HYDRO-SURFACE PREPARATION AND COATING FOR PAINTED STRUCTURAL STEEL

Final Report
For
TR-407

April 1999

Project Development Division

Iowa Department of Transportation

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Abstract

Cities and counties in Iowa have more than 8,890 steel bridges, most of which are painted with red lead paint. The Iowa Department of Transportation (Iowa DOT) maintains less than 35 bridges coated with red lead paint, including seven of the large border bridges over the Mississippi and Missouri Rivers. Because of the federal and state regulations for bridge painting, many governmental agencies have opted not to repaint, or otherwise maintain, lead paint coatings. Consequently, the paint condition on many of these bridges is poor, and some bridges are experiencing severe rusting of structural members.

This research project was developed with two objectives: 1) to evaluate the effectiveness of preparing the structural steel surface of a bridge with high pressure water jetting instead of abrasive blasting and 2) to coat the structural steel surface with a moisture-cured polyurethane paint under different surface preparation conditions.

During this research project, the researchers observed favorable results from the high pressure water jetting. Although the Wapsinonoc Creek samples were incomplete, the soil samples showed no contamination from high pressure water jetting. Air samples collected both inside and outside the containment showed no signs of contamination. In other words, the containment structure successfully contained the water and paint waste generated by the high pressure water jetting.

As expected in the Research Proposal for this project, hydro blast wastewater was filtered and discharged in a publicly owned treatment facility. The solid waste was classified as hazardous and disposed of in a Subtitle C facility in accordance with federal regulations. Although an employee showed an increase of lead in the blood, two other employees showed no significant increase of lead in the blood. All employees' air monitoring samples showed airborne lead levels below OSHA action levels.

Except for the areas in the surface steel where the small diameter rust pits were found, high pressure water blasting met the three surface steel cleaning standards. Using the high-pressure water jetting on any bridge to Surface Cleaning Standard 1, an engineer could have confidence that the surface steel was properly prepared for overcoating a bridge.

Until this overcoat paint has been on this bridge for a few years, the researchers will not know how well moisture-cured polyurethane is performing. The moisture-cured polyurethane will also have to be reviewed over time to assure that no thermal stress or bonding problems exist. If the stress between the existing paint system and overcoating is great enough to cause this paint system to shear, then the paint will peel off the bridge beams.

INTRODUCTION

Cities and counties in Iowa have more than 8,890 steel bridges, most of which are painted with red lead paint. The Iowa Department of Transportation (Iowa DOT) maintains less than 35 bridges coated with red lead paint, including seven of the large border bridges over the Mississippi and Missouri Rivers. Because of the federal and state regulations for bridge painting, many governmental agencies have opted not to repaint, or otherwise maintain, lead paint coatings. Consequently, the paint condition on many of these bridges is poor, and some bridges are experiencing severe rusting of structural members.

Engineers charged with bridge maintenance must decide how to address steel bridge members coated with red lead paint. Factors such as bridge maintenance budget, condition of the steel bridge, structural deficiency or functional obsolescence of the bridge, the estimated life span of the structure, and the condition and size of the entity's total bridge inventory all play into the decision on whether to preserve or replace an individual structure. In the case of old, posted, or short span bridges, allowing the bridge to deteriorate until replacement is required is a viable option to cleaning and repainting the bridge steel. Newer bridges, long multi-span bridges, or river bridges that are much more expensive to replace may require that the city, county, or state maintain a protective painted coating of the structural steel.

Sandblasting and containment of the hazardous waste created by the steel cleaning process is a costly part of the repainting process. The sand used for blasting the existing bridge steel coating is contaminated by the paint flakes removed during preparation for a new painted coating, generating large volumes of waste that require proper disposal. Alternatives to conventional steel preparation exist and this study will review one such alternative to sand blasting for paint removal and/or steel cleaning prior to repainting.

OBJECTIVE

This research project was developed with two objectives: 1) to evaluate the effectiveness of preparing the structural steel surface of a bridge with high pressure water jetting instead of abrasive blasting and 2) to coat the structural steel surface with a moisture-cured polyurethane paint under different surface preparation conditions.

Bridge coating does not need to involve complete removal and replacement of the existing paint system. This study will also review the feasibility of overcoating the existing red lead paint system, thus encapsulating it and protecting it from further deterioration. The bridge steel, and its hazardous coating, can remain encapsulated until the end of the bridge's useful life. The normal steel recycling process can capture the hazardous lead and chromium components of the paint system, thus limiting the environmental and worker health risks associated with the field removal of lead paints. To test the ability of hydro blast preparation of steel surfaces and the ability of the moisture-cured polyurethane paint to replace or encapsulate existing paint systems, three levels of surface preparation will be tested. Tested areas will be prepared by: 1) removal of the existing paint to bare steel, 2) removal to the top coat of paint, and 3) cleaning of the existing painted surface with removal of existing paint and or primer only in areas with surface rust or loose paint.

PROJECT LOCATION AND EXISTING CONDITIONS

Researchers sought a bridge in eastern Iowa for the project, due in part to the proximity of hazardous waste disposal sites in Illinois. The selected bridge is located three miles south of the West Branch exit of Interstate 80 on County Highway X30 in Cedar County. The bridge has 82 feet long steel beams with a concrete deck. The bridge is supported by timber piles with timber backwalls.

The bridge was built in 1956. The original paint was present on the bridge. The paint on the interior structural steel surfaces of the bridge was in good condition except for some rusting around the ends of the bridge beams. The paint on the exterior structural steel surfaces was in poor condition. On the exterior steel surfaces, the existing paint was flaking and chalking. The bridge had areas of rust scattered throughout the steel surfaces. Some rusted areas were characterized by deep, small diameter pits in the steel surface.

CONSULTANT AND CONTRACTOR

For this research project, the Iowa DOT and Cedar County selected KTA-Tator, Incorporated (KTA), Pittsburgh, Pennsylvania for the construction inspection, environmental evaluation, and coating evaluation. This research report contains test results, unless otherwise stated, from KTA's attached Water Jetting and Overcoating of the County Road X30 Bridge report. The appendixes to KTA's report are available through the Iowa DOT, Office of Materials.

Cedar County served as the project-administrating agency and arranged a local project letting. Cedar County awarded the contract for the water jetting and coating of the bridge to Cavi-Tech, Incorporated, Kennesaw, Georgia,.

PAINT REMOVAL

With the assistance of the materials staff of the Iowa DOT, Special Provisions were developed for this project. The Special Provisions required that the surface preparation be accomplished with equipment delivering water through a nozzle with water pressure greater than 18,000 pounds per square inch (psi). Nozzle pressure in excess of 18,000 psi is defined as high pressure water jetting.

REMOVAL OF ACCUMULATED FOREIGN MATERIAL

Prior to beginning high-pressure water jetting of the surface steel, the Special Provision required that the contractor remove all accumulated foreign material from the bridge. Since the Special Provision did not allow accumulated foreign material to fall on the land or in the water, the contractor had to collect and dispose of it according to Federal, State, and Local regulations.

HIGH PRESSURE WATER JETTING SYSTEM

The contractor selected a high-pressure water jetting system with a maximum pressure of 40,000 psi for surface preparation on the project bridge. Cavi-Tech used a high-pressure water-jetting gun with a rotating jetting head.

The rotating head on the high-pressure water-jetting gun had five nozzles. Depending on the required cleaning standard, Cavi-Tech would select different nozzle diameters to obtain the desired surface preparation as described in the standard.

During operation, the water-jetting gun produced a reaction of approximately 35 pounds of force, requiring Cavi-Tech to use two men to operate the gun. A laborer assisted operators by positioning the supply hoses and maneuvering within the containment. During the workday, operators traded off allowing one operator to rest while the other operated the high-pressure water jetting gun. Operators complained that high pressure water jetting gun was more physically draining than sandblasting in spite of having to wear less confining personal protective equipment.

Waste Water Pumping

Cavi-Tech placed a compressed air operated sump pump at the low point in the containment structure. The contractor used an in-line water filter to filter paint particles prior to discharging collected water into a tanker truck for temporary storage.

High Pressure Water Jetting the Surface Steel

With high pressure water jetting, surface preparation can be varied by any of the following means: (1) adjusting the water pressure supplied to the jetting gun; (2) varying the diameter of the nozzles in the jetting gun head; (3) varying the time spent jetting each square foot; (4) varying the distance between the nozzle and the surface of the steel, and (5) the angle between the nozzle and the steel surface. Changes in any of these variables will affect the amount of paint that is removed from the surface steel. The special provisions required that surface steel would be prepared to three different cleaning standards.

Cleaning Standards

When Cavi-Tech introduced hydro jetting to the Iowa DOT, they offered the Iowa DOT the seven surface preparation standards applicable to high pressure water jetting. Cavi-Tech's recommended standards were:

CB-1 **SWEEP OFF BLAST:** The surface finish shall be free of all oils, greases, and dirt. All loose rust, rust scale, and loose mill scale shall be completely removed. Remaining areas of tight rust scale must show numerous flecks of clean metal. All loose paint shall be completely removed. Remaining finish coat and exposed undercoat film surfaces shall be abraded with a light, irregular anchor pattern. Paint edges and remaining coating are considered reasonably adherent if they cannot be removed with a dull putty knife.

CB-1.5 **SWEEP OFF BLAST WITH CORROSION REMOVAL:** Similar to the CB-1 Blast Standard, but dictates that corrosion removal shall include all rust, rust scale, and loose mill scale, except where very tight rust scale in the pit bottoms and inert carbon shadows, inert streaks of discoloration caused by rust stain may remain.

CB-2 **COATING CUTBACK BLAST:** The surface finish shall be free of all oils, grease, dirt and foreign matter. Loose rust, rust scale, and loose mill scale, shall be completely removed, except that extremely tight rust scale may remain in pit bottoms, inert carbon shadows and rust stain may remain; discoloration may also remain. All loose paint and weakly bonded coatings shall be removed. Remaining paint shall be very tight, paint surfaces shall show an evenly abraded anchor pattern sufficient to provide good adhesion for overcoating. Paint edges shall be feathered.

CB-2.5 **CUTBACK TO SPECIFIED COATING BLAST:** The CB-2 blast standard applies excepting that existing coating removal shall be cutback to a specified intermediate coat.

CB-3 **FINISH AND INTERMEDIATE COATING REMOVAL BLAST:** All oils, grease, dirt and foreign contaminants shall be removed. All rust, rust scale, and loose mill scale shall be completely removed except that inert carbon shadows or inert rust stain may remain. All paint shall be removed to the existing prime coat. Remaining prime coat film surfaces shall be eroded back to show an evenly abraded pattern sufficient to provide good adhesion and bonding of overcoat.

CB-3.5 **FINISH AND INTERMEDIATE COATINGS REMOVAL WITH PRIME COAT STRESSED:** The CB-3 blast standard applies excepting that the remaining prime coat will be exposed to the Cavi-Blast pattern to a point whereby the paint is eroded back to less than 50% of existing dry film thickness (dft).

CB-4 **BARE BLAST STEEL:** The surface finish shall be free of all oil, grease and all foreign matter. Rust, rust scale, and loose mill scale must be completely removed, except inert carbon stains or inert rust stains may remain over 10% of each square inch. All existing paint or coating shall be removed, except that shadows of previously prime coat may be visible in 10% of each square inch.

Although the above hydro blast cleaning standards did adequately describe seven different types of surface steel cleaning, the Iowa DOT felt that one cleaning standard would suffice for most of the required surface steel cleaning. This would require hydro blast cleaning of the steel surfaces to remove all loose paint and abrade a pattern in the existing paint system for adhesion of the new coat. However, the Iowa DOT realized that there may be times when the existing surface may be highly contaminated with chlorides, and the engineer may feel that removing the existing top coat would be necessary.

After the reviewing potential needs and Cavi-Tech's standards, the Iowa DOT wrote the following three hydro cleaning standards:

Standard 1 The prepared surface shall be free of all oils, grease, dirt, and foreign matter. Rust, rust scale, and loose mill scale shall be completely removed except that tight rust scale may remain in pit bottoms of pitted areas. Inert carbon shadows, rust stain, and discoloration may remain. Remaining paint shall be tightly adhering. Painted surfaces shall show an etched anchor pattern sufficient for adhesion of the prime coat. Edges between tightly adhering and removed areas shall be feathered.

Standard 2 The prepared surface shall be free of all oils, grease, dirt, and foreign matter. Rust, rust scale, and loose mill scale shall be completely removed. Inert carbon shadows, rust stain, and discoloration may remain. Existing topcoat shall be removed, and the prime coat shall be scoured down to show an etched pattern sufficient for proper adhesion and bonding of the prime coat.

Standard 3 The prepared surface shall be free of all oils, grease, dirt, and foreign matter. Rust, rust scale, and loose mill scale shall be completely removed. Inert carbon shadows, rust stain, and discoloration may remain if less than 10% of each square inch. Existing coatings shall be removed to "bare" steel except that shadows around built-up sections, fasteners, and corners may have tightly adhering prime coats visible in not more than 10% of each square inch.

Since high pressure water jetting would not remove all of the rust scale from the steel surfaces in areas inaccessible to hydro blast cleaning, the following specification was added to the Special Provision for power tool cleaning:

> The contractor shall remove rust, deteriorated paint, detrimental foreign material, and loose mill scale by power tool cleaning in areas where high-pressure water blasting results in unacceptable surface preparation. All material removed by power tool cleaning shall be captured, containerized, and included with the paint waste generated on this project. Removal by mechanical methods shall be in accordance with SSPC-SP3 as modified below.
>
> Replace Articles 2.2, 2.3, and 5.3 of SSPC-SP3, Power Tool Cleaning, with the following:

2.2 It is intended that power tool cleaning remove rust, deteriorated paint, detrimental foreign material, and loose mill scale that can be removed by vigorous use of the power tools.

2.3 SSPC-VIS 3, Visual Standard for Power and Hand-Tool Cleaned Steel, shall be used in conjunction with SSPC-SP3 to evaluate the degree of cleaning.

5.3 Use power wire brush, power abrading, power impact or other power rotary tools to remove rust, deteriorated paint, and loose mill scale. Do not burnish the surface.

Project Requirements

To evaluate the effectiveness of high pressure water jetting on steel surfaces, the Special Provision required the contractor to use three different surface preparation levels on three areas of the bridge steel. The preparation areas were as follows:

- Standard 3. The west exterior beam.
- Standard 2. The east exterior beam.
- Standard 1. Center beams and all other steel surfaces.

High Pressure Water Jetting System Adjustment for Surface Steel Cleaning

To meet the three cleaning standards for this project, the contractor adjusted their equipment to:

- Standard 1 - 20,000 psi, at 5 gallons per minute, with 5 nozzles, each having a 0.016 inch tip
- Standard 2 - 20,000 psi, at 5 gallons per minute, with 5 nozzles, each having a 0.016 inch tip
- Standard 3 - 36,000 psi, at 2.5 gallons per minute, with 5 nozzles, each having a 0.011 inch tip

Field Results

Test areas on each beam were cleaned to the standards shown above. Cleaning continued in each test area until the contractor, consultant, and county engineer were satisfied that the required degree of cleaning had been reached. Photos of the cleaned areas were taken to be used as acceptance guides for inspectors and contractor's staff members. Since the paint and steel condition on each bridge will vary, this test process and agreement on preparation standards is a necessary part of the process.

Cavi-Tech was easily able to meet the requirements of Standard 1. Since the topcoat was tightly bonded to the prime coat, Standard 2 was more difficult to achieve due to the tight bond between the remaining top coat and prime coat. Cavi-Tech eroded the top coat down to the prime coat with some difficulty, but met standard 2.

The prime coat was tightly adhering to the bridge, and required a great deal of effort to remove. Cavi-Tech cleaned an area of the surface steel several times before all parties accepted that the cleaning had reached a point where only 10% of the prime coat was still adhering to the bridge. On the exterior side of the west beam, the steel had deep pits. Cleaning the small diameter pits was difficult with high pressure water jetting. The pits were too small and deep for cleaning with power tools. To meet the cleaning specification, the contractor spent extra time cleaning the pits on the exterior beam with the high-pressure water jetting equipment.

High Pressure Water Jetting Production Rates

As with abrasive blasting, high-pressure water jetting production rates vary with the condition and type of paint being cleaned or removed. As listed in the Report Number FHWA-RD-94-100, Lead-Containing Paint Removal, Containment, and Disposal, the researcher used a production rate of 100 square feet per hour for SSPC-SP10, near-white abrasive blasting. The hydro blast cleaning Standard 3 is comparable to SP-6, commercial cleaning standard for abrasive blasting. From the information provided by Cavi-Tech, high pressure water jetting would have the following production range of rates for each three cleaning standards:

- 130 to 110 square feet per hour for Standard 1;
- 95 to 70 square feet per hour for Standard 2; and
- 70 to 50 square feet per hour for Standard 3.

Adhesion Test

For Standards 1 and 2, the Special Provision required the contractor to do adhesion tests on at least three different locations on the bridge. If the average of the three tests was less than 400 pounds per square inch force (psif), Cavi-Tech was required to continue removal effort until remaining paint or primer tested greater than 400 psif or all paint had been removed to bare metal.

Since the west beam was cleaned down to bare steel, the adhesion testing was not done. For the east beam, the adhesion tests averaged 663 psif after cleaning to Standard 2, removal of the top coat. The adhesion test average for the inside beams was 863 psif after cleaning to Standard 1.

If we can predict success of the overcoating system by the adhesion test and if 400 psif baseline is adequate, then we can assume that this painting system will not peel or experience adhesion failure. However, the total paint system may fail for other reasons like shear stress between the new and old paint systems.

Rust Bloom

The Special Provision defines rust bloom as the development of visible rust on bare metal surfaces after cleaning. The structural steel surfaces did not experience any visible rust after the high pressure water jetting.

Although this section of the specification was not applicable during this research project, the summer time humidity in Iowa could cause rust bloom to form on the steel immediately after high pressure water jetting. Dealing with rust bloom should remain an essential part of the specifications for high pressure water jetting.

CONTAINMENT STRUCTURE

Cavi-Tech suspended a series of steel cables between the lower ends of the bridge beams, over the bridge abutments to support their simple containment structure. The floor of the containment was constructed of steel sheeting attached to the steel cables. The containment structure was encased by placing tarps over the steel sheeting and bringing the tarps up from the floor of the containment structure using cables tied to the bridge rail. To maintain a four feet clearance between the bridge beams and the floor of the containment structure, the contractor installed mid-span suspender cables from the bridge diaphragms. To provide a watertight seal of the containment structure at the abutment caps, the contractor used foam insulation between the tarps and the abutment cap. Since most of the containment structure was four feet below the bridge beams, workers and inspectors had room in the containment structure to move freely under the whole bridge.

The containment structure design was reviewed by a consulting engineer hired by the contractor. Since the contractor built the containment structure out of steel cable, steel sheeting, and tarps, the containment structure was light weight, and with the containment structure attached to the ends of the bridge, the dead load did not significantly increase the weight on the bridge. Continuous pumping of wastewater out of the containment structure also limited the dead load on the structure. Consequently, the additional load created by the containment did not affect the load carrying capacity of the bridge and traffic was able to use the bridge without interruption throughout the project. The containment structure was strong enough to withstand normal wind loads, as well as live loads created by workers and water being collected by the system. Since the containment structure was set only four feet below the low bridge steel, the cross section of the bridge was also not increased to the point that normal wind loads on the bridge were increased. If this type of containment structure was to be installed on a longer bridge, the contractor would have to complete a structural analysis to size the bridge containment structure appropriately without compromising the wind load, live load, and dead load capacities of the bridge.

The containment structure was not air tight as would be required for abrasive blasting. The containment structure adequately contained the blast water and mist generated during the high-pressure water jetting and waste removal operations. Although the certified industrial hygienist did find a small leak in the containment structure, the contractor sealed the leak, and the containment structure met the needs for containing wastewater generated by high pressure water jetting the steel surfaces.

Waste Water Filtering

Cavi-Tech used a two stage filtering system to filter the wastewater. As the contractor pumped water out of the containment structure, he filtered the water through "sock type" filters designed to remove particulate to a particle size of five microns. After completing the water jetting operations, the contractor filtered the water in the storage tank through filter bags that filtered the water to a particulate size of two microns. After filtering, Cavi-Tech removed the filters and placed them in the fifty-five-gallon drum used for hazardous waste collected in the project. The drum was tightly closed and stored in a secure area for testing and proper disposal after the project was completed.

PAINT SYSTEM

In addition to testing a new method of removing existing paint, the researchers felt that they should investigate alternative paint systems that would be compatible with the bridge's existing paint system and the application of this paint system in Iowa weather. After reviewing bridge paint systems, the researchers decided to try a moisture-cured polyurethane paint. This paint system has not been used on primary highway and interstate bridges. This bridge will be one of the first bridges in Iowa painted with moisture-cured polyurethane paint, and would serve as a benchmark for future bridges painted with moisture-cured polyurethane paint. With this in mind, the researchers were looking for a manufacturer with long term experience with moisture-cured polyurethane. A market search showed that Wasser, Inc. has the most experience supplying moisture-cure polyurethane paints; therefore, researchers specified Wasser high-tech coatings in the Special Provisions. This report should not be construed as recommending any particular paint system, because other suppliers manufacture moisture-cured polyurethane paint.

Wasser Paint System

For this project, the Special Provisions specified that all steel surfaces that were high pressure water jetted have an application of the following three coats of Wasser paint:

- Prime Coat: MC-Miozinc
- Intermediate Coat: MC-Miomastic
- Finish Coat: MC-Ferrox-A

Each coat of moisture-cured polyurethane paint listed above, had a minimum dry film thickness of three mils.

Requirements for a New Paint System

As the researchers were looking for a new paint system to use on this research bridge, they realized that the paint system for overcoating would have to meet the following requirements:

- Low in Volatile Organic Compounds (VOCs);
- No heavy metals;
- Applied over surface steel without a profile;
- Applied over chloride contaminated paint system;
- Applied over damp surfaces; and
- Not weaken the existing paint system.

Since high pressure water jetting does not develop a profile in the rusted steel, the researchers were committed to finding a paint system that could be applied over poorly prepared surfaces. Although the Special Provisions did not require power abrading of steel surfaces in areas of rusted steel, the researchers were concerned about the paint adhesion where the bridge was high-pressure water jetted to bare steel.

Manufacturer Requirements

For overcoating or spot priming, Wasser recommends a surface preparation of pressure washing with a minimum of 2,500 psi, Hand and Power Tool Cleaning to SSPC-SP2 and SSPC-SP3 in areas of corrosion or peeling paint. By using high water pressure jetting and Power Tool Cleaning to SSPC-SP3, the surface preparation for this research bridge exceeded Wasser's requirements.

Although Wasser only requires MC-Miozinc applied in the areas where the surface cleaning removed the existing paint to bare steel, the Special Provisions required the contractor to apply the MC-Miozinc paint to all surface steel surfaces prepared by high pressure water jetting. With many Iowa DOT bridges experiencing blush rust with the inorganic zinc, the researcher felt that they should apply and monitor an application of MC-Miozinc to all steel surfaces.

Moisture-Cured Polyurethane

The moisture-cured polyurethane does meet the paint system requirement that the researchers were trying to obtain as shown in the following listing:

- VOC compliance of the federal requirements (less than 3.5 pounds per gallon);
- Contains no heavy metals;
- Obtained the needed surface preparation with power washing of only 2,500 psi;
- Applied to damp steel surfaces; and
- Sacrificial zinc paint system*.

* Although this item was not required for a new paint system, the researchers did see the zinc as a benefit for a new paint system.

Since the VOCs for the three paint coatings used on this research bridge were less than 2.8

pounds per gallon, the moisture-cured-polyurethane does meet the federal requirements. With the moisture-cured-polyurethane meeting or exceeding the researchers' expectations, it was used for the Special Provisions.

PAINT APPLICATION

The Iowa DOT Supplemental Specifications for bridge painting specifies aluminum epoxy mastic and waterborne acrylic paints. Since these paints have strict weather restrictions, the painting season is quite short in Iowa and humid weather delays the contractor's painting application. These weather restrictions potentially increase the cost for bridge painting, therefore, the Iowa DOT is interested in finding a paint system that could lengthen the painting season and reduce weather delays.

Problems with the Current Paint System

The current inorganic zinc primer and vinyl topcoat painting system has experienced many failures from field applications on the Iowa bridges. Rusting around bolts, rivets, splice plates, cover plates, stiffeners, diaphragms, and the bottom of the bottom flange is a symptom of early failure on some bridges in Iowa. With all of the areas described above, the lack of zinc primer is the common cause of the rusting.

Specified Ambient Conditions

Manufacturers specify different types of paint for each ambient weather condition. With some paints, the specified ambient weather conditions can greatly restrict the number of months for painting bridges.

Requirements for Epoxy, Zinc Silicate, and Acrylics

The required surface temperature for the application of aluminum epoxy mastic used for spot painting is between 50 and 100 degrees Fahrenheit. Waterborne acrylic paint has a minimum surface temperature requirement of 40 degrees Fahrenheit. Since the difference in the dew point and the surface temperature has to be greater than five degrees Fahrenheit for the application of either of these two paints, weather delays occur throughout the painting season. These factors combine to make the painting season in Iowa very short.

Requirements for the Moisture-Cured Polyurethane

In contrast to the limitations in the currently used paint systems in Iowa, Wasser states that their moisture-cured polyurethane can be applied with the temperature down to 20 degrees Fahrenheit and humidity as high as 99 percent. The DOT, in the development of the Special Provisions, restricts the temperature to a range of 35 to 100 degrees Fahrenheit and a maximum humidity of 85 percent. The reason for the tighter weather restrictions was to reduce the potential for frost, the chance for pin holing, and condensation the painted surface.

Since surface preparation was done with high-pressure water jetting, and given the sometimes humid weather conditions in the state of Iowa, the researchers were looking for a paint system that a contractor could apply to steel under a wide range of atmospheric conditions. Because weather restrictions for moisture-cured polyurethane are not as limited as with the current paint systems, if the paint system proves successful, it is hoped the moisture-cured polyurethane will increase the length of the painting season.

Application Guidelines for Moisture-Cured Polyurethane

The Special Provisions required the painted coating to be dry before the contractor applies the succeeding coating. Although the Special Provisions specified the contractor to follow the manufacturer's recommendations to apply the succeeding coat, the Special Provisions did specify a minimum of six hours between coatings. Wasser's recommendation for the time between coatings ranged from four to six hours based on the temperature and relative humidity.

PAINTING THE RESEARCH BRIDGE

Wet Film Thickness Gauge

Cavi-Tech's quality control plan was to use a wet film thickness gauge during the painting of this research bridge. Although the paint gauge did leave a mark in the paint during the test, the mark was not noticeable after the paint cured.

The Iowa DOT has noticed that many paint system failures were due to problems with coating thickness (both excessive and inadequate). Since the wet film thickness gauge gives the painter a "real time" reading of the paint thickness during application, the painter has a chance to adjust his application rate to ensure the specified dry film tolerances are being maintained.

Striping

Although the DOT did not include striping the outside edges of the structural steel in specifications for this research project, the painter usually did apply a coat of paint to the outside edges before painting the flat structural steel. This practice of striping gives the painter a chance to build up the paint on the outside edges of the steel. This helps prevent capillary action from reducing the thickness of the coating on the outside edges of the surface steel.

Painting within the Containment Structure

A typical practice of paint contractors is to string a cable longitudinally from bridge bearing to bearing and to place a (narrow) aluminum scaffolding, usually eighteen inches wide, on the cables. The contractors commonly called the (narrow) scaffolding a "pick." Since the pick was usually no more than eighteen inches below the bottom flange, the painter did not have much room under the beam to paint the bottom of the bottom flange.

As noted in the Containment Structure section of this report, most of the containment structure was four feet below the bottom flange giving the painter an excellent chance to paint the bottom of the bottom flange. Furthermore, the painter had the whole floor of the containment structure to move around in to paint the bridge beams. Using the "pick" described above, contractors confined the painters to narrow scaffolding in which they could not paint any more than seven feet of the bridge beam without moving the scaffolding. This continual interruption of the painter's work can lead to segments of the beam not being correctly coated. The containment structure used by the contractor in this study gave the painter a chance to apply the paint evenly on the bridge beams. (Note: This research report is not implying that contractors should use containment structures to paint a bridge, but is pointing out the shortcomings of some common practices that are used during bridge painting.)

Paint Thickness

As described in the specifications for this research bridge, the minimum dry film thickness for each of the three coats of moisture-cured polyurethane is three mils for a total minimum coating thickness of nine mils. To obtain the correct dry film thickness for this research bridge, KTA measured the thickness of the existing paint after high-pressure water jetting and subtracted out this amount during subsequent measurements to figure out the "as-applied" coating thickness.

The following table shows the range of average dry film thickness for each coat of paint in mils after the existing film thickness is subtracted from the thickness reading:

	Low	**High**
First Coat	3.8	4.9
Second Coat	3.1	4.6
Third Coat	1.3	2.8
New System	8.2	12.3

The third coat did not meet the dry film thickness of three mils in any tested areas. Continued observations will determine if the reduced thickness will reduce the life of the paint system.

Painted Surfaces

As stated in the Special Provision, the painted surface shall have a smooth, uniform appearance free from runs, sags, cracks, and other defects. Paint defects could result from paint, ambient weather, or application problems, such as moisture content in the air, surface steel temperature, etc. KTA reported no defects or problems with the painted surface in its inspection report. It would appear that the selected paint system was not affected adversely by the conditions present on the site. These conditions during painting are noted in KTA's report.

TESTING RESULTS

Scrape Test

Before the contractor started this research project, KTA scraped paint off a small area of the structural steel and tested for heavy metals. After the paint chips from this test section were analyzed, the test results were 2,400 parts per million for lead and 43,900 parts per million for chromium. As described in the Iowa DOT Standard Specifications for Construction on Primary, Farm to Market and Secondary Roads and Maintenance Work on the Primary Road System, dated 1956, the high chromium content is likely in the top coat, although some lead silochromate primers were used in this period. Prior to any bridge painting in the state of Iowa, a scrape test and analysis of the existing paint components is done.

Soil Samples

The soil under and around this research bridge was sampled before and after the hydro blasting and painting project. The soil samples taken before this research project did detect small traces of lead and chromium. These traces could have been caused by agricultural chemicals or from the bridge paint flaking off the bridge beams. As stated in KTA's inspection report, the soil samples showed no additional soil contamination from the water jetting operations.

Wapsinonoc Creek Samples

Before Cavi-Tech started the project, KTA collected two (2) water samples from the Wapsinonoc Creek. The analytical results for the water samples showed that lead and chromium were below the detection limits. Since Wapsinonoc Creek was muddy after the construction project, KTA did not obtain any water samples.

Air Monitoring

During water jetting operations, KTA set out four high volume air monitors on both sides of the bridge within the containment. The laboratory results for lead were below the detection limits. While the Total Suspended Particulate results for chromium registered, they were less than 0.25 micrograms per cubic meter. Air quality regulations have no established limits for chromium.

During a four hour period, KTA monitored the air next to the bridge railing on top of the containment structure with a low volume air sampling pump. The air test result recorded measurable levels of lead and chromium, but the test results did not exceed the Action Level for lead or the Threshold Limit Value for chromium.

Waste Water Tests

Although the contractor filtered the wastewater twice, the chromium concentration showed no significant change after the second stage filtering. The four, filtered wastewater samples taken at the bridge site by Cavi-Tech ranged from 3.98 to 4.35 mg/L of chromium. These levels were below the acceptable limit of 6.7 mg/L for the Publicly Owned Treatment Works (POTW) facility in the city of East Moline. After filtering, the lead concentration and the concentration for other heavy metals, except chromium, were below the detection limit of the analytical method.

Prior to the wastewater being discharged at the POTW facility in the city of East Moline, KTA requested another sample of the wastewater be taken. This test result showed 7.5 mg/L of chromium, which is above the acceptable limit of 6.7 mg/l for the POTW. Due to the small quantity of wastewater generated on the project, the city of East Moline accepted the wastewater. While the 2,500 gallons of chromium contaminated wastewater generated on this project is a small fraction of the 4.4 million gallons of water that this POTW processes daily and could be handled within the city's EPA discharge permit, this quantity might cause concern for smaller wastewater facilities that might be looked at for disposal in other areas of the state.

Solid Waste Test

The sludge and filter media were tested with the Toxicity Characteristic Leaching Procedure for heavy metals; however, only the chromium concentration in the waste exceeded the Environmental Protection Agency's concentration limit. The solid waste was classified as hazardous waste, transported to Belleville, Michigan where it was stabilized and disposed in a Subtitle C facility.

Personal Air Monitoring

The contractor sent three personal air samples to the laboratory for testing. The test results for chromium and lead were below the requirements for the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL). Note: Four sampling events occurred, however, because of equipment failure, one event was unusable.

Personal Blood Monitoring

Cavi-Tech tested blood of two employees for both lead and zinc, before and after the completion of this research project. Although one employee showed no significant increase in lead or zinc, Cavi-Tech's second employee showed a significant increase in blood lead level. Since Cavi-Tech could not give sufficient reason for the increase in lead, KTA suggested that possibly this employee practiced poor hygiene while working around the water jetting operations. The employee's blood level for lead was below the level (50 ug/dl) for mandatory removal from the work site.

COST

Since this was a research project, it is difficult to project the cost of this small research bridge to the cost of production bridges. By definition, a research bridge should be small and in a place where researchers can adequately test the site for air, water, and soil contamination during the painting operations (a bridge over the Mississippi River would not be a good research bridge). In addition, a contractor has to include time for extra testing and observations by the researchers in the cost of the contract.

With this research bridge being small, the contractor has extra costs for mobilization, the containment structure, and waste testing. Since the cost is so high for a small bridge such as this research bridge, an agency could let several small bridges or a large bridge over a river or a reservoir to obtain an economic benefit.

The cost of the research bridge was $40,748, or $12.15 per square foot. As stated in the November 1997 *Journal of Protective Coatings and Linings*, the cost for abrasive blasting the steel surface to a Near-White Blasted surface (SP-10) and applying a coat of inorganic zinc primer and epoxy polyurethane topcoat can range from $5 to $20 per square foot. Based on these costs, the cost of high pressure water jetting is around the mid-range of the cost of abrasive blasting.

STEEL RECYCLING

One premise to be reviewed in the course of this project was the feasibility of encapsulating the existing lead based paint system until the time of the eventual replacement of the bridge. Very long river bridges or historic structures may justify complete removal of the lead based paint system since the bridge, for budgetary or other reasons, must be maintained indefinitely. For other bridges, encapsulation of the lead based paint could allow the service life of a steel bridge to be extended at a potentially lower lifetime maintenance cost. This may be an important option for the owners of bridges which, for budgetary or system integrity requirements, dictate preservation for an indeterminate period of time instead of replacement.

During the beginning stages of this research project, many in the painting industry stated that soon or later the red lead paint would have to be removed from the bridge. In other words, overcoating is just putting off the inevitable cost of removing the red lead paint. They would go on to say that an agency might as well absorb the cost of removing the red lead paint in the next painting application. Without complete removal of the lead based paint, each repainting of a bridge would in all likelihood result in some level of lead contaminated wastes being generated.

One of the researchers contacted Greg Crawford of the Steel Recycling Institute for information on paint removal during steel recycling. As expected, the steel companies do buy scrap steel coated with red lead paint for recycling. As a steel company melts down the scrap steel to molten steel, the process gives off smoke, gases, and dust collected in a bag house and separates molten metals which can be skimmed from the pot. Most lead is recoverable in liquid state floating in the molten steel. Included in the smoke and dust coming off the molten steel are other heavy metals which are collected in the bags. After the steel processor removes the bags from the bag house, harmful constituents can be disposed of in compliance with EPA regulations.

Hydro blast preparation of the research bridge generated less than 200 pounds of waste. Depending upon the level of paint removal desired, hydro blast surface preparation and overcoating the remaining paint appears to generate less waste than abrasive blasting and requires less expensive containment and a lower level of personal protection and health risk for workers. Waste is still generated that requires appropriate testing and disposal. Potential disposal of hazardous material and worker health risks still exist at the time of bridge demolition. This process offers bridge maintenance engineers an additional alternative to conventional surface preparation methods.

Overcoating does offer the option for the bridge owner to potentially avoid the full cost of hazardous waste disposal by sending the steel to the recycling mill after the service life of a bridge. Although the red lead waste is a small fraction of the paint waste gathered from an abrasive blasting bridge painting project, an agency is responsible for all of the hazardous paint waste disposed of in a Subtitle C facility.

CONCLUSION

Bridge painting decisions are based on engineering judgement and standardized evaluation techniques that yield quantifiable data. Before an engineer decides to paint a bridge, the engineer should evaluate the following physical criteria of a bridge:

- The amount of section loss (rust) on the bridge beams, diaphragms, and bearings;
- The amount of paint deterioration;
- The amount of blush rust;
- The estimated remaining life of the bridge;
- The replacement cost of the bridge;
- The condition of the bridge deck;
- The condition of the bridge deck joints;
- The structural deficiency or functional obsolescence of the bridge;
- Agency budgetary concerns;
- Bridge inventory concerns.

Once an engineer has evaluated a bridge using the criteria listed above, the engineer can make three choices:

- Do nothing and allow the bridge to deteriorate until its useful life has been consumed.

- Abrasive blast the bridge to remove all lead based paint and repaint the bridge.
- Spot paint the bridge, coating the areas where the existing paint system has failed.

If an engineer believes that a bridge has an undeterminable life span, then the engineer may decide to write a bridge painting proposal for abrasive blasting of the existing paint system. With the high replacement cost of a large bridge, the engineer may conclude that the structure has an indefinite life span due to the high differential cost between maintenance and replacement. In other words, if a bridge needs to last for an indefinite period of time, the agency should remove the heavy metal paint on the bridge and repaint the bridge with a coating system that meets the current state of the art. This option allows an agency to avoid the possibility of heavy metal paint peeling or flaking off the bridge in question.

If an engineer believes that a bridge has a definite life span, then an engineer may decide to place an overcoat on the structural steel of the bridge or allow the bridge to deteriorate until it reaches functional obsolescence. If the exiting paint system is in good shape overall, it may make sense to overcoat.

During this research project, the researchers observed favorable results from the high pressure water jetting. Although the Wapsinonoc Creek samples were incomplete, the soil samples showed no contamination from high pressure water jetting. Air samples collected both inside and outside the containment showed no signs of contamination. In other words, the containment structure successfully contained the water and paint waste generated by the high pressure water jetting.

As expected in the Research Proposal for this project, hydro blast wastewater was filtered and discharged in a publicly owned treatment facility. The solid waste was classified as hazardous and disposed of in a Subtitle C facility in accordance with federal regulations.

Although an employee showed an increase of lead in the blood, two other employees showed no significant increase of lead in the blood. All employees' air monitoring samples showed airborne lead levels below OSHA action levels. Speculation exists that the high lead level for this employee was due to poor hygiene, but further investigation may be necessary to assure that high pressure water blasting in a containment structure creates an environment where the construction workers can effectively remove the paint from the structural steel surfaces of a bridge with minimal health risk.

Except for the areas in the surface steel where the small diameter rust pits were found, high pressure water blasting met the three surface steel cleaning standards. These pitted areas may be unique to the surface steel on this bridge. Using the high-pressure water jetting on any bridge to Surface Cleaning Standard 1, an engineer could have confidence that the surface steel was properly prepared for overcoating a bridge.

Until this overcoat paint has been on this bridge for a few years, the researchers will not know how well moisture-cured polyurethane is performing. This study assumed that a minimum value of 400 psif for the adhesion test for overcoating the existing primer and paint, but only by observing the performance of the finished paint can we determine if 400 psif is the appropriate adhesion strength for existing coatings. The moisture-cured polyurethane will also have to be reviewed over time to assure that no thermal stress or bonding problems exist. If the stress between the existing paint system and overcoating is great enough to cause this paint system to shear, then the paint will peel off the bridge beams.

RECOMMENDATIONS

As stated in KTA's report, KTA and the researchers feel that high pressure jetting for surface preparation of structural steel and overcoating the existing paint system offers a promising alternative for dealing with painted steel bridges. KTA and the researchers do have a few recommendations for future applications of this process.

The researchers recommend the following changes to the Special Provision for this research project:

- Remove the Wasser name from the Special Provision and replace it with a generic product name.

- Require the contractor to use a wet film thickness gauge during the application of the paint. Specifications for measuring the paint with a wet film thickness gauge should include the locations on the bridge beams to be measured and the frequency along the bridge beams for the painter to measure the paint film thickness. The bridge painter should record the wet film thickness readings. The project inspector should conduct acceptance testing during painting by regularly measuring the dry film thickness on the bridge beams. This would hopefully catch deficiencies in film thickness as were discovered at the completion of this project.

- Require the contractor to stripe the exterior edges of the structural steel. *

- Require the contractor to ring all bolts and rivets.*

* Specifications should be written to address excessive paint film thickness on the flat steel surfaces for these operations.

Since the bridge beams were high-pressure water jetted to three cleaning standards, the researchers recommend that Cedar County annually review the performance of the paint system. By obtaining the adhesion testing equipment from the Iowa DOT Office of Materials, Cedar County should annually perform the tensile test on the three areas of surface cleaning and document any paint distress on the structural steel surface of the bridge. After five years of collecting tensile test data and documenting paint distress, the researchers recommend that the data be transferred to the Office of Materials and that the Research Section analyze the data for paint performance. After the Research Section evaluates the paint performance data, they can determine whether further monitoring of the bridge is needed and whether additional specification changes are needed. A supplemental report should also be published at the completion of the first five years of data collection.