Toward a 100 Year Bridge Coating System: Fluoropolymer Topcoats

Winn Darden, AGC Chemicals Americas

LUMIFLON®
FEVE RESIN

Presentation Overview

- Overview of Topcoats and FEVE Topcoats
- Weatherability of FEVE Topcoats
  - Accelerated weathering
  - Natural weathering
- Corrosion Resistance of FEVE Topcoats
- Specification Review
- Life Cycle Cost Analysis
- Case Studies

Topcoat Overview

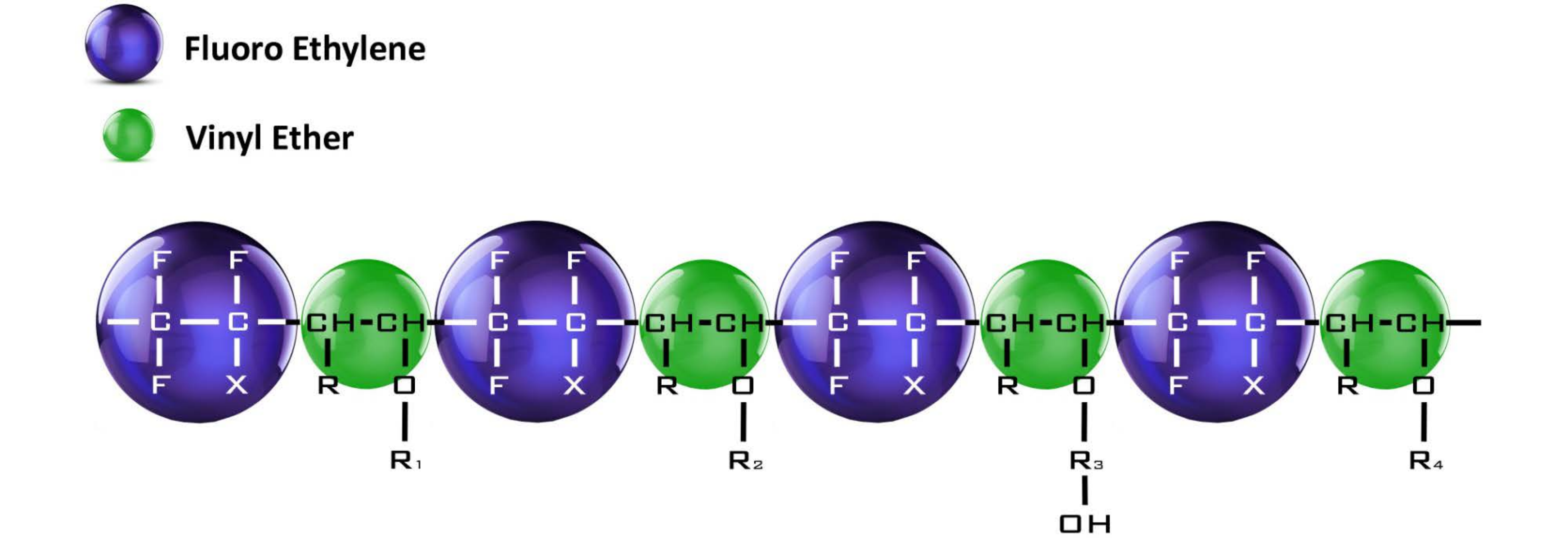
- **Conventional Coating Systems**
  - Zinc rich primer, epoxy, and polyurethane topcoat
  - Offer good corrosion protection
  - Topcoat begins to chalk and change appearance quickly

- **Fluoropolymer Coating Systems**
  - Zinc rich primer, epoxy, and fluorinated urethane topcoat
  - FEVE (FluoroEthylene Vinyl Ether) technology
  - Developed in the early 1980's; wide use by the 1990's

  – FEVE withstands UV exposure at least 2-3 times longer than conventional coating resins.

FEVE Fluoropolymer Structure

- The fluoroethylene (FE) segments impart durability, whereas the vinyl ethers (VE) give a range of positive attributes to the FEVE resin including gloss, hardness, solubility, flexibility and the ability to crosslink



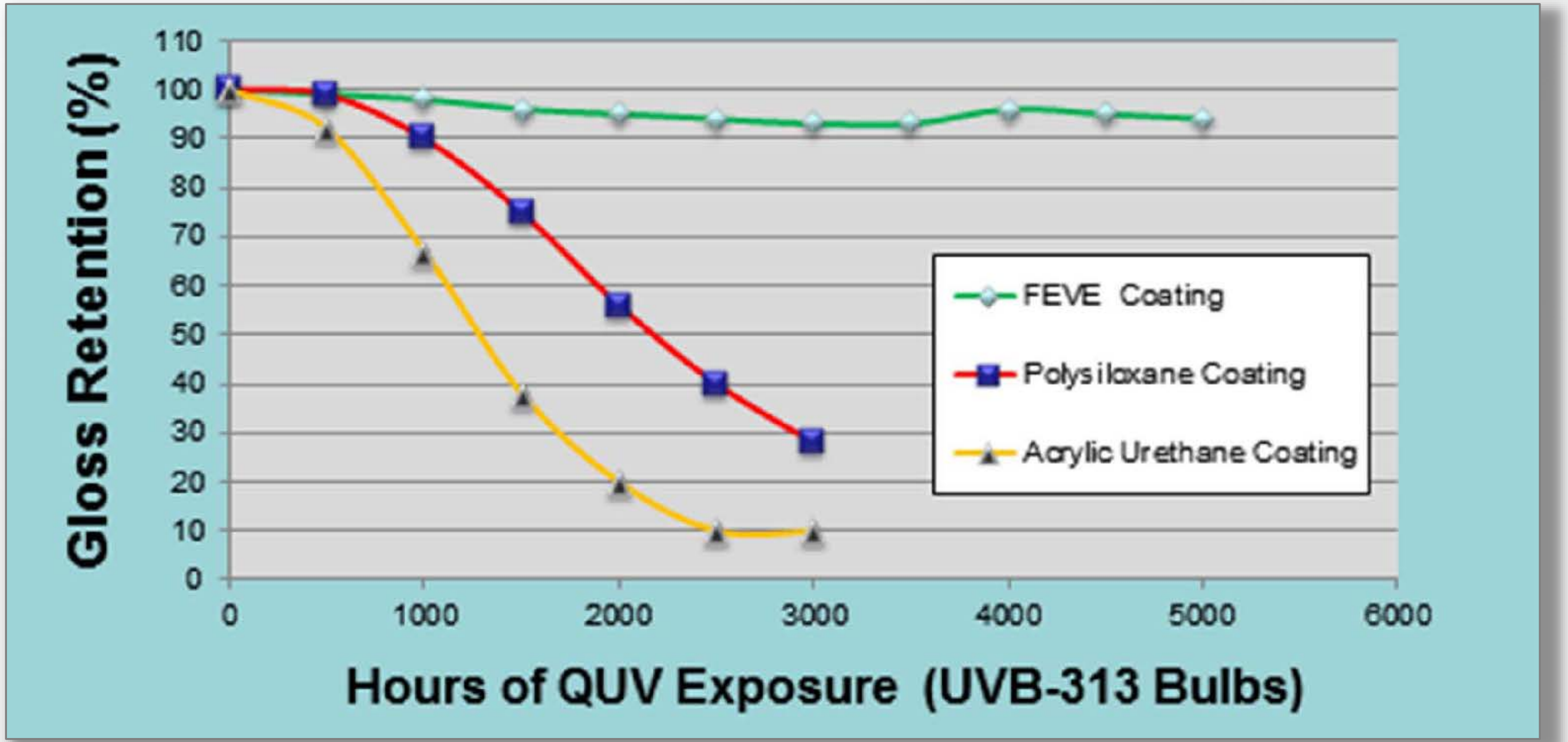
FEVE Resin Topcoat Advantages

- Excellent weatherability (30+ year topcoat life)
- Superior gloss and color retention
- Good corrosion resistance
- Superior resistance to chalking
- Shop or field applied (new construction and maintenance)
- Uses standard painting equipment & application methods
- Formulated to meet all air quality regulations
- Resistant to airborne chemicals and acid rain
- Resistant to cleaning solvents used to remove graffiti

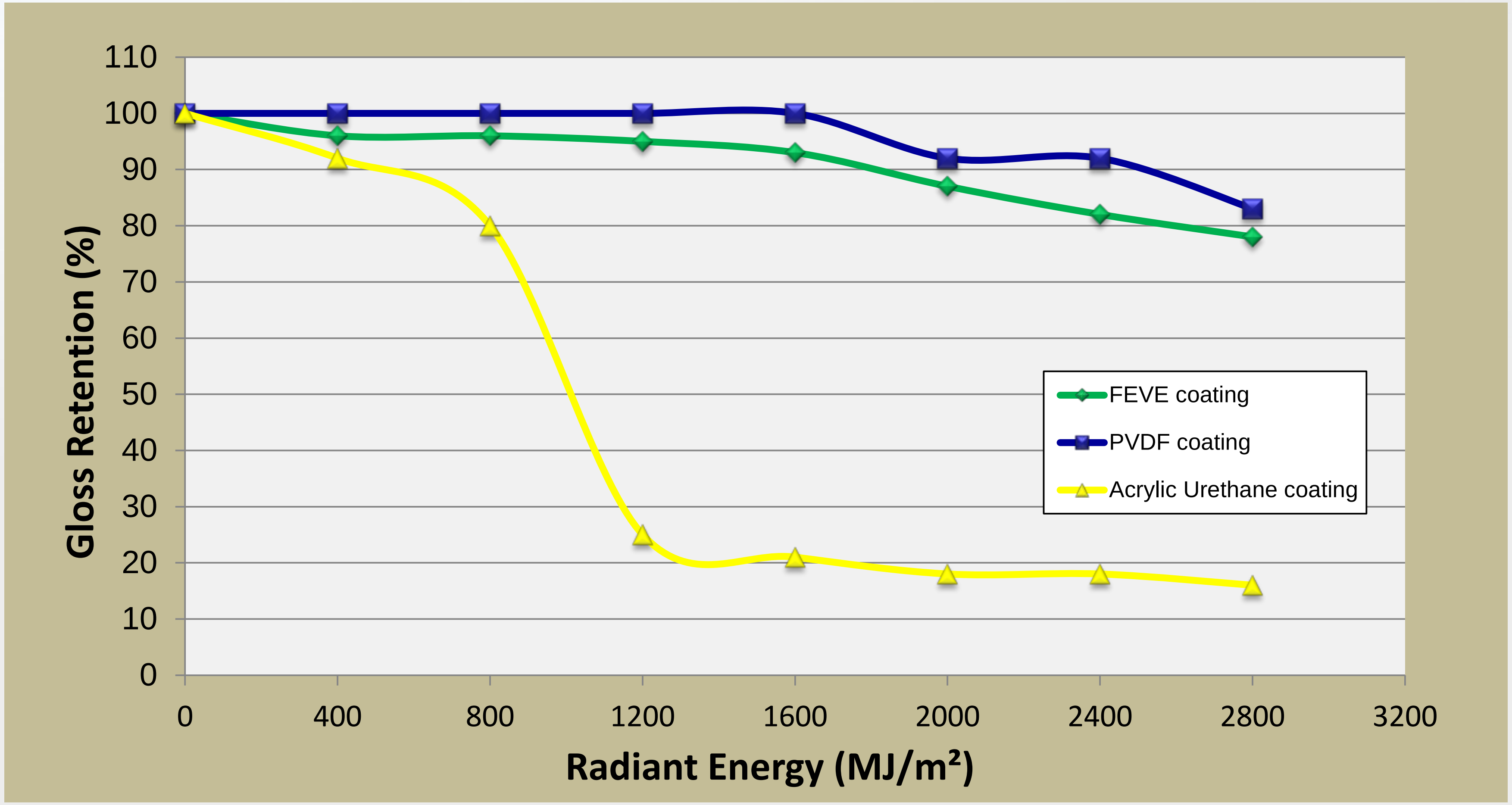
Weathering Resistance Testing

- Accelerated Weathering Tests
  - Short time frame for results
  - Limitations in accurately simulating real environment
  - Used as screening tool and comparing coatings
- Real Time Weathering Tests
  - Accurate results
  - Very time consuming: up to 20 years to complete
  - Often done in harsh conditions, e.g. South Florida

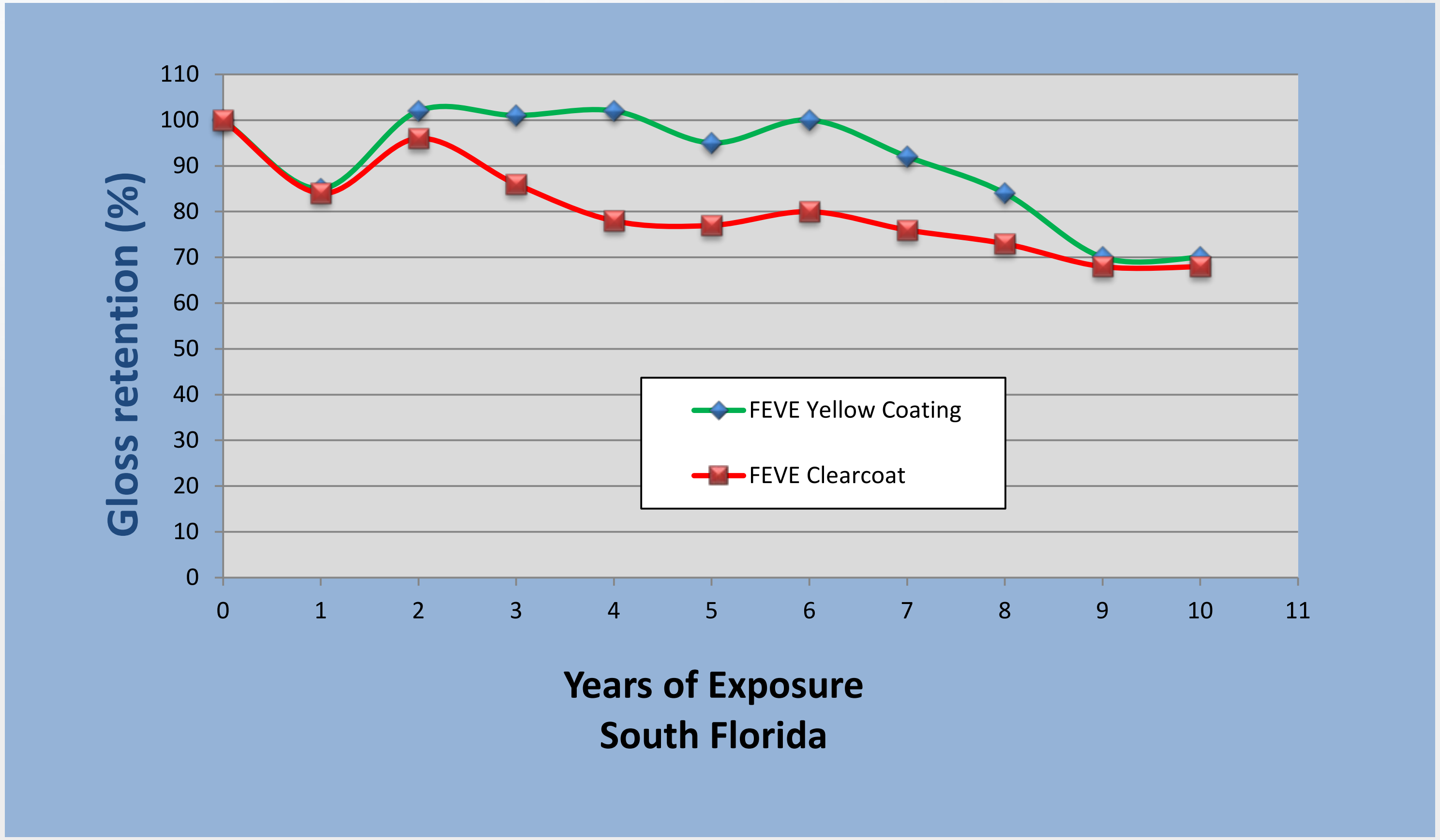
Accelerated Weathering: QUV-B Weatherometer Testing



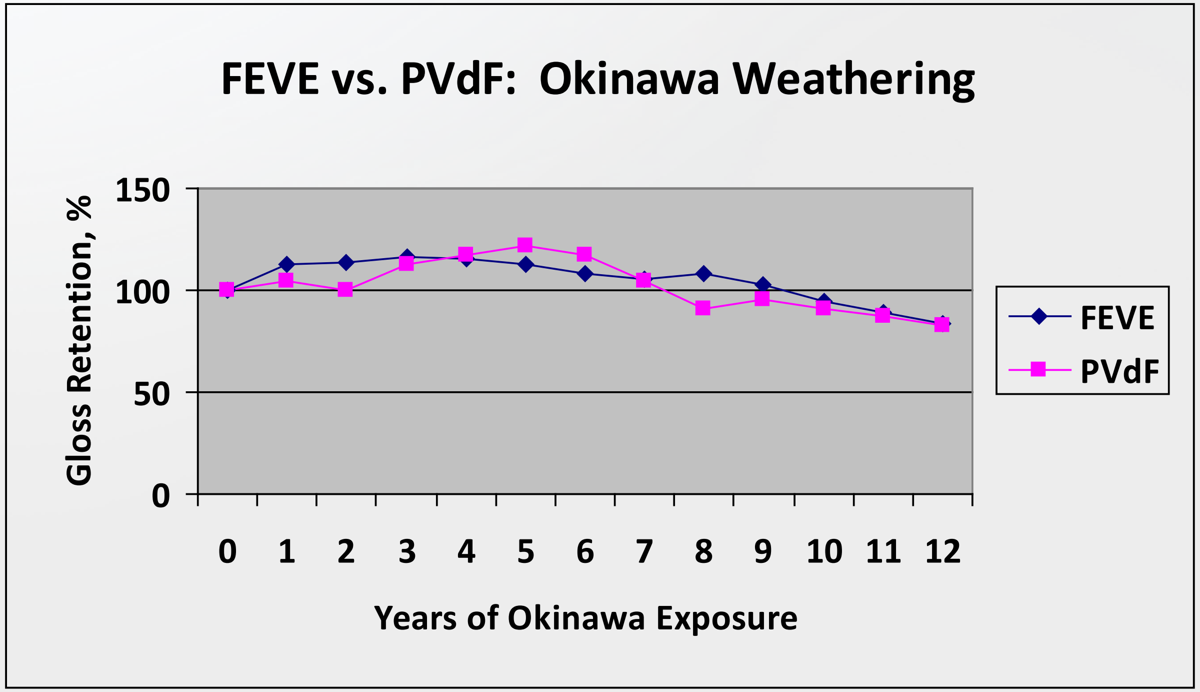
Accelerated Weathering: EMMAQUA Testing



Real Time Weathering: South Florida Testing



Real Time Weathering: Okinawa Weathering



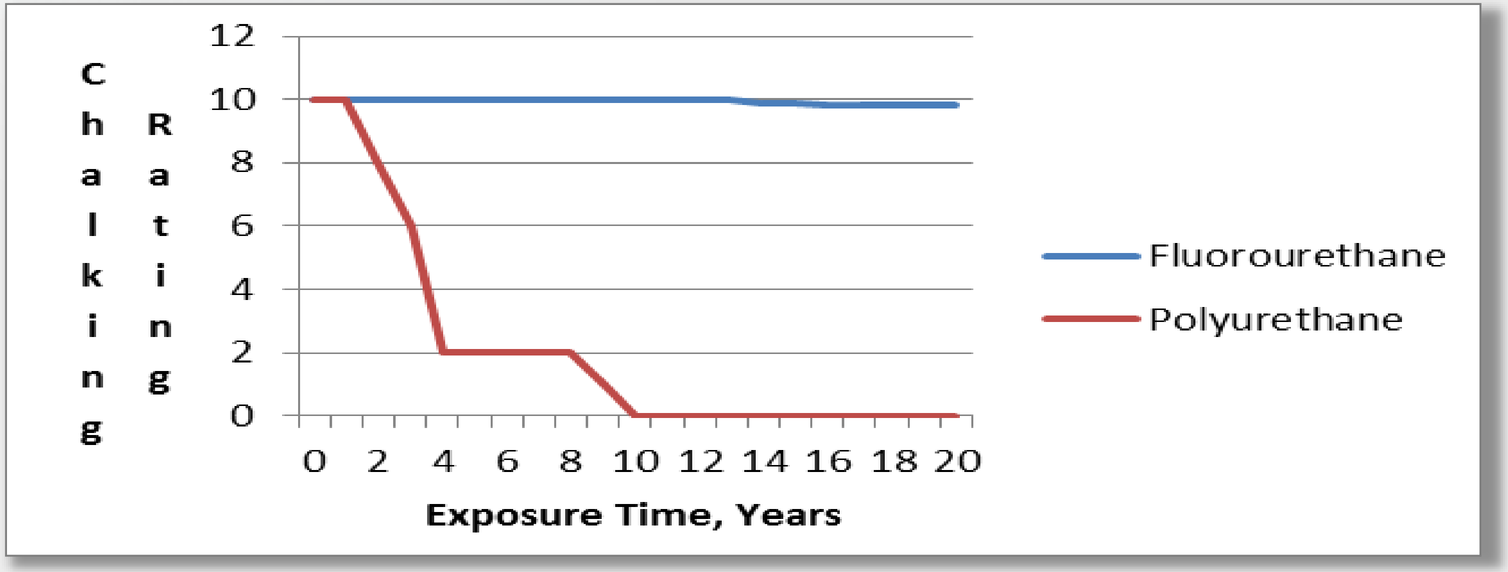
Real Time Weathering: Offshore Platform

- Two coating systems: Zn primer/Epoxy/Acrylic Urethane; Zn primer/Epoxy/FEVE tested on offshore platform in Suruga Bay, Japan (34.87 North 138.48 East)

	ACRYLIC URETHANE TOPCOAT	FLUOROURETHANE TOPCOAT
INITIAL MEASUREMENT (microns)	25	25
FINAL MEASUREMENT (microns)	0 (after 13 years)	21

Real Time Weathering: Offshore Platform

- Polyurethane and FEVE topcoats were evaluated over a 20 year period
- Rated on scale of 0 (severe chalking over entire coating surface) to 10 (no chalking)



Corrosion Resistance of Steel Bridges

- Corrosion Resistance Drives Use of Coatings on Steel Bridges
  - Primary corrosion resistance provided by zinc primer
  - Topcoat serves to block corrosion initiators like oxygen, water, and chloride
  - Fluorinated topcoats have low degradation rates maintaining corrosion protection over longer periods of time

Corrosion Resistance of FEVE Coatings: ASTM D5894, Cyclic Prohesion Test

- Coated scribed panels exposed to alternating UV/condensation and salt fog/dry exposure cabinet
- Salt solution is 0.05% sodium chloride and 0.35% ammonium sulfate
- 5,040 hours of total exposure

	Coating Type	**60^{o} Gloss Retention (%)**	**Max. Scribe Creep (mm)**
Primer	Organic Zinc Epoxy	NA	NA
Topcoats	Polyurethane	35.6	10
	Epoxy Polysiloxane	52.2	12
	Fluorourethane	73.2	8

	Coating Type	**60^{o} Gloss Retention (%)**	**Scribe Creep (mm)**
Primer	Organic Zinc Epoxy	NA	NA
Midcoat	Polyamide Epoxy II	NA	NA
Topcoats	Polyurethane	54.3	8
	Epoxy Polysiloxane	72.0	12
	Fluorourethane	91.0	8

Corrosion Resistance of FEVE Coatings: ASTM B-117 Salt Fog Test

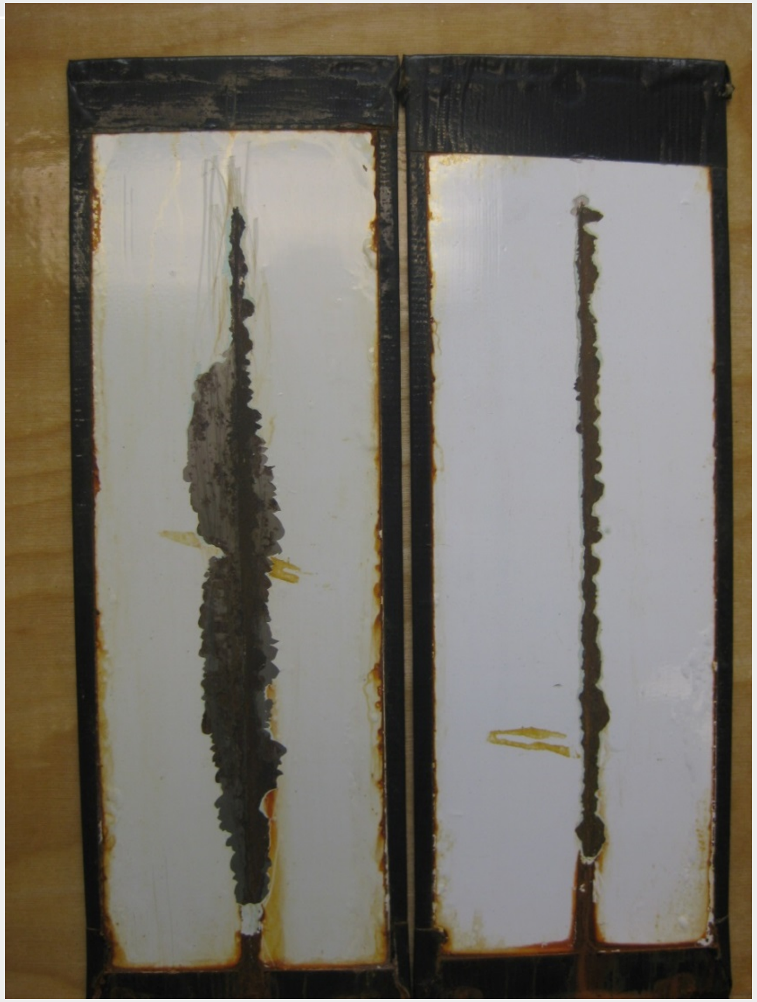
Scribed coated panels exposed to 5% salt solution for 3,000 hours.

Corrosion is measured by the amount of rust in the scribe and under the coating adjacent to the scribe as well as by blisters formed by corrosion products. In the test below, both topcoats were applied over a 3 mil epoxy primer.

Left Panel: Polysiloxane

Right Panel: FEVE coating

Corrosion Resistance of FEVE Coatings: ASTM B-117 Salt Fog Test



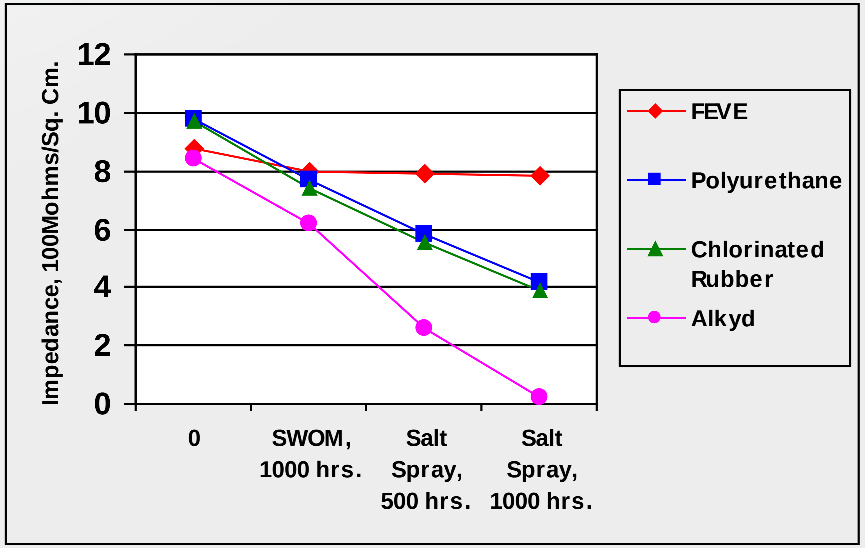
3,000 hours
Left Panel: Polyurethane
Right Panel: FEVE Coating

Corrosion Resistance of FEVE Coatings: ASTM B-117 Salt Fog Test (3,000 Hours)

Formula Name	DFT (mils)	Creep (mm)	Creep Rating (ASTM D1654)
Commercial Polysiloxane White	2.1	6	4
Commercial Clear Polysiloxane	2.0	4	5
Commercial Polyurethane White	2.6	7	3
Fluorourethane Clear	2.1	5	5
Fluorourethane White	1.5	3	5

Corrosion Resistance of FEVE Coatings: Electrochemical Impedance Spectroscopy (EIS)

EIS involves setting up a corrosion cell on a coated steel panel. As a coating degrades, water and other corrosion initiators move through the coating setting up a new corrosion cell. EIS measures the difference in impedance between the new and aged coating. The smaller the change in impedance, the better the corrosion resistance of the coating.



Bridge Topcoat Specifications

- This was the 1990 Japanese National Specification for Bridge Topcoats. FEVE topcoats were required for use only in the most severe environments

		General Environment	Slightly Severe Environment	Severe Environments
Coating Type		No salt or corrosives Non-industrial areas Little smog Easy to recoat	Salt in environment Slight pollution Moderate smog Difficult to recoat	High salt levels Severe pollution Heavy smog Difficult to recoat
	General Purpose Coating	A-1, A-2	B-1	C-1, C-2
	High Durability Coating	A-3, A-4	C-3, C-4	

A-1, A-2: Long Oil Alkyd Coating **B-1: Chlorinated Rubber**
A-3, A-4: Silicone Alkyd Coating **C-1, C-2: Polyurethane Coating**

C-3: Fluoropolymer Coating, Shop Applied **C-4: Fluoropolymer Coating Field Applied**

Bridge Topcoat Specifications

The Japanese National Specification was changed to focus on preventive maintenance and to yield lower life-cycle cost. Fluoropolymer topcoats were required for all environments.

		General Environment	Slightly Severe Environment	Severe Environment
Application		No salt or corrosives Non-industrial areas Little smog Easy to recoat	Salt in environment Slight pollution Moderate smog Difficult to recoat	High salt levels Severe pollution Heavy smog Difficult to recoat
	New Construction, Shop Application	C-5 Coating System, Fluoropolymer Topcoat		
	Repair Coatings, Field Application	Rc-I, RC-III, Fluoropolymer Topcoat		

Bridge Coating Specification

SP-150172
(New)

IOWA DOT

SPECIAL PROVISIONS
FOR
FLUOROPOLYMER PAINT FOR STRUCTURAL STEEL

Scott County
IM-NHS-074-1(197)5--03-82
IM-NHS-074-1(198)5--03-82
IM-NHS-074-1(199)5--03-82

Effective Date
April 25, 2017

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

150172.01 DESCRIPTION.
These Special Provisions describe surface preparation and shop painting of structural steel and incidental parts for the I-74 Mississippi River Crossing and Corridor project using a three coat fluoropolymer paint system.

150172.02 MATERIALS.
Approved fluoropolymer paint systems for this project are listed in Materials I.M. 482.09.

150172.03 CONSTRUCTION.
The work includes the following items: preparation of all surfaces to be painted, application of paint, protection, drying of paint coatings, and repairing and repainting of coating damaged in the shop or after erection, or both.

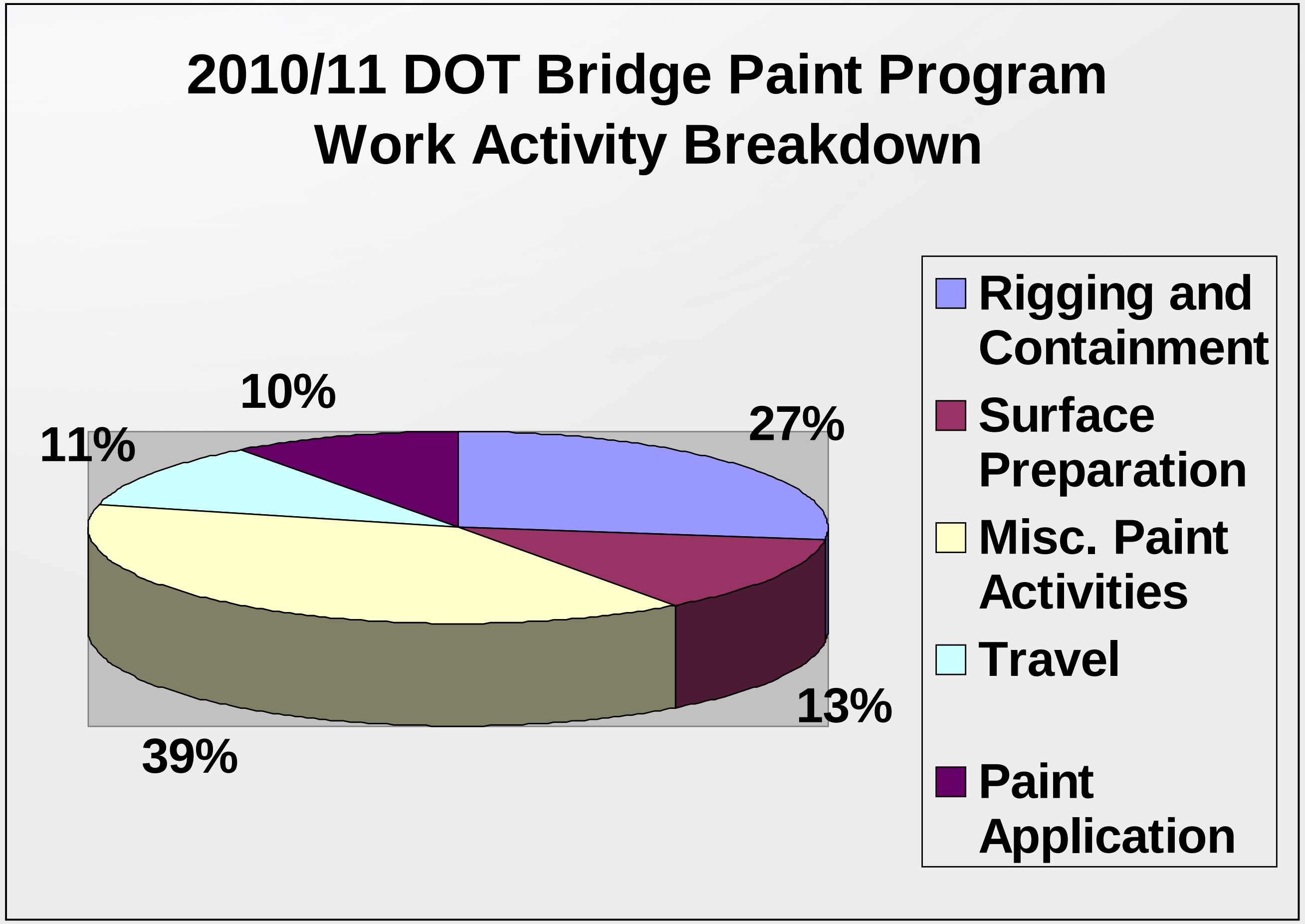
Steel Structures Coating Specification: ISO 12944 Updated 2018

- **6.2.5 Paints for polyurethane coatings (PUR)**
- Single pack polyurethane paints dry initially by solvent evaporation (where solvent is present) and by a chemical reaction with moisture from the air. The process is irreversible, meaning that the coating cannot be dissolved in the original solvent. Aromatic as well as aliphatic types of polyurethane coatings are available. Aromatic types are not recommended for top coats, as they tend to chalk.
- Two pack paints for polyurethane coatings dry by evaporation of solvents, if present, and cure by a chemical reaction between a base and a curing agent component. The mixture of base and curing agent has a limited pot-life.
- The binders of the base component are polymers with free hydroxyl groups e.g. polyester, acrylic, epoxy, polyether, fluoro resin, which react with suitable isocyanate curing agents. They can be combined with non-reactive binders, e.g. hydrocarbon resins.
- The curing agent component contains an aromatic or aliphatic polyisocyanate.
- **A special type of PUR is based on fluoropolymers.**
- **Paints for fluoropolymer/vinyl ether co-polymer (FEVE) coatings are two pack coating materials, and both water-borne and solvent-borne types are available. Solvent-borne paints dry by solvent evaporation and cure by a chemical reaction between a base resin and a curing component. Paints for FEVE coatings are ambient curable coating materials cross-linked with isocyanate hardener.**
- **The resin of the base component is fluoropolymer with free hydroxyl groups which reacts with suitable isocyanate curing agents.**

Life Cycle Cost: Topcoat Cost Analysis

Topcoat Type	Topcoat Thickness, µm	Coating Cost, $/m2
Alkyd	50	1.47
Polyurethane	55	4.08
Fluorourethane	55	24.02

Life Cycle Cost: Bridge Painting Activities



Life Cycle Cost Analysis: FEVE vs. Polyurethane and Alkyd

Coating System	Alkyd	Polyurethane	Fluorourethane	
Total Repainting Cost, $/m2	69.48	85.65	105.88	
Estimated Coating Life, Years	7	18	30	60
Total Applied Coating System Cost, $/m2/Year	9.93	4.76	3.53	1.76
Cost Index	100	48	35	18

Case Study: Tokiwa Bridge, Near Hiroshima, Japan

FEVE coating system applied in 1986.

1993

2008

2016

Gloss and Color Change		Initial Gloss	2008 Gloss	2016 Gloss	2008 Color Change
Before Wiping	Gloss	75.2	66.2	52.7	$\Delta E=3.5$
	Gloss Retention	N/A	88.0%	70.1%	
After Wiping	Gloss	75.2	77.6	73.2	$\Delta E=2.3$
	Gloss Retention	N/A	103.2%	97.3%	

Case Study: Daiichi Mukoyama Bridge, Near Tokyo, Japan

FEVE coating system applied 1986

30 years
No corrosion or degradation of topcoat

No chalking

Gloss and Color Change		Initial Gloss	2008 Gloss	2016 Gloss
Before Wiping	Gloss	52.4	46.5	28.3
	Gloss Retention	N/A	88.7%	54.0%
After Wiping	Gloss	52.4	49.9	38.7
	Gloss Retention	N/A	95.2%	73.8%

U. S. Bridges with FEVE Topcoats

- Shelby Street Bridge, Nashville, TN (2000)
- Gateway Bridge, Nashville, TN (2004)
- Woodland St. Bridge, Nashville, TN
- Victory Memorial Bridge, Nashville, TN
- Topeka Blvd. Bridge, Topeka, KS (2008)
- I-235 Pedestrian Bridge, Des Moines, IA (2003)
- I-17 Pedestrian Bridge, Phoenix, AZ
- Boynton Inlet Bridge, Boynton Beach, FL (2010)
- Skydance Pedestrian Bridge, Oklahoma City, OK (2012)
- Blue Bridge, Grand Rapids, MI (2013)
- Salmon Creek Bridge, Albion, CA, Test patch
- Duquesne University Skywalk, Pittsburgh, PA (2006)
- Georgetown Pedestrian Bridges, Washington, DC (2004)
- I-65 Arch Bridge, Columbus, IN, IN DOT (2007)
- Tucson Historic Depot Pedestrian Bridge, Tucson, AZ
- Navy Pier Pedestrian Bridge, Chicago, IL (2017)

Conclusions

- Based on accelerated and real time testing, fluoropolymer topcoats offer outstanding weathering and corrosion resistance
- Expected topcoat life in Japan is 30-60 years, as close as possible to 100 year coating
- Shop and field application
- Substantial life cycle cost advantages
- Environmental advantages

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