

# **Ultra-Durable Finishes for Zinc Primed Steel Bridges**



Tom Calzone

## **BIOGRAPHY**

Tom Calzone is the Director of Bridge Sales for the Carboline Co. He attained his B.S. in Chemistry from the University of Missouri – Rolla in 1979. Tom has worked at Carboline Co. since then in the capacity of Technical Service Engineer, Maintenance marketing, and Sales Management. Tom is active in the National Steel Bridge Alliance and the Steel Structures Painting Council and has been responsible for Carboline Company Bridge Market efforts for 18 years.

## **SUMMARY**

A coating “system” consists of the surface preparation, primer, intermediate and/or finish coats. There is now a trend toward color for expression and we have the means to upgrade the finish to the level of primer performance. This paper discusses the state of the art for bridge finish coats and the options for color durability.

# Ultra-Durable Finishes for Zinc Primed Steel Bridges

**Tom Calzone**  
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Zinc rich primers revolutionized corrosion protection of steel bridges. Many structures constructed in the early 1970's remain corrosion free even in the face of heavy de-icing salt exposure. Incremental improvements of earlier formulations made zinc primers more durable than ever. We expect maintenance-free service for more than 30 years in the most corrosive environments.

Long term corrosion protection places a greater demand on the durability of the finish. Sun sensitive vinyls have given way to acrylic and urethane formulations. These are indeed more than adequate for light colors of gray and white or with non-critical applications. But even the best of these finishes will fade and chalk in the sun well before corrosion occurs. The trend toward deep and vivid color application on bridges paves the way for new finish technology. This paper describes three approaches to long term aesthetics and gives examples of each on steel bridges.

The interstate highway system is 50 years old. During its rapid expansion period of the 1960's many steel bridges were constructed and protected with lead pigmented oil-alkyd paints. The American Association of State Highway and Transportation Officials (AASHTO) defined these paints in some detail with formulation specifications like AASHTO M 72 and M229 found in the AASHTO Materials Manual, Part I, Specifications. These coating formulations had provided very good service on steel containing mill scale in atmospheric service.

A dramatic increase in de-icing salt application through the 1960's and '70's took its toll on structural steel and concrete. Re-paint cycles for the old coatings shortened. Furthermore, when used as maintenance paints these formulations were shown to do poorly when applied to chloride contaminated steel.<sup>1</sup> The steel bridge industry needed a solution to corrosion. Inorganic zinc was widely used in chemical processing, refining, oil and gas exploration and many other industrial applications with outstanding success. These experiences and very convincing comparative test results lead many states to require inorganic zinc on new steel.

During the 1970's and 1980's many of the bridges built during the expansion were due for maintenance. If that wasn't enough to burden your Bureau of Bridge Maintenance, lead became a four letter word when lead paint containment and hazardous waste disposal was mandated. Lead abatement is expensive but necessary because of the primer's poor long term adhesion to mill scale. Many states then began using zinc for maintenance as well as construction.

The earliest states to adopt inorganic zinc include MD, DL, PA, FL, SC, MO, WA and IN. Most DOT's are using inorganic zinc routinely today. AASHTO developed a compositional and performance specification for inorganic zinc, AASHTO M 300. M 300 was fashioned after the Steel Structures Painting Council specification for inorganic zinc. The SSPC specification was in use by industry already and had the unique benefit of applying a performance standard to the loosely based compositional requirements. This approach allowed states to qualify existing technologies rather than to publish recipes. The most significant performance barometer in M 300 is the salt fog test.

A discussion on primers is included in this paper about finish coats only to put some perspective on the state of the art for bridge coatings. M 300 requires a single coat of inorganic zinc primer to survive 5,000 hours of salt fog exposure with no rusting. By contrast, the old multi-coat lead pigmented systems failed before the 1,000 hour grading.

The 5,000 hour exposure (7 months) is conservative. Some inorganic zincs perform for well over 40,000 hours before the appearance of rust. Perhaps what is more significant in terms of life cycle cost is the lack of cancerous undercutting corrosion. The absence of undercutting corrosion from a measured scribe on steel test coupons is indicative of durability. Undercutting corrosion protection gives zinc primed bridges a large re-

paint window and the primer actually becomes a permanent part of the structure. That, coupled with their corrosion resistance leads us to the issue of finish coat durability.

A coating “system” consists of the surface preparation, primer, intermediate and/or finish coats. We are finding now that our aged structures are corrosion free but appear faded and weathered. Not such a big deal when gray is the color, after all people have accepted bare concrete appearance for a long time. But now there is a trend toward color for expression and we have the means to upgrade the finish to the level of primer performance. If your coating system will be untouched for 30 years, why should it be faded for 25?

### Bridge Finish Coat Evolution

Vinyl was the first and most widely used color coat for inorganic zinc. Vinyl coatings had poor resistance to ultra-violet light degradation but were very popular for their simple application. If you see a faded and uncorroded bridge it is probably coated with inorganic zinc and vinyl. Now vinyls have been replaced entirely with polyurethane and acrylic finishes. The former going back around 20 years. Both of these types have been improved from earlier formulations yet both fall short of what is possible with today’s weathering finishes.

Carboline has seen most interest in ultra-durable finishes for pedestrian bridges. These are often architectural expressions using vivid colors. Pedestrian bridges often use custom specifications, not borrowing from the standard state DOT qualified products list (QPL). The supplier list for ultra-durable finishes is abbreviated and with conformance testing and verification it may be some time before many states have a viable QPL for ultra-durable finishes. California and Wisconsin have established ultra-durable products lists for large projects and several other states have explored the technology.

### Three Options For Color Durability

Fluoroethylene Vinyl Ether (FEVE) resin based coatings also known as fluoropolymers or fluorourethanes have the longest history as ultra-durable bridge coatings. This is similar technology to Kynar® a baked on finish used for curtain wall aluminum panels. The bridge versions will air dry making shop or field application practical. These finishes have been the products of choice in Japan for almost 20 years. In fact, the award winning Akashi Kaikyo Bridge in Kobe, Japan is protected by a FEVE based finish, with an inorganic zinc primer and epoxy intermediate coat.<sup>2</sup> Sixty years of protection is projected.



Akashi – Kaikyo Bridge, Kobe, Japan protected with inorganic zinc primer, epoxy intermediate coat and fluoropolymer finish. This is routine system for bridges in Japan.

The carbon-fluorine bond is very stable in fluoropolymer coatings. Carbon and fluorine are strongly bound, enough so to withstand high-energy UV photons. (Remember fluoro-carbon aerosol propellants that survive in the upper atmosphere and destroy ozone.) Resisting UV degradation is key to long-term film integrity, gloss and color retention.

Katsushika Harp Bridge Tokyo, Japan is fluoropolymer protected. Steel coated 1985; Concrete coated 1987.



### Features of FEVE Based Finishes

- Best available color and gloss capability.
- Creates a thin film finish that is a direct replacement for traditional polyurethane finishes in three coat systems.
- Typically low solids, high solvent content requiring special solvents to be compliant to regulations.
- Expensive. Expect to pay \$1/sq. ft. premium over traditional polyurethanes.
- Automotive grade pigments are required in some colors to realize color stability, adding cost.



Maryland Avenue Pedestrian Bridge over I-17, Phoenix, AZ coated with Fluorourethane finish to preserve the color scheme in the intense Arizona sun.

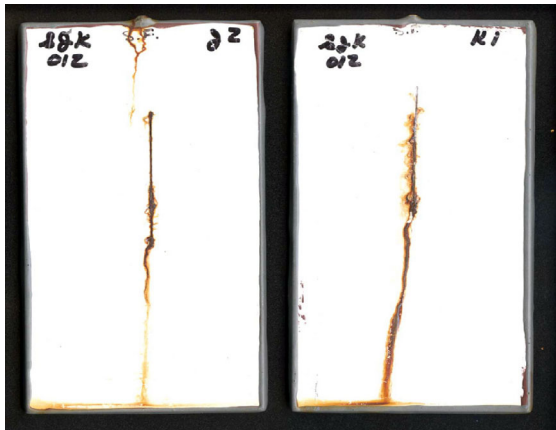
44<sup>th</sup> Street Pedestrian Bridge over the I-235 Corridor in Des Moines coated with inorganic zinc/epoxy/fluoropolymer, 2005. The special blue color had faded in both urethane and acrylic finishes on other corridor bridges in a few years prompting the IA DOT to upgrade their finish.



Polysiloxane coatings utilize an inorganic component to resist UV degradation. The silicon-oxygen bond is very strong and analogous to the carbon-fluorine bond in the fluoropolymers. Other inorganic compounds such as glass and other ceramics are immune to UV attack. They are also inherently brittle. Formulators combine various organic components to the siloxane to optimize flexibility, adhesion and cost.<sup>3</sup> This can result in a variety of formulations and the physical and performance differences between them can be significant. Specifier beware.

Properly formulated polysiloxane finishes offer a vast improvement in color and gloss stability to traditional bridge finishes. They also provide one significant feature that gives them an advantage as ultra-durable bridge finishes, thick films. The highly cross linked polymer is dense, with outstanding barrier properties. It replaces traditional epoxy intermediate coats and does double duty as the weathering coat. With high film thickness and high solids a two coat zinc/polysiloxane system has an installed cost comparable to three-coat systems and adds far superior weathering.





The panel on the left is a two coat system of epoxy zinc rich primer finished with a polysiloxane. The right panel is a traditional bridge coating system of epoxy zinc rich/epoxy/polyurethane. Both were exposed for 4,200 hours in the salt fog. Corrosion protection is not compromised and appearance is improved.

- | Features of Polysiloxane Finishes   |
|---|
| <ul style="list-style-type: none"> <li>• Color and gloss durability close to fluoropolymers.</li> <li>• Thick film, highly impermeable with great chemical resistance.</li> <li>• Naturally brittle. Requires modification with acrylic, epoxy or urethane compounds to achieve a practical formulation.</li> <li>• Low solvent content for regulatory compliance.</li> <li>• Isocyanate free.</li> <li>• Replaces two coats with one barrier/weathering coat.</li> </ul> |

Perhaps the most prominent use of polysiloxane is by the National Aeronautic and Space Administration. NASA started using inorganic zinc primers 40 years ago. Their single coat system is still protecting the Vertical Assembly Building in corrosive Cape Canaveral today. More recently NASA began using polysiloxane finishes directly over the inorganic zinc primer.



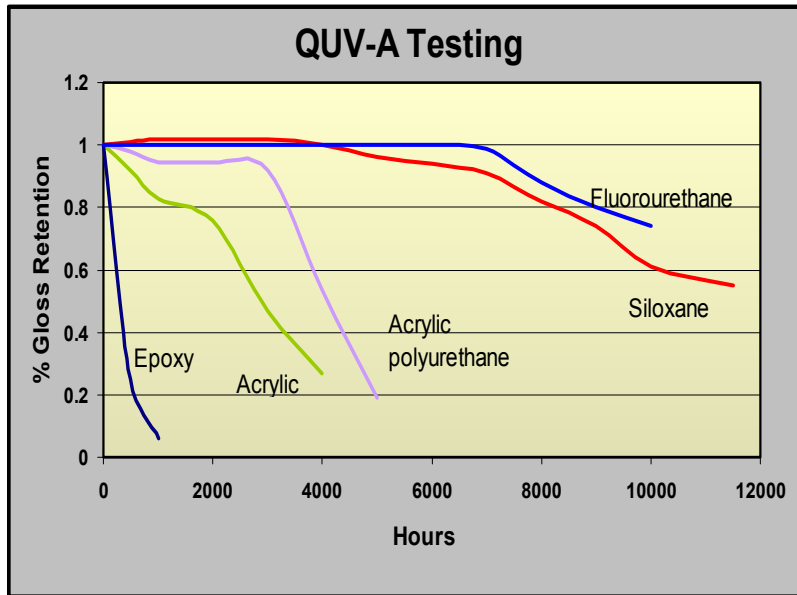
Red is prone to fading, particularly in the desert sun. NASA selected polysiloxane to retain high visibility for the shuttle gantry crane.



Polysiloxane application over inorganic zinc for Florida DOT, Bay County

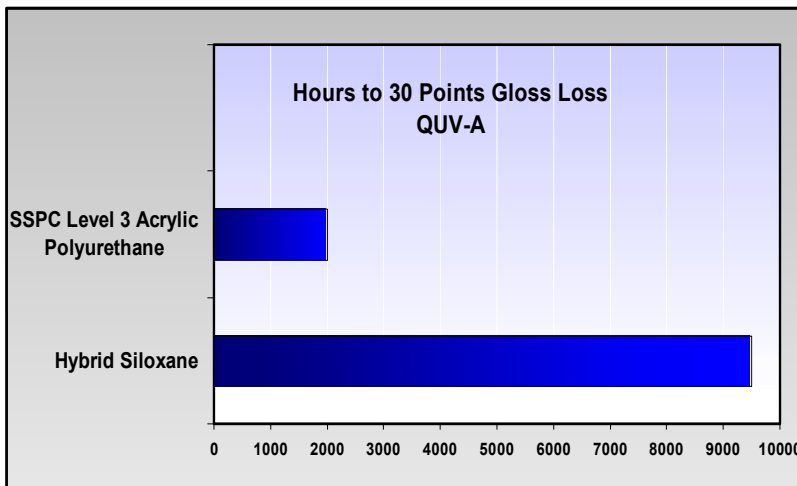
## Performance Testing

Extremely durable coatings require creative methods to predict longevity. Comparative testing using real time exposures may retire the researcher before the research. Just like highly corrosive test chambers we use high



doses of UV to predict finish life. The QUV test approximates 2 years of South Florida sun for each 1,000 hour exposure. With this tool we can approximate long term service appearance and compare our coating options. This chart compares the ultra-durable finishes to traditional bridge finishes.

Fading and chalking are cosmetic flaws to be sure but they are also indications of film degradation and coating damage. The ultra-durables sustain far less damage than the traditional finishes. They will be able to weather much longer before first maintenance, well beyond the point where they have lost gloss. If gloss loss is the criteria for painting, the new finishes will increase lifespan several fold.



## The Clear Coat Option

Standard polyurethane finishes can be enhanced by the addition of a clear coat of polyurethane. The concept is simple; the clear coat contains UV inhibiting compounds which protect the pigments from attack. Ultra-violet light must pass thru the clear film to reach the susceptible pigmented coat. Dramatic improvements result but there are some drawbacks. First, a uniform clear film is needed for

This chart gives a relative service life based on gloss retention



MI DOT chose a clear coat addition to their standard three coat system to enhance the vivid blue color on the Gateway Bridge in Taylor.



uniform weathering. The applicator must be able to control his application. A clear film applied to a glossy color coat gives little contrast. It is recommended the color coat be a lower gloss or the clear coat contain a fugitive dye which, when exposed to sunlight, disappears. The thickness of the clear is indicated by the intensity of the dye. It will not look as good fresh as it will when the dye has weathered and the shaded areas of the structure may look tainted for a long time.

Eventually UV will work on the pigmented coat and chalking will occur under the clear coat film. You may have seen the results of this on clear coated automobiles, particularly in metallic colors. Remember we are working with a permanent primer with very low life-cycle cost. We lose the option of a simple, cost effective refresher coat when the topcoat is peeling.

## **Summary**

Finish coat technology can now provide color and gloss durability worthy of the primers' performance to make our steel bridges look good longer, and extend the repaint period to reduce life-cycle cost. Engineers can choose between two coat zinc/siloxane protection at traditional installed cost or upgrade the finish to a fluoropolymer for a premium. Limiting the fluoropolymer to the fascia provides great value for plate girder structures. A clear coat of polyurethane upgrades traditional zinc/epoxy/urethane coatings adding only the cost of one coat and the labor to apply it. Clear coats have been used successfully but their drawbacks may limit future use. These three options in the engineer's tool box provide good value to bridge owners. High profile bridges and those with architectural significance are the first to apply the technologies. As experience grows and people learn from forums like this one, ultra-durable finishes will grow to help more bridges look good and remain corrosion free for 30 years or more.

## **References**

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3. Polysiloxane Modifications, Ian Rowell and Adrian Andrews, International Protective Coatings. Presented at NACE Northern Area Western Conference Feb. 16-19, 2004.