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Action of redispersible vinyl acetate and versatate copolymer powder in cement mortar

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ABSTRACT

Redispersible polymer powder of vinyl acetate and versatate copolymer (VA/VeoVa) is applied to modify cement mortar. The effect of VA/VeoVa powder on physical and mechanical properties of cement mortar is investigated. VA/VeoVa powder exhibits excellent water-reduction and water-retention effects in cement mortar and improves mortar properties effectively. Due to the air-entrainment effect of VA/VeoVa powder, the air content of fresh mortar is increased and the bulk density is decreased. VA/VeoVa powder makes the compressive strength decrease, but not so significant the effect on the flexural strength is, which results in the ratio of compressive strength to flexural strength goes down sharply with the increase of VA/VeoVa powder, indicating the toughness of cement mortar is improved markedly. Furthermore, VA/VeoVa powder reduces the shrinkage rate and improves the hydrophobicity and water impermeability of cement mortar.

1. Introduction

Polymer-modified mortars are good repair materials for excellent properties. Polymers can improve the flowability of fresh mortar, mechanical properties [1], anti-penetrability [2], freezing–thawing resistance [3], anti-corrosion [4], and so on of hardened mortar. Former research shows that polymers change the microstructure, have physical and chemical interaction with cementitious phase, effect the flowability, hydration, setting, hardening, pore structure, and thus physical and mechanical properties of hardened mortar [5–8].

In fact, different polymers have different influences on cement mortar. For example, styrene–butadiene rubber (SBR) latex improves the flexural strength, tensile bond strength, waterproofing property, carbonation resistance and anti-shrinkage of cement mortar [9–11]. Styrene–acrylic ester copolymer (SAE) latex decreases the elastic modulus and increases the toughness of cement mortar to a larger extent [12,13]. Ethylene–vinyl acetate copolymer (EVA), the most widely used polymer in mortar, improves the tensile bond strength, flexural strength, and toughness of cement mortar [14,15].

Whereas vinyl acetate and versatate copolymer (VA/VeoVa) is a special copolymer that introduces the versatate group with three long α-alkyl molecule side chains into the copolymer. The three long α-alkyl molecule side chains make the copolymer have many superior properties. The ester group of vinyl versatate is stable for the hindering effect of long side chains, resulting in good alkali resistance; the long side chains of vinyl versatate protect neighboring ester group of vinyl acetate too, making the copolymer have good alkali resistance. VA/VeoVa powder is a potential modifier for brittle cement mortar. In Ref. [16], lower degeneration of VA/VeoVa in an alkaline environment rather than other copolymers that contain vinyl acetate group was found. The former researches [17,18] show that with antifoamer together the VA/VeoVa powder increases the strengths of cement mortar. After that, little research on the application of VA/VeoVa powder in cement mortar is published. This paper focuses on evaluating the action of single VA/VeoVa powder in cement mortar, trying to compare the properties with other polymer powders and dispersions modified mortars those are tested using the same method.

2. Experimental

2.1. Materials

Portland cement type P·II 52.5R, according to Chinese standard GB 175, and standard sand, according to ISO 679, were used for preparing the specimens. The chemical composition and physical properties of the cement are listed in Table 1

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Table 1
Chemical composition of PII 52.5R Portland cement.

Component	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3	K_2O	TiO_2	BaO
Content (%)	21.3	65.1	5.1	2.9	1.1	1.8	0.7	0.2	0.3

and Table 2, respectively. The redispersible VA/VeoVa powder (density: 0.5 g/cm^3; average particle size: 80 μm; minimum film formation temperature: 6 °C) was used in the experiment.

2.2. Specimen preparation

The mortar specimens were prepared with VA/VeoVa powder to cement ratio by mass (m_p/m_c) of 0, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 12%, 15%, and 20%, constant flow of (170 ± 5) mm, and sand to cement ratio by mass of 3. The specimens with the dimension of 40 mm × 40 mm × 160 mm were prepared according to ISO679. The specimens were unmolded after 24 h. Mixed cure method, 1 day immersed in 20 °C water followed by 1 day in air of 20 °C and RH50% for specimens tested at the age of 3 days and 6 days immersed in 20 °C water followed by 21 days in air of 20 °C and RH50% for the specimens tested at the age of 28 days, was used.

2.3. Test methods

2.3.1. Flow

The flow table value of fresh mortars was measured according to GB/T2419-2005. A cone-shaped metal ring is filled with fresh cement mortar on a shock table, and after lifting the ring the mix is subjected to 25 drops of the table within 25 s. The final diameter is the so-called flow table value. The water to cement ratio (m_w/m_c) of VA/VeoVa powder-modified mortars was determined by fixing the flow table value at a constant of (170 ± 5) mm, as listed in Table 3.

2.3.2. Water-retention rate

The water-retention rate of fresh mortar was tested according to DIN18555-7. During test, the fresh mortar with settled volume was put on a filter-film allowing water filter through, fixed on absorbent filter papers. Then the water absorbed by the filter papers (lost water of fresh mortar) was measured after 5 min. The water-retention rate was calculated based on that.

2.3.3. Air entrainment test

The air content of fresh mortars was measured using an air entrainment meter made according to DIN18555/-557, from which the air content can be read directly.

2.3.4. Bulk density of fresh mortars

The bulk density of fresh mortars was tested according to JGJ70-90. One liter container was used during test. After the fresh mortar was cased into the container, it should be vibrated for 10 s before the mass was measured.

2.3.5. Compressive and flexural strengths

The compressive and flexural strengths were determined according to ISO679.

2.3.6. Shrinkage rate

The shrinkage rate of mortars was determined according to JGJ70-90. The initial length of mortar was tested right after the specimen was unmolded. The shrinkage rate was calculated according to the length of mortar at different curing ages and the initial length.

2.3.7. Water capillary adsorption

The water capillary adsorption was measured according to DIN52617. Before test, the mortar specimens were dried at 70 °C for 2 days. The four around surfaces were sealed with EP resin before the upside of the specimens was dipped into water. The water capillary adsorption was calculated based on the adsorbed water at different times.

2.3.8. Anti-penetration capacity

The anti-penetration capacity was measured according to DL/T 5126-2001. Conic specimens with upside and underside surface diameters of 70 mm and 80 mm, height of 30 mm were prepared. The curing is the same as that described in 2.2. Before test, the around surface of specimens was sealed with olefin and the underside surface was contacted with water. During test, the water pressure was increased step by step to 1.5 MPa within 8 h to observe whether the water penetrates through the mortar specimens. If water penetrates through three of six specimens under one pressure, then the pressure was determined as the pressure that the mortar survives.

3. Results and discussion

3.1. Water-reduction effect

The m_w/m_c of VA/VeoVa powder-modified mortars decreases significantly with the increase of m_p/m_c when the flow was fixed at a constant of (170 ± 5) mm (see Table 3). So it is apparent that the VA/VeoVa powder has water-reduction effect in cement mortar. Water-reduction rate is an important factor to evaluate water-reduction effect, which can be calculated according to the following equation: [13].

$$R = 1 - \frac{m_{w2} \cdot \rho_2 \cdot m_1}{m_{w1} \cdot \rho_1 \cdot m_2}, \quad (1)$$

where R is the water-reduction rate, m_{w2}, ρ_2 and m_2 is water mass, bulk density and mass of fresh VA/VeoVa powder-modified mortars, respectively; m_{w1}, ρ_1 and m_1 is water mass, bulk density and mass of fresh control mortar, respectively.

The water-reduction rate of VA/VeoVa powder-modified mortars calculated according to Eq. (1) is displayed in Fig. 1. A small amount of VA/VeoVa powder addition of 1% makes the water-reduction rate rise to about 6%. Then the water-reduction rate rises gradually with the increase of m_p/m_c. When the m_p/m_c is 15% the water-reduction rate increases to about 35%. With the m_p/m_c increasing from 15% to 20%, no significant change of water-reduction rate was observed. The experimental results explain that VA/VeoVa powder has good water-reduction effect in mortar, enhancing the flowability of fresh mortar, which is attributed to the dispersion and air entrainment functions of VA/VeoVa powder.

3.2. Water-retention effect

Good water-retention property is helpful for the construction and properties of mortar. Water-retention rate is a quantitative index to evaluate the water-retention effect of mortar. Fig. 2 presents the water-retention rate of VA/VeoVa powder-modified mortars.

Table 2
Physical properties of PII 52.5R Portland cement.

Specific gravity at 20 °C (g/cm^3)	Blaine's specific area (m^2/kg)	Setting time (min)		Flexural strength (MPa)			Compressive strength (MPa)		
		Initial	Final	3 days	7 days	28 days	3 days	7 days	28 days
3.20	385.5	125	190	6.9	7.8	8.4	39.0	49.0	60.6

Table 3
Water to cement ratio (m_w/m_c) of VA/VeoVa powder-modified mortars with a constant flow of (170 ± 5) mm.

m_p/m_c (%)	0	1	2	3	4	5	6	7	8	9	10	12	15	20
m_w/m_c	0.489	0.472	0.458	0.444	0.435	0.426	0.418	0.410	0.404	0.399	0.394	0.392	0.390	0.388