Corrosion Inhibition of Steel Rebar in Concrete with the Coated MCI 2022

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ABSTRACT

The induced chemical and salt solution in water or admixture are originated to the corrosion process of the steel rebar. These liquids penetrate into concrete as the accompanied by the chemical reaction and cause to attack the steel rebar in concrete. Concrete surfaces which is exposed to deicing, water and sea water is allowed to enter the chlorides in the structures. To prevent from the source of corrosion and deterioration is subjected to put an end to corrode or reduce to contaminate on the steel rebar.

As this reason the MCI 2022 products are applied to the surface of concrete and steel rebar. The concrete samples were made of to the kind of four, i.e. RF, MR, MS, and MM. Corrosion inhibitor is applied to coat on the surface of concrete after it had been cured for 28days. Specimen were immersed in a 3.5% sodium chloride solution. Concrete specimen were tested to determine the changes of the resistance polarization, Rp, over a 22 weeks period.

MCI 2022 is significantly shown the corrosion inhibition of steel rebar in 3.5% NaCl solution. In the each different concrete sample, MS and MM is seemed to be better than others. The results are proofed that MCI 2022 is promised to maintain the inhibition of corrosion with high resistance polarization of the steel rebar in concrete.

Keywords : MM(coated mortar), MR(coated rebar), MS(coated surface), RF(Not treated reference)

1. Introduction

The characteristics of the cement concrete is apt to be controlled by chemicals in the atmosphere and water. As this reason it has permeability, alkalinity and reactivity. Corrosion or degradation of steel rebar is exposed to air and its pollutants can be more serious rather than partly immersed in water. According to the penetration of water, the chemical reaction is taken place with cement and steel rebar.

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In the 1998, it was estimated that there were 583,000 bridges in the United States(200,000 steel bridge, 235,000 conventionally reinforced concrete, 108,000 prestressed concrete bridges, and the remainder constructed from other materials). Roughly 87,000 of these bridges were considered structurally deficient, largely because of corroded steel reinforcement. The annual direct cost of corrosion for high bridges is estimated to be $8.3 billion, consisting of $3.8billion to replace structurally deficient bridges over the next ten years, $2.0 billion for maintenance and cost of capital for concrete bridge deck, $2.0 billion for maintenance and cost of capital for concrete substructures (not including the decks), and $0.5 billion maintenance painting of steel bridges. Indirect costs due to traffic delays and lost productivity were estimated at more than ten times the direct cost of corrosion maintenance, repair, and rehabilitation.[1)]

Based on amino carboxylate, MCI is a effective corrosion inhibitors. The migrated MCI to the steel rebars surface is formed in state of molecular protective layer. MCI is developed to protect both the concrete and the reinforcement steel, and practically to reduce the rate of corrosion on the steel rebar. MCI is in available to a admixture and compensation on surface of concrete structures. In two MCI 2021 and MCI 2022 on steel rebar in concrete MCI 2022 is showed the excellent corrosion resistance performance in corrosion potential and resistance of polarization on rebar.[2)] The migrating corrosion inhibitors MCIs in an aqueous liquid carrier and MCI inhibited repair mortar showed an effective inhibiting system for protecting reinforced concrete.[3)] The influence of MCIs on the steel rebar corrosion in concrete is indicated significantly to retard corrosion processes and especially to act important role in delay of reinforcement steel corrosion in concrete.[4)] MCIs in mixed with inorganic paints showed an effective alternative in using of protective coatings on the surface of concrete. MCIs influence to both cathodic and anodic process bya protective layer at the surface of steel in according to the diffusing from surface through a great of surrounding steel rebars in concrete.[5)] As corrosion inhibitors are sprayed on the surface of concrete, it penetrates to the surface of concrete, and diffuses in vapor or in state of liquid to the steel rebar, and deposits a film layer of protection on the steel surface.[6)] The MCI 2022 products have successfully shown in corrosion inhibition of steel rebar in a 3.5%NaCl solution by maintaining high resistance polarization for the rebar in concrete. The other hand the untreated with MCIs concrete samples showed gradually declination in their resistance and corrosion potential, as it were , indicative of corrosion.[7)]

The purpose of this paper lies to analysis the corrosion inhibition of several different samples which is coated or mixed with MCI 2022 in concrete and steel rebar. Electrochemical techniques were applied while samples were perfectly immersed in 3.5% NaCl solution at ambient temperatures. During this investigation, changes in the resistance of polarization and the corrosion potential of the rebar were monitored to search the degree of effectiveness for different samples with the coated MCI 2022. The results were analyzed to compare with as the kind of the samples.

2. Experimental Procedure

Eight concrete samples with dimensions 8″x 4″x 4″were made. Each sample is consisted of one

8 inch steel (class60) rebar (3/8"diameter) and one 8 inch Inconel metal strip (counter electrode). The rebar prior to being placed in concrete were exposed to 100% RH(relative humidity) to initiate corrosion. Teflon tape was wrapped around the top 2-3 inches of inconel and rebar to prevent corrosion rust at the concrete/metal interface. Concrete was mixed with one half gallon water per 60-lb bag (.4-.5 cement to water ratio) in a mechanical mixer. Inconel and rebar were placed one inch apart and two inches from the bottom of the wood container before concrete was poured. Eight rebars were placed one inch from the side of the box. The concrete was cured in air for 24 hours ,and then removed from the wooden crates and placed in 8 inches of water to continue the curing process. The concrete specimens were removed from water and set out to dry (approx. 28 days; the attained compressive strength of concrete was about 2,800-3,200 psi). The concrete blocks were sandblasted to remove loose particles, debris, and rust deposited on the metal. This process left the concrete with a marginally smoother surface. Red shrink-wrap was placed on each of the exposed rebars to prevent additional corrosion.

Bode and Nyquist plot were yielded from the data obtained using the single sine technique. Potential values were recorded and plotted with respect to time. By comparing the Bode plots, changes in the slopes of the curves were monitored as a means of establishing a trend in the Rp value over time. To verify this analysis, the Rp values were also estimated by using a curve fit algorithm on the Nyquist plots. Based on these plots, the Rp and R combined values are displayed in the low frequency range of the Bode plot and R value can be seen in the high frequency range of the Bode plot. The diameter of the Nyquist plot is a measure of the Rp value.

CORTEC MCI 2022 was applied to the surface of rebar on the concrete samples (designated MR), the other the surface of the concrete samples(MS), and the other MCI mortar coated with 1/4" thickness on the surface of concrete samples(MM). The remaining two concrete samples which is not applied with MCI were used as control references(RF). These samples were immersed in 3.5% NaCl solution (roughly 6-7 inches of each sample was immersed in solution continuously). EIS testing was started after 24 hours of immersing using a Cu/CuSO4 electrode.

3. Result and Discussion

The corrosion inhibition of one commercially available migrating corrosion inhibitor(CORTEC MCI 2022) was investigated over a period 158 days using AC electrochemical impedance spectroscopy(EIS). Throughout this investigation, the change in the resistance polarization and the corrosion potential of the rebar were monitored to determine the degree of effectiveness for the Cortec MCI 2022 products. According to the ASTM(C876) standard, if the open circuit potential (corrosion potential) is between -50 and -170 mV, this indicates a 90% probability that no reinforcing steel has corroded. Cortec MCI 2022 samples showed around 120 mV as less than 200 mV on the test. Corrosion potential more negative than 350 mV are assumed to have a greater than 90% likelihood of corrosion.

In the beginning stage of the corrosion, the surface of the steel rebar will be in state of whether anodic or cathodic. At the higher frequency 103 Hz, the coated MCI is seen the affect of dielectric characteristics . The low frequency 10-1 to 10-3 Hz, it implies the electrochemical state is shown that rebar is in the passivated and corroded state.

Figure 1 shows corrosion potentials for the MCI 2022 and untreated control sample is apt to show to drop from -100mV which indicates a 90% probability of corrosion attack on the reinforcing steel. The treated samples with MCI 2022 are shown the corrosion potential, -110mV. All of the MCI 2022 samples had corrosion potentials in the non-corroding range per ASTMC876. The sample MS and MM are held at the high potential level compare with other samples. The potential of the samples continuously are sustained about 90 days with high potential -110mV. According to B. Bavarian 1) the treated MCI 2022 samples are maintained the certain value that is around 120 mV, and the untreated samples with MCI 2022 is dropped the corrosion potential from 120 mV to 500 mV on about 120days. After the potential of the samples are in drop down, the change of the fluctuation is arisen irregularly. On the whole all samples tendency is similar with the change of potential. Fig 2 shows the tendency of the resistant polarization on the relation Rp and time so that these imply the range of the potential.

EIS showed that MCI 2022 reference samples had a gradual reduction in their resistance polarization, from about 104 ohms to less than 103ohms, which is similar to the drop in their corrosion potentials and strongly indicative of steel rebar corrosion. Fig 3~4 show that resistance polarization for MCI 2022 gradually increased from 104 to 7 x 104 ohms ; for samples with inhibitor , the Rp value was 104 ohms at the beginning of the experiment ended at the close to 6 x 104ohms. An increase in Rp value was observed after about 60 days, indicating that MCIs require an induction period for diffusion into the concrete to reach the steel rebar. Fig 5 shows the Bode plot for Ms 1 and 157 days. That is shown the difference on Rp which is affected by the diffuse on the coated surface.

The samples coated with the MCI 2022, MS and MM were shown the greatest amount of corrosion resistance. These results are extremely verifying for MCI 2022 product in its ability to protect steel rebar in concrete in aggressive environments.

4. Conclusion

The MCI 2022 products have successfully inhibited corrosion of the rebar in a 3.5%NaCl solution for 158 days. Steel rebar corrosion potentials were maintained at approximately - 110mV, and rebar resistance polarization reached as high as 6×10^4 ohms. Both results indicate excellent corrosion resistance performance.

Consequently the experimental results demonstrate that MCI 2022 products offer an excellent inhibiting system for protecting reinforced concrete in an aggressive 3.5%NaCl solution. These results are perfectly promising for the protection for steel rebar in concrete in aggressive environments.

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