TECH**BRIEF**

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Federal Highway Administration 100-Year Coating Study

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This document is a technical summary of the Federal Highway Administration report, *Federal Highway Administration 100-Year Coating Study* (FHWA-HRT-12-044).

Introduction

The coatings industry switched from lead-based to zinc-based three-coat systems in the 1970s to protect steel bridges from corrosion after identification of health hazards associated with lead coatings.(1) Studies have shown that these three-coat systems with zinc-rich primer can have a service life up to 30 years, protecting steel from corrosion before a major touch-up is required.(2) Typical cost concerns with zinc-rich systems include the cost of removing mill scale before application of the coating system, the time and space required for shop application, and the logistics of moving heavy steel members to the field after shop application. A good alternative to addressing these cost issues is to extend the service life of the existing coating system on steel before any maintenance is required and/or replace the existing coating system.

The Federal Highway Administration (FHWA) 100-Year Coating Study is an in-house study initiated in August 2009 under the Congressionally mandated high-performance steel program. The objective of this study was to identify and evaluate coating materials that can provide 100 years of virtually maintenance-free service life for steel bridge structures at comparable costs to existing coatings. This TechBrief presents performance evaluation results and major findings for the eight selected coating systems based on experimental data from accelerated laboratory testing (ALT) and outdoor exposure testing.

Approach

Coating Systems

Table 1 summarizes the eight coating systems employed in this study. Two three-coat systems were used as controls, and the remaining coating systems comprised a three-coat system, four two-coat systems, and a one-coat system.

Test Panels

Two sizes of steel test panels were employed in this study. The small panels (type I) were 4 by 6 by 0.2 inches, and the large panels (type II) were 18 by 18 by 0.2 inches. All test panels were blast

Table 1. Summary of coating systems.

System Number	System ID	Coating Type		
		Primer	Intermediate	Top
1	Three-coat (control)	Inorganic zinc-rich epoxy (IOZ)	Epoxy (E)	Aliphatic polyurethane (PU)
2		Zinc-rich epoxy primer (ZE)	E	PU
3	Three-coat	Moisture-cured urethane zinc primer (MCU)	E	Fluorourethane (F)
4	Two-coat	ZE		PU
5		Inorganic zinc primer (Zn)		Polysiloxane (PS)
6		Thermally sprayed zinc primer (TSZ)		Linear epoxy (LE)
7		Experimental zinc primer (ZnE)		LE
8	One-coat	High-ratio one-coat calcium sulfonate alkyd (HRCSA)		

Note: One-coat systems contain only one coat of paint that acts as the primer/top coat and do not contain an intermediate coat. Blank cells indicate that the two-coat systems do not contain an intermediate layer.

cleaned to a Society for Protective Coatings surface preparation standard number 5 white metal blast cleaning condition, and coatings were applied on the cleaned test panels by a professional coating laboratory using airless spray.[3]

Type I Panels

All type I test panels were coated according to manufacturers' dry film thickness (DFT) recommendations. Half of the type I panels (48 out of 96) were scribed diagonally following the instructions specified in ASTM D1654-08.[4] The panels were scribed to study the potential performance of the coating systems with local film damage. The other half of the panels were used to measure physical properties such as gloss, color, pencil scratch hardness, etc. Two additional panels of each coating system were prepared exclusively for two destructive tests only: initial adhesion strength and Fourier transform infrared spectroscopy analysis.

Type II Panels

A new type of test panel design was adopted for this study to closely resemble steel bridge structure elements having bolt/nut assemblies, overlapped joints, angles attachments, and welding joints. Figure 1 and figure 2 show a type II panel. A wide-angle attachment and a fillet welded T-attachment were secured using bolts and nuts, while the V-notch was directly welded onto the surface of the panel. Type II panels were employed in the outdoor exposure testing only. Three type II panels were coated with each of the eight coating systems, and three uncoated test panels were employed as controls.

The test surface of each type II panel was divided into the following three areas of varying DFT values as shown in figure 1:

- Nominal: Target DFT.
- Low: DFT is 20 percent less than target DFT.
- High: DFT is 20 percent more than target DFT.

All DFT areas were scribed using a high-speed Dremel® tool.

Test Conditions

Both ALT and outdoor exposure testing were performed to evaluate performance of the coating systems. For ALT, 10 accelerated test cycles (each test cycle was 360 h) using 40 type I panels were conducted for 3,600 h. This method is similar to ASTM D5894-10, with the addition of a freeze cycle for 24 h.[5,6] Outdoor exposure testing was carried out with eight coated and one uncoated type II panels for 6 months at the Golden Gate Bridge in San Francisco, CA. Another outdoor exposure testing was conducted for 10 months using 44 type I and 18 type II panels in the backyard of FHWA's Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA. Among them, four type I and two type II panels were bare steel without coating, and half of the TFHRC exposure panels were salt sprayed once a day.

Performance Evaluation

The following parameters were used to evaluate coating performance:

- Gloss (ASTM D523-08) and color (ASTM D2244-05).[7,8]

Figure 1. Type II test panel.

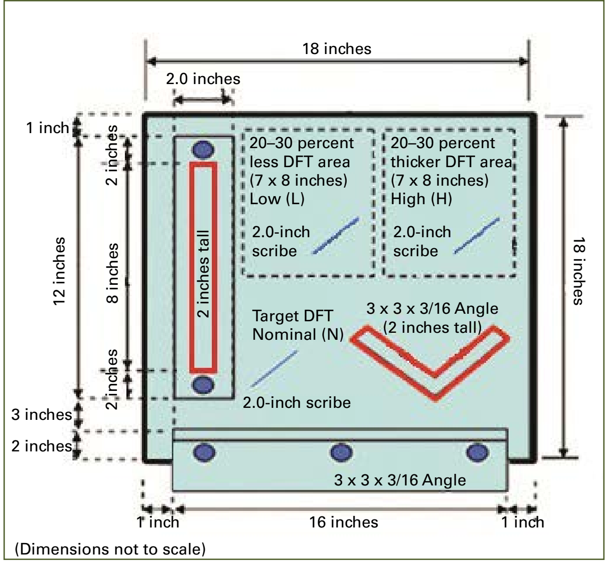

Figure 2. Images of type II test panels.

- Pull-off adhesion (ASTM D4541-09e1).(9)
- Number of coating defects/holidays (ASTM D5162-08).(10)
- Rust creepage (ASTM D7087-05a).(11)

All coating systems were evaluated for color, gloss, rust creepage, and holidays every 360 h in ALT and every 6 months in outdoor exposure conditions. At the termination of the study, all of the above as well as reduction of adhesion strength were evaluated.

Conclusions

Based on the study, the following conclusions were made:

- Test results from this study indicate that none of the selected coating systems, including the two three-coat control coatings, will provide maintenance-free corrosion protection to steel bridge structures for 100 years.
- The two control three-coat systems, IOZ/E/PU and ZE/E/PU (systems 1 and 2) and the one-coat system, HRCSA (system 8), were chosen for their good performance records in earlier FHWA studies. As expected, they performed well, and they were better than the other test coating systems in every category (see figure 3). The remaining five test coating systems, MCU/E/F, ZE/PU, Zn/PS, TSZ/LE, and ZnE/LE, were selected to possibly provide superior performance to commercially available products in the current market. However, they did not deliver desirable performance exceeding the three best coating systems.
- Unexpected premature failure of two of the two-coat systems, TSZ/LE and ZnE/LE (systems 6 and 7), was observed during the study (see figure 4). Their performance was the worst among the eight coating systems and made a negative impact on this study, leading to early termination of the ambitious research. Three test coating systems, MCU/E/F, ZE/PU, and Zn/PS (systems 3, 4, and 5), performed satisfactorily in some categories and poorly in others compared to the best performers. None of them showed consistently good performance.
- It was apparent that cutting-edge coating technology cannot yet deliver super durable coating systems, regardless of cost, that can last more than 100 years without significant maintenance interventions.
- Until future research and development efforts produce coating systems with extended service life, it should be a goal to use the proven legacy coating systems correctly by reducing human errors and improper applications. At the same time, researchers should strive to develop surface-tolerant primers against salt residue, adhered rusts, and mill scale, which is a simple yet reliable in situ test method for surface chloride concentration, as well as allowable chloride contamination(s) on the blasted steel surface. These significant advancements could help create more durable steel bridge coatings.

Figure 3. IOZ/E/PU coating system after 3,600 h in ALT.

Figure 4. ZnE/LE coating system after 3,600 h in ALT.

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