RAPID MACROCELL TESTS OF 2205 REINFORCING BARS

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ABSTRACT

The corrosion resistance of 2205 reinforcing steel (Heat H82489) was evaluated using the rapid macrocell test outlined in Annexes A1 and A2 of ASTM A955. The steel met the corrosion resistance requirements outlined in ASTM A955.

Keywords: chlorides, concrete, corrosion, macrocell, reinforcing steel, stainless steel

INTRODUCTION

This report describes the test procedures and results of rapid macrocell tests to evaluate the corrosion performance of 2205 stainless steel reinforcing bars. Six specimens are tested in accordance with Annexes A1 and A2 of ASTM A955. The reinforcement was supplied by Max Aicher North America Ltd and was tested in the as-received condition.

EXPERIMENTAL WORK

Materials

Tests were performed on 16L 2205 (Heat H82489) stainless steel reinforcing bars, pictured in Figure 1. The bars were inspected upon receipt and found to be in good condition.

Figure 1: 2205 reinforcing steel evaluated in this report.

Experimental Procedures

Six specimens were tested in accordance with the rapid macrocell test outlined in Annexes A1 and A2 of ASTM A955/A955M and illustrated in Figure 2. Each bar used in the rapid macrocell is 5 in. (127 mm) long and is drilled and tapped at one end to accept a 0.5-in. (12-mm), 10-24 threaded stainless steel machine screw. Bars are wiped down with acetone prior to testing to remove oil and surface contaminants introduced by machining. A length of 16-gauge insulated copper wire is attached to each bar via the machine screw. The electrical connection is coated with epoxy to protect the wire from corrosion.

A single rapid macrocell specimen consists of an anode and a cathode. The cathode consists of two bars submerged to a depth of 3 in. (76 mm) in simulated pore solution in a plastic container, as shown in Figure 2. One liter of pore solution consists of 974.8 g of distilled water, 18.81 g of potassium hydroxide (KOH), and 17.87 g of sodium hydroxide (NaOH). The solution has a pH of about 13.9. Air, scrubbed to remove carbon dioxide, is bubbled into the cathode solution. The anode consists of a single bar submerged in a solution consisting of simulated pore solution and 15 percent sodium chloride (NaCl). The "salt" solution is prepared by adding 176.5 g of NaCl to one liter of pore solution. The solutions are changed every five weeks to limit the effects of carbonation. The anode and cathode are connected electrically across a 10-ohm resistor. A potassium chloride (KCl) salt bridge provides an ionic connection between the anode and the cathode (Figure 2).

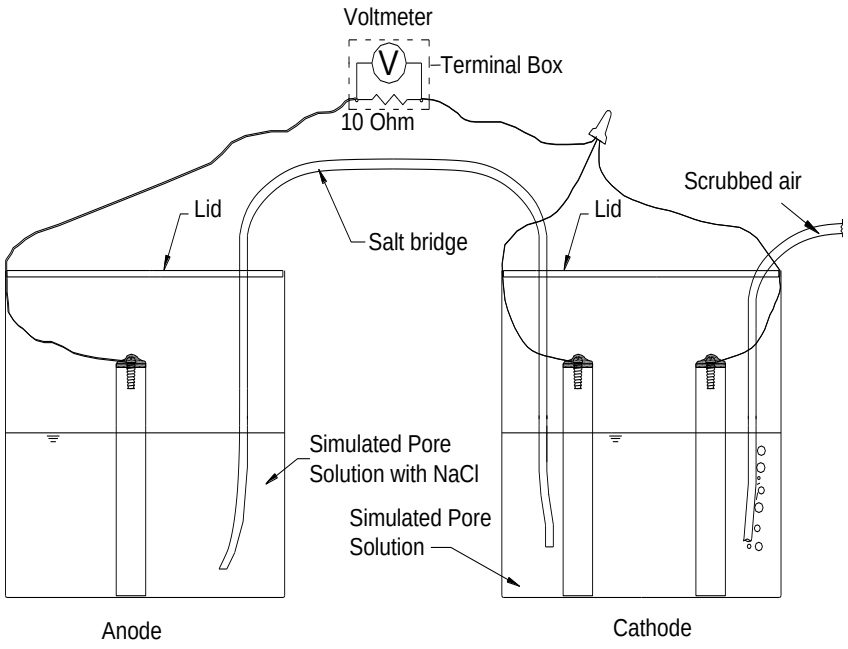


Figure 2: Rapid Macrocell Test Setup

The corrosion rate is calculated based on the voltage drop across the 10-ohm resistor using Faraday's equation.

$$\text{Rate} = K\frac{V \cdot m}{n \cdot F \cdot D \cdot R \cdot A} \tag{1}$$

where the Rate is given in μm/yr, and

K = conversion factor = $31.5 \cdot 10^4$ amp·μm ·sec/μA·cm·yr

V = measured voltage drop across resistor, millivolts

m = atomic weight of the metal (for iron, m = 55.8 g/g-atom)

n = number of ion equivalents exchanged (for iron, n = 2 equivalents)

F = Faraday's constant = 96485 coulombs/equivalent

D = density of the metal, g/cm^3 (for iron, D = 7.87 g/cm^3)

R = resistance of resistor, ohms = 10 ohms for the test

A = surface area of anode exposed to solution, 38.2 cm^2 for 16L bars

To satisfy ASTM A955, no individual reading may exceed 0.50 μm/yr and the average rate of all specimens may not exceed 0.25 μm/yr. In both cases, the corrosion current must be such as to indicate net corrosion at the anode. Current indicating a "negative" value of corrosion, independent of value, does not indicate corrosion of the anode and is caused by minor differences in oxidation rate between the single anode bar and the two cathode bars.

In addition to the corrosion rate, the corrosion potential is measured at the anode and cathode using a silver chloride electrode; these readings are converted to an equivalent measurement with respect to a copper sulfate electrode (CSE) for presentation. Readings are taken daily for the first week and weekly thereafter.

RESULTS

The individual corrosion rates for 2205 stainless steel are shown in Figure 3. One specimen, 2205-5 exceeded the 0.5 μm/yr limit specified by ASTM A955 at weeks 3, 4, and 10. Inspection of the specimen after testing, however, revealed cracking of the protective epoxy and corrosion at the electrical connection (Figure 4a). No corrosion products were visible on the bar itself, or any of the other 2205 specimens (Figure 4b), suggesting the corrosion activity observed on this specimen is due to the copper wire and not the bar itself. As such, specimen 2205-5 is considered invalid, and no other specimen exceeded the 0.5 μm/yr limit specified by ASTM A955.

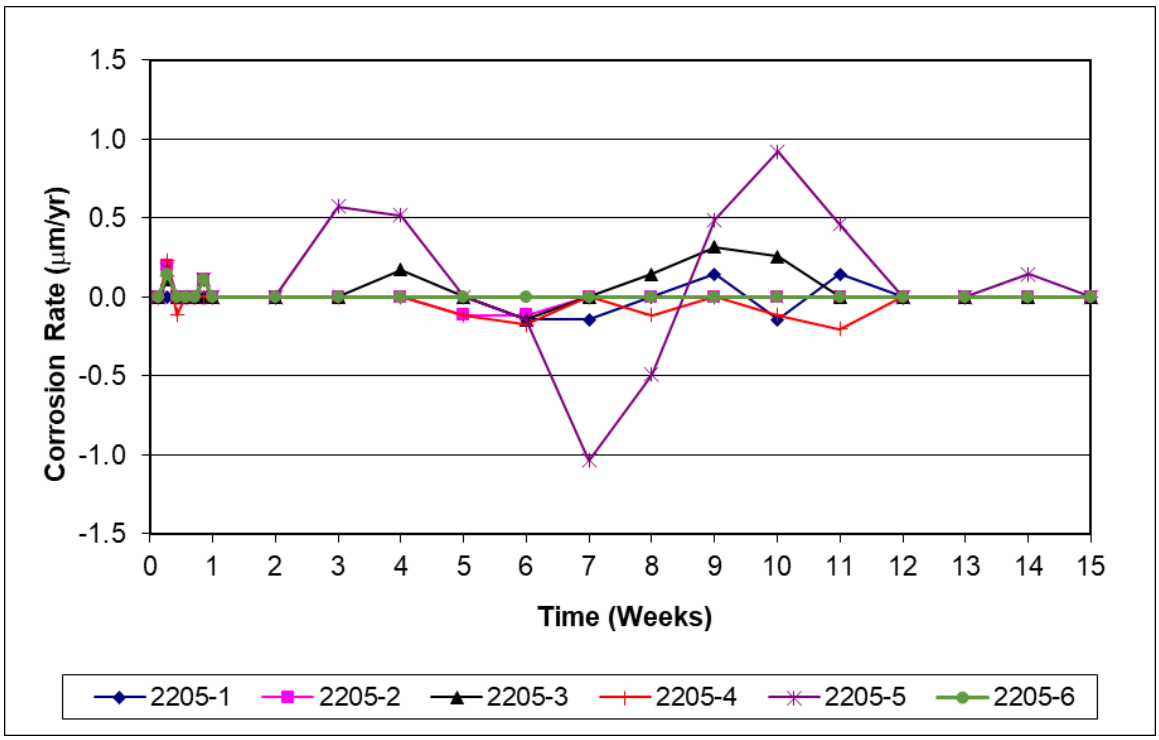
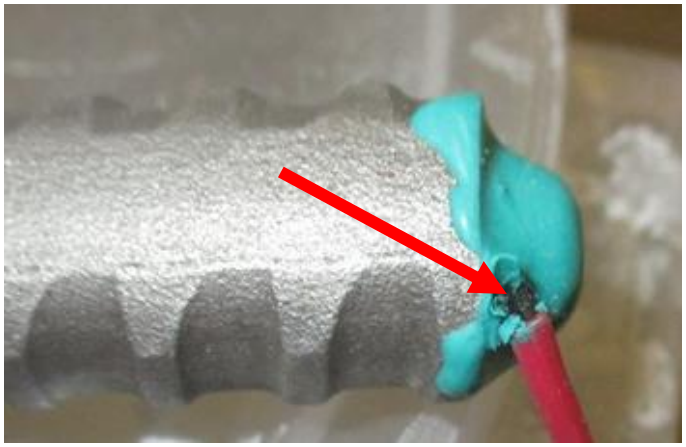


Figure 3: Individual corrosion rates (µm/yr) for 2205 stainless steel.



(a)

(b)

Figure 4: (a) Corrosion electrical connection of specimens 2205-5 after testing (b)Specimen 2205-5 after testing

The average corrosion rates for 2205 stainless steel (excluding specimen 2205-5) is shown in Figure 5. The maximum average corrosion rate for 2205 stainless steel was 0.14 µm/yr at day 2. The steel met the 0.25 µm/yr average corrosion rate limit established in ASTM A955.

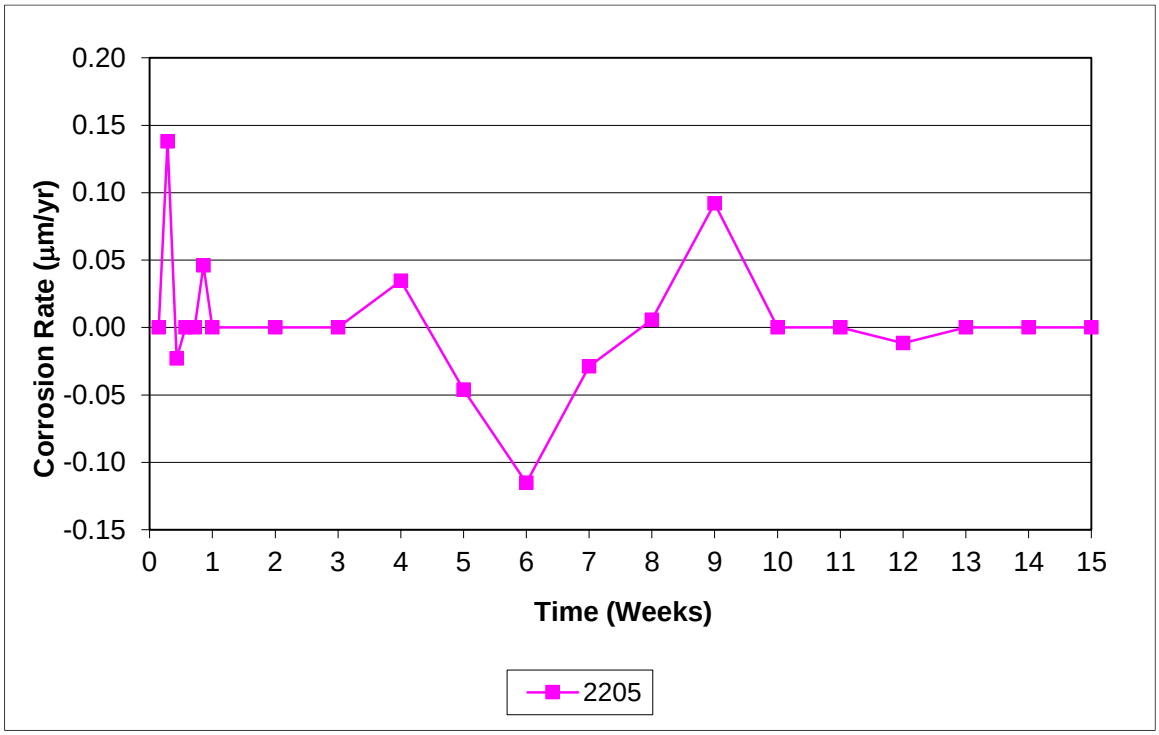


Figure 5: Average corrosion rates (µm/yr) for 2205 stainless steel.

The average anode corrosion potential with respect to CSE for 2205 stainless steel is shown in Figure 6. The steel exhibited a corrosion potential of approximately –0.20 V vs CSE throughout testing.

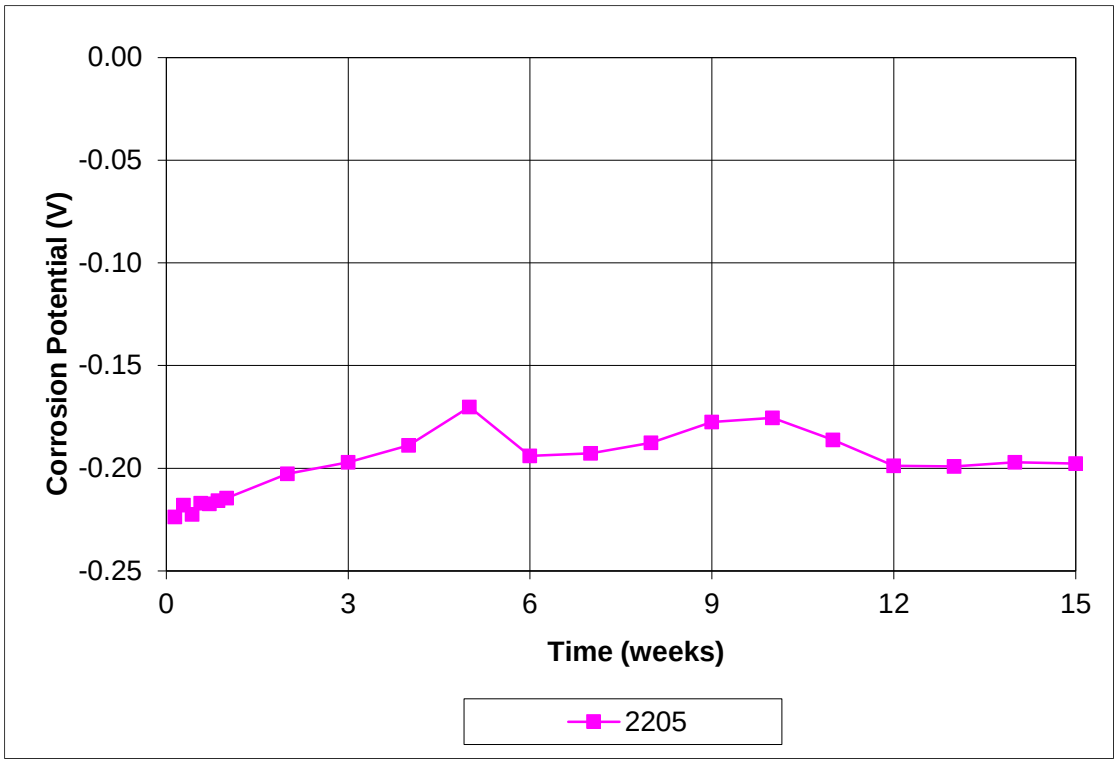


Figure 5: Average corrosion potential (vs. CSE) for 2205 stainless steel.

SUMMARY AND CONCLUSIONS

The corrosion resistance of 2205 stainless steel was tested using the rapid macrocell test in accordance with Annexes A1 and A2 of ASTM A955. The stainless steel met the corrosion rate requirements of ASTM A955.

REFERENCE

ASTM A955, 2020, "Standard Specification for Plain and Deformed Stainless-Steel Bars for Concrete Reinforcement (ASTM A955/A955M-20c)," ASTM International, West Conshohocken, PA, 15 pp.