Longer Service Life Bridge Coatings

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

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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Research Report
KTC-20-30/SPR17-551-1F

Longer Service Life Bridge Coatings

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The Kentucky Transportation Cabinet (KYTC) has maintenance oversight responsibilities for approximately 1,100 steel bridges; it also helps local governments and other entities with maintenance painting on other steel bridges. Because maintaining steel bridges is costly, Cabinet officials asked Kentucky Transportation Center (KTC) researchers to identify materials and methods that will prolong their service lives. Steel bridges are uniquely vulnerable to deterioration resulting from exposure to atmospheric conditions (e.g. moisture, ultraviolet rays) and chlorides, the latter due to the application of deicing materials. This study examines two strategies for extending service lives. First, it appraises a novel method of hot dip galvanization (HDG) and metallizing girders. Rather than dipping an entire girder in molten zinc at once, steel plates are immersed and then welded to form girders. In testing, all pieces that were coated using the method were adequately galvanized and metallized, thus establishing adequate protection against corrosion. The process can likely be scaled up and applied to larger steel pieces and girders. Next, researchers investigated whether carrying out an additional abrasive blast cleaning following power washing can reduce chloride levels. A second blast cleaning did not significantly lower chloride levels, and even led to slight increases, which may be the product of unreliable field testing or the use of recycled steel grit abrasive. Other methods of reducing chlorides should accordingly be investigated (e.g., specialized coating systems, high-performance coating systems).</td></tr>
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Executive Summary

The Kentucky Transportation Cabinet (KYTC) is currently responsible for maintaining roughly 1,100 steel bridges. It also assists local governments and railroads with maintenance painting on other bridges. Recognizing the importance of protecting steel bridges against corrosion and other forms of degradation, KYTC asked our team of Kentucky Transportation Center (KTC) researchers to identify materials and methods that can potentially extend the service lives of steel bridge coatings. Painting and coating steel bridges is an expensive activity, with the price of three-coat systems ranging from $10 to $20 per square foot, regardless of whether painting is done in the shop or field. Prolonging the service lives of coatings will thus yield significant savings across a bridge's life cycle. We divided the study into two parts, each of which addressed a different facet of bridge coatings. Taken together, they provide valuable guidance for fortifying bridge defenses against corrosion and agents of deterioration.

The first portion of this study proposes a novel method that combines hot dip galvanization (HDG) and metallizing, practices commonly used to slow corrosion and extend bridge service life. Executing HDG on longer girders can be problematic because most galvanizing facilities in North America possess kettles — in which girders are dipped during the galvanization process — ranging in length from 40 to 60 feet. If a girder exceeds the kettle length, progressive dipping is an option. The alternative method described does not require that an entire girder be dipped at once. Instead, steel plates are dipped and then welded to form girders. The report provides detailed instructions and specifications for this process, carefully describing the butt weld, fillet weld, abrasive blasting process, and metallizing. Demonstrations in the shop confirmed this method's feasibility. All pieces coated using the method received adequate galvanized and metallized coatings to inhibit corrosion. The prospects for scaling the process up to larger steel pieces and girders whose dimensions exclude the possibility of normal HDG appear promising. However, the method is restricted to straight girders due to the forming process demanding that steel be heated to a temperature above the melting point of zinc. Key benefits of the method include: 1) being able to use HDG on large welded girders that could not be galvanized following welding due to size and weight limitations and distortions caused by the HDG process, and 2) most girder surfaces are galvanized, which confers greater durability than metallizing. The Cabinet will benefit from carrying out additional demonstration projects which rely on this method.

The second portion of this study focuses on bridge coating systems, which are also designed to protect against coating degradation and corrosion. Primary drivers of coating failure include deterioration set in motion by atmospheric conditions (e.g., water intrusion and exposure to ultraviolet rays) and corrosion precipitated by chlorides found in deicing materials. At KYTC, painting entails applying onto the surface of steel structural members multiple coats made up of different liquid-applied inorganic and/or organic coatings. Currently, the Cabinet requires three-cost systems on paint projects — with base coats or primers establishing the necessary foundation to bond successive coats with the steel substrate. Coatings generally have service lives of 20 to 30 years, with coatings applied to new bridges tending to last longer. In pursuit of more resilient coatings, our team developed an experimental procedure to modify the abrasive blast cleaning process used on the steel surfaces of a bridge slated for coatings. The method calls for power washing beam ends followed by two abrasive blast cleanings, the goal of which is to reduce chloride levels below what can be achieved with a single abrasive blast cleaning. Executing the second abrasive blast cleaning did not significantly affect chloride levels, and in some areas slight increases in chloride levels were observed, possibly attributable to the inaccuracies of field soluble salt testing or the use of recycled steel grit abrasive. Although the experimental procedure did not significantly influence chloride levels, other methods of reducing chlorides should be investigated, such as using specialized coating systems which account for the different types and magnitudes of stress bridges are exposed to and testing high-performance coating systems.

Chapter 1 Introduction

1.1 Background

The goal of this project was to identify for the Kentucky Transportation Cabinet (KYTC) materials and methods capable of extending service lives of steel bridge coatings — on both new construction and maintenance projects. The Cabinet maintains approximately 1,100 steel bridges. Despite being fewer in number, steel bridges generally have longer span structures than concrete bridges. KYTC also periodically performs maintenance painting on bridges owned by other entities, including local governments and railroads. For most bridge maintenance painting work, the Cabinet employs total removal and replacement. As discussed below, the procedures for maintenance painting are similar to those used for new construction painting. However, on newly constructed bridges one or more coats of paint are applied in the shop before steel is installed in the field. Surface preparation methods used in the shop and the field also typically differ.

The painting/coating of steel bridges — whether done in the shop or field — is an expensive activity. The price of the three-coat systems frequently used for painting and coating range from \$10/ft^2 to \$20/ft^2 for shop and field applications. Coating manufacturers have developed generic structural steel coating systems for bridge applications that consist of a zinc-pigmented organic or inorganic primer (usually an epoxy or zinc silicate, respectively), an organic intermediate barrier coat (usually an epoxy — sometimes pigmented to improve barrier properties), and a two-component polyurethane or acrylic topcoat. These coatings are formulated to meet current standard test criteria and depending on environmental conditions have service lives of 20-30 years. Formulations are developed to meet a price point as there is significant competition on the structural coatings market. Consequently, these coatings are termed *commodity coatings* and are the standard against which any enhancement in coating durability must be compared.

The service lives of new construction and maintenance painting projects influence the backlog of KYTC bridges requiring maintenance painting. Extending the service lives of painting projects will alleviate the maintenance painting backlog and yield life-cycle cost savings. This project's goal was to identify methods for prolonging the service lives of painting projects and prepare guidance on their implementation. For new construction, our focus widened to include a range of protective coatings: hot-dip galvanizing, metallizing, duplexing, and conventional liquid-applied coatings. For maintenance painting, our remit expanded to include surface preparation activities that can maximize the service lives of any coatings (primarily the removal/treatment of soluble salt contamination on coating substrates).

Bridge painting is primarily intended to protect steel structures against corrosion, which degrades steel bridge elements and results in the need for expensive structural repair or element replacement. Corrosion is the product of exposure to atmospheric moisture and soluble (deicing) salts. Painting also enhances bridge aesthetics as a structure can be painted so that it blends into urban and rural environments. Coatings weather in response to UV exposure and atmosphere exposure (moisture, airborne chemicals). Weathering deteriorates bridge coatings, resulting in topcoat colors losing reflectance (down gloss), fading (loss of vividness or depth of color), or turning powdery (chalk). As weathering attacks coatings, their durability and capacity to protect against corrosion are impaired.

With respect to bridge aesthetics, colorfastness and gloss retention are important. Bridge coatings applied to achieve aesthetic goals should be very durable and retain their outward appearance throughout most of their service lives. Durability is the product of their ability to resist corrosion as well as the combined effects of temperature, sun light, moisture/wetness and airborne chemicals (weathering).

Irrespective of coating type — whether metallic or liquid-applied inorganic, or organic coatings or duplex coatings using both metallic and inorganic or organic topcoats — a coating's ability to impede corrosion of the underlying steel and resist weathering are critical for extending service lives of structural steel. Another essential consideration is the economics of coatings. High-performance coatings typically come at a higher price than commodity coatings.

While the upfront price of high-performance coatings exceeds that of the most popular commodity coating systems, because they significantly extend service lives their life-cycle costs are ultimately lower. Painting less frequently can also reduce inconvenience to motorists, although it may take several decades to realize this benefit.

1.2 Objectives

Seven objectives were established to work toward the incorporation of both galvanizing welded steel beams and bridge coatings with longer service lives into KYTC processes:

1. Document KYTC welding shop practices as well as galvanizing and steel fabricator practices/standards to ensure the production of acceptable galvanized welded girders.
2. Develop procedures for metallizing and applying duplex coatings to completed girders.
3. Monitor an experimental application of this technology and evaluate performance, challenges, and final costs.
4. Identify causes of structural steel protective coatings failure as well as materials and methods to address those failure mechanisms.
5. Develop special notes for longer service life bridge coatings which implement progressive materials and methods.
6. Include the special notes in KYTC experimental bridge maintenance-painting projects.
7. Document the use of the special notes in an experimental project. Place the project in long-term monitoring program to assess performance.

To fulfill these objectives, we carried out the following tasks:

1. Identify typical welded girder dimensions used for KYTC bridges and steel grades/types/splices. Reconcile those with galvanizing industry capacities/steel requirements and hot-dipping/finishing practices.
2. Determine shop inspection practices for specification/inspection of hot dip galvanization.
3. Identify current KYTC fabrication shop welding practices that would affect acceptance/inspection and assembly of galvanized steel plate by welding.
4. Work with galvanizers and steel fabricators to develop welding of galvanized steel as a practical fabrication method.
5. Work with steel fabricators to metallize non-galvanized welds. Prepare and paint beams to obtain duplex coatings. Monitor work to determine practicality, issues needing resolution, and costs.
6. Conduct a literature search and review KYTC's inventory to identify protective coating failure mechanisms for in-service bridges.
7. Develop a compendium of bridge coating failure mechanisms, microenvironments, and innovative materials and methods to address those mechanisms.
8. Identify KYTC bridges with deteriorated coatings located in the different microenvironments identified.
9. Develop draft special notes for longer service life bridge coatings to clean and paint the subject bridges. The special notes should include the materials and methods to achieve an extended coating service life.
10. Monitor the experimental bridge maintenance-painting projects and compare costs to a traditional bridge maintenance-painting project.
11. Document all findings and recommendations in a final report.

Chapter 2 Hot Dip Galvanized Girders

State transportation agencies (STAs) have recently focused considerable attention on the use of protective metallic coatings. Coatings typically consist of zinc applied through hot dip galvanization (HDG) or spraying (metallizing). Metallized coatings are generally more expensive than liquid-applied coatings, but they provide longer service lives and better protect bridge steel against corrosion.

HDG — which is commonly used for new construction — is done in a galvanizing facility, after which structural steel is shipped to the job site or fabricator. However, there are several documented instances of STAs dismantling existing bridges — usually small trusses — and performing HDG before reconstruction. During HDG, steel (usually a rolled beam or smaller structural components) is consecutively dipped in: 1) a caustic bath for cleaning, 2) a water bath for rinsing, 3) a hydrochloric or sulfuric acid bath to remove mill scale, 4) another water bath for rinsing, 5) a hot zinc ammonium chloride (flux) bath to remove surface oxides, and 6) after drying, a molten zinc bath to deposit the metallic zinc coating on the steel (Figure 1). The galvanized steel is then cooled, any surface imperfections are removed and, if necessary, localized repairs are made to the galvanized film. The primary focus of HDG inspection is coating thickness. Many factors that influence coating thickness, including steel thickness and geometry, zinc kettle temperature, steel chemistry, bath dwell time, steel surface condition, and rate of withdrawal from the molten zinc. Generally, thicker steel produces thicker galvanizing.[1] In the U.S. galvanized bridges have remained in service and in good condition for over 40 years. For new construction, the limiting factor in HDG is the size of the zinc tanks (kettles). In most galvanizing shops, tanks are typically 60 ft long or less and have a finite depth. They typically limit the length of structural members to the size of rolled beams.

The first KYTC bridge constructed with galvanized structural steel is the I-24 bridge that traverses KY 93. It was built in 1977 and underwent duplex coating in 2002 as part of a maintenance overcoating project. Very little distress was observed on the galvanized steel at the time of overcoating, and the remaining zinc thickness was measured at approximately 4 to 5 mils. Although metallizing has come into more widespread use because it can be used to coat larger girders, to date no metallized bridges have been constructed in Kentucky.

2.1 Hot-Dip Galvanized Girders

The use of HDG steel significantly extends the service lives of bridges. Yet one limitation associated with this process is the size of the zinc kettles. The average kettle length in North American galvanizing facilities is 40 ft with several between 50 and 60 ft. If a girder cannot be submerged all at once because it is too long, but more than half it can, progressive dipping is an option (Figure 2). Crane capacity and other material handling issues can pose challenges during the HDG process. Wanting to surmount these issues, this study sought to enable the use of HDG to the greatest extent possible on plate components before fabricating a welded girder. Our team sought information on girder capacities throughout the industry from the American Galvanizing Association but received very little response.

We developed a method to facilitate the use of HDG on girders larger than the process can normally accommodate after fabrication. Instead of dipping entire girders at once, steel plates are dipped and then welded to form girders. This process enables the assembly of longer girders as they can be fabricated using several plates that have already undergone HDG. For this method to work, portions of the plate edges that will be welded are masked before HDG to prevent zinc from interfering with welding. The size of the masked area can be extended to accommodate ultrasonic inspection of completed welds (skip distance). After welding, non-galvanized areas along the welds are abrasively blasted and metallized to establish galvanized protection over the entire girder. Pre-cut flange pieces are supplied to fabrication shops for dipping before welding is done in the fabrication shop. Flanges can also be stripped from welded galvanized plates, but that requires subsequent metallizing of the flange edges.

2.2 Prototype Hot-Dip/Metallizing of Girders

We reached out to AZZ Galvanizing, Inc. and Industrial Steel Construction, Inc. (ISC) to assist in developing procedures for HDG and welding steel girders. ISC, Inc. provided the structural steel used to fabricate experimental prototypes for this study. The steel, which met the ASTM A572 specification for Standard 50 grade structural steel, was shipped to an AZZ, Inc. facility in Joliet, Illinois, for galvanizing. Areas slated for welding were protected by Galvastop®, a liquid masking material, before galvanization. After galvanizing, the steel was returned to ISC, Inc. in Gary, Indiana. Masking was removed using an 8-in. angle grinder prior to fabrication (Figure 3). KTC personnel visited ISC, Inc. during fabrication, which consisted of butt welding two steel plates of different thicknesses, simulating the flanges of a girder. Fillet welding was also used to create two T beams, simulating welding the web and flange of a girder. After welding was complete, welded areas were abrasive blasted and metallized.

Our team inspected the galvanized steel and took thickness measurements prior to metallizing. The overall appearance was good with a few minor abrasions from handling. The masking had been removed before we arrived. HDG thickness on two of the four 0.750-in. plates averaged 10.5 mils; the other two averaged 18.2 mils. The 1.00-in. and 2.00-in. plates averaged 18.3 mils.

Butt Weld

The butt weld consisted of one 48” x 20” x 2” and one 48” x 20” x 1” piece of steel. Using an oxy-acetylene torch and Ten Well-Know Brand CG1-30N Track Cutting equipment, each piece was cut along the 48-in. edge, creating a 30° bevel (Figure 4). Another 60° transition cut was made on the 2-in. piece (Figure 5). To assist the cutting process, the steel was pre-heated prior to cutting. Additional heat was applied in advance of the torch during the transition cut (Figure 6). Using a Cen-Tech Infrared Thermometer, the temperature was recorded at 700°F to 800°F approximately 4 in. behind the cut and at the edge of the galvanizing. We observed no distortion to the steel or other temperature-related issues with the HDG. Angles were ground smooth and positioned for welding.

Using a Lincoln Electric IdealArc® TM-500 AC arc welder adjusted to approximately 200 amps, the plates were tack welded. After the tack welds were complete, sub-arc welding was performed using a Lincoln Electric Flextec® 650X welder and 74 HT Flex Feed™ coupled with a Bug-O transport system (Figure 7). Filling the v-notch required seven passes. Slight distortion was noted after welding (Figure 8).

ISC Welding Procedure Specification 20B1F (Appendix A) requires the following welding parameters:

- 30-32 VDC (actual – 32)
- 440-485 AMPS (actual – 465)
- Travel Speed 15-18 IPM (actual – 18)
- Electrode size 3/32”
- Filler Metal – Lincolnweld LA-75 Eni1K-Ni1-H8
- Flux – Lincoln 960 F8A2
- Minimum pre-heat temperature – 150°F
- Maximum temperature – 450°F

To verify compliance with temperature requirements, 150°F and 450°F temp-sticks were used. Additional 250°F and 325°F temp-sticks were used to measure the temperature at the edges of HDG. Temperatures rarely exceeded 325°F and never went above 450°F.

The plate was repositioned using a magnetic lift. With a Lincoln DC-600 Air Arc, the opposite side was back gouged (Figure 9). The gouge was filled with three passes of the sub-arc welder. An 8-in. angle grinder was used to smooth the welds. Distortion from the initial weld corrected itself during the back gouging and welding (Figure 10). The plate was dropped when it was being placed on a pallet for transport to the abrasive blasting/metallizing area, fracturing the HDG on one corner.

Fillet Weld

The fillet weld consisted of two 48” x 18” x 1” and two 48” x 16” x 0.075” pieces of steel. These four pieces were welded into two T beams. Steel was emplaced (Figure 11) and tack welded using a Lincoln Electric IdealArc® TM-500 AC arc welder adjusted to approximately 200 amps. Sub-Arc welding was done using a Lincoln Electric Flextec® 650X welder and 74 HT Flex Feed™. The weld was completed by hand (Figure 12) instead of using the Bug-O transport system. Although the travel speed was consistent at 14 IPM, this was slower than the required 15-18 IPM. The actual speed is approximate as it was measured manually with a stopwatch. One pass on each side completed the required 5/16-in. weld (Figure 13).

ISC Welding Procedure Specification 93B1H (Appendix B) requires the following welding parameters:

- 30-32 VDC (actual – 32)
- 440-485 AMPS (actual – 465)
- Travel Speed 15-18 IPM (actual – 14)
- Electrode size 3/32”
- Filler Metal – Lincolnweld LA-75 Eni1K-Ni1-H8
- Flux – Lincoln 960 F8A2
- Minimum pre-heat temperature – 150°F
- Maximum temperature – 450°F

To verify compliance with temperature requirements, 150°F and 450°F temp-sticks were used. Additional 250°F and 325°F temp-sticks were used to measure temperature at the edges of the HDG. Temperatures rarely exceeded 325°F and never went above 450°F. Both beams were placed on the pallet for transport to the abrasive blast/metallizing area.

Abrasive Blasting

After fabrication, welded areas were abrasive blasted and metallized to achieve levels of corrosion protection comparable to that of galvanizing. The shop area designated for blasting and metallizing had ongoing construction that disrupted the flow of work (Figure 14), which was not the ideal setting for this type of work — ISC personnel felt they could have done a better job under different circumstances.

The blaster stated that he could control the blast so that no masking tape was necessary when feathering the edges of the HDG (Figure 15). Initially coarse coal slag was used for blasting, creating an anchor profile between 4.5 to 5.0 mils. ISC, Inc. personnel recommended using a higher profile for surfaces being metallized. The blast media was changed to #16 Aluminum Oxide which achieved a profile between 5.0 to 6.0 mils. ISC personnel stated a profile of 6.0 to 7.0 was typical when using aluminum oxide. Coal slag was used on the bevel side of the butt-welded plate and both sides of one of the T beams. The flat side of the butt-welded plate and the other T beam were blasted with the aluminum oxide. Air pressure was set at 120 psi and the blast nozzle was a #8 (1/2”) for both types of media.

Metallizing

Metallizing was done using a Thermion® Precision Arc System, a twin wire electric arc system (Figures 16-18) using 85/15 zinc aluminum alloy wire. The operator thought that the spray could be controlled enough to render masking unnecessary. This assumption proved incorrect and masking was used, however, pressure from the spray removed most of the masking (Figure 19). The use of a more rigid type masking may have helped, however, in a production setting a more precisely controlled spray pattern is desirable. Overspray that fell onto non-blasted areas did not adhere well and cleanup was necessary after metallizing was complete. The DFT of all areas metallized were measured using a DeFelsko PosiTector®. All areas averaged between 8 and 12 mils.

The process did not emulate a production setting, however, several issues need to be addressed. Material handling practices may require modification to reduce the likelihood of damaging zinc coating. While the abrasive blasting process worked well, precision blasting is necessary to adequately feather HDG edges. Metallizing equipment with an adjustable spray pattern (Figure 20) would be required to eliminate or reduce overspray cleanup work. Several standards and guides listed by the Thermal Spray Society (TSS) commonly used in the metallizing industry (Table 1) include details on operator qualification, equipment inspection, surface preparation, thermal spray application, and testing (inspection).

Table 1 Metallizing Standards

ANSI/AWS C2.16/C2.16M:2002	Guide for Thermal Spray Operator Qualification
SSPC-QP 6	Standard Procedure for Evaluating Qualifications of Thermal Spray (Metallizing) Applicators
AWS C2.21M/C2.21:2015	Specification for Thermal Spray Equipment Acceptance Inspection
AWS C2.18-93	Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and Their Alloys and Composite
SSPC CS 23.00	Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel
ASTM C 633-01	Standard Test Method for Adhesion or Cohesion Strength of Thermal Spray Coatings
ASTM D4541	Test Method for Pull-Off Strength of Coating Using Portable Adhesion Testers
ASTM D6386	Standard Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting

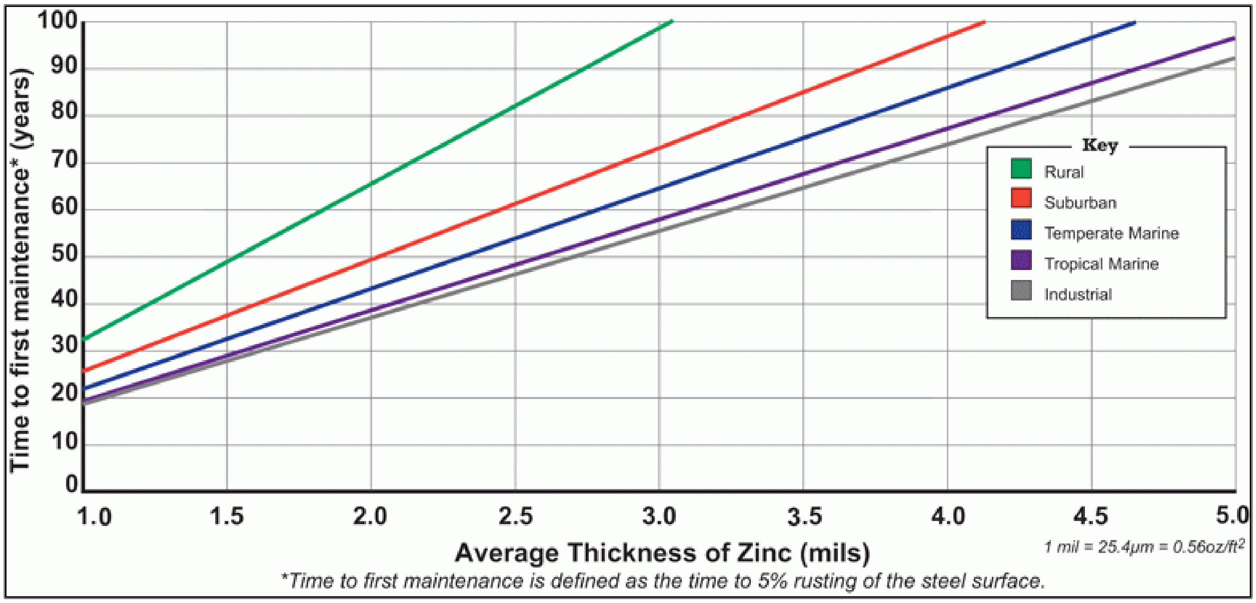
2.2 HDG Shop Inspection Practices

As in all manufacturing processes, quality control is essential. Quality assurance (QA) inspections are equally important to verify conformance to specifications and typically occur at a galvanizing facility after the galvanizing process is complete. Little information exists on quality inspections of surface preparations (pickling) prior to the galvanizing process. HDG facilities claim adherence to relevant standards (Table 2) used for the galvanizing process, however, currently no certification requirements have been established for HDG repair or inspection. A visual inspection will identify surface defects needing repair. Zinc thickness is typically measured using a magnetic thickness gauge. Destructive means of measurement are available but are typically used only to resolve measurement disputes. Different steel chemistries can influence zinc growth. Zinc thickness is proportional to the service life of the coating (Table 3), however, excessive thickness can lead to embrittlement, zinc flaking, and premature failures. Galvanizing facilities have limited control over these types of failures, which are primarily due to steel chemistry.

Table 2 ASTM Standards Used by Galvanizing Industry

ASTM A123/123M	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A143/143M	Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
ASTM A153A/153M	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A384	Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
ASTM A385	Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)
ASTM A767/767M	Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
ASTM A780/780M	Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM D6386	Standard Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting
ASTM E376	Standard Practice for Measuring Coating Thickness by Magnetic Field or Eddy-Current (Electromagnetic) Test Methods

Table 3 Relationship Between First Maintenance and Zinc Thickness *(American Galvanizers Association)*



2.2.1 KYTC Shop Welding Practices

All welders must be certified and qualified in accordance with Kentucky Methods KM 64-110 (*Qualification of Shielded Metal Arc Welders*) within the previous 24 months. All welding must be performed in accordance with the current edition of ANSI/AASHTO/AWS D1.1 (*Bridge Welding Code*). KYTC requires steel fabricators to participate in the American Institute of Steel Construction (AISC) certification program and be certified in the category, *Major Steel Bridge (CBR)*.

2.2.2 ISC Shop Welding Practices

The AASHTO/AWS D1.5 *Bridge Welding Code* is used by ISC, Inc. to cover welding requirements specified for bridge projects. It addresses base metals, welding processes, design of welded connections, workmanship, techniques, qualifications, and inspection requirements.

2.3 Conclusions

1. The shop demonstration of technical feasibility was successful. All test pieces were coated using the method outlined received sufficient galvanized and metallized coatings to guard against corrosion in normal bridge environments. The average thickness of metallized areas averaged between 8.0 and 12.0 mils. The HDG coating varied considerably on the four 0.750-in. plates used for the fillet welds. On two plates the average thickness was 10.5 mils, while on the other two the average was 18.2 mils. The 1.0-in. and 2.0-in. material — used for the butt weld — yielded more consistent average thicknesses of 19.0 and 17.6 mils, respectively.

2. The process can be scaled up to larger steel pieces and also used on girders whose dimensions preclude normal HDG. From a design standpoint, the primary limitation is that the method can only be used on straight girders and not curved girders as the forming process requires that the steel be heated above the melting temperature of the zinc. Girder designs should attempt to eliminate distortions that would necessitate heat straightening of girders.

3. If the proposed method is to be used, girder designs should minimize the number of horizontal stiffeners. This will limit the number of locations requiring hot-dip masking at the galvanizer's shop and subsequent shop blasting and metallizing at stiffener-to-web and stiffener-to-flange weld locations. It may be possible to galvanize complete flanges depending upon the length of galvanizer's dipping tanks. It may be possible to galvanize the upper flanges after the shear studs have been attached, eliminating the need to mask and subsequently clean the shear stud attachment points on the top face of the upper flange.

4. Unfortunately, KTC could not obtain complete hot-dipping capacities from various galvanizers. Of concern were zinc kettle sizes and crane capacities. One galvanizing facility provided limited information for some KYTC steel beam sizes. Another effort focusing primarily on galvanizers in areas near fabrication shops doing work for the Cabinet is probably needed to determine what size of steel plates for webs and flanges can be accommodated.

5. Coordination between the hot-dipping shop and the welding/metallizing shop is necessary to forestall any problems such as improperly masked steel plates. Handling of steel plates in the galvanizer's shop may require the addition of special handling equipment (e.g., strong backs for cranes handling thin plates used for girder webs). Field splice locations on girders can be masked during HDG and later painted in the fabrication shop with an inorganic zinc primer to achieve a Class B slip coefficient.

6. One advantage of this method is that it grants the use of HDG on large welded girders that cannot be galvanized after welding due to size/weight limitations and potential girder distortion problems caused by the HDG process. Another advantage is that most of the girder surfaces hot-dip galvanized, which will prove more durable than metallizing. This limits the use of expensive metallizing (compared to the low cost of HDG). Also, the durability of uncoated HDG exceeds uncoated metallizing. Metallized surfaces can be painted initially if the goal is to have HDG and metallizing with matching durability.

7. The performance of some HDG and metallized bridges (primarily outside of Kentucky) indicates that it is probable steel bridge girders using the combination of HDG and coated metallizing would not require maintenance painting for at least 30-40 years in most Kentucky environments. Beyond this timeframe, they would require minimal surface preparation (pressure washing) and painting with a one-coat system to establish duplex coating protection. That should enable the girders to last a minimum of 50-60 years without the need for follow-up maintenance painting.

8. This process is an extension of the rapid renewal/galvanizing/duplexing of steel girders used in the successful SHRP 2 demonstration project on two small rolled beam bridges built in 2014 on KY 6 in Knox County.

2.4 Recommendations

KYTC in conjunction with KTC should pursue a demonstration project that incorporates the HDG/metallizing method successfully used in this project. Project activities would include preparation of special notes, identification of galvanizers/fabricators willing to work on the project, tracking of costs, monitoring of shop and field installation, identification of problems/resolutions, and preparation of a final report documenting the project.

Chapter 3 Longer Service Life Coatings

3.1 Surface Preparation

For new construction, fabrication shops typically use large blast cabinets to carry out mechanical surface preparation of steel plates, rolled shapes, or completely welded girders. In these cabinets, steel is abraded by a blast stream usually consisting of a mixture of steel grit and shot, which is applied to achieve the proper profile and finish. In most cases, prior to cleaning steel has an existing mill scale coating. This is removed by blast cleaning to an SSPC – SP 5/NACE No. 1 (*White Metal Blast Cleaning*) standard — the highest cleaning standard in the painting industry.

Shortly thereafter, freshly abraded steel is painted with an inorganic or organic zinc primer to prevent flash rusting. Additional coatings may be applied at the shop or in the field as specified in the contract. Usually, no precautions are needed to address surface contamination of the unpainted steel prior to blasting. However, in the past, problems have been encountered with water-based primers applied to blasted substrates with oil contamination from the blast cabinets. That is usually not a problem with solvent-based primers.

For maintenance painting, applying paint over uncontaminated, properly abraded steel substrates is critical for achieving good performance. Existing oils, diesel fumes, tar, or other visible hydrocarbon residues on bridges must be removed from the existing substrates first. This is usually done by wiping the steel with solvent soaked rags or washing it with a detergent. For removal and replacement painting, mechanical surface preparation is commonly done by dry abrasive blast cleaning, which readies the steel surfaces by stripping all existing paint and adherent dry residues such as rust and dust. Abrasive blasting also creates a profile in the steel substrates, increasing the effective surface area and providing a mechanical bond to enhance adhesion of the coating applied first.

The system used for blast cleaning consists of an air compressor, blast pot, air lines, and blast nozzle. The air compressor creates a stream of high velocity air in a line which runs to the blast pot. There, abrasive particles (granites, coal slag, or recyclable steel shot/grit) are injected and carried at high speed through the lines to the blast nozzle. A blast operator points the nozzle at the steel and the abrasive rapidly cleans and abrades the steel. KYTC typically requires the use of a mixture of steel grit that is collected after use and run through a special machine that separates the reusable grit from waste, enabling it to be repeatedly recycled by the machine, and blasted, until it is ineffective and wasted. Recycling reduces abrasive media consumption and limits the generation of spent blast products.

A typical KYTC specification for maintenance painting requires SSPC SP- 10/NACE 2 (*Near White Metal Blast Cleaning*), while SSPC SP-5/NACE 1 (*White Metal Blast Cleaning*) is usually specified for shop coating. SSPC SP-5 is less cost-effective than SSPC SP-10 in the field due to surface contaminants and accessibility issues. Both SP-10 and SP-5 require that surfaces be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, corrosion products, and other foreign matter. However, a surface cleaned to the SP-10 standard allows up to 5% staining in any 9 sq. in. area. Staining is defined as light shadows, slight streaks, or minor discolorations caused by rust stains, mill scale stains, or stains from previously applied coating.

Additional steps need to be taken to avoid problems with abrasive blasting in the field. It is not effective in removing invisible soluble salt contamination and may embed salts in the prepared steel substrate, resulting in the new coating systems failing prematurely.[2] That problem can be addressed by measuring salt contamination on existing substrates prior to blasting and taking steps, as necessary (e.g., pressure washing) to reduce salts to acceptable levels. During blasting, the compressor can generate water in the blast lines that can cause blasted steel to flash rust before it is coated. Using ASTM D4285 (*Standard Test Method for Indicating Oil or Water in Compressed Air*) (Blotter Test) can help identify this problem. Once the blasting operation is complete, the resulting steel surface can be inspected visually to verify that it meets specified cleaning standards. KYTC specifications typically require an angular surface profile of 1.5 to 4.5 mils. To ensure proper roughness (surface profile), inspections conform with ASTM D4417. This standard specifies three methods: 1) Method A is a visual comparison to prepared standards; 2) Method B measures the profile depth with a fine-pointed probe to determine an average; and 3) Method C uses compressible tape to form a reverse image of the surface, which is then measured with a micrometer. KYTC Standard Specification 607.03.23 requires Method C.

3.2 Coatings and Their Application

New construction and maintenance painting, as currently performed for KYTC, consists of airless spraying of multiple coats, which are made up of different types of liquid-applied inorganic and/or organic coatings, onto the surface of structural steel bridge members. In part, this is done to achieve better film build and prevent misses or thin spots. Each coat provides different functions. KYTC currently specifies three-coat systems for paint projects. The base coat or primer bonds successive coats with the steel substrate. Primers specified by KYTC also protect against corrosion. They contain zinc dust and confer either galvanic protection (inorganic zinc primers) or a combination of galvanic and barrier protection (organic zinc primers). Intermediate coatings typically provide barrier protection and limit the penetration of harmful soluble salts down to the primer. Intermediate coatings include organic resins and may contain metallic or platelet pigments that enhance the coating's barrier properties. Topcoats use specific organic resins, and some employ light/UV stabilizers that provide resistance to weathering.

Most STAs and bridge authorities have adopted three-coat systems. Although each manufacturer has developed proprietary coatings, most coatings share somewhat generic formulations. They typically consist of epoxy-zinc primers, epoxy intermediate coats, and two-component polyurethane or acrylic topcoats. Most painting done in fabrication shops and in the field is contracted out. Typically, STAs maintain qualified coatings lists from which shops and painting contractors can select coatings. Due to significant competition between coating manufacturers that service the bridge painting market, bridge coatings within the painting industry have been commoditized. Coatings manufacturers have widely used bridge commodity coatings that meet established standards (e.g. NTPEP, NEPCOAT). In Kentucky those coatings typically have service lives between 25 and 30 years for newly constructed bridges and roughly 20 years for maintenance-painted bridges. Maintenance coatings have shorter service lives due to contamination and the difficulty of cleaning steel.[3]

Over the past several decades, STAs have sought to address high painting costs while managing growing backlogs of bridge coating needs. As part of that effort, they have looked at using more durable liquid-applied coatings (e.g., polyaspartic, polysiloxane, and fluoropolymer topcoats). They have also sought to improve their surface preparation methods to limit the negative effects of soluble salts on coating performance.

3.3 Literature Search

Our experience with testing and evaluation of various coating systems has consistently demonstrated that proper surface preparation and cleanliness improve longevity. Previous research has also found that chloride concentrations do not reliably predict protective coating performance on KYTC bridges. Our experience with abrasive blasting on Cabinet bridges has indicated that surface-level chlorides (both naturally occurring salts in the atmosphere and deicing salts) can become embedded in steel pits and result in premature failures. Evaluating 32 steel surface preparation methods for removal of chlorides, we concluded that wet cleaning methods were more effective than dry methods. To prolong the service lives of structural steel coatings, it is imperative to identify effective chloride remediation strategies and protective coatings that perform best when chlorides are present. In the current study our objective was to implement and evaluate a surface preparation method and observe its impacts on steel coating system performance and cost.

3.4 Coating Failure Mechanisms

Major causes of coating failures include degradation triggered by atmospheric conditions (e.g., water intrusion and UV exposure) and corrosion resulting from water and salt intrusion (deicing chemicals).[4] Areas in which coatings degrade and suffer from corrosion include fascias with high UV exposure, splash zones, beam ends under leaking joints, and areas that stay wet for extended periods. These areas are also exposed to higher levels of chlorides from previous coating failures. After abrasive blasting, residual chlorides remain in the surface profile and pitted steel. Without additional cleaning this contamination leads to premature coating failures. Coating systems currently specified by KYTC for new construction and replacement of existing coatings offer excellent protection outside of these areas.

3.5 Potential Longer Service Life Methods

The foremost purpose of a bridge coating system is to protect against coating degradation and steel corrosion. Corrosion occurs most frequently under leaking and/or open joints, in areas with extended times of wetness, on outer fascias, and in splash or aerosol zones. These critical areas must receive additional attention when a protective coating system is applied. They also benefit from the application of additional layers of protective barrier coating (epoxy). Fascia beams, trusses, and other areas with high UV exposure should garner additional UV protection.

Every year bridges are contaminated by significant quantities of deicing chemicals (chlorides) which initiate corrosion. During surface preparation these chlorides can become embedded in the steel and cause premature coating failures. Residual salts can be embedded in the profile of the steel, in shadowing, or in corrosion pits. SP 10 permits 5% shadowing. A previous KTC research study evaluated 32 methods of preparing corroded steel surfaces contaminated with chlorides. [3] Surface preparation methods included various wet and dry cleaning methods. Cleaned specimens were then examined using a Scanning Electron Microscope (SEM). The typical abrasive blast method (recyclable steel grit) used in Kentucky proved the least effective method for removing chlorides, however, using a double abrasive blast method was nearly as effective as some of the best performing wet methods. Several industry standards are available to measure chloride levels. Surface extraction and analysis procedures are the primary focus of these standards. They cover frequency and locations of testing as well.

Common standards include:

- SSPC Guide 15, *Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Surfaces*
- SSPC Guide 24, *Soluble Salt Testing Frequency and Locations on New Steel Surfaces*
- NACE SP0508, *Methods of Validating Equivalence to ISO 8502-9 on Measurement of the Levels of Soluble Salts*
- ISO 8502 *Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness*

Available field tests evaluate isolated/random areas of a few square inches. One common method using an adhesive patch that measures chlorides within a 12.5 cm^2 area. On a large structure it is impractical to perform sufficient testing to fully characterize the structure. Numerous corrosion hot spots may exist, inducing contamination in areas as small as a few thousandths of a square inch. Visual inspection is the most effective method for identifying salts in field. The approach should be to remediate previously corroded areas and contaminated surfaces. Two areas of concern warrant attention: free salts on uncorroded surfaces and embedded salts in corroded areas. These areas should be visually assessed and tested to verify for presence of chlorides.

Some materials that appear on KYTC's current List of Approved Materials (LAM) are no longer manufactured or need to be retested if their use is to be continued. Most coatings currently used in Kentucky will pass 5,000 hours of testing using ASTM D5894 (*Standard Practice for Cyclic Salt Fog/UV Exposure to Metal*). Newer, high-performance coatings should be considered, however, the testing (ASTM D5894) must be extended to distinguish top performers.

3.5.1 Dual Blasting Method on an In-Service Bridge in Kentucky

KYTC Contract ID 182951 was let in February 2018. The contract included of abrasive blast cleaning and painting of two bridges in Allen County; 002 0098 B00025N (KY 98 over Barren River) and 002 1855 B00034N (KY 1855 over Walnut Creek). The area of structural steel to be cleaned and painted for both bridges was approximately 19,500 ft^2 and 17,600 ft^2, respectively.

A special note was added to the contract via an Addendum (Appendix C) to include an experimental feature modifying the abrasive blast cleaning of the steel surface on B00034N. This special note stated: "All steel surfaces within 5 feet of each beam end on bridge number 002B00034N will remain uncoated, after achieving the specified surface cleanliness, for a minimum of 24 hours. Those steel surfaces will then be re-blast cleaned to the specified surface cleanliness prior to coating". The unit price to clean and paint structural steel on each bridge was $9.23 and $9.65 per square foot, respectively.

The intent of the procedures outlined in the special note was to reduce coating failures by removing additional chlorides that are not sufficiently removed by normal blast cleaning procedures. Studies have shown that abrasive blasting can embed surface-level chlorides into the steel, causing premature failures. To determine which bridge would receive the experimental surface preparation, we performed a preliminary assessment of the two bridges in January 2018. Bridge 002 1855 B00034N was selected to receive the experimental feature due to high chloride levels found during the initial survey. Our team pressure washed the beam ends (5 ft) at both ends of the bridge prior to abrasive blast cleaning.

The contract specified SSPC-SP 10/NACE No.2 (*Near White Metal Blast Cleaning*) for structural steel surface preparation and a Class II (Type I or Type II) paint system from the LAM on both bridges.

Both sides of Beams 1 and 2 of the KY 1855 bridge over Walnut Creek were pressure washed using a 0° spinner tip at 4,200 psi. Chloride measurements were obtained prior to washing and after washing. Maintenance coating operations began in June 2018 and were completed in July 2018.

3.6 Preliminary Survey of Bridges

KY 98 over Barren River Bridge (Project CID 182951) in Allen County is a steel girder bridge with 4-Beams (5'6" x 14") that was overcoated in 1996. Our initial inspection in January 2018 identified the current paint system on the bridge as lead alkyd primer overcoated with a two-coat urethane system. The beams had very little corrosion (Figure 21) except in areas with excess bird droppings on the outer flanges.

KY1855 over Walnut Creek (Project CID 182951) in Allen County is a steel-girder bridge with 4 beams (5' x 14"); it was last painted in 1986. Our January 2018 inspection identified its current paint systems as zinc primer with vinyl topcoat. The bridge steel was in good condition with some corrosion on the north end abutment (Figure 22) and very light rust in a few spots across the entire bridge. The bridge had expansion joints at 40-ft intervals and at 100 ft from each end. The joints had been patched at the deck and sealed at rail walls with bituminous material. Bresle Testing was performed on both bridges in accordance with SSPC Technology Guide 15 (*Field Methods for Extraction and Analysis of Soluble Salts on Steel and Other Nonporous Substrates*) Paragraph 4.2.2, "Adhesively Bonded Latex Patch or Cell/Probe Type Conductivity Meter Technique" (Figure 23). Conductivity measures were taken using a Horiba Model B-173 conductivity meter. Deionized water was used as extraction liquid with a conductivity measurement of 0 µS/cm.

3.7 Pressure Washing Beam Ends

We based our experimental surface preparation of the KY 1855 bridge over Walnut Creek on the higher chloride concentrations found during the preliminary survey. In April 2018, prior to pressure washing, we used the Bresle Method to measure chloride levels in the beam ends. Testing indicated higher chloride levels on Beams 1 and 2. The north and south ends of Beams 1 and 2 were pressure washed on both sides using a 0° spinner tip at 4,200 psi to approximately 6 ft from the ends. Each beam was washed from the top to the bottom with a maximum standoff distance of 12 in. while holding the pressure wand perpendicular to the surface (Figure 24). The surface was then allowed to dry and retested for chloride content, which indicated an average reduction in chlorides of approximately 70%.

3.8 Observations from Cleaning and Painting of Bridges

The contractor began surface preparation on the south end of the KY 1855 bridge over Walnut Creek on June 26, 2018, in accordance with SSPC-SP10/NACE No. 2 (*Near White Metal Blast Cleaning*). After cleaning, surfaces within 5' of each beam were left uncoated for a minimum of 24 hours. Due to inclement weather the blasting operation was postponed after three hours (see Table 4 for documented ambient conditions). Residual dust produced by blasting was not cleaned from the experimental areas. The dust, acting as a desiccant, prevented the surface from flash rusting overnight. The next day, in preparation of the second blast, contractor personnel cleaned the blasted beams using compressed air.

Abrasive blasting on the north end of the bridge began on July 3, 2018, at approximately 8:00 am. Residual dust on beam ends was cleaned using compressed air (requested by KTC personnel). After approximately 40 hours, very little flash rusting was observed prior to the second blast on July 5, 2018 (Figure 25).

Bresle Testing was done on the beam ends (north and south ends of bridge) after the first and second blast (Table 5). In some instances, chloride levels increased after the second blasting. Since the contractor used recyclable steel grit for blasting, some chlorides may have been deposited back on the cleaned surfaces. Blast profiles were measured using compressible tape (Figure 26). Profiles in these areas averaged 5.3 mils.

Table 4 Ambient Conditions During Abrasive Blasting

Date	Location	Relative Humidity	Air Temperature Ta (°F)	Dew Point Td (°F)	TΔ (°F)	Surface Temperature Ts (°F)
June 26, 2018	Outside	83.5%	79.1	73.6	6.2	
	Inside Containment	81.9%	81	74.9	6.7	81.9
June 27, 2018	Outside	76%	75.9	69.1	9	77.8
	Inside Containment	81.2%	77.5	71.3	6.6	77.9
July 3, 2018	Outside	73.2%	84	77		74.5
	Inside Containment	59%	75	78	16	95
July 5, 2018	Outside	74%	87	80		85

Table 5 Results of Bresle Testing from Pre-Wash Condition and After Final Abrasive Blast

Bresle Testing Results from B00034N, Allen Co. KY (μg/cm²)						
North End/ Beam 1 (east side)	Flange			Web		
	Test 1	Test 2	Average	Test 1	Test 2	Average
Pre-Wash (April 2018)	207.60	66.00	136.80	10.68	11.40	11.04
Post-Wash (April 2018)	24.00	10.44	17.22	6.96	4.44	5.70
First Blast	4.56	4.68	4.62	14.16	6.48	10.32
Second Blast	5.28	6.24	5.76	8.88	6.24	7.56
North End/ Beam 2 (west side)	Flange			Web		
	Test 1	Test 2	Average	Test 1	Test 2	Average
Pre-Wash (April 2018)	13.56	16.08	14.82	5.16	7.92	6.54
Post-Wash (April 2018)	6.96	5.52	6.24	7.08	6.12	6.60
First Blast	4.44	5.16	4.80	5.88	9.36	7.62
Second Blast	7.20	5.04	6.12	5.52	6.12	5.82
South End/ Beam 1 (west side)	Flange			Web		
	Test 1	Test 2	Average	Test 1	Test 2	Average
Pre-Wash (April 2018)	21.84	21.00	21.42	12.24	8.76	10.50
Post-Wash (April 2018)	6.60	6.00	6.30	5.40	5.88	5.64
First Blast	3.12	4.32	3.72	2.88	3.00	2.94
Second Blast	5.28	5.04	5.16	3.00	3.60	3.30
South End/ Beam 2 (east side)	Flange			Web		
	Test 1	Test 2	Average	Test 1	Test 2	Average
Pre-Wash (April 2018)	31.20	52.80	42.00	6.24	7.20	6.72
Post-Wash (April 2018)	13.56	12.24	12.90	3.00	4.08	3.54
First Blast	5.52	4.92	5.22	2.52	3.12	2.82
Second Blast	3.00	2.88	2.94	4.08	4.20	4.14

3.9 Conclusions

Time and cost constraints limited our initial field testing. The data we collected were insufficient to adequately characterize the chloride levels on the surface of the entire bridge. Limited data and field testing performed on just one bridge has influenced the conclusions we are able to draw.

Power washing the beam ends reduced the chloride levels by an average of 74%. After the initial abrasive blasting, chloride levels dropped to 83% of the pre-washed condition. Average results from the second blast were insignificant, revealing a 0.5% increase in chlorides. The bridge's north end, where residual dust was removed after the first blast cleaning — allowing approximately 40 hours of exposure — averaged an 85% reduction in chloride. The south end remained covered in dust until the second blast and averaged an 81% reduction.

After washing and the initial abrasive blast cleaning, chloride contamination ranged from ~3 to 14 $\mu g/cm^2$ and averaged 5 $\mu g/cm^2$ — a contamination level well within industry standards. We did not carry out post-blasting chloride tests on abrasively blasted steel that had not been pressure washed.

The primary objective of this field exercise was to evaluate the effectiveness of a second abrasive blast cleaning in areas with elevated levels of surface contamination. Washing plus the initial blast cleaning reduced chloride contamination to levels where the second abrasive blast did not have a significant effect. Some slight chloride increases were observed — averaging 1.7% — following the second blast cleaning, but inherent problems with field soluble salt testing and the use of recycled steel grit abrasive could explain the increase.

A second objective was to assess the cost impact of requiring a second abrasive blast cleaning of contaminated areas. The cost incurred due to the experimental abrasive blasting was insignificant. Cleaning and painting bridge B00025N was $9.23 per square foot. The experimental feature performed on B00034N cost $9.65 per square foot.

3.10 Recommendations

We selected the method of remediation used in this study based on our previous research, where testing and evaluations were performed under laboratory conditions.[5] Precisely duplicating these methods in the field is challenging, however, further research should be pursued on cost-effective methods for reducing chlorides to acceptable levels.

Other options include specialized coating systems which could be incorporated into highly stressed areas. The performance and cost of these coatings should be evaluated. Additional follow-up field studies are needed to design and incorporate new two-coat systems or barrier coats.

Engineered coating systems accounting for stress levels in different areas of bridges — where elements endure extended periods of wetness, an additional or different barrier coat system is necessary; additional UV protection is needed in areas with high UV exposure; areas where additional stresses are absent do not require three-coat systems. Specialized surface preparation and specialized coating systems require a more critical level of inspection.

High-performance coatings systems should be tested and included on the LAM. High-performance coatings will require extended weathering tests (ASTM D5894, *Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal*) or the development of other means of high-stress testing. For new construction, specialized coating systems should be designed which account for bridge microenvironments.

References

1. NCHRP SYNTHESIS 517, Project 20-05, Topic 48-03, "Corrosion Prevention for Extending the Service Life of Steel Bridges"
2. KTC Research Report SPR09-366 "Effects of Chloride Contamination on Coatings"
3. *Project 20-68A Scan 15-03: Successful Preservation Practices for Steel Bridge Coatings*.
4. NCHRP 14-30 Web Only Document 251 "Spot Painting to Extend Highway Bridge Coating Life"
5. KTC Research Report SPR14-484 "Chloride Contamination Remediation on Steel Bridges"

Figures

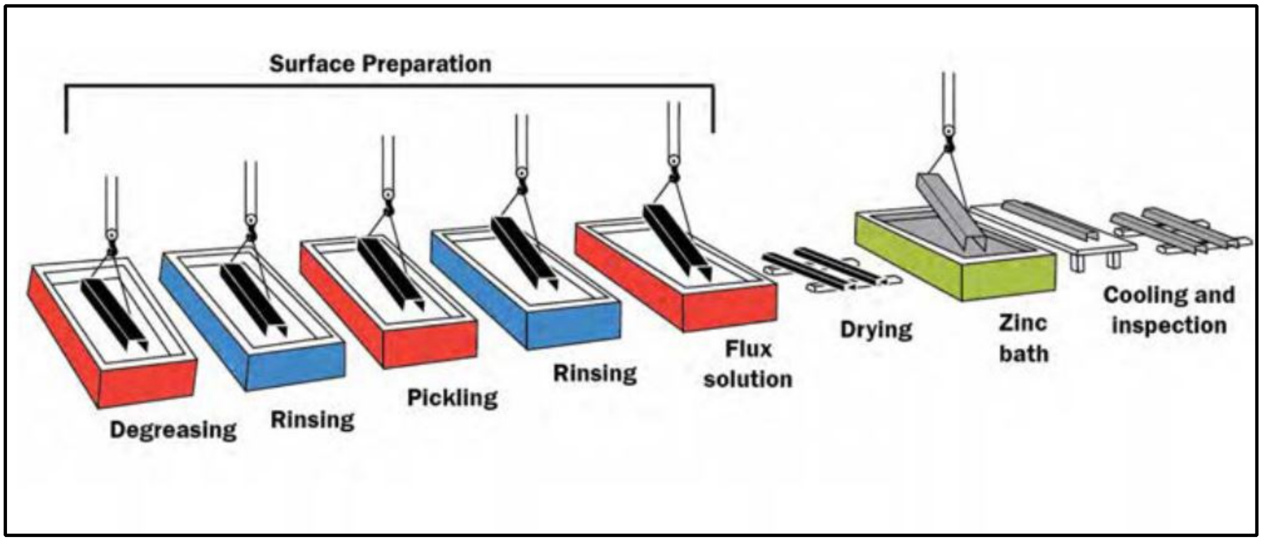


Figure 1 HDG Process
(Courtesy of American Galvanizers Association)

Figure 2 Steel Beams Progressively Dipped in Kettle Filled with Molten Zinc

Figure 3 Steel After Removal of Galvastop®

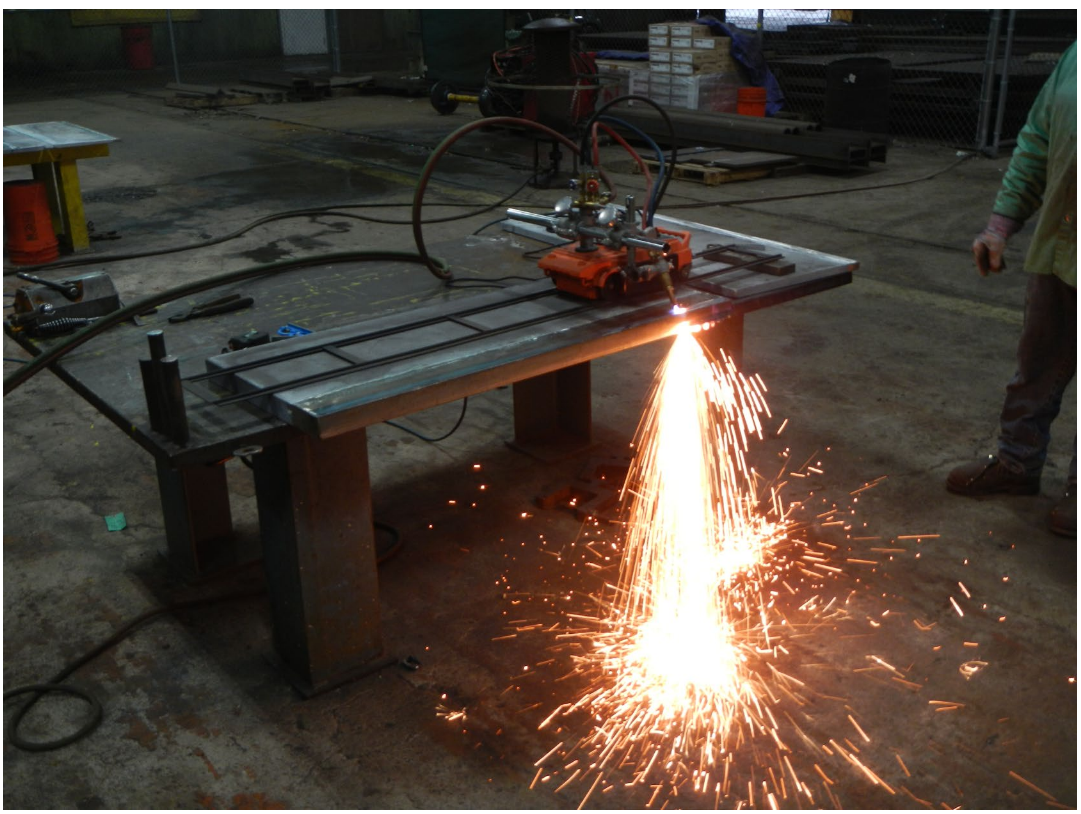


Figure 4 Steel Cutting Using Ten-Know Brand CG1-30N Track Cutting Equipment

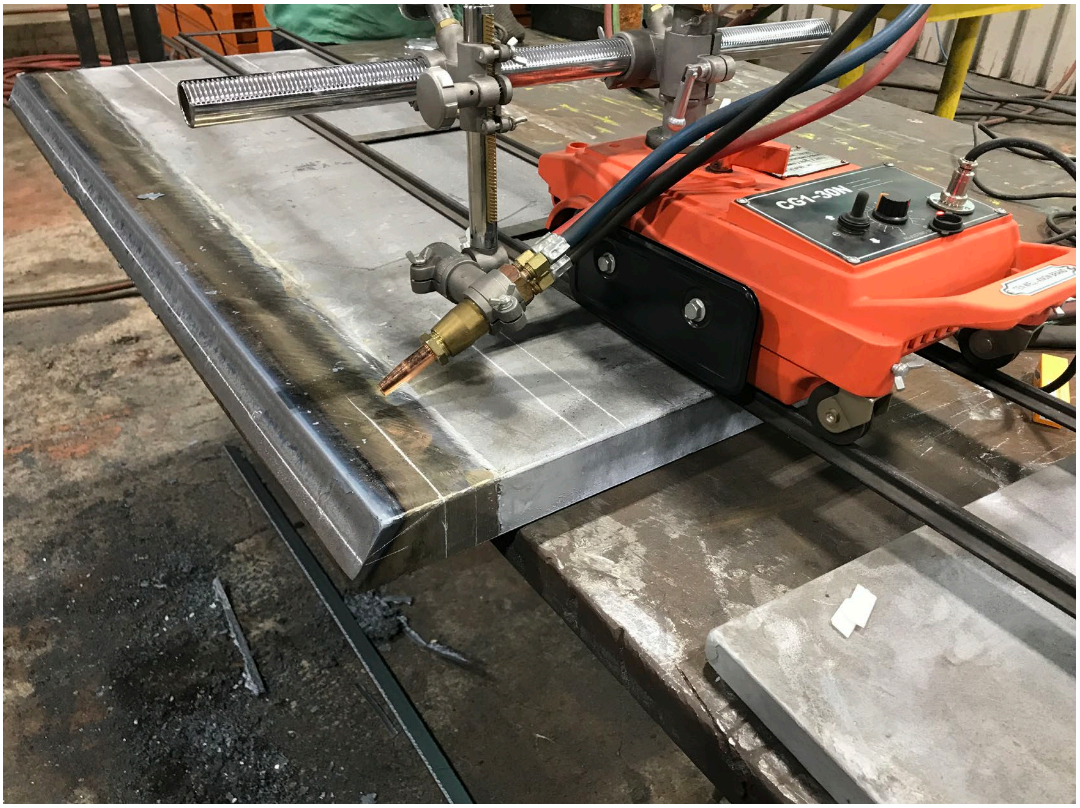


Figure 5 Setup for Cutting 60° Transition

Figure 6 Cutting a 60° Transition – (Pre-Heat Applied in Advance of the Cut)

Figure 7 Sub-Arc Welding Using Lincoln Electric Flextec® 650X Welder with a 74 HT Flex Feed™ Coupled with the Bug-O Transport System

Figure 8 Distortion From Welding Process

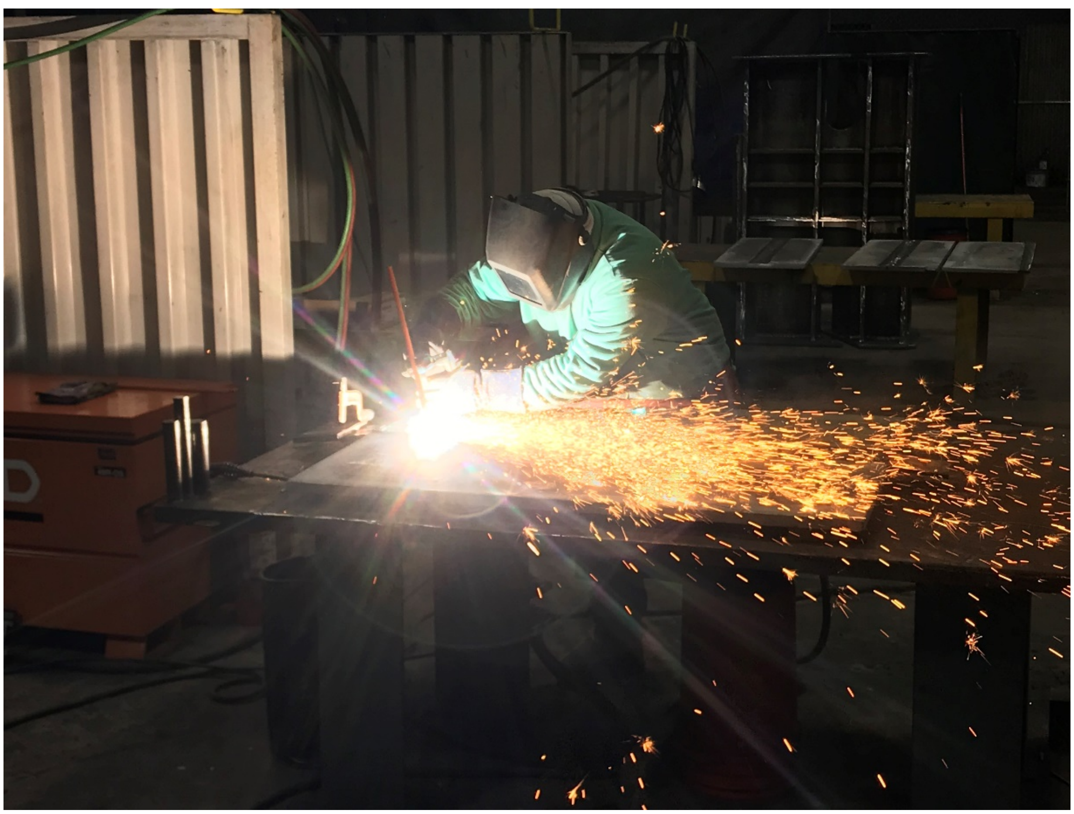


Figure 9 Lincoln DC-600 Air Arc Equipment Used to Back Gouge The Butt Weld

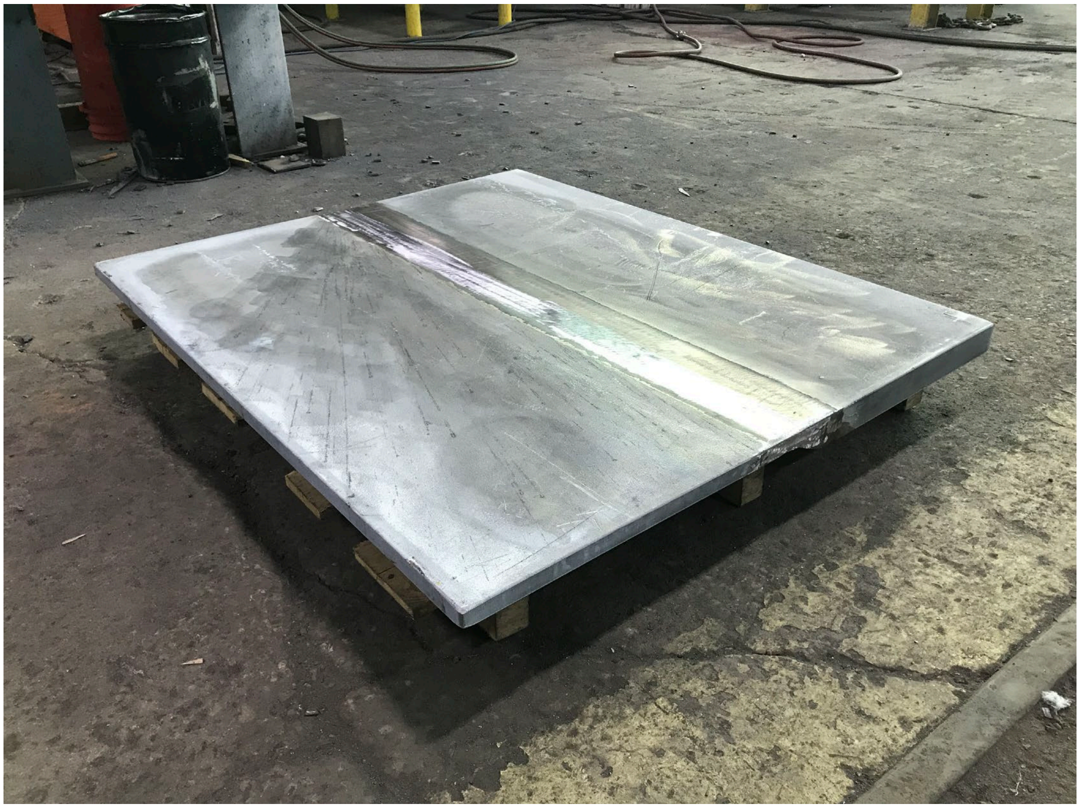


Figure 10 Moved to a Pallet For Transport After Welding Was Complete

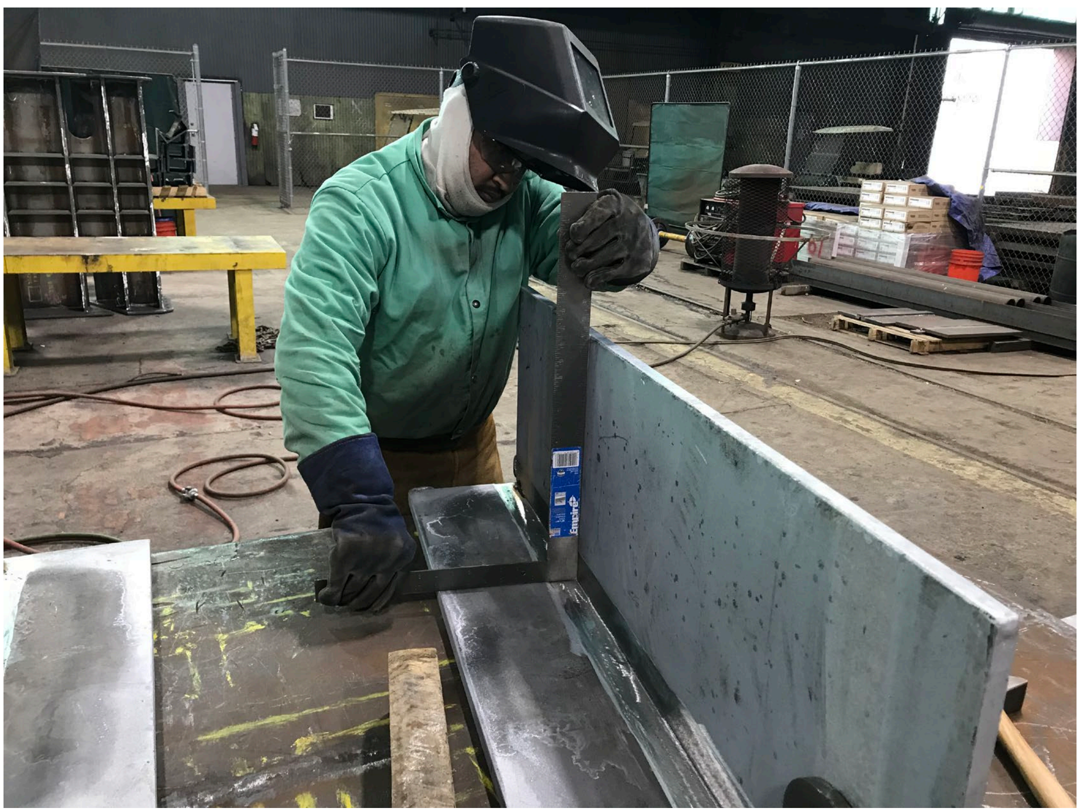


Figure 11 Setting Up for Fillet Weld

Figure 12 Manual Sub-Arc Fillet Weld

Figure 13 Completed 5/16” Fillet Weld

Figure 14 Abrasive Blasting/Metallizing Area

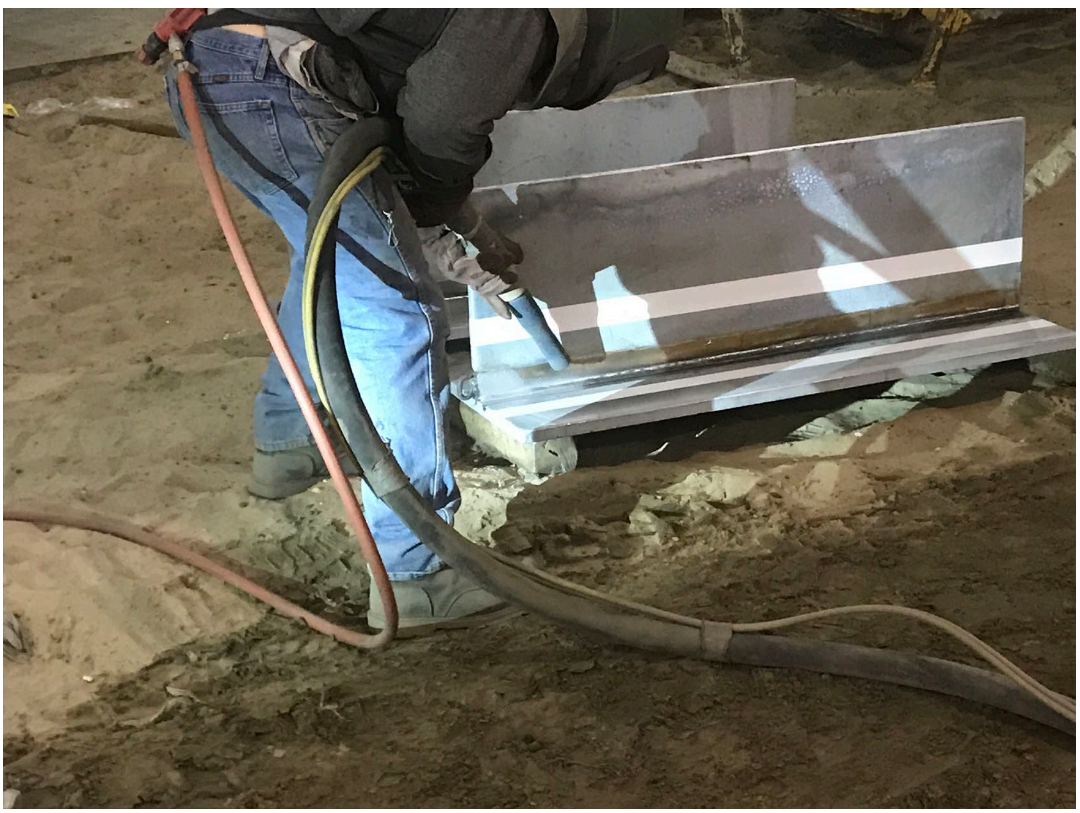


Figure 15 Abrasive Blasting Fillet Welds

Figure 16 Thermion® Twin Wire Feed Unit

Figure 17 Miller Deltaweld® 652 Power Source for Thermion® Precision Arc System

Figure 18 Thermion® Spray Gun

Figure 19 Metallizing T-Beams (Note Removal of Masking)

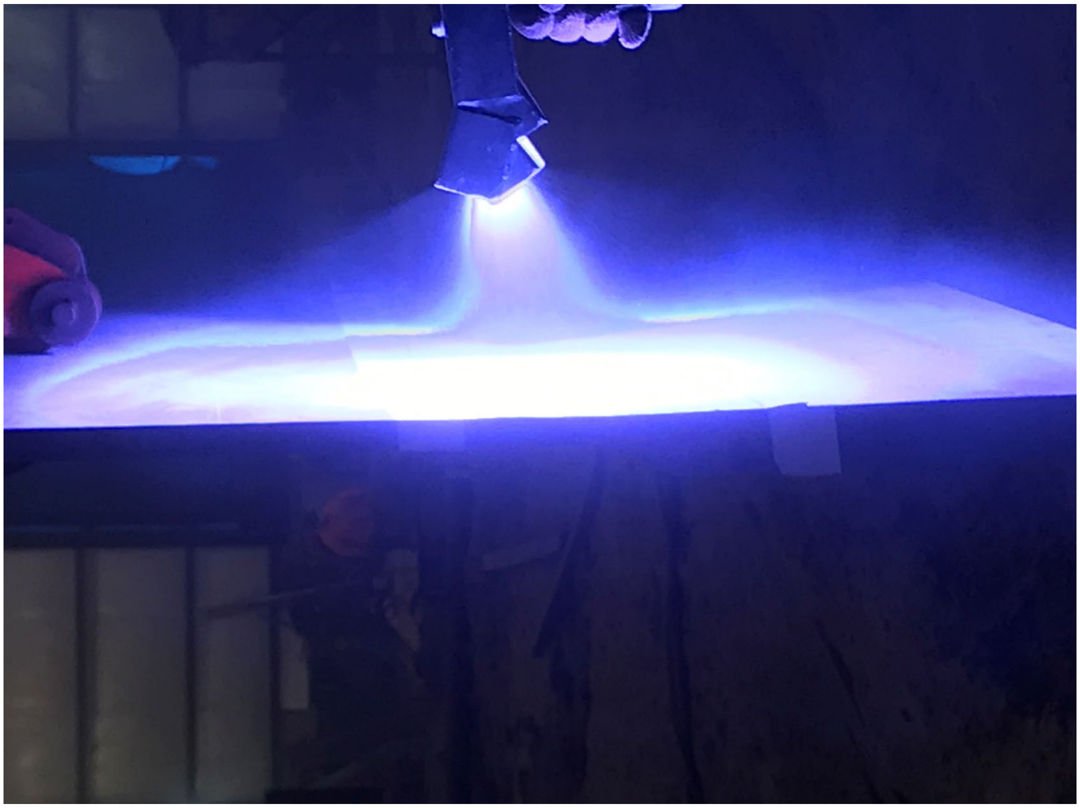


Figure 20 Smaller Spray Pattern May Reduce Overspray Cleanup


Figure 21 Example of the Initial condition of 002 0098 B00025N

Figure 22 Example of the Initial Condition of 002 1855 B00034N

Figure 23 KTC Personnel Pressure Washing Beam Ends

Figure 24 KTC Personnel Performing Cl Testing

Figure 25 North End of Bridge 40 Hours After Initial Blast

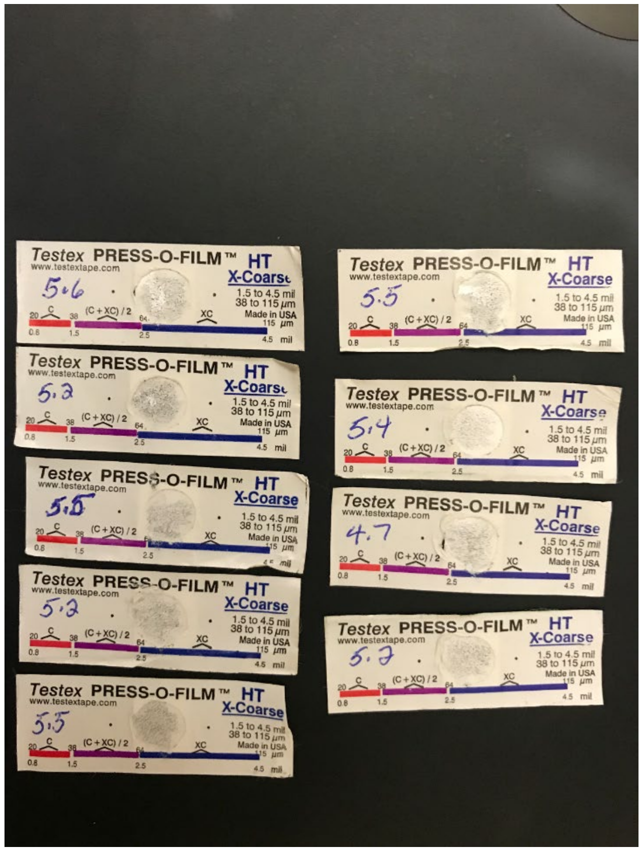


Figure 26 Compressible Tape Used to Measure Surface Profile

Appendix A Welding Procedure Specification 20B1F

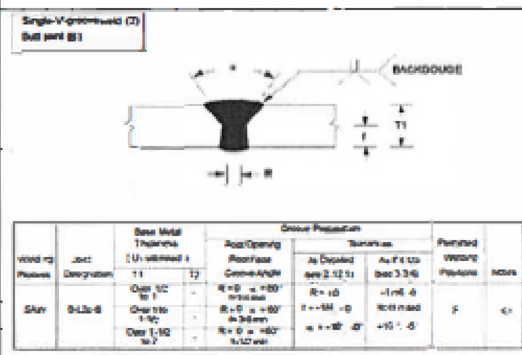
WELDING PROCEDURE SPECIFICATION

Industrial Steel Construction, Inc.	Procedure No: 20B1F Date Issued: 1/22/2019 Revision No: _____ Rev. Date: D1.5-2015

1. Prepared by (print or type name): Luis Tamayo
2. Non-Fracture Critical ☒ Fracture Critical ☐ WPS Expiration Date: 4/15/2022 (FCM ONLY)
3. Qualified in accordance with: 5.11 (prequalified) ☐ 5.12.1 ☒ 5.12.2 ☐ 5.12.4 ☐
   Referenced PQR No(s). 27B1F ____ ____ ____
   Referenced Fillet Weld Soundness Test No(s). na
4. Material specification(s) A709 Gr. 36,50,50S,50W,HPS 50W
5. Material thickness(es) (range) >1/2 to 2"max
6. Welding process SAW
7. Manual ☐ Mechanized ☒ Semiautomatic ☒ Automatic ☐
8. Position(s) of welding Flat
9. Filler metal specification AWS A5.23
10. Filler metal class, mfg., & brand name Lincolnweld LA-75 ENi1K-Ni1-H8
11. Flux class, mfg., & brand Lincoln 960 F8A2
    Type: Active ☐ Neutral ☒ Alloy ☐
    Shielding gas na Composition % na Flow rate na
12. Single pass ☐ Multiple pass ☒
13. Single arc ☒ Multiple arc ☐ Parallel arc ☐
14. Multiple Electrode Arc Spacing (SAW): Longitudinal na Lateral na
    Angle (degrees): Leading na Trailing na
15. Welding current DC
16. Polarity EP
17. Welding progression na
18. Root cleaning see coment below
19. Postheat treatment na
20. Calculated Heat Input (KJ/In) Min 37.51 Max 62.53
21. Electrode extension (electrical stickout) 1.25

For approver's use only

Joint Detail
Show relevant dimensions and AWS symbols



Weld size (In)	Pass No(s).	Electrode Size (In)	Welding Process Variables: AMPS/WFS*	Welding Process Variables: VOLTS DC	Travel Speed (IPM)
CJP	all	3/32"	440 – 485	30 – 32	15 – 18

*Wire feed speed, if used

Comments: per AWS D1.5 sec 3.2.1
"Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding or produce objectionable fumes. Mill scale that can withstand vigorous wire brushing, a thin rust-inhibitive coating, or antispatter compound may remain except that all mill scale shall be removed from the surfaces on which web-to-flange welds are to be made."

Preheat and Interpass Temperature Chart

Base metal thickness range	Minimum preheat (°F)	FCM Minimum preheat (°F)
≤3/4	50	
3/4 to 1-1/2	70	
1-1/2 to2-1/2	150	
>2-1/2	225	

Maximum Preheat and Interpass Temperature 450°F

Preparer's Signature

Luis Tamayo
CWI 10021191
QC1 EXP. 2/1/2019

Appendix B Welding Procedure Specification 20B1F

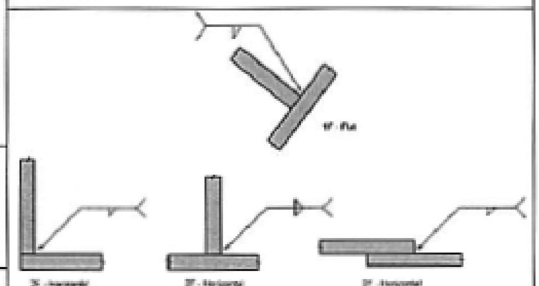
WELDING PROCEDURE SPECIFICATION

Industrial Steel Construction, Inc.	Procedure No: 93B1H Date Issued: 1/22/2019 Revision No: _____ Rev. Date: D1.5-2015

1. Prepared by (print or type name): Luis Tamayo
2. Non-Fracture Critical ☒ Fracture Critical ☐ WPS Expiration Date: (4/15/2022 FCM ONLY)
3. Qualified in accordance with: 5.11 (prequalified) ☐ 5.12.1 ☒ 5.12.2 ☐ 5.12.4 ☐
   Referenced PQR No(s). 27B1F _____ _____ _____
   Referenced Fillet Weld Soundness Test No(s). FWST 1 FWST-2
4. Material specification(s) A709 Gr. 70hps
5. Material thickness(es) (range) unlimited
6. Welding process SAW
7. Manual ☐ Mechanized ☒ Semiautomatic ☒ Automatic ☐
8. Position(s) of welding Horizontal
9. Filler metal specification AWS A5.23
10. Filler metal class, mfg., & brand name Lincolnweld LA-75 ENi1K-Ni1-H8
11. Flux class, mfg., & brand Lincoln 960 F8A2
    Type: Active ☐ Neutral ☒ Alloy ☐
    Shielding gas na Composition % na Flow rate na
12. Single pass ☒ (5/16 Max 2F) Multiple pass ☒
13. Single arc ☒ Multiple arc ☐ Parallel arc ☐
14. Multiple Electrode Arc Spacing (SAW): Longitudinal na Lateral na
    Angle (degrees): Leading na Trailing na
15. Welding current DC
16. Polarity EP
17. Welding progression NA
18. Root cleaning see comment below
19. Postheat treatment na
20. Calculated Heat Input (KJ/In) Min 37.51 Max 62.53
21. Electrode extension (electrical stickout) 1.25"

For approver's use only

Joint Detail
Show relevant dimensions and AWS symbols



Weld size (In)	Pass No(s).	Electrode Size (In)	Welding Process Variables AMPS/WFS*	VOLTS	Travel Speed (IPM)
1/4	1	3/32"	440 – 485	30 – 32	15 – 18
5/16	1	3/32"	440 – 485	30 – 32	15 – 18
≥ 3/8	mult	3/32"	440 – 485	30 – 32	15 – 18

*Wire feed speed, if used

Comments: per AWS D1.5 sec 3.2.1
"Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding or produce objectionable fumes. Mill scale that can withstand vigorous wire brushing, a thin rust-inhibitive coating, or antispatter compound may remain except that all mill scale shall be removed from the surfaces on which web-to-flange welds are to be made."

Preparer's Signature

Luis Tamayo
CWI 10021191
QC1 EXP. 2/1/2019

Preheat and Interpass Temperature Chart

Base metal thickness range	Minimum preheat (°F)	FCM Minimum preheat (°F)
≤3/4	50	
>3/4 to 1-1/2	70	
>1-1/2 to2-1/2	150	
>2-1/2	225	

Maximum Preheat and Interpass Temperature 450°F

Appendix C Addendum Adding Experimental Work

COMMONWEALTH OF KENTUCKY
TRANSPORTATION CABINET
Frankfort, Kentucky 40622
www.transportation.ky.gov/

Matthew G. Bevin
Governor

Greg Thomas
Secretary

February 13, 2018

CALL NO. 405
CONTRACT ID NO. 182951
ADDENDUM # 1

Subject: ALLEN COUNTY, 002GR18M012 - FE02
Letting February 23, 2018

(1)Added - Special Note - Page 17(a) of 51

Proposal revisions are available at http://transportation.ky.gov/Construction-Procurement/.

If you have any questions, please contact us at 502-564-3500.

Sincerely,

Rachel Mills

Rachel Mills, P.E.
Director
Division of Construction Procurement

RM:mr
Enclosures

Kentucky
UNBRIDLED SPIRIT
An Equal Opportunity Employer M/F/D

SPECIAL NOTE FOR ADDITIONAL SURFACE PREPARATION REQUIRMENTS
BRIDGE NUMBER 002B00034N ONLY

ADDITIONAL SURFACE PREPARATION
In addition to contract requirements stated in the Special Note for Surface Preparation and Pain Application, all steel surfaces within 5 feet of each beam end on bridge number **002B00034N** will remain uncoated, after achieving the specified surface cleanliness, for a minimum of 24 hours. Those steel surfaces will then be re-blast cleaned to the specified surface cleanliness prior to coating.

PAYMENT
All cost for the Additional Surface Preparation shall be considered incidental to the lump sum bid for: **Clean and Paint Structural Steel (08434).**