REPORT 2013 - 07

VERMONT AGENCY OF TRANSPORTATION

Materials & Research Section
Research Report

EVALUATION OF CORROSION RESISTANCE OF VARIOUS CONCRETE REINFORCING MATERIALS

Report 2013 – 07

June 2013

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Final Report

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STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIALS & RESEARCH SECTION

BRIAN R. SEARLES, SECRETARY OF TRANSPORTATION
RICHARD M. TETREAULT, P.E., DIRECTOR OF PROGRAM DEVELOPMENT
WILLIAM E. AHEARN, P.E., MATERIALS & RESEARCH

Prepared By:

Jason Tremblay, M.S., P.E., Research Engineer
George W. Colgrove III, Research Administrator

Reviewed By:

William E. Ahearn, P.E.,
Materials & Research Engineer

Date: June 12, 2013

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Technical Report Documentation Page

1. Report No. 2013-07	
4. Title and Subtitle EVALUATION OF CORROSION RESISTANCE OF VARIOUS CONCRETE REINFORCING MATERIALS	5. Report Date June 2013
7. Author(s) Jason Tremblay, M.S., E.I., Research Engineer George W. Colgrove III, Research Administrator.	8. Performing Organization Report No. 2013-07
9. Performing Organization Name and Address Vermont Agency of Transportation Materials and Research Section 1 National Life Drive National Life Building Montpelier, VT 05633-5001	11. Contract or Grant No. - - -
12. Sponsoring Agency Name and Address Vermont Agency of Transportation Materials and Research Section 1 National Life Drive National Life Building Montpelier, VT 05633-5001	13. Type of Report and Period Covered FINAL REPORT 2008 - 2012
15. Supplementary Notes	

16. Abstract

The Vermont Agency of Transportation undertook a simple experiment to determine the corrosion resistance ability of various reinforcing steels (rebar) that may be used in bridges and other concrete structures. Eight types of rebar were used in the study, including: black, MMFX2, epoxy coated, Z-Bar, stainless clad, high nickel stainless steel, high manganese stainless steel, and a duplex stainless steel. Rebar samples were subjected to a 3% sodium chloride salt water solution bath three days a week for eight hours. When not submerged, samples were left to dry under standard temperature and pressures. Samples went through this procedure for a total of 260 cycles, which was equated to an approximately 10 year outdoor lifecycle under Vermont's climatic conditions. Samples were measured for mass, diameter, and coating thicknesses prior to, periodically during, and at the completion of their exposure testing.

Results prove that each type of rebar show varying degrees of corrosion resistance to sodium chloride. Black bar showed not only extensive corrosion, but it also began rapidly from the onset of the immersions, while epoxy coated bars (ECR) showed adequate resistance to corrosion. Some ECR bars were intentionally cut and not repaired for the study showed a considerable increase in corrosion over intact bars. Bars that are designed to further combat construction damage, Z-Bar, stainless-clad, and solid stainless steels, exhibited far greater corrosion resistance.

17. Key Words

Corrosion Resistance, Reinforcing Steel

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ABSTRACT

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INTRODUCTION

The corrosion of rebar is one of the primary causes of deterioration of reinforced concrete. Climatic conditions are a large contributing factor to this. Vermont has a climate where conditions are rather wet, has a large number of freeze-thaw cycles, and harsh winters with considerable plowing and salting activities (1). These climatic conditions, coupled with road maintenance techniques, are very deleterious to concrete and rebar. As the concrete of our bridge structures cracks, the corrosive salts penetrate down to the reinforcing steel. The steel then corrodes, expands in volume, and causes the concrete to crack further, resulting in a negative cycle that begins to damage the concrete rapidly.

Using different coatings or different materials for reinforcing steel has been shown to slow down the rate of corrosion, dramatically. There are varieties of techniques used when protecting rebar, including physical protection, chemical protection, and simply using materials that are more corrosion resistant. With each increment of protection, however, is also an increase in cost.

In an effort to determine general, qualitative corrosion resistances between different types of readily available reinforcing steels, the Structures section of the Vermont Agency of Transportation (VTrans) requested a short-term study be performed by the Research unit. The Structures section was interested in investigating the commonly used rebar types, black bar and epoxy coated, with less used so-called high performance reinforcing steel such as Z-bar, MMFX 2, stainless steel clad, and solid stainless steels.

Through this research initiative, it was desired to develop recommendations on the relative service life estimates of the various rebar types, providing a basis for bridge designers to use when selecting higher performance rebar for long life structures. In addition, the information was expected to lead into the writing of a specification for its use.

TESTING PROCEDURE

In an effort to replicate environmental salting and wetting conditions, a specific regimen was developed for testing the rebar specimen. A 3% sodium chloride salt solution was mixed and placed in plastic storage bins. Each rebar sample was placed in the salt baths three times a week for a time of eight hours each. This occurred, in general, on Mondays, Wednesdays, and Fridays. After each immersion, samples were removed from the salt baths and placed on towels to dry until the next immersion day.

All samples underwent 260 immersion cycles. For our climatic conditions, assuming between one and two salting events during a 15 week winter season leads to 260 immersions simulating approximately 10 years of harsh, direct element and corrosive exposure. It should be noted that this would not directly simulate rebar encased in concrete, as the concrete itself provides a substantial barrier to corrosives, nor is there an increased concentration as a function of drying intervals.

Prior to the start of testing, periodically thereafter, and at the end of the 260 immersions, all samples underwent a battery of measurements. These included mass, diameter, and coating thickness. A brief description of each measurement is described below.

Mass

Mass was determined with the use of a balance down to a tenth of a gram. Masses were recorded immediately before their first immersion into the saltwater baths and then periodically thereafter.

Diameter

Diameter was measured with a set of precision calipers accurate to 0.001 inches. Measurements were made at every inch along each rebar sample, from rib to rib, for nine readings. These were averaged to determine the overall average diameter of each sample. Diameters were recorded immediately before their first immersion into the saltwater baths and periodically thereafter.

Coating Thickness

Coating thickness was measured with the use of an Elcometer, which measures the resistance between a probe on the device and the magnetic surface on which it is placed. Since it requires a magnetic surface to measure from, not all rebar in this study could be measured using this technique. The readings were recorded down to 0.1 mils (0.0001 inch). Measurements were taken every inch on both ribs of each rebar sample, for 18 readings per sample. These were averaged to determine the overall average coating thickness of each sample. Thicknesses were recorded immediately before their first immersion into the saltwater baths and then periodically thereafter.

MATERIAL DESCRIPTION

In total, eight material types were represented in this study. Brief descriptions of each are below.

Black Bar

Plain carbon-steel reinforcing bars are typically referred to as 'black bar'. The black bars used in this study, were of unknown origin and exact composition. They were in an unused and corrosion-free state at the commencement of the experiment. The bars were covered under ASTM A 615, "Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete

Reinforcement" (2) and ASTM A 706, "Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement" (3). Two samples of black bar were tested within this study.

MMFX-2

The MMFX-2 product is called a microcomposite steel. It was manufactured and provided by MMFX Technologies Corporation for this study. According to MMFX Technologies, MMFX-2's "patented process eliminates carbides and the 'battery effect' by forming packets of microcomposite austenite and lath martensite structure, which do not form microgalvanic cells. Thus, the microstructural corrosion mechanism existing in conventional steel is eliminated from microstructurally designed MMFX Steels." (4) One main selling point of these bars is that since the steel is designed to resist corrosion, there is no need for coating, thereby eliminating the worry of coating damage. MMFX Technologies literature also estimates a service life in excess of 100 years when used in conjunction with high performance concrete. Two samples of MMFX-2 were tested in this study.

Epoxy-Coated

Epoxy-coated reinforcing steel is comprised of basic black bar with a thermally bonded epoxy coating on the outside, typically green in color. The epoxy coating, when intact, prohibits the infiltration of corrosives to the underlying steel. The epoxy-coated bars used in this study, unfortunately, were of unknown origin and exact composition. They were in unused and free of corrosion at the commencement of the experiment. These bars were covered under ASTM A 775, "Standard Specification for Epoxy-Coated Steel Reinforcing Bars" (5), and ASTM A 934, "Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars" (6).

Two samples of epoxy-coated bars were tested in this study, for a total of eight bars. Each sample consisted of four configurations of bars. One bar was tested as-is, one was intentionally cut to expose the underlying steel, the third was cut and repaired with a typical spray epoxy, and the fourth was cut and repaired with a typical two-part epoxy.

Z-Bar

ZBar is similar to normal epoxy coated rebar, except with the addition of an inner layer of zinc between the black bar (A615 or A706) and the polymer (epoxy) coating. The zinc layer is thermally bonded to the black bar and acts as a sacrificial layer of protection if the outer epoxy layer is damaged. The epoxy layer, also thermally bonded to the zinc layer, is placed as yellow in color by the manufacturer only in an effort to distinguish it from the typically green color of normal epoxy coated rebar. Z-Bar is produced by Gerdau Ameristeel, who furnished the product for this project. Z-Bar has been evaluated using ASTM A944, "Standard Test Method for Comparing Bond Strength of Steel Reinforcing Bars to Concrete Using Beam-End Specimens" (7) and, according to Gerdau Ameristeel, is readily available and can be substituted for any reinforcing steel product; it has also demonstrated an estimated 100 year life span in initial accelerated lab testing. (8)

Two samples of ZBar were tested in this study, for a total of six bars. Each sample consisted of three configurations of bars. One bar was tested as-is, one was intentionally cut to expose the underlying zinc layer, and the third was cut and repaired with a typical spray epoxy. These bars were covered under ASTM A 1055, "Standard Specification for Zinc and Epoxy Dual-Coated Steel Reinforcing Bars" (9).

Stainless Clad

Two stainless steel clad bars were tested, manufactured and supplied by NX Infrastructure Ltd. of the United Kingdom. The product name is Nuovinox 316L Stainless Steel Clad Reinforcing Bar (Grade 420). Stainless clad rebar consists of a steel bar similar to black bar at the core with stainless steel clad on the outside, providing a solid barrier to the more easily corrodible steel at the core. The core steel composition was recorded, in weight percent, as 0.31 C, 0.29 Si, 1.07 Mn, 0.013 P, and 0.035 S, and the cladding material as 0.024 C, 0.40 Si, 1.68 Mn, 0.031 P, 0.001 S, 16.80 Cr, 2.01 Mo, 10.01 Ni, and 0.023 N. The average cladding thickness was measured as an average of 656 µm.

Stainless Steel, High Nickel

Two high nickel stainless steel bars were tested, manufactured by Talley Metals, a Carpenter Company, provided by Salit Specialty Rebar, and produced in the USA. The product name is EnduraMet 2205 and described as hot finish unannealed pickled. The composition, by weight percent, is: 0.02 C, 1.77 Mn, 0.42 Si, 0.024 P, 0.001 S, 21.40 Cr, 4.73 Ni, 2.56 Mo, 0.21 Cu, 0.15 N, 0.0023 B. These bars are solid stainless steel throughout, therefore should have high corrosion resistance throughout their structure.

Stainless Steel, High Manganese

Two high manganese stainless steel bars were tested, manufactured by Talley Metals, a Carpenter Company, provided by Salit Specialty Rebar, and produced in the USA. The product name is EnduraMet 32 (UNS-S24100) and described as hot finish unannealed pickled. The composition, by weight percent, is: 0.05 C, 11.90 Mn, 0.40 Si, 0.020 P, 0.002 S, 17.40 Cr, 0.75 Ni, 0.14 Mo, 0.06 Cu, 0.03 Co, 0.31 N, 0.0020 B. These bars are solid stainless steel throughout, therefore should have high corrosion resistance throughout their structure.

Duplex Stainless Steel

Two duplex stainless steel bars were tested, which were manufactured by Arminox under the designation of 1.4362 (2304), produced in the USA. Duplex stainless steels have a two-phase microstructure of ferritic and austenitic grains, reportedly leading to increased corrosion resistance, strength, and ductility over some other common stainless steels (10). These bars are solid stainless steel throughout, therefore should have high corrosion resistance throughout their structure.

PERFORMANCE AND OBSERVATIONS

Table 1 displays the averaged initial measured diameters, coating thicknesses, and masses for each type of bar. Table 2 displays the final values. Finally, Table 3 displays the percent change in each measurement from initial to final. From the initial value table, it is evident that all uncoated bars have virtually the same diameter, while ECR and Z-Bar have slightly larger diameters due to the coatings. Masses of the black bars, MMFX, and ECR were similar, while values for Z-Bar were approximately 20% higher. The different compositions of stainless steel ranged from similar to Z-Bar to 35% more massive than the non-high performance bars. The initial coating thickness measurements showed that the epoxy coating on both the ECR and Z-Bar averaged about 10 mils. An Elcometer is normally used by the Researchers for measuring the thickness for mostly flat surfaces. When using the measuring device for this project, the researchers are unclear as to how accurate the method was for measuring coating thickness, since it was being used to test round or circular surfaces. Since the use of the measuring device is used for comparative results, the need for accuracy was determined not to be essential.

As can be seen in Table 1, the measurement procedure gave thickness values for black bar, MMFX, and especially the stainless steel with high Ni content. It may be reasonable that a coating of some sort is present on the 'bare' bars, but probably not to the 5-mil level as for the Ni stainless steel. Please note the non-zero values for initial coating thickness for the black and MMFX bar samples, this may be due to the unconventional use of the Elcometer.

Table 1. Summary of average initial measured values prior to salt water immersions.

Bar	Initial Diameter (inches)	Initial Coating Thickness (mil)	Initial Mass (g)
Black Rebar	0.81	1.36†	550.8
MMFX	0.78	0.43†	543.2
ECR, Intact	0.86	11.57	548.5
ECR, Cut, Unrepaired	0.84	11.15	548.8
ECR, Cut & Repaired, Spray Epoxy	0.85	10.79	549.3
ECR, Cut & Repaired, 2 Part Epoxy	0.83	10.97	545.2
Z-Bar, Intact	0.84	9.81	661.2
Z-Bar, Cut, Unrepaired	0.84	11.92	663.3
Z-Bar, Cut & Repaired, Spray Epoxy	0.85	10.35	668.0
Stainless Steel, Clad	0.79	Non-Magnetic	771.8
Stainless Steel, High Ni	0.78	5.68	653.1
Stainless Steel, High Mn	0.79	Non-Magnetic	650.0
Stainless Steel, Duplex	0.80	Non-Magnetic	750.3

†The measuring device used in the study is not normally used for measuring coating thicknesses on bars. The results in the table for coating thickness may have some minor irregularities. The intent is to obtain relative thickness changes of the coating for the study.

Table 2. Summary of averaged final measured values after 260 salt water immersion cycles.

Bar	Final Diameter (inches)	Final Coating Thickness (mil)	Final Mass (g)
Black Rebar	0.79	11.19	536.0
MMFX	0.88	32.99	565.6
ECR, Intact	0.86	11.21	549.8
ECR, Cut, Unrepaired	0.85	19.11	551.4
ECR, Cut & Repaired, Spray Epoxy	0.85	10.98	549.5
ECR, Cut & Repaired, 2 Part Epoxy	0.83	11.14	545.5
Z-Bar, Intact	0.84	9.29	661.0
Z-Bar, Cut, Unrepaired	0.84	11.01	663.4
Z-Bar, Cut & Repaired, Spray Epoxy	0.85	10.91	668.1
Stainless Steel, Clad	0.79	Non-Magnetic	772.2
Stainless Steel, High Ni	0.78	4.14	653.1
Stainless Steel, High Mn	0.79	Non-Magnetic	650.0
Stainless Steel, Duplex	0.80	Non-Magnetic	750.2

Table 3. Summary of the percent changes of measured values between initial and final values.

Bar	% Change in Diameter	% Change in Coating Thickness	% Change in Mass
Black Rebar	-1.6	723.1	-2.7
MMFX	12.6	7611.7	4.1
ECR, Intact	-0.2	-3.1	0.2
ECR, Cut, Unrepaired	0.7	71.4	0.5
ECR, Cut & Repaired, Spray Epoxy	-0.2	1.7	0.0
ECR, Cut & Repaired, 2 Part Epoxy	0.1	1.5	0.1
Z-Bar, Intact	0.1	-5.2	0.0
Z-Bar, Cut, Unrepaired	-0.3	-7.7	0.0
Z-Bar, Cut & Repaired, Spray Epoxy	-0.2	5.4	0.0
Stainless Steel, Clad	-0.5	Non-Magnetic	0.1
Stainless Steel, High Ni	-0.8	-27.1	0.0
Stainless Steel, High Mn	-0.5	Non-Magnetic	0.0
Stainless Steel, Duplex	-0.6	Non-Magnetic	0.0

The most important results of this study lie in the percent changes in values from the first immersion to the last. The percent change of diameter of the bars show that all bars remained unchanged in diameter except for the MMFX, which gained 13% in diameter. This was due to a large amount of oxidation buildup on the surface, in the form of flaking. Due to this flaking, pockets of air were present between the flaking and the remaining intact bar, increasing both its diameter and coating thickness. Mass change for all high performance bars was negligible and for ECR it was near zero. Both black bars and MMFX changed in mass slightly with MMFX increasing by 4% and black bar decreasing by 3%.

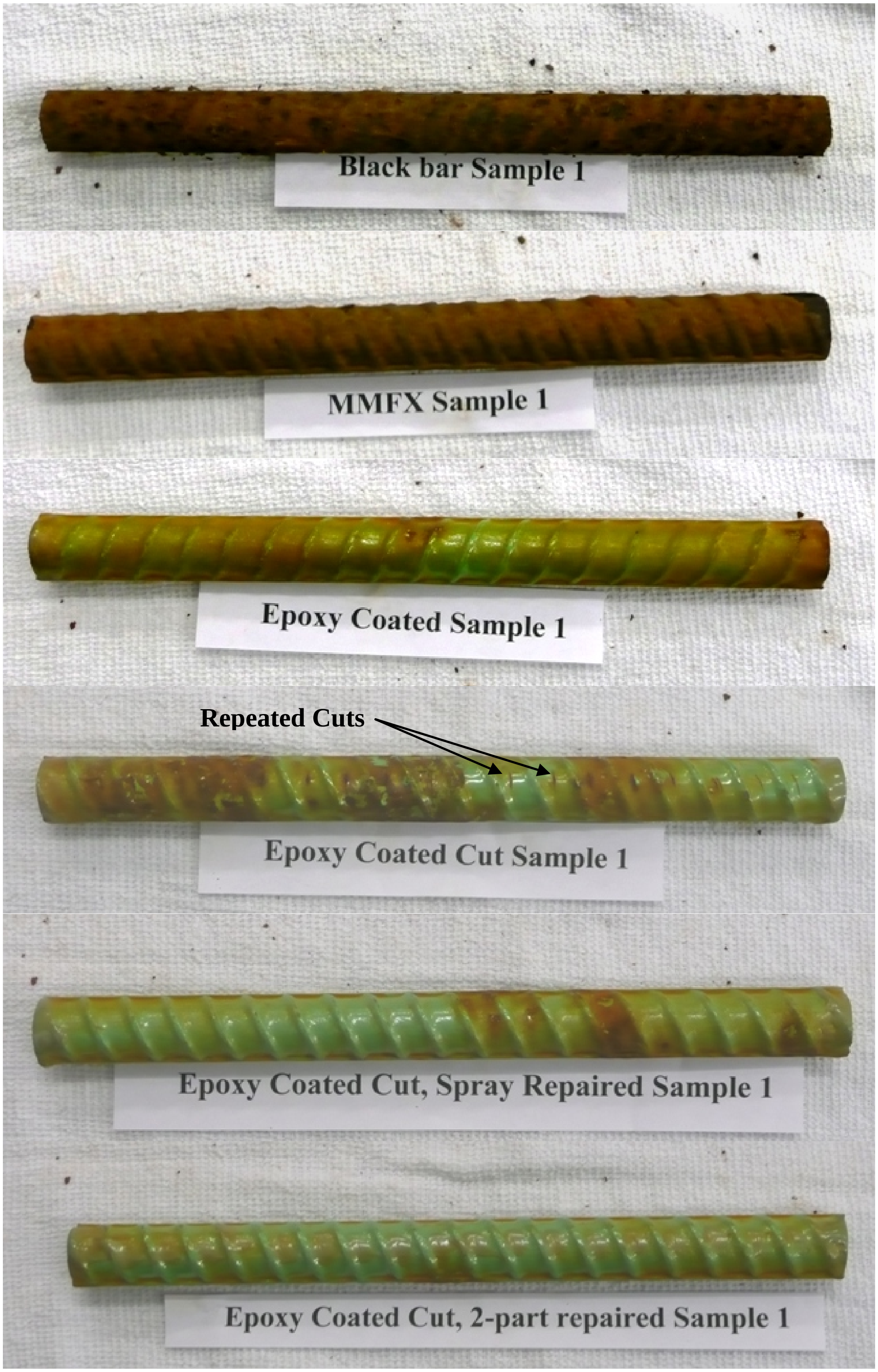
The change of coating thickness values better show a difference between individual bar configurations. As expected from discussion of past results, both the black bar and MMFX exhibited the largest percent increases in coating thicknesses by a large margin, especially the MMFX as 7,612%. The ECR series of measurements show an important aspect of the purposes behind this study. The intact and two cut-and-repaired sets of bars show somewhat negligible changes in coating thicknesses; the cut and unrepaired bars, however, show a 71% increase in coating thickness. This means that the cut provided a way in for contaminants, resulting in a considerable overall coating thickness increase of the bar. Even the small change to the overall diameter of the bar that this causes could cause major damage to the surrounding concrete due to the expansive forces.

The Z-Bar series also shows some variation between the intact, unrepaired, and repaired bars. The unrepaired bar, as with ECR, displaying the largest change (albeit a decrease). The magnitude, however, is on a much lower scale of change due to the extra sacrificial layer that is present under the epoxy. Most of the stainless steel bars could not be measured for this test since they are non-magnetic (and the test relies on a magnetic base). Surprisingly the high Ni stainless steel showed a large 27% decrease in coating thickness (31% and 23% for each of the 2 samples). This was unexpected; however, the original thicknesses were also unexpectedly high, so a large decrease may actually be expected.

A compilation of the final photographs of a bar from each set is shown in Figure 1, placed in the same order as the earlier tables. In it, the amount and extent of corrosion is readily visible in the pictures, with the black bar and MMFX displaying, visually, the most corrosion. The difference between the intact, cut and repaired bars in the ECR and Z-Bar series are easily distinguishable from the cut and unrepaired bars; the cuts in the epoxy coatings are visible and have turned the familiar brown color of oxidized metal. The end capping of the stainless clad bar is noticeable, and corrosion most likely due to metal contamination during cutting broke through the epoxy end capping.

Removal of the epoxy coating for both the ECR and Z-Bar was attempted to provide a better visual understanding of the extent of the corrosion of the underlying bar. This act, however, proved futile, as the epoxy was very difficult to remove with basic cutting and scraping tools. This indicates good thermal bond strength between the bars and the coatings.

Figure 1. Images of each bar in series 1 in their final condition following 260 salt water immersion cycles.



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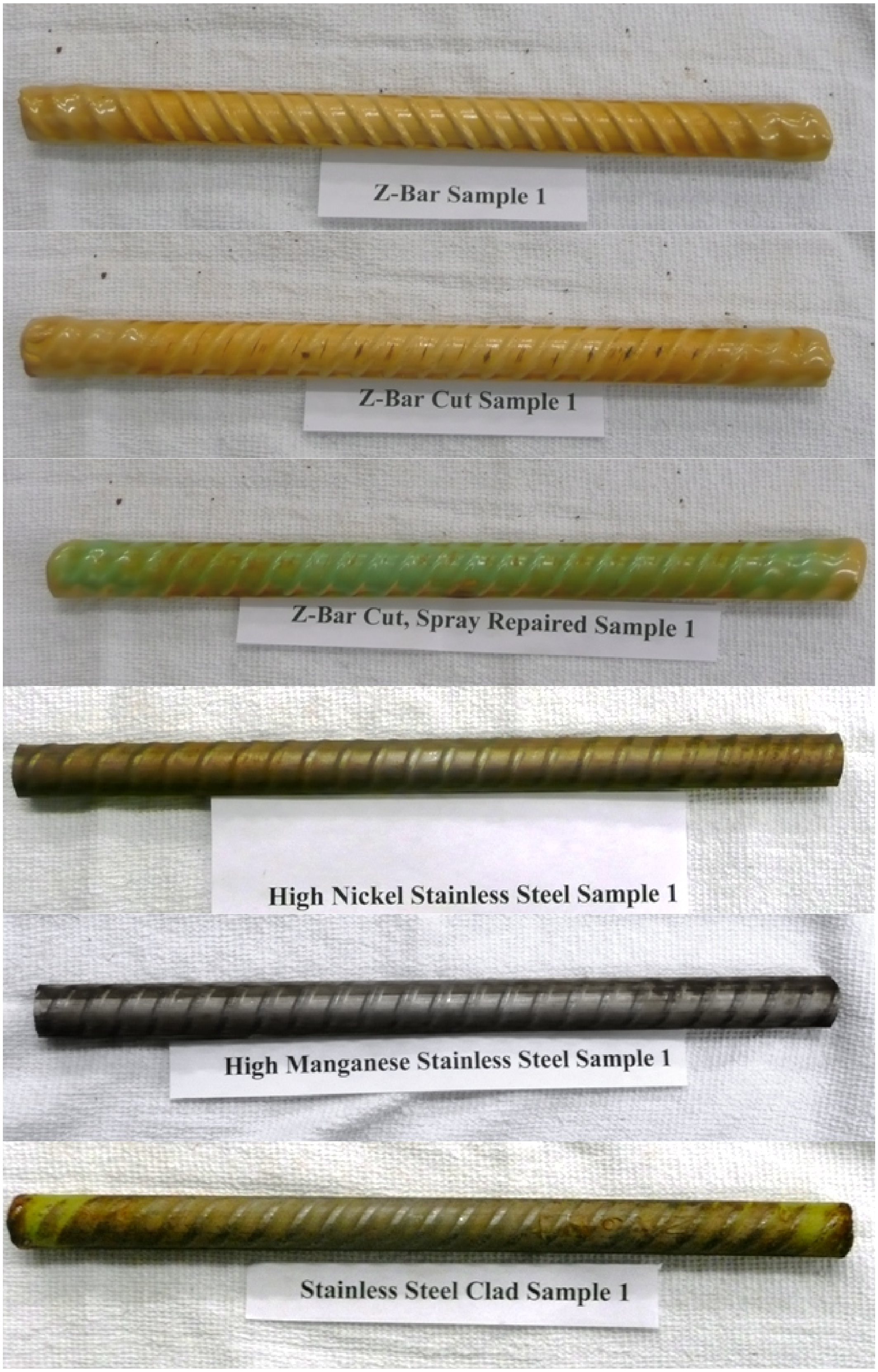

Figure 1 (cont.) Images of each bar in series 1 in their final condition following 260 salt water immersion cycles.

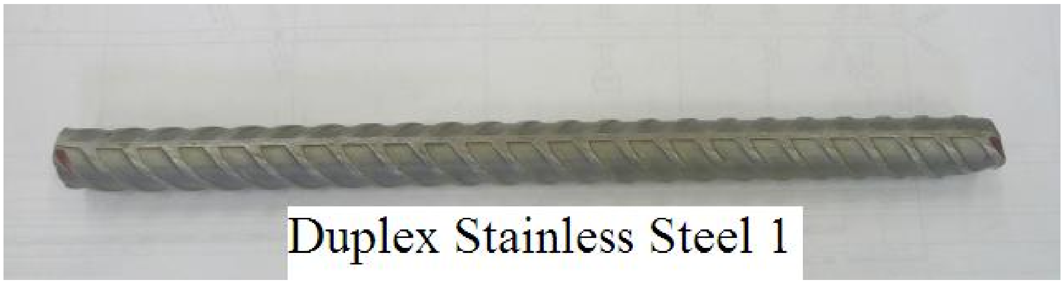

Figure 1 (cont.) Images of each bar in series 1 in their final condition following 260 salt-water immersion cycles.

LIFE EXPECTANCY ANALYSIS

Black Bar and MMFX

The black rebar and MMFX reinforcing bars were the two most reactive bars in the test. The results indicate that these alternatives would corrode quicker and due to their expansive tendencies, would cause the most spalling of concrete. The life expectancy of reinforced concrete with these two alternatives would be shortest of the group, with the MMFX alternative providing the least amount of life expectancy of the entire study.

ECR.

Though the study generally showed that the performance of Epoxy coated steel was good, when a cut in the epoxy coating is not treated, the bar performed poorly. The expansion was about 10% of the Black Bar and the corrosions proved to be much less than that seen from Black Bars and the MMFX bars. This expansion, however, may be too small to cause the concrete to spall for a long time. Overall, the epoxy coated reinforcement proved a good performer; however, the recommended care procedures must be followed. If the epoxy coating is compromised, the coating must be repaired. Essentially, intact and repaired epoxy coated reinforcement performed equally. Epoxy coated reinforcement would have a long life expectancy.

Z-Bar

Overall, the Z-Bar performed similarly as epoxy coated steel. When cut and left unrepaired, the bar did corrode more, but the effects would be negligible within concrete. The performance of the cut Z-Bar was almost near the performance of an intact or repaired Z-Bar, therefore the life expectancy of reinforced concrete would be essentially the same regardless whether a cut was repaired or not. The zinc layer proved to provide good protection once the epoxy coating was compromised. Though one could conclude that repairing cuts in the Z-Bar coating may not be necessary, the study did show that repairs might add more life to the reinforced concrete element.

Stainless Steel

Stainless Steel proved to be the best performers in the study. Due to the non-magnetic material, the coating thickness was not measured for all sample types. However, visual inspection (see figure 1) showed that the bars were resistant to corrosion. There was virtually no corrosive buildup or any signs of deterioration. The stainless clad reinforcing did exhibit some significant corrosion at the cut ends (see figure 2). As seen in figures 1 and 2, the clad bar was treated by dipping the ends into an epoxy liquid; however, this proved to be insufficient to protect the bar. Solid Stainless Steel reinforcement will provide the maximum life expectancy. Because of the cut ends, the clad reinforcement will need a thick application of epoxy coating at the cut ends to have the same life expectancy as the stainless steel reinforcing.

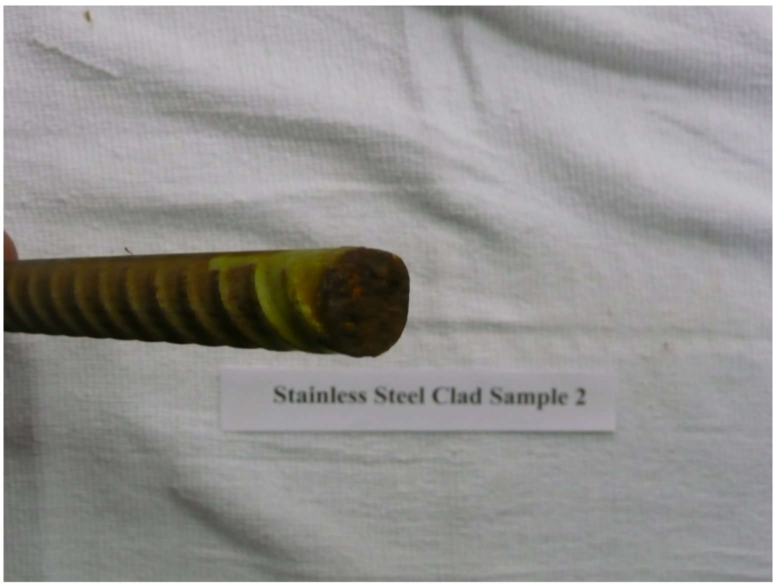

Figure 2 (cont.) The cut end of a stainless clad reinforcing bar showed signs of corrosion.

COST ANALYSIS

Very rough cost approximations, as received from the manufacturers, are presented in Table 4 below. They represent fabricated and delivered costs and are from early 2012. Many factors alter the cost of rebar, such as quantity ordered, delivery needs and distances, special fabrication needs, and the raw material cost at the time or order. While the costs represented can in no means be thought of as exact, it should at least serve as a basis of comparison between the levels of costs of the various types of reinforcing.

Table 4. Reinforcement Cost Comparison

	Cost ($ per lb)	Cost ($ per ton)	Relative Life Expectancy
Black Rebar	0.505	1,010	Short
MMFX	1.000	2,000	Very Short
ECR Intact or repaired	0.615	1,230	Long
ECR Unrepaired			Short
Z-Bar	1.250	2,500	Long
Stainless Steel, Clad	1.750	3,500	Very Long†
Stainless Steel, High Ni	3.000	6,000	Very Long
Stainless Steel, High Mn	2.350	4,700	Very Long
Stainless Steel, Duplex	2.600	5,200	Very Long

†The ends of the Stainless Clad reinforcement will need a protective treatment at the cut ends to prevent corrosion and deterioration and to ensure a very long life expectancy.

SUMMARY AND RECOMMENDATIONS

A large amount of research is available on the topic of corrosion resistance of various forms of reinforcing steel, much of which is not consistent. In addition to the inconsistencies in the research results, most rebar manufacturers boast increased corrosion protection with their products over their competitors. To this end, a basic research evaluation was undertaken to describe qualitatively, the corrosion resistance of eight different material types in comparison with one another. Samples were put alternately into a salt bath and then set out to dry, for 260 cycles approximately over a two-year period. This resulted in an estimated 10-year exposure time based on Vermont's climate and road maintenance practices. Samples were evaluated prior to the first immersion, after the final immersion, and periodically throughout for masses, diameters, and coating thicknesses.

The results of all tests and measurements prove that each type of rebar show varying degrees of corrosion resistance to sodium chloride. Black bar showed not only extensive corrosion, but it also began rapidly from the onset of the immersions. Intact and cut-and-repaired epoxy coated bars showed adequate resistance to corrosion; however, the bars that were intentionally cut and not repaired showed a considerable increase in corrosion. It is likely a common occurrence that reinforcing bars become damaged on a project and are not adequately repaired; in such instances, it is clear that further corrosion resistance would be beneficial to create a foolproof system. To this end, the Z-Bar, stainless-clad, and solid stainless steels exhibited far less corrosion as they have, theoretically and practically, superior methods of resistance.

The VTrans Structures Section has researched a wide variety of reinforcing steel. With their research and the findings from this study, Structures chose to divide the types of rebar into the following categories, in their effort to compose a new reinforcing steel specification:

- **Category I, Limited Corrosion Resistance**: consists of any black and low alloy steel bars, such as Black bar, MMFX-2, and ECR.
- **Category II, Improved Corrosion Resistance**: consists of any dual coated/protected bars, such as Z-Bar and Stainless-clad.
- **Category III, Excellent Corrosion Resistance**: consists of any Solid Stainless steels

The new general specification, as implemented on February 7, 2012, is included in Appendix A.

IMPLEMENTATION STRATEGY

Considering that there does appear to be certain ranges of corrosion resistant capabilities among reinforcing steel, it is recommended that VTrans move towards classifying reinforcing steel in the categories Structures has defined. The Structures Section has expressed an interest in using category III reinforcing steel alternatives rather than to continue with epoxy coated rebar, which they previously employed. Structures will begin using mostly category III rebars in all interstate bridges and category II rebars as a minimum, on all other state and US routes in Vermont.

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APPENDIX A

Vermont Agency of Transportation General Special Provisions, February 7, 2012

GENERAL SPECIAL PROVISIONS FOR ALL PROJECTS
2011 STANDARD SPECIFICATIONS

SECTION 507 – REINFORCING STEEL

507.01 DESCRIPTION, is hereby modified by adding the phrase "of the level specified" after the phrase "bar reinforcement".

507.01 DESCRIPTION, is hereby further modified by adding the following paragraphs:

Levels and associated types of reinforcing steel are specified as follows:

(a) Level I (Limited Corrosion Resistance). Level I reinforcing includes plain, low alloy, and epoxy coated reinforcing steel.

(b) Level II (Improved Corrosion Resistance). Level II reinforcing includes stainless clad and dual-coated reinforcing steel.

(c) Level III (Exceptional Corrosion Resistance). Level III reinforcing includes solid stainless reinforcing steel.

The location, level, and when specified, type of reinforcing shall be as indicated in the Plans. Reinforcing supplied shall meet the requirements of the level specified or any higher level. Only one type of reinforcing steel shall be used for each level for the Contract work, unless permitted in writing by the Engineer.

507.02 MATERIALS, is hereby modified by deleting the sixth (final) entry in the Subsection listing.

507.03 FABRICATION AND SHIPMENT, part (a) General, is hereby modified by adding the phrase "deformed bar" after the phrase "shall be" in the first paragraph.

507.03 FABRICATION AND SHIPMENT, part (a) General, is hereby corrected by deleting punctuation ".." and replacing it with punctuation "." at the end of the first paragraph.

507.04 PROTECTION OF MATERIAL, is hereby modified by adding the following as the second sentence in the first paragraph:

When multiple levels of reinforcing steel are used on a project, they shall be stored separately, including during transport in order that there is no direct contact between the bars.

507.04 PROTECTION OF MATERIAL, is hereby further modified by deleting the phrase "The epoxy coating" and replacing it with the word "Coatings" in the third sentence of the third paragraph.

507.04 PROTECTION OF MATERIAL, is hereby still further modified by deleting the phrase “as required for damaged areas” and replacing it with the phrase “per the coating manufacturer’s recommendations and to the satisfaction of the Engineer” in the third sentence of the fifth (last) paragraph.

507.04 PROTECTION OF MATERIAL, is hereby still further modified by adding the following paragraph:

All ends of Level II reinforcement where the mild steel core is exposed shall be capped in accordance with one of the following:

(a) Heat-shrink cap applied in accordance with the cap manufacturer’s instructions.

(b) Neoprene cap adhered with silicone or epoxy sealant.

(c) Stainless steel cap epoxied in place.

(d) Stainless steel seal weld.

507.05 PLACING AND FASTENING REINFORCING STEEL, is hereby modified by deleting the sixth paragraph in its entirety and replacing it with the following:

Tie wires and supports used for installation of reinforcement shall be composed of the same material as any steel being contacted or shall be nonmetallic or coated with a dielectric (electrically insulated) material to prevent reactions between dissimilar metals. When forms are to be removed in their entirety, uncoated steel chairs equipped with snug-fitting, high-density, polyethylene tips which provide 3 mm (1/4 inch) clearance between the metal and any exposed surface may be used.

507.10 METHOD OF MEASUREMENT, is hereby modified by deleting the phrase “, Epoxy Coated Reinforcing Steel, and Galvanized Reinforcing Steel” and replacing it with the phrase “of the type and size specified” in the first paragraph.

507.10 METHOD OF MEASUREMENT, is hereby further modified by adding the phrase “of the type specified” at the end of the second paragraph (beginning “The quantity of Drilling and Grouting Dowels…”).

507.11 BASIS OF PAYMENT, is hereby modified by deleting the following pay items:

Pay Item	Pay Unit
507.15 Reinforcing Steel (Pound)	Kilogram
507.17 Epoxy Coated Reinforcing Steel (Pound)	Kilogram
507.18 Galvanized Reinforcing Steel(Pound)	Kilogram

507.11 BASIS OF PAYMENT, is hereby further modified by adding the following pay items:

Pay Item	Pay Unit
507.11 Reinforcing Steel, Level I (Pound)	Kilogram
507.12 Reinforcing Steel, Level II (Pound)	Kilogram

507.13 Reinforcing Steel, Level III (Pound) Kilogram

SECTION 713 – REINFORCING STEEL, WELDED WIRE REINFORCEMENT, AND REINFORCING STRAND

713.01 BAR REINFORCEMENT, is hereby modified by deleting the phrase "conforming to AASHTO M 31M/M 31, including supplementary requirements" and replacing it with the phrase ", unless otherwise specified in the Contract Documents" in the first paragraph.

713.01 BAR REINFORCEMENT, is hereby further modified by adding the following new parts (a)-(f) and associated paragraphs:

(a) Plain Reinforcing Steel. Plain reinforcing steel shall conform to AASHTO M 31M/M 31, including supplementary requirements.

(b) Low Alloy Reinforcing Steel. Low alloy reinforcing steel shall conform to ASTM A 706/A 706M.

(c) Epoxy Coated Reinforcing Steel. Epoxy coated reinforcing steel shall have an electrostatically applied organic epoxy protective coating, which has been prequalified, fabricated, tested, and installed in accordance with AASHTO M 284M/M 284 or ASTM A 884.

(d) Stainless Clad Reinforcing Steel. Stainless clad reinforcing steel shall meet the requirements of AASHTO M 329M/M 329.

(e) Dual-Coated Reinforcing Steel. Dual-coated reinforcing steel shall meet the requirements of ASTM A 1055/A 1055M.

(f) Solid Stainless Reinforcing Steel. Solid stainless reinforcing steel shall meet the requirements of ASTM A 955/A 955M with one of the following UNS designations: S24100, S30400, S31603, S31653, S32101, S32201, S32205, or S32304. Different designations shall not be mixed within the same project.

Where no core steel requirements are specified in the above specifications, the steel core of the bar reinforcement shall meet the requirements of plain reinforcing steel.

Certification. A Type D Certification shall be furnished in accordance with Subsection 700.02. Certification for Epoxy Coated Reinforcing Steel shall include the coating and coating process.

713.07 COATED BAR REINFORCEMENT, is hereby modified by being deleted in its entirety.