Bridge Coatings Durability: Successful Today and Getting Even Better for Tomorrow

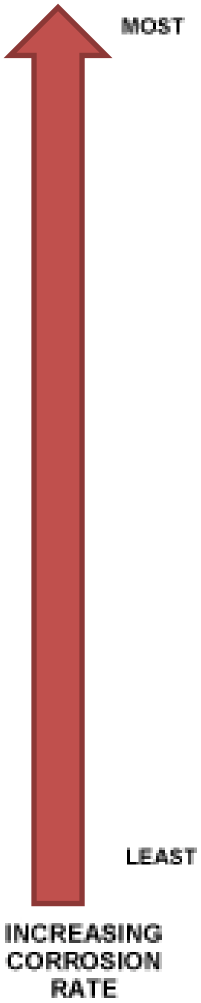
Presented to:
High Steel Structures, Inc.
Fall Open House – September 18, 2009
Presented by:
Eric S. Kline
Executive Vice President
KTA-Tator, Inc.

Aerial View of the Golden Gate Bridge

Photo used with permission from Golden Gate Bridge, www.goldengate.org

GALVANIC SERIES IN SEAWATER

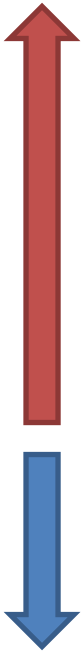
Material	Potential (VSCE)
Zinc	- 1.03
Aluminum 3003 (H)	- 0.79
Aluminum 6061 (T)	- 0.76
Cast Iron	- 0.61
Carbon Steel	- 0.61
Stainless Steel, Type 430 (active)	- 0.57
Stainless Steel, Type 304 (active)	- 0.53
Stainless Steel, Type 410 (active)	- 0.52
Naval Rolled Brass	- 0.40
Copper	- 0.36
Bronze, Composition G	- 0.31
90 Cu 10 Ni, 0.82 Fe	- 0.31
70 Cu 30 Ni, 0.47 Fe	- 0.28
Stainless Steel, Type 430 (passive)	- 0.25
Nickel	- 0.20
Stainless Steel, Type 410 (passive)	- 0.15
Titanium Silver	- 0.13
Hastelloy C	- 0.08
Stainless Steel, Type 304 (passive)	- 0.08
Stainless Steel, Type 316 (passive)	- 0.05
Zirconium	- 0.04
Platinum	+0.15



Electromotive Force Series

Metal	Electrode Reaction	Electrode Potential
Potassium	$K = K^+ + e^-$	- 2.922
Calcium	$Ca = Ca^{++} + 2e^-$	- 2.87
Sodium	$Na = Na^+ + e^-$	- 2.712
Magnesium	$Mg = Mg^{++} + 2e^-$	- 2.34
Aluminum	$Al = Al^{+++} + 3e^-$	- 1.67
Zinc	$Zn = Zn^{++} + 2e^-$	- 0.762
Iron	$Fe = Fe^{++} + 2e^-$	- 0.440
Titanium	$Ti = Ti^{++} + 2e^-$	- 0.336
Nickel	$Ni = Ni^{++} + 2e^-$	- 0.250
Tin	$Sn = Sn^{++} + 2e^-$	- 0.136
Lead	$Pb = Pb^{++} + 2e^-$	- 0.126
Hydrogen	$H_2 = 2H_2{}^{+} + 2e^-$	- 0.000
Copper	$Cu = Cu^{++} + 2e^-$	+ 0.345
Copper	$Cu = Cu^+ + e^-$	+ 0.522
Silver	$Ag = Ag^+ + e^-$	+ 0.800
Platinum	$Pt = Pt^{++} + 2e^-$	+ 1.2
Gold	$Au = Au^+ + e^-$	+ 1.68

MOST ACTIVE



MOST NOBLE

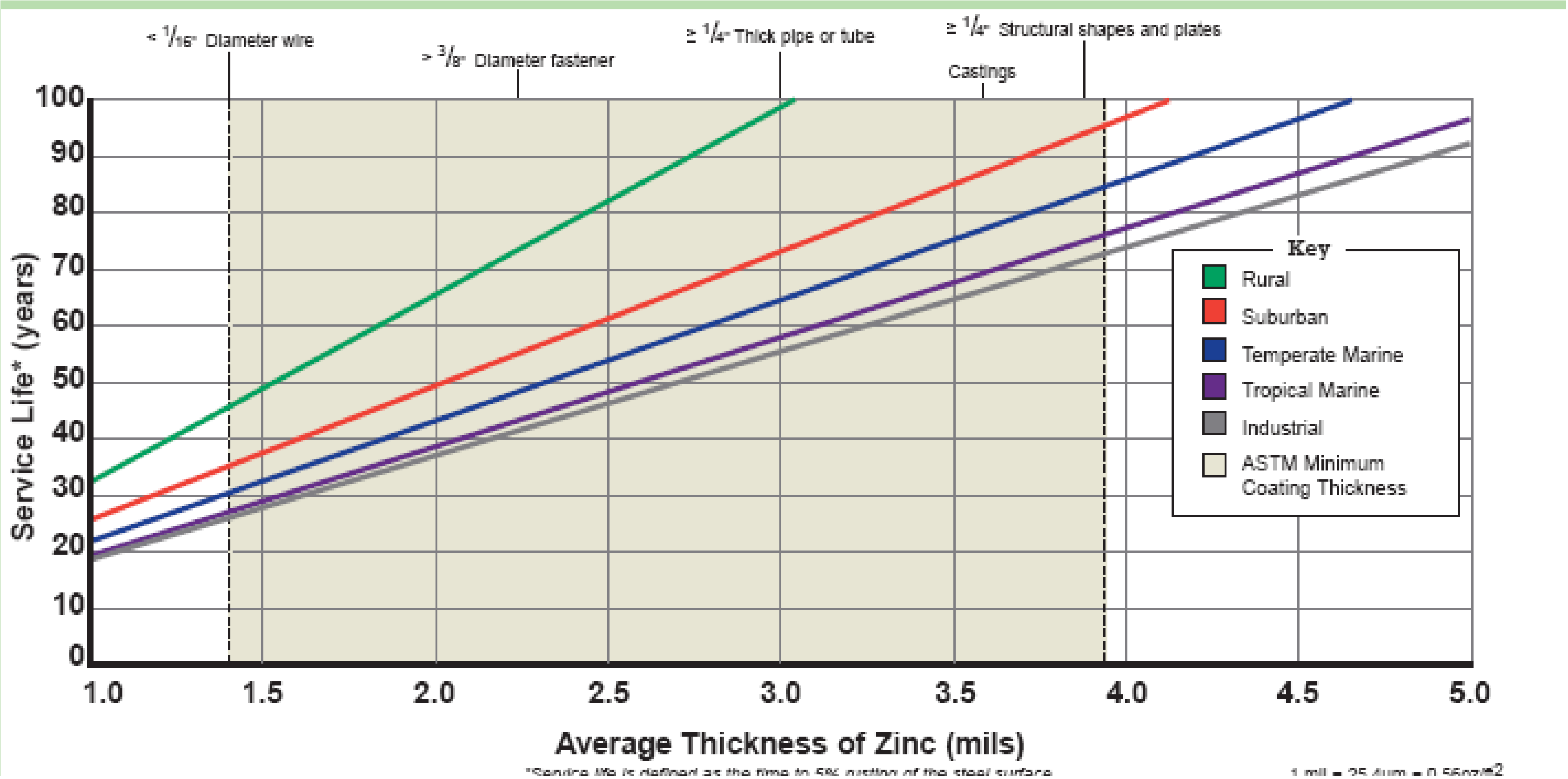


Figure 1 Service-life Chart for hot-dipped galvanized coatings in various environments. Source: American Galvanizers Association (AGA)

Carboline Salt Fog Machine Interior – machine opened

Carboline CZ 11 HS 70K 11 HS Panel1

Carboline 11 HS IOZ electron microscope pic 70K 11 HS Panel2

FIGURE 2. Space Shuttle Launch. Photo courtesy of NASA.

40 Year Old Untopcoated IOZ

35 YEARS OF CORROSION PROTECTION AT THE KENNEDY SPACE CENTER

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ABSTRACT

NASA began corrosion studies at the Kennedy Space Center (KSC) in 1966 during the Gemini/Apollo Programs with the evaluation of long-term protective coatings for the atmospheric protection of carbon steel. KSC's Beach Corrosion Test Site (BCTS), which has been documented by the American Society of Materials (ASM) as one of the most corrosive, naturally occurring, environments in the world, was established at that time.

With the introduction of the Space Shuttle in 1981, the already highly corrosive conditions at the launch pad were rendered even more severe by the acidic exhaust from the solid rocket boosters. In the years that followed, numerous studies have identified materials, coatings, and maintenance procedures for launch hardware and equipment exposed to the highly corrosive environment at the launch pad.

This paper presents a historical perspective highlighting the lessons learned in over thirty-five years of corrosion research, materials evaluation, and development work aimed at protecting and enhancing the safety and reliability of the nation's launch infrastructure and hardware.

TABLE 1
COMPARISON OF CORROSION RATES OF CARBON STEEL AT VARIOUS TEST LOCATIONS[1]

Location	Type Of Environment	µm/yr	Corrosion rate (a) mils/yr
Esquimalt, Vancouver Island, BC, Canada	Rural marine	13	0.5
Pittsburgh, PA	Industrial	30	1.2
Cleveland, OH	Industrial	38	1.5
Limon Bay, Panama, CZ	Tropical marine	61	2.4
East Chicago, IL	Industrial	84	3.3
Brazos River, TX	Industrial marine	94	3.7
Daytona Beach, FL	Marine	295	11.6
Pont Reyes, CA	Marine	500	19.7
Kure Beach, NC (80 ft. from ocean)	Marine	533	21
Galeta Point Beach, Panama CZ	Marine	686	27
Kennedy Space Center, FL (beach)	Marine	1070	42

(a) Two-year average

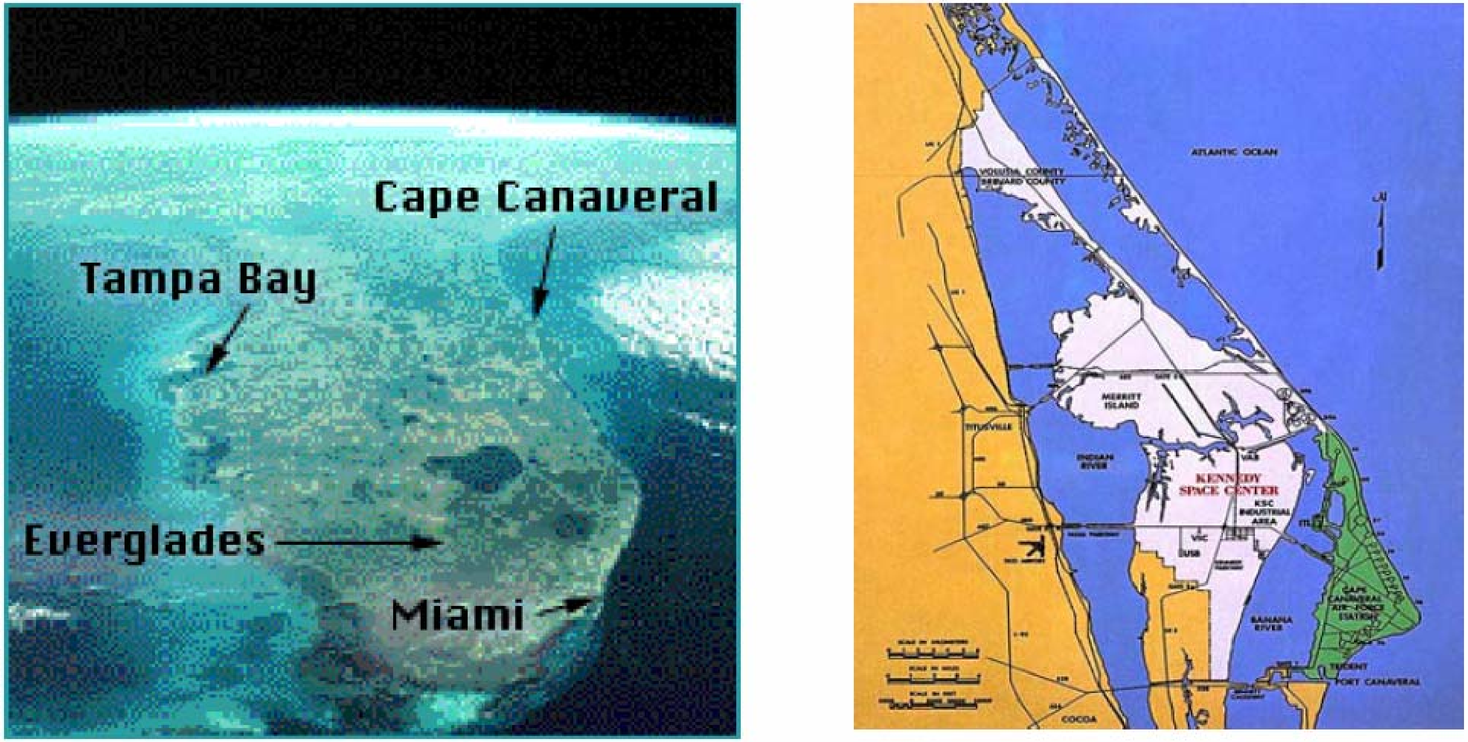


FIGURE 1. Aerial photograph of Florida showing the location of KSC (left) and map of KSC (right). Photos courtesy of NASA.

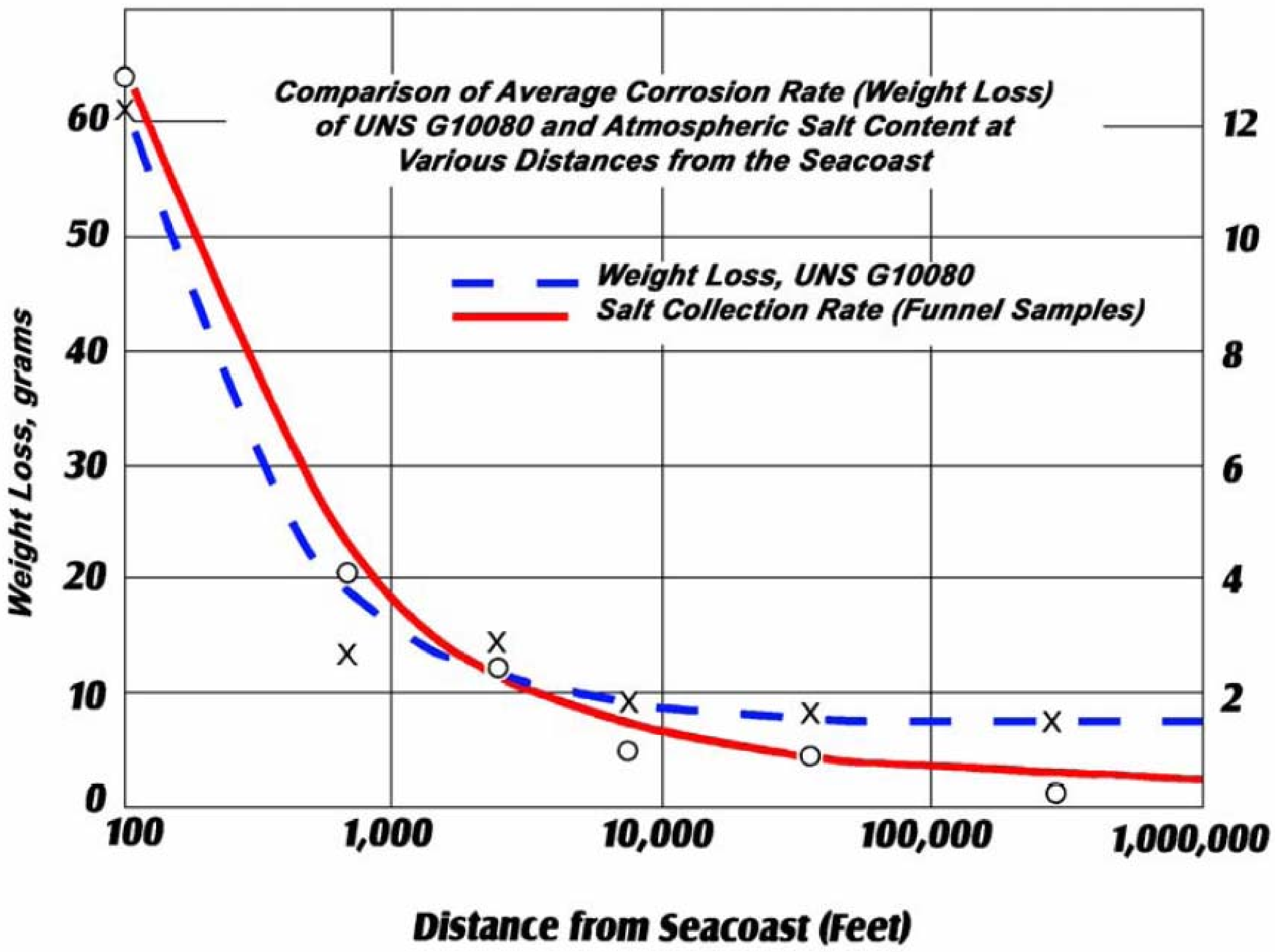


FIGURE 4. Changes of corrosion rate with distance from the ocean.[2]

CONCLUSIONS

The Kennedy Space Center is a major source of worldwide corrosion expertise with over 35 years of technical information on the long-term corrosion performance of many materials in its highly corrosive environment. This knowledge, which was not available when the launch pads were constructed, is critical for the design of spaceports that can be operated more safely and require less maintenance between lunches.

Results from coating evaluation studies at KSC have shown that: inorganic ZRPs outperform organic ZRPs in the KSC seacoast environment; inorganic ZRPs are the best choice to provide long-term protection of launch equipment and ground support structures; in general, organic topcoats are detrimental to the long-term performance of inorganic ZRPs; inorganic topcoats perform well when used with inorganic ZRPs.

Results from investigations including atmospheric exposure at KSC's BCTS and electrochemical evaluation have shown that the nickel-based alloys, such as UNS N06022 and the higher molybdenum containing stainless steels such as UNS N08367, have consistently outperformed the 300 series stainless steels in the launch environment at KSC. These materials are the best choices to prevent pitting failures in thin-walled bellows and tubing.

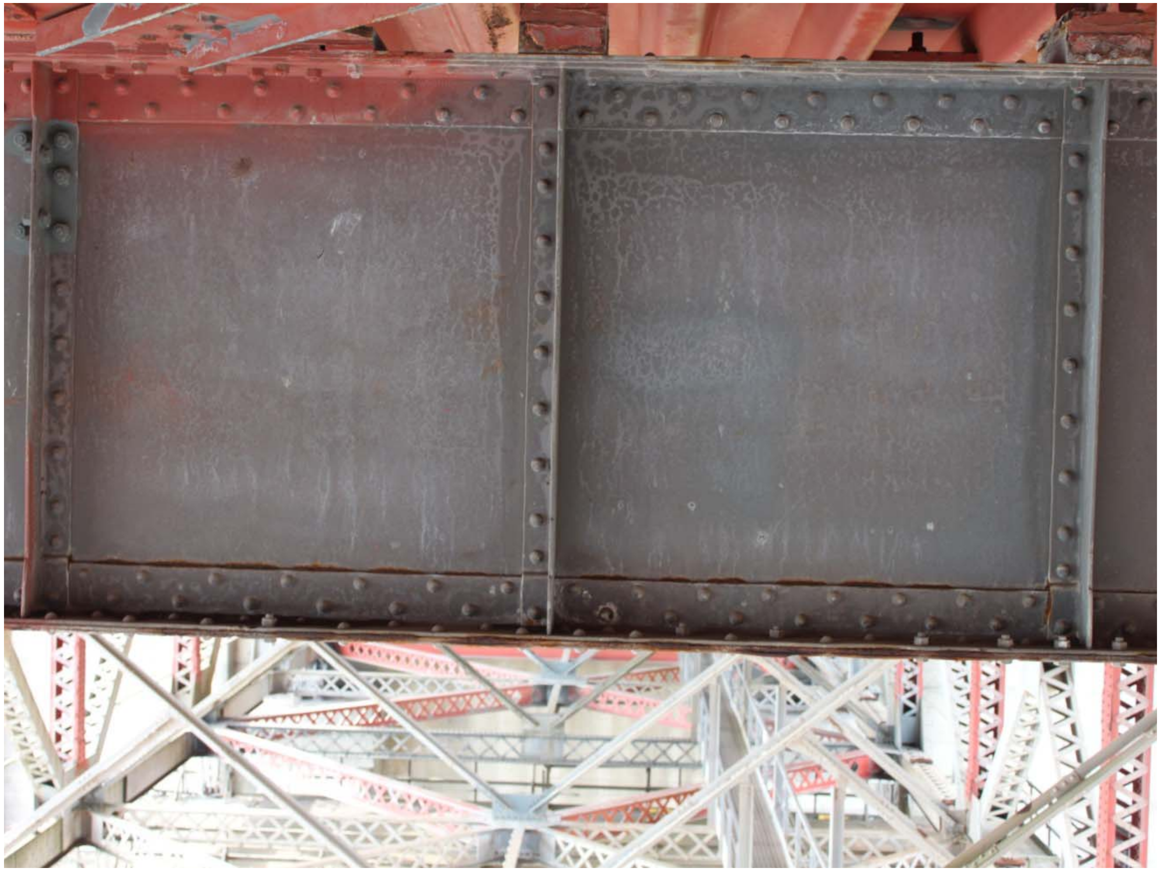
The use of electrochemical techniques predicted the behavior that has been confirmed with atmospheric exposure testing. Since atmospheric exposure testing typically takes a long time (1-2 years), the use of electrochemical techniques is recommended to narrow down the number of materials to be evaluated in long-term atmospheric exposure testing.

Aerial View of the Golden Gate Bridge

Photo used with permission from Golden Gate Bridge, www.goldengate.org

Golden Gate Bridge 566

Golden Gate Bridge 567



Untopcoated Inorganic Zinc-Rich Primer after 44 Years Exposure

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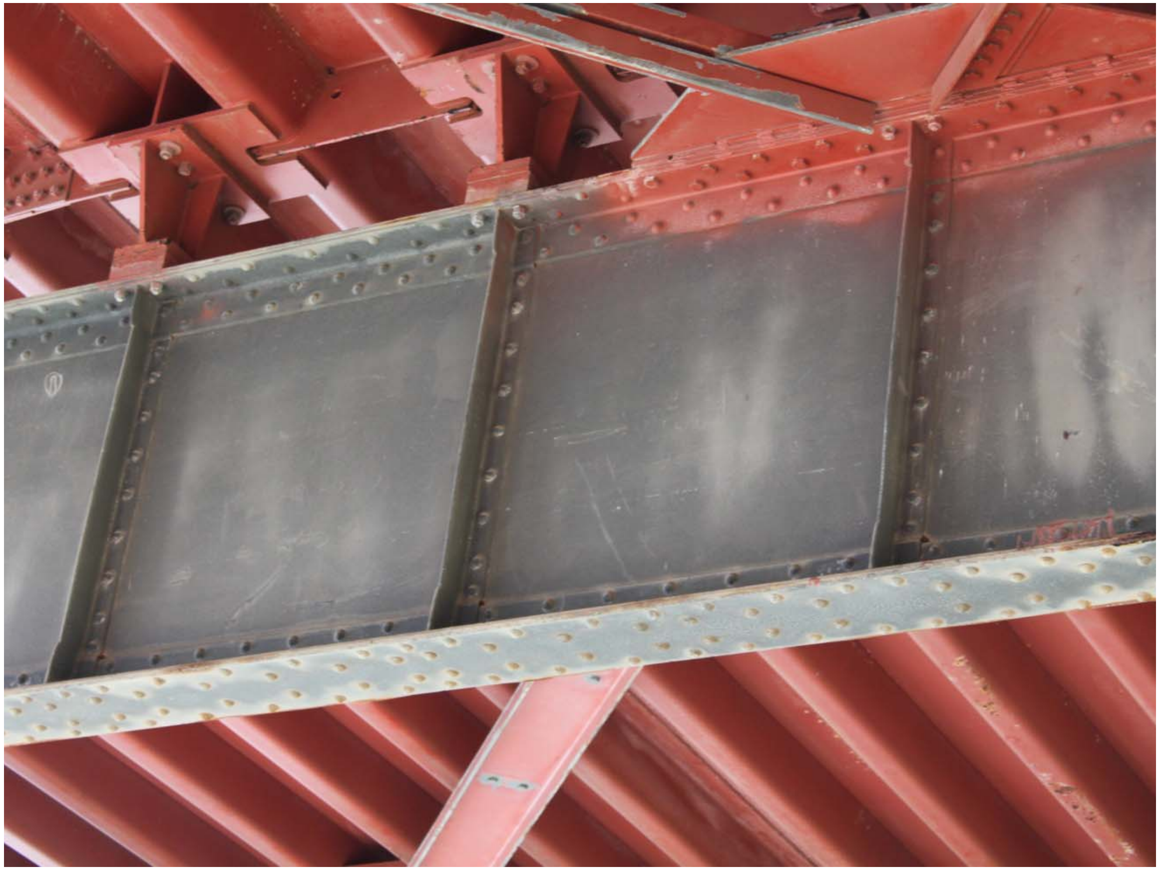

Golden Gate Bridge 568

General view of the Windgap Bridge showing typical good condition of coatings.

Photo courtesy of KTA-Tator, Inc., www.kta.com

Windgap Bridge – General view of bridge showing typical good condition of coatings

Windgap Bridge – Typical good coating appearance on various bridge members

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Windg[illegible]arance of coatings on the bottom flange face or girders. Rate of rusting was typically less than 0.03%

Windgap Bridge – Isolated rusting and coating breakdown at bearing/girder/end-frame connection beneath leaking north abutment expansion joint

Test Site No. 3 on east exterior fascia girder near north abutment of the Windgap Bridge. (Damages to the coating are the result of destructive adhesion tests, all of which indicate excellent adhesion.)

Photo courtesy of KTA-Tator, Inc., www.kta.com

Overview of Martin Luther King Bridge

Photo courtesy of Virginia Department of Transportation

Martin Luther King Bridge

Photo courtesy of Virginia Department of Transportation

Martin Luther King Bridge

Photo courtesy of Virginia Department of Transportation

Martin Luther King Bridge 005

Martin Luther King Bridge 006

MoDOT Bridge No. A2107 over Pin Oak Creek after 30 years (1999).

Photo courtesy of Tom Calzone

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