Corrosion of Steel Bar Embedded in Acrylamide Polymer Modified Smart Cement

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Abstract

In this study, steel bar embedded in cement and cement with acrylamide polymer were tested under complete immersion, in 3 % of sodium chloride solution. Monitoring of open-circuit potential measurement (ASTM 876- 15) and impedance spectroscopy (IS) were used to evaluate the corrosion of the steel bar. Potential reading showed that the steel bar embedded in cement was in the high corrosion zone and the steel bar in polymer modified cement was in the intermediate corrosion zone. The results obtained from open circuit potential test showed that the addition of acrylamide polymer led to improvement in the resistance to corrosion.

1. Introduction

Steel bars embedded in concrete are protected from corrosion by a thin oxide layer that is formed and maintained on their surfaces because of the highly alkaline environment of the surrounding cement (pH~11) (Montemor and Simoes 2000). In spite of the advantages of reinforced concrete, corrosion of the steel bar remains its most common durability problem. The worthiest cause of corrosion initiation of steel bar is the ingress of chloride ions to the steel surface (Liu and Weyers 1996). The organic compounds by acting as a continuous reinforcing network or by interaction with the hydrated cement enhance the corrosion resistance properties of the composite (Ben-Dor, et al., 1985). These remarkable improvements might be ascribed to the filling of pores in the porous cement paste with polyacrylamide. Thus, the protective coating created by the polymer and interaction of the hydrated cement phases with corrosion resistant polymer caused excellent improvement in the durability and corrosion resistance in modified composite product (Rai and Singh 2005).

2. Objective

The objective of this work is to investigate the corrosion behavior of steel bar embedded in acrylamide polymer modified cement and the normal Class H oil well cement, exposed to 3 % NaCl solution. Open-circuit potential (OCP) monitoring and Impedance spectroscopy (IS) were applied to evaluate the corrosion process.

3. Materials and Methods

To monitor and quantify the corrosion, two specimens were casted with polymer solution-to-cement ratio of 0.38 and the polymer solutions was prepared with 2% monomer (AV100), 0.75 % Activator (AV101) and 0.3 % Initiator (AV102) addition (P) and one control mix which was prepared without addition of polymer with the water-to-cement ration of 0.38 (NP). Two commercial steel bars with a cross section of 1” x 0.18”, previously cleaned with a sand paper, were embedded in each cement specimen (2” x 4”), with this configuration (Fig. 1) and the embedded depth of electrode was 3.5”. Concrete blocks were demolded after 10 days and kept it in a Salt solution as mentioned. OCP measurements were taken by using a volt meter and IS readings were taken using LCR device with the frequency range 20 Hz- 300 kHz.

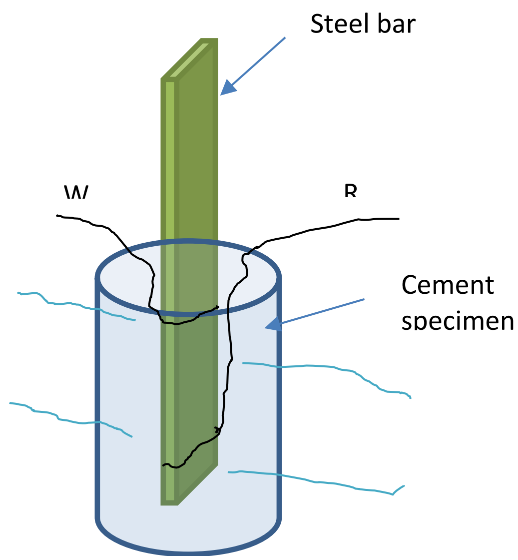

Figure 2. Schematic Configuration of test specimen

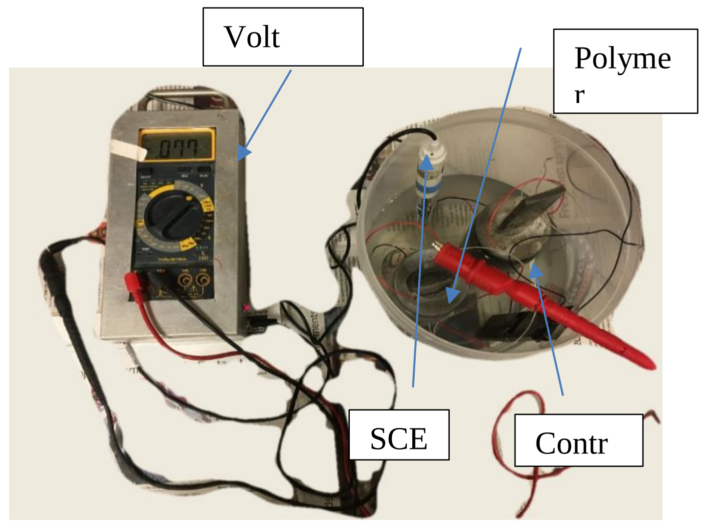

Figure 3.Experimental setup for corrosion potential measurement

4. Results and Discussion

Corrosion potential (Ecorr) was measured for 30 days and the results are shown in Figure 3. First measurements were made just after demolding of the samples (10 days after specimen fabrication). The lines at Ecorr = -126 and -276mV are separated the low, moderate and high corrosion zone suggested by the ASTM C876. The readings were in the range from -250 to -100 mVSCE until 3 days after immersion. After 5 days of immersion, large fluctuations between -100 and -500 mVSCE were found. From 15 to 30 days, more stable potential readings were registered. Those potential readings were in the range of -200 to -400 mVSCE.

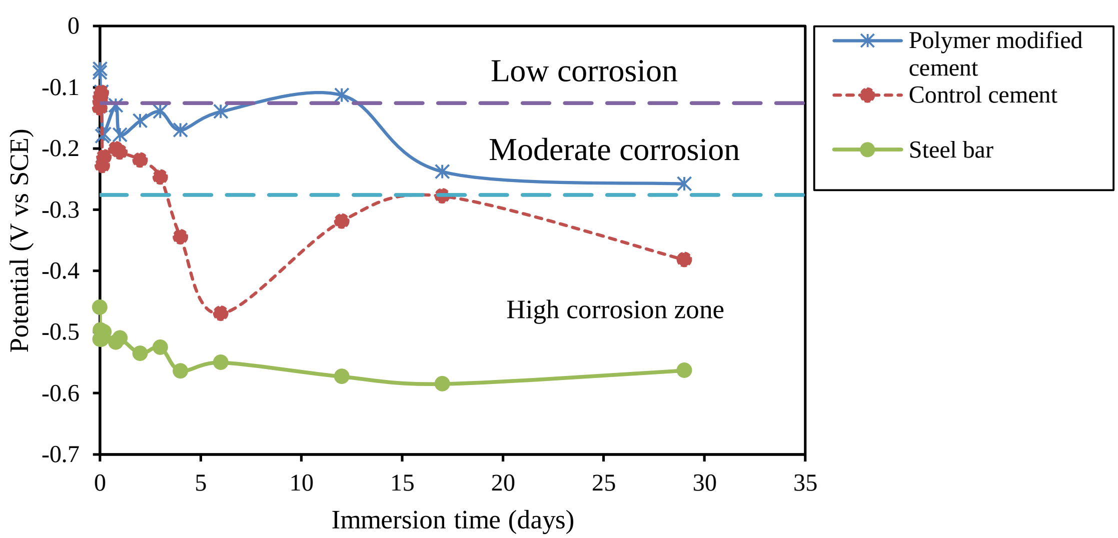

Figure 4. Open-circuit potential evolution for cement specimens immersed in a 3 % NaCl solution: with Acrylamide polymer (P) and without Acrylamide polymer (NP)

Moreover, open-circuit potential evolutions of cement specimens with acrylamide polymer were more constant than those of cement specimens without polymer. According to ASTM C 876, if the potential of steel in concrete becomes more negative than -273 mVSCE, there is a 90% probability that corrosion will occur. After 4 days, the potential of control cement specimen became more negative than -273 mVSCE and fluctuated. Other hand polymer modified specimen showed reading less than -273mVSCE till 30 days.

Figure 4 shows the resistivity of cement samples in salt solution. There was a initial drop in resistivity due to water penetration in to the speciemen. After one day the resisitivity of both samples start to rise gradually due to the hydration of cement paste but the resistivity change is very less for control cement specimen it could be a indication of salt penetration into the specimen. Other hand there could be a possibility that the polymer filled the voids and preventing the salt penetration.

From the impedance curve, it has proved that the specimens show Case 2 behavior (Vipulanandan and Prashanth 2013). Contact resistance (R_c), Contact capacitance (C_c), Interface resistance (R_i) and Interface capacitance (C_i) were calculated according to Case 2 using least square error method. Rc for the both specimens showed very similar trend till 30 days and it wasn't shown much change(Figure 5). It was an indication that the cantact conditions are similar in both specimens and did not change with time.
Interface resistance was high for the polymer modified specimen because the resistivity of the polymer is higher than cement and the polyer was played a big roll in the interface. Rate of RiCi index was used as a corrosion monitoring factor in IS and Figure 6 shows that the index is always higher for control cement specimen after 5 days.

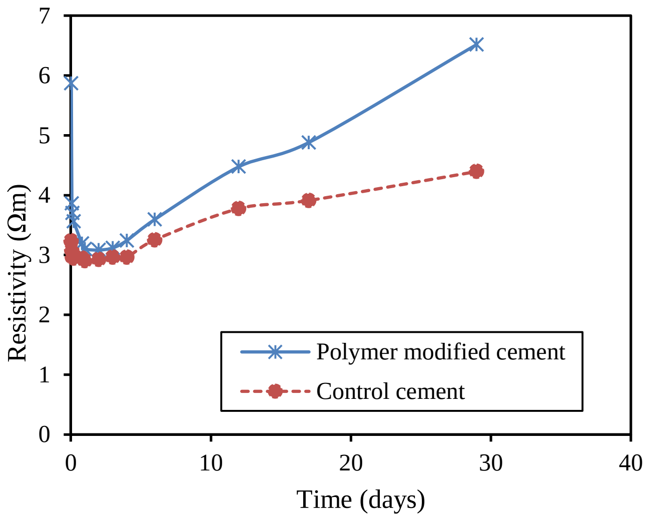

Figure 5. Electrical resistivity of cement under salt solution

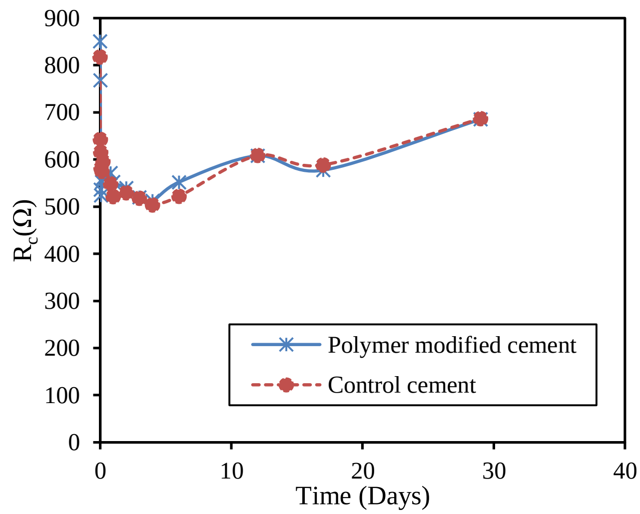

Figure 6.Contact resistance change with time

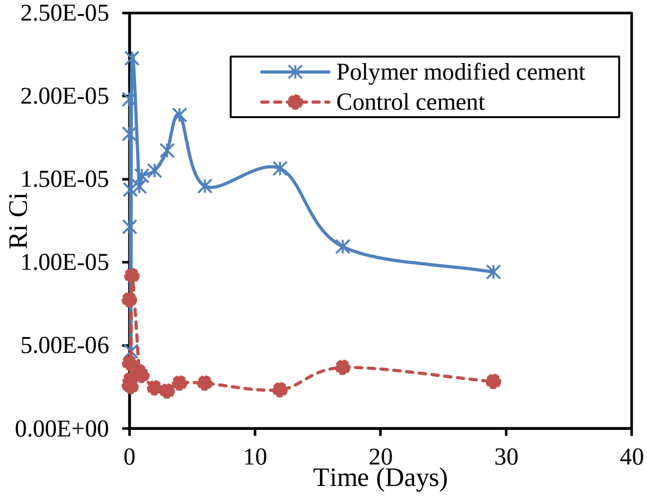

Figure 7. R_iC_i index with time

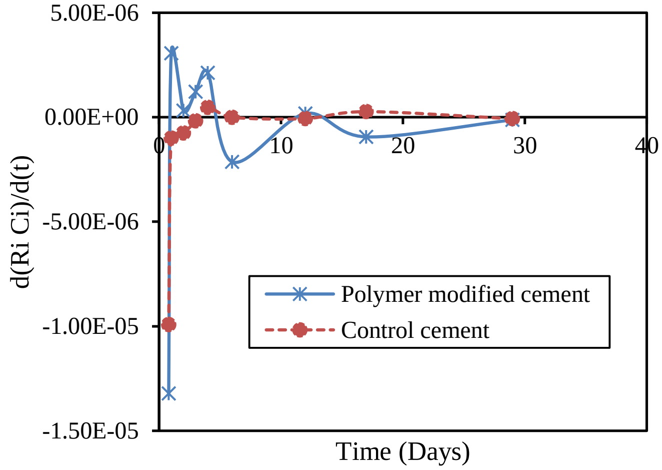

Figure 8. Rate of change in R_iC_i index with Time

4. Conclusions

The investigation of corrosion of steel embedded in cement shows the following results:

1. Open-circuit potential evolutions of cement specimens with Polyacrylamide were more constant than those of cement specimens without polymer.
2. EIS studies have revealed that polyacrylamide modified cement on steel acts as a protection layer against corrosion in 3 % NaCl.

5. Acknowledgment

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6. References

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