Assessment and Rehabilitation of Waste Water Treatment Structures Affected by Microbially-Induced Corrosion of Concrete

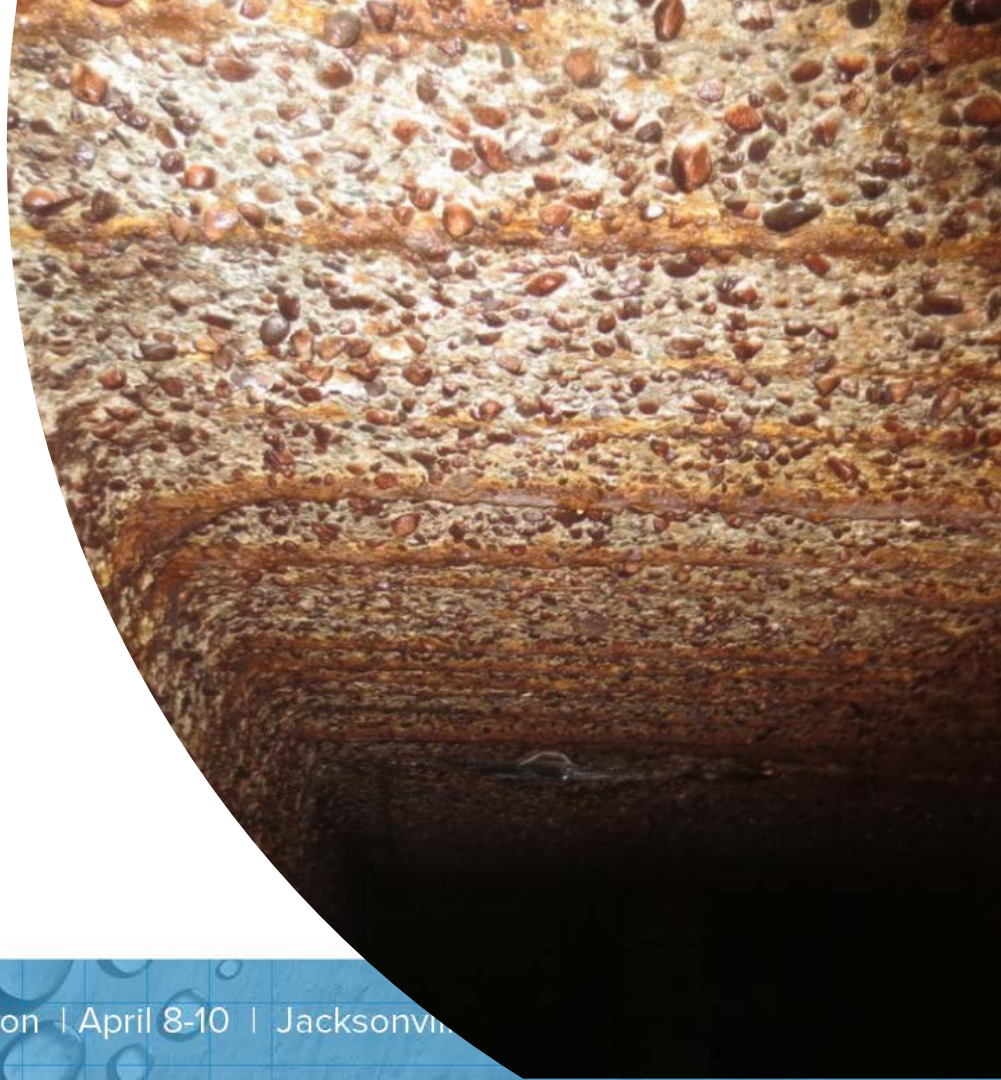
Meghdad Hoseini, Ph.D., P.Eng.
Senior Materials Engineer-Project Manager
WSP Canada- Vancouver

Outline

- Introduction
- Mechanisms of Action
- Where does it happen?
- Challenges in Assessment and Rehabilitation
- Assessment Methods (case study)
- Rehabilitation Methods
- Conclusions

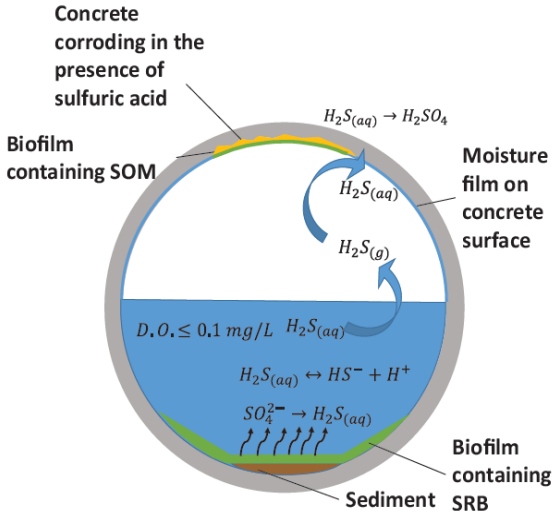
Introduction

- Most of the WWTP infrastructures suffer from Microbially Induced Deterioration which necessitates repair or rehabilitation to maintain or extend their service life



Deterioration Mechanism

- Sulfates in WW converted to H_2S
- H_2S is released into the vapour space where it oxidized to sulfuric acid (by several species of the aerobic bacteria *Thiobacillus)*
- Sulfuric acid attacks the cement paste portion of the concrete matrix
- Corrosion of reinforcement: Further concrete delamination, cracking, and spalling



- M. W. House and W. J. Weiss, Review of Microbially Induced Corrosion and Comments on Needs Related to Testing Procedures, 4th International Conference on the Durability of Concrete Structures, 2014

Signs of Deterioration

- Softening and removal of cement paste
- Dislodging of coarse aggregate
- Erosion of surface paste (due to combination of MIC and flow)
- Reduced cover
- Corrosion of reinforcement: cracking, delamination, and spalling

Credit: Daryl Prefontaine : Repair & Protection of Wastewater Infrastructure: Gold Bar Influent Channel No. 2, Concrete Repair Bulleting, 2016, ICRI

Factors Affecting Deterioration Rate

- Flow velocity and turbulence
- Availability of oxygen
- Temperature (Wastewater, Atmospheric)
- Vapour space above liquid effluent (covered spaces)
- Concrete quality

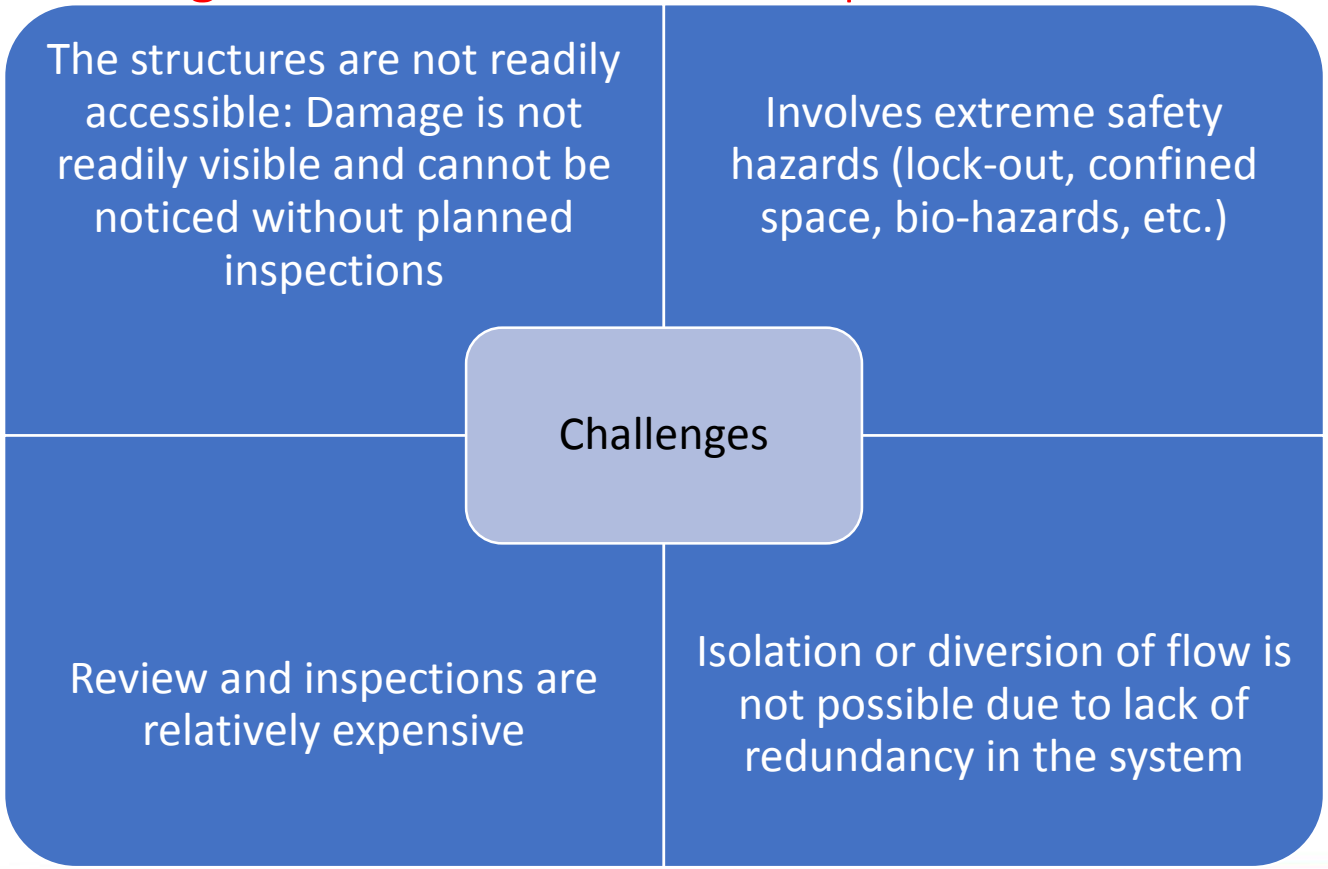
Terminology

- ACI Concrete Terminology (ACI CT-18)

bacterial corrosion — destruction of a material by bacterial processes brought about by the activity of certain bacteria that consume the material and produce substances, such as hydrogen sulfide, ammonia, and sulfuric acid.

- **MIC**: Microbially Induced Corrosion . It may be confused with MIC in metals.
- **MICC**: Microbially Induced Corrosion of Concrete
- **MID**: Microbially Induced Deterioration
- **MAC**: Microbial Attack of Concrete

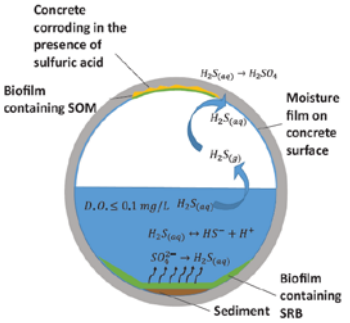
Challenges in Assessment and Repairs

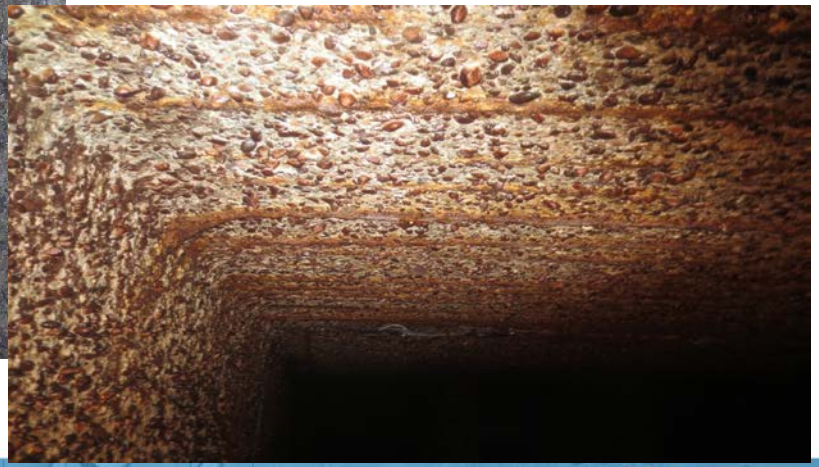


- Where it occurs in WWTPs?

Source: Google Photos

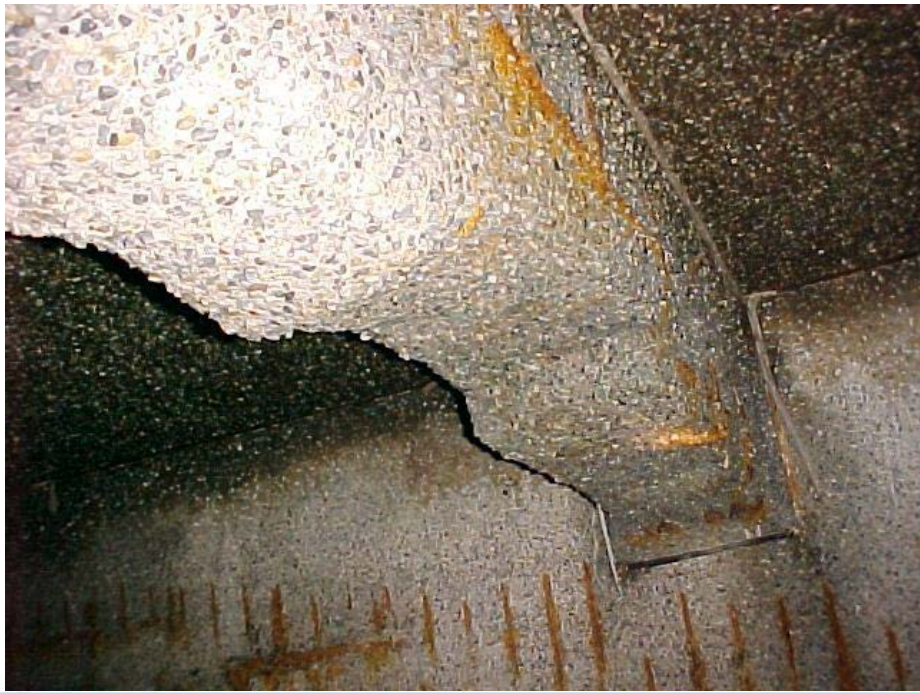
Vapour Zone above Effluent Level






0.00 m
23/07/2013 02:17:48


0.00 m
23/07/2013 02:17:34

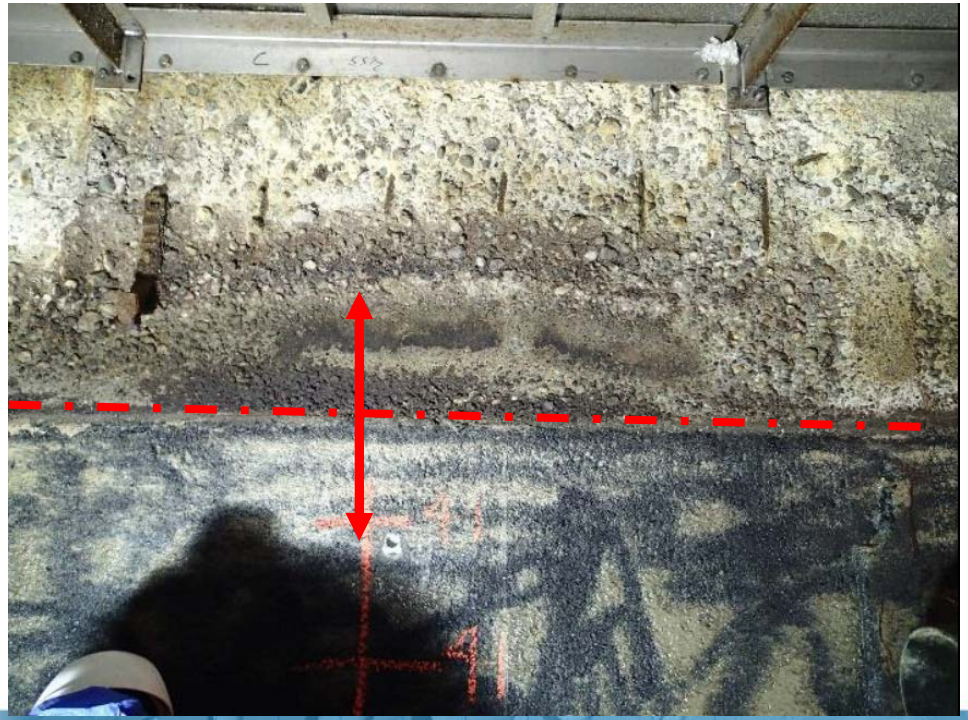


Credit: N. Cumming, C. Easton, Repair and Restoration of an Oxygen Activated Sludge Reactor, Unox Conference

Credit: Daryl Prefontaine : Repair & Protection of Wastewater Infrastructure: Gold Bar Influent Channel No. 2, Concrete Repair Bulleting, 2016, ICRI

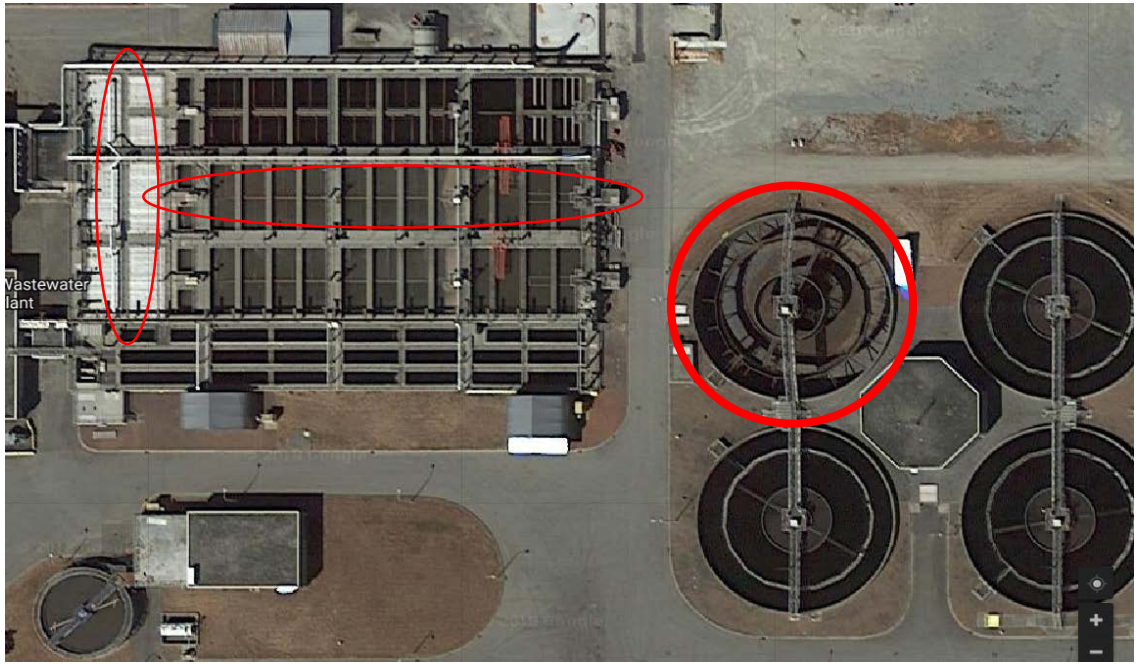
Concrete above/below effluent line

Concrete above/below effluent line



Not a Significant Issue below Effluent Level

Enclosed vs. Open Spaces



Source: Google satellite photo


00/1/1 13:36

ICRI CONCRETE REPAIR

proofing
esthetics
d appealing to the eye

Rebar below Effluent Line

Assessment

Visual Review

- Visual
- CCTV, Robot, etc.

Destructive Testing

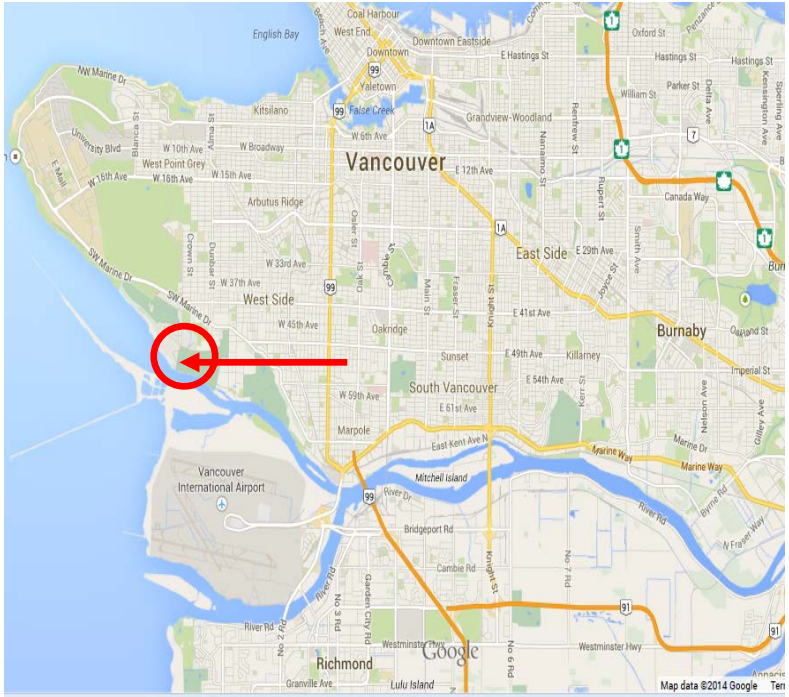
- Coring (strength, depth of deterioration, etc.)
- Chipping (rebar condition, etc.)
- Powder Sampling (pH)

NDT

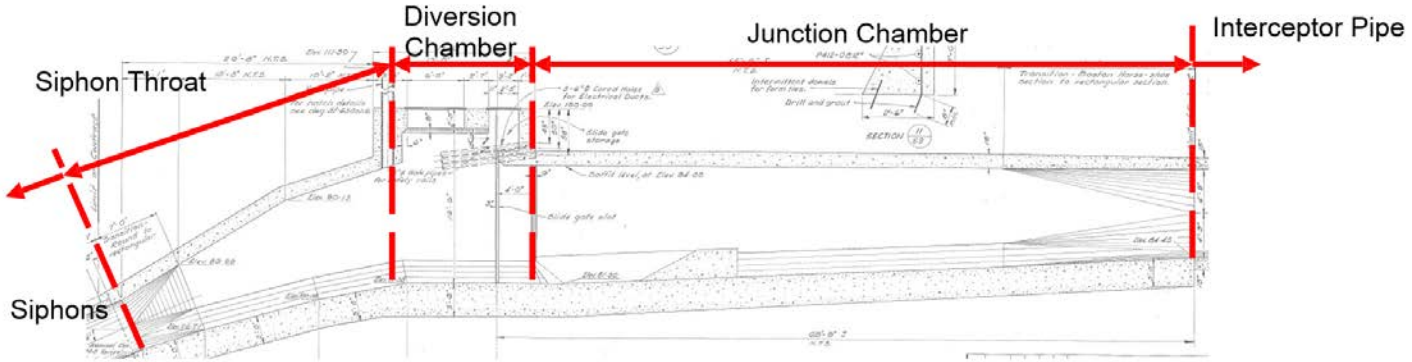
- GPR/Pachometer
- Impact-echo
- Delamination Survey
- Acoustic Emission
- etc…

Case Study
Highbury Interceptor Condition Assessment Using Non-Destructive Test Methods

Site Location



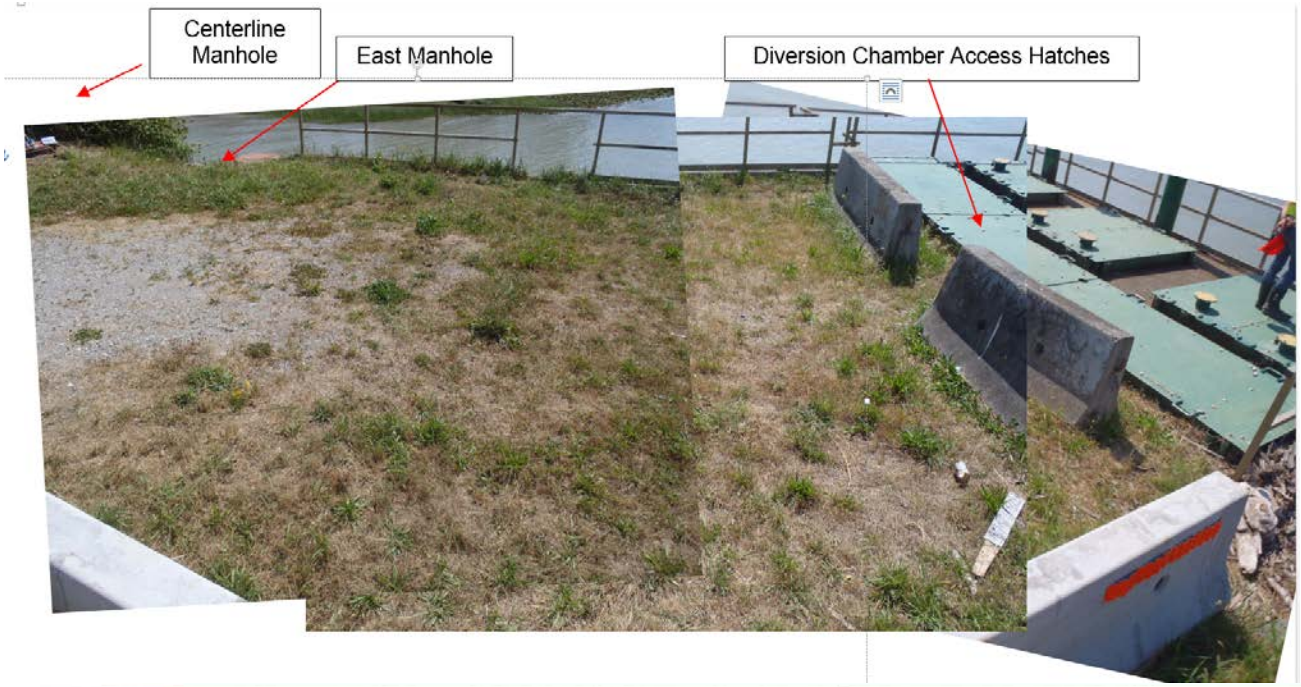
Cross-Section of Chambers

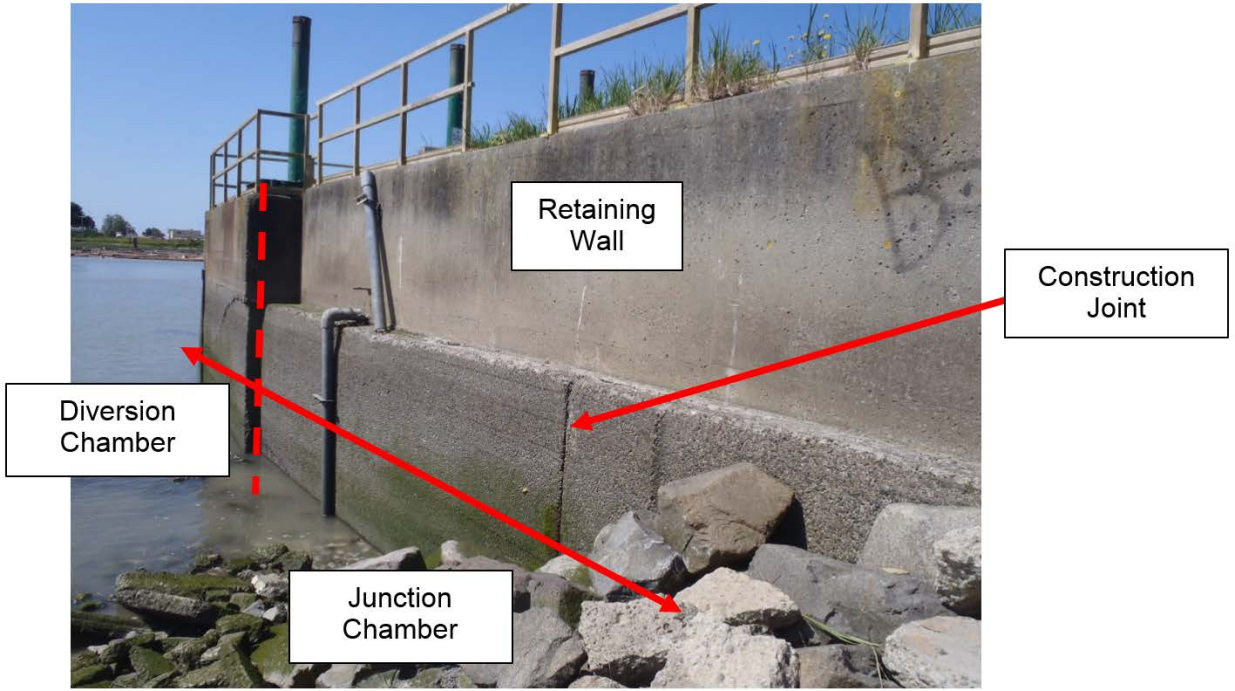


Overview

- The chambers convey an average daily flow of 471 million litres of untreated effluent to the Iona Waste Water Treatment Plant.
- Junction and diversion chambers were constructed circa 1962.
- Isolation of chambers upstream of the diversion chamber is not possible due to a lack of redundancy in the system.
- During siphon coating restoration work, Metro Vancouver personnel were able to visually observe deteriorated concrete within the junction and diversion chambers.

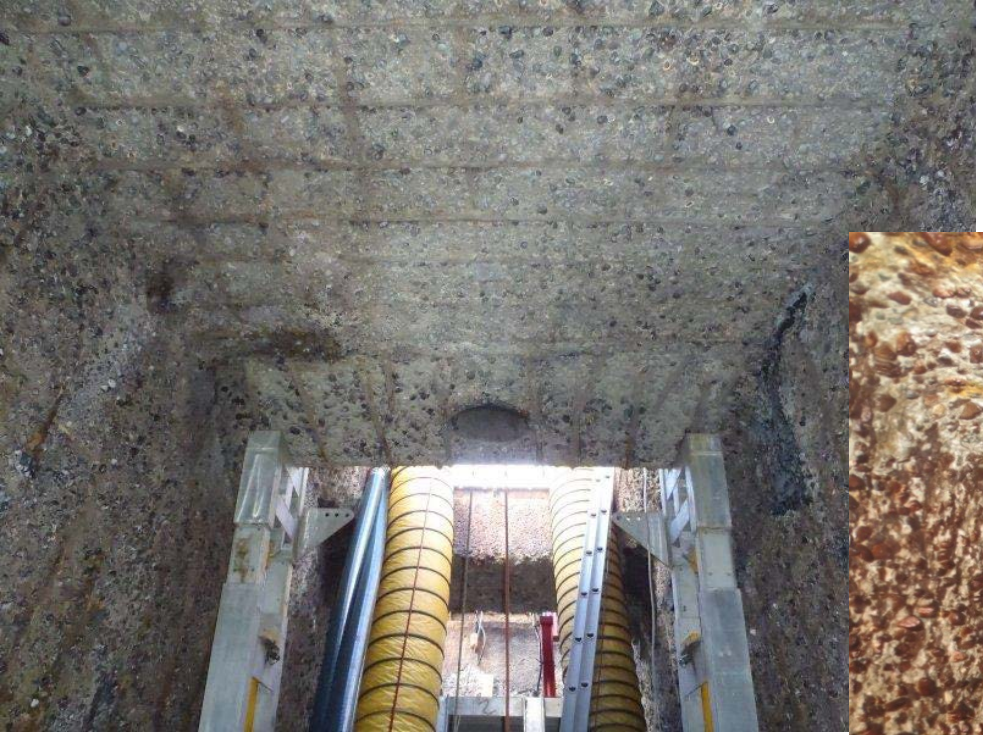
Top Surface


Centerline Manhole
East Manhole
Diversion Chamber Access Hatches


Retaining Wall
Construction Joint
Diversion Chamber
Junction Chamber


Diversion Chamber
Siphon throat


West
Construction Joint
East



- Due to safety concerns, there is no possible means of entry into the chambers to facilitate condition assessment.
- A non-destructive approach was favoured as it would provide considerably more information over a larger and more representative area and could be completed in a short period of time.
- In particular, the assessment was to include evaluation of the thickness of sound concrete and the remaining cover to steel reinforcement.

Condition Assessment Methodology

Interior

- CCTV Camera
- Still Photography
- 3D Laser Profiling

Exposed Surface

- Impact-echo (IE)
- Ground-Penetrating Radar (GPR)
- Level Survey

Assessment Methods from Interior of the Structure

CCTV Video

- A CCTV camera was lowered into the junction chamber through a manhole in the roof slab

CCTV Video

CCTV Video

CCTV Video

CCTV Video

- The images provided by the CCTV video footage show that loss of the cover concrete has occurred.
- A determination of the extent of the loss is not possible using the CCTV footage

- What is visible in the images is indecipherable and could either be:

  ✓ exposed rebar; or

  ✓ shadows cast on the soffit from a groove remaining in the concrete where the rebar was previously present.

Still Photography

- A SLR camera was lowered into the head space within the chamber using the same manhole used for the CCTV video footage.

- A high powered flash was used to illuminate the chamber

Still Photography

Still Photography

Still Photography

- Concrete beneath the average effluent level appears to remain in sound and serviceable condition.

Coring

- Four locations in the roof slab and at one location of the west sidewall

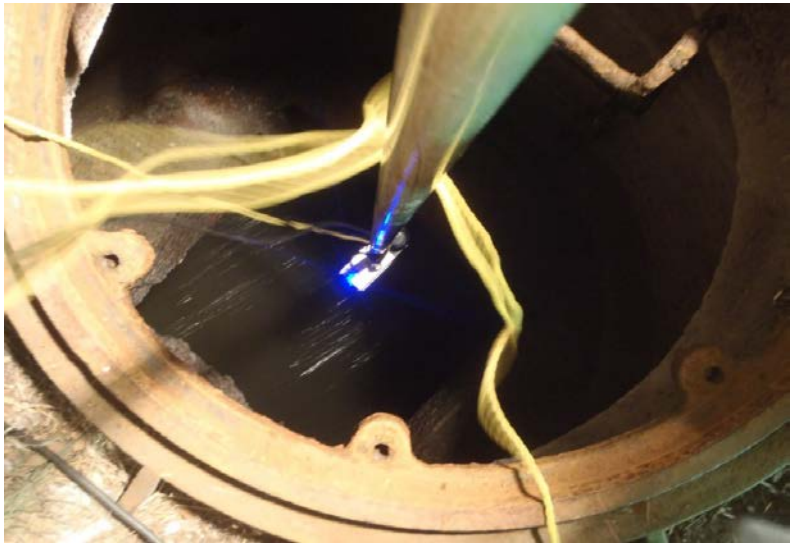
Coring

- Rebar was found to be unbonded to the concrete at core locations

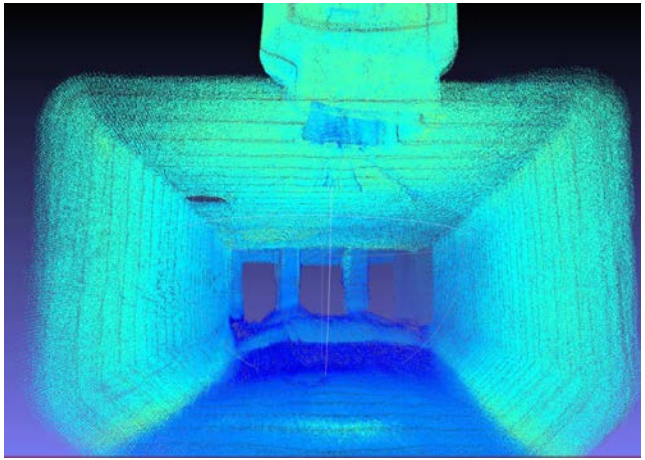
Three-Dimensional Laser Profiling

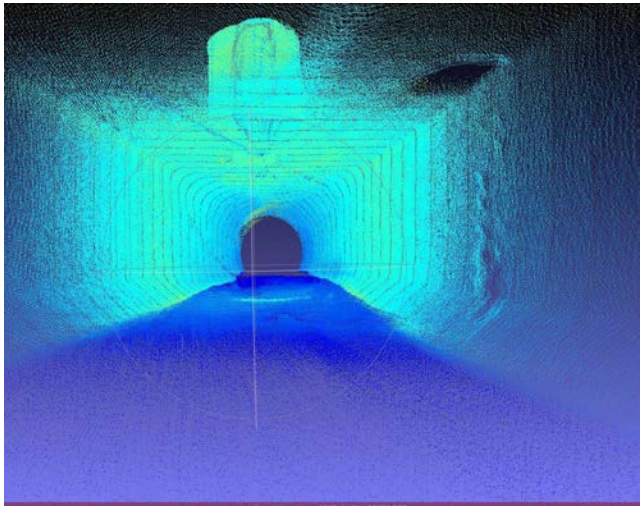
- Non-contact measuring system used for rapidly profiling the interior surfaces of pipes

- It was hoped that the measured intensity of the reflected laser light would be able to map out areas where rebar is exposed due to a loss of concrete cover.



Three-Dimensional Laser Profiling





Three-Dimensional Laser Profiling

- It was not possible to identify exposed rebar in the image rendered from the 3D laser profile.

Assessment Methods from Exterior of the Structure

Level Survey

- Top surface of the roof slab of the junction chamber was uneven

- Reconciliation of the top surface to a common benchmark was necessary to calculate the elevation of the slab soffit based on Impact Echo method.

Impact-Echo (IE)

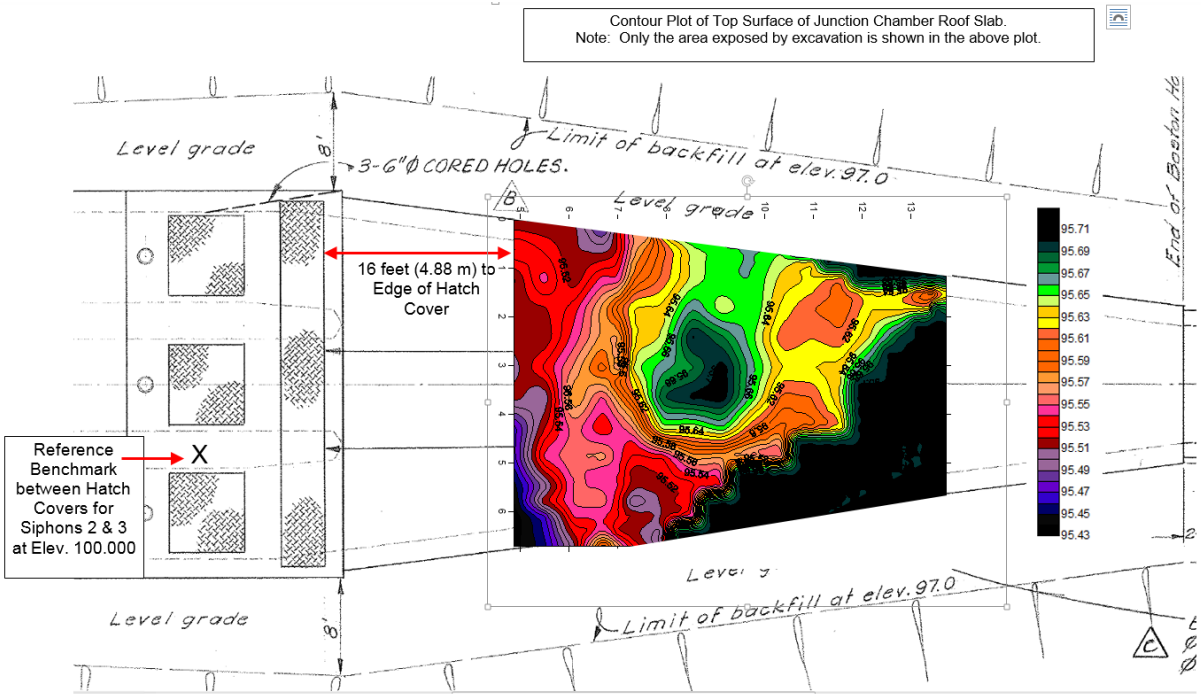
- Based on the use of impact-generated stress waves that propagate through concrete and are reflected by internal flaws and external surfaces.

Impact-Echo (IE)

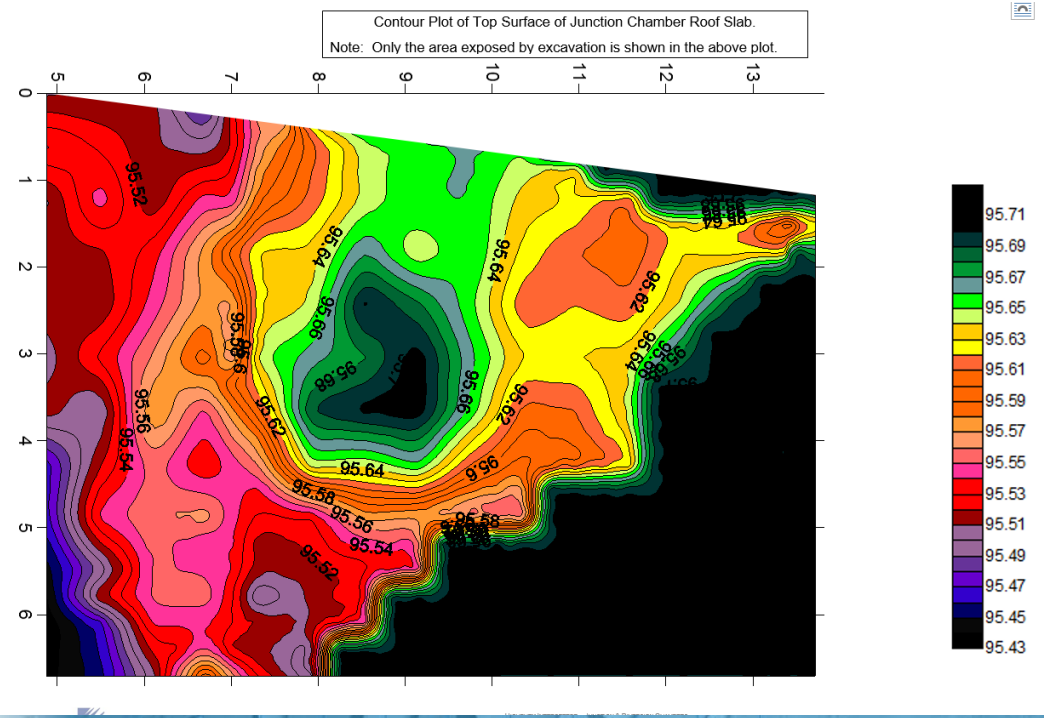
- Determine the location and extent of flaws such as cracks, delaminations, voids, honeycombing, and debonding in concrete structures.
- Thickness measurements of concrete (accuracy better than 3%).

- Wave speed calibrated at areas adjacent to core locations (i.e. area of known thickness).
- Gridlines were laid out on the top surface and the west side of the junction chamber; the lines were spaced at 600 mm intervals.

Impact-Echo (IE)



Impact-Echo (IE)

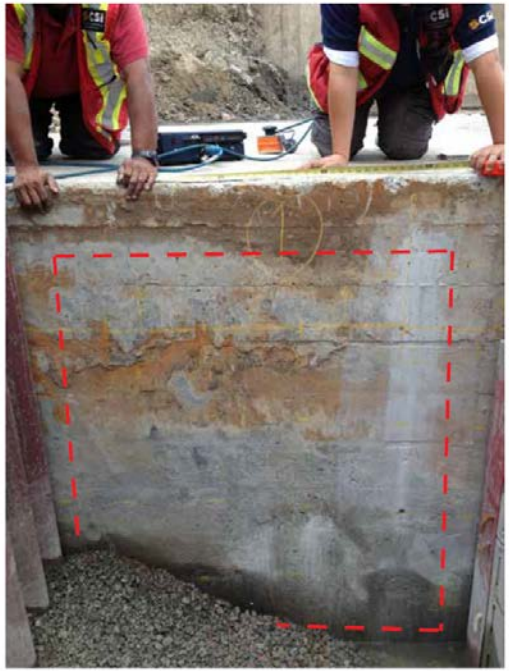


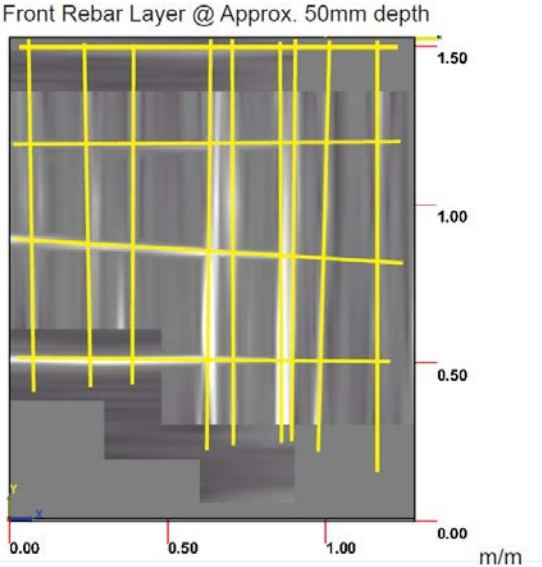
Ground Penetrating Radar (GPR)

- Used to locate embedments within concrete and determine approximate thickness of concrete elements

- Analogous to the stress-wave propagation methodology (IE method), except that electromagnetic waves are used instead of stress waves

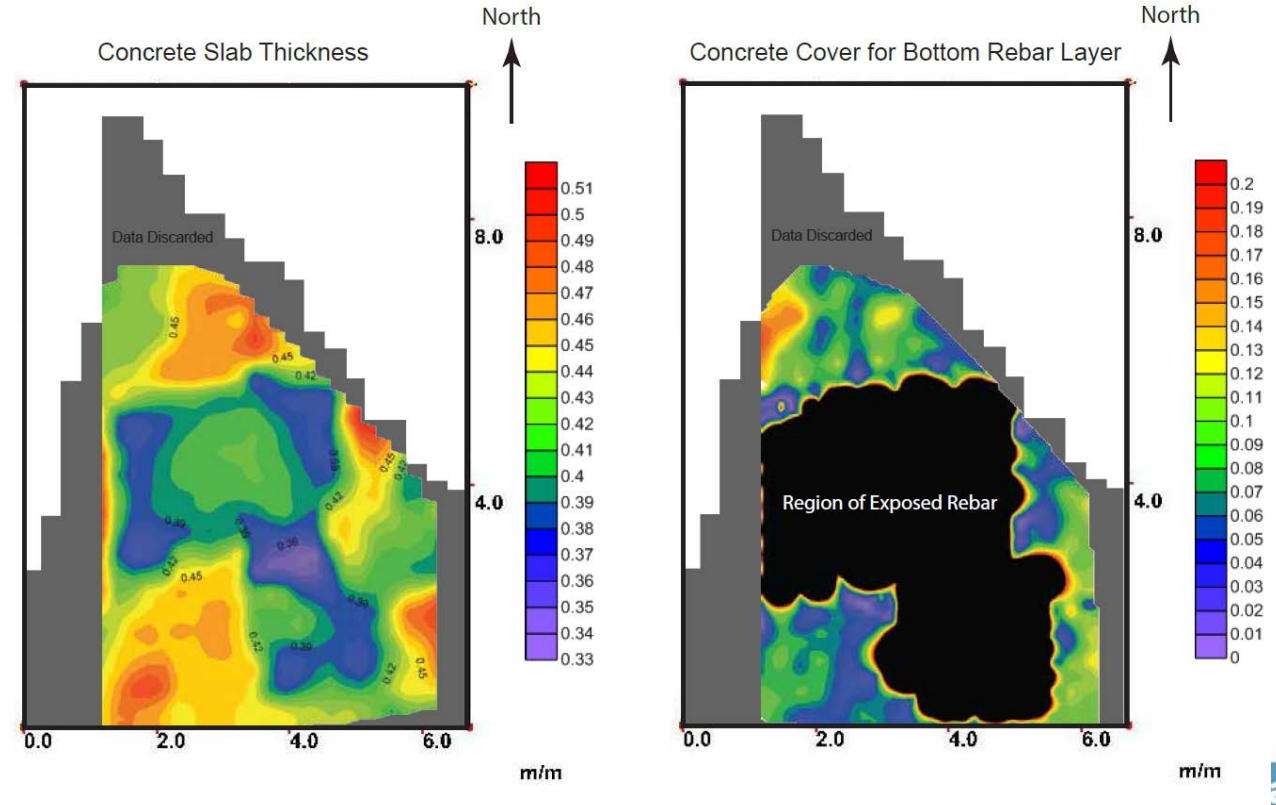
GPR Survey Results





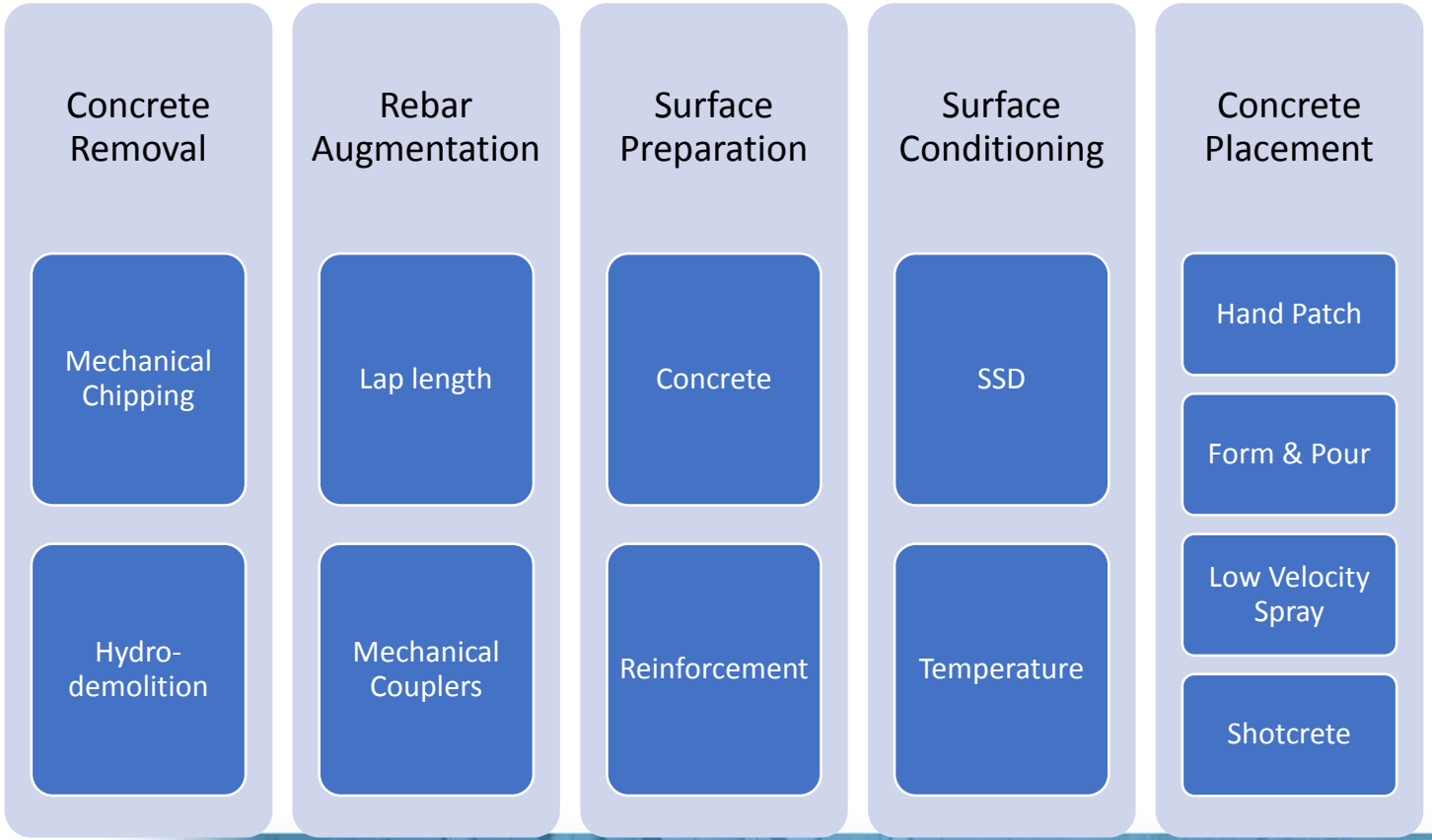
GPR Survey Results

GPR survey results



Units = meter

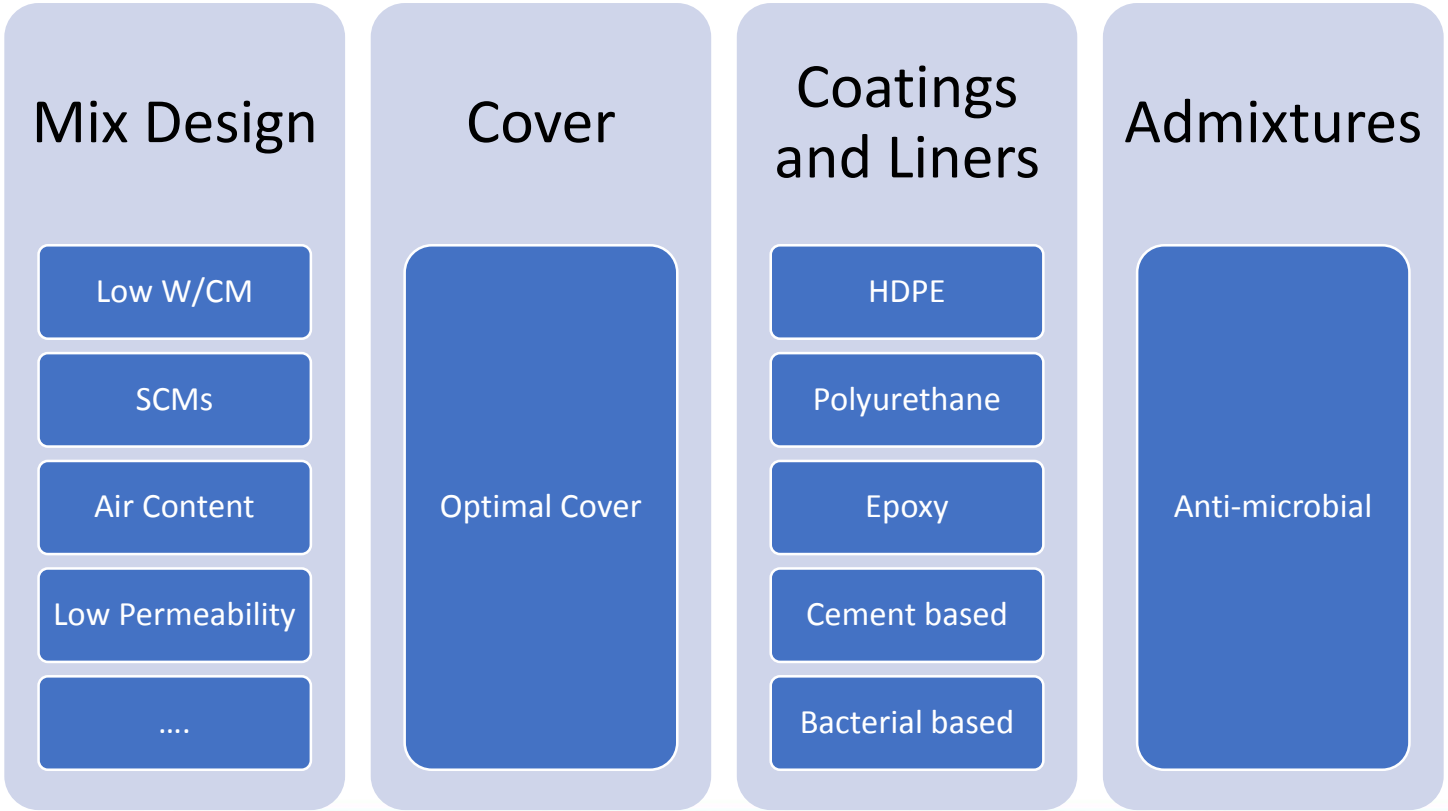
Rehabilitation

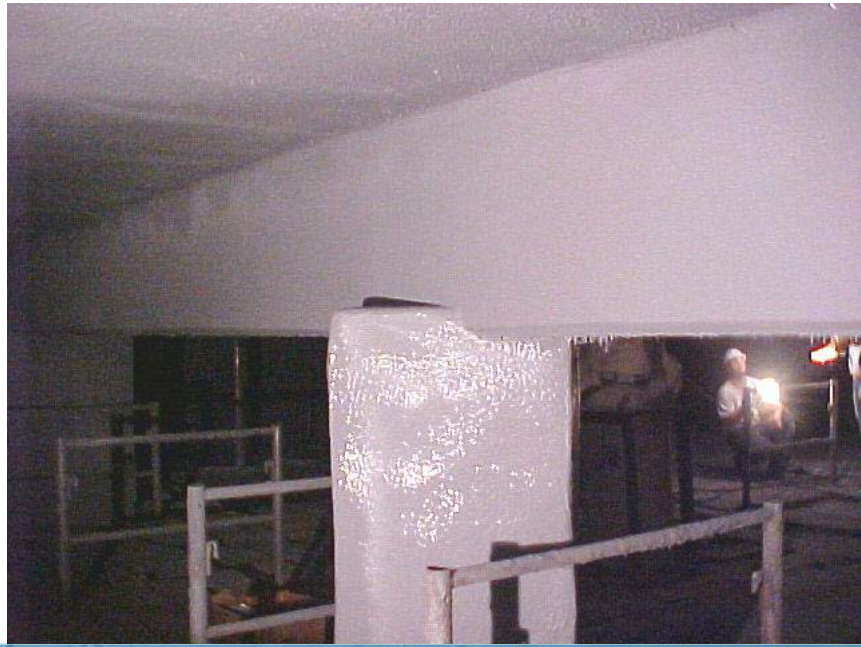


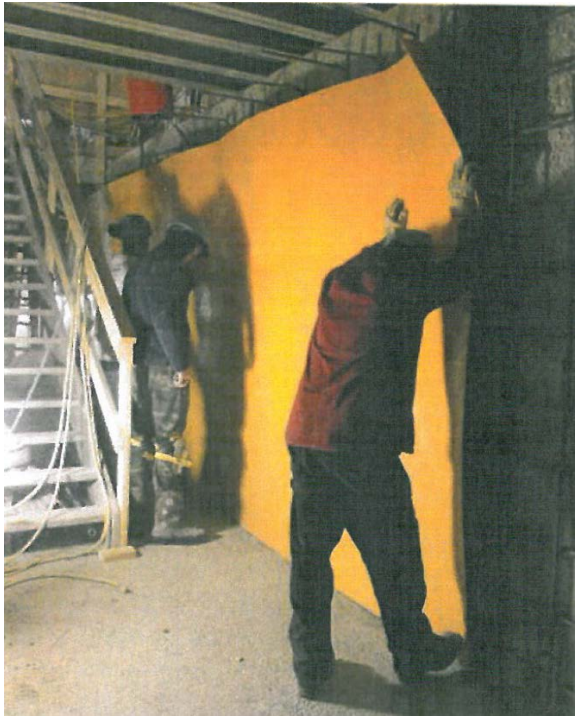
N. Cumming, C. Easton, Repair and Restoration of an Oxygen Activated Sludge Reactor, Unox Conference

Credit: N. Cumming, C. Easton, Repair and Restoration of an Oxygen Activated Sludge Reactor, Unox Conference

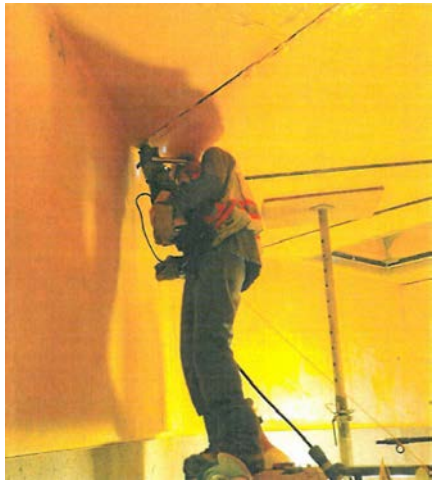
Protection


Mix Design
Low W/CM
SCMs
Air Content
Low Permeability
....
Cover
Optimal Cover
Coatings and Liners
HDPE
Polyurethane
Epoxy
Cement based
Bacterial based
Admixtures
Anti-microbial





Credit: Daryl Prefontaine : Repair & Protection of Wastewater Infrastructure: Gold Bar Influent Channel No. 2, Concrete Repair Bulleting, 2016, ICRI



Credit: Daryl Prefontaine : Repair & Protection of Wastewater Infrastructure: Gold Bar Influent Channel No. 2, Concrete Repair Bulleting, 2016, ICRI

Field Performance

SCM Makes a Difference!

Conclusions

- The attack is **NOT** everywhere (mostly at vapour zone)
- Need proper test methods representative of the field to verify the performance of concrete/admixtures/coatings
- Need redundancy in the design to facilitate in assessment and rehabilitation
- Where access is not possible, NDT (calibrated with visual review) can provide useful information about the extent of damage.

Meghdad Hoseini, Ph.D., P.Eng.

WSP Canada Inc.

Email: meghdad.hoseini@wsp.com

Vancouver, Canada