Testing and Evaluation of Existing Bridge Decks for Chloride Concentration

SHRP2 Service Life Design Workshop (R19A)

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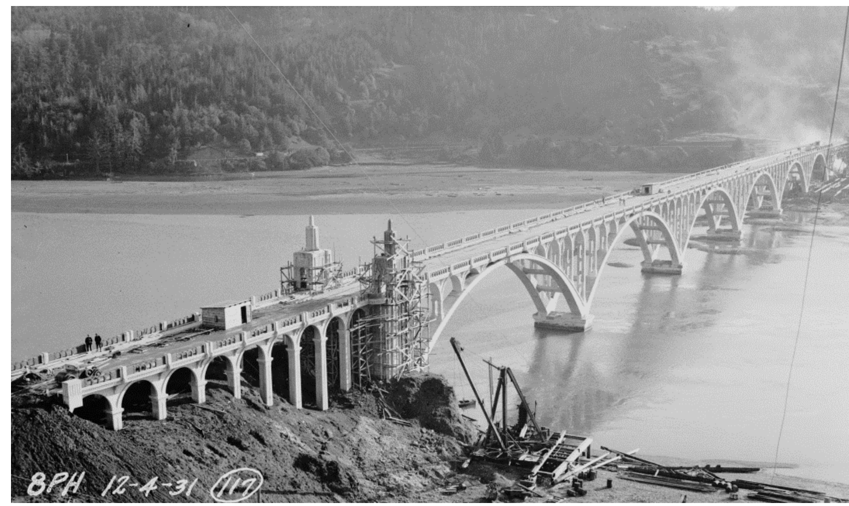
Testing and Evaluation of Existing Bridge Decks For Chloride Concentration

Outline

- Use of Service Life Design principles
- Sampling and Testing Methods
- Case Studies
- Summary, Conclusion, and Future Work

Use of Service Life Design principles

- Current SLD practice associated with RC is usually controlled by chloride induced corrosion.
- This is not always true for older structures but often controls service life of bridge decks due to deicing chemicals.



Use of Service Life Design principles

Due to this fact, chloride testing is included in field scoping for deck rehabilitation

Use of Service Life Design principles

Chloride Analysis $C(x,t) = C_{max} - (C_{max} - C_{min})erf\left[\frac{x}{2\sqrt{D_c \times t}}\right]$

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

User Input Data

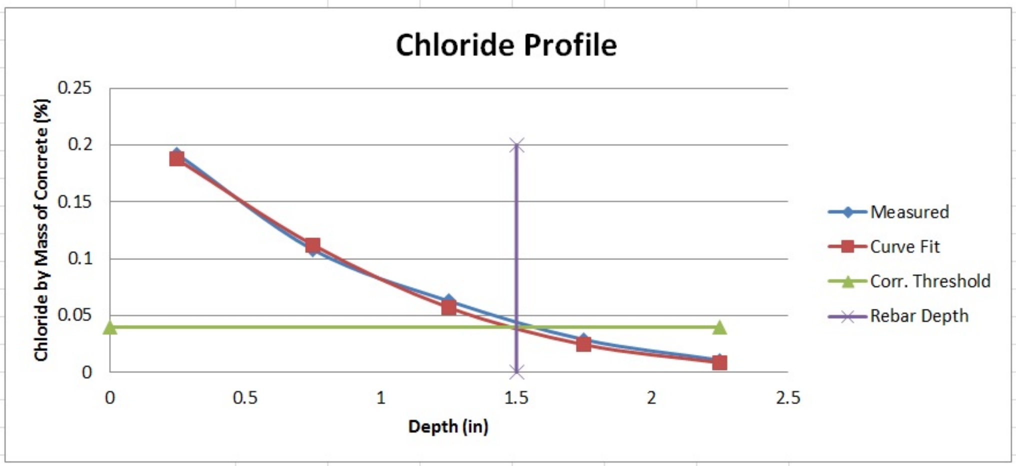
t[time, yr]	48
Diffusion Coefficient [Dc, in^2/yr]	0.0123
Surface Concentration [Cmax, %]	0.229

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



History

Deicer Usage in Oregon

- Early history of deicer usage in Oregon is undocumented but accounts of rock salt being used on roadways and bridge decks date back to before1980.
- In the mid 1980s, some ODOT crews experimented with acetates but found it impractical to apply.
- By the late 1980s, ODOT crews which apply deicer had [unofficially] adopted magnesium chloride as it is easy to handle and apply.
- In 1992 ODOT official policy changed from only applying sand (notably often containing NaCl to avoid freezing) to using MgCl deicers.

History

Deicer Usage in Oregon

- In 2012, ODOT started a rock salt study on I-5 in the Siskiyou Mountains and US-95 in the Southeast corner of the State..
- Safety and cost benefits from this study have expanded the use of rock salt.
- Affected areas include over 222 miles of Interstate 82 and Interstate 84 East of Boardman, OR as well as 100 miles of Interstate 5 between Canyonville, OR and the California border.

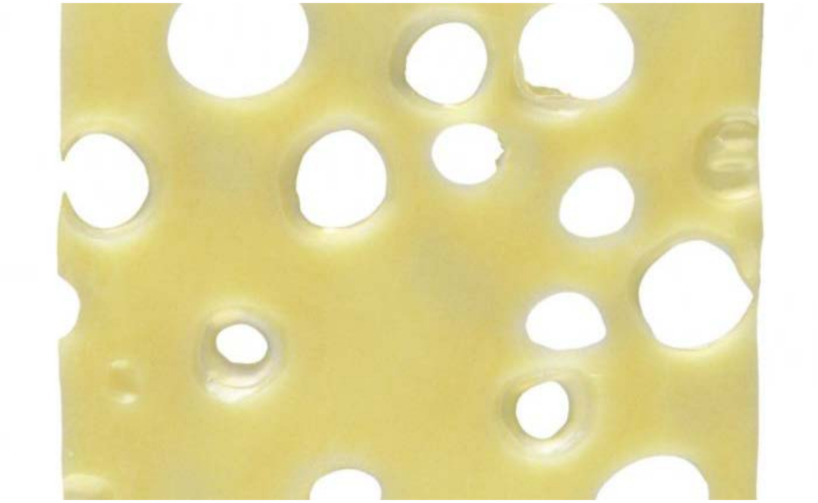
Sampling and Testing Methods

Powder sampling methods using a rotary hammer, coffee filters, and a vacuum have been used as illustrated to the left.

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."

Sampling and Testing Methods



Drilling enough holes to obtain 20g of powder would be more destructive than was originally intended when the powder sampling methods were developed.

A representative sample is not guaranteed since samples could still contain uneven portions of aggregate due to the way a rotary hammer pulverizes concrete. More holes also increase the risk of drilling into reinforcement and future defects.

Sampling and Testing Methods

Coring provides a much better specimen which is more representative of the structure.

Sampling and Testing Methods

Handheld GPR is used to locate reinforcement prior to drilling

Sampling and Testing Methods

Crushing core samples after sliced at ½” depth increments for chloride testing

Photos Courtesy Siva Corrosion Services, Inc.

Sampling and Testing Methods

Pulverizing samples for chloride testing (<850 µm per ASTM C1152 and AASHTO T-260)

Photos Courtesy Siva Corrosion Services, Inc.

Sampling and Testing Methods

Acid Digestion and Titration

Samples are digested into nitric acid as they are boiled and then vacuum filtered.

Samples are cooled and sodium chloride of a known concentration is added.

Samples are titrated with a silver nitrate solution until an equivalence point is reached.

Photos Courtesy of Siva Corrosion Services, Inc.

Case Study: Salt Creek Bridge #02071A

Case Study: Salt Creek Bridge #02071A

- Structure had “dense cracking” and approx. 20 sq. ft. of delaminations in span 1 prior to thin overlay installation in 2011.
- Since overlay installation, approximately 20% of the surface of the deck exhibits extensive spalling and/or cracking of the concrete and epoxy based wearing surface.
- Cores taken from this deck show that the concrete is near or has exceeded the corrosion threshold at the level of reinforcement.
- Corrosion will continue to occur unless significant concrete removal takes place.**

Case Study: Salt Creek Bridge #02071A

Chloride Testing Results

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

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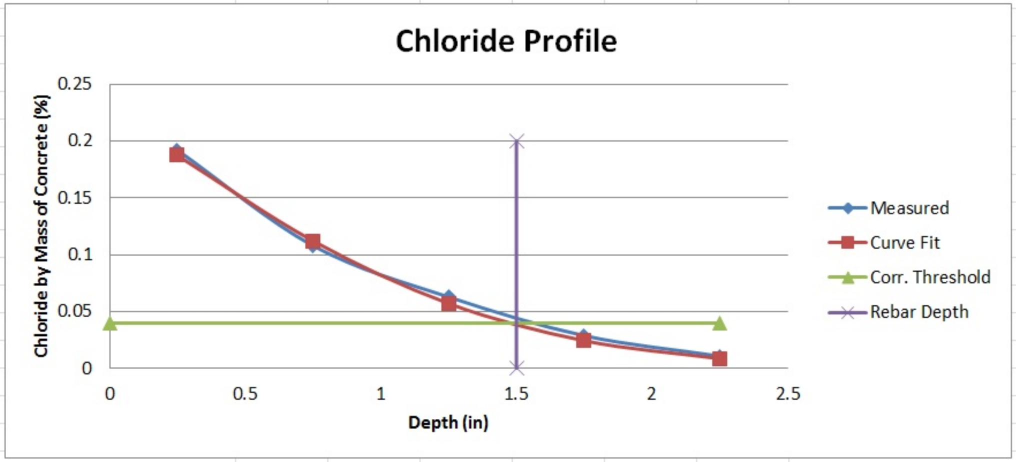


Case Study: I5 Over Crowson Rd. BR #08746N

Case Study: I5 Over Crowson Rd. BR #08746N

- This deck was replaced during a widening project that completed in 2001.
- At only 15 years old, this bridge deck is already showing signs of severe corrosion activity and damage.
- This damage is caused by a combination of heavy deicer usage and shallow reinforcement where the transverse bars are tied together which also corresponds to a wheel track.

Case Study: I5 Over Crowson Rd. BR #08746N

These issues can be avoided by:

- Additional third party QA testing of reinforcement clearances via GPR prior to acceptance.
- Application of a water impenetrable wearing surface after 3 months of aging.

Yamhill River Overflow BR #08492

Overview

- Constructed 1963
- RCDG w/precast beams on timber bents.
- Deck is 6” thick with 1” of (design) cover at the wearing surface.
- “2 inch wearing surface by others” was never installed as recommended by engineers in 1979…

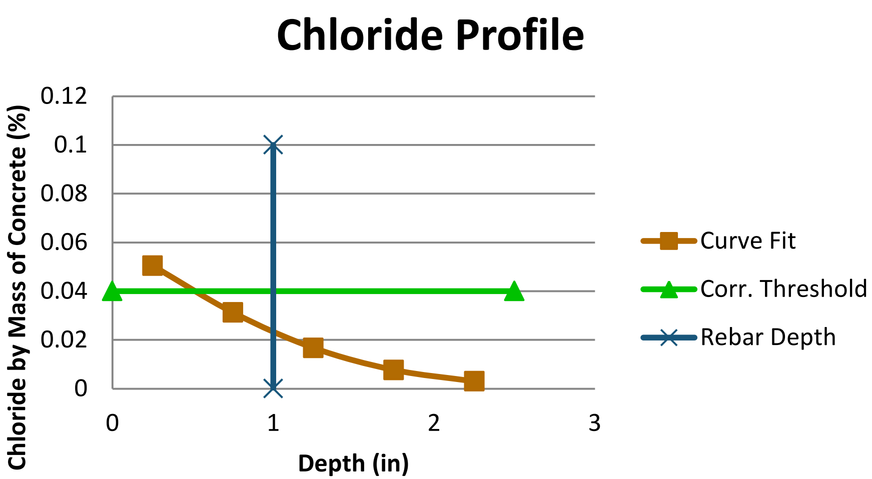
Yamhill River Overflow BR #08492

Inspection

- Programmed to receive a PPC overlay.
- Visual examination reveals there are issues with the deck that will likely not be resolved by a wearing surface.
- 43% of the surface is in CS3.

Yamhill River Overflow BR #08492

Chloride Tests



- Bridge has fairly low chloride content.
- However, the rebar was not placed with 1” of cover in many locations and rutting has further reduced cover.
- Any rebar within 0.5” of the surface likely has corrosion initiated.

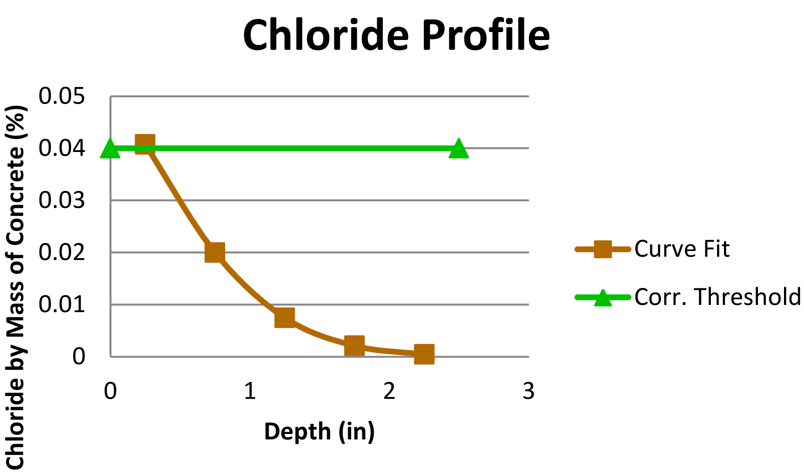
Yamhill River Overflow BR #08492

Recommendations

- A PPC wearing surface is not recommended. Even with Class 2 prep removing a portion of contaminated material, the remaining area has likely or is about to initiate corrosion.
- A structural overlay is recommended with at least 0.5” of contaminated concrete removal via hydro-demolition due to shallow reinforcement.
- Class 2 prep should be performed on all spalled or patched areas and where hydro-demo reveals cracking over rebar.

Yamhill River Overflow BR #08492

Recommendations



Predicted Chloride Concentration of LMC or SFC overlay after 30 years service life

- This curve was generated using a population of chloride samples from existing in-service overlays and the chloride loading derived from the sampling at BR08492.
- 0.5” additional cover will provide a 30 year service life for the overlay, but 1.5” is recommended to account for rutting, and construction tolerances.

Youngs Bay Bridge #08306

Overview

- Constructed 1964
- Pre-stressed girders with a pony truss vertical lift span and adjacent fixed pony truss.
- Deck is 7” thick with 1.5” of (design) cover at the wearing surface.
- Exposed rebar on the surface was first reported in 1996.

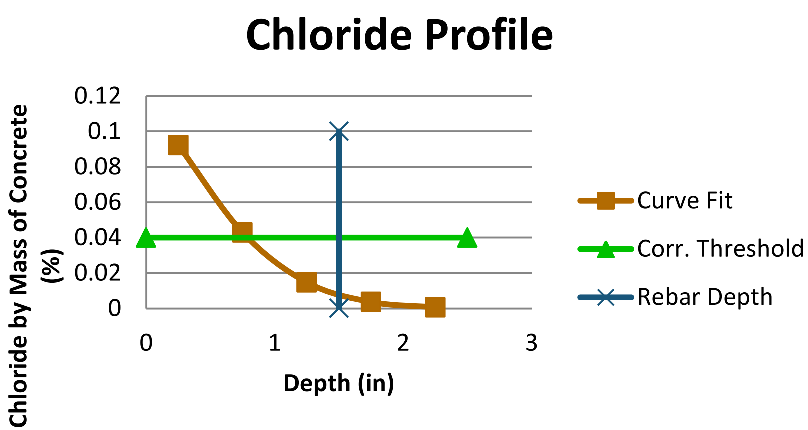
Youngs Bay Bridge #08306

Inspection

- Programmed to receive a PPC overlay.
- Visual examination reveals multiple bars exposed at the wearing surface.
- However, there are few spalls and spalls are shallow.

Youngs Bay Bridge #08306

Chloride Tests



- Deck is above chloride threshold to about 0.75” below the surface.
- The rebar was not placed with 1.5” of cover in many locations and rutting has further reduced cover.
- Any rebar within 0.75” of the surface likely has corrosion initiated.

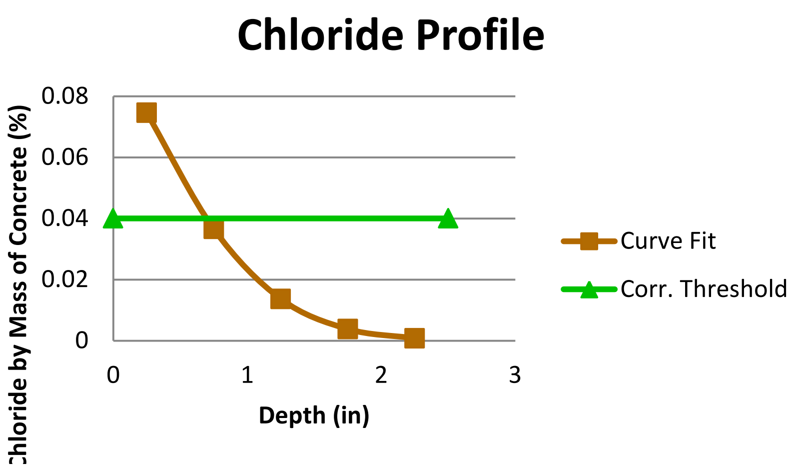
Youngs Bay Bridge #08306

Recommendations

- A PPC wearing surface is not recommended. It is unclear how much cover exists and corrosion has likely initiated on rebar that are within 0.75” of the surface PPC will not have an opportunity to reach its intended service life of 25 years.
- A structural overlay is recommended with at least 1” of contaminated concrete removal via hydro-demolition due to shallow reinforcement.
- Class 2 prep should be performed on all spalled or patched areas and where hydro-demo reveals cracking over rebar.

Youngs Bay Bridge #08306

Recommendations



Predicted Chloride Concentration of LMC or SFC overlay after 30 years service life

- 0.75” additional cover will provide a 30 year service life for the overlay, but 1.5” is recommended to account for rutting, and construction tolerances.

Hwy 1 Over Hwy 273 BR #09259 & #09259A

Overview

- Constructed 1965
- Pre-stressed girder design.
- Deck is presumed to be 7.5” with 2” cover.
- A repair called the “Iowa Method” was performed sometime between 1976 and 1978 due to rock salt induced corrosion damage.

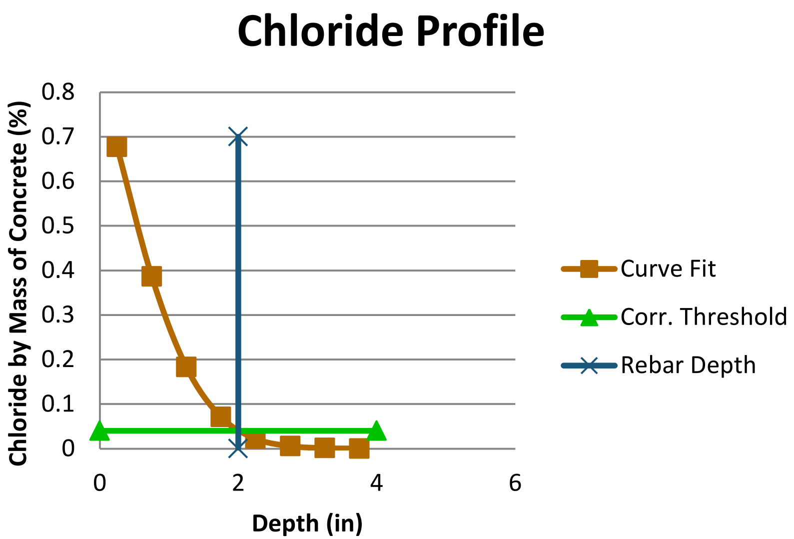
Hwy 1 Over Hwy 273 BR #09259 & #09259A

Inspection

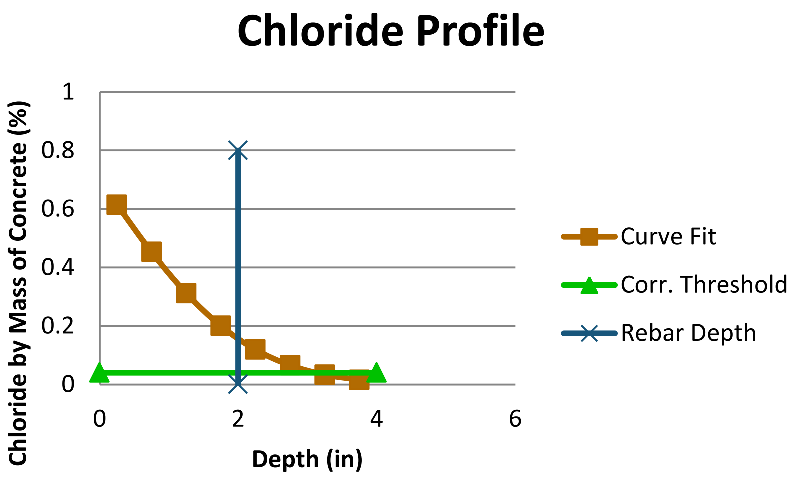
- Programmed for a PPC Overlay
- Visual examination reveals there are numerous spall repairs with a high concentration at the impact panel joints due to steel dowels used to hold grade.
- Cores reveal that the overlay has a thickness variation from 2” to 4”.

Hwy 1 Over Hwy 273 BR #09259 & #09259A

Chloride Tests



Average Overlay Chloride Profile
(SB Structure Similar)



Average Parent Material Chloride
Profile
(SB Structure Similar)

Hwy 1 Over Hwy 273 BR #09259 & #09259A

Recommendations

- A PPC wearing surface is not recommended. The overlay shows chloride contamination approaching the chloride threshold at the depth of reinforcement.
- There is significant chloride contamination in the original construction material and hydro-demolition would need to remove material to a depth of 4” to ensure further delamination does not occur and chlorides don’t migrate toward the bottom mat.
- The Iowa method utilized an extremely dense, low slump mix. The dense material in conjunction with variable thickness makes partial hydro demolition difficult and likely much of the deck will be removed to full depth with this quantity being unknown.

Hwy 1 Over Hwy 273 BR #09259 & #09259A

Recommendations

- The history and salt content of this structure suggests that reinforcement condition will vary and repairs will be difficult to quantify.
- Many of the dowels holding impact panels at grade have been removed as spalls have been repaired, but the remaining dowels will have to be removed and should be replaced with a corrosion resistant material.
- It is recommend that, due to these constructability issues, that the decks and impact panels be replaced.
- Alternative construction materials should be explored to increase corrosion resistance of any new construction on these structures.

Banfield Interchange BR #08588A, 08588B, & 08588C

Overview

- Constructed 1963
- Plate Girder and RCDG mixed construction.
- Deck is 6” thick with a 1.5” (design) cover.
- A 1.5” concrete wearing surface, planned for in design was added in 1985.

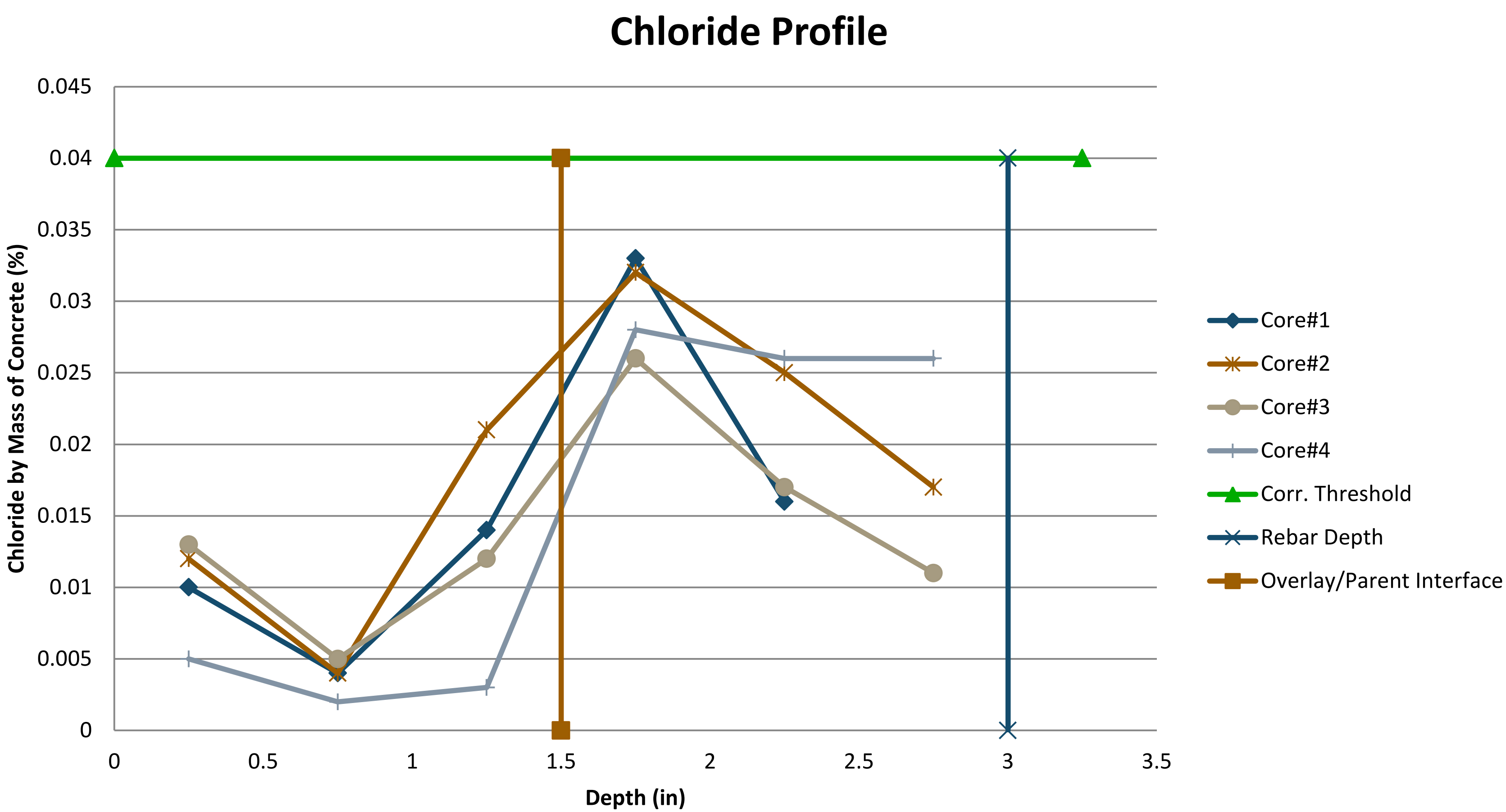
Banfield Interchange BR #08588A, 08588B, & 08588C

Inspection

- Programmed to receive a PPC overlay.
- Visual examination and chain drag reveals numerous delaminations and cracks throughout the overlay.
- Some joints have severe impact damage at header details with numerous patch materials.

Banfield Interchange BR #08588A, 08588B, & 08588C

Chloride Tests



"A" Structure Chloride Profile

Banfield Interchange BR #08588A, 08588B, & 08588C

Recommendations

- The overlay has reached the end of it's service life due to normal wear from impact. There may be small amounts of freeze/thaw forces at work, but degradation is not caused by widespread chloride induced corrosion.
- Due to the amount of delamination, the overlay should be removed and replaced by a new wearing surface.
- Soffit cracking and efflorescence indicate that the thin deck is flexing and may benefit from a structural concrete overlay. Care should be taken when deciding on a wearing surface material.

Conclusion

- Phase II of R19A which prompted chloride investigation of in-service bridge decks has evolved into State-wide testing during project development.
- This testing has successfully identified or ruled out degradation mechanisms on many structures.
- The service life design principles have avoided improper rehabilitation activities on many bridge decks.
- This exercise has given ODOT the tools to make better decisions on projects designed to extend the service life of our current inventory.

Current and Future Work

- Cores from 8 bridges in the expanded rock salt usage areas were taken late last summer. Testing is complete and a report should be available within the next month.
- A contract is being developed to test another 44 bridges this summer in the expanded rock salt usage areas.
- OSU is pursuing an ODOT research project to correlate MgCl and NaCl loading parameters so that previously collected data can be used to predict service life under the new winter maintenance conditions.
- Destructive testing to determine carbonation depths is being conducted when considering rehabilitation of older historic structures in low-humidity environments.


Questions?

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