Steel Bridge Design Handbook

Corrosion Protection of Steel Bridges

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Corrosion Protection and Durability Resources

There are several proven ways to protect steel bridges from corrosion, and no single solution is best for all circumstances.

The first consideration when selecting one of these techniques is, of course, a bridge’s anticipated exposure to corrosive elements over its lifetime. In addition, teams must consider initial and life-cycle costs, fabrication, productivity, and long-term performance and maintenance when choosing a corrosion protection approach for a given bridge.

General resources:

- *Volume 10 of The AISC Steel Bridge Design Handbook* focuses on corrosion protection.
- AASHTO’s National Transportation Product Evaluation Program (NTEP) offers a wealth of information about various structural steel coatings.
- The Society for Protective Coatings (SSPC) issues and maintains many coating standards, including the *SSPC Good Painting Practice and Systems and Specifications Manual*. Both the SSPC and the *National Association of Corrosion Engineers (NACE)* provide training and certification for coatings inspectors as well as coating contractors. These certifications help establish a quality threshold for the coatings industry.
Mitigation Strategies for Steel Bridges
What’s Right For you?

- Uncoated Weathering Steel (UWS)
- Liquid Applied Coatings
- Thermal Spray Coatings (TSC, aka - Metallizing)
- Hot-Dip Galvanizing (HDG)
- A709-50CR (previously known as A1010)
The Default System

- Start with the least cost. Move to the next system if there is a compelling reason to do so!
From ASTM A709

- Grade designations ending in “W” are weathering grades.
  - They develop a stable patina that provides barrier corrosion protection
  - The patina controls the rate that oxygen can reach the bare steel underneath

### Uncoated Weathering Steel (UWS)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield Strength (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>50S</td>
<td>50</td>
</tr>
<tr>
<td>50W</td>
<td>50</td>
</tr>
<tr>
<td>HPS 50W</td>
<td>50</td>
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<td>HPS 70W</td>
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<td>50CR</td>
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</tr>
<tr>
<td>QST 50</td>
<td>50</td>
</tr>
<tr>
<td>QST 50S</td>
<td>50</td>
</tr>
<tr>
<td>QST 65</td>
<td>65</td>
</tr>
<tr>
<td>QST 70</td>
<td>70</td>
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</tbody>
</table>
Uncoated Weathering Steel (UWS)

Well formed patina has a dark-chocolate, almost purple hue. Also has fine pinholes.

Provides “barrier” protection
ASTM A709-50CR

- ~11% chrome
- Ferrite / tempered martensite (formally it’s a martensitic stainless steel)
- Develops a brown colored patina like weathering steel

6yr. exposure McLean, VA (vertical)  
3 yr. exposure Hampton Roads, VA (horizontal)  
9 mo. And 3 yr. (inset) exposure North Topsail, NC (vertical)
Modern Liquid Applied Coatings

Types & Definitions:

- **IOZ** – Inorganic Zinc Primer
- **OZ** – Organic Zinc Primer
- **E** – Epoxy (intermediate coat)
- **U** – Urethane (topcoat)

Source: VDOT

Source: FHWA
This bridge utilized the old lead paint systems prior to implementation of current practices.
The Colorful History of Steel Bridge Paint Systems

1960 - 1977: Lead (Alkyd) Paints Widely Used

1990 - 2021: Modern Systems Widely Adopted

The Colorful History of Steel Bridge Paint Systems

- **1960 - 1977**: Lead (Alkyd) Paints Widely Used
- **1977 - 1989**: Lead Still Used Via Exclusion
- **1985 - 1990**: Zinc Rich Primers Adopted
- **1980 - 1990**: Benefits of Surface Preparation Realized
- **1990 - 2021**: Modern Systems Widely Adopted

**Key Events:**
- 1975: Zinc Rich Primers Introduced
- 1977: Lead Paints Banned
- 1980: Blasting Regulation Implemented
- 1992: VOC Regulations - Eliminate Vinyl Paint
Old Liquid Applied Coatings
Modern Liquid Applied Coatings

This bridge utilized a modern 3-coat paint system. Built in 1998.
Liquid Applied Coatings

- Primarily “barrier” protection, however zinc-rich primer provides “cathodic” protection if exposed
Liquid Applied Coatings – Cost Implications

![Graph showing coating thickness and dry/recoat time](https://data.ntpep.org/SSC)

Source: Random selection of qualified systems from http://data.ntpep.org/SSC (except for single-coat IOZ)


Consult With Local Fabricator
Liquid Applied Coatings

Workhorse systems
• 3-coat, OZ/Epoxy/Urethane
• 3-coat, IOZ/Epoxy/Urethane

Innovative systems
• IOZ only
• IOZ with acrylic topcoat
• 2-coat, OZ/polyaspartic
Tappan Zee Replacement

- Considered metalizing, IOZ, OZ
- Chose OZ due to time savings
Thermal Spray Coatings (TSC) – aka Metallizing

Common Alloys
Aluminum (Al)
85/15 (Zn/Al) -------------- Most common
Zinc (Zn)
Thermal Spray Coatings (TSC)

Source: FHWA
Thermal Spray Coatings (TSC)

- TSC are porous – sealing is common, but not necessary
- Sealers are low-viscosity, liquid applied coatings meant to penetrate through pores
- Mechanical process, whereas HDG is chemical process

Mostly “cathodic” protection
Hot-Dipped Galvanizing

- Dipping steel in ~830°F zinc creates the chemical bond

Both “barrier” and “cathodic” protection

Source: VDOT

Source: AGA

η
100% Zn

ζ
94% Zn

δ
90% Zn

Source: AGA
Hot-Dipped Galvanizing

- Steel immersed in bath (kettle) of molten zinc (~830 F)
- Bath chemistry >98% pure zinc
  - Up to 2% additives (Al, Bi, Ni)
- Molten zinc reacts with iron in steel to form metallurgically-bonded coating
- Reaction is complete when steel reaches bath temperature
Hot-Dipped Galvanizing

Surface Preparation

Degreasing  Rinsing  Pickling  Rinsing  Flux solution  Drying  Zinc bath  Cooling and inspection

Source: AGA
Hot-Dipped Galvanizing – Surface Preparation

• Thorough cleaning is necessary as zinc will only react with clean steel

• Three cleaning solutions:
  • **Degreasing** – removes dirt, oils, organic residue
  • **Pickling** – removes mill scale and oxides
  • **Fluxing** – mild cleaning, protective layer

• Unclean areas will not grow zinc coating
Relative Cost of Coating Systems
2020 Cost of Coatings Survey

Relative % cost increase* over ASTM A709 Grade 50W (unpainted)

Note: VERY important to know the capability and expertise of the local fabricators regarding TSC!!!

* - defined as FOB cost delivered to jobsite.
• Start with the least cost. Move to the next system if there is a compelling reason to do so!

Recall……The Default System

UWS → Paint → TSC → Galv → 50CR
Cost of Corrosion Protection Example

Total Length = 350 ft (2-175 ft spans)
Width = 60 ft
Total Area = 350 ft x 60 ft = 21,000 ft²
Using NSBA Span/Weight Curves:
Assuming: 2-span, 9’ to 11’ girder spacing, 175’ span length, routine fabrication

- Weight of steel = 35 psf

Total weight of steel = 21,000 ft$^2$ x 35 psf
- 735,000 lbs = 368 tons
Example (cont)

For straight, routine, steel bridge – for illustration purposes......assume $1.00/lb (UWS) for fabrication and delivery

\[ 735,000 \text{ lbs} \times \$1.00/\text{lb} = \$735,000 \text{ cost of steel for fab and delivery} \]
Example (cont)

Compare to other systems

- UWS Cost = $735,000 (baseline)

<table>
<thead>
<tr>
<th>System</th>
<th>% Inc</th>
<th>$/lb</th>
<th>$ Steel</th>
<th>Diff from Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIOZ</td>
<td>6%</td>
<td>$1.06</td>
<td>$779,000</td>
<td>$44,000</td>
</tr>
<tr>
<td>OZ/E/P*</td>
<td>13%</td>
<td>$1.13</td>
<td>$831,000</td>
<td>$96,000</td>
</tr>
<tr>
<td>TSC/HDG</td>
<td>30%</td>
<td>$1.30</td>
<td>$956,000</td>
<td>$221,000</td>
</tr>
</tbody>
</table>

* - IOZ/E/P is an approximate 16% increase over UWS
Thank you
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