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Mechanical properties and resistance to chloride ion permeability of epoxy emulsion cement mortar reinforced by glass flake

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HIGHLIGHTS

- Glass flake could improve the flexural strength and fracture toughness of modified mortar.
- Glass flake made the water absorption of mortar reduce by about 39.8%.
- 120 mesh glass flake reduced chloride diffusion coefficient of mortar by about 48.2%.
- The bridging connection effect and hinder effect of glass flake was the reason for the improvement.

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ABSTRACT

There is a higher demand for the resistance of chloride ion of the buildings in coastal environment. In this paper, glass flake was used to improve the mechanical properties and chloride ion permeability resistance of epoxy emulsion cement mortar. The effects of polymer/cement ratio (P/C), glass flake content (glass flake/cement ratio) and size of glass flake on the properties of modified mortar were studied. The results indicated that glass flake could simultaneously improve the mechanical properties and chloride ion permeability resistance of epoxy emulsion cement mortar. The flexural strength of modified mortar was improved by 20.4% by incorporation of 120 mesh glass flake. More significantly, water absorption and chloride diffusion coefficient of modified mortar reduced by 39.8% and 48.2%, respectively. The morphology of samples observed by scanning electron microscopy (SEM) confirmed the effect of bridging connection and barrier action of glass flake on epoxy emulsion cement mortar.

1. Introduction

Ordinary Portland cement mortar as a kind of common building materials has loose structure [1,2], and the easy penetration of moisture, oxygen, chloride and other substances brings the quick corrosion of steel and the reduction of building durability [3–6]. It is generally acknowledged that polymer cement mortar has not only excellent adhesion and water resistance, but also good fracture toughness and compatibility with concrete substrates, in modern and coastal buildings in the increasingly widespread [7–13].

Epoxy resin is a kind of highly cross linked thermosetting resin with excellent adhesion, mechanical properties, chemical resistance, good compatibility with concrete, using as a modified material for polymer cement mortar [14]. However, a small amount of epoxy resin is not enough to improve the anti-penetration properties of mortar to meet the requirement of coastal buildings. Moreover, epoxy emulsion modified mortar is still brittle and its improvement in the anti-cracking property of concrete is insufficient and limited [15]. Increasing the dosage of epoxy resin can further enhance its fracture toughness, water resistance and resistance to permeability [16,17], however, its compressive strength will be reduced and high cost restricts its application to some extent [18].

The researchers had found that the resistance to chloride ion permeability of epoxy emulsion modified mortar could be further enhanced by adding some inorganic fillers. Kim et al. found that nitrite-type hydrocalumite (calumite) had a significant effect on the corrosion inhibition performance, obviously improving the anti-chloride ion permeability and anti-carbonization ability of epoxy resin modified mortar [19]. Rahman et al. found that rice

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husk ash could improve the anti-chloride ion permeability and mechanical properties of epoxy resin mortar and epoxy resin concrete [20]. The inorganic fillers could not only improve the resistance to chloride ion permeability of epoxy emulsion cement mortar, but also benefit for mechanical properties. The flexural strength, ratio of flexural strength to compressive strength and impact toughness of epoxy resin mortar were all greatly increased by the addition of ground calcium carbonate (GCC), reported in the work of Li et al. [21], however, the fluidity and compressive strength of epoxy resin mortar decreased. Lokuge et al. selected three types of resins (polyester, vinylester and epoxy resin) to combine with fly ash and sand to prepare the organic polymer concrete mortar, achieving the compressive strength in a range of 90–100 MPa and the tensile strength high up to 15 MPa [22].

Glass flake is a kind of flaky inorganic materials with excellent chemical resistance and aging resistance. It was usually applied in anti-corrosion coating [23–25], and the overlapped and parallel arrangement could form a compact impermeable layer. It effectively improved permeability resistance of materials, thereby enhancing the chemical resistance and aging stability. Simultaneously, the corrosion resistance of concrete was also increased by incorporation of glass flake. Yang et al. invented an anti-corrosive concrete with 80–160 parts of glass flake, and the corrosion resistance coefficient of concrete was high up to 0.85–0.94 [26]. Hu et al. used glass flake and aluminum hydroxide to improve the mechanical properties and water resistance of concrete [27]. Gao et al. utilized glass flake to enhance the impermeability and crack resistance of concrete [28]. It is expected to obtain a kind of corrosion-resistant, high strength and low cost modified mortar material by adding glass flake and epoxy emulsion. In this paper, the effects of glass flake content, glass flake dimension and polymer/cement ratio (P/C) on the mechanical strength and chloride ion permeability of modified mortar were studied. In addition, the fracture surface morphology of modified mortar was observed by scanning electron microscopy (SEM). The bridging connection effect of glass flake in epoxy emulsion cement mortar were discussed.

2. Experimental

2.1. Materials

Glass flakes were purchased from Hejian Chaohui Glass Flake Co., Ltd. (Hejian, China), with the particle size of 60–400 mesh, and the SEM micrographs of 120 mesh glass flake are shown in Fig. 1. The chemical composition of glass flake used is given in Table 1. The waterborne epoxy resin (H123A) and curing agent (H123B) were supplied by Shanghai Hanzhong Chemical Industry Co., Ltd. (Shanghai, China). The ordinary Portland cement (P.O. 42.5) was provided by Yingde Conch Cement Co., Ltd. (Yingde, China). The sand was the product of Xiamen ISO Standard Sand Co., Ltd. China, meeting China ISO Standard Sand. The water was common tap water. The silane coupling agent was γ-aminopropyltriethoxysilane (KH-550), coming from Shenzhen Benno Industrial Co., Ltd. (Shenzhen, China).

2.2. Specimen preparation

Glass flake was surface treated by silane coupling agent KH550 before using. The waterborne epoxy resin and curing agent were first blended with the ratio of 1: 1.3, and then water was added to form homogeneous emulsion. At the same time, glass flake, cement and sand were dry-mixed uniformly in a mortar mixer (JJ-15, Wuxi, China), and the epoxy emulsion was added into the mortar mixer to continue mixing the slurry. Afterwards, the well-blended slurry was cast into the corresponding moulds. According to the specified criteria in DL/T 5126–2001 (China) [29], glass flake modified epoxy emulsion cement mortar specimens were removed to a wet curing box with water depth 50–100 mm in the bottom (temperature = 20 ± 3 °C, relative humidity ≥80%) for two days. After that, they were immersed in water (20 ± 3 °C) for 5 days, and transferred to a dry curing box (temperature = 20 ± 3 °C, relative humidity ≥60%) for 21 days. All specimens were fixed with the water-cement ratio of 0.40 and the cement-sand ratio of 1: 3.

2.3. Test methods

2.3.1. Mechanical strength test

According to the China standard DL/T 5126–2001, three prism specimens of $40 \times 40 \times 160\ mm^3$ were selected to measure the flexural strength and compressive strength on the constant loading cement bending compression testing machine (YZH-300 10) at loading rates of 50 ± 10 N/s and 2400 ± 200 N/s, respectively.

2.3.2. Water absorption test

At 28 days curing age, the specimens were dried for 48 h in a drying box with the temperature of 80 °C, and weighed when cooling (G_0). Then, the specimens were immersed in water at 20 ± 2 °C for 48 h, removed, and weighed after wiping off the surface water with a damp cloth (G_1), water absorption of the specimens was calculated according to DL/T 5126–2001, as follows:

$$W_A = \frac{G_1 - G_0}{G_0} \times 100\%$$

where W_A is the water absorption (%); G_0 is the weight of the specimen after drying (g); G_1 is the weight of the specimen after water absorption (g).

2.3.3. Rapid chloride migration test (RCM)

Cured for 28 days, cylindrical specimens with a size of $\Phi\ 100 \times 50\ mm^2$ were used in the RCM test. Prior to RCM test, each sample was saturated with limewater under vacuum conditions [30–32]. Then, test samples were immersed in a saturated calcium hydroxide solution for 18 ± 2 h. The samples were then put in the bottom of rubber sleeve and the side of samples were sealed by the clamping of two stainless steel hoops. Before test, cathode test sink was injected with 10% NaCl solution and the rubber sleeve was filled with 0.3 M anodic NaOH solution [33–35]. The test time and the applied voltage were determined by the initial current generated on 30 V voltage. After the migration test, three mortar samples were respectively sprayed with 0.1 M $AgNO_3$ solution to confirm the penetration depth of chloride ion. The chloride ion diffusion coefficient was calculated using the following formula [36,37]:

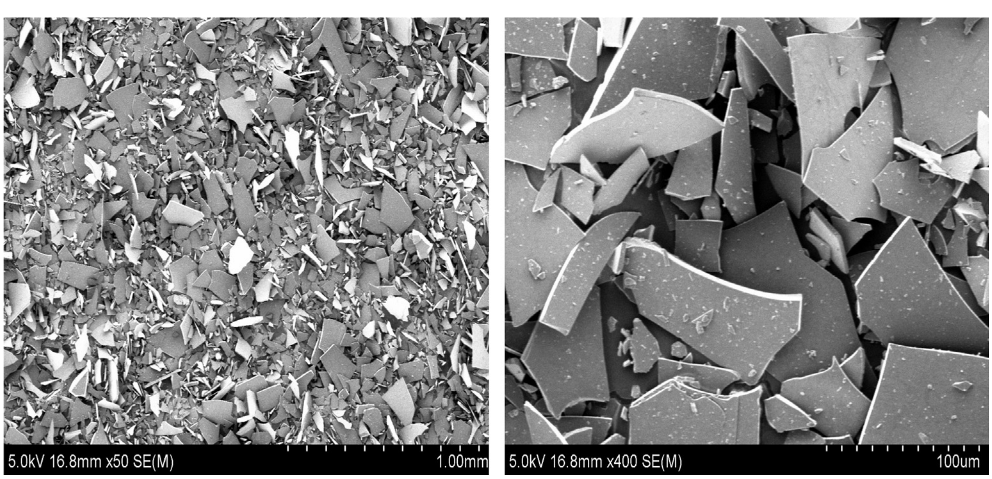

Fig. 1. The SEM micrographs of 120 mesh glass flake.