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**Corrosion Resistance of A709 Grade 50CR Steel –
Applications for Bridges in Corrosive Environments**

September 10, 2019



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Course Description

Corrosion Resistance of A709 Grade 50CR Steel – Applications for Bridges in Corrosive Environments
September 10, 2019

ASTM A709 Grade 50CR, also specified as ASTM A1010, is a utility-grade stainless steel which performs well in corrosive environments. To date, six bridges have been constructed in five different states across the United States, with more bridges planned. Material availability and compatibility with other common bridge steels have driven recent research addressing weldability, bolted connections, and galvanic corrosion. This webinar will provide an introduction to the material properties of A709 50CR, a summary of recent applications, and a review of recent and ongoing research.



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Learning Objectives

- List the environments where corrosion can impact the service life and safety of structures.
- Identify the fabrication and inspection practices that have been employed for safe application of A709 Grade 50CR steel.
- Describe galvanic corrosion and crevice corrosion, and identify the detail features that give rise to these processes.
- Compare, quantitatively and aesthetically, the corrosion performance of A709 Grade 50CR steel when subjected to different types of blast media.



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Corrosion Resistance of A709 Grade 50CR Steel – Applications for Bridges in Corrosive Environments



NSBA/AISC Webinar
September 10, 2019

Matthew H. Hebdon, Ph.D., P.E.
Virginia Tech
Blacksburg, Virginia



COLLEGE OF ENGINEERING
THE CHARLES E. VIA, JR. DEPARTMENT OF
CIVIL AND ENVIRONMENTAL ENGINEERING
VIRGINIA TECH.



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Outline

- Background
 - History/material
- US Bridge Projects
 - Summary
 - VDOT Bridge
- Research
 - Corrosion study at VT



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Corrosion



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Corrosion



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Corrosion

- Significant Impact on life-cycle cost



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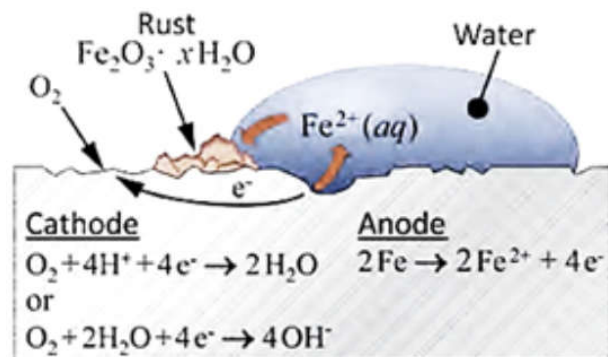
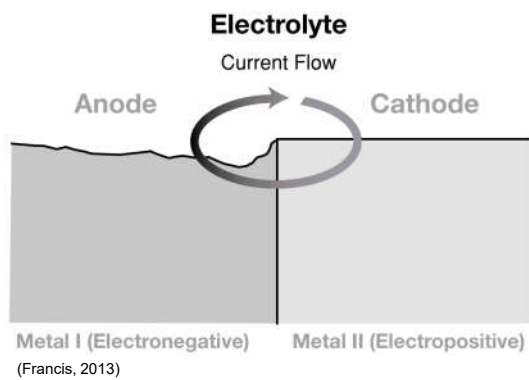
Corrosion

- Significant Impact on life-cycle cost



Corrosion

- Electro-chemical process



Corrosion

- Corrosion prevention = environment specific



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Corrosion

- Active corrosion
 - Large corrosion product
 - Continual flaking away

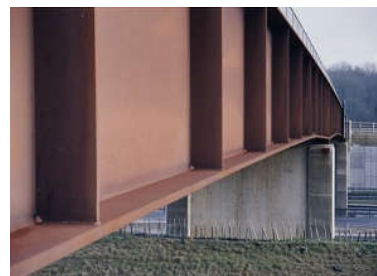


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Corrosion

- Active corrosion
 - Large corrosion product
 - Continual flaking away
- Passive corrosion
 - Small corrosion product
 - Tight adherence



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ASTM A709 Grade 50CR (A1010)

- UNS S41003
 - ArcelorMittal – US Market
 - Marketed as Duracorr®
 - Corrosive applications



(ArcelorMittal, 2015)



(ArcelorMittal, 2015)



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ASTM A709 Grade 50CR (A1010)

- UNS S41003
 - ArcelorMittal – US Market
 - Marketed as Duracorr®
 - Corrosive applications
 - Attractive for Bridges
 - Improved corrosion resistance
 - Economical
 - Incorporated into A709 in 2017



(ArcelorMittal, 2015)



(ArcelorMittal, 2015)

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ASTM A709 Grade 50CR (A1010)

- Material properties
 - Dual-phase stainless steel
 - Ferrite/tempered martensite
 - 10.5%-12.5% Chromium
 - 1.5% Nickel

	Chemical Composition, % wt.				
	50 (A709)	50W (A709)	50CR (A709)	316L (A240)	2205 (A240)
C	0.23	0.19	0.03	0.03	0.03
Mn	1.35	0.80-1.25	1.50	2.00	2.00
P	0.03	0.03	0.04	0.045	0.03
Si	0.40	0.30-0.65	1.00	0.75	1.00
Cr	-	0.40-0.65	10.5-12.5	16.0-18.0	22.0-23.0
Ni	-	0.40	1.50	10.0-14.0	4.5-6.5

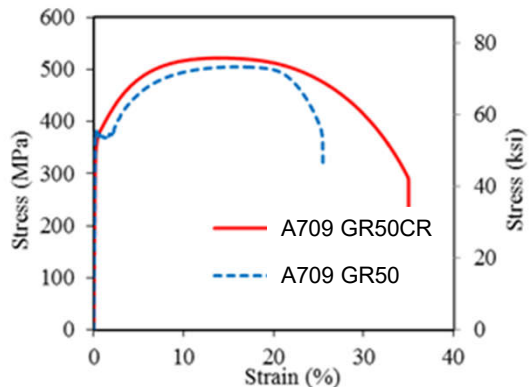
Note: Maximum, unless range indicated

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ASTM A709 Grade 50CR (A1010)

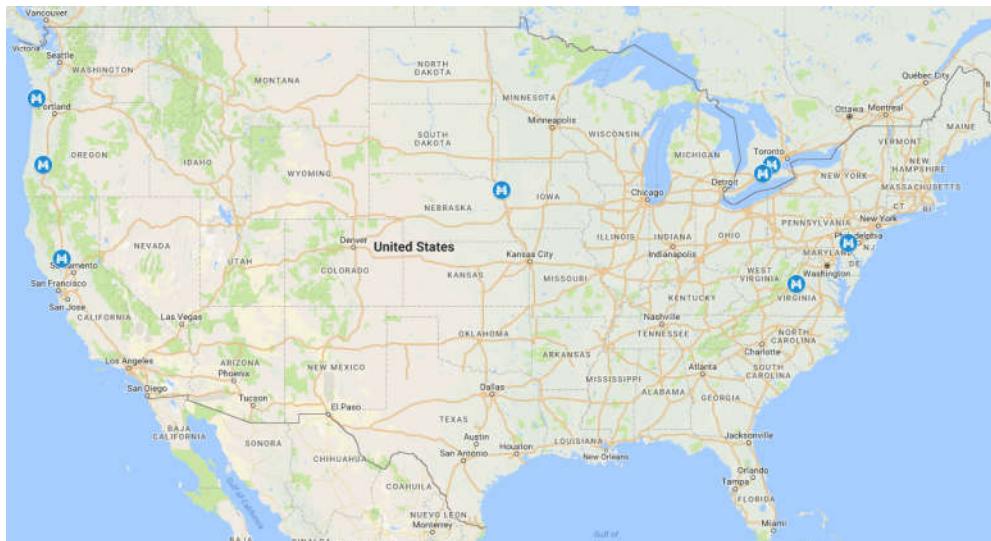
- Material properties
 - Dual-phase stainless steel
 - Ferrite/tempered martensite
 - 10.5%-12% Chromium
 - 1.5% Nickel
 - Mechanical behavior similar to A709 GR50



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North American A709 GR50CR Projects



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Fairview Road Bridge

- Colusa County, CA, 2004: (2) 35 ft spans
- FHWA IBRC program
- Multi-cell bridge girder modules



(Fletcher, 2011)

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ArcelorMittal Bridge

- Coatesville, PA, 2012: (2) 49 ft spans
- 1st A1010 plate girder bridge in US
- Plate thicknesses: 3/8" – 1½"



(ArcelorMittal, 2015)

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Dodge Creek, Mill Creek Bridges

- Sutherlin, OR, 2012: 132.5 ft span
 - High time-of-wetness (TOW)
- Astoria, OR, 2013: 123 ft span
 - Columbia River estuary



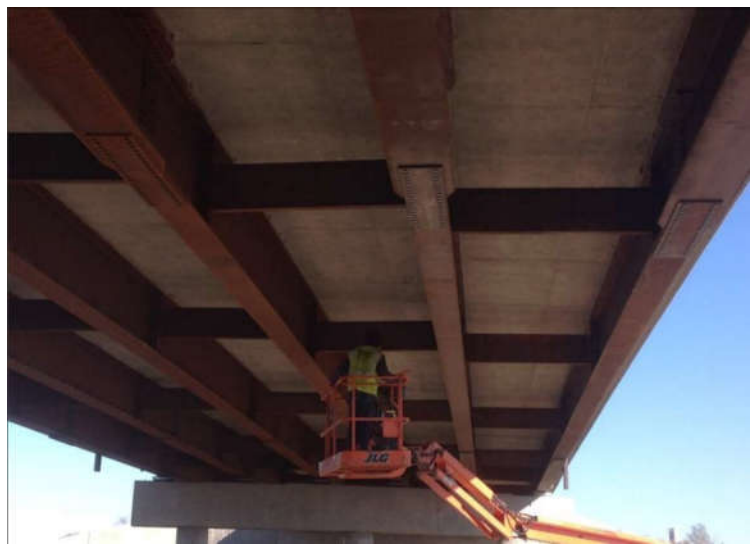
Mill Creek Bridge (Seradj, 2015)

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Salix Interchange Bridge

- Salix, IA, 2016
- 4-span bridge
 - 81.5 ft, 120 ft, 120 ft, 81.5 ft
- 6 girder lines
 - 2 A1010 girder lines
 - Fascia, 1st interior



(Iowa DOT, 2016)

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Route 340 Bridge

- Waynesboro, VA, 2017
- Why A1010?
 - Industrial site upstream of bridge
 - Proximity to water



(Courtesy of VDOT)

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Route 340 Bridge

- Waynesboro, VA, 2017
- Why A1010?
 - Industrial site upstream of bridge
 - Proximity to water
 - Aesthetics



(Courtesy of VDOT)



(Courtesy of VDOT)

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Route 340 Bridge

- 2 equal spans of 110 ft
- 1st A1010 Bridge to include:
 - Haunched girders
 - Bolted splice w/ SS fasteners
 - A1010 cross-frames
 - Non-metallic blast cleaning



(Courtesy of VDOT)

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Route 340 Bridge: Fabrication

- Safety: Hexavalent chromium in fumes
- Cannot be cut w/ traditional oxy-acetylene
 - Use plasma, laser, or water jet
- Dedicated shop area and tools
- Similarities to A709 GR50
 - Drilling, bending, grinding



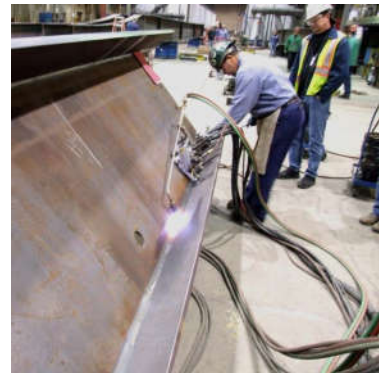
(Courtesy of VDOT/ High Steel Structures)

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Route 340 Bridge: Welding

- 309L Electrodes
 - Buy America challenges
 - 309L-C electrodes produced (1st time used)
- Interpass temp. limitations
- SAW process
 - Same as Oregon bridges



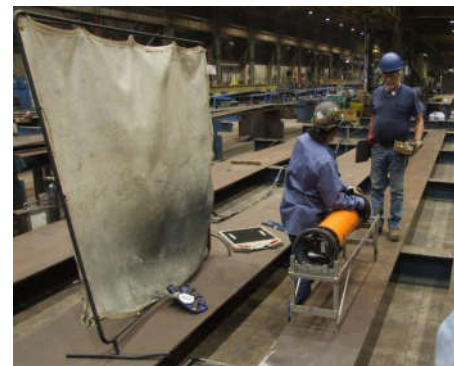
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Route 340 Bridge: NDE

- Dye Penetrant – OK
- Mag Particle
 - Non magnetic
- Ultrasonic (UT)
 - Sensitive to grain size
- Radiographic (RT)
 - Challenges w/ thin plate



(Courtesy of VDOT/ High Steel Structures)

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Route 340 Bridge: Bolting

- Stainless steel fastener assemblies
 - ASTM A193 Grade B8 bolts, A194 nuts, 303 Washers
- New tightening specs required
 - Less force per bolt than A325 bolts (30 kips vs. 39 kips)
 - Lubrication is critical



(Courtesy of VDOT)

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Route 340 Bridge: Cross-frames

- A1010 rolled shapes not currently available
- Bent shapes from A1010 plate



(Courtesy of VDOT/High Steel Structures)

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Route 340 Bridge: Erection

- Began placing girders in December 2016



(Courtesy of VDOT)

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Route 340 Bridge: Finished Surface

- Girders arrived on 3 separate days:
 - Day 1: Clear, sunny day
 - Day 2: Snow showers, de-icing salts applied to roadway
 - Day 3: Rain showers



(Courtesy of VDOT)

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Route 340 Bridge: Finished Surface

- Girders arrived on 3 separate days:
 - Day 1: Clear, sunny day
 - Day 2: Snow showers, de-icing salts applied to roadway
 - Day 3: Rain showers



(Courtesy of VDOT)

Day 1

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Route 340 Bridge: Finished Surface

- Girders arrived on 3 separate days:
 - Day 1: Clear, sunny day
 - Day 2: Snow showers, de-icing salts applied to roadway
 - Day 3: Rain showers



(Courtesy of VDOT)

Day 1

Day 2

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Route 340 Bridge: Finished Surface

- Girders arrived on 3 separate days:
 - Day 1: Clear, sunny day
 - Day 2: Snow showers, de-icing salts applied to roadway
 - Day 3: Rain showers



(Courtesy of VDOT)

Day 1

Day 2

Day 3

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Research Motivation

- Dissimilar connection cases
- Determine corrosion rates
- Recommend materials

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Research Motivation

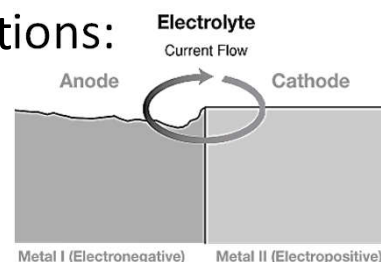
- 4 primary concerns for bridge applications:
 - General corrosion



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Research Motivation

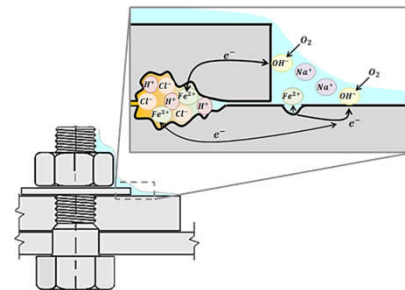
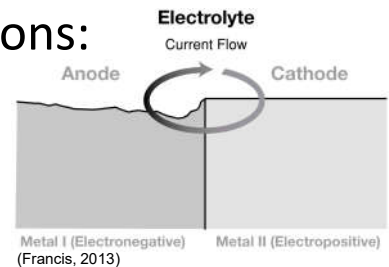
- 4 primary concerns for bridge applications:
 - General corrosion
 - Galvanic corrosion
 - Dissimilar metals
 - Connections



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Research Motivation

- 4 primary concerns for bridge applications:
 - General corrosion rate
 - Galvanic corrosion
 - Dissimilar metals
 - Connections
 - Crevice corrosion
 - Moisture infiltration
 - Increased acidity

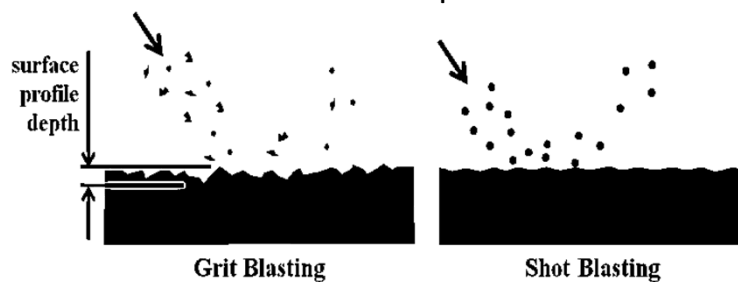


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Research Motivation

- 4 primary concerns for bridge applications:
 - Surface preparation
 - Abrasive blasting after fabrication
 - Multiple types of blast media available
 - Effect of blast media on surface profile

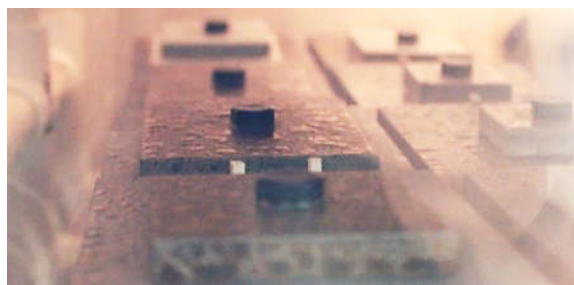


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Corrosion Research

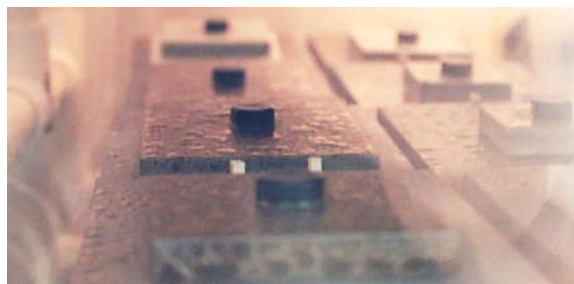
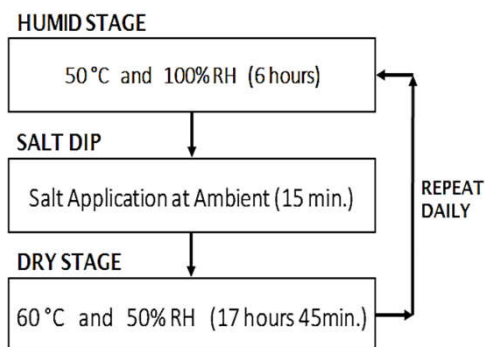
- Accelerated cyclic corrosion testing
 - Modified SAE J2334 Surface Vehicle Standard
 - Produced corrosion products expected in service



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Corrosion Research

- Accelerated cyclic corrosion testing
 - Modified SAE J2334 Surface Vehicle Standard
 - Produced corrosion products expected in service



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Corrosion Research

- Specimen types:
 - Control plate specimens:
 - A1010, A709 (50, 50W, 50 HDG)
 - Galvanic corrosion plate specimens:
 - A1010 attached to A709 (50, 50W, 50 HDG)
 - Galvanic corrosion fastener specimens:
 - A1010 plate attached to A325 (1, 3), A490, A325 HDG, A193 B6, A193 B8
 - Crevice corrosion plate specimens:
 - A1010 plate attached to A1010 plate
 - Surface preparation specimens:
 - 3 types of grit media



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Corrosion Research

- Data analysis
 - Photographic timeline of corrosion condition
 - Mass/thickness loss measurements (per ASTM G1)
 - HDG coating thickness measurements
 - Linear regression analysis (OLS) & statistical hypothesis testing

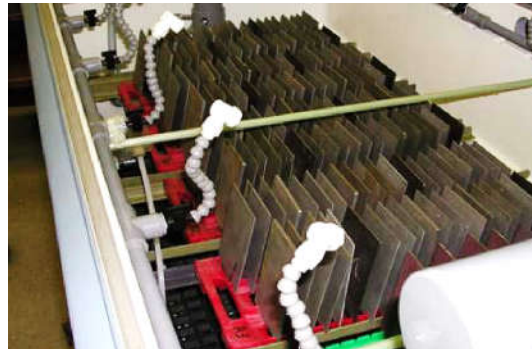


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Research: General Corrosion

- FHWA (2011)
 - A1010 Corrosion rate:
 - $10x < GR50W$
 - Near-vertical orientation



(Fletcher, 2011)



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Research: General Corrosion

- FHWA (2011)
 - A1010 Corrosion rate:
 - $10x < GR50W$
 - Near-vertical orientation
- VT (2017)
 - Affected by Orientation
 - $10x < -$ Near-vertical
 - $4x < -$ Near-horizontal



(Fletcher, 2011)



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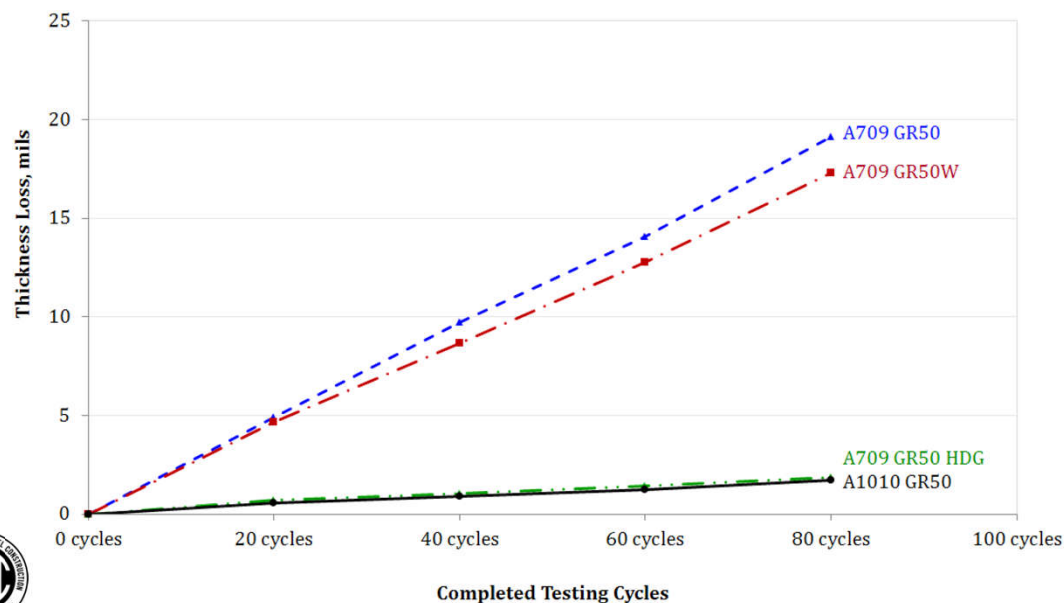
Research: General Corrosion

- 4 Common bridge materials
 - A709 GR50
 - A709 GR50W
 - A709 GR50 HDG
 - A709 GR50CR (A1010)



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Research: General Corrosion

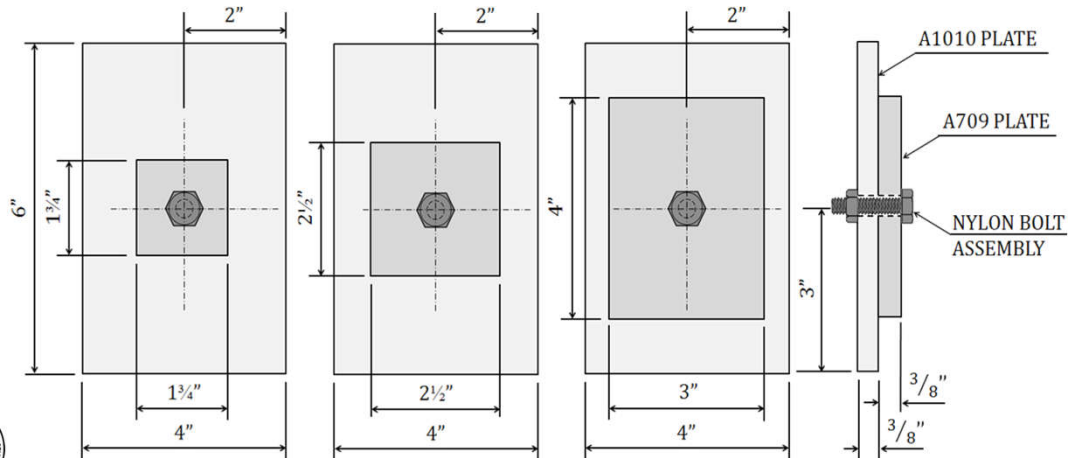


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Research: Galvanic Corrosion

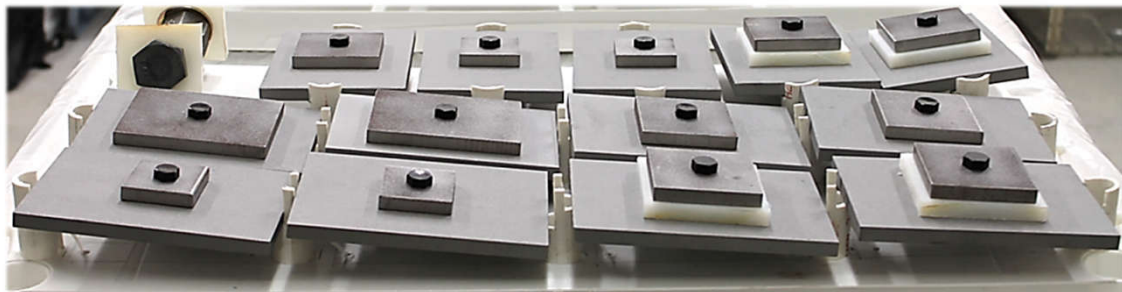
- A1010 plates w/ dissimilar carbon steel plate



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Research: Galvanic Corrosion

- A1010 plates w/ dissimilar carbon steel plate



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Research: Galvanic Corrosion

- A1010 plates w/ dissimilar carbon steel plate

Corrosion Rate ($\mu\text{m}/\text{cycle}$)				
	A1010 Plate		Carbon Steel Plate	
	Control	Galvanic	Control	Galvanic
A709 Gr50	1.95	1.46	8.39	8.93
A709 Gr50W	1.79	1.80	8.06	9.09
A709 Gr50 HDG	1.44	0.85	1.62	2.68



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Research: Galvanic Corrosion

- A1010 plates w/ dissimilar carbon steel plate

Corrosion Rate ($\mu\text{m}/\text{cycle}$)				
	A1010 Plate		Carbon Steel Plate	
	Control	Galvanic	Control	Galvanic
A709 Gr50	1.95	↓ 1.46	8.39	↑ 8.93
A709 Gr50W	1.79	1.80	8.06	↑ 9.09
A709 Gr50 HDG	1.44	↓ 0.85	1.62	↑ 2.68

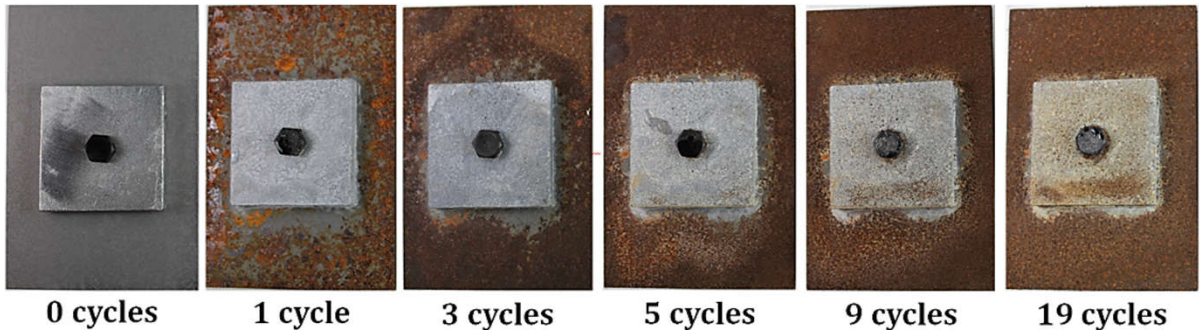


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Research: Galvanic Corrosion

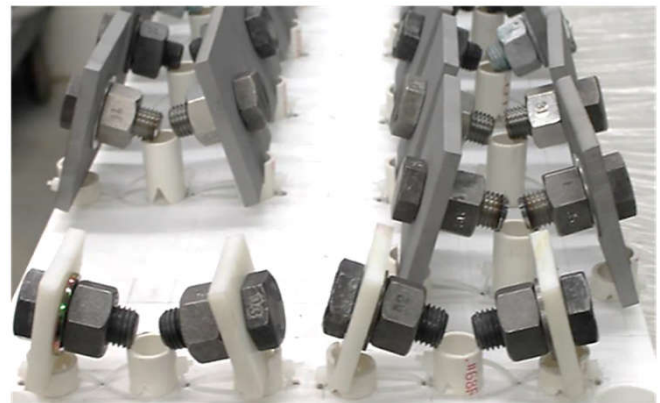
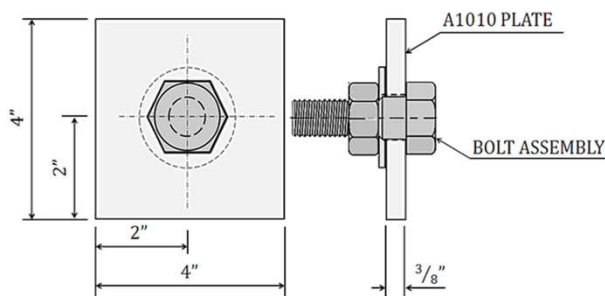
- A1010 plates w/ dissimilar carbon steel plate
– HDG specimens



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Research: Galvanic Corrosion

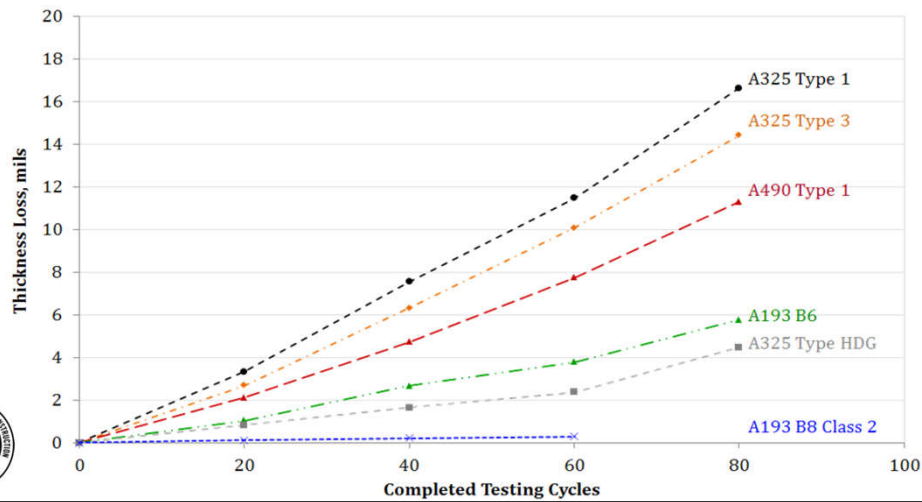
- A1010 plates w/ dissimilar fasteners



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Research: Galvanic Corrosion

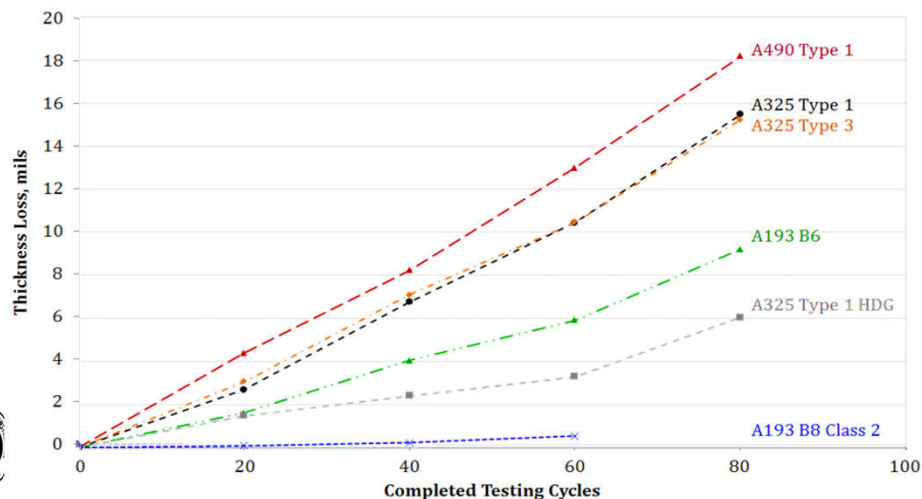
- Control fastener specimens



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Research: Galvanic Corrosion

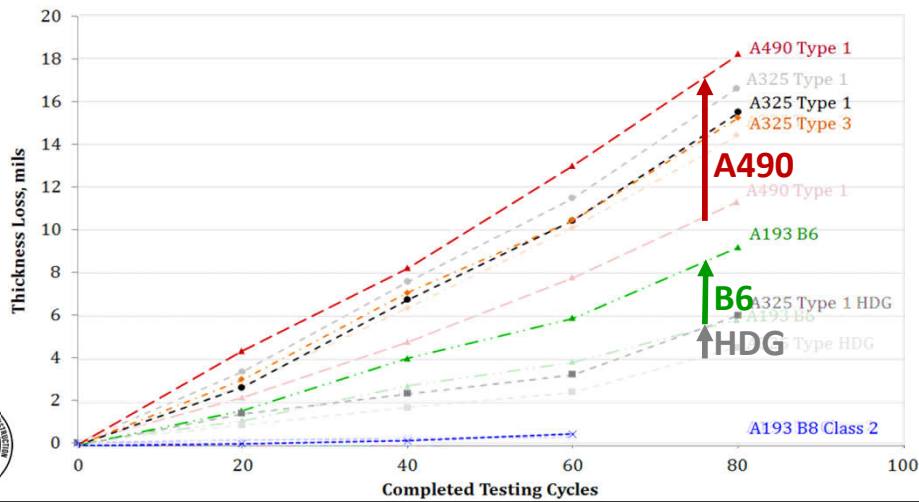
- A1010 plates w/ dissimilar fasteners



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Research: Galvanic Corrosion

- A1010 plates w/ dissimilar fasteners



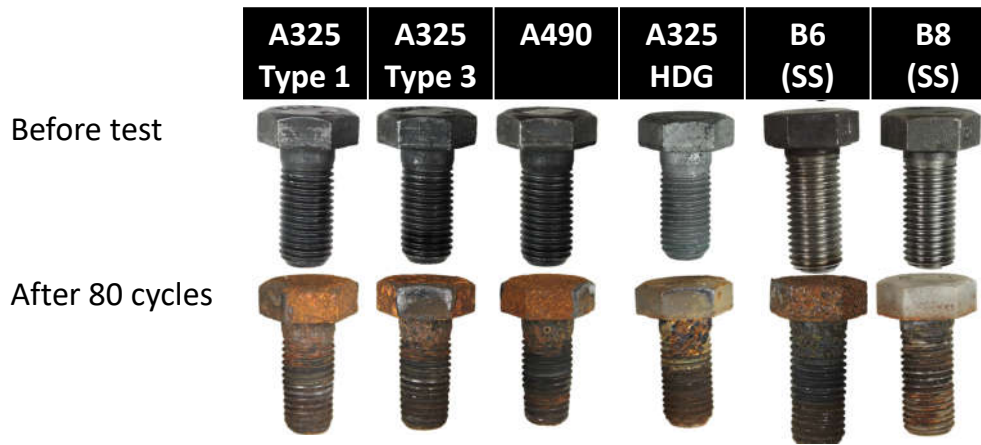
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Research: Galvanic Corrosion



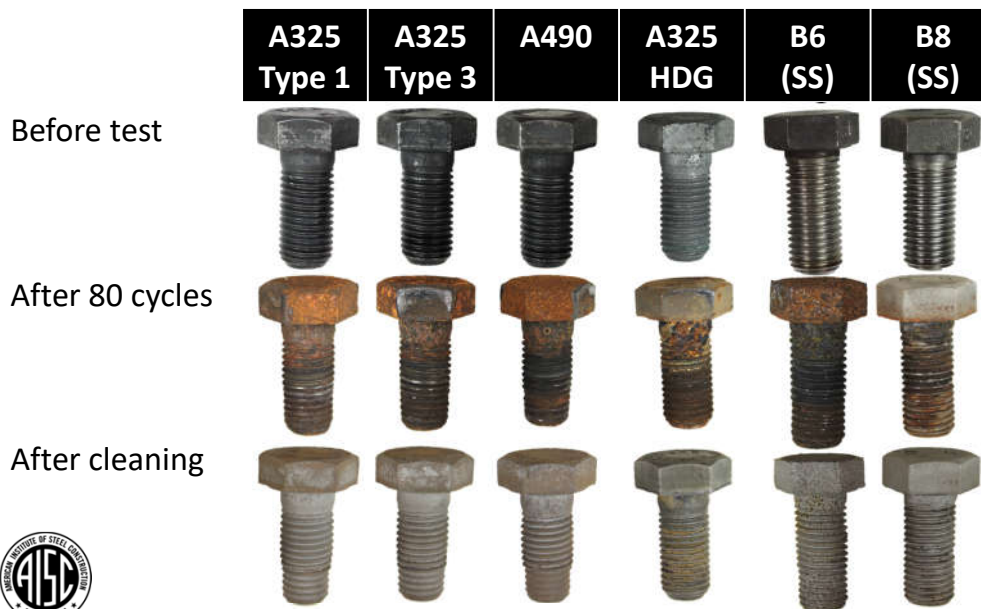
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Research: Galvanic Corrosion



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Research: Galvanic Corrosion

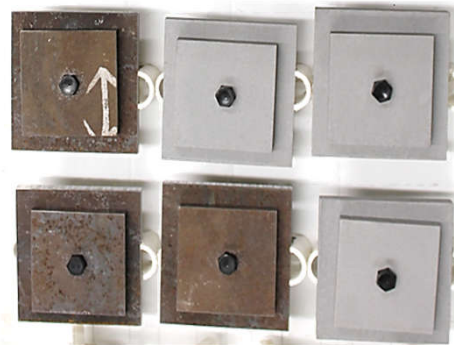
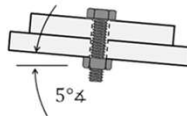
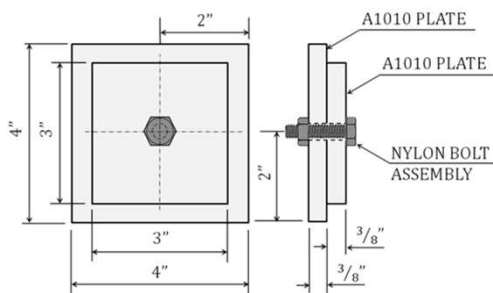


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Research: Crevice Corrosion

- A1010 to A1010 plates



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Research: Crevice Corrosion

- A1010 to A1010 plates
 - Corrosion rate = ~4x A1010 control plates
~1/4x GR50W control plates
 - Significant contribution to galvanic corrosion



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Research: Crevice Corrosion



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Research: Surface Preparation

- 3 types of media tested



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Research: Surface Preparation

- Garnet & steel shot
 - 0.01 mils/cycle
- Aluminum oxide & No prep.
 - 0.02 mils/cycle
- Grit media
 - More uniform appearance at early stages of corrosion



Research: Corrosion Results

- General Corrosion
 - A709 GR50CR has significant corrosion resistance
 - 10x in near vertical applications
 - 4x in near horizontal applications
 - In highly corrosive environments



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Research: Corrosion Results

- Galvanic Corrosion
 - Target stainless alloys where possible/economical
 - Otherwise:
 - HDG plates & fasteners
 - Be aware that corrosion protection is affected by zinc depletion
- Galvanic Corrosion
 - HDG plates = cathodic protection, zinc migration



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Conclusions

- Growing interest in stainless steel in North American bridge market
 - Corrosive environments
 - Target longer design life
 - Economy
 - Balance initial vs. lifecycle costs
 - Targeted applications



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Contributions from:

- VTRC/VDOT
 - Jason Provines
 - Stephen Sharp
 - Bill Via
- Graduate Student
 - Isaac Groshek (AECOM)
- Industry
 - Ronnie Medlock



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Acknowledgements

- Plate material
- Fasteners
- Galvanizing services



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Questions?



(Courtesy of VDOT)



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References

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