Use of UV-Spectroscopy for Detection of MCI Migration Depth in Concrete

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Abstract

Migrating Corrosion Inhibitors (MCI) are organic inhibitors based on amino-carboxylate chemistry. MCIs have been effectively used for the protection of embedded steel rebar in concrete. They can be incorporated as admixture or as topical treatment on existing concrete structures through surface impregnating or MCI repair mortar application. Detection of the presence of MCI in treated concrete is important in a number of circumstances for example, dosage rate verification for MCI admixture or understanding migration depth at a given time for topically applied MCI. A reliable and accessible detection method has been very much sought after. This work discusses the methods of MCI detection through simple physical-chemical means. Using UV spectrophotometric detection method it was found that, 5 weeks after a surface was impregnated with MCI, the inhibitor migrated to a depth of more than 3 inches below the treated surface. The UV method can also be use to verify admixture MCI dosage rate in various concrete mix designs.

Keywords: migrating corrosion inhibitors, reinforced concrete, detection of MCI, migration depth of MCI in concrete

Introduction

Migrating Corrosion Inhibitors (MCI) technology was developed to protect embedded steel reinforcement and the concrete structure. MCIs are organic compounds that protect by forming a monomolecular barrier film on the metal surface to prevent the attack of the harsh elements[1,3].

In new and well-constructed concrete, cement paste provides an alkaline environment. Steel forms a protective ferric oxide film in this alkaline environment and is protected. However, with time carbonation occurs in concrete, deducing the pH of pore water in concrete and destroying the ferric oxide film. Ingression of chloride ions also destroys the ferric oxide film. Corrosion of rebar starts when the protective ferric oxide film is compromised, resulting the subsequent spalling and cracking of a concrete structure. Thus, corrosion inhibition measures are necessary to ensure a safer concrete structure of a longer life. This is particularly true in corrosive environments such as coastal areas, areas in which de-icing salts are commonly used, acid-rain affected regions and regions where high humidity is common. According to a recent report, the estimated annual costs of repairing and protecting concrete structures is between $18 and 21 billion in the U.S. alone[2].

MCIs have been used effectively for the protection of rebar in concrete[1,3,4,5]. MCI can be incorporated as concrete admixtures or as topical treatment on existing concrete structures -- through surface impregnating or MCI repair mortar application. MCIs have been shown, with XPS analysis[6], to migrate through concrete capillary networks and form a protective layer on rebar, providing protection in the presence of chlorides[4,5,6,7].

When MCI is topically applied, there is interest in understanding its migration profile in the concrete at a given time. When MCI is used as an admixture there is also interest in verifying the dosage. Both call for a detection method for MCI. The challenges of developing a reliable MCI detection method are that the method needs to be able to detect minute amount of MCI which is typically dosed at very low rates in concrete, concrete mix designs vary considerably, and concrete itself is highly alkaline.

Currently the following detection methods of MCI in concrete exist:

A. Alkalinity Test by titration
B. Quaternary Ammonium Compound Test Kit
C. Detection of tracer
D. Detection using UV spectroscopy
E. X-ray photoelectron spectroscopy (XPS)

This work focuses on detecting MCI using UV spectroscopy. UV spectroscopy was chosen because it is routinely used in analytical chemistry and is easily accessible. It also provides the ability to detect low concentrations.

Using UV spectroscopy, the inhibitor was detected at 3" below a concrete surface treated with a topical MCI (MCI-2020) after 5 weeks. This method also can be easily applied to verify admixture dosage rate of MCI-2005.

Experimental Procedures

Concrete specimen Concrete specimens were prepared using Portland Type I cement, playground sand and tap water. The water/cement/sand ratio is 0.45/1/3 by weight and the cylinder dimensions were approximately 7cm (D) x10cm (H). The concrete was cured for 28 days.

Topical MCI application A surface applied MCI product, MCI-2020, was coated to the top face of a cured concrete cylinder (Figure 1). The coverage was $0.026 g/cm^2$. The MCI coating was allowed to stay on the concrete surface for 4 or 5 weeks.

MCI migration depth profile analysis The above MCI impregnated specimens were cross-cut into 1.3cm (0.5") thick discs (Figure 1), 4 and 5 weeks after MCI treatment, respectively. Each disc was labeled with its distance to the MCI treated top. The concrete discs were pulverized and the powers that passed a #20 sieve were saved for analysis.

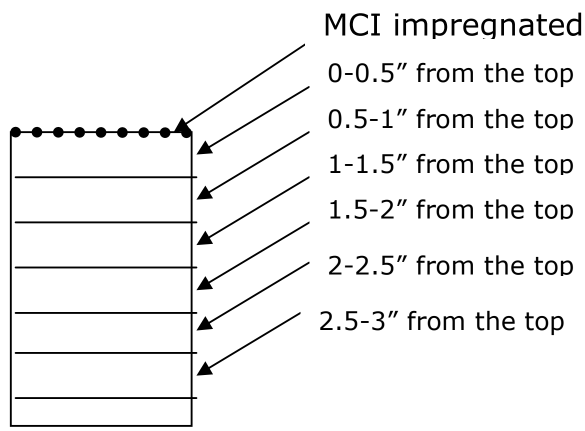


Figure 1 Illustration of MCI migration depth analysis in concrete

Extraction of MCI Equal weight of the concrete powder and de-ionized water were mixed thoroughly in a capped jar, and allowed to stand at least 4 hours. The extracted liquid was filtered (0.45um PTFE) and used for UV analysis.

UV detection Water extracts of the concrete samples were analyzed using a UV-Vis spectrophotometer (Thermo Scientific Evolution 201) with a 1cm light path disposable UV cuvette (Brand Tech). De-ionized water was used to obtain a machine background. Scans were performed in UV range. The spectrum of each sample was compared with that of a control, a concrete of the same mix design but without MCI treatment, to derive at MCI presence in the sample.

Results

The inhibitor in MCI-2020 is detected as a distinctive peak in UV spectroscopy and the height of the peak represents the abundance of the inhibitor. The water extracts of the MCI treated concrete slices all exhibited this distinctive peak in their spectra. When compared to the spectrum of the control, MCI was shown at 7.62cm (3") below the treated surface, Figure 2. The spectra also showed that 5 weeks after the application, the inhibitor abundance in concrete at 1.27cm (0.5") below the treated surface was similar to that at the surface. In addition, a logical progression of MCI migration in the concrete cylinder is demonstrated in Figure 3.

Figure 2, Spectra of Concrete Extract at Different Depths 5 Weeks after Treatment

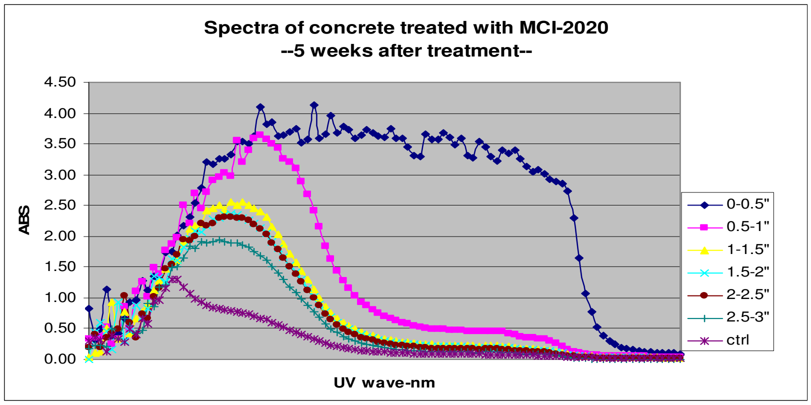
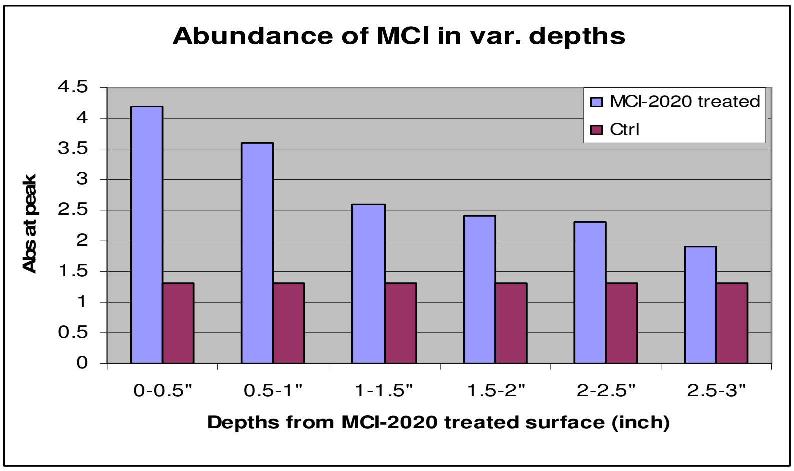


Figure 3, Progression of MCI Migration 5 Weeks after Treatment



By examining the spectra of concrete slices cut at 4 weeks (Figure 4) and 5 weeks (Figure 2) after the topical treatment of MCI-2020, it was found that there was considerable progression of MCI moving deeper into the concrete interior and become available for rebar protection. Between week 5 and week 4, the increase in MCI abundance was about 60% at the depths 1 to 2 inches below the treated surface, the area where the steel reinforcement is typically located. It would be reasonable to anticipate this migration of MCI from surface into the interior of concrete continues with time.

Figure 4, Spectra of Concrete Extract at Different Depths 4 Weeks after Treatment

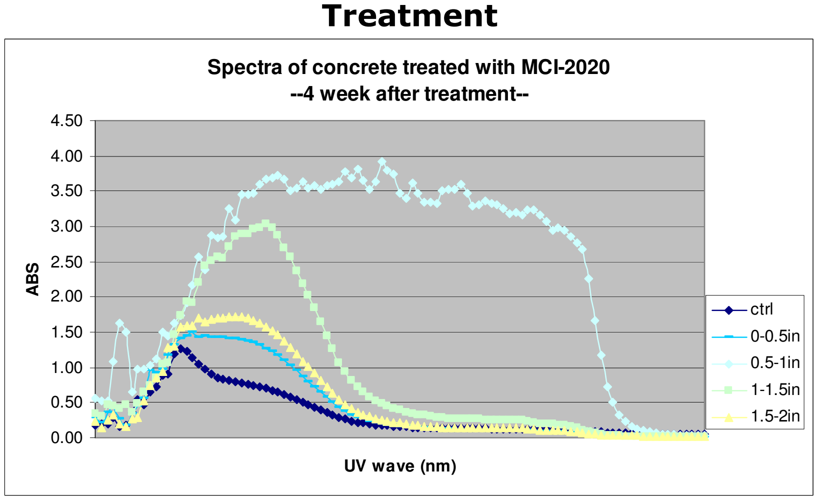
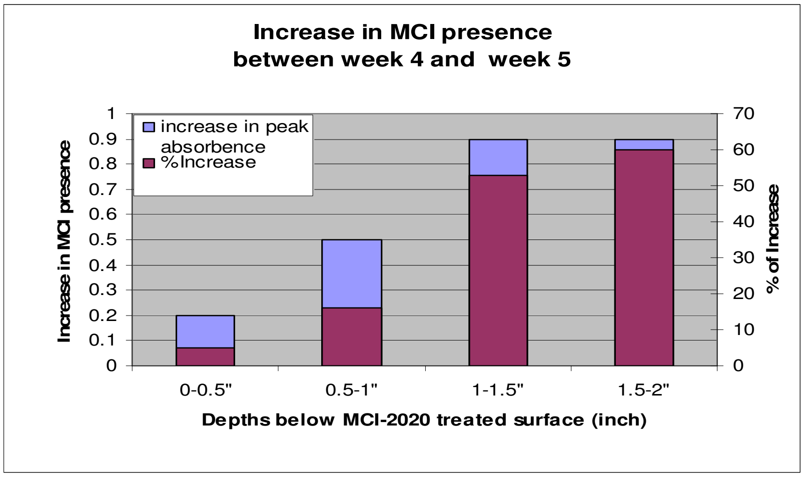


Figure 5. Increase in MCI Abundance in Concrete Interior between Week 4 and Week 5



Conclusion

UV spectroscopy showed that the inhibitor in MCI-2020 was detectable in UV range. Using UV spectroscopy, the MCI was found at 7.62cm (3") below a treated surface. Furthermore, it was found that the inhibitor migrated at considerable rate from a treated surface into concrete interior. The abundance of MCI at 1 to 2 inches below the treated surface increased about 60% between week 5 and week 4 following a surface treatment.

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