EXPERIMENTAL STUDY ON THE CORROSION BEHAVIOUR OF CARBON STEEL AND REINFORCING BARS

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ABSTRACT: *Reinforcing bars (rebar) are utilized to help solid structures and are commonly produced using carbon metallic. Because of the enormously helpless erosion obstruction of carbon metal, elective metals with higher consumption opposition had been recommended as choices. Type 316LN chrome steel and smaller scale composite metal (MMFX-2) are among those metals. Be that as it may, the exorbitant expense of those open door rebar materials and the lack of trustworthy insights with respect to the erosion conduct of these compounds in concrete have made it intense to legitimize their utilization. The basic target of this examination is to give a quantitative evaluation of the consumption conduct of these amalgams in engineered solid pore arrangements. Manufactured solid pore arrangements that copy arrangements in each shining non-carbonated and carbonated cement under chloride particle attack were utilized in this analyze. The overall exposure time frame became seven days. Electrochemical Impedance Spectroscopy (EIS), that is a substituting front line approach, got used to watch uninvolved film arrangement on the metallic floor in arrangements exposed to steady chloride particle increments from chloride free to two M.*

I. INTRODUCTION

Erosion of fortifying bars (rebar's) inside cement is one of the most significant marvels that decrease the administration life of a solid structure, and it causes an immense burden on the upkeep spending plan of the influenced structure. Once started, consumption items, which have igher volume than the parent metal, will gather in the space between the rebar and concrete, and since there is inadequate space to oblige these items, splitting and spalling of the solid spread will happen. In the event that the rebar cross sectional misfortune is extreme, auxiliary issues may begin to happen. Figure 1.1 shows a case of solid spread spalling because of the consumption of

Figure 1. 1 Corrosion of a cross girder that supports the main bridge deck

the fortifying bars of a bar that bolsters a scaffold superstructure. This sight, in spite of the fact that may not be basically perilous, is a source of concern to the public. Thus, a repairing process is required.

In order to avoid such high repair costs, new types of rebar's have been developed that are more corrosion resistant than conventional reinforcements. These include rebar made from stainless steels (as an instance 316LN, 304), micro-composite metal (MMFX-2), epoxy-covered metallic, zinc-coated metallic and stainless steel clad over carbon metal. However, there are problems the usage of a number of these substances. For instance, whilst the use of epoxy-covered steel and stainless steel clad over carbon steel, more care ought to be taken when coping with and setting the rebar's to avoid making holes or defects inside the coating or cladding. If defects are induced, the carbon steel may also corrode at very high prices. For stainless steel and micro-composite metallic, the excessive preliminary price and the dearth of records at the corrosion behaviour of those metals in concrete environments (mainly Micro- composite metal) can also make the usage of these materials unattractive.the main objectives of the work are:

- Determine the important chloride ion attention in concrete pore solution (carbonated and non-carbonated) this is sufficient to provoke corrosion (chloride threshold stage) for carbon metal, micro-composite steel (MMFX-2) and 316LN stainlesssteel;
- Quantify the effect of gradually increasing the awareness of the chloride ions in the solution on the electrochemical residences of the passive layer fashioned at the floor of the metals below research while immersed in carbonated and non-carbonated concrete poresolution;
- Determine the effect of the trade of water content and the diploma of pore saturation at the corrosion current of carbon metal in mortar;and
- Determine the impact of the presence of chloride ions on Time Domain Reflectometry (TDR) measurements for moisture content material inner mortar

II. METHODOLOGY

This task meant to investigate the electrochemical behaviour (i.E. Crucial chloride threshold and corrosion currents) of 316LN chrome steel and micro-composite steel (MMFX-2) in evaluation with the behaviour of conventional carbon steel in artificial answers emulating each instances of sparkling and carbonated concrete beneath chloride ion attack the use

of direct cutting-edge DC corrosion measurements strategies (open circuit capability EOC, linear polarization RP and potentiodynamic test). The Electrochemical Impedance Spectroscopy (EIS) method changed into used to investigate the change in the electrochemical residences of the passivemovie shaped at the metallic floor while immersed in fresh and carbonated concrete pore solution and subjected to incremental will increase in the awareness of chloride ions. Furthermore, a fixed of carbon metal samples embedded in mortar and subjected to a chloride contamination of five% of cement weight were examined to achieve the real corrosion currents interior mortar. Finally, the effect of the presence of chloride ions on TDR measurements of volumetric water content in concrete became examined. The information of the experimental work are described in thisbankruptcy.

Experimental Details of Experiments Conducted in Synthetic Solutions
The analysis was covered under following headings
- Composition of the concrete pore solutionsused
- Sample size, shape and description of the corrosion cell
- Electrochemical Measurements
- Direct Current (DC) measurements: Fixed chlorideconcentrations
- Open Circuit Potential MeasurementsEOC
- Potentio dynamic Scan

PotentiodynamicScans
For every sample, the potentiodynamic scan was applied after 1 hour, 24 hours and 7 days of exposure to determine the corrosion current density icorrat that time. The test parameters are:
- Initial E: is the starting point for the potential sweep in Volts. The initial potential E was- 0.15 V vs.EOC.
- Final E: is the ending point for the potential sweep in Volts. The final potential E was +0.15 V vs. EOC. This scan range (EOC ± 0.15V) enabled the estimation of icorrwithout destroying the sample. Testing further anodic potentials would force the sample to corrode (i.e.,destructivetesting).
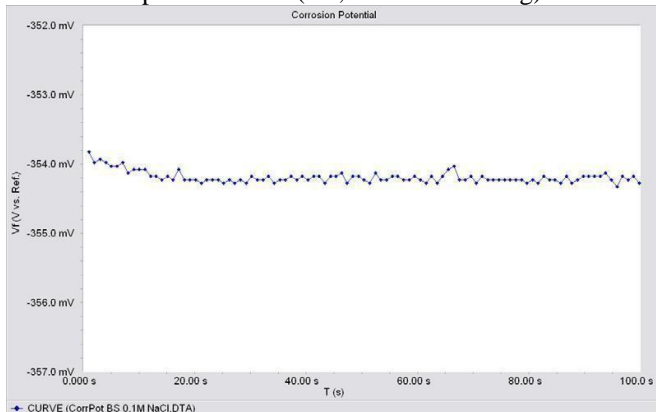

Figure Example of the graphical output for open circuit potential EOC measurement (carbon steel sample after 24 hours of immersion in non- carbonated concrete pore solution

with Cl-concentration of 0.1 M)The sample period: the sample period was1second.
- Scan Rate: is the speed of the potential sweep during data acquisition. Its unit is mV/sec. Very high scan rates lead to unreliable data; however, very low scan rate elongate the test period. The applied scan rate was 0.5 mV/sec. No change in the shape of the curve was noticed when using slower scan rates (see Figure3.6).
- Density: is the density of the metal tested in g/cm3. This parameter is used for corrosionratecalculation.
- Equivalent Weight: is the theoretical mass of metal that will be lost from the sample after one Faraday of anodic charge has been passed. This parameter is used in corrosion ratecalculations.
- Initial Delay: this option is used to allow the open circuit potential of the sample to stabilize prior to the potential scan. The delay time is the time that the sample will be held at its open circuit potential EOC prior to the scan. The delay may stop prior to the delay time if the stability criterion for EOC is met. The delay time parameter is active only if the initial delay is turned on. This option was turned off in all theexperiments
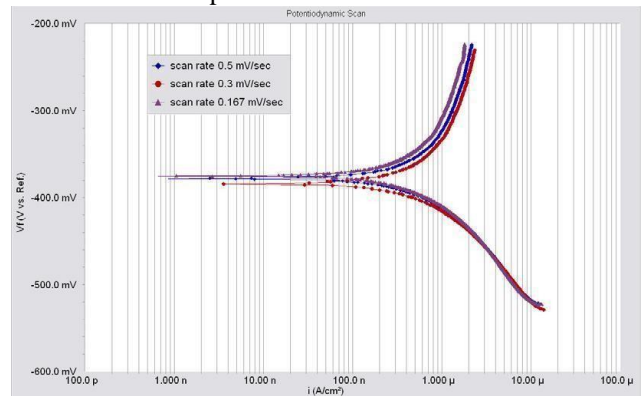

Figure Potentiodynamic scans for carbon steel in non-carbonated concrete pore solution with Cl- ion concentration of 0.1 M using three different scan rates.

Extrapolation of the corrosion current density icorr was made with the help of GAMRY Echem Analyst (v.1.35) software. Figure 3.7 shows an example of the graphical output of the potentiodynamic scan.
- Linear Polarization Resistance (For every sample, the linear polarization test was applied after 1 hour, 24 hours and 7)
- Electrochemical Impedance Spectroscopy(EIS)
- Incremental chloride addition

Corrosion Current Measurements of Carbon Steel Samples Embedded in Mortar
Measurements of Mortar Volumetric Water Content Using TDR Technique

III. RESULTS AND DISCUSSION
In this part, the experimental results were presented and discussed. It was found that 316LN stainless steel had much higher corrosion resistance than carbon steel and micro-

composite steel (MMFX-2) in both the non-carbonated (pH 13.2) and carbonated (pH 8.5) concrete pore solutions. In both solutions, the increase of chloride ion concentration (up to 2 M) did not cause any change to the free corrosion potential or the polarization resistance, which suggests that the chloride threshold level of 316LN stainless steel ishigherthan 2 M. The corrosion current density of 316LNstainlesssteelcanbetolerated,fromadurabilitypointofview(icorr<0.1 μA/cm2), at all tested chloride concentrations. However, it was found that the parameters associated with the passive film formed on the metal's surface were more sensitive to chloride ion addition in the carbonated solution than the non-carbonated one. Micro-composite steel (MMFX-2) showed better performance than carbon steel in both of the testing environments. In the fresh concrete pore solution, the chloride concentration threshold of MMFX-2 was found to be between 0.1 and 0.5 M(Cl-/OH-

= 0.63 to 3.16). This is 2 to 10 times higher than the chloride threshold of carbon steel (Cl-=0.05 M, Cl-/OH- = 0.32). In the carbonated concrete pore solution, the corrosion currents of MMFX-2 exceeded the 0.1 μA/cm2 limit at the same range of Cl- concentration of 0.1-0.5 M. However, the corrosion currents at Cl- concentration$\geq$ M were very severe (icorr>> 0.1 μA/cm2). Thus, the use of MMFX-2 rebar's is not recommended in the highly aggressive environments (i.e. low pH, high Cl- concentrations).

The chloride threshold level measured for carbon steel (Cl-/OH- = 0.32) was in agreement with the published literature. Once the chloride concentration in the solution exceeded the threshold level, unacceptable corrosion rates were obtained (icorr>> 0.1 μA/cm2). It was also found that carbon steel would suffer severe corrosion in the carbonated solution regardless the chloride ion concentration in the solution. For carbon steel samples tested in mortar pre-contaminated with chloride ions at 5% of cement weight, although the measured corrosion current was high in the first three days after casting, the corrosion current decreased continuously with time after two months of casting. This was attributed to the decrease of free chloride

IV. CONCLUSIONS

- In the non-carbonated concrete pore solution, it was found that the chloride threshold level CTL of carbon steel is 0.05M. In the carbonated concrete pore

    solutionitwasfoundcarbonsteelwillcorrodeinveryhighcurrents(icorr>>μA/cm2) regardless the concentration of chloride ions in the solution.

- For micro-composite steel (MMFX-2), in both the non-carbonated and the carbonated concrete pore solution, it was found that the CTL is between chloride concentrations of 0.1 to 0.5 M. However, in the carbonated solution and at chloride concentration $\geq$ 0.5 M, the corrosion currents measured were significantly higher than those obtained at the same chloride concentration in the non-carbonatedsolution.

- For 316LN stainless steel, the CTL was not reached even at chloride concentration of 2M in both the non-carbonated and the carbonated concrete poresolution.

- For all the metals under investigation EIS results showed that, generally, the increase of the chloride ion concentration in the solution would reduce the resistance of the passive film (Rct+Rf) and increase its faradic capacitance (Cf). That change becomes more noticeable when the chloride concentration in the solution exceeds the metal's threshold level. EIS data of carbon steel in the carbonated concrete pore solution could not be fitted using the chosen representative circuit. This was explained by the absence of any passive film on the metal surface in thatsolution.

- It was found that the corrosion currents of carbon steel embedded in mortar contaminated of NaCl at 5% per cement weight, would decrease due to the decrease in the degree of pore saturation PS. Regardless the high chloride content, the corrosion current was as low as 0.06 μA/cm2 when PS dropped to about 20% after 60days.

Future Scope

In this study, the effect of the presence of chloride ions in both fresh and carbonated synthetic concrete pore solutions on the corrosion behaviour of carbon steel, micro- composite steel (MMFX-2) and 316LN stainless steel was investigated using direct current corrosion measurements and electrochemical impedance spectroscopy techniques. In addition, the effect of the presence of chloride ions on the TDR measurements of volumetric moisture content inside mortar was investigated. There are certain investigations to be followed in future where in accordance to this analysis. The signification of the study may accommodate the steel into the concrete by verifying that it is corrosion resistant. Ions in the paste and to the decrease in the degree of pore saturation, due to water consumption in the hydration process.

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