



SCAN TEAM REPORT

NCHRP Project 20 68A, Scan 15-03

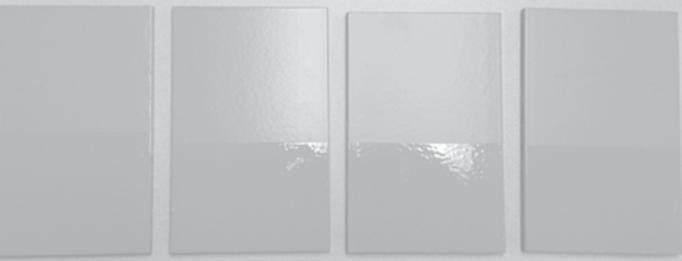
Successful Preservation Practices For Steel Bridge Coatings

Supported by the

National Cooperative Highway Research Program

The information contained in this report was prepared as part of NCHRP Project 20-68A U.S. Domestic Scan, National Cooperative Highway Research Program.

SPECIAL NOTE: This report IS NOT an official publication of the National Cooperative Highway Research Program, Transportation Research Board, or the National Academies of Sciences, Engineering, and Medicine.



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The purpose of each scan, and of Project 20-68A as a whole, is to accelerate the integration of innovative ideas into practice by information sharing and technology exchange among state transportation agencies. Experience has shown that personal contact with new ideas and their application is a particularly valuable means for sharing information about practices. A scan entails peer-to-peer discussions between practitioners who have implemented practices of interest and who are able to disseminate knowledge of these practices to other peer agencies. Each scan addresses a single technical topic that is selected by AASHTO and the NCHRP 20 68A Project Panel. Further information on the NCHRP 20-68A U.S. Domestic Scan program is available at <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1570>.

This report was prepared by the scan team for Scan 15-03, *Successful Preservation Practices for Steel Bridge Coatings*. The members of the scan team are listed below. Scan planning and logistics are managed by Arora and Associates, P.C. Harry Capers served as the Principal Investigator. Melissa Jiang provided valuable support to the team. NCHRP Project 20-68A is guided by a technical project panel and managed by Andrew C. Lemer, PhD, NCHRP Senior Program Officer.

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Disclaimer

The information in this document was taken directly from the submission of the authors. The opinions and conclusions expressed or implied are those of the scan team and are not necessarily those of the Transportation Research Board or its sponsoring agencies. This report has not been reviewed by and is not a report of the Transportation Research Board or the National Academies of Sciences, Engineering, and Medicine.

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Scan 15-03

Successful Preservation Practices for Steel Bridge Coatings

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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
BCI	Bridge Coating Inspector Program
BMS	Bridge Management System
BrM	Bridge Management Software (formerly known as Pontis)(AASHTO)
Caltrans	California Department of Transportation
CIP	Coating Inspector Program
DOT	Department of Transportation
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
IOZ	Inorganic Zinc
KSC	Kennedy Space Center
KTC	Kentucky Transportation Center
MnDOT	Minnesota Department of Transportation
NACE	National Association of Corrosion Engineers
NASA	National Aeronautics and Space Administration
NCHRP	National Cooperative Highway Research Program
NTPEP	National Transportation Product Evaluation Program
NYSDOT	New York State Department of Transportation
OZ	Organic Zinc
QA	Quality Assurance
QC	Quality Control
SHA	State Highway Agency
SSPC	The Society for Protective Coatings
TRB	Transportation Research Board
TSP 2	Transportation System Preservation Technical Services Program
TxDOT	Texas Department of Transportation
USDA	United States Department of Agriculture
UV	Ultra Violet
VDOT	Virginia Department of Transportation
VOC	Volatile Organic Compound
WSDOT	Washington State Department of Transportation

Executive Summary

Coatings provide the primary corrosion protection system for steel highway bridges. There are currently approximately 610,000 highway bridges in the U.S.; approximately 180,000 of these are constructed from steel. Although steel bridges are still being built, the majority of steel bridges were constructed between 1920 and 1970. In recent years, the construction of new highway mileage has slowed and the use of concrete for construction of new bridges has increased. These factors indicate that the primary issues regarding steel bridge coatings lie with maintenance of the many existing—and aging—inventory of steel bridges. The median age of the existing inventory now exceeds 40 years, and a large percentage of coating systems protecting steel bridges have met or exceeded their useful service lives. There is currently an increasing demand for maintenance and replacement of coating systems on steel bridge structures.

Bridge painting practices have changed significantly over the past two decades. Typical, evolutionary changes in surface preparation and coatings material technology have been accelerated by environmental and health and safety regulations to produce revolutionary changes in bridge painting methodology. Specifically, the requirement to build controlled containment structures around surface-preparation and coating-removal operations and requirements for dramatic reductions in solvent content of industrial coatings have forced significant changes in painting practices. These changes have not only created cost increases of 200% to 500%, but have also made innovation a key driver for success in the bridge painting arena. According to a study by the National Association of Corrosion Engineers (NACE), “Corrosion Costs and Preventive Strategies in the United States,” the annual cost of corrosion for highway bridges is estimated to be between \$6.43 billion to \$10.15 billion and is increasing.

Bridge painting is a cost-effective means of extending the functional performance of steel bridges. It should be in the toolkit of every state highway agency; all state highway agencies will be required to use it due to its economic impact to the taxpayer and its function viability. The applied polymeric coating (where pertinent) should serve in an aesthetic and corrosion preventive manner for an extended period of time; based on the results of this scan, at least 15 years and up to 30 years. The range is an estimate and should only be dependent on localized structure environment, not other controllable parameters such as surface preparation and application methods. Additionally, the painting work must meet regulatory requirements regarding both environmental and worker/public safety and health. The seemingly simple act of applying paint to bridge steel must accommodate all of these needs for it to be a practical solution to preventing corrosion.

The scan team identified several factors that would result in premature coatings failure (singly or in combination with others), including:

- Inadequate surface preparation or coating application
- Residual surface contamination
- Incorrect coating thickness

-
- Improper environmental conditions for application
 - Incorrect mixing or agitation
 - Inadequate/incorrect coatings/materials
 - Extreme exposure conditions
 - Inadequate inspections
 - Inadequate qualified contractors
 - Inadequate specifications

The scan team's observations from the workshop to mitigate premature coating failures are:

1. Agency Funding Levels
 - Dedicated bridge painting funds – utilize algorithms incorporating biannual inspections data, etc., to determine appropriations
2. Evaluation Practices for In-Situ Coatings Prior to Recoating
 - Inspection elements – database containing element-specific conditions
 - Agency-developed elements – ranking system and cataloguing method
3. Surface Preparation
 - Removal/application techniques
 - ◆ Crevice sealers
 - ◆ New technology – laser coating removal
 - ◆ Cable painting/removal techniques – Golden Gate Bridge, Highway and Transportation District
 - Removal of pack rust
 - ◆ Ultra-high-pressure washing
 - ◆ Soak pack rust and apply heat to remove
4. Coating Option Decision Making
 - Better use of innovative coatings
 - ◆ Ultra-weatherable coatings – fluoropolymers, microcapsules, and smart release of corrosion inhibitor
 - ◆ Thermal spray
 - ◆ Un-top-coated inorganic zinc (IOZ)
5. Use of Performance-Based Contracts (i.e., Warranties)

- Warranties – bonding amount withheld, short terms not to exceed three years, and inspection prior to expiration; issues with implementing warranties on railroad bridges
6. Performance Evaluation of Coatings
- Modify national test protocols to be appropriate for additional coating types
 - Incorporate colorimetry into national test protocols
7. Specifications for Coating Systems (including removal and replacement, overcoating, and spot/zone coating)
- Specification improvements
 - ◆ Paint beam ends – weathering steel
 - ◆ Incorporate hold points for inspection
 - ◆ Full-time inspection
 - ◆ In-house paint team
 - ◆ Shop coating using IOZ for better service life
 - ◆ SSPC-SP 10 or better for paint removal
 - ◆ Eliminate mist coats – difficult to inspect
 - ◆ Priming faying surfaces
 - Stripe coating
 - ◆ Use edge-retentive coating – use contrasting colors for the stripe coat for inspection; specify which coats to be striped
 - Structure prioritization – use spot coating
 - Bridge washing – remove surface contaminants like chlorides
 - Bridge debris cleaning (removing debris from deck drains and increasing drain size); raptors to keep pigeons away from bridges
8. Quality Assurance Coating Inspection Requirements
- Specify SSPC Bridge Coating Inspector (BCI) Program¹ and NACE for inspectors and consultants with 100% inspection required on paint projects
9. Quality Control Inspection Qualifications and Contractor Qualifications
- Specify SSPC BCI and NACE for inspectors and consultants with 100% inspection

¹ Bridge Coating Inspector (BCI) Program, The Society for Protective Coatings,
<http://archive.sspc.org/bridge-coating-inspector-program-bci>

required on paint projects

10. Agency Commitment to Supporting Future Preservation of Coatings

- Tracking project coating information – bridge ID/tagging/radio-frequency identification (RFID)
- Communication
 - ◆ Paint success/failure
 - ◆ Publications
 - ◆ Memberships/training
 - ◆ Agency-controlled (i.e., membership) blogs
- Joint Elimination (when possible)
- Waste Disposal – specify as hazardous unless proved otherwise

Potential implementation activities that CTC & Associates² will be assisting the team are in writing articles for publication in coatings publications, like *CoatingsPro Magazine*, *Modern Steel Construction*, *Journal of Protective Coatings & Linings* (PaintSquare), *Durability + Design*³, and others.

Many AASHTO committees and subcommittees, like TSP 2, Subcommittee on Bridges and Structures Technical Committees 9 and 18, and the Subcommittee on Maintenance; the North East Protective Coating Committee; and the National Steel Bridge Alliance, were identified for presenting domestic scan results. Many national conferences (e.g., The Society for Protective Coatings, the National Association of Corrosion Engineers, and the Transportation Research Board) were also identified to reach a wide audience.

² CTC & Associates LLC, <http://ctcandassociates.com/>

³ Durability + Design, Technology Publishing Co., <http://www.durabilityanddesign.com/>

Introduction

Background

Over 30% of the 607,000 bridges in the Federal Highway Administration’s (FHWA’s) National Bridge Inventory have steel superstructures. Most of those are protected from corrosion damage by thin film coatings or paints. Those coatings have a finite life in relation to the steel they protect. Over time, they degrade, eventually requiring repair or replacement. When selecting this type of superstructure for a bridge, the operating agency incurs an obligation to maintain the coating on the steel to protect it from corrosion to obtain its full service life. However, recoating existing steel bridges is a major and costly task for transportation agencies. According to a study by the National Association of Corrosion Engineers (NACE) titled “Corrosion Costs and Preventive Strategies in the United States,”⁴ the annual cost of corrosion for highway bridges is estimated to be between \$6.43 billion and \$10.15 billion and is increasing.

Many agencies are faced with significant challenges in balancing available resources with major rehabilitation, reconstruction, and complete replacement needs due largely to corrosion caused by failing coating systems. Beyond direct costs, repainting projects frequently impact the driving public through reduced capacity (i.e., lane closures) and also put workers in the right of way, exposing them to additional safety risks. State Department of Transportation (DOTs) are seeking to identify improved coating and recoating methods that will offer extended service life and save significant costs by reducing the frequency of recoating, or the need to recoat at all, thereby delaying costly rehabilitation and replacement activities caused by corrosion.

Objectives, Purpose, and Scope of Scan

This scan’s objectives are to facilitate the collection and dissemination of effective strategies and best practices used by state Departments of Transportation and other highway agencies. Some of the focus areas of the proposed scan include, but are not limited to:

- Coating option decision-making
- Surface preparation
- Specifications for coating systems (including complete removal and replacement of coating, overcoating, and spot/zone coating)
- Performance-based contracts

4 Corrosion Costs and Preventive Strategies in the United States, NACE International, FHWA-RD-01-156, <http://impact.nace.org/documents/ccsupp.pdf>

- Evaluation practices for in-situ coatings prior to recoating
- Evaluation of performance of overcoat and replacement coatings
- Inspector qualifications
- Contractor qualifications
- Resource management
- Agency accountability

This scan identified effective strategies and practices transportation agencies use in these areas:

- Determination of agency funding levels
- Evaluation practices for in-situ coatings prior to recoating
- Surface preparation
- Coating option decision-making
- Use of performance-based contracts (i.e., warranties)
- Performance evaluation of overcoat and replacement coatings
- Specifications for coating systems, including:
 - Removal and replacement
 - Overcoating
 - Spot/zone coating
- Quality assurance coating inspection requirements
- Quality control inspector qualifications
- Contractor qualifications
- Agency commitment to supporting future preservation of coatings

Scan Approach and Planning

The scan team chose to use a Type 3 scan method to identify agencies with assets in aggressive corrosive environments and have successful programs, to identify the aspects of those programs (e.g., innovative coating systems and recoating practices) that lead to success. A Type 3 scan brings together the scan team and a large number of practitioners and innovators together in a single location, where participants discuss their experiences in a workshop or symposium. Information was exchanged using presentations, roundtable discussions, and webinars.

The scan team researched significant challenges and successful corrosion-mitigation and recoating strategies. Of special interest were successful strategies, technologies, and approaches in addressing concerns associated with environmentally hazardous materials. There is much information relevant to the factors that encompass bridge painting; however, it exists in many

Figure 1.1 Map of workshop participating DOTs and non-DOTs

Tour of NASA's Kennedy Space Center

On the May 26, 2016, the scan team and practitioners visited the National Aeronautics and Space Administration's (NASA's) Corrosion Technology Laboratory at the Kennedy Space Center (KSC). The group toured the NASA Beachside Atmospheric Exposure Test Site and viewed two presentations by the office of the director of the NASA Corrosion Technology Laboratory: "Coatings Qualification for NASA" and "Anticipate, Manage, and Prevent Corrosion." These presentations included information on the use of innovative coatings (e.g., smart release of corrosion inhibitor)

developed by NASA.

Current State of Bridge Painting Practice

Overview of Survey of Relevant Agencies

Several surveys performed outside of this scan reflect changes in DOTs practices over a 22 year period. Two of those previously performed by the Kentucky Transportation Center (KTC) will be briefly reviewed. In 2013, KTA-Tator⁵ performed a more thorough survey of DOTs and other bridge owners for the Minnesota Department of Transportation (MnDOT). A KTC survey in April 2014 (part of the National Cooperative Highway Research Program [NCHRP] 14-30 study⁶) is also reviewed. Some of the findings have a direct bearing on this scan.

In 1991, KTC performed a detailed survey of DOTs, addressing all bridge practices, including spot painting⁷ (Table 2-1).

43 DOTs responded	30 DOTs used spot painting 3 DOTs used washing or steam cleaning 1 DOT used solvent cleaning
Mechanical surface preparation	5 DOTs used hand tools 4 DOTs used hand tools or power tools 2 DOTs used power tools only 1 DOT used a combination of hand tools and power tools 9 DOTs used abrasive blasting
Coating systems used	9 DOTs used lead free oil-alkyds and water based alkyds 3 DOTs used epoxies 5 DOTs used mixed systems incorporating epoxy primer/intermediate coats with polyurethane and alkyd topcoats 1 DOT used calcium sulfonate alkyds

Table 2-1 1991 Kentucky Transportation Center survey of DOTs addressing all bridge practices

5 KTA-Tator, Inc., <http://kta.com/>

6 NCHRP 14-30, Spot Painting to Extend Highway Bridge Coating Life, Transportation Research Board, The Academies of Sciences, Engineering, and Medicine, <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3412>

7 Hopwood T and CM Oberst, Survey of Current Bridge Painting Practices and Related Literature Search, July 1992, Kentucky Transportation Center, Report No. KTC-92-8, http://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1476&context=ktc_researchreports

In August 2012, KTC distributed a brief survey on spot painting practices to officials of approximately 25 DOTs that participate in the Midwest Bridge Working Group⁸ meetings. The two survey questions were:

- Does your agency perform spot painting?
- If so, does it use state forces or does it contract work?

The survey indicated that barriers to DOTs using spot painting by state forces exist, primarily as limited personnel and tasks that have higher agency priorities. Interestingly, aesthetics was considered a factor. In addition, some DOTs believe spot painting is not cost effective. Most of the work appears to be reactive rather than programmatic. See Table 2-2.

19 DOTs responded	12 DOTs used spot painting
Spot painting by contract	7 DOTs (Michigan, Texas, Louisiana, Idaho, Kansas, California, and Wisconsin)
Spot painting by state forces	7 DOTs (New York State, Louisiana, Minnesota, Missouri, California, West Virginia, and Arkansas)
Zone painting	1 DOT (Iowa)
Total removal and recoat	1 DOT (Illinois)

Table 2-2 2012 Kentucky Transportation Center survey of state highway agency on spot painting

In 2013, MnDOT contracted with KTA-Tator to conduct a survey of U.S. DOTs and other bridge owners/agencies to determine their current bridge maintenance painting procedures/practices. The survey was sent to 52 transportation agencies; 42 responded. Of these, 30 were from the northeast and north central regions. Table 2-3 represents the survey’s key findings. The survey’s intent was to:

- Develop a custom photographic guide for assessing the condition of bridge elements
- Develop a bridge maintenance painting manual for:
 - Conducting coating condition assessments
 - Providing guidance on maintenance strategies
 - Assisting with prioritization of structures
 - Determining the scope of maintenance painting projects
 - Establishing surface preparation and coating system selections
 - Determining compatibility when overcoating

⁸ Midwest Bridge Working Group, Kentucky Transportation Center, <http://www.ktc.uky.edu/special-initiatives/midwest-bridge-working-group/>

Coating condition assessments	4 respondents did not perform any 14 respondents used in-house personnel 5 respondents used consultants 19 respondents used both in-house personnel and consultants
Bridge coating maintenance strategies	23 respondents used spot touch-up painting 27 respondents used zone painting 21 respondents used overcoating 38 respondents used total removal and recoat
Surface preparation methods	20 respondents used low-pressure water cleaning 25 respondents used hand-tool cleaning to SP2 31 respondents used power-tool cleaning to SP3 9 respondents used power-tool cleaning to SP15 23 respondents used power-tool cleaning to SP11 7 respondents used brush-off blasting
Coating systems	24 respondents used qualified products list for all work 9 respondents used qualified products list for contract painting 9 respondents did not use any qualified products list
Use of in-house painting forces versus contractors	1 respondent used only in-house forces 27 respondents used only contractors 14 respondents used a mix

Table 2-3 2013 KTA-Tator survey of DOTs for Minnesota DOT

In April 2014, KTC distributed a survey to DOTs and other bridge owners as part of the NCHRP 14-30 study. The survey was distributed using a contact list of DOT officials the NCHRP 14-30 study panel provided (primarily the DOTs’ TSP 2⁹ meeting representatives). The original e-mail list contained 50 DOT contacts. The NCHRP 14-30 study panel also provided several non-DOT transportation agency contacts (e.g., municipal transportation agencies and toll authorities). The International Bridge and Tunnel Turnpike Association¹⁰ provided another contact list of non-DOT transportation agencies that was included in another survey distribution. The e-mail list to non-DOT agencies included 42 contacts. Of the 36 survey responses received, 31 were from DOTs and five were from non DOT agencies. Table 2-4 represents the key findings from the survey

Bridge coating maintenance strategies	18 DOTs and 5 non- DOTs used spot painting 25 respondents used zone painting 23 respondents used overcoating 28 respondents used total removal and recoat
Inspection methods	35 respondents used a mix of in-house personnel and consultants 14 respondents used in-house personnel 13 respondents used consultants
Coating systems	22 respondents used qualified products list for all work
Use of in-house painting forces versus contractors	12 respondents used only in-house personnel 18 respondents used only contractors 8 respondents used a mix
Estimates of expected service life for spot painting	7 respondents at 15+ years 12 respondents between 10 and 14 years 12 respondents between 5 and 9 years 4 respondents between 2 and 4 years

Table 2-4 2014 KTC survey for the NCHRP 14-30 study

9 Transportation System Preservation Technical Services Program (TSP 2), American Association of State Highway and Transportation Officials, <https://www.tsp2.org/>

10 International Bridge, Tunnel and Turnpike Association, <http://www.ibtta.org/>

Bridge Painting Operations and Factors

Following is a general discussion about the different factors that are considered and operations that are undertaken as part of bridge painting. It also includes some historical perspective of DOT practices.

Bridge Environment

Local environment of the metal on a structure has substantial influence on the rate of corrosion of the exposed steel and the deterioration of the protective coating. Volume 2 of the The Society for Protective Coatings¹¹ (SSPC) Painting Manual¹² lists and classifies exposure environments. For highway bridges, the following types of environments are considered most relevant.

- **Mild (Rural):** Little to no exposure to natural airborne and applied deicing salts; low pollution in the form of sulfur dioxide, low relative humidity, absence of chemical fumes, usually an interior (inland) location
- **Industrial:** High sulfur dioxide or other potentially corrosive airborne pollutants, moderate or high humidity. This classification has become less important in recent years as long-term corrosion data shows the corrosive effects of airborne pollutants has diminished with the implementation of clean stack gas regulations. However, this atmospheric classification is still a consideration directly downwind of known corrosive process stream contaminants.
- **Moderate:** Some (occasional) exposure to airborne salts or deicing salt runoff
- **Severe (Marine):** High salt content from proximity to seacoast or from deicing salt; high humidity and moisture

The macro environment can be determined from the geography (proximity of seacoast, industry, and cities) and climate (acidity and quantity of rainfall, relative humidity, and pollution levels) as previously described. However, the decision on painting should require individual inspection of the structure to determine the microenvironment of specific areas of a bridge. In particular, the performance of the coating system used previously and the pattern of coating deterioration and corrosion must be considered to select the most suitable coating for repainting.

Surface Preparation

Surface preparation typically involves either abrasive blasting or hand- and power-tool cleaning. Abrasive blasting has been and continues to be the predominant method for surface preparation of bridges prior to repainting. Blasting is accomplished with either recycleable steel grit or expendable abrasives. Specification requirements differ among bridge agencies, with some requiring steel grit in an effort to minimize the volume of waste generated during surface preparation. Other agencies allow the contractor to choose the method of blasting based on the particular economics of a bridge painting operation.

11 The Society for Protective Coatings (SSPC), <http://www.sspc.org/>

12 SSPC Painting Manual, Volume 2, The Society for Protective Coatings, <http://www.sspc.org/PB-00802>

Historically, the specification for existing bridges was that they be cleaned to an SSPC SP-6 commercial blast. In recent years, the practice has been to specify SSPC SP-10, near-white metal (see Figure 2-1). There are several reasons for this practice. First, as the cost of this work has increased, greater attention has been given to the resultant quality of maintenance painting work. In addition, many of the structures being repainted today were originally constructed leaving intact mill scale coated with lead-containing alkyds. For the majority of the structure, a blast job that sufficiently removes mill scale (as required by SSPC-SP-6 and SSPC-SP-10) tends to leave a final surface closer in appearance to SSPC-SP-10. This phenomenon has led to several disputes between owners and contractors. Hence, the trend had been to specify SSPC SP-10 up front to avoid potential disagreement.

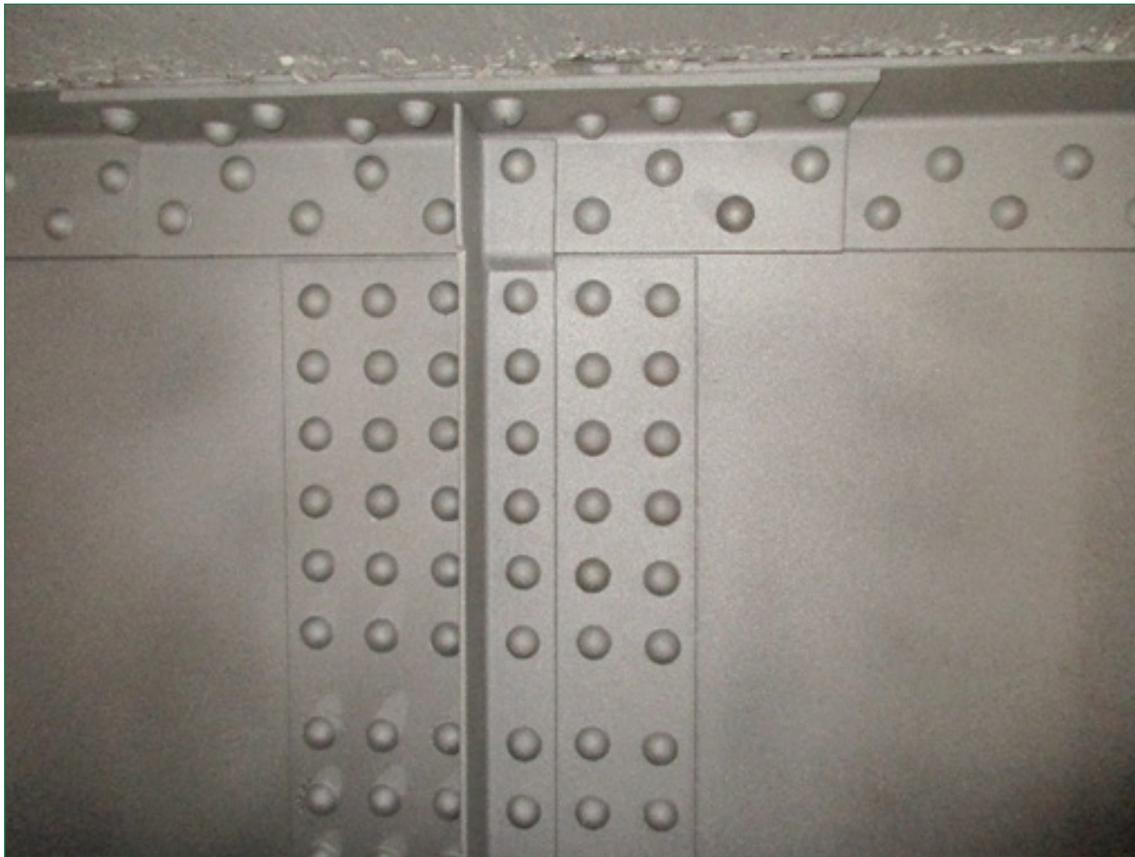


Figure 2-1 State Highway 310 over Trinity River in Dallas, TX, blasted to SSPC-SP-10

Abrasive blasting is still considered the most productive method available to provide a clean surface capable of receiving high-performance coatings (e.g., zinc-rich primers). Typical production rates seen on bridge painting jobs range from 50 to 250 square feet of steel cleaned per man-hour of blasting, depending on the particulars of the job, the abrasive, and the equipment. Typical production rates for recyclable steel grit are around 200 square feet per man hour.

About half of the bridges painted annually are overcoated. This method of maintenance painting usually entails washing of the steel with water and mechanical surface preparation using power tools to remove loose paint and rust from the existing surface. The predominant specification calls for SSPC-SP-3, power tool cleaning, in the areas where deteriorated paint or rust is visible.

Other power tool methods, SSPC-SP-11, “Power Tool Cleaning to Bare Metal,” and SSPC SP-15, “Commercial Grade Power Tool Cleaning, can be used with high-performance coatings. Power tool cleaning is labor intensive, with slow production rates. It is only suitable for preparation of surfaces without extensive deterioration and for cleaning and repairing small areas in an otherwise intact existing coating. In addition, power tool cleaning with vacuum systems generally requires much less stringent containment and produces less waste than abrasive blasting.

In recent years, the bridge painting industry has seen an influx of new technology, particularly in the area of surface preparation. Cleaning methods using high-pressure water have gained a foothold in the market and are often attractive due to the improved productivity of newer water blasting equipment. The inherent low-dust nature of this approach and the added benefit of a reduction in surface chemical contaminants (e.g., chlorides) as compared to other (i.e., dry) surface preparation technologies are advantages of high-pressure water surface preparation techniques. SSPC-SP WJ 1, WJ 2, WJ 3, and WJ 4 provide guidance for the specification of pressurized water paint removal methods.

One limiting factor in the use of water for surface preparation for bridge steel is that the vast majority of bridges were constructed with adherent mill scale beneath the original paint system. Since water alone, regardless of pressure, will not give a surface profile, this limits the application of this technology for bridges intended for painting over a fully cleaned and profiled surface. For newer bridges that did receive initial blasting in the shop (i.e., those built after about 1970) or for bridges that have been previously blasted and painted, wet methods provide some attractive benefits. Water blasting will also cause flash rusting that needs to be re-blasted if zinc primers are to be used.

In addition, many pieces of equipment can offer water blasting in conjunction with some type of abrasive injected into the working water stream. These set ups have proven very versatile in their initial use in bridge maintenance applications. In particular, these methods are an attractive substitute for surface preparation using hand-held power tools. Productivity can be up to 100 square feet per man-hour, and injection of various grits into the water stream can allow for selective removal of deteriorated paint and rust, while leaving areas of intact paint as is.

In certain situations, nonabrasive dry methods are needed to remove existing coatings. Among these methods are chemical strippers and methods using electrical current. These methods are not widely used but may have a larger role in the market in the future. Chemical strippers have been used on some structures that are in sensitive areas where the potential release of lead-containing dust from abrasive blasting is a concern (i.e., aspiration hazards and skin corrosion to workers).

Coating Materials

In the past, bridge steel was painted in the lowest cost manner to achieve steel throughput from the shop and a marginal level of corrosion protection and aesthetics. Until the 1970s, steel was shop and/or field painted using alkyd coatings, which contained high amounts of lead. These coatings were applied directly over intact mill scale with little to no significant surface preparation. In addition, several states used alkyds with aluminum pigments as standard

topcoats. Typically, any maintenance painting was done with coatings similar to the original to avoid compatibility problems; this repeated overcoating of lead alkyds resulted in bridges having film builds approaching over 30 mils.

In the 1970s, state highway agencies began to specify shop blasting to remove all mill scale and provide a clean, profiled surface for painting. This led to the extensive use of zinc-rich primers. This system has shown consistent performance of 25 years or more on many of the original applications.

Today, the use of lead-containing paints has been eliminated. New laws governing paint solvent content (i.e., volatile organic compound [VOC] regulations) have prompted new formulations for industrial maintenance coatings. Presently, coating materials used to protect steel bridges can be divided into two categories: coating systems for new and blasted steel using zinc-based coatings systems and coatings for maintenance painting without abrasive blasting using barrier or inhibitive coatings/systems.

Most DOTs currently specify the use of some type of zinc-based coating system in conjunction with abrasive blasting. For new steel, although the use of full shop application for all coats is increasing, the predominant approach is to blast and prime in the shop and apply topcoats following erection of the structure. Inorganic zinc primers are commonly used for shop painting. For field painting, when abrasive blasting is employed, there is a split between the use of inorganic and organic zinc-rich primers. A 1996 survey by the Transportation Research Board (TRB) found that 42 of 54 bridge agencies specify zinc-rich primers for new construction. Fewer states specify zinc-rich primer systems for maintenance painting of existing structures.

Topcoats for zinc-rich systems vary widely. The early inorganic zinc-based coatings employed vinyl topcoats in the 1970s. Regulations limiting the amount of solvent in coatings eliminated the use of vinyl coatings for structural painting. The predominant topcoat system used for zinc-rich primers is an epoxy mid-coat with a polyurethane topcoat. Three-coat polyurethane systems have become popular with bridge owners and bridge painting contractors. These systems are predominantly two coats of moisture-cured polyurethane (including a zinc-based primer) with a two-component aliphatic polyurethane as the topcoat to resist weathering.

Other agencies have gone to a system in which waterborne acrylic is substituted for the vinyl topcoat previously used over inorganic zinc. A small but growing number of bridges have been metalized. Metalizing requires at least an SSPC-SP-10 or SP-5 abrasive blast cleaning and application of 8 to 12 mils of thermal sprayed metal (either zinc or zinc/aluminum alloy). This system has many years of demonstrated durability, and recent improvements in application equipment have made metalizing more attractive for both shop and field applications to bridge steel. It remains an expensive option compared to liquid-applied coatings.

In maintenance painting applications where the existing coating system is not completely removed, bridge agencies specify a range of coatings. Zinc-based coatings are typically not used for more than spot applications as they do not function properly unless in contact with bare steel. Barrier and inhibitive coatings/systems are used for most spot and overcoating painting; these

typically are marketed as “surface tolerant” coatings. Among the most popular coatings are (generically) high-build epoxies (epoxy mastics), moisture-cured polyurethanes, calcium sulfonate modified alkyds, low-VOC alkyds, and direct-to-metal acrylics.

Several variables identified as critical to the success of overcoating applications include the:

- Adhesion of the existing coating that remains after surface preparation to the steel substrate
- Compatibility of the remaining existing coating with the new topcoat
- Amount and condition of the exposed steel substrate
- Thickness of the remaining existing coating

Coating Application Techniques

Bridge coatings can be applied by spraying, brushing, or rolling, depending on the requirements of the particular job. Most coatings are applied using airless spray. However, in many cases where nearby traffic or facilities may be impacted by overspray, DOTs may restrict the use of spray equipment; brushing or rolling may be required in lieu of spraying in the containment. With the use of containment on all blasting jobs (see Figure 2-2), specifications commonly require the containment to remain in place for spraying of the primer and subsequent topcoats. The containment can also be moved after spraying the primer; the final coats can be brush or roll-applied.



Figure 2-2 **Containment for US 67 over Texas Pacifico Railroad in Ballinger, TX**

There has been a renewed emphasis on stripe painting technique for the complex surfaces of bridges. Most striping is specified as hand striping using only a brush. Stripe painting is considered good painting practice for slower drying coatings. These coatings tend to “thin” at edges and acute angled surfaces due to the surface tension of the wet-applied paint film. Often, this phenomenon has caused paints to fail prematurely on edges of flanges and fasteners. Stripe coating of these areas will ensure proper paint film build and should alleviate this potential problem.

Summary of Impact of Regulations

Federal and local regulations have effectively eliminated the use of traditional lead-based alkyd paints and high-solvent paints. Specific environmental and worker health and safety regulations have been established to limit the generation, handling, and disposal of waste containing toxic heavy metals (e.g., lead, arsenic, and chromium). Air pollution regulations continue to reduce the allowable solvents in coatings that are linked to the development of low-level ozone (i.e., smog) in populated areas. Table 2-5 provides an outline of the critical regulations and their direct impact on the coatings industry.

Impacting regulation	Effect on coating operations
OSHA; CFR 29 1926.62, Lead in Construction	Establishes guidelines for protection and monitoring of workers removing lead paint from bridges; requires lead training and monitoring for workers
EPA; Resource Conservation and Recovery Act (RCRA)	Regulates the handling, storage, and disposal of waste containing lead (and other heavy metals); can increase the cost of disposal of waste from bridge paint removal by 10X
EPA; Title X, Residential Lead-Based Paint Reduction Act of 1992	Mandates training and supervision requirements for workers associated with lead-containing paint removal
EPA; Comprehensive Environmental Response Compensation and Liability Act (CERCLA or Superfund)	Assigns ownership of and responsibility for hazardous waste to the generator “into perpetuity”
EPA; Clean Water Act	Regulates discharge of materials into waterways
EPA; Clean Air Act Amendments	Mandates restrictions on allowable VOC content of paints and coatings; regulates discharge of dust into air from bridge painting operations

Table 2-5 *Regulations impacting the bridge painting industry*

Industry has responded to these regulatory drivers by providing a broader spectrum of coating materials that are compliant with new regulations. These factors have combined to make the selection and specification of coating materials for steel structures a more complex practice requiring a significant knowledge of the performance and application properties of a wide range of coating materials.

Additionally, compliance with environmental and health and safety regulations has created significant change in the methods used for bridge maintenance painting. “Open” abrasive blasting, the dominant method of surface preparation until the 1990s, is a thing of the past. Specifications and regulations requiring containment of surface preparation activities vary and continue to evolve; however, the time, labor skill, oversight, and equipment requirements for steel surface preparation have all increased dramatically over the past 15 years. In fact, a “typical”

simple overpass repainting job that may have required less than \$100,000 in capital equipment to accomplish can now require nearly \$1 million in specialized gear at the jobsite. These new methods have produced a general increase in maintenance painting costs of 200% to 500% over the past decade. Although these cost increases caused a significant reduction in the number of bridges being painted during the 1990s, this trend is reversing. The costs are now decreasing somewhat and the new requirements (and their associated costs) have placed a higher premium on work quality in maintenance painting operations.

Scan Findings and Observations

Determination of Agency Funding Levelst

The best approach for DOTs is to have an overarching preventive maintenance program or, more desirably, a steel bridge preservation program with dedicated funding for bridge painting based on an algorithm incorporating inventory, structure condition, and other structure-specific attributes. The objective of any preservation program is to utilize available preservation funds in the most effective manner and. More often than not, utilizing these funds to restore or replace coatings systems to prevent corrosion provides the greatest benefit system-wide.

DOT use of lifecycle costs is the most effective means of coatings decision-making. Many times the cost to the traveling public is disregarded in these processes. However, these costs often dwarf capital investment costs when assessing the investment on larger, more critical, high-ADT (average daily traffic) structures. Guidance by coatings experts can help DOTs select the best approach and provide historic performance cost and service life data for use in project level decision-making.

All participating DOTs have preventive maintenance programs; six had dedicated steel bridge preservation programs. The scan team found that those with dedicated programs were the most organized and effective at implementation. However, the scan team also recognizes that those with dedicated programs also have large inventories of existing steels bridges and that dedicated funding for bridge painting may not be the best practice for all owners.

FHWA's Origins of the Interstate Maintenance Program website¹³ gives detailed information about the program.

Evaluation Practices for In-Situ Coatings Prior to Recoating

For coatings condition assessments, all DOTs indicated that they performed evaluations to some degree before making maintenance painting decisions by following National Bridge Inspection Standards¹⁴. All DOTs used the biennial bridge safety inspection to qualitatively assess coating condition to some degree and prioritize bridges for more rigorous special coating inspection. Some participating DOTs performed their special coating condition assessments with in-house personnel, while others used consultant staff; some used a combination of both. In the field,

13 Origins of the Interstate Maintenance Program, Federal Highway Administration, U.S. Department of Transportation, <https://www.fhwa.dot.gov/infrastructure/intmaint.cfm>

14 National Bridge Inspection Standards, Federal Highway Administration, U.S. Department of Transportation, <https://www.fhwa.dot.gov/bridge/nbis.cfm>

coating inspectors typically used: SSPC-VIS 2, “Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces,” custom photographs, tensile adhesion testers, tape/knife adhesion, Tooke gage¹⁵, coatings thickness gauges, steel thickness gauges, pit depth gauges and soluble salt kits for painting evaluations.

DOTs that have fully transitioned¹⁶ to element-level bridge inspection have better data to work with to prioritize their coatings rehabilitation candidates since there is a specific element for coatings. With element-level inspection according to the AASHTO Manual for Bridge Element Inspection¹⁷, the coating condition of individual elements is documented, rather than just giving an overall superstructure condition rating. DOTs should consider the mechanism of coating system deterioration and include agency-defined element conditions in their reports to help make more refined, data-driven decisions. These decisions cannot be realized by using just the National Bridge Elements¹⁸ tagged with additional Element 515 “Steel Protective Coating” condition data. Here are some examples of what owners have done:

- **Virginia DOT (VDOT)** developed two elements for tracking the condition of just beam ends and beam ends with coatings. For instance, uncoated weathering steel superstructures often have the beam ends painted, and Element 515 may have a biased condition state because it would not be known if poor or severe conditions were distributed throughout the element or were isolated to areas.
- **Oregon DOT** created an NBI element for inspectors to rate the condition of the coating system of an entire superstructure, not the structural element itself as Element 515. This helped the agency expedite data filtering of its inventory and allowed it to quickly prioritize its bridge candidates without having to link all structural elements along with their associated Element 515 condition states.
- **Iowa DOT** uses microenvironments to identify localized areas of a bridge. The environments include areas subject to deicing chemicals, such as beneath joints, areas exposed to weather, and protected areas. With this approach, the areas subject to accelerated deterioration are more easily discernible in overall condition assessment.

There may be advantages to DOTs that develop elements for generic coating systems (e.g., if existing paint has lead or if the owner specifically wants to track the deterioration of zinc-rich, three-coat systems or track the service life of coatings in wet areas, areas exposed to UV radiation, or areas exposed to deicing salts).

15 Micro-Metrics Company, <http://www.micro-metrics.com/T>

16 At the time this report was written, 23 USC 144(d)(2) required all owners to begin reporting element-level data to FHWA for all bridges on the National Highway System (NHS).

17 Manual for Bridge Element Inspection, 1st Edition, with 2015 Interim Revisions, American Association of State Highway and Transportation Officials https://bookstore.transportation.org/collection_detail.aspx?ID=129

18 Specification for the National Bridge Inventory Bridge Elements, January 21, 2014, Federal Highway Administration, U.S. Department of Transportation, https://www.fhwa.dot.gov/bridge/nbi/131216_a1.pdf

Surface Preparation

Surface preparation typically involves mechanical removal of loose paint and rust by hand tool cleaning (SSPC-SP-2). Sometimes pressurized water washing is used to remove surface contaminants. This operation may be followed by power tool cleaning or abrasive blast cleaning to a visual standard. The level of cleaning specified is dependent upon a number of factors, including the severity of the environment, the extent of paint failure and corrosion, the location/area of failed paint, the desired service life of the applied maintenance system, the type of paint system to be used, and the available budget for the operation. Depending on the level of cleaning, this step will remove loose particles (e.g., rust/nonadherent paint for SSPC-SP-3) or, to various degrees, tight mill scale and paint (SSPC-SP-5, SP-6, SP-7, SP-10, SP-11, SP-14, SP-15, SP WJ-1, SP WJ-2, SP WJ-3, and SP WJ-4).

DOTs participating in the scan workshop overwhelmingly specified a SSPC-SP-10 level of cleanliness for total removal and replacement remediation. Some DOTs continue to overcoat and spot coat; the specified level of surface preparation was varied. In the past two decades, the environmental and safety regulations have leveled the cost advantage between overcoating and total removal and replacement; as a result, many DOTs have moved away from overcoating. This is in contrast to the 1997 FHWA Study Tour for Bridge Maintenance Coatings¹⁹, when overcoating was becoming popular.

California DOT (Caltrans) was the only participant that performed overcoating and they used in-house painting crews with 100% containment to perform overcoat painting on structures with less than 20% rust. The agency actively pursued extending service life of their original lead-based primer coatings by using overcoating.

All DOTs mandated that their contractors comply with all local and federal regulations regarding the protection of personnel health and the environment. All DOTs utilized SSPC Guide 6, “Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations” to help establish the appropriate levels of containment during coating removal operations.

Some intriguing practices the scan team noticed were the following:

- **Oregon DOT** employed ultrahigh pressure (>20,000 psi) washing to remove pack rust before applying a sealer (Figure 3-1 through Figure 3-3).
- **Texas DOT (TxDOT)** specifications included a water blast (SSPC-SP WJ4) before any mechanical surface preparation.
- **New York State DOT (NYSDOT)** employed wet methods for surface preparation, such as hot pressure washing (180 °F at 3,000 psi), primarily to remove chlorides, bird droppings, and other environmental contaminants.

19 FHWA Study Tour for Bridge Maintenance Coatings, Federal Highway Administration, U.S. Department of Transportation, January 1997, <https://international.fhwa.dot.gov/Pdfs/BridgeMaintenanceCoatings.pdf>



Figure 3-1 *Ultra-high-pressure washing to remove pack rust on Willamette River Bridge in Corvallis, OR*



Figure 3-2 *Pack rust between eyebolt head and adjacent gusset plate before ultra-high-pressure washing*



Figure 3-3 *Pack rust removed using ultra-high-pressure washing*

Coating Option Decision-Making

Most DOTs that participated in the scan specified three-coat systems for maintenance painting involving zinc-rich primer for total removal and replacement. DOTs participating in the workshop estimated the service life of total removal and replacement using a three-coat system at between 15 to 30 years, and 10 to 20 years for overcoat projects. NASA's beachside atmospheric corrosion has shown that a single coat of inorganic zinc (IOZ) has outperformed most other coatings. The scan team was interested in uncoated IOZ or with a breathable topcoat as an option.

Due to the increased cost of maintenance painting of bridges, there is a significant interest among DOTs to adopt better performing (i.e., longer lasting) bridge coatings. This movement has been slow, in part because of the high degree of satisfaction with the current generation of zinc-rich coating systems; however, the use of coating systems such as galvanizing and thermal spraying is growing. Thermal sprayed metal coatings are not new and several bridges have been metalized for many years; however, the cost associated with the relative low productivity of the thermal spray application equipment has inhibited the specification of this coating in the bridge market. With new equipment and standards, prices for thermal spray have become more competitive and there is a current influx of metalizing for bridges.

NYSDOT and Ohio DOT had good experience using thermal spray in preventing corrosion; however, with time, the thermal spray does not provide an aesthetic coating (i.e., the spray pattern becomes evident or the coatings retained dirt and dust). Metalized bridges in NYSDOT had a service life comparable to three-coat systems. Many DOTs also had some galvanized bridges in their inventories.

DOT practitioners now have access to high-performance coating systems, such as 100% solids technology (epoxy and polyurea), fluoropolymers, powder coatings, and others. However, lack of U.S historical data and current coating laboratory evaluations/test methods/results do not differentiate them from conventional three-coat systems. As a result, high-performance coating systems are categorized with three-coat systems on DOTs' approved product lists and the contractor usually selects the cheapest coating system (which is also impacted by its availability or a relationship with a coating manufacturer) unless directed otherwise. For the same reason, vendors are reluctant to submit high-performance systems for testing with AASHTO/National Transportation Product Evaluation Program (NTPEP). The scan team identified this as a deficiency.

Scan team members identified a need for testing high-performance (ultra-weatherable) coating systems, both outdoors and by modified accelerated weathering testing, to generate data that will help DOTs justify using more expensive, longer lasting coating systems. Currently AASHTO/NTPEP evaluation involves topcoats with only one color. The scan team believes that different colors (i.e., red, blue, yellow, and green) should be tested to better differentiate performance of topcoats.

Use of Performance-Based Contracts (i.e., Warranties)

Four participating agencies (Maryland DOT, Oregon DOT, Michigan DOT, and the Golden Gate Bridge, Highway and Transportation District) have used or are in the process of using some form of warranty contracts for replacing existing coating systems. The contracts mandated warranties lasting two to 10 years, including withholding varying bonding amounts. The Maryland and Michigan DOTs utilized a two-year coating condition performance warranty backed by a bond equal to 25% of the total project value. In addition, the Maryland DOT inspected each of its structures about three months prior to the expiration of the warranty contract to provide ample time for both parties to fully enact the contract agreement to the satisfaction of the owner. The

Oregon DOT also uses warranties, but expects a three-year warranty with about 90% of the value of line items for surface preparation, temporary work platforms and containment, barges, pack-rust removal, coating materials, and coating application held as a performance bond. The Golden Gate Bridge, Highway and Transportation District requires five-year warranties on contracted painting work that encompasses labor and materials only.

The Ohio DOT had used three-year warranties in the past (i.e., eight years ago). The Florida DOT (FDOT) had one bridge warrantied for 10 years. VDOT is currently moving in a similar direction. It is implementing specifications that utilize warranties for bridge painting and requires a 12-month observation period that begins on the date of final acceptance of the contract.

Several issues that have been observed with warranties involved enforcement; follow-up actions were burdensome on DOTs. Many DOTs had very loose or overly restrictive language regarding “failure” definition that was either unenforceable or too specific. The scan team observed that Maryland DOT’s failure definition as described in its warranty specification is well written. See Appendix G for the warranty specification; section c for the failure definition) is well written.

Performance Evaluation of Coatings

Some DOTs use data from AASHTO’s NTPEP program to establish pass/fail criteria to create approved product lists. Many DOTs also perform in-house characterization of coatings for chemical composition. Two DOTs (TxDOT and Caltrans) specify in-house formulations.

Specifications for Coating Systems (Including Removal and Replacement, Overcoating, and Spot/Zone Coating)

All DOTs participating in the scan have their own standard field cleaning and painting specifications, standard special notes, and paint material specifications for painting work done by contract. The specifications varied in language for:

- Containments (restrictions for wind speed, responsibility over analysis of load rating, type of flooring, and air-flow requirements)
- Illumination requirements
- Surface preparation requirements
- Coating systems allowed from approved product lists
- Qualifications for contractors and consultant inspectors
- Recordkeeping requirements
- Hold points for quality control/quality assurance (QC/QA) inspections
- Stripe coating (primer and/or intermediate coat, tinting)
- Safety

- Waste designation and removal
- Traffic control restrictions

Some DOTs included plans of bridges in their specifications to aid the contractor.

The scan team identified a number of factors during the workshop that DOTs should take into consideration. For example, DOTs that had hold points had better experience with coatings and they provided for appropriate QC and agency inspection before moving on to next phase of work. There was varied practice among DOTs on which coating (i.e., primer, intermediate, or topcoat) to stripe. Using an edge-retentive coating with contrasting colors for striping helps distinguish it for inspection. In addition, best practices for shop priming have shifted from organic zinc (OZ) to IOZ and from masking faying surfaces to priming faying surfaces with IOZ. This helps in streamlining fabrication operations by eliminating masking and significantly improves corrosion protection at the faying surface, significantly delaying the formation of pack rusting. DOTs have issues with inspection of mist coats, even though they are sometimes necessary to properly apply coatings (e.g., mist coat of thinned epoxy over IOZ to fill rough spaces not well covered by subsequent full coat of unthinned epoxy).

Bridge preservation activities include using spot coating to preserve existing coats to improve their performance, bridge washing to remove surface contaminants, and bridge debris cleaning (i.e., removing debris from deck drains and increasing drain size). Washington State DOT (WSDOT) had such difficulties cleaning (Figure 3-4) and protecting its bridges (primarily from bird excreta) that it resorted to some innovative ideas. These included screening bridges, trapping and relocating birds with assistance from the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service, and encouraging raptors, like peregrine falcons, to nest near the structures to keep pigeons away (Figure 3-5 through Figure 3-7).



Figure 3-4 WSDOT bridge before cleaning



Figure 3-5 Screening used on WSDOT bridges to keep birds out



Figure 3-6 *USDA - approved traps for relocating birds from bridges*



Figure 3-7 *Encouraging peregrine falcons to nest near structures*

Quality Assurance Coating Inspection Requirements

All DOTs had some form of QA coating inspection as part of their maintenance coating operations. One agency performed inspections with in-house personnel, five used consultants, and the largest group, six agencies, used a mix of in-house personnel and consultants. All participating DOTs required consultants performing coating inspections to have a minimum of NACE Coating Inspector Program (CIP) Level 1²⁰ or SSPC Bridge Coating Inspector (BCI) Level 1 certification²¹; some DOTs also required the higher NACE CIP Level 3 or SSPC BCI Level 2. Requirements for their in-house personnel varied.

Quality Control Inspector Qualifications and Contractor Qualifications

All DOTs required that their QC inspectors have training in coatings evaluation and inspection methods before being assigned to a bridge painting project. Training of inspection workers was primarily on-the-job, followed by industry-based training (NACE and/or SSPC) or in-house instructor-led training. For contractor qualifications, nine DOTs required SSPC QP1²² and SSPC QP2²³, three required SSPC QP3²⁴ for shop painting, one DOT did not use the SSPC QP certification system, and one allowed SSPC QP7²⁵ for new contractors as a substitution for QP1 in limited circumstances.

²⁰ Certification Programs, National Association of Corrosion Engineers, <http://www.naceinstitute.org/Certification/>

²¹ Bridge Coating Inspector Program, The Society for Protective Coatings, <http://www.sspc.org/trn-crs-bci>

²² SSPC QP1 Certification (Field Application to Complex Industrial and Marine Structures), The Society for Protective Coatings, <http://www.sspc.org/qp-qp1>

²³ SSPC QP2 Certification Program (Field Removal of Hazardous Coatings), The Society for Protective Coatings, <http://www.sspc.org/qp-qp2>

²⁴ SSPC QP3 Certification Program (Shop Painting Certification Program), The Society for Protective Coatings, <http://www.sspc.org/qp-qp3>

²⁵ SSPC QP7, SSPC Painting Contractor Introductory Program, The Society for Protective Coatings, <http://www.sspc.org/qp-qp7>

Documentation used to ensure proper work included coating manufacturer product data sheets and application instructions, agency standard specifications/technical special notes, contractor QC records, agency best practices manuals, and other DOT-specific document requirements.

Agency Commitment to Supporting Future Preservation of Coatings

DOTs and most other bridge-owning agencies are employing asset management personnel/groups to determine their overall maintenance budgets on a system level. Typically, they use a bridge management system (BMS) such as BrM²⁶ (formerly known as Pontis) to determine network-level trends and to prioritize bridge needs based on system wide constraints. A BMS should be able to:

- Predict bridge deterioration, both with and without maintenance or repair activity
- Develop alternatives to improve bridges
- Estimate costs for improvement options
- Determine network-level maintenance strategies
- Generate budget reports

A BMS tool provides information that supports bridge management budget requests and provides an overall indication of the consequences of postponing remediation reliant upon different funding levels by predicting the future condition of an agency's bridges.

A bridge maintenance management system, on the other hand, is dedicated to project-level needs. It should be used to plan, schedule, budget, and monitor individual maintenance projects. Some DOTs have predetermined maintenance actions that can be programmed to identify specific bridge maintenance needs and prioritize work. BrM assists by performing project-level management decision making.

Each owner's central management needs to establish appropriate performance measures to assess how well the districts are using the available funding. Maintenance painting expenditures and painting option determinations may be made at the district level, but some accountability is needed and may require maintenance action reporting, which includes performance metrics that indicate whether the performance of coating projects are in conformance with the criteria upper management has established to reach longer lasting maintenance objectives. To support maintenance painting decision-making and reporting, and accurate project cost per work completed data for proper asset preservation, the districts should be provided with the necessary tools to promote consistent, agency-wide procedures.

To promote uniform decision making at the district level—especially in determining whether to select a painting option versus a “do nothing” option—service life cost estimates should be utilized to provide guidance and can be prepared for specific maintenance actions to address specific bridge coating conditions and alternatives. To facilitate that effort, simplified grading systems need to be provided that can be matched to the desired maintenance actions.

26 AASHTOWare™ Bridge Management (BrM) software (formerly Pontis), American Association of State Highway and Transportation Officials, <http://aashtowarebridge.com/>

Recommendations

Bridge painting is a cost-effective means of extending the functional performance of steel bridges. It should be in the toolkit of every DOT and all DOTs will be required to use it due to its economic impact to the taxpayer and its function viability. The applied coating should serve in an aesthetic and corrosion-preventive manner for an extended period of time, at least 15 years and up to 30 years based on the results of this scan. That service life range is an estimate and should only be dependent on the structure environment, not on other controllable parameters, such as surface preparation and application methods. Additionally, the painting work must meet regulatory requirements regarding both environmental and worker/public health. The seemingly simple act of applying coatings to bridge steel must accommodate all of these requirements for it to be a practical solution to preventing corrosion.

The scan team identified several factors that would result in premature coatings failure (singly or in combination with others), including:

- Inadequate surface preparation or coating application
- Residual surface contamination
- Incorrect coating thickness
- Improper environmental conditions for application
- Incorrect mixing or agitation
- Inadequate/incorrect coatings/materials
- Extreme exposure conditions
- Inadequate inspection
- Lack of qualified contractors
- Inadequate specifications

The recommendations in this report are based exclusively on the scan workshop and on the practices of the participating DOTs and facility owners.

The scan team recommends that the best approach for determination of agency funding levels of DOTs is to have an overarching preventive maintenance program or, more desirably, a steel bridge preservation program with dedicated funding for bridge painting based on an algorithm incorporating inventory, structure condition, and other structure-specific attributes. The objective of any preservation program is to utilize available preservation funds in the most effective manner. More often than not, utilizing these funds to restore or replace coatings systems to

prevent corrosion provides the greatest benefit system-wide by extending the service lives of bridges.

The scan team recommends that the best approach for evaluation practices for in-situ coatings prior to recoating is to have three types of elements for bridge protective coatings: agency-developed, national, and bridge-management elements. Better coating decisions can be made when field inspectors understand SSPC VIS 2, “Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces,” adhesion testing, and dry film thickness testing.

Oregon DOT’s surface preparation technique using ultrahigh-pressure washing to remove pack rust was the most prominently recommended practice coming out of the workshop. Other techniques include the California Golden Gate Bridge, Highway and Transportation District’s cable paint removal and painting practices. The scan team also considered Oregon DOT’s practice for removing pack rust by soaking it and applying heat to eliminate it to be effective. Michigan DOT was testing a coating removal process using lasers at the time this report was being prepared; the team believes this to be a cutting edge tool worthy of follow-up evaluation.

Several innovative coating systems the scan team recommends are:

- **Thermal spray** – Zinc spraying, or metallizing, is accomplished by feeding zinc wire or powder into a heated gun, where it is melted and sprayed onto the part using combustion gases and/or auxiliary compressed air to provide the necessary velocity.²⁷
- **Ultra-weatherable coatings** – The team identified a need for testing high-performance (ultra-weatherable) coating systems both outdoors and by performing modified accelerated weathering testing to generate data that will help DOTs justify using more expensive, longer lasting coating systems.

The scan team recommends the use of warranties for painting projects with the appropriate specification language to avoid possible conflicts and with terms not exceeding three years (refer to Appendix G for an example). Maryland DOT’s warranty specification provides a failure definition (refer to Appendix G, section c) and is recommended as a worthy definition. DOTs need to be aware of issues with using warranties on railroad bridges, as coordination between the railroad company and the contractor executing the warranty work will be challenging.

The scan team recommends that the current national test protocols need to be modified to test for high-performance coatings (i.e., ultra-weatherable), both outdoors and by modified accelerated weathering testing in the laboratory. The scan team also recommends incorporating colorimetry into testing so that more different-colored topcoats can be evaluated. In addition, vendors must be encouraged to submit high-performance systems for testing by AASHTO NTPEP program.

The scan team’s recommendations for specifications for coating systems include:

- Removal and replacement
- Overcoating

27 SSPC-CS 23/NACE No. 12/AWS C2.23M, Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc and Their Alloys and Composites for the Corrosion Protection of Steel

- Spot/zone coating containing specific specification improvements, like:
 - Painting beam ends (if a bridge employs weathering steel)
 - Incorporating hold points for inspection
 - Having full-time qualified inspectors on projects involving painting
 - Having an in-house paint team to resolve any disputes in the field

The scan team acknowledges that IOZ tends to outperform OZ based on NASA's beachside atmospheric exposure test site and recommends specification of IOZ for shop-coated steel for better service life and SSPC SP-10 abrasive blasting (or better) for field surface preparation of steel prior to coating. The team also recommends that mist coats be eliminated, as they are difficult to inspect except to hold blasted steel. The scan team recommends that faying surfaces be primed, and an edge-retentive coating for striping with different color contrasts be used as it improves inspectability.

Several bridge preservation activities the scan team recommends are using spot coating to preserve existing coats, bridge washing to remove surface contaminants, bridge cleaning (i.e., removing debris from gutter lines, pier caps, and abutment caps and clearing deck drains), increasing the size of deck drains, and encouraging raptors to nest near structures to keep other birds away from bridges.

For quality control inspection qualifications and contractor qualifications, the scan team recommends that DOTs specify SSPC BCI- or NACE-certified inspectors and consultants with 100% inspection required on painting projects.

For agency commitment to supporting future preservation of coatings, the scan team's recommendations are that communication between DOTs be established through publications, memberships/training, and agency-controlled (i.e., membership) blogs. Tracking detailed project coating information by stenciling that information on bridges or using tags or radio-frequency identification would help preserve coating information for future activities. The scan team also recommends eliminating joints when possible to reduce corrosion under joints. For waste disposal, the scan team recommends that waste be specified as hazardous unless proved otherwise. The scan team recommends TxDOT's specification language for handling waste²⁸.

²⁸ Managing Universal Waste, Texas Commission on Environmental Quality,
https://www.tceq.texas.gov/permitting/waste_permits/ihw_permits/ihw_universal_waste.html

Implementation Plan

CTC & Associates in coordination with Arora and Associates²⁹ will maintain contact with the scan team's members after the scan tour has been completed to support the team in detailed planning and dissemination activities. CTC will assist the team in identifying potential methods for communicating scan findings that are a match for the background, expertise, geographical location, and availability of the various team members. CTC will also provide planning, writing, editing, and coordination services to support the team's members in carrying out the activities.

CTC will also assist the team with creating tailored PowerPoint presentations and supplementary materials that focus on the specific scan technologies or practices most pertinent to each audience. CTC will track where team members make presentations and will post names and dates of presentations on the domestic scan website³⁰.

Potential implementation activities discussed on the last day of the workshop that CTC will be assisting the team with are in writing articles for publication in coatings magazines like *CoatingsPro Magazine*³¹, *Modern Steel Construction*³², *Journal of Protective Coatings & Linings (PaintSquare)*³³, *Durability + Design*³⁴, and others..

Many AASHTO committees and subcommittees, like TSP 2, Subcommittee on Bridges and Structures³⁵ Technical Committees 9 and 18, and the Subcommittee on Maintenance³⁶; the North East Protective Coating Committee³⁷; and the National Steel Bridge Alliance³⁸ were identified for presenting domestic scan results. Many national conferences (e.g., SSPC, NACE and TRB) were also identified to reach a wide audience.

29 Arora and Associates, P.C., <http://www.arorapc.com/>

30 U.S. Domestic Scan Program, <http://www.domesticscan.org/>

31 CoatingsPro Magazine, NACE International, <http://www.coatingspromag.com/>

32 Modern Steel Construction, American Institute of Steel Construction, <https://www.aisc.org/modernsteel>

33 PaintSquare, Technology Publishing Co., <http://www.paintsquare.com/>

34 Durability + Design, Technology Publishing Co., <http://www.durabilityanddesign.com/>

35 Subcommittee on Bridges and Structures, American Association of State Highway and Transportation Officials, <http://bridges.transportation.org/Pages/AnnualMeetingPresentations.aspx>

36 Subcommittee on Maintenance, American Association of State Highway and Transportation Officials, <http://maintenance.transportation.org/Pages/default.aspx>

37 North East Protective Coating Committee, <http://www.nepcoat.org/>

38 National Steel Bridge Alliance, <https://www.aisc.org/nsba/>

Appendix A: Resources

National/Industry Standards, Specifications, and Guidance

ASTM International³⁹

ASTM B117-11, Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM D16-11, Standard Terminology for Paint, Related Coatings, Materials, and Applications

ASTM D523-14, Standard Test Method for Specular Gloss

ASTM D610-08(2012), Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces

ASTM D660-93(2011), Standard Test Method for Evaluating Degree of Checking of Exterior Paints

ASTM D714-02(2009), Standard Test Method for Evaluating Degree of Blistering of Paints

ASTM D1014-09, Standard Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates

ASTM D1654-08(2016), Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

ASTM D3359-09e2, Standard Test Methods for Measuring Adhesion by Tape Test

ASTM D4138-07, Standard Practices for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive, Cross-Sectioning Means

ASTM D4214-07(2015), Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films

ASTM D4414-95(2013), Standard Practice for Measurement of Wet Film Thickness by Notch Gages

ASTM D4541-09e1, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5043-04(2009), Standard Practice for Field Identification of Coatings

ASTM D5064-07(2012), Standard Practice for Conducting a Patch Test to Assess Coating Compatibility

ASTM D 5065-13, Standard Guide for Assessing the Condition of Aged Coatings on Steel Surfaces

ASTM D5702-07(2012), Standard Practice for Field Sampling of Coating Films for Analysis for Heavy Metals

ASTM D5894-10, Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)

³⁹ ASTM International, <https://www.astm.org/>

ASTM D6677-07(2012), Standard Test Method for Evaluating Adhesion by Knife

ASTM D7055-09, Standard Practice for Preparation (by Abrasive Blast Cleaning) of Hot-Rolled Carbon Steel Panels for Testing of Coatings

ASTM D7091-13, Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

ASTM E337-02(2007), Standard Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

ASTM G85-11, Standard Practice for Modified Salt Spray (Fog) Testing

International Organization for Standardization (ISO)⁴⁰

ISO/TC 35/SC 12, Preparation of steel substrates before application of paints and related products

ISO 787-13:2002, General methods of test for pigments and extenders – Part 13: Determination of water-soluble sulfates, chlorides and nitrates

ISO 2808, Paints and varnishes – Determination of film thickness

ISO 4628-1:2016, Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 1: General introduction and designation system

ISO 4628-2:2016, Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 2: Assessment of degree of blistering

ISO 4628-3:2016, Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 3: Assessment of degree of rusting

ISO 4628-4:2016, Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 4: Assessment of degree of cracking

ISO 4628-5:2016, Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 5: Assessment of degree of flaking

ISO 4628-6:2011, Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 6: Assessment of degree of chalking by tape method

ISO 8501-1:2007, Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 1: Rust grades and preparation grades of

⁴⁰ International Organization for Standardization, <http://www.iso.org/iso/home.html>

uncoated steel substrates and of steel substrates after overall removal of previous coatings

ISO 8501-2:1994, Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 2: Preparation grades of previously coated steel substrates after localized removal of previous coatings

ISO 8501-3:2006, Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 3: Preparation grades of welds, edges and other areas with surface imperfections

ISO 8502-3:2017, Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)

ISO 8502-4:2017, Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 4: Guidance on the estimation of the probability of condensation prior to paint application

ISO 8502-6:2006, Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 6: Extraction of soluble contaminants for analysis– The Bresle method

ISO 8502-9:1998, Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 9: Field method for the conductometric determination of water-soluble salts

ISO 8504-1:2000, Preparation of steel substrates before application of paints and related products – Surface preparation methods – Part 1: General principles

ISO 8504-3:1993, Preparation of steel substrates before application of paints and related products – Surface preparation methods – Part 3: Hand- and power-tool cleaning

ISO 12944-1:1998, Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 1: General introduction

ISO 12944-2:1998, Paints and varnishes – Corrosion protection of steel structures by protective paint systems Part 2: Classification of environments

ISO 12944-4:1998, Paints and varnishes – Corrosion protection of steel structures by protective paint systems Part 4: Types of surfaces and surface preparation

ISO 12944-5:2007, Paints and varnishes – Corrosion protection of steel structures by protective paint systems Part 5: Protective paint systems

ISO 12944-6:1998, Paints and varnishes – Corrosion protection of steel structures by protective paint systems Part 6: Laboratory performance test methods

ISO 12944-7:1998, Paints and varnishes – Corrosion protection of steel structures by protective paint systems Part 7: Execution and supervision of paint work

ISO/TR 15235:2001, Preparation of steel substrates before application of paints and related products – Collected information on the effect of levels of water-soluble salt contamination

ISO 16276-1:2007, Corrosion protection of steel structures by protective paint systems – Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating – Part 1: Pull-off testing

ISO 16276-2:2007, Corrosion protection of steel structures by protective paint systems – Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating – Part 2: Cross-cut testing and X-cut testing

ISO 19840:2012, Paints and varnishes – Corrosion protection of steel structures by protective paint systems– Measurement of, and acceptance criteria for the thickness of dry film on rough surfaces

ISO 20340:2009, Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures

ISO 29601:2011, Paints and varnishes – Corrosion protection by protective paint systems – Assessment of porosity in a dry film

SSPC⁴¹ and NACE International⁴²

SP0108-2008, Corrosion Control of Offshore Structures by Protective Coatings

SP0213-2013, Definition of Set Soluble Salt Levels by Conductivity Measurements

SSPC Guide 6, Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations

SSPC Guide 7, Guide to the Disposal of Lead-Contaminated Surface Preparation Debris

SSPC Guide 9, Guide for Atmospheric Testing of Coatings in the Field

SSPC Guide 10, Guide to Specifying Coatings Conforming to Volatile Organic Compound (VOC) Content Requirements

SSPC Guide 15, Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates

SSPC Painting Manual Volume 1, Good Painting Practice

SSPC Painting Manual Volume 2, Systems and Specifications

SSPC Technology Update No. 1 (SSPC-TU 1), Surface Tolerant Coatings for Steel

SSPC Technology Update No.3 (SSPC-TU 3), Overcoating

SSPC Technology Update No. 5 (SSPC-TU 5), Accelerated Testing of Industrial Protective Coatings

41 The Society for Protective Coatings, <http://www.sspc.org/>

42 NACE (National Association of Corrosion Engineers) International, <http://www.nace.org/home.aspx>

SSPC Technology Update No. 8 (SSPC-TU 8), The Use of Isocyanate-Containing Paints as Industrial Maintenance Coatings

SSPC Technology Update No. 9 (SSPC-TU 9), Estimating Costs for Protective Coatings Projects

SSPC-PA Guide 4, Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems

SSPC-PA Guide 5, Guide to Maintenance Coating of Steel Structures in Atmospheric Service

SSPC-PA Guide 10, Guide to Safety and Health Requirements

SSPC-PA-1, Shop, Field and Maintenance Painting of Steel

SSPC-PA-2, Procedure for Determining Conformance to Dry Coating Thickness Requirements

SSPC-PA 14, Field Application of Plural Component Polyurea and Polyurethane Thick Film Coatings to Concrete and Steel

SSPC-PS 12.00, Guide to Zinc-Rich Coating Systems

SSPC-PS 12.01, One Coat Zinc-Rich Painting System

SSPC-PS 28.01, Two-Coat Zinc-Rich Polyurethane Primer/Aliphatic Polyurea Topcoat System, Performance Based

SSPC-PS 28.02, Three-Coat Moisture-Cured Polyurethane Coating System, Performance Based

SSPC-SP-1, Solvent Cleaning

SSPC-SP-2, Hand Tool Cleaning

SSPC-SP-3, Power Tool Cleaning

SSPC-SP-5/NACE No. 1, White Metal Blast Cleaning

SSPC-SP-6/NACE No. 3, Commercial Blast Cleaning

SSPC-SP-7/NACE No. 4, Brush-off Blast Cleaning

SSPC-SP-10/NACE No. 2, Near-White Blast Cleaning

SSPC-SP-11 Power Tool Cleaning to Bare Metal

SSPC-SP-14/NACE No. 8 Industrial Blast Cleaning

SSPC-SP-15 Commercial Grade Power Tool Cleaning

SSPC-SP-16 Brush-off Blast Cleaning of Non-Ferrous Metals

SSPC-SP-WJ-1/NACE WJ-1, Waterjet Cleaning of Metals—Clean to Bare Substrate

SSPC-SP-WJ-2/NACE WJ-2, Waterjet Cleaning of Metals—Very Thorough Cleaning

SSPC-SP-WJ-3/NACE WJ-3, Waterjet Cleaning of Metals—Thorough Cleaning

SSPC-SP-WJ-4/NACE WJ-4, Waterjet Cleaning of Metals—Light Cleaning

SSPC VIS 2, Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces

SSPC-VIS 3, Guide and Reference Photographs for Steel Surfaces Prepared by Power and Hand Tool Cleaning

Applicable Code of Federal Regulations (CFR)

Title 29 Labor⁴³

29 CFR 1910, Occupational Safety and Health Standards

29 CFR 1910.134, Respiratory Protection

29 CFR 1926, Safety and Health Regulations for Construction

29 CFR 1926.20, General Safety and Health Provisions

29 CFR 1926.21, Safety Training and Education

29 CFR 1926.28, Personal Protective Equipment

29 CFR 1926.52, Occupational Noise Exposure

29 CFR 1926.55, Gases, Vapors, Fumes, Dusts, and Mists

29 CFR 1926.59, Hazard Communication

29 CFR 1926.62, Lead

29 CFR 1926.100, Head Protection

29 CFR 1926.101, Hearing Protection

29 CFR 1926.102, Eye and Face Protection

29 CFR 1926.103, Respiratory Protection

29 CFR 1926.104, Safety Belts, Lifelines, and Lanyards

29 CFR 1926.302, Power-Operated Hand Tools

29 CFR 1926.451, General Requirements (under Scaffolds)

29 CFR 1926.500, Scope, Application, and Definitions Applicable to This Subpart (under Fall Protection)

29 CFR 1926.501, Duty to Have Fall Protection

29 CFR 1926.502, Fall Protection Systems Criteria and Practices

29 CFR 1926.503, Training Requirements

⁴³ Electronic Code of Federal Regulations (CFR) – Title 29,

<http://www.ecfr.gov/cgi-bin/text-idx?SID=c47f39569184aae7c586993ad34eaa75&mc=true&node=pt29.8.1926&rgn=div5>

Title 40 Protection of Environment⁴⁴

40 CFR Subchapter C, Air Programs

40 CFR Subchapter D, Water Programs

40 CFR 50, National Primary and Secondary Ambient Air Quality Standards

40 CFR 261, Identification and Listing of Hazardous Waste

40 CFR 262, Standards Applicable to Generators of Hazardous Waste

40 CFR 263, Standards Applicable to Transporters of Hazardous Waste

40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

40 CFR 268, Land Disposal Restrictions

40 CFR 302, Designation, Reportable Quantities, and Notification

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⁴⁴ Electronic Code of Federal Regulations, U.S. Government Publishing Office,

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Appendix B: Scan Team Contact Information



Figure B-1 *Scan team members*
Front (left to right): Tom Schwerdt, Charlie Brown, and Ray Bottenberg; back (left to right): Sudhir Palle, Mike Todsén, Justin Ocel, and Paul Vinik

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Appendix C: Scan Team Biographical Sketches

PAUL VINIK, PE (AASHTO Chair) currently serves as the state Structural Materials Engineer with the Florida Department of Transportation (FDOT) and has worked at the FDOT State Materials Office in different roles since joining FDOT in 2004. He is responsible for the FDOT structural materials program, which includes quality assurance activities for cementitious, prestressed concrete and steel manufacturing facilities as well as managerial oversight of the chemical, physical, and corrosion laboratories. Vinik is on the board of governors for the Society of Protective Coatings (SSPC). He chairs the National Transportation Product Evaluation Program's (NTPEP) Epoxy and Resin Based Adhesives technical committee. Vinik graduated from the University of South Florida with a bachelor's degree chemical engineering in 1994 and a master's degree in chemical engineering in 1997; he earned his professional engineer's license in 2004.

RAY BOTTENBERG, PE is the manager of the bridge preservation engineering unit at the Oregon Department of Transportation (ODOT) in Salem. In this role he oversees the design of steel bridge painting projects, concrete bridge cathodic protection projects, and movable bridge projects throughout the state. He has been with ODOT for 17 years, working as a designer of bridge preservation projects for 11 years. Prior to joining ODOT, Bottenberg worked for 11 years as an aircraft structures engineer for The Boeing Company. He holds a bachelor's degree in mechanical engineering from Oregon State University, is a member of NACE, and is a registered professional engineer in Oregon and Washington State.

CHARLES BROWN is a senior coatings consultant with Greenman-Pedersen, Inc. (GPI), providing services for the Maryland State Highway Administration as an area engineer for its coatings division. Brown helps manage the paint design section, which includes conducting quality assurance inspections on bridge painting operations, reviewing budget requirements, and compiling bridge painting contracts for the State Highway Administration. Before joining GPI, Brown worked for over 14 years as an operations manager for an industrial bridge painting contractor, overseeing all aspects of the company's operations. He also worked for 10 years as a manager of an industrial hygiene/safety consulting firm, providing training and OSHA audit inspections for federal, state, and local governments as well as contractors and manufacturing companies. Brown is currently a member of the AASHTO TSP 2 NBPP Coatings Group, chairman of the Education Program Advisory Committee for 2017 national conference and show of the Society for Protective Coatings (SSPC), a member of the SSPC QP-2 revision committee, and a past SSPC chairman for the Painting Contractor Certification Program Advisory Committee (PCCP). He is an SSPC protective coatings specialist and a NACE Level 3 certified coatings inspector with bridge certification.

JUSTIN OCEL has been an employee of the Federal Highway Administration since 2009, working at the Turner-Fairbank Highway Research Facility in McLean, VA, as the Structural Steel Research Program manager. His duties include developing and executing a research program for steel bridges that covers all aspects of steel bridges, including design, materials, and fabrication. Selection and performance of steel bridge corrosion protection systems falls under his program's purview. Ocel received his bachelor's degree from the University of Minnesota, master's degree from the Georgia Institute of Technology, and his doctoral degree from the University of Minnesota.

TOM SCHWERDT is a chemist and materials expert for the Texas Department of Transportation (TxDOT) materials lab in Austin, focused on paints and corrosion. His primary duties include field auditing of onsite bridge painting inspectors, coatings condition assessments, specifications development, and materials evaluation. He is active in numerous industry standards and training committees, including ASTM D01, SSPC, and NACE. Before joining TxDOT in 2005, Schwerdt worked as a chemist for an independent paint laboratory in Houston after an internship at the Naval Surface Warfare Center. He holds a bachelor's degree in chemistry, with honors, from the University of Delaware.

MIKE TODSEN, PE is the special projects engineer for the Iowa Department of Transportation (Iowa DOT) Office of Bridges and Structures. In this position, he serves and the lead specialist on the inspection, evaluation, maintenance, and management needs for major highway structures. Additionally, he manages the ancillary structure inspection, underwater inspection, and nondestructive evaluation programs. He has been with Iowa DOT since 1994. Todsen holds a bachelor's degree in civil engineering from Iowa State University and is a licensed professional engineer.

SUDHIR PALLE, PE (Subject Matter Expert) is a senior research engineer at the Kentucky Transportation Center (KTC), a research center attached to the College of Engineering at the University of Kentucky. He has been employed at KTC since 1997 and worked on a wide variety of transportation research topics, including coatings development and testing, corrosion analysis and prevention, environmental issues, facilities management, nondestructive testing, maintenance practices, and project development. He helped in facilitating meetings of the Midwest Bridge Working Group, which focused on assisting state highway agencies and other stakeholders improve practices related to bridge maintenance and inspection. Palle is the lead manager for concrete coatings evaluation for AASHTO NTPEP at KTC, is active in numerous TRB committees, and is a member of SSPC. Palle graduated from the University of Kentucky with a master's degree in civil engineering in 1997 and a master's degree in business administration in 2010.

Appendix D: Amplifying Questions

1. Tell us about your agency
 - a. Do you have a formal steel bridge preservation program? If so what type of funding mechanism do you have (dedicated and managed)? # of staff do you have for bridge preservation? # of staff you have for bridge painting program?
 - b. What kind of trends do you see for capital funding for maintenance at your agency? What legislation/laws or policy do you have specifically earmarking funds for maintenance?
 - c. How are the bridge preservation funds appropriated? What steps has your agency taken to sustain future funding for bridge maintenance painting?
 - d. Who selects/identifies potential projects? What criteria does your agency use for programming and prioritizing painting projects?
 - e. What type of protective coatings does your agency use: conventional 3-coat, 2-coat, galvanizing, metalizing, conversion coatings, or duplex systems? Can you provide an approximate number/percentage of bridges that use the above coatings?
 - f. Does your agency have standard specifications or project-specific specifications for bridge maintenance painting? If so, please provide a link to those documents. Are your maintenance painting contracts developed by in-house or consultant employees?
2. Scan questions for evaluation of coatings in the field
 - a. What criteria do you have for evaluating existing paint condition?
 - b. What type of service environments (e.g., salt-water marine, fresh water marine, desert, snow, ice, etc.) does your agency deal with?
 - c. Who evaluates existing paint conditions (i.e., in-house, consultants, or independent)?
 - d. Does your agency have a defined frequency for paint evaluations?
 - e. What qualifications does your agency require for performing coatings evaluations?
 - f. What criteria do you use to select a coating method (i.e., spot, zone, overcoating, or recoat)?
3. Scan questions on types of painting systems DOTs use
 - a. What criteria do you use to select appropriate paint system for use on a particular bridge?
 - b. Does your agency have a material specification and/or approved list for coatings?
 - c. What criteria does your agency use to develop material specifications or list of approved materials? Who approves the materials?
 - d. What is your agency's working definition of the following terminology: spot, zone, overcoat, and total removal?
 - e. What type of surface preparation does your agency specify for total removal, spot, zone, and overcoat (e.g., SSPC SP5, SP 10, or SP 6)?

- f. How does your agency specify containment? How do you address wind speed issues? Structural load concerns? Abrasive accumulation? Type of flooring? Clearance above navigable waters? Airflow inside containment?
- g. How do you specify or limit the types of blast abrasive used?
- h. Please respond to the matrix describing the different coating systems your agency uses, the life expectancy of those coatings, and the typical failure mechanisms observed and the remedies.

Coating Options	Types of Coatings Used/ Service Environment	Life Expectancy of the System and Actual Service Life of the System	Average Total Cost Per Square Foot
Spot Coating			
Zone Coating			
Overcoating			
Total Removal and Recoat			

Coating Options	Describe the Failure Mechanisms Observed		Remedies	
	Aesthetics - Down Gloss, Discoloring, Delamination/ Debonding, etc.	Corrosion - Delamination/ Debonding, Rust Through, Staining, etc.	Aesthetics	Corrosion
Spot Coating				
Zone Coating				
Overcoating				
Total Removal and Recoat				

4. Scan questions on paint warranties for DOTs
 - a. Are warranties working? How does your agency provide support for warranty contracts? Is your agency able to enforce warranties? If so, on what types of projects (i.e., total removal, over coat, spot, or zone painting)?
 - b. What coatings are you specifying when you require warranties?
 - c. What are your performance criteria for the warranty?
 - d. How and who determines the repair method for warranty repair work?
 - e. What is the approval process for the method in which the contractor will repair defective work?
 - f. Do you require bonding or some type of insurance for the paint warranty?
 - g. How is the bond or insurance amount determined for your paint warranties?
 - h. What is the typical length of your warranty?
 - i. How does your agency pay for warranty (i.e., incidental or line item)?

5. Scan questions on paint inspection during painting operations for DOTs
 - a. Do you use consultants or in-house staff to conduct paint inspections?
 - b. How is the funding for third-party inspection administered?
 - c. What are the required qualifications/certifications or training for in-house inspectors?
 - d. What are the required qualifications/certifications/training for consultant inspectors?
 - e. Are paint inspectors used on job-specific assignments or do they work year round on different jobs?
 - f. How does your agency handle inspections in the field (i.e., full-time inspectors or hold point inspection)?
 - g. What are the defined hold points in your agency's specification?
 - h. Who manages/oversees QA paint inspectors in the field?
 - i. Who is responsible for the ongoing training of the paint inspectors out in the field?
 - j. How do you maintain consistency of inspection in the field between paint inspectors?
 - k. Who has final authority regarding issues in the field (i.e., paint inspector; project engineer; or district, region, or headquarters)?
 - l. How does your agency evaluate inspectors after the job is completed?
 - m. What requirements do you have pertaining to QA inspection (e.g., access, safety, etc.)?
 - n. What type of documentation do you retain for completed projects?
6. Scan questions on QA/QC
 - a. Does your agency require QP1 and QP2 qualifications for the contractor?
 - b. Does your agency review the contractor's past performances before letting a contract? If so, what is the process; how is it done (e.g., OSHA, SSPC, etc.)?
 - c. Does your agency audit the contractor and the projects after completion of projects? If so, what type of documentation and reports are required.
 - d. What type of records do the QA and AC inspectors require (e.g., daily, weekly, monthly information records, photographs, progress charts etc.)?
 - e. Do your contracts explicitly require the contractor to perform QC? Please share the operative language.
 - f. Do you specify minimum requirements for the contractor's QC plan?
 - g. Do you require the contractor to provide a QC manager and allow the contractor's superintendent to perform this function? If a QC manager is required, what authority is associated with this position? Does the QC manager have to be an employee of the contractor?
 - h. Do your contracts include any payment for QC separate from payment for the coating work?

-
- i. What is your typical ratio of contractor QC inspectors to agency and/or third-party QA inspectors?
7. Miscellaneous questions:
 - a. Any specific problems with maintenance painting and/or innovative practices employed in any ongoing or planned projects that your agency would like to share with the scan team?
 - b. How does your agency address the above problems?
 - c. Does your agency experience life-cycle problems related to coating systems? If so, what remedies are undertaken?
 - d. Does your agency have a database for all the above collected data? If so, is it proprietary or AASHTOWare™ software.
 - e. What did we miss? Is there some better technique or approach to steel bridge maintenance painting you use that we didn't address?

Appendix E: Scan Workshop Agenda

NCHRP 20-68A – US Domestic Scan Program

Domestic Scan 15-03

Successful Preservation Practices for Steel Bridge Coatings Workshop

Orlando, FL

Monday, May 23 – Friday May 27, 2016

(May 27, 2016 final team meeting – scan team ONLY)

Caribe Royale All-Suite Hotel & Convention Center

8101 World Center Drive, Orlando, FL 32821

Phone: (407) 238-8000

WORKSHOP AGENDA

Scan Workshop Schedule

Sunday May 22, 2016	Monday May 23, 2016	Tuesday May 24, 2016	Wednesday May 25, 2016	Thursday May 26, 2016	Friday May 27, 2016	Saturday May 28, 2016
<i>Workshop participants travel to the meeting location</i>	Whole day workshop from 8am to 5:45pm	Whole day workshop from 8am to 5:30pm	Whole day workshop from 8am to 5:30pm	Whole day workshop in Kennedy Space Center from 9am to 6pm	(SCAN TEAM ONLY) Scan team final meeting from 8am to 5pm <i>(Invited participants travel back home)</i>	<i>Scan team members travel back home</i>

Scan Workshop Agenda

Team Kick-off Meeting (Sunday, May 22, 2016)

Hotel conference room: Barbados

(located in main reception building lower level)

(Scan team ONLY)

Start Time	Discussion Topic	Moderator
8:00 pm – 8:30 pm	<u>Brief Kick-off Meeting</u> Review of Final Agenda and Logistics Team Assignment Collect team presentations General Discussion, Rehearsal	Mike Wright Paul Vinik Melissa Jiang

Day 1 (Monday, May 23, 2016)
Hotel meeting room: Martinique 2
 (located in Main Reception Building lower level)

Start Time	Discussion Topic	Presenter	Moderator
7:00 am	Breakfast (Breakfast Buffet for Tropicale restaurant, voucher provided when check in at hotel)		
8:00 am	Opening and Overview Greeting and Welcome (5 minutes) Welcome and Introduction (40 minutes) Team Introduction Participant Introduction and Expectations Overview of the agenda	Mike Wright Paul Vinik Scan 15-03 AASHTO Chair	
8:45 am	Florida Department of Transportation Presentation	Paul Vinik	Charlie Brown
10:45 am	Break		
11:00 am	Maryland State Highway Administration Presentation	Greg Roby Charlie Brown	Ray Bottenberg
Noon	Lunch (Roundtables at the back of the meeting room)		
12:45 pm	Maryland State Highway Administration Presentation (cont'd)	Greg Roby Charlie Brown	Ray Bottenberg
1:45 pm	Oregon Department of Transportation Presentation	Ray Bottenberg Joel Boothe	Mike Todsen
3:45 pm	Break		
4:00 pm	Washington State Department of Transportation Presentation	Chris Keegan	Tom Schwerdt
6:00 pm	Open Discussion on Day's Presentations		Paul Vinik
6:15 pm	Adjourn for Day (Closing and Announcement)		Mike Wright Paul Vinik

Day 2 (Tuesday, May 24, 2016)
Hotel meeting room: Martinique 2
 (located in Main Reception Building lower level)

Start Time	Discussion Topic	Presenter	Moderator
7:00 am	Breakfast (Breakfast Buffet for Tropicale restaurant, voucher provided when check in at hotel)		
8:00 am	Virginia Department of Transportation Presentation	Jeff L. Milton	Justin Ocel
10:00 am	Break		
10:15 am	WEBINAR New York State Department of Transportation Presentation	William R. Feliciano	Charlie Brown
12:15 pm	Lunch (roundtables at the back of the meeting room)		
1:00 pm	Texas Department of Transportation Presentation	Johnnie Miller Tom Schwerdt	Mike Todsén
3:00 pm	Break		
3:15 pm	Golden Gate Bridge District Presentation	Noel Stampfli Herb Gabriel	Justin Ocel
4:15 pm	Open Discussion on Day's Presentations		Paul Vinik
4:30 pm	Adjourn for Day (Closing and Announcement)		Mike Wright Paul Vinik

Day 3 (Wednesday, May 25, 2016)
Hotel meeting room: Martinique 2
(located in Main Reception Building lower level)

Start Time	Discussion Topic	Presenter	Moderator
7:00 am	Breakfast (Breakfast Buffet for Tropicale restaurant, voucher provided when check in at hotel)		
8:00 am	Michigan Department of Transportation Presentation	John Belcher	Tom Schwerdt
10:00 am	Break		
10:15 am	WEBINAR Ohio Department of Transportation Presentation	Tim Keller	Ray Bottenberg
12:15 pm	Lunch (Roundtables at the back of the meeting room)		
1:00 pm	WEBINAR California Department of Transportation Presentation	John C. Rogers Dave Annis Jeff Butte Dan Cabral Carlos Herrera Barry Marcks Lisa Dobeck John Gillis	Charlie Brown
3:00 pm	Break		
3:15 pm	WEBINAR Pennsylvania Department of Transportation Presentation	Dave Rostron	Mike Todsén
4:45 pm	Open Discussion on Day's Presentations		Paul Vinik
5:00 pm	Adjourn for Day (Closing and Announcement)		Mike Wright Paul Vinik

Day 4 (Thursday May 26, 2016)
Meeting location: Kennedy Space Center
Space Station Processing Facility (SSPF) Conference Center

Start Time	Discussion Topic	Presenter	Moderator
	Breakfast (Breakfast Buffet for Tropicale restaurant, voucher provided when check in at hotel)		
6:30 am	Group gathers together at hotel lobby and loads the bus.		
6:45 am	Group travel from hotel to Kennedy Space Center Visitor Complex by bus, go through security, get badged, and then take the bus to SSPF Conference Center*		
9:00 am	Attendee Sign-In and Equipment Setup		
9:15 am	Welcome and Opening Remarks		
9:30 am	NASA's Corrosion Technology Laboratory at the Kennedy Space Center: Anticipating, Managing, and Preventing Corrosion	Dr. Luz Marina Calle	Ray Bottenberg
10:00 am	Group takes the bus to Exposure Test Site		
10:30 am	Tour of KSC Beachside Atmospheric Exposure Test Site*	Dr. Luz Marina Calle	
Noon	Group take the bus back to SSPF meeting room		
12:30 pm	Lunch (Catered lunch in meeting room) (Tour of Italy Hot Lunch Buffet) – The Blue Sky Catering Company		
1:30 pm	Coatings Qualification for NASA	Jerry Curran	Tom Schwerdt
2:00 pm	Open Panel Discussion Significant Findings and Conclusions Recommendations Identify Next Steps		Paul Vinik Sudhir Palle
5:40 pm*	SpaceX Falcon9 Commercial Launch (Scheduled KSC launch)		
6:00 pm	Adjourn for Day		Mike Wright Paul Vinik
	Group heads back to hotel and has dinner en route.		

*Notes:

1. Each individual will need 2 forms of ID, one of which must be a government-issued photo identification
2. Tour attendees must wear closed toe shoes and long pants. A hat is also recommended.
3. Attendees may bring cameras and take pictures.
4. Mosquito repellent and water will be provided at the Beachside Atmospheric Exposure Site.

Kennedy Space Center Beachside Atmospheric Exposure Test Site



Figure E 1 *NASA Kennedy Space Center beachside corrosion test site*



Figure E 2 *Test panels exposed to weather at the Kennedy Space Center test site*

- Located approximately 100 feet from the median high tide line of the Atlantic Ocean (at latitude 28.59406N, longitude 80.58283W) and documented as having the highest corrosion rates in the country
- Over 40 years of historical exposure data
- Continuous online monitoring of temperature, humidity, wind speed, rainfall, total incident solar radiation, and UVB radiation
- Real-time data acquisition and internet video of samples during exposure capability
- Remote electrochemical measurements capability
- On-site laboratory to gather data on exposed samples
- Capable of accommodating exposure-test samples of all sizes and shapes, such as metal coupons, painted panels, concrete articles, composite materials, solar panels, and airplane wings
- On-site capability for testing under different exposure conditions: Seacoast atmosphere (beach-front) exposure, seawater immersion exposure, tidal exposure, and seawater spray/splash (splash zone) exposure
- Samples exposed to an extremely corrosive and aggressive environment as a result of the high atmospheric salt content, high humidity, time of wetness, and high Florida UV intensity
- Samples are oriented toward the Atlantic Ocean affixed to racks designed according to ASTM G-50 (1997) Standard Practice for Conducting Atmospheric Corrosion Tests on Metals

Final Scan Team Meeting (Friday, May 27, 2016)
Hotel conference room: Barbados
(Located in main reception building lower level)
(Scan team ONLY)

Start Time	Discussion Topic	Moderator
7:00 am	Breakfast (Breakfast Buffet for Tropicale restaurant, voucher provided when check in at hotel)	
8:00 am	Scan Team - Team discussion and finalization of Significant Findings, Conclusions and Recommendations	Harry Capers Paul Vinik Sudhir Palle
10:00 am	Break	
10:15 am	Scan Team - Development of Report Outline	Paul Vinik Sudhir Palle
Noon	Lunch (Catered lunch in meeting room)	
1:00 pm	Scan Team - Development of Draft Dissemination Plan	Greg Waidley, CTC & Associates
5:00 pm	Adjourn Scan Meeting	Paul Vinik Harry Capers

Appendix F: Workshop Presenter Contact Information

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Appendix G: Maryland SHA Warranty Specification

PAINT SYSTEM PERFORMANCE WARRANTY

DESCRIPTION. Provide and install the paint system in accordance with the Contract Documents, and warrant the bridges cited in the Notice to Contractors located elsewhere in this Invitation for Bids for a two-year period starting from the date of acceptance of the Construction Phase of this bridge by the Administration.

MATERIALS. All materials shall be the same as specified in these Contract Documents and from the same manufacturer as the original construction of this Contract. Provide the Administration with a certification showing compliance with the materials requirements specified in Sections 436 and 912.

CONSTRUCTION. All work shall be done in accordance with Section 436.

Warranty Requirements.

(a) **Bond and Liability Insurance.** Furnish a Warranty Performance Bond equal to 25 percent of the total Contract price for all items prior to the date of acceptance of the Construction Phase of the project by the Administration. This Warranty Performance Bond shall be for the entire warranty period and until all required repairs are completed, and shall be in addition to any other construction performance bond requirement. Submit an affidavit from an insurance carrier prior to Award of the Contract showing that the Contractor will be capable of providing this Warranty Performance Bond.

Furnish proof of, and maintain, liability insurance as specified in TC 5.01 for all Contractor authorized operations, persons, and equipment for the warranty period.

Satisfy the following criteria to be released from its responsibility:

(1) Conform to the performance requirements as noted under the Warranty Work and Performance Criteria at the completion of the warranty period.

(2) Satisfy warranty work requirements of repair, replacement, traffic control, performance bond, liability insurance, and incidentals at no additional cost to the Administration.

(b) **Warranty Work.**

(1) **The Administration.** The Administration will identify all work that does not conform to the performance criteria, and notify the Contractor in writing of any required warranty work.

(2) **The Contractor.** The Contractor shall correct all defective areas in accordance with Section 436. The materials shall be the same as originally applied while the surface preparation may be SSPC-SP10, near white or SSPC-SP11. All paint work shall be done by the end of the warranty period unless prevented by the seasonal limitations stated in Section 436. In this case the corrective work shall be completed in the beginning of the following season. The Contractor shall provide certification that the replacement material conforms to Section 912, and shall warrant the work for the remainder of the warranty period. The warranty performance bond shall be held until all corrective work is satisfactorily completed.

The Engineer shall be given at least two weeks notification before the Contractor begins the corrective work. The Contractor shall provide the Engineer safe access to all areas being repaired for full inspection of all operations.

The Contractor shall maintain traffic (vehicular, pedestrian, marine, etc.) throughout this work as specified in the original Contract Documents at no additional cost to the Administration.

(c) Performance Criteria. The work shall be considered defective if visible rust or rust breakthrough, paint blistering, peeling, cracking, chalking, shadow-through, scaling or scaling conditions as noted in the Performance Criteria table occurs during the warranty period. In addition, repairs to fascia beams and fascia bearings that are considered unsightly by the Administration due to spot repair areas shall require the entire fascia beam to be recoated.

Exclusions to the warranty will be damage to the coating resulting from abuse, fire, or other catastrophe not caused by the Contractor or subcontractor. The warranty will evaluate failures defined as visible rust or rust breakthrough, paint blistering, peeling, cracking, chalking, shadow-through, and scaling; and determine the total surface area of the failure for any bridge element. Bridge element is defined as any combination of structural steel plates/shapes that constitute a member or a portion thereof such as rolled beams, plate girders, box girders, columns, webs, flanges, cover plates, splice plates, stiffener plates, connection plates, gusset plates, retrofit plates, lateral bracing, cross bracing, sway bracing, diaphragms, upper and lower chords, truss verticals and diagonals, pin and hanger assemblies, bearing assemblies, access hatches, railing and machinery. Failures resulting from water and salt leaking through the deck slab, open grid deck, or joints in the bridge shall not be excluded from this warranty.

PERFORMANCE CRITERIA TABLE	
THRESHOLD LEVEL	REMEDIAL ACTION
Less Than 1 Square Foot Failure of a Bridge Element	No action required
1 Square Foot to Less Than 20 Square Feet Failure of a Bridge Element	Remove defective paint, rust, etc., and repaint defective area of Bridge Element.
20 Square Feet or More Failure of a Bridge Element	Totally reclean and repaint entire Bridge Element.

MEASUREMENT AND PAYMENT. All costs associated with the required warranty work including access for inspection, and maintenance and protection of traffic will not be measured but the cost will be incidental to the pertinent cleaning and painting or construction items specified in the Contract Documents.

