

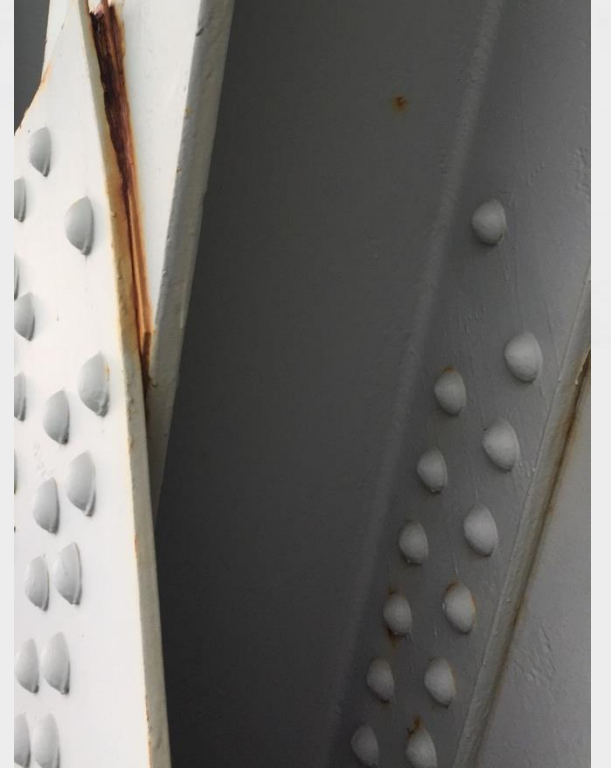
Preventing Crevice Corrosion in New and Existing Steel Structures

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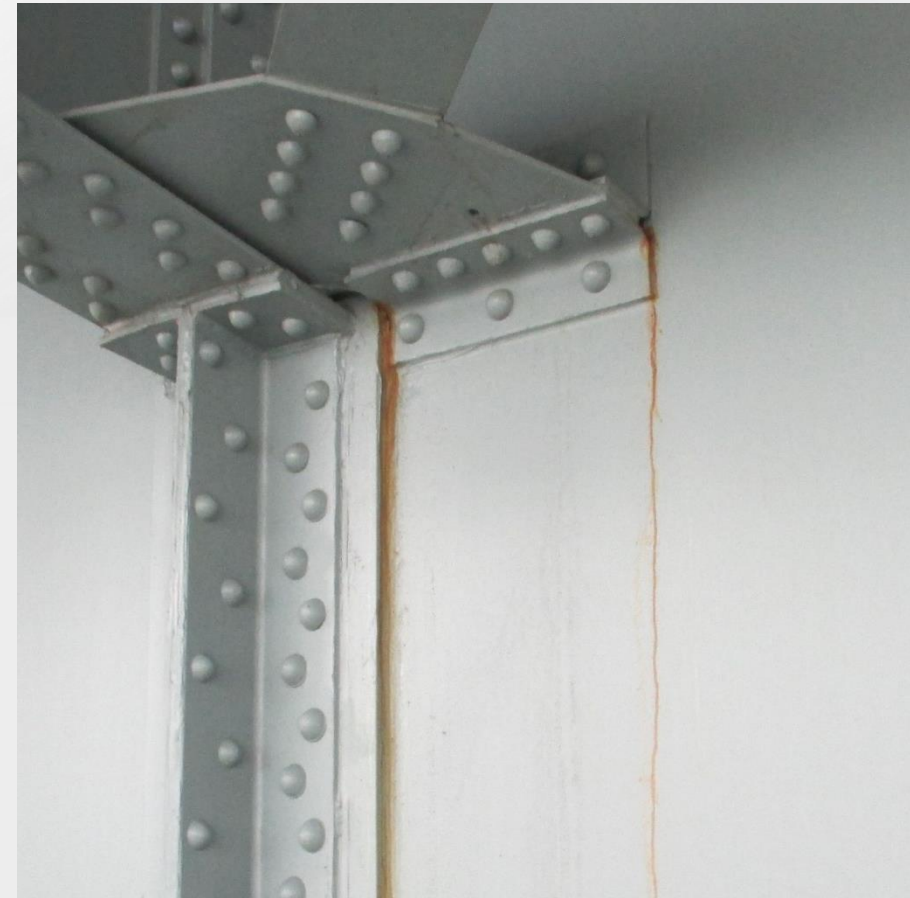
Background

- New structures the state-of-the-art approach is to apply zinc-rich primer to mating surfaces prior to assembly and to use galvanized fasteners during assembly unfortunately, there are cases where this is not always possible.
- Existing structures, stripe coats and caulking are often used to provide added protection to crevice areas.
 - Though effective, caulking can be expensive and may not be necessary on all surfaces.

Background



Background - Examples

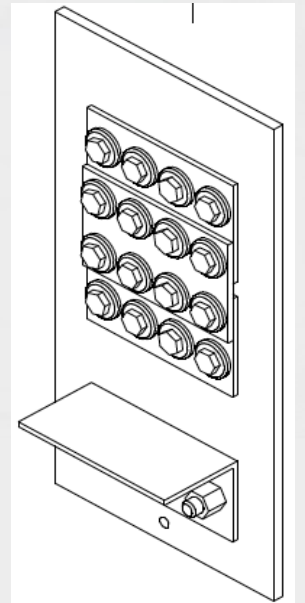
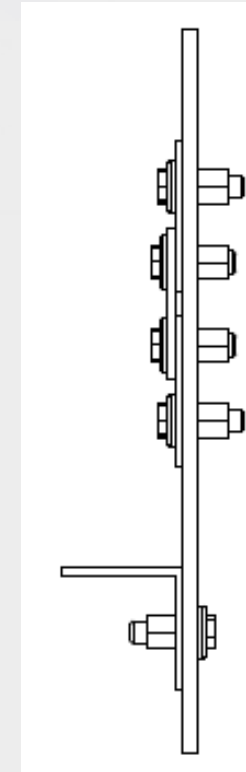
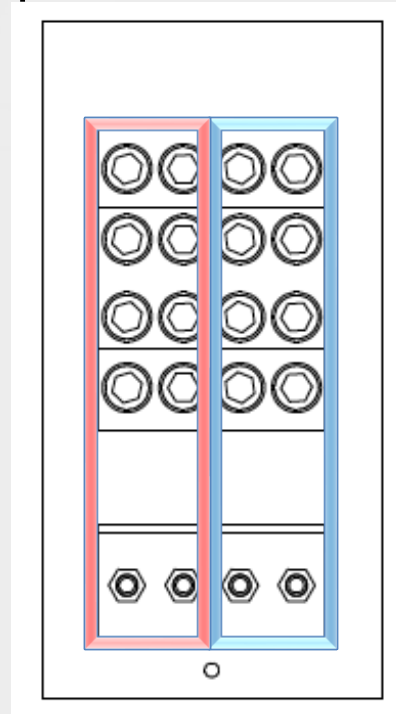


Introduction

- Twenty different test combinations
 - Surface preparation
 - Fastener material
 - Caulking extent
 - Coating sequence
 - On aged and new steel assemblies.
- Test assemblies were exposed to a cyclic accelerated corrosion test
 - Evaluated for rust staining, blistering, and pitting within the crevice area.

Test Panel Design

- 6" by 12" by 1/8" steel
 - Three 2.5" by 4" steel coupons
 - Assembled to create crevices for water penetration
 - One 4-inch long 2.5-inch Angle
 - 10 Black Oxide bolts
(highlighted in blue box)
 - 10 Galvanized bolts
(highlighted in red box)



Test Matrix

Four different surface preparation methods were evaluated in this project, they are:

- New Steel – Assembled then Abrasive Blast (SP-10)
- New Steel – Abrasive Blast (SP- 10) as individual parts, zinc primed then assembled
- Weathered Steel – Abrasive Blast (SP-10) prior to coating
- Weathered Steel – Power tool Clean (SP- 11) prior to coating

System	Panel Condition			
	Assembly and Surface	Stripe Coat	Caulk	
1	New - Primed After Assembly	No	None	
2		Stripe Coated	Top	
3			3/4	
4			Full	
5			No	None
6	New - Primed Before Assembly	No	None	
7		Stripe Coated	Top	
8			3/4	
9			Full	
10			No	None
11	Weathered	No	None	
12		Stripe Coated	Top	
13			3/4	
14			Full	
15			No	None
16		SP-11	No	None
17			Stripe Coated	Top
18				3/4
19				Full
20				Full

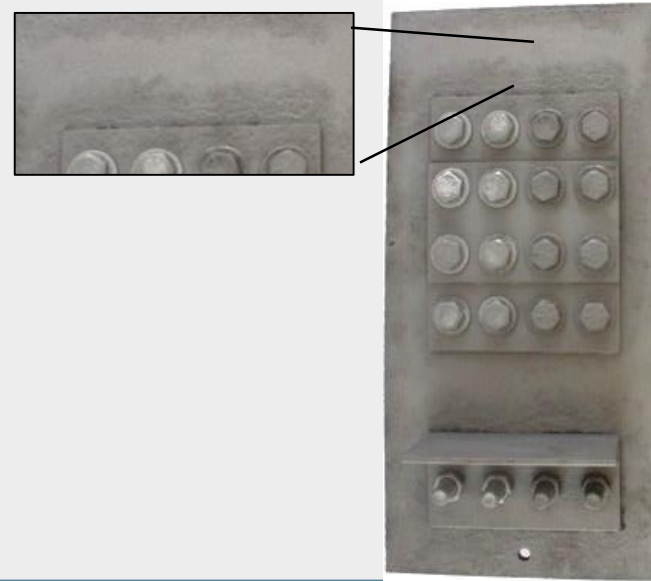
Preparation of “Aged” Steel

- 10 panels were assembled/ coated/ pre-weathered
 - Coated with 3 mils of Epoxy
 - ~150 hours ASTM B117 Corrosion Exposure
 - 9 months of Outdoor Exposure (Vineland, NJ)



- Pre-Weathering Panel surface preparation

SP-10 Near-White
Metal Blast

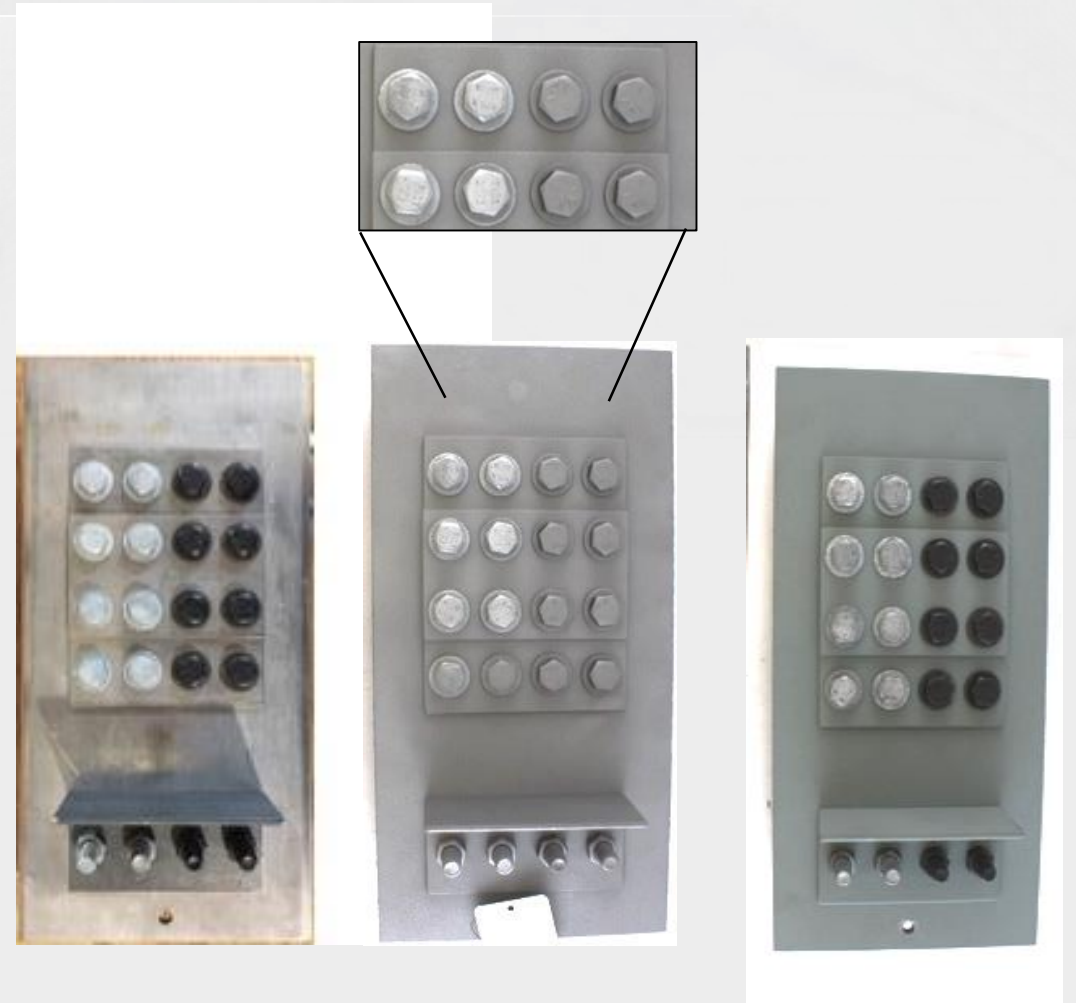


SP-11 Power Tool
Cleaning to Bare Metal
using a Needle Gun &
Grinding Wheel



New Steel Panels

- Two fabrication sequences :
 - Assembled, abrasive blasted (SP-10), and coated with a OZ/E/URE System
 - Abrasive blasted (SP-10), OZ primed, assembled, and then finish coated (EP/URE)
 - All bolts where scuff sanded prior to intermediate coating



Coating Application

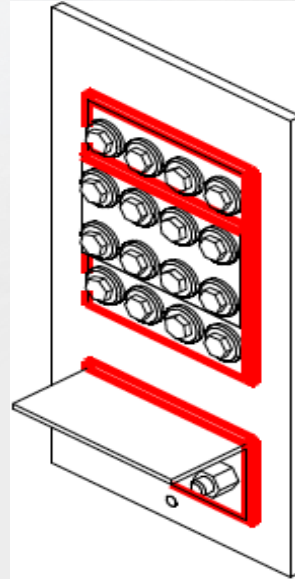
Coating Application procedure:

- Perform designated surface preparation (e.g., Abrasive blast (SP-10) or Power tool clean (SP-11) per Test Matrix)
- Solvent Cleaning (using Isopropyl alcohol)
- Zinc Prime (3-5 mils)
- Zinc Stripe (3-5 mils)
- Intermediate Coat (3-5 mils)
- Intermediate Stripe (3-5 mils)
- Caulk application
- Finish Stripe (3-5 mils)
- Finish Coat (3-5 mils)

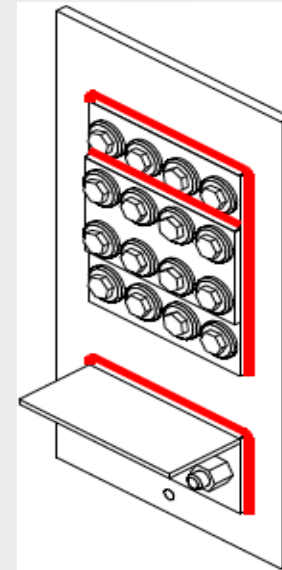
Caulking Scenarios

Four scenarios evaluated:

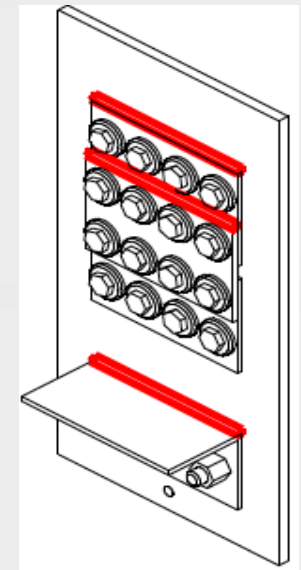
- Full Method
- $\frac{3}{4}$ Method
- Top Method
- None



Full Method
Caulking applied to
all crevices



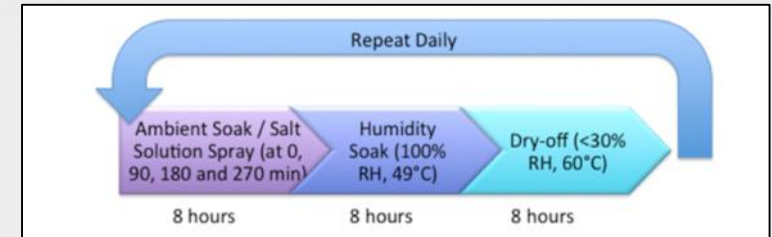
$\frac{3}{4}$ Method
Caulking applied
to all except
bottom crevices



Top Method
Caulking only
applied to top
crevices

Performance Testing

- Corrosion (GMW14872)
 - 120 cycles – Underbody method C
 - Inspections 20/40/80/120 cycles
 - ASTM D-610 (rusting)
 - ASTM D-714 (blistering)
 - Crevice corrosion locations
 - Rusting bolt count
 - Note: panels are rotated positions every 20 cycles
 - At end of test, panels were disassembled for pitting analysis within crevices



Quick Review

- 10 panels were assembled/ coated/ pre-weathered
 - Coated with 3 mils of Epoxy
 - 150 hours ASTM B117 Corrosion Exposure + 9 months of Outdoor Exposure (Vineland, NJ)
 - After exposure panels were prepped one of two methods:
 - Abrasive Blast (SP-10)
 - Power tool clean (SP-11)
- 10 panels represent two fabrication sequences for new steel:
 - 5 panels were assembled, abrasive blasted (SP-10), and coated with an OZ/EP/URE System
 - 5 Panels were abrasive blasted (SP-10), OZ primed, assembled, and then finish coated (EP/URE). Note: All bolts were scuff sanded prior to intermediate coating
- Three different Caulking methods were used post coating application for each preparation scenario
- All Panels were then exposed to 120 cycles of GMW 14872 testing

Results –New Steel

- Primed After Assembly

	20 cycles	40 cycles	80 cycles	120 cycles
No Stripe + No Caulk				
Stripe + No Caulk				
Stripe + Top Caulk				
Stripe + 3/4 Caulk				
Stripe + Full Caulk				

- Primed Before Assembly

	20 cycles	40 cycles	80 cycles	120 cycles
No Stripe + No Caulk				
Stripe + No Caulk				
Stripe + Top Caulk				
Stripe + 3/4 Caulk				
Stripe + Full Caulk				



Results – Weathered Steel

- Abrasive Blast (SP-10)

	20 cycles	40 cycles	80 cycles	120 cycles
No Stripe + No Caulk				
Stripe + No Caulk				
Stripe + Top Caulk				
Stripe + 3/4 Caulk				
Stripe + Full Caulk				

- Power tool Clean (SP-11)

	20 cycles	40 cycles	80 cycles	120 cycles
No Stripe + No Caulk				
Stripe + No Caulk				
Stripe + Top Caulk				
Stripe + 3/4 Caulk				
Stripe + Full Caulk				



Results – Black Oxide Bolts

- Most bolt corrosion were panels primed prior to assembly.
- The black-oxide bolts that did not receive a zinc prime or zinc stripe coat displayed corrosion at the first inspection (cycle 20).
- Less evident on abrasive blasted panels than the power tool cleaned panels.

			20		40		80		120		
Panel Condition			Front of Black Bolts	Back of Black Bolts	Front of Black Bolts	Back of Black Bolts	Front of Black Bolts	Back of Black Bolts	Front of Black Bolts	Back of Black Bolts	
New/Primed After Assembly	SP-10	No	60%	100%	10%	100%	100%	100%	100%	100%	
		Stripe Coated	None	10%	0%	30%	10%	30%	10%	40%	50%
			Top	10%	40%	10%	40%	20%	40%	30%	80%
			3/4	40%	20%	50%	20%	50%	20%	50%	50%
			Full	20%	0%	20%	0%	30%	0%	40%	40%
New/Primed Before Assembly	SP-10	No	100%	100%	100%	100%	100%	100%	100%	100%	
		Stripe Coated	None	0%	0%	0%	0%	80%	0%	90%	100%
			Top	20%	0%	30%	30%	70%	30%	100%	100%
			3/4	0%	0%	40%	30%	70%	30%	100%	100%
			Full	10%	0%	20%	10%	70%	10%	90%	100%
Weathered	SP-10	No	70%	100%	70%	100%	70%	100%	70%	100%	
		Stripe Coated	None	0%	0%	0%	0%	0%	0%	0%	30%
			Top	10%	10%	10%	10%	20%	10%	20%	20%
			3/4	0%	10%	10%	10%	10%	10%	20%	10%
			Full	20%	0%	20%	0%	20%	0%	20%	0%
	SP-11	No	40%	100%	80%	100%	90%	100%	100%	100%	
		Stripe Coated	None	20%	0%	30%	0%	30%	0%	30%	70%
			Top	10%	40%	30%	40%	30%	40%	30%	90%
			3/4	20%	20%	50%	40%	60%	40%	80%	100%
			Full	0%	20%	20%	50%	20%	50%	20%	70%



Results –Galvanized Bolts

- Corrosion on the was less on galvanized bolts than the corroded black-oxide bolts.
- There are clear benefits to stripe coating the galvanized bolts.

				20		40		80		120	
Panel Condition				Front Galvanized Bolts	Back Galvanized Bolts	Front Galvanized Bolts	Back Galvanized Bolts	Front Galvanized Bolts	Back Galvanized Bolts	Front Galvanized Bolts	Back Galvanized Bolts
New Primed After Assembly	SP-10	Stripe Coated	No	0%	0%	50%	100%	70%	100%	70%	100%
			None	0%	0%	0%	0%	0%	10%	20%	10%
			Top	0%	0%	0%	10%	0%	30%	10%	30%
			3/4	0%	0%	0%	0%	10%	10%	20%	10%
			Full	0%	0%	0%	0%	20%	0%	30%	10%
New Primed Before Assembly	SP-10	Stripe Coated	No	0%	0%	50%	10%	100%	100%	100%	100%
			None	0%	0%	0%	0%	0%	0%	20%	40%
			Top	0%	0%	0%	20%	0%	30%	20%	40%
			3/4	0%	0%	0%	20%	20%	50%	20%	50%
			Full	0%	0%	30%	20%	50%	40%	50%	40%
Weathered	SP-10	Stripe Coated	No	0%	0%	20%	80%	40%	100%	40%	100%
			None	0%	0%	10%	0%	10%	0%	10%	30%
			Top	0%	10%	0%	10%	0%	20%	0%	20%
			3/4	10%	0%	10%	10%	10%	10%	20%	10%
			Full	0%	0%	0%	0%	0%	10%	0%	20%
	SP-11	Stripe Coated	No	0%	0%	20%	70%	20%	90%	20%	90%
			None	0%	0%	20%	0%	30%	0%	30%	10%
			Top	0%	0%	0%	10%	0%	10%	0%	10%
			3/4	0%	0%	20%	0%	20%	0%	20%	10%
			Full	0%	0%	0%	0%	0%	10%	0%	30%

Results - Disassembly

- $\frac{3}{4}$ caulking applied to new steel that is primed after assembly is the best way to prevent corrosion in these crevices.
- In one of the two crevice areas, the full caulking appears to hold moisture within the crevice of the new steel panels.
- Panels with neither a stripe coat nor caulking experienced the most crevice corrosion.
- For weathered steel under repair conditions, the benefits of a full caulk system can be observed.
- The remaining caulking schemes visually appear better than the schemes without caulking.

	No Stripe + No Caulk	Stripe + No Caulk	Stripe + Top Caulk	Stripe + $\frac{3}{4}$ Caulk	Stripe + Full Caulk
New-Primed After Assembly					
New-Primed Before Assembly					
Weathered - SP-10 Remediation					
Weathered - SP-11 Remediation					



Pit Depth Analysis

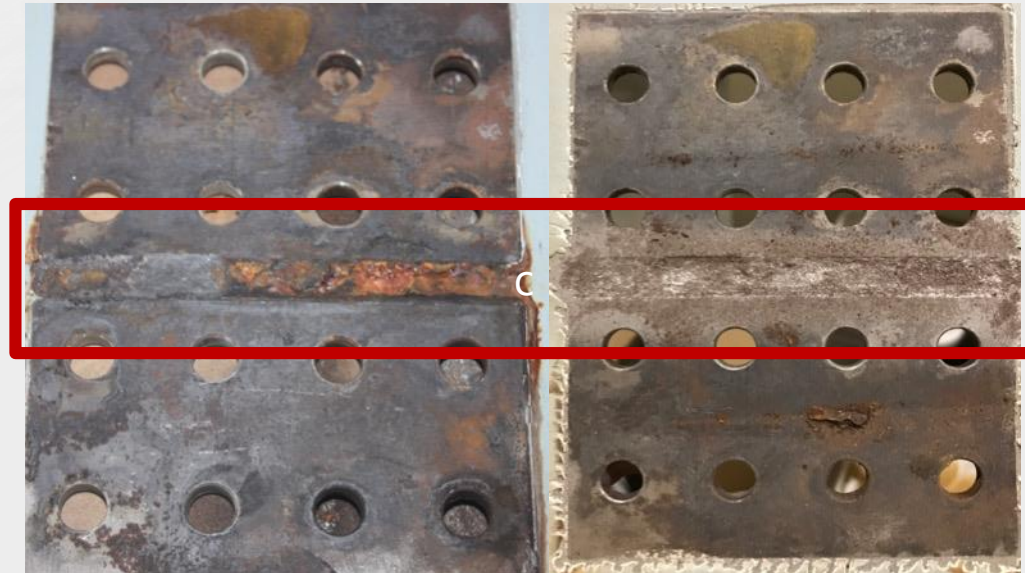
- In an attempt to better quantify the crevice corrosion, pit depths were measured on two different surfaces.
- After disassembling the panels, all corrosion products were removed from the crevice surface of the angle using abrasive glass bead blasting.
- Ten measurements were made to find the highest pits for each surface

Pit Depth

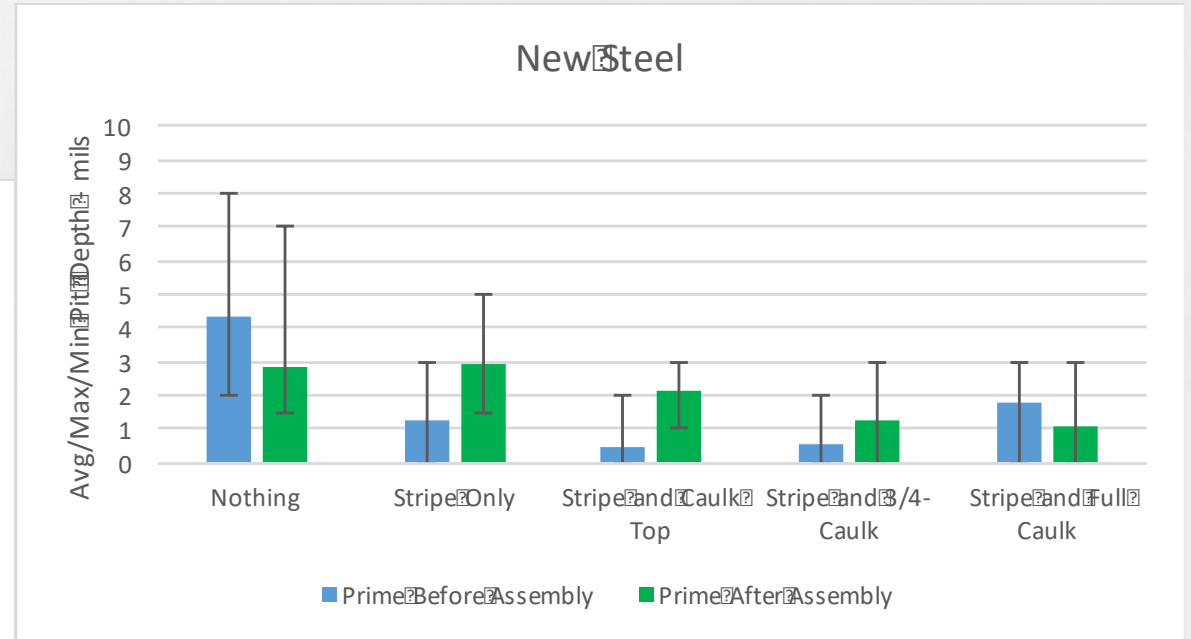
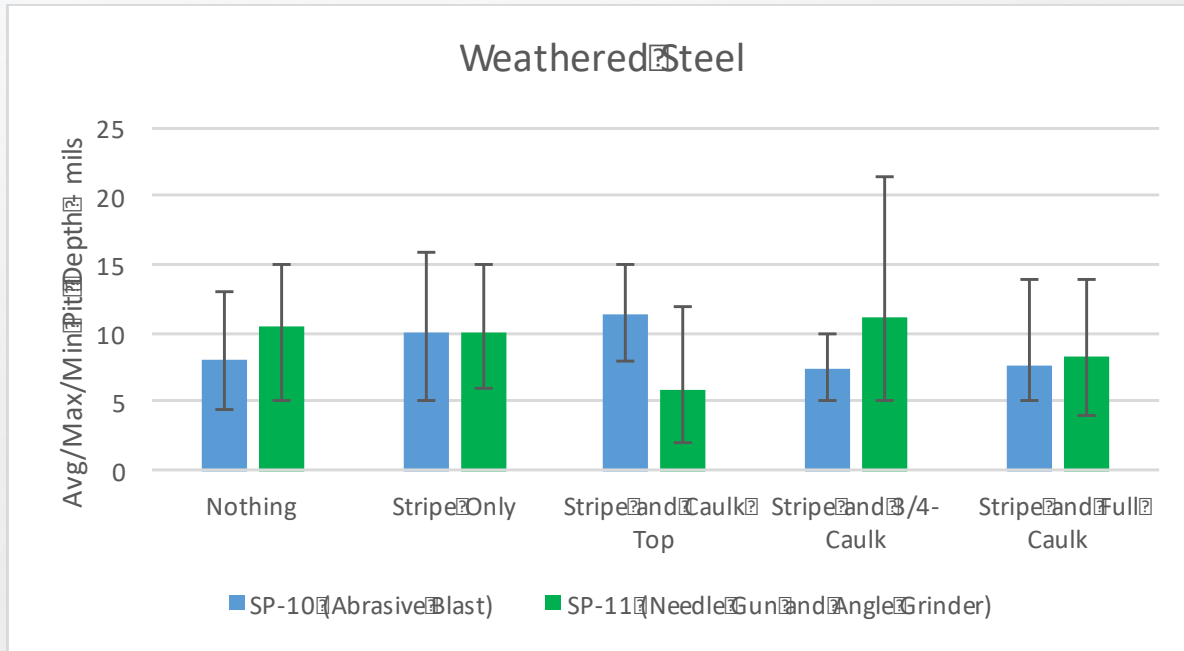
- L - Bracket



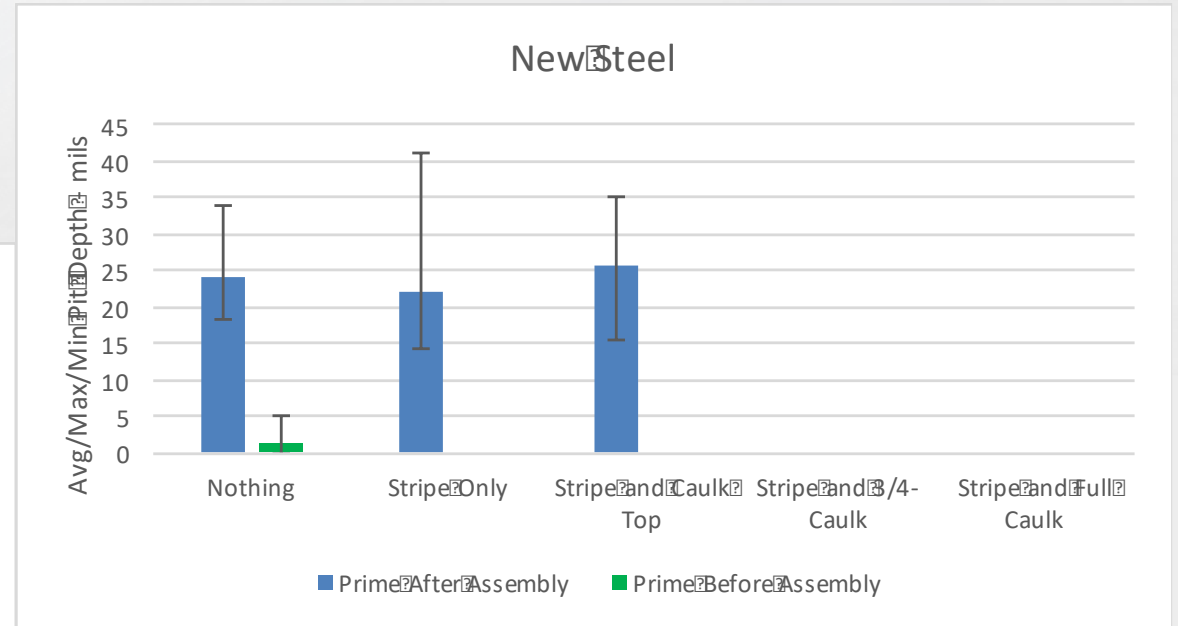
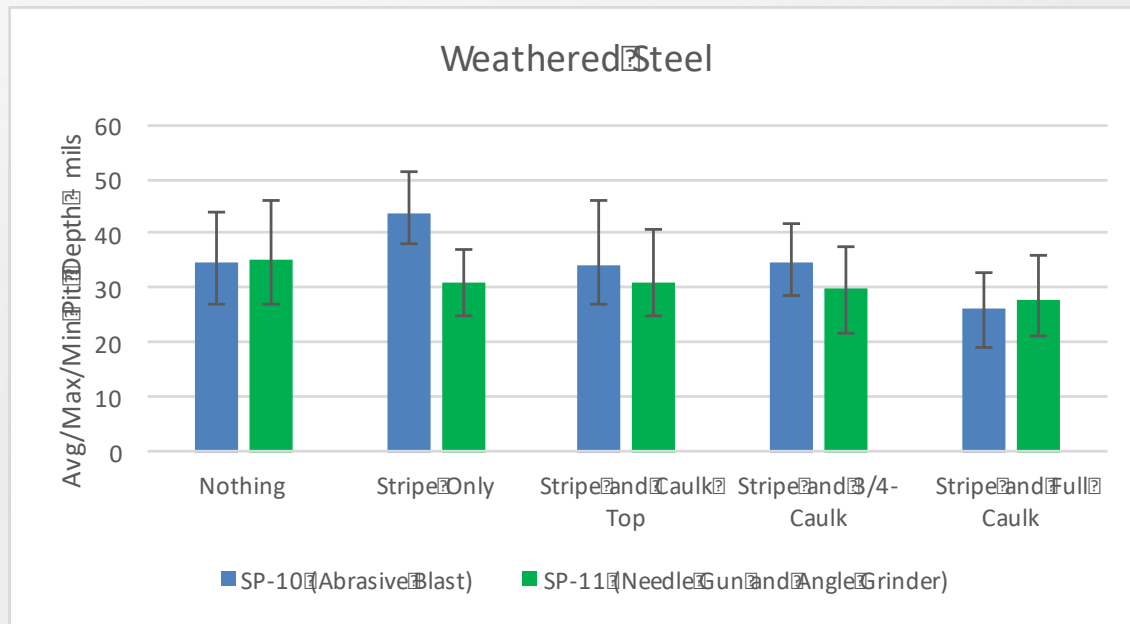
- Larger Plate



Results – Pit Depth – L Bracket



Results – Pit Depth – Middle Crevice



Conclusions

- Galvanized bolts perform better over time than black oxide bolts.
 - If black oxide bolts are utilized, proper surface preparation along with additional stripe coats will help prevent corrosion from occurring.
- Stripe coats and caulking of crevices directly exposed to water/moisture will help prevent crevice corrosion on new steel.
 - When caulking newly applied steel consider leaving the bottom crevice uncaulked to allow moisture to escape.
- When working with weathered steel, full stripe coats and caulking of all crevices provided the best results in regards to reducing crevice corrosion and pitting.
- As a best practice, mating steel surfaces should receive a primer coating prior to assembly

Acknowledgements

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Thank you

Any Questions?

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