Performance Specification Compliance for Design-Build and P3 Projects

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Overview

- Performance specifications are replacing descriptive specifications in large projects with service lives > 75 years
- In design-build and P3 Projects the ultimate owner has the structure turned over to them at some point typically > 25 years
- The design-build team maintains the structure in good condition
  - Protects the owner
  - Incentive to design-build team to use performance specifications
- Performance specifications allow the team to:
  - Build the structure at the lowest cost that meets service life requirements
  - Differentiate the team through innovative use of existing technologies
  - Demonstrate performance with modeling
- Firm specializing in concrete durability and corrosion is a key member of the design-build team

Today's Presentation

- Short review of service life guidelines and available modeling programs
- Examples from the design-build and owner's perspective on large bridges
  - Tappan Zee Bridge
  - Kosciuszko Bridge
  - NBSL

Common Service Life Issues

- Projects need to demonstrate that the service life can be met requiring modeling of performance based on element type, concrete properties, corrosion protection systems, and exposure.
- Large bridges will have several different concretes and exposures.
  - The same concrete doesn't need to be used as severity of the exposure differs
  - Corrosion protection needs can change with exposure
- Concrete durability issues such as freezing and thawing, scaling, and ASR are addressed by testing and evaluation of materials used.
- Corrosion performance is determined by modeling the ingress of chlorides (and carbonation depth) and the protection system used.
- Probabilistic approaches are required, typically time for 10% of the structure to show corrosion initiation or time to cracking and spalling.

Models

- Models for chloride ingress fall into two groups
  - Fickean models based on Fick's Law for diffusion
  - Mass transport and chemical interaction models
- Available Fickean Models
  - Life 365™ and Concrete Works
  - R19A from FHWA based on assumptions in fib Bulletin 34
  - Similar programs to R19A
- Mass transport and chemical interaction models
  - STADIUM®
- Assume cracks are repaired

Fickean Models

- Pluses
  - Easy to use and quick results
  - Good for relative comparisons
- Negatives
  - Diffusion not applicable to non-water saturated concrete
  - Assumptions made for wetting and drying
  - Cementitious chemistry effects not addressed
  - Only estimates chloride ingress
  - Can overestimate the effects of aging on reducing permeability

Mass Transport and Chemical Reaction Models

- Pluses
  - Can predict chloride ingress in unsaturated concrete without using empirical relationships that are specific to a specific concrete and exposure condition
  - Concrete chemistry is accounted for in prediction of chloride ingress
  - Can show hydroxide to chloride ratios in the pore water
  - Shows concentrations of other ions and phases formed as function of time and depth
  - Well defined test methods for determination of transport parameters
  - Field verified
  - Can be used to estimate existing life from field data
- Negatives
  - Requires longer time and more powerful computer to get results, as chemical reactions need to be balanced at each finite element step.
  - User training is necessary

Example for Owners Side

- Owner's team evaluates design-build teams Corrosion Protection Plan (CPP) to make sure it addresses the Owner's stated requirements.
  - Verify parameters and assumptions used
  - Use alternative more rigorous models for chloride ingress if needed
  - Confirm concrete properties especially those related to chloride-ion transport
  - Provides guidance to owner as requested
  - Specialized concrete testing
    - e.g., transport properties, restrained shrinkage, mass concrete
- Example
  - Tappan Zee Bridge

Tappan Zee Bridge

- Owners Representatives
  - Owner – New York State Thruway Authority
  - Engineer – HNTB Corporation
  - TCG subcontractor to HNTB
- Design-Build Team
  - Tappan Zee Constructors, LLC (Consortium)
    - Fluor Enterprises
    - American Bridge Company
    - Granite Construction
    - Traylor Bros.
  - Lead Designer – HDR Inc.

Tappan Zee Bridge

- Required Service Life
  - 100 Years

Tappan Zee Bridge Rendering
Source: http://www.newnybridge.com/rendering/

Tappan Zee Bridge

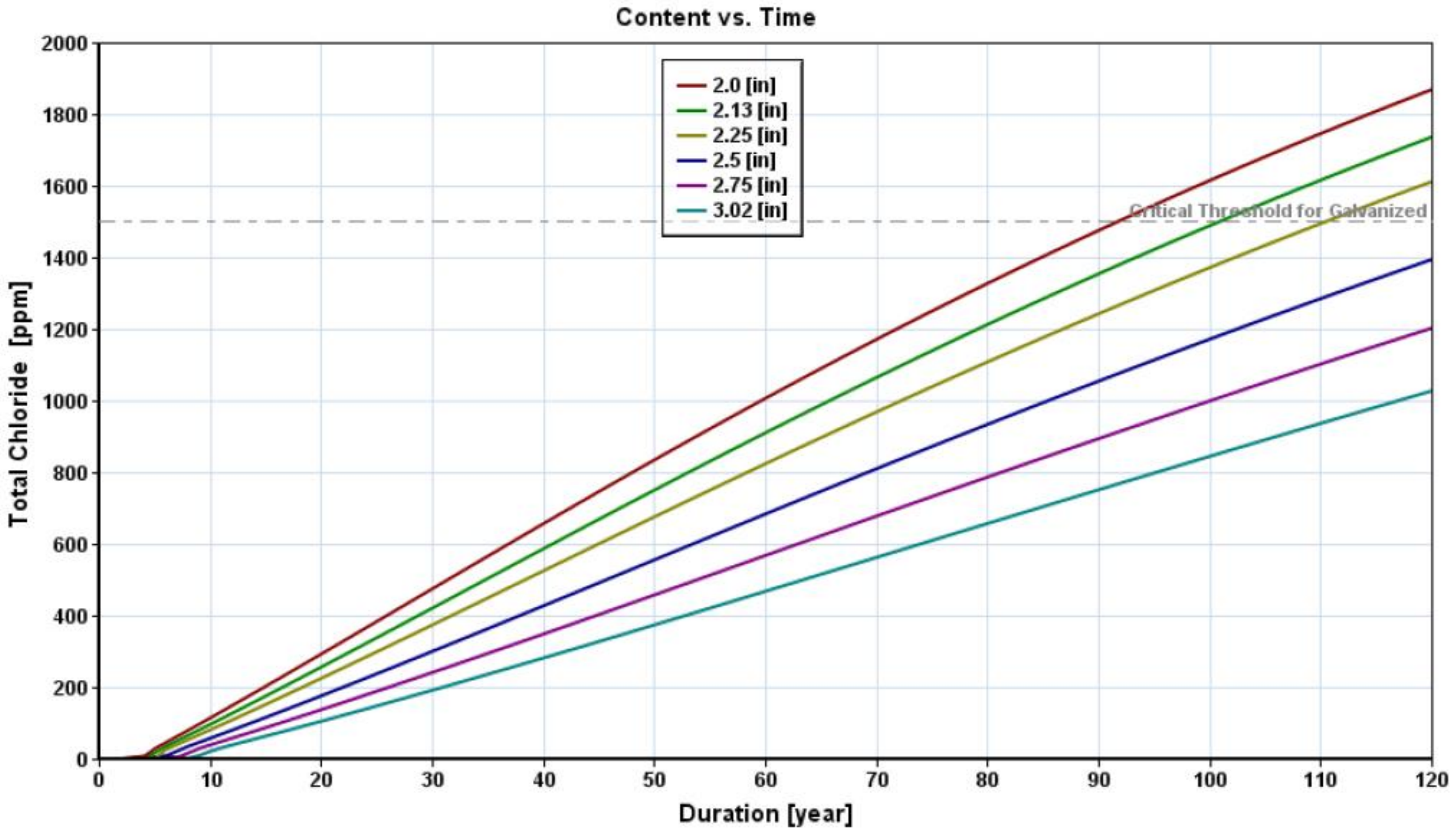
- Concrete Elements
  - Towers
  - Concrete plugs for steel piles
  - Drilled shafts
  - Pile caps
  - Pier columns
  - Pier caps
  - Abutments
  - Concrete barriers
  - Deck
  - PPC concrete overlay

Tappan Zee Bridge

- Verification Laboratory Testing of the Deck Closure Mix
  - ASTM C39 Compressive Strength
  - ASTM C1218 Water-Soluble Chloride Content
  - NT Build 492 Chloride Migration Coefficient
  - ASTM C157 Length Change of Hardened Concrete (modified)
  - ASTM C1581 Age at Cracking under Restrained Shrinkage
  - ASTM C672 Scaling Resistance
  - ASTM C666 Freeze/Thaw Resistance
  - FM 5-578 Florida Test Method for Concrete Resistivity

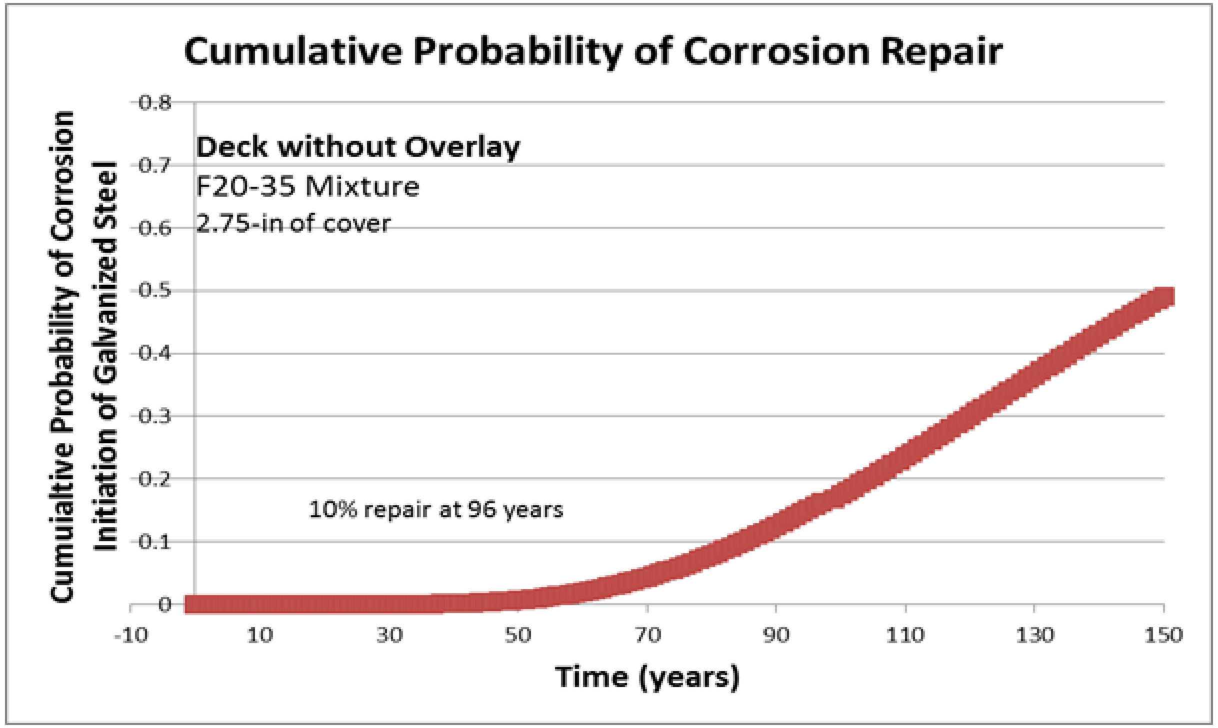
Tappan Zee Bridge

- Example STADIUM Output for Concrete Deck Without Overlay



Tappan Zee Bridge

- Example Probabilistic Service Life Modeling Results



Tappan Zee Bridge

Construction Photo
Source: http://www.newnybridge.com/photo/

Examples for Design-Build Side

- The Design-Build Team
  - Address owner's needs for service life and construction issues
  - Rigorous modeling to demonstrate concrete with specific properties will meet the chloride ingress requirements
    - Based on time of exposure
    - Exposure conditions
    - Corrosion protection systems
  - Confirm concrete properties especially those related to chloride-ion transport are met in preproduction batches and during construction (QC/QA)
  - Address mass concrete issues, freezing and thawing, ASR, abrasion
  - Address potential cracking
- Examples
  - Kosciuszko Bridge (K-Bridge)
  - New Bridge over the St. Lawrence (NBSL)

Kosciuszko Bridge (K-Bridge)

- Owner – New York State Department of Transportation (NYSDOT)
- Design-Build Team
  - Skanska-Kiewit-ECCO III, Joint Venture (SKE)
  - TCG subcontractor to SKE
  - Lead Designer – HNTB Corporation

Kosciuszko Bridge (K-Bridge)

- Required Service Life
  - 100 years

K-Bridge Rendering
Source: https://www.dot.ny.gov/kbridge

Kosciuszko Bridge (K-Bridge)

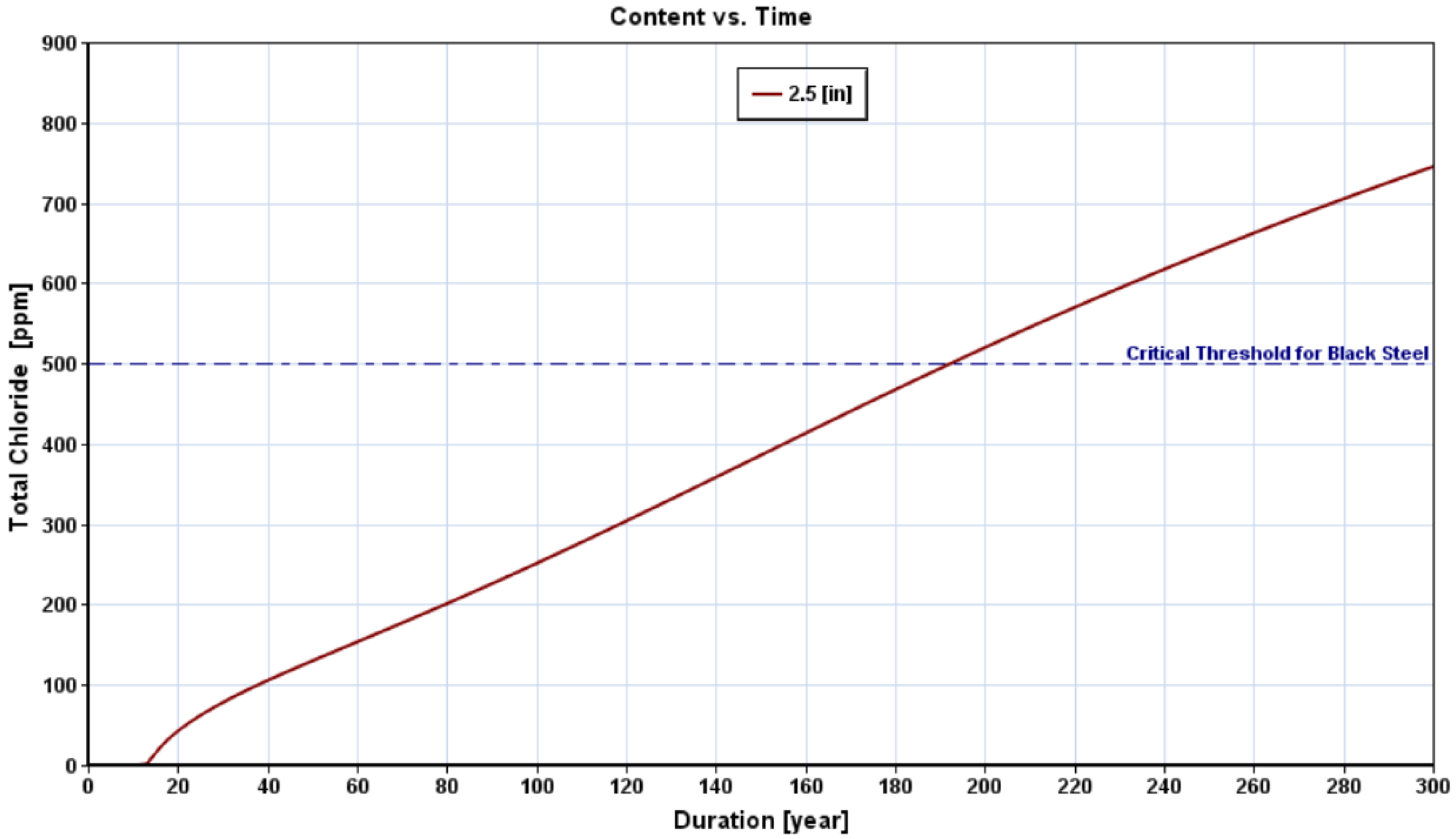
- Concrete Elements
  - Tapertube steel piles (concrete core)
  - Pile cap/Footing
  - Towers
  - Abutments
  - Pier columns
  - Pier caps
  - Girders
  - Deck
  - Moment slab
  - Concrete barriers

Kosciuszko Bridge (K-Bridge)

- Concrete Mix Design Qualification Laboratory Testing
  - ASTM C39 Compressive Strength
  - ASTM C1202 Rapid Chloride Permeability
  - Modified ASTM C1202 Ion Migration
  - SIMCO Test Method – Moisture Migration
  - ASTM C642 Porosity
  - ASTM C666 Freeze/Thaw Resistance
  - ASTM C672 Scaling Resistance
  - ASTM C512 Creep
  - AASHTO T160 Drying Shrinkage

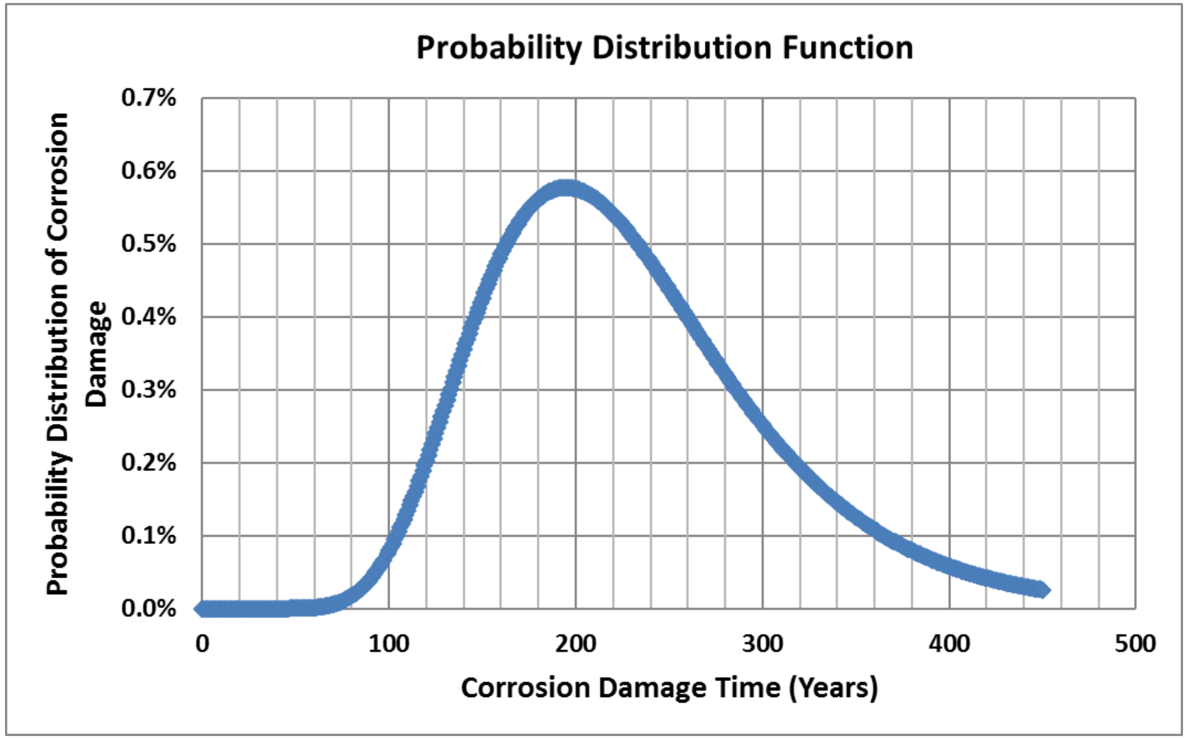
Kosciuszko Bridge (K-Bridge)

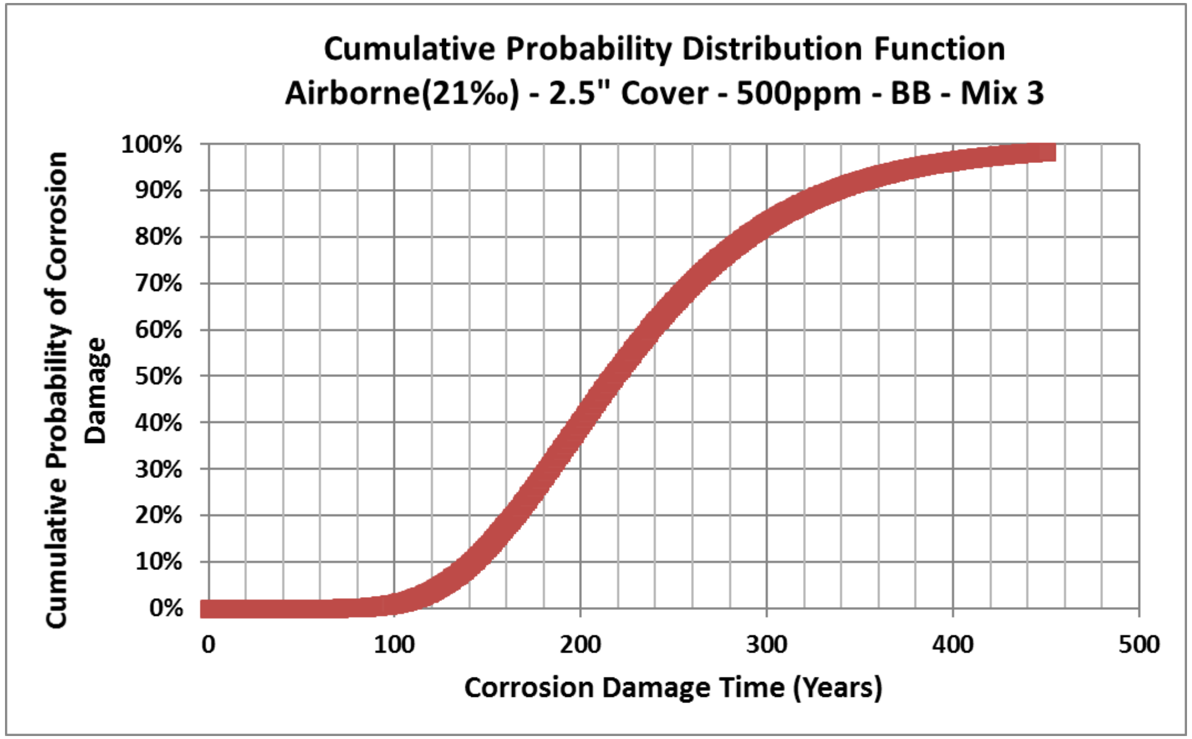
- Example STADIUM Output for Pier Cap



Kosciuszko Bridge (K-Bridge)

Ex. Probabilistic Service Life Modeling Result (note: includes propagation)





Kosciuszko Bridge (K-Bridge)

Construction Photo January 2017
Source: https://www.dot.ny.gov/kbridge/photos

New Bridge Across St. Lawrence (NBSL)

- Owner – Canada
- Design-Build Team
  - TY LIN International – International Bridge Technologies – SNC Lavalin, Joint Venture (SSL – Signature on St. Lawrence)
  - Lead Designer – TY LIN International
  - TCG subcontractor to TY LIN
- Team operates bridge for 30 years and turns it over to MTO Quebec in good condition

New Bridge Across St. Lawrence (NBSL)

- Required Service Life
  - 125 years

NBSL Rendering
Source: http://www.infrastructure.gc.ca/nbsl-npsl/architecture-eng.html

New Bridge Across St. Lawrence (NBSL)

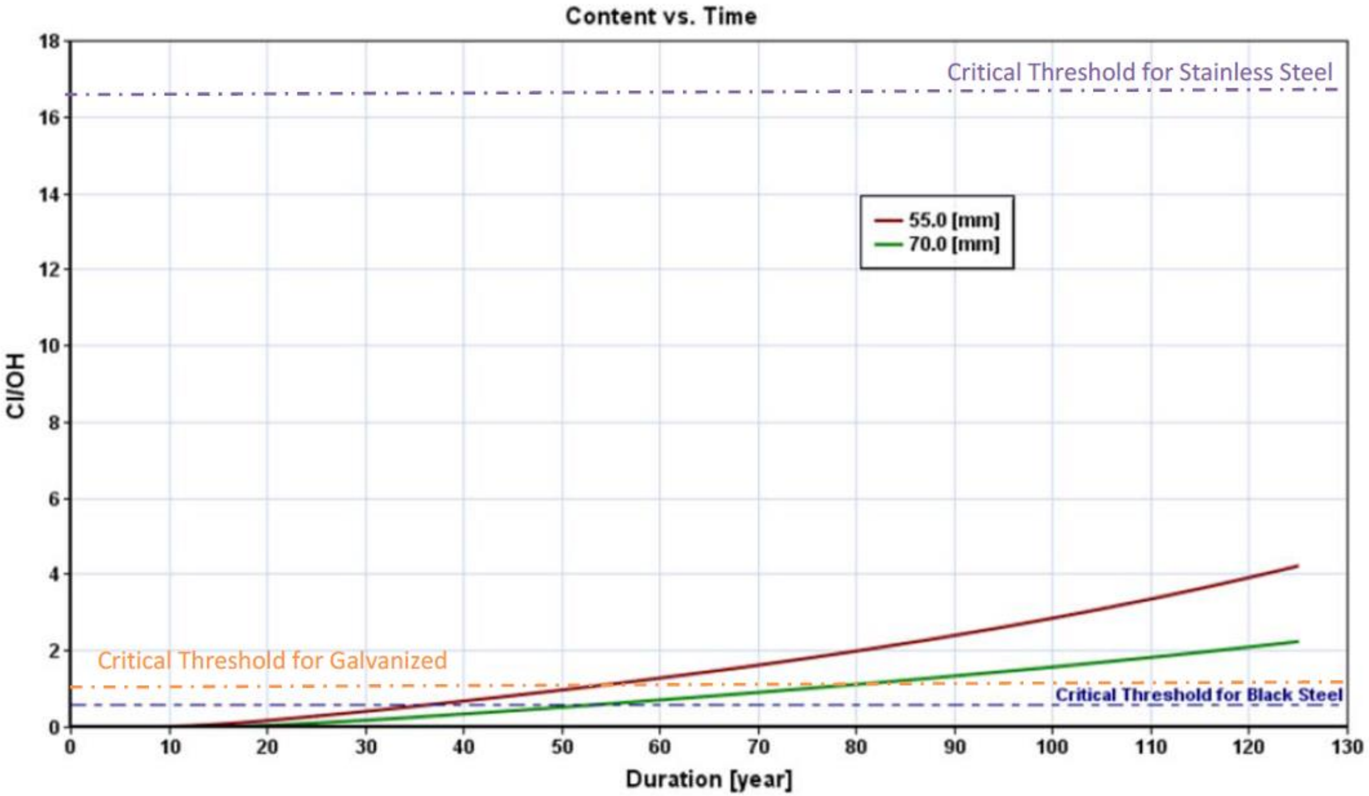
- Service life defined as time to corrosion initiation at 90% confidence
- Concrete Elements
  - Piles
  - Pile cap/Footing
  - Towers
  - Abutments
  - Pier columns
  - Cross Beams
  - Girders
  - Deck/Multi-Use paths
  - Transit Corridor (Future Light Rail System)
  - Concrete barriers

New Bridge Across St. Lawrence (NBSL)

- Concrete Mix Design Qualification Laboratory Testing – performed by SIMCO Technologies (Independent from durability consultant)
  - ASTM C39 Compressive Strength
  - ASTM C1202 Rapid Chloride Permeability
  - Modified ASTM C1202 Ion Migration
  - SIMCO Test Method – Moisture Migration
  - ASTM C642 Porosity
  - ASTM C666 Freeze/Thaw Resistance
  - ASTM C672 Scaling Resistance

New Bridge Across St. Lawrence (NBSL)

- Example STADIUM Output – Deck, SS reinforcement, HPC

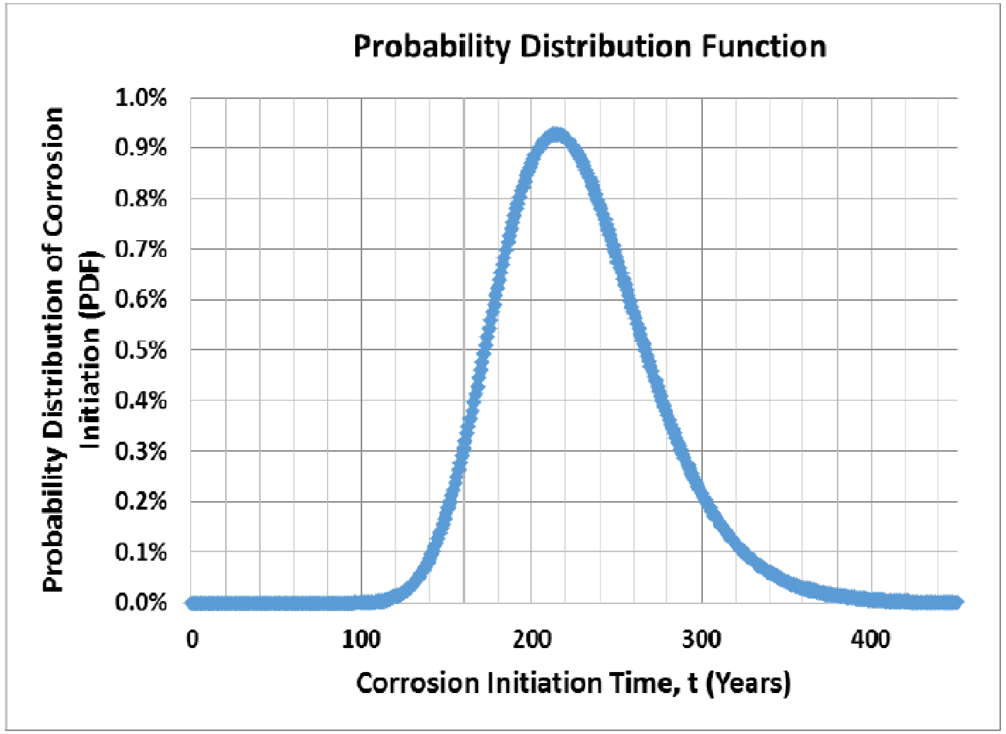


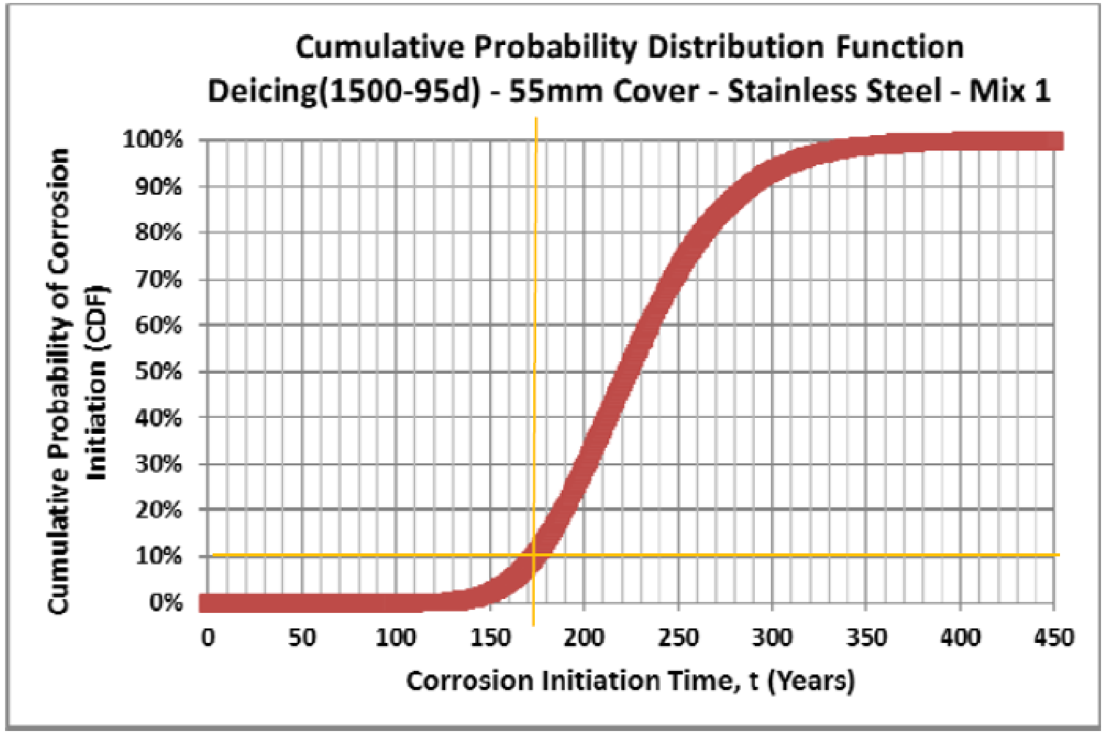
W/Cm – 0.32
SF – 5%
FA – 25%

Deicing Salts: 80% NaCl, 20% $CaCl_2$

New Bridge Across St. Lawrence (NBSL)

- Ex. Probabilistic Service Life Modeling Result – Deck, SS, HPC





New Bridge Across St. Lawrence (NBSL)

Construction Photo: October 2016

NBSL Rendering
Source: http://www.infrastructure.gc.ca/nbsl-npsl/architecture-eng.html

Summary

- Performance Specifications are being used in major concrete bridges with the owner providing a required service life as the overall performance standard
  - Typically over 100 years
  - Probabilistic analysis used
- Design-Build Teams need to demonstrate that they can meet the service life required at a competitive cost to the owner
- This is a complicated process and both the design-build and owners teams have service life experts.