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Experimental study on repair of concrete structural members by electrochemical method

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Abstract

The aim of the electrochemical technique in concrete rehabilitation is to fill the cracks and to coat the concrete surface by precipitating deposition materials on the surface of the concrete. X-ray diffraction, scanning electron microscopy, and flexural tests were used in order to assess the effectiveness of this method.

Keywords: Concrete; Deposition; XRD; SEM; Flexural test

1. Introduction

Concrete cracking is of the utmost importance for the infrastructure and is caused by various factors involving construction technique and environmental conditions. Depending on the type of cracks, there are many repair methods available such as epoxy injection, routing and sealing, and grouting [1–3]. One of the techniques of dealing with crack repair is the electrochemical method. Investigations proved that it was possible to close the cracks in reinforced concrete by applying an electric current, especially under special environments where other traditional repair systems are inefficient.

This electrochemical technique is currently restricted to the repair of underwater structures; this closes concrete cracks and improves the concrete water-tightness and mechanical properties by precipitating deposition materials on the surface of the concrete. The present research builds on the earlier efforts by considering further the materials likely to be used in the practical application of this method. Experiments are performed to examine the feasibility and the advantages of the electrodeposition technique as a means of repair for cracked reinforced concrete, as well as to investigate the effects of this method on the physical and the mechanical properties of concrete structural members.

Twelve reinforced concrete specimens were made in this study. The development of crack closure and the amounts of surface coating from the precipitation of electrodeposits were evaluated. The properties of the electrodeposited concrete were determined, through visual observation, water permeability and flexural behavior studies. In addition, X-ray diffraction, scanning electron microscopy (SEM), and pore size distribution analyses were conducted in order to assess the effectiveness of this method.

2. Experimental

A Portland cement with specific gravity of 3.14 was used in this investigation. The fine aggregate was river sand while the coarse aggregate was crushed sandstone

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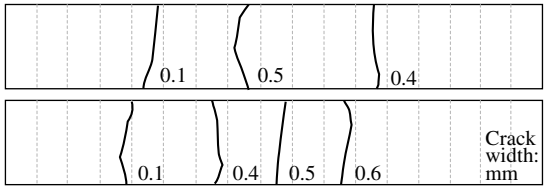

Fig. 1. The crack shape of beams after loading.

with G_{max} of 20 mm. The diameters of the main steel bar and stirrups were 13 mm and 6 mm, respectively. The 28-day compressive strength of cylinder specimen was 31 MPa and water–cement ratio was 0.5.

Reinforced concrete beam specimens, having a cover depth of 2 cm, were made for investigation. After curing in the laboratory air at a temperature of 20 ± 3 °C for 28 days, load-induced cracks of 0.1–0.6 mm in width on the concrete surface were made in all specimens, which simulated concrete bending cracks in the actual environment. The crack shape of beams after loading is shown in Fig. 1. Except for the cracked side, all five sides of each of these specimens were sealed with epoxy. Then, they were placed in plastic containers containing electrolyte solution. The environmental conditions were kept constant throughout the period of investigation.

An electric current of 0.5 A/m^2 to the concrete surface was fed by a power supply between the embedded steel and a titanium mesh anode immersed in the electrolyte solution and located at the bottom of the container. The embedded steel was connected to the negative terminal of the potentiostat and the titanium mesh anode was connected to the positive terminal of the potentiostat. The electric current was applied for 4 weeks. Based upon previous investigations conducted by the authors, an electrolyte solution ($MgCl_2$) was selected for this study [4–6]. From the results of the previous study, it can be concluded that the $MgCl_2$ solution is most effective for the purpose of precipitating the deposition product inside and outside the crack in concrete. The concentration of the solution was 0.1 mol/l. In order to maintain the same concentration, the solution was replaced every week.

For the purpose of the observation of precipitation, the development of crack closure was measured every week from the beginning of the test. The development of crack closure was defined as the percentage of the length of closed crack with respect to the total length of crack. Observation on cross sections of specimens was also carried out. This observation was carried out by cutting the specimens.

In order to evaluate the coefficient of permeability in the concrete specimens, a water permeability test was used. It involved measuring the level of water in the pipette while the water percolated into the specimen (Fig. 2). In order to avoid errors caused by evaporation of water, liquid paraffin was placed on the water surface

Fig. 2. The view of the permeability test.

in the pipette. Measurement was conducted over the cracked part of the specimen. A mercury intrusion porosity meter was used to evaluate the microstructure of the electrodeposited concrete specimen.

After the test period, a flexural failure test of the beams was carried out. Load and deflection at mid-span were measured. The loading condition of the test beam was the same as the initial cracking loading. The average of values obtained from three specimens was taken in this investigation. And the crack width was measured by attaching eight pieces of π-type strain gage under the concrete specimen continuously.

3. Results and discussion

The main purpose of the electrodeposition method is to close the cracks in concrete and to coat the concrete surface by electrodeposits of chemical compounds. These layers of inorganic compounds are known to provide a physical barrier and to reduce the flux of gas or solution inside the concrete. This can be accomplished by feeding a weak direct current between the embedded steel (the cathode) in the concrete structure and an electrode (the anode) located in electrolyte solution (Fig. 3).

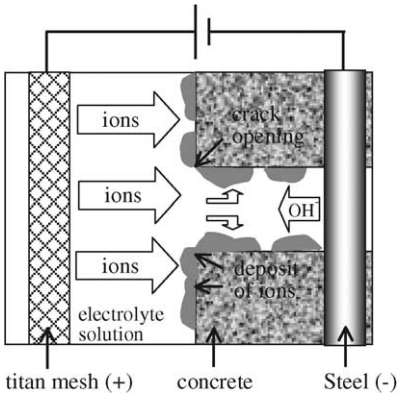

Fig. 3. Deposition process of reinforced concrete.