


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Update of SHRP2 R19A Activities

AASHTO COB, Burlington, VT
Technical Committee T-9 – Bridge Preservation

Mike Bartholomew, P.E., Senior Principal Bridge Engineer
Jacobs

June 25, 2018

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Presentation Overview

- Service Life Introduction

- SHRP2 R19A Implementation Action Program
  - Program Goals
  - Work Focus Areas
  - Tools Developed
  - Participating Agency (Lead Adopter) Project Updates

Service Life Design (SLD)

- Design approach to resist deterioration caused by environmental actions
  - Also called Durability Design
  - Often referred to as Design for 100-year Service Life

- Not designing for the Service Limit States I, II, and III per LRFD 3.4

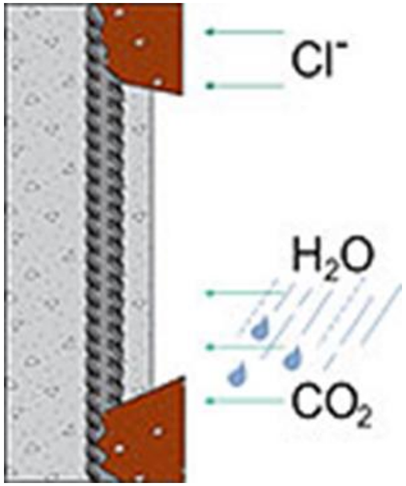
Common Deterioration Types

- Reinforcing steel corrosion
- Concrete cracking, spalling, delamination

- Structural steel corrosion following breakdown of protective coating systems

Environmental Exposure

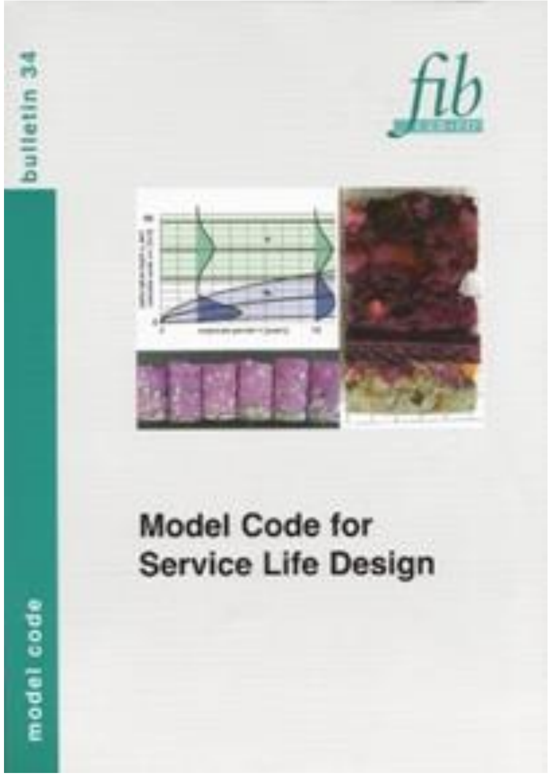
- Chlorides from sea water or de-icing chemicals
- CO_2 from many wet / dry Cycles
- Temperature / Relative Humidity
- Freeze / Thaw Cycles
- Abrasion (ice action on piers, studded tires on decks)
- Internal / Alkali-Aggregate Reaction (AAR/ASR), DEF



Service Life Design Concepts

- Performing Service Life Design using the principles outlined in *fib* Bulletin 34 – Model Code for Service Life Design (2006)

- Focuses on resisting deterioration from environmental exposure



Need for Service Life Design

- Increasing interest by the industry to make bridges more durable with longer expected lives
- Popular for politicians to state that a new bridge will last 100+ years…
- Evident by requirements in recent Owner's RFPs – particularly on Design Build projects

Service Life Designed Structures

- Confederation Bridge, Canada –1997 (100years)

Service Life Designed Structures

- Mario Cuomo Bridge, NY – 2018 (100 years)

Need More Focus on These

- Representing the majority of the 600,000+ bridges in the US

Need for Service Life Design

- Expectations of SLD requirements often unclear

- A more robust definition was needed for SLD

- FHWA in conjunction with AASHTO and TRB through the 2nd Strategic Highway Research Program (SHRP2) initiated project R19A
  - Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems and Components

SHRP2 Project R19A

SHRP2 R19A Team

RESEARCH – **TRB**

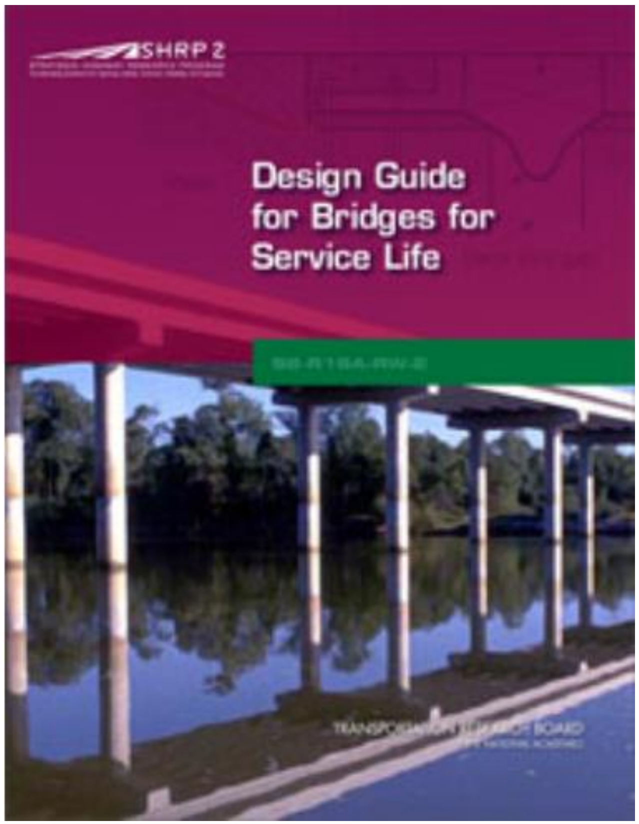
IMPLEMENTATION – **FHWA/AASHTO**

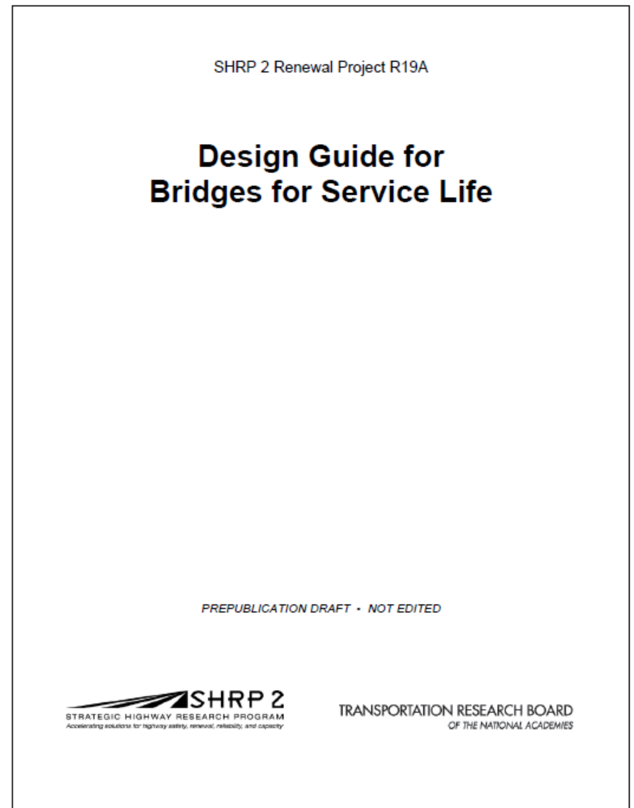
SUBJECT MATTER EXPERTS /
LOGISTICS SME LEAD – **Jacobs**
TECHNICAL SMEs –
COWI

LEAD ADOPTER AGENCIES

Research Work Completed

- Project R19A – Service Life Design Guide




SHRP 2 Renewal Project R19A

Design Guide for Bridges for Service Life

PREPUBLICATION DRAFT • NOT EDITED

SHRP 2 STRATEGIC HIGHWAY RESEARCH PROGRAM

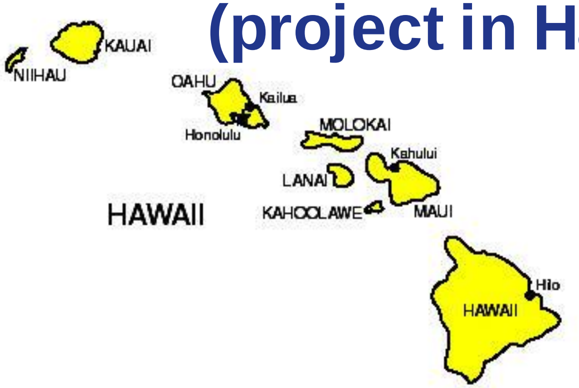
TRANSPORTATION RESEARCH BOARD *OF THE NATIONAL ACADEMIES*

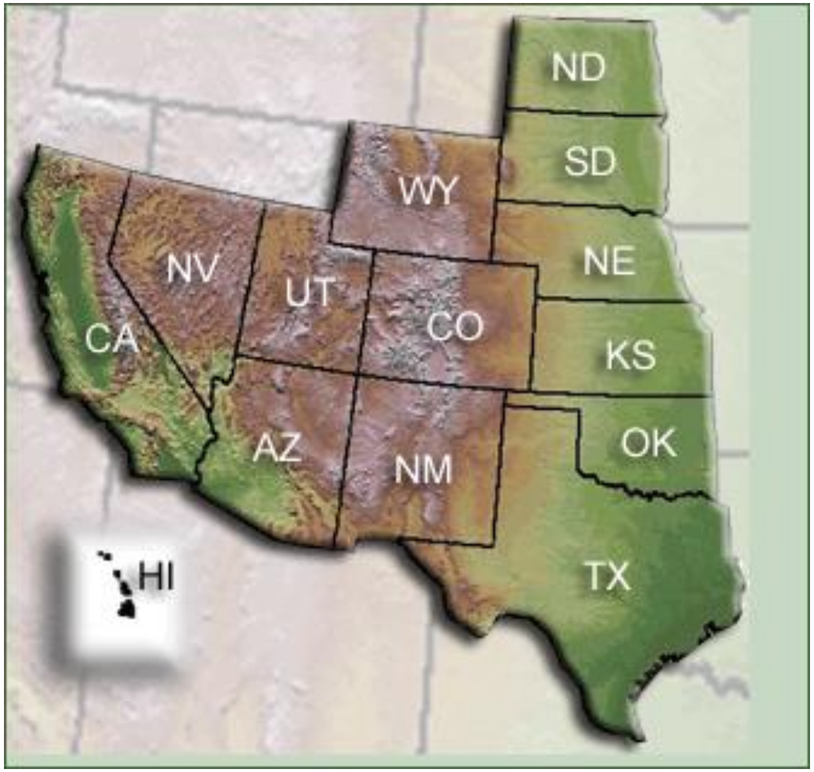
  - http://www.trb.org/Main/Blurbs/168760.aspx

IAP Lead Adopter Agencies

Oregon

Central Federal Lands (project in Hawaii)





IAP Lead Adopter Agencies

Iowa

Maine

Pennsylvania

Virginia

IAP Team Leaders

- FHWA Central Federal Lands
  - Bonnie Klamerus, Mike Voth
- Iowa DOT
  - Ahmad Abu-Hawash, Norm McDonald
- Maine DOT
  - Dale Peabody
- Oregon DOT
  - Bruce Johnson, Paul Strauser, Zach Beget, Ray Bottenberg, Andrew Blower, Craig Shike
- Pennsylvania DOT
  - Tom Macioce
- Virginia DOT
  - Prasad Nallapaneni, Soundar Balakumaran

Current R19A Work Focus Areas

- Performing tests on material durability properties of concrete mix designs
  - Concrete chloride migration coefficient (NT Build 492)
  - Measurement of as-constructed concrete cover

Elcometer

Chloride Migration Test
NT Build 492

nordtest method

NT BUILD 492

Approved 1999–11

- **Chloride Migration Coefficient** from Non-Steady State Migration Experiments
  - Known as the Rapid Chloride Migration (RCM) Test
  - Determines Concrete Chloride Migration Coefficient, $D_{RCM,0}$ used directly in fib Bulletin 34 deterioration model
  - 28 day cure, test duration usually 24 hours

NT Build 492

- Schematic Test Setup
  - 4” diameter x 2” thick specimen sliced from concrete test cylinder
  - 10% Solution of NaCl in water
  - Subjected to electrical current to accelerate chloride ingress

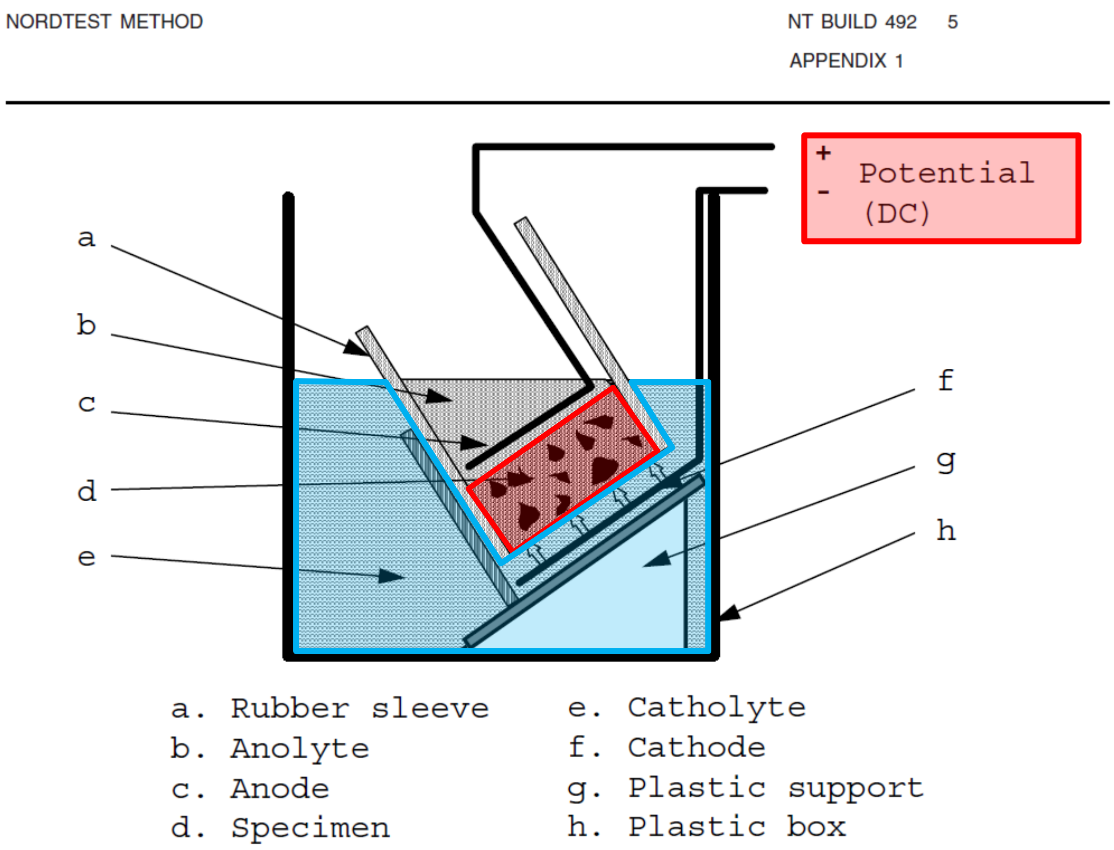


Fig. 1. One arrangement of the migration set-up.

NT Build 492

- Split specimen axially into 2 pieces
- Spray silver nitrate solution on broken surface
- Measure chloride penetration depth
- Calculate Chloride Migration Coefficient, $D_{RCM,0}$

NORDTEST METHOD

NT BUILD 492 7

APPENDIX 1

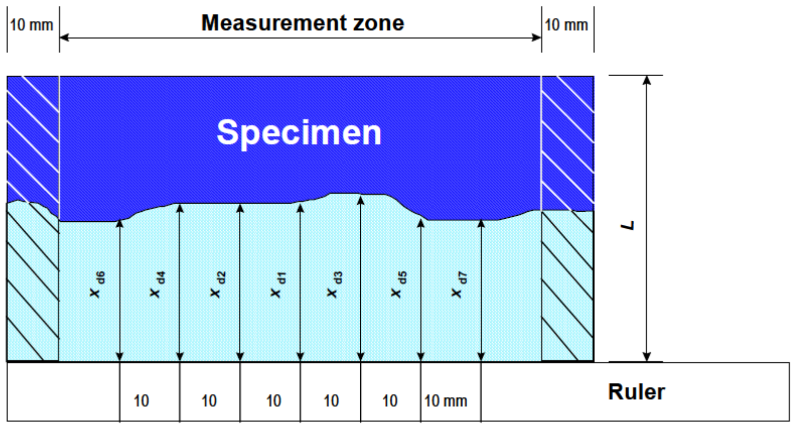
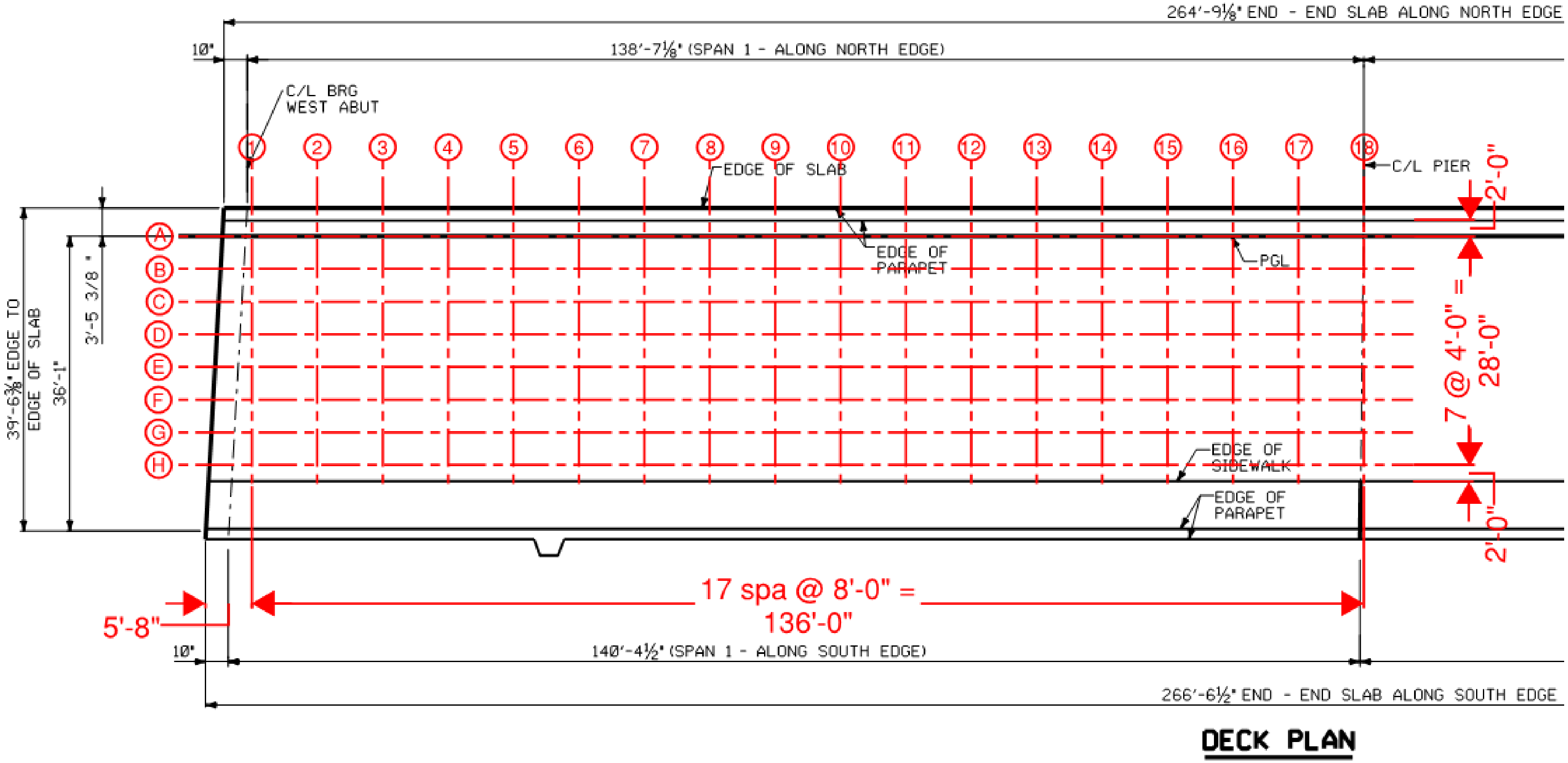


Fig. 5. Illustration of measurement for chloride penetration depths.

Cover Measurements



Cover Measurements

Component Name	Deck		Standard	German Concrete and Construction Association - DBV,
Location	Span 1	top mat		Concrete Cover and Reinforcement per Eurocode 2
			Sampling	Grid sampling

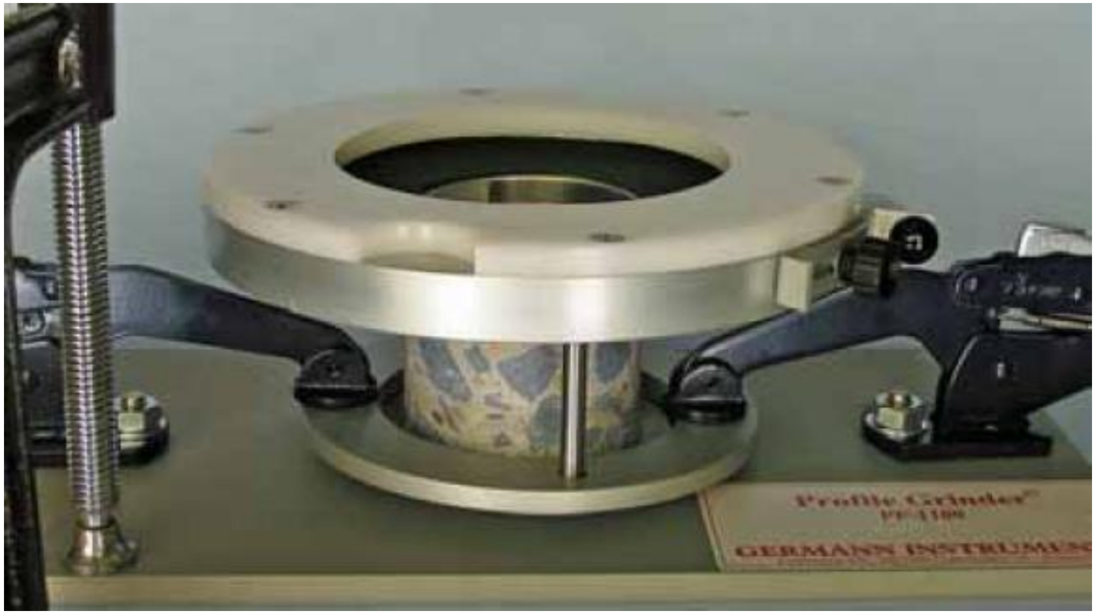
As-Constructed Cover Dimensions at Grid Points [in]																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	2.52	2.20	2.60	2.99	2.05	2.87	2.72	2.80	3.11	2.99	3.11	2.83	2.52	2.62	3.11	2.83	2.52	2.20
B	2.40	2.20	2.48	2.72	2.72	2.76	2.91	2.99	2.17	2.83	2.99	2.09	2.40	2.71	2.99	2.09	2.40	2.20
C	2.24	2.24	***1.46***	***1.57***	2.52	2.20	2.36	2.20	2.20	2.17	2.20	2.24	2.34	2.44	2.54	2.56	2.45	2.51
D	1.93	2.01	***1.65***	2.01	2.24	2.28	2.24	2.13	2.32	2.48	2.52	2.80	2.62	2.56	2.52	2.80	2.51	2.01
E	2.28	2.40	2.09	1.93	2.01	***1.89***	2.17	1.97	2.46	2.60	2.56	2.32	2.28	2.40	2.56	2.32	2.28	2.40
F	2.99	3.11	2.48	2.09	3.15	2.91	2.83	2.56	2.83	2.72	2.83	2.28	2.99	3.11	2.83	2.28	2.99	3.11
G	2.24	2.99	3.15	***1.75***	2.60	2.91	2.44	2.99	2.24	2.48	2.24	2.40	2.24	2.99	2.24	2.40	2.24	2.99
H	2.13	***1.85***	2.20	2.20	2.13	2.83	2.52	2.40	2.20	2.26	2.32	2.48	2.13	2.65	2.32	2.48	2.13	2.75

Statistical Evaluation of Measured Cover Depths, all units [in]

Target threshold %		5%	Qualitative Procedure					
Nominal cover	c_{nom}	2.5	# measurements < c_{min}	6		# allowed per N	11	OK
Safety margin	Δc	0.6						
Req'd minimum cover	c_{min}	1.9	Quantitative Procedure					
Sample size	N	144	Outlier cover	X_{OG}	$= 2.5X_M - 1.5X_{min}$		3.91	
Median	X_M	2.44	Location parameter	r	$= (X + X_M)/2$		2.45	
Min	X_{min}	1.46	Form parameter	k	$= 1.8\ r/s$		12.36	
Mean	X	2.47	Threshold value	c(5%)	$= r/(19^{1/k})$		1.93	
Std. Dev.	s	0.36	Parameter p(x)	p(x)	$= c_{min}/r$		0.77	
			% of cover depth < c_{min}	F(x)	$= p(x)^k/(1+p(x)^k)$		4%	OK

Current R19A Work Focus Areas

- Tests on existing bridges to assess environmental loading and material behavior
  - Taking concrete cores to measure chloride loading from de-icing chemicals or sea water



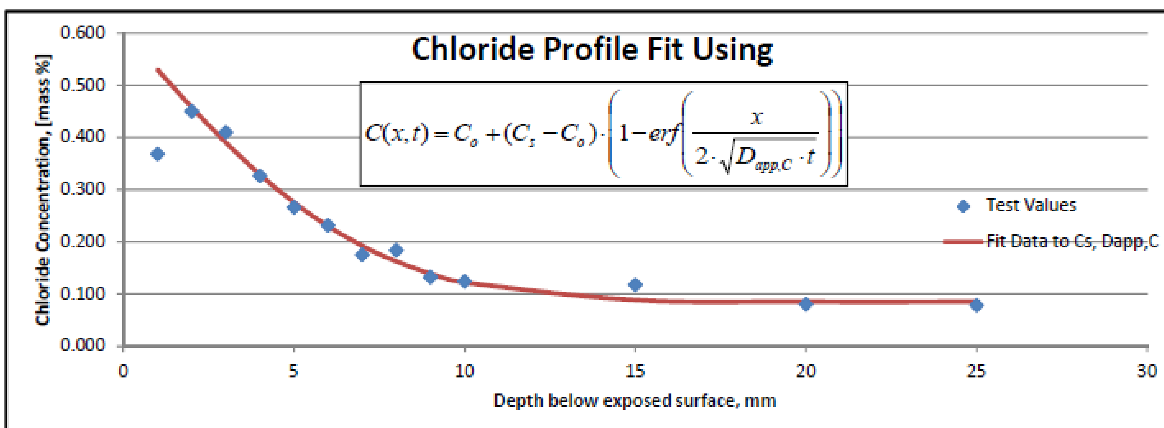
Source: Germann Instruments

Current Work Focus Areas

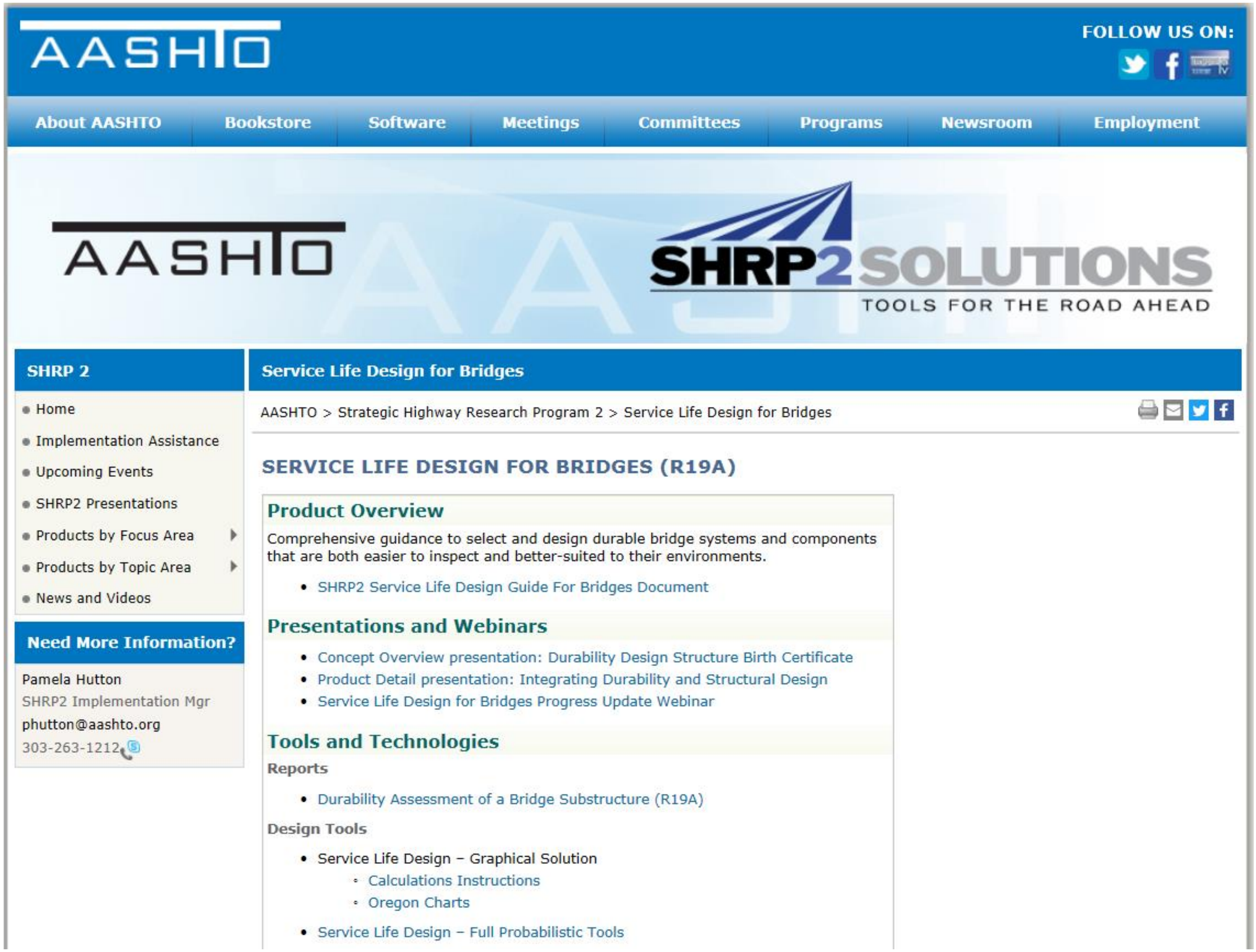
- Developing design tools and processes to aid in SLD
  - Excel spreadsheet for chloride profiling

d	depth from surface	[mm]	1	2	3	4	5	6	7	8	9	10	15	20	25	
C_m	Test Values	[mass %]	0.368	0.450	0.410	0.326	0.266	0.231	0.175	0.183	0.132	0.124	0.117	0.080	0.078	
C_c	Fit Data to C_s, $D_{app,C}$	[mass %]	0.530	0.458	0.391	0.329	0.275	0.230	0.192	0.162	0.139	0.122	0.089	0.085	0.085	$\sum (C_m-C_s)^2$
$(C_m - C_s)^2$	Sum of least squares			6.72E-05	3.76E-04	1.10E-05	9.01E-05	1.55E-06	2.93E-04	4.34E-04	5.00E-05	4.66E-06	8.12E-04	2.66E-05	4.90E-05	2.22E-03

C_o	Initial chloride content (measured)	[mass %]	0.085
t	Exposure time	[yr]	1
C_s	Chloride content at exposed face	[mass %]	0.605
$D_{app,C}$	Apparent coefficient of chloride diffusion	[mm^2/yr]	15.324



Implementation Products – Dedicated Webpage



- http://shrp2.transportation.org/Pages/ServiceLifeDesignforBridges.aspx

Recent Tools/Activities

- Academic Toolbox – guide for university professors to teach basic principles of SLD design (in final review/editing)
- IBC Workshop June 14, 2018 – Worked SLD example bridge

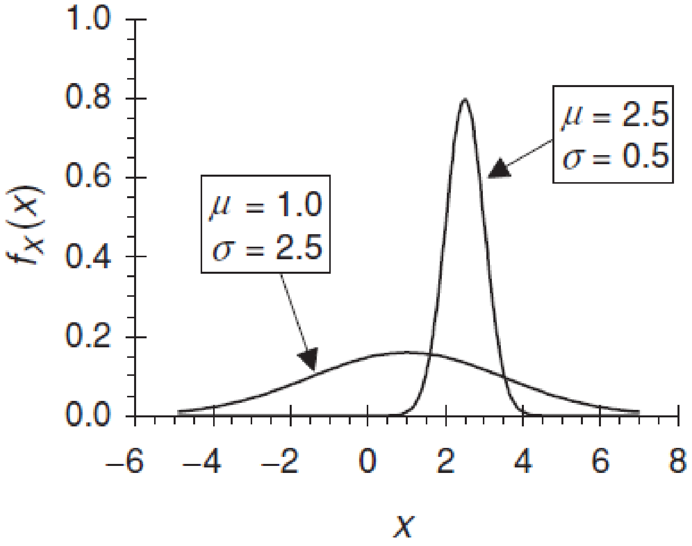
Academic Toolbox

Academic Toolbox

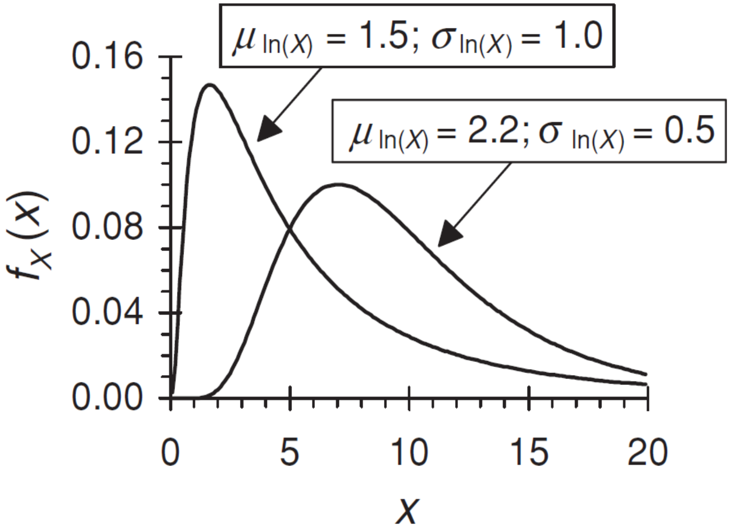
- Sections
  - 1.0 Introduction (overview of SLD)
  - 2.0 Probability and Reliability Analysis
  - 3.0 Service Life Design of Concrete Components
  - 4.0 Service Life Design of Steel Components

Academic Toolbox

- 2.1 Probability Distribution



Standard Normal Density Function



Log-Normal Density Function

- 2.2.2 Monte-Carlo Simulation

1. Defining the problem in terms of all the random variables
2. Quantifying probabilistic characteristics of the random variables and corresponding parameters
3. Generating the values of these random variables
4. Determining the accuracy and efficiency of the simulation
5. Extracting probabilistic information from a number N of such realization
6. Evaluating the problem deterministically for each set of realizations of all the random variables

Example 2.3.2

The chloride content (the demand, S) at the reinforcing steel level of a concrete footing is estimated to follow a normal distribution with statistical properties as follows:

$$\mu = 0.45 \text{ (wt\% of cement)} \quad \sigma = 0.4$$

According to Section 2.1.1, this can also be written as N(0.45,0.4) because the variables are normal random variables. In the same way, the critical chloride threshold (the resistance, R) is estimated to be N(0.6,0.15).

Table 2: Demand and Resistance Parameters

			Mean, μ	Std. dev, σ
Chloride content	Demand, S	N(0.45,0.4)	0.45	0.4
Critical chloride threshold	Resistance, R	N(0.6,0.15)	0.6	0.15

What probability of failure (corrosion initiation) is estimated using the Monte Carlo method if R and S are independent?

Example 2.3.2

Table 3: Random Numbers Generated for this Example and Calculations of Probability of Corrosion Initiation

Random Number z_i	Resistance r_i	Random Number z_i	Demand s_i	r>s?(*)
0.9311	0.82	0.4537	0.40	1
0.7163	0.69	0.1827	0.09	1
0.4626	0.59	0.2765	0.21	1
0.7895	0.72	0.6939	0.65	1
0.8184	0.74	0.8189	0.81	0
0.3008	0.52	0.9415	1.08	0
0.3989	0.56	0.4967	0.45	1
0.0563	0.36	0.2097	0.13	1
0.1770	0.46	0.4575	0.41	1
0.2036	0.48	0.4950	0.44	1
(*) 0 = failure, 1 = success				
Number of samples				10
Number of failures				2
P_f				20%

- 3.0 Service Life Design of Concrete Structures
  - 3.1 Sulfate Attack
    - Deleterious reactions occur when Portland cement with a moderate-to-high tricalcium aluminate (C_3A) content is used in concrete in contact with sulfate bearing soil or groundwater. Effects include extensive cracking, expansion, loss of bond between the cement paste and aggregates, and alteration of the paste composition that will cause an overall loss of the concrete strength.

Academic Toolbox

– 3.2 Delayed Ettringite Formation

- Delayed ettringite formation (DEF) is a form of internal sulfate attack that can occur in concrete cured at elevated temperatures such as in precast units or mass concrete placements.
- Maximum temperatures allowed during curing to mitigate risks of DEF are typically 150 to 160 degrees Fahrenheit (˚F).

Academic Toolbox

– 3.3 Alkali-Aggregate Reaction (ASR, ACR)

– 3.4 Freeze-Thaw

Academic Toolbox

– 3.6 Corrosion

For concrete structures, a two-phase service life model can be used to represent the development of corrosion over time as illustrated in Figure 11. Often, the nominal service life is assumed equal to the corrosion initiation time, which is at the end of the initiation phase…

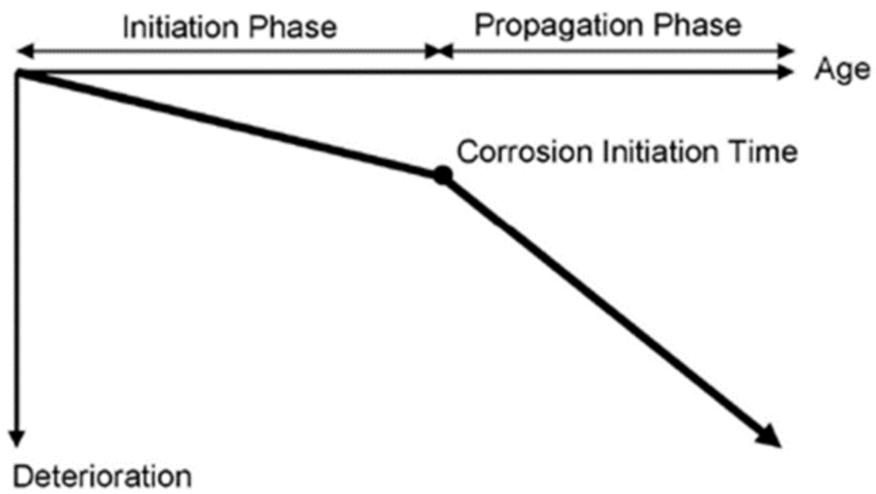


Figure 11: Two-phase modelling approach of corrosion deterioration

Academic Toolbox

– 3.6.2 Chloride-Induced Corrosion

- 3.6.2.1 Chloride-Induced Corrosion Modeling

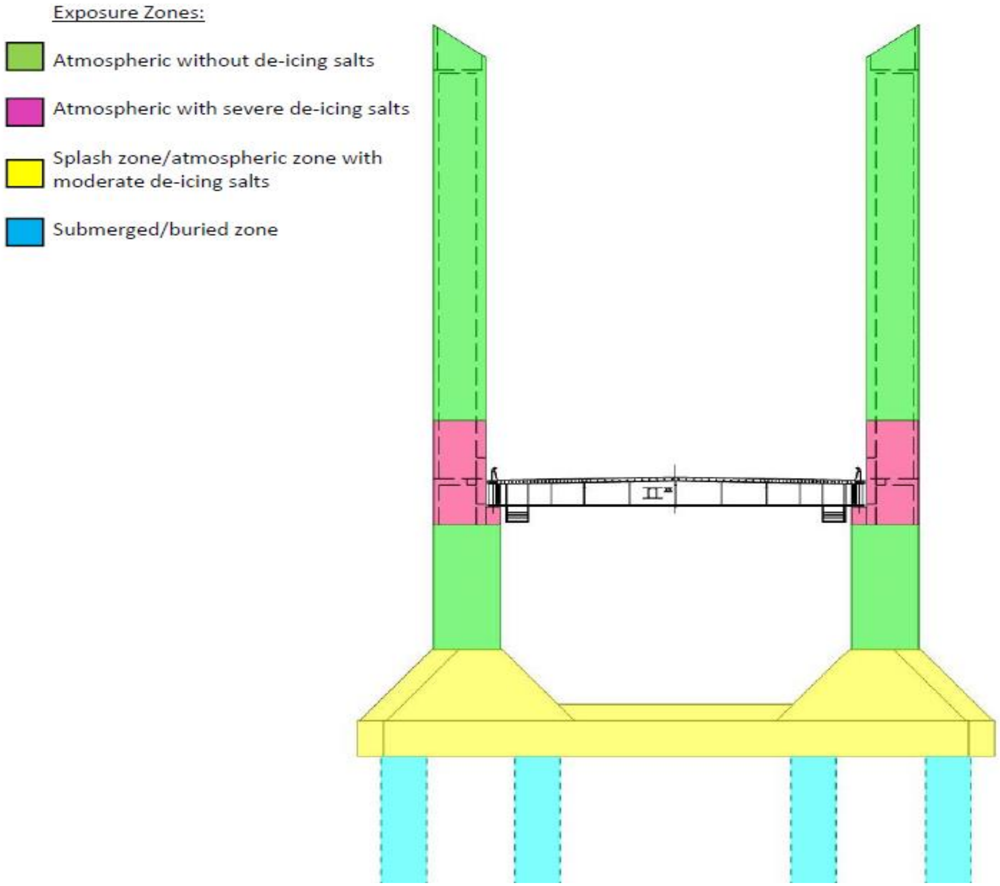
One established service life design methodology that is built on a broad base of experience and that resides in the public domain is the *fib* Model Code for Service Life Design (2006).

Three different design strategies for concrete structures are typically adopted:

- Strategy A: Avoid the potential degradation mechanism.
- Strategy B: Apply protective measures that are deemed-to-satisfy the durability requirements.
- Strategy C: Select material composition and structural detailing to resist, for the required period, the potential degradation mechanism based on a full probabilistic approach.

Academic Toolbox

– 3.6.2.2 Definition of Exposure Zones and Degradation Mechanisms



Academic Toolbox

– 3.6.2.3 Selection of the Limit State

- The limit states vary based on the project requirements. For example, a limit state can be corrosion initiation with a confidence level of 90 percent that corrosion will not be initiated within the targeted service life. This corresponds to a reliability index of 1.3 and is consistent with guidance provided in the Model Code for Service Life Design (fib, 2006).

– 3.6.2.4 Determination of the Design Parameters Required through the Mathematical Modelling

$$C(x,t)=C_0+\left(C_{S,\Delta x}-C_0\right)\left(1-\mathrm{erf}\left[\frac{x-\Delta x}{2\sqrt{D_{app,C}\cdot t}}\right]\right)$$

Academic Toolbox

– 3.6.2.5 Chloride Profiles

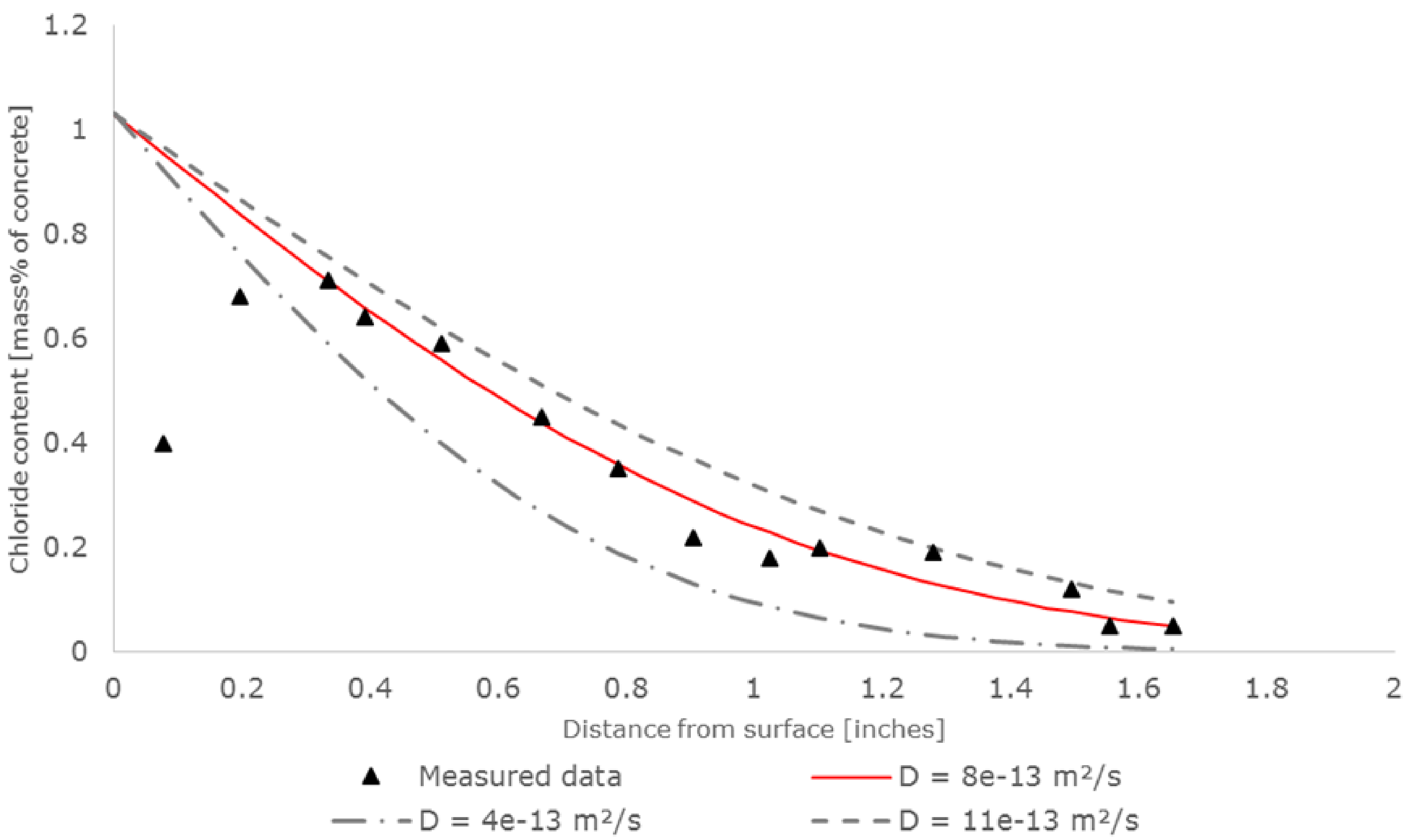


Figure 13: Example of chloride profile from the Danish Farø Bridge at t=9 years

Example 3.9.2

Calculate the probability of failure (time to corrosion initiation) for t = 25, 50, 75, 100 years using a full probabilistic approach with the input values, according to:

Table 6: Input Parameters for the Chloride Ingress Mathematical Tool

Parameter	Value		Unit	Type of Statistical Distribution
	Mean	Standard deviation		
Cover	55	8.3	mm	Lognormal
$C_{S,\Delta x}$	2.64	0.83	wt%/c	Lognormal
C_0	0.12		wt%/c	Deterministic
C_{crit}	0.65	0.15	wt%/c	Lognormal
$D_{RCM,0}$	6	0.38	10^{-12} m²/s	Lognormal
a	0.47	0.2		Beta (lower limit=0 and upper limit=1)
Δx	8.9	5.6	mm	Beta (lower limit=0 and upper limit=50)
b_e	4800	700	Kelvin	Normal
T_{real}	286.5	4.2	Kelvin	Normal
T_{ref}	293		Kelvin	Deterministic
t_0	28		days	Deterministic
t	25, 50, 75, 100		years	Deterministic

Example 3.9.2 Answer

A second order reliability method was used to calculate the following probability of failure:

Service Life (years)	P_f (%)
25	20
50	31
75	37
100	40

The use of the Monte Carlo approach yields similar results

Academic Toolbox

- 4.0 Service Life Design of Steel Components
  - 4.3 Galvanized Steel

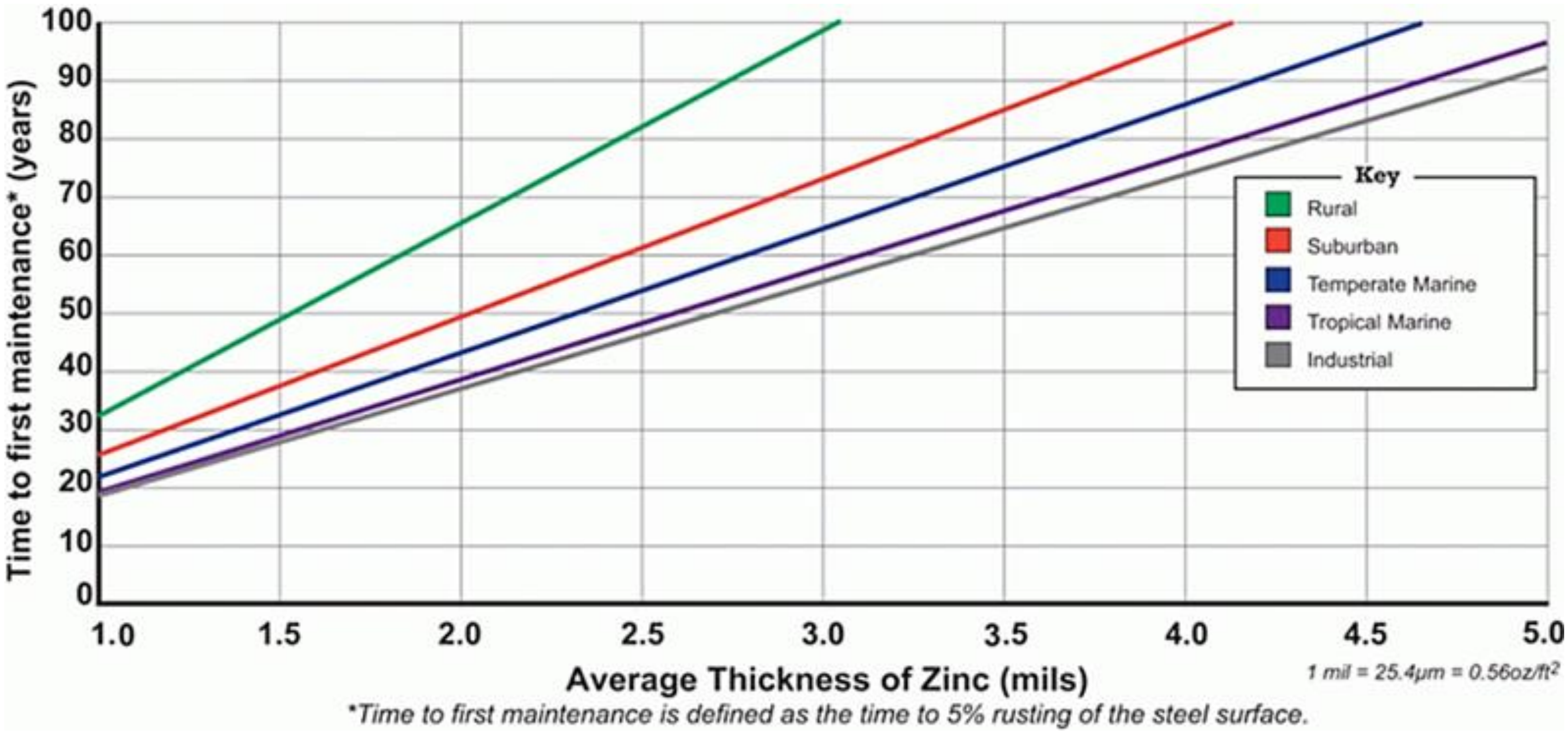


Figure 19: End of service life for various thicknesses of hot-dip galvanizing and environments
Source: American Galvanizers Association

IBC Workshop – Worked Design Example

IBC Workshop – Agenda

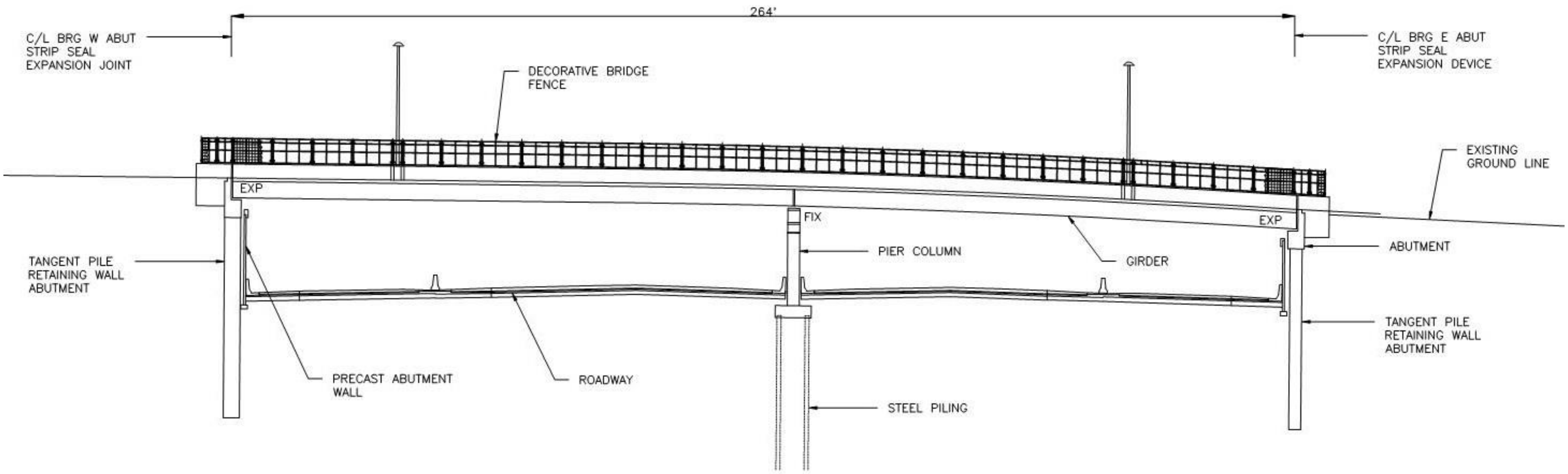
IBC Workshop W-8 Service Life Design – Worked Design Example		
June 14, 2018 – National Harbor, MD		
Time	**Topic**	**Speakers**
8:00 – 8:10 am	**Welcome and SHRP2 Introduction** • 1 – FHWA Introduction (10 min)	Raj Ailaney, FHWA
8:10-9:15	**Service Life Design Background** • 2 – Introduction to Service Life Design (35 min) • 3 – Introduction to *fib* Bulletin 34, Model Code for Service Life Design (30 min)	Mike Bartholomew, Jacobs Neil Cumming, COWI
9:15-9:45 am	**Introduction to Example Bridge** • 4 – Design Criteria and Exposure Zones (30 min)	Mike Bartholomew, Jacobs
9:45-10:00 am	**Break**	
10:00-11:00 am	**Design** • 5 – Service Life Design of Concrete Elements (30 min) • 6 – Service Life Design of Steel Elements (30 min)	Neil Cumming, COWI Mike Bartholomew, Jacobs
11:00-11:45 am	**Construction** • 7 – Implementation of Testing During Construction (20 min) • 8 – Documenting Service Life Design & Construction Parameters (20 min)	Neil Cumming, COWI Mike Bartholomew, CH2M
11:45-12:00 pm	**Questions & Wrap-Up**	

Project Description

- Location:
  - New York City.
  - Highway under the bridge.
  - Urban environment with periods of snow and freeze-thaw cycles.
  - Annual mean temperature of 11.5ºC (52.7ºF).
  - Heavy use of de-icing salts.
  - Some sulfate present in soil: 0.14% by mass of water soluble sulfate was measured.

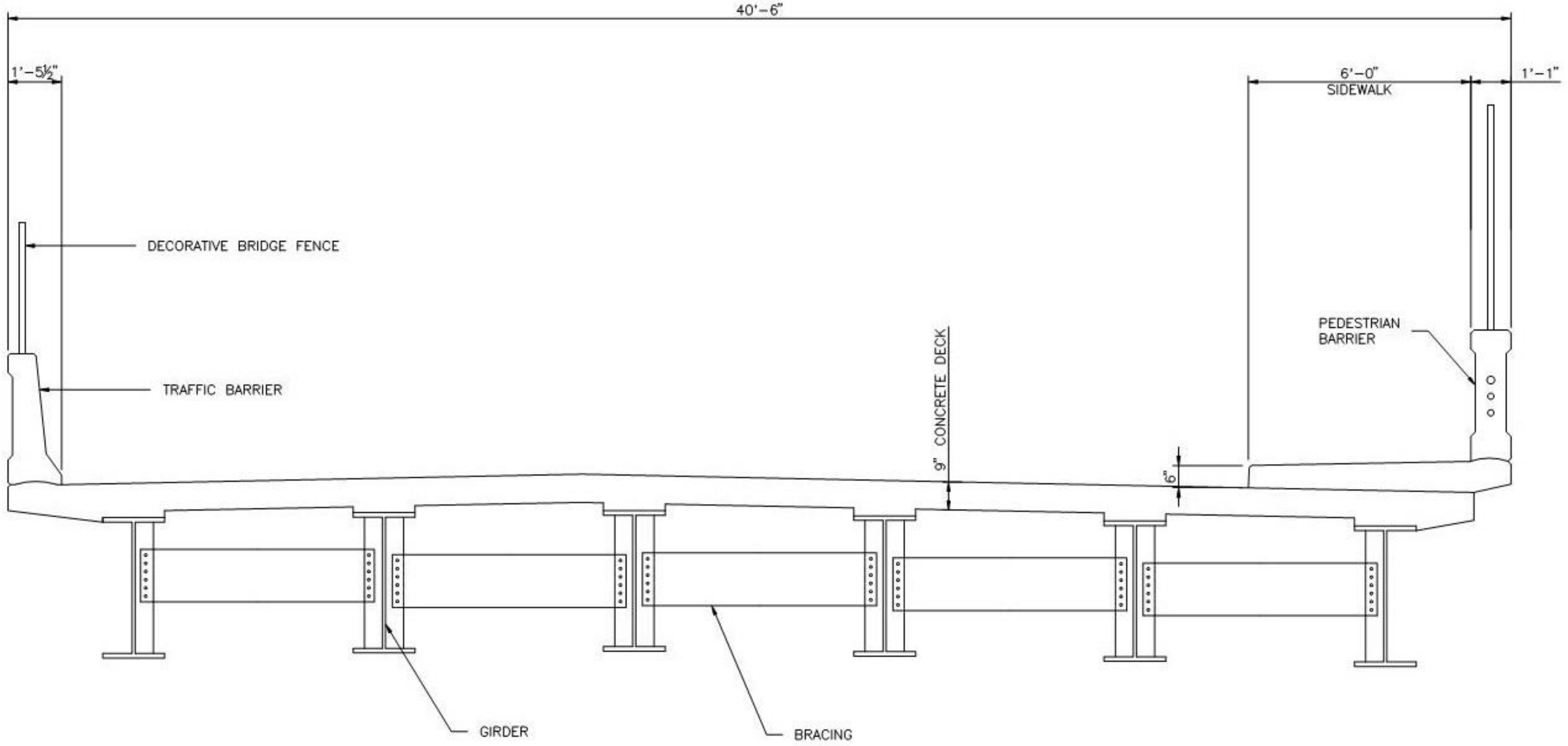
General Bridge Layout

- 264 ft. steel girder bridge with two spans (139 ft. and 125 ft.).
- Over the abutments, the girders are supported on elastomeric bearings and at the piers, the girders are supported on fixed bearings.
- Deck and girders are continuous over the pier.
- Uncoated reinforcement (black steel) used everywhere.



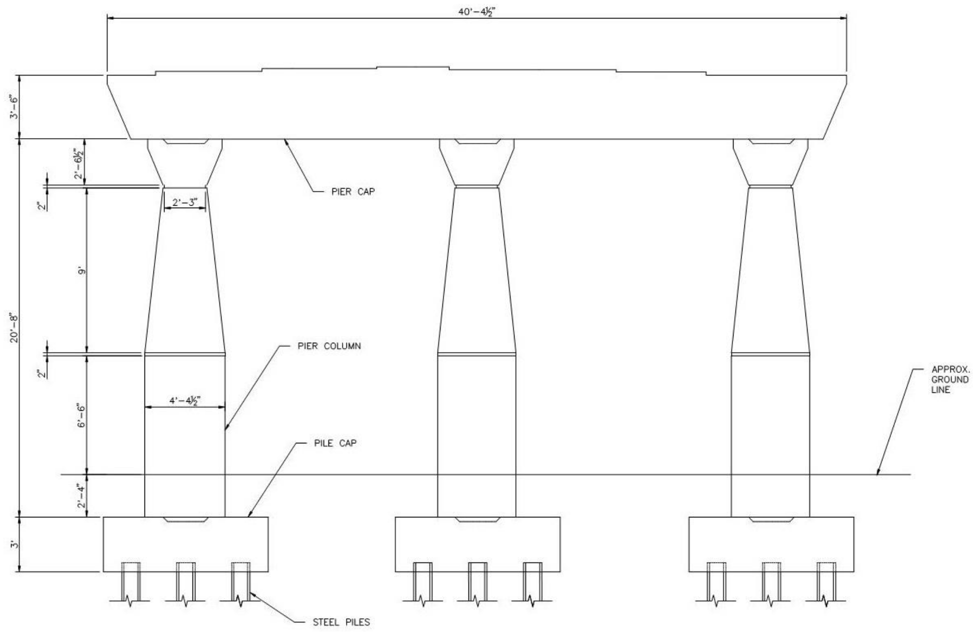
Superstructure Description

- Roadway is 30 ft. wide with two traffic lanes and shoulders, and a 6 ft. sidewalk.
- Composite cast-in-place, high performance concrete deck on steel girders.
- Deck is 9 in. thick with 2 ¾” in. top cover and no wearing surface.



Substructure Description

- The central pier has three columns each supported by a pile cap and steel piles driven into bedrock:



- Uncoated reinforcement (black steel) used everywhere.
- No mass concrete.

Expected Service Life

Non-replaceable components	Minimum service life (years)
Foundations (piling), abutments, piers, structural steel, and deck	75
Replaceable components	**Minimum service life (years)**
Bridge bearings	50
Expansion joints	30
Painting (includes structural steel, metal rocker bearings, expansion joint extrusions, and decorative fencing	25
Barriers	50

Deterioration Mechanisms

- Main deterioration mechanism for buried steel and steel exposed to seawater or de-icing salts is corrosion
- Mitigation methods (AASHTO LRFD 10.7.5) may include:
  - Protective coatings (painting, galvanizing, metalizing)
  - Concrete encasement
  - Cathodic protection
  - Use of special steel alloys
  - Increased steel area (corrosion allowance)

Exposure Classification

- Defined Exposure Conditions
  - International Standard ISO 12944 – Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classifications of environments
    - 5 Classification of environments
      - Table 1 – Atmospheric-corrosivity categories and examples of typical environments
      - Table 2 – Categories for Soil and Water

ISO 12944 Exposure Categories

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

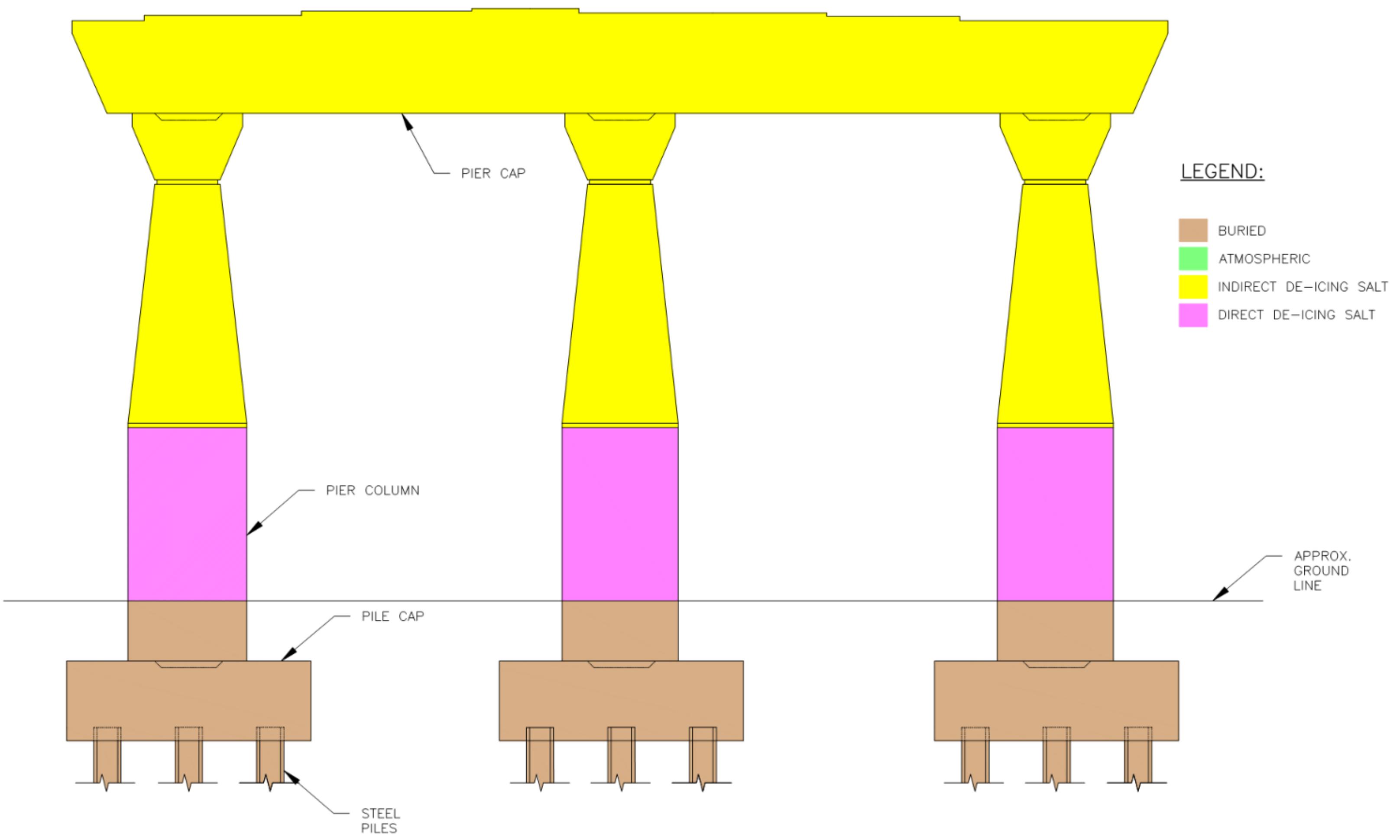
Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments in a temperate climate (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m^2	Thickness loss µm	Mass loss g/m^2	Thickness loss µm		
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution.

ISO 12944 Exposure Categories

Table 2 — Categories for water and soil

Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro-electric power plants
Im2	Sea or brackish water	Harbour areas with structures like sluice gates, locks, jetties; offshore structures
Im3	Soil	Buried tanks, steel piles, steel pipes

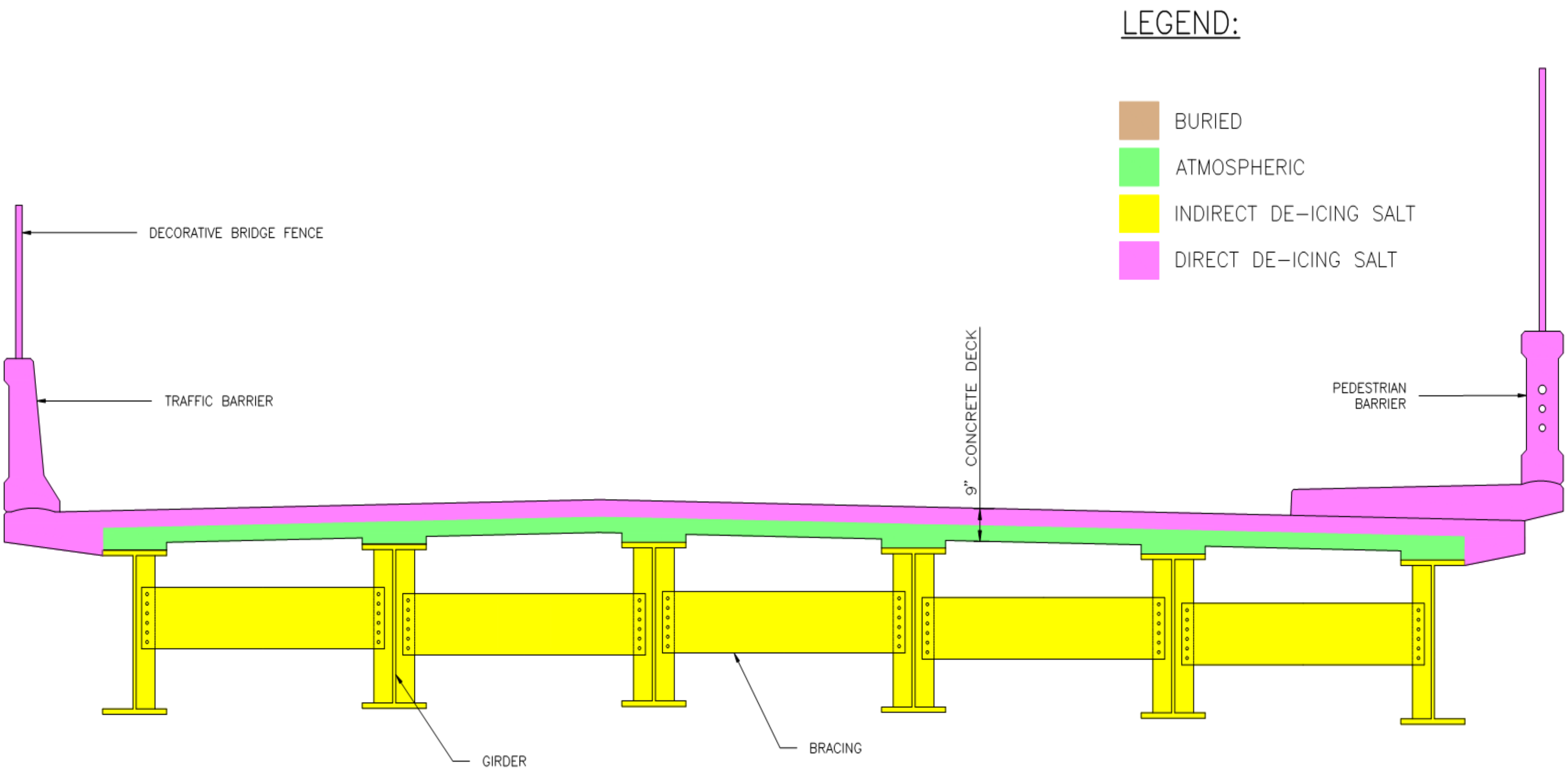
Substructure Exposure Zones



Buried Piles

Exposure Zone	Examples of Elements	Exposure Conditions	Steel Corrosivity Category ISO 12944-2 [2]
Buried	Steel piles at pier.	Limited chloride exposure in soil. Limited O_2. Freeze-thaw above frost line. Sulfates.	Im3: soil

Superstructure Exposure Zones



Steel Girders

Exposure Zone	Examples of Elements	Exposure Conditions	Steel Corrosivity Category ISO 12944-2 [2]
Indirect De-icing Salts	Girders.	Alternating wetting and drying. Atmospheric O_2 and CO_2. Freeze/thaw with indirect exposure to de-icing salts, leakage from deck joints, temperature and humidity variations.	C4: Temperate zone, atmosphere with moderate salinity

Steel Decorative Fence

Exposure Zone	Examples of Elements	Exposure Conditions	Steel Corrosivity Category ISO 12944-2 [2]
Direct De-icing Salts	Decorative fence.	Alternating wetting and drying. Atmospheric O2 and CO_2. Freeze/thaw with direct exposure to de-icing salts applications, temperature and humidity variations.	C5-M: Temperate zone, aggressive atmosphere

Deterioration Mitigation Methods

All mitigation design strategies are "Deemed to Satisfy"

Steel component	Exposure zone	Corrosivity category ISO 12944-2	Mitigation method
Steel H piles	Buried	Im3	Corrosion allowance
Girder	Indirect de-icing salts	C4	Painting
Decorative fence	Direct de-icing salts	C5-M*	Painting

Corrosion Allowance References

- AASHTO LRFD Section 10.7.5
- FHWA Design and Construction of Driven Piles Foundations, V1 – Section 6.12.1
- FDOT Structures Design Guidelines – Section 3.1
- EN 1993-5, Eurocode 3: Design of Steel Structures, Part 5: Piling – Section 4.4

Florida DOT Structures Design Guidelines

Table 3.1-1Usage Limitations and Corrosion Mitigation Measures for Steel Piles and Wall Anchor Bars

Steel Component	Embedment	Corrosion Protection	Minimum Required Sacrificial Thickness (inches) and Usage Limitations Based on Substructure Environmental Classification and Pile/Wall Anchor Bar Location			
			Slightly Aggressive	Moderately Aggressive	Extremely Aggressive	
			Land and/or Water	Land and/or Water	Land	Water
Pipe and H-Piles	Completely Buried	None[1]	0.075	$\boxed{0.15}$	0.225[2]	Use Internally Redundant Pipe Piles Only, See ***SDG*** 3.1.F.2
	Partially Buried	***Specifications*** Section 560	0.09	0.18	0.27[2]	N/A
		None[1]	0.15	0.30	Use Internally Redundant Pipe Piles Only, See ***SDG*** 3.1.F.2	
Anchored or Cantilever Sheet Piles	All	***Specifications*** Section 560	0.045	0.09	0.135	
Wall Anchor Bars	All	See Footnote[3]	0.09	0.18	0.27	

Florida DOT Structures Design Guidelines

- Environmental Classification versus Corrosion Rate per side
  - For partially buried piles and wall anchor bars:
    - Slightly Aggressive: 0.001 inches/year
    - Moderately Aggressive 0.002 inches/year
    - Extremely Aggressive 0.003 inches/year
  - For completely buried piles:
    - Slightly Aggressive: 0.0005 inches/year
    - Moderately Aggressive 0.001 inches/year
    - Extremely Aggressive 0.0015 inches/year
  - Design Life – 75 years

Florida DOT Structures Design Guidelines

- H-Piles
  - HP 12 x 53 (flange and web thickness = 0.435 inch) required for strength and geotechnical requirements

  - Moderately aggressive environment (1400 ppm sulfates)
  - Fully buried
  - 0.001 inches/year x 75 years x 2 sides = 0.15 inch thickness loss
  - Required thickness for corrosion loss = 0.585 inch

  - Replace with HP 12 x 74 (flange = 0.610 inch, web = 0.605 inch)

Service Life of Coating Systems

- Primary reference used for estimating coating system life

Paper No.
7422

NACE INTERNATIONAL CORROSION 2016 CONFERENCE & EXPO

Expected Service Life and Cost Considerations for Maintenance and New Construction Protective Coating Work

Jayson L. Helsel, P.E.
Robert Lanterman
KTA-TATOR, Inc.
115 Technology Drive
Pittsburgh, PA 15275

Service Life of Coating Systems

- NACE Paper No. 7422 Includes a table of Estimated Service Life for 53 Coating Systems
  - Different corrosion exposure conditions (ISO 12944)
  - Various combinations of Acrylic, Alkyd, Epoxy, Epoxy Zinc, Organic and Inorganic Zinc, Metalizing, and Moisture Curing Polyurethane coats
  - Hand, Power Tool, and Sandblasted surface preparation
  - 1, 2, and 3 coat systems
  - Based on surveys of Coating Suppliers, Galvanizers, Steel Fabricators, Painting Contractors, and Owners

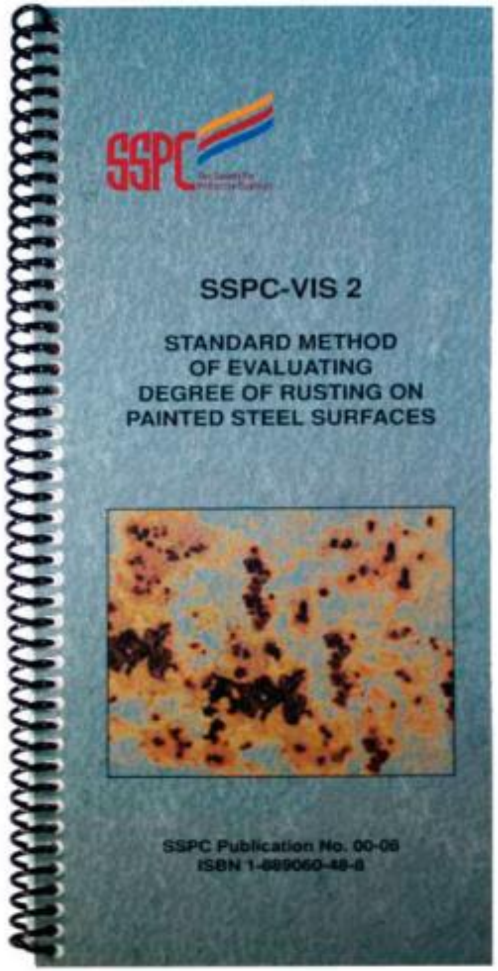
NACE 7422 Practical Service Lives

Table 1A: Estimated Service Life for Practical Maintenance Coating Systems for Atmospheric Exposure
(in years before first maintenance painting)[4]

Type	Coating Systems for Atmospheric Exposure (primer/midcoat/topcoat)	Surface Preparation[2]	Number of Coats	DFT Minimum (mils)	Service Life[1,3]			
					Mild (rural)/C2	Moderate (industrial)/C3	Severe (heavy industrial)/C5-I	Seacoast Heavy Industrial/C5-M
Acrylic	Acrylic Waterborne/Acrylic WB/ Acrylic WB	Hand/Power	3	6	12	8	5	5
Acrylic	Acrylic Waterborne/Acrylic WB/ Acrylic WB	Blast	3	6	17	12	9	9
Alkyd	Alkyd/Alkyd	Hand/Power	2	4	6	3	2	2
Alkyd	Alkyd/Alkyd/Alkyd (AWWA OCS-1C)	Blast	3	6	11	6	3	3
Alkyd	Alkyd/Alkyd/Urethane Alkyd	Blast	3	6	12	7	4	4
Alkyd	Alkyd/Alkyd/Silicone Alkyd (AWWA OCS-1D)	Blast	3	6	14	9	5	5
Epoxy	Surface Tolerant Epoxy (STE)	Hand/Power	1	5	12	8	5	5
Epoxy	Surface Tolerant Epoxy/STE	Hand/Power	2	10	17	12	9	9
Epoxy	Surface Tolerant Epoxy/STE	Blast	2	10	21	15	12	12

Service Life of Coating Systems

- Practical Life
  - Time until 5-10% coating breakdown occurs and active rusting of the substrate is present
  - Corresponds to rust scale grade 4 in accordance with Steel Structures Painting Council, SSPC-VIS 2 (also ASTM D610)

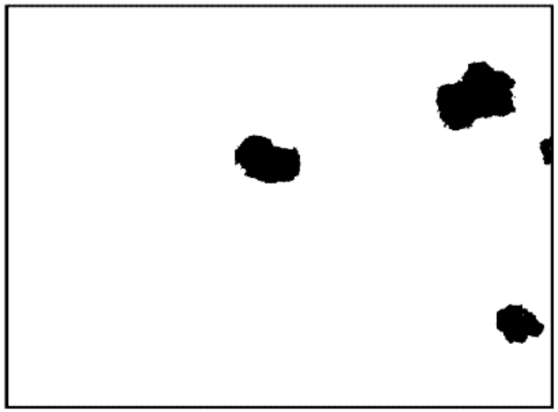


Rust Grades 5 (3%) and 4 (10%)

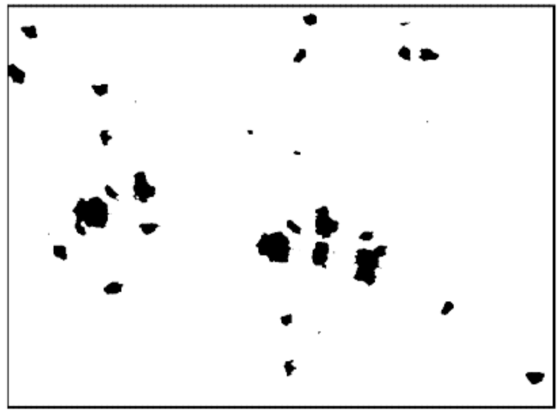
S-Spot

G-General

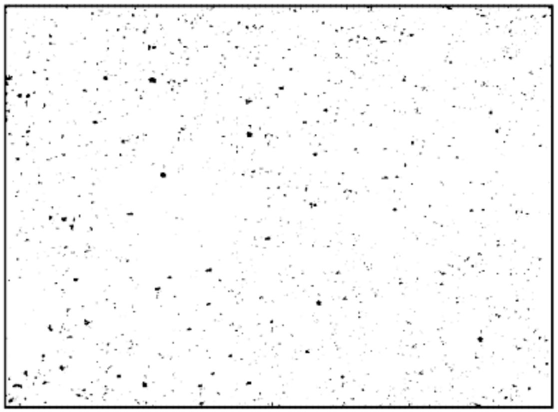
P-Pinpoint



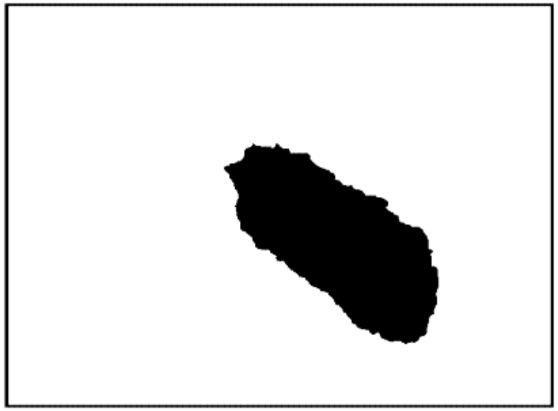
Rust Grade 5-S, 3% Rusted



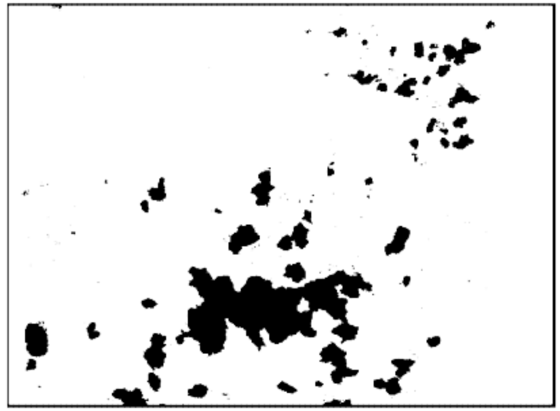
Rust Grade 5-G, 3% Rusted



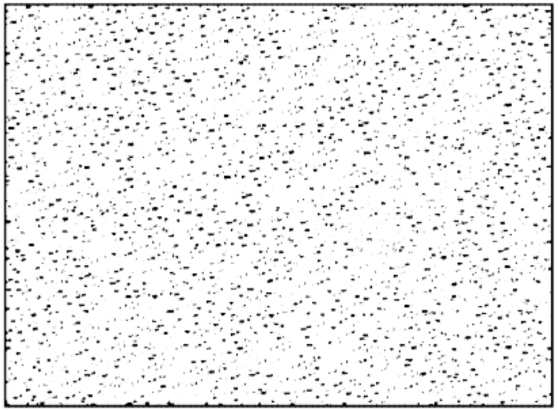
Rust Grade 5-P, 3% Rusted



Rust Grade 4-S, 10% Rusted



Rust Grade 4-G, 10% Rusted



Rust Grade 4-P, 10% Rusted

NACE 7422 Painting Practices

- Spot Touch-Up and Repair is when first time coating repairs are made and occurs at the Practical Life (P)
- Maintenance Repaint (M) includes spot priming and a full overcoat
- Full Repaint (F) involves total coating removal and replacement and marks the actual end of service life

Operation	Painting occurs in year
Original Painting	0
Spot Touch-Up and Repair	Practical life (P)
Maintenance Repaint	M = P x 133%
Full Repaint	F = P x 183%

Planned Tools/Activities

- Life Cycle Cost Analysis – comparison of initial and long-term costs using different materials and protection strategies
- 5 Peer Exchanges
  - Northwest in Portland, OR – July 24
  - Southeast in Richmond, VA – August
  - Midwest in Ames, IA – September
  - Northeast in Philadelphia, PA – October
  - Southwest in Denver or Salt Lake City - November

Planned Tools/Activities

- Develop 2 complete SLD Design Examples
  - Steel bridge in de-icing environment in NE US
  - Prestressed concrete bridge in coastal environment in SE US
  - Other deterioration types will be documented (AAR, DEF, freeze-thaw, coating failure, etc.)
- Develop calculations to determine example load and resistance factors to be used with chloride deterioration model

Planned Tools/Activities

- Develop 2 RFP example specifications for design-build projects
  - Multiple conventional highway bridges on a new or reconstructed corridor project
  - Major bridges (segmental, arch, cable-stayed)

IAP Next Steps

- Conduct Agency Final Training Workshops for CFL, IA, ME
- Develop Reference Material Documentation / add to AASHTO/SHRP2 web page
  - Life Cycle Cost Example
  - Summary Guide to Service Life Design
  - Lessons Learned Summaries
- Develop 5 FHWA Peer Exchanges in non-IAP states

Questions?

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Resource: AASHTO's R19A Product Page

- http://shrp2.transportation.org/Pages/ServiceLifeDesignforBridges.aspx