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A Report on Research Sponsored by

TALLEY METALS

Structural Engineering and Engineering Materials
SL Report 16-3
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THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.
2385 Irving Hill Road, Lawrence, Kansas 66045-7563

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ABSTRACT

The corrosion resistance of XM28 (EnduraMet® 32) stainless steel reinforcing bars produced by Talley Metals was evaluated using the rapid macrocell and cracked beam tests outlined in Annex A3 of ASTM A955. In addition, the Southern Exposure test was used to determine critical chloride corrosion threshold (CCCT). Six specimens were tested for the rapid macrocell test; neither individual corrosion rates nor average corrosion rate of those exceeded the limits set in ASTM A955 (0.5 μm/yr and 0.25 μm/yr, respectively). Six specimens were cast for each cracked beam and Southern Exposure tests. The bars did not initiate corrosion in the Southern Exposure test, precluding the determination of an exact chloride threshold. It can be concluded that the CCCT of the bars exceeds the end-of-life chloride content of the concrete, 9.35 lb/yd^3 (5.55 kg/m^3). For the cracked beam test, individual corrosion rates of four out of the six specimens were greater than 0.5 μm/yr for the majority of the test duration. In addition, the average corrosion rate for the cracked beam specimens exceeded 0.2 μm/yr at week 30 and every week thereafter. The bars in the cracked beam test showed visible corrosion after the autopsy of the cracked beam specimens at the end of the test, supporting the corrosion rate measurements. Thus, the XM-28 stainless steel satisfied the requirements of ASTM A955 in the rapid macrocell test but failed in the cracked beam test.

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

ACKNOWLEDGEMENTS

The research described in this report is supported by Talley Metals, Inc.

INTRODUCTION

This report describes the evaluation of the corrosion resistance of XM28 (EnduraMet® 32) stainless steel bars produced by Talley Metals. The steel was evaluated using the rapid macrocell and cracked beam tests described in the Annex of ASTM A955, as well as the Southern Exposure test. The rapid macrocell test was performed for 30 weeks, while the Southern Exposure and cracked beam tests were performed for 96 weeks.

EXPERIMENTAL WORK

MATERIALS

XM28 Reinforcing Bars

Tests were performed on No. 5 (No. 16) XM28 (EnduraMet® 32) reinforcing bars. The bars were inspected upon receipt and found to be in good condition. After several months in a dry storage area, however, signs of corrosion were observed on the surface of the bars. Figure 1 shows the bar surface after sitting in dry storage. According to the supplier, the bars were cleaned using an acid solution to remove the mill scale and then rinsed with water.

Figure 1: Bar appearance after several months in dry storage

Concrete

The mixture proportions used for the Southern Exposure and cracked beam specimens are shown in Table 1. Materials consisted of Type I portland cement, Kansas River sand, and crushed limestone. The air entraining agent was Daravair 1400, with a target air content of 6±1% for mixture.

Table 1: Mix proportions (SSD basis)

Water lb/yd^3 (kg/m^3)	Cement lb/yd^3 (kg/m^3)	Coarse Aggregate[a] lb/yd^3 (kg/m^3)	Fine Aggregate[b] lb/yd^3 (kg/m^3)	Air-entraining Agent mL/m^3 (oz/yd^3)
269 (160)	598 (355)	1484 (880)	1435 (851)	90 (2.33)

[a]Bulk Specific Gravity (SSD) = 2.59
[b]Bulk Specific Gravity (SSD) = 2.63

All specimens were cast from a single batch of concrete. The material properties of the plastic and hardened concrete are shown in Table 2.

Table 2: Properties of plastic and hardened concrete

Property	
Slump	2.75 in. (64 mm)
Temperature	60° F (16° C)
Air Content	5.3 %
Unit Weight	145.4 lb/ft^3 (2329 kg/m^3)
28-day Compressive Strength	4160 psi (28.7 MPa)

RAPID MACROCELL

Description

Six specimens were tested in accordance with the rapid macrocell test outlined in Annexes A1 and A2 of ASTM A955/A955M-10 and detailed in Figure 2. Each bar used in the rapid macrocell is 5 in. long and is drilled and tapped at one end to accept a 0.5-in., 10-24, stainless steel machine screw. Bars are cleaned prior to testing with acetone 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 an 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 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).

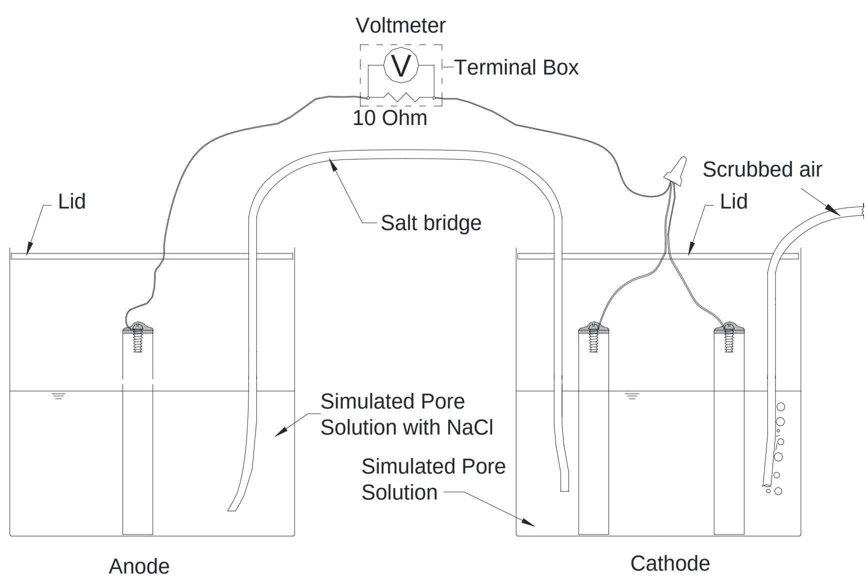

Figure 2: Rapid macrocell test setup

SOUTHERN EXPOSURE AND CRACKED BEAM TESTS

Description

The Southern Exposure (SE) and cracked beam (CB) tests subject test specimens to cyclic ponding and drying with a 15% sodium chloride (NaCl) solution. Southern Exposure specimens (Figure 3) are prisms measuring 12 × 12 × 7 in. (305 × 305 × 178 mm). No. 5 (No. 16) reinforcing bars are cast in the specimen in two mats. The top and bottom mats consist of two and four bars, respectively, each with 1-in. (25.4-mm) clear cover. The bars in each mat are centered horizontally within the prism and are spaced 2.5 in. (64 mm) from each other. The bars in the top and bottom mats are electrically connected through a terminal box across a 10-ohm resistor to allow for macrocell corrosion rate measurements. A 0.75-in. (19-mm) deep concrete dam is cast integrally with the specimen to contain the ponded salt solution. Southern Exposure tests represent conditions in uncracked reinforced concrete.

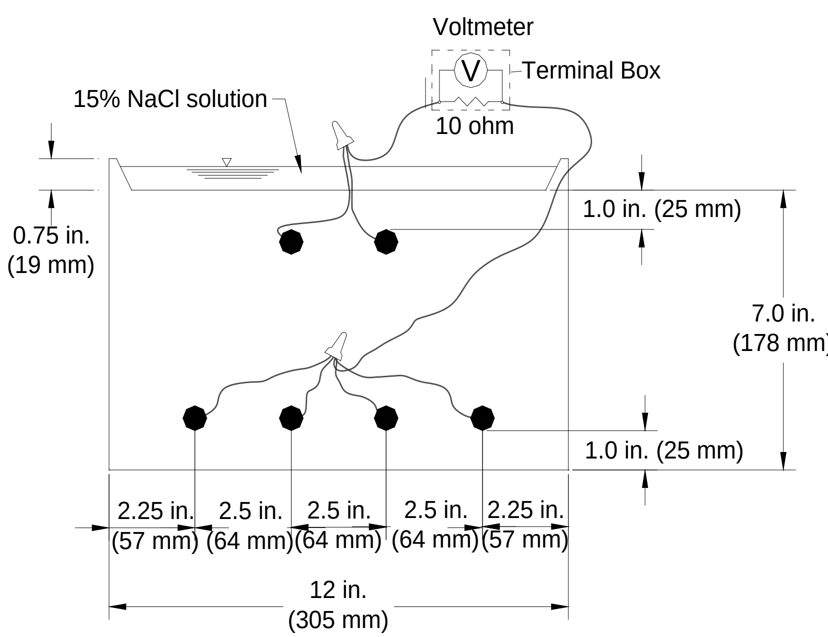

Figure 3: Southern Exposure (SE) specimen

The requirements for the cracked beam tests are described in Annex A3 of ASTM A955. Cracked beam specimens (Figure 4) are half the width of the Southern Exposure specimens, measuring 12 × 6 × 7 in. (305 × 152 × 178 mm). These specimens also contain two mats of steel. The top mat consists of a single No. 5 (No. 16) bar; the bottom mat consists of two No. 5 (No. 16) bars. This test simulates exposure conditions in cracked concrete. Prior to casting, a 12-mil (0.3-mm) thick × 6-in. (152-mm) long stainless steel shim is affixed in the mold in direct contact with the top reinforcing bar. This results in direct infiltration of chlorides at the beginning of the test. The shim is removed about 12 hours after casting.

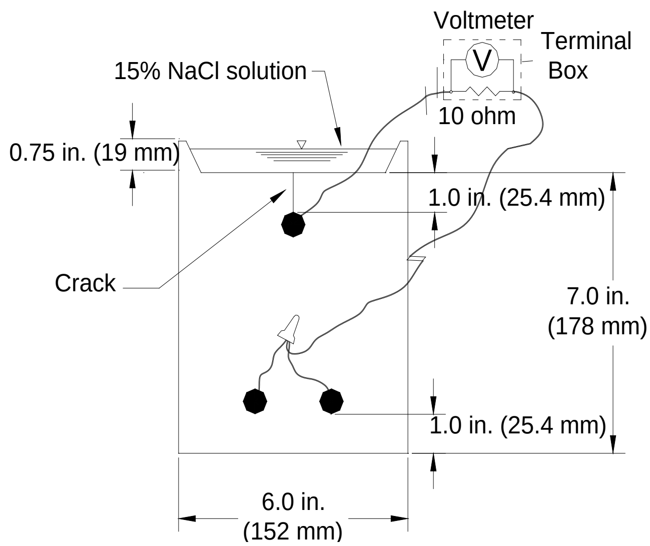

Figure 4: Cracked Beam (CB) specimen

Fabrication

Specimen fabrication for Southern Exposure and cracked beam specimens proceeds as follows:

1. Reinforcing bars are cut to 12 in. (305 mm) with a band saw.
2. Both ends of each bar are drilled and tapped to a 0.75-in. (19-mm) depth with 10-24 threading.

3. The bars are soaked in acetone for a minimum of two hours and scrubbed to remove any oil.
4. The forms are assembled, and the reinforcement attached. Forms and reinforcement are held in place using 1.25-in. (32-mm) long 10-24 threaded stainless steel machine screws.
5. Specimens are cast using concrete with properties listed in Table 1. Specimens are filled in two layers, with each layer consolidated using a 0.75-in. (19-mm) diameter vibrator. The free surface of the concrete (the bottom of the specimen) is finished with a trowel.
6. Specimens are cured for 24 hours at room temperature. A plastic cover is used to minimize evaporation. Stainless steel shims are removed from CB specimens after 12 hours.
7. Formwork is removed after 24 hours.
8. Specimens are cured for an additional two days in a plastic bag containing deionized water, then air-cured for 25 days.
9. Prior to test initiation, wire leads are connected to the test bars using 10-24 × 0.5 in. (13 mm) stainless steel screws and a No. 10 stainless steel washer. Sewer Guard HBS 100 Epoxy is applied to the vertical sides of the specimens, while the top and bottom of the specimens are left uncoated.
10. The two mats of steel are connected to the terminal box. Specimens are left connected across the 10-ohm resistor, except when readings are taken (see the section on Corrosion Measurements). Specimens are placed on 2 × 2 studs to allow air flow under the specimens. Tests begin 28 days after casting.

Test Procedure

Southern Exposure and cracked beam test procedures involve alternate cycles of ponding and drying. The test begins with 12 weeks of ponding and drying, followed by 12 weeks of ponding, for a total of 24 weeks. This exposure regime is then repeated for the duration of testing. The tests conclude after 96 weeks. The procedures are described below.

Ponding and Drying Cycles:

The specimens are ponded with a 15% NaCl at room temperature, 68 to 76°F (20 to 24°C). SE specimens receive 600 mL of solution; CB specimens receive 300 mL of solution. The specimens are covered with plastic sheeting during ponding to minimize evaporation. Readings are taken on day 4. After all readings are completed, the specimens are vacuumed to remove the salt solution, and the heat tents are placed over the specimens to maintain the temperature at 100 ± 3° F (38 ± 2° C) for three days. The tent is then removed, and the specimens are again ponded with the NaCl solution to start the second week of testing. Ponding and drying cycles continue for 12 weeks.

Ponding Cycle:

After 12 weeks of the ponding and drying, specimens are ponded at room temperature for 12 weeks with the 15% NaCl solution and covered with plastic sheeting. Readings continue on a weekly basis. Deionized water is added to maintain the desired solution depth on the specimens. After 12 weeks, the specimens are again subjected to the weekly ponding and drying cycles. The two testing regimes are repeated for a total of 96 weeks.

Corrosion Measurements

Measurements, taken weekly in the rapid macrocell, Southern Exposure, and cracked beam specimens, include macrocell voltage drop, mat-to-mat resistance, and corrosion potential. The corrosion rate is calculated based on the voltage drop across the 10-ohm resistor using Faraday's equation.

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

where the Rate is given in µm/yr, and

K = conversion factor = $31.5 \cdot 10^7$ mA·µm ·sec/µA·cm·yr

V = measured voltage drop across resistor, millivolts

m = atomic weight of the metal (for iron, m = 55.85 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, 304 cm^2 for Southern Exposure specimens, 152 cm^2 for cracked beam specimens and 39.9 cm^2 for rapid macrocell specimens.

Using the values listed above, the corrosion rate simplifies to:

$$\text{Rate} = 3.81V \text{ (Southern Exposure)} \qquad (2a)$$

$$\text{Rate} = 7.62V \text{ (Cracked Beam)} \qquad (2b)$$

$$\text{Rate} = 29.9V \text{ (Rapid Macrocell)} \qquad (2c)$$

Along with the rapid macrocell test, the cracked beam is used in ASTM A955 as a means of qualifying stainless steel reinforcing bars. To satisfy ASTM A955, no individual corrosion rate reading for the rapid macrocell and cracked beam specimens may exceed 0.50 µm/yr. In addition, the average corrosion rate of all specimens (minimum of five) may not exceed 0.2 μm/yr and 0.25 μm/yr at any time during the initial 75-weeks and 15-weeks for cracked beam test and rapid macrocell test, respectively. Cracked beam and rapid macrocell tests, however, was extended to 96 and 30 weeks, respectively, to gather additional data. 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 saturated calomel electrode (SCE); corrosion potentials presented in this report have been converted to the equivalent copper sulfate electrode (CSE) reading for Southern Exposure and cracked beam specimens. Readings are taken weekly.

RESULTS

CORROSION RATE

The individual corrosion rates calculated from voltage drops of the rapid macrocell test specimens, using Eq. (2c), are shown in Figure 5. The maximum corrosion rate of 0.3 μm/yr was observed for specimen XM28-5 at week 1. No individual corrosion rate exceeded 0.5 μm/yr, the ASTM A955 limit for stainless steel bars. As seen in Figure 5, some specimens exhibited "negative" corrosion rates during portions of the test. These "negative" values are usually the result of a small current drift from the cathode to the anode due to the difference in surface area, and are not indicative of chloride-induced corrosion.

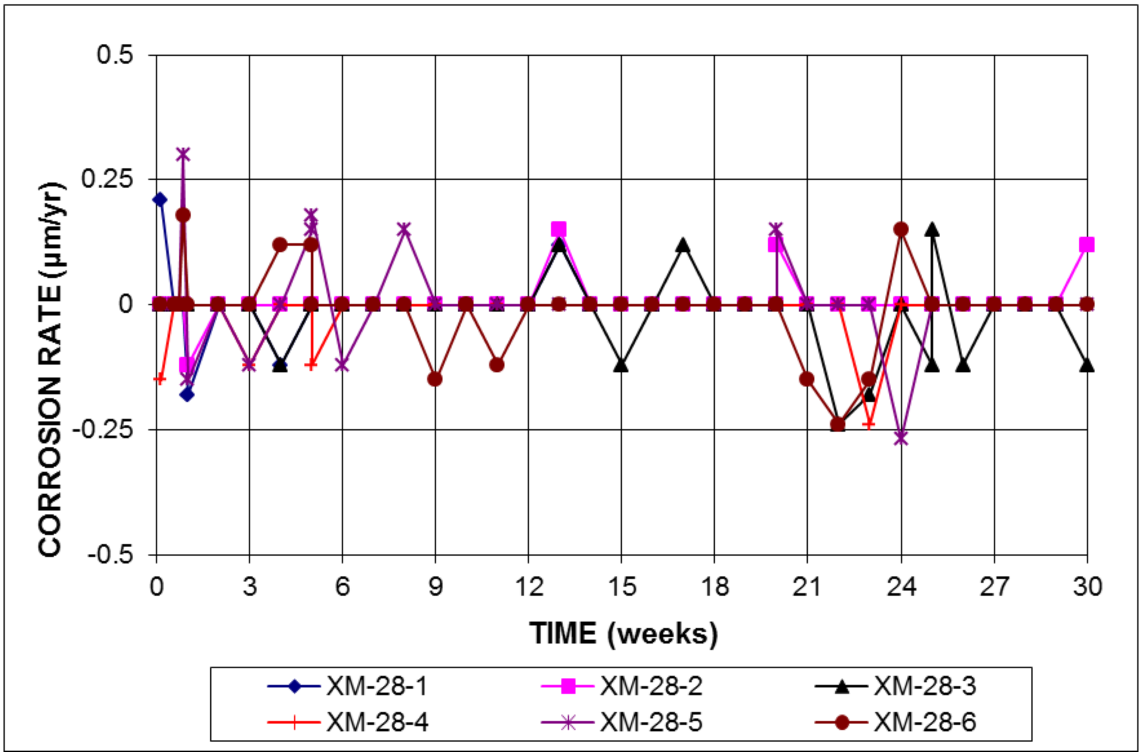

Figure 5: Individual corrosion rates for XM-28 rapid macrocell specimens

The average corrosion rate for the rapid macrocell specimens is shown in Figure 6. For the rapid macrocell test, the average corrosion rate was below 0.25 µm/yr, satisfying ASTM A955. Therefore, the individual specimens and the average corrosion rates met the requirements of ASTM A955 for rapid macrocell test.

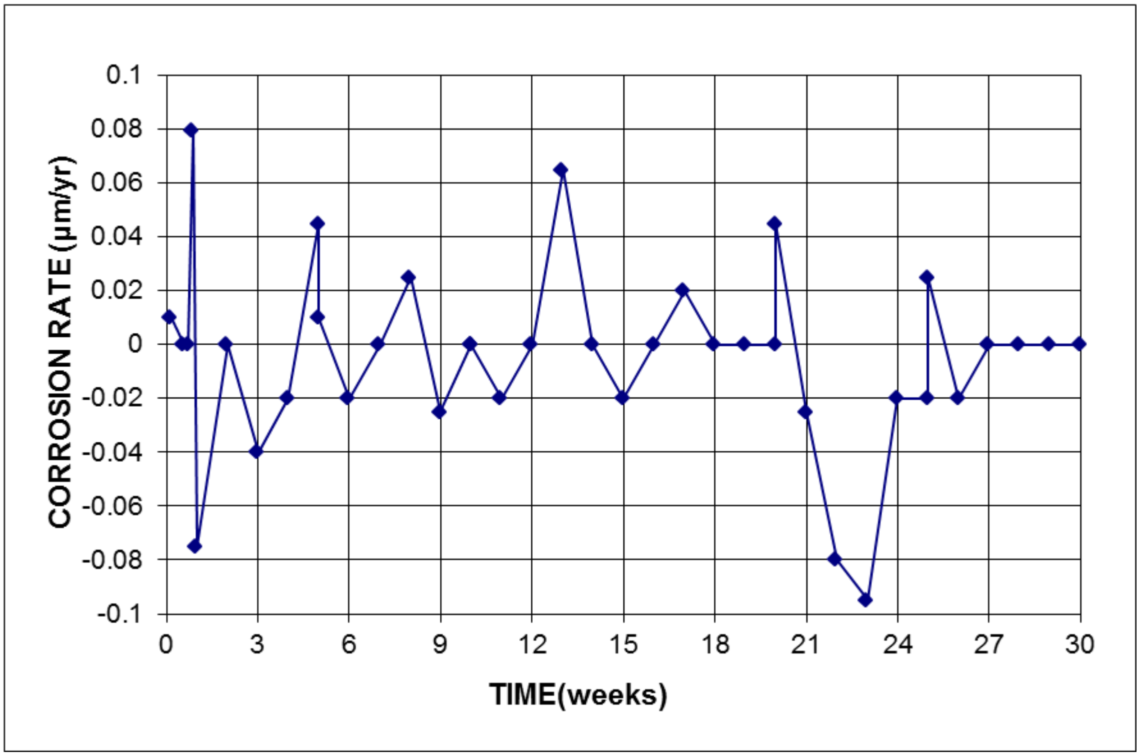

Figure 6: Average corrosion rate for XM-28 in rapid macrocell test

The corrosion rates calculated from voltage drops for the individual Southern Exposure and cracked beam specimens are shown as a function of time in Figures 7 and 8, respectively. Corrosion rates were calculated by using Eq. (2a) and (2b) for the Southern Exposure and cracked beam tests, respectively. In the Southern Exposure test (Figure 7), all specimens exhibited very low corrosion rates (below 0.25 µm/yr) throughout the test. Prior to week 74, no specimen exhibited a corrosion rate above 0.15 µm/yr for two consecutive weeks. Specimen XM28-2 exhibited the highest corrosion rate, 0.221 µm/yr at week 89. No visible corrosion products were observed on any of the Southern Exposure specimen bars at the end of the test (see Autopsy section).

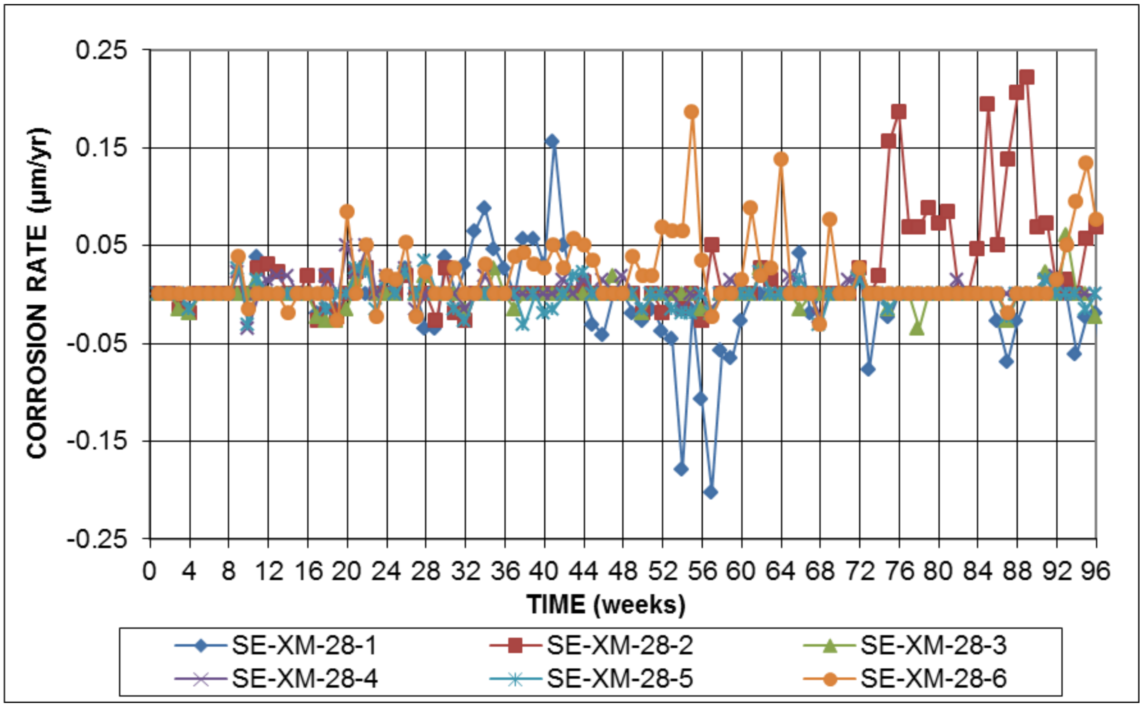

Figure 7: Individual corrosion rates for XM-28 Southern Exposure specimens

The corrosion rates for the individual cracked beam specimens, shown in Figure 8, were significantly higher than those in the Southern Exposure test. The peak corrosion rate, 2.31 µm/yr, was observed for specimen XM28-6 at week 43. Two of the specimens, XM28-3 and XM28-5, exhibited corrosion rates below 0.50 µm/yr for the majority of the test. Specimens XM28-6 and XM28-2 exhibited the highest average corrosion rates. The XM28 bars tested did not meet the 0.5 µm/yr maximum individual corrosion rate limit specified by ASTM A955.

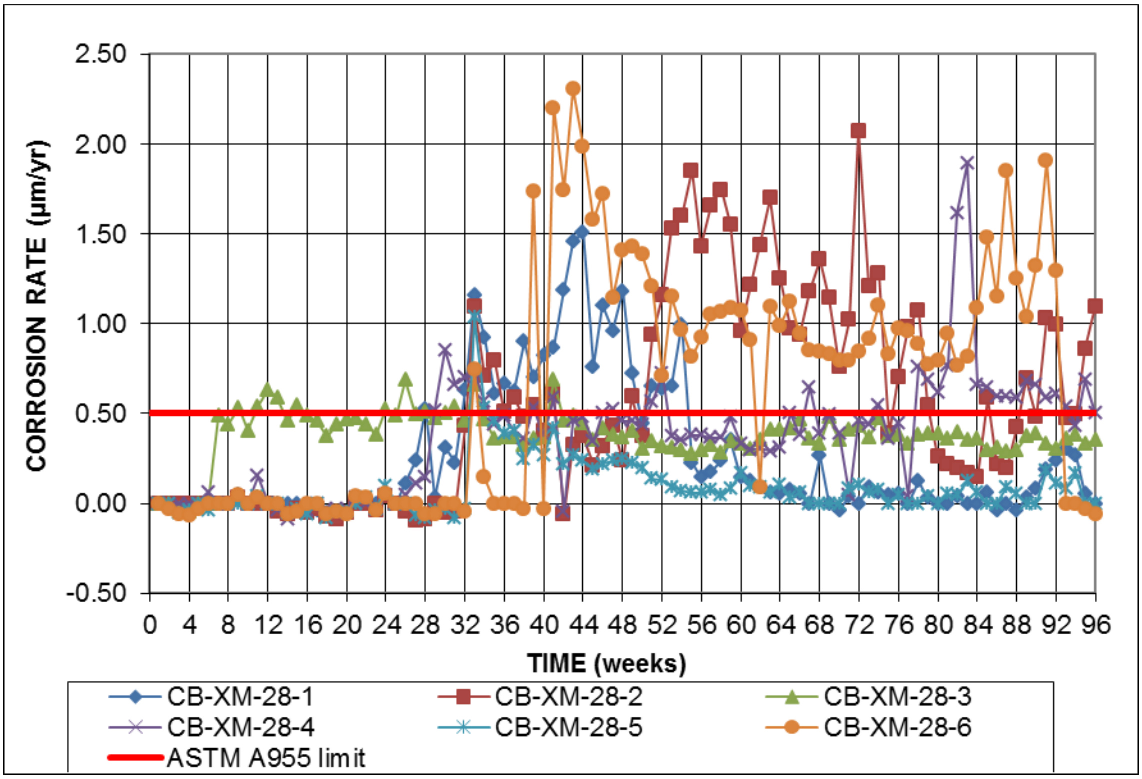

Figure 8: Individual corrosion rates for XM-28 cracked beam specimens

The average corrosion rates for the Southern Exposure and cracked beam specimens are shown in Figure 9. The average corrosion rate for Southern Exposure (SE) specimen was close to zero throughout the test period, with the average rate never exceeding 0.1 µm/yr. The average corrosion rate for cracked beam (CB) specimens exceeded 0.2 µm/yr at week 30 and every week thereafter. Thus, the XM28 bars exceeded the 0.2 µm/yr average corrosion rate limit specified in ASTM A955 for the cracked beam test. Therefore, although the individual specimens and the average corrosion rates met the requirements of ASTM A955 for rapid macrocell test, they did not satisfy the specifications for cracked beam test.

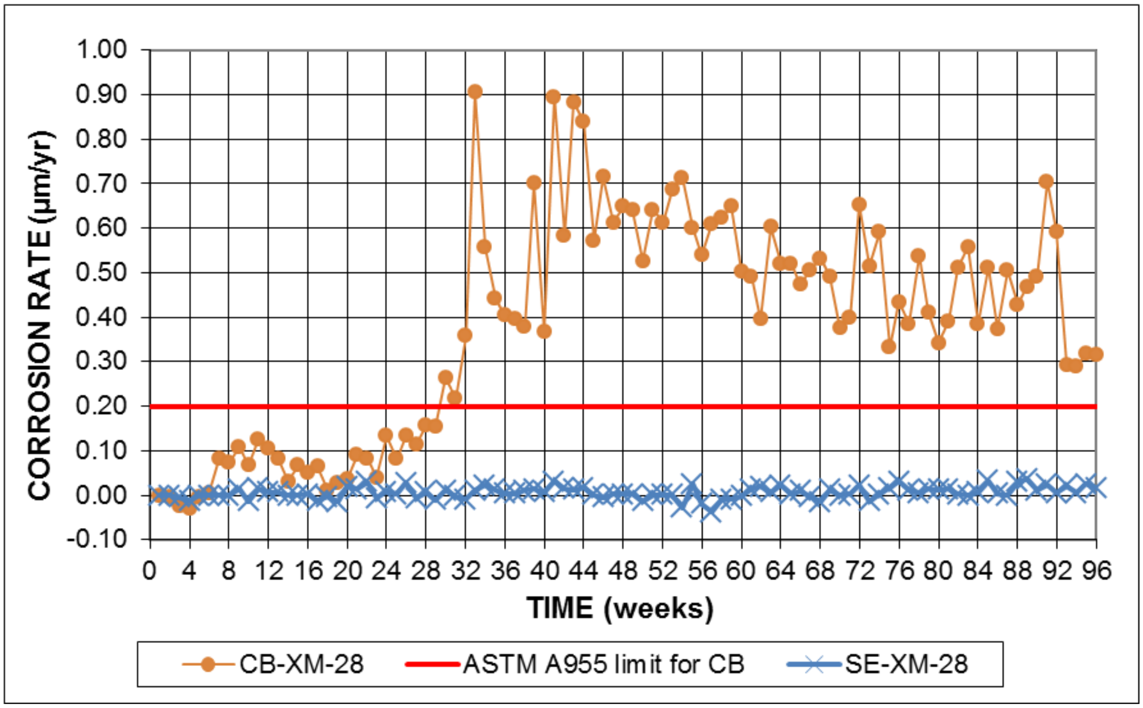

Figure 9: Average corrosion rates for XM-28 in Southern Exposure and cracked beam tests

CORROSION LOSS

The individual and average corrosion losses at 96 weeks for Southern Exposure and cracked beam specimens are shown in Table 3. The Southern Exposure specimens exhibited low corrosion losses through 96 weeks. The corrosion losses for the cracked beam specimens ranged from 0.158 to 1.18 µm, with the average of 0.704 µm.

Table 3: Corrosion loss (µm) at 96 weeks for Southern Exposure and cracked beam specimens

System	Specimen						Average	Std. Deviation
	1	2	3	4	5	6		
SE	-0.011	0.038	-0.001	0.007	-0.002	0.034	0.011	0.020
CB	0.482	1.01	0.707	0.690	0.158	1.18	0.704	0.365

CORROSION POTENTIAL

For rapid macrocell specimens, individual corrosion potential data were taken with respect to a saturated calomel electrode (SCE) for the bars in pore solution with salt (anode) and the bars in pore solution (cathode) (Figures 10 and 11). As shown in Figure 10, the anode bars exhibited potentials ranging from −0.150 to −0.250 V versus the SCE. The cathode bars, shown in Figure 11, exhibited potentials ranging from −0.150 to −0.300 V through week 15. Starting at week 21, the potentials of the cathode bars for specimens XM28-3 and XM28-6 gradually decreased to –0.440 V and then returned back to –0.200 V at week 28. ASTM C876 states that a potential more negative than −0.275 V with respect to an SCE (−0.350 V with respect to a copper/copper sulfate electrode (CSE)) indicates a 90% probability that corrosion is occurring. Two important differences between this macrocell test and ASTM C876 prevent a direct comparison of this test to ASTM C876: the bars being tested are stainless steel, not a conventional steel alloy, and they are placed in a pore solution, not concrete. Overall, the average potential, shown in Figure 12, was slightly more negative for bars in pore solution than for bars in pore solution plus salt through week 20. From week 21 to 27 cathode bars potentials were more negative by –0.040 to –0.090 V. This further explains the negative corrosion values in Figure 5.

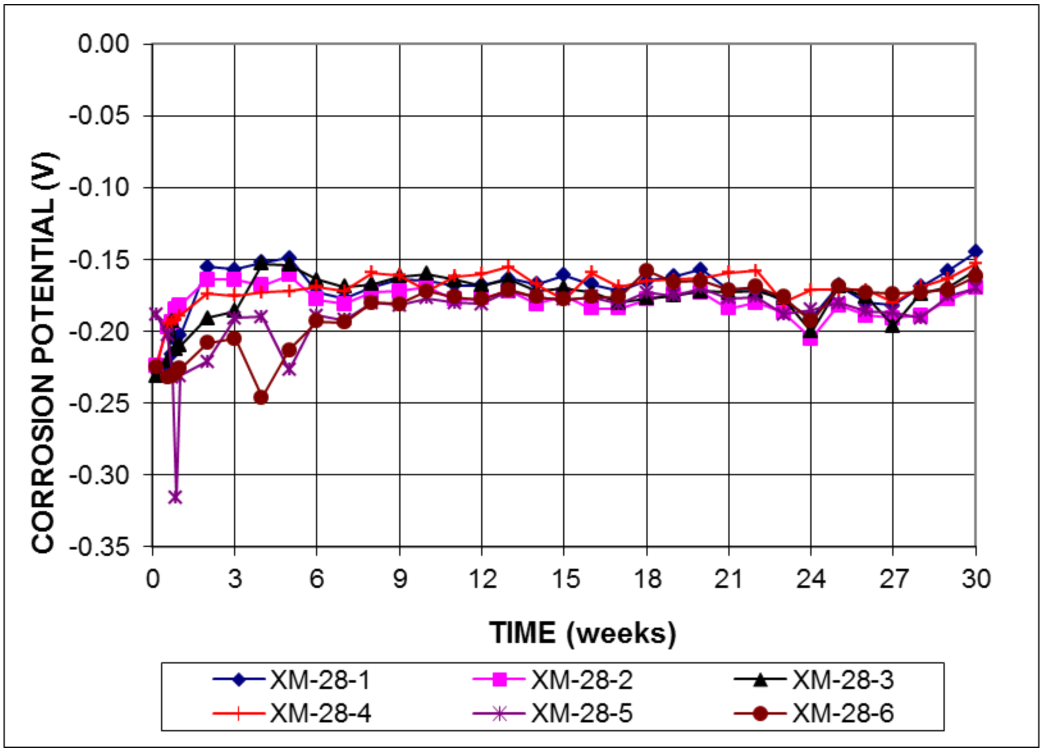

Figure 10: Individual corrosion potentials for XM-28 rapid macrocell anode (vs. SCE)

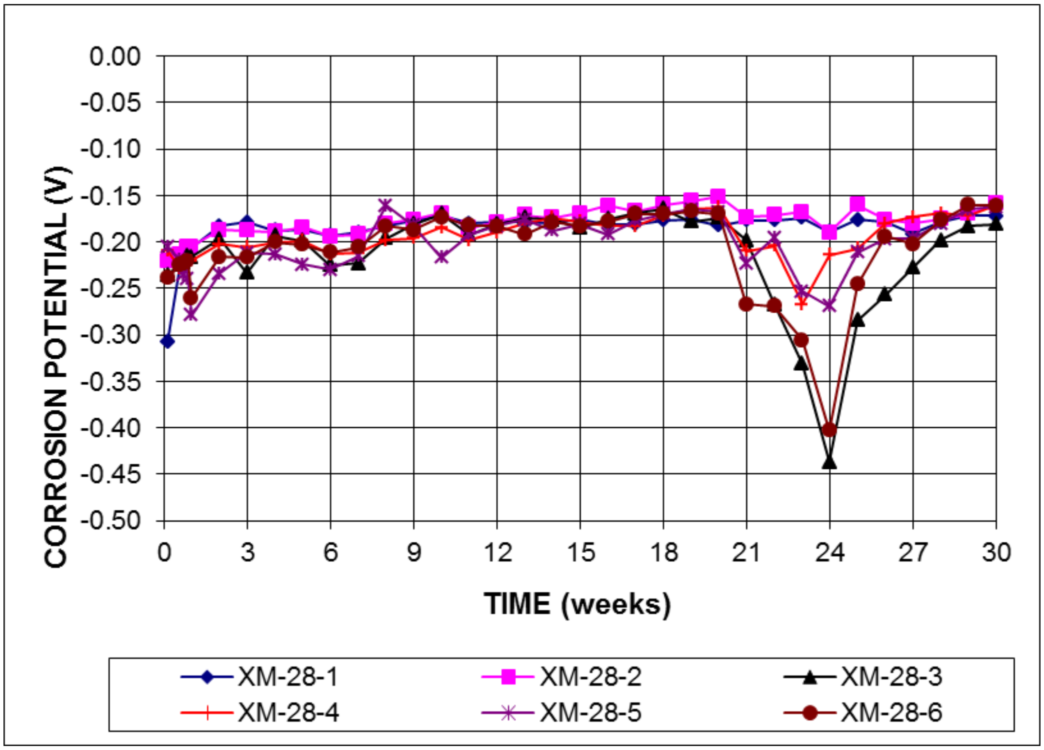

Figure 11: Individual corrosion potentials for XM-28 rapid macrocell cathode (vs. SCE)

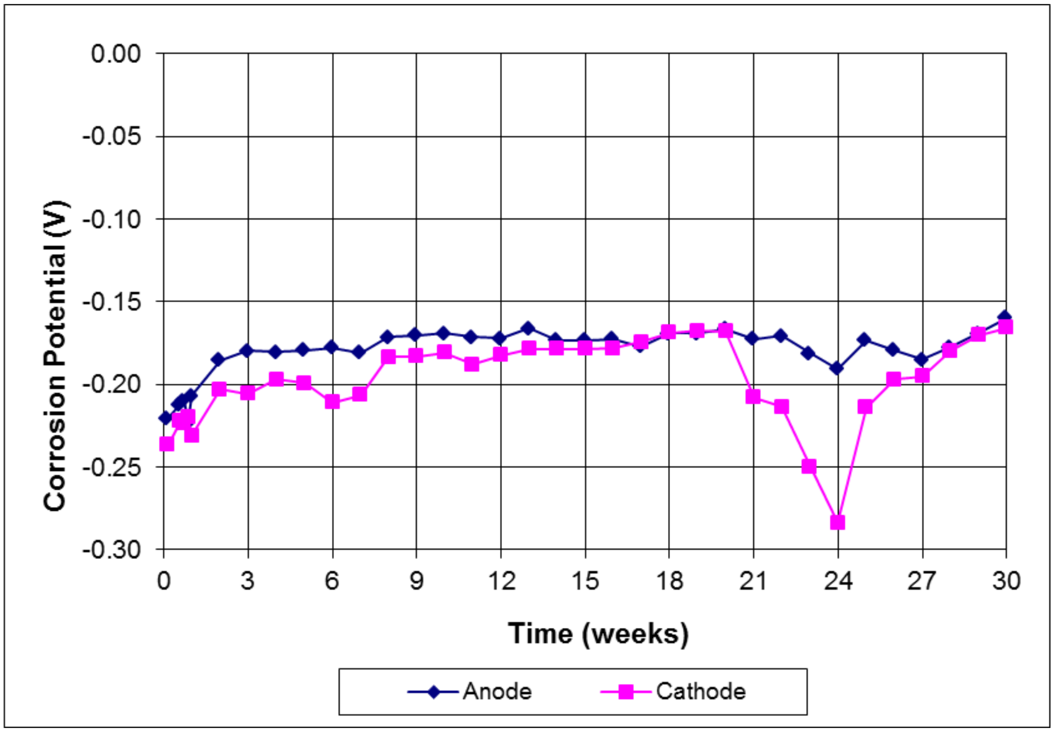

Figure 12: Average corrosion potential for XM-28 rapid macrocell (vs. SCE)

The individual top mat (anode) corrosion potentials (vs. CSE) for the Southern Exposure and cracked beam specimens are shown in Figures 13 and 14, respectively. Potentials for the Southern Exposure specimens (Figure 13) ranged from –0.289 to –0.352 V at the beginning of the test. The potentials gradually increased to about –0.15 V by week 48, and except some isolated drops or peaks exhibited after week 60, remained near –0.15 V for much of the test.

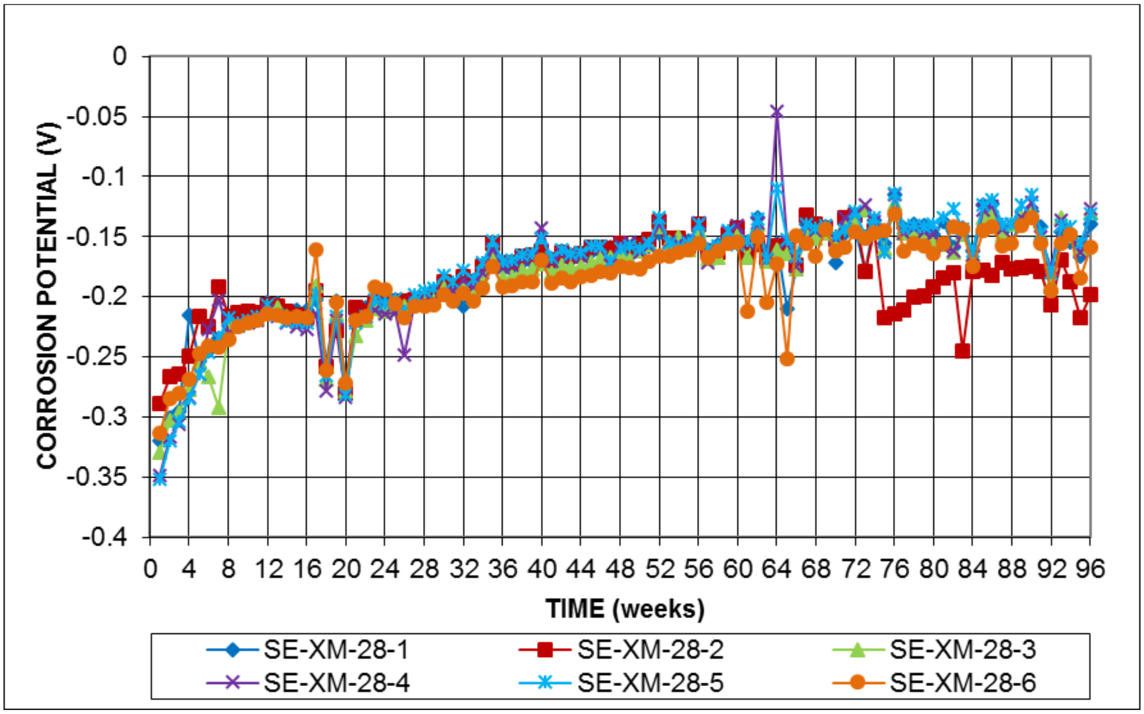

Figure 13: Individual top mat corrosion potentials for XM-28 Southern Exposure specimens (vs. CSE)

Potentials for the cracked beam specimens (Figure 14) were close to –0.30 V at the beginning of the test. The potentials gradually increased to near –0.20 V by week 7 and remained near –0.20 V to about week 30, except for specimen XM28-3, which dropped to –0.532 V at week 7. After week 30, the measured potentials became significantly more negative, with potentials measuring about –0.500 V for all specimens for the remainder of the test. At week 48, the potentials of three specimens started to slowly increase. Specimens XM28-1, XM28-2, and XM28-5 ended the test with potentials ranging from –0.328 to –0.204 V.

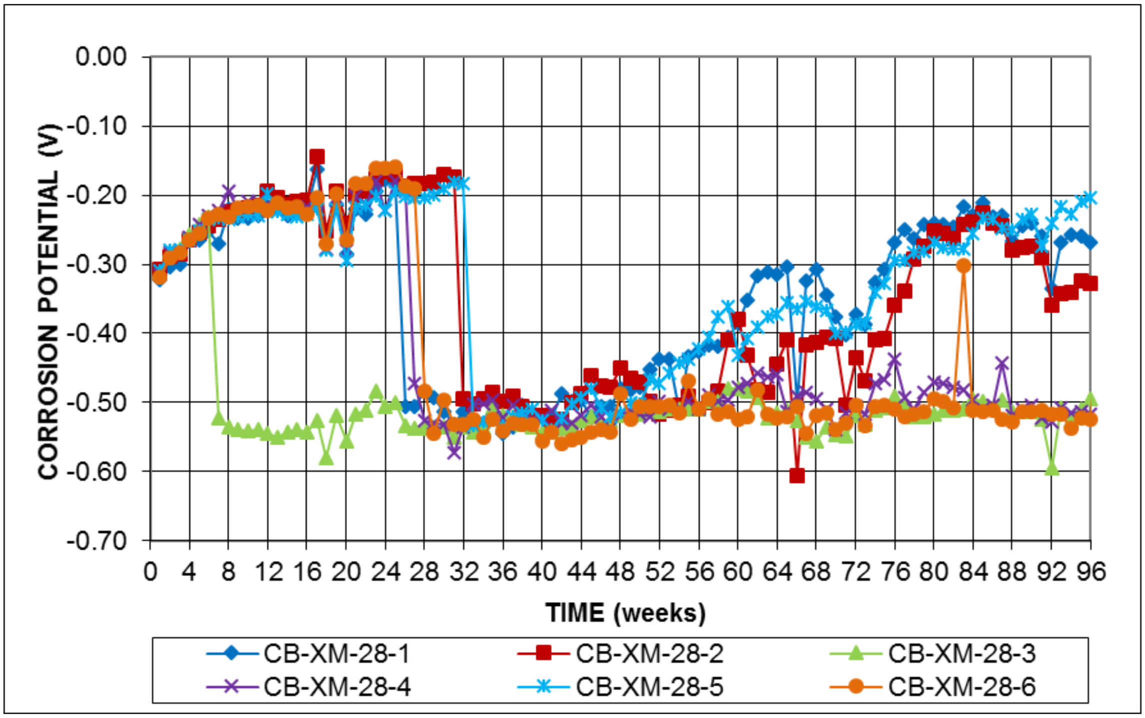

Figure 14: Individual top mat corrosion potentials for XM-28 cracked beam specimens (vs. CSE)

CHLORIDE CONCENTRATIONS

The chloride concentrations at 96 weeks for the Southern Exposure specimens are shown in Table 4. At 96 weeks, specimens exhibited individual chloride readings ranging from 2.92 to 17.7 lb/yd^3 (1.73 to 10.5 kg/m^3) and average chloride concentrations for individual specimens ranging from 7.62 to 10.8 lb/yd^3 (4.51 to 6.40 kg/m^3). For specimen XM28-4, one of the measured chloride contents, 2.15 lb/yd^3 (1.27 kg/m^3), was more than two standard deviation less than the mean; it is, therefore, treated as an outlier and not included in the average. The overall average was 9.35 lb/yd^3 (5.55 kg/m^3). No specimen initiated corrosion, indicating that the critical chloride corrosion threshold for XM-28 stainless steel is above 9.35 lb/yd^3 (5.55 kg/m^3). These values can be compared with average critical chloride corrosion thresholds of 1.63 lb/yd^3 (0.97 kg/m^3) for

ASTM A615 plain carbon-steel reinforcing bars, 2.57 lb/yd^3 (1.52 kg/m^3) for ASTM A767 galvanized bars, and 6.34 lb/yd^3 (3.76 kg/m^3) for ASTM A1035 low-carbon, chromium bars (Darwin et al. 2009).

Table 4: Chloride Concentrations at 96 weeks for Southern Exposure specimens

Specimen	Chloride Content (lb/yd^3)[a]										Average	Standard Deviation
	1	2	3	4	5	6	7	8	9	10		
XM28-1	7.86	7.49	9.29	7.67	14.5	7.36	7.70	8.24	3.88	2.92	7.69	3.11
XM28-2	17.7	14.6	14.4	10.8	12.6	4.58	6.40	5.69	9.91	10.6	10.7	4.25
XM28-3	9.17	14.2	6.96	13.0	8.95	13.0	6.22	7.60	11.0	6.27	9.63	2.99
XM28-4	6.65	7.30	8.24	4.44	2.15[b]	10.7	6.54	9.70	10.5	4.59	7.62	2.34
XM28-5	16.9	17.1	8.96	13.5	5.69	7.18	10.1	6.03	14.0	8.44	10.8	4.28
XM28-6	7.85	-	8.57	6.23	7.66	14.7	16.0	9.64	9.70	6.59	9.66	3.44
											9.35	**3.40**

[a]1 (lb/yd^3) = 0.592 (kg/m^3)
[b]Outlier; excluded from analysis

AUTOPSY RESULTS

All specimens were autopsied upon completion of the tests. Once the specimens completed 30 weeks in the rapid macrocell test, the specimens were removed from the solution, rinsed with tap water, examined for corrosion, and photographed. As shown in Figure 15, signs of corrosion were observed on both anode and cathode bars in all tests, with the cathode bars having more discoloration. The specimens did, however, satisfy the requirements of ASTM A955.

Figure 15: XM-28 rapid macrocell specimen 4 after the test

After 96 weeks, the bench-scale specimens were autopsied to inspect for the presence of corrosion products. No Sothern Exposure bars exhibited signs of corrosion, as shown in Figures 16 and 17 for specimen XM28-1.

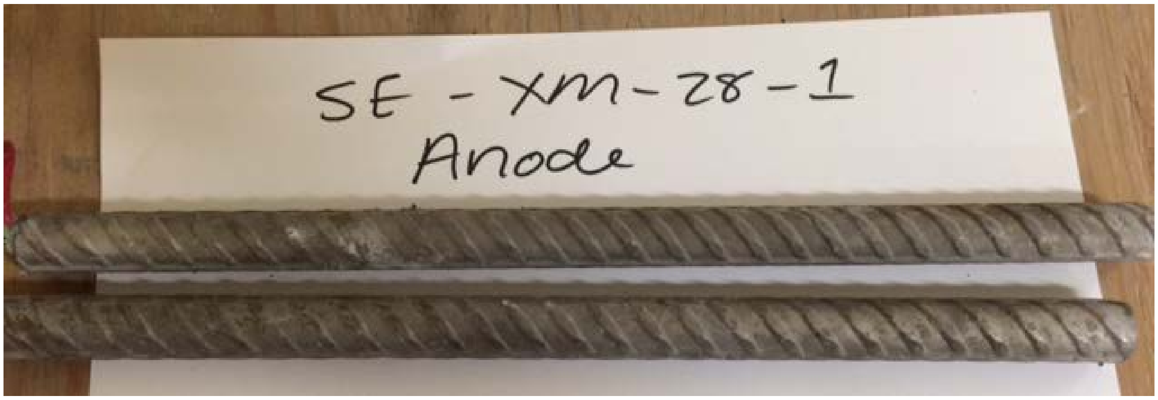

Figure 16: Bars from Southern Exposure specimen XM28-1 top mat (anode)

Figure 17: Bars from Southern Exposure specimen XM28-1 bottom mat (cathode)

All top mat bars in cracked beam specimens exhibited some corrosion, while the bottom bars exhibited no signs of corrosion, as shown in Figure 18 for specimen XM28-1.

Figure 18: Bars from cracked beam specimen XM28-1 bottom mat (top) and top mat (bottom)

SUMMARY

The corrosion resistance of XM28 (EnduraMet® 32) stainless steel reinforcing bars produced by Talley Metals was tested using the rapid macrocell, Southern Exposure, and cracked beam tests (rapid macrocell and cracked beam tests in accordance with Annex A3 of ASTM A955). Six specimens were tested for the rapid macrocell test. The results for the rapid macrocell test showed that individual corrosion rates and the average corrosion rate did not exceed the limits set in ASTM A955 (0.5 μm/yr and 0.25 μm/yr, respectively). Although the results of rapid macrocell test satisfied the ASTM A955 limits, signs of corrosion were observed on both anode and cathode bars in all tests, with the cathode bars having more discoloration. Six specimens were cast for cracked beam test. Unlike rapid macrocell test, the results of cracked beam test did not satisfy the requirements for ASTM A955; individual corrosion rates for four out of the six specimens were greater than 0.5 μm/yr for the majority of the test, and the average corrosion rate for the cracked beam specimens exceeded 0.2 μm/yr at week 30 and every week thereafter. Corrosion products observed on all top mat bars for the cracked beam specimens after autopsy further supported the observed corrosion rates. Six Southern Exposure specimens were cast to determine the critical chloride corrosion threshold (CCCT). The bars, however, did not initiate corrosion in the Southern Exposure test, preventing the determination of the chloride threshold. The average end-of-life chloride content of the concrete for Southern Exposure specimens was 9.35 lb/yd^3 (5.55 kg/m^3); thus, it can be concluded that the CCCT of the bars exceeds 9.35 lb/yd^3 (5.55 kg/m^3), significantly higher than the CCCT of 1.63 lb/yd^3 (0.97 kg/m^3) for ASTM A615 plain carbon-steel reinforcing bars, 2.57 lb/yd^3 (1.52 kg/m^3) for ASTM A767 galvanized bars, and 6.34 lb/yd^3 (3.76 kg/m^3) for ASTM A1035 low-carbon, chromium bars (Darwin et al. 2009). The bars in the Southern Exposure specimens showed no visible corrosion after the autopsy, supporting the corrosion measurements that exhibited no corrosion initiation.

CONCLUSIONS

The following conclusions are drawn based on the results presented in this report:

1. The XM28 (EnduraMet® 32) stainless steel reinforcing bars evaluated in this study satisfied the requirements of ASTM A955 in the rapid macrocell test but not in the cracked beam test.
2. The critical chloride corrosion threshold of XM28 stainless steel bars exceeds 9.35 lb/yd^3 (5.55 kg/m^3).

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