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ACCELERATED LOW WATER CORROSION

A Problem for Reinforced Concrete?

PIANC APAC 2024

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ALWC

What it is:

- rapid and aggressive (> 1 mm/year section loss)
- localised → large pits & perforations
- microbially-influenced
- at or below low-water level
- often associated with bright orange corrosion tubercules

Image from J. Breakall, Port Technology, Vol. 32

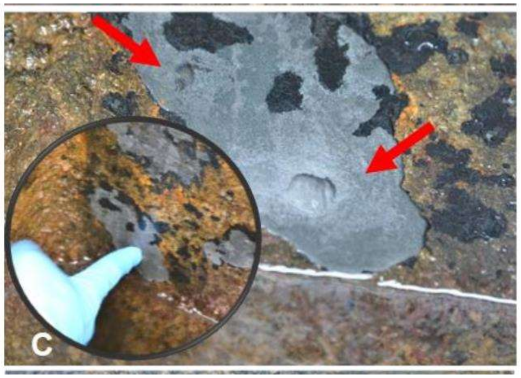


Image from H.C. Phan, Applied and Environmental Microbiology, Vol. 86.

Image from B. Kopczynski, Port Technology Int, December 2010

THE PROBLEM

- Seawater-filled tunnels, made of reinforced concrete
- >40 years old. Drained annually for investigation and maintenance works
- Similar tubercules to ALWC on steel piles and SPW at nearby wharves
- Concentrated in areas of high steel density and lower concrete cover
- Substantial localised reinforcement section losses (sometimes through a 28 mm bar).
- Concrete not necessarily "drummy"

AIM

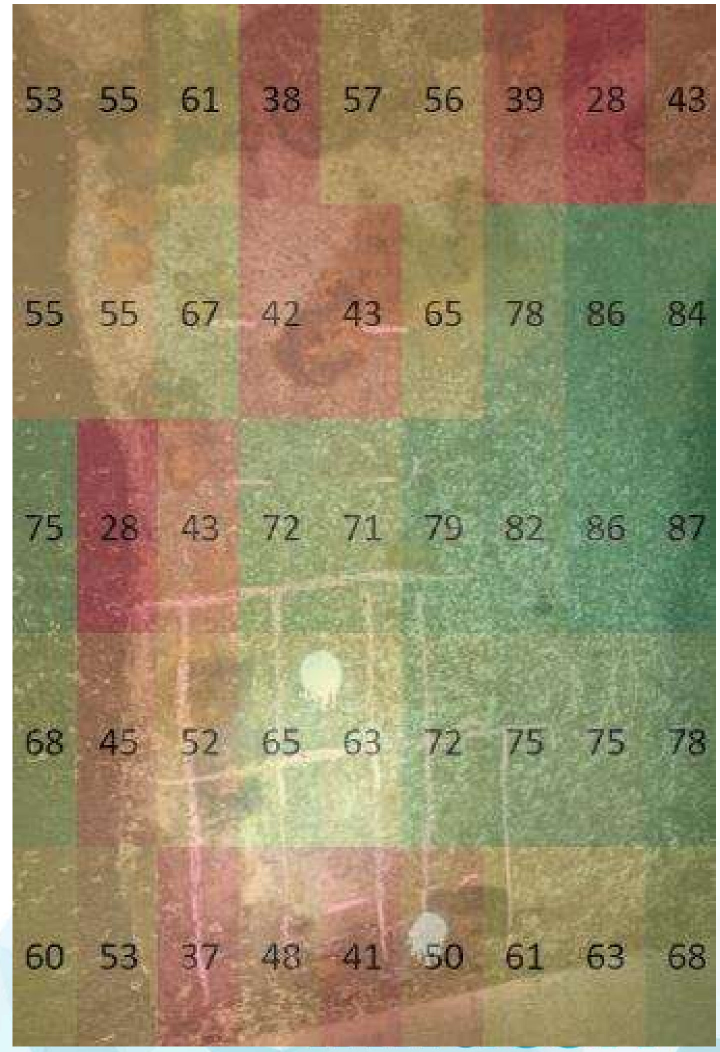
1. Preliminary study to confirm if tubercules on concrete were associated with microbial reinforcement corrosion.

2. Investigate mechanism of corrosion cell formation to help inform remedial strategies.

RESULTS - CONSTRUCTION

Different concrete cover?

- Evaluated with ground-penetrating radar
- Tunnel wall shown:
  - (left) following pressure cleaning, and
  - (right) overlayed with concrete cover to reinforcement depth map (stated in mm)



RESULTS – MIC BACTERIA

- Evaluate with Biological Activity Reaction Test (BART)
- Test for iron-related bacteria (IRB), sulphate-reducing bacteria (SRB), acid-producing bacteria (APB) and slime forming bacteria;
- Compare results for source water and process water with results for water + tubercule material

Findings:

- Far more slime forming bacteria present in tubercule than in source or process water alone
- Stronger response to SRB and IRB in most tubercules than source water or process water

➢ Results indicate that SRB growth is supported by the bacterial community within the tubercules

➢ Likely slime forming bacteria is supporting MIC related bacteria

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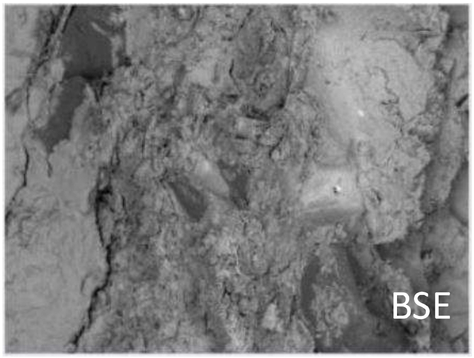
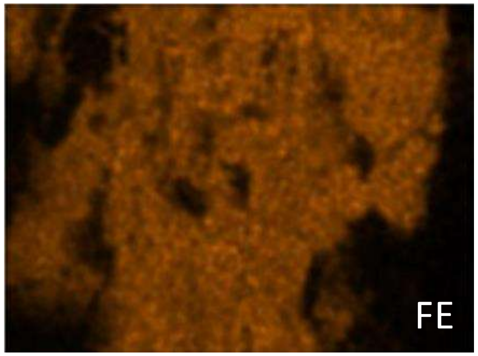
RESULTS – ELEMENTAL DISTRIBUTION

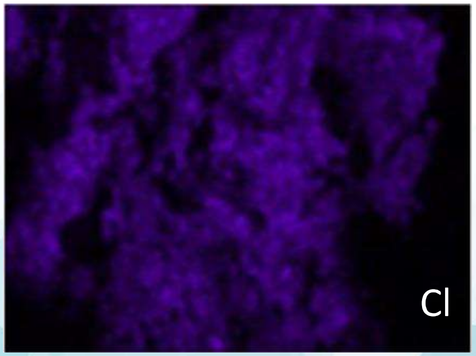
- Characterisation using SEM/EDS
- Examine concrete and corrosion products/tubercules for distribution of Fe, Cl, S, Mg, Si etc



- Confirmed tubercules were composed of corrosion products
- Chloride levels elevated at reinforcement
- No evidence of Fe ion diffusion between reinforcement and tubercule



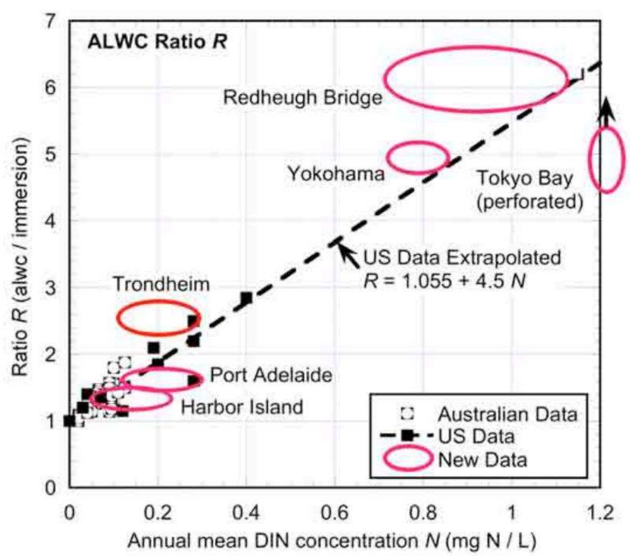
➢ Points towards possible diffusion via cracks and defects



REMEDIAL STRATEGIES FOR ALWC

General approaches – may use more than one.

(1) Reduce the nutrients in the water to decrease bacterial growth (stopping run-off and pollution is a good thing to do, but not generally something that an asset owner controls)



Correlation between dissolved inorganic nitrogen in water and contribution from ALWC

Plot from Melchers, Eurocorr 2014, paper 7199

(2) Barriers

- e.g., jackets, coatings, FRP sheet-pile wall "wraps"

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(3) Cathodic Protection

- Protection criteria in standards do not necessarily apply in the presence of ALWC. Need greater polarisation and target -900 $mV_{Ag/AgCl}$ and not -800 mV *(ISO 15589-1)*
- Effectiveness of CP to mitigate ALWC may depend on bacteria present. SRB may require potentials as negative as -1032mV vs Ag/AgCl *(Little, Corrosion, 1993)*
- New construction, Hunter River. Within 12 months, 50-70% of piles had orange corrosion blooms and 1 to 2mm pitting (*Kreher, Corrosion and Prevention, 2015*)

(Photo by Pacific P/L. Report 187/09 for Aurecon Hatch)

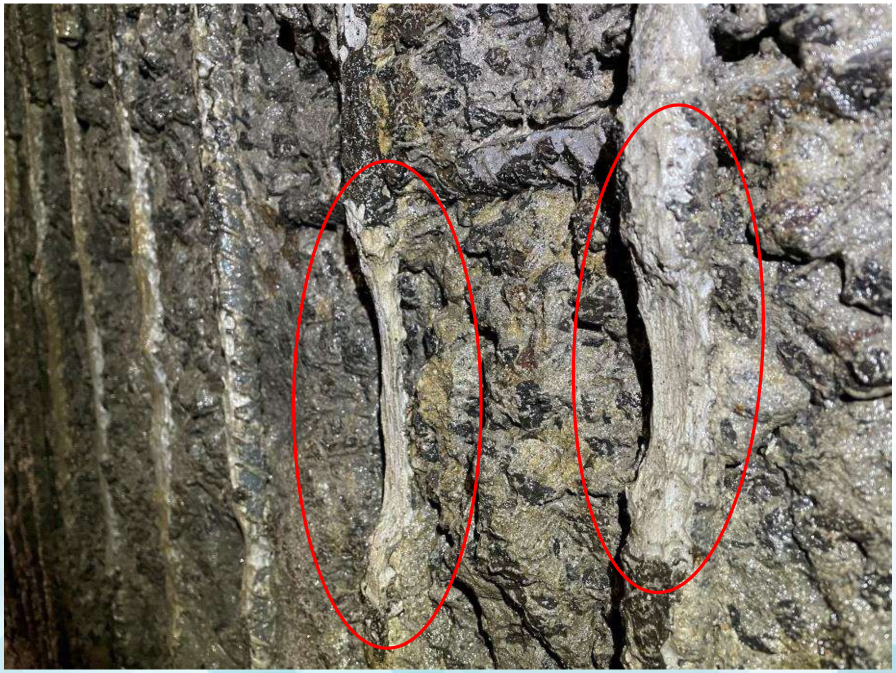
Figure 2

Figure 3

- Sacrificial CP required during construction prior to ICCP system installation .
- CP was effective "…indicating that polarisation levels greater -1000mV vs Ag/AgCl are sufficient to achieve protection under the very aggressive ALWC conditions in the Hunter River mouth area"

FINDINGS AND NEXT STEPS

- Corrosion products in tubercule originate at rebar, despite 3 to 11 cm cover
- Tubercules do not penetrate to reinforcement > Fe transport is occurring
- Black friable oxides with little expansion at rebar > reinforcement corrosion is largely anaerobic
- Tubercules can help locate areas with likely major section loss – focus maintenance works on those areas.



Next steps:

- Assess reinforcement loss in areas of high suspected MIC/ALWC activity
- Feed into residual capacity assessment
- CP trial followed by regular tubercule mapping
- Crack mapping in area of tubercules

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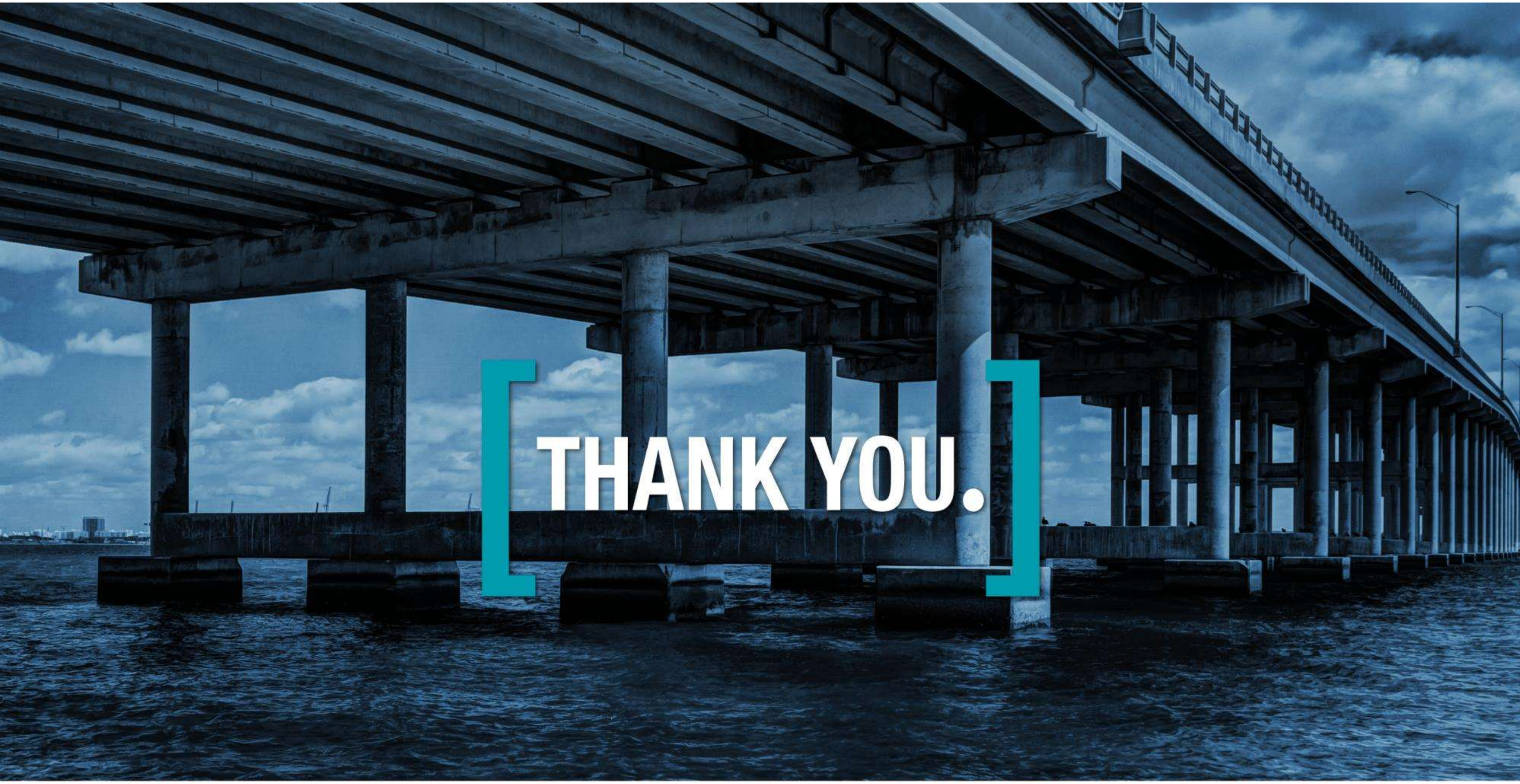
- Our Client.



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