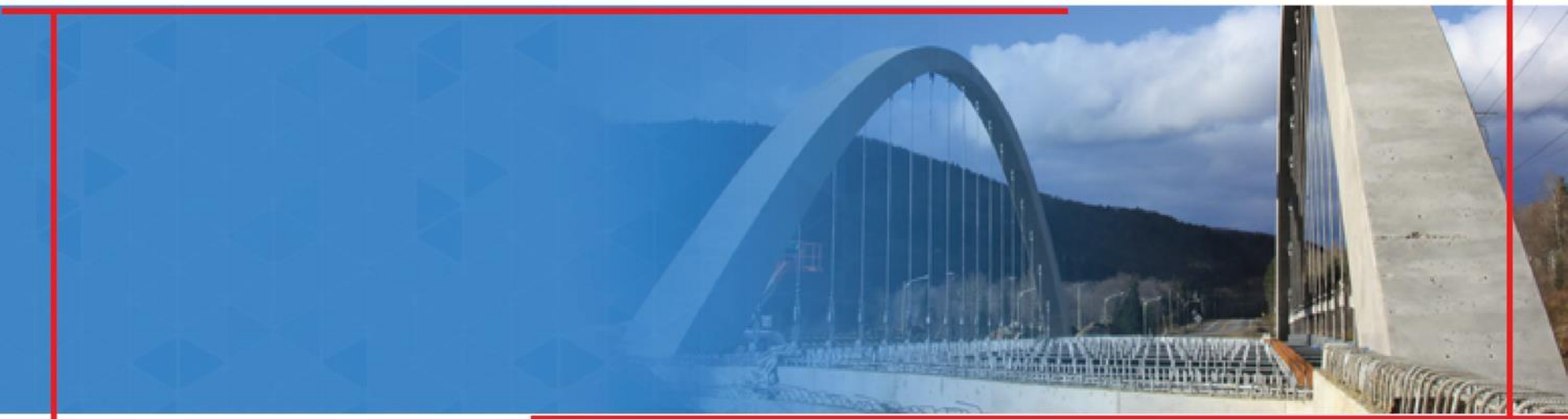
Hot-Dip Galvanized Steel Bridges



Rich Collins
Sales & Marketing Manager , V&S Galvanizing

Vice Chair, Market Development, American Galvanizers Association

Michigan Bridge Conference
March 20, 2018

GalvanizeIt!

V&S Galvanizing

GalvanizeIt!

American Galvanizers Association

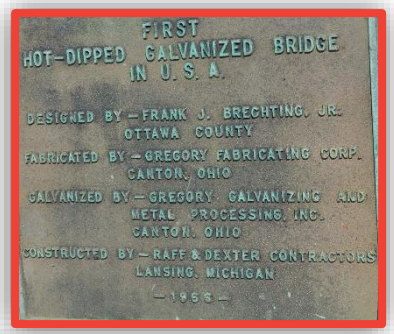
- Non-profit trade association established in 1933
  - Dedicated to serving as a unified voice and expertise in the after fabrication hot-dip galvanizing industry
- Provides technical support on innovative application and technological developments in hot-dip galvanizing for corrosion protection
  - Free assistance for North American specifiers
  - Resource for our members

AGA Zn American Galvanizers Association
Protecting Steel for a Sustainable Future

Galvanized Bridge History/Market

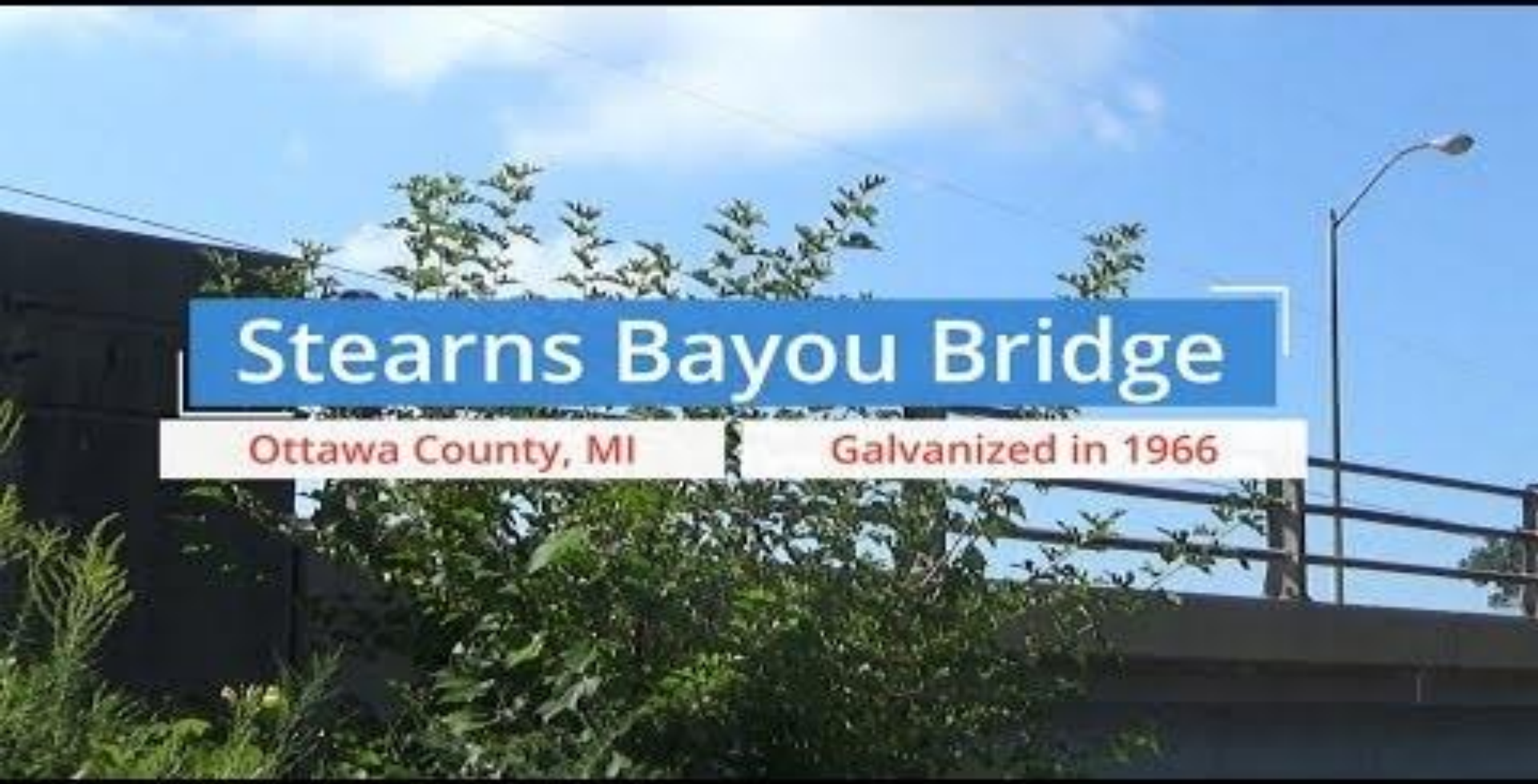
- Stearns Bayou Bridge – 1966
  - First (known) galvanized superstructure installation in the US
- Approximately 5% of steel bridges are galvanized; primarily in short span (<60 ft)
  - Current capacity allows up to 92 ft
- In last decade, specification of galvanized steel in bridges is growing
  - Also growth in galvanized reinforcing steel (rebar)

Stearns Bayou Bridge

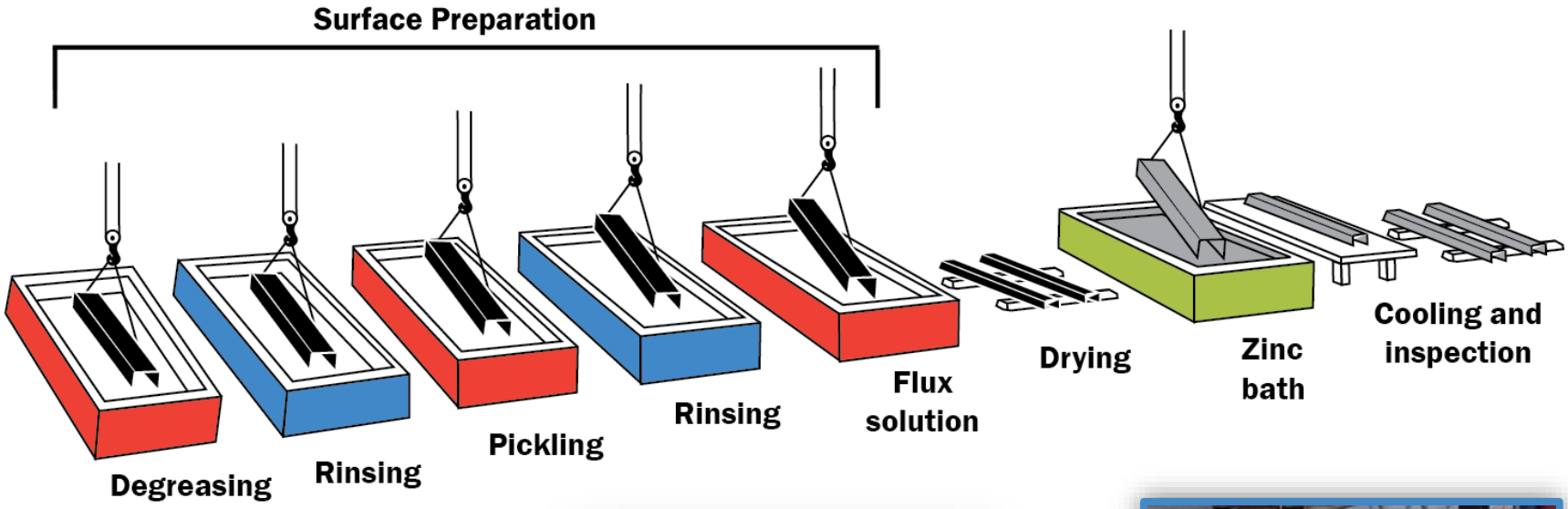


Ottawa County, MI • 1966

GALVANIZE IT!


Stearns Bayou Bridge
Ottawa County, MI
Galvanized in 1966

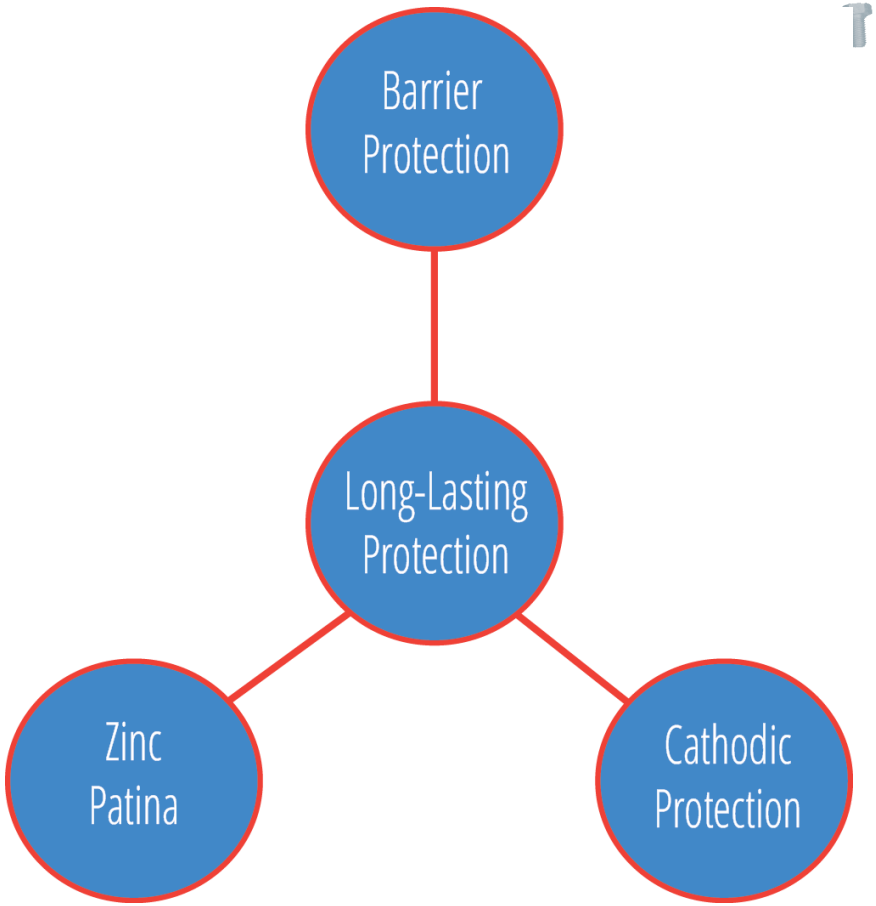
Hot-Dip Galvanizing Process



HDG PROCESS

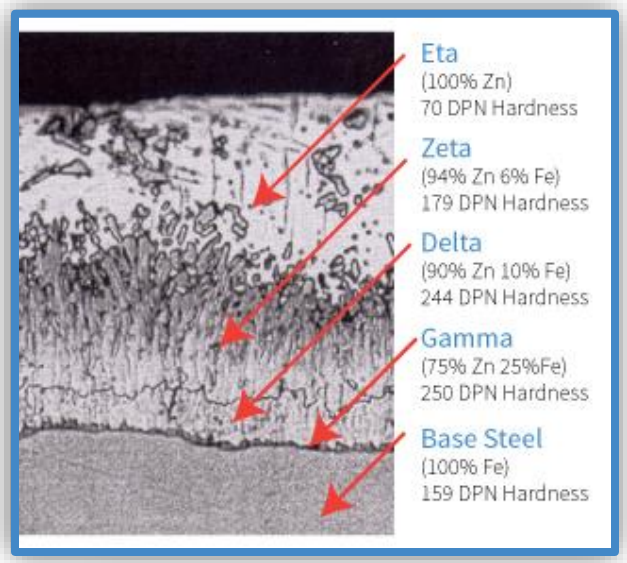
GALVANIZE IT!

Corrosion Protection

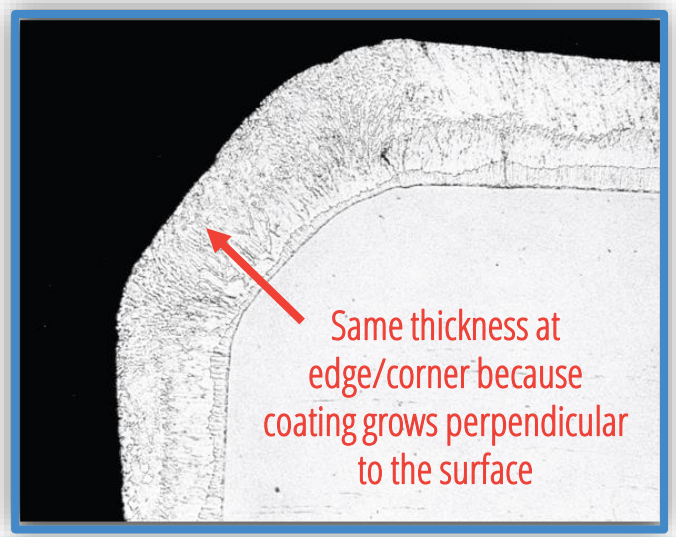


- Three levels of protection
  - Barrier – isolation from environment
  - Cathodic – sacrificial action
  - Zinc Patina
    - Natural weathering of zinc surface during wet/dry cycles
    - Zinc byproducts build on surface – additional passive barrier slows corrosion rate

Durability



- Abrasion resistance
  - Metallurgically-bonded layers
- Uniform Protection
  - Corner/edge thickness
- Complete coverage
  - Interior/threads



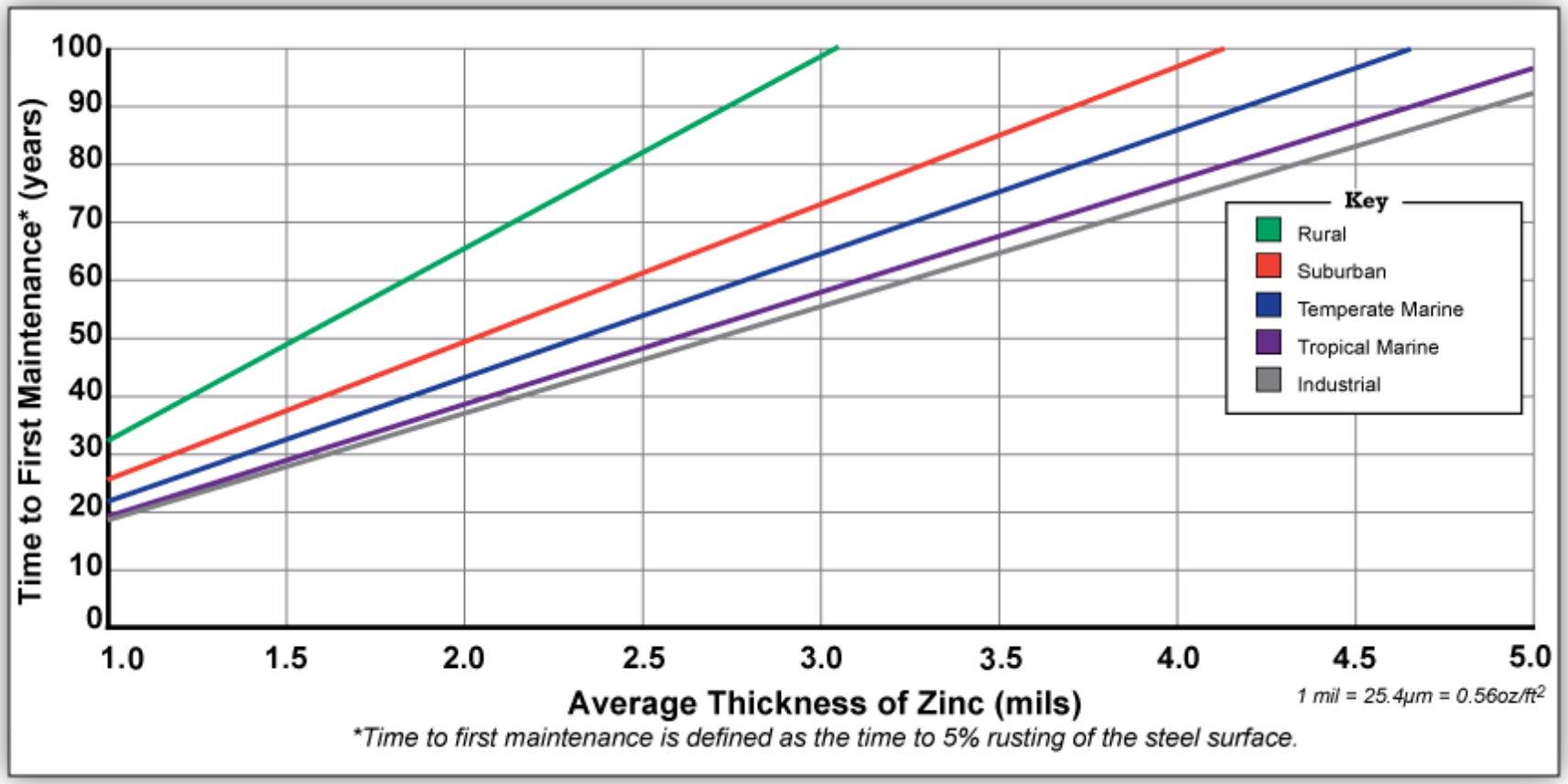
Castleton Bridge

Castleton, IN • 1970

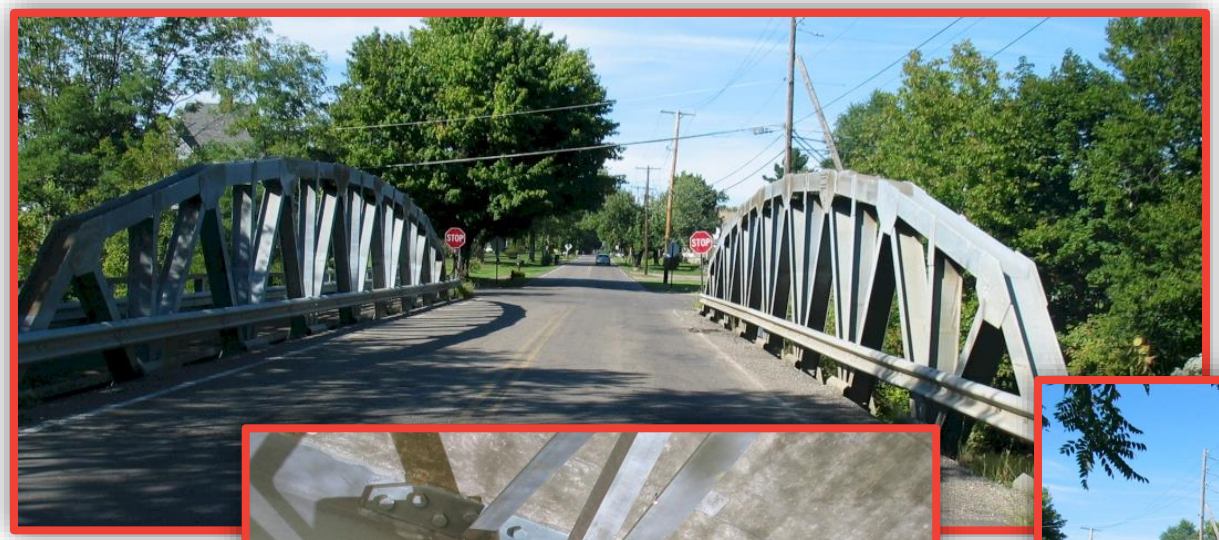
LONGEVITY

- Atmospheric – Most common
  - Zinc Coating Life Predictor (ZCLP)
  - 5 categories of environments
  - Corrosion Rate Based On
    - Temperature
    - Relative humidity
    - Rainfall
    - Sheltering condition
    - Airborne salinity
    - Sulfur dioxide concentration
- Fresh Water
  - Dissolved gasses, flow rate, other ions
  - Hard water is less corrosive than soft
- Sea Water
  - Dissolved salts – passive compounds
  - Lower temp = less corrosion
- Soils – varying properties
  - 0.2 µm/year to 20 µm/year
  - Changes in short distance
  - Primary Factors
    - Chlorides
    - pH
    - Moisture content
  - Secondary
    - Resistivity, Temp, Aeration

LONGEVITY


Time to First Maintenance* (years)
100
90
80
70
60
50
40
30
20
10
0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Average Thickness of Zinc (mils)
1 mil = 25.4µm = 0.56oz/ft²
Key
Rural
Suburban
Temperate Marine
Tropical Marine
Industrial
*Time to first maintenance is defined as the time to 5% rusting of the steel surface.

Bridges of Stark County



Canton, OH • 1975

GALVANIZE IT!

WHY HDG?

Availability & Versatility

- Factory-controlled process located across North America
  - Environmental factors do no affect turnaround time
  - No Curing
- Abundant Materials
  - Zinc/Iron both readily available
  - Infinitely renewable resources
- Efficiency & Safety
  - More with Less
  - Easily retrofitted
  - Seismic Advantage
- Stockable Inventory

Lane Avenue Bridge

Columbus, OH • 2003

AESTHETICS

- Modern, Natural Appearance
  - Blends with surroundings
  - Uniform, matte gray
  - Design freedom
- Duplex Coatings
  - Paint/Powder coating galvanized steel
  - Synergistic Effect
    - Two coatings work in synergy
    - Extends topcoat maintenance cycle 1.5 to 2.0 times

Bergen County Bridge

Fairlawn/Patterson, NJ • 2009

Sustainability: Galvanizing is Green

- Zinc is natural, abundant, essential to life
- Zinc and steel are 100% recyclable
  - Multi-cycled indefinitely without loss of any properties
  - Steel most recycled material in world
  - 30% of world zinc supply from recycled sources
- LCA in 2008
- EPD and HPD in 2016

KNOX COUNTY BRIDGE REHAB

KNOX COUNTY, OHIO • 2011

GALVANIZE IT!

WHY HDG?

Michigan M-102 Bridge Rail

Detroit, MI • 2007

Sustainability: Economic Advantages

- Initial cost benefits
  - Overall material cost, as well as time savings
- Life-cycle cost savings
  - Total cost of project throughout its life
    - Includes maintenance costs and time value of money
    - HDG often initial cost IS life-cycle cost
- Life-cycle cost calculation automated online at lccc.galvanizeit.org

Boggs Road Bridge

Muskingum County, OH • 2014

WHY HDG?

GALVANIZE IT!

Cost Case Study

- Data Sources:
  - Paint – 2016 KTA Tator paper (newest published)
    - Nationwide survey of the paint industry
    - Presented at NACE 2017
  - Galvanizing – 2016 AGA Industry Survey
    - Using US average
    - Can input customized cost

- Project Parameters:
  - Typical mix of size/shapes
  - 50,000 ft^2 project
  - 75 year design life
  - Moderately industrial environment (C3)
  - 3% inflation, 2% interest

Initial Cost

Coating System	$/ft^2	Total
Hot-Dip Galvanizing	$1.76	$88,000
Epoxy/Epoxy	$2.92	$146,150
Epoxy/Polyurethane	$3.14	$157,050
Inorganic Zinc/Epoxy	$3.17	$158,650
Inorganic Zinc/Epoxy/Polyurethane	$4.53	$226,300
Galvanizing/Epoxy/Polyurethane	$5.28	$263,950
Metallizing	$8.37	$418,550

Total Life-Cycle Cost (75 Years)

Coating System	$/ft^2	Total
Hot-Dip Galvanizing	$4.17	$208,500
Galvanizing/Epoxy/Polyurethane	$22.84	$1,142,000
Inorganic Zinc/Epoxy	$39.92	$1,996,000
Inorganic Zinc/Epoxy/Polyurethane	$41.53	$2,076,500
Epoxy/Epoxy	$42.88	$2,144,000
Epoxy/Polyurethane	$57.73	$2,886,500
Metallizing	$62.80	$3,140,000

HDG Bridge Specification & Design

GalvanizeIt!

ASTM Specifications

- ASTM A123 – iron and steel products (general)
  - Minimum coating thickness
  - Finish
  - Adherence
- ASTM A153 – hardware
  - Centrifuged/spun after galvanizing
  - Minimum coating thickness
  - Finish & Adherence
- ASTM A767 – rebar
  - Finish – no bare spots, free from sharp spikes/tears
  - Bend diameters
  - Minimum coating thickness

ASTM INTERNATIONAL
Standards Worldwide

SUPPORTING SPECIFICATIONS

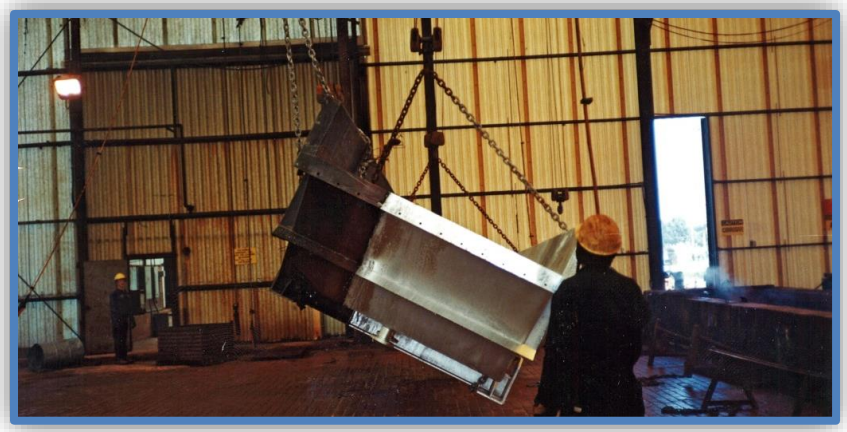
- Pre-galvanizing specs (design)
  - ASTM A143 – Safeguarding against embrittlement
  - ASTM A384 – Minimizing warpage & distortion
  - ASTM A385 – Practices for high-quality coatings
  - ASTM A1068 – Life-cycle cost analysis of steel corrosion protection
- Post-galvanizing specs
  - ASTM A780 – Touch-up and repair of galvanized products
  - ASTM D6386 – Surface preparation for painting over galvanizing
  - ASTM D7803 – Surface preparation for powder coating over galvanizing

Design Considerations

- Communication is key
  - AGA Design Guide
- Steel Selection
- Process Temperature
  - Dissimilar Thickness
- Venting & Drainage
- Welding
- Size Limitations
- Material Handling
- Marking/Masking
- Connection Concerns

Bridge Size Considerations

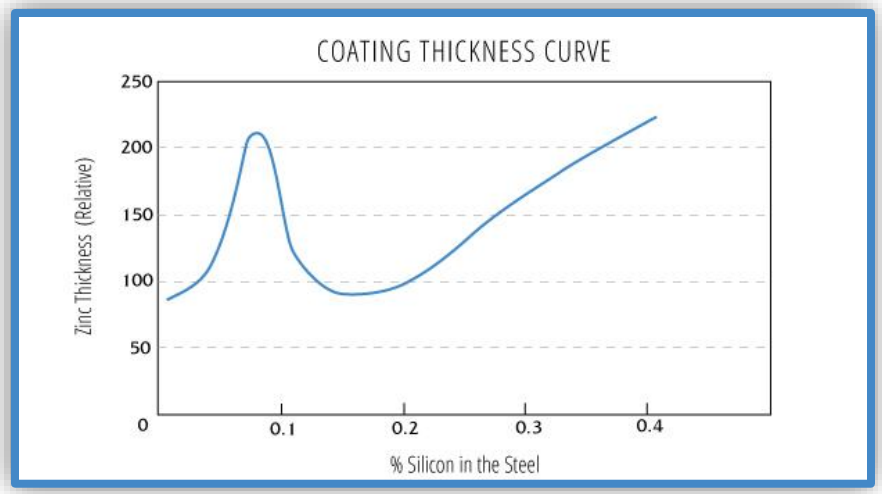
- Galvanizing limited by the size of the kettle
  - Average in North America 40 feet
  - Many 50-60 feet
- Modular Design
  - Design in modular or sub-units to fit
  - Connect after galvanizing
    - Bolting, Welding
- Progressive Dipping
  - Coat the steel in two passes
  - Communication is essential

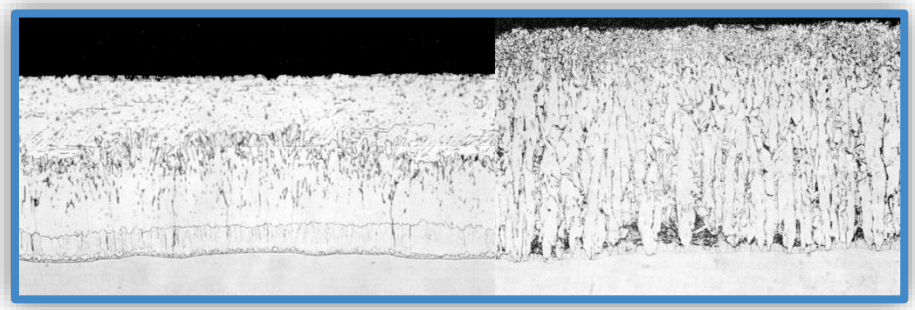


- Tandem Coating: Metallizing & HDG
  - Used for large or complex structures
  - To coat the middle of progressively dipped piece
  - Both coatings comprised of zinc – no dissimilar metals, similar appearance

Bridge Design Considerations: Steel selection

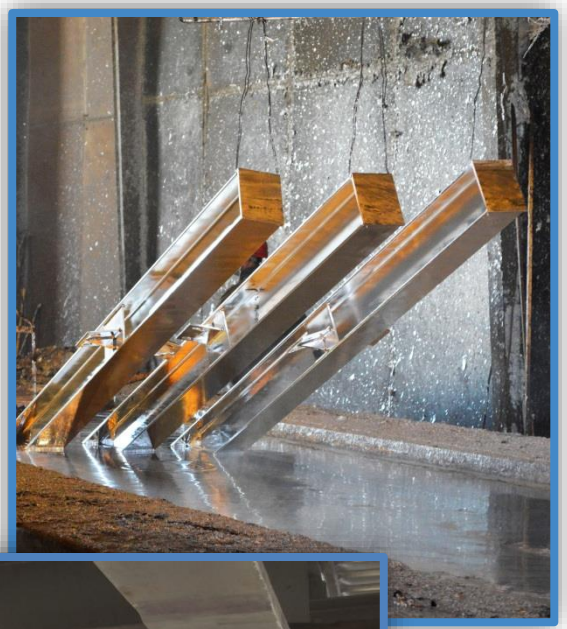
- Steel Selection
  - Silicon & Phosphorous: two trace elements are most important
  - Guidelines in steel selection
    - Level of carbon less than 0.25%, phosphorous less than 0.04%, manganese less than 1.35% are beneficial
    - Silicon level less than 0.04% or between 0.15%-0.22% are desirable
- Coating Thickness
  - Large, heavy girders are more susceptible to producing thicker coatings
  - Longer bath times = thicker coating
  - Bridge Specification: Max Silicon range at 0.40% = highly reactive steels





Bridge Girder Design Considerations

- Effective Girder Design for HDG
  - Flange-to-web thickness: 3 to 1 maximum
  - Air cool, not quenched
  - Continuous welding to prevent weld fracture from stress or trapped liquids expanding
  - Cambered beams
    - Process temps can accentuate or relieve internal stresses
    - Lay down on strong axis with support
  - Stiffeners should be cropped
  - Minimize immersion time
  - Lift at quarter points to distribute weight



Causes of Warpage & Distortion

- Heat of process can relieve stresses
  - Can lead to distortion and warping of parts/assemblies

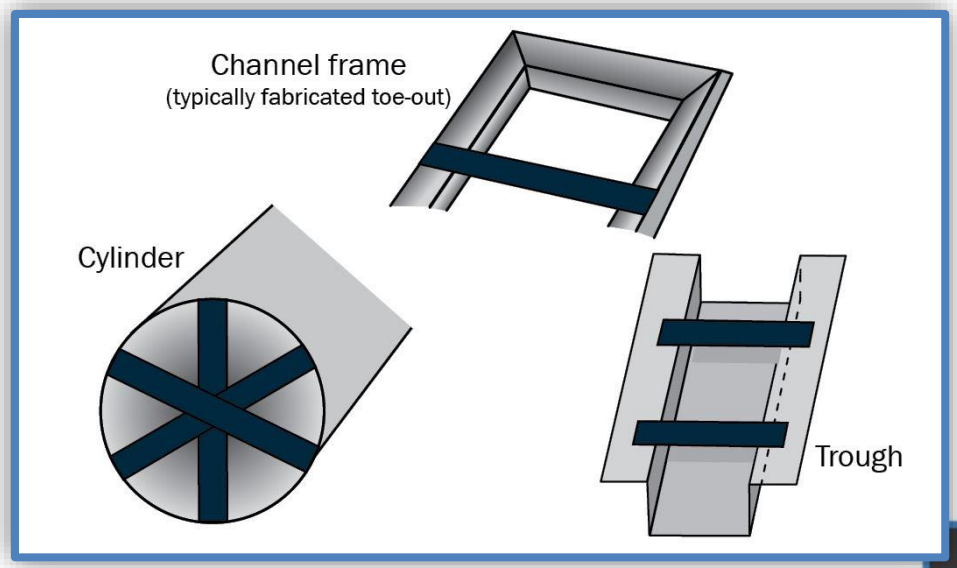
- Avoid designing assemblies with susceptibility
  - Asymmetrical design
  - Unequal thickness in assemblies
  - Unequal thickness at joints
  - Excessive welding
  - Overlapping joints
  - Progressive dipping

Best Practices to Avoid Warpage & Distortion

- Thermal Treatment per ASTM A143
- Use Temporary Bracing
  - Thin-walled items
  - Asymmetrical designs
- Use Bolted Connections or Weld After HDG
- Optimize Venting/Drainage
- Account for Thermal Expansion When Progressive Dipping
- Avoid designing assemblies with susceptibility
  - Follow guidelines in ASTM A384
    - Thermal treatment after cold working
  - Symmetrical design
  - Equal or near equal thickness in assemblies
  - Overlapping joints
  - Progressive dipping

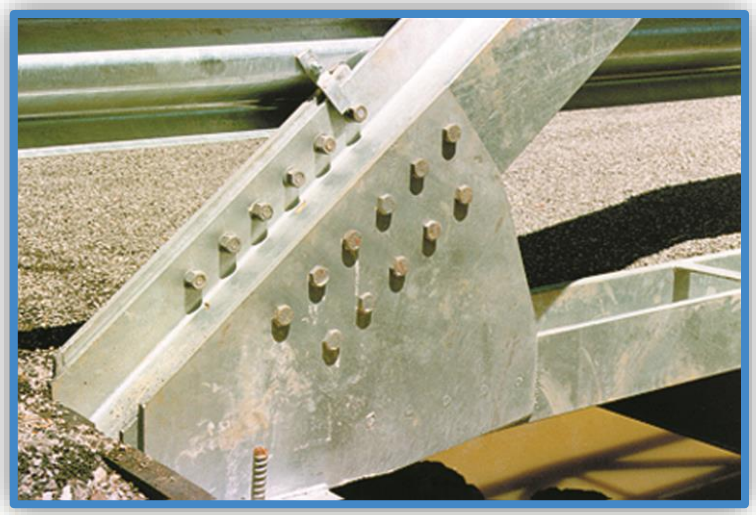
Best Practices to Avoid Warpage & Distortion

- Process Controls
  - Perform immersions quickly and at largest possible dip angle
  - Skip the quench
  - Proper lifting and laydown techniques



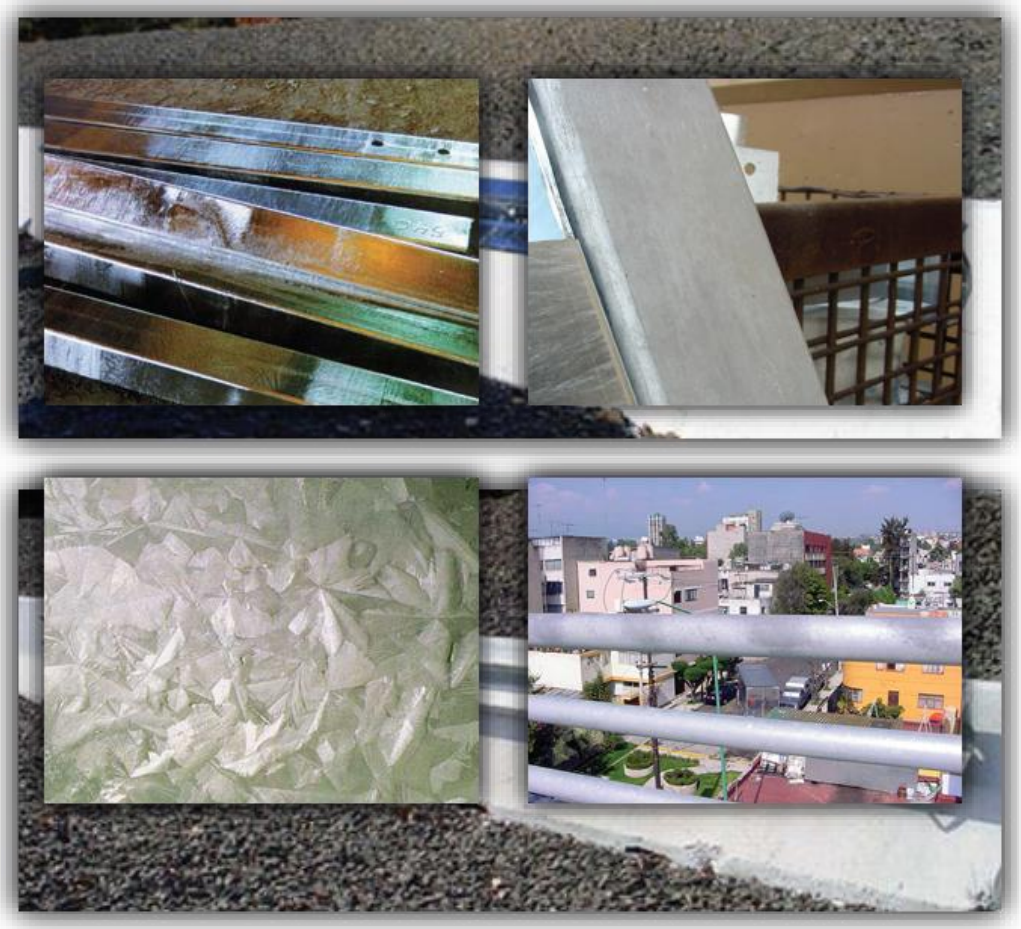
BEARING & SLIP CRITICAL TENSIONING

- Bearing Type Connections
  - Presence of HDG does not affect performance
  - Oversized clearance holes not to be used
- Slip Critical Concerns
  - Newly galvanized steel is very smooth
    - Lower slip coefficient than bare steel
  - Weathered galvanized steel is rough
    - Increased slip resistance
  - Lock-up Effect
  - Oversize clearance holes 1/16in or per AISC LRFD
- Tensioning Galvanized Joints
  - Use a washer underneath turning points
  - Calibrated Wrench, Direct tension indicator, or turn of nut
  - Lubrication to prevent galling



Inspection & Repair

- Repair to ASTM A780
  - Three acceptable methods of touch-up
- Initial inspection
  - Coating thickness
  - Finish & Adherence
- Field inspection
  - Coating Thickness
  - Areas where fabrication and/or touch up done in the field
- galvanizeit.org/repairseries



QUESTIONS & COMMENTS

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