DEPARTMENT OF TRANSPORTATION

Maintenance Painting for Steel Bridges: Evaluation of Coating Systems Over Minimally Prepared Surfaces to Delay Rehabilitation

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August 2019

Research Project
Final Report 2019-37

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Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2019-37		

4. Title and Subtitle Maintenance Painting for Steel Bridges: Evaluation of Coating Systems Over Minimally Prepared Surfaces to Delay Rehabilitation	5. Report Date August 2019 6.
7. Author(s) Christopher Wolfgram / Daniel J. Zienty, Short Elliott Hendrickson, Inc.	8. Performing Organization Report No.
9. Performing Organization Name and Address Short Elliott Hendrickson Inc. 3535 Vadnais Center Drive St. Paul , Minnesota 55110	10. Project/Task/Work Unit No. 11. Contract (C) or Grant (G) No. (c) 06401
12. Sponsoring Organization Name and Address Minnesota Department of Transportation Office of Research & Innovation 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes
http://mndot.gov/research/reports/2019/201937.pdf
http://mndot.gov/research/reports/2019/201937S.xlsx

16. Abstract (Limit: 250 words)

The purpose of this project was to identify efficient and cost-effective methodologies for maintenance painting of steel bridges for MnDOT bridge crews to extend the service life of the coating system by at least five years before complete coating rehabilitation would be warranted. Five generic coating systems, chosen for their compatibility with existing MnDOT coating systems and minimal requirements for surface preparation and application, were applied over minimally prepared surfaces on two St. Paul bridges. Coating performance was evaluated annually over a three-year period through visual field observation following the MnDOT Steel Bridge Coating Condition Assessment Photographic Field Guide and MnDOT Bridge and Structure Inspection Program Manual. Adhesion testing was performed in accordance with ASTM D3359 in conjunction with the third-year evaluation. The results were photographed and documented in a matrix, identifying key performance characteristics. The predominant failure affecting two of the coating systems was delamination due to application over an anti-graffiti finish coat. Otherwise, each system performed to a standard aligning with the pre-established project goal for expanded serviceability of five years. Because developing a Bridge Maintenance Coating Program requires critical timing in the inspection process to identify existing coating condition, a Bridge Coating Repair Reference Table was developed to assist MnDOT crews with determining the appropriate preventive maintenance painting strategy based on condition and existing coating system. This work also determined that surface conditions demonstrating pitting with rusting, or surfaces with an anti-graffiti coating should not be addressed through maintenance painting but instead should be considered for coating removal and replacement.

17. Document Analysis/Descriptors	18. Availability Statement
Coatings, Steel bridges, Evaluation and assessment, Maintenance, Guidelines	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	129	

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FINAL REPORT

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AUGUST 2019

Published by:

Minnesota Department of Transportation
Office of Research & Innovation
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

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EXECUTIVE SUMMARY

The purpose of this project was to identify efficient and cost-effective methodologies for pre-cleaning, surface preparation, and selection and application of maintenance coating systems for MnDOT bridge crews to extend the service life of the coating system by at least five (5) years before complete coating rehabilitation would be warranted. Since the condition of the existing coating systems and underlying steel primarily drives the development of an appropriate maintenance painting strategy, this project also provided best practice recommendations for appropriate scheduling of bridge maintenance coating repairs.

Four major coatings manufacturers were requested to submit applicable maintenance coating systems that could be applied over minimally prepared surfaces and still meet the requirements of a five-year service life. Considerations for selecting generic coating systems for evaluation included their compatibility with existing state coating systems, coating system tolerance respective of Minnesota climate, and assessed compatibility with surface preparation and coating application requirements.

Five generic coating systems were applied over minimally prepared surfaces at two St. Paul bridges. Coatings were evaluated annually over a three-year period using a combination of visual inspection and field testing. Visual inspection performed to evaluate holidays (voids), runs, sags, surface contaminants, overspray, dry spray, delamination, steel condition under the coating system, and other deficiencies as objectively compared to American Society for Testing and Materials (ASTM) and industry standards. Field testing was performed in accordance with Society for Protective Coatings (SSPC) PA-2 "Measurement of Dry Film Thickness with Magnetic Gages," using a Type 2 field probe and magnetic flux gage.

Inspection instruments such as a dry film thickness gage, cross-cut guide kit, putty knife, and a 30X microscope were used to support coating serviceability estimates for remaining service life. This information was assessed and categorized in accordance with applicable ASTM standards, which included but were not limited to:

- ASTM D 3359 Test Method for Measuring Adhesion by Tape (Completed at conclusion of the observations phase in 2018 to prevent creation of a failure during the maintenance test project)
- ASTM D 610 Method for Evaluating Degree of Rusting
- ASTM D 714 Test Method for Evaluating the Degree of Blistering Paints

Field evaluations were conducted annually for three years following application. Each year, the coating systems were given a rating in accordance with the *MnDOT Steel Bridge Coating Condition Assessment Photographic Field Guide* and *MnDOT Bridge and Structure Inspection Program Manual*. In general, the coating systems were categorized as good to fair condition. Rust bleed was present at most locations where concrete and steel intersections occurred; however, it was not considered a coating failure due to location of the deficiency. The primary coating failures consisted of localized spot rusting and minor cracking. However, a predominant failure that affected two of the coating systems was cracking and delamination due to application over an anti-graffiti finish coat. Adhesion testing was also completed three years following application.

Additional test patches, requested by MnDOT following first-year observations, considered an even more minimalistic surface preparation and coating application approach. Consideration was made to limit surface preparation to an SSPC SP1 and a single application of each prime coat product.

Although the five coating systems performed at a varying degree of success (Appendix B Matrix), each system performed to a standard aligning with the pre-established project goal for expanded serviceability of five years. Based on the results, preventive maintenance painting, if performed at the appropriate condition level, will extend the life of steel bridge elements displaying localized coating deterioration for at least five years, allowing MnDOT to delay coating replacement. The additional test patches support the conclusion that efficiencies, in the form of labor, cost and time, can be realized if maintenance painting is performed before the coating condition reaches poor to severe condition.

Many factors affect the decisions surrounding maintenance painting operations, including pre-existing coating type and condition, the presence of anti-graffiti coatings, coating compatibility, coating system selection, ease of mixing and application, environmental conditions, and environmental and safety considerations and training.a Bridge Coating Repair Reference Table was developed to provide recommendations for maintenance painting based on some of these factors, including the existing condition rating and existing coating system. Implementation of a Bridge Maintenance Painting Program requires critical timing in the inspection process to identify existing condition and schedule the appropriate maintenance painting strategy. In addition, any location with a severe condition rating, an anti-graffiti coating or pitting with rusting should not be considered for maintenance painting; it instead should be considered for coating removal and replacement.

CHAPTER 1: INTRODUCTION

1.1 PROJECT OVERVIEW

Bridge maintenance painting is performed to address areas of localized deterioration and extend the service life of existing steel coating systems and postpone major painting projects. The intent is to provide extended corrosion protection of critical structural areas, which often exhibit signs of deterioration prior to the need for full coating rehabilitation.

Typically, coating life cycles are expected to provide protection of a structure for a span of 15 to 20 years. Achieving a full life cycle will require additional maintenance in various environments where the structure has been exposed to road salts, abrasive damage, graffiti, bird nests and waste, etc. Some exposures may be eliminated by way of flushing critical structural components with water. Where this is not feasible on a regular basis or where other exposures have induced physical coating damage, the use of maintenance coatings provides a solution for correction without having to completely rehabilitate the structure.

In circumstances of funding or scheduling constraints, the use of maintenance coatings may extend the life cycle of a coating system beyond its intended service life span of 15 to 20 years.

Prior to this project, the Minnesota Department of Transportation (MnDOT) conducted a Transportation Research Synthesis (TRS) of representative transportation agencies' policies, guidance and manuals related to best practices for bridge maintenance painting operations. Best practices for conducting coating condition assessments, selecting maintenance painting strategies, performing surface preparation and applying coatings were identified from the synthesis to outline an in-house maintenance painting program. However, field trial and evaluation were needed to select proper surface preparation methods and coating products for bridge maintenance painting specific to Minnesota's climate and conditions.

To field develop effective maintenance painting methodologies, MnDOT and Short Elliott Hendrickson, Inc. (SEH) initiated a maintenance painting test site research project. This project evaluated the field performance of five (5) manufacturer recommended maintenance coating products applied over minimally prepared surfaces for a period of three (3) years. Annual coating inspections provided analytical data to determine acceptable maintenance coating systems.

1.2 PROJECT GOAL

The overall project goal was is to identify efficient and cost-effective methodologies for pre-cleaning, surface preparation, and selection and application of maintenance coating systems for MnDOT bridge crews to successfully extend the service life of the steel coating system of critical structural areas for at least five (5) years. Since the condition of the existing coating system and underlying steel primarily drives the selection of an appropriate maintenance painting strategy, this project also provides best practice recommendations for appropriate scheduling of bridge maintenance painting.

CHAPTER 2: TEST SITE SELECTION

2.1 SITE SELECTION REQUIREMENTS

Selecting a suitable location was key to the overall success of the project. Considerations for the test site location included:

- Suitable testing surfaces to accommodate personnel, equipment and the application of multiple coating systems;
- Representative coating conditions; and
- Sufficient access to the abutments and fascia beams without the need for traffic control and access equipment.

In addition, it was important to select a bridge which would not be scheduled for maintenance or rehabilitation within the time frame of field testing. This required coordination with existing MnDOT schedules to ensure that the selected site would not be disturbed during the test phase.

2.1.1 Test Site Size Considerations

In coordination with the MnDOT Office of Environmental Stewardship, a 500 square foot maximum test area would be allowable for the project to meet existing criteria for permitting and disposal. To provide a location of suitable size, the test site location needed to be large enough for MnDOT evaluation staff and painting personnel, SEH staff and inspectors and coating manufacturer representatives. In addition, because five (5) coating systems were selected for testing, the test site needed to include adjacent bridges with consistent existing coating systems in order to provide a sufficient number of test surfaces and to minimize varying environmental conditions and substrates.

2.2 PROPOSED SITES

Three (3) locations were selected for consideration for the maintenance painting test site: Blackhawk Road over I-35E in Eagan, MN, The I-494 and I-94 interchange in Maple Grove, MN, and I-35E/Randolph Ave Exit over Ayd Mill Road in St. Paul, MN.

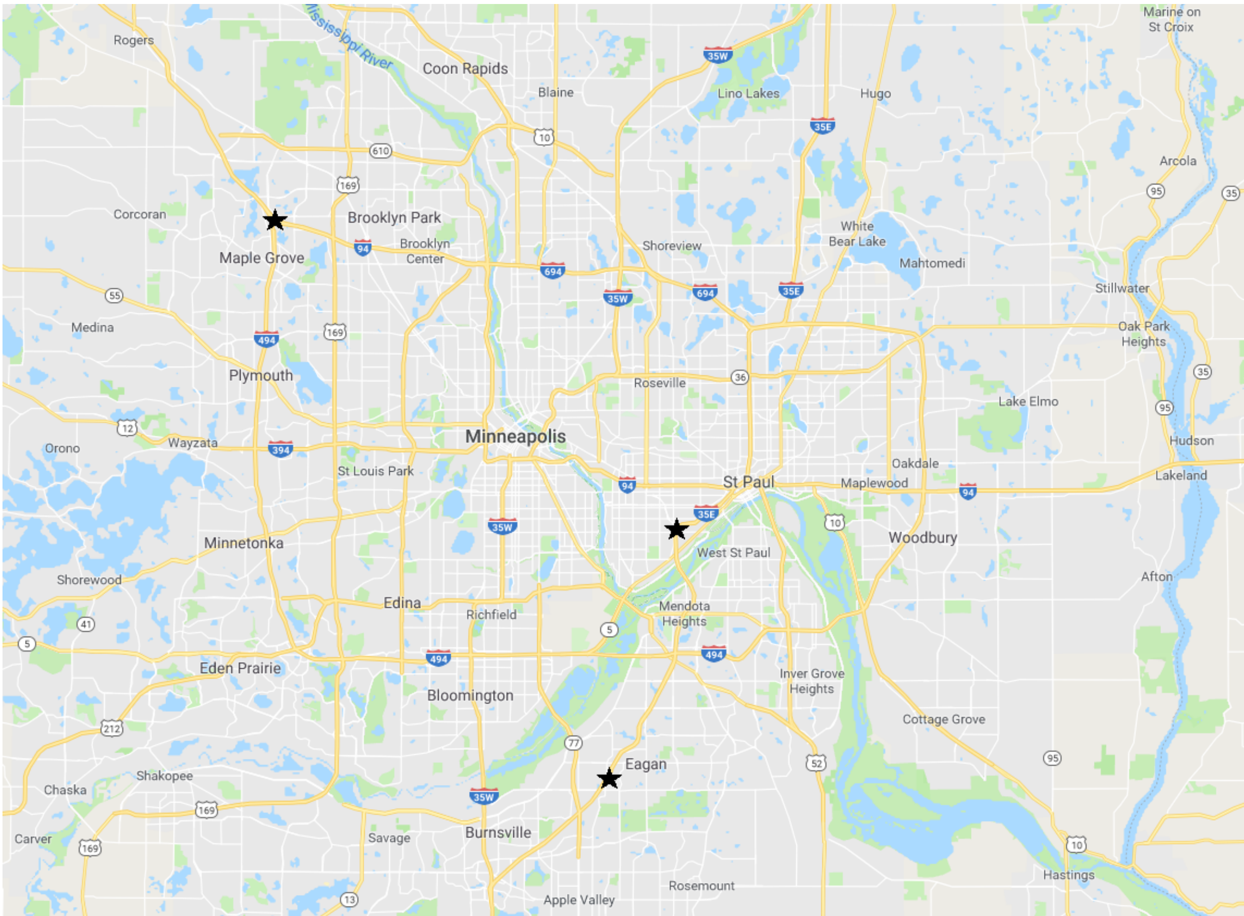

Figure 2.1 Proposed Sites

2.2.1 Blackhawk Road over I-35E – Eagan, MN

Blackhawk Road over I-35E in Eagan, MN was considered as a test site based on its current maintenance schedule and existing coating conditions. However, the site was eliminated due to insufficient accessibility of the fascia beam locations without scaffolding or access rigging and the lack of space available for personnel and equipment.

2.2.2 I-494 and I-94 Interchange – Maple Grove, MN

The I-494 and I-94 interchange in Maple Grove, MN was considered because the site provided sufficient area on two (2) bridges for the application of the five (5) coating systems selected for testing, the existing coating systems were comparable between the bridges and the surrounding area and abutments provided reasonable accessibility with sufficient space for equipment, painting personnel, and associated staff.

Unfortunately, maintenance schedule conflicts and safety concerns due to the high traffic volume of intersecting Interstates led to the elimination of this site for selection.

2.2.3 I-35E over Ayd Mill Road – St. Paul, MN

Interstate 35E southbound and the Randolph Avenue exit in St. Paul, MN provided sufficient space for accessibility and for equipment and vehicles. Application and evaluation at this test site would also not require any traffic control measures.

Each of the bridges within the site had similar coating systems and demonstrated similar existing coating conditions. Future maintenance was not programmed within the four year test site duration allowing for undisturbed testing throughout the duration of the project. Because this site met the criteria set forth by the project team and posed minimal safety and traffic concerns, it was selected for testing.

Figure 2.2 Project Site

Figure 2.3 Project Site

Figure 2.4 Project Site Aerial Photograph

CHAPTER 3: COATING SYSTEMS

3.1 COATING SYSTEM SELECTION CRITERIA

The selection of coating products is key in the development of a maintenance painting program. Consideration must be made for the existing coating systems, the current condition(s) of the structure, the amount of surface preparation required for the maintenance coating system, ease of application and intended duration of the maintenance coating system. For this project, the recommended techniques and coating systems shall be appropriate for spot repair of deteriorated areas and provide a service life of five (5) or more years.

Another consideration is the ability for MnDOT crews to perform effective coating system preservation without neglecting other bridge preservation operations. In order to reduce training requirements and production time, the project team elected to minimize the complexities associated with surface preparation, pre-application (mixing) and application processes.

3.1.1 Surface Preparation

Surface preparation needs can vary widely based upon the type of coating system, the condition of the coating system, the condition of the underlying steel element (substrate) and the goal of the maintenance painting program. Options can range from hand and power tool cleaning to abrasive blasting and pressure washing. Pressure washing was not permitted as a paint removal option for this test site because it may cause loose paint to dislodge from the structure and contaminate the ground or nearby waterways.

Consideration of surface tolerant coatings limited the level of surface preparation cleanliness required, which also reduced equipment and containment requirements. In coordination with the MnDOT Office of Environmental Stewardship and acknowledgement of local, state, and federal laws, the project team developed a minimal surface preparation procedure utilizing Society for Protective Coatings (SSPC) standards. The proposed procedure included a level of cleanliness equivalent to SSPC SP2 – Hand Tool Clean and/or SSPC SP3 – Power Tool Clean inclusive of SSPC SP1 – Solvent Wipe to remove oil, grease, dirt, soil, salts, and contaminants.

3.1.2 Pre-Application Preparation

Utilizing coatings that only require promoting (mixing a single component) or mixing of two-component products also reduced equipment and training needs. This minimal pre-application process allowed the use of an electric or air powered drill (depending on power source availability) and a mixing paddle.

3.1.3 Application

It was imperative that the selected coating systems had the ability to provide coverage, speed and accuracy of application, while also minimizing training requirements and cost. Airless or conventional spray application would require training, additional equipment on site and the use of solvents for cleaning the equipment after each use. Due to the need for an air compressor and pressurized lines, spray application methods occupied larger access areas. The use of battery powered spray equipment was also considered to promote coverage, speed, and accuracy of application. Though less on-site equipment would be required, this method still involved additional training and the use of solvents for cleaning the equipment after each use. To reduce training and equipment needs, the project team determined that the selected coating systems would need to have the ability to complete application through use of brush and roller methods.

3.1.4 Availability and Cost

The availability of coating products affects lead times and project scheduling. For the purposes of the maintenance painting program, it was preferred that coating manufacturers have the ability to provide coating products within two (2) business days to prevent delays and increased costs due to scheduling and wait times.

Costs are also a key variable in determining acceptable coating systems for maintenance painting. Cost is inclusive of the material raw cost, the equipment required to prepare the surface and apply the coating, the labor involved as well as the duration the coating is intended to maintain its corrosion protection properties. Smaller sized packages of coatings were considered to minimize waste and overall material cost. Higher levels of cleanliness such as abrasive blasting and more technical application methods will typically increase cost.

3.1.5 Environmental and Safety Considerations

Environmental and safety considerations surrounding existing coatings, waste, surface preparation, application, chemical (solvent and thinner) use, and test area size were evaluated in coordination with the MnDOT Environmental Stewardship and Safety Offices. Paint removal operations performed by MnDOT crews must be limited to non-lead paint systems or surface areas less than 500 square feet in accordance with permitting and disposal guidelines. Since a TCLP paint chip analysis identified lead within the existing coatings, the test site area was limited to 500 spare feet. To meet this requirement, each test location was limited to an average size of 100 square feet. The bridges within the selected test site at I-35E over Ayd Mill Road provided approximately five (5) square feet of surface area per lineal foot of fascia beam, which allowed for 20 lineal feet of coating application at each test location.

Strategies for surface preparation and application were employed to reduce the amount of expendable materials, waste generation, containment and safety requirements. The selection of brush and roll coating application methods also reduced the amounts of solvents and thinners by eliminating cleanup operations of paint spray application equipment.

3.2 PROPOSED COATING SYSTEMS

Four (4) major coatings manufacturers were asked to recommend applicable maintenance coating systems that could be applied over minimally prepared surfaces and still meet the requirements of a five (5) year service life. The generic coating system options, surface preparation requirements and application methods are included in Table 1 below.

Table 3.1 Coating System Options

Manufacturer 1		
Option 1		
Surface Preparation	SSPC SP1, then SP2/SP3 and/or SP11*	
Coat	**Generic Type**	**Application Method**
Primer	Epoxy Mastic	Conventional or Airless Spray, Plural Component, or Brush & Roll
Intermediate	Epoxy Mastic	Conventional or Airless Spray, Plural Component, or Brush & Roll
Finish	Aliphatic Acrylic-Polyester Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 2		
Surface Preparation	SSPC SP1, then SP2/SP3 and/or SP11*, abrade all	
Coat	**Generic Type**	**Application Method**
Primer	Epoxy Mastic	Conventional or Airless Spray, Plural Component, or Brush & Roll
Intermediate	Polymeric Epoxy Amine	Brush & Roll
Finish	Aliphatic Acrylic-Polyester Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 3		
Surface Preparation	SSPC SP1, then SP6*	
Coat	**Generic Type**	**Application Method**
Primer	Organic Zinc-Rich Epoxy	Conventional or Airless Spray, or Brush & Roll (Small Areas)
Intermediate	Cycloaliphatic Amine Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Aliphatic Acrylic-Polyester Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 4		
Surface Preparation	SSPC SP1, then SP6*	
Coat	**Generic Type**	**Application Method**
Primer	Organic Zinc-Rich Epoxy	Conventional or Airless Spray, or Brush & Roll (Small Areas)
Intermediate	Cycloaliphatic Amine Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Modified Siloxane Hybrid	Airless Spray, or Brush & Roll
Manufacturer 2		
Option 1		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**

Primer	Polyamide Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Acrylic Aliphatic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 2		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	High Solids Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Acrylic Aliphatic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 3		
Surface Preparation	SSCP SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Rust Penetrating Epoxy Sealer	Conventional or Airless Spray, or Brush & Roll
Intermediate	High Solids Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Acrylic Aliphatic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 4		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Single Component Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Acrylic Polysiloxane	Conventional or Airless Spray, or Brush & Roll
Manufacturer 3		
Option 1		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Aluminum Filled Polyamine Epoxy	Conventional or Airless Spray, or Brush & Roll
Intermediate	Aluminum Filled Polyamine Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Aliphatic Acrylic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 2		
Surface Preparation	SP1, then SP10 or SP11*	
Coat	**Generic Type**	**Application Method**
Primer	Moisture Cure Urethane Zinc-Rich Primer	Conventional or Airless Spray, or Brush & Roll
Finish	Polyaspartic Urethane	Conventional or Airless Spray, or Brush & Roll (Small Areas)
Option 3		
Surface Preparation	SSPC SP1, then SP2/SP3	

Coat	Generic Type	Application Method
Primer	Moisture Cure Urethane with Micaceous Iron Oxide	Conventional or Airless Spray, or Brush & Roll
Intermediate	Aluminum and Micaceous Iron Oxide Filled Urethane	Conventional or Airless Spray, or Brush & Roll
Finish	Aliphatic Acrylic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 4		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Finish	Aliphatic Acrylic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Manufacturer 4		
Option 1		
Surface Preparation	SSPC SP1, then SP10*	
Coat	**Generic Type**	**Application Method**
Primer	Zinc-Rich Aromatic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Surfacing Epoxy	Modified Polyamine Epoxy	Trowel
Intermediate	Modified Polyamine Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Advanced Thermoset Solution Fluoropolymer	Conventional Spray, or Brush & Roll
Option 2		
Surface Preparation	SSPC SP1, then SP11*	
Coat	**Generic Type**	**Application Method**
Primer	Modified Polyamine Epoxy	Conventional or Airless Spray, or Brush & Roll
Surfacing Epoxy	Modified Polyamine Epoxy	Trowel
Finish	Aliphatic Acrylic Polyurethane	Conventional or Airless Spray, or Brush & Roll
Option 3		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Mastic Waterborne Acrylic	Airless Spray, or Brush & Roll (Small Areas)
Finish	HDP Acrylic Polymer	Conventional or Airless Spray, or Brush & Roll

**NOTE – REFERENCE 3.1.1 – SSPC SP-6, SP-10, AND SP-11 REFERENCE CLEANING METHODS NOT UTILIZED IN TESTING AS THESE EXCEED THE PROCEDURAL TARGET FOR MINIMAL SURFACE PREPARATION.*

3.3 SURFACE PREPARATION REQUIREMENTS AND COATING SYSTEM SELECTION FOR

Considerations for selecting generic coating systems for evaluation included their compatibility with existing state coating systems, coating system tolerance respective of Minnesota climate, evaluation of compatibility with surface preparation and coating application requirements. Within this test site project, the results of the coating evaluation will be used to identify generic coating system types for inclusion on an Approved Products List (APL) for maintenance coatings.

Since the proposed surface preparation procedure was determined to include a level of cleanliness equivalent to SSPC SP2 – Hand Tool Clean and/or SSPC SP3 – Power Tool Clean, any of the proposed coating system options that required a greater level of cleanliness were eliminated. Coating options eliminated due to more extensive surface preparation requirements included Manufacturer 1 Options 3 and 4, Manufacturer 3 Option 2 and Manufacturer 4 Options 1 and 2.

Pre-application and application procedures of each coating system option were reviewed based upon promoting and mixing of the products, required equipment for application, and number of coats for a complete system. Coating systems requiring the following additional and/or special equipment were omitted:

- Mixing equipment other than a drill and mixing paddle,
- Application by methods other than brush and roll, or
- Three-coat or single coat application.

Consideration was made for three-coat systems, however these systems were either modified to a two-coat system or eliminated from consideration due to the adverse effect on duration to apply an additional coat and cost.

After considering the above factors, the project team selected the coating systems shown in Table 2 for field testing.

Table 3.2 Selected Coating Systems

Manufacturer 1		
Option 1		
Surface Preparation	SSPC SP1, then SP2/SP3 and/or SP11	
Coat	**Generic Type**	**Application Method**
Primer	Epoxy Mastic	Conventional or Airless Spray, Plural Component, or Brush & Roll
Finish	Aliphatic Acrylic-Polyester Polyurethane	Conventional or Airless Spray, or Brush & Roll
*Omit Intermediate Coat		
Manufacturer 2		

Option 1		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Polyamide Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Acrylic Aliphatic Polyurethane	Conventional or Airless Spray, or Brush & Roll
<u>Manufacturer 3</u>		
Option 1		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Aluminum Filled Polyamine Epoxy	Conventional or Airless Spray, or Brush & Roll
Finish	Polyaspartic Urethane	Conventional or Airless Spray, or Brush & Roll (Small Areas)
*Omit Intermediate Coat and Utilize Option 2 Finish Coat		
Option 3		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Moisture Cure Urethane with Micaceous Iron Oxide	Conventional or Airless Spray, or Brush & Roll
Intermediate	Aluminum and Micaceous Iron Oxide Filled Urethane	Conventional or Airless Spray, or Brush & Roll
Finish	Aliphatic Acrylic Polyurethane	Conventional or Airless Spray, or Brush & Roll
*Omit Primer, Utilize Intermediate Coat as Primer, and Utilize Option 2 Finish Coat		
<u>Manufacturer 4</u>		
Option 3		
Surface Preparation	SSPC SP1, then SP2/SP3	
Coat	**Generic Type**	**Application Method**
Primer	Mastic Waterborne Acrylic	Airless Spray, or Brush & Roll (Small Areas)
Finish	HDP Acrylic Polymer	Conventional or Airless Spray, or Brush & Roll

CHAPTER 4: TEST SITE APPLICATION

4.1 TRAINING

Prior to field application, each coating manufacturer provided classroom training. Training was inclusive of product review, surface preparation requirements, mixing, thinning and application procedures. Considerations for safety, chloride removal, minimizing environmental variables, and waste disposal were also discussed.

At the site, hands on training was provided for surface preparation and cleanliness of the existing substrate, as well as correct mixing and application procedures. Proper safety equipment was issued to personnel and provided by MnDOT per local, state, and federal regulations inclusive of respirators, skin protection, eye protection, etc. Exposure monitoring was also performed by MnDOT safety personnel during surface preparation and coating application.

4.2 PREPARATION

Field testing was conducted over a period of two (2) consecutive days, August 11 and 12, 2015. The first day included field safety discussions for the day's operations, environmental protection setup at the test locations, surface preparation, and prime coat application. The second day included field safety discussions for the day's operations and finish coat application. Field personnel evaluations of the operations were also completed.

Onsite personnel included MnDOT bridge office, safety, research and environmental stewardship staff, coating manufacturer representatives and members of the SEH Protective Coatings Group. MnDOT staff completed general documentation, photographs and video of the testing for representation of the project. MnDOT bridge maintenance crews performed the surface preparation and coating application. Coating manufacturer representatives provided guidance and oversight to ensure that operations were in conformance with manufacturer recommendations. SEH developed setup protocols and provided NACE inspection services throughout the field processes to maintain conformance with acceptable surface preparation and coating practices.

4.3 PRE-EXISTING CONDITIONS

Pre-existing conditions of the coating systems were documented prior to surface preparation or application of the test maintenance coatings in order to provide a baseline at each test location. Reference Appendix A: Photographic Storyboards. Records, provided by MnDOT, identified the existing systems at each Test Location to be a Phenolic Resin Aluminum over Red Lead primer. Though each test area was similar, there were minor differences with respect to existing coating thickness, amount of chlorides present, and rust conditions on the bridges. Existing conditions at each test location is documented in Table 3.

Table 4.1 Pre-Existing Conditions

Manufacturer	Location	Location Number	Degree of Rusting (ASTM D-610)	Dry Film Thickness (DFT)	Chloride Test (PPM)
1	I-35E NB over Ayd Mill Exit (NE Corner)	1	Top Flange = 6	11.5	48
			Web = 5		
			Bottom Flange = 1		
2	Randolph Ave over Ayd Mill On-Ramp (SE Corner)	2	Top Flange = 7	7.4	9
			Web = 5		
			Bottom Flange = 1		
3	Randolph Ave over Ayd Mill Exit (NE Corner)	3	Top Flange = 6	5.2	40
			Web = 5		
			Bottom Flange = 0		
3	Randolph Ave over Ayd Mill Exit (NW Corner)	4	Top Flange = 6	2.8	2
			Web = 5		
			Bottom Flange = 0		
4	I-35E SB over Ayd Mill Exit (NW Corner)	5	Top Flange = 6	10.8	0
			Web = 6		
			Bottom Flange = 2		

The degree of rusting evaluation was completed in conformance with ASTM D-610 Evaluating Degree of Rusting which provides a scale of 10-0 based on the observed condition. 10 is equivalent to rust on <0.01% of the surface, 0 is equivalent to rust on approximately 100% of the surface. Existing Dry Film Thickness (DFT) was measured with a Type 2 electronic gauge. Chloride testing was completed using a Chloride Test kit. Recommendation for external/atmospheric substrate salt levels is a maximum of 10-20 ppm as soluble salts accelerate the corrosion of steel. Test Locations 1 and 3 identified high levels of chlorides. Pressure washing was determined ineligible for this project based on possible contamination from the dislodging of loose paint, therefore no correction was made to reduce inherent salt levels. Standard procedure recommends annual flushing of bridges. Test location numbers are identified in Figure 5. Representative photos of the pre-existing conditions within the test site are shown in Figures 6 through 8.

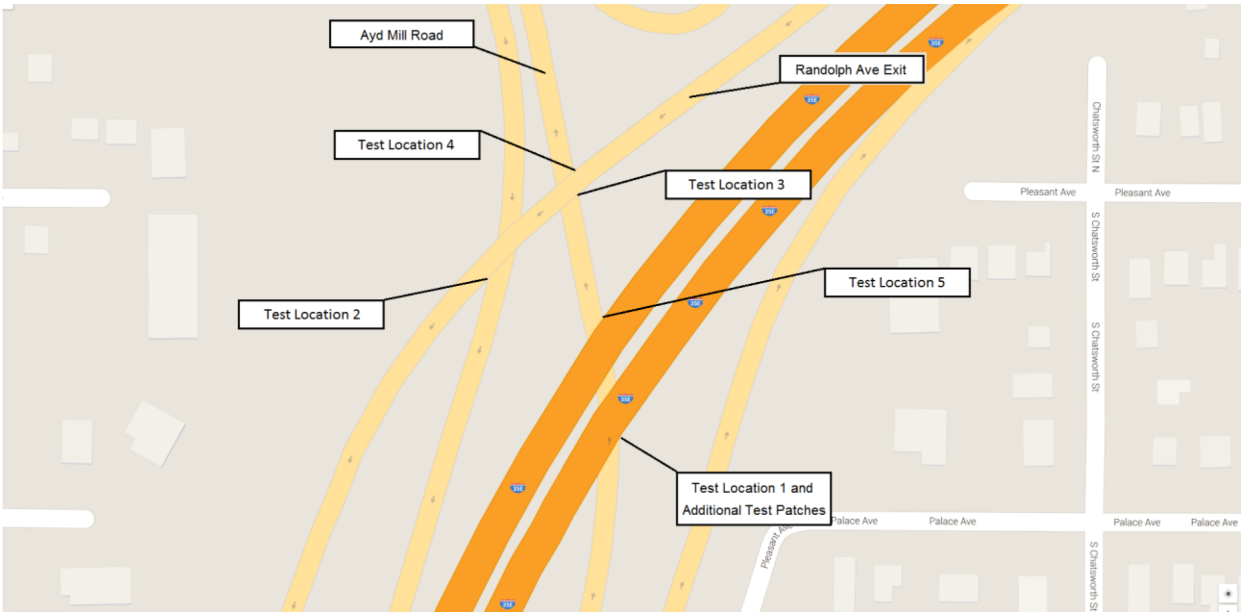

Figure 4.1 Project Site Test Locations

Figure 4.2 Pre-Existing Conditions – Test Location 1

Figure 4.3 Pre-Existing Conditions – Test Location 3

Figure 4.4 Pre-Existing Conditions – Test Location 5

4.4 ENVIRONMENTAL OBSERVATIONS

SEH NACE inspectors monitored surface and air temperature, humidity, dew point and wind speed throughout surface preparation and coating application operations. Temperatures, humidity, and dew point were monitored to ensure that corrosion was not promoted during surface preparation and that conditions were acceptable per coating manufacturer's recommendations for coating application. Air and surface temperature deviations, as illustrated in the table below, were attributed to changes in sunlight exposure and the configuration of the bridge at each Test Location. Wind was monitored as a precaution to limit the possibility for coatings to drift onto vehicular traffic or adjacent property. Environmental observation are shown in Table 4.

Table 4.2 Environmental Observations

Test Location		**1**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
8/11/2015	1:30pm	80.1	81.0	45.9	53.2	8.1	NNW
8/12/2015	10:10am	75.0	76.6	62.5	62.8	5.8	SSW
Test Location		**2**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
8/11/2015	9:50am	73.9	80.2	64.8	60.2	10.4	NNW
8/12/2015	10:58am	78.1	87.7	49.7	65.8	6.9	SW
Test Location		**3**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
8/11/2015	11:45am	84.7	85.1	46.8	61.7	9.2	N
8/12/2015	9:42am	75.0	75.5	61.9	61.7	5.8	SSW
Test Location		**4**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
8/11/2015	2:30pm	85.7	84.1	42.8	60.5	11.5	NNE
8/12/2015	9:42am	75.0	75.5	61.9	61.7	5.8	SSW
Test Location		**5**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
8/11/2015	1:00pm	80.1	80.0	48.3	57.7	10.4	NW
8/12/2015	10:29am	76.7	77.6	61.1	63.7	6.9	SW

4.5 ENVIRONMENTAL PROTECTION

A TCLP paint chip analysis revealed that the existing coatings at the test site contained lead. Prior to completion of surface preparation operations, containment was constructed applicable to the operations being conducted. Containment included tarpaulins and barrier protection to prevent dust, debris, and paint chips from contaminating the surrounding environment. Upon completion of surface preparation, paint chips and debris were vacuumed and disposed of in accordance with local, state, and Federal regulations.

4.6 SURFACE PREPARATION

One of the goals of the maintenance painting test site was to identify coating systems that successfully perform over minimally prepared surfaces. Therefore, only hand and power tool cleaning were employed. Each test location included a section of SP3 Power Tool Clean surface preparation (approximately 25 square feet) utilizing electric grinders with wire wheels or needle guns and an adjacent section of SP1 Solvent Clean only surface preparation with a clean dry rag. Three (3) of the manufacturers also opted to designate a section of SP2 Hand Tool Clean surface preparation utilizing sand paper and wire brushes. All surface preparation was completed by MnDOT personnel under the direct observation of the coating manufacturers and NACE Inspectors.

4.6.1 Test Location 1

All three (3) methods of surface preparation, SP1, SP2, and SP3, were utilized at Test Location 1.

4.6.1.1 SP1 was accomplished with a clean dry rag to remove any existing loose dirt, paint chips, and foreign debris.

4.6.1.2 SP2 was accomplished with 80 grit sand paper. Resulting surface profile for SP2 was 2.5 mils. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants

4.6.1.3 SP3 was accomplished with an electric grinder and wire wheel. Resulting surface profile for SP3 was 2.6 mils. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants

Figure 4.5 Test Location 1 Surface Preparation

4.6.2 Test Location 2

All three (3) methods of surface preparation, SP1, SP2, and SP3, were utilized at Test Location 2.

4.6.2.1 SP1 was accomplished with a clean dry rag.

4.6.2.2 SP2 was accomplished via hand sanding. The surface profile following surface preparation was 2.3 mils for areas cleaned to meet SP2. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants.

4.6.2.3 SP3 was accomplished with an electric grinder and wire wheel. The surface profiles following surface preparation was 2.6 mils for areas cleaned to meet SP3. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants.

Figure 4.6 Test Location 2 Surface Preparation

4.6.3 Test Location 3

Test Location 3 had been previously coated with an anti-graffiti coating which required a more aggressive SP3 Power Tool Clean to remove.

4.6.3.1 SP1 surface preparation was completed with a clean dry rag.

4.6.3.2 SP3 removal was accomplished with a needle gun. An average 2.7 mil surface profile was achieved through power tool cleaning. SP2 Hand Tool cleaning was not completed at this location. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants.

Figure 4.7 Test Location 4 Surface Preparation

4.6.4 Test Location 4

Test Location 4 surface preparation was completed to meet SP1 and SP3. SP2 Hand Tool cleaning was not completed.

4.6.4.1 Similar to the other test locations, SP1 was accomplished with a clean dry rag.

4.6.4.2 SP3 was accomplished with an electric grinder and wire wheel, resulting in an average profile of 2.9 mils. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants

Figure 4.8 Test Location 4 Surface Preparation

4.6.5 Test Location 5

Surface preparation was completed to meet SP1, SP2, and SP3 at Test Location 5.

4.6.5.1 The methodology was similar through use of clean dry rags for SP1.

4.6.5.2 Hand sanding was completed to meet SP2 with an achieved surface profile of 2.0 mils. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants.

4.6.5.3 An electric grinder with wire wheel to meet SP3 was complete with a surface profile of 2.4 mils. Followed by SP-1 using manufacturer recommended solvent to reduce residual contaminants.

Figure 4.9 Test Location 5 Surface Preparation

4.7 PRIME COAT APPLICATION

Prime coat application was conducted the same day and shift as surface preparation to prevent corrosion issues related to exposure. As with the surface preparation, coating manufacturers remained on site to provide technical assistance and to observe application for conformance with manufacturer recommendations. All coating operations were completed by MnDOT bridge maintenance crews using the brush and roll method. NACE certified inspection was also conducted on site during prime coat application to include observation of product mixing, method of application, wet mil thickness, and environmental conditions.

4.7.1 Test Location 1 (Two Part Epoxy Mastic Primer)

Prior to applying the two-part Epoxy Mastic primer, the surfaces that were prepared to meet SP2 or SP3 were wiped down with a manufacturer recommended solvent. Coatings were mixed under the supervision of the manufacturer by means of an electric drill and mixing paddle. This product required a mix ratio of 1:1 and required no sweat in time prior to use. Crews applied a thin tack coat followed by a complete coat using a 9” roller to achieve an actual average DFT thickness of 11.5 mils, which was slightly outside the specified coating thickness range of 7-10 mils DFT. Use of a respirator was required for this product application.

Figure 4.10 Test Location 1 Prime Coat Application

4.7.2 Test Location 2 (Two-Part Polyamide Epoxy)

A two-part Polyamide Epoxy was used as the prime coat at Test Location 2. Coatings were mixed with an electric drill and mixing paddle at a ratio of 1:1. For this product, a 15 minute sweat in time was also required at the temperatures observed on application day. The prime coat included a stripe coat to edges and corners by brush followed by a full application with a roller and back roll to achieve the required thickness. A DFT of 7.8 mils was achieved, which was within the specified coating thickness range of 3-8 mils. Use of a respirator was required for this product application as demonstrated.

Figure 4.11 Test Location 2 Prime Coat Application

4.7.3 Test Location 3 (Aluminum Filled Polyamine Epoxy)

The primer utilized at Test Location 3 was an Aluminum Filled Polyamine Epoxy mixed at a 1:1 ratio with an electric drill and mixing paddle. Prior to application, this product required a 30 minute sweat in time. Prime coat application was completed by means of brush and roll. The achieved thickness average was 5.2 mils DFT, which was within the specified coating thickness range of 4-6 mils DFT for this product. Note, no respirator was required for the mixing or application of this product's constituents per the Safety Data Sheets as no known significant effects or critical hazards were present.

Figure 4.12 Test Location 3 Prime Coat Application

4.7.4 Test Location 4 (Moisture Cure Urethane with Micaceous Iron Oxide)

The primer at Test Location 4 was a single component Moisture Cure Urethane with Micaceous Iron Oxide. This product required only promoting with a drill and mixing paddle; no mixing of components was required. The product was spot applied to edges, corners, and spots prior to application of a full coat. The average thickness achieved was 2.8 mils DFT, which is inside the specified coating thickness range of 2-3 mils DFT. Use of a respirator was required for this product application.

Figure 4.13 Test Location 4 Prime Coat Application

4.7.5 Test Location 5 (Mastic Waterborne Acrylic)

The prime coat utilized as Test Location 5 was a Mastic Waterborne Acrylic. The product is a single component which requires no mixing. The product is also water soluble, can be cleaned up with just water and requires no thinners. This product was applied to edges, corners, welds, and spots with a brush followed by a complete coat with a roller. The achieved average thickness was 9.7 mils DFT, which was just outside the recommended coating thickness range of 6-9 mils DFT. This product is a waterborne product and does not require the use of a respirator during application.

Figure 4.14 Test Location 5 Prime Coat Application

4.8 FINISH COAT APPLICATION

The finish coat was applied on August 12, 2015, the day after surface preparation and prime coat application in order to adhere to the specified recoat times. As with surface preparation and prime coat application, the coating manufacturers provided on-site technical assistance and observed application for conformance with their recommendations. All coating operations were accomplished with the brush and roll method. Inspection also occurred on site for finish coat application to monitor mixing, coating thickness, and environmental conditions as similar to the prime coat application to observe and document compliance.

During application of the finish coat(s), MnDOT staff and SEH introduced an additional test area at each location in order to further evaluate each manufacturer's finish coat applied directly over the existing substrate. The additional area was prepared with a dry, clean rag to remove any existing debris/contaminants and then the finish coat was applied directly over the existing substrate. Each finish coat was applied to the manufacturer's recommended thickness.

4.8.1 Test Location 1 (Two-Part Epoxy Mastic /Aliphatic Acrylic-Polyester Polyurethane)

At Test Location 1, an Aliphatic Acrylic-Polyester Polyurethane was applied over the two-part Epoxy Mastic primer. This product is a two (2) component product which is mixed at a 6:1 ratio. A tack coat was applied followed by back rolling the entire test surface where finish coat was applied. The average total coating system thickness was 17.0 mils DFT resulting in a finish coat average thickness of 5.5 mils DFT, which was just outside the specified coating thickness range of 3-5 mils DFT. This minimal change in finish coat thickness will not affect the performance or life cycle of the coating system and may be attributed to the locations selected during thickness measurements. Use of a respirator was required for this product application.

Figure 4.15 Test Location 1 Finish Coat

4.8.2 Test Location 2 (Two-Part Polyamide Epoxy/Aliphatic Polyurethane)

At Test Location 2, an Aliphatic Polyurethane finish coat was applied over the two-part Polyamide Epoxy. This product is a two (2) component finish coat which is mixed at a 4:1 ratio. Application was completed by brushing welds and edges prior to rolling a complete finish coat. The achieved finish coat average thickness was 1.6 mils DFT, which was just under the specified coating thickness range of 2-5 mils DFT; this is within the manufacturers tolerance and compliant with SSPC PA-2. This minimal change in finish coat thickness should not affect the performance or life cycle of the coating system due to the intended 5 year maintenance coating duration and may be attributed to the locations selected during thickness measurements. The total coating system average thickness was 9.0 mils DFT. Use of a respirator was required for this product application.

Figure 4.16 Test Location 2 Finish Coat

4.8.3 Test Location 3 (Aluminum Filled Polyamine Epoxy/Polyaspartic Urethane)

At Test Location 3, a Polyaspartic Urethane was applied over the Aluminum Filled Polyamine Epoxy prime coat. This finish coat product required a 2:1 mix ratio and was specified for application at an average thickness of 6-9 mils DFT. The achieved average thickness was 6.1 mils DFT, resulting in a total coating system thickness of 11.3 mils DFT. Use of a respirator was required for this product application.

Figure 4.17 Test Location 3 Finish Coat

4.8.4 Test Location 4 (Moisture Cure Urethane/Polyaspartic Urethane)

Test Location 4 received a Polyaspartic Urethane (similar to Test Location 3) applied over the Moisture Cure Urethane with Micaceous Iron Oxide prime coat. This finish coat product required a 2:1 mix ratio. The coating was applied achieving an average coating thickness of 5.3 mils DFT, which was just under the specified coating thickness range of 6-9 mils DFT. This minimal change in finish coat thickness will not affect the performance or life cycle of the coating system and may be attributed to the locations selected during thickness measurements. The total coating system thickness was 8.1 mils DFT. Use of a respirator was required for this product application.

Figure 4.18 Test Location 4 Finish Coat

4.8.5 Test Location 5 (Mastic Waterborne Acrylic/HDP Acrylic Polymer)

An HDP Acrylic Polymer was provided for use as a finish coat over the Mastic Waterborne Acrylic prime coat at Test Location 5. Similar to the prime coat, this finish coat product is a single component which requires no mixing. Prior to application, and in accordance the manufacturer's product data sheet, the surface was mildly hand abraded with sandpaper. Application was completed with a stripe coat to edges, seams, and hardware prior to a full finish coat. The specified thickness for the finish coat was 2-3 mils DFT. This system achieved an overall average total coating thickness of 10.2 mils DFT resulting in a finish coat average thickness of 0.5 mils DFT, which is not within the manufacturer's tolerance. This finish coat thickness will contribute to a reduced life cycle over time due to decreased UV protection; however, because the intended maintenance coating life cycle is five years, the performance would likely not be affected over this short duration. This product is a waterborne product and does not require the use of a respirator during application.

Figure 4.19 Test Location5 Finish Coat

Table 4.3 Surface Preparation and Coating Application Summary

Test Location	Coat	Generic Coating Type	Degree of Rusting (ASTM D-610)	Surface Preparation	Specified DFT	Total Specified DFT	Total Field DFT
1	Primer	Epoxy Mastic	Top Flange = 6	SP1/SP2/SP3	7-10		11.5
	Finish	Aliphatic Acrylic-Polyester Polyurethane	Web = 5		3-5	10-15	17.0
			Bottom Flange = 1				
2	Primer	Polyamide Epoxy	Top Flange = 7	SP1/SP2/SP3	3-8		7.4
	Finish	Acrylic Aliphatic Polyurethane	Web = 5		2-5	5-13	9.0
			Bottom Flange = 1				
3	Primer	Aluminum Filled Polyamine Epoxy	Top Flange = 6	SP1/SP3	4-6		5.2
	Finish	Polyaspartic Urethane	Web = 5		6-9	10-15	11.3
			Bottom Flange = 0				
4	Primer	Aluminum and Micaceous Iron Oxide Filled Urethane	Top Flange = 6	SP1/SP3	2-3		2.8
	Finish	Polyaspartic Urethane	Web = 5		6-9	8-12	8.1
			Bottom Flange = 0				
5	Primer	Mastic Waterborne Acrylic	Top Flange = 6	SP1/SP2/SP3	6-8		9.7

	Finish	HDP Acylic Polymer	Web = 6		2-3	8-11	10.2
			Bottom Flange = 2				

CHAPTER 5: INITIAL OBSERVATIONS

During the on-site coating application phase, a Field Evaluation Report was provided to MnDOT personnel performing the maintenance coating application for purposes of recording the coating usability and performance from an applicator's perspective. Each applicator provided responses in the Field Evaluation Report for both the prime coat and the finish coat. Performance was rated on a scale from 1-5 (1 = very poor and 5 = very good) with the following factors addressed:

- Wet Hide (Coverage)
- Ease of Mixing
- Ease of Application
- Flow and Leveling
- Viscosity
- Film Build
- Sag Resistance
- Final Appearance
- Dry Time
- Pot Life
- Ambient Temperature

The following tables represents the field applicator ratings and comments received for each coating system:

5.1 EPOXY MASTIC/ALIPHATIC ACRYLIC-POLYESTER POLYURETHANE (TEST LOCATION 1)

This coating system was rated very well based on its overall performance. The finish coat required a tack coat followed by an additional complete coat to achieve the specified mil thickness. The finish coat also presented a strong odor. A respirator was required for application.

Table 5.1 Epoxy Mastic/Aliphatic Acrylic-Polyester Polyurethane Field Evaluation (Test Location 1)

	Prime Coat	Finish Coat	Comments
Wet Hide (Coverage)	5	5	
Ease of Mixing	4	4	
Ease of Application	5	5	
Flow & Leveling	5	5	
Viscosity	5	4	
Film Build	5	5	
Sag Resistance	5	4	
Final Appearance	5	5	
Dry Time		5	

Pot Life		5	
Ambient Temperature		5	

5.2 POLYAMIDE EPOXY/ACRYLIC ALIPHATIC POLYURETHANE (TEST LOCATION 2)

The applicators identified concerns with the primer regarding coverage and sagging. The finish coat was rated very good overall. This system also required use of a respirator during application.

Table 5.2 Polyamide Epoxy/Acrylic Aliphatic Polyurethane Field Evaluation (Test Location 2)

	Prime Coat	Finish Coat	Comments
Wet Hide (Coverage)	2	5	Prime coat required dual coat
Ease of Mixing	4	4	
Ease of Application	4	5	Prime coat good coverage was difficult
Flow & Leveling	4	5	
Viscosity	5	5	
Film Build	3	5	
Sag Resistance	3	4	Some sag of prime coat
Final Appearance	4	5	Prime coat looked heavy
Dry Time			
Pot Life	5		
Ambient Temperature			

5.3 ALUMINUM FILLED POLYAMINE EPOXY/POLYASPARTIC URETHANE (TEST LOCATION 3)

This coating system received good to very good ratings for all noted factors. No comments were provided for the observed factors. The use of a respirator was required for application of this coating system.

Table 5.3 Aluminum Filled Polyamine Epoxy/Polyaspartic Urethane Field Evaluation (Test Location 3)

	Prime Coat	Finish Coat	Comments
Wet Hide (Coverage)	4	5	
Ease of Mixing	4	4	
Ease of Application	5	5	
Flow & Leveling	5	5	
Viscosity	4	5	
Film Build	5	5	

Sag Resistance	4		
Final Appearance	5		
Dry Time	3	5	
Pot Life	5	4	
Ambient Temperature	5		

5.4 ALUMINUM AND MICACEOUS IRON OXIDE FILLED URETHANE/POLYASPARTIC

An overall rating of very good was provided for this coating system. The single component prime coat was favored and the only slightly lower rating was provided for ease of mixing and pot life of the finish coat because it was a two (2) component product. A respirator was required during the application of this coating system.

Table 5.4 Aluminum and Micaceous Iron Oxide Filled Urethane/Polyaspertic Urethane Field Evaluation (Test Location 4)

	Prime Coat	Finish Coat	Comments
Wet Hide (Coverage)	5	5	
Ease of Mixing	5	4	
Ease of Application	5	5	
Flow & Leveling	5	5	
Viscosity	5	5	
Film Build	5	5	
Sag Resistance	5	5	
Final Appearance	5	5	
Dry Time			
Pot Life		4	
Ambient Temperature			

5.5 MASTIC WATERBORNE ACRYLIC/HDP ACRYLIC POLYMER (TEST LOCATION 5)

This coating system was waterborne and did not require the use of respirators, which was favored by MnDOT personnel. The single component products was also preferable to personnel. Overall, the coating system was rated good with concerns identified regarding coverage, sagging, and final appearance.

Table 5.5 Mastic Waterborne Acrylic/HDP Acrylic Polymer Field Evaluation (Test Location 5)

	Prime Coat	Finish Coat	Comments
Wet Hide (Coverage)	4	5	Prime coat dries too quickly
Ease of Mixing	5	5	Single component
Ease of Application	5	5	
Flow & Leveling	5	5	
Viscosity	5	5	
Film Build		5	
Sag Resistance	4		Some runs in prime coat
Final Appearance	3	3	
Dry Time		5	
Pot Life		5	
Ambient Temperature		5	

CHAPTER 6: COATING EVALUATION PROCEDURES

6.1 COATING EVALUATION AND SERVICEABILITY

Coatings, are evaluated using a combination of visual inspection and field testing. Field testing is performed in accordance with Society for Protective Coatings SSPC PA-2 “Measurement of Dry Film Thickness with Magnetic Gages”, using a Type 2 field probe and magnetic flux gage. Since the underlying steel plates and structural members appeared to be in good condition, an ultrasonic thickness gage was not used during this evaluation.

Visual inspection is performed to evaluate holidays (voids), runs, sags, surface contaminants, overspray, dry spray, delamination, steel condition under the coating system, and any other deficiencies as objectively compared to ASTM and industry standards.

Coating serviceability estimates the remaining service life of the coating system(s) through the use of the following inspection instruments: dry film thickness gage, cross-cut guide kit, putty knife, and a 30X microscope.

6.2 COATING ASSESSMENT CRITERIA

The overall condition of each test location was assessed within the following condition categories of good, fair, poor and severe. These categories are consistent with AASHTO National Bridge Element Condition State Ratings and the MnDOT “Steel Bridge Coating Condition Assessment Photographic Field Guide”. In order to qualify the degree of failure observed, applicable ASTM standards for adhesion, rusting, blistering and pitting were aligned with these condition categories. The applicable ASTM standards include, but are not limited to:

- ASTM D 3359 Test Method for Measuring Adhesion by Tape (Completed at conclusion of the observations phase in 2018 to prevent creation of a failure during the maintenance test project)
- ASTM D 610 Method for Evaluating Degree of Rusting
- ASTM D 714 Test Method for Evaluating the Degree of Blistering Paints

Table 6.1 Coating Assessment Categories

Standard	ASTM	Severe	Poor	Fair	Good
Adhesion	D 3359	0	1	2	3 to 4
Rusting	D 610	4	5	6 to 7	8 to 9
Blistering	D 714	Dense	Medium Dense	Medium	Few
Pitting	G-46	5	4	3	1 to 2

CHAPTER 7: YEAR ONE (2016) OBSERVATIONS

Field observations, following one year of maintenance coating service life, were conducted July 26, 2016 in accordance with the evaluation parameters identified in Chapter 6. Overall, the selected coating systems were evaluated as good or fair condition. Though rust bleed was present at most locations where concrete and steel intersections occurred, this was not a coating failure. The primary noted coating failures consisted of cracking and peeling at bridge bearings and cracking along edges of steel.

7.1 TEST LOCATION 1 (EPOXY MASTIC/ALIPHATIC ACRYLIC-POLYESTER POLYURETHANE)

Overall, the Epoxy Mastic/Aliphatic Acrylic-Polyester Polyurethane coating utilized at Test Location 1 was in good condition except for minor failures, which were anticipated based on pre-existing conditions of the substrate and the surface preparation standard utilized for this project. Observed failures included three (3) areas of spot rust, two (2) of which were located at the steel/concrete intersection on the top flange and the top of the bottom flange. Additional noted deficiencies included rust bleed at the bridge diaphragm where the steel and concrete intersected on the top flange. There was no evidence of blistering, cracking, peeling, pitting, chalking, or delamination at this test location.

Table 7.1 Test Location 1 – Year One Coating Assessment (2016)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 7.1 Test Location 1 - One Year Exposure

7.2 TEST LOCATION 2 (POLYAMIDE EPOXY/ALIPHATIC POLYURETHANE)

Overall, the coating system applied at Test Location 2, a Polyamide Epoxy primer and an Aliphatic Polyurethane finish coat, was in good condition with one localized area of spot rust noted on the top of the bottom flange Rust bleed was also present at the steel/concrete intersection on the top of the diaphragm. There was no evidence of blistering, cracking, peeling, pitting, chalking, or delamination at this location. These minor failures were anticipated based on the pre-existing conditions of the substrate and the surface preparation standard utilized for this project.

Table 7.2 Test Location 2 – Year One Coating Assessment (2016)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X

Chalking				X
Delamination				X

Figure 7.2 Test Location 2 – One Year Exposure

7.3 TEST LOCATION 3 (ALUMINUM FILLED POLYAMIDE EPOXY/POLYASPARTIC URETHANE)

Several deficiencies with the coating system, an Aluminum Filled Polyamide Epoxy primer over a Polyaspartic finish coat, were observed at Test Location 3. Spot rusting, in a localized area, was observed on the top flange at the steel/concrete intersection and was also prominent along approximately 60% of the top of the bottom flange. Additionally, cracking and inter-coat delamination were present in a localized area on the web, throughout the top of the bottom flange, along edges and where surface preparation cleanliness was limited to an SP1 Solvent Clean. Cracking and peeling were also present at the bearing where movement has taken place. There was no observed blistering, pitting, or chalking at this location.

Failures noted at Test Location 3 are likely attributed to the pre-existing anti-graffiti coating which was present prior to testing. This is evident through observation of cracking where the coating system was directly applied over the anti-graffiti coating. Remaining areas with noted failures may be related to remaining anti-graffiti coating within pre-existing pitting present on the substrate.

Table 7.3 Test Location 3 – Year One Coating Assessment (2016)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking		X		
Peeling			X	
Pitting (ASTM G-46)				X
Chalking				X
Delamination			X	

Figure 7.3 Test Location 3 - One Year Exposure

7.4 TEST LOCATION 4 (MOISTURE CURE WITH MICACEOUS IRON OXIDE/POLYASPARTIC

The coating applied at Test Location 4, a Moisture Cure Urethane with Micaceous Iron Oxide prime coat and a Polyaspartic Urethane finish coat, performed well except for some observed cracking, and localized spot rusting. Spot rusting was present near the bridge bearing and in localized areas along edges and seams where concrete and steel intersect. Cracking was present along edges and where surface preparation met only an SP1 level of cleanliness over anti-graffiti coating. There was no observed blistering, peeling, pitting, or chalking at this location.

As similar to Test Location 3, failures noted at Test Location 4 are likely attributed to the pre-existing anti-graffiti coating which was present prior to testing. This is evident through observation of cracking where the coating system was directly applied over the anti-graffiti coating. Remaining areas with noted failure may be caused due to remaining anti-graffiti coating within pre-existing pitting present on the substrate.

Table 7.4 Test Location 4 – Year One Coating Assessment (2016)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking			X	
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 7.4 Test Location 4 - One Year Exposure

7.5 TEST LOCATION 5 (MASTIC WATERBORNE ACRYLIC/HDP ACRYLIC POLYMER)

The coating system applied at Test Location 5, a Mastic Waterborne Acrylic primer with HDP Acrylic Polymer finish coat performed well overall with the least observed deficiencies of all of the Test Locations. Localized spot rusting was present at the steel/concrete intersection at the top flange and where previous coating failures were present on the substrate. There was no observed blistering, cracking, peeling, pitting, chalking, or delamination at this location.

Table 7.5 Test Location 5 – Year One Coating Assessment (2016)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X

Chalking				X
Delamination				X

Figure 7.5 Test Location 5 - One Year Exposure

7.6 YEAR 1 COATING EVALUATION SUMMARY

Following one (1) year of environmental exposure, it was observed that the coating systems were exhibiting varying levels of performance depending on location and the existing substrate. Additional testing was deemed necessary in order to limit variability and the effect of factors such as existing conditions and the graffiti coatings present at Test Locations 3 and 4. It was determined that the additional Test Patch Locations would be applied on a single bridge beam with the same orientation and existing substrate conditions.

CHAPTER 8: ADDITIONAL TESTING

8.1 RE-EXAMINING PROJECT SCOPE AND PURPOSE

The initial annual inspection yielded results and provided insight to the abilities of the selected coating systems and their performance during use as maintenance coating systems. Since the overall project goal was to identify efficient and cost-effective methodologies for maintenance painting performed by MnDOT bridge workers, the project team re-evaluated the surface preparation and coating system requirements for the Test Patch Locations.

Current observations of the Test Locations where coatings received only an SP1 surface preparation showed promising results. These results allowed the project team to consider an even more minimalistic surface preparation and coating application approach. Therefore, the additional Test Patch Locations would be inclusive of an SP1 surface preparation and a single application of each prime coat product. The only exception was the Aluminum and Micaceous Iron Oxide filled Urethane primer because the minimal film thickness would not achieve enough thickness to cover the existing substrate profiles. The prime purpose of a finish coat is to provide protection against degradation from the sun's ultraviolet rays, which was deemed unnecessary for a maintenance coating with an anticipated service life of five (5) years.

8.2 SURFACE PREPARATION AND COATING SYSTEMS

Surface preparation for the Test Patch Locations was reduced to a bare minimum SP1 Solvent Clean utilizing a clean rag with water and spot SP2 Hand Tool Clean where evidence of blistering, cracking, peeling, and delamination of the existing coating had occurred. The prime coat products originally selected for use within the maintenance coating project were maintained for additional testing. A finish coat was not applied at the Test Patch Locations to reduce cost in labor, equipment, and materials.

Table 8.1 Additional Test Patch Locations - Specified Surface Preparation and Coating Systems

Test Location	Generic Coating Type	Surface Preparation	Specified DFT
A	Epoxy Mastic	SP1/Spot SP2	7-10
B	Aluminum Filled Polyamine Epoxy	SP1/Spot SP2	4-6
C	Polyamide Epoxy	SP1/Spot SP2	3-8
D	Mastic Waterborne Acrylic	SP1/Spot SP2	6-8

8.3 TEST LOCATION SELECTION

The location for the additional patches was selected based on criteria set forth for the original test locations. Fortunately, there was available space adjacent to Test Location 1 that would provide suitable space and conditions equivalent to the original testing. Each test patch would be inclusive of the outer edge of the bottom flange, the top of the bottom flange, the web, and bottom of the top flange similar to the original test locations.

Figure 8.1 Additional Test Patch Locations (at Test Location 1)

8.4 ADDITIONAL TEST PATCH SITE APPLICATION

8.4.1 Preparation

Surface preparation and coating application was accomplished on September 29, 2016. On-site personnel consisted of MnDOT bridge office staff and members of the SEH Protective Coatings Group. MnDOT bridge maintenance crew personnel completed surface preparation, mixing and preparation of coatings, and application. SEH provided NACE inspection services throughout the field processes and test patch layout for application.

8.4.2 Pre-Existing Conditions

Pre-existing conditions were documented prior to surface preparation and application to provide a baseline for the additional test patch locations. However because the additional test patch locations were applied on a single beam on the same bridge, variables such as orientation, traffic conditions, differing film thicknesses, pre-existing conditions, degree of rust, and chloride exposure were minimized.

Figure 8.2 Additional Test Patch Locations - Pre-Existing Conditions

Figure 8.3 Additional Test Patch Locations - Pre-Existing Conditions

8.4.3 Environmental Observations

Environmental monitoring, inclusive of surface and air temperatures, humidity, dew point, and wind, was conducted by SEH NACE inspectors. These factors were monitored to ensure corrosion was not promoted during surface preparation and that conditions were acceptable per coating manufacturer's recommendations for coating application. Observed environmental data for additional test patches are shown in Table 18.

Table 8.2 Additional Test Patch Locations - Environmental Observations

Test Location		**A**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
9/26/2016	10:45am	64.4	58.5	65.2	52.4	12.1	NNE
Test Location		**B**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
9/26/2016	10:57am	64.0	60.7	63.3	51.2	10.2	NNE
Test Location		**C**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
9/26/2016	11:05am	65.5	67.3	65.1	53.5	10.0	NNE
Test Location		**D**					
Date	Time	Air Temperature (°F)	Surface Temperature (°F)	Humidity	Dew Point	Wind Speed	Wind Direction
9/26/2016	11:15am	64.6	71.4	59.7	50.3	9.5	NNE

8.4.4 Environmental Protection

A TCLP paint chip analysis conducted prior to testing indicated that the existing coatings contained lead. With the re-examination of means and methods for the additional test patch locations and the selection of minimized surface preparation, the environmental impact and barrier protection for maintenance painting could be reduced. Paint chips were collected upon completion of surface preparation and were disposed of in accordance with local, state, and Federal regulations.

8.4.5 Surface Preparation

The additional Test Patch Locations received an SP1 Solvent Clean utilizing a clean rag with water. The use of water in lieu of solvents limited the need for respirators during this phase. Areas demonstrating loose paint, corrosion, or rough edges were scraped with a dull putty knife in accordance with SP2 Hand Tool Clean to achieve a tightly adhered existing coating system. Surface preparation was completed simultaneously utilizing identical surface preparation methods for all coatings to further reduce variability between test patch locations.

Figure 8.4 Additional Test Patch Locations – SP2 Hand Tool Clean Surface Preparation

Figure 8.5 Additional Test Patch Locations – SP1 Solvent Clean Surface Preparation Employing a Dry Rag

8.4.6 Coating Application

A single coat of each selected primer was applied immediately after completion of surface preparation. All coating operations were accomplished by MnDOT bridge maintenance crews using the same brush and roll methodology and use of PPE as the original test locations under the direct supervision of SEH NACE inspection.

8.4.6.1 Additional Test Patch Location A (Two-Part Epoxy Mastic)

The two-part Epoxy Mastic that was utilized at Test Location 1 was applied over the prepared surfaces at Additional Test Patch Location A. The coating was mixed under the supervision of NACE inspectors by means of an electric drill and mixing paddle at a 1:1 ratio. Application was completed with brush and roller by applying a thin tack coat followed by a complete coat to achieve the specified 7-10 mils WTF. Actual average DFT thickness upon cure was 11.8 mils. Though the coating application was thicker than the specification, this mastic product allows for additional product during application without detriment to the performance or life cycle. Use of a respirator was required during application of this product as identified in Figure 34 below.

Figure 8.6 Additional Test Patch Location A - Coating Application

8.4.6.2 Additional Test Patch Location B (Aluminum Filled Polyamine Epoxy)

The Aluminum Filled Polyamine Epoxy utilized at Additional Test Patch Location B was the same product utilized as a primer at Test Location 3. The product was mixed with an electric drill and mixing paddle at a ratio of 1:1. Application was completed by means of brush and roll. The specified coating thickness was 5-7.5 mils WFT. The actual achieved DFT thickness was 12.8 mils. Achieved coating thickness was equivalent of a 2-coat system. As noted in Chapter 4, a respirator is not required during application of this product.

Figure 8.7 Additional Test Patch Location B - Coating Application

8.4.6.3 Additional Test Patch Location C (Two-Part Polyamide Epoxy)

The two-part Polyamide Epoxy applied at Test Location 2 was also applied at Additional Test Patch Location C. The product was mixed with an electric drill and mixing paddle at a ratio of 1:1 and applied over the prepared area with brush and roll application to meet 4.5-11.5 mils WFT. The achieved DFT thickness was 10.5 mils. Use of a respirator was required during application of this product.

Figure 8.8 Additional Test Patch Location C - Coating Application

8.4.6.4 Additional Test Patch Location D (Mastic Waterborne Acrylic)

At Additional Test Patch Location D, the Mastic Waterborne Acrylic utilized in Test Location 5 was applied. This is a single component, water soluble product which only requires promoting, which was completed with an electric drill and a mixing paddle. Application was completed by the brush and roll method and was applied to a wet film thickness of 9-10 mils WFT. The average completed thickness was 7.3 mils DFT. The applied DFT of this product achieved the manufacturer's recommend DFT range of 6-8 mils. Use of a respirator was not required during application of this product.

Figure 8.9 Additional Test Patch Location D - Coating Application

Table 8.3 Additional Test Patch Locations - Surface Preparation and Coating Application Summary

Surface Preparation and Coating Application Summary						
Test Location	Coat	Generic Type	Degree of Rusting (ASTM D-610)	Surface Preparation	Specified DFT	Total Field DFT
A	Primer	Epoxy Mastic	Top Flange = 6	SP1/Spot SP2	7-10	11.8
			Web = 5			
			Bottom Flange = 1			
B	Primer	Aluminum Filled Polyamine Epoxy	Top Flange = 6	SP1/Spot SP2	4-6	12.8
			Web = 5			
			Bottom Flange = 1			
C	Primer	Polyamide Epoxy	Top Flange = 6	SP1/Spot SP2	3-8	10.5
			Web = 5			
			Bottom Flange = 1			
D	Primer	Mastic Waterborne Acrylic	Top Flange = 6	SP1/Spot SP2	6-8	7.3
			Web = 5			
			Bottom Flange = 1			

CHAPTER 9: YEAR TWO (2017) OBSERVATIONS

Field observations following two (2) years of environmental exposure were conducted on August 14, 2017 in accordance with the observation criteria set forth in Chapter 6. Overall, the selected coating systems were performing similar to the previous year; however, some additional failures were observed. Primary noted coating failures during this inspection included spot rusting, cracking, and localized areas of delamination within some of the Test Locations. Rust bleed, though not a coating failure, was more prevalent than the previous year.

9.1 TEST LOCATION 1 (EPOXY MASTIC/ALIPHATIC POLYESTER URETHANE)

Additional observed failures at Test Location 1, which consists of the Epoxy Mastic/Aliphatic Polyester Polyurethane coating system, were minimal. Minor spot rust was slightly more prevalent in the same locations as the first year. Additional rust bleed was present on the diaphragm flanges and the bridge bearing. It also appears that a section of finish coat was missed along the upper web to flange interface, which likely became visible due to UV exposure of the exposed Epoxy Mastic prime coat. No additional coating failures were observed. This coating system has performed well since application and has demonstrated little to no failure.

Table 9.1 Test Location 1 – Year Two Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 9.1 Test Location 1 - Two Year Exposure

9.2 TEST LOCATION 2 (POLYAMIDE EPOXY/ALIPHATIC POLYURETHANE)

Additional observed failures at Test Location 2, the Polyamide Epoxy/Aliphatic Polyurethane coating system, included spot rusting, cracking, and delamination. Spot rusting was observed at the bridge bearing and along the edge of the bottom flange. Cracking was present on the top of the bottom flange in a single localized area. Delamination was noted on the bottom of the bottom flange. Additionally, rust bleed was present on the diaphragm structure and the web of the main beam. Overall, minimal deficiencies have become visible since application.

Table 9.2 Test Location 2 – Year Two Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X

Chalking				X
Delamination			X	

Figure 9.2 Test Location 2 - Two Year Exposure

9.3 TEST LOCATION 3 (ALUMINUM FILLED POLYAMIDE EPOXY/POLYASPARTIC URETHANE)

Test Location 3 is inclusive of an Aluminum Filled Polyamide Epoxy primer and Polyaspartic Urethane finish coat. Fine cracking is predominant throughout the bottom flange of the test location with rust and rust bleed covering approximately 80% of the bottom flange. Cracking and peeling are now visible at the bridge bearing and the bottom flange/stiffener interface above the bridge bearing. Additionally, delamination of the top coat is present where surface preparation was minimally prepared. Note, the delamination is occurring where the coating system was applied directly over the pre-existing anti-graffiti coating. The anti-graffiti coating has proven challenging to coat. Areas which are exposed to ponding and running water through bridge joints have also demonstrated early deficiencies. A change in conditions over an extended period can alter the service performance for a product for which it was not intended

Table 9.3 Test Location 3 – Year Two Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)		X		
Blistering (ASTM D 714)				X
Cracking		X		
Peeling		X		
Pitting (ASTM G-46)				X
Chalking				X
Delamination		X		

Figure 9.3 Test Location 3 – Two Year Exposure

9.4 TEST LOCATION 4 (MOISTURE CURE URETHANE WITH MICACEOUS IRON

Test Location 4 was coated with a Moisture Cure Urethane with Micaceous Iron Oxide primer and a Polyaspartic Urethane finish coat. Inspection revealed cracking of the coating system at the weld seam adjacent to the stiffener. No additional coating failures were noted other than those observed during the first annual exposure inspection. This coating system is performing acceptably as of time of inspection after two (2) years of exposure.

Table 9.4 Test Location 4 – Year Two Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking			X	
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

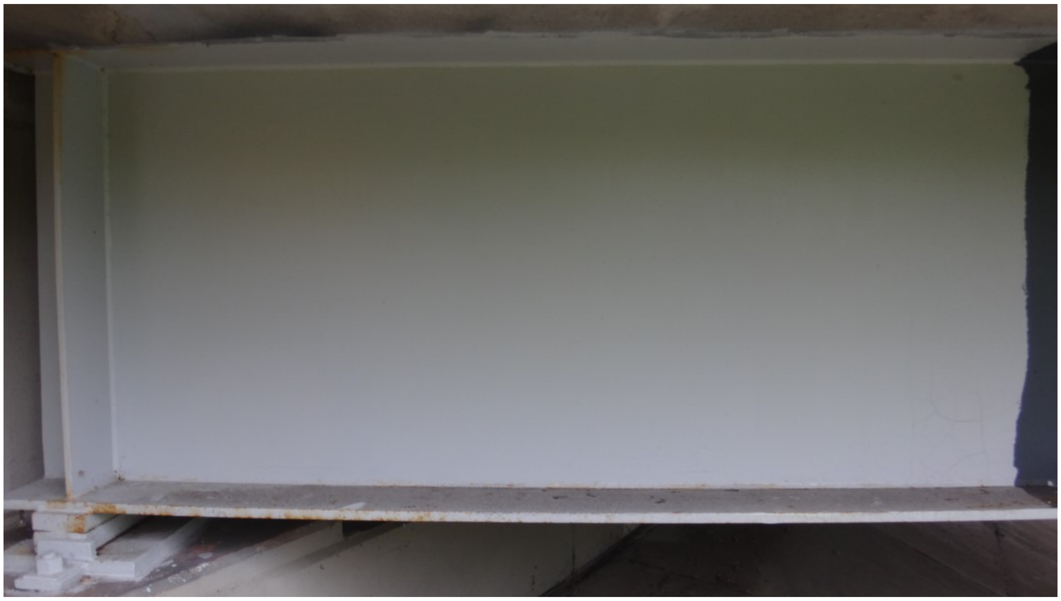

Figure 9.4 Test Location 4 - Two Year Exposure

9.5 TEST LOCATION 5 (MASTIC WATERBORNE ACRYLIC/HDP ACRYLIC POLYMER)

Test Location 5 was completed using a Mastic Waterborne Acrylic primer with an HDP Acrylic Polymer finish coat. Spot rust was noted on the top of the bottom flange, and rust bleed was observed at the diaphragm. In addition, chalking is evident of the prime coat where the finish coat was applied too thin and the prime coat is exposed. The chalking does not affect performance and is not considered a failure of the product. Test Location 5 demonstrates the least amount of coating deficiencies and failures.

Table 9.5 Test Location 5 – Year Two Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X

Chalking				X
Delamination				X

Figure 9.5 Test Location 5 - Two Year Exposure

CHAPTER 10: ADDITIONAL TEST PATCH OBSERVATIONS – YEAR ONE (2017)

Field observations of the Test Patch Locations were completed in conjunction with Test Locations 1 through 5 on August 14, 2017 in accordance with the evaluation criteria identified in Chapter 6. Spot rusting on the top of the bottom flange was observed for each additional test patch location, representing the primary coating failure observed. Other noted deficiencies included minor spot rusting on the lower edge of the web where previous failures had been observed during surface preparation and coating application prior to coating application.

10.1 ADDITIONAL TEST PATCH LOCATION A (TWO-PART EPOXY MASTIC)

Additional Test Patch Location A was coated with a two-part Epoxy Mastic, the prime coat utilized at Test Location 1. Observed failures at this location were inclusive of spot rusting along the web to bottom flange weld seam, the top of the bottom flange and the fascia edge of the bottom flange. Noted failures were in areas where ponding water is likely to occur.

Table 10.1 Additional Test Patch Location A – Year One Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 10.1 Additional Test Patch Location A - One Year Exposure

10.2 ADDITIONAL TEST PATCH LOCATION B (ALUMINUM FILLED POLYAMINE EPOXY)

The Aluminum Filled Polyamine Epoxy prime coat applied at Test Location 3 was also used at Additional Test Patch Location B. Spot rusting was observed on the top of the bottom flange, weld seam and fascia edge. Similar to Additional Test Patch Location A, the areas demonstrating coating failure were areas where ponding water is likely to occur.

Table 10.2 Additional Test Patch Location B – Year One Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 10.2 Additional Test Patch Location B - One Year Exposure

10.3 ADDITIONAL TEST LOCATION PATCH C (TWO-PART POLYAMIDE EPOXY)

The product applied at Additional Test Patch Location C was the same two-part Polyamide Epoxy used at Test Location 2 as a prime coat. Observed coating failures at this Additional Test Patch Location included spot rusting at the top of the bottom flange, the edge of the bottom flange, and along the weld seam at the web to bottom flange interface. Overall, failures noted during inspection were similar to Additional Test Patch Locations A and B.

Table 10.3 Additional Test Patch Location C – Year One Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 10.3 Additional Test Patch Location C - One Year Exposure

10.4 ADDITIONAL TEST PATCH LOCATION D (MASTIC WATERBORNE ACRYLIC)

Additional Test Patch Location D was coated with the Mastic Waterborne Acrylic, which was the prime coat applied at Test Location 5. Observed failures at this location were inclusive of spot rust in locations where previous failures were noted for the existing coating system (identified in Chapter 8), along with failures noted at the web to bottom flange weld seam, top of the bottom flange, and the fascia edge of the bottom flange. As in the other test patch locations, failures were in areas where ponding water is likely to occur.

Table 10.4 Additional Test Patch Location D – Year One Coating Assessment (2017)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 10.4 Additional Test Patch Location D - One Year Exposure

CHAPTER 11: YEAR THREE (2018) OBSERVATIONS

Field observations following three years of environmental exposure were completed on August 1, 2018 in accordance with the observation criteria set forth in Chapter 6. These observations represented the final observations completed for this project and included adhesion testing of the coating systems in accordance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Tape Test. Failures were minimal during this inspection other than the increased prevalence of rust bleed.

11.1 TEST LOCATION 1 (EPOXY MASTIC/ALIPHATIC ACRYLIC POLYESTER)

Changes in the observed failures at Test location 1, the Epoxy Mastic/Aliphatic Acrylic Polyester Polyurethane coating system were minimal. Observance of additional rust bleed was limited in location to the lower bearing beneath the lower flange. Overall condition of this test location remained in the good category.

Table 11.1 Test Location 1 – Year Three Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 11.1 Test Location 1 - Three Year Exposure

Adhesion Testing on the web and top of the bottom flange was also performed in accordance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Test Tape. The initial adhesion test on the web indicated a 0A (Removal beyond the area of the X) result due presumably to graffiti that was previously coated over, and prior to application at this maintenance test location in 2015. This is identified by a blue delamination layer beneath the coating system. A subsequent adhesion test on the web, and an additional test on the flange, indicated a 4A (Trace peeling or removal along incisions) result respective of each location.

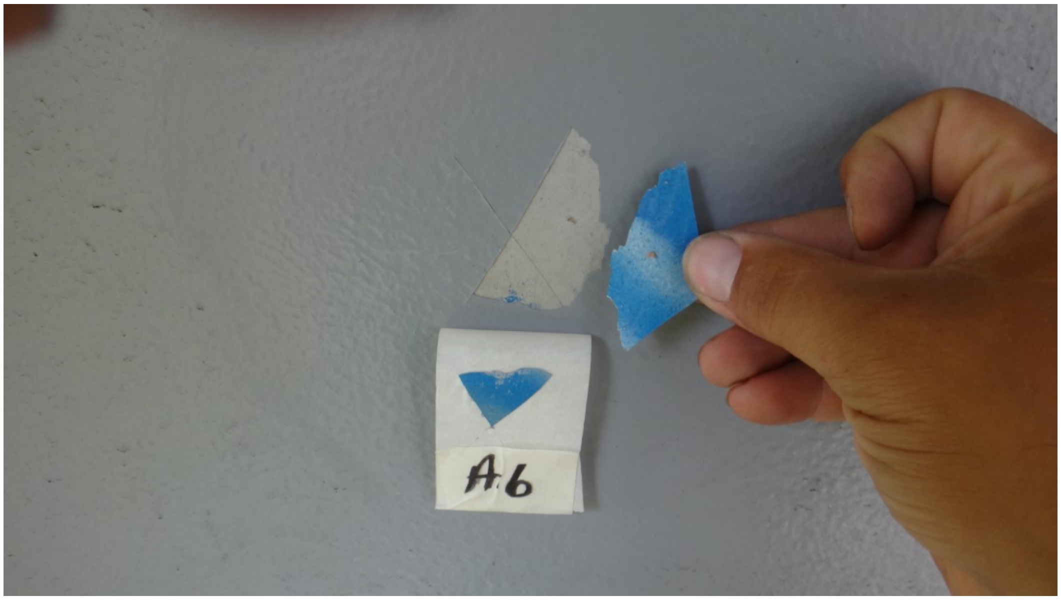

Figure 11.2 Test Location 1 Adhesion Test A6 - Web

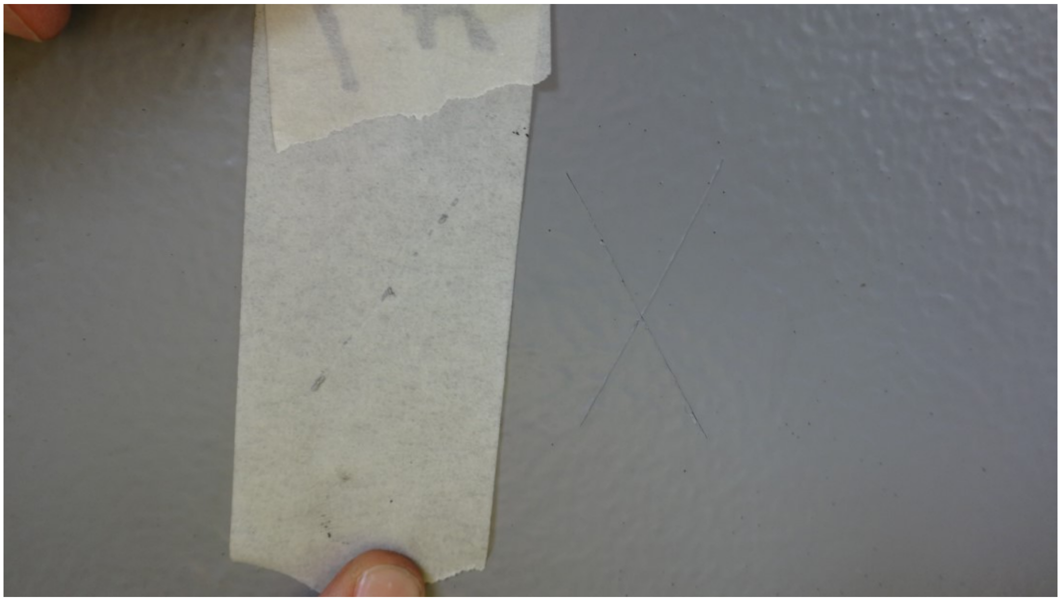

Figure 11.3 Test Location 1 Adhesion Test A7- Flange

11.2 TEST LOCATION 2 (POLYAMIDE EPOXY/ALIPHATIC POLYURETHANE)

Test Location 2 was coated with the Polyamide Epoxy/Aliphatic Polyurethane coating system. There were no additional failures noted during this inspection. Conditions remained consistent with prior inspections including spot rusting, cracking, and delamination at the bridge bearing, bottom flange, and bottom of the bottom flange as identified in Chapter 9.

Table 11.2 Test Location 2 – Year Three Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X

Delamination			X	

Figure 11.4 Test Location 2 - Three Year Exposure

Adhesion testing was performed in conformance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Test Tape at the fascia of the web and the top of the bottom flange. The adhesion test on the web resulted in a 4A (Trace peeling or removal along incisions) result indicating excellent adhesion to the existing substrate. The bottom flange adhesion test also resulted in a 4A reading (Trace peeling or removal along incisions).

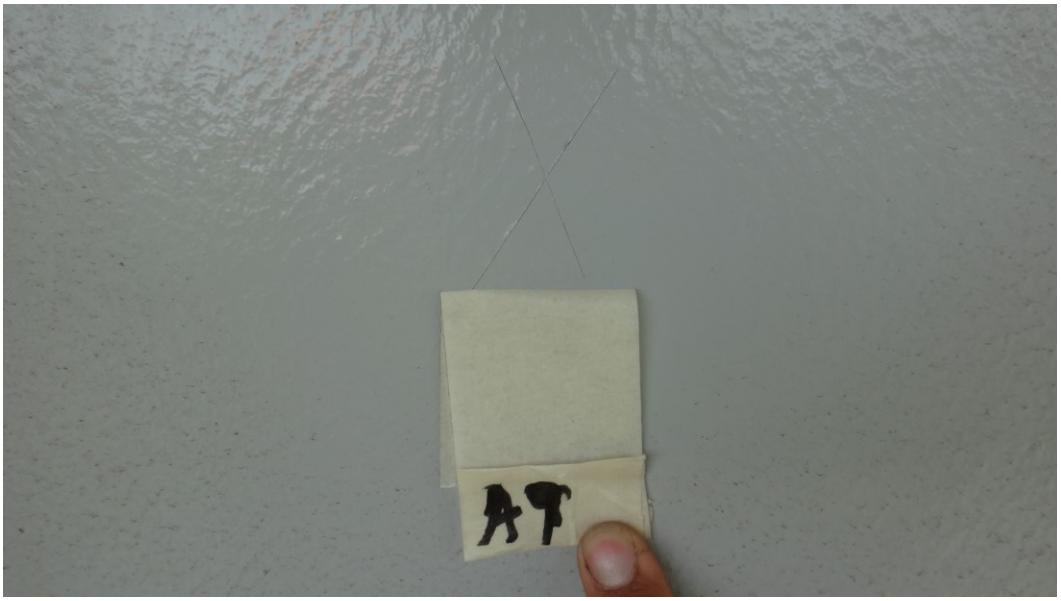

Figure 11.5 Test Location 2 Adhesion Test A9 -Web

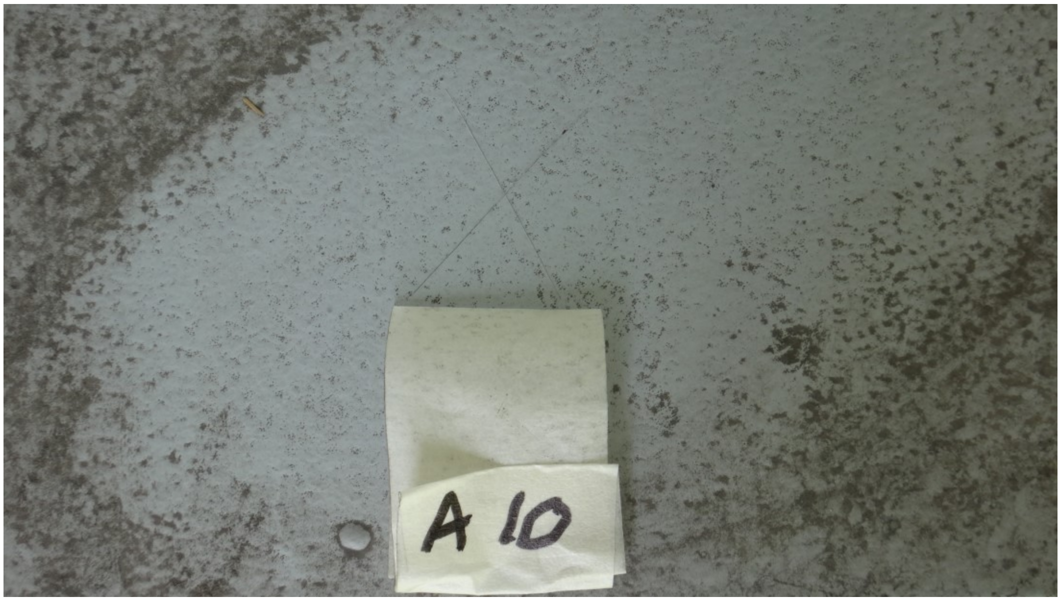

Figure 11.6 Test Location 2 Adhesion Test A10 - Flange

11.3 TEST LOCATION 3 (ALUMINUM FILLED POLYAMINE EPOXY/POLYASPARTIC

An Aluminum Filled Polyamine Epoxy primer and Polyaspartic Urethane Finish coat are represented at Test Location 3. Observation during the Year 3 inspection included rusting on the web, which increased to approximately five percent (5%) of the overall surface area. In addition, delamination of the area where surface preparation was minimally prepared over pre-existing anti-graffiti coating has increased slightly. Remaining surfaces at this location remained unchanged from previous inspections.

Table 11.3 Test Location 3 – Three Year Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)		X		
Blistering (ASTM D 714)				X
Cracking		X		
Peeling		X		
Pitting (ASTM G-46)				X

Chalking				X
Delamination		X		

Figure 11.7 Test Location 3 - Three Year Exposure

Adhesion testing was performed in conformance with ASTM D 3359 on the web. Surface conditions on the top of the bottom flange did not permit an adhesion test due to excessive corrosion. The adhesion test on the web, however, resulted in a 4A (Trace peeling or removal along incisions) result, which is excellent adhesion to the existing substrate.

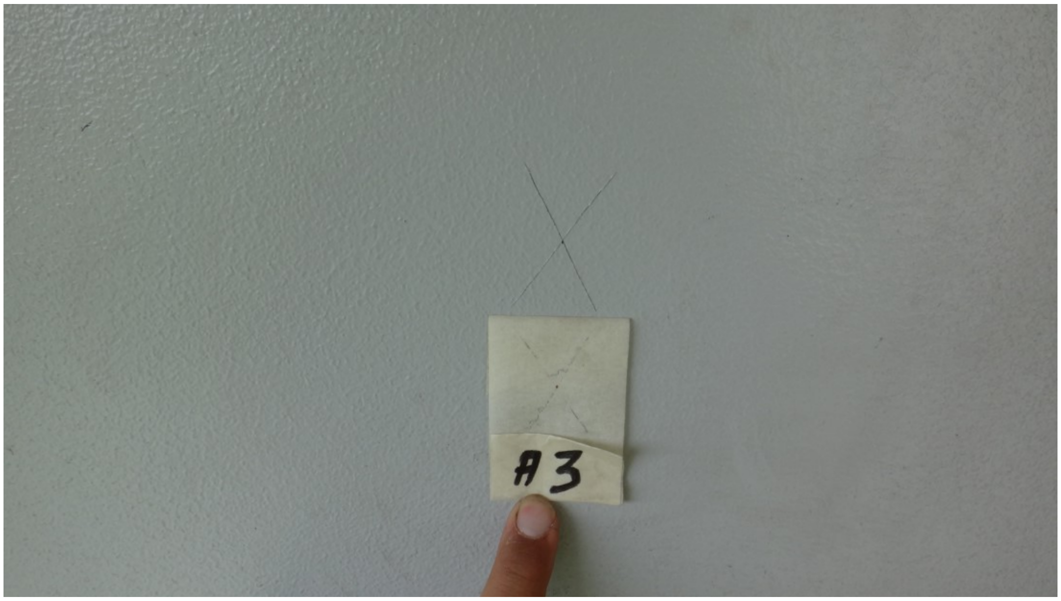

Figure 11.8 Test Location 3 Adhesion Test A3 - Web

11.4 TEST LOCATION 4 (MOISTURE CURE URETHANE WITH MICACEOUS IRON

Test Location 4 was coated with a Moisture Cure Urethane with Micaceous Iron Oxide primer and a Polyaspartic Urethane finish coat. Year 3 inspection revealed additional rusting of the top and outer edge of the bottom flange when compared with the previous year's observation. Remaining inspections were consistent with previously noted cracking at the weld seam adjacent to the stiffener.

Table 11.4 Test Location 4 – Year Three Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking			X	
Peeling				X
Pitting (ASTM G-46)				X

Chalking				X
Delamination				X

Figure 11.9 Test Location 4 - Three Year Exposure

Adhesion testing was performed in conformance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Test Tape on the top of the bottom flange and the web. The adhesion test on the flange and web both resulted in a 4A (Trace peeling or removal along incisions) result.

Figure 11.10 Test Location 4 - Adhesion Test 1A - Flange

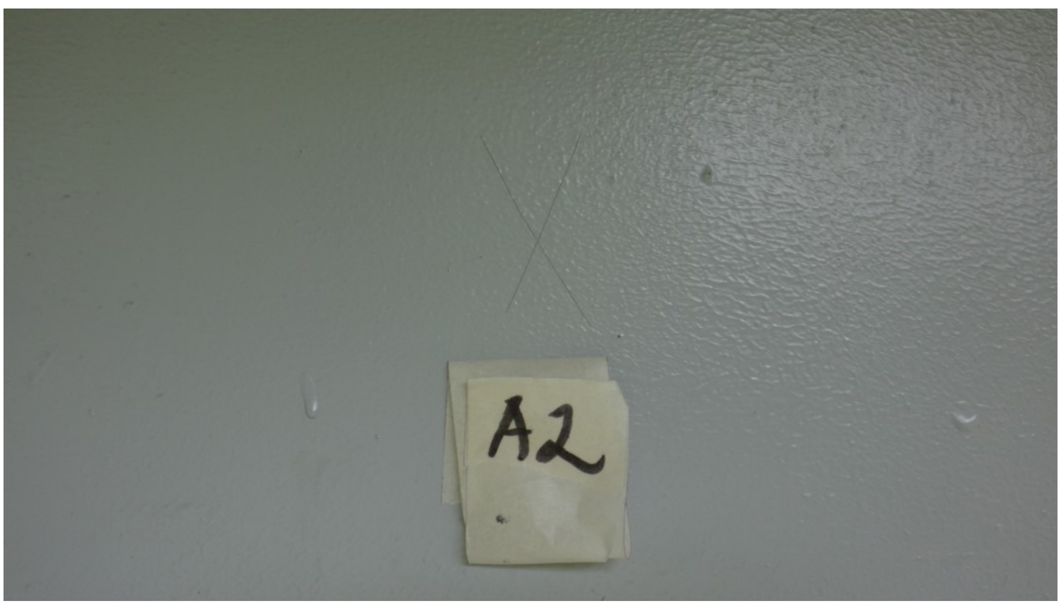

Figure 11.11 Test Location 4 - Adhesion Test A2 - Web

11.5 TEST LOCATION 5 (MASTIC WATERBORNE ACRYLIC/HDP ACRYLIC POLYMER)

Test Location 5 was coated using a Mastic Waterborne Acrylic Primer with an HDP Acrylic Polymer finish coat. No change was noted in coating condition from previous inspections. Test Location 5 demonstrates the least amount of coating deficiencies and failures.

Table 11.5 Test Location 5 – Three Year Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)				X
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 11.12 Test Location 5 - Three Year Exposure

Adhesion Testing was performed in conformance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Test Tape, at the fascia of the web and the top of the bottom flange. The adhesion test on the web resulted in a 4A (Trace peeling or removal along incisions) reading, which is indicative of excellent adhesion to the existing substrate. The bottom flange adhesion test also provided results of 4A (Trace peeling or removal along incisions).

Figure 11.13 Test Location 5 - Adhesion Test A4 - Flange

Figure 11.14 Test Location 5 - Adhesion Test A5 - Web

CHAPTER 12: ADDITIONAL TEST PATCH OBSERVATIONS – YEAR TWO (2018)

Field observations of the Additional Test Patch Locations were completed on August 1, 2018 in conjunction with the observations of Test Location 1 through 5, and in accordance with the criteria set forth in Chapter 6. Similar to Year 3 Observations for Test Locations 1 through 5, adhesion testing was completed in conformance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Test Tape.

12.1 ADDITIONAL TEST PATCH LOCATION A (TWO-PART EPOXY MASTIC)

Additional Test Location A was coated with the same prime coat as applied at Test Location 1, a two-part Epoxy Mastic. No additional coating failures or deficiencies were noted at this location when compared with the previous year's field observations, which noted spot rust along the web to bottom flange weld seam, the top of the bottom flange, and the fascia edge of the bottom flange.

Table 12.1 Additional Test Patch Location A – Year Two Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 12.1 Additional Test Patch Location A - Two Year Exposure

Final testing consisted of Adhesion Testing in conformance with ASTM D 3359 – Standard Test Methods for Measuring Adhesion by Test Tape at the fascia of the web and the top of the bottom flange. The adhesion test on the web indicated a 3A (Jagged removal along incisions up to 1.6 mm (1⁄16 in.) on either side) result which indicates good adhesion to the existing substrate. The bottom flange adhesion test resulted in a 4A reading (Trace peeling or removal along incisions) representative of excellent adhesion to the existing substrate.

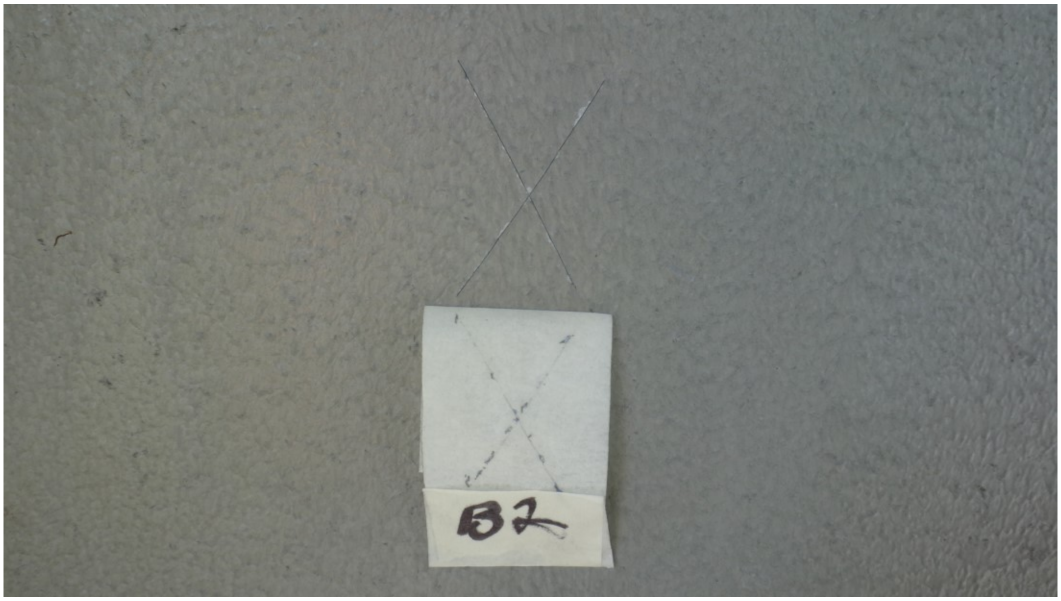

Figure 12.2 Additional Test Patch Location A - Adhesion Test Web

Figure 12.3 Additional Test Patch Location A - Adhesion Test Flange

12.2 ADDITIONAL TEST PATCH LOCATION B (ALUMINUM FILLED POLYAMINE EPOXY)

Additional Test Patch Location B was coated with the Aluminum Filled Polyamine Epoxy prime coat applied at Test Location 3. Similar to Additional Test Patch Location A, no additional coating failures were noted during inspection. Observed coating failures remain limited to the bottom flange as previously noted in Chapter 10.

Table 12.2 Additional Test Patch Location B – Year Two Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 12.4 Additional Test Patch Location B - Two Year Exposure

Adhesion testing was completed on the fascia of the web and the top of the bottom flange. The adhesion test on the flange resulted in a 3A (Jagged removal along incisions up to 1.6 mm (1⁄16 in.) on either side) reading indicates good adhesion to the existing substrate. The web adhesion test resulted in a 1A (Removal from most of the area of the X under the tape) reading which represents poor adhesion to the existing substrate. Similar to the adhesion testing completed at Test Location 1, this result is likely due to graffiti that was previously covered over prior to the original application of the test patch coating system in 2016, as identified by a blue delamination layer beneath the coating system.

Figure 12.5 Additional Test Patch Location B - Adhesion Testing Flange

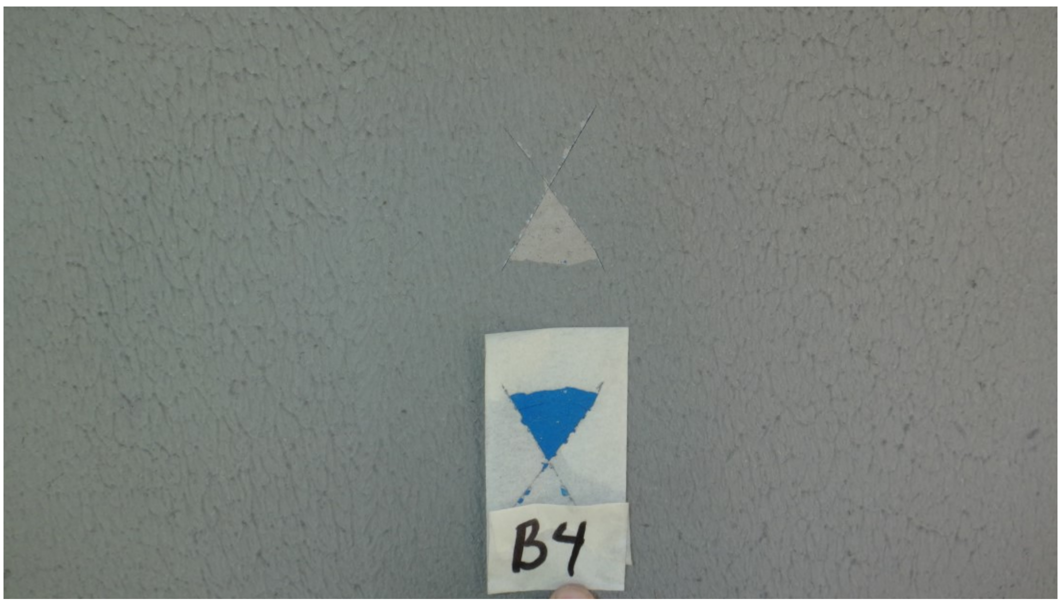

Figure 12.6 Additional Test Patch Location B - Adhesion Testing Web

12.3 ADDITIONAL TEST PATCH LOCATION C (TWO-PART POLYAMIDE EPOXY)

The prime coat applied at Additional Test Patch Location C is the same two-part Polyamide Epoxy applied at Test Location 2. Observed coating failures remain consistent with the previous year's observations resulting in deficiencies noted along the bottom flange.

Table 12.3 Additional Test Patch Location C – Two Year Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 12.7 Additional Test Patch Location C - Two Year Exposure

Adhesion testing was completed on the fascia of the web and the top of the bottom flange. The adhesion test on the flange resulted in a 4A (Trace peeling or removal along incisions or at their intersection) reading which indicates good adhesion to the existing substrate. The web adhesion test resulted in a reading of 3A (Jagged removal along incisions up to 1.6 mm (1⁄16 in.) on either side), demonstrating fair adhesion to the existing substrate.

Figure 12.8 Additional Test Patch Location C - Adhesion Testing Flange

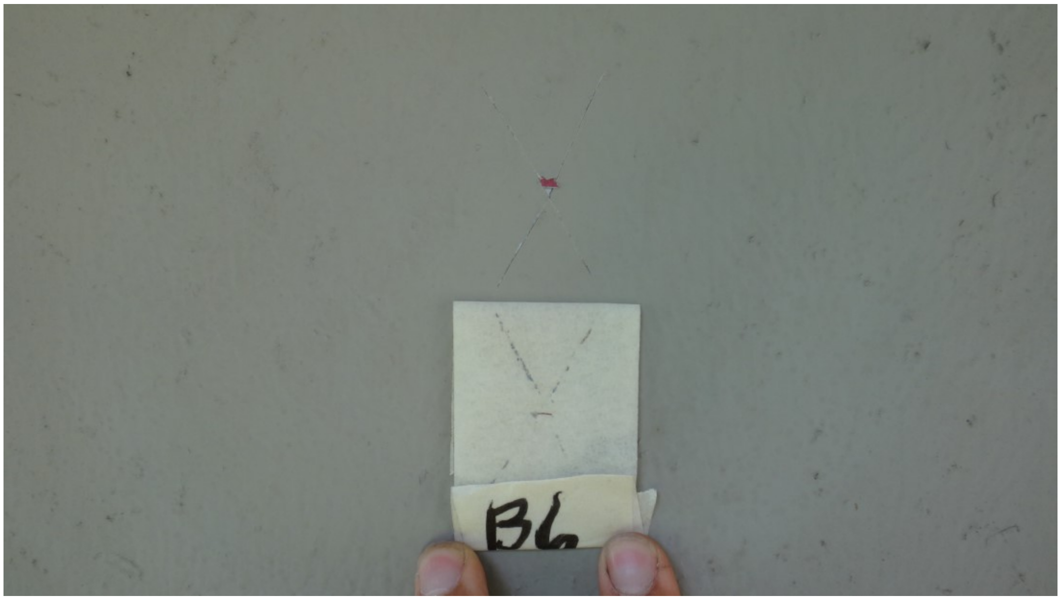

Figure 12.9 Additional Test Patch Location C - Adhesion Testing Web

12.4 ADDITIONAL TEST PATCH LOCATION D (MASTIC WATERBORNE ACRYLIC)

Additional Test Patch Location D was coated with the Mastic Waterborne Acrylic, the prime coat applied at Test Location 5. Coating failures/deficiencies remained unchanged from the previous year's inspection. Failures are inclusive of spot rust in locations where previous failures were noted with the existing coating system, along with failures noted at the web to bottom flange weld seam, the top of the bottom flange, and the fascia edge of the bottom flange.

Table 12.4 Additional Test Patch Location D – Two Year Coating Assessment (2018)

Condition	Severe	Poor	Fair	Good
Rusting (ASTM D 610)			X	
Blistering (ASTM D 714)				X
Cracking				X
Peeling				X
Pitting (ASTM G-46)				X
Chalking				X
Delamination				X

Figure 12.10 Additional Test Patch Location D - Two Years Exposure

Adhesion testing completed at this location resulted in 4A adhesion on the flange (Trace peeling or removal along incisions or at their intersection) an indication of a very good adhesion, and 4A adhesion (Trace peeling or removal along incisions or at their intersection) on the web resulting in excellent adhesion to the substrate.

Figure 12.11 Additional Test Patch Location D - Adhesion Testing Flange

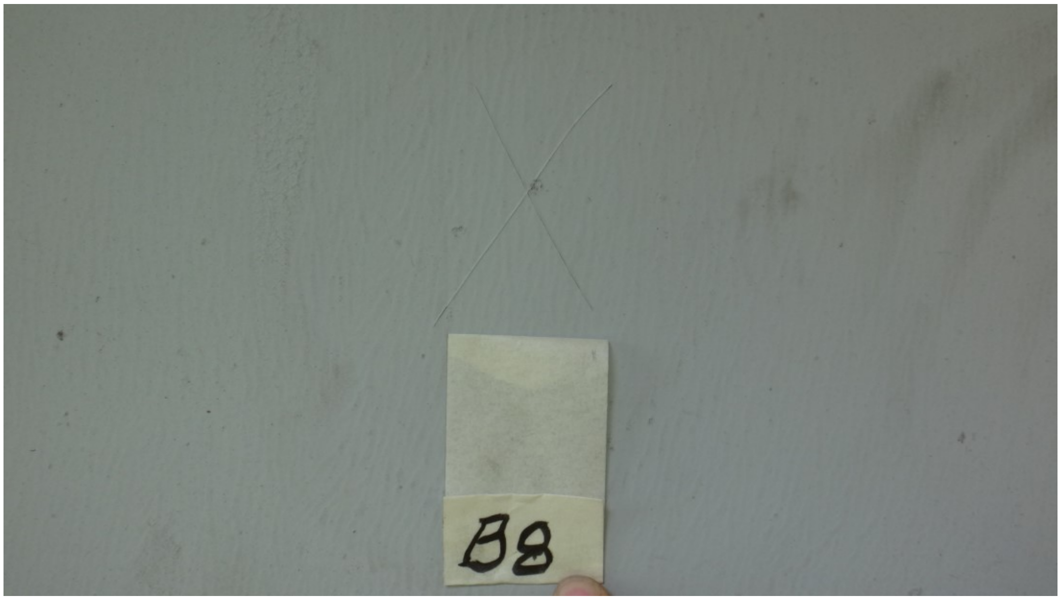

Figure 12.12 Additional Test Patch Location D - Adhesion Testing Web

CHAPTER 13: SUMMARY AND CONCLUSIONS

The purpose of this project was to evaluate the condition of bridge coating systems and determine appropriate scheduling of efficient and cost-effective preventive maintenance with the intent of extending the time period before total coating replacement would be required. Test locations for this investigation were chosen to provide a comprehensive representation of conditions at critical structural areas.

13.1 PROJECT SUMMARY

This project explored various maintenance painting procedures including:

- Pre-Cleaning
  - SSPC SP1 Solvent Cleaning, inclusive of pre and post surface preparation cleaning.
  - Note:
    - Flushing was not performed as part of this project; however, it is recommended to flush no later than two-weeks prior to scheduled maintenance painting, allowing for time to dry.
- Surface Preparation
  - SSPC SP2 Hand Tool Cleaning and SSPC SP3 Power Tool Cleaning
  - Note:
    - Efficiency and cost were considered when selecting the surface preparation methods to provide the best results with the least amount of labor, equipment and time yet still meet the manufacturers' stated recommendations.
- Coating Application
  - Solvent-Based Coating Systems
    - Prime Coat: *Epoxy Mastic*, Finish Coat: *Aliphatic Acrylic-Polyester Polyurethane*
    - Prime Coat: *Polyamide Epoxy*, Finish Coat: *Acrylic Aliphatic Polyurethane*
    - Prime Coat: *Aluminum Filled Polyamine Epoxy,* Finish Coat: *Polyaspartic Urethane*
    - Prime Coat: *Aluminum and Micaceous Iron Oxide Filled Urethane,* Finish Coat: *Polyaspartic Urethane*
  - Water-Based Coating System
    - Prime Coat: *Mastic Waterborne Acrylic,* Finish Coat: *HDP Acrylic Polymer*
  - Note:
    - Coating manufacturers recommended systems for evaluation are based on surface tolerance and minimal requirements for surface preparation, as well as compatibility with existing MnDOT coating systems.
    - For ease of application and to reduce equipment needs, brush and roll methods were used.

Field trials were conducted at five test locations over the course of three years where these maintenance painting procedures were performed. Annual evaluations were conducted at each test location to measure the coating performance. A summary of the annual evaluation results are included in Appendix A: Photographic Storyboards and Appendix B: Matrix.

Considerations

Many factors affect the decisions surrounding the timing of maintenance painting operations and the selection of maintenance painting strategy, surface preparation and coating, including:

- Pre-existing coating type
- Pre-existing coating condition
- Anti-graffiti coatings
- Coating compatibility
- Coating system selection
- Ease of mixing and application
- Environmental conditions
- Environmental and Safety
- Training

13.1.1 Substrate Identification/Pre-Existing Conditions

Applying coatings over degraded conditions, or applying a non-compatible coating system will significantly reduce the effective life of the coatings. In addition, pitting with rusting requires more extensive surface preparation, which falls outside the parameters that were set to achieve efficient and cost-effective maintenance painting.

When anti-graffiti systems (whether sacrificial or semi-sacrificial) are present, they prohibit adhesion unless removed prior to applying a maintenance coating system.

13.1.2 Coating System Selection

Coatings used for maintenance painting should be surface tolerant, compatible with the existing coating system, and provide ease of application.

13.1.2.1 Ease of Product Use

Products comprised of a single component reduce mixing requirements and eliminate measuring and combining of multiple components. To reduce required site equipment and mobilization, selected products are those that can be applied by brush and roll methods.

13.1.2.2 Availability

Product availability can play a role in completing a project in a timely manner; delivery of product in rural areas can be different than that for metropolitan areas. The generic products represented by this project are not classified as specialty products.

13.1.2.3 Cure Times and Environmental Tolerances

Climate and location play a key role when considering product curing and environmental tolerances. Specific to Minnesota, a seasonal window exists limiting the time in which maintenance coatings may be applied. These changes can also be regional within the state, from the southern plains to the North Shore. Cure time can vary greatly in the spring and fall from year to year. In addition, humidity, dew point, and temperature may limit the use of particular coating systems (refer to the manufacturers' product data sheets).

13.1.3 Environmental and Safety

Consider the environmental and safety impact related to the identification of the existing coating system, surface preparation methods, coating system mixing and application associated with the coating repair.

Safety equipment (respirators, ventilations and personal protective equipment) varied depending on coating systems used at each test location.

13.1.3.1 Respirators

Respirators need to be used during surface preparation to limit exposure to dust and possible heavy metal exposures. In addition, solvent-based coating systems and those that require solvents for clean-up necessitate the use of a respirator for personnel protection.

13.1.3.2 Protective Clothing

Personnel conducting physical inspection, coating identification tests, surface preparation, mixing or coating application need to use appropriate protective clothing. Protective clothing includes, but may not be limited to, protective footwear, coveralls or disposable jumpsuits, gloves and eye protection.

13.1.3.3 Training

Utilizing properly trained personnel for surface preparation, mixing of coating systems, and application will greatly enhance the success of the program. Training of maintenance painting personnel should focus on potential hazards, environmental variables and operations related to surface preparation, mixing, application, and waste disposal.

13.2 CONCLUSIONS AND RECOMMENDATIONS

Though each of the test locations performed at a varying degree of success (Appendix B: Matrix), all coating systems performed within acceptable limits for the duration under observation and therefore may be considered for maintenance painting over minimally prepared surfaces. Preventive maintenance painting will extend the life of steel bridge elements displaying localized coating deterioration, allowing MnDOT to delay coating replacement.

Moving forward with a Bridge Maintenance Painting Program will require critical timing in the inspection process to identify existing condition to determine the appropriate maintenance painting strategy. The Condition column of the Bridge Coating Repair Reference Table contains recommendations for maintenance painting based on the existing condition rating. The time periods included in the recommendations take into consideration the benefit in taking corrective measures before the coating reaches the next condition level. Note that a location receiving a Severe rating should not be considered for maintenance painting; it instead should be considered for coating removal and replacement.

Table 13.1 Bridge Coating Repair Reference Table

Condition*(1)	**Existing Finish Coat (‖)**	**Surface Preparation †**	**Compatible Coating System(s) ‡**
Good (2) Record, monitor and re-evaluate at next inspection cycle	Solvent-based (1)(2)(4)(5) Water-based (3)(4)	1 – SP1 Solvent Clean	Solvent-based (1.a)(2)(3) Water-based (1.b.i)(3)
Fair (3) Complete maintenance painting within 24 months	Solvent-based (1)(2)(4)(5) Water-based (3)(4)	1 – SP1 Solvent Clean 2 – SP2 Hand Tool Clean [Removal to tightly adhered coating and achieve smooth transition] Small/localized areas only	Solvent-based (1.a)(2)(3) Water-based (1.b.i)(3)

Poor (4) Complete maintenance painting within 12 months	Solvent-based (1)(2)(4)(5) Water-based (3)(4)	1 – SP1 Solvent Clean 2 – SP3 Power Tool Clean [Removal to tightly adhered coating and achieve smooth transition] Small/localized areas only	Solvent-based (1.a)(2)(3) Water-based (1.b.i)(3)
Severe Schedule coating removal and replacement by contract	Solvent-based (1)(2)(4)(5) Water-based (3)(4)		

* For information on the condition rating system (Good, Fair, Poor and Severe) for painted surfaces, reference *Bridge and Structure Inspection Program Manual* and *Steel Bridge Coating Condition Assessment Photographic Field Guide*. This rating system is consistent with ASTM D-610 Evaluating Degree of Rusting.

1. Blistering is not a failure until broken.
2. Good: Inclusive of previously pitted surfaces where coating continues to provide protection.
3. Fair: If pitting with rusting or anti-graffiti coating are present, do not perform maintenance painting.
4. Poor: If pitting with rusting or anti-graffiti coating are present, do not perform maintenance painting. Consider coating removal and replacement of the affected zone by contract.

‖ Existing Coating Systems

1. *Solvent-based* – Primers: Red Leads, Red Lead-Iron Oxide, Lead Silica-Chromate, Organic Zinc Rich, Inorganic Zinc Rich, Moisture Cure Zinc.
2. *Solvent-based* – Finish Coat: Red Lead, White Lead, Lead Silica Chromate, Alkyd Iron Oxide, Phenolic Resin Iron, Phenolic Resin Aluminum, Chlorinated Rubber Aluminum, Urethane or Polyurethane, Moisture Cure Urethane, Polyaspartic.
3. *Water-based* – Finish Coat: Vinyl, Latex, Acrylic.
4. If existing coating system is unknown, reference original plan and proposal, inventory records or historical documents.
    a. When documentation is unavailable, conduct solvent wipe test to determine if solvent-based or acrylic (water)-based.
        i. Reference ASTM D5402 *Standard Practice of Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs.*
    b. Lab analysis may be required.
5. Additionally, a swab test should be conducted to identify any presence of lead.

a. Positive result requires implementation of appropriate PPE and Containment | Disposal requirements.

† Surface preparation requirements depend on existing coating conditions.

1. If there is any uncertainty with regard to overall condition level, follow the surface preparation recommendations described in the lower condition level category.
2. A steel element may display varying condition levels. For any portion of a steel element that is in good condition, utilize SP 1 Solvent Cleaning to prepare the surface.

‡ Recommendation is made to conduct a test patch for adhesion and compatibility.

1. Application of individual coating system products should follow manufacturer's available product data sheets.
    a. Solvent-Based Coating Systems
        i. Prime Coat: *Epoxy Mastic*, Finish Coat: *Aliphatic Acrylic-Polyester Polyurethane*
        ii. Prime Coat: *Polyamide Epoxy*, Finish Coat: *Acrylic Aliphatic Polyurethane*
        iii. Prime Coat: *Aluminum Filled Polyamine Epoxy,* Finish Coat: *Polyaspartic Urethane*
        iv. Prime Coat: *Aluminum and Micaceous Iron Oxide Filled Urethane,* Finish Coat: *Polyaspartic Urethane*
    b. Water-Based Coating System
        i. Prime Coat: *Mastic Waterborne Acrylic,* Finish Coat: *HDP Acrylic Polymer*
2. Solven- based coating systems can only be used over compatible solvent-based coating systems.
3. Water-based coating systems can be used universally over any existing water-based or solvent-based coating system.

REFERENCES

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The Society for Protective Coatings. (2010). *SSPC Pocket Guide to Coating Information* (Second Ed.). SSPC, Pittsburgh, PA.

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APPENDIX A – PHOTOGRAPHIC STORYBOARDS

Test Location Number:	1
Existing Conditions:	Poor to Severe rusting present, mild to no pitting present, average dry film thickness of 11.5 mils DFT
Surface Preparation:	SP1/SP2/SP3
Coating System:	Prime Coat: Epoxy Mastic Finish Coat: Aliphatic Acrylic-Polyester Polyurethane

Pre-Existing Conditions

Surface Prep

(Prime) Initial Coat

Finish Coat

Year One (2016)

Year Two (2017)

Year Three (2018)

Test Location Number:	2
Existing Conditions:	Poor to Severe rusting in localized areas, mild to no pitting present, average dry film thickness of 7.4 mils DFT
Surface Preparation:	SP1/SP2/SP3
Generic Coating System:	Prime Coat: Polyamide Epoxy Finish Coat: Acrylic Aliphatic Polyurethane

Pre-Existing Conditions

Surface Prep

(Prime) Initial Coat

Finish Coat

Finish Coat (2)

Year One (2016)

Year Two (2017)

Year Three (2018)

Test Location Number:	3
Existing Conditions:	Poor to Severe rusting present, mild to no pitting present, average dry film thickness of 5.2 mils DFT, Anti-Graffiti coating present
Surface Preparation:	SP1/SP3
Generic Coating System:	Prime Coat: Aluminum Filled Polyamine Epoxy Finish Coat: Polyaspartic Urethane

Pre-Existing Conditions

Surface Prep

Surface Prep (2) (Removed Anti-Grafitti Coating with Power Tools)

(Prime) Initial Coat

Finish Coat

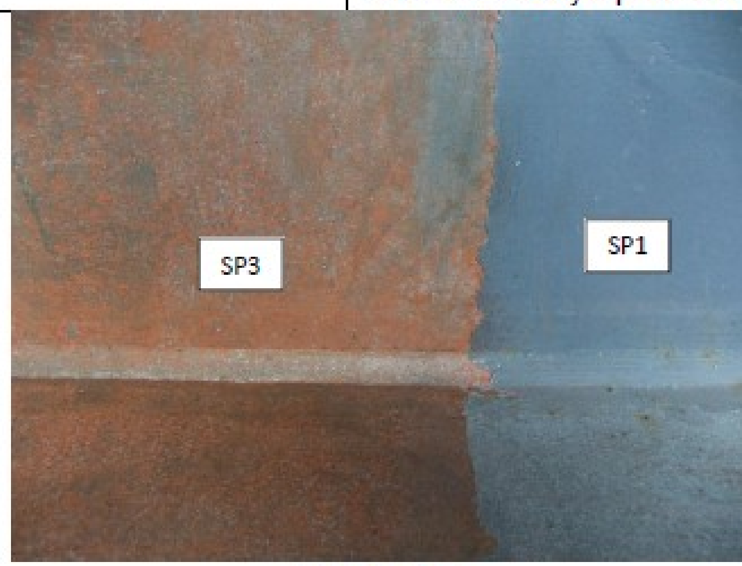
Year One (2016)

Year Two (2017)

Year Three (2018)

Test Location Number:	4
Existing Conditions:	Poor to Severe rusting present, mild to no pitting present, average dry film thickness of 2.8 mils DFT, Anti-Graffiti coating present
Surface Preparation:	SP1/SP3
Generic Coating System:	Prime Coat: Aluminum and Micaceous Iron Oxide Filled Urethane Finish Coat: Polyaspartic Urethane

Pre-Existing Conditions



Surface Prep

(Prime) Initial Coat

Finish Coat

Year One (2016)

Year Two (2017)

Year Three (2018)

Test Location Number:	5
Existing Conditions:	Fair to Severe rusting in localized areas, mild to no pitting present, average dry film thickness of 10.8 mils DFT
Surface Preparation:	SP1/SP2/SP3
Generic Coating System:	Prime Coat: Mastic Waterborne Acrylic Finish Coat: HDP Acrylic Polymer

Pre-Existing Conditions

Surface Prep

(Prime) Initial Coat

Finish Coat

Year One (2016)

Year Two (2017)

Year Three (2018)

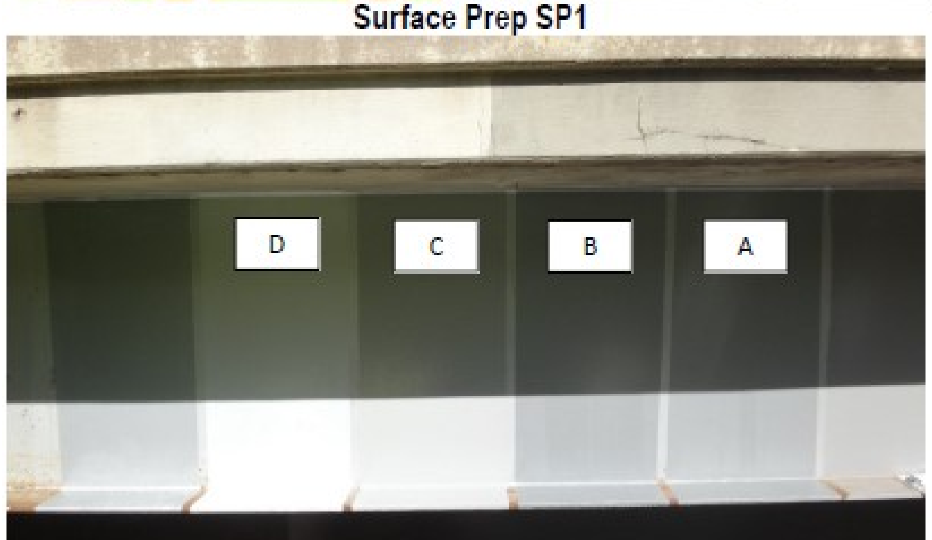
Test Location Number:	Additional Test Patches A, B, C, D
Existing Conditions:	Slight to severe rusting in localized areas, mild to no pitting present, average dry film thickness of 11.5 mils DFT
Surface Preparation:	SP1/Spot SP2
Generic Coating System:	A: Epoxy Mastic B: Aluminum Filled Polyamine Epoxy C: Polyamide Epoxy D: Mastic Waterborne Acrylic

Pre-Existing Conditions

Surface Prep SP1

Surface Prep Spot SP2 at Bottom Flange

Test Location Division for Patches A, B, C, D



Initial Application Year One (2016)

Year Two (2017)

Year Three (2018)

APPENDIX B – MATRIX

The following matrix is also available in its original form at http://www.dot.state.mn.us/research/reports/2019/201937S.xlsx

			Pre-Existing Condition(s)								Application Process			Final Field Application Data						
			Degree of Rusting			Existing Pitting												Rusting (ASTM D 610)		
Test ID	Test Location	Coating System	Top Flange	Web	Bottom Flange	Top Flange	Web	Bottom Flange	Dry Film Thickness	Chloride Test (PPM)	Surface Preparation	Prime Coat	Finish Coat	Primer - Specified DFT	Finish - Specified DFT	Primer - Actual DFT	Total Actual DFT	Top Flange	Web	Bottom Flange
1	I-35E NB over Ayd Mill Exit (NE Corner)	Epoxy Mastic / Aliphatic Acrylic-Polyester Polyurethane	6	5	1	4	4	3	11.5	48	SP1/SP2/SP3	Brush & Roll	Brush & Roll	7-10	3-5	11.5	17.0	4	4	4
2	Randolph Ave over Ayd Mill On-Ramp (SE Corner)	Polyamide Epoxy / Acrylic Aliphatic Polyurethane	7	5	1	4	4	3	7.4	9	SP1/SP2/SP3	Brush & Roll	Brush & Roll	3-8	2-5	7.4	9.0	4	4	3
3	Randolph Ave over Ayd Mill Exit (NE Corner)	Aluminum Filled Polyamine Epoxy / Polyaspartic Urethane	6	5	0	4	4	2	5.2	40	SP1/SP3	Brush & Roll	Brush & Roll	4-6	6-9	5.2	11.3	3	3	2
4	Randolph Ave over Ayd Mill Exit (NW Corner)	Aluminum and Micaceous Iron Oxide Filled Urethane / Polyaspartic Urethane	6	5	0	4	4	2	2.8	2	SP1/SP3	Brush & Roll	Brush & Roll	2-3	6-9	2.8	8.1	4	4	4
5	I-35E SB over Ayd Mill Exit (NW Corner)	Mastic Waterborne Acrylic / HDP Acrylic Polymer	6	6	2	3	3	2	10.8	0	SP1/SP2/SP3	Brush & Roll	Brush & Roll	6-8	2-3	9.7	10.2	4	4	4
A	I-35E NB over Ayd Mill Exit (NE Corner)	Epoxy Mastic	6	5	1	2	2	3	11.5	-	SP1/Spot SP2	Brush & Roll	-	7-10	-	11.8	-	-	-	-
B	I-35E NB over Ayd Mill Exit (NE Corner)	Aluminum Filled Polyamine Epoxy	6	5	1	2	2	3	11.5	-	SP1/Spot SP2	Brush & Roll	-	4-6	-	12.8	-	-	-	-
C	I-35E NB over Ayd Mill Exit (NE Corner)	Polyamide Epoxy	6	5	1	2	2	3	11.5	-	SP1/Spot SP2	Brush & Roll	-	3-8	-	10.5	-	-	-	-
D	I-35E NB over Ayd Mill Exit (NE Corner)	Mastic Waterborne Acrylic	6	5	1	2	2	3	11.5	-	SP1/Spot SP2	Brush & Roll	-	6-8	-	7.3	-	-	-	-

Year 1 (2016) Observations						Year 2 (2017) Observations									Year 3 (2018) Observations								
Conditions						Conditions									Conditions								
						Rusting (ASTM D 610)									Rusting (ASTM D 610)								
Blistering (ASTM D 714)	Cracking	Peeling	Pitting (ASTM G-46)	Chalking	Delamiantion	Top Flange	Web	Bottom Flange	Blistering (ASTM D 714)	Cracking	Peeling	Pitting (ASTM G-46)	Chalking	Delamiantion	Top Flange	Web	Bottom Flange	Blistering (ASTM D 714)	Cracking	Peeling	Pitting (ASTM G-46)	Chalking	Delamiantion
4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	3	4	3	4	4	4	4	4	4
4	4	4	4	4	4	3	4	3	4	4	4	4	4	3	2	4	3	4	4	4	4	4	3
4	2	3	4	4	3	3	3	2	4	2	2	4	4	2	2	3	1	4	2	2	4	4	2
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-	-	-	-	-	-	4	4	3	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4

Adhesion Testing		Applicator Product Ratings																					
		Prime Coat											Finish Coat										
Web	Flange	Wet Hide (Coverage)	Ease of Mixing	Ease of Application	Flow & Leveling	Viscosity	Film Build	Sag Resistance	Final Appearance	Dry Time	Pot Life	Ambient Temperature	Wet Hide (Coverage)	Ease of Mixing	Ease of Application	Flow & Leveling	Viscosity	Film Build	Sag Resistance	Final Appearance	Dry Time	Pot Life	Ambient Temperature
4	4	5	4	5	5	5	5	5	5				5	4	5	5	4	5	4	5	5	5	5
4	4	2	4	4	4	5	3	3	4		5		5	4	5	5	5	5	4	5			
4	0	4	4	5	5	4	5	4	5	3	5	5	5	4	5	5	5	5			5	4	
4	4	5	5	5	5	5	5	5	5				5	4	5	5	5	5	5	5		4	
4	4	4	5	5	5	5		4	3				5	5	5	5	5	5		3	5	5	5
3	4	5	4	5	5	5	5	5	5				-	-	-	-	-	-	-	-	-	-	-
1	3	4	4	5	5	4	5	4	5	3	5	5	-	-	-	-	-	-	-	-	-	-	-
3	4	2	4	4	4	5	3	3	4		5		-	-	-	-	-	-	-	-	-	-	-
4	4	4	5	5	5	5		4	3				-	-	-	-	-	-	-	-	-	-	-