A User’s Guide to Removal and Replacement of Bridge Coatings
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Introduction

This guide has been developed to encourage a better understanding of the process to completely remove and replace bridge coatings for the structural steel elements of bridges in service. The guide describes how to plan and execute a coatings removal and replacement operation with an emphasis on the three primary activities of containment, surface preparation and painting. This guide does not cover shop applied coatings or spot painting operations, however much of the information presented represents best practices for all bridge coating work.

Background

The structural steel for a bridge is painted primarily to resist corrosion but can also be painted for aesthetic purposes. The original coating is often fully or partially shop applied as part of the original construction and when combined with bridge preservation activities such as bridge cleaning and joint repairs, the original coating should perform well for many years. Invariably, exposure to chlorides from deicing operations or a coastal climate, failed drainage systems, UV light, foreign chemicals and debris all conspire to degrade the coating system. Without proper maintenance the coating will eventually require a complete replacement.

Properly applied coatings offer the maximum corrosion protection for passive protection systems. There are “active” systems such as cathodic protection which offer corrosion protection through the principle of metals with differing electrochemical potential, but active systems are beyond the scope of this guide.
The corrosion of steel is promoted by higher temperatures, higher relative humidity (or exposure to moisture), and the presence of pollutants such as soluble salts. Any faults or imperfections that compromise the integrity of the coating will lead to premature corrosion of the steel. If the corrosion is not contained, over time it will migrate and eventually the extent of corrosion will make spot repairs impractical. While different owners will invoke a removal and replacement strategy at different percentages of structure surface area corrosion, it is common to implement a complete removal and replacement operation when the surface area corrosion exceeds 20%.

The final decision whether to replace the coating or the structural steel depends on several other variables related to the structural and functional capacity of the bridge. Structural steel has proven itself to be a very durable and resilient material and under the right conditions will last a very long time. The removal and replacement of a bridge coating is a cost-effective bridge preservation activity when applied to the right bridge at the right time.
Planning and Preparation

Each bridge will present its own unique challenges so investing the time to carefully plan the operation will allow the crews to work efficiently and focus on the requirements that directly influence the quality and safety of the work. This section outlines the steps involved with planning and preparing for the work.

Condition Assessment

A visual coating assessment alone will generally not provide the necessary information to characterize the condition of the existing coating system as not all deficiencies are visible. A complete assessment may require an evaluation of the physical and chemical properties of the coatings. Both a visual and chemical analysis may be required to determine the appropriate maintenance strategy.

Heavily corroded areas will require closer examination and measurements to assess whether section loss is present, and if so, to what extent. A pull-off adhesion test may help assess the bond of the remaining coating. A chemical analysis will help identify lead or other chemicals that need to be considered as part of the removal and surface preparation phases. The results of these tests can influence the maintenance strategy and the budget for the work.


Coating Inspection Tools and Equipment

The equipment required for evaluation of physical and chemical properties of the existing coating depends on the specific tests being performed. Here is a sample of some of the tools and equipment:

- Tooke gauge
- Dry film thickness gauge (electronic)
- Hand held microscope
- High Resolution Camera
- Dull Putty Knife
- Anemometer
- Copper Sulfate Solution
- Razor Knife
- Replica Tape (e.g., Testex™)
- Mirror with telescoping and adjusting angle handle
- ASTM D3359 Adhesion Testing Tape
- SSPC VIS 1
- SSPC VIS 2
- SSPC VIS 3
Site Assessment

It is recommended practice to perform a site visit in advance of the work to help identify the site constraints and to answer the following questions:

• How can the work be staged and aligned with the Maintenance and Protection of Traffic (MPT) plan?

• What are the options for the rigging and containment systems based on the type of bridge and the MPT plan?

• Where can the compressors, blast media recycling and storage of hazardous waste be located?

How the equipment and personnel will access the work area safely?

It is recommended that at a minimum, a site-specific Job Hazard Analysis be developed in accordance with the OSHA regulations. In addition, the following best practices will enhance the safety throughout the work:

• Identify the toxicity of the existing coating (Lead, PCBs, cadmium, chromium, hexavalent chromium).

• Identify the removal, safe handling and disposal methods of hazardous materials.

• Maintain a safe and uncluttered passageway for foot traffic in the containment system, and between staging and work areas.
• Ensure employees are trained on the proper fit and use of a respirator.

• Review Personal Protective Equipment (PPE) protocols including fall protection requirements.

• Review the procedure for decontamination and handling of contaminated clothing.

• Confirmation that Safety Data Sheets (SDS) information for the paint systems and solvents are available and reviewed with the Safety Administrator.

**Maintenance and Protection of Traffic (MPT)**

The Maintenance of Traffic (MPT) plan is directly influenced by the type of structure, the highway facility and the speed of traffic. The MPT plan must account for the location of the containment system and the presence of workers adjacent to and above live traffic. During the initial site assessment, here are a few questions that may help formulate the MPT plan:

• What impact will the containment system have on the movement of traffic including pedestrians?

• Can the equipment be positioned outside of the travel lanes and behind a rigid barrier?

• Can the work be performed over live traffic, or will the overhead work require lane closures on or below the structure being painted?
A site-specific MPT plan in lieu of standard details is the preferred approach for bridge coating removal and replacement operations to ensure the safety of the workers and the traveling public.

**Environmental Stewardship**

The State and Federal environmental regulatory agencies have permitting and compliance requirements that must be followed and the permittee is generally required to comply with the more restrictive regulations. The permitting process and the development of the Environmental Protection Plan should be a collaborative process, working with the regulators to convey the scope of work and to develop the proper course of action. The protection of the environment is central to the work of coatings removal and replacement.

The Environmental Protection Plan should address the containment, capture, collection, air monitoring, storage, transportation and disposal of waste generated from the removal and replacement of bridge coatings.

The abrasive blast and painting operations must be properly contained to minimize the contamination of soil, surface waters, groundwater and the atmosphere. The primary emphasis should be on containment within the project area rather than on recovery systems, such as floating booms and skimmers. Any spills or release of materials must be immediately contained until remediation procedures can be deployed. All spills and releases must be immediately reported to local environmental and HAZMAT agencies. The regulatory levels and toxins are defined by 40 CFR 261.24 Toxicity Characteristics. Soil samples may be tested in advance of the work to establish a baseline of existing contamination. Many generators
choose to treat all waste from a coating removal operation as hazardous.

**Containment System**

A containment system is designed to provide access to the work area, prevent hazardous contaminants from escaping beyond a controlled boundary and to prevent entrance by unauthorized personnel.

The containment is supported by rigging. Rigging is the hardware and fasteners designed to carry the loads generated by the containment, the workers, the equipment and the waste. Since worker safety is critically inherent to the rigging, as is the structural integrity of the bridge (the containment system can add significant dead load and wind load to all structures, especially truss bridges), it is recommended the design for the containment system be performed by a licensed professional engineer.

A consequence of a containment system is that it limits the amount of natural light entering the work area. Lighting should exceed 15 ft-candles while applying coatings and higher levels of lighting are required for inspection. SSPC Guide 12, “Illumination of Industrial Coatings Projects” is helpful in determining the appropriate levels of lighting.

In addition, the SSPC Guide 6 “Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations” establishes different classes of containments; it is recommended that at a minimum Level 2 containment criteria are adopted. SSPC Guide 7 “Guide to the Disposal of Debris” establishes protocols for handling, testing and disposal of solid debris generated during surface preparation activities.
Surface Preparation

Surface preparation is the process of removing all materials that would prevent a new coating from bonding and performing as intended. Prior to installing the new coating, all surfaces must be clean and free from rust, non-adherent or brittle paint, chalking, oil, grease, salt contaminants, dirt, and other substances that would prevent coatings from tightly adhering to the surface.

The surface preparation strategy will need to mitigate the conditions uncovered during the Condition Assessment phase.

Methods

The removal of rust and other contaminants can be performed effectively using the following techniques and methodologies. Select the best practice to satisfy the specific site criteria from the following options:

- **Abrasive Blasting**

  There are several media types used for abrasive blast cleaning operations. Some media are less abrasive and afford better operator control while others are larger in size facilitating increased production rates and a deeper profile.

  The abrasive used for blast cleaning should be dry and free of any contaminants, such as oil, grease and salts. Cleanliness and abrasive composition requirements are dictated by SSPC AB1, AB2, or AB3 depending on whether the media is a mineral, manufactured slags, recyclable or disposable. The air source utilized should be checked for oil and water contamination by the Blotter Test.
For dry abrasive blasting methods:

- Use compressed air, blast nozzles, and an abrasive.

- Use a closed-cycle, recirculating system with compressed air, blast nozzle, and an abrasive, with or without vacuum for recovery of abrasives and dust.

- Use a closed-cycle, recirculating system with centrifugal wheels and an abrasive.

- Additional methods can be utilized to meet the needs of the work and available equipment.

Vapor blasting with aggregate leaves very little residue. The water vapor captures the fractured particles and evaporates, leaving only grit and residue.

Wet abrasive blasting propels the aggregate in a liquid stream rather than a gaseous compressed air stream.
Figure 1 Example of a holiday after blast cleaning operation.

- **Power Tools**
  For areas where abrasive blasting may not be effective, such as tight areas like bearings and gusset plates, use mechanical methods of surface cleaning like wire brushing, scraping, chipping and sanding. Power tools are normally energized by electricity or compressed air. These customarily include sanders or wire brushes, power chipping hammers, abrasive grinding wheels and needle guns. SSPC-SP11 provides guidance for achieving bare metal through power tool cleaning.

- **Hand Tools**
  Hand tool cleaning is considered the slowest, least
time efficient means of preparing a substrate but can be used for mild exposure conditions. It is not normally intended to remove adherent mill scale, rust and paint or to produce a surface profile, but it can be effective at removing loosely adherent materials. Loosely adherent material is defined as anything removable with a dull putty knife.

• **Solvent Cleaning**
Solvents such as water, alcohols, mineral spirits, xylene and toluene are used to remove solvent-soluble foreign matter from the surface of ferrous metals. Low-pressure (1500 - 4000 psi) high volume (3 - 5 gal/min.) water washing with appropriate cleaning chemicals is a common “solvent cleaning” method.

Many solvents produce toxic fumes and require adequate ventilation and other precautions during their use. The manufacturer’s recommendations should be strictly followed.

The Society for Protective Coatings (SSPC) Manual, Volume I “Good Painting Practice” and SSPC-SP1-“Solvent Cleaning” provides explicit instructions on simple solvent wiping, immersion in solvent, solvent spray, vapor degreasing, steam cleaning, emulsion cleaning, chemical paint stripping, and the use of alkaline cleaners.

Heavy deposits should be removed with a scraper followed by scrubbing or wiping with an appropriate cleaning solution. All visible traces of contaminants are to be removed with final wiping performed with clean rags and clean solvent.

Inorganic compounds such as chlorides, sulfates, weld flux, rust and mill scale cannot be removed by cleaning with organic solvents.
Level of Cleanliness

By far the most prevalent level of cleanliness specified for bridge coating application is SSPC SP10/NACE 2 – near white metal blast. This level of cleanliness allows 5% rust staining in the bottom of pits but does not allow the presence of any remaining paint, mill scale or foreign contaminants of any kind.

Other levels of cleanliness that are less frequently specified are SSPC SP5/NACE 1 (0% staining) and SSPC SP6/NACE 3 (33% staining). SP5/NACE 1 is common in conjunction with application of metallizing. SP6/NACE 3 is sometimes utilized in areas where an SP5/NACE 1, or SP10/NACE 2 cannot be easily achieved, but where abrasive blast is still more pragmatic than hand tools or power tools.

The ambient conditions and substrate surface temperature must be suitable for final surface preparation. Substrate temperature should always be 5°F greater than the dew point temperature. This is intended to prevent the possibility of condensation on blasted steel. Any flash rust or rust-back must be remediated prior to the application of the coating.

Anchor Profile

The anchor profile produced by blasting is controlled by the selection of blast media, media particle size, and the magnitude of air pressure used as a propellant.

Dry film thickness measurements are defined as the dry film thickness above the peaks of the anchor profile (not the depth to the bottom of the valleys). Insufficient film thickness or a profile that is too deep will lead to pin point rusting and premature failure.
Anchor profile must be specified, and it is common to see a required paint film thickness of 2-3 mils, but each primer is different, and it is recommended that the coating manufacturer’s published product data sheet be referenced to specify the correct anchor profile.

The Anchor Profilometer with Stylus is the latest technology. It offers quicker and more accurate data collection, but also contains an offset from the traditional foam tape method of measuring profile. Either methodology can be utilized successfully when properly applied.

Surface conditions and finished surface profiles shall conform to SSPC-Vis Standards or the National Association of Corrosion Engineers (NACE) Comparators.

When blast cleaning is specified for surface preparation, the SSPC PA-17 “Procedure for Determining Conformance to Steel Profile Requirements”, including information in Appendix B, “Determining Compliance Based on Process Control Procedure” provides a comprehensive approach to determine the surface profile.

**Coating Application**

There are a variety of methods to apply coatings to a steel substrate including spraying, rolling and brushing. The coating manufacturer’s product data sheet will provide the equipment and techniques which are compatible with each coating. The SSPC PA1 “Shop Field and Maintenance Painting of Steel” guide also offers general requirements for the application of paint.
It is important to follow the manufacturer’s recommendations and these best practices:

- Visually inspect the steel to ensure it provides a suitable substrate and promotes optimum adhesion. Substrate cleanliness and anchor profile should be as specified.

- Coated surfaces should be smooth, uniform, with a continuous film in the range of the wet film thickness requirements.

- Suitable lighting is required for the coating application and inspection. SSPC Guide-12 provides guidance on lighting criteria for these purposes.

- Coat as soon as possible, preferably within 24 hours of the final surface preparation to avoid flash rust. If rust inhibitor is used, it must be certified by the coating manufacturer to be compatible with the primer or base coat.

- Verify the ambient conditions such as relative humidity, dew point, temperature and the substrate surface temperature are suitable for the application of coatings. The ambient conditions relevant to specific coating products can be referenced in the manufacturer’s product data sheet.

- Coating application beyond these limits should not be allowed. It may be necessary to control the environmental conditions to provide conditions meeting the manufacturer’s recommendations.
• Substrate temperature should always be 5°F greater than the dew point temperature. This is intended to prevent the possibility of condensation on newly painted steel.

• Do not apply coatings when the temperature is equal to or below 45°F unless expressly allowed by the manufacturer.

Brushing

• Best “wet-in” for irregular surfaces and working the coating into edges and crevices.

• Flat brushes are best for planar surfaces; round brushes are best for bolts and rivets. All runs, and sags should be repaired as soon as possible.

• Daubers and mitts can be used in special circumstances and are frequently used to coat cables and hard to reach surfaces. They can also be used for spot painting inaccessible areas.

Rolling

Faster than brushing for flat surfaces, but usually not allowed for the typical zinc-rich coatings.
Spray application

Quicker application rate than brushing or rolling. Useful to apply coatings in a single high film build. Whether conventional or airless spray, the dispensing parameters must be adjusted to ensure proper coating application.

Figure 2 Example of paint sag and runs

Stripe Coating

- Stripe Coating is a technique used to coat problematic areas where specified film thickness will not be achieved without additional coats. Areas that are customarily stripe coated include: crevices, sharp angles, plate seams, back to back angle seams (built-up members), bolt heads and nuts, rivet heads, welds and any other sharp discontinuities.
• The SSPC PA 11 “Protecting Edges, Crevices and Irregular Surfaces by Stripe Coating” guide discusses stripe coating techniques and limitations in achieving the required coating thickness.

**Coating Storage and Handling**

The storage and handling requirements are provided by the coating manufacturer and included on the product data sheet. Follow the manufacturer requirements for mixing, thinning, pot life, recoat windows, induction time, film thickness (ranges) or coverage, application methods and equipment, safety, handling, clean-up, and disposal. Take note of the following:
• The coatings should be well mixed and homogenous prior to use.

• Any skin formed on the coating should be discarded. Coating materials with substantial skinning should be discarded.

• Ensure that no entrained air is mixed into the paint.

• Multi-component coatings must be mixed in the specified proportion. Mixing of open or partial kits should not be allowed. Pigments remaining in the can are indicative of improper or inadequate mixing.

• Thinners are added to coatings to lower the viscosity and enhance wet-in or improve the application attributes. Thinning is accomplished by adding solvents which can increase the volatile organic compounds (VOCs) content of the coating. Whether thinning is allowed and how it is to be done should be contained in the project specification and should never exceed the manufacturer’s published limits. All applicable atmospheric regulations regarding VOCs content should be followed and waste solvents must be captured and disposed of properly.

• Pot life is the amount of time that a coating can be used after mixing components (resin with activator). Once the pot life has expired the coating materials must be discarded and the equipment cleaned properly.

• Each coating material is subject to a minimum and maximum recoating time, including the stripe coat.
• Induction time is the period necessary to initiate a reaction. It is the duration that must elapse after mixing multi-component paint materials before starting to apply them.

Quality

A successful coating operation depends on selecting the correct coating for the work, having the proper environmental conditions throughout the work, following the manufacturers recommendations and best practices.

A few examples of typical failure mechanisms follow:

• Insufficient coating thickness on edges, faying surfaces, corners and fasteners.

• Excessive anchor profile of the substrate visible through the coating.

• Old coating that has developed brittleness and cracking over time.

• Excessive coating thickness leading to blistering, bubbling, disbonding, mud cracking or solvent entrapment.

• Ultra-Violet (UV) light exposure leading to chalking and loss of gloss.

• Poor environmental controls during the application resulting in mud cracking or blushing.
In general, a failure of a coating system can be attributed to one of three causes:

- The coating is over-stressed due to environmental exposure or improper surface preparation.
- Poor coating system choice for the application.
- Coatings were improperly mixed and/or improperly applied.

It may be necessary to retain a professional coatings specialist to perform a forensic analysis and identify the root cause of the failure mechanism.

**Inspection Hold Points**

“Hold Points” are designated times in the specifications when work halts and affords the inspector an opportunity to assess the work completed for compliance with the specification and to identify defects. Once the inspection is complete, the work is allowed to continue, or corrections made before the next operation begins. Hold points are commonly used at the completion of significant steps in the process. Below is a list of typical hold points:

- At the completion of the surface preparation.
- Before the application of each coat (full, intermediate, stripe, finish).
- After repair work is performed.
- As part of the development and reconciliation of the punch list items. Process Control Measures
Process Control Measures

Throughout the surface preparation and coating operation it is important to have process controls in place to ensure a quality product. The following process control measures represent known defects which can lead to premature failure of the coating:

- Properly trained and credentialed contractors and inspectors.
- The presences of water or oil in the compressed air.
- Adequate Illumination in containment.
- The presence of oil or grease.
- Testing for the presence and the remediation of chlorides, sulfates and nitrates.
- Assessing the prepared surfaces against the surface preparation standards.
- Measuring the surface profile throughout the surface preparation.
- Recording and documenting the coating storage, preparation, mixing and handling activities.
- Measuring the wet and dry film thickness for compliance with the upper and lower bounds of the specification.
Certification and Qualifications

• The contractor should be certified to SSPC QP1 (Field Application to Complex Industrial and Marine Structures) and QP2 (Field Removal of Hazardous Coatings).

• An SSPC C3 certified individual should always be present on a project where coatings pigmented with heavy metals are being disturbed.

• SSPC C7 is the Abrasive Blaster Certification.

• SSPC Coating Application Specialist: various levels for surface preparation and coating applications.

• Bridge Coating Inspector’s (BCI) should possess SSPC BCI L1-L2 or NACE CIP L1-L3

References and Standards

**ASTM International** (formerly American Society for Testing and Materials)

• D1212 “Standard Test Method for Measurement of Wet Film Thickness of Organic Coatings”

• D3359 “Standard Test Methods for Rating Adhesion by Tape Test”

• D4285 “Standard Test Method for Indicating Oil or Water in Compressed Air”
• D4417-14 “Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel”

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

The Society for Protective Coatings (SSPC)

• Technology Update TU 1 “Surface Tolerant Coatings for Steel”

• AB 1 “Abrasive Blast Standard No. 1 Mineral and Slag Abrasives”

• AB 2 “Abrasive Blast Standard No. 2 Cleanliness of Recycled Ferrous Metallic Abrasives”

• AB 3 “Abrasive Blast Standard No. 3 Ferrous Metallic Abrasives”

• Guide 6 “Guide for Containing Debris Generated During Paint Removal Operations”

• Guide 7 “Guide to Disposal of Debris”

• Guide 15 “Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates”

• PA 1 “Paint Application Specification No. 1 Shop, Field and Maintenance Painting of Steel”
• PA 2 “Procedure for Determining Conformance to Dry Coating Thickness Requirements”
• SP 2 “Hand Tool Cleaning”
• SP 3 “Power Tool Cleaning”
• SP 5 (NACE 1) “White Metal Blasting”
• SP 6 (NACE 3) “Commercial Blast Cleaning”
• SP 10 (NACE 2) “Near-White Blast Cleaning”
• SP 11 “Power Tool Cleaning to Bare Steel”
• SP 15 “Commercial Grade Power Tool Cleaning”
• VIS 1, “Guide and Reference Photographs for Steel Surfaces Prepared by Abrasive Blast Cleaning”
• VIS 3, “Guide and Reference Photographs for Steel Surfaces Prepared by Power and Hand Tool Cleaning”
• VIS 4, “Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting”
Notice:

The contents of this guide on Removal and Replacement of Bridge Coatings reflect the views of the Bridge Preservation Expert Task Group, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA). The content does not constitute a standard, specification, or regulation. FHWA does not endorse products or manufacturers. Trade or manufacturers’ names appear herein solely because they are considered essential to the object of this report.