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Repair of concrete crack by pulse electro-deposition technique

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HIGHLIGHTS

- The pulse electro-deposition method in repair of concrete cracks is studied.
- The healing effect were compared between using pulse and direct current.
- The composition, morphology and developing process of deposit are analyzed.

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ABSTRACT

Electro-deposition is a new technique that has been developed recently to rehabilitate cracked reinforced concrete. While pulse current has been proven to be superior to direct current in the electro-deposition method, there is lack of research on applying pulse current electro-deposition method in repair of concrete cracks. Using electro-deposition method with two different types of current, this study investigated the healing effect of reinforced concrete cracks, and the behavior was compared between pulse current and direct current. The results indicate that using pulse current brings a better healing effect in terms of higher ratios of weight gain, surface coating, crack closure and crack filling depth. In addition, X-ray diffraction and scanning electron microscopy were used to assess the effectiveness of the electro-deposition method, and it is found that the pulse current has no impact on the composition of the sediments, but changes the morphology.

1. Introduction

Electro-deposition is a new technique developed in recent years, which has been used to repair cracks of reinforced concretes in both marine and terrestrial environments. The technique involves the application of a current density for a short period, typically a few weeks. The steel in the cracked marine concrete structure acts as the cathode, and an extended anode is placed in a suitable electrolyte in the seawater. The cations and anions move towards the two electrodes under the action of potential difference, following which a series of reactions happen. The purpose of electro-deposition technique is to fill the crack in concrete and coat the concrete surface by electrodeposits with chemical compounds. These deposits provide physical protection layer to the concrete and prevent various hazardous substances to corrode concrete.

In addition to good technical formula, novel raw materials and production regulation, an ideal and suitable power supply is also critical in the electro-deposition process. Among the power supplies with different usages and waveforms, pulse power was introduced into electro-deposition technology in mid-1960s as an attempt to improve the speed of electro-deposition. However, it was found that the pulse current had little effect on increasing the electro-deposition speed, but significantly improved the performance of the electro-deposition layer [1]. Since the first international pulse current electro-deposition meeting was held in 1979, extensive work has been done to promote the theory, application and development of pulse current electro-deposition technology [2]. Compared with direct current, using pulse current in the electro-deposition method can bring quite a few advantages such as reducing the concentration difference polarization, eliminating hydrogen brittleness, reducing dosage of admixtures, obtaining electro-deposited layer with high purity and density, and improving physical properties of the layer [3]. The particles deposition models of direct current and pulse current electro-deposition are shown in Figs. 1 and 2, respectively. It can be observed that, by using pulse current electro-deposition, it is difficult for the large particles to be co-deposited and thus the particles that are compounded into the deposited layer are relatively small, which results in a dense and compact deposition layer.

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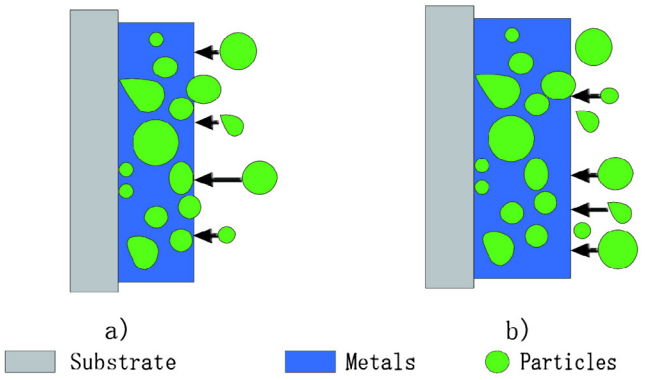

Fig. 1. Particles deposition model of direct current electro-deposition.

Currently, the pulse current electro-deposition is mainly applied in metal plating [4–6], and there is few report on its application in the repair of concrete cracks. This research investigates the feasibility of using pulse current electro-deposition method to improve the healing effect in repairing concrete cracks.

2. Experimental procedure

2.1. Raw materials

P·II 42.5 cement produced by China Cement Plant was used. The physical properties of the cement were shown in Table 1 and the chemical composition is given in Table 2. River sand with fineness modulus of 2.6 was adopted as fine aggregate. The physical properties of the fine aggregate were shown in Table 3.

2.2. Specimen preparation

Reinforced mortar prism specimens with dimensions of 40 mm × 40 mm × 160 mm were prepared for the investigation. The cover depth of these specimens was 15 mm. The water-cement ratio of the specimens was 0.60 and the cement-sand ratio was 1:2.5. The diameter of the plain steel bar was 6 mm. After curing the specimens under standard conditions (RH > 95% T = 20 °C) for 28 days, load-induced cracks with widths of 0.3 mm ± 0.05 mm on the mortar surface were produced for all the specimens, which were used to represent the flexural cracks in practical engineering. Except the cracked side, all the other five sides of these specimens were sealed with silicone rubber. Afterwards, the specimens were placed in electrolytic tanks containing electrolyte solutions.

2.3. Design of experimental device

Direct current or pulse current was employed between the embedded reinforced steel and a flaky titanium mesh anode which was immersed in the solution and located at the bottom of the electrolytic tank. The steel embedded in the mortar specimens was connected to the negative terminal of the power supply and the external anode was connected to the positive terminal of the power supply. In this way, the specimens, electrolyte solution, auxiliary electrode, wire and power supply formed a circuit as shown in Fig. 3. The positive and negative ions in the solution moved respectively to the two electrodes and brought a series of reactions on the electrodes as the current passed through. Then sediment would grow in the cracks of the specimens and thus the crack remediation can be accomplished.

2.4. Experimental procedure

The detailed experimental procedure was listed in Table 4. The environmental conditions were kept constant throughout the period of investigation. In order to maintain the same concentration, the solutions were refreshed every 5 days. When direct current electro-deposition was adopted, the power supply was adjusted to provide a current density of 2.0 A/m^2 to the mortar surface for 20 days.

3. Evaluation indexes of electro-deposition healing effect

The electro-deposition speed could be reflected by the weight gain. The improvement in erosion resistance of concretes with cracks by the electro-deposition treatment was closely related to sediment coverage, crack closure, and the filling of cracks by sediments [7–9]. Therefore, ratios of weight gain, surface coating, crack closure as well as crack filling depth were used to evaluate the formation of electrodeposits in concrete cracks.

3.1. Ratio of weight gain

The specimens were tested at an interval of 5 days. After taking the specimens out from the solution, they were cured for 24 h at

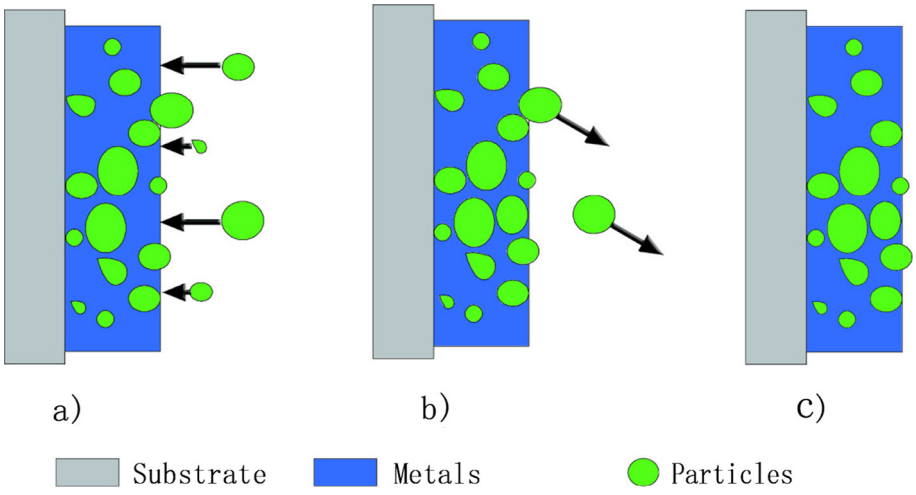

Fig. 2. Particles deposition model of pulse current electro-deposition.