TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

http://www.fhwa.dot.gov/research/

Performance Evaluation of One-Coat Systems on New Steel Bridges

FHWA Publication No.: FHWA-HRT-11-047

FHWA Contact: Paul Virmani, HRDI-60, (202) 493-3052, paul.virmani@dot.gov

This document is a technical summary of the Federal Highway Administration report, *Performance Evaluation of One-Coat Systems on New Steel Bridges* (FHWA-HRT-11-046).

Introduction

The current state of practice in bridge coating usually involves multilayer coating typically consisting of a zinc-rich primer over an abrasive blast-cleaned surface and two additional coating layers on top of the primer. Although this current coating technology provides a comprehensive solution for better corrosion protection of steel bridges, the overall cost involved is relatively higher than its lead-based predecessors. The purpose of this study is to evaluate the performance characteristics of various commercially available high-performance coating materials that can be applied as one-coat systems to steel bridges in shop application.

Eight one-coat systems and two controls, a three-coat system and a two-coat system, were chosen, and their performance was evaluated using accelerated laboratory testing (ALT) and outdoor exposure conditions.

Performance of these coating materials was evaluated on the basis of variations in color and gloss, changes in adhesion strength, changes in pencil scratch hardness, and the development of surface defects (holidays, blisters, and rusting) and rust creepage. Regression analysis was used to identify correlations among the various performance parameters, and a comprehensive system was developed to rank the coating systems based on overall performance.

Approach

Coating Systems

Eight one-coat systems and two controls that performed well in the field and in earlier Federal Highway Administration (FHWA) studies, were evaluated in this study.[1,2] Table 1 lists all of the 10 coatings systems.

Test Panel Preparation

Steel test panels of two sizes were used in this study. The small panels were 4 x 6 x 0.2 inches (10 x 15 x 0.48 cm), and the large panels were 6 x 12 x 0.2 inches (15 x 30 x 0.48 cm). All test panels were blast cleaned to Scientific Society for Protective Coatings

Surface Preparation 10 standard, and coatings were applied on the cleaned test panels using airless spray. Half of the total test panels (111 out of 222) were scribed diagonally following the instructions specified in American Society for Testing Materials (ASTM) D1654-08.[3] Panels were scribed to study the potential performance of the coating systems at local film damage. The other half of the panels were left unscribed to characterize undamaged conditions and physical properties such as gloss, color, pencil scratch hardness, etc. Two additional panels of each coating system were prepared exclusively for initial adhesion strength and Fourier transform infrared spectroscopy; they were not used in any of the tests.

Test Conditions

ALT and outdoor exposure conditions were used to test the coating systems. For ALT, 19 accelerated test cycles (each test cycle = 360 h) were conducted for a total test period of 6,840 h. This method is similar to ASTM D5894-05, with the addition of a freeze cycle for 24 h.[4,5]

Outdoor exposure conditions involved the following:

- Marine environment exposure (ME) occurred in Sea Isle City, NJ, for 24 months.[6]
- Mild natural weathering exposure (NW) occurred at the Turner-Fairbank Highway Research Center (TFHRC) in Mclean, VA, for 18 months.
- Mild natural weathering plus 15 percent salt solution spray (NWS) sprayed manually every 24 h also occurred at TFHRC for 18 months.

Performance Evaluation Techniques

Coatings were evaluated before and after exposure for the following parameters:

- Gloss (ASTM D523-08) and color (ASTM D2244-09A).[7,8]
- Pencil scratch hardness (ASTM D3363-05).[9]
- Pull-off adhesion (ASTM D4541-09).[10]
- Number of coating defects/holidays (ASTM D5162-08).[11]
- Rust creepage (ASTM D7087-05A).[12]

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. Adhesion strength was evaluated once before testing and once at the termination of testing.

Results

Correlation Among Performance Parameters and Exposure Conditions

Correlation among test parameters, such as color or gloss, for various coating systems can help researchers better understand interactions among test variables. This correlation would be specific to the type of exposure condition such as ALT or outdoor exposure testing. Linear regression analysis was performed to identify relationships between the various performance characterization

Table 1. Summary of coating systems.

System Number	System ID	Coating Type		
		Primer	Intermediate	Top
1	Three-coat	Zinc-rich epoxy	Epoxy	Polyurethane
2	Two-coat	Zinc-rich moisture curing urethane		Polyaspartic (ASP)
3	One-coat*	ASP		
4		Epoxy mastic (EM)		
5		Calcium sulfonate alkyd (CSA)		
6		Glass flake reinforced polyester (GFP)		
7		High-build waterborne acrylic (HBAC)		
8		Waterborne epoxy (WBEP)		
9		Polysiloxane (SLX)		
10		Urethane mastic (UM)		

* One-coat systems contain one coat of paint that acts as the primer/top coat and do not contain an intermediate coat.
Note: The blank cell indicates that the two-coat system does not contain an intermediate layer.

parameters. The objective of this analysis was to observe whether any correlation(s) existed among performance parameters. Regression analysis was also performed to examine if any correlations existed between the exposure conditions. Panels with a GFP coating system were not available for outdoor testing. As a result, the GFP system was excluded from the regression analysis.

Performance Ranking

Based on final performance data in ALT and the outdoor exposures, all one-coat systems and the two controls were ranked. A comprehensive numerical analysis was used to assign weighted coefficients to the four exposure conditions. The calculated coefficients for the four exposure conditions are as follows:

- ALT: 0.64.
- ME: 0.11.
- NW: 0.12.
- NWS: 0.13.

Coefficients were also assigned to the performance parameters based on the authors' knowledge and past experience with their overall impact and significance in evaluating a coating system. Weighted coefficients of the various performance parameters are as follows:

- Rust creepage: 0.35.
- Holidays: 0.25.
- Adhesion: 0.10.
- Color reduction: 0.15.
- Gloss reduction: 0.15.

Final performance ranking of all coating systems is shown in table 2.

Table 2. Comprehensive rank of one-coat and control systems.

Coating System	Rank
Three-coat	1
CSA	2
HBAC	3
SLX	4
WBEP	5
ASP	6
Two-coat	7
UM	8
EM	9

Conclusions

- Although some of the one-coat systems demonstrated promising performance, none of the coating systems performed as well as the three-coat control in ALT and outdoor exposure conditions.
- High-ratio calcium sulfonate alkyd performed well in ALT and the outdoor exposures. While this system is limited by its long curing time after application, it presents an interesting alternative for maintenance applications on existing structures.
- Several of the one-coat systems showed promising performance in ALT and the outdoor exposure conditions in terms of surface failures and rust creepage. GFP and HBAC were among the top performing candidates.
- Comprehensive performance evaluation showed that the three-coat system was the best performing system, followed by CSA, HBAC, and WBEP.
- The two-coat system developed many coating defects in ALT and had significant gloss reduction and rust creepage in outdoor exposure conditions, resulting in a low overall ranking.
- Regression analysis showed that color correlated with gloss in all exposure conditions as well as coating defects with adhesion strength variation of unscribed panels in NW.
- NW correlated with NWS for color, gloss, and adhesion strength variations. Similarly, adhesion strength variations of unscribed panels in ME correlated well with unscribed panels of NWS.

References

1. Chong, S.L. and Yao, Y. (2003). *Laboratory Evaluation of Water Borne Coatings on Steel*, Report No. FHWA-RD-03-032, Federal Highway Administration, Washington, DC.

2. Ault, J.P. and Farschon, C.L. (2009). "20-Year Performance of Bridge & Maintenance Systems," *Journal of Protective Coatings and Linings*, 16–32.

3. ASTM D1654-08. (2010). "Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments," *Annual Book of ASTM Standards*, Volume 06.01, ASTM International, West Conshohocken, PA.

4. ASTM D5894-05. (2010). "Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)," *Annual Book of ASTM Standards*, Volume 06.01, ASTM International, West Conshohocken, PA.

5. Chong, S.L., Jacoby, M., Boone, J., and Lum, H. (1995). *Comparison of Laboratory Testing Methods for Bridge Coatings*, Report No. FHWA-RD-94-112, Federal Highway Administration, Washington, DC.

6. Ault, P., Ellor, J., Repp, J., and Shaw, B. (2000). *Characterization of the Environment*, Report No. FHWA-RD-00-030, Federal Highway Administration, Washington, DC.

7. ASTM D523-08. (2010). "Standard Test Method for Specular Gloss," *Annual Book of ASTM Standards*, Volume 06.01, ASTM International, West Conshohocken, PA.

8. ASTM D2244-09A. (2010). "Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates," *Annual Book of ASTM Standards*, Volume 06.01, ASTM International, West Conshohocken, PA.

9. ASTM D3363-05. (2010). "Standard Test Method for Film Hardness by Pencil Test," *Annual Book of ASTM Standards*, ASTM International, Volume 06.01, West Conshohocken, PA.

10. ASTM D4541-09. (2010). "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers," *Annual Book of ASTM Standards*, Volume 06.02, ASTM International, West Conshohocken, PA.

11. ASTM D5162-08. (2010). "Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates," *Annual Book of ASTM Standards*, Volume 06.02, ASTM International, West Conshohocken, PA.

12. ASTM D7087.-05A. (2010). "Standard Test Method for An Imaging Technique to Measure Rust Creepage at Scribe on Coated Test Panels Subjected to Corrosive Environments," *Annual Book of ASTM Standards*, Volume 06.01, ASTM International, West Conshohocken, PA.

Researchers—This study was performed by SES Group and Associates, Chesapeake City, MD, 21915, Contract No. DTFH61-08-D-00001.

Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Divisions and Resource Center.

Availability—This TechBrief may be obtained from FHWA Product Distribution Center by e-mail to report.center@dot.gov, fax to (814) 239-2156, phone to (814) 239-1160, or online at http://www.fhwa.dot.gov/research/.

Key Words—One-coat, Two-coat, Three-coat, Steel bridge coatings, Corrosion protection, Accelerated testing, Outdoor exposure, and Coating performance evaluation.

MAY 2011

FHWA-HRT-11-047
HRDI-60/5-11(600)E