


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP2 Service Life Design for Bridges (R19A)

Progress Update Webinar

December 17, 2015

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Agenda

- **Introductions and Program Updates**
  - *Matt DeMarco, FHWA Bridge Program Lead; Mike Bartholomew, CH2M HILL, Subject Matter Expert (SME)*
- **Updates from Implementation States** *(Oregon, Virginia, Iowa, Pennsylvania, Central Federal Lands)*
  - Activities completed
  - Activities ongoing
  - Schedule and updates to deadlines
- **SHRP2-Developed Tools Now Available**
  - *Mike Bartholomew and Anne-Marie Langlois (SMEs)*
- **Questions and Discussion**
- **Action Items / Conclusion**

SHRP2/SME-Developed Tools

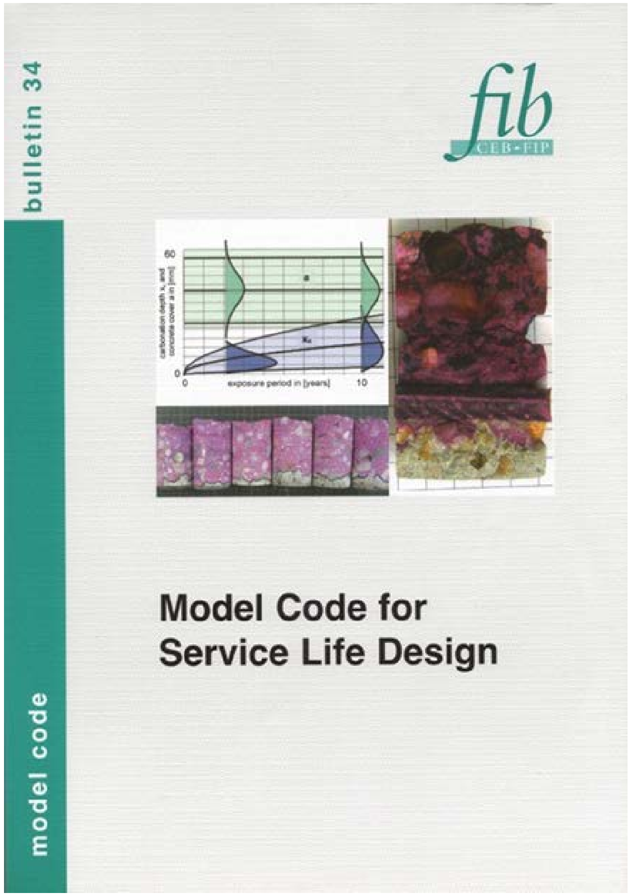
- AASHTO – SHRP2 Product Page for ***Service Life Design for Bridges*** – http://shrp2.transportation.org/Pages/ServiceLifeDesignforBridges.aspx

- ***Full Probabilistic Tool for Chloride Ingress Modeling*** – Mike Bartholomew

- ***Graphical Solutions to Chloride Ingress*** – Anne-Marie Langlois

Service Life Design – Full Probabilistic Model

- Uses the methodology from *fib* Bulletin 34 – *Model Code for Service Life Design*



Fick's 2nd Law of Diffusion

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

Chloride Diffusion Coefficient, $D_{app,C}$

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

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

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

Environmental Transfer Variable, k_e

Aging Function, $A(t)$

Chloride Loading

- All units are in mass % of binder (cement plus supplemental cementitious materials)

- C_o – Initial Chloride Content of the concrete, constant value equal to maximum chloride content allowed in specifications (use Normal Distribution if data available)

- C_s – Surface Chloride Concentration in submerged or atmospheric zones, uses Log-Normal Distribution

- $C_{s,\Delta x}$ – Substitute Surface Chloride Concentration in zones of intermittent exposure (splash/spray zones), uses Log-Normal Distribution

Cover & Resistance Parameters

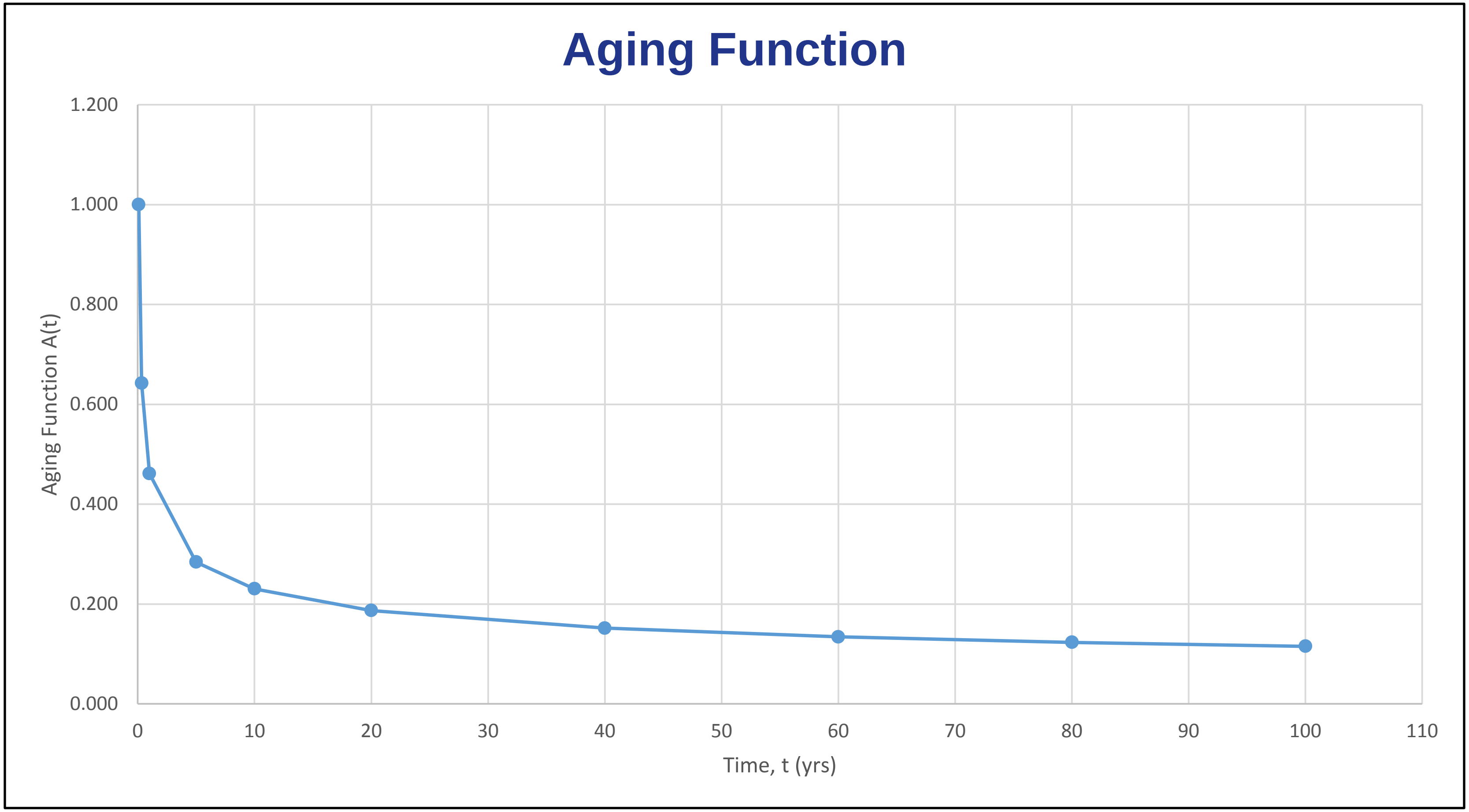
- a – Concrete Cover Dimension, uses Log-Normal Distribution with nominal cover depth as mean and standard deviation allowed in specifications
- Δx – Transfer Function for intermittent chloride exposure (splash/spray zones), uses Beta Distribution with 0.35" mean and 0.22" std. dev., 0" in atmospheric and submerged zones
- C_{crit} – Critical Chloride Content to initiate corrosion at the level of ***plain*** reinforcing, uses Beta Distribution with 0.6 mass % of binder as mean and 0.25 coefficient of variation.

Aging Function

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

- t, age of interest (generally t_{SL}, the Target Service Life, e.g., 100 years)
- t_o, reference age – 1 day = 0.0767 years
- α, aging exponent – Dependent on concrete composition & exposure, no units, uses Beta Distribution
  - Tidal, Splash, Spray Zones
    - Ordinary Portland Cement (OPC) Type I Cement, 0.3 mean, 0.12 std. dev.
    - 20% or more Fly ash, 0.6 mean, 0.15 std. dev.
    - Type III Cement with Blast Furnace Slag, 0.45 mean, 0.2 std. dev.
  - Atmospheric Zones
    - All Concretes, 0.65 mean, 0.15 std. dev.

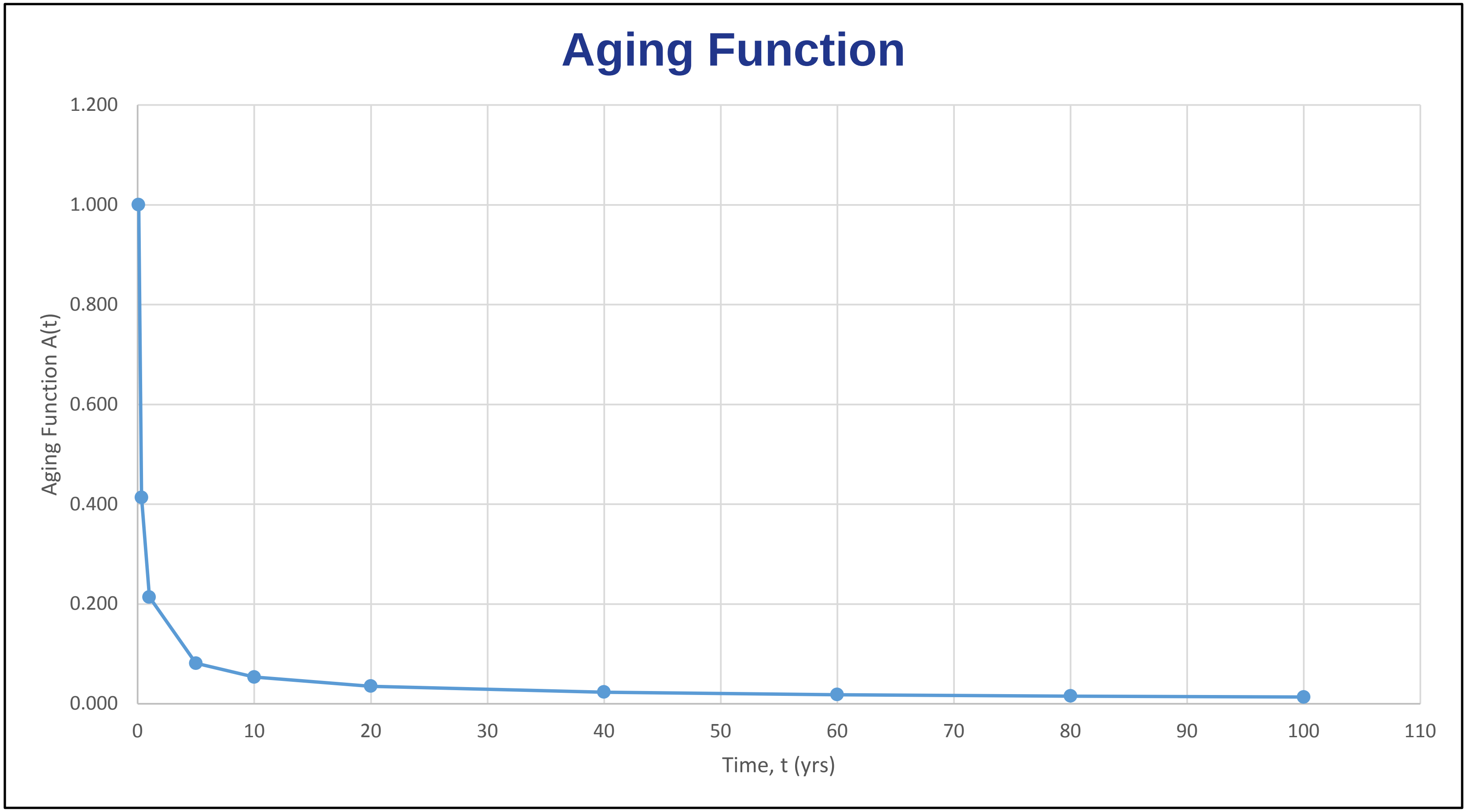
Aging Function – Splash Zone
Ordinary Portland Cement Concrete



t, (yrs)	0.0767	0.3333	1	5	10	20	40	60	80	100
A(t), Aging Function	1.000	0.647	0.468	0.290	0.237	0.193	0.157	0.139	0.128	0.120

Aging Function – Splash Zone

Concrete containing min. 20% Fly Ash



t, (yrs)	0.0767	0.3333	1	5	10	20	40	60	80	100
A(t), Aging Function	1.000	0.412	0.212	0.080	0.053	0.035	0.023	0.018	0.015	0.013

Environmental Transfer Variable

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

- b_e – Regression coefficient, uses Normal Distribution 4800º K mean and 700º K std. dev. (values limited to 3500º K to 5500º K)

- T_{ref} – Standard Test Temperature, constant, 292.9º K (67.6º F, 19.8º C)

- T_{real} – Temperature, needs to be converted to º K, uses Normal Distribution with mean and std. dev. obtained from local weather station statistical data

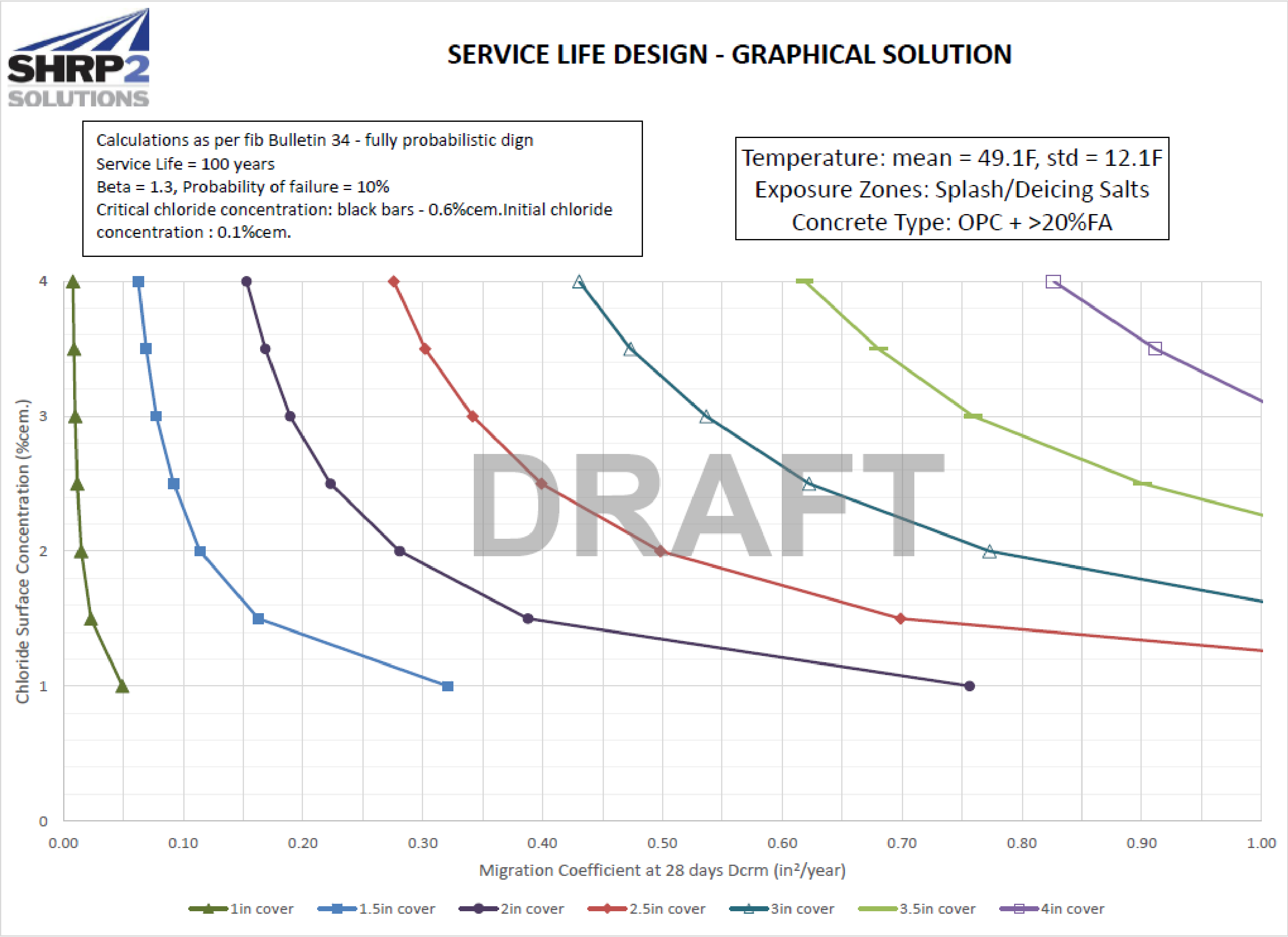
Chloride Diffusion Coefficient

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

- $D_{RCM,0}$ – Chloride Migration Coefficient, in^2/yr, uses Normal Distribution with mean value from the Nordtest NT Build 492 test results and a coefficient of variation of 0.20

- k_t – Transfer Parameter, constant value = 1

Service Life Design – Graphical Solution



Questions?

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