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)
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.