Abridgment

Visualization of Chloride Distribution in Concrete

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Chloride contents of concrete are usually measured by dry drilling and chemical analysis of the drilled samples. However, the conventional method does not provide any information on chloride distribution. A visualization technique involving color mapping was developed for the determination of chloride ion distribution and concentration near the reinforcement in concrete.

Localized corrosion of reinforcements in concrete is caused by the impurities of the reinforcement material, deformation of the reinforcement surfaces, concentration difference of chloride ion near the reinforcement, and the complex interactions of the preceding factors (*1,2*). Deformed or defective surfaces of reinforcements could be the corrosion initiation sites even under very low chloride ion concentrations because of their thermodynamic instabilities, whereas no corrosion may be found on the deformation-free or defect-free surfaces, respectively, under relatively high chloride ion concentrations. Galvanic interactions between corroding and noncorroding areas accelerate the localized corrosion at the surfaces of reinforcements.

Similarly, the concentration differences of chloride ion near reinforcements create galvanic cells between the high- and low- or no-chloride concentration surfaces of the reinforcements (*2*). Areas of high chloride concentration become the anode, and areas of low or no chloride concentration the cathode. Corrosion rates increase as the chloride concentration difference increases.

Chloride contents of concrete are usually measured by dry drilling and chemical analysis of the drilled samples. However, the conventional method does not provide any information on chloride distribution near the reinforcement in concrete, particularly along hairline cracks. Such information would be essential in understanding the localized corrosion mechanisms and kinetics.

A visualization technique is in use for the determination of chloride ion distribution and concentration near the reinforcements in concrete, as described in the following sections.

EXPERIMENTAL

Concrete blocks containing reinforcements were collected in the field, cut, and ground to expose flat, smooth surfaces. The concrete surfaces were finished with 320 grit silicon carbide abrasive papers. A crack was intentionally made from one edge of the concrete block to the reinforcement, as shown in Figure 1a. A solution of 10 percent $CaCl_2$ was applied repeatedly to the crack to simulate the chloride penetration through the crack.

The indicator solutions used for detection and determination of chloride ion on the surface of the concrete block were 0.025 percent mercuric nitrate in 0.008 M nitric acid, and 0.25 percent diphenylcarbazone in methanol. A filter paper was wetted by the mercuric nitrate solution uniformly. The filter paper was placed over the flat, smooth concrete block and pressed firmly for about 5 min. Then, the filter paper was peeled off and the diphenylcarbazone solution was sprayed over it and air-dried. For the purpose of calibration, 0, 0.01, 0.1, 1, and 10 percent $CaCl_2$ solutions were also applied to filter papers, and the color was developed as before.

RESULTS AND DISCUSSION

Chloride ion concentrations in aqueous solutions can be determined by titration with mercuric nitrate in the presence of diphenylcarbazone as an indicator (*3*). This method was adapted to this investigation. Chloride ion on the concrete block surface reacted with mercuric ion to form insoluble mercuric chloride. Excess mercuric ion produced violet color when the diphenylcarbazone solution was sprayed over the filter paper as follows:

$$Hg^{++} + 2Cl^{-} \rightarrow HgCl_2$$

$$\text{Excess } Hg^{++} + \text{diphenylcarbazone} \rightarrow \text{violet color}$$

The color map of Figure 1b shows the chloride ion distribution and concentration in the concrete. The light area indicates where chloride ion is present, and the different shades of purple represent chloride ion concentrations that may be estimated from the calibration strips shown in Figure 1c. This technique for the determination of chloride ion concentration and its distribution in concrete is simple and rapid.

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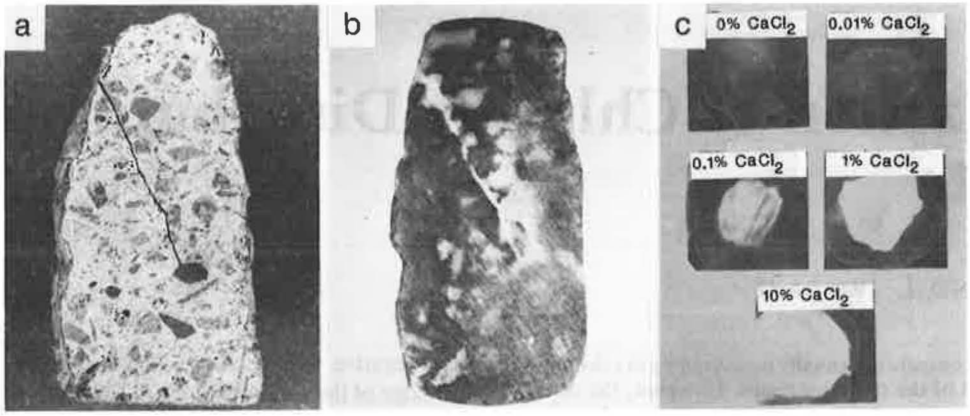

FIGURE 1 Visualization results for chloride ion distribution and concentration in concrete: *a*, concrete sample with rebar; *b*, color map; and *c*, calibration strips.

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