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Experimental Study on Preparation of Fly Ash Polystyrene New Insulation Building Material

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Fly ash and waste polystyrene foam are two major killers of the environment. By turning waste into treasure, we use it rationally. This is a new way to develop new materials. The lime fly ash and gypsum were used as the activator of fly ash, and the modified polystyrene foam was added to develop a good insulation properties and durability of fly ash polystyrene insulation mortar and block. This is a new type of environmental protection and energy-saving insulation materials. It can be well adapted to the hot summer and cold winter climatic conditions, so as to meet the requirements of building energy efficiency. In this paper, the composition of raw materials, experimental ideas, technical means, hydration, hardening and other properties of the thermal insulation mortar block have been studied comprehensively and systematically.

1. Introduction

Energy issues are the concerns of the world today, and building energy conservation is one of the most important tasks in energy conservation (Dissanayake et al., 2017). Building energy conservation is conducive to the protection of energy resources, energy security and the development of national economy (Abdulkareem et al., 2014). With the development of economy in our country, the production of EPS is increasing year by year (Marques et al., 2017). Therefore, turning waste into treasure and the comprehensive utilization of resources have a very positive effect on environmental protection (Ghafoori et al., 2015).

In recent years, with the development of modern concrete technology and the deepening of the understanding of the potential effects of fly ash, high volume fly ash cement concrete is more and more widely used in hydraulic engineering (Han et al., 2015). However, some studies have shown that the early strength of concrete mixed with fly ash is too low (Posi et al., 2015). Through the appropriate technical approach, the early activity of fly ash is stimulated. Therefore, the early strength of fly ash concrete is improved. This is of great practical significance (Sayadi et al., 2016). In this paper, the experimental study on the new type of insulation material modified by fly ash was carried out. Lime and gypsum are used to stimulate the potential activity of fly ash and cement. It can make up for the loss of the strength of insulation mortar caused by fly ash and modified EPS.

The innovation is reflected in the following aspects: (1) By using abundant raw materials such as fly ash, polystyrene foam and lime, a new type of energy saving and environmental protection building material was developed. The process flow has the advantages of convenient use and operation, low energy consumption and high yield. A cost-efficient facile and high purity synthetic route is suitable for large-scale preparation of aim compound. (2) A new exploration is made on the activity of fly ash and cement with lime gypsum as activator. The durability of fly ash modified thermal insulation mortar and block under the action of lime gypsum was revealed. (3) Compared with the commonly used materials of the same type, the performance of the product meets the technical requirements. The utility model belongs to the environmental protection and new energy saving material, and has the advantages of low cost, high efficiency and simple construction. There is a broad potential market for developing the new type products as green products which have high economic, social and ecological effects.

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2. Modification theory of waste polystyrene foam and selection of modifier

EPS is the abbreviation of Expanded Polystyrene, which is referred to as polystyrene foam. The molecular formula is $[CH_2CHC_6H_5]$ n. It is a kind of general thermoplastic, with a very low density, closed cell structure, low water absorption (hydrophobic), high strength, insulation, anti-mold, low thermal conductivity and a series of excellent physical properties. It has the characteristics of stable chemical properties, aging resistance and corrosion resistance (Sheth et al., 2014). Waste EPS is a kind of closed cell and light insulation material. In the case of proper construction and waterproofing, it has the advantages of energy saving, good long-term R (thermal resistance) value, water resistance and dimensional stability, and can be used to produce all kinds of insulation building materials, such as building insulation mortar, insulation board and various commercial roof systems (Sancho, et al., 2014). The water absorption of EPS is very low, and the surface is hydrophobic, so it is necessary to solve the problem of compatibility between polystyrene particles and cement mortar by EPS. The use of waste polystyrene foam can meet the requirements of wettability of cement mortar by physical modification.

It is the most important in this experiment to find a suitable modifier to modify EPS. Polystyrene foam is a kind of high molecular compound. According to the principle of similarity compatibility, the reagents used for modification must be an organic solvent. In order to make the modified waste polystyrene foam play the role of insulation components, and the modified waste polystyrene foam on the cement mortar is only a simple physical adsorption, the selected modifier must be adapted to the wettability, dispersibility, pH, electrical, and weather resistance of the cement mortar. The selected modifier should be nonionic surfactant. In the cement mortar system, it is not an ionic state, and its stability is high. It is not easy to be influenced by inorganic salts and acids. It has good compatibility with other types of surfactants and has good solubility in water and organic solvents. Although this kind of surface modifier is not ionized in water, it has hydrophilic (-CH2CHO-, -OH, etc.) and oil (hydrocarbyl-R). At the same time, the selected modifier must meet the following principles: (1) the agent is non-irritating odor and non-toxic; (2) the reagent can be mass produced and will not affect production due to out of stock; (3) the reagent is cheap and easy to buy.

3. Preparation of waste polystyrene foam modified fly ash cement mortar

3.1 Experimental raw materials

Cement is the 42.5 grade ordinary portland cement produced by Huainan Mineral Bureau cement plant. Fly ash is the original ash of Huainan Luohe power plant. Solid waste EPS is the garbage collection of life. The chemical composition of cement and fly ash is shown in Table 1. The waste polystyrene foam is broken into an average particle size of 2.0-2.5mm. The appearance is irregular polyhedron, and the unit weight is 24kg/m^3. NF-30 superplasticizer (the coking waste water is used to synthesize homemade oil), vinyl acetate (molecular formula: $C_4H_6O_2$, $CH_3COOCHCH_2$), the specific performance indicators as shown in Table 2.

Table 1: The chemical composition of cement and fly ash

Raw material	SiO_2	Al_2O_3	FE_2O_3	MGO	CaO	K_2O	SO_3	TiO_2
Cement	21.4	4.58	2.69	2.02	63.65	0.67	2.63	0.20
Fly ash	58.75	31.48	4.52	1.34	1.74	0.60	0.15	0.15

Table 2: The properties of the vinyl acetate

Name	Vinyl acetate
Melting point	-93°C
Boiling point	71.8°C
Relative density	0.93
Solubility	Slightly soluble in water, soluble in alcohol, acetone, benzene
Stability	Stable
Appearance and traits	Colorless liquid with sweet ether flavor
Dangerous mark	7 (flammable liquid)
Application	Organic synthesis, mainly used for synthetic vinylon, also used in adhesives and coatings industry.

3.2 Experimental method

The appropriate amount of binder is diluted with water. The same mass of cement is replaced by 0, 1.0%, 2.0%, 2.5%, 3.0%, 3.5%, 4.0%, 4.5% polystyrene foam particles. The surface of the particles is coated with a

layer of cement slurry, and then a layer of silicate is formed on the surface of the polystyrene foam particles. The amount of vinyl acetate is added to make it mixed with the cement paste. Fly ash is 25% of the weight of cement, and NF-30 water-reducing agent is 50% of the weight of cement. According to GB/T17671-1999 "cement mortar strength test method (ISO method)" to produce test pieces, the model size is 40mm×40mm×160mm. Modified cement paste as shown in figure: the thermal conductivity of mortar is measured by DRX-I-PB thermal conductivity coefficient tester, and the mechanical properties are tested after 20 days after the standard curing 24h. The best-like central site is used to perform DSC-TG (Differential Scanning Electron Microscopy) scanning according to the test requirements. The X / ray-Diffractometer (X-ray Diffractometer) is used to analyze the phase composition.

Chapter 2 Figure 1 is the EPS modification test. Figure a is the pre-modified EPS particles. Figure b is the EPS particles treated with vinyl acetate. At this point, EPS has become a sticky material. Figure c is a modified EPS wrapped with cement particles. It can be seen that there is a good bond between cement and EPS. Figure d is the contrast between EPS before and after modification.

(a)

(b)

(c)

Figure 1: Schematic picture of the experiment of modifying the EPS (continue)

(d)

Figure 1: Schematic picture of the experiment of modifying the EPS

4. Results and discussion

4.1 Comparative experimental analysis

By doing comparative experiments, it can be found that pretreatment of EPS surface is hydrophilic, and the bonding strength of EPS particles is greatly improved. In the case of unmodified EPS thermal insulation mortar, the interface between the EPS particles and the cement paste is broken, and the bonding strength of the cementitious material is low, and the interfacial area is weak. However, the fracture surface of the modified EPS thermal insulation mortar can be seen as a large number of tear EPS, the bond strength of the surface cementitious material to EPS is greatly improved, and the performance of the mortar is easy and the strength is significantly improved.

Table 3: Effects of EPS size and grade scale on performance of EPS insulating mortar

Average particle size / mm and ratio / W%			Consistency / cm	Separation / cm	Bending strength / Mpa	Construction performance
EPS1	EPS2	EPS3				
1.0	1.5	2.5				
100	0	0	7.4	1.0	2.90	Worse
0	100	0	7.6	1.3	2.71	Better
0	0	100	7.5	1.9	2.65	Bad
70	30	0	7.3	1.4	2.77	Bad
50	50	0	7.0	1.9	2.70	Better
30	70	0	7.1	1.2	2.75	Good
10	90	0	7.8	0.7	2.89	Good
5	25	70	7.7	2.5	2.58	Bad

4.2 Analysis of physical properties of EPS grain gradation and thermal insulation mortar

Table 3 shows the effect of particle size and gradation on the mechanical properties of mortar. EPS particles play the role of aggregate support in the material. The larger the dosage, the greater the volume space occupied, thus reducing the bulk density of the material. Although it is in line with the requirements of lightweight materials for roof engineering, improper dosage will reduce the strength of materials. As can be seen from Table 5, with the increase in particle size, the mortar's stratification is increased, and the water retention, workability and bending strength are decreased. When the grain size of EPS particles is 2.5mm, the stratified degree of the prepared thermal insulation mortar is 2.5cm, and the cohesion and workability are very poor. Therefore, in order to ensure EPS insulation mortar has a good construction performance, EPS particle size should be less than 2.5mm. The EPS particles with different particle size are mixed in different proportions to obtain EPS light aggregate with certain gradation. The mechanical properties of the prepared thermal insulation mortar are improved. For example, according to 10:90 (mass ratio), EPS1 and EPS2 are mixed, the preparation of the thermal insulation mortar mechanical properties is better. The results show that the cement content is 2%~3% of EPS, which can significantly improve the mechanical properties and

workability of thermal insulation mortar. When the particle size and gradation of ESP1 and EPS2 are 10:90, the physical properties of the test block, such as the consistency of the test block, the degree of delamination of the EPS cement casing and the slurry, and the bending strength of the test block are the best.

Table 4: Fly ash admix rate (%) on strength performance of mortar

28 days' compressive strength (Mpa)	56.6	50.5	48.0	45.6	42.3	37.5	35.6	33.5	30.5
Ratio of fly ash (%)	0	5	10	15	20	25	30	35	40

Table 5: EPS1/EPS2=10/90 and fly ash admix rate (%) on performance of EPS insulating mortar

Average particle size / mm and ratio / W%			Work performance	Viscosity	28 days' compressive strength / (Mpa)	Content of fly ash	Construction performance
EPS1	EPS2	EPS3					
1.0	1.5	2.5					
0	100	0	Worse	Better	50.	20	Worse
0	100	0	Worse	Better	49.5	20	Better
0	0	100	Bad	Bad	42.0	20	Bad
70	30	0	Better	Bad	38.0	20	Bad
50	50	0	Better	Better	41.5	20	Better
30	70	0	Good	Better	40.0	20	Good
10	90	0	Good	Good	41	20	Good
5	25	70	Bad	Better	35.8	20	Bad

Table 4 and Table 5 show that the particle size and gradation of EPS1 and EPS2 are 10:90, and the mass is 2.5% of the mass of cement.

4.3 Construction and thermal conductivity of fly Ash - EPS thermal insulation mortar block

According to GB/T10294 thermal conductivity standard and JTG E30-2005-concrete frost resistance test (rapid method) (T0565-2005), GB GB82-85, it can be seen from Table 6 that the workability of the modified insulation mortar on the EPS surface is good. EPS insulation mortar bonding strength is much higher than the expansion of perlite insulation mortar. The strength of the 28 day is 51MPa. It can be compared with the best polyurethane insulation performance on the current market. Fly ash and modified EPS insulation mortar and the base layer has a good bond, and the dust is less at the time of construction. EPS insulation mortar water absorption rate is 12.3%, it is less than 30% of expanded perlite, which creates favorable conditions for the improvement of weather resistance. The loss of strength of freezing and thawing cycle and drying and watering cycle of EPS thermal insulation mortar is only about half of the expansion of perlite insulation mortar. It has little difference with the best insulation material polyurethane (PU). The thermal insulation coefficient of EPS insulation mortar was 0.455 (W / m.K). The thermal insulation mortar and EPS were measured under the same conditions with DRX-I - PB thermal conductivity tester.

Table 6: Properties of fly ash-EPS insulating mortars

Performance	EPS	Expanded pearlite	PU
Dry bulk density (kg/m^3)	500	500	500
Operating hours /h	4	4	4
Block water absorption /%	12.3	45.6	10.6
Thermal conductivity (W/m.k)	0.455	0.537	0.415
28 days' compressive strength /MPa	41	47	55
Strength loss of freeze-thaw cycles at 15 times	6.5	14.3	6.2
Strength loss of dry and wet cycles at 15 times	4.7	9.8	4.6

5. Conclusions

This paper mainly studies the new building materials with fly ash modified insulation. Lime and gypsum were used to stimulate the potential activity of fly ash and cement, thus making up for the loss of strength of the insulation mortar due to the addition of fly ash and modified EPS. First, based on the mechanism of lime and gypsum to stimulate fly ash, the optimum blending ratio of fly ash was obtained. Second, the synthesis performance experiment and the EPS modification experiment were carried out. The comprehensive

performance of EPS modified mortar was studied under the action of additive. In summary, the durability, weather resistance and thermal insulation properties of the new building insulation materials are very good. The utility model can fully satisfy the requirements of the present building insulation and environmental protection materials, and belongs to the green and environmental protection building materials.

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