way of developing and preparing new materials.

In this paper, we use lime and gypsum as the activators for fly ash activity, and add modified polystyrene foam to develop fly ash polystyrene insulation mortar and masonry with excellent thermal insulation performance and the durability, which fully meets the needs of China's current situation of building thermal insulation mortar and building insulation blocks, belonging to green energy-saving building materials (Herki et al., 2013). NF-30 additives main synthetic material used in thermal insulation mortar and block uses the coal washing oil fractions to wash oil. Since that wash oil and naphthalene belong to the same kind of compounds, synthetic additive not only has excellent performance, but also is the use of another waste in raw materials of the insulation mortar.

2. Preparation background of fly ash -EPS thermal insulation mortar block under lime gypsum excitation

The production of building materials uses fly ash at room temperature directly mixed with cement-based materials. In improving the cement base material density, workability, and self-levelling, the durability index declines; as a result, the research on how to improve activity of fly ash has been a hot topic in the field. The research methods of adding calcium to fly ash in the presence of external gypsum were rarely reported. Then, in the lime - gypsum - fly ash system, add modified waste polystyrene foam (EPS) to develop new insulation mortar, and analyse the durability performance, hydration and hardening effect mechanism of new thermal insulation mortar in the function of enhancement of calcium (Antonio et al., 2016; Nasser and Duwairi, 2016; Thakur et al., 2015; Hill et al., 2014). The additive used in coal tar is one of the important fraction oils instead of part of the self-synthesized NF-30 naphthalene superplasticizer - at present commonly used NF naphthalene superplasticizer in the market. A large number of references show that: the research ideas, experimental methods, product development methods have not been reported at home and abroad. The development of new insulation mortar makes use of a variety of wastes, which is the new way and technique of resources recycling technology.

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3. Experimental study on fly ash -EPS thermal insulation mortar block under lime gypsum excitation

3.1 Experiment materials

(1) Cement

The cement used in this experiment is a composite ordinary Portland cement (Ji et al., 2014). The chemical composition and mineral composition of clinker are shown in table 1.

Table 1: Chemical composition and mineral composition of cement

Chemical compositions		Mineral compositions							
SiO_2	Al_2O_3	CaO	MgO	SO_3	f-CaO	C_3S	C_2S	C_3A	C_4AF
24.58	6.45	67.8	3.39	0.38	0.73	51.99	23.88	9.20	13.18

(2) ISO standard sand

GB/T17671 China ISO standard sand, net content of per bag is 13509 ± 59.

(3) Fly ash

The physical and chemical compositions of the fly ash used in the experiment are shown in Table 2 and 3.

Table 2: Chemical compositions of fly ash

Chemical compositions	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3 loss on ignition
W (%)	62.47	31.12	1.90	1.55	1.23	0.450.25

Table 3: Chemical compositions of fly ash

4900 hole/cm^2 residue (%)	Porosity (%)	specific surface area ($m^2.g^{-1}$)	Loose dry density (kg/m^3)	Compaction density (kg/m^3)
10-25	60-75	0.25-0.35	550-750	1300-1600

(4) Lime and gypsum

Lime CaO used in the test is the calcium lime content of 78% (MgO ≦ 5%). Broken into 180 target square hole sieve, sieve <10%. Gypsum is a material for desulfurization gypsum (Khotbehsara et al., 2015).

(5) EPS foam particles

EPS particles used in the test are less than 2.5mm different particle sizes EPSl (average particle size of 1.0mm) and EPS2 (average particle size of 1.0mm), the appearance mixed according to 10:90 (mass ratio) was irregular polyhedron, bulk density of 250g/m^3.

(6) Water reducing agent

This laboratory made NF-30 type high-performance water reducing agent, and the water reducing rate is 18.7%.

(7) Modifier vinyl acetate (CH3COOCHCH2)

3.2 Experimental proportion scheme

In order to make use of the waste effectively, and to obtain the mortar block with good thermal insulation performance without affecting the strength of the mortar, the optimum proportion of fly ash and EPS under the lime - gypsum excitation system was determined.

Based on the experiment of lime - gypsum cement base material, the content of gypsum is 5% and the lime content is about 10%. In accordance with the instruction of ordinary naphthalene water reducing agent, the laboratory made high-performance water reducing agent NF-30 is 0.5%. The test scheme is shown in table 4. The percentages in the table all take the cement as the reference quantity, and the experiment is carried out according to GB/T17671-1999 "cement mortar strength test method (ISO method)".

Table 4: Test sample ratio

No.	Lime (%)	Gypsum (%)	Fly ash (%)	EPS (%)	NF-30 (%)
0	10	5	0	0	0.5
1	10	5	5	0.5	0.5
2	10	5	10	1.0	0.5
3	10	5	15	2.0	0.5
4	10	5	20	2.5	0.5
5	10	5	25	3.0	0.5
6	10	5	30	3.5	0.5
7	10	5	35	4.0	0.5
8	10	5	40	4.5	0.5
9	10	5	45	5.0	0.5

4. Performance test of fly ash -EPS thermal insulation mortar block under lime - gypsum excitation

According to the ratio in table 4, weight the raw materials required for the test. The EPS, according to EPSI and EPS2 particle size and gradation, is prepared with 10:90. When the quality is 2.5% modification of cement quality, according to GB/T17671-1999 "cement mortar strength test method (150 method)", produce and maintain the insulation mortar test block in several groups, for performance test under the same condition.

(1) Mechanical properties test of mortar

The compressive strength test was carried out according to GB/T17571-1999 "cement mortar strength test method" (ISO), JGJ70-90 "building mortar basic performance test method" and G158-2004 "powder polystyrene particles exterior insulation system", specimen size of 40mm * 40mm * 160mm (Mazlee et al., 2013). After the specimen is formed, maintain in the standard curing box to a certain age, put (65 ± 2) Deg oven for drying 24h, cooling to room temperature, and then test the flexural, compressive strength.

(2) Mortar insulation performance test

It was carried out in accordance with GB/T10294-1998 and GB/T3392-82 "plastic thermal conductivity test method and hot plate method", specimen size of 40mm * 40mm * 160mm. Specimen maintenance to a certain age, dry to constant weight, grind the surface, and measure the mortar thermal conductivity with DRX-1-PB thermal conductivity measurement device (Hot plate method) (Pei et al., 2013). Test reference value: concrete number: 1.74W/m. K; cement mortar: 0.93W/m.K.

(3) Durability test

It was performed according to GB/158-2004 "powder polystyrene particles exterior insulation system," JGJ70-90 "building mortar basic performance test method" and GB/T9966.1-2001 "natural stone decoration and drying, water saturation, freeze-thaw cycle then compression strength test method".

4.1 Age strength test

Table 5: Mortar strength at different ages

No.	3d strength/MPa		28d strength/MPa		60d strength/MPa	
	Flexural prevention	Compression prevention	Flexural prevention	Compression prevention	Flexural prevention	Compression prevention
0	4.52	34.2	5.74	56.6	6.12	58.5
1	4.50	31.6	5.71	53.2	6.05	55.7
2	4.42	30.5	5.68	52.0	5.98	54.8
3	4.19	29.1	5.50	50.6	5.81	53.2
4	4.18	28.8	5.45	48.8	5.52	51.3
5	3.38	25.6	5.26	41.2	5.75	47.6
6	2.95	24.5	4.90	40.8	5.26	42.9
7	2.70	23.0	4.78	35.0	5.10	41.8
8	2.45	20.6	4.64	33.6	4.89	39.4
9	2.26	20.4	4.30	30.8	4.70	35.3

ISO method preparation was used for preparation and maintenance of samples to the specified age sample, and then in accordance with GB/TI7671-1999 "cement mortar strength test method (ISO method)" to determine flexural and compressive strength. Test results are shown in table 5:

From the analysis of table 5, it can be seen that:

(1) The flexural prevention strength and compression prevention strength in 3d, 28d and 60d decreased with the increase of fly ash and EPS content. Mainly because the incorporation of fly ash reduces the relative content of cement. Although adding lime and gypsum as fly ash potential volcano ash activator, making up for the loss of strength, the strength is still not as good as lime - gypsum cement effect in a separate excitation;

(2) The addition of EPS will decrease the cement content. EPS itself cannot be hydrated, without the gel performance. Although after modification, the combination of it and cement particles and hydration products is not so solid as the combination between hydration products, which will lead to the strength of mortar decreased;

(3) From the strength decline trend, it can be seen that: when the EPS content is 2.0%-2.5%, the strength declined relative to the reference sample, but compared with fly ash - EPS thermal insulation mortar strength with no lime - gypsum excitation, only fly ash with 20% dosage of 28 days, the strength is increased by about 7 MPa. Therefore, to choose lime - gypsum to stimulate the activity of fly ash to make up for the loss of strength further explains the rationality (Sayadi et al., 2016). Analysis shows that: 60d strength and 28d strength, comparing the growth rate, the increase is not so obvious in 28d relative to 3d, which further illustrates that the excitation effect of lime - gypsum on fly ash -EPS thermal insulation mortar system, is rapid in the middle development and stable in the late period, providing a good guarantee for the durability of thermal insulation mortar;

(4) From table 5, comparing the mortar, namely with no fly ash and EPS, but add mortar sample of lime and gypsum, then the 28d compressive strength gets 56.6MPa, which exceeds the strength 12 MPa of the cement used 42.5 grade. This is because that the added gypsum itself has gelling property, and calcium hydroxide generated after lime digestion is a kind of hydration products, so as to improve the strength of mortar. It shows that the addition of lime - gypsum not only plays a role in stimulating the activity of fly ash, but also beneficial to the development of mortar strength. The results show that the addition of lime gypsum not only stimulates the activity of fly ash, but also makes up for the strength loss caused by the addition of EPS to a certain extent;

(5) The building insulation mortar used for load-bearing, its compressive strength is more important. Among them, the strength of 3d is relatively low when the content of fly ash and EPS content are low, and it shows that the effect of lime - gypsum on the fly ash - EPS insulation mortar system is weak in the early period. The 28d and 60d strength trend is gentle when the content of fly ash and EPS was low, and the strength decreased obviously when the fly ash and EPS content were higher. In particular, the sample 4 compared with the sample 5, it indicated that the excitation effect of lime and gypsum on thermal insulation mortar was good in the low age period when the content of fly ash and EPS is low (Singh et al., 2015). It is seen that gypsum has not been very good to show up in the early stage of gelation, while in hydration middle stage, gelation of gypsum has been fully played out, and the calcium hydroxide generated by lime digestion made up the insulation mortar strength loss rate.

Analysis of the strength of the composite age: the ratio sample of the best insulation mortar takes the sample 4 closest to the basic requirements. Performance measurement and analysis of thermal insulation mortar block are carried out in the following.

4.2 Thermal insulation performance test

4.2.1 Thermal conductivity

The so-called thermal conductivity refers to, in the steady state of heat transfer, when the material thickness is 1m, two surface temperature difference of 1K, the thermal conductivity amount through 1m^2 cross-sectional area within 1 hour.

Thermal conductivity of materials is an important parameter index of physical properties of materials, and it requires prediction and actual measurement of thermal conductivity ratio of related materials in aviation, atomic energy, building materials, non-metal materials and other industrial sectors. The test method is divided into steady state method and dynamic test method (Song et al., 2013). This experiment belongs to the principle of heat preservation plate method The smaller the thermal conductivity of the general engineering material, the better the thermal insulation of the material. The thermal conductivity of various building materials is very different, roughly between 0.035W/ (m.K) -3.50w/ (m.K). It is expected that the thermal conductivity of thermal insulation mortar produced in this study should be much smaller than that of ordinary mortar.

4.2.2 Determination and analysis of thermal conductivity

In accordance with the requirements of the DRX-I-PB thermal conductivity tester (hot plate method), the thermal conductivity of the samples was tested in turn. The results are shown in table 6.

Table 6: Thermal conductivity of samples

Sample number	0	1	2	3	4	5	6	7	8	9
Thermal conductivity	0.938	0.706	0.604	0.586	0.531	0.501	0.498	0.485	0.460	0.405

Figure 1 is the variation curve of the sample section and thermal conductivity. As can be seen from Figure 1 that, from sample 0 to 9, with the increase of EPS content, the thermal conductivity of the sample showed a significant downward trend. The decrease slope of the thermal conductivity between sample 2 and sample 3 becomes smaller, and the decrease slope of the thermal conductivity between sample 8 and sample 9 becomes larger. Remove the influence of the error analysis, from the overall point of view, when the content of EPS is low, the thermal conductivity sharply declines with the addition of EPS; when the EPS content is large, the thermal conductivity is decreased with increasing EPS, but no dramatic decrease than the former. Especially starting from the sample 4, the thermal conductivity decrease gradually became more gentle. Table 6 shows that the thermal conductivity of sample 4 was 0.53lW/ (m.K), much smaller than the thermal conductivity 0.938W/ (m.K) of blank sample (Yan et al., 2014), fully meeting the insulation requirements of building energy-saving on external wall insulation materials, and in this experiment, thermal insulation properties are excellent. The thermal conductivity of blank samples without EPS is 0.938W/ (m.k). The results show that the thermal conductivity of the mortar is decreased due to the addition of EPS with thermal insulation performance. From the analysis, it is seen that when the amount of doped EPS is relatively few, the hydration status of insulation mortar system was good, and the mortar structure formed had relative density, with low porosity, so the thermal conductivity is relatively high; analyzing sample 8 and sample 9 thermal conductivity, it is known that, with increasing EPS dosage, mortar system hydration rate became slow, the pore of mortar system structure became more, the strength was relatively increased, the thermal conductivity decreased, while the thermal insulation performance was enhanced.

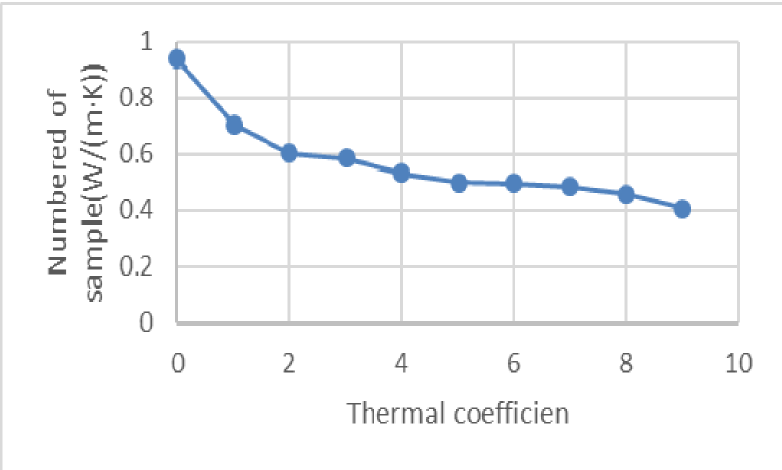

Figure 1: Variation curve of thermal conductivity

5. Conclusion

In this paper, taking lime and gypsum as fly ash activators, we use waste polystyrene (EPS) as the insulation components for the preparation of block material, study the optimum proportion of block material, and analyse the age hydration mechanism and insulation of block material. The results show that the lime ratio is 10%, gypsum ratio is 5%, the amount of fly ash is 20% ~ 25%, and when the modified EPS is 2.5%, the thermal conductivity of block material is 0.505W/ (m.K), excellent in insulation.

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