Inorganic Zinc Coatings: Corrosion Control Comparisons and Use Cases

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Steel: a Critical Material for Infrastructure

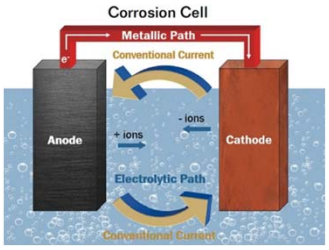
Design Flexibility
Quality-Controlled Construction
Long Service Life
Circular Economy



The Threat to Mitigate: Corrosion

Mechanism of Protection

- Use a less corrosive alloy
- Add a barrier: prevents moisture, oxygen, and contaminants from reaching the steel surface
- Employ cathodic protection: important for exposed steel



Corrosion Protection Systems

PAINT

METALLIZING

GALVANIZING

WEATHERING STEEL

STAINLESS STEEL

Less Active Metals	Barrier Protection	Cathodic Protection
STAINLESS STEEL	PAINT	PAINT
WEATHERING STEEL	GALVANIZING	GALVANIZING
	METALLIZING	METALLIZING

Zinc for Barrier and Cathodic Protection

Cathodic:
zinc preferentially corrodes over carbon steel when "coupled" together

Barrier:
as zinc corrodes, corrosion by-products protect underlying zinc against further corrosion

ZINC-RICH PRIMER

GALVANIZING

SPRAY-ON METALLIZING

Zinc and Paint

1962
Single-coat inorganic zinc patented

Late 1980s
The regulation of lead made way for widespread adoption of zinc-based paints

Zinc-rich primers introduced
Mid 1970s

AASHTO/NSBA Guide Spec for Systems with Zinc-rich Primers published
2014

Zinc-Rich Paint

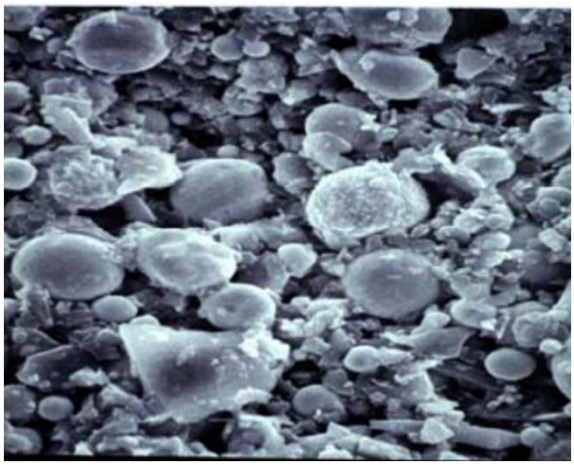
- What is it?
  Zinc dust in a resin
- What are the main types?
  Organic and Inorganic

Organic vs Inorganic

MOSTLY CARBON BASED

MOSTLY NOT CARBON BASED

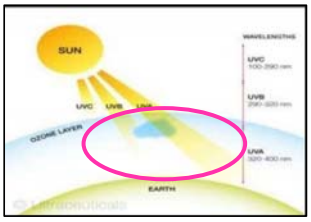
Inorganic Zinc – What is it and Why it Works

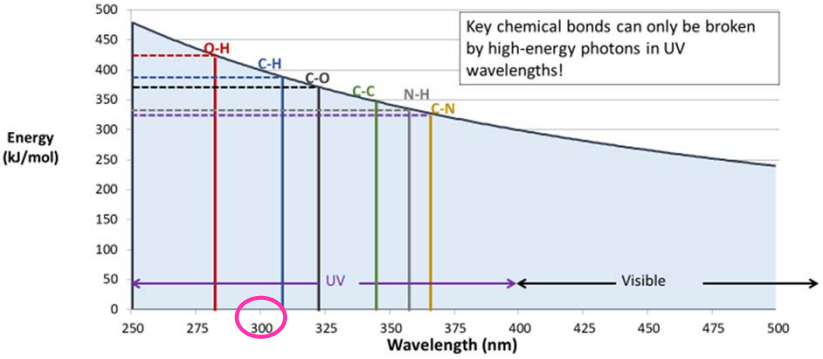


- Inorganic zinc-rich coating
  - Primer
  - Single Coat Inorganic Zinc (SIOZ)
- Based on ethyl silicate resin technology
- Silicates cure through atmospheric moisture over time
- Initial structure is permeable
- The permeability allows the zinc particles closest to the air-coating interface to oxidize (create a “patina”)
- This results in an impermeable, inorganic layer
  - The result: a barrier coating that will not degrade in UV light

Why Does the Type of Chemistry Matter?

Carbon bonds can be broken by UV light





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How Do We Know? Testing

Service Life and Testing per ISO 12944

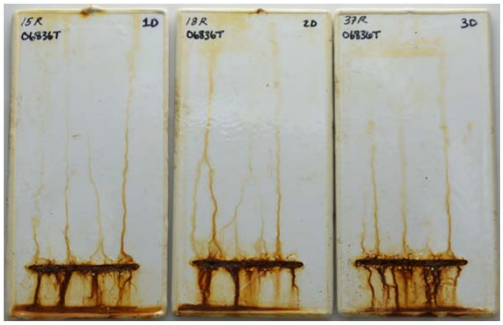
Service Life Expectations

DURABILITY CATEGORY	12944:1998	12944:2018
Low (L)	2-5 years	Up to 7 years
Medium (M)	5-15 years	7-15 years
High (H)	More than 15 years	15-25 years
Very High (VH)	–	More than 25 years

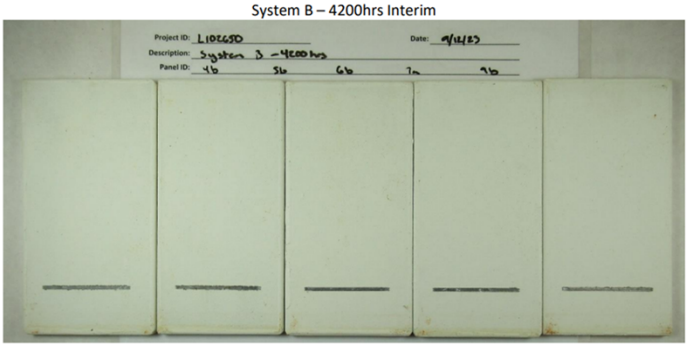
Testing Protocol

	C3	C4	C5	CX
LOW (<7 YEARS)	Non-cyclic testing Durations as 1998 (E) revision ISO 6270 / ISO 9227		Non-cyclic testing: linear durations TBC ISO 6270 / ISO 9227	N/A
MEDIUM (7-15 YEARS)				N/A
HIGH (15-25 YEARS)			Phased introduction of Cyclic ageing testing: 10 cycles / 1680 hours	N/A
VERY HIGH (25+ YEARS)	Non-cyclic testing durations as 1998 (E)	Phased introduction of Cyclic ageing testing: 10 cycles / 1680 hours	Cyclic ageing testing: 16 cycles / 2688 hours	Cyclic ageing testing: 25 cycles / 4200 hours

Results: Three Coat vs Two Coat Inorganic



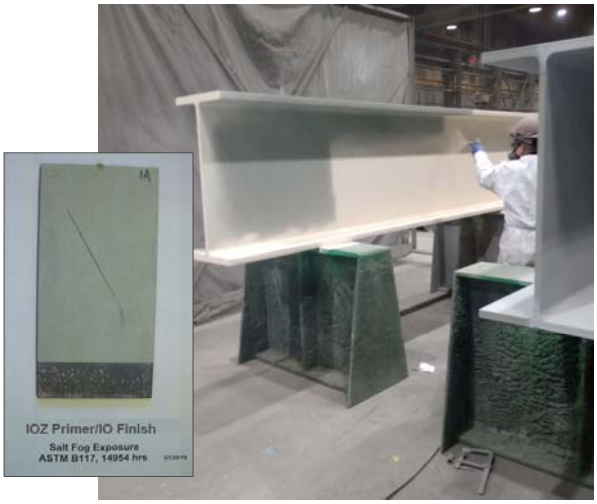
System B – 4200hrs Interim



Inorganic Topcoat

Two-Coat Inorganic System

- *Inorganic topcoat maintains permeability, allowing a patina to form in primer*
  - Maintains long corrosion protection
  - Offers color and a more uniform finish
  - Quick recoat window over IOZ
  - Class B Slip rating to reduce labor (masking)



What about Zinc Paint vs HDG and TSM?

Thermal Spray Metallizing

Benefits

- Long design life

Limitations

- High cost
- Edge retention
- Slow schedule
- Safety & environmental
- Color

Galvanizing

Benefits

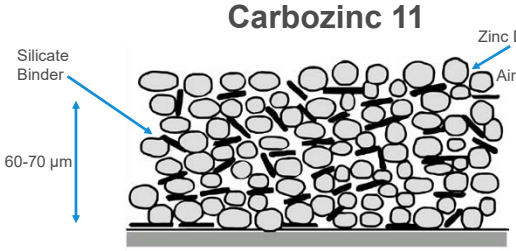
- Good rural protection
- Small parts
- Proven performance

Drawbacks

- Size limitations
- Costly
- Slow schedule
- Warped pieces
- Coastal/industrial environment limitations

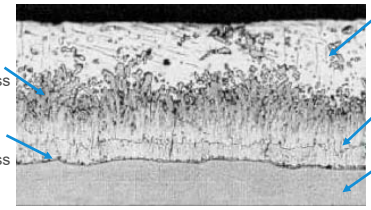
Coating Structure

Carbozinc 11

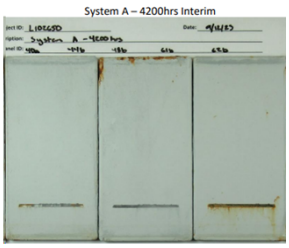


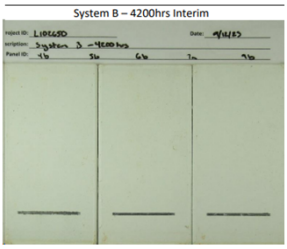
Idealised coating showing zinc dust, joined by silicate with many air gaps

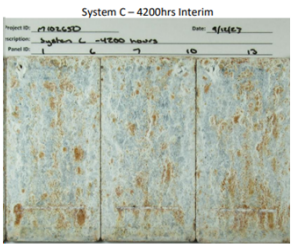
Hot Dipped Galvanizing

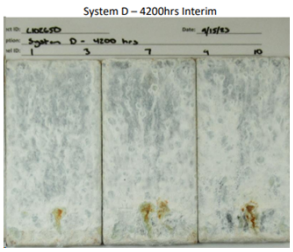


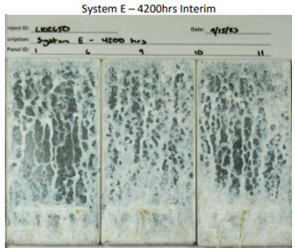
ISO 12944-9 Test Panels After 4200 Hours Exposure











System ID	Description with DFT (mils)
A	Low VOC Inorganic Zinc Primer (2-3)/ Low VOC Inorganic Finish (3-5)
B	Inorganic Zinc Primer (2-3)/ Inorganic Finish (3-5)
C	Galvanizing
D	Thermal Spray Metallizing (10- 20)
E	Thermal Spray Metallizing (10-20)/ Polyurethane Clear Clear (2-3)

Structural Steel - Shop Installation Cost

Inorganic Zinc Primer

Material Cost	
333	SF/ Gal @ 3 mils
60%	Transfer Efficeiency
199.8	SF applied/ gallon
$100	$/ Gallon
$0.50	Material Cost/ SF
Surface Prep	
$70	Cost per Man Hour
0.005	SF/HR Blast
$0.35	Surface prep cost per SF
Application Cost	
$70	Cost per Man Hour
165	Square Feet per Man Hour
$0.42	SF for paint application
$1.27	**Total Applied Cost / SF**

Inorganic Finish

Material Cost	
183	SF/ Gal @ 5 mils
60%	Transfer Efficeiency
109.8	SF applied/ gallon
$120	$/ Gallon
$1.09	Material Cost/ SF
Application Cost	
$70	Cost per Man Hour
165	Square Feet per Man Hour
$0.42	SF for paint application
$1.51	**Total Applied Cost / SF**

$2.78 System Applied Cost / SF

Thermal Spray Metallizing – Bridge Girder Example

Cost

$15 - $26 / square foot – TSM

$2.78/ square foot – two coat IO system

CARBOZINC 11 / ARMORLAST				
WORK DAYS	1	2	3	4
BLAST				
PAINT				
LOAD FOR SHIPPING				
DELIVER TO JOBSITE				

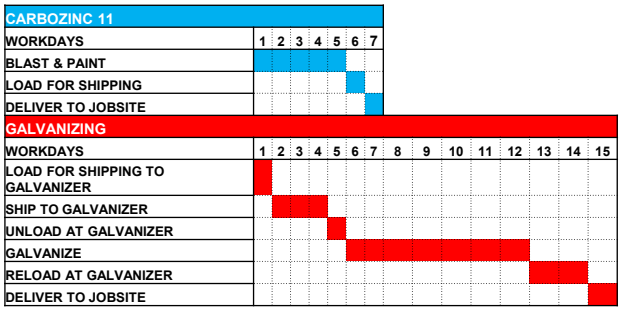
THERMAL SPRAY METALIZING												
WORK DAYS	1	2	3	4	5	6	7	8	9	10	11	12
BLAST - 4 MIL PROFILE												
THERMAL SPRAY INSTALL												
LOAD FOR SHIPPING												
DELIVER TO JOBSITE												

AESS Truck Load Steel – Galvanizing Cost/Schedule

HOT DIP GALVANIZING

$/ CWT	$/ Ton	SF/ Ton	$/ SF
$40.00	$800.00	165	**$4.85**

Two Coat IO System- $2.78/ Square Foot



Traditional Three Coat – Shop Installation Cost

ORGANIC ZINC

Material Cost	
212	SF/ Gal @ 5 mils
60%	Transfer Efficeiency
127.2	SF applied/ gallon
$90	$/ Gallon
$0.71	Material Cost/ SF
Surface Prep	
$70	Cost per Man Hour
0.005	SF/HR Blast
$0.35	Surface prep cost per SF
Application Cost	
$70	Cost per Man Hour
165	Square Feet per Man Hour
$0.42	SF for paint application
$1.48	**Total Applied Cost / SF**

EPOXY

Material Cost	
192	SF/ Gal @ 6 mils
60%	Transfer Efficeiency
97.2	SF applied/ gallon
$75	$/ Gallon
$0.77	Material Cost/ SF
Application Cost	
$70	Cost per Man Hour
165	Square Feet per Man Hour
$0.42	SF for paint application
$1.19	**Total Applied Cost / SF**

POLYURETHANE

Material Cost	
374	SF/ Gal @ 3 mils
60%	Transfer Efficeiency
224.4	SF applied/ gallon
$100	$/ Gallon
$0.46	Material Cost/ SF
Application Cost	
$70	Cost per Man Hour
165	Square Feet per Man Hour
$0.42	SF for paint application
$0.88	**Total Applied Cost / SF**

$3.55	**System Applied Cost/ SF**

2 Coat IO System - $2.78/ Square Foot

Traditional Three Coat – Schedule

CARBOZINC 11 / ARMORLAST							
WORK DAYS	1	2	3	4	5	6	7
BLAST & PAINT							
LOAD FOR SHIPPING							
DELIVER TO JOBSITE							

3 COAT PAINT									
WORK DAYS	1	2	3	4	5	6	7	8	9
BLAST & PAINT									
LOAD FOR SHIPPING									
DELIVER TO JOBSITE									

- IO Zn Primer – 2 hour dry before topcoat
- IO Finish – dry to handle in 2 hours at 75°F

Lifecycle and Maintenance

Life Cycle Cost

System	Cost Per Sq Ft.	Life Cycle (Years)	Cost Per Year
TSM	20	50	**$0.40**
Galv	4.85	50	**$0.10**
3 Coat	3.55	25	**$0.14**
2 Coat IO	2.78	50	**$0.06**
SIOZ	1.48	50	**$0.03**

Maintenance Considerations

Inorganic finishes can be touched up with organic zinc, as is commonly done now

The best approach to ensure long service life is to abrade where necessary and touch up with a thinned-down inorganic zinc primer

The two-coat inorganic system has a comparable maintenance schedule to galvanizing

Damage Resistance

Inorganic finishes dry to hard glass or rock-like coatings that are very tough to damage

Because both the inorganic primer and inorganic finish have a Class B slip rating, they can be finished at any point in the fabrication, as no roughening of surfaces is needed prior to installing bolted connections

Applications

Two-Coat Inorganic Corrosion Protection System

- Long-life corrosion protection in a range of color
- Reduced schedule time compared to other long-life systems like galvanizing and thermal spray metallizing
- Flexible fabrication with class B slip-rated coatings
- Long-life and the use of inorganic, non-carbon-based materials reduce environmental impact

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