


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP2 R19-A Service Life Guide Implementation Update

AASHTO SCOBS Technical Committee T-9 Meeting
Minneapolis, MN

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Technology Director, North American Bridges
CH2M

June 28, 2016

U.S. Department of Transportation
Federal Highway Administration

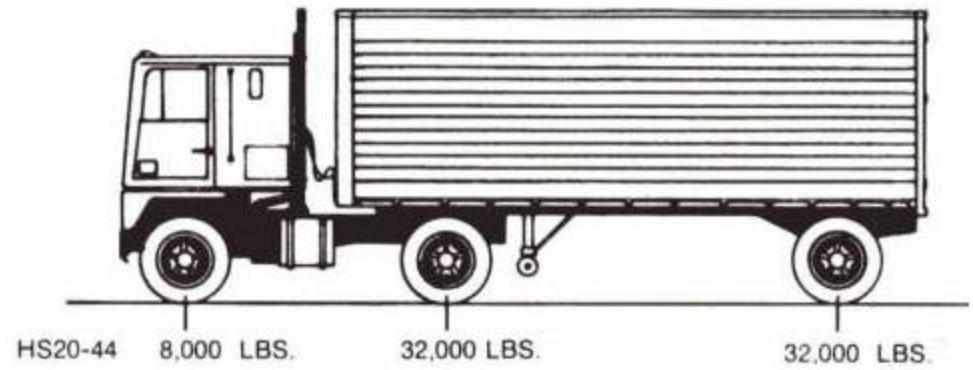
American Association of State Highway and Transportation Officials
AASHTO

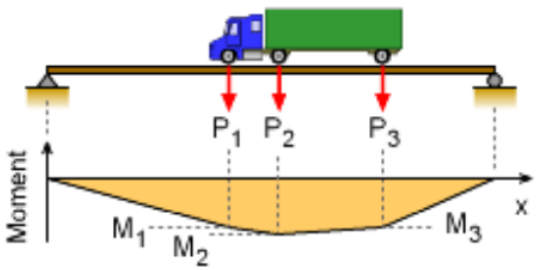
Presentation Overview

- Introduction to Service Life Design
- SHRP2 R19A Project Team
- Implementation Action Program (IAP) Goals
- Lead Adopter Projects
- Guides/Tools Developed
- Future Work
- Summary

Service Life Background

- Bridge design focuses on **structural engineering**
  - Determining loads, sizing components, and selecting materials by their strength properties (f'c, fy, etc.)



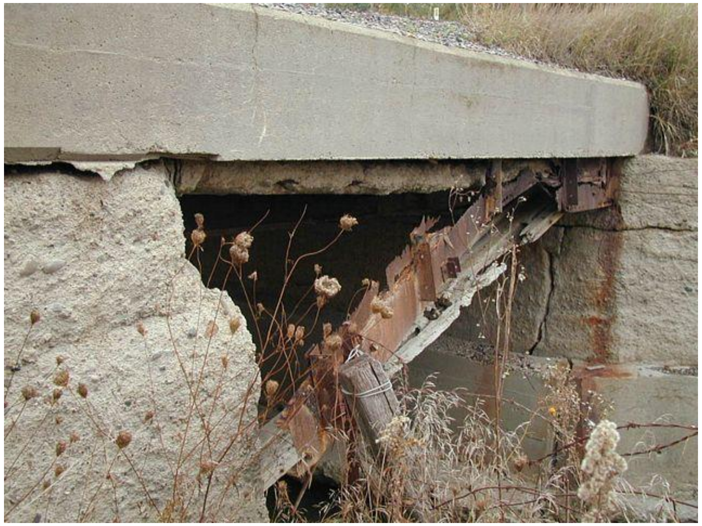


Typical Moment Diagram for a Series of Point Loads

  - But it is only one component to help ensure that a structure will remain in use for a given period of time

Service Life Background

- When a structure reaches the end of its life
  - The cause is primarily from material deterioration



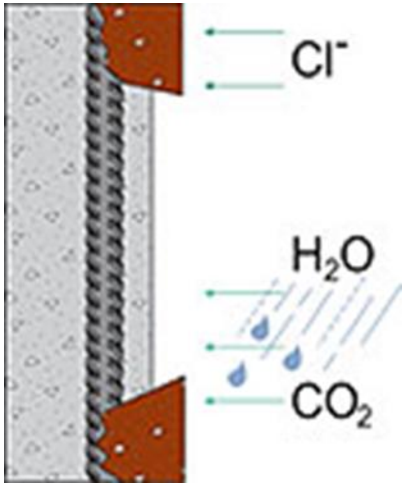
  - Due to environmental exposure conditions

Service Life Design Principles

- All materials deteriorate with time
- Every material deteriorates at a unique rate
- Deterioration rate is dependent on:
  - Environmental exposure conditions
  - Material's protective systems – durability properties

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)



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

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

Service Life Design (SLD)

- Similar to strength design to resist structural failure caused by external loads
  - External Loads ← → Environmental Actions
  - Material Strength ← → Durability Properties
- Both strength and Service Life Designs satisfy scientifically based modeling equations

Goals of Service Life Design

- **Owners** – Need assurance that a long-lasting structure will be designed, built, and operated (Effective use of public funding $$)

- **Engineers/Contractors/Asset Managers** – Need quantifiable scientific methods to evaluate estimated length of service for bridge components and materials

SHRP2 R19A Team

RESEARCH – **TRB**

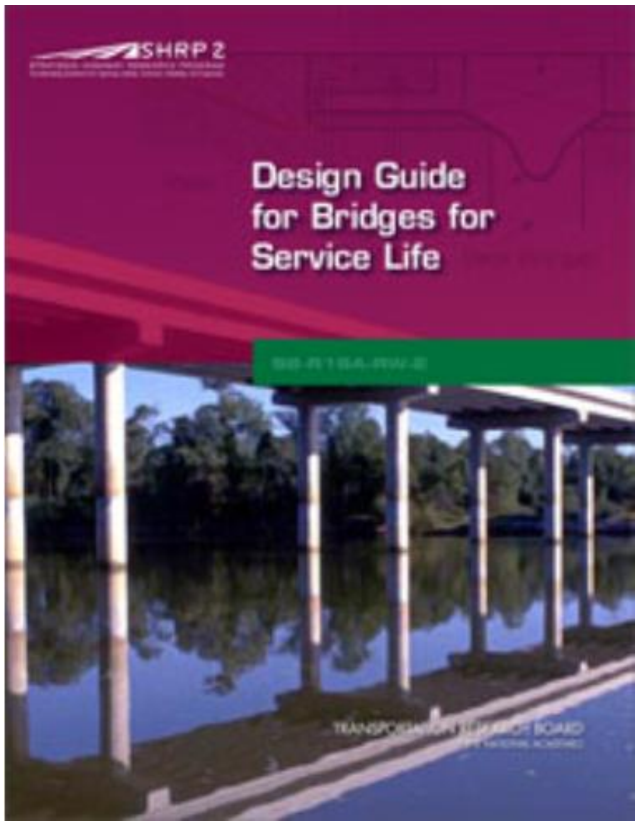
IMPLEMENTATION – **FHWA/AASHTO**

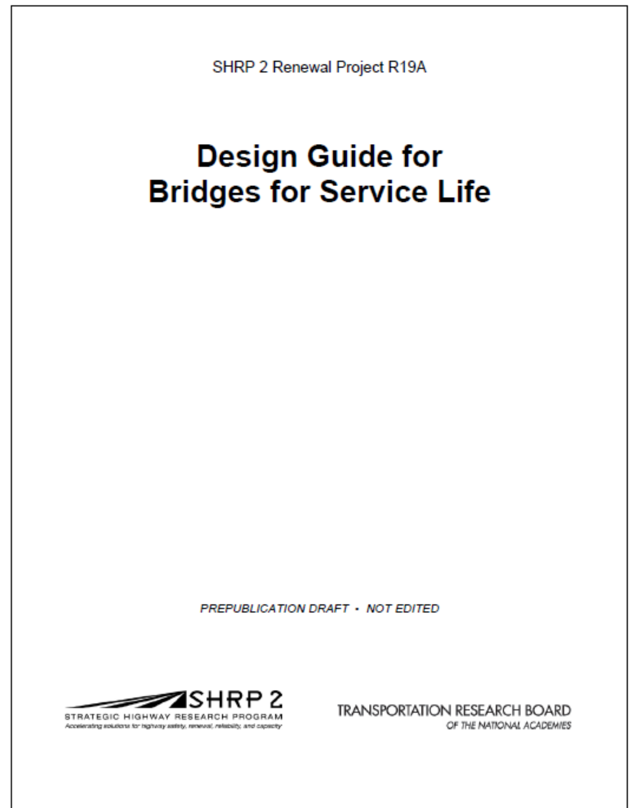
SUBJECT MATTER EXPERTS /
LOGISTICS SME LEAD – **CH2M**
TECHNICAL SMEs –
COWI

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

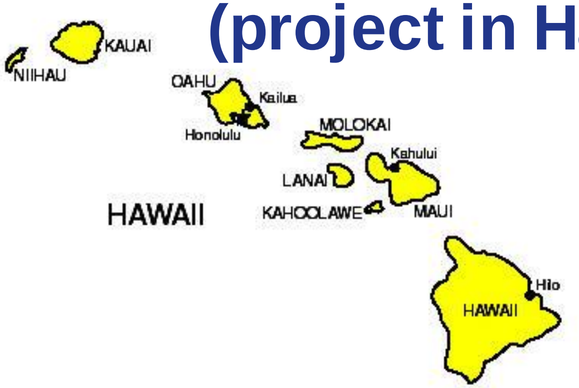
TRANSPORTATION RESEARCH BOARD OF THE NATIONAL ACADEMIES

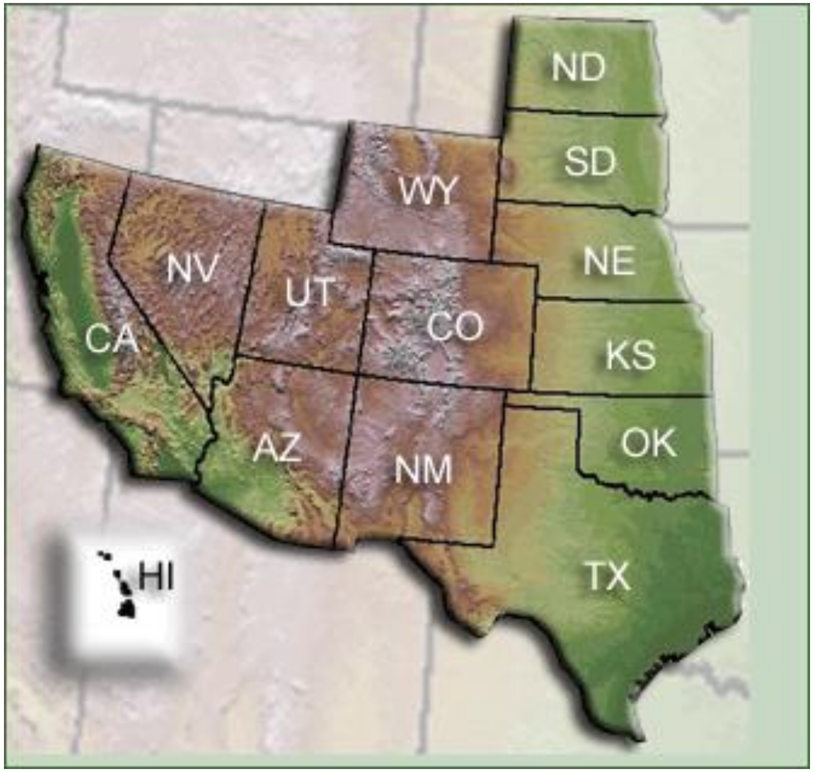
  - http://www.trb.org/Main/Blurbs/168760.aspx

IAP Lead Adopter Agencies

Oregon

Central Federal Lands (project in Hawaii)





IAP Lead Adopter Agencies

Iowa

Pennsylvania

Virginia

IAP Funding

- State agencies were awarded $150,000 each as Lead Adopters
- FHWA CFL was awarded $75,000
- Funding for technical assistance from the SME team is through SHRP2, and <u>NOT</u> part of agency awards

IAP Goals

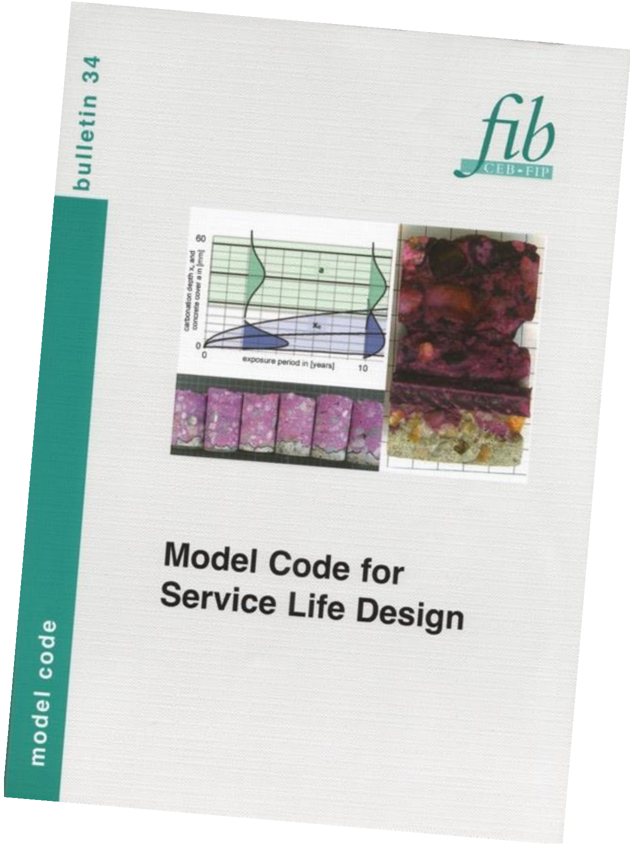
- Promote Service Life Design concepts
  - Marketing, Outreach & Training
  - Target 15% of State DOTs by 2016
- Produce basic elements for inclusion in an *AASHTO Service Life Design Guide*
  - Coordinate with SCOBS and T-9
- Build a strong technical foundation
  - Develop training & reference materials
  - Lessons learned summaries

Current Work Focus Areas

- Tests for durability design of new bridges and deck preservation of existing bridges
  - Testing concrete cores to evaluate chloride loading from de-icing chemicals and sea water
  - Concrete diffusion (permeability) properties
  - Measurement of as-constructed concrete cover
- Development of Service Life Design specification language for Requests for Proposals

Design Standard

- International Federation of Structural Concrete
- *fib* Bulletin 34 – Model Code for Service Life Design (2006)
  - Establishes design procedures
    - To resist deterioration
    - From environmental actions



Deterioration Model

- Chloride Ingress – Fick's 2nd Law of Diffusion to Corrosion Initiation

$$\boxed{C_{crit} \geq C(x = a, t) = \mathbf{C_o} + (\mathbf{C_{s,\Delta x}} - \mathbf{C_o}) \cdot \left[1 - \operatorname{erf}\left(\frac{\mathbf{a} - \Delta x}{2\sqrt{D_{app,C} \cdot t}}\right)\right]}$$

$$D_{app,C} = k_e \cdot \mathbf{D_{RCM,0}} \cdot k_t \cdot A(t)$$

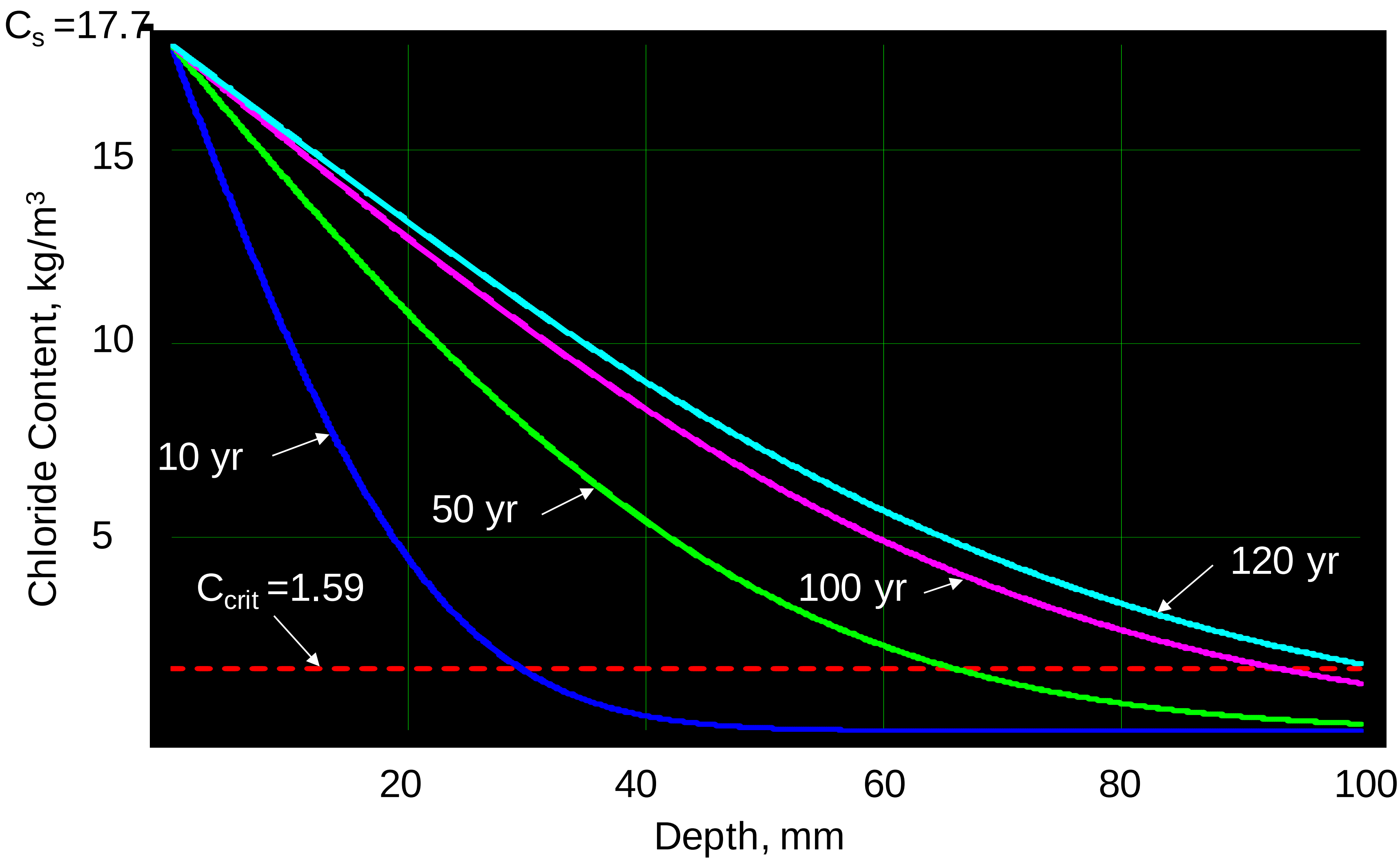
$$k_e = \exp\left(b_e\left(\frac{1}{T_{ref}} + \frac{1}{\mathbf{T_{real}}}\right)\right)$$

$$A(t) = \left(\frac{t_o}{t}\right)^{\boldsymbol{\alpha}}$$

- **Red – Environmental Loading**
  - $\mathbf{C_o}$ & $\mathbf{C_s}$ are the Chloride Background and Surface Concentrations
  - $\mathbf{T_{real}}$ is the annual mean Temperature at the project site
- **Green – Material Resistance**
  - $\mathbf{D_{RCM,0}}$ is the Chloride Migration Coefficient, α is the Aging Exponent, both are functions of the concrete mix
  - **a** is the Concrete Cover

Chloride Profiles vs. Age

constant $D_{app,c}$ = 15.1 mm^2/yr



New Design Issues

- Environmental exposure of coastal marine bridges
  - Chloride loading (C_s) based on natural salinity of sea water
  - Data collected from existing documentation or perform salinity tests
- Environmental exposure from de-icing chemicals
  - Chloride loading (C_s) much more difficult to assess
  - Best source of data is from test coring existing structures in similar environment

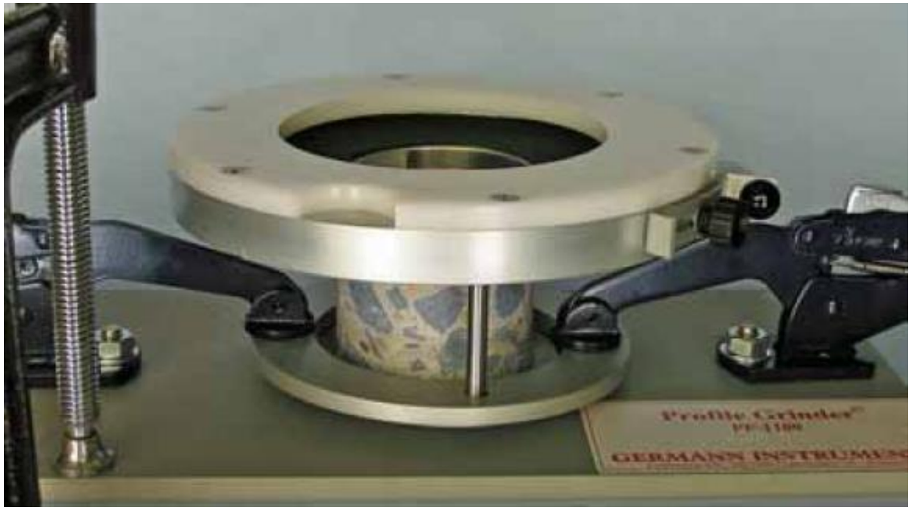
Determining Chloride Loading

Designation: C1543 – 10

Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding[1]

- Known as the Salt Ponding Test
- Used to develop chloride profiles in test specimens or existing concrete taken from cores
- Results include Surface Chloride Concentration (C_s) and Concrete Apparent Coefficient of Diffusion ($D_{app,C}$) at age of core

Chloride Grinding/Profiling



Source: Germann Instruments

Determining Chloride Loading

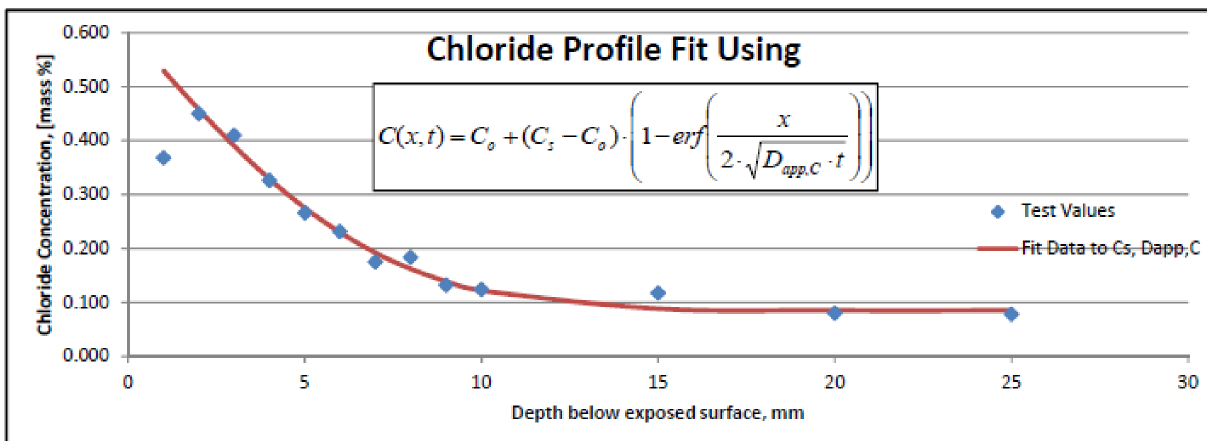
ASTM INTERNATIONAL

Designation: C 1556 – 04

Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion[1]

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	$\sum (C_m\text{-}C_s)^2$
$(C_m - C_s)^2$	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	[mm²/yr]	15.324



New Design/Construction Issues

- **Resistance to Chloride Ingress by Diffusion** is a function of the:
  - Concrete Chloride Migration Coefficient ($D_{RCM,0}$)
  - Cover Depth (a)

$$\boxed{C_{crit} \geq C(x = a, t) = \mathbf{C_o} + (\mathbf{C_{s,\Delta x}} - \mathbf{C_o}) \cdot \left[1 - \mathrm{erf}\left(\frac{\mathbf{a} - \Delta x}{2\sqrt{D_{app,C} \cdot t}}\right)\right]}$$

$$D_{app,C} = k_e \cdot \mathbf{D_{RCM,0}} \cdot k_t \cdot A(t)$$

$$k_e = \exp\left(b_e\left(\frac{1}{T_{ref}} + \frac{1}{\mathbf{T_{real}}}\right)\right)$$

$$A(t) = \left(\frac{t_o}{t}\right)^{\boldsymbol{\alpha}}$$

New Design/Construction Issues

- **Resistance to Chloride Ingress** influenced by concrete mix proportions:
  - Type of Cement
  - Water/Cement Ratio
  - Supplemental Cementitious Materials
    - Fly Ash (FA)
    - Ground Granulated Blast Furnace Slag (GGBFS)
    - Silica Fume (SF)

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 – Test Setup

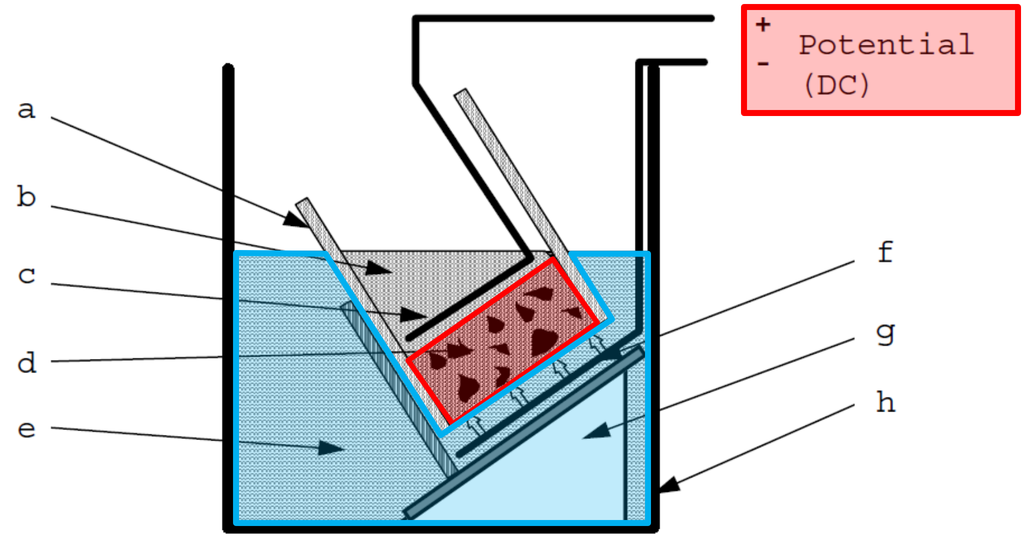
NT Build 492

- **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

NORDTEST METHOD

NT BUILD 492 5

APPENDIX 1



a. Rubber sleeve
b. Anolyte
c. Anode
d. Specimen
e. Catholyte
f. Cathode
g. Plastic support
h. Plastic box

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, $D_{RCM,0}$

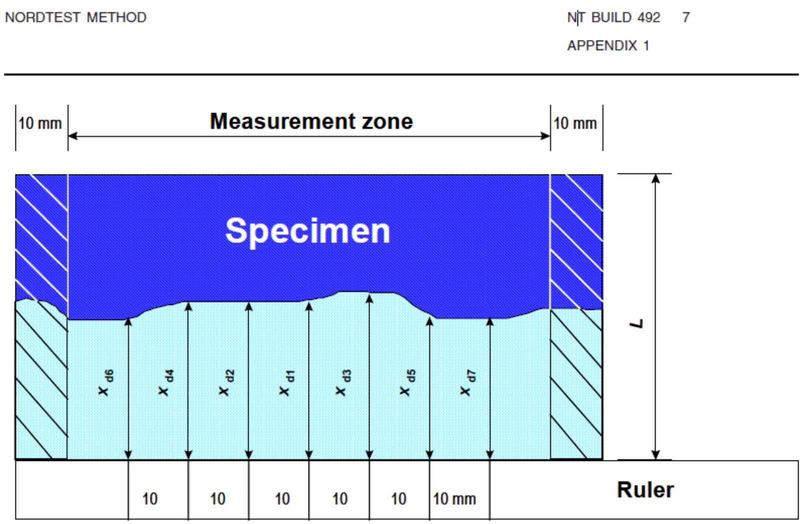


Fig. 5. Illustration of measurement for chloride penetration depths.

NT Build 492 Test Summary

- Important to perform test at 28 days
- Test takes 24 hours
- One test includes 3 specimens
- Cost of a single test is approximately $1,000

Concrete Cover Depth

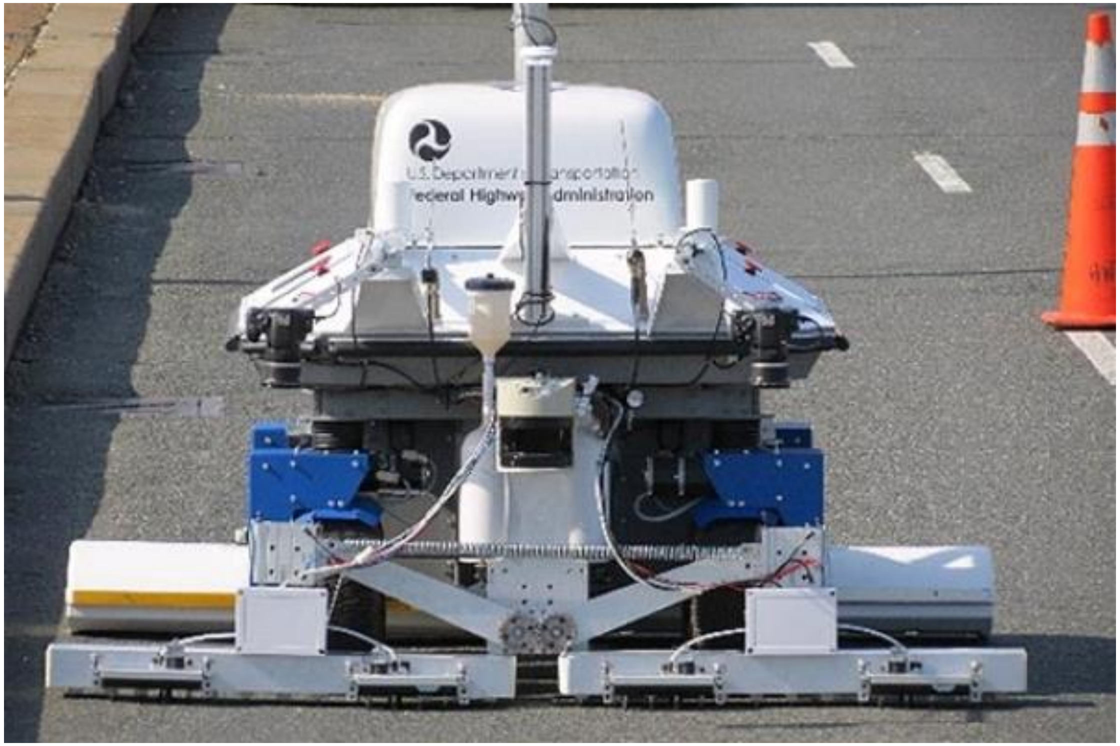
- Lack of U.S. standards for measuring cover depth in hardened concrete
- Service Life goal is for complete mapping
  - Min/Max Depths
  - Used to calculate mean & standard deviations
- International Standard
  - British Standard 1881-204:1988 – Testing Concrete. Recommendations on the use of electromagnetic covermeters

Covermeters

- Sources: Proceq Elcometer

Concrete Cover Depth

- FHWA's Robotic Assisted Bridge Inspection Tool (RABIT) with Ground Penetrating Radar (GPR)



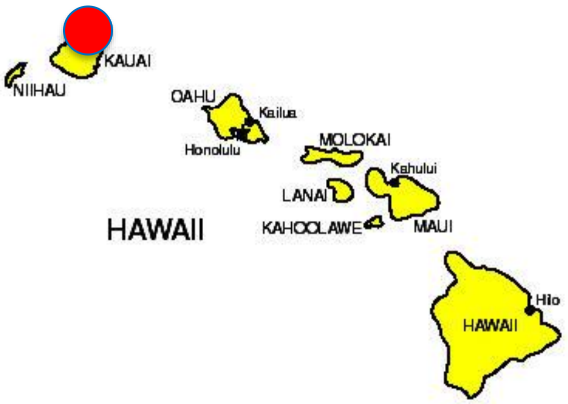
IAP Projects

IAP Team Leaders

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

FHWA Central Federal Lands

- **Tropical Coastal Exposure on North Shore, Island of Kauai, HI**
  - Three bridge replacements on Highway 560 over Wainiha Stream
  - 500' to 1,000' from the coastline in remote setting
  - Single lane, 14' wide roadway



FHWA Central Federal Lands

FHWA Central Federal Lands

- **Tropical Coastal Exposure on North Shore, Island of Kauai, HI**
  - Initial water samples taken for salinity measurements showed low chloride content
  - Additional samples to be taken at different times of year and at high and low tide
  - NT Build 492 tests will be performed on baseline concrete mix designs and will be contracted through the University of Hawaii during the design process
  - Coring of existing abutments at water line / splash zone for surface chloride concentration will be performed under the construction contract permits

Iowa DOT

- **New Bridge at Site with Extreme De-Icing Chemical Spray Exposure**
  - Woodbury County Highway K-25 over I-29 in western Iowa

  - 403’ Long by 43’-2” Wide 4-Span Continuous Steel Plate Girder Bridge
  - Using A1010 High Chromium Structural Steel for two girder lines along with A709 Grade 50W for the remaining four girder lines
  - Lab and field testing of the A1010 steel for structural and corrosion resistance performance
  - Industry Workshop – March 18, 2015
  - Currently under construction, fabrication nearly complete

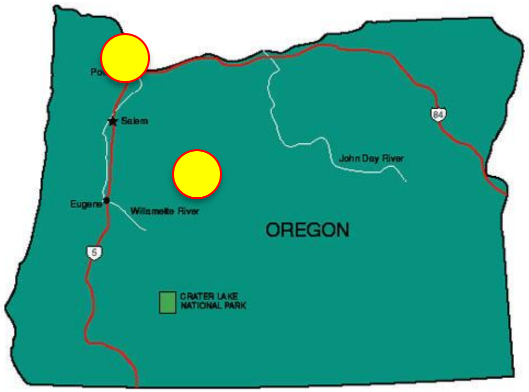
Iowa DOT

- **Replace Twin Structures on I-35 over South Skunk River near Ames**
  - Performed chloride profile testing to determine chloride loading (6 cores from existing structures, 126 cores from 19 bridges on 2 route corridors)
  - Performed NT Build 492 tests on representative concrete mix designs to evaluate expected deck/railing service life

  - Southbound structure – Under construction
  - Designed using current Iowa DOT policies
  - Northbound structure – Scheduled for January 2018 Letting
  - Will be designed using proposed methodology for deterioration from the environmental loading
  - Report on direct comparison between the two structures

Oregon DOT

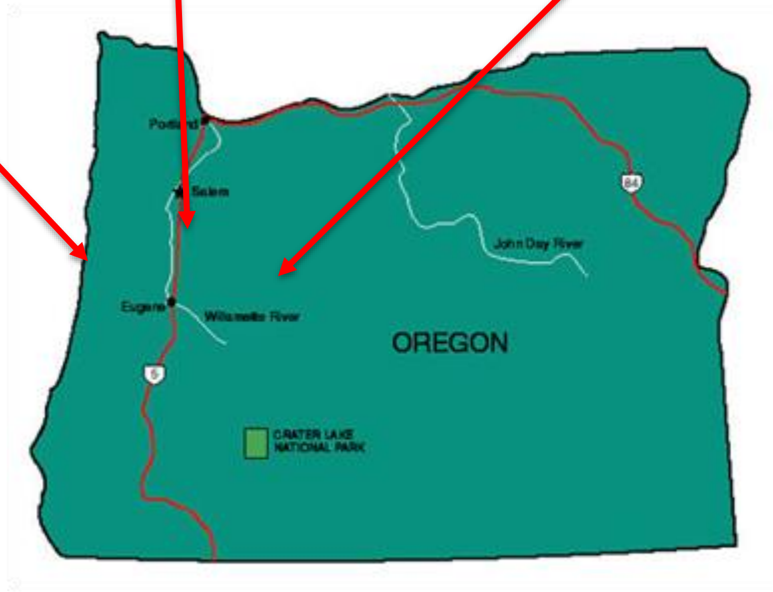
- **I-5 Columbia River Crossing Design/Build – Portland to Vancouver**
  - Evaluate/modify RFP requirements for contractor to design/document to a 100-year service life



- **Replacement Bridge over Ochoco Creek in Prineville**
  - Single 66’ span by 65’-8” wide w/ precast spread box beams
  - Performing chloride profile testing to determine chloride loading (4 cores from existing structure)
  - Performing NT Build 492 tests on representative concrete mix designs to evaluate expected deck service life
  - Evaluating expected service life

Oregon DOT

- **Bridge Deck Evaluation in Various Chloride Exposure Zones**
  - Performed chloride profile testing to determine chloride loading (42 cores from 12 existing structures)
  - Additional structures scheduled to be tested through end of year
  - Categorization of chloride loading by geographic/climatic zones (Pacific Coast, Willamette Valley, Cascade Mountains and east)



Pennsylvania DOT

- **Statewide Evaluation of Chloride Resistance of Concrete**
  - Contracted with Lehigh University to perform NT Build 492 chloride migration coefficient tests on 105 samples from mix designs produced by 7 ready mix and 2 precast concrete suppliers in the state

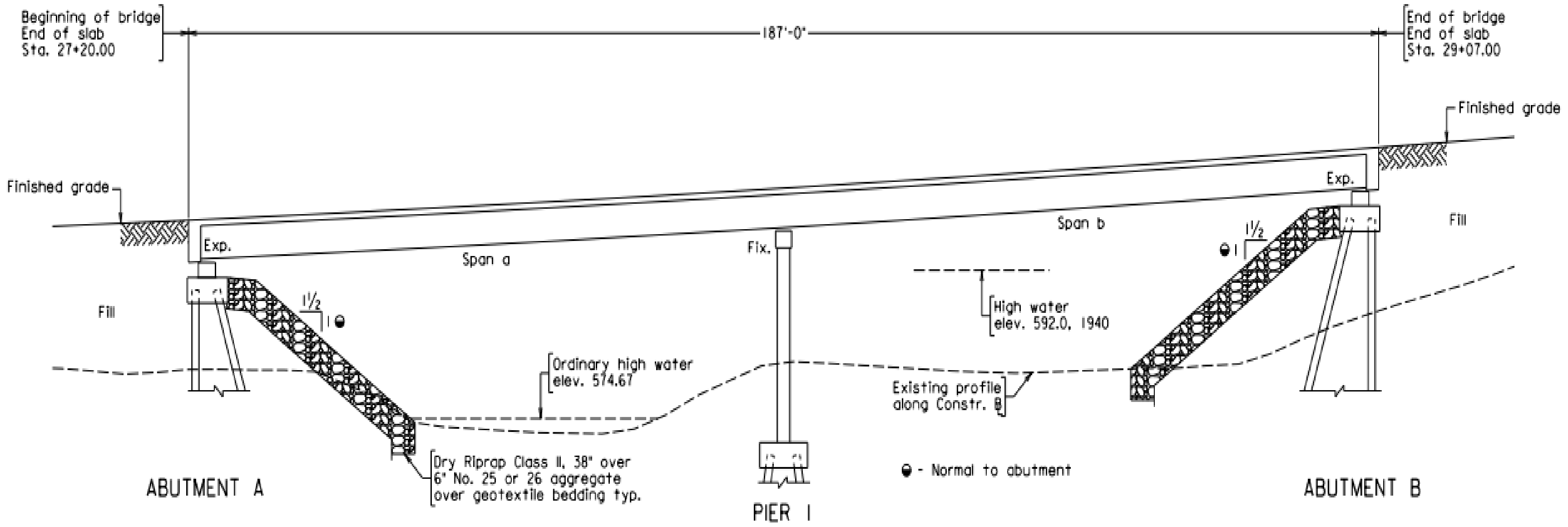
Figure 1: Company location map relative to PennDOT districts

Pennsylvania DOT

- **Statewide Evaluation of Chloride Resistance of Concrete**
  - Tests included standard, high performance (HPC) and self consolidating (SCC) concrete mixes
  - Tests were performed at 28, 56, and 112 days to evaluate effects of age
  - Performed evaluation of chloride migration coefficient versus concrete mix type, age, w/c ratio, unit weight, slump, and strength
  - Developed a full probabilistic assessment tool based on the fib Bulletin 34 methodology, and evaluated PennDOT certified mixes for a 100 year life
  - Initial indications are that most standard mix designs would not satisfy a 100 year life in a salt splash/spray zone

Virginia DOT

- **Model Corrosion Service Life of a Typical Virginia Bridge Deck**



Service Environment

- Air Temperature
- Surface Chloride Concentration, C_s

Concrete Mix Properties

- Concrete Initial Chloride Concentration, $C_{(x,t=0)}$
- Chloride Migration Coefficient, D

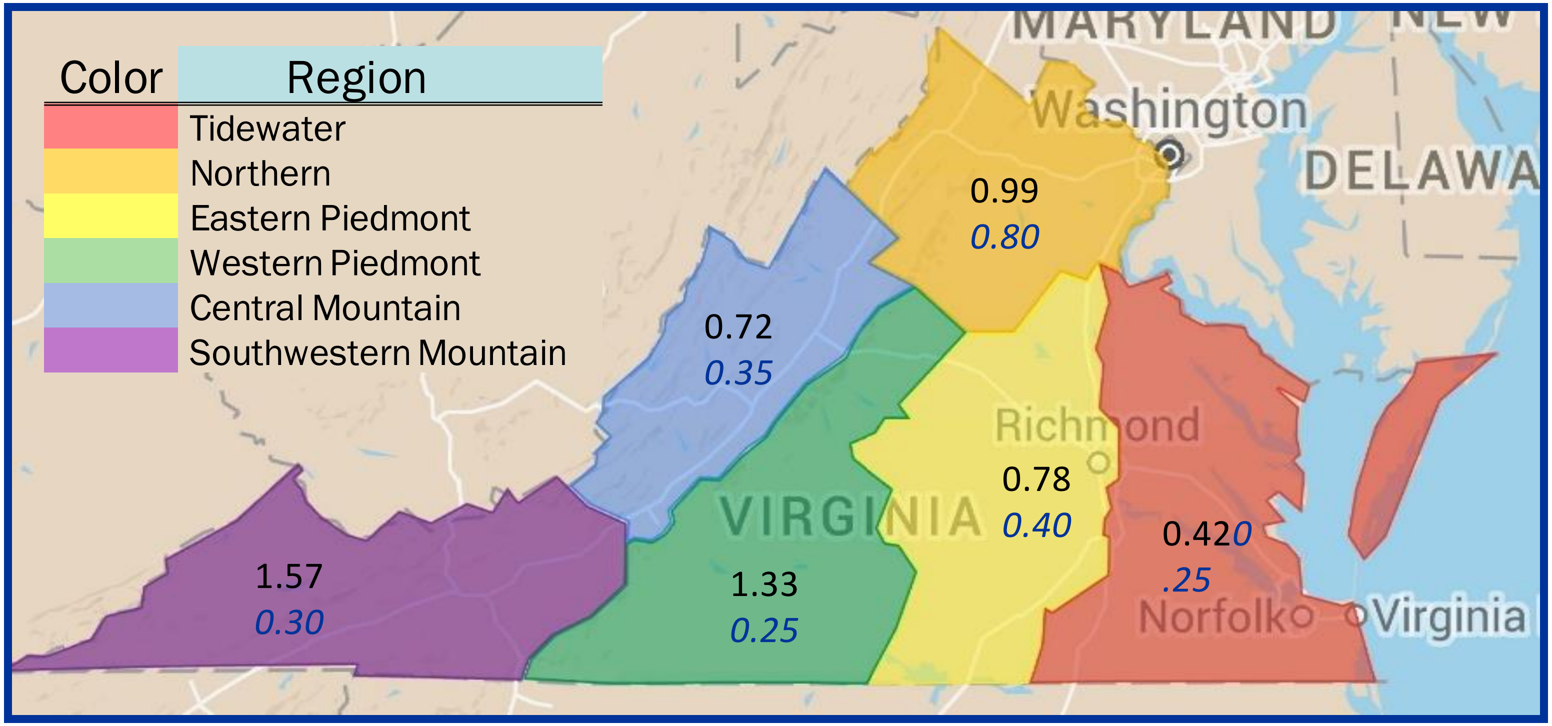
Virginia DOT

Virginia’s Goals:

- Consider proposed methods to model for service life design
- Demonstrate how models can be used to support decision-making in design
- Develop a database of reference values specific to Virginia for use in modeling

Virginia DOT

- **Evaluation of Chloride Surface Concentration from De-Icing**
  - Categorization of chloride loading by zones



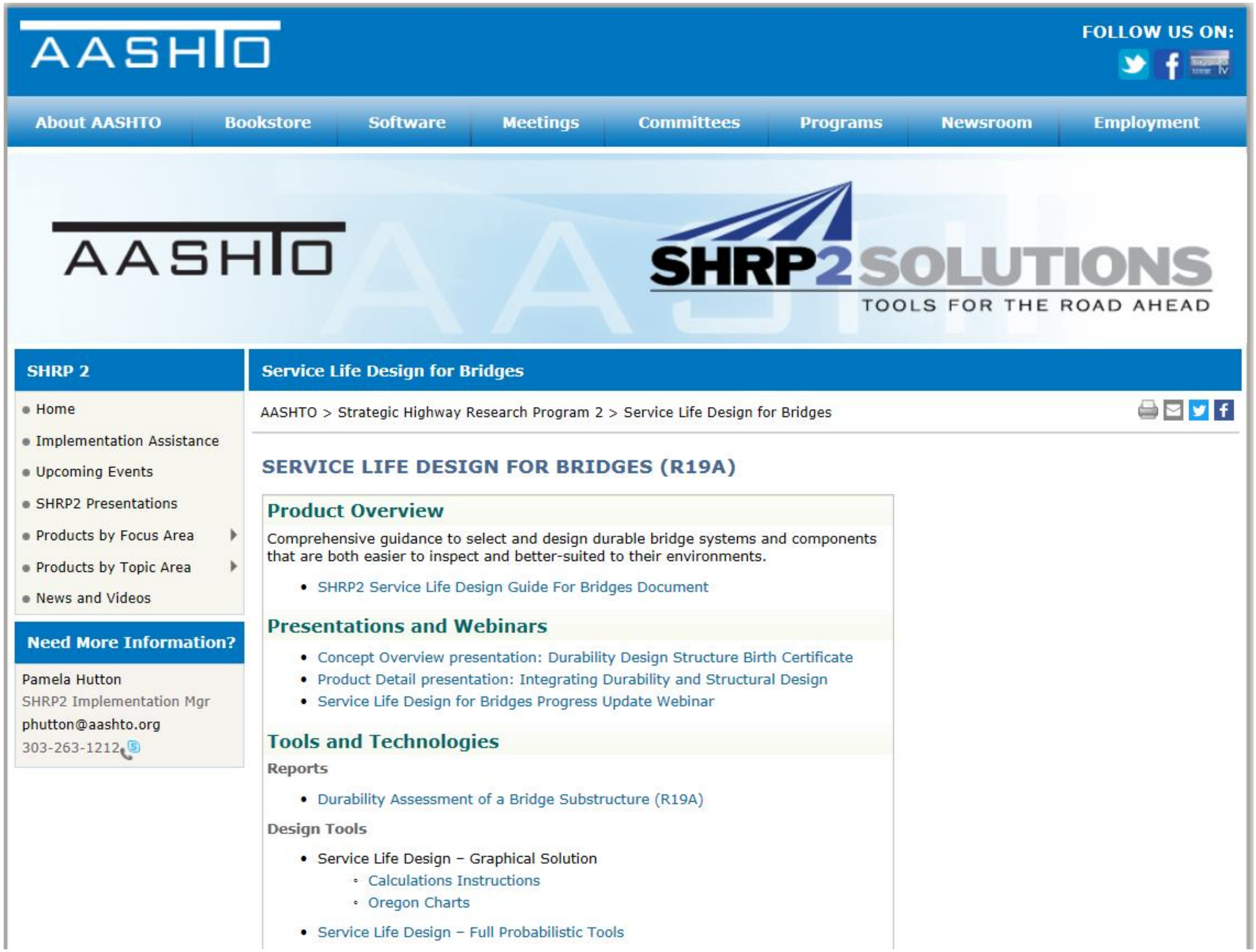
  - Historical data (Williamson, 2007)
  - *fib 34-predicted*

$$\left(\% \frac{mass\ Cl^-}{mass\ binder}\right)$$

Virginia DOT

- **Evaluation of Chloride Diffusion Properties of Statewide Concrete Mix Designs**
  - Typical Deck mix (A4) – 4,000 psi HPC
    - All Virginia DOT concrete mixes contain mineral admixtures to reduce permeability
  - Variety of source materials statewide
  - New low-cracking concrete specification
  - NT Build 492 tests performed on 9 current bridge construction projects (8 additional bridges to be tested later this year)
  - Developed a full-probabilistic analysis tool for evaluation of data

Implementation Products – Dedicated Webpage



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

SHRP2 Sponsored Presentations/ Workshops

- Project Introductory Webinar – February 2, 2015
- NACE – Dallas, TX, March 17, 2015
- AASHTO SCOBS T-9 – Saratoga Springs, NY, April 21, 2015
- Lead Adopter State Workshops
  - Oregon DOT – Salem, OR, May 7-9, 2015
  - Pennsylvania DOT – Pittsburgh, PA, June 10, 2015
  - Virginia DOT – Richmond, VA, June 12, 2015
  - FHWA Central Federal Lands – Denver, CO, June 16, 2015
  - Iowa DOT – Ames, IA, July 16, 2015
  - Combined Team Webinar (Tool rollout) – December 17, 2015
- Round 7 Offering Webinar – March 9, 2016
- IBC Workshop W05 – National Harbor, MD, June 7, 2016

Example Documents/Reports

- **Durability Assessment Report**
  - Identifies environmental exposure zones
  - Addresses deterioration mechanisms
- **Summary of Standard Material Tests**
  - Tests to measure Chloride Ingress
  - Tests to assess Concrete Permeability Properties
  - Calculation template to develop Chloride Profiles

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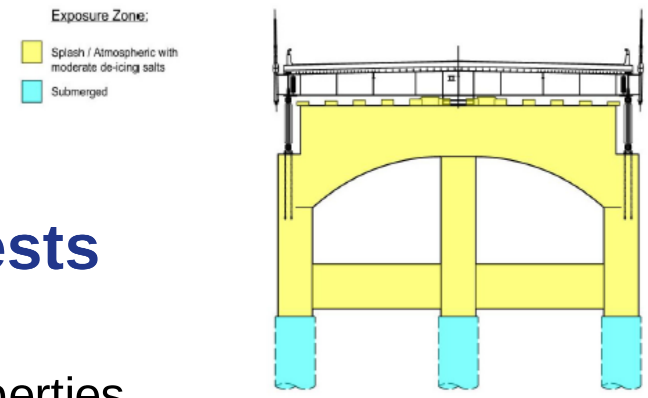
Figure 3: Typical Exposure Zones for the Anchor Piers



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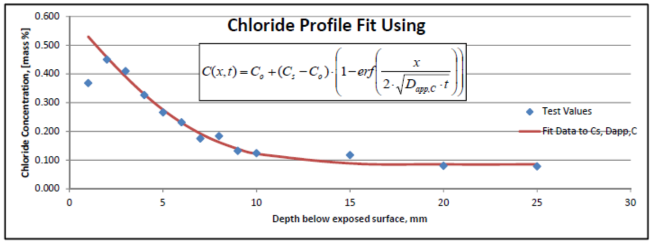

Design Tools

A | B

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Chloride Ingress Deterioration Model

Instructions for use of Full-Probabilistic Spreadsheet Design Tool

This tool has been developed to follow the full-probabilistic design method detailed in *fib* Bulletin 34 - Model Code for Service Life Design (2006), for chloride-induced corrosion in uncracked concrete. Uncracked concrete is defined as concrete in which the ordinary crack width is less than 0.3 mm or 0.012". Service life design is based on the solution to the mathematical model for depassivation (or initiation of corrosion) in the reinforcing steel of a concrete section exposed to chlorides. The model uses Fick's 2nd Law, defined in equations (B2.1-1 to B2.1-4), to compare the chloride concentration in the concrete at the depth of the reinforcing steel at a specified time, to the critical chloride concentration for the reinforcement. The method uses a Monte Carlo approach to solve Equation (B2.1-1) repeatedly, by varying each of the variables in the equation according to a probablistic distribution of values. Each variable is defined by a mean value, a standard deviation, and a distribution type (Normal, Log-Normal, Beta, etc.). Each individual calculation solution either passes or fails the comparison of chloride concentrations. The total number of times that the critical chloride content is exceeded is compared to the number of trials and results in a probability of failure and reliability index. The reliability index recommended by *fib* Bulletin 34 is 1.3. Other reliability indices can be

Instructions | Input Parameters | Monte Carlo Trial Results | Chloride Diffusion Coefficient

Full Probabilistic Tool - Input

				Normal Distr Coefficients		
Parameter	Description	Units	Distribution Function	Mean, μ	Std Dev, σ	Coeff of Variation, σ/μ
$D_{RCM,0}$	Chloride Migration Coefficient (from Nordtest NT Build 492 - results are given in m^2/sec)	in^2/yr	Normal	0.420	0.084	0.20
		mm^2/yr		271.0	54.2	
		m^2/sec		8.59E-12	1.72E-12	
b_e	Regression variable, (limited to 3500 °K to 5500 °K)	°K	Normal	4800	700	
T_{real}	Temperature (from Local Weather Data)	°F	Normal	49.1	12.06	
		°C		9.5	6.70	
		°K		282.65	6.70	
T_{ref}	Standard test temperature	°F	Constant	67.6		
		°C		19.8		
		°K		292.9		
k_e	Environmental transfer variable	n/a	n/a			
k_t	Transfer parameter	n/a	Constant	1.0		
α	Aging exponent - All types in atmospheric zone	n/a	Beta	0.65	0.15	
t_o	Reference point of time (28 days = 0.0767 yrs)	yrs	Constant	0.0767		
A(t)	Aging function	n/a	n/a			
C_o	Initial Chloride Content of Concrete	mass% of binder	Normal	0.10	0.00	0.001
C_s or $C_{s,\Delta x}$	Chloride Concentration at surface, or at substitute surface Δx	mass% of binder	Log-Normal	3.00	1.50	0.50

Monte Carlo Trial Results

Trial Results of Randomly Generated Values of Input Parameters to Fick's 2nd Law

Trial	$D_{RCM,0}$ (mm^2/yr)		b_e (°K)		T_{real} (°K)		k_e	α		$A(t_{SL})$
	rand 0-1	RESULT	rand 0-1	RESULT	rand 0-1	RESULT		rand 0-1	RESULT	
1	0.392	256.08	0.117	3967	0.918	292.0	1.0	0.921	0.853	0.0022
2	0.924	348.42	0.607	4990	0.690	286.0	0.7	0.236	0.541	0.0207
3	0.547	277.42	0.325	4482	0.682	285.8	0.7	0.473	0.650	0.0094
4	0.510	272.31	0.118	3970	0.025	269.5	0.3	0.094	0.439	0.0430
5	0.422	260.27	0.379	4585	0.203	277.1	0.4	0.757	0.766	0.0041
6	0.995	412.47	0.158	4099	0.160	276.0	0.4	0.935	0.864	0.0020
7	0.965	369.00	0.104	3920	0.320	279.5	0.5	0.398	0.619	0.0118
8	0.654	292.43	0.844	5500	0.626	284.8	0.6	0.102	0.447	0.0406
9	0.899	340.12	0.979	[illegible]	0.223	277.5	0.4	0.136	0.475	0.0330
4999	0.892	338.07	0.897	5500	0.238	277.9	0.4	0.610	0.705	0.[illegible]
5000	0.911	344.10	0.347	4524	0.702	286.2	0.7	0.865	0.819	0.00[illegible]

SUMMARY	$D_{RCM,0}$	b_e	T_{real}	k_e	α	$A(t_{SL})$
Computed Mean	270.47	4740	282.6	0.6	0.65	0.0[illegible]
Input Mean	270.97	4800	282.7		0.65	
Max	469.64	5500	309.08	2.41	1.00	0.[illegible]
Min	92.56	3500	259.46	0.10	0.09	0.0[illegible]

Trial	cover (mm)		C_{crit} (mass% of binder)		$C(x=cov,t_{SL})$	Pass (1) /Fail (0)
	rand 0-1	RESULT	rand 0-1	RESULT	RESULT	
1	0.528	50.9	0.788	0.716	0.10	1
2	0.411	49.0	0.372	0.538	0.46	1
3	0.005	36.5	0.666	0.654	0.55	1
4	0.432	49.3	0.240	0.486	0.27	1
5	0.172	44.8	0.517	0.592	0.10	1
6	0.520	50.7	0.623	0.635	0.10	1
7	0.336	47.8	0.511	0.590	0.15	1
8	0.782	55.5	0.296	0.509	0.71	0
9	.266	46.6	0.112	0.424	0.43	0
4999	0.116	43.4	0.279	0.502	0.10	1
5000	0.805	56.1	0.669	0.655	0.10	1

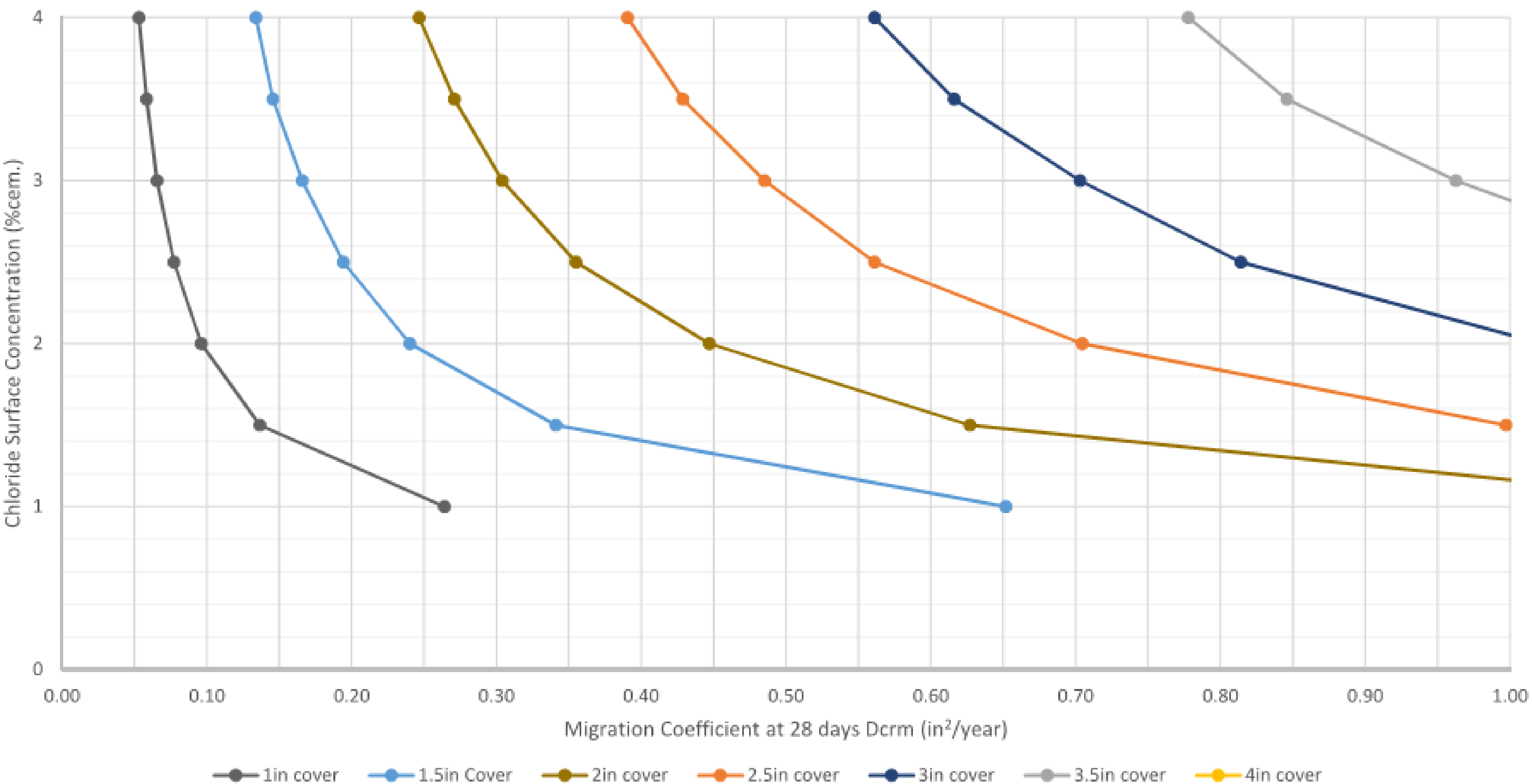
SUMMARY	cover	C_{crit}
Computed Mean	50.76	0.60
Input Mean	50.80	0.60
Max	76.30	1.21
Min	32.65	0.24

Total Passing	4526	
Total # of Trials	5000	
Reliability	0.91	
P_f, Probability of failure	0.09	
β, Reliability Index (calculate	1.312	Passes
β, Target Reliability Index	1.3	

SERVICE LIFE DESIGN - GRAPHICAL SOLUTION

Calculations as per fib Bulletin 34 - fully probabilistic design
Service Life = 100 years
Beta = 1.3, Probability of failure = 10%
Critical chloride concentration: black bars - 0.6%cem.
Initial chloride concentration : 0.1%cem.

Temperature: mean = 49.1F, std = 12.1F
Exposure Zones: Buried/Submerged
Concrete Type: OPC + >20%FA



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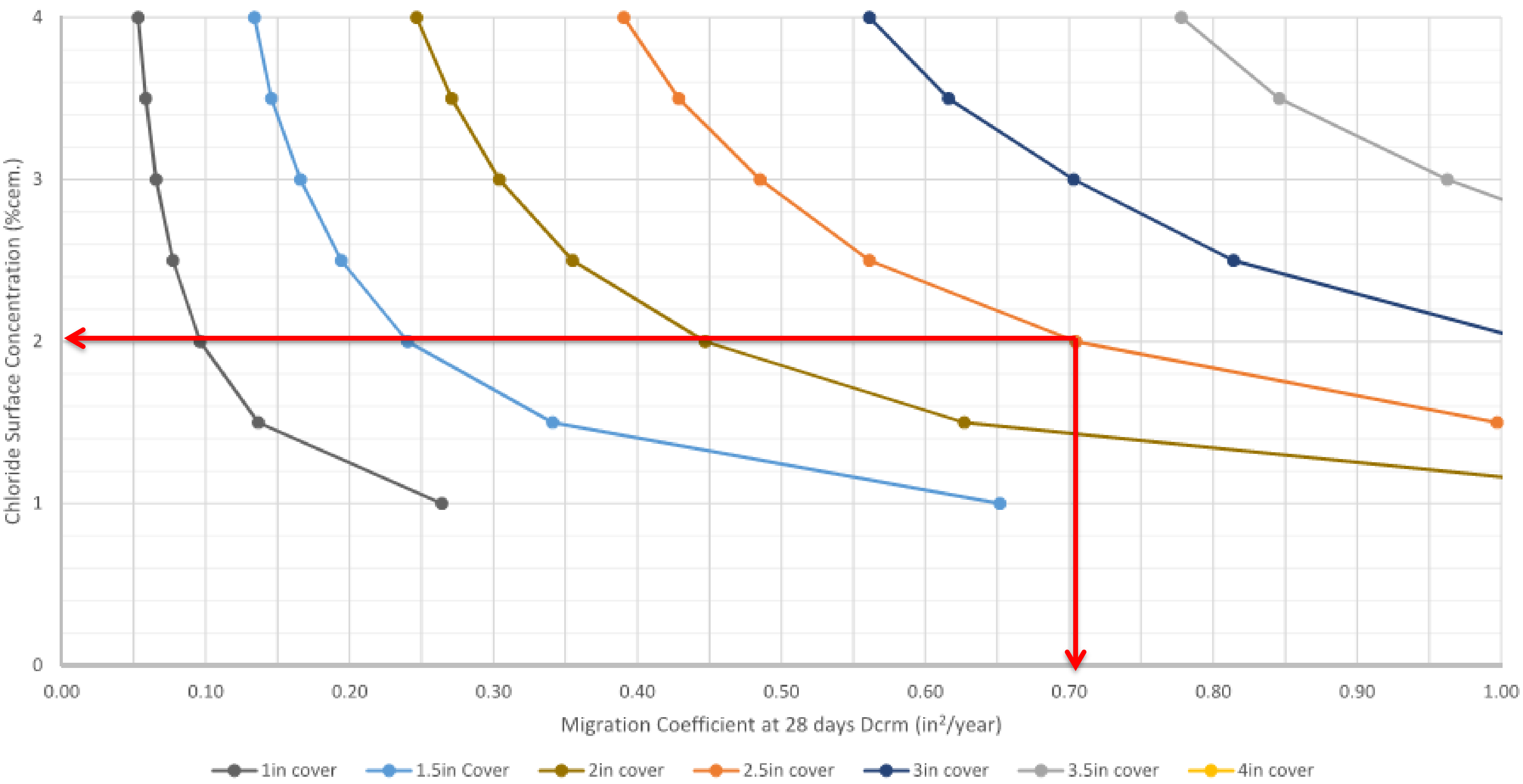

IAP Next Steps

- Conduct Agency Training Workshops
- Develop Reference Material Documentation
- Round 7 Implementation Assistance
  - $500,000 in Lead Adopter awards made available
  - 2 awards for $100,000 each:
    - Iowa DOT
    - Maine DOT

Questions?

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