Weathering Steel: Use and Maintenance Options

Harry L. White 2nd
Transportation Research and Development Bureau
Office of Technical Services
2015
History of Weathering Steel

• Originally Developed in 1930s for Coal Cars
• First Used in Bridges in 1960s
• Limitations on Weathering Steel Use
  – 1980: Michigan DOT Banned Weathering Steel
  – 1982/1995 - AISI Reports
  – 1989 - FHWA Technical Advisory
  – 1990 - Michigan Rescinded Ban
• NYSDOT: 2,466 Spans of Weathering Steel
Stages of Patina Formation

0.5 months 1.5 months 6 months 2 years 5 years 22 years 40 years
Corrosion Products

• Goethite ($\alpha$-FeOOH)
  – 80% of Protective Rust
• Lepidicrocite ($\gamma$-FeOOH)
  – 20% of Protective Rust
• Maghemite ($\gamma$-Fe$_2$O$_3$)
  – Non-Protective
  – Resulting from excessive wetness
• Akaganeite ($\beta$-FeOOH)
  – Non-Protective
  – Resulting from Chloride/Sulfide contamination
FUN FACTS ABOUT SALT WATER

• The ocean is 3.5% salts
• NYSDOT Brine solution is 28% salt
• NYSDOT uses 200 lbs. salt/lane mile
• Salt Spray has been measured as high as the 59th floor of high rise buildings
• Road salt spray is as concentrated as sea water 400 ft. away from a high traffic roadway
Bridge Near Rochester
Bridge Near Rochester

![Bridge Near Rochester Image](image-url)
I-81 North of Syracuse
I-81 North of Syracuse
I-81 Near Watertown
Built in 1993
Moore Drive

- Rochester, NY
- Goes over I-390 and the Erie Canal
- Uncontrolled Corrosion Noticed
- Regional Survey Indicates Other Locations
Findings

• 3.0+ mil/year at Moore Drive
  – 0.1 mil/year in a good environment
• Corrosion Study on Steel Coupons Initiated
• 1, 2, 4 and 8 years for coupon analysis
• Corrosion monitor failed in 1 year due to cold
• Sheet rust on all surfaces
Results of Initial Study

• Led to 2004 Changes in Bridge Manual
  – Add $\frac{1}{16}$” per exposed face
  – Paint Steel Near Joints
  – Paint length Along Girder is 1.5 x Beam Depth
• New Bridge Washing Specification
  – 3,000 psi minimum
Chateaugay River Bridge: Visual Corrosion Conditions

Salt Build-up on fascia of Girder 201N at Pier#2, (2014).

Heavy Loose Rust on Fascia/Stiffener G101N at Pier #2, Sample 26 (2014).

Low Corrosion on G101S, Interior (south) of North Facia Girder, (2014)

Heavy Loose Rust on G101N Fascia and Splice Plates (2013)
Route 11 over Chateaugay River
Way Up There
Chateaugay River Bridge: Rte 11 Looking East
26 Samples from Pier #1
Girders 1, 5
Leaking Joint at P#2
Total Length 760 ft.
7 spans
5 WS Beams

W E
Chateaugay River Bridge: Visual Corrosion Conditions

Salt Build-up on fascia of Girder 201N at Pier#2, (2014).

Heavy Loose Rust on Fascia/Stiffener G101N at Pier #2, Sample 26 (2014).

Low Corrosion on G101S, Interior (south) of North Facia Girder, (2014)

Heavy Loose Rust on G101N Fascia and Splice Plates (2013)
# Explanation of Rust Compositions

**Typical Protective Adherent Rust on Weathering Steel**
- **A:** 0  (10%) allowed
- **L:** 40 - 20%
- **G:** 60 - 80%

**Medium chloride and corrosion on Weathering Steel**
- **Non-Adherent Rust**
- **A:** 40 - 60%
- **L:** 10 - 20%
- **G:** 30 - 50%

**High Chloride and Corrosion of Weathering Steel**
- **Non-Adherent Rust**
- **A:** 80 - 90%
- **L:** 5 - 10%
- **G:** 5 - 15%
- **A:** Akaganeite
- **L:** Lepidocrocite
- **G:** Goethite
### Chateaugay River Bridge Rust Compositions

**All Rust Outer Layer (Type 1 on sample bottles)**

#### Girder 101

<table>
<thead>
<tr>
<th>Component</th>
<th>Cl%</th>
<th>XRD</th>
<th>Ciment</th>
<th>XRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>(fascia)</td>
<td>7.7</td>
<td>A: 52%</td>
<td>L: 5%</td>
<td>G: 43%</td>
</tr>
<tr>
<td>(fascia)</td>
<td>4.6</td>
<td>A: 62%</td>
<td>L: 7%</td>
<td>G: 31%</td>
</tr>
<tr>
<td>(fascia)</td>
<td>6.4</td>
<td>A: 57%</td>
<td>L: 5%</td>
<td>G: 38%</td>
</tr>
</tbody>
</table>

#### Girder 105

<table>
<thead>
<tr>
<th>Component</th>
<th>Cl%</th>
<th>XRD</th>
<th>Ciment</th>
<th>XRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>(fascia)</td>
<td>5.0</td>
<td>A: 48%</td>
<td>L: 16%</td>
<td>G: 36%</td>
</tr>
<tr>
<td>(fascia)</td>
<td>4.9</td>
<td>A: 64%</td>
<td>L: 6%</td>
<td>G: 30%</td>
</tr>
<tr>
<td>(fascia)</td>
<td>5.2</td>
<td>A: 62%</td>
<td>L: 6%</td>
<td>G: 32%</td>
</tr>
</tbody>
</table>

**Stiffener**

- Millscale Present
- Girder 1 Interior

<table>
<thead>
<tr>
<th>Component</th>
<th>Cl%</th>
<th>XRD</th>
<th>Ciment</th>
<th>XRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>cN</td>
<td>1.7</td>
<td>A: 16%</td>
<td>L: 18%</td>
<td>G: 66%</td>
</tr>
<tr>
<td>cS</td>
<td>3.7</td>
<td>A: 63%</td>
<td>L: 6%</td>
<td>G: 31%</td>
</tr>
</tbody>
</table>

**Bridges**

- N (fascia) - S (fascia)
- S (Interior) - N (Interior)

**Notation**

- cN, cS: Calcium Oxide
- eN, eS: Ferrous Oxide
- gN, gS: Magnesium Oxide
- fN, fS: Sulfur Oxide
Summary of Findings

• Fascia Girders heavily corroded on exterior Surfaces due to Chlorides.
• Non-protective Rust present on both exterior Fascia Girders.
• North and South fascias have similar corrosion characteristics (58% Akaganeite, 6% Chloride).
• HOWEVER amount of Akaganeite (58%) much less than Moore Drive Bridge ROC (>90%).
• Interior of fascia girders much lower corrosion except bottom flange.
• Corrosion initiated by wind driven saltwater run-off from pavement.
• Akaganeite and Chloride too high on interior of fascias for protective patina.
• Chloride data appears too high for % Akaganeite formed (RECENT CHANGE IN SALTING PROTOCOLS?).
Salt Build-up on fascia of Girder 201N at Pier#2, (2014).

Heavy Loose Rust on Fascia/Stiffener G101N at Pier #2, Sample 26 (2014).

Low Corrosion on G101S, Interior (south) of North Facia Girder, (2014)

Heavy Loose Rust on G101N Fascia and Splice Plates (2013)
Diaphragm Mid-Span Between Pier 3 and Pier 4
Diaphragm Over Pier 3
Moore Dr. v. Route 11

- Route 11 bridge rust is different than Moore Dr.
- Moore Dr. is worse – all interior surfaces are corroded similar to fascia of Route 11 bridge
- 1.5 – 2.0 times as bad as Route 11 bridge in intensity
- Chlorides > 1.0% prohibits protective patina formation
- Moore Drive is highest at the steel surface
- Brines are creating issues above what happened before
- CAG wants to redo Moore Drive rust profile/analysis along with Chateaugay and Maryland Bridges
- CAG wants to redo the rust profiles after
Integral Abutment Bridges
Capillary Corrosion
NOTE:

THE UNPAINTED WEATHERING STEEL STRINGER (or girder) AND ATTACHED PLATES EMBEDDED IN THE ABUTMENT (or in the concrete end diaphragm) AND WITHIN 12” OF THE ABUTMENT FACE (or face of the concrete end diaphragm) SHALL BE PAINTED IN ACCORDANCE WITH THE STANDARD SPECIFICATIONS. THE FINISH COAT COLOR SHALL MATCH COLOR CHIP NO. 30045 OF FEDERAL STANDARD 595B. THE STEEL DIAPHRAGM SHALL NOT BE PAINTED.
Current Activities

• Re-write Bridge Inspection Manual
  – Inspectors Aware and Report to Bridge Maintenance
  – Easily Corrected but Will Cause Future Problems

• Evaluate the Efficacy of the 2004 Changes Regarding Weathering Steel
  – Painting Steel Beam Ends
  – Overhang Minimums
  – Bridge Washing

• Re-write Bridge Manual
  – Experience and European/Other State DOT Standards
Bridge Washing

• Studies Show Effects of Washing are Positive
  – Pressure
  – Volume
  – Temperature
  – Duration
  – Interval

• No Definitive Study
Weathering Steel is Different

• Item 641.(310/320/330)nn 16 – Maintenance Cleaning of Weathering Steel Bridges
  – Water Pressure of 1,750-2,000 psi
  – Wand Held 6-12 in. from surface

• Item 641.340nn 16 – Maintenance Cleaning of Weathering Steel Bridges
  – Water Pressure of 3,000 psi minimum
  – Wand Held Perpendicular and <12 in. from Surface
BRIDGE WASHING EFFECTIVENESS
= Flow + Time + Energy + Frequency
As a general guideline, the minimum cleaning pressure for loose rust and paint is 4,500 psi (31 MPa); for most paints and moderate rust, it is 10,000-15,000 psi (69-103 MPa); for heavy rust, it is 15,000 psi to 30,000 psi (103-207 MPa).

- Lydia Frenzel, PhD
UPCOMING TRIALS

• Ultra-High Pressure Water Jetting
  – >40,000 psi
  – Removes >95% of all Surface Salts
    • Chlorides
    • Sulfates
    • Nitrates
  – No Containment or Disposal
CONCLUSIONS
• Proper Site Location
  – Proper Macro-Climate
  – Proper Micro-Climate
  – Chloride Laden Water/Dust
    • Run-Off
    • Dripping
    • Blowing
    • Scuppers

• Chloride Laden Spray
  – Reaches up to 25 ft. high with high speed traffic
  – Can go up to 400 ft. laterally