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& Materials

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FLOWING FORWARD: INNOVATION & SUSTAINABILITY IN WATER & WASTEWATER INFRASTRUCTURE

THE AUSTRALASIAN CORROSION ASSOCIATION INC.

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Dear ACA Members,

I was pleased to provide a good report to our AGM on our 2024 results. The ACA Board and Team have been working hard to put the ACA's operations back on a sustainable financial footing. Although we had some technical difficulties connecting everyone at the AGM, overall, we had some positive news to provide. The key financial outcome was as follows:

- In 2024 we delivered a **$323k surplus** (although $243k of this surplus was from one-off events we still reported an $80k underlying operational surplus).
- Compared to the 2023 operational outcome ($113k loss), this is an **improvement of $436k** (or **$193k** excluding extraordinary one-off items).

At the AGM our Board Director and Finance and Risk Management Committee Chair, Dr Alexandra Sidorenko, resigned from her role for personal reasons. I want to take this opportunity to thank Alexandra for her work ethic and diligent in-depth analysis of exchange rates, contract payments, policy updates, and financial budgeting and reporting. Attention to these matters has been instrumental in ensuring an improvement in ACA's current financial position. The Board wishes her well in her future endeavors.

I am now looking at filling a casual Board Director role before a new Director is voted in at the next election in November.

Other news includes reappointing our two Independent Directors, Madeline Laurenson (Chair of the Education & Training Committee) and James Cherry (Chair of our Governance Committee), who have both been reappointed by the Board for a further two years.

Finally, the Project for Alignment of Governance with Structure (PAGS) is moving along well. We have had confirmation that the ACA Council supports our direction, and we have now received a new draft constitution that we are consulting with the Council and will be made available to all members very soon.

I am hoping that ACA Members will be able to consider and vote for our new Constitution at our November conference in Melbourne if all goes well. If you need more information about PAGS check out our FAQ's on the website here: PAGS (Project to Align Governance to Structure) - The Australasian Corrosion Association Inc.

I look forward to discussing this further with all ACA members soon.

Kingsley Brown

ACA Board Chair

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Greetings Fellow Corrosionists,

We are well halfway through an eventful year.

Firstly, Kingsley Brown, Maree Tetlow and I, attended the AMPP Annual Conference and Expo that was held in Nashville, Tennessee. For those of you who have not attended one of these events, it was an overwhelming experience with over 370 exhibitors, 300 presentations and 6000 attendees over four days. This included the Sunday (prior to the conference) with the three of us attending a number of sessions discussing collaboration between the ACA, AMPP and other sister corrosion associations, such as EuroCorr and UK's ICorr. Overall, it was a busy and exciting week, coming up to speed with the latest developments in our industry.

Further to the above, May saw the successful conclusion of the Australian leg of the Applicators and Coatings Roadshow that were run in Sydney and Perth. Both of which were well attended, with over 65 attendees in each location. A mixture of technical presentations and live equipment demonstrations were well received. At the time of writing, the New Zealand leg should have been held, in Auckland and Christchurch, which I am looking forward to attend.

In other news, your Council has been working closely with the ACA Board and Centre, in reviewing our Constitution that we are aiming to ratify at our upcoming conference in November.

Finally, I am happy to report that we have a Junior Vice President! Aaron Skeates-Udy from Sydney, NSW Branch has taken up the challenge and is on his journey to lead our Association in due course. Please join me in thanking Aaron for his commitment!

Raed El Sarraf

ACA President.

Dear ACA Members

We have lots of activities and improvements underway at the ACA.

Since we were advised earlier this year that we must vacate our premises at the Polytechnic at Preston by the end of the year, Adrian Ruggiero has been busy investigating alternative premises. We are close to securing premises not too far from our current Preston location, however we won't have the training facilities, and we will need to make alternative arrangements for Melbourne-based training plans.

Our plans for the Corrosion & Prevention Conference at the Marvel Stadium in Melbourne are going very well. We have secured all our exhibitors and there are only a few sponsorship opportunities remaining. We also have around 100 great quality papers that are currently being peer reviewed. It looks like we will need four tracks of technical content on offer this year compared to the usual three streams. We do appreciate this makes it harder for conference delegates to make a choice, but it also means you will have a wonderful array of presentations on offer!

We also have some great social and networking options for you – more about that will be announced soon.

In addition to these developments, we are also using new purpose-built conference software for this year's conference to make it easier for you to connect and enjoy your conference experience. Please register for the conference at: Corrosion & Prevention 2025

I also wanted to thank all our members that responded to the Member Survey in April this year. Based on the feedback you provided we are improving the following:

- Communications about how to access the ACA Portal
- Tailoring our emails more to your Branch
- Investing more in branch events
- Investigating new member benefits
- Planning communications for our new Certification Scheme (and our grandfathered certified practitioners)
- Supporting our New Zealand members with more events.

Thank you once again for your feedback as it helps the ACA team prioritise the work we need to do.

If you have any feedback, get in touch at maree.tetlow@corrosion.com.au

All the best

Maree Tetlow

ACA CEO

From Risk to Resilience: Risk Assessment and Repair in Corrosion Management

By Masoud Mike Dehghan –
Operations Director of Mechanical Integrity Engineering Services, Perth.

Introduction

Corrosion management is a dynamic, multi-layered strategy centered on prevention, early detection, and long-term resilience. In previous articles, we've explored the foundational pillars of a robust corrosion program: policy and leadership, data-driven inspections, and strategic planning. This article focuses on two critical elements that translate information into actionable strategies: Risk Assessment and Mitigation & Repair.

While inspections reveal current conditions, risk assessments prioritize where to focus attention and resources. Once risks are identified, implementing appropriate mitigation or repair strategies is essential to prevent costly downtime, safety incidents, or catastrophic failures. Together, these elements form the operational core of an effective corrosion integrity framework.

Risk Assessment – Prioritizing What Matters Most

Risk assessment in corrosion management involves evaluating the likelihood and consequences of degradation across critical assets. It informs decisions regarding inspection frequency, monitoring techniques, material upgrades, and more.

Core Components of a Corrosion Risk Assessment Framework:

- **Identification of Damage Mechanisms:** Each operating environment presents unique corrosion threats—pitting, chloride stress cracking, microbial corrosion, and more. Correctly identifying these mechanisms is the first step in quantifying risk.
- **Probability of Failure (POF):** Based on asset age, operating conditions (e.g., temperature, pressure, flow), historical data, and inspection findings, engineers estimate the likelihood of failure.
- **Consequence of Failure (COF):** Consequences are categorized by safety, environmental impact, operational disruption, and financial loss. For instance, a failure in a subsea pipeline carries a vastly different risk than corrosion in a handrail.
- **Risk Ranking and Mitigation Planning:** Utilizing risk matrices or Risk-Based Inspection (RBI) software (e.g., API 580/581-compliant tools), assets are ranked by criticality, allowing for prioritization of mitigation actions and resource allocation.

Case Study 1: Internal Corrosion Risk in Crude Pipeline-D

A 2023 risk assessment conducted on Pipeline-D, a 26-year-old crude oil pipeline, revealed accelerated internal corrosion rates near low-flow segments. The study leveraged operational data, flow simulations, and corrosion coupon analysis.

- **Findings:** Approximately 78% of high-risk zones were associated with low velocity and water dropout conditions—ideal for under-deposit corrosion.
- **Mitigation Strategy:** Corrosion inhibitors were optimized, slug cleaning was introduced, and several Condition Monitoring Locations (CMLs) were relocated based on risk zones.
- **Outcome:** The approach avoided over $7.5 million in potential repair and unplanned outage costs.

Reference: AMPP MECC 2023-19965, OnePetro (Source: https://onepetro.org/amppmecce/proceedings-abstract/MECC23/All-MECC23/AMPP-MECC-2023-19965/540245)

This case underscores the power of integrating data and environmental knowledge into a structured risk framework to guide decision-making.

Mitigation and Repair – Bridging Diagnosis and Action

Once risks are identified, the next challenge is effectively reducing them. Depending on severity, mitigation may involve condition monitoring, material upgrades, surface protection, or repairs.

Common Mitigation Techniques in Industry:

- **Protective Coatings:** Epoxy, polyurethane, and ceramic coatings form physical barriers against environmental exposure. Surface preparation is critical for long-term adhesion.
- **Cathodic Protection (CP):** Extensively used in buried and submerged structures, CP systems (sacrificial anodes or impressed current) reduce the electrochemical potential of metal surfaces.
- **Process Adjustments:** Controlling variables such as pH, flow velocity, and inhibitor injection rates can prevent localized corrosion, particularly in pipelines and vessels.
- **Material Substitution:** In extreme environments, upgrading from carbon steel to duplex stainless steel or using cladded components may be economically justified.

Repair Strategies:

- **Composite Wraps:** Non-intrusive, non-metallic systems that restore strength to corroded piping or tanks without halting operations. Widely used in oil & gas and water infrastructure.
- **Welded Section Replacement:** Necessary when corrosion exceeds repairable limits. Repairs must match the original material's mechanical and metallurgical properties.
- **Thermal Spray Coatings (e.g., HVTS):** Ideal for high-temperature or highly corrosive environments like amine units or flare systems.

Case Study 2: Amine Column Protection in a Gas Processing Plant

At a Middle Eastern gas plant, two carbon steel amine contactor columns suffered from recurring internal corrosion, especially near the vapor-liquid interface.

- **Problem:** Existing coatings failed after a few months due to acid gas-induced degradation and high internal temperatures.
- **Solution:** Engineers implemented High-Velocity Thermal Spray (HVTS) alloy cladding (Inconel 625 equivalent), applied in situ.
- **Results:** Five years post-installation, inspections revealed negligible metal loss and intact protective cladding. The plant avoided major shutdowns and asset replacement.

Reference: Gas Processing News, 2022 (Source: https://gasprocessingnews.com/articles/2024/04/the-science-behind-amine-column-corrosion-and-remedial-solutions/?utm_source=chatgpt.com)

This case highlights the role of engineered surface treatments as a long-term mitigation strategy in high-risk chemical processing systems.

Bringing It Together – A Lifecycle View

Risk assessment and mitigation are not one-time events. They are iterative, interconnected elements within a broader corrosion management cycle:

1. **Assess:** Understand degradation mechanisms and asset vulnerabilities.
2. **Mitigate:** Apply tailored, cost-effective solutions to reduce risk.
3. **Inspect and Reassess:** Monitor for effectiveness and emerging risks.
4. **Adapt:** Continuously refine strategies based on evolving data.

When executed systematically, these steps build resilience into industrial systems—extending operational life, reducing failures, and enhancing safety.

Conclusion

Risk assessment and mitigation are dynamic, interconnected processes that transform insight into action. By identifying vulnerabilities through structured risk evaluation and addressing them with targeted mitigation or repair strategies, organizations lay the groundwork for safer, more reliable, and cost-effective operations.

The case studies shared in this article illustrate how data-driven assessments and engineering-based interventions can prevent failures and extend asset life. Whether through predictive modelling or advanced surface protection technologies, the tools are available—but their success depends on strategic integration into everyday integrity practices.

In the next and final article of this series, we will explore the human and organizational elements that support long-term corrosion control—Training and Competency, Communication and Reporting, and Continuous Improvement. These components ensure that corrosion management becomes a sustained, evolving discipline embedded within an organization's culture and operational rhythm.

AS/NZS 4020: Testing of Products for Use in Contact with Drinking Water

Michael Glasson

AS/NZS 4020 – 'Testing of products for use in contact with drinking water' was developed to assess the suitability of materials used in contact with drinking water. Water Authorities strive to maintain drinking water at a high standard for customers and cannot afford to introduce into their supplies, products that may jeopardise water quality.

Consequently, there is a need to ensure products that come into contact with drinking water do not introduce substances that will cause a deterioration in quality. A wide range of products are tested to the Standard including valves, pipes, coatings and end-of-line fittings which includes tapware.

The Standard requires that products do not affect the taste or appearance of water; do not support the growth of microorganisms; and do not release cytotoxic compounds, organic compounds of concern, mutagenic compounds or metals. The tests required are specific to the type of product submitted.

The products are assessed by exposure to test waters. The exposed surface areas to volume test requirements are detailed in the Standard. After the product has been exposed to test water, a sample of the test water extract is analysed in accordance with the specifications in each Appendix of the Standard. Scaling factors or dilution factors may be applied depending on the end use of the product. There may also be a requirement for hot water tests for products that are used at high temperature including water-heating systems.

The following points provide a brief description of the Appendices that relate to the test methods associated with AS/NZS 4020:

Taste

Trained panellist's taste water extracts to determine whether products leach compounds that impart a discernible taste.

Appearance

Water extracts are analysed for an increase in colour and turbidity.

Growth of aquatic microorganisms

The test is performed by immersion exposure with products examined for the ability to support bacterial growth by monitoring dissolved oxygen levels in water extracts.

Cytotoxic activity

Water extracts are tested for cytotoxicity using mammalian cell lines. An adverse effect on the health of the cells is recorded as a cytotoxic effect.

Mutagenic activity

The Ames test is a reverse mutation assay. The test is used to determine whether elastomeric products, or products containing elastomeric components, release mutagenic compounds into water extracts. The water extracts are mixed with specific bacteria. Any change in the genetic nature of the bacteria is regarded as evidence of mutagenic activity.

Metals

Water extracts are examined for the release of Aluminium, Arsenic, Antimony, Barium, Boron, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium and Silver. The limits are in-line with the Australian Drinking Water Guidelines.

Organic Compounds

Water extracts are analysed for organic compounds using USEPA methods. The limits are in line with the Australian Drinking Water Guidelines.

In the past 25 years the Australian Water Quality Centre (AWQC) "a business unit of SA Water, has tested over 5000 products in accordance with the Standard. Listed in Table 1 are examples of products tested to the Standard and the respective materials used.

TABLE 1:
PRODUCTS AND MATERIALS TESTED TO AS/NZS 4020

Product	**Materials**
Pipes/Tubes	Polybutylene, Polyethylene, Polypropylene, PEX, Copper, Stainless Steel, Cement
O-rings	EPDM, Nitrile, Natural Rubber, Silicone, NBR
Gaskets	EPDM, Nitrile, Natural Rubber, Silicone
Water Connectors	Polypropylene, HDPE, Brass
Filter Housings	Polycarbonate, Acetal Copolymer, Polypropylene
Sink Mixer Components	Brass, EPDM, Nitrile, Natural Rubber, Acetal
Olives	Acetal, Brass
Flexible Hoses	EPDM, Soft PEX
Hoses (dishwasher)	Plastic PVC
Jumper Valves	EPDM, Nitrile, Natural Rubber, Acetal

The current edition of the Standard (AS/NZS 4020:2018 Amd 1:2022) includes test water requirements for the organic compound test to reflect the use of elastomeric materials in chlorinated reticulated systems.

The importance of the Standard will be highlighted with the testing of alloys, as there is a national mandate to approve only lead-free brass by the end of 2025.

It should be noted that similar products that are manufactured using different processes may have different performance characteristics affecting the ability of the product to leach compounds into drinking water.

The challenge for manufacturers is to produce commercially viable products that will not leach harmful compounds into drinking water, or compounds that alter drinking water making it aesthetically undesirable. Testing to AS/NZS 4020 provides an important step in assuring the suitability of products for use with drinking water.

For more information please contact: Australian Water Quality Centre Tel: 1300 883 171

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https://youtu.be/Na46iQ1X3pI

Corrosion of a Thermally Sprayed Aluminium Coating in Geothermal and Marine Environments

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Keywords:

atmospheric corrosion; aluminium; thermally sprayed coating; marine; geothermal

Abstract:

Thermally sprayed aluminium coatings are widely used to protect steel structures exposed to aggressive environments. Even though they have been included in engineering practice guidance and standards, their long-term performance in New Zealand's unique and diverse built environment is not always clear. In this study, aluminium coatings were thermally applied onto carbon steel substrates and then exposed to geothermal and marine environments. After 5 years, no significant surface morphological changes were observed on the samples exposed at the geothermal sites. Meanwhile, the samples at the marine site had an obvious coating thickness reduction, due mainly to sand-blasting effects. Energy-dispersive X-ray spectroscopy elemental mapping revealed an inward diffusion of oxygen (and/or sulphur in geothermal environments), particularly after extended exposures. However, their presence in the coating did not significantly affect the overall structural integrity and corrosion performance.

1. INTRODUCTION

Metallic materials such as steel and aluminium are widely used for New Zealand buildings and their embodied infrastructure services that need to meet the minimum durability requirements of the performance-based New Zealand Building Code. This is always challenging since their corrosion is influenced by multiple factors and varies considerably across New Zealand's diverse and unique environments.

As an island country in the southwestern Pacific Ocean, New Zealand has more than 15,000 kilometres of coastline. Many buildings and infrastructure assets are located within 5 kilometres of the coastline – a relatively harsh environment with marine-sourced salt deposits that can accelerate metal corrosion. In the North Island, the Taupō Volcanic Zone (TVZ) runs northeast from Mount Ruapehu through Taupō and Rotorua areas and offshore into the Bay of Plenty. This zone features numerous geothermal fields and volcanic vents that can emit sulphur-containing gaseous species such as hydrogen sulphide (H2S) and sulphur dioxide (SO2).

Metallic materials and components in these environments need to be protected, and various types of coatings have been used to slow down corrosion and to extend their service lives. For example, aluminium-based coatings have been used to protect steels and their structures in industrial and marine environments.

Aluminium-based coatings can be applied onto steels through aluminising, hot dip galvanizing and high velocity oxy fuel, plasma and thermal spraying. Among these techniques, thermal spraying is economically and logistically feasible for coatings of greater than 50 μm thickness [1]. In a typical thermal spraying process, molten coating material particles are impacted onto the substrate surface at high velocities, solidify and build up a coating layer by layer, making a lamellar structure. The interfacial bonding between coating and substrate is primarily mechanical and, in some cases, metallurgical.

Thermally sprayed aluminium (TSA) coatings can provide resistance to corrosion, erosion and wear for steels in some environments. In open atmospheres, TSA coatings can reduce corrosion through a sacrificial protection and a barrier effect offered by the corrosion products [2–4]. TSA coatings can also provide long-term mitigation of corrosion in splash/tidal zones and even under seawater. Some studies found that TSA coatings with optimised microstructure and thickness could provide a service life longer than 30 years in splash zones [5–9].

These studies have provided important findings and data for use in academic and industrial fields. However, the long-term corrosion performance of TSA coatings in the New Zealand built environment is not always clear, particularly when exposed to environments with extraordinary aggressive media.

In this study, corrosion performance of an arc thermal spray aluminium coating was investigated through a 5-year field exposure in geothermal and marine environments typically found in New Zealand.

2. EXPERIMENTAL

2.1 Sample preparation

Aluminium coatings were applied onto abrasive-blasted carbon steel substrates by electric arc thermal metal spraying. Commercially available pure aluminium wire was used as the feeding material.

2.2 Field exposure

Atmospheric corrosion performance was investigated using a 5-year exposure at three sites.

The first site lies to the south of Sulphur Bay, Rotorua (a large population centre in the TVZ). Sulphur Bay has a large number of geothermal features – fumaroles, mudpools and steaming grounds. This site is known to have high emissions of H2S [10] and is denoted as a severe geothermal site in this study. The second site is within Rotorua Airport, which is approximately 6 kilometres northeast of Rotorua city. This site experiences medium concentrations of H2S [10] and is denoted as a light geothermal site. The third site is on the beachfront of Oteranga Bay, Wellington. It is approximately 60 metres from the breaking surf and can be exposed to extremely strong winds in some seasons. It is a typical sea spray zone with a very high risk of deposition of salt particles and very high mild steel corrosion rates [11]. This site is denoted as a severe marine site. The field exposure at these three sites was started in November 2018.

All TSA coating samples were fixed onto exposure racks specially designed and built with aluminium extrusions. They were oriented north at the light geothermal site and towards geothermal features and seawater at the severe geothermal and marine sites with an angle of 45°. Nylon fasteners and washers were used to fix samples.

Some uncoated carbon steel samples (150 × 100 × 3 mm, surface blasted to Sa2½ using garnet media) were also exposed for time-dependent atmospheric corrosion kinetics. Their chemical composition is given in Table 1.

Table 1. Chemical composition of carbon steel.

Material	Element (wt.%)							
Carbon steel	C	Al	Cr	Si	Mn	Mo	Ti	V
	0.08	0.039	0.02	0.02	0.60	<0.01	<0.005	0.01
	Ni	Cu	Nb	S	P	B	Fe	
	0.02	0.01	<0.0005	0.024	0.016	0.0006	Bal.	

2.3 Sample characterisation

TSA coating samples were retrieved for laboratory analysis after 2 years, 3 years and 5 years of exposure. Their surfaces were visually inspected for any corrosion-induced products or damage. Samples of ~15 × 15 mm were cut for characterisations using scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD). The XRD analysis was conducted on the sample surface using parallel beam and Co K-α radiation. Diffraction data were collected using a Rigaku SmartLab instrument from 20° to 90° (2ϑ).

To measure corrosion rates of carbon steel samples, corrosion products were cleaned thoroughly following the procedure recommended by ASTM G1–03(2017)e1 *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.*

3. RESULTS

3.1 Atmospheric corrosivity

The corrosion rates of carbon steel samples measured within this 5-year exposure are shown in Figure 1.

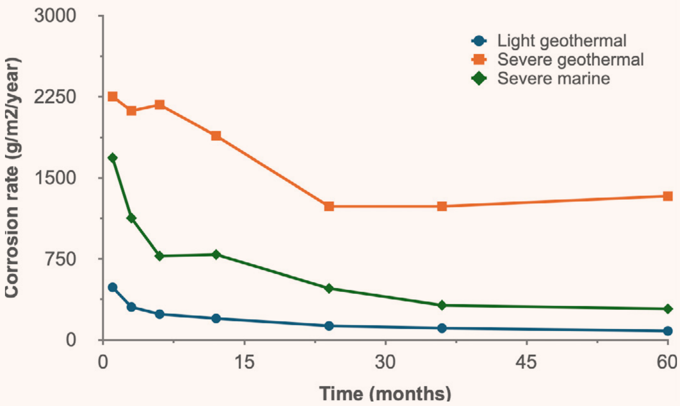

Figure 1. Corrosion rates of carbon steel measured at three exposure sites.

The corrosion rate decreases with exposure time at the light geothermal and severe marine sites. The corrosion kinetic of carbon steel shows a slightly different behaviour at the severe geothermal site. Its corrosion rate decreases sharply in the first 2 years, from 2251 to 1235 g/m^2/year, and then increases slowly.

Based on first-year corrosion rates, atmospheric corrosivity can be defined using ISO 9223:2012 *Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination and estimation*. Accordingly, the corrosivity categories of the light geothermal site, severe geothermal site and severe marine site are C2 – Low, CX – Extreme and C5 – Very high, respectively.

3.2 As-prepared TSA coatings

The as-prepared TSA coatings have a relatively rough top surface with some physical defects such as pores and inclusions, which are typical for thermally sprayed metal coatings (Figure 2a). The overlapping plate-like microstructure can be clearly seen from the polished cross-section (Figure 2b). The average coating thickness, measured at 12 locations from cross-sections under SEM, was approximately 360 μm.

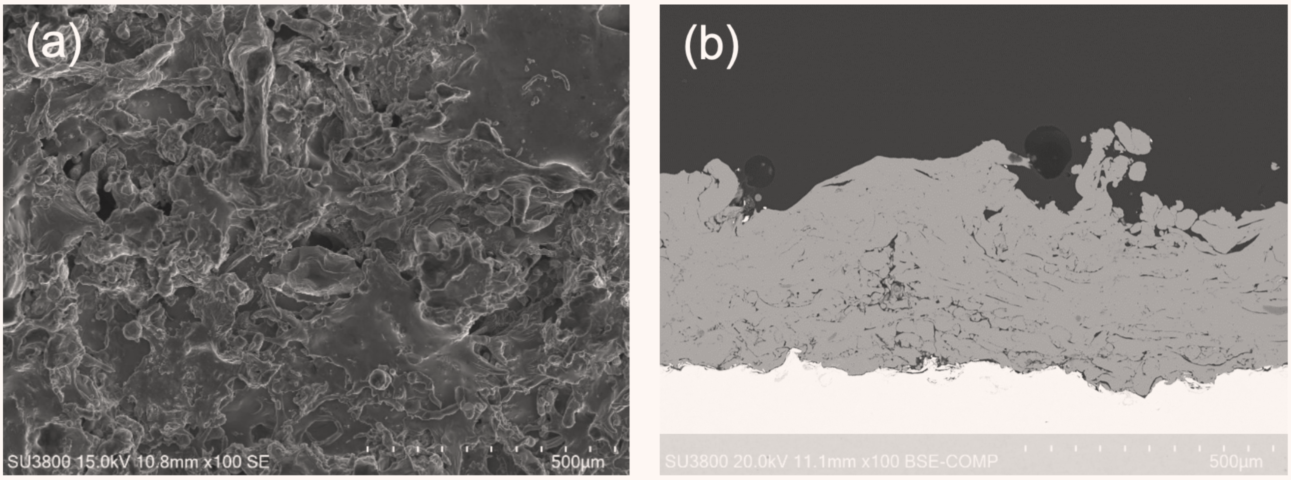

Figure 2. SEM (a) surface and (b) cross-sectional morphologies of the as-prepared TSA coatings.

EDS elemental mapping revealed the presence of oxygen at several locations in the coating layer (see green spots in O Kα1 map in Figure 3). This is as expected since the high temperature spraying could lead to partial oxidation of in-flight aluminium particles by oxygen in the atmosphere. Some locations with oxygen present are associated with physical defects such as pores.

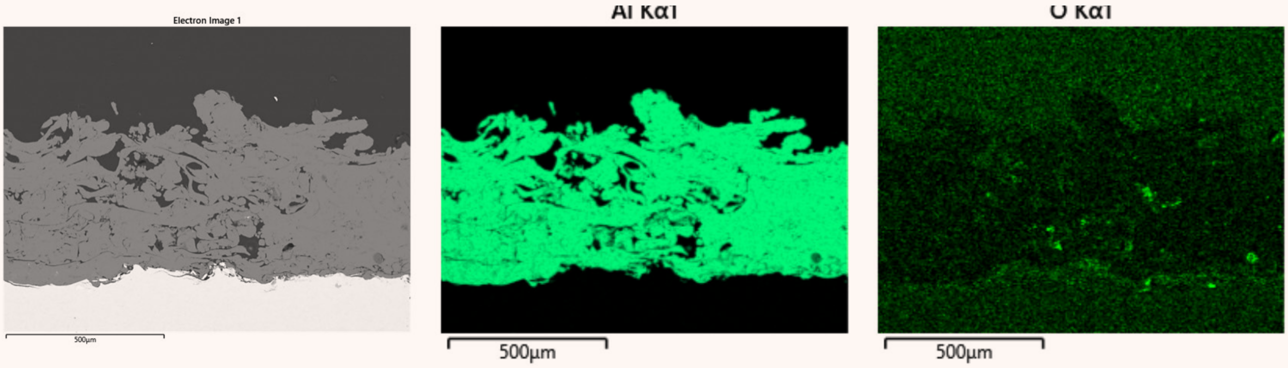

Figure 3. The presence of oxygen in the as-prepared TSA coatings.

XRD analysis identified aluminium as the main component of the as-prepared TSA coatings (Figure 4). There was a trace of unidentified crystalline phases. In consideration of the findings in Figure 3, these might be oxides because of partial oxidation of aluminium during spraying. However, due to their small quantities, it is challenging to identify them with confidence by XRD.

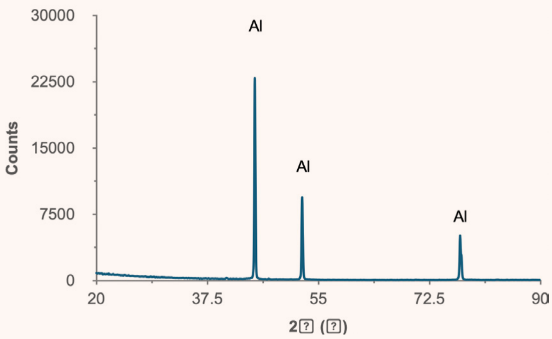

Figure 4. XRD pattern of the as-prepared TSA coatings.

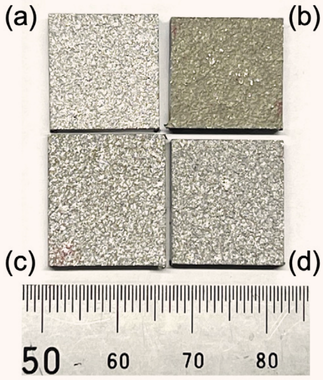

Figure 5. Visual surface inspection TSA coatings after 5-year exposure – (a) control sample, (b) severe marine site, (c) light geothermal site, (d) severe geothermal site.

3.3 Exposed TSA coatings

TSA coating samples after 2-year, 3-year and 5-year exposures at the three exposure sites do not show distinct surface morphological changes (Figure 5). The samples exposed for 5 years at the two geothermal sites became dull, while the sample exposed at the severe marine site had a sandy grey colour and seemed to be flatter.

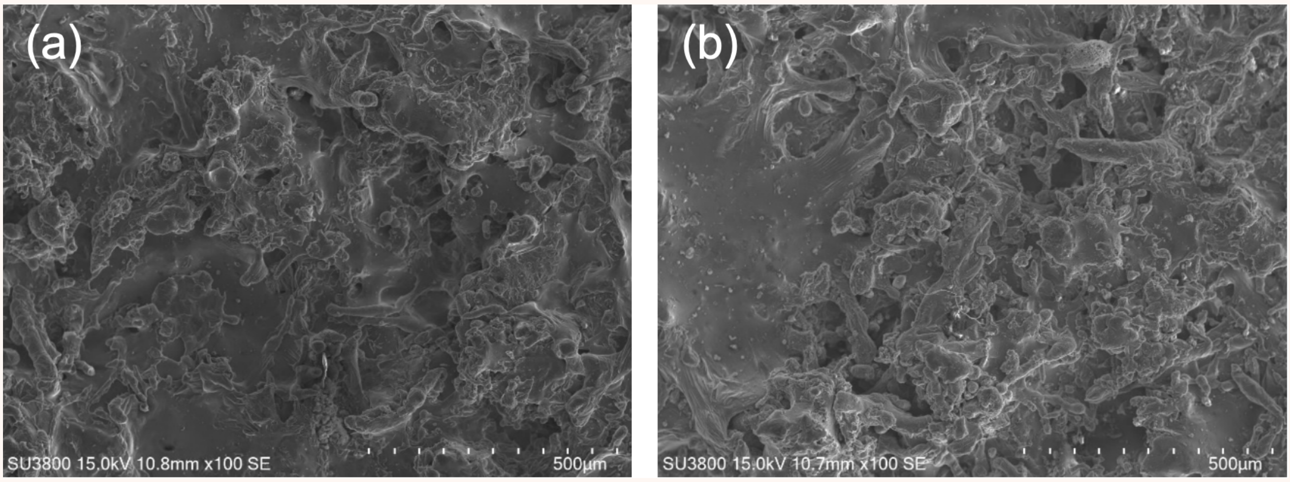

Figure 6. SEM surface morphologies of TSA coatings at the light geothermal site – (a) 2-year exposure, (b) 5-year exposure.

Oxygen was also detected from the top to the coating/substrate interface of the polished cross-section samples (Figure 7). Its presence is particularly obvious in the internal interfacial areas of the overlapping coating layers. Although sulphur was detected on the sample surface after 5 years of exposure, mapping of the cross-section did not confirm its presence inside the coating.

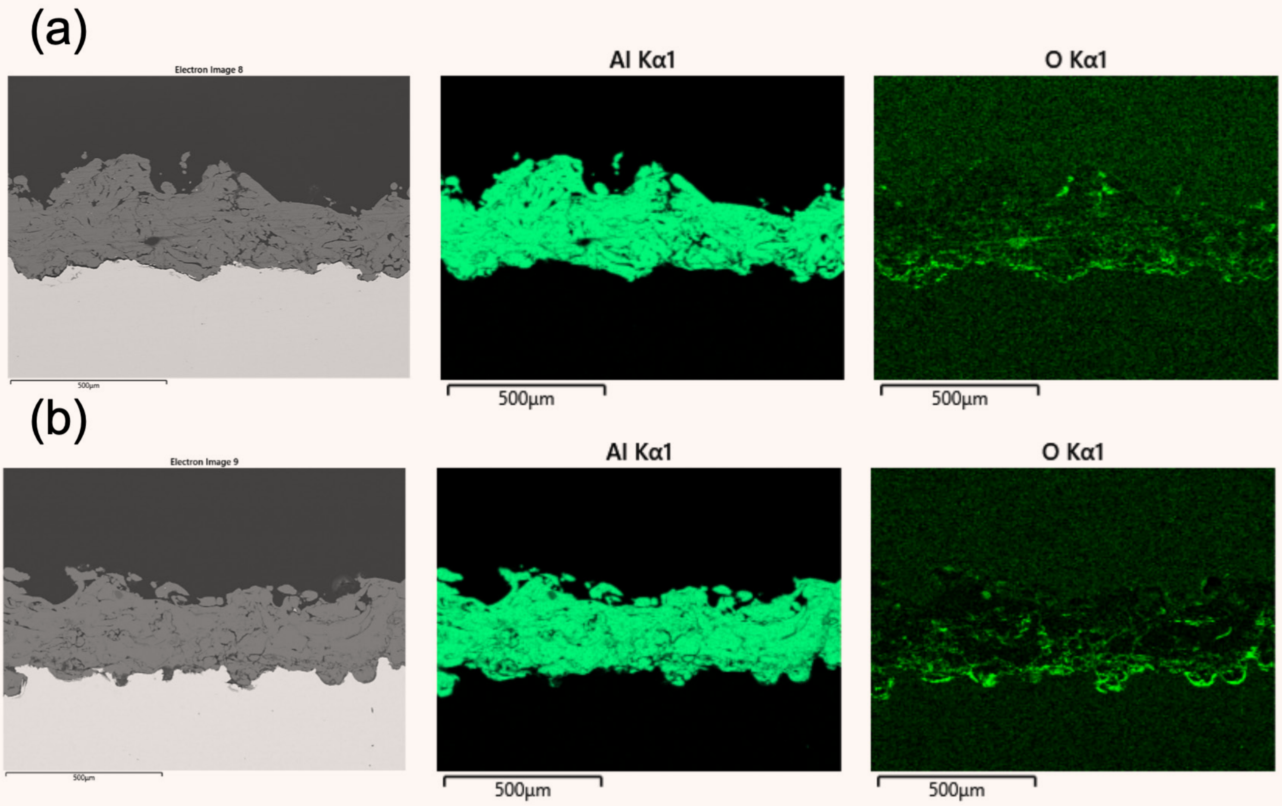

Figure 7. The presence of oxygen in the TSA coatings at the light geothermal site – (a) 2-year exposure, (b) 5-year exposure.

Some localised damage was observed on the TSA coating samples exposed at the severe geothermal site (Figure 8). Oxygen (27.8–50.4wt.%) and sulphur (3.1–11.3wt.%) were detected in these areas. Cracks were also observed, indicating reactions between aluminium and oxygen/sulphur produced corrosion products that caused additional stresses in the coating. This surface damage could also facilitate the ingress of corrosive media from the surrounding atmosphere.

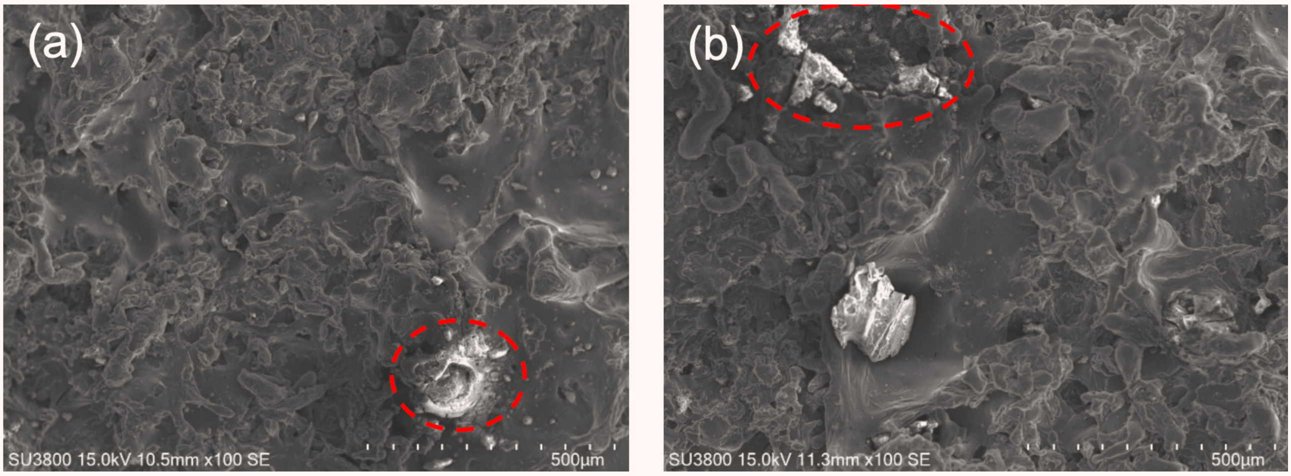

Figure 8. SEM surface morphologies of TSA coatings at the severe geothermal site – (a) 2-year exposure, (b) 5-year exposure.

After a 5-year exposure, the presence of oxygen in the TSA coatings was obvious. Sulphur was also detected in a smaller number of locations from the cross-section. Sulphur tended to be distributed in short, discrete lines. In some areas, its presence was also associated with the presence of oxygen (Figure 9).

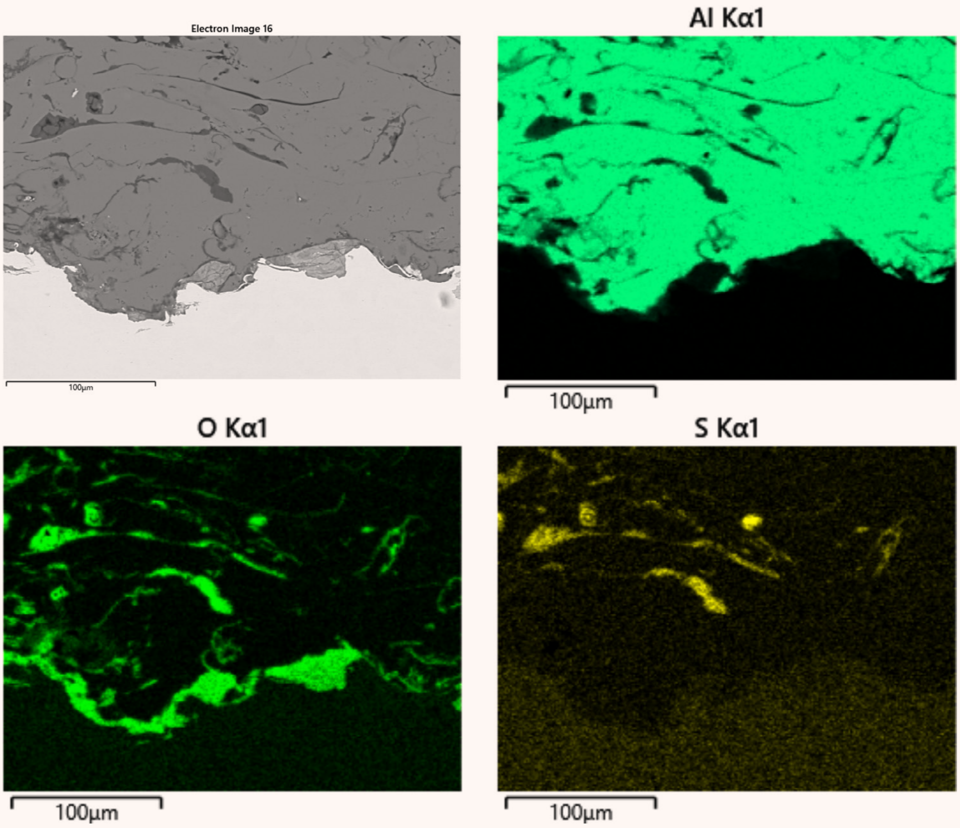

Figure 9. The presence of oxygen and sulphur in the TSA coatings after 5-year exposure at the severe geothermal site.

The surfaces of the TSA coating samples exposed at the severe marine site appeared to be less rough when compared with that of the as-prepared coatings, particularly after 5 years. Some areas showed a significantly different morphology (Figure 10a). Cracks were observed in these areas as well. EDS analysis conducted in these areas revealed the presence of oxygen, sodium, magnesium, silicon, chlorine and sulphur. This implies that salt particles from the nearby rough seas have deposited onto the coating surface and reacted with aluminium to form various corrosion products.

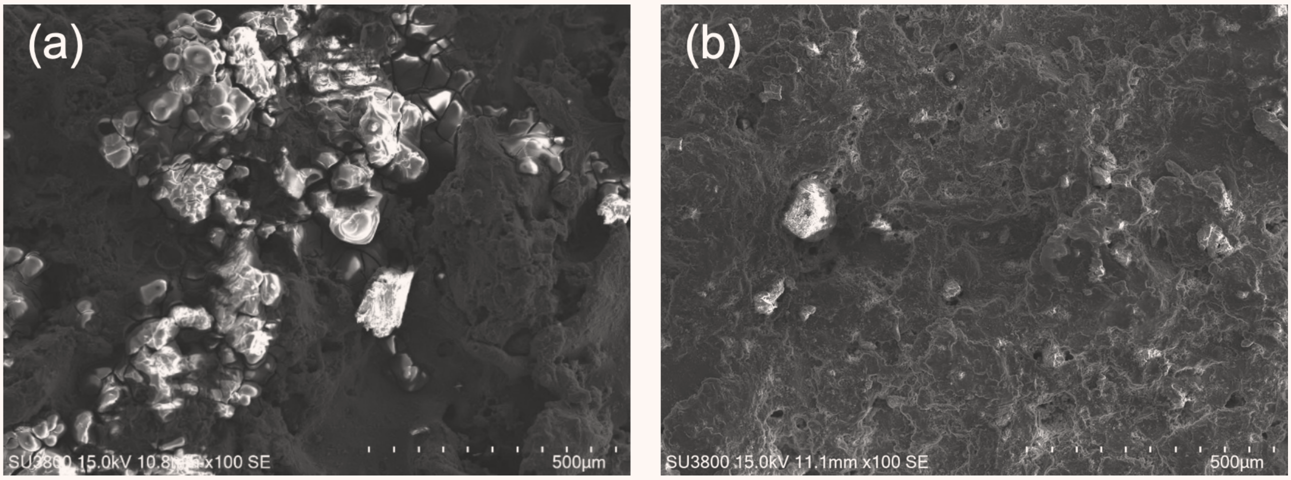

Figure 10. SEM surface morphologies of TSA coatings at the severe marine site – (a) 2-year exposure, (b) 5-year exposure.

For the cross-sections, the presence of oxygen was detected in the coatings after a 2-year exposure and a 5-year exposure (Figure 11). The average coating thickness after 5 years of severe marine site exposure was measured to be approximately 192 µm, which is significantly lower than the original coating thickness of 360 µm.

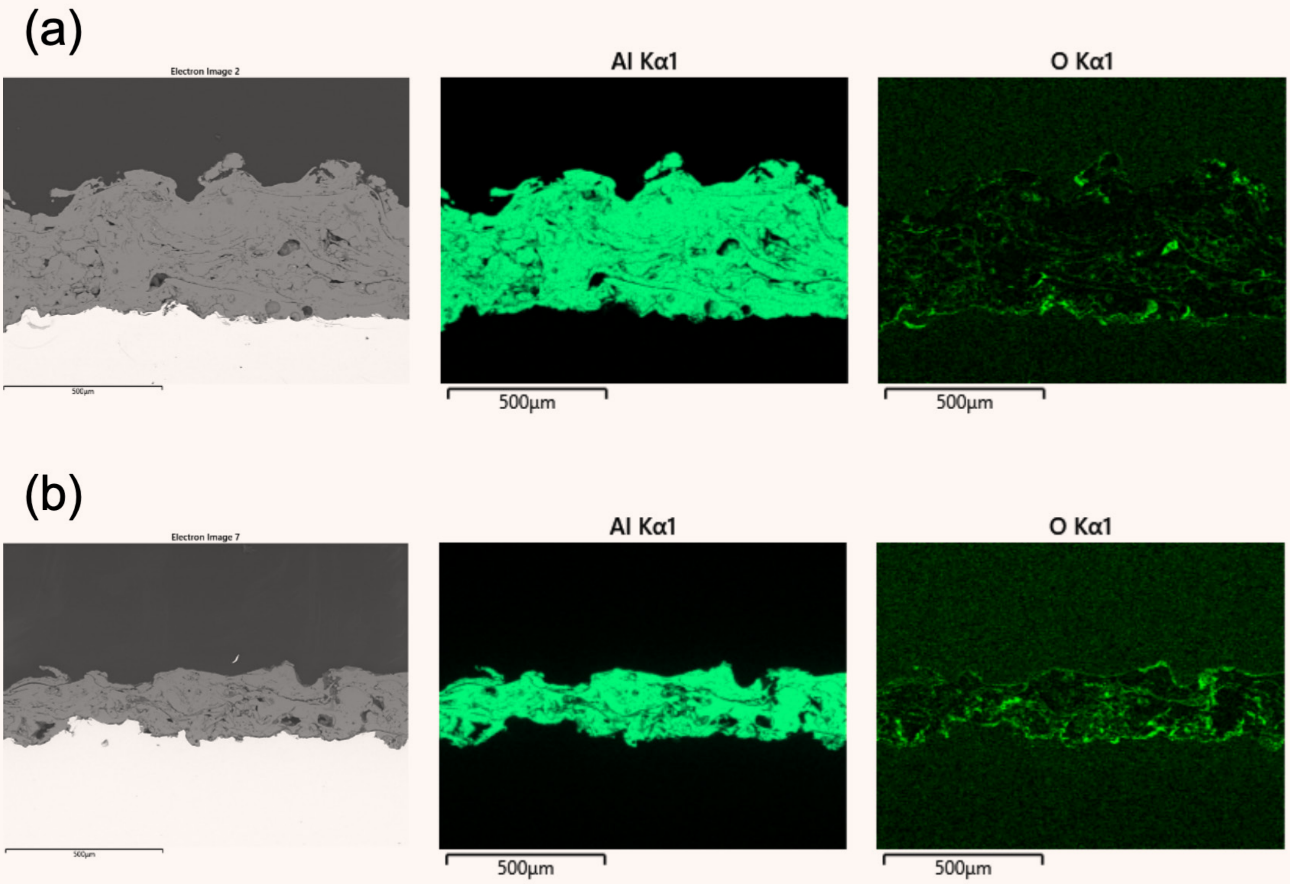

Figure 11. The presence of oxygen in the TSA coatings at the severe marine site – (a) 2-year exposure, (b) 5-year exposure.

3.4 XRD analysis of exposed TSA coatings

XRD analysis shows that the predominant constituent in the TSA coating samples after a 5-year exposure in geothermal and marine environments is aluminium (Figure 12). This is basically the same as when the TSA coatings were prepared. That said, oxygen and/or sulphur had found their way into the coating through pores, cracks and other physical defects, but these interactions with aluminium were still slow and limited within this field exposure. This is consistent with SEM morphological characterisations and EDS elemental mapping done on the top surfaces and from cross-sections.

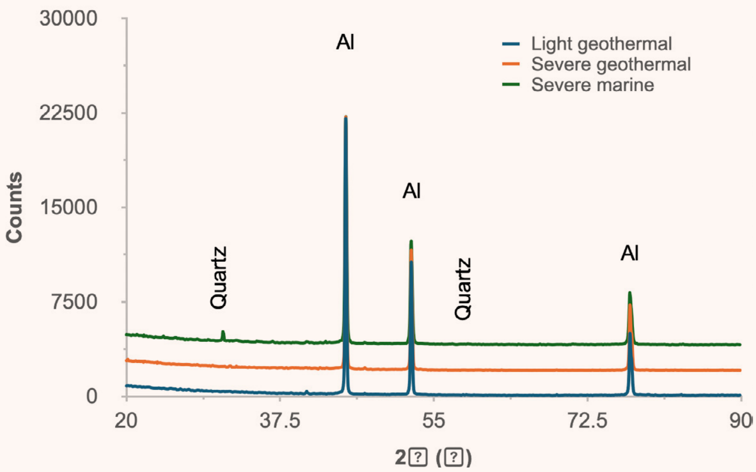

Figure 12. XRD pattern of TSA coatings after 5-year exposure in geothermal and severe marine environments.

XRD analysis revealed the presence of a small quantity of quartz in the samples exposed at the severe marine site. TSA coatings have a rough surface and physical defects that provide anchoring points for sand (primarily quartz and crystalline in structure) carried by strong winds. Visual inspection shown in Figure 5b supported this.

4. DISCUSSION

SEM observations show that TSA coatings suffered more severe deterioration when exposed to the severe marine environment (ISO 9223 C5 – Very high). This is a synergistic result of corrosion induced by airborne chloride-containing salt particles and mechanical impingement (erosion) of sand particles carried by strong winds.

These coatings have a rough surface and provide anchoring points for deposition and accumulation of marine-sourced salt particles. Under favourable environmental conditions, these salt particles initiate and accelerate corrosion, which produces chloride-containing corrosion products and leads to localised damage as observed in Figure 10a. Meanwhile, strong winds at the severe marine site carry sand at some times of the year, lending a blasting effect on the coating surface, as previously observed with aluminium samples [12]. This mechanical action can remove some salt particles and corrosion products. This means salt-induced corrosion can be retarded to some extent. However, some aluminium coating mass is removed.

Sulphur-containing gas species such as SO2 and H2S have been detected in the two geothermal environments in this study. SO2 concentrations of approximately 37.8 ppb and H2S concentrations of 31.0 ppb have been measured at the severe geothermal site (ISO 9223 CX – Extreme) using passive tube sensors [12]. Meanwhile, their concentrations at the light geothermal site (ISO 9223 C2 – Low) were lower – 7.7 ppb and 0.5 ppb for SO2 and H2S, respectively [13]. Their presence in the air, together with moisture/water, can significantly increase atmospheric corrosivity and accelerate corrosion of susceptible materials such as copper, iron, lead, silver and zinc [14]. However, they seem to have had limited effects on the TSA coatings in this study.

Though chemically active, aluminium is naturally passive in many environments since it can react rapidly with oxygen or moisture in the atmosphere to form a thin and stable passive film on its surface. This film can slow down the reactions between a corrosive medium and the underlying substrate. However, under acidic or caustic conditions or when exposed to certain types of salts and gases, this passivation can be lost, initialising localised corrosion such as pits [15–16].

A previous study found that aluminium has low corrosion rates (<3 g/m^2/year) in many New Zealand environments [17]. The first-year corrosion rate of pure aluminium was measured to be 0.22 g/m^2/year at the severe geothermal site in Rotorua [12]. This implies a high passivation stability on the aluminium surface when exposed to sulphur-containing gases. Further, TSA coatings in this study have low concentrations of oxygen and probably partial oxidation of aluminium. This may help prevent the inward diffusion of airborne sulphur-containing gases since oxide is thermodynamically more stable than sulphide.

EDS elemental mapping reveals the ingress of oxygen and occasionally sulphur into the TSA coatings. However, XRD does not reveal the formation of oxides or sulphides even after a 5-year exposure. This may indicate the reactions between oxygen/sulphur and aluminium is slow within the coating. When considering the lamellar structure of the coating, it is postulated that oxygen may tend to distribute along the internal interfaces of overlapping coating layers that have defects. It may react with interfacial aluminium to form thin oxide scales and act as a barrier to further ingress.

5. SUMMARY AND CONCLUSIONS

This 5-year field exposure study shows that thermally sprayed aluminium coatings had no significant morphological changes on their outer surfaces when exposed in geothermal environments. However, some localised damage, mainly induced by the reactions between sea salt and aluminium, was observed on coating samples exposed to the severe marine environment. In addition, sand-blasting effects due to strong winds reduced the coating thickness significantly.

The presence of oxygen and/or sulphur (when exposed to geothermal environments) became more obvious with extended exposure. However, this ingress of oxygen and/or sulphur did not lead to the formation of oxides and/or sulphides that were identifiable by X-ray diffraction. This implies that, even if oxides and/or sulphides were formed in the coating, their quantities were still very low after 5 years of exposure.

Overall, the results collected with SEM, EDS and XRD show that this thermally sprayed aluminium coating has reasonably high corrosion resistance when exposed to severe geothermal and marine environments. This information could help in specifying and maintaining thermally sprayed aluminium coatings to achieve service life goals in some New Zealand environments.

Acknowledgements

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Stainless Partially Corrugated Tube (SPCT); A Material for Sustainable and Leakage Resistant Connection to Water Mains

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Keywords:

Stainless steel, stainless partially corrugated tube (SPCT), leakage reduction, competitive materials, cost benefit.

Abstract:

A brief history of plumbing materials used to connect water sources to individual domestic, commercial and industrial premises is presented. Lead pipes have been used for this purpose since Roman times, but since modern municipal water supply systems were introduced in the late 19th Century, other materials such as galvanized steel have also been used for service lines. Lead dominated service lines prior to WW2 with then unperceived health and durability issues still present today. After WW2 copper pipe became the default material in some countries until replaced in its turn by plastics, mainly polyethylene (PE), which predominates today.

Whilst austenitic stainless steels have been used as plumbing materials for over half a century, they have not achieved parity with either copper or PE due to misplaced perceptions of high material costs, although superior corrosion resistance and longevity was readily apparent. For the last few decades, however, a grade 316 stainless partially corrugated tube (SPCT) has been introduced to great benefit in Tokyo, Taipei, Seoul and elsewhere as a main-to-meter connection, principally to reduce treated water loss and provide 100-year life expectancy. Whilst well over 2 million connections using stainless steel tube have been used in these cities, the use of the SPCT system has for over 20 years been the specific methodology of choice for stainless steel main-to-meter connections. SPCT minimises the use of in-line fittings and allows for hand bending during installation, which for retrospective installation in underground services means significant labour saving. In these cities lead was largely the main-to-meter material replaced, and total leakage reduction the main driver for installation of the new material.

Cost/benefit and whole-of-life costing data is presented to show that this long-term approach is both financially and environmentally positive, particularly regarding leakage reduction. Data is also presented to demonstrate that the use of stainless steel in plumbing pipework has both medium and long term benefits when compared with polymer alternatives.

Finally, case histories of implementation of SPCT and resultant water savings are shown to demonstrate the ongoing need for robust water connections in the 21st century capable of achieving a 100-year operational life.

1. INTRODUCTION

Materials used to convey drinking water to the point of use have been around for millennia but have only been capable of classification in the last half of the 19th century when treated and reticulated water became introduced into first world population centres. Prior to this time both small and large diameter pipe could be made of a variety of materials including clay pipes in Iraq circa 4,000 BCE and even hollowed wood pipes used as late as 18th century North America. By the early 19th century, however, cast iron became the material of choice of mains using a bell-and-socket arrangement capable of being lead sealed and thus providing a seal essential to providing a pressure main system (Nicholas et al, 2022).

This paper is not directly concerned with the network of pressure main systems used to distribute drinking water across potentially large distribution systems, but the small diameter pipes or tubes used to deliver water directly to the premises. Although in antiquity water was provided directly to houses, this was extremely rare and only provided to the most affluent in the ancient empires. This was originally not controlled by any tap, until the Romans introduced a sophisticated end-of-line bronze fitting similar to a ball valve (Lorenze, 2013). With the disintegration of the Roman empire, this technology was completely lost. The screw tap was invented by a Thomas Grill circa 1800 (Mistry, 2022) and various permutations and developments of this are with us today. By the time large scale water distribution systems were being introduced the issues of main-to-premise connection was becoming important, although until the middle of the 20th century many industrial cities had communal, not individual water connections, to local housing.

Main-to-premises, or main-to-meter pipe systems, were originally of either galvanized steel or lead depending on geographical location, and these issues are discussed more fully in Section 2 of this paper. The initial problems of water leakage and material deterioration were not widely considered at the time as the focus was to provide water connection to as many premises as possible in as short as possible time frame. Water meters, invented in the mid nineteenth century, only became universal and compulsory in the last quarter of the 20th century in most urban cities, largely as a first stage to limit water usage and control demand through a pay for use regime.

2. COMPETITIVE MATERIALS

a) Lead

Lead pipe for water reticulation famously originates in the Roman era when it was widely used to convey water into both homes and communal areas. It was a soft, easily worked metal at room temperature and capable of cold forming into pipes. Lead was also relatively easily extracted from its ore and the Latin for lead, 'Plumbum', gave us our word 'plumbers'. Lead water pipes have erroneously been blamed for the demise of the Roman empire from its well-known toxic effect, but it is more likely any ill-effects came from the Roman habit of fermenting wine in lead vessels to give the sweetness of lead acetate to the drink.

The collapse of the Roman Empire meant that reticulated water supply had to wait over 15 centuries before revival and lead again seemed to provide a malleable and easily worked material for main-to-premises connections.

During the 1920's and 1930's, the strong marketing by the Lead Industries Association (Rabin, 2008), led to a large-scale use of lead pipes for main connections, particularly in the USA, UK and Southeast Asia, although curiously Oceania (Australia and New Zealand) were spared what later became a material and environmental catastrophe. Lead was used in this region, but almost solely in wastewater applications.

The main drawback of lead pipes is largely put down to now well- understood contamination of waters by toxic levels of dissolved lead. Not only are lead pipes banned but lead solder is also banned and the allowable levels of lead in copper alloy fittings is currently also being reduced. However, from a mechanical viewpoint lead is also susceptible to low cycle fatigue and creep that means that over a 100-year period of exposure or less the pipe can suffer physical failure. This applies particularly in areas where ground movement due to traffic or seismic activity can cause premature failure. Lead is a very soft metal and, as such, is not robust unless restricted by cementitious or very well compacted surround backfill.

Nevertheless, in areas such as Glasgow where lead pipes are ubiquitous, water treatment has largely reduced the contamination problems associated with soft, acidic water to manageable levels using water treatment inhibitor additions (Watt et al, 2000). Nevertheless, in early years lead levels in Glasgow tap water were orders of magnitude greater than what is considered acceptable today.

A final warning with the continued use of lead pipes is given by experience in Flint, Michigan, USA where the water source was altered to save expense and the new river supply, without corrosion inhibitor, caused existing lead plumbing systems to corrode and put lead levels well above health limits (Ray, 2023).

b) Hot dip galvanized (HDG).

Hot dip galvanizing of steel products started in Europe in the early 19th century and was rightly considered a cheap and highly effective means of providing corrosion protection for steel. By the late 19th century hot dip galvanized (HDG) steel pipes were frequently used for house connections and their use extended to the 1960's or later. Curiously, there is little literature on the use of HDG steel in water supply although there has been research into galvanized fire services (Nicholas et al, 2004)

The main issues with HDG pipes are that in buried conditions, particularly clay soils, they will corrode from the outside in. And in potable waters internal corrosion from iron fixing bacteria also can block the pipe with corrosion product (Nicholas et al. 2004). Note that once a corrosion layer is produced, low levels of disinfectant will not penetrate into the interface region and corrosion rate will continue unaffected. HDG pipe rarely fails through mechanical or fatigue causes, but the corrosion issues have meant that it is no longer a viable main connection material in most countries. Less well known is that the zinc galvanizing itself could contain up to 2% lead and still comply with the then existing standards. Thus, low levels of lead contamination could still occur, although this was rarely properly investigated. Nevertheless, HDG steel is still used in some countries where its perceived low scrap value means it is less likely to be stolen.

c) Copper

The use of copper as a water pipe famously extends back to King Tutankhamen in Egypt circa 1500 BCE, but the widespread use of copper globally as a plumbing tube had to await the development of thin-walled capillary pipe post World War 2. In many first-world counties copper became the default material for main-to-meter connections, being mandated by several water utilities in place of HDG. The corrosion issues, which did not become apparent until after the widespread use of copper, have influenced the continued use of the material. These copper corrosion issues have been extensively reviewed by many researchers, including Nicholas, (1980, 1987 and 2014), Nuttal (2010) and Edwards et al (1994).

Corrosion issues include 'blue water' or 'blue-green water' (BGW) extensively researched in New Zealand, Australia and elsewhere in the last 45 years, pitting corrosion in both hot and cold water plus erosion/corrosion at relatively low water velocities as copper is a relatively soft metal. All these forms of corrosion are internal and dependent to some extent on water composition and system operation. External corrosion of buried copper is rare but not unknown. The perceived benefit of copper as a plumbing material is its high thermal conductivity, which means joining using various solder and brazing techniques is relatively simple. Nevertheless, increasing labour costs mean copper is also now assembled using 'press fit' and other mechanical jointing methodologies.

The issues of copper pipe corrosion/contamination, along with high material installation costs, have combined to severely reduce the use of copper as a main-to-meter material.

Figure 1: "Blue Water" from author's laboratory, 1980

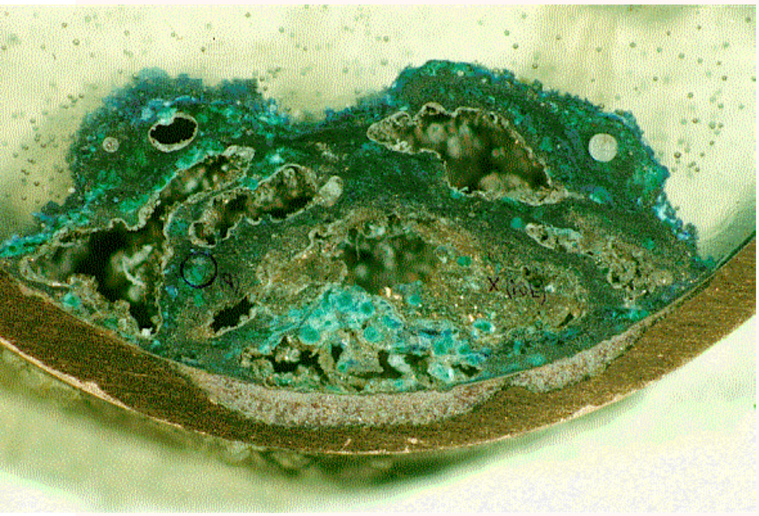

Figure 2: Cross-section of copper corrosion pit in cold water (Nicholas, 2014)

d) Polymers

Polymers, principally polyethylene (PE) have almost entirely replaced copper as the material of choice for both main-to-meter connections and, for that matter, internal plumbing in low rise housing. This change is almost entirely driven by upfront cost considerations, although a perception that the material is free from corrosion problems and flexible enough to be installed quickly and easily has obvious attraction.

There are, however, some systematic issues with polymers, including PE, which may have an unwelcome impact on life expectancy in main-to-meter installations. Firstly, the material is inherently susceptible to high levels of chlorine-based disinfectant despite the addition of anti-oxidants to the polymer formulation. This process has been investigated by Duvall and Edwards (2009) and the polymer chemistry involved more recently summarised by George (2019). This clearly has ramifications for the water industry where emphasis on meeting exacting water quality standards has inevitably increased the level of both chlorine and/or chloramine into the water distribution system.

Further, the actual installation of PE as a main-to-meter material requires careful consideration of backfill, as do all pipe systems- especially flexible piping such as PE. This is clearly of added importance in high traffic areas which is the default condition in major cities. Despite detailed recommendations from manufacturers and others (PPI, 2008), it is frequently observed that these requirements are ignored, particularly those relating to imported granular backfill. As a result, the pipe is exposed to premature failure from both external and internal degradation mechanisms. Further, plastic pipes in general, including PE, are highly susceptible to exposure to chemically contaminated ground where organic solvents can penetrate the material contaminating the water supply.

It is worth noting that PE, and indeed most polymers, are typically considered to have a 50 year life expectancy in normal operation.

There is some evidence from a local Queensland water utility that PE main-to-meter connections are already developing signs of premature failure. Data supplied shows that even with relatively new installations there are over 300 failures in a period of two years; the majority of these being leaks at the ferrule. Figure 3 below shows such a failure.

Figure 3: Leakage of PE main-to-meter connection at ferrule.

3. STAINLESS PARTIALLY CORRUGATED TUBE (SPCT)

Stainless steel as a material was first commercialised by Brearly in 1913 as a 'stainless' (he originally called it 'stainfree') steel cutlery knife. This was a high chromium hardenable (martensitic) stainless steel which is still used today for cutlery knife blades. The development of austenitic stainless steels containing both nickel and chromium continued after WW2 to the point where the basic 304 (UNS S30400) and molybdenum bearing 316 (UNS S31600) now represent a substantial portion of total stainless steel production. Austenitic stainless steel offers good strength and ductility as well as weldability and excellent corrosion resistance. Stainless steel usage in water supply systems has increased substantially over the last few decades and is now the default material for pipework within most water and wastewater treatment plants (Nicholas and Moore, 2002)

The use of both these grades for potable water tubes was developed in various countries in the 1970's, quite often to remediate specific issues with existing materials such as copper. For example, the copper cold water pitting issues with very soft water in some Scottish Hospitals (BSSA Report, 2003) resulted in replumbing with 304 grade stainless steels.

In Australia, the 'blue water' issues in the Hunter Region of NSW resulted in a number of major buildings, including two hospitals, being plumbed in 304 stainless steel. Whilst this was successful, the main issue with the use of stainless steel was not the initial tube cost, but the supply of appropriate fittings and methodology of joining. This significantly affected the take-up of stainless steel as a preferred plumbing material, noting that the poor conductivity of stainless steel when compared with copper and copper alloys was seen as a practical impediment to further use at a time when most tube assembly was done with hot solder or brazing methods. Most of the buildings constructed with stainless used TIG welded prefabricated sections which were joined in situ using copper alloy compression fittings.

Locally, stainless steel was not considered as a main-to-meter material as this market was then (early 1980's) dominated by copper which itself replaced the leak-prone HDG steel previously used. That is, system leaks from main-to-meter connections were not considered a significant issue.

This, however, was definitely not the case in many Southeast and East Asia urban cities where the old default main-to-meter material was mainly lead. Here, leakage from the existing main-to-meter connections were high, with Tokyo water losses estimated at 15%. Tokyo reduced these losses by installing stainless steel main-to-meter connections over the entire network over a 20-year period (Van Hecke & Kinsman, 2024). In this case, the material selected was grade 316 stainless as this was capable of better performance in a wider variety of water composition data, soil chemistries, temperature and residual disinfectant levels than grade 304. The difference in price between the grades was considered insignificant when compared with main-to-meter retrofit costs.

Originally, the grade 316 stainless steel was straight tube conventionally joined using available fittings, but this was supplanted in the 1990's with a partially corrugated product, developed in South East Asia, which allowed hand bending when being retrofitted in difficult and confined spaces to eliminate the need for most in-line fittings. A schematic of the stainless partially corrugated tube (SPCT) is shown below in Figure 4, whilst the effects of leakage reduction in Tokyo over the life of the retrofit of main-to-meter SPCT is also demonstrated in Figure 5 below.

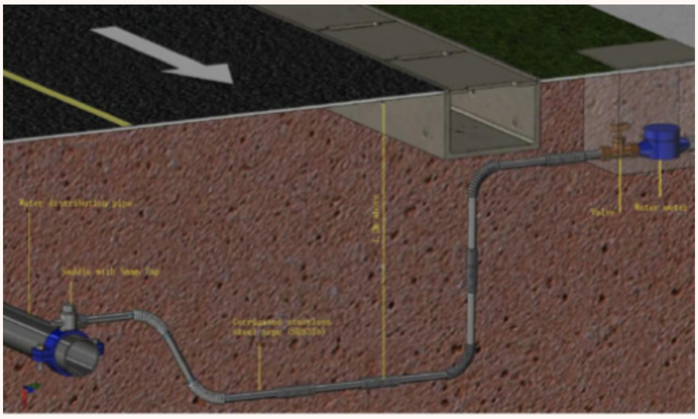

Figure 4: Schematic of SPCT as used for main-to-meter in Tokyo, Japan

These water savings are also reflected in data from Taipei, where service line replacement with grade 316 SPCT has resulted in leakage reductions from 26% to 11% over the course of 20 years (Van Hecke and Kinsman, 2024).

A summary of the cost/benefit analysis from retrofit of SPCT is given below in Section 4.

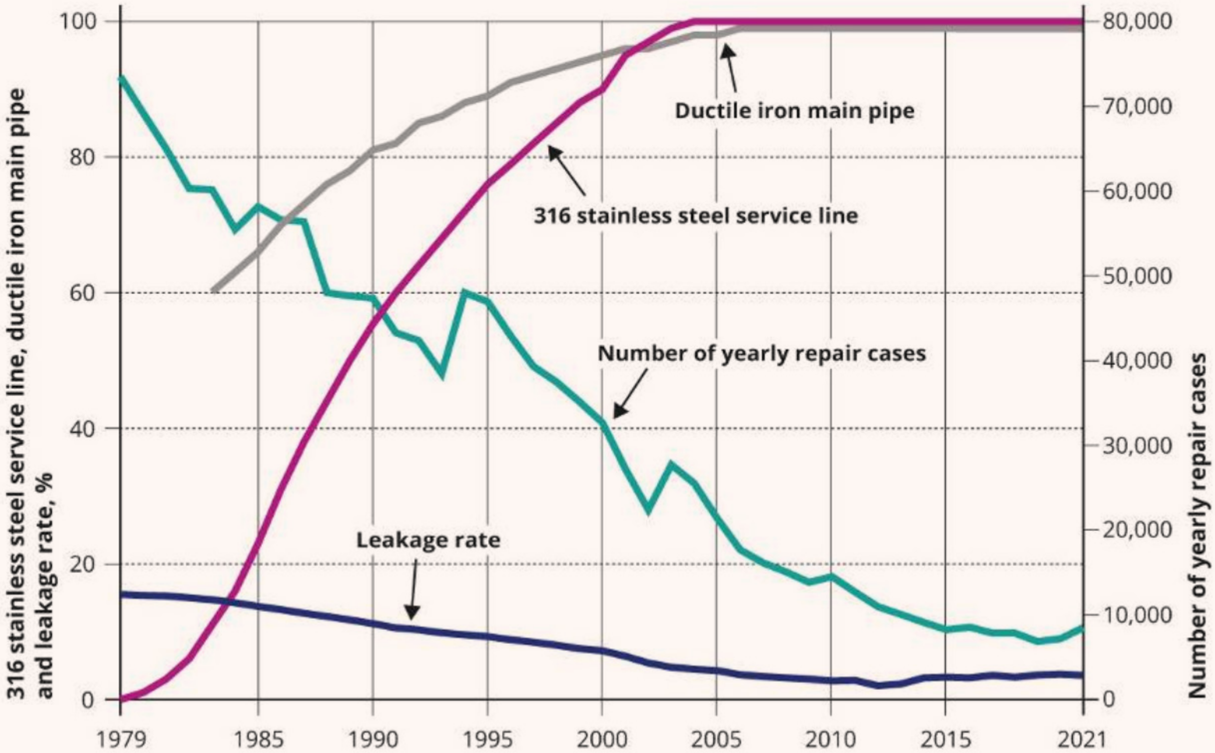

Figure 5: Reduction in repair cases and leakage rate in Tokyo in proportion to the retrofit of stainless steel main-to-meter sytems.

4. LIFE CYCLE COST/BENEFIT ANALYSES

There has been significant work done (Nickel Institute, 2023) to demonstrate the benefits of using grade 316 SPCT for main-to-meter connections. Whilst acknowledging the higher upfront cost of the stainless steel option over PE, it can easily be shown that the advantages accrue from a purely financial viewpoint using a life cycle costing (LCC) approach. This uses a discounted cash flow model which corrects the forward cost estimate for inflation.

Table 1 and Figure 6 below show the LCC calculations for a single water service connection in Australia in 2021;

Life cycle cost summary for one water service connection		
Present value costs - Australia 2021 - all values in AUD		
Real interest rate	2.75%	
Desired life	100 years	
	316 SPCT	**Polyethylene**
Component costs	284.31	163.04
Installation costs	3,950.00	3,950.00
Component cost is only 7% (316) or 4% (PE) of the initial cost		
Total initial costs (today's value)	**4,234.31**	**4,113.04**
Discounted maintenance costs (100 years)	21.52	138.28
Discounted replacement costs (once for PE)	-	1,088.56
Discounted water loss cost	43.53	564.69
Total operating costs (discounted)	**65.05**	**1,791.53**
Total LCC (discounted to NPV)	**4,299.36**	**5,904.57**
Noteworthy: the 316 solution becomes less expensive than the PE one after only 15 years		

Table 1: Life cycle cost summary for a single water service main-to-meter connection in Australia. (From Nickel Institute, 2021)

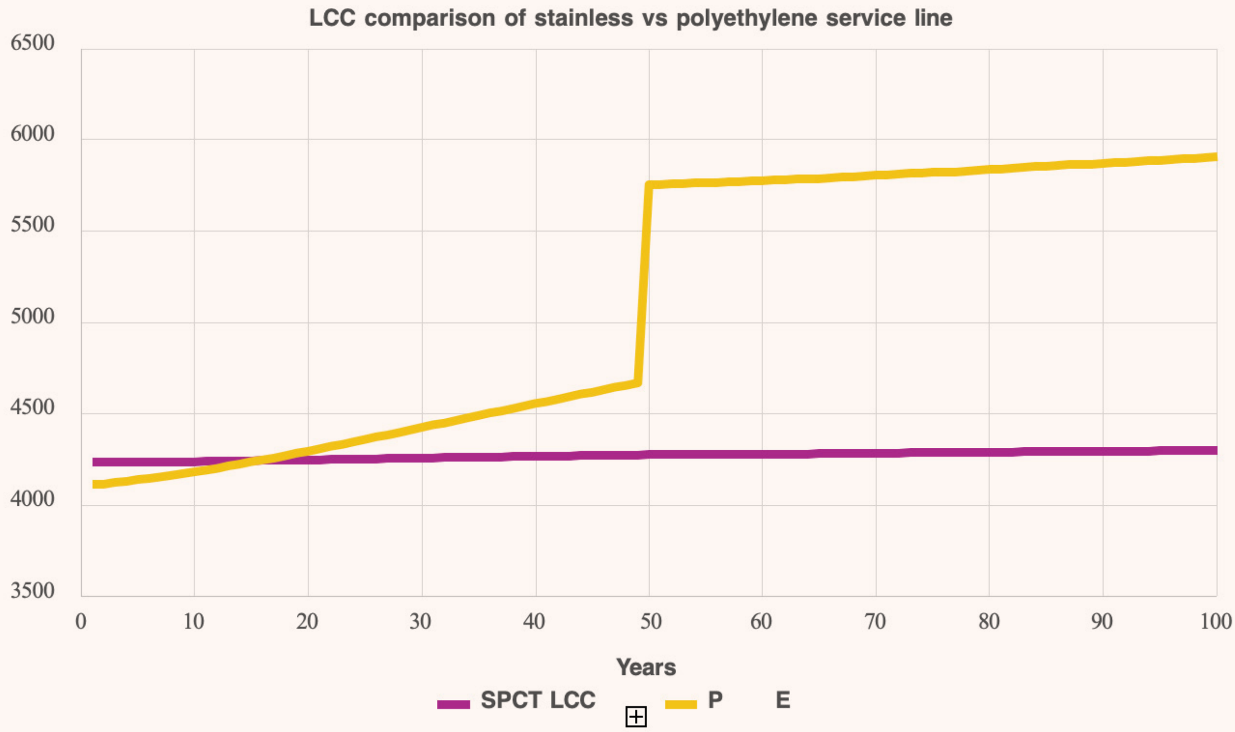

Figure 6: Graphical representation of Type 316 stainless (SPCT) versus polyethylene service line life cycle cost. Note that advantage of using stainess steel option accrues in year 15.

The data shown above shows that the benefit of using stainless steel grade 316 SPCT accrues in year 15 when compared with the current industry usage of PE as the default main-to-meter service pipe; in terms of the normal water industry life requirement of major assets of 100 years this is a short return on investment.

Some data from Tokyo suggests that the total saving of using 316 stainless steel SPCT could reach over $US150 million /year by using the stainless steel option of main-to-meter connections.

5. AUSTRALIAN SPCT TRIALS

Worldwide, several trials are currently underway to demonstrate the ease and practicality of using stainless steel grade 316 SPCT in both retrofit and new main-to-meter connections. One trial connection in the Shoalhaven region of NSW is instructive to demonstrate both the ease of installation and the potential longevity of the SPCT main-to-meter connection.

Figures 7 and 8 below show installation photos taken December 2018 and excavation photos taken after 3.5 years exposure in June 2022.

Figure 7: SPCT as installed, left, and right, exhumation after 3.5 years exposure. Note patina on copper alloy fittings (right) showing corrosive atmosphere present at site.

Figure 8: SPCT as installed, left, and right, exhumation after 3.5 years exposure. Note that stainless tube on right still bright and uncorroded despite burial in corrosive clay soil without granular backfill.

It is worth noting that even in a controlled trial such as this one imported granular backfill was apparently not used at the time of installation. This is a common fault with all classes and materials of water supply pipes to the authors' knowledge and is particularly of concern if flexible pipes such as PVC or PE are used, as these rely on well-consolidated backfill to provide essential structural support.

The installation itself was successful given the SPCT was unfamiliar with the installers, but the benefits of the corrugations was immediately apparent. Similarly, the exhumation clearly showed that the material was coping well with the conditions and was on track to provide the required 100-year life.

6. CONCLUSIONS

Stainless steel has already shown itself to be an ideal material for water and wastewater supply and is the default material for both Water and Wastewater treatment plant pipework and general infrastructure. For main-to-meter pipework, grade 316 SPCT is an established material of choice in East and Southeast Asia cities due to its perceived longevity and ability to reduce leakage and water loss.

The high initial cost of stainless steel when compared with competitive polymers has been seen as a drawback to a more universal application of SPCT, but in fact this is a flawed economic argument as the cost/benefit analysis shown above in Section 4 amply demonstrates. The upfront cost of the stainless steel option is clearly dwarfed by the installation and other associated water utility costs. Moreover, an installation using grade 316 stainless steel PCWT is clearly a superior technical advancement over polymers due to vastly increased mechanical strength, resistance to chlorine-based disinfectants and a realistic 100 year life expectancy with very low or zero maintenance costs. Competitive materials such as PE arguably cannot meet this longevity criteria and thus a whole-of-life costing model will show that the stainless steel main-to-meter option is by far the best solution for the water industry.

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8. AUTHOR DETAILS

David Nicholas is the principal of Nicholas Corrosion Pty Ltd, a consultancy firm specialising in corrosion and materials engineering issues in the Water Industry. David has over 44 years' experience in this Industry working for both Hunter Water Corporation and Hunter Water Australia for much of this time. He is a former president of the ACA, holder of the Corrosion Medal, and a Life member of the Association. David has been a consultant for the Nickel Institute for the last 10 years. He is quite a silly person, but you probably haven't read this far.

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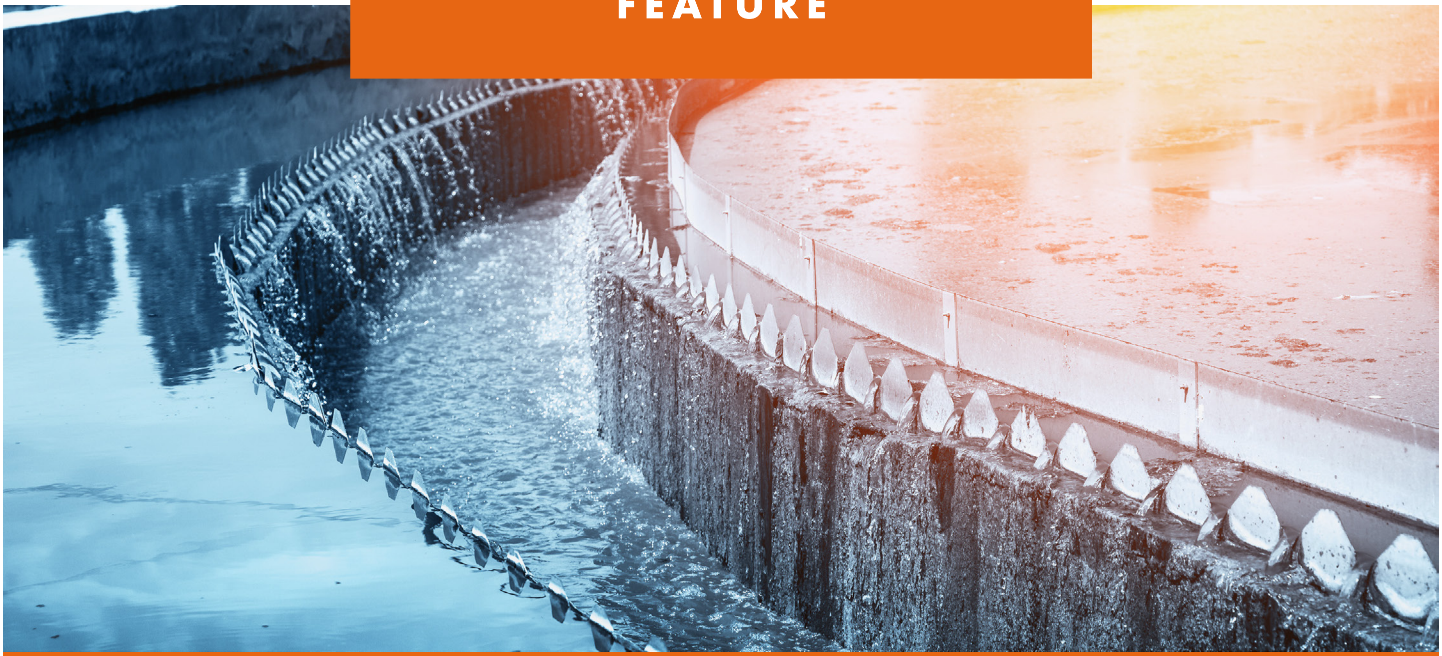

Selecting Suitable Coating Solutions for Concrete in Water and Wastewater Industries

Chesterton. Leading with Purpose. Innovating for Change.

Concrete, the second most widely used material after water, is a mix of cement, sand, aggregate, and water, with cement acting as the binder. Its durability, cost-effectiveness, and corrosion resistance make it ideal for water and wastewater treatment systems. However, the cement in concrete is alkaline and low pH and other chemical exposures can cause severe degradation, making protective coatings essential for long-term integrity.

Environmental Exposures in Water and Wastewater Systems

Potable Water:

Potable water systems expose concrete to erosion and chemical attack from coagulants, disinfectants, and pH buffers. Chemicals like **aluminium sulphate** can cause cracking by forming expansive ettringite crystals, while **chlorine and ozone** can degrade surfaces over time. **Impermeable coatings** help prevent contamination and chemical damage.

Wastewater:

Concrete in wastewater treatment plants is exposed to **highly corrosive conditions**, including human waste, oils, detergents, industrial chemicals, and in some cases, abrasive stormwater runoff. These contaminants contribute to erosion and chemical attack. Given the aggressive nature of wastewater treatment processes, **protective coatings** are crucial to extending the lifespan of concrete infrastructure.

Concrete Degradation in Water & Wastewater Facilities

Concrete in treatment facilities faces multiple forms of degradation, affecting its integrity and lifespan.

- **Abrasion & Erosion:** Solids in flowing water wear down the cement paste, exposing and dislodging aggregates, especially in high-flow areas.
- **Chloride Attack:** Chlorides from groundwater or wastewater penetrate concrete, corroding steel reinforcement and causing expansion and cracking.
- **Carbonation:** CO_2 reacts with moisture, lowering pH and reducing concrete's ability to protect steel reinforcement, leading to corrosion.
- **Freeze-Thaw Damage:** Trapped moisture expands when frozen, causing surface cracks and structural weakening.
- **Biological Corrosion:** Bacteria in wastewater produce sulfuric acid, rapidly degrading concrete, particularly in humid, enclosed spaces.

Selecting the Right Protective Coating

Protective coatings should be selected based on exposure conditions, durability, and ease of application. The main types of coatings include:

High-Solids Epoxies (Thin Film & High Build):

- **Pros:** Excellent chemical resistance, low moisture permeability, and strong adhesion to damp surfaces.
- **Cons:** Limited flexibility, poor UV stability.

Polyester/Vinyl Ester Systems:

- **Pros:** High chemical resistance and good mechanical strength.
- **Cons:** High shrinkage, complex application process.

Fig. 1 Repair of Abrasion Damage on inclined Screw Pump trough

Polyurethanes:

- **Pros:** High impact resistance and good film build.
- **Cons:** Poor resistance to strong acids and oxidisers.

Polyureas:

- **Pros:** High abrasion resistance, rapid cure time.
- **Cons:** Poor UV resistance and high cost.

Protective coatings have been successfully applied across various industries, including potable water systems, where sand filters and cisterns are coated with high-build, high-solids epoxy to prevent contamination and chemical degradation; wastewater facilities, where manholes, wet wells, and junction boxes are protected with high-solids epoxy and novolac epoxy to resist microbial corrosion and chemical exposure; and screw pumps, which are coated with reinforced novolac epoxy for enhanced abrasion and chemical resistance.

Fig 2. Corroded manhole

Fig 3. Coated manhole

EFFICIENCY THAT WORKS. COATINGS THAT DELIVER.

Chesterton ARC Industrial Coatings offers powerful, long-lasting protection for concrete in harsh water and wastewater environments. Our 100% solids, low-VOC coatings resist chemical attacks, abrasion, and corrosion, ensuring durability and cost-effective maintenance. From resurfacing to thin-film composites, our solutions keep concrete infrastructure strong and resilient for years.

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Steven Reinstadtler
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PPG Speaker
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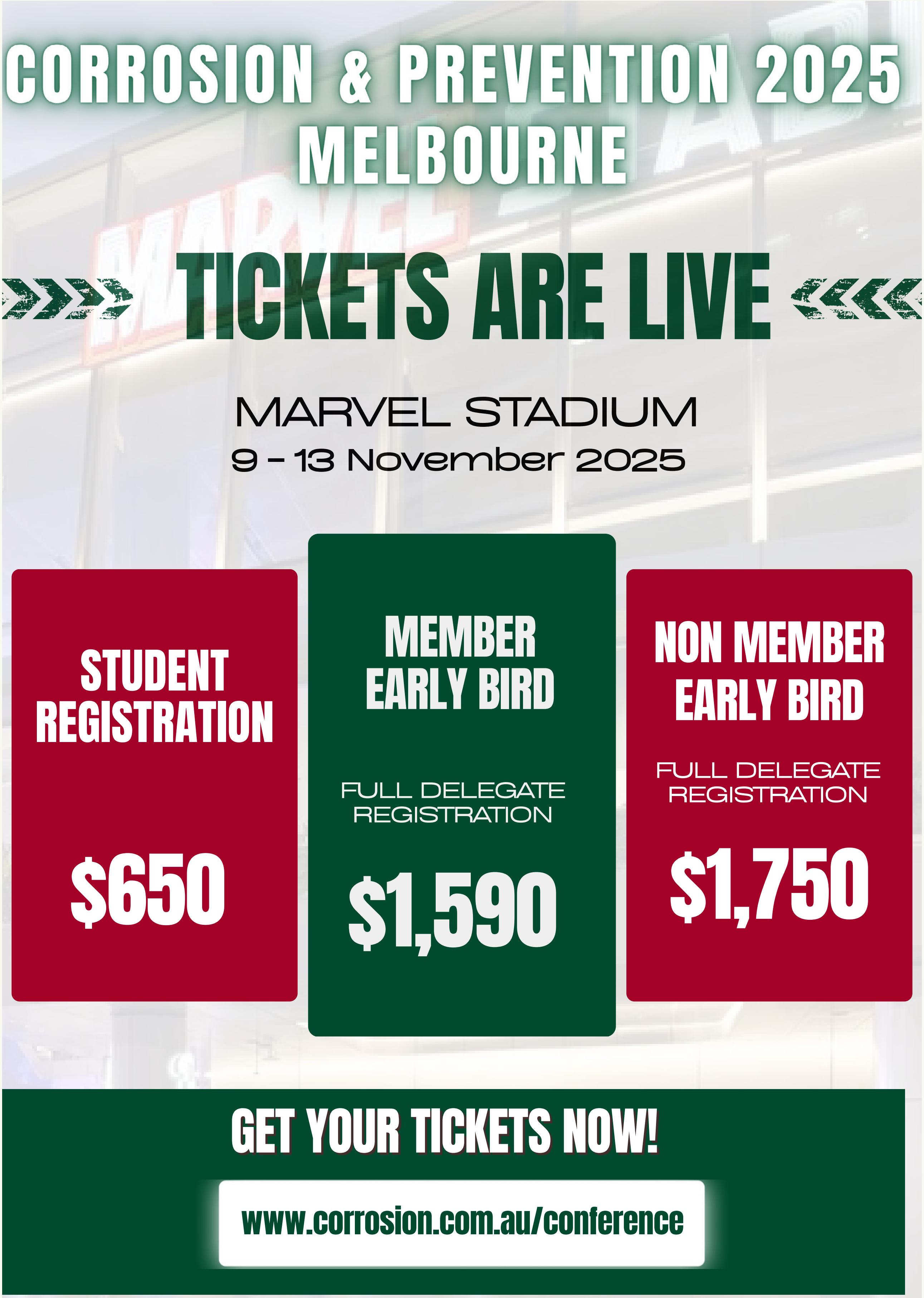
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Waterproofing Black Hill Reservoir, New South Wales.

Mr. David Johnstone
Regional Maintenance & Repair Manager, Strategic Accounts, South Asia,
Akzo Nobel Pty Limited, South Australia, 5251, Australia

Keywords: **Long term durability, Waterproofing, Design life, Advanced cementitious coatings.**

This paper provides a historical overview regarding the Black Hill Reservoir site, the expectations of the asset owner, Hunter Water Corporation (HWC) regarding extending the anticipated service design life of the asset by an additional twenty (20) years, project time frames, the waterproofing system that was selected for use, why this technology was nominated and approved for use by HWC, and the site challenges encountered during application

caused by SSD (saturated surface dry) concrete and a very short application time-frame.

INTRODUCTION

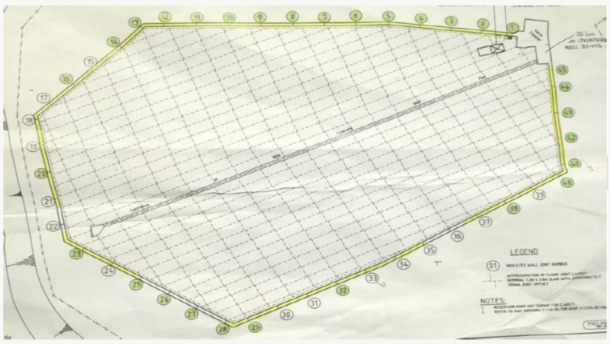
Hunter Water Corporation (Hunter Water) is a state-owned corporation (SOC) responsible for providing quality water, wastewater and storm water services for over half a million people in the lower hunter region. Theor services include operation, management and maintenance of systems for the supply of drinking water, collection of treatment of wastewater, the provision or recycled water and storm water services.

Hunter Water's area of operations covers some 5,366 square kilometres and incorporates six local government areas across a diversified landscape encompassing the vineyard and farming regions of Cessnock, Maitland and Dungog, the ever-growing cosmopolitan areas of Newcastle and Lake Macquarie and the tourism peninsula of Port Stephens.

Constructed Circa 1939 *(formally named Stoney Pitch Reservoir)* from gravity mass concrete walls and an unreinforced concrete slab on grade floor placed on bedrock, the structure has a floor area of 11,000sqm, providing critical drinking water reserves for the Hunter region.

The major axis length of the asset is 135L/m and a minor axis length of 90L/m and a total perimeter of 410L/m with reservoir capacity to store 86ML of potable water.

Agricultural drains are installed under the floor slab just inside the wall of the reservoir with seepage drains installed around the walls and the perimeter around foundation level. Both the internal and external drains discharge to four separate outlets at the toe of the embankment.



Site plan of Black Hill Reservoir.


Hypalon Bandage system (bonded using epoxy paste) installed to vertical joints and wall/floor intersection.


Cracks in existing concrete floor slabs

Originally the reservoir was open top, however during the 1990's a steel support structure was installed to support metal sheet roofing, primarily to prevent contamination from a Cryptosporidium outbreak at the time and to reduce evaporation.

The concrete floor consists of staggered rectangular slabs, each measuring approx. 3.6m x 7.2m x 230mm thick, with a concrete toe slab extending around the perimeter of the floor approx. 600mm out from the walls.

The joints between the concrete slabs were originally 'V Shaped', measuring approx. 50mm x 80mm (nominal) and filled with a rubberized bitumen sealant with approx. 5,000L/m of floor joints.

The reservoir is periodically cleaned to remove accumulated sediment and maintain hygiene. This was typically undertaken using a squeegee attached to a rubber tracked bobcat as well as high pressure water blasting, which was costly as it required pumping the water from the reservoir to other water retaining assets within the network during cleaning, then pumping the water back into the reservoir. Cleaning is now undertaken using divers and a vacuum system so removing the water is not required.

DISCUSSION

Excessive seepage was historically observed at the drainage outlets with the seepage occurring through deteriorated joint seals, cracks in slabs and from excessive joint movement. In 2016 works were undertaken to seal wall and floor joints, which were identified as being the most significant contributors to the water seepage.

Prior to any remedial works being undertaken (2016), it was estimated the asset was losing approx. 1ML of water per day, which represented considerable environmental and financial impacts.

In 2016 all wall joints and the floor to wall joint intersection joint were installed with a Hypalon rubber membrane embedded in epoxy paste which reduced the amount of water loss, however water loss from the asset remained substantial.

The concrete floor slabs were showing an exposed aggregate profile, and most had a full width crack along the minor axis in line with the joints of the adjacent slabs and there were minor cracks, spalling & defects in the 600mm toe slab. The crack widths in concrete slabs varied in size but were no larger than that of the floor joints.

Surveys in 1999 found that there has been minor vertical movement in the floor (up to 5mm) between emptying and filling the reservoir. There was 1km of cracks in the floor slabs.

PROJECT SCOPE

The principal objective of the scope was to address the leakage from the reservoir by sealing the joints and cracks on the floor of the structure and on the internal perimeter toe slab and waterproofing the internal floor surfaces. The waterproofing system was required to achieve a minimum anticipated 20-year service design life before first major maintenance and be certified for contact with potable water to AS/NZS4020:2005.

The joint waterproofing system needed to be sufficiently flexible and structurally sound to accommodate the observed movement of the walls and floor slabs and expected stresses associated with the ongoing use of the site (including daily partial depletion and filling and periodic emptying for maintenance).

THE CHALLENGES

No condition assessment had been undertaken to identify the locations, length, width and depth of the cracks and how the cracks should be remediated, with the condition assessment and repair methodology left up to the subcontractor and product supplier, which was difficult at the time of tender as the tank was in service and full of water so there was no opportunity to undertake an inspection.

Tender discussions progressed until a site inspection was attended by representatives from Hunter Water Corporation, the applicator (McElligott Partners) and product supplier.

Following the site inspection Hunter Water Corporation advised they would issue a contract, however as the asset needed to back in service prior to Summer, the construction program was only six (6) weeks, therefore Fast Return to Service (FRTS) and application to SSD concrete capabilities of the waterproof coating was critical.

Upon the condition assessment, HWC also requested to waterproof the entire 11,000sqm floor area in an attempt to further reduce the potential of water loss through the concrete slabs, which significantly increased the volume of product required.

With a very short construction program, a two-component advanced, polymer modified cementitious coating was chosen because product could be applied to damp SSD (saturated surface dry) concrete and as the concrete was damp during application, products not tolerant of substrate moisture were not considered.

As the chosen cementitious coating is manufactured in England, there was a substantial amount of operational work undertaken to procure the 60T of material and airfreight to Australia.

Further challenges with x-raying the material posed problems with the scanning equipment at Heathrow Airport (LHR) unable be effective to scan each pallet of Part A powder, so the decision was made to individually scan each bag, total of 2,000 bags.

Due to the high porosity of the concrete floor slabs, it was decided to "double prime" with water based acrylic bonding agent to minimize outgassing and improve adhesion of the cementitious coating.

Generally cracks were full of water so the nominated system needed to be damp surface tolerant.

Generally cracks were full of water so the nominated system needed to be damp surface tolerant.

WHY A CEMENTITIOUS COATING WAS SELECTED

The properties that were required of the selected material included the following:

- Excellent waterproofing capabilities – resists up to 10 bar (145 psi) positive and negative pressure
- 30 years successful track record
- Can be used on damp and green concrete ensuring rapid return to service
- High resistance to freeze thaw cycles from -36°C (97°F) to 180°C (356°F)
- 2mm coating provides concrete cover equivalent of 100mm for resistance to chloride induced corrosion
- Approved to EN1504-2 (Protective Coatings)
- Zero VOC*, water-based technology ideal for use in confined spaces
- Multiple potable water approvals including being listed under DWI Regulation 31, AS/NZS 4020:2005, and WRAS approval.

Flexible Sealing Tape over joints is tear-resistant, flexible waterproofing material with good resistance to a wide range of chemicals, used in-conjunction with advanced cementitious coatings to provide an impermeable seal over 'live' cracks and expansion or construction joints.

- Excellent waterproofing capabilities – resists up to 10 bar positive and negative pressure
- Permanently flexible with 600% elongation and is highly tear-resistant
- Classified as a breathable material (BS EN 7783-2:1999) and so allows free passage of water vapour

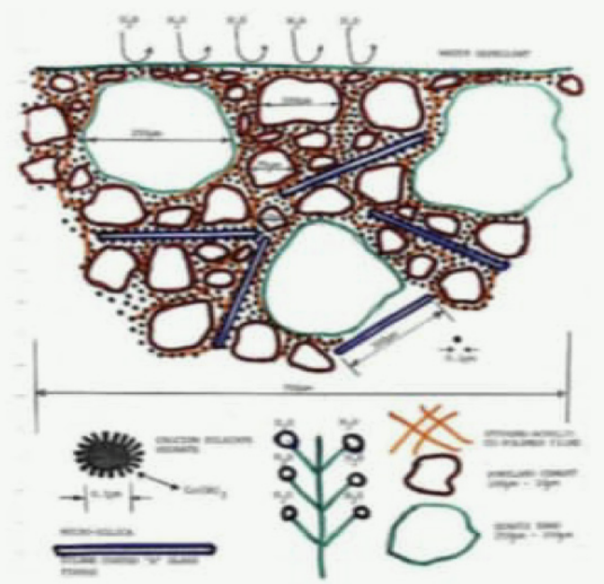
- Versatile system capable of accommodating movement in many different situations
- Can be used on damp or green concrete and steel surfaces
- Certified to AS/NZS 4020:2005 standards for the potable water applications

THE TECHNOLOGY

Formulation of high-performance Cementitious coatings (providing a coating with very low permeability).

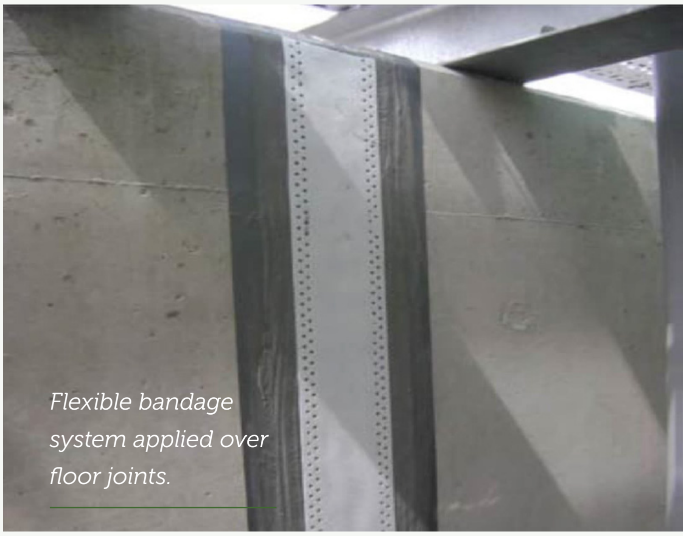
- Low water: cement ratio.
- Pozzolanic materials such as fly ash.
- Micro-glass fibers.
- Silica fume*.

*This modification in the pore structure also affects other properties resulting in 2mm coating resisting 10 bar hydrostatic head of water pressure (100m head of water). Gas diffusion resistance is also enhanced so that 2mm will provide the same resistance to carbon dioxide as 100mm of good quality concrete.



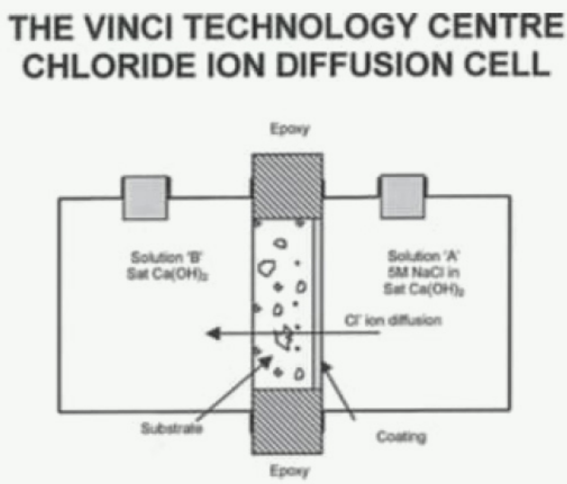
Cementitious Coating under Microscope

The test cells were maintained at 23±2°C and the chloride diffusing though the specimens was determined at various intervals. The accuracy of



Flexible bandage system applied over floor joints.

the method was checked using control samples of known chloride content (0.10±0.01%, by weight of sample). Taywood Engineering Test Procedure (No. TP014H/85/2763) *Determination of Chloride Ion Diffusion.*



METHOD OF APPLICATION

The cementitious coating was mixed in bulk using a rotor stater pump and flow applied onto the concrete slabs. The applicator (McElligott Partners) was careful to ensure a wet edge was maintained on the material. The material was constantly checked for correct WFT (2mm) and immediately spiked rolled to remove any air that was entrained in the freshly applied coating.

Panoramic photo of the installed waterproof coating.

CONCLUSIONS

Advanced cementitious coating systems have more than 30 years of successful track records in the water industry and therefore achieved the minimum 20-year service design life extension.

60T of Advanced Cementitious Coating was supplied for waterproofing the floor, along with 6km of flexible bandage for providing durability over the existing cracks and expansion joints.

The asset was returned to service on time and subsequent measurement of water volume shows very minimal water loss remains, which is most likely through walls. Waterproofing of walls is being considered.

ACKNOWLEDGEMENTS

McElligott Partners
2-6 Hume Road, Laverton North, Victoria, 3026

Hunter Water Corporation (HWC)
36 Honeysuckle Drive, Newcastle, 2310

AUTHOR DETAILS

David Johnstone has worked in the construction chemical and coatings industry for the past 23 years, predominately with concrete repair, engineered coatings, waterproofing and performance flooring systems, in roles from applicator, technical sales, strategic business development and people management.

His current role is Regional Maintenance & Repair Manager, Strategic Accounts, South Asia, managing a sales team targeting maintenance opportunities in various market segments including Oil & Gas Downstream, Mining & Infrastructure market segments, offering our range of protective linings and specialist services including digital asset integrity survey program, equipment rental and applicator certified training.

David is a qualified SSPC Level 2 Concrete Coatings Inspector and qualified NACE Level 2 Coating Inspector.

Concrete Institute of Australia (CIA)
South Australia Branch President (2012-2015)

Concrete Institute of Australia (CIA)
South Australia Committee Member (2002 to 2016)

- SSPC Level 2 Concrete Coatings Inspector – ID#: 69879
- NACE Level 2 Coating Inspector – ID#:61150

BRANCH REPORT
QUEENSLAND

Upcoming Technical Event: Protective Coatings Insights
Wednesday 30 July 2025 | Cairns

The Queensland Branch is excited to announce plans for an upcoming technical event in Cairns, set to take place on Wednesday 30 July.

The session will cover a range of practical topics related to protective coatings, including an introduction to the newly released AS 2312.3 (Thermal Metal Spray Coatings), insights on coating repairs, and how structural steel design impacts coating performance.

Further details and speaker confirmations will be shared soon. Keep an eye on our Upcoming Events page for registration info when it becomes available: https://www.corrosion.com.au/events/upcoming-events/

BRANCH REPORT
NEWCASTLE

Upcoming Event Planning:
Coatings Seminar | September 2025

The Newcastle Branch is currently in the planning stages for a Coatings Seminar to be held this September in Newcastle.

The event will focus on protective coatings, practical applications, and local industry insights. We're calling for expressions of interest from potential speakers, if you'd like to present, please contact frances.marshpaaki@corrosion.com.au.

Stay tuned for more details and registration info via our Upcoming Events page: https://www.corrosion.com.au/events/upcoming-events/

BRANCH REPORT
SOUTH AUSTRALIA

Event Recap: A Young Corrosion Group Forum
Bridging Research and Industry:
Thursday 24 July 2025 | UniSA – Future Industries Institute

The SA Branch, in collaboration with the Young Corrosion Group and UniSA's Future Industries Institute, hosted a successful evening focused on connecting early-career professionals with industry.

The forum featured engaging talks on corrosion science, surface engineering, and strategies for bridging research and real-world applications. Attendees included students, engineers, researchers, and industry professionals, all keen to explore collaboration and career development in corrosion and materials science.

For those interested in future events like this, visit our registration page: https://events.blackthorn.io/5j1hxgo7/4a2ZObwL2T

70th Anniversary Event: Thursday 21 August 2025 Billie's Bites & Bar, South Wharf, Melbourne

The Victoria Branch will proudly mark the 70th anniversary of the Australasian Corrosion Association (ACA) with a special evening event in Melbourne.

Attendees will be treated to a memorable presentation, "70 Years of Progress: Reflections from ACA Life Members", featuring insights from Bruce Hinton, Rob Francis, and Richard Brodribb. They will share personal stories, industry milestones, and the evolution of corrosion practice in Australasia.

Held at Billie's Bites & Bar, the event combines knowledge-sharing and celebration, honouring the legacy and future of corrosion professionals across the region. Register now to avoid mission out on recognising this important milestone.

Registration Link: https://events.blackthorn.io/5j1hxgo7/4a2ZObt2CT

MINISTERIAL VISIT TO MEMBER COMPANY

On 4 June'25 the Minister for Small Business and Manufacturing, Chris Penk, braved a very wet and windy Wellington afternoon to visit the Porirua factory of ACA Platinum Corporate Member, Steam and Sand. He was accompanied by members of his staff, and representatives from MBIE and Standards NZ. Also present was Elenora Stepanova, Steam & Sand's PCCP auditor and Executive Officer from CSIRO in Melbourne, and ACANZ members Matt Vercoe and Willie Mandeno.

Steam & Sand's GM, Matt Trail, led a tour of their facilities that included seeing the NZ first custom made WIWA plural component spray for 100 percent VS epoxy intumescent coatings and a demonstration of zinc metal arc spray. This was followed by a demonstration by Director Holly Harding of the unique software she developed (ie BLAST © FoxDog Ltd), to track their jobs using operator and inspector smart phones to produce progress reports, QC records

and invoices. This was of particular interest to MBIE staff and Hon Chris Penk, who is also the Minister for Building & Construction who is introducing changes to the Building Act to allow qualified contractors to self-certify their work.

ACA NZ President visits the SouthMach trade exhibition Christchurch, 27th May 2025

The ACA NZ Branch President Grant Chamberlain recently attended the SouthMach trade exhibition held at the Wolfbrook Arena, Christchurch, on 27th May 2025. The exhibition was very interesting, with lots of high-tech equipment that included some displays of interest to corrosionists. These ranged from the equivalent of the well-known PA10 protective coating in an aerosol can to high-tech compressors.

For people interested in CP there was a firm selling NZ-made specialised electric cables. There was a display of a range of air compressors, abrasive blast hoppers, wheel abraders, and cabinets for the abrasive blasting industry. Grant also attended a seminar talk on preventive maintenance, which discussed a recent Cook Strait Ferry issue.

The wide range of "state-of-the-art" technology was impressive. As they say, you don't know what you don't know.

For students looking for career options, this biennial engineering and machinery exhibition could be inspirational.

Technical Event: Protective Coatings Theme Wednesday 25 June 2025

The NSW Branch was proud to host a successful Technical Event with a Protective Coatings theme, drawing strong interest from across the local corrosion community. With over 40 attendees, the evening brought together industry professionals for insightful presentations, networking, and knowledge-sharing.

The event featured three expert speakers:

- Sam Hughes (Freyssinet) shared insights from a remedial engineering perspective
- Ryan Houston (BlueScope) covered materials investigations and inspection practices
- Vincent Wong (Ironbridge Engineering, ACA Young Corrosion Group) discussed developments in material testing and remedial strategies

Based on the positive engagement, we consider the evening a great success and are now planning our next event for September/November.

Our Industry to Academia program continues to gain momentum. We've received enthusiastic feedback from UP Education (Acknowledge Education), who have requested ongoing presentations following a successful session earlier this year. We're also preparing for our second round of technical presentations at Sydney UTS later this year.

Additionally, we've delivered three Lunch and Learn presentations to engineering firms in 2025 and plan to continue offering these throughout the year.

Overall, the NSW Branch is operating with strong purpose. We are currently conducting surveys to guide future decisions and are reviewing strategies to engage more effectively with key architects across NSW.

Looking ahead, I would also like to focus on increasing ACA member engagement in NSW over the coming months. We'll explore potential methods to support this initiative at our next branch meeting.

The NSW Branch extends a sincere thank you to our 2025 Branch Partners: Dulux Protective Coatings and Remedy Asset Protection for their valued support, and to everyone who attended and contributed to the success of the night.

Featuring Philip Horsford, General Manager of Zerust Integrity Solutions and their local distributor Red Tail Group (RTG), the WA branch held a technical event on Thursday 10th July, where Philip presented "Volatile corrosion inhibitor (VCI) based integrity solutions". The discussion provided deep insights into pipeline casing protection, equipment preservation, and spare parts management. Through recent project case studies, Philip and David Chetty (RTG) demonstrated the practical effectiveness of VCI technology in preventing corrosion, offering valuable strategies for maintaining the integrity of critical infrastructure.

The event highlighted the growing importance of advanced corrosion prevention methods in industries where equipment lifespan and reliability are crucial. Philip's presentation highlighted how VCI technology not only safeguards valuable infrastructure but also helps reduce long term maintenance costs and downtime, making it a critical component of modern integrity solutions. More than 30 attendees engaged in networking opportunities before hand and discussions following over a refreshment and bite to eat. Overall it was an enlightening evening for everyone involved and fantastic to see many familiar faces enjoying our technical events.

A special thank you to our Event Sponsor, Red Tail Group and Zerust Integrity Solutions, and the WA branch committee for making this event possible.

Paul Mukhin

Paul is a Business Development Officer at Alkyon, where he works to commercialize the remedial solutions of the company and identify new opportunities for services in the sector.

On a daily basis, this means undertaking research on the big questions of remedial solutions both from Alkyon and the sector, and writing papers and articles on the matter to educate others in the sector.

His background is in science, and he also works on international environmental governance matters. He also has an academic focus on industrial ecology and the study of human society's material demands.

Q1.

What is your current level of membership with the Australasian Corrosion Association (ACA), and how long have you been a member?

Individual Membership, since the end of 2023.

Q2.

What state or region are you representing within the Young Corrosion Group (YCG), and what is your current role or position? How long have you been in this role, and in what ways do you contribute to the group's activities and goals?

In New South Wales, and am currently the Chair of our Young Corrosion Group for over half a year now. Before being the Chair, I was a member of the YCG Subcommittee for almost as long as my membership.

The main tasks I undertake is coordinating and planning webinars, socials, and other events with the rest of the subcommittee members. What this mostly looks like is discussing with each other what we want the technical side of a webinar to look like or what sort of social gathering we want to hold next, sending out the emails and write-ups to everyone involved in that, then finally letting it run on the day and usually enjoying either a good chat or to see each other face-to-face in a nice setting.

Q3.
In your own words, what is the Young Corrosion Group (YCG), and what role does it play within the ACA?

The YCG is a place for people of a similar demographic and professional development stage to come together, share their experiences, and socialise with similar people. Most of us are roughly at the same stage of professional career, having good knowledge on our technical expertise but lacking the 30+ years of networking that older members of the ACA have. Similarly, most of us have similar life experiences and cultural norms, so is nice to chat with one another about matters that older demographics aren't able to.

Q4.
What motivated you to become a member of the YCG, and what have you gained from being involved?

My primary motivation was to learn about and contribute to the Association, volunteering my time to help run development and social opportunities for other young professionals, while also figuring out how the organisation operates so I can go further with my studies and work. Since then, I've gotten a fairly strong understanding of everything.

Q5.
What inspired you to pursue a career in corrosion science, engineering, or asset integrity?

My motivation was to make a tangible positive impact on our material bound world in the face of major challenges such as climate change and gradual resource depletion. Our society is fundamentally dependent upon the materials we extract and our methods of turning them into goods and services, and while our current industrial base has given many of us material wealth, it's come with several challenges, most notably climate change. As such, if we want to live in a stable, secure, and rich world, we really need to address this matter in the appropriate way. As a general rule of thumb, most economies saturate their need for various resources at a rough GDP per capita, so as the economy grows, steel demand wouldn't have increased as much as it did in the past, and instead of new steel going into new building stock, larger amounts go into maintaining degrading building stocks instead. As such, one of the greatest ways that we can reduce CO2 emissions and degradation of our finite natural resources is extending the life of our assets as greatly as possible. It's for this reason that I entered the sector, seeing the opportunity to commercialise a breakthrough remedial method to address carbonation-induced corrosion of reinforced concrete through passive realkalization. It's with this that I see the greatest opportunity to maximize my impact.

Q6.

From your perspective, what are some of the most pressing corrosion-related challenges facing your sector today, particularly in the Australasian region?

A combination of knowledge on corrosion generally, alongside adoption of innovation. Despite often being the issue which can prematurely end the life of assets and necessitate replacement, many asset owners and policymakers appear to lack understanding on the preventative and remedial measures to address corrosion issues which can significantly save money and time. We see how carbonation-induced corrosion can be addressed with a range of proactive remedial measures, though too often we see assets run to dire states requiring repairs at a magnitude greater costs. The other matter is on the adoption and assessment of innovations, particularly understanding the strengths and limitations of the practices we use to address corrosion issues. We see new solutions emerging regularly, though a lack of knowledge on how to assess them and their performance against other remedial measures appears to limit to our ability to adopt more affordable or easier solutions.

Q7.

How have the ACA and YCG supported your early-career development in corrosion? Are there any specific programs, events, or people that have helped shape your journey?

In general, the networking and technical events have been great to ground oneself on the current affairs and hot topics in the sector, finding out what the big developments are over the coming months in the policy sector or industry developments, as well as where the gaps in knowledge and opportunities lie.

Q8.

What advice would you give to other young professionals or students who are interested in joining the YCG or pursuing a future in corrosion?

There's a range of engagement you can do with the organization, whether you want to join for social opportunities, learn more about your technical field, or contribute towards your peers professional development.

AEC – ACA Vic Branch Joint meeting

02 May 2025

The Australasian Electrolysis Committee (AEC), which is also the Cathodic Protection (CP)Technical group of the ACA, held its half-yearly meeting in May at the ACA's Preston office.

In collaboration with the ACA's Victorian Branch, the event brought together a mix of in-person and online attendees. More than 50 participants joined virtually, while a solid local turnout made the most of the face-to-face format – and the hospitality, with morning tea, lunch and afternoon tea kept conversations flowing throughout the day.

Chaired by Dr. Bruce Ackland, with the support of Alireza Kouklan, the meeting offered a valuable platform for corrosion protection professionals to engage in real-world challenges and exchange practical insights with industry experts. These joint gatherings are a hallmark of the CP community - open, collaborative, and rich in technical depth.

For anyone in the Cathodic Protection field these meetings are a great opportunity to discuss CP issues, either online or in person, in a friendly manner with people who know that area well.

A wide array of topics were explored and discussed with the audience by leading voices in the field, including:

- Updates from NSW Electrolysis Committee.
- Classic paper review.
- Demonstration of closed-loop CP.
- Modelling DC stray current interference.
- Proposed changes to Victorian Electrolysis (VEC) standards.
- Discussions on AC corrosion and the impact of data logging.

The formal presentations wrapped up with a lively Q&A session, chaired by Richard Brodribb, where the topical questions sparked robust discussion and audience participation.

The day concluded with the AEC Annual General Meeting (AGM) – conducted with customary speed - wrapping up a successful event that reaffirmed the value of collaboration across the corrosion and CP community.

Whether attending in person or online, participants left with new insights, stronger networks, and a renewed enthusiasm for tackling the technical challenges of CP.

Event Recap:
95th Cathodic Protection / AEC Technical Group Meeting

Held at ACA Head Office, Preston & Online | 70+ Registrations

The 95th meeting of the Cathodic Protection / AEC Technical Group was held in a hybrid format, bringing together over 70 participants both in-person at the ACA Head Office in Preston and online. The strong turnout and lively engagement made for a highly successful event.

The program featured a mix of technical updates, research insights, and industry knowledge-sharing. Highlights included a review of classic cathodic protection papers, field demonstrations of emerging technology, and updates on electrolysis impacts and stray current management. A key focus of the day was the evolving role of remote monitoring and data logging technologies in CP systems.

The afternoon session encouraged open discussion across a range of industry-relevant topics, from backfill materials and AC/DC train interference to LFI/EPR incidents and monitoring solutions. The event concluded with a Q&A hosted by the Victoria Branch, followed by the group's AGM.

Thank you to all speakers, participants, and organisers for contributing to another valuable and collaborative technical session.

Water Industry Group Water Seminar – May 2025

Proudly Sponsored by Remedy Asset Protection | Venue: SA Water

Held in May 2025, the ACA Water Seminar brought together over 40 industry professionals for a full day of knowledge sharing focused on the protection, maintenance, and sustainability of water and wastewater infrastructure.

The seminar covered a range of topics relevant to the water industry, including the use of 3D printing in infrastructure applications, sustainability considerations for sewerage systems, and approaches to assessing the condition of ageing assets. Sessions also addressed asset quality through testing, welding, and protection of materials used in contact with drinking water. Maintenance planning and strategies for extending asset life were discussed, along with a panel session that explored practical approaches to asset inspection under the WSA 201 framework. The seminar highlighted practical innovations and technical solutions to support long-term asset performance and sustainability in the water industry.

Thanks again to all speakers, attendees, and organisers. We look forward to continuing the conversation at future ACA events.

Thank you to Remedy Asset Protection for sponsoring the event and to SA Water for providing the Learning Centre as the venue.

Applicator & Coatings Groups Event Recap:

Applicator & Coatings Roadshows – Sydney & Perth 2025
Proudly supported by our Major and Supporting Sponsors

Our national Applicator & Coatings Roadshow 2025 kicked off with two powerhouse events in ***Sydney*** *and* ***Perth****, bringing together industry professionals for a full day of technical presentations, hands-on demonstrations, and sector insights.*

In **Sydney**, attendees enjoyed a packed agenda featuring expert talks, real-world case studies, and a high-impact outdoor demo by **MCU-Coatings® Aus/NZ**, our Major Sponsor. The day highlighted everything from protective coatings performance to surface preparation innovation.

Perth followed with equal energy, drawing around 80 participants to **BlastOne's Henderson facility**. With a focus on field-applied pipeline coatings, atmospheric corrosion protection, and anti-abrasion systems, the event also featured dynamic outdoor demos from **BlastOne, Denso, MCU-Coatings,** and **Universal Corrosion Coatings**.

Both events showcased the latest in coating technologies, application techniques, and asset protection strategies, made possible thanks to the generous support of our sponsors:

Major Sponsors: MCU-Coatings® (Sydney), BlastOne (Perth). **Supporting Sponsors:** AkzoNobel, Remedy Asset Protection

A huge thank you to our attendees, presenters, demo teams, organisers, and ACA staff for delivering two seamless, high-impact events.

Next stop: New Zealand!
Auckland and Christchurch — get ready, we're heading your way.

For more information, programs and registration, please see: https://www.corrosion.com.au/coatings-roadshow-2025-auckland-new-zealand/

***Webinar* - Concrete Structures & Building Technical Group**

This webinar is essential for professionals seeking to stay at the forefront of developments in concrete technology and standards. Don't miss this opportunity to deepen your understanding and engage with industry experts.

Presenters:

Frank Papworth; Building & Construction Research & Consultancy (BCRC) - Managing Consultant. Presentation Title: Concrete Durability and fib Model 2020

Justin Rigby; Remedy Asset Protection – Director. Presentation Title: Australian Standards Proposal for Adoption of EN1504 for Concrete Repair

Registration Link: https://events.blackthorn.io/5j1hxgo7/4a2ZObwJwj

***Webinar* – Oil, Gas & Energy Technical Group. Hosted by the Oil, Gas & Energy Technical Group**

Join us for an exciting online session showcasing the latest research and real-world projects from the next generation of corrosion professionals in Australia.

This webinar will feature insights from:

- A PhD candidate from Curtin University
- A graduating student from Deakin University
- A graduate engineer from Santos

Get a glimpse into the future of corrosion science and industry innovation as these rising experts share their current work and perspectives.

More details coming soon — stay tuned via this link: https://www.corrosion.com.au/events/upcoming-events/

***Webinar* – Young Corrosion Group Report: An Insight into the ACA's Young Corrosion Group + Corrosion in a Coastal Climate**

The National Young Corrosion Group (YCG) Steering Committee invites ACA members to join an engaging online webinar showcasing the group's activities alongside expert presentations on corrosion challenges in coastal climates.

The event features speakers from diverse sectors including the ACA, Concrete Institute of Australia, Australian Steel Institute, and RILEM. Presentations will cover contractor perspectives on coastal remediation, condition assessment of marine coatings using electrochemical methods, and more.

This webinar is open to all, with a special invitation to university students, young researchers, and early-career professionals interested in corrosion science and industry applications.

Confirmed presenters include:

- **Nate Berends (VIC):** Contractor's perspective on remediation in coastal environments
- **Joe Davies & Geoffrey Will (QLD):** Condition assessment of marine coatings via electrochemical impedance spectroscopy
- **Michael Widjaja (WA):** Topic to be confirmed
- **NZ Presenter:** To be confirmed

Wednesday 30 July 2025 | 1:00 PM AEST | Online via Zoom
Register here: https://events.blackthorn.io/5j1hxgo7/4a2ZObvedR

News from the ACA Foundation Chairman

Wayne Burns, Chair – ACA Foundation Limited

The Australasian Corrosion Association Foundation has finalised their drive for sponsorships for education scholarships and attendance at the 2025 Corrosion and Prevention Conference in Melbourne in November. We have had an overwhelming response with the many of companies confirming their support for the next three years. We are grateful for the generous donations, which is an incredible show of support, and we are so thankful for the generosity of the sponsoring companies.

Your financial support has enabled The ACA Foundation to grow. It is making a huge impact on our mission of promoting corrosion education opportunities for the community generally. We can't thank sponsors enough for believing in us and supporting the ACA Foundation. The investment by sponsoring companies and individuals is a terrific commitment in our cause to sustainably develop the future generations in the corrosion prevention and asset management industry.

The ACA Foundation offers annual scholarships to ACA members and the community generally. In collaboration with the Australasian Corrosion Association, we assist persons and associates in the field of corrosion prevention and corrosion asset management to either attend recognised training courses or attend the annual Corrosion & Prevention Conference. The scholarships are made possible through the generous support from corporate partners who aim to foster and support the professional development of our future technical community. This support mechanism includes partnerships with kindred associations who often share similar objectives in this amazing field of corrosion and its prevention.

The ACA Foundation has posted on our web site details for the 2025 scholarship applications. This details key information about the ACA Foundation's mission and how to submit your application. Also included is our 2025 prospectus for new sponsors.

Links to our 2025 supporting sponsor companies have also been added to this Call for Applications page, to highlight the support from and commitment by our sponsors to our cause. [please stay tuned]

ACAF Future Succession Planning

Following being awarded a scholarship at the Cairns ACA Conference, Board members were approached by Ms Maddie Huynh, expressing her gratitude plus her ongoing enthusiasm to participate in future growth ideas for our young corrosion management community. This has seen Maddie offered a trainee directors role on the ACAF board.

It goes without saying that the ACAF Board, and on behalf of all of its sponsors and donors, that it is offers such as has been made by Maddie, which makes all our efforts worthwhile.

Below is a message received by the Board from Maddie; however we would like to reiterate that many of the ACAF Scholarship recipients also share Maddie's feelings (see our web site for more acknowledgements).

My name is Maddie Huynh, and I had the privilege of crossing paths with you during the ACAF board meeting at the ACA conference 2024. I am immensely grateful to have received the Final Year Student ACA Conference Scholarship, generously sponsored by Infracorr Consulting P/L. This scholarship has profoundly enriched my experience as a student at the conference, further fuelling my passion for learning and growth in the field of corrosion studies. Additionally, I was deeply inspired by the conference last year, particularly by the close-knit committee and the remarkable sense of community support. I would be honoured to contribute as part of the committee if the opportunity arises. Although I am still early in my career, I have some experience working with committees and am eager to bring enthusiasm and a willingness to learn. If a committee position is not yet feasible, I would still love to assist and get involved in any capacity.

Maddie is now on the ACA Foundation board as Trainee Director and an active member of the ACA Foundation sponsorship team. We hope that other YCG members might also show similar enthusiasm to potentially participate in the growth of the ACAF fund raising programs and help grow the support for careers within the corrosion management and asset integrity industry across the many educational platforms in the community generally.

New ACA Foundation Scholarships.

We are pleased to announce that Carboline NZ, Metspray, CRL, CPT & Freyssinet have each agreed to sponsor new ACA Foundation awards. We also wish to acknowledge the ongoing support from Denso Australia, Infracorr, Marine & Civil and UCC. These scholarships will contribute towards the cost of attending the ACA Conference or an ACA training course.

Please visit https://www.corrosion.com.au/foundation/ for more information.

Denso® CORROSION PREVENTION
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MCM Marine & Civil Maintenance
UCC

CONSTRUCTIVE ENGAGEMENT: A Draft Guidance for PCBUs, Keeping healthy and safe while performing Abrasive Blasting in New Zealand

By Paul Griffin, Managing Director, Blast Worx Limited

The corrosion industry is marked by a rich diversity of experience, opinion, and approaches. This variety of perspectives—shaped by operational demands, regional regulations, and evolving standards—is both a strength and a challenge as we strive to develop safer and more consistent practices across Australasia.

Recently, I submitted a **Draft Guidance for Persons Conducting a Business or Undertaking (PCBUs)** for review and input relating to **Abrasive Blasting in New Zealand.** This draft is not a final or WorkSafe New Zealand–endorsed document. Rather, it is an early step in what must be a collaborative process. The goal is to provide a practical, constructive contribution to the ongoing conversation around corrosion management practices, particularly those that directly impact worker safety and long-term asset performance.

The draft guidance document has been modelled off the Australian Code of Practice, serving as a foundational framework for its structure and content. However, all references to legislation, regulations, and legal obligations have been carefully reviewed and adapted to align with current New Zealand Acts and Regulations. This ensures that the guidance is both locally relevant and legally compliant, reflecting the unique regulatory environment of New Zealand while maintaining the proven best practices established in the Australian model.

It's important to clarify that this draft was never intended to speak on behalf of all suppliers or stakeholders in the industry. I fully recognise that the corrosion and protective coatings sector in New

Zealand—and indeed internationally—includes a wide range of viewpoints and operational models. That diversity is invaluable, and any successful guidance must reflect it.

This draft guidance document provides a comprehensive overview of critical health and safety responsibilities across various workplace environments in NZ. It outlines who holds specific duties under relevant legislation, ensuring accountability at all organizational levels. Core topics include the identification and management of workplace risks, supported by strategies for effective hazard recognition and mitigation. The importance of adequate training is emphasized to ensure workers are equipped with the knowledge and skills to maintain safe practices. Specific risks such as exposure to prohibited chemicals, dust, excessive noise, and heat are examined in detail, along with appropriate control measures. The document also covers the safe handling and disposal of waste materials, reflecting best practices and regulatory compliance. Special attention is given to high-risk areas, including work in confined spaces, where additional precautions and procedures are necessary. Overall, the document serves as a practical guide for employers, managers, and workers, promoting a proactive approach to health and safety in the workplace.

My intention was to **start a conversation**, not to dictate its direction. In doing so, I hope to stimulate discussion that leads to more refined, balanced, and applicable industry recommendations. This is especially critical in the area of **health and safety obligations**, where clarity and consensus can significantly impact outcomes for both businesses and workers.

I am passionate about our industry and deeply committed to the people who work in it. Corrosion control plays a vital role in infrastructure longevity, economic sustainability, and—most importantly—workplace safety. Every worker has the right to go home safely to their family at the end of the day. That ethos underpins everything we do and must remain at the heart of any guidance developed.

The process of drafting guidance is, by necessity, iterative. It requires open minds, expert critique, and input from a broad spectrum of stakeholders including regulators, industry practitioners, suppliers, engineers, and asset owners. I warmly welcome this involvement. If there are areas where the draft falls short—whether through ambiguity, omission, or lack of nuance—I am committed to reviewing and, where appropriate, revising it. Transparency and fairness are essential to credibility and uptake.

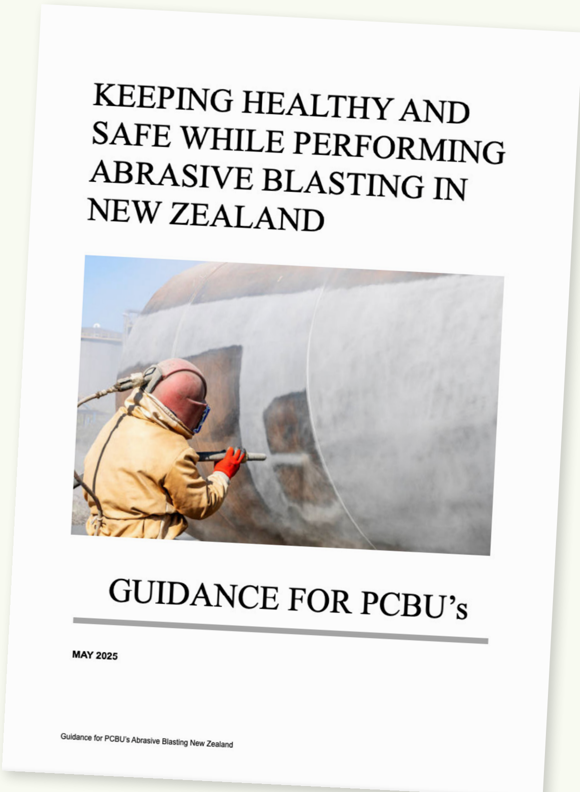
At its core, this draft document is a **beginning**, not an endpoint. It is a contribution toward the broader effort to align industry best practices with regulatory expectations, technical advancements, and on-the-ground realities.

Let's continue this dialogue together—openly, constructively, and with shared purpose. Our collective experience and passion for corrosion management can drive improvements that benefit the entire industry, and most importantly, the people within it.

To view this document, simply go to www.blastworx.co.nz website, scroll to the bottom of the page and you will find it under the resources tab.

For any correspondence, questions, thoughts or input please email paul.griffin@blastworx.co.nz

Reviewed by Willie Mandeno for C&M.



ANNOUNCEMENT

RPR Technologies AS is proud to announce that **Australasian Coating Removal Pty Ltd (ACR Tech)** has acquired a majority stake in the company, marking a significant step forward in its global growth strategy. ACR Tech, is Australia's premier induction coating removal company using electromagnetic heat induction to remove tough coating systems. This strategic partnership brings enhanced expertise and resources. Tom Arne Baann, CEO of RPR Technologies, welcomes ACR Tech's Luke Emery and Shannon Hobbs to the Board of Directors, where they will help steer the company through its next phase of innovation and expansion. "This partnership is a natural evolution of our shared vision," said Shannon Hobbs, Managing Director of ACR Tech. "The RPR Technologies induction solution is the unparalleled world leader in induction-based coating removal. We want to provide Australian based asset owners with a real choice—to remediate assets by integrating innovative, efficient, and environmentally responsible solutions. We're excited to be at the forefront of this shift and are committed to ensuring the continued development and global growth of this game-changing technology.

Device for Non-Intrusively Installing C.P. Isolating Joints on Pipelines

By Michael Molyneaux

Many buried steel pipelines for transporting water from reservoirs to purification plants and distribution networks in large cities are decades old and requirements for providing protection against corrosion are increasing. Cathodic protection is usually the most cost-effective solution, but introducing points of electrical isolation for retrofitting such protection systems can be challenging for pipelines in continuous service.

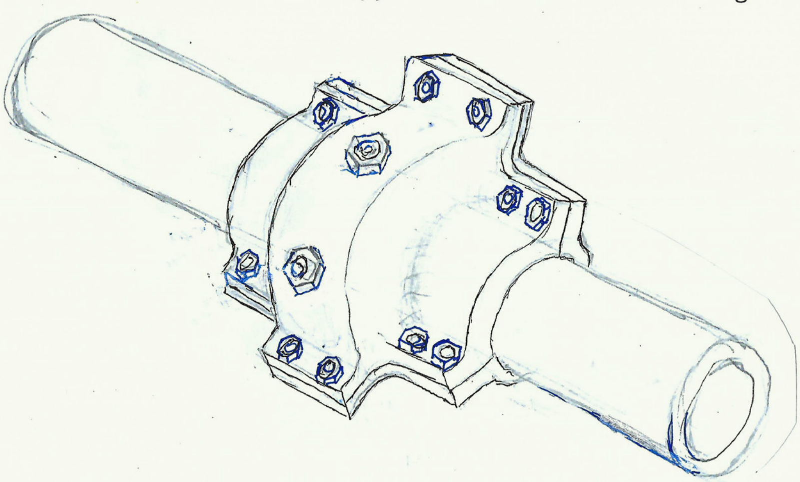
Similar challenges may be encountered with pipelines in hydrocarbon service where cathodic protection has become inadequate along limited sections or when neighboring buried structures or railway lines counteract or interfere with protection. An innovative method has recently been devised and a mechanical tool designed to introduce electric isolation joints on steel pipelines in these situations without taking them out of service to cut through the pipe.

Pipeline owners and operators will appreciate the value of this device when considering the high costs and usually week-long disruption of services to allow technicians to cut through a pipeline and weld either a monolithic isolating joint or a new flanged joint to establish the required point of electrical isolation.

A prototype of this innovative tool now requires fabrication and testing in a workshop situation to demonstrate ease of use and prove its value in the cathodic protection industry. For expressions of interest and more details, please contact the author.

Mechanical device for introducing an electrical isolation joint in a pipeline without taking the pipeline out of service

This illustration shows how the device will appear after installation and testing



Galvanise or Galvanize?

By Willie Mandeno

This article has been written to clarify the correct spelling of this and associated words, often confused by misunderstandings relating to the Americanisation of some English words (e.g. analyze and hypnotize) or use of 'Spellcheck' software. The use of -ize endings is preferred for words that derive from the Greek etymon -izein but according to Merriam- Webster, in the middle 1800s many British words borrowed the Middle French suffix, -iser (e.g. mobilise, polarise and galvanise).

The Oxford and Cambridge Dictionaries define galvanise (preferred British English spelling) or galvanize as "to cause someone to suddenly take action, especially by shocking or exciting them in some way".

Some history into the origins of these words follows:

Luigi **Galvani** was an early Italian researcher into bioelectricity who in 1780, famously reported twitching of (dead) frog legs hanging on a brass hook when touched with a steel scalpel. It was another Italian physicist, Alessandro Volta, who confirmed that the contractions were in fact due to an external (not internal) electrical current generated by dis-similar metals in contact and coined the term "**Galvanism**" to describe this effect.

The first patent for the process of protecting cleaned steel by dipping it in molten zinc was taken out in 1836 by Sorel in France, followed by a British patent granted in 1837 to William Crawford. They described the protection property offered by zinc to steel as "**galvanizing**".

This spelling has been codified in the titles of many relevant standards used in corrosion prevention both in Australasia and in Europe as listed below;

- AS/NZS 4680 Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods
- AS/NZS 1214 Fasteners — Hot dip galvanized coating
- AS/NZS 2312.2 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings — Part 2: Hot dip galvanizing
- ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods
- ISO 10684 Fasteners — Hot dip galvanized coating
- ISO 14713-2 Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel — Part 2: Hot dip galvanizing
- ISO 10348-2 Galvanized reinforcing steel products.
- AS/NZS 4792 Hot dip galvanized (zinc) coatings on ferrous hollow sections, applied by a continuous or a specialised process
- BS 7372: Part 6 Coatings on metal fasteners — specification for hot dip galvanized coatings

In our region, some galvanizers choose spelling following the Greek etymon, while others choose the Middle French suffix and use galvanising. In official publications from the GAA and GANZ, we prefer to use the codified version of galvanizer, galvanizing and galvanized.

Revised Galvanizing Standard

The 2025 edition of AS/NZS 4680 now provides a mandatory method for inspection of the coating thickness and significantly improves the wording around assessment of the inspection of appearance. Other key changes are to reflect modern steel making practices, particularly related to 'laser plate', provide details on the application of coating repair, while the Standard also provides guidance on specification of galvanized rebar including assessment inspection for AS/NZS 4671.

The new Standard reinstates the long-standing technical alignment with ISO 1461 (itself revised in 2022), although AS/NZS 4680 has a strong Australian and New Zealand flavour, reflecting local steel Standards, local renovation procedures, and improved language over the ISO Standard. It has also considered elements of ASTM A123, with an adoption of a local flow chart for measurement of coating thickness. Importantly for ACA GAA/GANZ HDG Inspectors, the methods incorporated into AS/NZS 4680 are the same as taught since 2016 in the Inspector Course, meaning an upgrade for existing inspectors will be relatively straightforward. The ACA and GAA/GANZ will be delivering an on-line refresher course over the next few months for all existing accredited inspectors to ensure the key changes are understood.

AS/NZS 4680:2025 is available in the Standards Australia store and New Zealand Standards store. Further information is available from the GAA by scanning the QR code (see the QR code below).

Standards activities over past 6 months.

By Rob Francis & Willie Mandeno

Standards published

[MT-009]

AS 1627.6, Metal finishing - Preparation and pretreatment of surfaces, Part 6: Phosphate and chromate conversion treatment of metals

AS 3715, Metal finishing - Thermoset powder coatings for architectural applications of aluminium and aluminium alloys

Publishing Date: 2025-02-28

AS/NZS 4680, Hot dip galvanized coatings on fabricated iron and steel articles – Specification and test methods

Publishing Date 2025-06-27

[MT-014]

AS/NZS 2312.3, Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings, Part 3: Thermal metal spray coatings

Publishing Date 2025-05-02

Standards under development

[CH-003]

AS 3894.1 (Site testing of protective coatings Method 1: Non-conductive coatings—Continuity testing—High voltage (brush) method) [CH-003]

Currently with SA editing team being prepared for Public Comment.

AS/NZS 2311 Guide to the Painting of Buildings [CH-003]

A proposal has been submitted to make minor changes.

Work continuing on reviewing approx. 80 aged standards on paints and related topics

Discussion of proposal for **AS 4049.4** Paints and related materials - Pavement

marking materials, Part 4: High performance pavement marking systems

[MT-014]

Kick off meeting for review and update of **AS 2312.1**:2014 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings, Part 1: Paint coatings

The committee endorsed reconfirmation of the following aged standards: **AS 4312**:2019, **AS 4827.1-**2008, **AS 4036-**2006, & **AS 2345-**2006.

Concrete Asset Inspections on Wastewater Infrastructure

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Keywords:

concrete diagnostic, concrete inspection, remedial concrete, concrete asset condition, concrete investigation.

Abstract:

Environmental exposure, poor concrete quality and aspects of structural design will affect the initiation and propagation of steel reinforcement corrosion. A relatively short time is required between the occurrence of the first visible crack along the reinforcement and actual structural damage. This paper describes concrete degradation prior to corrosion occurring on the reinforcing steel and explanation of how a diagnostic approach to asset inspection can be employed to meet and extend asset lifecycles. Discussion is provided on the embodied carbon of concrete materials and a case study of an asset inspection to a 90-year-old wastewater well.

INTRODUCTION

The processes of concrete degradation, resulting in corrosion of steel reinforcement, are dependent on exposure condition and concrete quality.

Exposure conditions cannot be controlled without relocation or change of processes. However, concrete quality can be controlled because it is influenced by the mix design, quality of the constituents, placement, compaction, curing conditions, design and detailing. The water-to-binder ratio together with the total binder content of the mix design, and the extent of curing afforded to the concrete, are key factors in controlling permeability and, hence, concrete durability.

When concrete is correctly placed, and exposure conditions remain static, the interaction between exposure and concrete quality will show a near linear deterioration over the lifecycle until the time that passivation of the steel reinforcement is lost and corrosion can initiate.

Using both as-built and in-service inspection data, modelling can be used throughout the structure's service life to identify the predominate degradation mechanism and predict asset service life. This information provides understanding of when interventions are most appropriate to prevent premature concrete failure or to ensure an extended service life.

An inspection of a wastewater infrastructure asset is discussed in this case study.

RELEVANT CONCEPTS

Concrete Degradation

Concrete quality and aspects of structural design affect the initiation and propagation of steel reinforcement corrosion.

The deterioration reactions occur mainly because of the transport of aggressive substances either from the environment to the concrete or internally within the concrete matrix. Moisture is required for most of the chemical reactions which cause concrete to deteriorate. By itself, moisture or water does not normally degrade concrete, rather it transports deleterious solids or gases into concrete and serves as an electrolyte to enhance chemical reactions.

The structural and crack control requirements in steel-reinforced concrete design propose that the steel be placed as close to the concrete surface as possible, where tension forces are high, to control crack formation. However, an adequate cover of good quality concrete to the reinforcement is needed to serve as a physical barrier against the ingress of aggressive substances.

The key environmental factors that initiate corrosion of steel are carbonation and chloride. Other factors which may influence either the initiation or rate of reinforcement corrosion include cracks in concrete, temperature, moisture, oxygen, chemical attack and inadequate concrete quality or cover.

Concrete Quality

The solution contained in the pore structure of concrete is highly alkaline as a result of cement hydration, with a pH of about 13 for Portland cements. The alkaline pore solution is particularly beneficial to steel reinforcement as it provides chemical protection in the form of a passive iron oxide film. This film is adherent and protects against corrosion.

High quality concrete can significantly retard corrosion initiation. This is because good quality concrete, made with low water-to-cement content ratio and suitable materials, well compacted and cured, has low permeability and hence a greater resistance to the ingress of liquids and gases.

Adequate concrete quality and cover to steel reinforcement is necessary because the transport of chlorides, atmospheric carbon dioxide and other aggressive substances occurs at rates that typically show a parabolic curve. This implies that if the concrete cover is halved, the time to corrosion initiation is reduced to about a quarter of the time [1].

The effect of cracks on the risk and severity of corrosion of reinforcing steel is determined by the origin, width, intensity and orientation of the cracks. CO_2 and chlorides tend to penetrate more readily towards the reinforcement along cracks compared to sound concrete.

Where the crack is perpendicular to the reinforcement, corrosion is usually confined to a small area. Cracks aligned parallel to reinforcement bars present a larger exposure area and thus a higher risk of causing damage from spalling of the concrete.

Exposure Environment

Environmental exposure will affect the initiation and propagation of steel reinforcement corrosion. Some of these are summarised below:

- Carbonation deteriorates reinforced concrete structures by reducing the alkalinity of concrete
- The diffusion of chloride ions into concrete from external sources is dependent on concrete quality, cement type, cover and exposure conditions. Alternating wet and dry exposure conditions severely enhances corrosion rates
- Chemical attack from sulphate, soft water or acidic solutions.

Furthermore, within AS 3735, four basic exposure classifications for exposure to chemical or penetrating agents are defined in terms of their resultant effect on a concrete member as follows [2]:

- **A –** Where the concrete is in a non-aggressive environment or is protected from aggressive agents. This classification may be appropriate for surfaces protected or isolated from the attacking environment or where a lower level of durability is applicable

- **B –** Where the concrete is in an aggressive environment but only subjected to agents to which normal concrete of adequate quality is resistant. This is the lowest category applicable to concrete members in contact with water or condensation
- **C –** Where aggressive agents will attack the concrete, but provision of a superior quality will enable the member to remain serviceable for the required design life
- **D –** Where the concrete is subject to an environment that will attack the concrete to such an extent that the required design life cannot be met, i.e. cannot retain or exclude the liquid in an acceptable manner.

During design, most water and wastewater structures fall into exposure classification B, concrete bunds for storage of sodium hypochlorite and other chemicals are group C. However, in-service exposure conditions are often dynamic and variable, and areas of early degradation occur where exposure is greatest.

Furthermore, biogenic corrosion and soft water attack need to be considered.

Biogenic Corrosion

Domestic sewage, both fresh and stale, is non-aggressive to concrete. The main risk is the anaerobic generation of sulphides within the sewage, which occurs particularly in slowly moving or stagnant systems. This results in the formation and release of gaseous hydrogen sulphide (H_2S) into the space above the liquid. H_2S combines with oxygen to form sulphuric acid and attacks the cementitious material of the concrete which leads to eventual structural failure.

Soft Water Attack

Soft water is water which has relatively low concentration of calcium carbonate and other ions and dissolves the calcium hydroxide Ca(OH)2 from the hardened cement paste, increases the porosity and reduces the alkalinity and strength of the concrete and therefore may initiate the corrosion of reinforcement.

Where Ca(OH)2 is leached from the concrete matrix, the concrete becomes weak and friable.

To determine potential for waters to leach Ca(OH)2, an approximate value of Langelier Saturation Index (LI) may be obtained from the equation (Clause 4.2, AS 3735):

$$L_I = pH\ of\ water - pH\ when\ in\ equilibrium\ with\ calcium\ carbonate$$

$$= pH - 12.0 + log10\,[2.5 \times Ca^{2+}\,(mg/L) \times total\ alkalinity\ (as\ CaCO_3\ mg/L)]$$

A negative value for LI means the water has a demand for calcium carbonate (CaCO3).

Lifecycle

Within major water retaining structures a design life is usually specified in accordance with AS 3600 which nominates up to 50 years ± 20%, and owners may seek greater design life for reservoirs and other structures [3].

Often the design life is not realised, primarily because of aggressive environments, combined with deficiencies in design, detailing, supply or construction, leading to corrosion of steel reinforcement which substantially reduces the service life of many structures.

In terms of the life of a concrete structure, concrete durability issues can be divided into four phases [4]:

- **Phase A:** Design, construction and concrete curing
- **Phase B:** Corrosion initiation processes are underway, but propagation of damage has not yet begun
- **Phase C:** Propagating deterioration has just begun
- **Phase D:** Propagation of corrosion is advanced, with extensive damage manifesting.

In these phases, $1 extra spent in Phase A is equivalent to saving $5 of remedial expenditure in Phase B, or $25 remedial expenditure in Phase C, or $125 remedial expenditure in Phase D [4].

A relatively short time is required between the occurrence of the first visible crack along the reinforcement and actual structural damage in the form of large prominent cracks running parallel to the steel reinforcement. When corrosion reaches an advanced stage, the concrete cover to the reinforcement simply delaminates and spalls off.

It is therefore advisable to manage degradation prior to corrosion occurring on the reinforcing steel. This requires a diagnostic approach to identify chemical degradation prior to physical signs of distress.

Sustainability

On the path to net-zero carbon emissions asset owners should consider the production of embodied carbon (CO_2e) from asset maintenance versus run to failure.

Embodied Carbon In Reinforced Concrete

There have been several studies looking at the correlation between the concrete grade and its embodied carbon factors.

One example is the Institution of Civil Engineers (ICE) freely available carbon calculator (inventory of carbon and energy) equation. This was used by the author to measure CO_2e using a concrete mix common to local industry [5] for 32 MPa, 40 MPa and 50 MPa concrete mixes and each assuming 200 kg/m^3 of reinforcing steel where:

$$\sum EC = (ms)(ECFs) + (mc)(ECFc)$$

where:

- ƩC = total embodied carbon (kg)
- ms = reinforcement steel mass (kg)
- mc = concrete mass (kg)
- ECFs = embodied carbon factor for steel (kg·CO2e/kg)
- ECFc = embodied carbon factor for concrete (kg·CO2e/kg).

An embodied carbon value is calculated for reinforced concrete as 531, 579 and 581 kg·CO2e/m^3 respectively.

This includes carbon emissions during the extraction, processing, transportation and manufacture of materials up to the point where they leave the factory gate [6].

Material suppliers are starting to publish environmental product declarations (EPD) that measure the CO_2e of their materials and as an industry we will see society demanding CO_2e be considered within future feasibility and design stages of infrastructure works.

Likely maintaining structures for longer will produce less CO_2e in relation to use of new materials such as concrete and reinforcing steel that would otherwise be needed for replacement of old structures hence, there is a renewed focus on improved design and design for durability.

CASE STUDY

REINFORCED CONCRETE WASTEWATER PUMP STATION

Considerable expertise is required for proper diagnosis and remediation of concrete since the chemical processes of deterioration are complex, involving several contributory factors which give rise to very localized or extended forms of damage.

An experienced assessor was used to review all the information provided including:

- analysis of exposure conditions provided by the owner
- in-situ testing by the inspector
- laboratory testing of samples retrieved by the inspector
- visual defects recorded by the inspector.

The following case study is discussed to illustrate the scientific approach necessary to accurately assess and diagnose a concrete structure.

This is a real-life condition assessment of a reinforced concrete wastewater pump station built in circa 1930. The pump station is situated on a traffic island at the intersection of two busy streets in Melbourne.

The pump station comprises of two wells – dry and wet. The wet well is the focus of this case study [7]. The wet well is divided into three levels by intermediate concrete slabs as shown in Figure 1.

Given the difficult roadside conditions, a visual check using pole inspection cameras was undertaken by the owner. The visual check revealed spalling concrete and widespread coating breakdown.

The owner approached Remedy Asset Protection (RemedyAP) as they assumed needing to replace the structure and required a condition assessment to support development of a feasibility study.

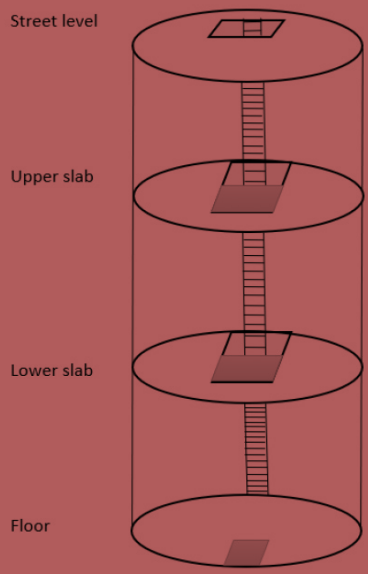

Figure 1: Sketch Indicative Of The Wet Well Layout.

Figure 2 - Access Into The Well

Figure 3 - General Condition Of The Well

CONDITION ASSESSMENT PLANNING

A Level 3 Condition Assessment includes investigation of physical and chemical properties of the concrete structure. These are recommended in the following scenarios [8]:

- The asset is approaching one third of its design life
- There are no previous reports on asset condition
- The asset is showing signs of distress
- The asset has a change of exposure or function.

For this structure, all four prerequisites were applicable and so, RemedyAP developed a Level 3 inspection plan for the pump station.

The main objectives of the condition assessment were agreed as follows:

- To establish and record the current physical and functional condition of the structure
- To identify likely future material and/or structural issues and the approximate timing of those issues
- To determine and measure the type and extent of the maintenance needs
- To establish a history of material performance and concrete chemistry; or
- To provide feedback to design, construction and maintenance engineers in relation to residual service life.

The inspection plan considered the relevant history of the structure, including engineering design and drawings, construction practice, previous inspections, maintenance and repair records. The highest corrosion rates tend to occur in concrete subjected to periodic wet and dry cycles, at the waterline within liquid retaining structures. The test plan therefore included testing locations in relation to the waterline.

There are several forms of deterioration or distress signals which were considered, including:

- specific attention to isolate the types and forms of cracks, particularly crack widths, location, orientation, depth, length and classification as either affecting the structural properties of the structure or non-structural
- wherever possible, structural cracks needed to be further identified as flexure, shear or direct tension
- signs and details of corrosion of steel reinforcement, including rust stains and extent and amount of lost cross-section
- evidence of loose, corroded or otherwise defective access systems, electrical items and mechanical items including lifting points used to hoist the pumps
- surface defects such as spalling, scaling, honeycombing and efflorescence
- condition of penetrations and seals
- signs of differential settlement, heave, water leakage, aggressive chemical attack or deterioration, poor drainage and related distress.

Procedures were adopted for sampling/coring and an overall program of the inspection and testing were integral to the objectives of the investigation. Other inspection requirements, such as ease of accessibility, equipment, power and water supplies and personnel requirements were essential however are not discussed in this case study.

The conditions of exposure, in relation to aggressiveness of the environment, drainage, and climatic conditions were considered during the assessment stages of the investigation to identify potential sources of observed deterioration.

Both sophisticated and simple equipment were used in this investigation and the results generated, analysed by our specialists who have the expertise and experience to complete the condition assessment that includes: defects notification, results of in-situ testing, sampling and laboratory testing, condition assessment, estimation of residual service life (RSL), preservation and intervention options, sustainability considerations and repair recommendations.

In Situ Testing

Testing in place (In situ) is required to test and measure the physical and chemical properties of the reinforced concrete. The data returned from in situ testing is used to assess the concrete and its condition. Tests used in this investigation included:

- Delamination survey
- Rebound hammer
- Crack mapping
- Cover meter
- Ground penetrating radar
- Depth of erosion and carbonation/ neutralisation.

The inspector could provide the following observations:

- The well was lined, and widespread coating failure was observed throughout
- Several areas of significant spalling of concrete with exposed reinforcement was observed to the intermediate slabs. The spalling was concentrated around the slab openings (interfaces between concrete and metal grates)
- Areas of exposed and corroding reinforcement were observed in these slabs
- Steel pipes inside the well were showing signs of coating failure and general corrosion
- A neutralisation depth of approximately 30 mm was observed on the well walls, with a concrete cover over steel at 55 mm
- Reinforcing steel was visually observed in the walls by means of concrete breakout, with no signs of corrosion.

Sampling

Core samples are the preferred method for concrete sampling and provide a means of determining the strength of the in situ concrete as a basis for evaluating structural integrity.

Procedures were adopted for sampling/coring and an overall program of the inspection and testing was integral to the objectives of the investigation.

Other inspection requirements, such as ease of accessibility, equipment, power and water supplies and personnel requirements were essential however are not discussed in this case study.

Laboratory Testing

Laboratory tests for concrete chemistry included cement content and concentration of chlorides within the concrete.

The results of the laboratory testing were as follows:

- The estimated the cement content in the concrete mix (295 to 384 kg/m^3) was considered relatively high for the age of the well and the type of construction.
- The concentrations of chlorides measured inside the well were low and significantly below the corrosion threshold level commonly assumed as 0.4% by weight of cement (0.049% by weight of concrete assuming cement content of 295 kg/m^3). Hence the risk of chloride-induced corrosion of reinforcement was considered low to very low.

CONDITION ASSESSMENT FINDINGS

Concrete Elements

In general terms, the condition of the concrete elements in the well ranged from 'poor' (intermediate slabs), 'fair' (invert slab) to 'good' (walls).

The significant deterioration of the intermediate slabs in the well was associated with corrosion-induced delamination from spalling around the openings. The corrosion, in turn, is related to low concrete cover. Although the history of the protective coating applied in the dry well was not known, it likely was applied quite some time after construction of the well. This allowed moisture ingress (potentially from ingress from the street level) into the slabs which then led to neutralisation of concrete and onset of corrosion of reinforcement and steel angles embedded in the slabs around the openings. The slabs in the well were in a poorer condition and were built using a lower quality concrete than the wall of the well.

Structural analysis concluded that the loss to reinforcement was not significant enough for needing steel replacement.

Load testing of the lifting points confirmed they were serviceable and were retagged.

The recorded concentrations of chlorides were significantly below the threshold level. Therefore, the risk of chloride-induced corrosion of reinforced was considered low to very low.

The current condition of the protective coating applied to all concrete elements was poor with up 80% of the lining failed (blistered or missing). Although the cause of failure of the coating had not been investigated in detail, it was likely to be attributable to surface preparation and/or application of the product.

Presence of the protective coating is likely to have reduced the rate of neutralisation of the concrete. The measured depths of neutralisation are considered low to moderate for an approximately 90 years-old structure.

Figure 4 - Condition as viewed from within the well base

Figure 5 - Inspection Of Rebar At Areas Of Spalling

Steel Elements

The steel pipes at the lower section of the well displayed extensive failure of the coating. These pipes appear to have been coated in-situ using a similar coating system as the one used on the concrete components. Although the cause of failure of the coating has not been investigated in detail, it is likely to be attributable to product selection, surface preparation and/or application of the product.

The upper parts of the steel pipes remained intact and were protected using the original (factory applied) fusion bonded epoxy coating system.

The steel angles supporting the steel grates within the intermediate slabs were significantly corroded and required replacement.

Residual Service Life

Once all the information was reviewed, the assessor considered primary and secondary degradation mechanisms that may affect RSL. An exact or definitive RSL can never be calculated, however a reasonable prediction was made based on the visible evidence, relevant laboratory results, modelling results and existing literature regarding deterioration of reinforced concrete.

The assessment concluded RSL would be extended up to 15 years if the repair recommendations were adopted. Further extension of RSL could be achieved by maintaining the protective coatings and operating conditions within the well.

Defects Notification

Where extreme distress was observed such as the access platforms, these were reported immediately rather than waiting for the pending condition assessment report.

REPAIR RECOMMENDATIONS

The correct specification of a repair system is very much dependent on the proper examination of the structure and an accurate diagnosis of the causes of deterioration.

For this structure the recommended remedial works were to include repair to all areas of spalled concrete and refurbishment of protective coating to both steel and concrete elements summarized as follows:

- Remove all defective coating from concrete elements
- Break out all delaminated and unsound concrete
- Clean steel reinforcement and replace if necessary
- Remove and replace angles and steel grates
- Reinstate removed concrete using high quality, proprietary repair material and introduce adequate slopes to allow moisture to drain off the platforms and into the well base
- Apply a new protective lining system to all concrete elements
- Remove all defective coating from steel elements
- Apply a new protective coating system to all steel elements.

The remedial actions were further assessed to inform the owner:

- Expected service life of the proposed remedial works (time to next major maintenance) was 10 to 15 years.
- At an estimated cost of AUD $84,000 with a ±30% accuracy [9].

CONCLUSIONS

In this case study the assessment showed the structure could achieve an extension of service life by performing maintenance and, by performing maintenance, would have nothing left to do for 10 to 15 years. This was a significant finding for the owner who first believed the asset to have minimal residual life and shows the value of a detailed concrete condition assessment.

Key learnings are:

- Replacement of the structure may cost over $3.5M however the condition assessment that cost the client under $50k identified how $84k of maintenance would provide an extension of service life.
- Testing of material condition after construction, establishes a reference from which to measure and monitor deterioration (establishing a benchmark)
- Building a register of asset condition provides an owner with baseline data for future inspections
- Having a proper assessment can provide the necessary information to determine specific preservation and maintenance interventions.

On the path to net-zero carbon emissions asset owners will start considering the production of embodied carbon (CO_2e) from asset maintenance versus run to failure.

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Understanding the Corrosion Mechanisms of Concrete Columns in Potable Water Tanks

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Keywords:

reinforcement corrosion, chloride, concrete, potable water tanks, capillary action

Abstract:

Within concrete water tanks, the columns are key structural components supporting the roof structure. Based on visual inspection observations of various potable water tanks, it was found that the top region of the reinforced concrete columns (approximately 1m below water line extending to roof level) commonly exhibit reinforcement corrosion defects resulting in concrete delamination and spalling. This highlights the need for a greater understanding of the general corrosion mechanism(s) and the factors that contribute to it. The available field test data showed instances where, above the water line, there was higher levels of chloride ions in the centre of the column compared to the surface which is likely due to the capillary effect of the water moving up the columns. The relative humidity and temperature fluctuations in the air space above the water line are also contributing factors to the corrosion reaction and hence progression of the corrosion damage. In addition, the quality of the concrete (concrete mix, placement, compaction and curing), concrete cover and workmanship, could also have a significant influence on durability of the concrete and the extent of reinforcement corrosion damage on the concrete columns.

INTRODUCTION

Major water authorities, such as SA Water, need to ensure reliable and uninterrupted water supply to their customers. Consequently, continued operation of their water storage tanks with an optimum long-term performance is of significant importance. Typical potable water tanks, within the SA Water network, are constructed from reinforced concrete tank structure covered by a steel roof structure. The concrete tank designs comprise of concrete walls (precast or cast in-situ), concrete floor with a ring beam and concrete columns (precast or cast in-situ) supporting the steel roof structure (see Figure 1).

Figure 1 Typical reinforced concrete tank – internal

The authors have undertaken condition inspections of numerous concrete potable water tanks over the past 3 years. Based on their visual inspection observations, the commonly observed internal defect is that the top region of the reinforced concrete columns (approximately 1m below water line extending to roof level) experiences reinforcement corrosion defects resulting in concrete delamination and spalling. Such defects have not been observed on the internal walls of the tanks.

Figure 2 shows typical examples of such observed defects. Paul Vince [1] reported on observed defects where it was suggested that migration of chlorides to the reinforcement surface and leaching of alkalis away from the surface contributed to the reinforcement corrosion.

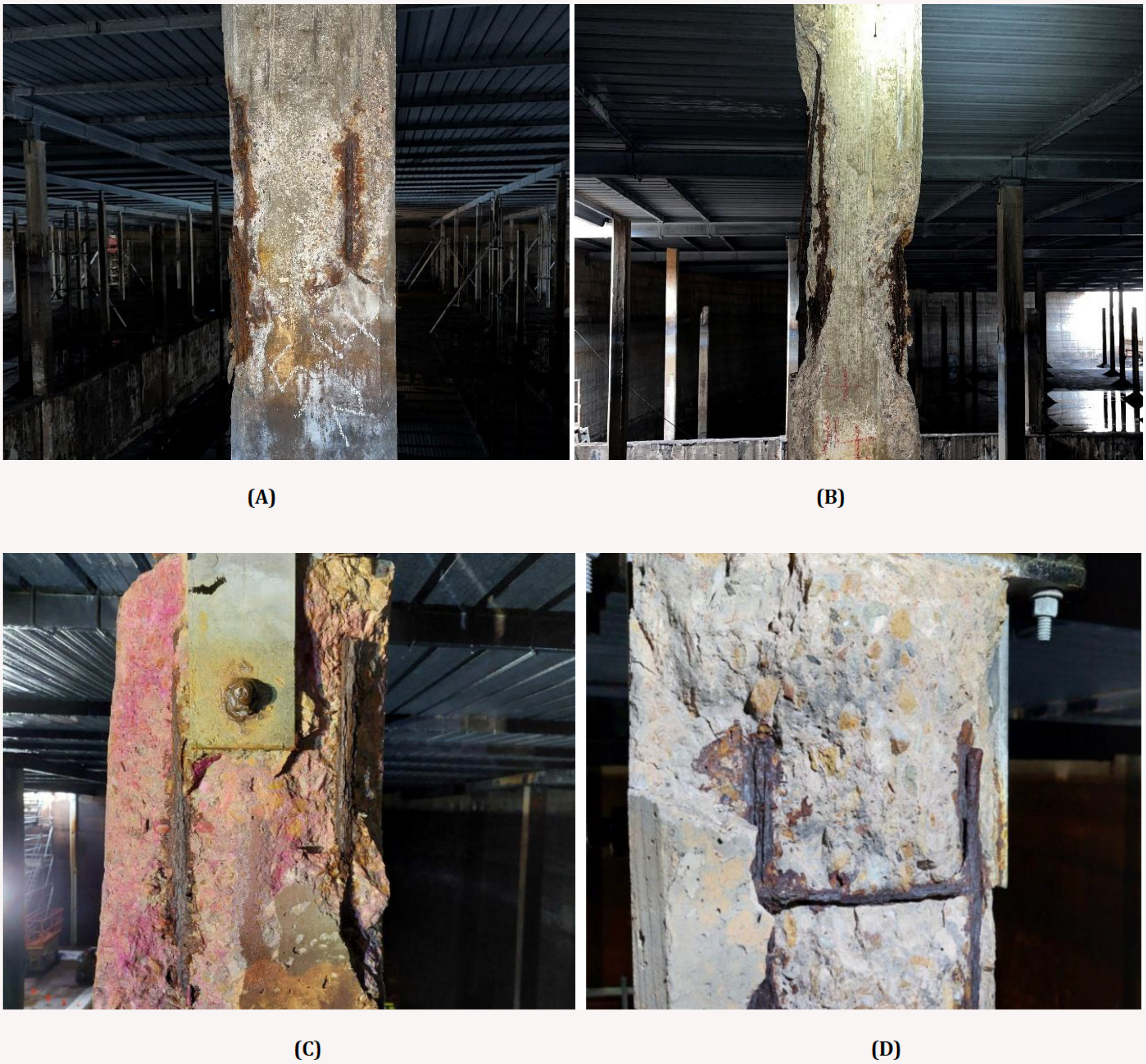

Figure 2 Typical reinforcement corrosion defect on concrete columns above the water line – (a) shows less and (b) shows a more severe corrosion on the columns and (c) and (d) showing corrosion in top of column

As the columns are key structural components supporting the roof structure, having a better understanding of the corrosion mechanism(s) will lead to the implementation of more effective repair methodologies to achieve longer asset life contributing towards SA Water sustainability targets and, more importantly, ensuring continued safe water supply and security for the customers.

A tank (Tank A) was chosen as a case study and testing was undertaken to investigate this corrosion defect further as the existing available test data on concrete columns in tanks was limited. This paper discusses the testing undertaken and the findings highlighting the possible contributing factors for the corrosion defects on the concrete columns and analyse the current repair methodologies being implemented by SA Water that ensure continued operation of the tanks and optimum long-term performance.

CASE STUDY

TANK A

Tank A was chosen as a case study and testing was undertaken to investigate this corrosion defect further. The details of Tank A are mentioned in Table 1 below.

Parameters	Details
Year of Construction	1925
Age (years)	99
Capacity (ML)	23
Diameter (m)	72.5
Height (m)	5.5
Columns	Reinforced square concrete columns 280mm x 280mm. Design concrete cover of 50mm.

Table 1: Details of Tank A

Sampling and Testing Scope

Given the nature and type of the observed defects, the likely primary deterioration mechanism was considered to either be carbonation-induced corrosion or chloride-induced corrosion noting that other factors such as quality of the concrete, concrete cover and tank environment above the water line (temperature and humidity) will also influence the severity of the defect.

The sampling and testing scope was developed accordingly as below.

- Measurement of concrete cover
- 2 no. of columns were selected for testing (Column 1 and Column 2) (see Figure 3)
- A total of 4 no. of cores were extracted (approximately 75mm diameter and 120mm long)
  - 2 no. of cores from Column 1 – one above the water line (AWL) and one below the water line (BWL)
  - 2 no. of cores from Column 2 – one above the water line (AWL) and one below the water line (BWL)
- Carbonation test, in accordance with WA 620.1 [2], performed on all samples
- Chloride ion concentration test, in accordance with AS1012.20.1 [3], performed on all samples at depth increments 0-10mm, 10-20mm, 20-35mm and 35-50mm

All cores were sent to a NATA approved laboratory for testing. The test results are discussed in the next section.

Figure 3 Example of cores taken locations below the water line and above the water line

TEST RESULTS

Concrete Cover

The concrete cover was measured on several columns across the tank using a cover meter prior to undertaken the coring. The measured cover varied from as low at 10mm to around 45 to 50mm – the latter being as per the required design cover. These areas of lower concrete cover would be one of the first likely areas where reinforcement corrosion initiates and the concrete delamination and spalling manifests – the visual observations also align with this as most of the defective areas typically have low concrete covers (see Figure 4). However, there were also areas of low cover away from the defective areas where the concrete did not show any signs of defects – this suggests though the low concrete cover may be a contributing factor of the reinforcement corrosion, it is not the primary factor.

Figure 4 Low concrete cover (less than design cover of 50mm) on concrete column especially at the corners

Such variation in concrete cover and deviation from the design cover would also indicate workmanship issues during construction of the tank. Such variation in concrete cover or areas of very low cover have not been observed on the internal tank walls.

Chlorides

As mentioned above, chloride ion concentration test, in accordance with AS1012.20.1 [3], was performed on all the 4 cores samples at various depth increments. The results are shown in Figure 5 below.

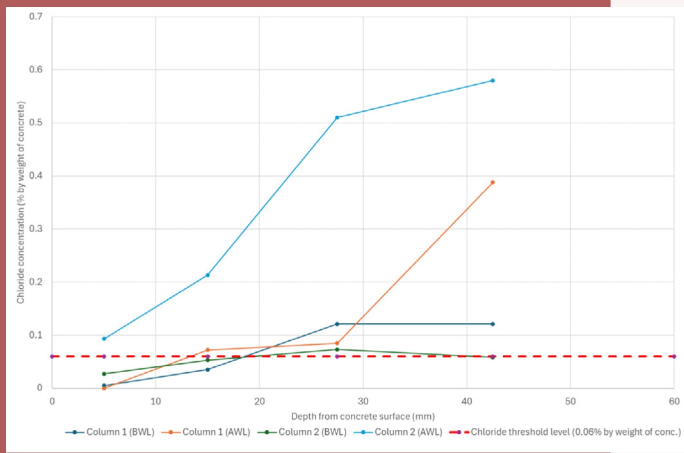

Figure 5 Chloride concentration profile results

Based on the test results, illustrated in Figure 5, the chloride ion concentrations seem to increase with depth i.e. higher chloride ion concentrations at the reinforcement level compared to the surface, and generally, at depth, are higher than the typical chloride ion threshold for corrosion initiation (0.06% by weight of concrete).

Initially, it was suspected that these may be built-in chlorides possibly through the inclusion of admixtures such as Calcium Chloride as accelerators in the original mix design which was general practice for 1930's construction. At lower dosages, these would not be of concern as the chlorides would bind with the cement hydration products and accelerate the hardening process as intended, however at higher dosages, the excess chloride ions could contribute to the initiation of corrosion. However, looking at the results, the chloride ion concentrations, especially for the AWL cores, increase sharply with depth whereas if there were built-in chlorides, the concentration profiles would be expected to be more gradual with depth. Furthermore, the chloride ion concentration, at 35-50mm depth increment, are much lower for the BWL cores relative to the AWL cores. Based on the above, the possibility of built-in chlorides being a factor was considered to be low.

Given the above, the other more likely mechanism could be water rising within concrete (from the water line) and evaporating from external face of the columns (wicking action/capillary action) building up salts in concrete cover zone in the regions above the water line. Though the chloride concentrations in the potable water are typically low (<300ppm), this cyclic process of water rising and evaporating could, over time, result in the salt concentrations within the cover zone to increase past the corrosion initiation threshold. It is important to note that the chloride ion threshold for corrosion initiation is only one factor of many that influence corrosion initiation, for example, for areas below the water line, the low availability of oxygen hinders the corrosion mechanism even though the chloride ion concentration exceed the initiation threshold. Peek et al [4] also observed and reported similar wicking phenomenon and similarly suggest that this is the main migration mechanism of chlorides from below to above the water line. However, the study by Adelkhah et al [5] did not observe this phenomenon even though they found relatively higher chloride concentrations below the water line.

Adelkhah et al [5] also undertook testing on the tank walls however, like the columns, did not observe this wicking phenomenon. In this study, testing on the reinforced concrete tank walls was not undertaken and this has been suggested as a recommendation for the future works. Spalling and reinforcement corrosion defects have not been previously observed on the internal wall face of the tanks nor has such variations in concrete cover or areas of very low cover which highlights the difference in concrete quality and/or workmanship between the tank walls and columns. Additionally, the exposure of column cross section from all sides to water, compared with a single surface of the wall, could also be a contributing factor to deterioration of column more than walls. The tank walls do experience concrete spalling and reinforcement corrosion but mainly at wall corbels and cut-out for roof members support due to ponding of water on these flat surfaces.

Carbonation Depth

The carbonation depth test was performed on all the 4 cores samples by using a phenolphthalein indicator. It is noted this test is not a direct measure of the carbonation depth but rather a measure of depth of concrete with reduced pH values (below 8.3) which can be caused by other mechanisms such a leaching or soft water attack on the concrete [6]. The maximum carbonation depths were 0 and 7mm for the BWL and AWL cores respectively. Carbonation dept of 0mm measured for the BWL core is expected as it is fully submerged. For the AWL core, the maximum carbonation depth was 7mm which is plausible as it is assumed that the moisture level on the concrete surface of the columns above the water line is high, given the combined effect of high relative humidity during the day and condensation during the night, hence impeding the rate of carbonation reaction.

OTHER CONTRIBUTING FACTORS

Environmental Factors

The relative humidity and temperature fluctuations in the air space above the water line are also a contributing factor to the corrosion reaction and hence progression of the corrosion damage. Furthermore, the temperature fluctuations (ranging from single digits to around 70°C) could lead to formations of cracking in the concrete which can intensify the severity and extent of corrosion.

Concrete Quality Factors

The quality of the concrete (concrete mix, placement, compaction and curing), concrete cover and workmanship, could also have a significant influence on durability of the concrete and the extent of reinforcement corrosion damage on the concrete columns. Improper concrete placement, compaction and curing would result in concrete with inferior durability (higher permeability, larger voids) i.e. higher rate of ingress of deleterious elements. Low concrete cover would reduce the distance these deleterious elements need to travel to reach the reinforcement. Both factors would lead to premature reinforcement corrosion.

REPAIR METHODOLOGY

The currently adopted repair methodologies for the columns, depending on the extent of damage, are as follows:

1. Small patches of exposed/corroded reinforcement

a. Break out unsound concrete until sound concrete and to a minimum 25 mm behind exposed reinforcement.

b. Saw cutting perimeter of breakout to 20 mm depth of cut to eliminate feathered edges.

c. Clean and assess the corroded reinforcement – where the section loss of the reinforcement exceed 25%, supplement it with new bars of the same size.

dFor replacement, chase the reinforcement bar until clean reinforcement is exposed on both sides for the new bar to be welded on to.

e. Apply zinc-rich primer to the exposed reinforcement bars.

f. Patch repair concrete using an approved cementitious repair mortar.

g. Apply an approved protective coating to the concrete surface, where specified.

2. Larger patches of exposed/corroded reinforcement or where severe corrosion has occurred

a. Demolish the column to 1m below water level

b. Install new reinforcement bars

c. Re-cast the upper section of the column using an approved flowable cementitious micro-concrete mortar

d. Apply an approved protective coating to the surface of the concrete around the joint between the old and new concrete

3. Large number of columns have exposed/corroded reinforcement

a. Demolish and replace all concrete columns with concrete/grout-filled FRP circular columns.

CONCLUSIONS AND LESSONS LEARNED

Based on the analysis of the testing results, it is concluded that:

- The carbonation depth in the concrete columns both below and above the water line is limited.
- The chloride ion concentrations increased with depth from the surface with a likely cause of that being due to wicking action/capillary action of the water rising the concrete column and evaporating depositing salts within the concrete cover zone. This is likely the primary mechanism for the reinforcement corrosion observed in the concrete columns.
- The concrete cover on the columns ranged from as low as 10 mm to 50 mm indicating the construction quality control and workmanship is variable within a tank and between different tanks

Avenues to be pursued next would be:

- Undertake similar sampling and testing on other tanks and tank walls
- Undertake testing to better quantify the tank environment and the moisture state of the concrete above the water line during operations identifying daily and seasonal changes
- Review repair method for small patches to include the use of galvanic anodes as a standard patch repair would not be adequate for reinforcement corrosion mechanisms driven by chlorides.

ACKNOWLEDGMENTS

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H. Habib is a Principal Civil and Structural Engineer at SA Water, a position he has held since 2016. He is responsible for assessment of SA Water technical risks, technical governance, development of technical standards and typical concrete remediation techniques relating to water and wastewater assets. He is the primary author of TS 0711 concrete remedial works standard series, the first of its kind in Australian water industry.

R. Salazar Romero is the Principal Materials Engineer at SA Water, a position he has held since 2023. He is responsible for providing specialist design and technical auditing of SA Water projects to meet time and budget constraints and act as a Subject Matter Specialist (SMS) in Material discipline matters across the Corporation.

2025 Training Calendar

AMPP Coating Inspector Program Level 1	
WA - Perth	04-09 Aug 2025
NSW - Sydney	18-23 Aug 2025
WA - Perth	13-18 Oct 2025
QLD - Brisbane	13-18 Oct 2025
VIC - Melbourne	17-22 Nov 2025

AMPP Coating Inspector Program Level 2	
WA - Perth	11-15 Aug 2025
NSW - Sydney	25-29 Aug 2025
QLD - Brisbane	20-24 Oct 2025
VIC - Melbourne	24-28 Nov 2025

ACA Corrosion Technology Course	
NSW - Sydney	01-05 Dec 2025

ACA Coating Selection and Specification	
Online/AEST	20-22 Oct 2025

ACA GAA Hot Dip Galvanizing Inspector Program	
WA - Perth	16-17 Sep 2025

AMPP Corrosion Under Insulation	
Online/AEST	08-11 Sep 2025

AMPP Concrete Coating Inspector	
VIC - Melbourne	08-12 Dec 2025

ACA ACRA Concrete Structures and Buildings	
Online/AEST	15-16 Sept 2025

AMPP Craftworker Series (CWS) C6/C7/C12	
SA - Adelaide	15-20 Sep 2025

Note: Training Calendar for 2026 is coming soon!

Click here to review the Training Schedule:
www.corrosion.com.au/training/training-course-schedule/

Course Spotlight: ACA Corrosion Technology Course (CTC)

More information & Registration

Overview:

The Corrosion Technology Course (CTC) course covers the basic principles of corrosion, the forms it takes and the methods of control.

Who should attend

Anyone interested in gaining a better understanding of corrosion and its control, including Researchers, Project Managers, Engineering Students, Maintenance and Quality Assurance/Control Personnel, and Contractors and Specification Writer.

Course highlights:

- The importance of corrosion
- The Corrosion Process
- Predicting Corrosion Reactions
- Types of Corrosion
- Corrosion in Natural Environments
- Design Improvement
- Corrosion Properties of Metals
- Inhibitors & Water Treatment
- Protective Coatings
- Cathodic & Anodic Protection
- The Corrosion Technology Course is beneficial if you would like to become an ACA Certified Corrosion Technician or Technologist

Joining the Australasian Corrosion Association offers a whole host of benefits for indviduals seeking to advance their careers and expand their networks.

Membership provides access to a wealth of resources including cutting-edge industry research, professional development opportunities through workshops and seminars, and exclusive updates on trends and regulatory changes.

Networking events and conferences enable members to connect with peers, mentors, and industry leaders, fostering valuable relationships and collaborations.

By joining the ACA, you gain a competitive edge, stay informed, and enhance your professional growth and opportunities.

Become a Member

KNOWLEDGE BUILDING

The ACA's trainings and development pathways cater to a variety of skillsets , from entry-level corrosion novices to those seeking advanced specialist training. Training arrangements have flexible capacities and are both locally and internationally recognised for their quality, accreditation, and applicability. The Annual Corrosion & Prevention Conference offers an array of technical initiatives, including industry and research programs, social functions and awards ceremonies to highlight innovation in the corrosion industry. Our Branches offer a year-round calendar of events, including seminars, on-site visits, technical presentations, networking events, Young Corrosion Group events, and more.

RESOURCES

Joining ACA gives you access to our library of resources, papers, and material expertise to assist your business and further your career. The ACA sends out weekly newsletters, social media updates, and one-off packages about news and events to keep members informed. Members also have the option to promote their own people and initiatives through our updates. The ACA has accrued over 2,000 case studies, research papers, technical articles, presentations and more covering a range of subjects written by some of the most respected industry experts. Members can also access papers, publications and seminars from the European Federation of Corrosion.

COMMUNITY

ACA is committed to building an active, engaged, and passionate membership. Networking is both online and in-person; meet people online through seminars, discuss the future of corrosion with your peers at a convention, and join the AGM and other Branch events. Join one of the ACA Committees to become more involved, learn new skills, and access career opportunities with some of the most ambitious and connected in the industry. The ACA acts as your voice and representation; we engage with governmental organisations, other non-for-profits, big business, and others to get the best outcomes for our industry and our Membership. Members can use our Corrosion Control Directory to contact the best industry person to meet your needs or ask your questions.

RECOGNITION

Get involved in the ACA's scholarship program and picking up new skills through the Association's direct financial and administrative support. Obtain certification as either a Corrosion Technician or Corrosion Technologist to receive extended public recognition for your qualifications. Use ACA's logo to demonstrate your qualification. Sign into ACA's website, build your personal profile, and connect with likeminded peers within the corrosion industry.

MEMBER BENEFITS

Membership Benefit	Diamond	Platinum	Gold	Silver	Bronze	Individual
Number of Corporate Delegates accessing benefits (Delegates receive the same benefits as individual members)	30	12	8	5	3	1
Additional Young Corrosion Group (YCG) Delegates YCG Delegates receive the same benefits as individual members. YCG should be students or in early stage of their corrosion career (under 35 years)	Unlimited	10	5	3	2	✗
Join our Technical Groups Applicators Technical Group, Cathodic Protection Technical Group, Coatings Technical Group, Concrete Structures & Buildings Technical Group, Oil & Gas Technical Group, Young Corrosion Group, Water Industry Group.	✓	✓	✓	✓	✓	✓
Discounted prices for Training, Events and Conference attendance for Delegates Upskill with member prices on ACA and AMPP Training Courses, ACA events and our Annual Corrosion and Prevention Conference	✓	✓	✓	✓	✓	✓
Access to our online Corrosion & Materials Journal (Quarterly) Receive four (4) online issues of the Corrosion & Materials Journal for all members, featuring technical articles, latest news, new products, and industry events.	✓	✓	✓	✓	✓	✓
Access to Exclusive ACA Member resources Over 4,500 Technical Papers, Webinar Recordings, 2,000 past ACA conference papers, recorded presentations from ACA events, past issues of Corrosion & Materials, technical articles, case studies and more.	✓	✓	✓	✓	✓	✓
Access to past Conference papers from the European Federation of Corrosion (EFC) congress & access to be appointed on Membership of EFC Working Groups	✓	✓	✓	✓	✓	✓
Access to local, Australia wide & New Zealand networking Branch & Technical Group events	✓	✓	✓	✓	✓	✓
NEW **Exclusive Membership Portal** Renew and pay your membership dues, download invoices, access ACA events and training, update your details, review past training or events, access the technical library, read C&M Journal, and, for corporate members, manage corporate membership. *NEW*	✓	✓	✓	✓	✓	✓
Entitlement to use the ACA Corporate Partner Logo on company's promotional material By submitting a Membership Application Form, you acknowledge that you have read and understood the ACA Terms & Conditions and agree with and consent to the practices described.	✓	✓	✓	✗	✗	✗
Free listing in the Corrosion Control Directory on the ACA website	✓	✓	✓	✗	✗	✗
Priority for annual Branch and Technical Group Sponsorship Opportunities	1st	2nd	2nd	3rd	3rd	✗
Acknowledgement at the Conference + Awards Dinner	1st	2nd	2nd	3rd	3rd	✗
Preferential Lead Service	1st	2nd	2nd	3rd	3rd	✗
Discounts on Advertising	✓	✓	✗	✗	✗	✗
Company Name, Logo and Website listed on Corporate Members Page Linked to your website.	✓	✓	✗	✗	✗	✗
Company Logo used on the homepage of the ACA website	✓	✗	✗	✗	✗	✗
One free advertorial on ACA website & feature in global mail out on sign-up	✓	✗	✗	✗	✗	✗
One annual special feature in Corrosion & Materials Journal	✓	✗	✗	✗	✗	✗