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Cover photo courtesy of Tom Inglis

SSPC The Society for Protective Coatings

FEATURES

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DOTs ON MAINTAINING CORRODED CONNECTIONS: CLEANING, CAULKING & COST

By Tom Inglis and Nick Volk, IDOT District 4; Dan Brydl, FHWA-Illinois Division; and Ken Trimber, KTA-Tator, Inc.

Because of the intricate design of the Shade-Lohmann Bridge bridge, Illinois Department of Transportation District 4 decided that connections should be caulked to provide additional protection. After hearing about both successes and failures when caulking was used, IDOT wanted to better understand the use of caulking and develop plan notes or special provisions to clearly delineate the expectations. This article provides specification language provided by various DOTs, summarizes the variety of approaches that are taken, and presents the process followed by IDOT for the Shade-Lohmann Bridge.

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PUTTING THE PIECES TOGETHER: INTEGRATING STEEL REPAIRS WITH BRIDGE PAINTING PROJECTS

By Kevin H. Keith, PE, LiRo Engineers, Inc.

Many bridge painting projects include steel repairs as part of the contract. Painting and steel repairs are performed by separate trades and often by separate contractors, but both must work together and be installed as a system to perform as intended. This article is a discussion about the process of installing steel repairs and painting a bridge simultaneously. It includes lessons learned by a resident engineer with experience managing major bridge painting and steel repair contracts.

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FIGHT THE PHENOL: BAKED PHENOLIC RAILCAR LININGS FOR EXTENDED SERVICE

By John Myers, Carboline Company

With more than 400,000 tank cars carrying raw materials, intermediate chemicals and finished products for both industrial use and direct or indirect human consumption on railroads throughout North America, interior linings are critical for protecting these commodities from contamination and maximizing rail car service life. This article outlines the materials and methods required for application of baked phenolic linings to railcar interiors, using one 24-year-old lining as a case history in success.

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SSPC ON THE FRONT LINE

SSPC INTERNATIONAL ACTIVITIES

Photo courtesy of SSPC

PHILIPPINES CHAPTER HOLDS SYMPOSIUM, EIGHTH ANNIVERSARY MEETING

The SSPC Philippines chapter held its eighth anniversary gala in cooperation with the SSPC Asia Pacific Advisory Council at the SMX Convention Center in Taguig City on June 14, 2018.

Forty SSPC members and guests attended, including the chairman of the SSPC Asia Pacific Advisory Council, Aaron Williams (Schmidt); Arnie Denaga (Manila Water); Daniel Ihada (PPG); Cezar Layag (Davies Paints Philippines); Roberto Alonzo (Jotun); Milo Cuarentas (Maincoat); Cherrie Sandoval (Hempel); Rondulf Go (Shell); Bonifacio Pangan and Jessie de la Cruz (Central Bank Philippines); and Eric Piotrowski (SSPC).

The event included a full-day symposium with four technical presenters, plus a panel discussion with all speakers. Williams provided an update on the efforts of the Asia Pacific Advisory Council along with a scorecard with key metrics and target goals. Boyet Pangan, Philippines chapter chair, discussed chapter activities for the remainder of 2018 and early 2019. The chapter thanks PPG for its generous sponsorship of the event.

CHINA CHAPTER HOLDS FIRST TECHNICAL CONFERENCE

The newly reorganized SSPC China Chapter held its first technical conference, Greencoat China, from October 11 to 13, 2018 at the

Photo courtesy of SSPC

Radisson Exhibition Center in Shanghai. Approximately 300 coatings professionals attended the event to hear speakers from 38 different organizations present on relevant coatings topics. The conference also received support from various governmental bodies in Shanghai, Changyuan and Nantong.

Dejin Feng, secretary of the China chapter, was very pleased with the results of the chapter's first event and hopes for even more success next year. SSPC Executive Director Bill Worms attended and was also impressed, commenting, "I was inspired by the dedication and hard work of the officers and members of the new China chapter. They have set some very aggressive goals for the future and I am very confident that they will meet them."

SSPC and the China chapter would like to thank the companies that sponsored the event, including Graco Inc.; Elcometer; Thermec Company, Inc.; TitH Chemicals; Haimen Sanhao Anticorrosive Engineering Co. Ltd; Xian Tianyuan Chemical Co., Ltd; Attaining (Shanghai) Macromolecule Materials Co., Ltd; Shanghai QXQC Coating Technology Co., Ltd.; Shanghai Zhenhua Heavy Industry (Group) Changzhou Coating Co., Ltd; Wuhan Onew Technology Co., Ltd.; ShanDong OBO New Material Co., Ltd; Nanjing Bluewind New Material Science and Technology Co., Ltd.; PPG; and China Shipbuilding Industry Group Changjiang Technology Co., Ltd.

Photo courtesy of SSPC

PANAMA CHAPTER HOSTS TECHNICAL CONFERENCE

The SSPC Panama Chapter conducted its second annual protective coatings conference on

October 17, 2018 in Panama City, Panama.

The one-day conference featured 10 speakers from six Latin American countries who provided technical presentations on surface preparation, coating application, concrete coatings, coatings inspection and craft worker training.

More than 100 individuals from eight countries outside of Panama attended the event. At the conclusion of the technical program, there was an evening social reception, dinner and an acknowledgement ceremony for the conference speakers and sponsors.

SSPC Executive Director Bill Worms, who presented at the conference, said, "I am so impressed with the Panama chapter and all they have accomplished in the short time they have existed. I know it takes a dedicated team to put on such a great event, and SSPC appreciates their efforts to spread SSPC's mission here in Panama."

The conference sponsors included Camara Maritima, College Ingenieros Civiles, Panama; Setmix Orgullosamente Ecuatorianos; Mexicana de Poliurea; AkzoNobel; Fischer; Pintuco; Twilight Instrumentos De Medicion Industrial; Ascor Association Colombiana de Corrosion y Proteccion; TruQC; and Terramar Oil & Services.

SSPC CELEBRATES 10TH YEAR OF PCI TRAINING IN INDONESIA

On October 21, 2018, almost 200 SSPC members, certified inspectors, instructors and staff gathered at the Harmony Hotel in Indonesia to celebrate the 10th anniversary of the first Protective Coating Inspector (PCI) training in Indonesia and commemorate the extraordinary efforts of the SSPC members who helped establish the PCI certification in the region.

Photo courtesy of SSPC

The event, sponsored by International Paint, honored the efforts of Alex Wijaya and Abdul Rashid, both deceased, who championed the program from the beginning. After the first few classes, current SSPC instructors Muniandi Dewadas and Bani Quim (SBM Offshore), Patrick Tan (In-Spec Corporation, Pte. Ltd.) and Kevin Yeo (Arkco Thailand) became the core group supporting the training initiative. The efforts of this dedicated group have resulted in more than 350 individuals with current PCI Level 1, 2 and 3 certifications in this area.

A master of ceremonies conducted the festivities, which included games, entertainment and contests. Each attendee received a commemorative shirt from the sponsors. Eric Piotrowski, SSPC business development specialist, handed out certification documentation to the latest class of PCI recipients.

Getty Images / ricardocostaphotography

Report: Bolt Failures in Cuomo Bridge

A number of steel bolts used in the construction of the Mario Cuomo Bridge broke apart during the building process, according to reports. There are also allegations that some in leadership positions tried to cover up the issue. According to NBC New York, the New York state attorney general is investigating the issue, as well as the allegations of corruption.

The new Cuomo Bridge consists of twin cable-stayed spans, each stretching 3.1 miles total, with a 1,200-foot-long main span. The first of the two new spans opened in August 2017, at which point demolition of the old Tappan Zee Bridge began; parts of the old bridge have recently been scuttled in the sea near Long Island to create artificial reefs. The original Tappan Zee Bridge was a 3-mile-long cantilever bridge opened in 1955.

The first of the new spans was converted to handle westbound traffic only after the newer, eastbound span opened to traffic; traffic had been traveling in both directions on the one span for the past year.

The new Tappan Zee project has been touted as the largest bridge construction job in the state's history, and managed to remain largely on schedule and on budget. According to the New York State Thruway Authority, which has overseen the project, the construction required 14 miles of main span cables, 300,000 cubic yards of concrete and 200 million pounds of American-made steel.

The design-build team behind the bridge, Tappan Zee Constructors, includes Fluor, American Bridge, Granite Construction, Traylor Bros., HDR, Buckland & Taylor, URS and GZA.

In mid-September, the opening of the bridge's second span was delayed after a piece of the old Tappan Zee Bridge became unstable and threatened to fall. At the time, the Tappan Zee was being disassembled. Later that same month, after the opening of the second span was delayed twice, a paper trail revealed that Tappan Zee Constructors was concerned about whether the job could be completed on time, even after the opening date was pushed from Aug. 24 to Sept. 7.

While engineers have stressed that the both spans are safe for use, the corruption allegations have raised concerns over how many of the 1 million bolts used in the project will need to be inspected or eventually replaced.

NBC New York obtained reports of roughly 60 bolt failures. The person who raised the alarm used to work as a safety inspector. In response to a question regarding why the bolt issue was not being reported, an engineer in charge said on a tape from February 2016 that others would instantly think it was a "manufacturing defect," and from there it would "get blown way out of proportion."

The whistle-blower went on to allege that throughout the project, bolt issue evidence was discarded and documents were falsified. State Thruway officials first became aware of the problem in 2016 and began monitoring and testing. In 2017, repeated testing was conducted to determine if there was a manufacturing defect or other issue. Thruway spokesperson Jennifer Givner noted that over a year ago, the Authority had hired "independent experts" to check the bolts. The conclusion was that both bolts and bridge were safe.

The whistle-blower has filed a lawsuit, however, alleging that hydrogen embrittlement, which occurs when hydrogen contaminates steel, could be the culprit behind the breakage. Engineering firm Alta Vista said in a report that the likely cause of the past bolt issue was preexisting cracks in a small percentage of bolts used in the structure.

"To date, all bolt testing performed by multiple parties indicates there is not an issue with the bolts," a spokesperson for Tappan Zee Constructors told NBC New York.

DOT Announces $1.5 Billion in Infrastructure Grants

Getty Images / Sean Pavone

On Dec. 11, the U.S. Department of Transportation announced $1.5 billion in infrastructure funding to 91 projects across 49 states, including the District of Columbia, with bridge projects taking home more than two-thirds of the grant money.

Funding for the Better Utilizing Investments to Leverage Development (BUILD) grants was selected as part of the program for fiscal 2018.

DOT Secretary Elaine Chao noted that highway and bridge projects received the largest portion of funding — totaling 69 percent, or more than $1 billion. The total was split among 60 projects in that category, which include the following.

- $25 million, the maximum amount that could be given to a single project, will go to the rehabilitation of the Brooklyn Bridge's masonry arches and foundations, located on the Manhattan and Brooklyn approaches.
- $20 million will go to Vermont for the replacement of 31 railroad bridges over roughly 53 miles of track on the Vermont Railway's Western Corridor.
- $25 million will go to Missouri for the replacement of the Buck O'Neil Bridge, which carries US 169 over the Missouri River in Kansas City.

Chao also noted that rail projects received $165 million, transit received $141 million and ports received $146 million. These grants only provide partial funding for each project; the remaining amount must be pieced together with private, state, local or other federal funds. Out of the 91 projects, 12 received $25 million each, including Louisiana's project to widen and rehabilitate a 3.8-mile stretch of Interstate 12.

Demand for grants exceeded funding available — there were 851 applications from all 50 states, as well as the U.S. territories and the District of Columbia. Projects were selected based on safety, economic competitiveness, quality of life, environmental protection and state of good repair. Other criteria also accounted for innovation, broadband service to underserved communities and demonstrating partnerships between the public and private sectors.

"BUILD transportation grants are major investments in road, rail, transit and port projects that serve as a down payment on this administration's commitment to America's infrastructure," said Chao.

PPG ACQUIRES LOW-FRICTION COATINGS COMPANY

Global coatings company PPG recently announced that it has reached an agreement to acquire Whitford Worldwide Company of Elverson, Pennsylvania, a manufacturer that specializes in low-friction and nonstick coatings for industrial applications.

"The acquisition of Whitford will allow PPG to further drive value for its customers and shareholders by enhancing our range of product offerings, research and development capabilities, and global market reach in the growing industrial coatings sector," said Michael McGarry, PPG chairman and chief executive officer.

According to Pittsburgh-headquartered PPG, Whitford specializes in manufacturing low-friction, wear-resistant coatings for industrial applications in automotive, aerospace, energy and construction products, as well as nonstick coatings for household items. Whitford employs more than 700 people and operates 10 manufacturing facilities around the world.

"Whitford's leadership in low-friction and nonstick coatings will provide strategic additions to the robust portfolio of industrial coatings solutions we deliver today, while PPG's research and development organization will leverage Whitford's extensive expertise in fluoropolymer chemistry across the markets we serve," said Tim Knavish, PPG senior vice president, industrial coatings.

"In addition, Whitford's global footprint and customer-centric, high-touch business model are highly complementary to PPG's business, allowing for a seamless integration process."

The transaction is expected to close in the first quarter of 2019, subject to closing conditions. Financial terms were not disclosed.

PAINTSQUARE COMMENTS


Photo courtesy of KTA-Tator, Inc.

In Response to "The Really Premature Coating Failure" *(Investigating Failure, JPCL December 2018)*

Author Rob Lanterman of KTA-Tator, Inc., outlined a case in which improperly stored and shop-coated items at a new natural gas compressor station exhibited failure before field erection and touch-up had even been completed. The uncovering of the causes got PaintSquare users talking in the comments section.

Sandy Bates:
"This story tells why proper inspection is needed during the preparation and application periods ... cheaper to do it right than to redo."

Warren Brand:
"Great and detailed article, Rob, perhaps you can explain the thought process of the investigation. We get requests all the time for comprehensive failure analysis. Unless litigation is being considered, our approach to a failure analysis is that we do the least-costly (for the client) investigations first, and then drill deeper (lab work, destructive testing, etc.) only if required ... In this case, the coating was clearly too thin, which could have been determined in a few hours with the use of a DFT gauge. Once it was determined the coating was too thin, why charge the client for further investigations?"

Robert Lanterman:
"Warren, the client in this case requested the investigation to see if the coatings conformed to the specification. The case was likely to go to litigation and they wanted to know as much about what had been done as they could to direct that decision. While dry film thickness measurements were part of the problem, they did not tell the whole story. A comprehensive investigation was needed to determine all of the issues and know how they could best be addressed going forward. Knowing all of the issues with the existing coating application is invaluable in the event of pushback and helps the client decide to pursue litigation. The lab tests in this case were not very costly and provided valuable evidence to what was done in the field. A last-minute flight can cost considerably more than some IRs."

David Lemke:
"All I can say is, 'You get what you pay for.' I work for a company that is a pipe fabricator and oversee the coatings department. The procurement individuals at some facility owners only look at the bottom line on estimates when they make their decisions and they should not wonder why episodes like this occur. Sure, they can back-charge after litigation for the improper workmanship in an instance like this, but what is the true cost? Fixing the problem will mean a delay in start-up operations, which in turn leads to loss of profit when the facility should be up and running. Time and money spent on litigation adds to [the] cost of the project as well ... The thing I wonder about this article is, has someone learned a lesson here?"

PAINT POLL

paintsquare.com/poll, Dec. 10 to 14, 2018

Over the past few weeks, a number of announcements regarding multi-billion-dollar infrastructure projects have been made. Do you think such large-scale projects will become the norm in the future?

Yes.	77%
No.	23%

Aloys Cabell III:
"With the age of the current infrastructure, large-scale maintenance and new construction project[s] will be the norm."

David Zuskin:
"Unfortunately, death and destruction must precede meaningful infrastructure renewal, but considering the condition of so many structures, watch out!"

COATINGS CONVERSATION

In Response to "IN Man Scraps Bridge for Metal"

The ownership of the Monon Bridge, a decommissioned railroad bridge in Hammond, Indiana, is up for a federal jury debate in an unusual case in which a nearby resident dismantled the bridge and sold it across state lines for scrap. Kenneth Morrison, owner of T&K Metals, allegedly took the metal from the over 100-year-old bridge and sold it to a scrap dealer in Illinois for $18,000, according to The Chicago Tribune.

Jeffery Smith:
"Doesn't the [government] have something better to do?"

Scott Youngs:
"How many hundreds of thousands of dollars will be spent for the $18k in scrap?"

John Schultz:
"They should be happy to be rid of a potentially dangerous structure and return the environs to its 'natural' state."

Michael Halliwell:
"Morrison should send them a bill [for] $35,000 minus the salvage amount for 'dismantling and recycling of a derelict structure' and 'site restoration.' You can bet if the City of Hammond put the removal of the bridge out for tender, Morrison's bill would be a steal of a deal."

Problem Solving Forum

paintsquare.com/psf

What is the best primer system for galvanized steel?

Josh Skinner, The Sherwin-Williams Company:
"Galvanized steel can be primed with epoxies, acrylics, wash primers [and more]. Primer selection should depend on the desired outcome. Are you looking for a thicker 'barrier' coating? Do you need abrasion resistance, or chemical resistance? Are you painting the steel for aesthetic purposes only?"

Frank Gerace, O.W. Hubbell and Sons:
"The American Galvanizers Association has a guide, "Duplex Coatings- Painting Over Hot Dipped Galvanized Steel." Pages 9 and 10 of the Guide list appropriate paint and powder coat types. However, a word of caution: alkyds should never be applied directly over unprimed galvanized surfaces. The zinc in the galvanizing produces alkaline salts that can react with the alkyd and lead to 'saponification' failure with blistering, peeling and poor adhesion."

Erik Andreassen, CPS:
"There is no mention [of] if the galvanized surface is aged or new. This should be taken into account before specifying a suitable primer. In many cases, major manufacturers have removed etch primers from their assortment and rely on good epoxy coatings at a higher film build. Some contractors found it very difficult to keep their applications to under 25 microns. If figures like this were exceeded, the coating could peel off. Surface preparation is also a major factor in the selection of primers. Often, specifiers would list the surface preparation for galvanized surfaces as sweep or brush-off blasting. This is extremely difficult for some operatives to achieve without damaging the galvanized surface. After washing, roughening of the surface with course sand paper is an alternative. This should be carried out to a degree where there is no damage to the substrate. If the substrate is relatively old, surface-tolerant primers can be a very good alternative to standard epoxy, followed by a final coat of polyurethane if appearance is required."

PAINTSQUARE NEWS TOP 10

paintsquare.com/news, Dec. 3–Jan. 6

1. **IN Man Scraps Bridge for Metal**
2. **Report: Bolt Failures in Cuomo Bridge**
3. **Commuters Avoiding KY's New Infrastructure**
4. **Texas Bullet Train Gets Construction Date**
5. **Amazon Latest to Restrict Paint Strippers**
6. **PPG Acquires Low-Friction Coatings Company**
7. **Scientists Attempt to Hush Noisy WA Bridge**
8. **Keystone XL Pipeline to Undergo Review**
9. **DOT Announces $1.5B in Infrastructure Grants**
10. **US Border Wall Plans Move Forward**

THE CRUDE TRUTH ABOUT LINING TANKS FOR OIL TRANSPORT

BY MICHAEL MCGLAMRY, HEMPEL (USA), INC.

Getty Images / madsci

In the past, tank cars carrying crude oil had no protective linings for corrosion protection. Cargoes of light sweet crude (containing less than 0.5 percent sulfur) have a passivating effect on the steel of the cars, and very little corrosion was ever identified during routine inspections. Why is there now significant concern about corrosion in railcars, when the industry has a track record (pun intended) of over 100 years with very low corrosion rates in unlined cars? What has changed? Is crude becoming more corrosive? Are fracking chemicals mixing with the oil and corroding our steel?

Before we answer these questions, let's consider some numbers about the rail business concerning crude shipments from a May 2013 report from the Association of American Railroads: The 2013 report noted that five years previously, in 2008, "U.S. Class I railroads originated just 9,500 carloads of crude oil,"[1] but the number of carloads originated had increased to 234,000 in 2012, and in the first quarter of 2013, the number was 97,000.

That number has continued to climb: since the May 2013 report, there has been a huge increase in the amount of crude oil transported by tank cars. A 2018 report from the AAR cited "increased volumes of crude oil moving by rail," bolstered by about $25 billion a year in private investment over the past several years [2].

Given these numbers, maybe we are seeing more corrosion on tanker cars just because we have a whole lot more steel exposed. Or maybe we are carrying crude that's not only crude. The answer to our problem can be found by understanding oil production and the constituents in crude. For this discussion, we are focusing on the developments in the unconventional onshore oil market in North America, which is pushing the overall rail crude oil tank requirement capacity.

We must understand that there are several advanced completion techniques within the unconventional market, including traditional welling/fracking, in-situ mining, steam-assisted gravity drainage (SAGD), and cyclic steam stimulation (CSS). For this article, we will focus specifically on the fracking completion technique.

There has been a lot of discussion in the unconventional oil and gas market and in the media about fracking, so we won't go into great detail here, but the fact is, there are corrosive chemicals used in the fracking process.

The presence of corrosive chemicals in fracking raises a question about transporting oil: When those chemicals are pumped into the formation, do they return to the surface with the oil extracted and with enough

Editor's Note: This year marks the 35th anniversary of the publication of JPCL, the definitive source of technology and information about protective and marine coatings. To celebrate, JPCL will be highlighting archival content — updating previously published technical articles throughout the year and looking back on past practices and technologies. This article initially ran in the September 2013 issue and has been updated by the original author for publication in this issue.

corrosion potential to cause problems? The answer is "No." While the chemicals can be found in the produced crude, the concentrations are so low that they are not seen as problematic. It's important to note that with traditional extraction methods, crude oil also contains water, chlorides, oxygen, and up to 0.5 percent sulfur for sweet crude or higher for sour crude.

What about bitumen produced from mining oil sands? Oil sands are a naturally occurring mixture that typically contains 10-to-12 percent bitumen, 80-to-85 percent minerals (clays and sands), and 4-to-6 percent water. Bitumen is a mixture of large hydrocarbon molecules containing sulfur compounds (equivalent to up to 5 percent elemental sulfur by weight), small amounts of oxygen, heavy metals, and other materials.

Now that we are starting to get a clear picture of the composition of the cargo, we should take a closer look at the water, sulfur, and oxygen. When we do, the "ah-hah" moment comes. Bitumen is extremely viscous at ambient temperatures, but crude can be just as viscous in extremely cold temperatures, such as those occurring in North Dakota winters. In an effort to make the bitumen or crude flow into the tank cars, it is heated. This heating causes the water, sometimes with high levels of chloride, to naturally separate from the oil and sink to the heel, or bottom, of the railcar. So, we've created an environment that contains sulfur, high chloride levels and hot water — an environment ideal for supporting corrosion. To put this environment into perspective, even at ambient temperatures, wet elemental sulfur has been shown to corrode mild steel up to 1 mm/year (0.04 inches/year), with localized pitting rates of up to 7 mm/year (0.27 inches/year). With the addition of chlorides, the corrosion rates have been shown to double and even triple, in research conducted by Fang, Young, and Nešić.[3]

Now that we have a better idea of what we're fighting, another question arises: How do we protect the interiors of tank cars carrying crude oil or bitumen from oil sands? We'll need an interior lining that must be resistant to high temperatures, and since high-pressure steam is often used during the cleaning of the tank cars, with steam temperatures as high as 330 F (166 C), the lining also must be resistant to thermal shock. In addition, during crude loading in the winter, the steel temperature could be -40 F (-40 C), while the crude temperature will be around 180 F (82 C). This condition leads to an immediate 200-degree F (111-degree C) temperature swing, resulting in thermal expansion of the steel as well as the lining material. So, the lining will also need to have some level of flexibility to cope with the flexing of the tank car during loading and unloading operations, as well as the general movement associated with transportation. This is a tall order, even before adding the chemical resistance requirements of hot chloride water and the low pH environment associated with sulfur compounds.

These considerations cover the onloading aspect of what a tank car lining must be capable of performing. The unconsidered factor which became an issue takes place during the offloading process. During offloading, steam coils are typically used to increase temperature and reduce viscosity of the crude oil. This is done in order to help with the flow when emptying a tank car. The steam coils can operate at very high temperatures which can lead to premature failure of internal tank car linings.

When selecting an internal lining, all of the aforementioned factors must be considered.

The good news is that advanced technology phenolics and thick-film epoxy novolac linings on the market can withstand the environment. Coating manufacturers focused on the rail industry have long, successful track records for this type of service. The real question becomes, should you risk an unscheduled release and loss of an asset because the tank car wasn't lined?

ABOUT THE AUTHOR

Michael McGlamry is the Americas Protective Product Manager for Hempel (USA) Inc., with 25 years in the protective and lining segments. He has worked in a variety of roles including product manager, lining technical manager, technical service manager, and upstream offshore engineering sales. He is NACE Level I-certified and also holds an international certification for project management.

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Electronic Inspection of a Field Painting Project

Part 1: Uncovering Application Issues

BY CORY ALLEN, VULCAN PAINTERS INC.

Fig 1: Clarifier bridge structure. Photos courtesy of the author.

Coating inspection has been made more efficient and effective through the use of electronic equipment, which can collect, store, transmit and populate inspection reports with data taken directly from the field. This article will not only outline some of the advantages of using electronic equipment on a real-world field painting project, but will also use the data generated to bring some important surface preparation and application considerations to the forefront.

PROJECT BACKGROUND

A certified inspector monitored the cleaning and coating of equipment in a municipal wastewater treatment facility, performed by an SSPC-QP 1- and QP 2-certified painting contractor. The scope of work required abrasive blast-cleaning to remove existing coatings for both immersed and non-immersed steel and concrete surfaces, followed by recoating with high-performance industrial coating systems for 14 clarifiers. Removal of lead-based paint and recoating of a methane gas sphere was also included.

The customer required a battery of inspection tests for each of the clarifiers, including pH, conductivity, dust and soluble salt measurements, adhesion tests on the primer and finish coats; and concrete surface profile measurements. More routine tests required by the owner included dry-film thickness (DFT) measurements according to SSPC-PA 2, "Procedure for Determining Conformance to Dry Coating Thickness Requirements;" blast-cleaned steel profile depth; cleanliness of blast-cleaned steel and wet sponge holiday testing of coatings over conductive surfaces.

On the jobsite, there were multiple paint crews working in different areas of the facility. To collect and report data efficiently for all of the required tests for multiple work sites with minimal interruption to the production, inspectors elected to use electronic instruments with paperless daily reporting. Tests could be performed quickly and reports could be customized to include non-routine tests. Data collection was generally performed when tests did not interrupt the blast-cleaning and painting and when blast dust and paint overspray would not cause damage to the electronic instruments.

Measurements were often made while climbing and adhering to the "three-point rule" regarding safety, with one hand used for taking measuring and recording data points. Measurements of environmental conditions, lighting, DFT, surface profile depth and conductivity were performed relatively quickly. Data was collected and stored in the gauges' memory as batches and, in some cases, multiple sub-batches, and was then downloaded to a computer to incorporate into daily inspection reports. General inspection data, such as paint batch numbers, surface cleanliness, adhesion test results, mixing times, pot life, air cleanliness and percent of thinner added were manually added into the paperless report.

Capturing DFT data electronically proved to be much faster as it was automatically stored, eliminating the need to document manually.

Another advantage was the ability to continuously monitor ambient conditions overnight to determine the minimum recoat time. Hourly measurements were recorded and automatically calculated by the gauge to show an average

Table 1: Field Values Using ASTM D4417 Method B.

Structure Measured	Profile Average (mils)	Profile Range (mils)	Standard Deviation, s
Primary Clarifier 6 Bridge	3.65	2.1–5.0	0.66
Final Clarifier 4 Feed Well	2.75	1.8–3.9	0.60
Primary Clarifier 5 Bridge	3.90	2.0–5.4	0.81
Final Clarifier 4 Sweeps	4.83	2.2–6.6	1.16
Gas Sphere Shell	3.14	1.4–4.8	0.61
Primary Clarifier 3 Rake Arm	2.85	2.0–4.3	0.55
Primary Clarifier 10 Cage	4.85	2.4–6.4	1.00

Table 2: Values in ASTM D4417, Method C.

Coded Surface ID Number	Replica Tape Profile Average (mils)	Standard Deviation, σ
102	1.29	0.12
114	2.65	0.23
124	2.79	0.18
121	3.75	0.15
119	4.22	0.18

Table 3: Precision Profiles, σ Different Coating Systems on Complex Shapes.

	1st	2nd	3rd
Immersion Epoxy	2.79	4.11	5.83
Zinc, Epoxy, Polyurethane	1.46	3.00	3.31

Fig 2: Sweep for a rake arm on a final clarifier.

Fig 3: Truss on a rake arm in a final clarifier.

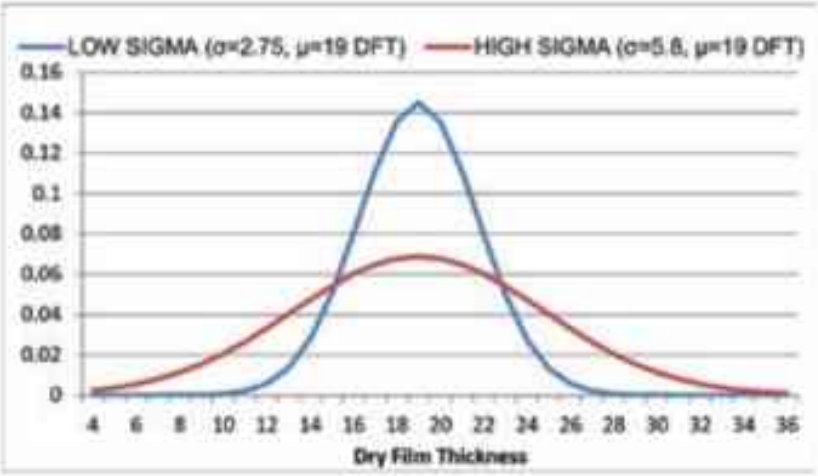

Fig 4: Normal distribution curves for different film thickness distributions. σ.

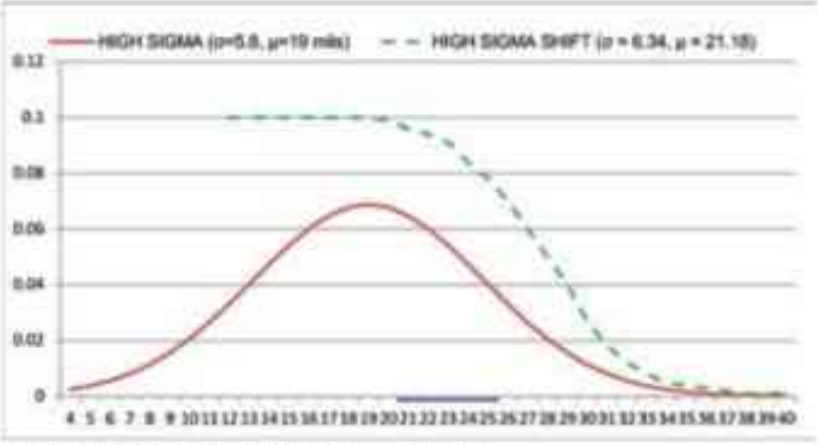

Fig 5: High sigma shift for low dry-film thickness measurements.

overnight temperature, which was then plotted on an Excel spreadsheet using the coating manufacturer's data for minimum recoat time. The annotated graph was included in the electronic report to document conclusively that the recoat time had been achieved before the next coat was applied.

Reports included photographs to promote a higher level of credibility in the data. By date-stamping photographs, the reports showed which test was done, and when and where it was performed.

Daily reports for each work site at the facility were converted into PDF files, which were then posted into the job-specific folder on a file-sharing service for the customer's viewing. Every day, the batch memory on the gauge was deleted and new batches were created. The year-long project was completely paperless.

SURFACE PROFILE MEASUREMENTS

For this project, ASTM D4417 Method B was employed using an electronic depth micrometer with a pointed probe and a memory to capture the data points. This method requires only 10 readings and the maximum peak-to-valley height to be ported. However, using the electronic depth micrometer, a much larger number of data points were recorded at each work site. For example, on this project, 32 data points were measured in only 10 minutes while walking across a clarifier bridge structure and climbing beneath it on scaffolding (Fig. 1). The electronic gauge calculated and reported the true average as 3.65 mils, the standard deviation was 0.66, the lowest value was 2.1 mils and highest value was 5.0 mils.

Table 1 shows the standard deviation of values obtained on various work sites during hold-point inspections using an electronic depth micrometer gauge. For comparison, Table 2 shows standard deviation values published in Method C of ASTM D4417 using replica tape. The relatively low standard deviation values for Method C are due to measurement of the high peaks on deformed replicas.

The standard deviation values for Method B in Table 1 are much greater than for Method C in Table 2, because Method B is the roughness measure of the variation achieved by blast-cleaning. The electronic depth micrometer measures and

records each peak-to-valley height. Figure 2 (p. 25) shows a sweep for a rake arm on a final clarifier. The profile on the sweep ranged from 2.2-to-6.6 mils with an average of 4.83 mils and a standard deviation of 1.16.

DRY-FILM THICKNESS MEASUREMENTS

The customer's specification required DFT to be measured using SSPC-PA 2, which calls for selecting each 100-square-foot area and performing five spot measurements. Each spot measurement is the average of three separate readings within a 1.5-inch-diameter circle. Figure 3 (p. 25) illustrates one-half of a rake arm, which is a truss fabricated of angle iron making up an area of more than 300 square feet but less than 1,000 square feet.

The SSPC-PA 2 requirement for an area larger than 300 square feet but smaller than 1,000 square feet is for selection of three separate 100-square-foot areas and performing five spot measurements for each area. This results in a total of 15 spot readings for the 1,000-square-foot area. For complex structural shapes, the sampling frequency leaves out most of the total area. For a 1,000-squre-foot area, only 26.5 square inches of the 144,000-square-inch total area — just 0.018 percent — will be measured. To put this into perspective, the same percentage of area (0.01 percent) on an 8.5-by-11-inch sheet of paper would be a 0.01683-inch square.

Table 4: Precision Profiles, σ Shape and Application Method.

	Brush & Roller			Airless Spray		
	1st Coat	2nd Coat	3rd Coat	1st Coat	2nd Coat	3rd Coat
Simple Shape (feed wells)	2.73	3.37	4.30	1.36	2.32	2.75
Complex Shape (rake arms)	2.79	4.11	5.83	1.81	3.26	4.14

Table 5: Precision Profiles, σ Validation of σ Influence.

	Brush & Roller			Airless Spray		
	1st Coat	2nd Coat	3rd Coat	1st Coat	2nd Coat	3rd Coat
Complex Shape (rake arms)	2.79	4.11	5.83	1.81	3.26	4.14
Maintenance Deck	-	-	-	2.5	3.4	3.9

By following the specified SSPC-PA 2 method, the sampling error was large leaving a high degree of uncertainty for the inspection results. For areas greater than 1,000 square feet, this standard requires performing the above frequency for the first 1,000 square feet and measuring only one randomly selected 100-square-foot area for any additional 1,000 square feet. This leaves less than 0.01 percent of the structure with no measurement.

After the first clarifier was completed and passed DFT inspection according to the SSPC-PA 2, the customer examined the film thickness and immediately detected nonconformities. Upon review of the PA 2 method, it was found that a sample size of only 15 spot readings for less than 0.01 percent of the total surface area provides a margin of error of 25.3 percent.

To reduce the uncertainty and to pass the customer's inspection, the sampling error was reduced by calculating a sample size for a 144,000-square-inch surface area at a 95-percent confidence level and a 5-percent margin of error. The sample size was determined to be about 400 readings. For inspection of the 1,000-square-foot area as a complex shape fabricated mostly of angle iron, the sample size was increased thirtyfold, from the required 15 spot readings to about 500 readings — or one measurement for every 2 square feet. This sample size provided greater accuracy, and reduced the margin of error to less than 5 percent.

This increased level of inspection would be overly time-consuming with a manual magnetic pull-off gauge. However, with the faster measurement speed using an electronic gauge, the increase in data points was reasonable. Nonconforming film thickness areas were identified and corrected. With the increased sample size to reduce sampling error, the customer accepted all future film-thickness measurements.

STATISTICAL ANALYSIS OF DRY-FILM THICKNESS

In addition to film thickness measurements, electronic instruments provide real-time statistical analysis. Figure 4 (p. 25) illustrates normal distributions of film thickness at different standard deviations. In this normal distribution graph there are two examples of distributions: for an airless spray application of σ = 2.75, and for a brush and roller application of σ = 5.8, each with a mean, μ, of 19 mils thickness. For σ = 2.75 film thickness, 65 percent of the measurements will lie between 16.2 and 21.7 mils, and for σ = 5.8 film thickness, 65 percent of the measurements will lie between 13.2 and 24.8 mils.

Clearly, the smaller the value of σ, the smaller the spread of thickness values. This means the painter has applied a more uniform film thickness, but not necessarily centered on the target mean. Larger σ values mean a greater need for the inspector to search for the nonconforming thicknesses on the tails of the distribution.

At 95 percent of the thicknesses for σ = 2.75, Z2 (the value of two standard deviations away from the mean) will lie between 13.5 and 24.5 mils; at 95 percent of the thicknesses for σ = 5.8, Z2 will lie between 7.4 and 30.6 mils. Even though average film thickness may be the same for both applications, the high σ application has more nonconforming areas that must be identified by the inspector.

During final hold-point inspection of film thickness on these complex structures, high σ values were found, particularly when low film thicknesses resulted from brush and roller applications onto angle iron. Using a normal distribution, a σ of 5.8 was calculated to have a 9.23-percent lower film thickness. This required additional film thickness to be applied in areas to achieve the minimum film thickness. Touch-up applications resulted in a high sigma shift (Fig. 5, p. 25).

As more coating was applied during touch-up to resolve nonconforming conditions, the σ was shifted to give a right-shouldered distribution. For brush and roller applications over complex structures, such as on rake arms and the center column cages, increased inspection frequency was necessary to identify nonconforming areas and reduce σ to produce right-shouldered distributions of dry-film thickness.

INFLUENCES ON DRY-FILM THICKNESS STANDARD DEVIATION (σ)

During the course of the year-long project, influences on the DFT standard deviation (σ) were revealed. Electronic gauge batch measurements from more than 100 applications were categorized and averaged to determine the influence of common variations, such as each coat sequence, application method, material and shape of the part.

For example, separate electronic batch measurements were recorded for simple structures, such as feed wells, suction boxes and center columns; and for complex structures, such as rake arms, skimmer arms, center column cages and other structures fabricated from angle iron. The standard deviation, σ, for DFT was found to be influenced by the following.

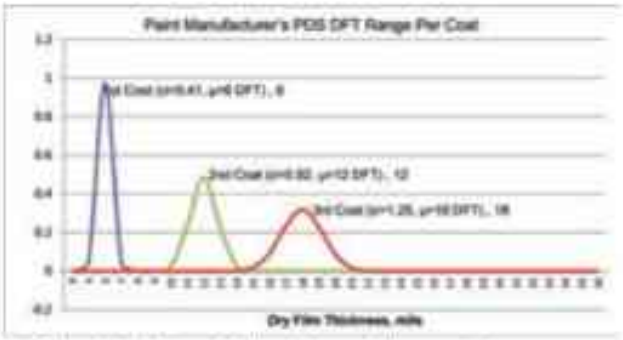

Fig 6: Normal distribution of dry-film thickness for three coats of epoxy according to manufacturer's paint data sheet (PDS).

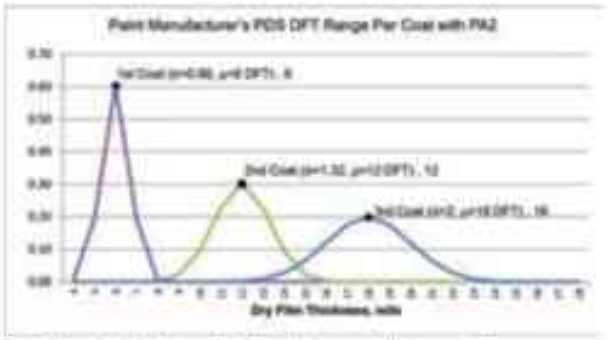

Fig 7: Normal distribution of dry-film thickness for three coats of epoxy according to manufacturer's paint data sheet (PDS) and SSPC-PA 2.

- Painter skills.
- Shape of the part (simple or complex).
- Number of coats (mean thickness).
- Application method (brush and roll, spray).
- Material (rheology, thinning, cure).

Film thickness distributions for the epoxy system applied to immersed surfaces on the clarifiers were studied. Three coats of an immersion-grade epoxy lining system were roller-applied at 5-to-7 mils per coat onto simple surfaces. For each coat the distribution, σ, increased as the mean increased from 6 mils to 12 mils to 18 mils.

The three-coat system for non-immersion-service surfaces consisted of a zinc primer, a high-build epoxy intermediate coat and an aliphatic polyurethane applied to complex shapes. Each coat had a different target film thickness, rheology and cure rate.

A comparison of the immersion-service epoxy system to the non-immersion-service system applied to complex shapes by brush and roller application is shown in Table 3 (p. 24). The zinc primer specified at 3-to-4 mils DFT has an average standard deviation of 1.46, when roller-applied to complex shapes such as a truss structure on an access bridge.

Table 4 (p. 26) summarizes application influences on film thickness distribution found from over 100 applications. The average σ value for multiple applications for each influence has been determined. Predicted trends are illustrated; the lowest σ value, 1.35, resulted for the primer coat

for airless spray on simple structures. The highest σ value, 5.83, resulted for the third coat for brush and roll applications on complex shapes.

Of interest was how this field empirical σ data might compare to theoretical σ values based on the thicknesses specified by the paint manufacturer's product data sheet (Fig. 6). In this case, the paint manufacturer specified a film thickness of 5-to-7 mils per coat. Normal distributions were calculated and drawn to fit in the paint manufacturer's film thickness range per coat to develop the theoretical σ values.

If considering the use of SSPC-PA 2 guidelines, which allows 80 percent of the minimum thickness and 120 percent of the maximum thickness, then a normal distribution can be estimated to fit within the allowed ranges for each coat as shown in Figure 7.

Figure 8 (p. 30) shows the DFT distribution values (σ) per coat for each application method on simple and complex surfaces.

Using these theoretical σ values based on the paint manufacturer's product data sheet to fit in the PA 2, film thickness ranges can be plotted as a line graph and visually compared to the same field empirical average σ values shown in Table 4. This comparison shows how precision is not accounted for according to application methods and structural shapes by the paint manufacturer or by the specifier, who relies on the paint manufacturer's product data sheet for selection of acceptance criteria to be met by the contractor. This comparison also explains why a field painting contractor could anticipate rework, and accurately predict the percentage based on this field-collected statistical data.

To validate the empirical results in Table 4, electronic batches were compared to a similar multi-coat system application. Batches from a shop application of a similar three-coat, immersion-grade epoxy system applied to a maintenance deck skid (complex structure) are shown in Table 5 (p. 36). Data seemed to correlate well with the two immersion-grade systems applied by airless spray, but by different painters.

CONCLUSIONS, TO BE CONTINUED

The use of electronic inspection instruments for monitoring and reporting coating applications provides more accurate, complete and transparent data for analysis by reducing systematic errors resulting from the operator, instrument and process bias. Since data points are recorded into memory and then downloaded into paperless reports, inspects results are transparent and more data points can be collected and analyzed.

Reliance on electronic instruments to populate reports generates "gauge independence," also known as "organizational freedom." This means less dependence on third-party inspectors and more on field application foremen using smart gauges.

This field project work found the specified method to measure film thickness provided unacceptable sampling errors. Sampling frequency had to be increased to reduce the

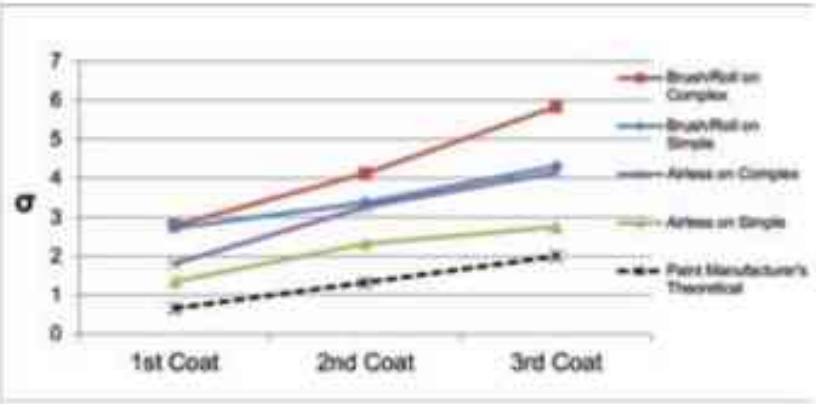

Fig 8: Average dry-film thickness distributions (σ) by application method

percent margin of error. With the use of an electronic DFT gauge, all DFT inspection measurements were relatively fast and recorded into memory.

Precision profiles from statistical analysis of data collected from applications showed that the distribution of DFT was affected by common causes consisting of painter skills, the shape of the part painted, the method of application and the material applied.

Sampling frequency should be dictated accordingly, which will be explained in an upcoming installment of this article, as well as a blind study undertaken to determine painters' influence on the standard deviation.

ABOUT THE AUTHOR

Cory Allen serves as the director of quality systems for Vulcan Painters, Inc., administering the company's quality management system and its adherence to the SSPC QP and QS programs. He is a member of the American Society of Quality and is certified as a Quality Manager, Quality Auditor and Six Sigma Green Belt. He holds a Master's degree in polymer chemistry and a Bachelor's degree in chemistry from the University of Southern Mississippi.

DOTs ON MAINTAINING CORRODED CONNECTIONS: CLEANING, CAULKING & COST

Photo: Tom Inglis

BY TOM INGLIS AND NICK VOLK, IDOT DISTRICT 4; DAN BRYDL, FHWA-ILLINOIS DIVISION; AND KEN TRIMBER, KTA-TATOR, INC.

The Illinois Department of Transportation (IDOT) District 4 is headquartered in Peoria and is responsible for 700 bridges across 12 counties. The Shade-Lohmann Bridge was scheduled for repainting during 2017 and 2018. Constructed in 1975, the Shade-Lohmann Bridge is a 3,473.5-foot-long, fracture-critical, 16-span twin girder with an 1,140-foot cantilever truss. Because of the intricate design of the bridge, District 4 decided that connections should be caulked to provide additional protection because many were exhibiting substantial corrosion. District engineers had heard of both successes and failures when caulking was used and decided it was important to better understand the use of caulking and to develop plan notes or special provisions to clearly delineate expectations. Before developing plan notes, District 4 wanted to identify which surfaces should be caulked, the extent of surface preparation that should be required, and at what point in the application sequence the caulking should be installed. Tom Inglis and Nick Volk of District 4 reached out to other states for copies of their specifications and subsequently, Dan Brydl of FHWA-Illinois Division reached out to his counterparts for additional information. Ken Trimber of KTA-Tator, Inc., a coatings consulting firm under contract with IDOT, was engaged to assist with the final review.

This article outlines the specification language provided by the states that were contacted, summarizes the various approaches that are taken and presents the process followed by IDOT for the Shade-Lohmann Bridge.

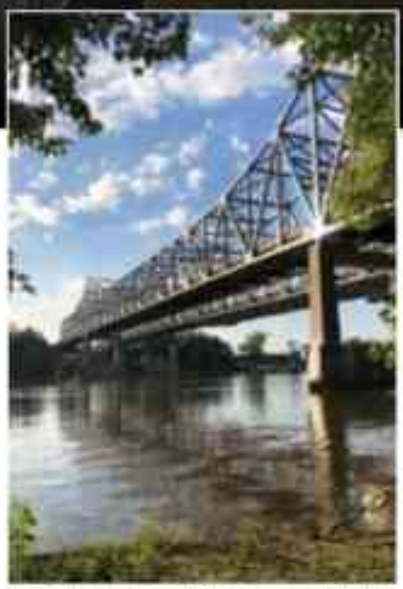

Fig. 1: Shade-Lohmann Bridge. Figures courtesy of the authors.

SURVEYS OF DEPARTMENTS OF TRANSPORTATION

Specification information was received from 18 Departments of Transportation and analyzed for requirements in three areas: surfaces to be caulked, at what point in the coating sequence is the caulking to be applied and how caulking is measured and paid for. The results are summarized in Tables 1, 2 and 3. Note that the numbers in each of the tables do not add up to 18 because all specifications did not address each of the categories, and in some cases, the specifications covered more than one type of response within a category.

IDOT APPROACH TO CAULKING FOR THE SHADE-LOHMANN BRIDGE

The bridges were painted with IDOT System 1 consisting of an epoxy zinc-rich primer, epoxy intermediate and an aliphatic urethane finish with stripe coats of both the zinc primer and urethane finish applied. The first bridge (westbound) was cleaned and painted in 2017. The

caulking was a near-perfect color match to the finish and was applied after the finish coat. Before designing the 2018 work for the eastbound bridge, research was conducted to determine whether a different approach should be taken. A few changes were made and are summarized ahead in this article.

For the 2018 work, caulking was applied to the tops and sides of all connections along the lower and upper chords of the truss members. The bottoms were left open. Areas caulked included the inside and outside of the outer faces of the gusset plates, all sway and lateral bracing connections above the deck, the gusset plates of all lateral connections to floor beams and the underside of the lower chord, all connections within the splash zones 25 feet above the deck and any other locations as directed by the engineer.

The cleaning of crevices and removal of pack rust was done as thoroughly as possible by blast-cleaning rather than using rivet busters or other pneumatic power tools in an attempt to remove all of the pack rust. Power-tool cleaning had been used in the past, was very costly and did not remove more of the pack rust than was achieved by blast-cleaning alone. For this work, concentrated blast-cleaning of the crevices removed all loose pack rust and most of the tight pack rust. A full coat of zinc primer was applied after blast-cleaning, followed by the primer stripe coat. In areas

Fig. 2: Prior to blast-cleaning.

Table 1: Summary of Surfaces Being Caulked.

Surfaces to be Caulked	Number of Responses
Cracks, crevices, seams, joints of tapping members, joints of built up members, skip welds (any size gap)	7
Areas showing pack rust (some require grinding to a specific depth)	6
Cracks, crevices, seams, joints, but leave bottoms open	5
Cracks, crevices, seams, joints where water may collect	4
As directed	3
Cracks, crevices, seams <½ inch	2
Cracks, crevices, seams >6 mils	1
Cracks, crevices, seams >1/16 inch	1
Between bearing plates and concrete piers	1
Crevices along bolted splice plates	1
Surfaces Not to be Caulked	
Do not caulk crevices less than 3 mils wide in interior of boxes	2
Do not caulk perimeter of bolted connections (Note that 1 response above caulks the perimeter)	2
Do not caulk pack rust (Note that 6 responses above caulk pack rust)	1

Table 2: Point in Application Sequence When Caulking is Applied.

Caulking is Applied	Number of Responses
Before the finish coat	11
After the finish coat	3
After the primer (for shop work)	1

Table 3: Measurement and Payment for Caulking.

Measurement and Payment	Number of Responses
Linear feet (one DOT uses plan quantity as the quantity for payment)	4
Included in lump sum price	2
Mitigation of pack rust and penetrating sealer - incidental	1
Excluded from contract price, but no indication how it is paid	1
Not measured	1

where there was a visible gap between plates or severe section-loss in the crevice, a stripe coat of the intermediate was added to the system prior to the application of the full intermediate. The purpose was to coat the interior surfaces of gaps and crevices as thoroughly as possible by working another stripe coat into the irregularities. If the mating plates were tight, the intermediate stripe coat was not applied. After application of the full intermediate coat, the urethane finish was applied.

After the urethane was sufficiently dry to recoat (typically one or two days) the caulking was applied. Backer rod was not used in any of the crevices as it is time-consuming to install and if installed incorrectly can lead to premature failure. When large gaps were encountered, caulking was installed in lifts to fill each crevice. After the caulking dried, a final stripe coat of finish was applied to all applicable surfaces, including the caulking.

The advantage of this approach was related to scheduling. By applying the caulking after the finish coat, the contractor had the option of continuing to move the containment across the bridge rather than leaving it to sit idly by while the finish and caulking dried. Painters could come back and install the caulking after the finish adequately dried and wait for a few days to apply the final stripe coat, all without

tying up the containment. If the caulking had been applied before the finish, additional downtime would be required for the caulking to adequately dry before applying the finish. In addition, applying the stripe coat after the caulking was applied, rather than before, provided additional UV protection of the caulking and tied the appearance of the entire finish coat together. Even though a satisfactory color match of the caulking and finish can be achieved, the caulking is going to look different in time as the finish and caulking age. The application of the stripe coat to the caulking prevents these differences from occurring.

For payment, an attempt

Fig. 3: Typical removal of pack rust by blast cleaning.

was made to establish an agreed-upon price per linear foot before the work began, but the initial estimates were high and unacceptable to IDOT. In order to move forward, a decision was made to do the work on a time-and-materials basis (force account). Time and materials were tracked and the change from unit price resulted in a cost savings of over $7 per linear foot. The cost savings in this case were obviously worth the extra paperwork that was needed to determine the additional time and materials furnished. In the future, if the size of the project warrants the extra effort, the force account payment method will likely be used again.

Although the longest exposure time of the caulking on the Shade-Lohmann Bridge is only about one-and-a-half years, IDOT is optimistic that it will significantly minimize or completely eliminate the formation of pack rust in the joints in the future and that it is worth the investment. For future work, IDOT is considering adding the following text regarding caulking to the general notes state-wide.

"All connections along the lower chord, all connections in the expansion joints 10 feet each side of the deck joints, all connections within the splash zones 25 feet above the deck and any other locations as directed by the engineer shall be caulked. The bottom of the connections shall remain free of caulk. All caulking shall be done according to the product data sheets. The caulk shall be applied after the application of finish coat and prior to the final stripe coat. Caulk shall have time to dry or outgas according to the product data sheet prior to the final stripe coat. This work will be paid according to Article 109.04 and shall not be deleted from the contract."

Note that Article 109.04 is the article in the IDOT Standard Specifications for Road and Bridge Construction that explains the force account payment process and would be invoked for those projects where the size warrants the extra effort required to track time and materials.

SPECIFICATION LANGUAGE FROM VARIOUS DEPARTMENTS OF TRANSPORTATION

California

Caulk contact surfaces of stiffeners, railings, built-up members or open seams more than 6 mils wide with sealing compound or other authorized material. Apply the sealing compound at least 72 hours after the last application of undercoat unless otherwise authorized. Cure the sealing compound under the manufacturer's instructions before performing subsequent painting activities. If no finish coats are applied, the sealing compound color must be gray.

Florida

560-9.3 Sealing Using Caulk (New Steel): Apply caulk after the intermediate coat has cured to a condition suitable for recoating in accordance with the manufacturer's product data sheet and before application of the finish coat. Completely seal the perimeter of all cracks and crevices, joints open less than ½-inch and skip-welded joints using caulk. Apply the caulk to the joint following the caulk manufacturer's recommendations. Ensure the caulk bead has a smooth and uniform finish and is cured according to the caulk manufacturer's curing schedule prior to the application of the finish coat. It is unnecessary to caulk the perimeter of bolted friction splice plates unless otherwise directed by the engineer. In addition, it is unnecessary to caulk cracks or crevices less than 0.003 inches in width located on the interior surface area of box girders.

Indiana

Joints of all lapping members shall be caulked after either the application of the epoxy intermediate coat of the structural steel paint system or the application of the organic zinc primer of the partial paint system. The intermediate or primer coat shall be cured to the manufacturer's recommended coating cure time prior to caulking. The caulk used shall be compatible with either the structural steel paint system or the partial paint system and in accordance with the

Fig. 4: Typical removal of pack rust by blast-cleaning.

paint manufacturer's recommendations as described in the QCP.

1. All vertical and diagonal lapping members shall be caulked along the top and sides. The bottom shall remain open for drainage.
2. All horizontal lapping members shall be caulked along the leading edge and sides of steel members facing toward oncoming traffic or facing toward the prevailing wind direction.
3. All horizontal members shall remain uncaulked along the side of steel members facing away from oncoming traffic or prevailing wind direction.

Cleaning drain castings and caulking joints of lapping members will not be measured for payment.

Maine

506.09 Paint Application: Caulk all gaps between abutting surfaces and at areas of pack rust that cannot be removed, as between the intermediate and topcoat. Apply caulking between the bearing plates and the concrete piers. Provide the name, generic type, technical data sheets and application instructions for the material to the resident. Provide written concurrence from the coating manufacturer that the caulking is compatible for use with the coating.

506.12 Method of Measurement: Field painting of existing and new structural steel shall be measured for payment as one lump sum, complete and accepted.

506.13 Basis of Payment: The accepted quantity of field painting of existing and new structural steel will be paid at the contract lump-sum price, which shall be full compensation for furnishing all material, labor, equipment, scaffolding, QC activities and incidentals necessary for the satisfactory performance of the work.

506.144 Field Painting of Existing and New Structural Steel: Lump sum.

Maryland

This state requires 2,500 linear feet of caulking 2,500 linear feet of caulking at a price of $10.00/linear foot from two contractors and $16.00/linear foot for another.

Minnesota

Fillet seal crevices and cavities along the edge of the faying surfaces that are separated by 1/16-inch or more with an approved sealant that is listed on the Approved/Qualified Products List for Bridge Structural Steel Coating Sealants and apply per the coating manufacturer's installation instructions. Do not seal the bottom edge of vertical faying surfaces, allowing the juncture to release trapped moisture. Ensure the sealant color is a match to the finish paint color by submitting a sample to the MnDOT lab for color approval or utilize an approved clear caulk. Apply the caulk in a smooth manner.

Provide all labor, equipment and materials to remove pack rust corrosion, prime, apply

Fig. 5: All coats, caulking and stripe coat of finish applied.

a compatible penetrating sealant with corrosion inhibitors as listed on the Department's Approved/Qualified Product List for Bridge Products, Bridge Structural Steel Coating, Three-Coat Systems – Organic. Apply intermediate and finish coats and caulk per 2478.3.F.5, "Finish Coats." The engineer will visually inspect and identify the areas of pack rust.

Basis of Payment: Payment for materials and labor required to mitigate pack rust and apply penetrating sealer shall be considered an incidental expense to Item No. 2478.518, "Organic Zinc-Rich Paint System (old) for which no direct compensation will be made.

Nevada

Caulk open seams at contact surfaces of built-up members after the prime coat has been applied and accepted at the fabrication site. Use non-sag polysulfide or polyurethane material conforming to FSS TT-S-230, Type II or approved equal.

New York City

The work shall consist of cleaning and applying penetrating sealer to crevices, joints and back-to-back angles of the existing structural steel. The work shall also include applying caulking material to seal the joints and crevices of the existing steel.

Cleaning: The contractor is specifically forewarned that cleaning of corrosion, pack rusting, rust staining shall be required by this item at locations indicated by the contact documents or where ordered by the engineer.

Remove all rust scale and loose pack rust. Remove tight pack rust until highest point is a minimum of ⅛-inch below the surface or the surrounding sound steel. Pack rust that cannot be removed by prying and probing with a dull putty knife is considered to be adherent. Pay particular attention to the crevice areas when removing pack rust and rust scale. Exercise care to avoid nicking and gouging the steel during removal.

Caulking: Apply caulking to seal the crevices, joints between plates and areas of pack rust. The contractor shall apply caulking between the applications of the intermediate coat and finish coat of paint system.

Basis of Payment: The unit price bid per linear foot shall include the cost of all labor, material and equipment necessary to complete the work. Painting shall be paid for under the respective painting items.

Ohio

560-2.3 Caulking: Use caulks that are paintable, compatible with the coating system and recommended by the coating manufacturer as part of the coating system.

560-9.3 Sealing Using Caulk: Apply caulk after the intermediate coat has cured to a condition suitable for recoating in accordance with the manufacturer's product data sheet and before application of the finish coat. Completely seal the perimeter of all cracks and crevices, joints open less than ½-inch and skip-welded joints using caulk. Apply the caulk to the joint following the caulk manufacturer's recommendations. Ensure the caulk bead has a smooth and uniform finish and is cured according to the

Fig. 6: Finish coat applied prior to caulking.

caulk manufacturer's curing schedule prior to the application of the finish coat. It is unnecessary to caulk the perimeter of bolted friction splice plates unless otherwise directed by the engineer. In addition, it is unnecessary to caulk cracks or crevices less than 0.003 inches in width located on the interior surface area of box girders.

Oklahoma

Installation of Stripe Coats and Caulking Materials (Required for Category E and O Paint Application): Caulk locations shown on the plans or as required by the engineer including seams at joints, plates, seams and field splices where water may collect. Do not apply caulking to pack rust. Use a product compatible with the coating system and as recommended by the coating manufacturer. Provide MSDS and PDS to the engineer and Materials Divisions.

512.06 Basis of Payment: The Department will pay for each pay item at the contract unit price per the specified pay unit as follows.

Pay Item	Pay Unit
Painting existing structures	Lump Sum
Collection and handling of waste	Lump Sum

For new structural steel, the Department will consider the cost of cleaning, painting, caulking, enclosure and related work to be included in the contract unit price for the relevant structural steel pay item.

The Department will pay for the painting of existing steel structures as "Painting Existing Structures" unless otherwise required by the contract. The Department will consider the cost of painting, caulking, enclosures, providing access, and related work to be include in the contract unit price for "Painting Existing Structures."

Oregon

00594.12 Caulking: Furnish structural steel caulking from the QPL and approved for use by the coating manufacturer. The caulking color shall be clear, approximate the color of the top coating or be overcoated. Furnish industrial-grade polystyrene or polyurethane backing material of sufficient diameter to fill the crevices or gaps as required. Obtain the engineer's approval of the caulking and backing material before using.

(f) Caulking: Apply caulk after complete application of the topcoat. Fill and seal crevices and gaps between structural shapes and plates, around bolt heads and nuts and similar areas that would retain moisture with the following.

- Caulk if the crevice or gap cannot be filled with coating materials.
- Backing material and caulk to fill the crevices and gaps that exceed ¼-inch.

Apply caulk over the backing material to form a watertight seal. In areas that collect or channel water, apply caulk even if coating fills the gap.

Pennsylvania

1070.3(c) 4. Pack Rust and Rust Scale: Remove heavy corrosion (rust scale) and loose pack rust (e.g., as found in crevice areas) by hand and power tool cleaning before abrasive blast cleaning. Exercise extreme care to avoid nicking or gouging the steel during removal. If nicks or gouges occur, the representative may suspend activities until appropriate adjustments are made to prevent a recurrence. Caulk areas as directed.

1070.4 Measurement and Payment: Lump Sum. The price includes abrasive blasting/paint removal, waste disposal, soluble salt/chloride remediation and application of the three-coat paint system. The price also includes removal of coatings from surfaces not designated to be painted; repair of any damage resulting from the painting operation; removal of coating that does not meet specifications and recoating of the surfaces and controls necessary to comply with the requirements of regulatory agencies. The price does not include caulking.

South Dakota

Bolted Splice Plate Sealant:

1. The sides of all bolted splice plates shall be sealed using a polyurethane sealant.
2. The polyurethane sealant shall be a single-component, moisture-cure, non-sag, smooth formulation, gun-grade elastomeric sealant. The sealant shall

meet the requirements for ASTM C920, Type S, Grade NS, Class 25, Use-A.

3. Contact surfaces shall be cleaned in accordance with the manufacturer's recommendations. The contractor shall supply the engineer with written instructions regarding the manufacturer's recommended surface treatment for the in-place surface condition at least 48 hours before application for review and acceptance.
4. The polyurethane sealant shall be applied and tooled as recommended by the manufacturer. Product data sheets and material safety data sheets shall be supplied to the engineer at least one week prior to installation. In no case shall the thickness of the material be less than ¼-inch. Feathering of the joint material shall not be allowed. Adjacent surfaces shall be masked to avoid application of the material outside the limits of the final seal. Application surfaces shall be clean and free of material contaminants. Application shall not be allowed on a wet or damp surface.
5. Polyurethane sealant shall be installed and allowed to cure prior to the application of any field-applied paint.
6. Field measurement for polyurethane sealant for structure will not be made. The plan quantity will be the quantity accepted for payment.
7. Polyurethane sealant for structure will be paid for at the contract unit price per foot. Payment will be full compensation for labor, equipment, materials and incidentals for furnishing, preparing surfaces for application and installing the polyurethane sealant.

Texas

Caulking: Before applying the appearance coat but after application of the intermediate coat, caulk gaps or crevices greater than 1/16 inch throughout the length of the project. Use a paintable caulk meeting the requirements of DMS-8142, "Paintable Caulk for Concrete and Steel" and that is listed on the MPL, "Paintable Caulk for Concrete and Steel." Apply sealant in a manner that does not trap moisture.

Note: TXDOT comment received regarding the last sentence: "Apply sealant in a manner that does not trap moisture" typically means a gap in the caulking on the underside/low point of the caulked areas (i.e., if one caulks around a gusset plate, leave the bottom open) to allow for drainage of any water that eventually gets past the caulk.

Utah

Sealing: Fill and seal crevices and gaps between structural shapes and plates, around bolt heads or nuts, and similar areas that would retain moisture with the following.

- Coating materials where possible.
- Sealant if the crevice or gap cannot be

bridged with coating materials. Apply the sealant after complete application of topcoat.

- Backing material and sealant to fill crevices and gaps that the sealant cannot bridge. Apply sealant over the backing material to form a watertight seal.

Drawing Notes: Remove remaining pack rust by grinding to the satisfaction of the engineer. Fill gap between gusset plate and bottom lateral brace with paintable silicone caulking to the satisfaction of the engineer.

RESOLUTION OF PROJECT-SPECIFIC ISSUE

Issue: Rust had created a gap between the bottom flange cover plates and the bottom flange.

Resolution: Grind back the rust to a depth equal to the gap or ¼-inch (whichever is larger). A rust inhibitor will then be applied and sealed with caulking. Gaps of ⅛-inch or larger will be considered.

Virginia

Wherever a depressed area is formed where water can be trapped or held, such as the juncture between a beam or girder web and splice plate on a bottom flange, the area shall be completely sealed with polyurethane or other approved sealant conforming to FS TT-S-00230C, Type II, Class A, prior to painting.

Washington

6-07.3(10)G Treatment of Pack Rust and Gaps:

Pack rust is defined as the condition where two or more pieces of steel fastened together by rivets or bolts have been pressed apart by crevice corrosion caused by the buildup of corrosion products at the interface of the steel pieces.

Pack rust forming a gap between steel surfaces of 1/16-inch or greater shall be cleaned to a depth of one half of the gap width, up to a maximum of ¼-inch. The cleaned gap shall be treated with rust-penetrating sealer and caulked to form a watertight seal along the top edge and the two sides of the steel pieces involved, using the rust-penetrating sealer and caulk as accepted by the engineer. The bottom edge or lowest edge of the steel pieces involved shall not be caulked.

The type of rust-penetrating sealer and caulk used shall be compatible with the paint system used and shall be applied in accordance with the rust-penetrating sealer and the caulk manufacturer's instructions. When caulking joints where only one steel piece edge is exposed, a fillet of caulk shall be formed that is not less than ⅛-inch or the width of the pack rust gap. The fillet is not required where there is no separation of the steel pieces due to pack rust.

At locations where gaps between steel surfaces exceed ¼-inch, the contractor shall fill the gap with foam backer rod material and sealant as accepted by the engineer. The foam backer rod material shall be

Fig. 7: Caulking being smoothed. Stripe coat of finish to be applied after caulking dries.

of sufficient diameter to fill the crevice or gap. The contractor shall apply sealant over the foam backer rod material to form a watertight seal.

6-07.4 Measurement: Cleaning, sealing and caulking pack rust will be measured by the linear foot along the edge of the steel connection interface cleaned, sealed, and caulked.

Washington requires 4,487 L.F. of caulking with bids ranging from $7.00/L.F. to $75.00/L.F. and a statewide average for 2017 of $40.05/L.F. The price includes removal of pack rust up to ¼-inch deep, the sealing of the rust and then the caulk. This inclusion is likely the reason for a higher average price than other states.

West Virginia

Caulking shall be applied before the application of the topcoat. This includes all seams between diaphragm connections to stiffeners and splices and seams between any connection that is riveted or bolted. Any welded connections that are not fully sealed by the weld shall be caulked with a paste-type caulk. The caulk shall be pressed into the seams between the adjoining surfaces by wetted finger or specialty tool to ensure bond and provide a smooth uniform surface. Bottom seams shall not be caulked on vertical surfaces.

Caulking in a three-coat system shall be applied after the intermediate coat has cured. Caulking on a two-coat system shall be applied after prime coat has cured. The top coat shall not be applied until the caulking has fully cured in accordance with the manufacturer's recommendations.

The caulking material shall be compatible with the paint system being applied and shall be by written recommendation of the paint manufacturer. The caulking material shall be tested for compatibility with the paint system at the same time that the paint is tested for intercoat compatibility. Caulking operations shall be performed only when weather conditions are within

the parameters as specified in section 688.2.3.1.

688.8 Basis of Payment: Basis of payment for "Clean and Paint Existing Steel Bridges," "Containment and Disposal of Spent Material," "Field Painting of Shop Primed Steel" shall be lump sum price bid. "Zone Cleaning and Painting Steel Bridge" shall be square-foot price bid.

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PUTTING THE PIECES TOGETHER

INTEGRATING STEEL REPAIRS WITH BRIDGE PAINTING PROJECTS

BY KEVIN H. KEITH, PE, LIRO ENGINEERS, INC.

Many bridge painting projects include steel repairs as part of the contract. Steel repairs and coatings must work together and be installed as a system to perform as intended. This article discusses the process of installing steel repairs and painting a bridge at the same time. The goal is to prevent compromised repairs and coatings by integrating the design with the installation.

Steel repairs included with bridge painting projects can be designed for known deficiencies on the bid set or designed "on the fly" after blasting reveals unknown repairs or the true extent of a deficiency that was covered with rust and paint. In either case, there can be great impact to a project schedule, paint operations and coordination between parties. Painting and repair work are performed by separate trades and often by separate contractors. Either trade contractor may be a subcontractor to the other, or both may be subcontractors to a general contractor.

Next, the steel repair pieces are generally not off-the-shelf and must be detailed, reviewed, fabricated and delivered before being installed. Surface preparation and painting requirements are different from general painting. For repairs discovered after blasting, the deficiencies have to be field-measured, with repairs designed and then sent to the detailer and fabricator. Change orders are required for any repairs that are not part of the bid set. Although decisions made during design can affect the outcome and prevent unwanted change orders and schedule delays, cooperation and coordination is required in the field to minimize undesired outcomes.

It can be challenging for trades to work together or perform work that is considered part of the other trade. On a non-union job, this can potentially be worked out by a superintendent or the resident project manager. Union jobs will generally require agreements by the separate trade unions, known as project labor agreements or tenuous informal agreements on-site. Project labor agreements are typically done in advance of a project starting because the negotiations take time. Informal agreements can collapse suddenly or be prohibited by the unions involved, so they can stop work without warning and for an unknown period of time. Every contract leadership arrangement, whether the lead entity is a paint contractor, steel contractor or general contractor, faces this difficulty. The overlapping work involves paint (frequently lead paint) removal, surface preparation, painting, bolt cleaning and caulking. These are paint-trade tasks, but the challenge is scheduling the painters to fit into the steel repair installation schedule.

Fig. 1: Lack of surface preparation led to paint failure on this retrofitted connection plate. Images courtesy of the author.

The steel repair process first involves an inspection to find the deficiency that needs to be repaired. This can be done before or after the blasting. Before blasting,

an inspection can find obvious deficiencies and determine the approximate extent of the problem. After blasting, the exact extent of the deficiency can be measured and unknown deficiencies can be discovered. Many contracts have provisions for possible extra repair work by having additional units of designed repairs, stock repair designs (that only require dimensional changes) and/or contingency funds of either additional money or additional pounds of generic steel. These provisions can speed up approval of change orders. After inspection, deficiencies are evaluated by an engineer to determine if a repair is required, desired or not necessary. Next, the repair is designed — the parameters such as thickness, dimensions, configuration, type of steel, temporary support requirements and other installation requirements are addressed. After the design is done, it's sent to the contractor to fabricate and install. The contractor will check field dimensions and possible installation problems and review any contradictions with the designer. After field problem resolution, the design is revised if needed and sent by the contractor to the detailer. The detailer prepares the instructions for the fabricator. These instructions are known as shop drawings and before the fabricator receives them, they're reviewed by the designer to make sure the details are correct. After the review is accepted, the shop drawing is sent to the fabricator, the repair is fabricated and delivered.

Fig. 2: Bolts rusted after improper preparation.

The process from inspection to delivery can last from one month to six months or more. Additional money for overtime or the pressure of an emergency situation can expedite delivery of fabricated repairs, but the minimum amount of time to include each step is usually a month. If everything has been designed for the repair in the bid set, the time can be cut in half because the initial steps of inspection, evaluation and checking field installation and measurements are eliminated. However, rarely is every repair on the bid set because additional deterioration is discovered after blasting. In any case, this time must be considered in the scheduling and coordination of installing the repair. Two weeks is the shortest possible time for a repair to be delivered under a perfect design. Rarely is a design perfect and rarely does the repair process go that fast. Even a minor mistake on shop drawings can result in several days of delay by the time the mistake is corrected and reviewed. Thus, steel repair work and how it has been designed and specified must be considered carefully in the overall schedule.

Fig. 1: Flash rusting on a gusset plate resulting from incorrectly applied primer. Photos courtesy of the author.

After delivery, the faying surfaces must be ready before the repair is installed. There are different ways to prepare faying surfaces depending on the assumptions the designer used to specify the preparation. The surfaces can be primer-to-primer or unfinished-to-unfinished. Other combinations are possible, but generally not specified. The surface preparation specification depends on the amount of friction between pieces that the designer desires. Because bolt holes are slightly bigger than the bolts, there is a potential for slip between the pieces. A connection where the potential slip is acceptable is called a bearing connection. The requirements for surface preparation are not important, because the bolts will resist movement beyond the size difference between the holes and the bolts. A connection where the slip is not acceptable is called a slip-critical connection. For these

connections, bolts are tightened to a specified force so the movement between the pieces is resisted by friction. Slip-critical connections require either unpainted surfaces or surfaces primed with a tested and certified primer. The primer's certificate includes whether or not it meets Class A, B or C requirements. The classes are different coefficients of friction specified by the Research Council on Structural Connections (RCSC). They also specify the testing procedures. The designer determines the class required for the design.

Testing is done under standardized conditions with the same primer on each surface. Thus, in the field, the test parameters specified on the certificate must be followed. Some of the parameters specified include maximum thickness, cure time and amount of thinner. These requirements can be different than the general painting of the steel. If fabricated repairs come primed by the fabricator, it may not be the same product used for other priming; the maximum thickness may be higher for other painting and cure times may be different for overcoated versus a full cure. Again, all of these factors have to be considered in the project scheduling.

Fig. 3: Paint will need to be removed from this painted-over, masked repair area in order to install the repair.

After installation of the repair, the exposed surfaces must be prepared for painting. If they are not primed already, the repair surfaces will have to be prepared to the specified level of cleanliness and have the specified anchor profile. Blasting may not be possible, so a needle gun or other tool that gives the surface a profile should be used. Solvent cleaning should also be done to eliminate any residual oils on the surface. Before priming or subsequent painting (if the repair piece was primed in the shop), the protective wax coating must be removed from the bolts. This involves rotating solvent cleaning, wire brushing and wiping with a cloth until no more residue is visible on the cloth. The bolts can be cleaned before or after installation since only the exposed areas need to be cleaned. After all of these steps are complete, the repair can be painted and caulked, if specified. Replacing pieces that involve existing connections, such as gusset plates on a truss, will add another step before installation. The old paint on the remaining part of the existing connection must be removed and the area prepared as specified for the connection faying surface. Obviously, for most bridges, this old paint contains lead and must be removed properly. Just like painters, if the paint removal is left to ironworkers, they must follow the same rules and be protected by a lead health and safety plan that includes biological monitoring. Most repairs on bridges are bolted, but occasionally welding is used. All paint must be removed from the area being welded and also from a specified distance from the weld.

Peeling paint, rust bleeding and other paint failures can occur if the painting process is not followed step-by-step. Just like any other painting project, atmospheric conditions must be favorable and checked during the work. Mixing and application must also be conducted properly. Quality control and record keeping

are the same for production painting and faying surface painting. The quality control individual must document the atmospheric conditions before, during and after the painting; record batch numbers; record the mixing process; record the amount of thinner used; take wet-film tests and record how the paint is applied. Cold, rain or snow may not bother ironworkers, but a repair can be delayed if it cannot be painted.

Traffic-control requirements, temporary support requirements, equipment needed (for example, cranes and lifts), the fabricator's schedule, the delivery schedule, and the time it takes for the detailer and the reviewers can also influence the installation schedule. All of these items require significant coordination between all of the separate parties.

The best time to plan is during design, but the contractor's input is missing and designers usually don't have an in-depth knowledge of painting and will work only with standard painting specifications. Thus, it is important to begin the discussion of the repair process during the pre-construction meeting or even during the pre-bid meeting. The baseline schedule should be checked for a realistic time frame for repairs. Often, steel repairs can be the schedule-driver for a project. A painting schedule is rather straightforward and most painting contractors know their production rates for structure types they've worked on, leaving weather as the primary chance variable. Ironwork, because of the long process, has many chance variables and the planning does not end until the project is over.

RECOMMENDATIONS FOR THE DESIGNER

- Inspect the structure carefully before designing repairs. Do not rely exclusively on routine inspections to design repairs. Take field measurements, note fatigue-prone details and note areas where deficiencies may be hidden or be larger than is visible. At least one day per span for two individuals should be dedicated to the pre-design inspection.
- Try to design stock repairs that only require dimensional changes using a combination of rolled angles, standard plates and other standard rolled shapes.
- Discuss contingency plans with the owner and how any contingency will be paid for. If it is anticipated that unforeseen repairs will have to be designed and/or intricately detailed, then it is probably best to recommend a bid with a price-per-pound for additional repairs. That way, the owner gets a competitive bid price for the detailing in addition to the steel. If the anticipated repairs are already designed plate sections (or other standard repairs), then additional units of these repairs are appropriate. A cash contingency can be recommended for unforeseen repairs.
- As a corollary, quantities will generally be underestimated, so a contingency is needed. Consider adding an inspection component to the construction contract or the construction-monitoring contract for fatigue details, post-blast inspections, field measurements for repair dimensions, or other items that may be discovered on the bridge such as plug welds. Be sure to factor this into the designer's schedule and to specify qualifications of the inspectors.
- Specify criteria for unforeseen repairs and specify the limits of repair dimensions. For example, "Repair all areas with greater than 50 percent section loss to the thickness of the component. The final row of bolts for a repair shall be in full thickness area of the component and three inches beyond the limits of deterioration." Analyze the components of the bridge to determine the criteria for repairs.
- Don't arbitrarily specify slip-critical connections. Specify when required by code or when needed for the design.
- Carefully specify faying surface preparation and coatings (if applicable). Reference following the manufacturer's slip-critical certification criteria if it is a coated slip-critical connection. Each manufacturer has different criteria, so this should be referenced rather than

specified if multiple paint manufacturers are permitted. For example, "Faying surfaces shall be primed with a Type B slip-critical certified primer. Submit the manufacturer's slip-critical certification with the product data sheet for the primer. Prepare surfaces using mechanical tool cleaning to SSPC-SP 11 with an anchor profile as specified by the manufacturer's slip-critical certification. Prime the surfaces with the same primer on each surface following curing, thickness and any other criteria on the manufacturer's slip-critical certification."


Fig. 4: A completed repair done correctly.

- Use primed faying surfaces when the surrounding area is painted and the repair is bolted. For weathering steel and welded repairs, bare faying surfaces can be specified. Welding will seal the repair to prevent rust bleeding. If the repair is not slip-critical, then the area can be painted. Specify caulking around the perimeters of repairs to provide supplemental protection from rust bleeding. Make sure to add the quantity to the overall quantity of caulking.
- For the designer's schedule, allow at least three months from the time field measurements are taken to the time that the steel is delivered to the site. For repairs discovered after blasting, add more time — at least four months from field measurements to delivery.
- Allow masking repairs so that painting in the surrounding area can be completed. Specify the size of the mask beyond the repair area to allow for welding or caulking. If the entire area is left in primer, then additional surface preparation will most likely need to be done before paint is applied. If the repair area is painted, then the paint must be removed from the repair. In either case, the extra work can cause delays. Masking the area avoids additional surface preparation over a large area and keeps production painting moving.
- Carefully review standard specifications or cut-and-paste specifications. Rewrite the specifications if needed.

- Specify galvanized bolts because they do not require coating. If galvanized bolts will be painted, notes about surface preparation and cleaning described previously should be added. Black bolts are covered with mill scale, which inhibits coating adhesion. The most efficient way to remove the mill scale is by blasting. This is not practical for individual bolts before installation and adds another step to the repair sequence if done in place. However, black bolts can be specified for weathering-steel connections.
- Once plans and specifications are done, double-check repair locations on-site. On a large bridge, it can be easy to locate repairs in the wrong locations. Remember that steel repair and painting are a system and not separate components.

RECOMMENDATIONS FOR THE OWNER

- Always have a contingency for steel repairs (explained previously) along with recommendations of how to set up the contingency.
- Allow changes to standard specifications or allow special provisions if recommended by the designer.
- Expedite changes and change orders for unforeseen repairs to prevent delays.
- Include inspection time with access equipment — at least two inspectors and required support in the designer's budget. This is well worth the expense.
- Avoid the temptation to have all repairs bid by the pound. Bid prices will have a large range if the contractor doesn't know how much detailing and complex fabrication will need to be done. Even a set of stock designs without dimensions is better than nothing.
- Allow flexibility in the field. There are some situations in which the contractor can find a better way to do something.
- Arrange for engineering and design support during construction, either from the designer or from a suitably qualified construction monitoring firm.
- Take advantage of in-place platforms and structural access during painting for inspections and completion of additional repairs which will save the cost of access in a future contract.

RECOMMENDATIONS FOR THE CONTRACTOR

- Hire one party to manage the detailing, fabrication and installation of steel repairs — the best insurance that priorities for each entity will be aligned.
- Carefully review priorities and the painting schedule with the steel contractor. Emphasize getting field measurements and shop drawings done in the same order of areas that the painting contractor is following. This prevents on-site stockpiles of repairs that can't be installed until other work is completed. The steel contractor should be giving the same priorities to the detailer and the fabricator. Monitor shop drawing submissions, deliveries and installation to ensure that everyone's priorities are aligned.
- Even though it can be difficult to manage two contractors in the same space, avoid having the steel and painting split up. This is to make sure faying surfaces are done correctly, required touch-up and paint repairs are reduced, platforms (if used) and containment can be taken down promptly and the entire area can be closed out at the same time.
- Clearly define the work that painters and ironworkers will do. Painters should prepare and coat faying surfaces, caulk and conduct paint repairs. Ironworkers should install repairs, clean bolts, tighten bolts and clean up reaming or other debris from the installation. If ironworkers are responsible for any painting tasks, they should be properly trained, have proper personal protective equipment and have any required biological monitoring for the task. Bolt cleaning, caulking and clean-up are often forgotten and can cause finger pointing between trades.
- Caulking is generally done between paint coats.

- Assign a small paint crew to work with ironworkers. Usually two dedicated painters for up to three ironworking crews is sufficient. The need for coordination increases exponentially when the ratio of painters is lower. Dedicated painters will work out responsibilities and timing more efficiently than sending a couple of workers over from paint crews doing other work. This helps to ensure that tasks are not forgotten and improves the quality of the finished product.
- Another difficulty can be avoided by having painters and ironworkers work the same hours. Managing repair work is easier when one trade does not leave before the other. If switching hours is not possible, then extra time should be coordinated between trades.
- Do not be afraid to prepare RFIs for constructability problems based on the plans or specifications. Standard specifications, cut-and-paste specifications, arbitrary requirements (such as specifying every connection as slip-critical) or unforeseen issues may cause problems in the field that require changing plans.
- Follow cure times and certification requirements for slip-critical connections.
- If steel repair pieces are shop-primed, the same primer must be used in the field. Inorganic zinc is often used in the shop and may be difficult to apply in the field at the repair location, so the shop may have to switch to organic zinc.
- The primer must also be compatible with the paint system for the edges around the repair that were not previously primed. Most specifications require the same brand be used to help guarantee compatibility. The type of primer and the brand must be coordinated with the shop.
- Steel must be bare for welding. Make sure to leave enough bare space around the weld to dissipate the heat so that the surrounding paint is not damaged. Clean flux and weld splatter before coating welds and the surrounding areas.

- Welds and bolts should be stripe coated with the layer of paint specified (primer, intermediate and/or final coat).
- Check with ironworkers about cleaning bolts before installation to make sure they can be installed and torqued correctly.
- Caulk around repairs to add additional protection and to avoid rust bleeding. If it is not specified, consider posting the question during the bid if caulking around repairs will be required and if it is paid for under general caulking or as part of the repair.
- Quality control and good painting practice apply to painting repairs and faying surfaces. Atmospheric conditions should be checked at repair locations, and mixing should be done properly (with only whole kits used) as well as documentation of details such as atmospheric conditions, batch numbers and application method.
- For two-component primers, whole packs must be used, to ensure that the base-to-hardener ratio is correct, especially for zinc rich systems. Some primers are formulated by volume of zinc and some by weight. Whole kits from the same manufacturer will have the correct ratios. Buy small-volume kits or plan ahead for priming multiple areas to reduce primer waste.

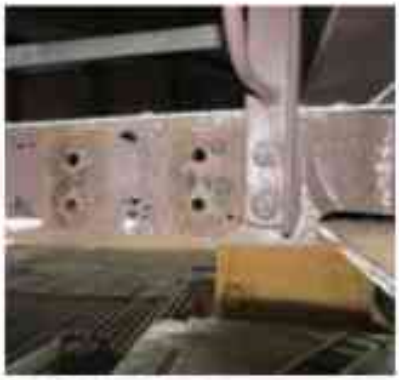

Fig. 5: Faying surface locations.

RECOMMENDATIONS FOR THE CONSTRUCTION MONITOR (IF APPLICABLE)

- Begin planning steel repairs during the pre-construction meeting. Go over requirements for faying surfaces, bolt cleaning, painting and slip-critical connections.
- Examine the schedule carefully and check for realistic time frames and synchronicity with the painting and recommend any applicable changes. Be sure to look for steel repair work being done in the winter. Heating plans or paint substitutions may be required for the painting during the winter depending on the local climate.
- Make sure the required support is in place for the repairs. For example, work involving jacking or temporary support may not be able possible under live loads. Have road closure plans been submitted? Have the road closures been coordinated with the agency and adjacent agencies? Has the public been informed about road closures far enough in advance?
- Check the contractor's painting procedure and quality plan. Have the proper procedures and quality control for steel repair work been included?
- Continue planning for steel repairs throughout discussions in progress and pre-activity meetings. Things will change after blasting.
- Perform post-blast inspections soon after priming if the construction monitor is responsible for them. Identify areas to be masked and coordinate with the owner and designer about repairs to add. Consider masking off potential repair areas as well.
- Monitor shop drawing submissions, deliveries and installations to ensure that work is being prioritized correctly.
- Monitor installation procedures to check for contract compliance.
- Check steel storage and lay-down areas for protection from the elements. Also

FEATURE

FIGHT THE PHENOL:

BAKED PHENOLIC RAILCAR LININGS FOR EXTENDED SERVICE

Getty Images / Istvan Bajzat

BY JOHN MYERS, CARBOLINE COMPANY

Have you ever wondered how all those products upon which we rely in our everyday personal and professional lives are delivered throughout North America? American highways are clogged with trucks, trailers and transporters of all sorts moving packaged and bulk goods throughout the country. Barges and pipelines move countless millions of gallons and pounds of materials every day without fail. And the railroads, with its transportation infrastructure of over 2,000,000 pieces of rolling stock are moving autos, lumber, plastics and bulk liquids by the millions of tons every year.

Tank cars comprise over 20 percent of the rail rolling stock in North America. More than 400,000 tank cars ply the rails throughout the continent, delivering raw materials, intermediate chemicals and finished products for both industrial use and direct or indirect human consumption.

A vast network of independent service facilities located throughout the U.S. and North America maintain the equipment railroads and private fleet owners use to move all these products from point of origin to your front door.

These cars are made of mild steel, not exotic materials that are impervious to corrosion, so how is it that they stay intact and keep the products being hauled pure and safe? The answer: with coatings and linings not only applied by skilled technicians to exacting standards, but also inspected consistently and maintained accordingly.

Interior protective coatings and linings are applied to either maintain the purity of the product being transported or to protect the railcar from corrosion. A wide range of coatings may be used as the protective barrier depending upon the severity of the service environment. Epoxies, epoxy phenolics, novolacs, zinc and baked phenolics are typical spray-applied coating types used. For any interior coating system to perform at a high level, the surface preparation and application processes must be closely followed, with attention to detail paid at every step.

Where the commodity is known to be corrosive, progressively thicker-film coatings are used, such as vinyl esters applied at 40 mils or thicker. For severely aggressive and corrosive services such as strong acids (HCl, HF, and H_3PO_4), sheet rubber linings are also used. Title 49 of the Code of Federal Regulation Section 180, Subpart F governs the inspection and maintenance of tank cars. By this Subpart, interior coatings must receive a periodic inspection or requalification when the commodity is known to cause a corrosion rate of greater than 2.5 mils per year on mild steel. Most liquid commodities shipped by rail fall into this category, including chlorides, sulfides, fertilizer solutions, other oxidizing agents and crude oil from the tar sands and shale fields.

For commodities considered non-corrosive according to this standard, such as glycols, corn sweeteners, solvents and phenol, no periodic interior coating inspection is required. The owner of the coating may choose to periodically inspect the coating and make repairs as needed based on their own product purity requirements. The owner of the coating must prove their commodities to be non-corrosive if a product purity claim is made. If requalification is required, the owner must be able to document the analysis used in establishing the requalification cycle.

Without specified periodic maintenance cycles, coating systems for these non-corrosive commodities need to be all the more reliable in order to prevent premature failure.

A case in point is baked phenolics in phenol service. Baked phenolics are normally used for product purity where corrosion is not a concern. Phenol is not corrosive to mild steel, but will be discolored by contact with bare steel. Color and clarity of phenol is critical in its applications as a starting chemical for plastics, explosives and some medicines such as aspirin. Phenol is also an excellent antiseptic and is used in household cleaner and disinfectants.

Very few sprayable coatings are resistant to phenol, but baked phenolics have proven over many decades of use to be outstanding performers, given that surface preparation and application protocols adhere to the proper specifications.

Tank cars are considered a permit-required confined space according to 26 CFR 1926, and therefore, before each shift begins, a confined space entry permit must be present, and the interior environment must be monitored for proper air quality.

Railcar relining begins with the cleaning and decontamination process. Depending on the previous service and the degree of coating failure (if any), a thorough cleaning must be performed to remove any contaminants from the

substrate and to achieve a neutral pH on the surface. Although a railcar may appear clean, the previous service may have permeated the substrate or become engrained in such a way that the substance must be removed to prevent contamination of the blast media, which would lead to cross-contamination of other railcars, and to remove substances that can promote osmotic blistering or interfere with adhesion of the coating to the substrate. The surface should be tested for contaminants such as oils and non-visible soluble salts, especially if an acidic or alkaline environment exists.

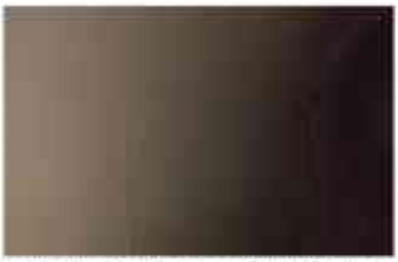

Fig. 1: A baked phenolic lining applied to the interior of a phenol-carrying tank car has protected the underlying substrate from both corrosion and chemical attack for 24 years, passing two different inspection cycles. Photos courtesy of Carboline Company.

If additional cleaning or neutralization is required, the appropriate method will be repeated before the final blast is performed. This may include prebaking, steam injection, hot water wash or chemical wash/cleaning. Prebaking involves heating the railcar until the surface temperature reaches 450 F and holding it for four-to-six hours to remove any volatile compounds that have a relatively high decomposition temperature. Steaming is used for water-soluble substances that can be washed from the surface relatively easily. Where highly acidic or alkaline services are involved, the surface is neutralized and steam-cleaned. The nature of the previous service will dictate the appropriate method for decontamination.

The generally accepted specification for abrasive blast-cleaning is SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning." Depending on the film thickness to be applied, the blast profile may be specified between 1.5 and 4.5 mils. Recyclable metallic abrasives are the common media used in the railcar repair industry for surface preparation. Steel grit, not shot, of a size and hardness to assure the necessary depth with a dense angular profile should be used.

After interior blast, the car should be cleaned of all debris, dust and loose abrasive by vacuum and hand-cleaning. With the internal environment controlled to prevent condensing moisture to form and maintain at least 60 F substrate temperature, baked phenolics are then applied in two or three spray coats to achieve a final dry-film thickness of 5-to-8 mils.

Phenolics are thermosetting coatings, so each coat must be baked to a substrate temperature of at least 225 F. Following the application and intermediate baking of the final coat, a thorough inspection of the coating should be performed to verify that proper film thickness has been achieved and that the coating is holiday-free prior to the final baking stage.

Final baking requires gradually raising the steel temperature at least 375 F and holding it there for at least 90 minutes or until a minimum color change is achieved, which can best be described as caramel to milk chocolate brown. All baked phenolic coatings darken during final baking, although coatings from different manufacturers have differing degrees of color change. The final bake process takes 10-to-12 hours in most railcars, but larger cars or other factors may require a longer bake cycle. The complete process from start to finish can take five-to-six days, including cleaning and decontamination.

Generally speaking, the service life of an interior coating is five-to-10 years, with repairs to the coating possibly extending that usable life of the applied system. A well-applied coating system can last far longer in some commodities.

One example is a railcar serviced recently, in which the 24-year-old dark brown phenolic coating was found to be free of any defects with the minor exception of damage at the manway opening, which is typical and unavoidable. Applied in 1994 to these exacting specifications, the coating and the railcar have been through at least two routine inspection events required by regulation. In each case the interior coating was found to be in perfect condition (Fig. 1).

When properly maintained and loaded over the course of its service life, an interior lining can provide many years of protection both to the railcar and the products being hauled, as evidenced by the nearly quarter-century and still counting for this baked phenolic coating.

ABOUT THE AUTHOR

John Myers is the rail technical manager for Carboline Company. He has been with the company for 20 years, holding applications specialist, technical sales, and rail technical manager positions. Prior to joining Carboline, Myers spent 25 years with various companies in the rail industry as an applicator, quality assurance manager and facilities manager. He is a NACE-certified Coating Inspector. ***JPCL***