SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Oregon DOT Service Life Design Implementation

IBC W05: Service Life Design and Engineering of Bridges

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U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Overview

- Ochoco Creek New Bridge Construction
- NT Build 492 Results
- Deck Repair and Preservation
- Chloride Testing Method Refinement
- Chloride Ingress Modelling
- Review: Future Work

Ochoco Creek Bridge

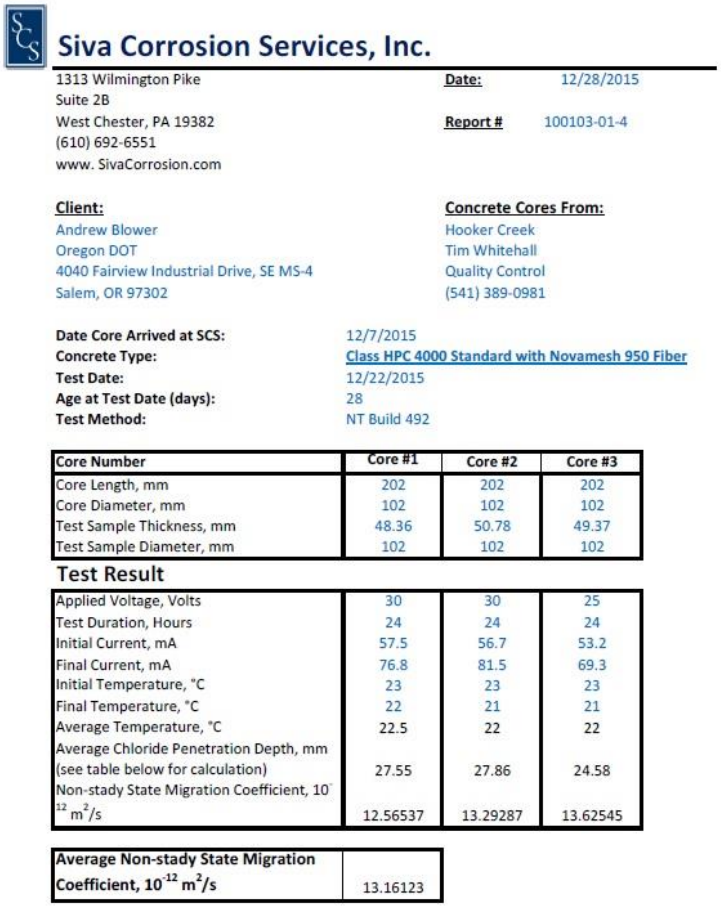
- Insufficient load rating.
- Programmed for replacement.
- ODOT designated bridge for participation in R19A design efforts.

Ochoco Creek Bridge

- Cores were taken to obtain effective chloride loading from deicers.
- Cores of various mix designs were cast at 2 supplier plants and tested per NT Build 492 to find a chloride migration coefficient.
- Design engineers ran the simulation spreadsheet provided by partners at CH2M and B-T.
- Found that concrete mix design and rebar cover satisfied 100 year design criteria.

NT Build 492 Results

- 3 mix designs tested
  - Class 3300; 0.46 w/c with slag
  - Class 4000 HPC; 0.4 w/c with SF and FA
  - Alt. Class 4000 HPC; 0.4 w/c with slag
- Found combination slag and lower w/c ratio resisted Cl best.



Siva Corrosion Services, Inc.

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West Chester, PA 19382
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Date: 12/28/2015
Report # 100103-01-4

Client:
Andrew Blower
Oregon DOT
4040 Fairview Industrial Drive, SE MS-4
Salem, OR 97302

Concrete Cores From:
Hooker Creek
Tim Whitehall
Quality Control
(541) 389-0981

Date Core Arrived at SCS: 12/7/2015
Concrete Type: Class HPC 4000 Standard with Novamesh 950 Fiber
Test Date: 12/22/2015
Age at Test Date (days): 28
Test Method: NT Build 492

Core Number	Core #1	Core #2	Core #3
Core Length, mm	202	202	202
Core Diameter, mm	102	102	102
Test Sample Thickness, mm	48.36	50.78	49.37
Test Sample Diameter, mm	102	102	102

Test Result

Applied Voltage, Volts	30	30	25
Test Duration, Hours	24	24	24
Initial Current, mA	57.5	56.7	53.2
Final Current, mA	76.8	81.5	69.3
Initial Temperature, °C	23	23	23
Final Temperature, °C	22	21	21
Average Temperature, °C	22.5	22	22
Average Chloride Penetration Depth, mm (see table below for calculation)	27.55	27.86	24.58
Non-stady State Migration Coefficient, 10^{-12} m^2/s	12.56537	13.29287	13.62545

Average Non-stady State Migration Coefficient, 10^{-12} m^2/s	13.16123

Deck Repair and Preservation

- Decks are typically the cause of reduced service life.
- Spalls affect travelling public long before damage is structural.
- Maintenance often fails to address the Cl contamination causing spalling.

Deck Repair and Preservation

Chloride Testing Method Refinement

- Per ASTM C1152/C1152M regarding rotary hammer powder sampling:

  "Such samples may be unrepresentative, especially when the nominal maximum coarse aggregate size is 25mm (1 in.) or more. … obtain a representative sample of the concrete mixture of at least 20g or more."

Chloride Testing Method Refinement

Chloride Testing Method Refinement

Photos Courtesy Siva Corrosion Services, Inc.

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Chloride Ingress Modelling

- Chloride testing is reported in ½" (13mm) depth increments from the surface.
- A chloride profile is created and a curve fit is used to determine effective surface concentration and diffusion coefficient.

Table 1
Summary of Chloride Content for Bridge #02071A

No.	Core ID	Sample Depth (in)	Sample Number	Chloride Content, % Cl by mass concrete	Comments
1	BR02071A D2	0.25	Depth 1	0.192	Surface
2		0.75	Depth 2	0.108	
3		1.25	Depth 3	0.063	
4		1.75	Depth 4	0.029	
5		2.25	Depth 5	0.011	
6	BR02071A D3	0.25	Depth 1	0.187	Surface
7		0.75	Depth 2	0.134	
8		1.25	Depth 3	0.066	
9		1.75	Depth 4	0.043	
10		2.25	Depth 5	0.023	
11	BR02071A D4	0.25	Depth 1	0.184	Surface
12		0.75	Depth 2	0.143	
13		1.25	Depth 3	0.102	
14		1.75	Depth 4	0.047	
15		2.25	Depth 5	0.020	
16	BR02071A D5	0.25	Depth 1	0.243	Surface
17		0.75	Depth 2	0.113	
18		1.25	Depth 3	0.042	
19		1.75	Depth 4	0.028	
20		2.25	Depth 5	0.010	
21	BR02071A D6	0.25	Depth 1	0.220	Surface
22		0.75	Depth 2	0.187	
23		1.25	Depth 3	0.088	
24		1.75	Depth 4	0.052	
25		2.25	Depth 5	0.014	
26	BR02071A D7	0.25	Depth 1	0.103	Surface
27		0.75	Depth 2	0.086	
28		1.25	Depth 3	0.056	
29		1.75	Depth 4	0.041	
30		2.25	Depth 5	0.021	

Chloride Test Results
ASTM C1152

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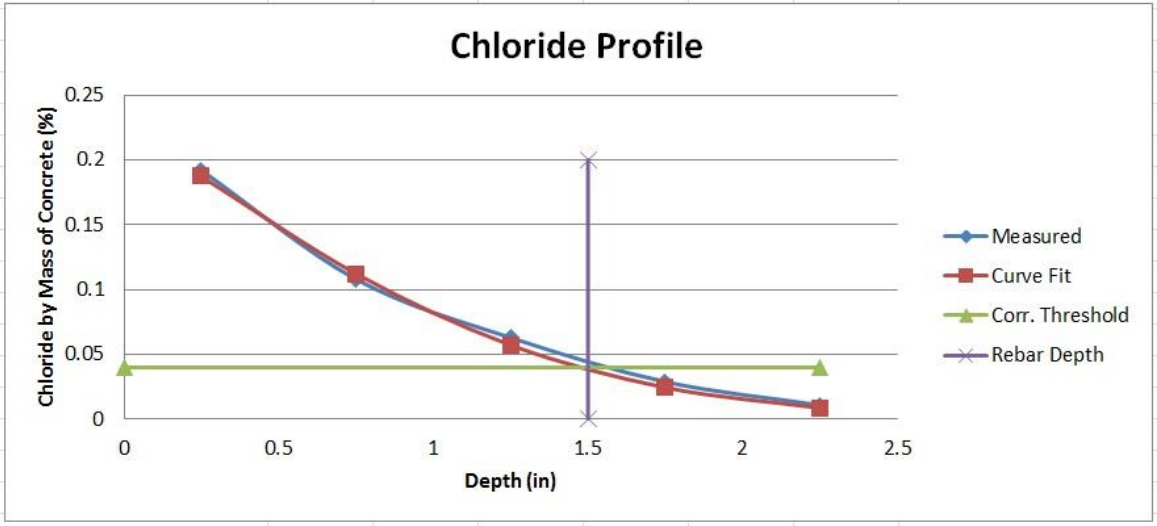
SCS Project # 100109-01
Page 1 of 2

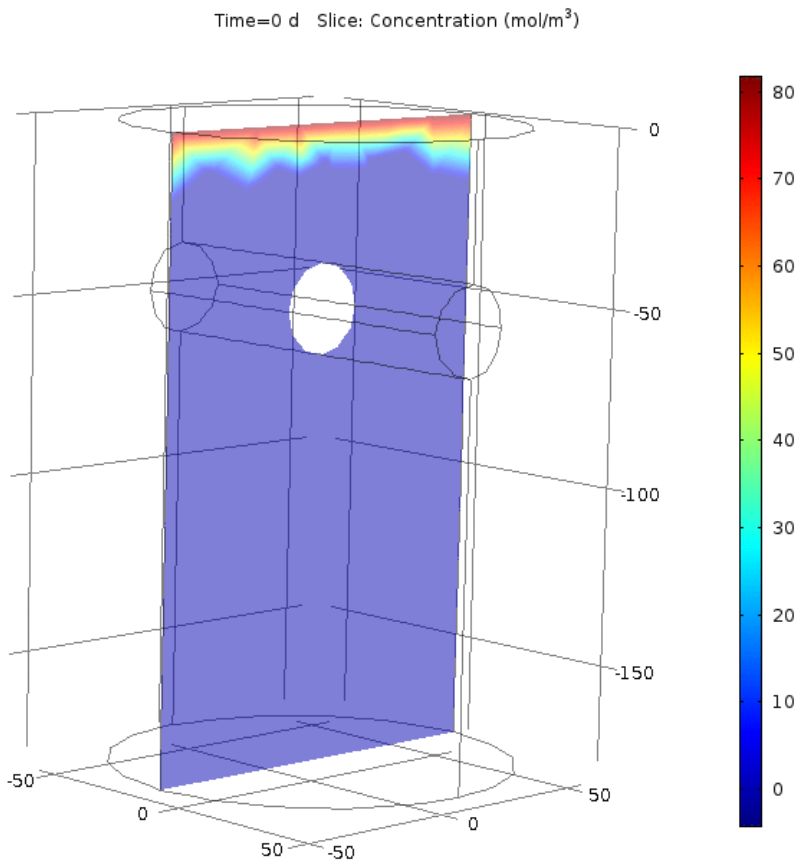
Chloride Ingress Modelling

Field Test Data						
X[Depth, in]	0.25	0.75	1.25	1.75	2.25	
Cf [Chloride Concentration, %]	0.192	0.108	0.063	0.029	0.011	
Calculated Values						
C(x,t) [Chloride Concentration, %]	0.187331	0.112226	0.057252	0.024571	0.008793	
Sum of Least Squares						
(Cf-C(x,t))^2		1.79E-05	3.3E-05	1.96E-05	4.87E-06	
Sum[(Cf-C(x,t)^2]						7.54E-05

User Input Data	
t[time, yr]	48
Diffusion Coefficient [Dc, in^2/yr]	0.0123
Surface Concentration [Cmax, %]	0.229



Chloride Ingress Modelling



- A workable model has been developed in Comsol.
- This is currently being developed to model various repair techniques including concrete removal, deck seals, membranes, cathodic protection, and electrochemical chloride extraction.

Review

- Ochoco Creek Bridge verified to meet R19A service life design simulations for 100 year service life.
- Chloride testing methods have been refined for scoping and design of deck rehabilitation projects.
- A working model for chloride ingress has been developed and will be used to prescribe rehabilitation/preservation methods on bridge decks.

Future Work

- ODOT intends to standardize chloride testing for rehabilitation projects and provide guidance for proper repair practices through its Bridge Design and Drafting Manual.
- ODOT will review durability tests for concrete such as resistivity, permeability, and ground penetrating radar for rebar clearances. These may be added to boilerplate specifications as quality control items.
- Carbonation models should be developed when designing for 100 years with superstructure details that typically have 1.5” (38 mm) reinforcement clearances.

Questions?