Spot, Zone and Overcoat Painting of Steel Bridges

Report Number: KTC-25-03

DOI: https://doi.org/10.13023/ktc.rr.2025.03

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

The Kentucky Transportation Center is committed to a policy of providing equal opportunities for al persons in recruitment, appointment, promotion, payment, training, and other employment and education practices without regard for economic, or social status and will not discriminate on the basis of race, color, ethnic origin, national origin, creed, religion, political belief, sex, sexual orientation, marital status or age.

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

Kentucky
Transportation Center

Kentucky Transportation Center • University of Kentucky
176 Raymond Building • Lexington, KY 40506 • 859.257.6898 • www.ktc.uky.edu

University of
Kentucky

Research Report
KTC-25-03

Spot, Zone and Overcoat Painting of Steel Bridges

Christopher Goff
Transportation Technician

and

Sudhir Palle, P.E.
Program Manager

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

In Cooperation With
Kentucky Transportation Cabinet
Commonwealth of Kentucky

September 2024

1. Report No. KTC-25-03	**2. Government Accession No.**	**3. Recipient's Catalog No.**

4. Title and Subtitle Spot, Zone and Overcoat Painting of Steel Bridges	**5. Report Date** September 2024 **6. Performing Organization Code**
7. Author(s): Danny Wells, and Sudir Palle	**8. Performing Organization Report No.** KTC-25-03
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, KY 40506-0281	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** SPR 22-613
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, KY 40622	**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**

15. Supplementary Notes
Prepared in cooperation with the Kentucky Transportation Cabinet

16. Abstract
Over the past 25 – 30 years, the Kentucky Transportation Cabinet (KYTC) has replaced lead-based coatings on many bridges, often with zinc-based systems. But many of these coating systems are now degrading and reaching the ends of their service lives. Historically, KYTC has relied entirely on remove-and-replace painting, however, given the programmatic costs associated with remove-and-replace painting and constraints imposed by limited funding, the agency needs to explore more economical options, such as spot, zone, and overcoat painting. This report discusses use cases for spot, zone, and overcoat painting and lays out guidelines staff can use to determine what method of painting is the best fit based on a project context. It provides an in-depth discussion of issues that need to be addressed in special notes prepared for different types of painting operations and gives a step-by-step description of work completed during a painting project. Over the long-term, the Cabinet will benefit from establishing a more robust bridge painting program. For this type of program to function effectively, KYTC needs to maintain a complete, up-to-date inventory of bridges. Its staff must have expansive knowledge of funding sources that are available to pay for maintenance painting. Staff must also possess the requisite knowledge to conduct in-depth investigations of candidate projects, and understand how different features of project context may influence painting operations so they can determine the optimal maintenance procedure. Moving forward, the Cabinet should explore having in-house personnel execute spot painting and zone painting projects on bridges that do not have lead based coatings. The agency should also continue refining its guidelines and best practices for maintenance painting and develop special notes to guide the selection of surface preparation methods and bridge coatings.

17. Key Words bridge, maintenance, inspection, bridge painting, corrosion	**18. Distribution Statement** Unlimited with approval of the Kentucky Transportation Cabinet

19. Security Classification (report) Unclassified	**20. Security Classification (this page)** Unclassified	**21. No. of Pages** 61	**19. Security Classification (report)**

Table of Contents

List of Figures

Acknowledgements

The authors would like to thank the members of the Study Advisory Committee, and FHWA personnel that reviewed the contents of this report for accuracy and for their efforts on this study.

Executive Summary

Over the past 25 – 30 years, the Kentucky Transportation Cabinet (KYTC) has replaced lead-based coatings on many bridges. The typical replacement coating has been a zinc-based system. But now many of these coating systems are reaching the ends of their service lives and need to be replaced. Others are in various stages of degradation. Remove-and-replace painting typically lasts 20 years, maintaining protective coatings of more than 1,100 Cabinet steel bridges in acceptable condition will require the agency to paint 50 bridges per year. However, given the programmatic costs of remove-and-replace painting, KYTC needs to explore more economical options, such as spot, zone, and overcoat painting.

This report begins with high-level descriptions of spot, zone, and overcoat painting as well as guidelines for evaluating structural steel and determining what method of painting is most appropriate for a given project context. Next, it provides an in-depth treatment of issues that need to be considered when KYTC prepares special notes for different types of painting operations. Topics addressed in this discussion include methods used to clean and prepare surfaces for painting (citations for relevant industry standards are provided), the process of selecting the most appropriate coating system, and application of coatings, including acceptable techniques. Following this review, the report offers detailed discussions of work that must be completed during a painting project, from mobilization and onsite deployment, to carrying out painting operations and inspecting work.

The report wraps up with recommendations for establishing a robust bridge painting program at KYTC. The foundation of such a program is an up-to-date and complete inventory of Cabinet bridges as well as structures that the agency does not own but which it assumes responsibility for maintaining. Staff who are responsible for programming bridge maintenance activities need to have solid knowledge of the funding sources KYTC can tap to pay for maintenance painting. These staff also need to have a good understanding of strategies which underwrite programmatic decision making and how they can be implemented in a way that optimizes the Cabinet's return on investment. While KYTC has relied entirely on remove-and-replace maintenance painting for bridges, the agency will need to expand the use of spot, zone, and overcoating because these methods can perform better from the standpoint of life-cycle costs. Enacting these changes will demand that staff complete more in-depth investigations of candidate bridge painting projects and determining the most feasible/optimal maintenance option. When preparing proposals for projects that cover single or multiple bridges, staff must be attentive to features of the project context that will influence painting operations. Several additional recommendations for improving KYTC's programmatic approach to painting operations round out the repot:

- Explore carrying out spot and zone painting projects using in-house personnel, but only on bridges that do not have lead-based coatings.
- Adapt guidelines from other DOTs for programming spot, zone, and overcoating projects.
- Establish best practices for implementing spot, zone and overcoat projects based on monitoring of Kentucky projects.
- Develop special notes for surface preparation and coating options in the field.
    - They should address jobsite preparation, inspection, field operations, waste handling, monitoring of surface conditions, applying coatings, and cleanup.
- Prepare guidance on methods for inspecting and handling coating materials. This is critical since coatings will be stored in District garages.

Chapter 1 Introduction

1.1 Background

Preventive maintenance is critical for extending bridge service lives (i.e., bridge preservation). An important component of preventive maintenance is preventing the corrosion of steel bridges. It constitutes a major portion of bridge maintenance expenditures nationwide, with many state departments of transportation (DOTs) having extensive backlogs of steel bridges that need painting.

Protective coatings on conventional steel and patinas on unpainted weathering steel (UWS) prevent the corrosion of exposed bridge elements. Over time (typically 20+ years) protective coatings and patinas degrade for multiple reasons. When they fail, the resulting corrosion can result in high section loss in structural members, weakening them. This creates situations where structural integrity can be compromised, resulting in expensive steel repairs (Figures 1.1 and 1.2).

Conventional steel elements are coated prior to or during bridge construction — typically by shop priming and application of several topcoats in the field. Up through the late 1980s, multi-coat lead-alkyd systems were widely used by KYTC on steel bridges for both new construction and maintenance painting. They were gradually phased out in favor of inorganic zinc/vinyl two-coat systems. Use of these new systems expanded from the late-1980s onward in both maintenance and construction activities. They were employed on remove-and-replace projects where the existing coating was completely removed by abrasive blasting and a new coating system was applied over abraded steel substrates. Since 2010, the coating systems used on KYTC's new construction projects have consisted a primer (organic zinc), an intermediate (epoxy) and a finish coat (polyurethanes or acrylics) on abraded steel substrates.

During the 1990s into the early-2000s, KYTC used multi-coat polyurethane barrier coatings as overcoating maintenance painting systems, primarily atop aged lead-alkyd coatings. During the early-to-mid 2000s, KYTC also used calcium sulfonate alkyd coatings for complete maintenance painting projects on both remove-and-replace and overcoating projects. And from the early-2000s through 2010, multi-coat polyurethane systems incorporating zinc-pigmented primers were used by the Cabinet on both new construction and several remove-and-replace maintenance projects. KYTC currently performs most steel bridge maintenance painting projects with the remove-and-replace method using the same coating systems employed for new construction.

Wanting additional options for protecting steel bridges, KYTC commissioned the research study documented in this report. The study had several objectives:

1. Identify best practices employed by other DOTs for spot, zone, and overcoat of steel bridges, including guidelines for employing spot, zone and overcoat as part of bridge maintenance strategies.
2. Develop criteria for KYTC to identify steel bridges for spot, zone, and overcoat.
3. Develop special notes that includes surface preparation techniques for employing spot, zone, and overcoat strategies in the field.
4. Monitor spot, zone, and overcoating projects for KYTC to improve criteria and special notes.

Figure 1.1 Web Crippling of a Girder
This is due to coating failure and resulting corrosion-induced section loss (Source: Connecticut DOT).

Figure 1.2 Web Rust-Through of a UWS Diaphragm
This is due to a patina failure on a KYTC bridge.

1.2 Coating and Patina Deterioration on Bridges

When bridge coatings and patinas age, they deteriorate, which leads to internal failure. As failure progresses, the coatings and patinas no longer afford protection to the underlying steel. Failures generally result in issues with steel corrosion. Coating systems commonly employ organic resins that allow for the internal transmission of ambient moisture. Typically, they act as barriers to corrosion-promoting elements (e.g., salts) or contain chemicals that inhibit corrosion at the coating-steel interface. Constant condensation-evaporation and freeze-thaw cycles in normal environments eventually increase the internal coating's porosity and result in leaching of key protective chemicals from the coatings. These actions weaken coating structure and reduce their corrosion resistance.

Commonly, the deterioration of protective coatings and patinas across an individual steel bridge is not uniform. For coatings, this can be due to painting process defects (e.g., misses, blisters, thin spots, painting during unfavorable atmospheric conditions). Localized failures can also be due to variations in environmental (i.e., service) stresses. Coatings on exterior surfaces are subject to ultraviolet radiation from the sun (UV exposure), periodic freezing-and-thawing, and condensation-evaporation cycles. This is termed bold exposure and results in uniform deterioration of coatings on surfaces with more prominently exposed surfaces that experience greater coating deterioration. In the past, industrial environments generated harmful atmospheric-borne contaminants such as sulfates and nitrates that could be deposited on exterior surfaces and accelerate coating deterioration and corrosion. However, this problem has subsided due to more restrictive environmental regulations.

Some exterior surfaces of bridges, such as overpasses, are exposed to salt-laden aerosols kicked up by traffic (splash zones). Exterior surfaces, especially horizontal orientations, are also subject to deposits from fine airborne soils that promote coating breakdown. Coated steel surfaces in sheltered locations under bridges do not suffer bold exposure or exhibit harmful issues associated with airborne pollutants or aerosol deposits. However, portions of these surfaces near/under leaking joints or improperly designed drains can be wetted by deck runoff from rain or melting ice/snow that is typically contaminated with roadway de-icing /anti-icing salts. Sheltered coatings do not dry as quickly as those on the exterior. As such, they experience extended times-of-wetness (TOW), allowing ionized salts from de-icing/anti-icing applications to more effectively penetrate coatings and corrode underlying steel. As most deck joints leak, corrosion of underlying steel (e.g., beam ends, floor beams, stringers) is a common problem associated with steel bridges except for jointless bridge designs (Figure 1.3).

Coating failures are not always due to external stresses. Over time, build-up of resin-curing stresses in aging coating systems can break the bond between coating layers, resulting in inter-coat disbonding (Figure 1.4). Older lead-alkyd coatings were usually applied directly over steel mill scale. As mill scale surfaces are slick, the resulting coating curing stresses can also lead to large-scale coating disbonding. Freeze-thaw cycles can instigate fracturing and detachment of mill scale from the steel substrate, resulting in coating disbonding. Moisture attack can also cause coatings to become detached from intact mill scale by cathodic disbonding. All these situations can result in complete sheeting failures of aged alkyd coatings rarely seen with most other coating types (Figure 1.5).

The steel composition of weathering steel bridges differs from existing steel bridges; the protective patinas formed on them are tightly adherent corrosion products that slow the surface corrosion loss rate in steel (typically one-third that of plain structural steels). In ideal atmospheric environments (bold exposure), uncoated weathering steel (UWS) bridge members are subject to periodic wetting and drying. This typically occurs on exterior-facing bridge surfaces exposed directly to sunlight, wind, and rain as well as interior surfaces under bridge decks where high humidity and good air flow are present. Under these conditions, patinas form, erode, and are gradually renewed in an ongoing process. When UWS bridges were originally introduced, the general concept was that weathering steel could eliminate the need for two painting cycles (40 – 50 years). KYTC has maintained UWS bridges by applying coatings about five feet from piers and abutments (zone painting) to prolong their service lives.

As with protective coatings, weathering steel patinas become less protective as they age. The regeneration process produces fewer patina components that protect the underlying steel. When this occurs, the steel corrosion rate increases. The underlying steel can also experience pitting that further inhibits proper patina regeneration (Figure 1.6). At some point, the corrosion rate increases to the point where it is equivalent to that of plain structural steels. Steel components of UWS truss and arch bridges can have structural members that trap water or debris (e.g., horizontal H-beam chord members) or fail to dry sufficiently when wetted (e.g., undersides of H-beam diagonal chord members), resulting in high corrosion rates. Patinas cannot provide protection if exposed to corrodents (e.g., salts). Salt exposures have proven to be harmful to weathering steels even at locations where bold exposure-type atmospheric conditions were present. De-icing and anti-icing salts runoffs, industrial pollution, and splash-zone aerosols are typical of bridge exposures in which UWS fails to perform properly. As such, a UWS bridge needs to be painted to maintain proper corrosion protection.

Local ambient conditions around a bridge can influence the patina regeneration cycle. Sheltered locations, such as vegetation-shrouded girder/beam ends at abutments, are shielded from airflow. These locations often experience extended TOW, which prevents proper patina formation. This can result in aggressive localized corrosion. Interior girders/beams or faces of fascia girders of deck girder bridges may also lack sufficient airflow to permit proper drying, especially at girder/beam ends which can experience moisture exposure due to leaking joints (Figure 1.2).

Improper patina formation has the same effect as complete coating loss on conventional steel structural members — namely, excessive loss-of-section due to unhindered corrosion. Typically, this is evidenced by the presence of scaling corrosion products and coarse or loose, flakey ferrous rust (Figures 1.7, 1.8). Color differences sometimes indicate improper patina formation (Figure 1.9).

Figure 1.3 Typical Girder/Beam End Corrosion
This results from coating failure due to a combination of a leaking deck joint and the application of de-icing/anti-icing salts on roadways.

Figure 1.4 Intermediate Coat Adhesion Failure Between Lead-Alkyd Primer and Alkyd Topcoat
This is due to curing stresses in the topcoat.

Figure 1.5 Aged Lead-Alkyd Sheeting-Type Complete Disbonding Failure from a Mill Scale Substrate

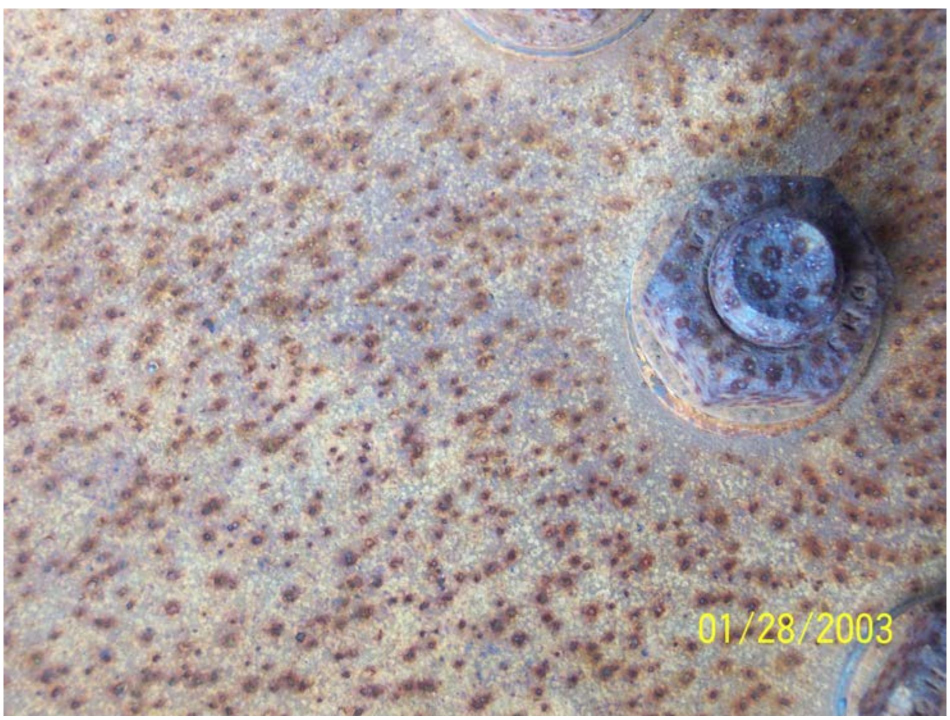

Figure 1.6 Pitting on Patina of KYTC UWS Bridge

Figure 1.7 Surface Scaling Rust of a UWS Patina on a KYTC Bridge

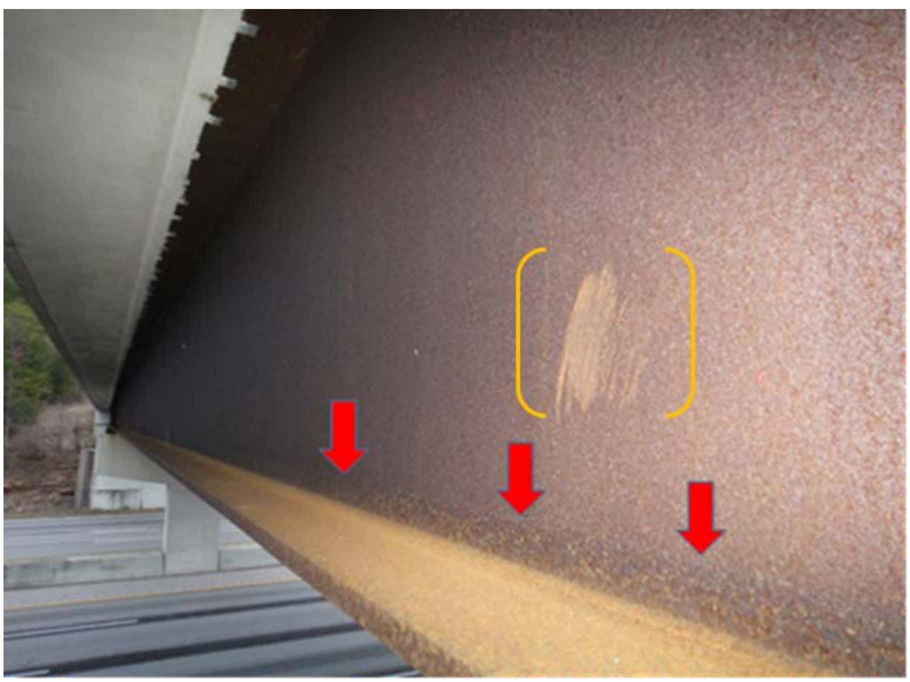

Figure 1.8 Proper Patina Formation on a Fascia Beam

This image of a KYTC overpass bridge shows tight rust in middle of web (scrape marks bordered by orange brackets), indicating proper patina formation. Coarse/flakey rust on the lower flange is caused by salt-laden aerosols kicked up by traffic below the overpass. Corrosion on the lower part of the web (red arrows) is due to capillary action with the porous rust drawing up moisture from aerosol deposits on the lower flange.

Figure 1.9 Inhibited Patina Formation on a UWS Girder Bridge
This image shows the effects of inadequate drainpipe clearance, which allows deck runoff to spill from the pipe and impede proper patina formation (light areas on adjacent flanges).

Chapter 2 Maintenance Painting Options

2.1 Issues Justifying Alternative Maintenance Painting Methods

Along an individual bridge, coatings tend to deteriorate at different rates. Uneven coating performance results in localized coating failures which, in turn, expose underlying steel to corrosion. Generally, the primary sources of coating failure, excess moisture, and deicing salt exposure are the same ones that accelerate corrosion. Usually, most a bridge coating (90+ percent) will be intact when the decision is made to repaint it by the remove-and-replacement method. If repairs are made to failed coating areas, the remaining intact coatings can often last an additional 10 – 20 years.

Due to the high cost of remove-and-replace bridge painting, KYTC has a continual backlog of bridges that need painting. This can result in circumstances where localized structural corrosion damage can occur on Cabinet bridges that do not have enough coating failure to warrant complete repainting. If localized failures result in corrosion, they can lead to load postings or necessitate expensive emergency repairs.

To address localized coating/patina failures and the high cost of remove-and-replace maintenance painting, three other maintenance painting options can be considered: 1) spot painting, 2) overcoating, and 3) zone painting. Each has different purposes and benefits. They attempt to preserve most bridge coatings or patinas while repairing problem areas and maintaining corrosion protection. This extends the overall functional service lives by ensuring existing coatings and patinas remain intact.

Spot Painting

Spot painting is used to repair localized coating failures that occur randomly on structural members (Figure 2.1). Failures can be complete or partial (e.g., topcoat disbonding). When localized failures result in the complete loss of existing coatings, the exposed steel or mill scale encountered has corroded to some extent (Figure 1.3). In this case, surface rust removal becomes part of the coating repair process. When localized coating failures occur due to the loss of one or more topcoats (i.e., intercoat failures), the exposed substrate of existing paint (e.g., primer or intermediate coat — Figure 1.4) may need to be slightly abraded by rubbing with sandpaper or abrasive pads before it can receive new wet paint.

From a unit area–cost perspective, spot painting is the most expensive maintenance painting method. However, its benefits extend beyond providing durable local repairs. It helps extend the service life of the entire bridge coating by 7 – 15 years. It offers attractive low per-bridge costs for achieving longer overall coating service lives. Spot painting has less elegant aesthetics than complete repainting projects as the color of the spot repairs usually does not match the existing coating. This limits its use on bridges where aesthetics are important.

Overcoating

During overcoating, spot repairs are made on areas where existing coatings have failed (partially or completely) like those carried out in spot painting. Additionally, one or two new topcoats are painted over the entire existing intact coating along with the areas that have received spot repairs. Unlike spot or zone painting, overcoating can be considered a complete bridge maintenance painting project (Figure 2.2).

When employed on bridges where the amount of existing coating deterioration is not extensive, overcoating can be about one-half the cost of remove-and-replace maintenance painting. Overcoating can protect and extend the service life of an existing coating 10 – 15+ years and on some KYTC projects much longer (25+ years). As the entire steel surface is coated with at least a new topcoat in overcoating, it can have similar aesthetics as a new remove-and-replace maintenance painting project. Overcoating can be used on an existing UWS bridge in the same manner — spot repairing failed patina areas and top coating all the bridge steel. The coating system used over the intact patina should probably incorporate a prime coat using a penetrating sealer over areas where the patina is still intact.

Zone Painting

Zone painting can be used to repair or reinforce existing coatings and patinas in similar locations on a bridge where they have failed or are susceptible to failure (e.g., girder/beam ends, outer faces of fascia girders/beams on overpass bridges). This involves surface preparation of areas/zones that have the potential for, or existing, problems. These areas are painted with one or more new topcoats to provide renewed or additional corrosion protection. With zone painting, matching areas at different structural elements are prepared and painted (Figure 2.3). This enables the use of abrasive blasting and zinc primer–based coating systems, which can offer long life even in highly stressed areas such as beam/girder ends under joints. Using more durable repair coatings in zone painting means that existing coatings can be removed from locations at risk for future corrosion problems even if existing coatings are intact.

Zone painting can also be used to protect weathering steel in areas where it is exposed to excessive corrosion. Due to the localized nature of most patina problems, most UWS repairs are performed using zone painting rather than overcoating or spot painting (Figure 2.4). Currently, it is the only feasible method for addressing UWS patina failures other than eliminating the sources through redesign or, in some cases, with vegetation management. Widespread patina failures, such as those which occur at the end of a patina life cycle, usually need to be addressed by remove-and-replace painting, or possibly overcoating.

Like spot painting, the unit cost of zone painting is usually high on a per-square-foot basis compared to remove-and-replace and overcoating options. However, zone painting offers the same overall cost benefits as spot painting. It extends coating service lives in high-stress areas where coating failures typically begin. It can provide 10 – 20 years of service in areas where existing coatings usually fail. The aesthetics of zone painting projects generally depend on the ability to match the color of the new topcoat with the existing one (Figure 2.5). Spot painting can be differentiated from zone painting in that: 1) spot painting is limited to areas where coating failures have occurred and 2) zone painting is applied to multiple identical (fixed) areas regardless of whether coating/patina failures are present.

New construction bridge coatings should undergo a spot/zone painting after about 15 – 20 years. After 25 – 40 years of service (depending on structure type and location), a bridge can receive an overcoat, which extends the expected coating service life by 10 – 20 years (Figure 2.6). After that painting cycle, a bridge would receive a remove-and-replace maintenance coating application. Experts consider this approach providing the lowest life-cycle cost for the bridge coating.

Figure 2.1 Spot Coating Applied to a Beam End, Diaphragm, and Bearing

Figure 2.2 An Overcoating Project on a KYTC Truss Bridge

Figure 2.3 Zone Painting on Beam Ends of a KYTC Overpass Bridge
New paint was used to repair coating damage due to joint leakage above the beams.

Figure 2.4 Kansas DOT UWS Zone-Painted Bridge
Note the area about 20 feet wide from girder end.

Figure 2.5 Color Matching on a Zone Painting Project
The project involved girder ends and floor beams under deck joints.

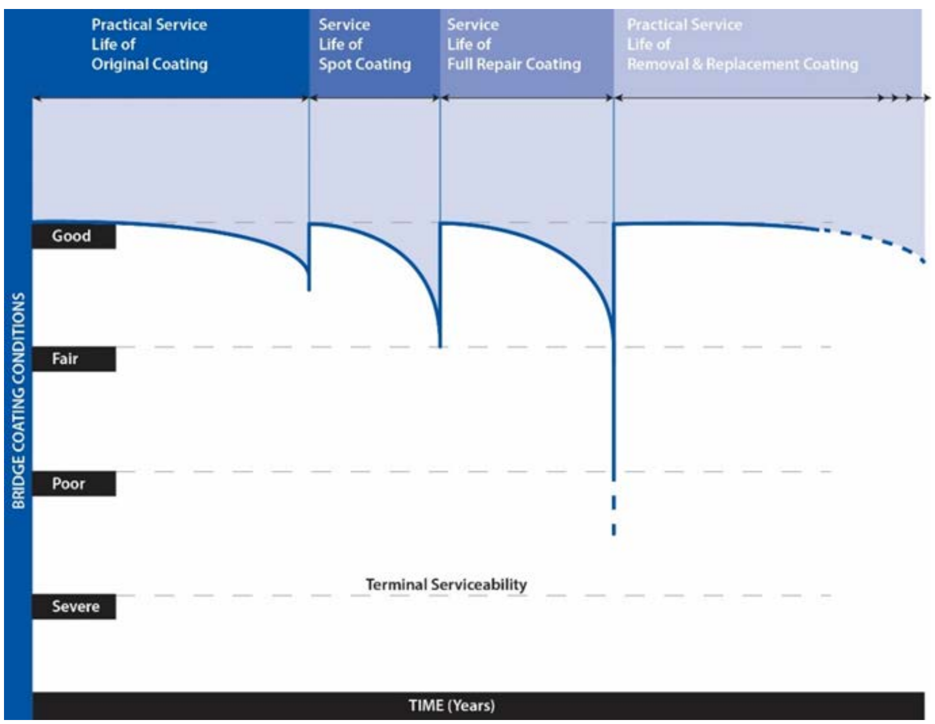

Figure 2.6 Idealized Life Cycle of a Steel Bridge Coating Subject of Maintenance Painting
Source: NCHRP Report 14-30

2.2 Determination of Maintenance Painting Options

Achieving benefits from maintenance painting options requires monitoring the condition of bridge coatings and making the proper repair decisions in a timely manner. Information on coating conditions found in KYTC's Bridge

Management System (BrM) helps pinpoint bridges that are candidates for coating maintenance actions. But more in-depth assessments are warranted so that proper maintenance painting actions can be determined. BrM data are also needed to prepare maintenance painting contracts. As there are relatively few Cabinet UWS bridges, those can be targeted periodically for field assessments.

Field assessments should be performed by personnel knowledgeable about bridge painting and, for UWS bridges, patina evaluation. Plans, biennial inspection reports, and other relevant documents should be reviewed prior to assessing candidate bridges onsite. A field assessment should include an overall visual examination of the bridge, its environment, and the existing bridge coating/patina. The inspector should take notes and pictures to document conditions, coating/patina failures, or potential problem areas. Tests and measurements should be performed to determine:

- Coating type(s) and thickness(es)
- Coating adhesion/ductility
- Coating/patina failure types
- Surface contamination (chalking, soils, graffiti, diesel fumes or liquid deposits and salts typically from past anti-icing/de-icing applications)
- Existing coating date if marked on the bridge (Figures 2.7 – 2.11).

Other maintenance needs, such as deck replacement or joint repair, should also be noted for consideration during follow-up bridge maintenance work.

Sites with severe corrosion should be noted and, if possible, measurements taken of steel section loss. For existing coatings, field measurements/tests should be performed at several locations. Samples of the coating system should be taken and sent to a laboratory for analysis to identify coating type(s) and detect the presence/content of hazardous constituents (typically heavy metal pigments — typically lead oxides such as red lead). During coating extraction, the substrate type (mill scale or abrasively blasted steel) should also be determined.

For weathering steel patinas, the field assessment process is generally similar, but less complex. Visual inspection should focus on areas where problems have been most common. Typically, this includes beam ends near joints and at locations sheltered by neighboring vegetation, fascia girders of overpass bridges, and structural members of truss and arch bridges that can collect and retain soils and moisture (Figures 2.12 – 2.14). Weathering steel can be removed by scraping/brushing areas of both satisfactory and questionable/poor performance for comparisons. Inspections should focus on areas where the patinas are loose and flakey, scaley, or discolored compared to the balance of the weathering steel (Figure 1.9). Testing for soluble salts should be performed at locations where patinas are exposed to deck runoff (e.g., under leaking joints) or aerosols are kicked up by traffic (e.g., fascia girders/beams on overpass bridges). When problematic locations are identified, zone painting is usually the most viable option (e.g., girder/beam ends). However, lower chords on truss bridges may need to be completely painted if patina problems are encountered. When pitting is observed (Figure 1.6), its extent and severity needs to be assessed. Individual pit depths can be assessed using a depth micrometer per Method B in ASTM D4417 (*Field Measurement of Surface Profile of Blast Cleaned Steel*).

After the field assessment is complete, a decision can be made on the appropriate maintenance work, including selection of a maintenance painting option. Peripheral factors such as environmental/context sensitivity, route classification, and traffic volumes and budget constraints can all factor into decision making. In some cases, the proximity of other bridges that need maintenance painting can also impact selection of a maintenance painting option.

Proposed criteria for maintenance painting repairs of existing coatings is provided in Appendix A. Options besides maintenance painting may be considered as well. A do-nothing option is available, but if chosen the reason for doing so should be recorded in the BrM for future reference.

Figure 2.7 Diesel Fume Deposits on Girders of a KYTC Overpass Bridge

Figure 2.8 Measuring Coating Thickness with a Tooke (Scratch) Gage

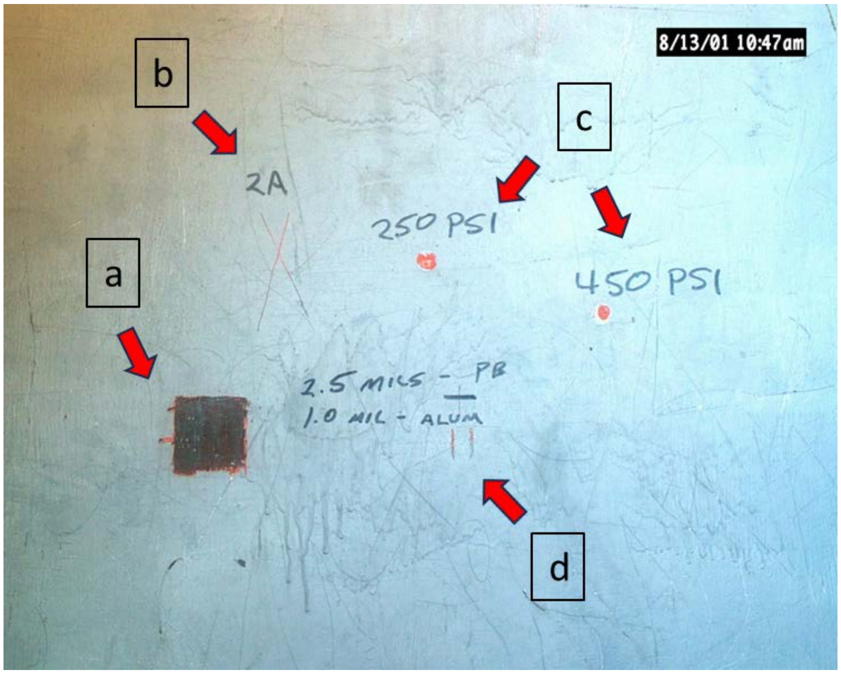

Figure 2.9 Existing Coating Evaluation Tests at Potential Overcoating Bridge Site

Notes: a) coating patch extracted for lab testing, b) X-cut tape adhesion test — 2A, c) coating tensile tests — 250 and 450 psi, and d) two Tooke coating layers/film thickness tests — red lead-alkyd primer (2.5 total mils thickness) with an aluminum-pigmented alkyd topcoat (1 mil thick). The 2A adhesion at 3.5 mils total film thickness is a low risk for overcoating. The tensile tests provide relatively high values (250 and 450 psi) supporting an overcoating decision.

Figure 2.10 Bresle (Patch) Test to Measure Soluble Salt Contamination

Figure 2.11 Maintenance Date on KYTC Bridge Girder
Date of maintenance painting is marked on end of girder (November 2006) along with county number (056) and KYTC bridge number (B00150).

Figure 2.12 KYTC UWS Railroad Overpass with Adjacent Vegetation
Vegetation surrounding abutments of the overpass inhibits proper drying of the weathering steel.

Figure 2.13 Patina Failure on UWS Beam End and Bearing
This is the same bridge shown in Figure 2.12. Patinas are performing properly on other portions of the steelwork with better environmental exposure.

Figure 2.14 H-girder Lower Chord with Problematic Debris and Moisture Buildup

Chapter 3 Special Notes Development Processes

For repairs of existing coatings, actions taken in preparation for painting are usually similar for spot painting, overcoating, and zone painting. Some types of surface cleaning and/or mechanical surface preparation are necessary on all surfaces that will be painted. For spot painting and overcoating, deteriorated areas are delineated and undergo surface preparation, such as washing, solvent cleaning, and mechanical surface preparation involving hand- and/or power-tool cleaning. For zone painting, locations are designated for painting and related processes. The latter can involve surface preparation methods used for spot painting and overcoating or can entail complete coating removal by power tools or abrasive blasting. For localized zone surface preparation, spot painting repairs are used along with one or two topcoats over the entire zone. When the entire existing coating is to be removed throughout each zone, painted is typically done using a coating system incorporating a zinc-pigmented primer. For repairs of weathering steel patinas, delineated zones that require coating protection will receive either surface preparation treatments like those used for spot painting or complete patina removal to an abraded steel substrate using power-tool cleaning or abrasive blasting. Typically, they would be painted with a barrier coating system.

Applying coatings to clean steel or existing coatings helps to achieve proper adhesion and results in optimum performance of the maintenance coating. Before a coating is applied, painters remove contaminants such as oils, diesel fumes, tar, or other hydrocarbon residues from existing substrates. These materials can be removed by wiping substrates with solvent-soaked rags or washing them with a detergent per SSPC-SP1 (*Solvent Cleaning*).

For any maintenance painting project, stratified or pack rust should also be removed by hammering, chipping, sanding, or scraping per SSPC-SP 2 (*Hand Tool Cleaning*) (Figure 3.1). Pressure washing is usually employed to remove soils, poorly adherent existing coatings, or soluble salt build-up (Figure 3.2). When KYTC performed overcoating projects in the past, the best washing results were obtained using pressure washers equipped with 0^o spinner tips using washing pressures between 4,500 and 5,000 psi at a minimum of 4 gpm per SSPC-SP 12/NACE No. 5 (*Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting*) prior to recoating.

When painting over an existing coating, most new coatings have sufficient “bite” (Surface Profile) to adhere to the existing coating. However, if an existing coating has a visible gloss, its surface should be lightly abraded to promote adhesion with the new finish coating. Some existing coatings may exhibit surface deterioration in the form of a tightly adherent white powder (i.e., chalking). Usually, chalking cannot be removed by washing, and before the surface is painted it must be removed. That is typically performed by hand wiping the chalked surface with burlap (Figure 3.3).

Where existing coatings have completely failed and the exposed steel/mill scale substrate is intact or corroded to some extent, the level of surface preparation can vary based upon the coating system to be applied, anticipated project cost, and repair life-cycle expectations. A range of cleaning methods and hand- and power tools are available to meet the project’s specific surface preparation requirements.

For typical spot painting or overcoating projects, power tools are commonly used for mechanical surface preparation (e.g., needle guns, grinders, flappers). The tools are usually equipped with vacuum shrouds to collect dust generated by tools and route it to a vacuum cleaner for collection and disposal. For less costly projects that trend toward shorter service lives, low levels of surface preparation meeting SSPC-SP 1 (*Solvent Cleaning*), SSPC SP-SP 2 (*Hand Tool Cleaning*), or SSPC-SP 3 (*Power Tool Cleaning*) are typically employed. In some cases, possibly for overcoating of UWS bridges, SSPC-SP7/NACE No. 4 (*Brush-Off Blast Cleaning*) can be considered. Repair coatings applied to projects with these types of surface preparation usually consist of barrier-coating primers and intermediate coats with weatherresistant finish coats. When more durable (costly) repairs are desired, higher levels of surface preparation are employed that include SSPC SP-1 and SP-2 cleaning followed by SSPC-SP 11 (*Power Tool Cleaning to Bare Metal*) or SP-15 (*Commercial Grade Power Tool Cleaning*) (Figures 3.4 – 3.7). In the case of zone painting, SSPC-SP6/NACE No.3 (*Commercial Blast Cleaning*), SSPC-SP 14/NACE No. 8 (*Industrial Blast Cleaning*) or SSPC-SP 10/NACE No. 2 (*Near-White Metal Clast Cleaning*) can be used for mechanical surface preparation (Figure 3.8).

On most maintenance painting projects, multiple coats are applied. In part, this is to achieve a proper film build and prevent missed or thin spots. Each coat has designated functions. KYTC currently mandates the use of three-coat systems for remove-and-replace paint projects. A primer, or base coat, is used to bond successive coats with the steel substrate. KYTC-approved primers contain zinc dust and provide either galvanic protection (inorganic zinc primers) or a combination of galvanic and barrier protection (organic zinc primers). Intermediate coatings typically provide barrier protection, which limits the penetration of soluble salts. These coatings incorporate organic resins and may contain metallic or platelet pigments that enhance their barrier properties. Finish coats integrate organic resins that resist atmospheric degradation (i.e., weathering) caused by direct exposure to the environment (wind, rain, abrasion, and UV radiation from sunlight). In applying multi-coat systems, all coatings used must come from the same manufacturer.

For spot painting, overcoating, and zone painting, what coating system is chosen will depend on the type and condition of the existing coating system and the type of maintenance painting selected. For zone painting of weathering steel, the finish coat can be pigmented to match the color of the weathering steel patina. For spot painting and overcoating, higher levels of surface preparation are used when the existing paint contains a zinc-pigmented primer. The repair coating can incorporate an organic zinc primer, possibly in conjunction with an epoxy or moisture-cure urethane intermediate coat and a polyurethane or acrylic weather-resisting finish coat. If the existing coating system does not contain a zinc-pigmented primer (e.g., a lead-based alkyd system), the repair coating system normally is a barrier type (e.g., epoxy primer/polyurethane finish coat, epoxy primer/acrylic finish coat, moisture-cure urethane primer/polyurethane finish coat). For zone painting, the choice of maintenance coating system does not depend on whether the existing coating is a barrier or zinc-based system. If the zone repair area is abrasively blasted, the repair system can include a zinc-pigmented primer along with a barrier intermediate coating (epoxy or moisture-cure urethane) and a polyurethane or acrylic finish coat.

Where existing coatings have partially failed (i.e., intercoat, intracoat disbonding) or where surface preparation is necessary to remove rust, tapering the exposed surfaces and interfaces between exposed edges of intact coatings by sanding is commonly used to promote bonding with the applied repair coatings (i.e., feathering; Figure 3.5). Prior to painting, those edges should be probed with scrapers to verify they are adherent (Figure 3.9).

Zone painting is the most widely used method for UWS patina repair. The areas to be cleaned and painted (e.g., girder/beam ends) should be marked off to prevent over- or under-repairs. For girder/beam ends, the repair should extend about one-foot beyond the point where patina protection is required. For this type of patina repair/protection, there is no standard practice for painting beam ends including the width of the painted zone (Figure 3.10 – compare with Kansas DOT zone painting in Figure 2.4). Based on responses from other state DOTs, painting of girder/beam ends ranges from 2 – 20 feet. Typically, the repair areas are pressure washed for soil and salt removal and then degreased (if necessary). That is followed by some level of mechanical surface preparation ranging from hand-tool cleaning to some level of abrasive blasting depending upon the type of repair coating(s) to be applied. The painting method for weathering steel will vary depending on the bridge location, size of the repairs, and type of coating system used. For small projects, brushing is commonly used (Figure 3.11).

For remove-and-replace painting associated with zone repairs, KYTC specifies a form of surface preparation that incorporates dry abrasive blast cleaning. A system consisting of an air compressor, blast pot, air lines, and blast nozzle is used to perform blast cleaning. The air compressor generates a stream of high- velocity air in a line attached to the blast pot. Abrasive media (e.g., granite, coal slag particles, recyclable steel shot/grit) are injected into air lines from the blast pot and carried at high speeds through the lines to the blast nozzle. An operator points the nozzle at the structural steel to be cleaned (Figure 3.12). The abrasive stream emerges rapidly from the blast nozzle, impacting the steel and removing surface debris, mill scale, and existing paint (Figure 3.13). It also abrades the surface, creating a fine, rough texture (Figure 3.14). This texture increases the effective surface area of the steel substrate, enhancing adhesion of the primer coat. Blast cleaning of existing lead-based coatings generates toxic fines, and spray painting causes paint to mist. Both can potentially endanger the public and property if released into the air. When blast cleaning or spray painting, sophisticated containment enclosures are required (Figure 3.15). Different methods of containment can be used depending on the importance of potential receptors (e.g., urban vs. rural areas) and the type of maintenance painting project (Figure 3.16).

KYTC typically requires the use of a mixture of steel shot/grit for abrasive blasting on large projects. Spent steel abrasive is collected and processed through a recycling machine that separates reusable shot/grit from blast wastes (Figure 3.17). The shot/grit may be used repeatedly in blasting operations until it is no longer effective and is discarded by the machine. Recycling abrasives minimizes their disposal; these wastes could negatively impact the environment if paint debris contains lead or other hazardous materials. Hazardous lead-based paint wastes generated in painting operations are treated and then deposited in landfills. Wastes generated by using steel abrasives can be sent to a lead smelter for recycling, eliminating ground disposal (Figure 3.18).

A few issues must be considered to avoid problems with dry abrasive blasting. First, it is not effective for removing invisible soluble salt contamination — it may embed salts in prepared steel substrates, resulting in the premature failure of new coatings. This can be avoided by measuring salt contamination on existing substrates prior to blasting and taking steps such as pressure washing to reduce salts down to acceptable levels. During blasting, the compressor can generate water in the blast lines, which causes blasted steel to rust before it is coated. An ink blotter can be placed at the nozzle to test the compressor's air stream; if moisture is present, steps should be taken to eliminate it. Once the blasting operation is complete, the steel surface must be visually inspected to verify it meets specified cleaning standards.

Once surface preparation is complete within a control area, the contractor's quality control (QC) inspector will conduct a complete arm's length inspection and approve it or, if needed, have improperly prepared surfaces corrected.

KYTC's remove-and-replace painting procedure consists of spraying liquid-applied inorganic and/or organic coatings onto the surface of structural steel bridge members (Figure 3.19). Spraying can also be used to apply intermediate and finish coats on overcoating and larger zone painting projects. Brushing and rolling can be used to apply primers for spot painting and overcoating (Figures 3.20, 3.21). They can also be employed for intermediate and finish coats on smaller spot and zone painting projects. Painting mitts and daubers can be used for hard-to-access or irregular surfaces, such as those found on riveted structural members (Figure 3.22).

Figure 3.1 Removal of Stratified Rust and Pack Rust with a Hammer
Rust is found between riveted steel members.

Figure 3.2 Pressure Washing a Steel Member

Figure 3.3 Chalking Removal with Burlap Wiping

Figure 3.4 SSPC-SP 3 Power Tool Cleaning
The technician is using a vacuum-shrouded grinder with a non-woven abrasive pad.

Figure 3.5 Surface Prepared to the SSPC SP-3 Standard
A visual standard used for inspection is shown at the bottom of the picture. Note that the edges of the existing coating adjacent to the repair areas have been feathered.

Figure 3.6 SSPC SP-11 Power Tool Cleaning of a Girder
The technician is using a vacuum-shrouded rotary peening tool.

Figure 3.7 Surface Prepared to the SSPC SP-11 Standard.
Note the typical abraded surface resulting from mechanical surface preparation.

Figure 3.8 Girder Cleaned to the SSPC-SP 10/NACE No. 2 Standard
This approach is commonly used on remove-and-replace projects with zinc-based primers.

Figure 3.9 Probe of Coating Failure to Verify Adherence.
A worker is using a small scraper to probe the edge of a coating failure area to verify the intact coating is firmly adherent.

Figure 3.10 Small Zone Painting Repair on a Minnesota DOT UWS Bridge
The repair coating is pigmented to approximate the color of the weathering steel patina.

Figure 3.11 New York State DOT Technicians Brush Coating on a Bearing
Note the complete patina removal by power tools on the UWS girder end in preparation for zone painting.

Figure 3.12 Blast Cleaning of a Girder End Prior to Zone Painting

Figure 3.13 Girder Cleaned to the SSPC-SP 14/NACE No. 8 Standard
Compare this finish to the one shown in Figure 3.8.

Figure 3.14 Surface Profile of Steel Cleaned to the SSPC-SP 10/NACE No. 2 Standard

Figure 3.15 Containment Structure Attached to Girder Ends.

The containment structure prevents releases of abrasive blasting debris and mists from spray painting. Suspended hoses are for applying negative pressure in the containment to prevent releases of dust and paint mists into the atmosphere and to remove solid wastes for recycling on equipment located on the ground.

Figure 3.16 Permeable Tarp Diaper

This type of containment is sufficient to collect large paint chips or other debris generated during surface preparation and lets water filter through during washing.

Figure 3.17 Recycling Unit on Blast Cleaning Operation

The recycling unit removes waste material from a blast cleaning operation and allows reuse of steel abrasive. This unit was used on a large-scale zone painting project.

Figure 3.18 Lead-Contaminated Paint Debris

This was generated by abrasive blasting and the use of recycled steel abrasives shown after the recycling operation. The material can be recycled.

Figure 3.19 Spray Application of a Finish Coat

Figure 3.20 Brush Application of Primer on Bolts

Figure 3.21 Paint Application Using a Roller

Figure 3.22 Use of Paint Mitt to Apply Coatings

Chapter 4 Preliminary and Jobsite Work

KYTC currently contracts out all bridge maintenance painting. The contracting process can be facilitated through a pre-letting site assessment in conjunction with a pre-bid conference and pre-construction conference. Proper scheduling is necessary to avoid disruptions during periods of high traffic volumes (e.g., workdays, holidays). Steel bridge maintenance painting projects are complex and typically have eight work phases:

- Mobilizing the Painting Operation
- Deployment at the Work Site (Field Operations)
- Preparation for Waste Handling and Disposal
- Surface Preparation
- Monitoring Surface and Atmospheric Conditions
- Applying Coatings
- Inspecting Work and Affecting Repairs
- Demobilization

4.1 Mobilizing the Painting Operation

Mobilization encompasses multiple steps to ensure all project-related factors are addressed prior to fieldwork. Tasks include:

- Scoping/scheduling of projects
- Addressing environmental issues
- Addressing worker safety issues

KYTC may consider performing small spot and zone painting projects, including repairs on UWS bridges, using in-house personnel. These personnel, however, should not be used if bridges have lead-based coatings. For in-house painting, coatings will likely be stored at District shops or garages. The Cabinet may also provide contactors with coating storage facilities when there are no alternatives.

If multi-component coatings are to be used, they should be furnished in pre-measured kits from the coating manufacturer. When containers are delivered, they should be checked for labelling and damage. Containers with signs of leakage should be returned to the manufacturer for replacement. Crew supervisors should keep all paperwork and verify its completeness. In many cases, coatings may be stored for some time before application (Figure 4.1). Shelf life and storage conditions, especially temperature, are critically important. Manufacturer guidelines should be complied with both at the KYTC shop and in the field (if coatings are stored onsite). Coatings stored for long periods may liver, skin, gel, or settle to form a hard layer that will not disperse. In such cases, coatings should be discarded and replaced.

If KYTC personnel will complete the painting, before they begin the supervisor should prepare a list of equipment and supplies necessary for work. This includes general work equipment/stores, waste handling equipment/supplies, personal protective equipment/supplies, hygiene equipment, consumable supplies, test/inspection equipment, signage and traffic control devices, and necessary documentation (i.e., work standards/special notes, coating product data and safety sheets, worker safety plans, relevant industry standards) and applicable environmental clearance documents.

Before a painting crew departs for a jobsite, the supervisor should make a hands-on determination that all necessary materials are on hand. If the work is to be performed by contract, the KYTC project manager needs to verify the contractor has completed any environmental and worker safety paperwork. If necessary, the paperwork should be available for inspection at the jobsite.

4.2 Deployment at the Work Site (Field Operations)
Deployment at the work site encompasses all tasks completed onsite before spot painting begins:

- Establishing traffic control (including lighted signs for night work)
  - Field work should not begin until the approved traffic control is complete.
- Initiating painting support activities in the staging area
- Creating onsite waste storage (if necessary)
- Performing necessary preliminary site cleanup
- Placing access equipment at repair sites
- Installing necessary waste containment
- Establishing work areas

4.3 Preparation for Waste Handling & Disposal
All maintenance painting operations generate waste. Work prior to painting operations typically involves collecting, bagging, and disposing of wastes, typically left by individuals trespassing on and about bridge abutments (Figure 4.2). Disturbance/removal of existing coatings generates solid wastes which, depending upon their elemental content, may be classified as hazardous based upon Kentucky and US EPA regulations. These materials may co-mingle with rust, mill scale, spent supplies, and soils that were removed during cleaning and mechanical surface preparation work. Prior to their disposal, all of these materials must be collected and evaluated to determine if they constitute hazardous wastes. Some spent coatings and solvents used during the painting process may also be classified as hazardous, which means they must be collected for disposal as waste or for recycling. Each day, the painting crew should collect and properly store all wastes generated onsite. Hazardous wastes must be collected daily and placed in USDOT-standard containers such as 30- and 55-gallon steel drums. These must be stored onsite during the project in fenced-in areas and removed when the project is completed (Figure 4.3).

When hazardous materials are present (e.g., lead pigment in existing coatings, spent volatile solvents) cleaning, surface preparation, and painting methods must be evaluated prior to project inception. Washing existing leaded coatings and depositing the wastewater into receiving bodies of water may be acceptable under some conditions because of dilution, but not under others (e.g., when a bridge is located near a drinking water inlet). In the latter case, an impermeable bib must be draped under a bridge to collect wash water. This water must be treated prior to disposal. For mechanical surface preparation methods that do not involve abrasive blasting, suitable solid waste collection can involve the use of ground tarps to collect paint chips along with the use of vacuum-shrouded hand or power tools that collect resulting debris in vacuum systems (Figure 4.4).

Workers involved in spot painting must take special precautions to protect themselves from hazards associated with painting operations. This is addressed under the federal Occupational Safety and Health (OSH) Act (1970) as regulated by the Occupational Safety and Health Administration (OSHA). Contractor employees are covered by OSHA regulations. State workers, including KYTC inspectors, are not covered by federal OSHA but have OSH protections if they work in states that have OSHA-approved state programs — such as the Kentucky Safety and Health Program (KOSH). Where painting operations disturb lead-based coatings, onsite sanitary stations are usually provided by contractors. For larger projects, sanitation trailers are sometimes available (Figure 4.5). Coating manufacturer safety data sheets provide information on safe handling and application of products.

On all painting projects involving existing lead-based coatings, the contractor should designate a person who will be onsite that has the requisite knowledge to identify lead hazards and possesses the authority to take prompt corrective measures to eliminate resulting problems.

4.4 Monitoring Surface and Atmospheric Conditions

Actions described in this section apply prior to all paint application methods — both partial and full applications, regardless of the coating application method(s). After the contractor's QC inspector approves the surface preparation in a control area but prior to painting, KYTC's quality assurance (QA) inspector visually examines the areas where cleaning and mechanical surface preparation have been performed. They may perform additional tests, including rag wiping to inspect for surface cleanliness, scraper probing of feathered edges in existing coatings to assess coating adherence, and Bresle testing to gauge surface contamination by soluble salts (Figure 4.6). A blasted steel surface must be free of rust, and abraded steel must have the appropriate surface profile to accept painting (Figure 4.7). Inspectors often use mirrors to detect areas where abrasive blasting has been conducted improperly (Figure 4.8). All surfaces must comply with KYTC specifications and paint manufacturer criteria for acceptable surfaces before Cabinet QA inspectors will authorize painting.

Once prepared surfaces are approved, the contractor's QC inspector must measure atmospheric and steel surface conditions to verify liquid coatings will not be applied to wet substrates. Rain, mist, fog, or condensation can deposit moisture on substrates. Weather forecasts can indicate if rain is imminent and inform workers if they should delay painting operations. Painting is prohibited during rain, even inside of containment enclosures. While visual inspections are typically sufficient to detect surface moisture, the relative humidity and surface temperature should be measured as well (Figure 4.9). Doing so helps workers avoid painting in conditions where condensation will moisten surfaces and prevent coating adhesion. Atmospheric conditions should be measured periodically to identify existing/imminent condensation threats, especially when painting at night, and to ensure that conditions have not changed since the start of painting. Because atmospheric conditions can vary along a bridge, workers must measure relative humidity and temperature in locations where painting will be performed. Coating manufacturer product data sheets provide information about substrate and ambient conditions necessary for acceptable coating performance.

4.5 Applying Coatings

If surface preparation and atmospheric conditions are acceptable, workers can apply coatings. Coatings are mixed and agitated onsite according to manufacturer instructions (Figure 4.10). Workers should prepare only enough coating to cover the steel in a (control) area designated by the KYTC QA inspector. Prepared coatings must be applied within time limits specified by the coating manufacturer.

Once preparation is complete, the coating is taken to the application site using buckets, or when spraying is used to a pump that forces it through a hose and into a painter's spray gun nozzle (Ref. Figure 42). On small projects or projects with just a few spot repairs, battery-powered spray guns can be employed in place of conventional hand-application methods (Figure 4.11). Following application, each coat must cure sufficiently according to manufacturer directions before the next coat can be applied.

Past KYTC specifications mandated that contractors apply a test patch of the coating system that is kept throughout the project to serve as a site standard (Figure 4.12). After the primer cures and is inspected and approved, workers apply successive coats, typically consisting of an intermediate and finish coat. During spot painting, overcoating, and zone painting, the primer and (where used) intermediate and finish coats should overlap the borders of existing coatings (or stable patinas) and previously applied coats by several inches. For overcoating, all coated steel surfaces will receive one or two topcoats including a finish coat for weathering protection.

During the application process, painters use wet film gauges to measure the coating thickness (Figure 4.13). Measuring coating thickness at this stage helps ensure that when the coating cures it will be within manufacturer-specified thickness tolerances. Following the application and curing of each coat in a control area, the contractor's QC inspector visually examines the dried coating to detect flaws indicative of coating defects (e.g., runs, blisters, pinholes, thin spots, misses — Figure 4.14). Coating flaws must be repaired before successive coats are applied or the finish coat is completed. The contractor's QC inspector also uses a coating thickness gage to measure the dry film thickness and verify the proper film build has been achieved (Figure 4.15). After the KYTC QA inspector approves each coating, painters complete the coating application phase of work in a control area and move to other areas, where they perform painting until all work is complete.

4.6 Inspecting Work and Affecting Repairs

Once the KYTC QA inspector approves all painting work, the Division of Construction chief coatings inspector performs a final site inspection. The chief coatings inspector reviews the coating work and notes deficiencies that require corrective action (e.g., paint flaws, overspray on concrete, paint spills on the ground, bulkhead misses, rigging scrapes). Contractors correct deficiencies before removing containment and access rigging (Figure 4.16). KYTC's chief coatings inspector examines remedial work, in consultation with the contractor, to verify its satisfactory completion.

4.7 Demobilization

Contractors remove work-related materials/wastes from the jobsite before leaving. They remove all waste storage enclosures once waste and/or paint residues are taken for disposal/recycling. Containment tarps used on projects that involve lead paint removal must be cleaned before they are taken offsite or disposed of. Waste found on the ground must be collected, tested for lead contamination, and disposed of in the proper manner (Figure 4.17). Traffic signs must be removed. If the environment has been disturbed, it must be remediated before the contractor departs the jobsite. A contractor must leave the jobsite in the same condition it was in before maintenance painting began (Figure 4.18). The KYTC QA inspector checks the worksite after demobilization to ensure that all cleanup tasks have been completed and the worksite was restored to its original condition.

Figure 4.1 Proper Storage of Coatings at KYTC Facility

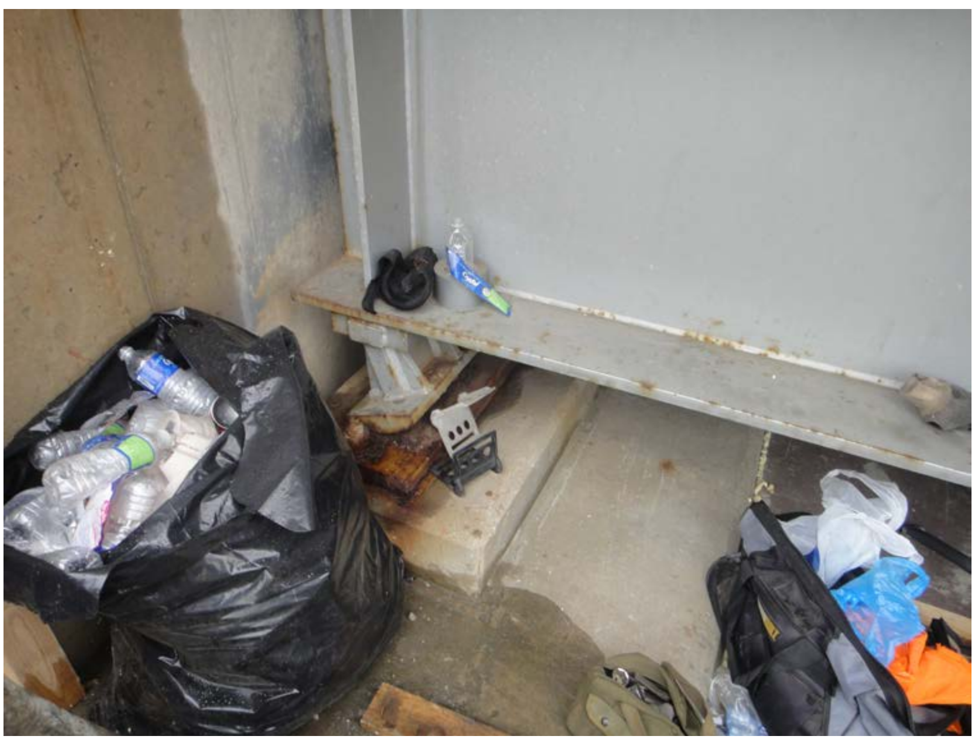

Figure 4.2 Debris Accumulated on and Near a Bridge Abutment
Litter must be collected and disposed of prior to painting operations.

Figure 4.3 Fenced-In Area for Hazardous Waste Storage

Figure 4.4 Ground Tarp Used to Collect Hazardous Waste
At this site, the tarp collected lead-based paint chips generated during hand and power-tool cleaning on a spot painting project.

Figure 4.5 Sanitation Trailer for Workers

These are typically equipped with lockers, vacuum cleaners, showers, lavatories, laundries, and refrigerators.

Figure 4.6 Inspector Wiping a Prepared Surface

This is done to determine if the surface is suitable for top coating on an overcoating project.

Figure 4.7 Measurement of Surface Profile Impression on Blast-Cleaned Steel
The tape test is used to determine if the steel roughness (profile) is in an acceptable range.

Figure 4.8 Mirror Inspection of Hex Nuts
This technique is used by inspectors to detect locations incompletely cleaned by abrasive blasting.

Figure 4.9 Electronic Dew Point Gage
This device is used to measure the ambient temperature, relative humidity, dew point, and steel temperature to ensure conditions are satisfactory for painting.

Figure 4.10 Onsite Mixing of a Multi-Component Coating Prior to Application.

Figure 4.11 Spot Repair Spray Painting Using a Portable Spray Gun

Figure 4.12 Test Patch Used as Site Standard on Overcoating Project
Different layers of coating are applied to serve as suitable examples should questions arise. The primer is yellow, the intermediate coat is red, and the finish coat is gray.

Figure 4.13 Measuring Wet Film Thickness Using a Tooth Gage

Figure 4.14 Coating Defects

These were marked by a contractor’s QC inspector for follow-up repairs by painters.

Figure 4.15 Dry Film Gage
Measuring the thickness of a cured (dried) coating using a dry film gage. The gage reads a coating thickness of 6.1 mils (0.0061 inches).

Figure 4.16 Painter Brushing a Spot Repair
This was done on a coating miss caused by the presence of a containment hanger (arrow), which was moved after initial painting to expose the unpainted area.

Figure 4.17 Worker Collecting a Soil Sample on Project that Involved Lead Paint Removal

Figure 4.18 Contractor Demobilization at the End of a Painting Project

Chapter 5 Developing A Bridge Painting Program

5.1 Inventory

KYTC conducts maintenance painting on steel bridges it owns as well as bridges owned by other jurisdictions. While the primary painting inventory is the Kentucky-owned group (structures designated with a *B* in the BrM database), multiple agreements or policies cover bridges from county, city, parks, railroad, or adjoining state inventories. The Cabinet is responsible for painting most bridges that connect to adjoining states. Border state maintenance agreements are developed to fund these major projects.

The Cabinet's inventory of steel bridges specifies bridge type (e.g., multi-girder, non-redundant girder, pony truss, through truss, deck truss, suspension, cable stay). Bridge type significantly impacts the complexity — and cost — of a painting project. The inventory specifies the location of each bridge and contains data on latitude, longitude, stream crossed, route, intersecting route, and county. This information is important for programming maintenance activities as grouping bridges helps KYTC achieve economies of scale and improve project management.

Other data in the inventory include vertical clearance, existing coating type, steel surface (mill scale), and condition of the existing coating. Data pertaining to coating condition should note the following:

- Failure mechanism (corrosion, steel disbondment, chalking, inter-coat adhesion)
- Failure location (beam ends, fascia, general)
- Degree of failure (approximate percentage of area)

5.2 Programming

KYTC staff developing and programming bridge maintenance activities must have knowledge of funding sources which can underwrite their maintenance painting budget, including:

- Maintenance (FE02) Budget
- 6-Year Highway Plan, Special Projects
- End of Fiscal Year Adjustments

Several factors influence the bridge painting program's scope, including the available budget, project complexity, and market conditions (i.e., amount of work in a region). When making programmatic decisions, the Specifier/Programmer considers spot painting, overcoating, and zone painting options along with patina repairs:

- Selection of bridges for maintenance painting
- Optimizing maintenance painting expenditures based on need, maintenance painting option selection, and costs (option selection may be impacted by availability of KYTC personnel for project management)
- Scheduling (spreading work over multiple construction lettings)
- Contract administration (coordinating with the Division of Construction)
- Projects requiring extended development (e.g., railroads)
- Project time requirements (e.g., multi-season projects, completion dates, other projects)

Other considerations when developing the bridge painting program include:

- Disturbing lead on bridges (e.g., remove/replace, encapsulate)
- Leaded and other hazardous/non-hazardous residues (to be recycled or sent to an appropriate waste facility)

- Distributing funding across KYTC districts
- Reciprocal agreements with other bridge owners (e.g., states, cities, parks)
- Rehab and/or repair work

Currently, KYTC relies solely on remove-and-replace maintenance painting for bridges. While this technique offers the longest life cycle of any maintenance painting option, it is not always the most effective from a life-cycle cost standpoint, especially when the durability of the entire coating system is considered in light of other options discussed in this document. Because the Cabinet has limited funds for bridge maintenance and other maintenance issues must also be addressed, the agency needs to adopt more cost-effective approach to bridge maintenance painting. On the front end, this will require more in-depth investigations of candidate bridge painting projects and determining the most feasible/optimal maintenance option: remove-and-replace, overcoating, spot painting and zone painting.

Optimization programming can deliver maximum maintenance painting benefits to KYTC's steel bridge inventory based on criticality of repair, number of bridges impacted, repair options selected, current coating conditions and life-cycle years per unit coating area gained for the options selected. Prior to the early-2000s, KYTC painting projects were usually performed using overcoating and zone painting. The specifications for those proved technically effective when used (including addressing environmental controls). As such, they are still viable and can be used in future maintenance painting work. The Kentucky Transportation Center has conducted a national study on spot painting and can provide guidance on that practice as well. KYTC will need to update its approved products list to incorporate current coatings (and coating systems). Also, the Cabinet needs to review the performance of weathering steel bridges to identify locations where patinas exhibit substandard performance. These can be addressed using zone painting or, if necessary, complete maintenance painting using the remove-and-replace method.

Historically, KYTC has adopted a continuous improvement approach, whereby newly developed materials and/or methods are incorporated into the painting program so that projects are completed in the most cost-effective manner possible. This has resulted in incremental project improvements while maintaining or reducing project costs.

Under the bridge painting program, individual bridge painting proposals go to letting. Proposals often encompass several smaller bridges. However, proposals for large bridges (e.g., Ohio River bridges) are usually limited to a single bridge or pair of bridges. When developing bid proposal packages for cleaning and painting projects, it is important to bear in mind that each bridge is unique. As such, proposals should address specific features of the project context that will influence painting operations, including:

- Construction details
- Steel condition
- Coating condition
- Presence of heavy metals
- Protected habitats
- Protected waters
- Temporary traffic control issues
- Sensitive environmental receptors
- Worker access issues
- Oversize loads (e.g., farm equipment)

While biennial inspection data (i.e., Structure Inventory and Appraisal [SI&A]) provide some of this information, the individual developing a proposal should conduct an onsite visit to fully understand site conditions in addition to the aforementioned investigations of existing coatings. Helpful resources to consult during proposal development include (note, the following bullets link to the relevant publications):

- KYTC Standard Specifications for Road and Bridge Construction
- KYTC Standard Drawings
- KYTC List of Approved Materials (for remove-and-replace coatings)
- KYTC Work Zone Safety Policy
- FHWA Manual on Uniform Traffic Control Devices (MUTCD)
- Other Industry Standards and Guides

KYTC maintains a list of prequalified bridge painting contractors, and the bridge coatings industry has certifications for contractors and trades (e.g., coatings inspectors) which can be referenced to improve the quality of work. While these resources are critical for developing a proposal-type bid package, Special Notes are the most important component of a proposal as they address the unique characteristics of each bridge and specify the bridge location. Special Notes provide detailed explanations of specific requirements for cleaning and painting individual bridges.

Chapter 6 Recommendations

KYTC can strengthen its bridge maintenance painting program by implementing the following recommendations:

- Explore carrying out spot and zone painting projects using in-house personnel, but only on bridges that do not have lead-based coatings.
- Adapt guidelines from other DOTs for programming spot, zone, and overcoating projects.
- Establish best practices for implementing spot, zone and overcoat projects based on monitoring of Kentucky projects.
- Develop special notes for surface preparation and coating options in the field.
    - They should address jobsite preparation, inspection, field operations, waste handling, monitoring of surface conditions, applying coatings, and cleanup.
- Prepare guidance on methods for inspecting and handling coating materials. This is critical since coatings will be stored in District garages.

References

1. Kentucky Standard Specifications for Road and Bridge Construction
2. KYTC Bridge Inspection Procedures Manual
3. KYTC Field Operations Guide (FOG)
4. KYTC Maintenance Manual (MAIN)
5. KYTC Construction Manual (CST)
6. KYTC Structural Design Manual (SD)
7. Kentucky Methods Guidance Manual (KM)
8. KYTC Materials Field Sampling Manual (MFS)
9. KYTC Division of Materials Manual (MAT)
10. List of Approved Materials (LAM), Structural Steel Coating Systems, Class II (Type I and Type II)
11. Virginia DOT Bridge Maintenance Manual.
12. Joseph Saleeby, "Common Coating Inspection Practices, Standards, & Equipment." Joseph Saleeby
13. Iowa DOT Bridge Maintenance Manual
14. Federal Highway Administration (Spring 2018). "Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility." McLean, VA.
    https://www.fhwa.dot.gov/bridge/preservation/guide/guide.pdf
15. Publication No. FHWA-NHI-14-050 "Bridge Maintenance Reference Manual"
16. FHWA Bridge Inspector's Reference Manual
17. Florida Department of Transportation Maintenance and Repair Handbook
18. Georgia Department of Transportation Bridge Structure Maintenance and Rehabilitation Repair Manual
19. Michigan DOT Bridge Spot Painting Standards and Guidelines
20. Hopwood, T., Fairchild, J., Meade, B.W. and Palle, S., "Preventive Maintenance Program for Bridges", Kentucky Transportation Center, Report No. KTC-15-07/SPR11-424-1F, July 2015.
21. Danny, W., Meade, B.W., Hopwood, T., and Palle, S., "A Programmatic Approach to Long-Term Bridge Preventive Maintenance", Kentucky Transportation Center, Report No. KTC-16-22/SPR15-504-1F, March 2017.
22. Danny, W., Palle, S., and Hopwood, T., "Developing Work Standards, Special Notes, and Specifications for Proposed Bridge Preventive Maintenance Actions", Kentucky Transportation Center, Report No. KTC-19-11/KHIT-112-1F, May 2019.

Appendix A Field Analysis of Existing Coatings on Bridges

When deciding on the type of coating method to use, gather and evaluate data on existing coating conditions. Some data used to assess coating conditions can be collected from bridge files and/or during the biennial bridge safety inspection program that acquires element-level inspection data. These data include bridge construction date, date of last coating application (depending on the date, it may suggest the presence of lead), type of existing coating, presence of mill scale, and presence of soluble salts.

SSPC-TU 3 outlines a process for evaluating a structure's existing coating. Use the following checklist to guide data collection.

Data from AASHTOWare BrM	
1) Type of Bridge:	2) Construction Date of Bridge:
3) Last Coating Application Date:	4) Method of Coating Application: • ☐ Total Removal and Recoat • ☐ Overcoat
5) Existing Coating Type:	6) Presence of Lead:
7) Presence of Soluble Salts:	8) Presence of Mill Scale:
9) AADT:	10) Cost of Overcoating • Estimated cost of total removal and recoat is \$12 to \$18 per square foot. • Estimated cost of zone painting using SP10 cleaning is \$18 to \$30 per square foot. • Estimated cost of spot painting is \$20 to \$25 per square feet.
11) Project to be Contracted or Performed by In-House forces:	12) Total square footage of steel on the bridge that needs to be protected:
Field Data to be Obtained	
1) Existing Coating Thickness	
2) Adhesion Factor of Existing Coating	
3) Degree of Rusting (Should give % of Rust)	
4) Soluble Salt Readings	
5) Approximate Square Footage of Area to be Coated	
6) Site Assessment/Conditions for Mobilization	

SSPC-TU 3 also includes an *Inspection of Coating System To Assess Risk of Overcoating* form that field inspectors can use. Once field data are gathered, the engineer must assess them to identify the most appropriate coating remediation strategy. If a structure contains lead, hazardous coatings and environmental factors may demand total removal and recoat (KYTC's current model). Based on coating thickness and adhesion values, the engineer can determine if the existing coating can accept any new coating. Table A1 can be used to evaluate the risk of salvaging existing coatings (SSPC-TU 3).

Table A1 Risk of Salvaging Existing Coating Based on Adhesion/Thickness Characteristics

ADHESION CLASSIFICATION		COATING THICKNESS		
ASTM D6677	ASTM D3359 METHOD A	LESS THAN 254 µm (10 mils)	254 to 508 µm (10 to 20 mils)	GREATER THAN 508 µm (20 mils)
10	5A	OK	OK	OK
8	4A	OK	OK	OK
6	3A	OK	OK	OK
4	2A	LR	LR	MR
2	1A	MR	HR	HR
0	0A	NO	NO	NO

OK = Essentially no risk
LR = Low Risk
MR = Moderate Risk
HR = High Risk
NO = Integrity too poor to salvage

Next, a strategy is developed based on the amount of rust and paint that needs to be removed, cleaning of rusty areas to an SSPC-SP 6 standard, and removing of loose or non-adherent coatings. A strategy is chosen based on the percentage of rusted and degraded surface area:

0-1% Rust:

Overcoating is the best option when the risk rating is OK. Think of this as a *paint when it does not need re-painting* situation and is typically the lowest-cost option with the least amount of risk. Use of a surface-tolerant coating combined with the washing of surfaces is viable in these cases.

If the coating's integrity is too poor to salvage (a risk rating of NO) the structure is not a good candidate for overcoating, or any coating. This is a possible do-nothing situation. Despite poor adherence, the existing coating provides excellent corrosion protection and there is no imminent danger of section loss except (possibly) in localized areas. Some type of spot or zone repair may be considered. Coating work must be deferred until total removal is warranted or it is viable to replace the structure during a major rehabilitation.

If the risk rating is MR or LR, risk tolerance will influence the decision. Spot or zone painting is an option, but full overcoating may not be an option.

1-15% Rust:

When rust covers more surface area, the level of surface preparation and cost both increase. If the adhesion and thickness ratings are OK, overcoating is an excellent alternative. The engineer must decide on the type of surface preparation needed (e.g., minimal scraping, blasting). If the risk rating is NO, coating should be deferred until a total removal is done or replacement of the steel is viable as part of rehabilitation.

If the risk rating is MR or LR, spot or zone coating may be less risky than a full overcoat, depending on rust distribution. The remaining service life must be weighed against the cost of a total paint coating removal now or in the future.

<u>> 16% Rust</u>:

As rust coverage becomes more widespread the cost of spot or zone painting approaches that of fully removing existing paint. The AASHTO *Bridge Painting Guide* (1994) indicates that whenever the surface preparation area exceeds 15 to 20 percent of the total surface area, total removal lead paint is the most economical option. Overcoating may not be as viable an alternative, depending on the type of surface preparation specified. Overcoating a structure with extensive corrosion should probably be limited to structures with an expected remaining service life of less than 10 years. Otherwise, do nothing until a full removal or replacement has to be undertaken.

The final selection of spot painting, zone painting, or overcoating must be justified by a cost assessment. The Virginia DOT has developed a flowchart to guide decision making (Figure A1). Information on the percentage of surface area corroded, compliance with SSPC-TU 3, aesthetic considerations, and prevailing cost rates per square foot of steel for spot painting, zone painting, and overcoating is used to help engineers devise a coating strategy.

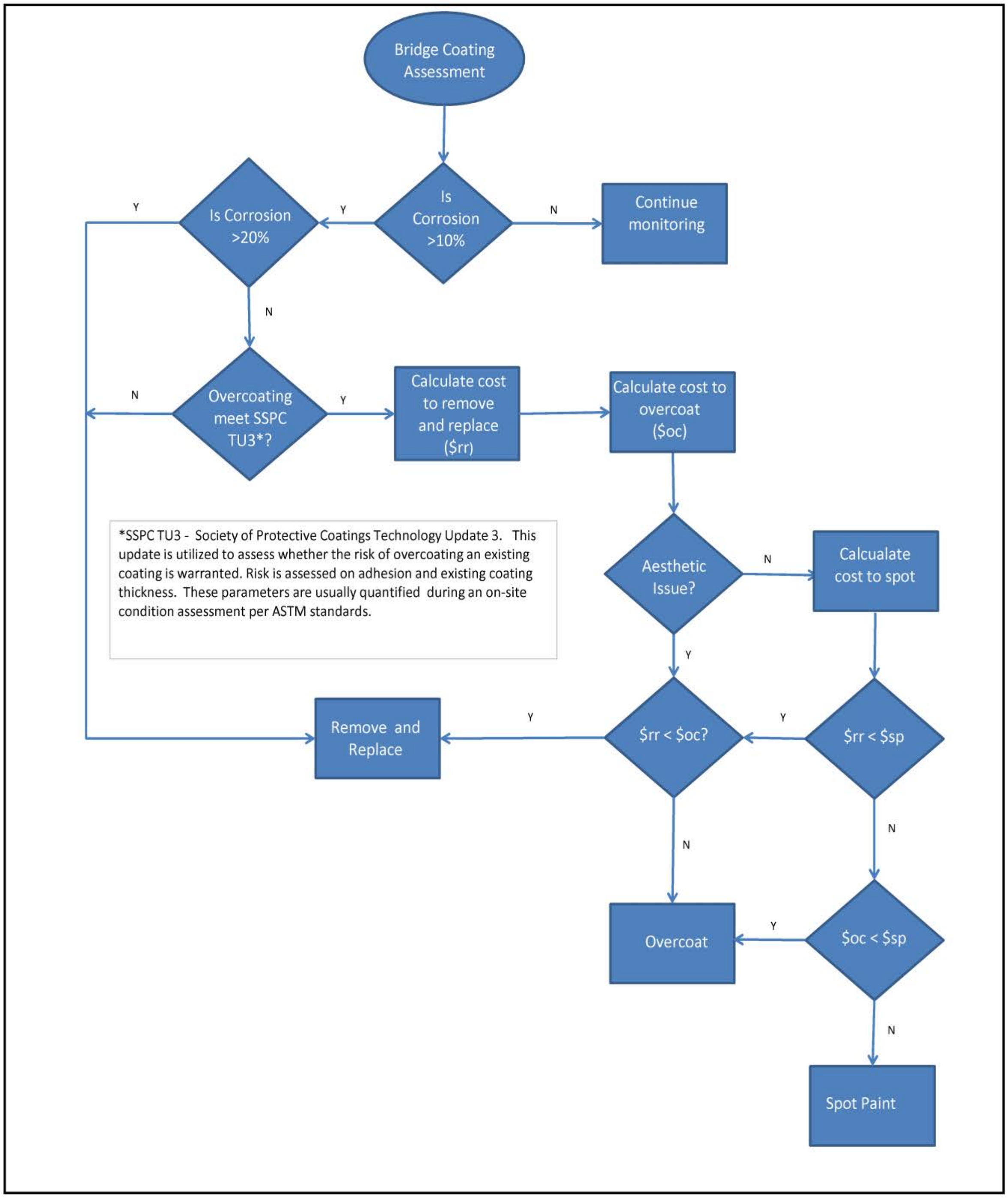

Figure A1 Virginia DOT Spot, Zone, and Overcoat Decision Flowchart