Photo used with permission from Golden Gate Bridge, www.goldengate.org

Successful Today and Getting Even Better for Tomorrow

Durable **Bridge** Coatings

BY ERIC KLINE

COATINGS NOW BEING SPECIFIED AND APPLIED to steel bridges are completely different from and perform much better than those applied until about 1965. That said, there is still the often articulated perception that bridge painting is expensive, troublesome, and that bridge coatings simply "do not last." However, one does not have to look far to find strong evidence to the contrary. In 1965, the Golden Gate Bridge in San Francisco became one the first large bridges to be painted using a modern zinc-rich, steel bridge paint. It provides an outstanding example of how well today's coatings protect bridges across America and around the world.

Prior to 1965 coatings were generally oil- or alkyd-based and contained pigments using lead and/or chromium compounds as the corrosion inhibitors. In addition, they often were applied directly to steel covered with shiny, slick mill scale that had been subjected to only power tool cleaning (SSPC-SP 3 "Power Tool Cleaning") for surface preparation. The old axiom was "the more paint the better," as additional coating thickness meant that more inhibitive pigment was applied to resist corrosion. These old-technology coatings were expected to last about eight to ten years before requiring some level of maintenance intervention. As a result, there were so many coating layers on some bridges that apart from other forces, the sheer weight of the paint would overcome the adhesion of the coating layers to one another and/or to the smooth mill-scale-covered steel beneath. Subsequently, the coating would simply fall off, sometimes in sheets. Coatings with an overall thickness of ¼ in. or more have been encountered.

Bridge owners and maintenance engineers still are living with the complex issues brought about by the 100-plus years of use of this long-ago-discontinued coatings technology. A recent survey of 20 state departments of transportation (DOTs) regarding bridge painting practices revealed that, in those states, only about half of the bridges originally painted with lead-based paint have been repainted. Repainting in this context refers to complete removal and replacement of all old coating. That leaves thousands of bridges with the "old" coatings that must be addressed in the future. Accordingly, the removal/replacement expense, often for

Beginning about 1965, the lead-based paint that had protected the Golden Gate Bridge in its early years was removed and replaced with an inorganic zinc-rich paint system.

Photo used with permission from Golden Gate Bridge, www.goldengate.org

Four decades after being primed with the inorganic zinc-rich paint but never topcoated, these members on the north end of the bridge continue to be in very good condition.

coatings containing lead, will continue in many states. In many areas, the current cost is around $12 per sq. ft of steel surface area, including access, lead removal, containment, worker protection, disposal, repainting, etc.

Modern Era Technology

There is good news for the owners of the bridges built or repainted with modern-era coatings, meaning those made available since about 1965. Around that time, many DOTs began specifying the use of blast cleaning to a near white condition (SSPC-SP 10) in order to completely remove mill scale. They also began applying a "new generation" primer.

The coatings introduced at that time employed an entirely different technology than earlier products. They contained metallic zinc powder as the pigment providing corrosion resistance. Why zinc? When zinc and iron (or steel) are joined in presence of moisture and oxygen (air)—a corrosive environment—zinc will be consumed first, and the iron (and steel) will be protected from corrosion. This consumption of the zinc will continue until the available zinc is depleted.

The innate ability of zinc to protect steel from corrosion is referred to as "galvanic" protection. This provides long-lasting protection because the zinc reaction normally occurs at a fraction of the rate of corrosion of bare steel in the same environment.Many everyday items are galvanized, including fencing, guard rails, sign structures, light standards, and even automobile parts.

Basically, zinc can be applied to steel in three ways. Galvanizing is a process in which the bare piece of steel is dipped in molten zinc. It is limited by the size of the "kettle" in which the article is immersed. Metallizing requires melting wire containing zinc and spraying the molten metal onto the steel surface, with a stream of air. Both galvanizing and metallizing are excellent means of protecting steel from corrosion. However, many steel bridge members and components are best protected by the use of zinc-rich paint, which is the focus of this article.

Service Life of Zinc

The metallic zinc pigment in zinc-rich paint is able to provide galvanic protection for the steel until the zinc itself is consumed. When the zinc is depleted, the steel will eventually rust. Therefore one important consideration is how long the zinc will last. The time it takes for zinc to be consumed is affected by many variables, e.g., weather, duration of wetness, the number of wet/dry cycles encountered, etc. The service life of zinc-coated items often is measured in decades. In a recent article, the American Galvanizers Association (AGA) projected that hot-dipped galvanized (HDG) items will last 75 to 100 years in an aggressive marine environment.

There are a number of important differences between zinc-rich coatings and galvanizing. In zinc-rich paint part of the coating consists of binder materials whereas galvanizing is 100% zinc. The AGA data for HDG are based on a bare zinc coating. A plus factor in terms of service life for zinc-rich coatings is that they are often paired with additional coating layers (topcoats). These additional layers protect the zinc by limiting the amount of moisture and oxygen in direct contact with the zinc. The extensive and impressive 40-plus-year field performance history of zinc-rich coatings, in combination with the AGA calculations, suggests strongly that steel which has been properly coated with a zinc coating and which has additional coating layers can provide permanent or nearly permanent protection for the steel beneath.

The Gold Standard

The current "gold standard" for bridge coating entails the use of a three-coat system consisting of an inorganic zinc-rich primer, an epoxy midcoat, and a urethane topcoat (IOZ/E/U). Literally thousands of steel bridges constructed since about 1965 are coated with a zinc-rich primer paint as a part of a paint system and are in excellent condition.

One such structure is the world famous Golden Gate Bridge (GGB). This structure measures 8,981 ft long (1.7 miles), weighs about 887,000 tons, has two massive towers that stand 746 ft-tall and a roadway about 220 ft above the Golden Gate Strait. When the bridge was built, from 1933 to 1937, it was coated with lead-based paint. Through an extensive undertaking from 1965 to 1995, the lead paint was removed and an inorganic zinc-rich paint system was applied.

Some areas on the north end of this iconic suspension bridge structure were primed with IOZ, but never topcoated. These areas were recently examined and were in very good condition. According to Dennis Dellarocca, the bridge's paint

Eric Kline is part of the management team at KTA-Tator, Inc., Pittsburgh, Pa. He received a B.S. in Chemistry from Ursinus College, Collegeville, Pa., an MBA from the University of Pittsburgh, and is an SSPC Certified Protective Coatings Specialist. He has been involved in the coating, both shop and field, of literally all types of industrial structures. Mr. Kline is a member of SSPC: The Society for Protective Coatings (chairman, co-chairman, or past chairman of several committees), NACE International, and others. He was the general chairman of the 2008 International Bridge Conference (IBC) and also serves on its executive committee.

KTA-Tator Inc.

This coating damage is the result of destructive adhesion tests on the east exterior fascia girder of the Windgap Bridge, near the north abutment. All indicate excellent adhesion.

superintendent, there are no plans to disturb the corrosion-free coating that has been in place for more than 44 years.

Another example of good long-term coating performance is the Windgap Bridge near Pittsburgh, Pa. This 849-ft-long, seven-span, composite steel, multi-girder bridge carries Windgap Road across Chartiers Creek. This Allegheny County-owned bridge is being protected by the 23-year-old coating system applied during its construction in 1986.

The coating system consists of an organic zinc-rich primer, an epoxy midcoat, and a urethane topcoat (OZ/E/U). When the bridge was evaluated in 2007, the coating was found to be in excellent condition. The overall rate of coating breakdown was very low and confined to areas beneath leaking joints plus a few tiny areas damaged by rock-wielding vandals. Some minor graffiti was also noted. Accordingly, the 23-year-old bridge paint was in need of only a small amount of touch-up around the bearings.

The Martin Luther King Bridge in Richmond, Va., provides another example of excellent long-term IOZ-based coating system performance. This 2,000-ft long bridge has six lanes plus two sidewalks and rises 100 ft as it crosses Interstate 95 and the Shockoe Valley. When the bridge was constructed in 1975, the orthotropic steel girders were painted with an inorganic zinc-rich primer and vinyl coatings layers.

A recent examination of this structure revealed that the coating system was in excellent condition overall. There are a few areas with apparent loose or debonded topcoats, aggregating a tiny percentage of the steel surface. These small areas are in need of touch-up attention, but only from a cosmetic perspective as only a small amount of rust is evident, indicating that the IOZ coating material is still performing its intended function—corrosion protection.

An example of one of the older zinc-coated steel bridges is in Franklin County, Mo. Known as MoDOT Bridge No. A2107, this two-lane, 185-ft-long bridge on Route E crosses Pin Oak Creek. It was painted in October 1969 with an inorganic zinc-rich system; the coating was examined in 1999. At that time the coating condition was very good.

The bridge was overcoated in 2000 with a calcium sulfonate topcoat as part of the state's bridge maintenance program. Having been recently overcoated, the bridge should be well protected for decades to come.

These long-ago painted bridges are illustrative of the thousands of painted structures constructed over the past 40-plus years whose coatings have already stood the test of time. With periodic paint touch-up and overcoating the primer will be able to provide complete corrosion protection for decades to come, likely for the life of the structure, perhaps extending a century, or more.

Modern Painting Costs

The cost of painting in the shop as part of the initial fabrication is about $1.50 per sq. ft, far less than the cost of full lead paint removal and repainting in the field. Maintenance overcoating in the field, where no lead paint remediation is required, currently costs about $1 per sq. ft.

After overcoating a zinc-rich primer based coating system, it is expected that the bridge will not need to be painted for 15-25 years. At that time, after a now-total service life of about 55 years, another overcoating is possibly required, costing an additional $1 per square foot.

The costs for such a bridge, in 2009 U.S. dollars, are summarized below in Table 1:

Lifetime Cost Per Sq. Ft (Three-Coat System)	
Year 1	$1.50 for the initial blast cleaning surface preparation and prime coating in the shop during fabrication.
Year 1	$2 for the application of the second/third coating layers at the construction site after steel erection.
Year 30	$1 for the first touch-up/overcoating.
Year 45-55	$1 for the second touch-up/overcoating.

Table 1

There are ways to reduce even these modest costs. U.S. Federal Highway Administration research and other testing has shown that the performance of newer two-coat paint systems, while lacking the 44-year field history of the three-coat "gold standard" coating systems, are possibly capable of equaling its performance. If a two-coat system were to be widely used, the lifetime costs would be expected to be similar to those shown in Table 2:

Lifetime Cost Per Sq. Ft (Two-Coat System)	
Year 1	$2.50 for the initial blast cleaning surface preparation and application of both coats of paint in the shop.
Year 30	$1 for the first touch-up/overcoating.
Year 45-55	$1 for the second touch-up/overcoating.

Table 2

Caution: Periodic Maintenance is Required

It is unlikely that any steel bridge can be painted and simply remain untouched for its entire service life, extending perhaps a century or more. No epoxy or urethane coating currently known to the author is likely to be able to perform well for that long. Current topcoat materials generally will serve very well for about 20-30 years, at which time at least a first touch-up/overcoat is expected.

There are three good reasons for adding additional protection at that time. First, there likely will be some reduction of the gloss and/or fading of the color of the topcoat due to weather (sunshine, rain, air pollution). Second, there likely will be locations on the bridge where traffic or wind-blown debris have nicked, scratched, or otherwise damaged the coating. Finally, girders and bearings beneath leaking joints often are bathed in corrosive salt-laden water from storms or from winter deicing activities.

During the touch-up/overcoating operation, all such locations can be repaired and the entire structure can then be completely overcoated. In this scenario the zinc-rich coating, which provides the basic corrosion protection, is not disturbed in the repair/overcoating process. Consequently, the zinc layer will remain beneath the existing coating and any new coating(s) applied during the touch-up/overcoating process. It is expected that this zinc-rich paint layer should be able to perform its corrosion resistance function for the life of the structure.

Note that other very good zinc-rich primer coating systems currently are available, and widely used, in addition to the IOZ/E/U system discussed above; however, it is that "gold standard" system that already has stood the test of time, since at least 1965, and is widely specified and successfully used.

Rapid Deployment

Two areas of technology have been developed in recent years to assist in field cleaning and repainting low-rise overpass bridges located in high traffic areas that cannot be shut down for long periods. These practices, dubbed "rapid deployment," involve the use of mobile, blast cleaning equipment and containment platforms—usually flat-bed trailer mounted—that are used to completely enclose the area to be cleaned and painted. The mobile platform can be deployed overnight to enable cleaning and painting to occur. The trailer is removed from the roadway before rush hour begins the next morning.

The second aspect of a rapid deployment approach is the use of a matching two-coat coating system consisting of a fast-curing organic zinc-rich primer along with a fast-curing high-build topcoat. Using this tandem approach allows the contractor to mobilize the platform, clean an area and apply both coating layers in an overnight shift, thereby completing the work on that area. Economies associated with rapid deployment are readily apparent.

Coatings Prequalification

In days gone by, the myriad vendors in the coatings industry offered the bridge engineering community many materials. Each state was forced to provide its own prequalification test program and to develop and maintain a qualified products list (QPL). Testing by every state was expensive and duplicative.

Since then standard test protocols have been developed under the auspices of the AASHTO National Testing Product Evaluation Program (NTPEP). Suppliers of coatings to the bridge painting industry are now required to have their products tested in accordance with the AASHTO NTPEP testing standard for Structural Steel Coatings (SSC). In these laboratory "torture tests," the performance of candidate bridge coating systems is evaluated using tests identical to those required to qualify the IOZ/E/U system described above.

Test results are accumulated in the AASHTO DataMine which is available to state DOTs for the purpose of coating system comparison. Each state can apply its own performance criteria. For example, a state with a mild, less-corrosive environment may have different criteria for adding a coating system to its QPL. Information about the AASHTO NTPEP coating testing program can be found online at **http://www.ntpep.org/ContentManagement/PageBody.asp?PAGE_ID=30**.

The New England states also have their own separate prequalification testing standard by which materials are prequalified and listed on a QPL accepted by the member states and several others. The NEPCOAT member states are: Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The NEPCOAT Qualified Products Lists can be found online at **http://www.state.me.us/mdot/nepcoat/qualprod.htm**. Approved two-coat systems like that discussed above for rapid deployment are presented in NEPCOAT Appendix C.

Many states use either/or the AASHTO DataMine or

Tom Calzone

This 1999 photo shows the excellent condition of the inorganic zinc-rich coating on bridge A2107 in Missouri 30 years after its application.

NEPCOAT for coating performance data. See **http://www.state.me.us/mdot/nep-coat/**.

Conclusion

Bridge engineers are properly cautious professionals who are charged with safely building and protecting our modern infrastructure from attacks of all kinds, including corrosion. For nearly a century following construction of the Eads Bridge in St. Louis, which heralded the beginning of the steel bridge era, bridge engineers did the best they could to protect steel bridges with various coatings systems. Since the advent of the modern age of bridge coatings, in 1965, many improved user-friendly, color-retentive, adherent, corrosion-preventing and durable coatings have emerged from the coatings industry. Literally thousands of improvements have been made in every aspect of bridge paint and painting leading to improved durability.

Effective means of corrosion protection via corrosion preventive protective coatings have proved themselves in the field for more than 44 years. Progress is steadily being made toward the development of even better, more durable, safer, and more cost-effective coatings, ensuring that there always is a solution in steel. MSC